The Mixed Use Residential Building: A building block for the cities declared saturated by air pollution in Chile's Mediterranean Climate.

Christopher Whitman[1], Gabriela Armijo[2], Leticia Roubelat[3]

Abstract

This paper presents an analysis of the problem faced by the cities of Chile's central valley and a study of the current international and Chilean situation of a specific building typology: the mixed use residential development. Chile's central valley has a Mediterranean climate characterized by cold winters and hot summers. Almost all of the cities located in this region have been declared saturated by airborne pollution PM10 directly resulting from thermally inadequate housing stock and the inefficient burning of poor quality wood for heating and cooking. Through their emphasis on single function zoning and mono-functional modernist planning, the Chilean planning instruments lead to increased journey times and a reliance on the private car for daily transport, adding to the airborne pollution. In 2007 the Chilean government introduced thermal building regulations for residential properties; however their low requirements have been criticized at both a national and international level. Some private and public residential projects have attempted to improve their energy efficiency but to date these projects have focused on the single family dwelling, a housing typology inherently inefficient due to its high surface to volume ratio and its implied land use. The sustainable mixed use residential building offers the opportunity to provide efficient housing, workplaces and basic services in the same built form thereby reducing unnecessary journeys and promoting community cohesion. The international case studies show that there exist the necessary technologies and theoretical knowledge, whilst the review of the national situation concludes that although there exists interest and political will, developers are unwilling to innovate and take a risk on an as yet unproved market. Time is therefore required to allow research and the testing of a business plan for a prototype of a building block for a sustainable future for Chile's contaminated cities.

Keywords: Housing, mixed-use, energy efficiency, airborne contamination

1. Introduction

According to the latest national census of 2012 (INE 2012) over 50% of Chile's population are concentrated in the Central Valley. The climate of this region is classified by Kottek et al.

1 Researcher; Laboratorio de Bioclimática; Facultad de Arquitectura, Urbanismo y Paisaje; Universidad Central de Chile; Santa Isabel 1186, Santiago Centro, Santiago de Chile; cwhitman@ucentral.cl

2 Director; Laboratorio de Bioclimática; Facultad de Arquitectura, Urbanismo y Paisaje; Universidad Central de Chile; Santa Isabel 1186, Santiago Centro, Santiago de Chile; gabyarmijo@ambiente.cl

3 Research Assistant; Laboratorio de Bioclimática; Facultad de Arquitectura, Urbanismo y Paisaje; Universidad Central de Chile; Santa Isabel 1186, Santiago Centro, Santiago de Chile; leticiaroubelat@hotmail.com

(2006) and Russo et al. (2008) as Mediterranean, a warm temperate climate with short cold winters of 4 to 5 months, dry summers with intense insolation and diurnal thermal oscillation averaging around 20ºC in summer and 10ºC in winter. The region runs north-south from latitude 32.8º South to latitude 37.2º South over a distance of 480km and is bounded to the west by the Andes and to the east Chile's coastal range. The topography formed by these mountain ranges and their lateral spurs creates a series of interconnected bowls with poor ventilation which, coupled with a thermal inversion layer approximately 500m above ground level in winter, traps the airborne pollution produced by the regions cities and industry. As a result many of the cities have been officially declared saturated by airborne contamination PM10 by the Ministry of the Environment (Table.1).

Table 1: Zones declared saturated PM10. Source: SINIA Sistema Nacional de Información Ambiental

Location	Region	Year declared saturated (PM10)	Principal source of airborne contamination	Decontamination plan
Chuquicamata	II Region, Altiplano	1991	Mining Industry (smelting)	Implemented 2001, zone declared latent 2005
María Elena y Pedro de Valdivia	II Region, Altiplano	1993	Mining Industry (smelting)	Implemented in 1997. Complied in 2010
Santiago	Metropolitan Region, **Central Valley**	1996	41% Industry, **38% transport**, **16% firewood** 5% agricultural fires.	In place since 2003 – Definitive Project currently being considered by the President of Chile
Temuco-Padre las Casas	IX Region, **Central Valley**	2005	**93% Firewood**, **7% Transport** and others	Definitive Project currently being considered by the President of Chile
Concepción	VIII Region, Coastal	2006	37% industrial **32% Firewood** **3% Transport** 34% Other	Feasibility study being developed
Tocopilla	II Region, Coastal	2006	2 Coal fired Power Stations	Definitive Project being developed
Rancagua y valle central de la IV Región	VI Region, **Central Valley**	2007	**28% Firewood** 32% dust 25% Mining Industry (smelting) 15% Other	Feasibility study being developed
Calama	II Region, Altiplano	2009	Mining Industry (smelting)	Feasibility study being developed
Talca	VII Region **Central Valley**	2010	**Mainly Firewood**	
Chillán	VIII Region, **Central Valley**	2012	**Mainly Firewood**	
Osorno	X Region Lake district	2012	**Mainly Firewood**	

In many of the cities declared saturated, emissions from firewood for heating and cooking play a major role. Given that all middle class and social houses are not provided with central heating, inhabitants must post-fit their own heating solutions, in many cases opting for the most economical solution rather than the most efficient. In the case of the cities of Temuco–Padre las Casas the Plan for Decontamination (CONAMA 2009) identified three major contributing factors; poor quality firewood with a high relative humidity; inefficient stoves and fireplaces lacking double combustion; and the poor quality of the building stock with insufficient thermal insulation. The other common factor present in many of the cities is the airborne pollution produced by transport, a direct result of planning policies which create ever greater commuting distances and a reliance on private cars.

1.1 Official Plans for Decontamination

By law those cities and regions declared saturated by airborne pollution must develop an Atmospheric Decontamination Plan (Plan de Descontaminación Atmosférica PDA). In the case of the Metropolitan Region of Santiago this plan concentrates principally on improving the quality of fuels used by industry, transport and residential. It does however mention the need to promote the best use of the capacity of existing urban fabric, that is to say densification (Congreso Nacional de Chile 2010). The plan for the twin cities of Temuco-Padre Las Casas in Chile's 9^{th} Region is more specific in its reference to the built environment. The thermal improvement of residential building envelopes forms one of the four key measures, alongside the improvement of firewood quality, replacement of inefficient wood burning stoves quality, and an education program to increase public awareness (Congreso Nacional de Chile 2010). The plan highlights the need for both the refurbishment of existing housing stock and the efficiency of new residential projects. Studies have shown that improvements to the building envelope above and beyond that required by Chilean thermal building regulations could reduce household heating energy consumption by between 54 & 68% (Ambiente Consultores 2007), with an estimated overall financial benefit of US$48.8 million when both savings in fuel and healthcare are included (Congreso Nacional de Chile 2010). Initiatives are currently in place for thermal reconditioning of existing dwellings, however as yet there is no requirement or incentives for raising the standard of the 15,000 new dwellings built every year in the region (INE 2012).

It therefore appears that an additional part of the solution to the problems faced by the cities of Chile's Central Valley should be the search for a new residential building form that is designed to be energy efficient and that incorporates a mix of uses with the intention of reducing unnecessary journeys and maximising the use of already urbanized land.

1.2 Housing in Chile

1.2.1 Thermal conditions

Of the 5.7 million dwellings in Chile (INE 2012) 63% were built prior to the introduction of the Chilean Thermal Building Regulations. These regulations were introduced in two phases. The first introduced in 2000 required only thermal insulation of the roof with thermal conductivity (U-values) defined according to 7 thermal zones calculated according to the heating degree days. U-values requirements for roofs in the Central Valley range from 0.47 W/m^2K in the north of the region to 0.38 W/m^2K in the south (Instituto de la Construcción 2006). In 2006 the second phase of the regulations was introduced covering the insulation of walls and ventilated floors. U-vales for walls range from 1.9 W/m^2K in the north of the Central Valley to 1.7 W/m^2K in the south. Although Chile was the first Latin American country to introduce Thermal Building Regulations the required thermal conductivity has been criticized both at a national (Bustamante et al. 2009) and internationally (Caldera Sánchez 2012) for their leniency. Many believe that six years on from their introduction the requirements for walls require revision and updating.

A survey by the Instituto de la Construcción (2008) of 402 dwellings located in 29 housing complexes in 4 different Chilean cities showed an average indoor winter temperature of 15°C. These dwellings were constructed in 2002, that is to say after the first phase of the regulations but prior to the second and so therefore should have insulation in there roof build up. It also indicated problems of overheating in summer and 80% of the properties presenting problems related to condensation and mold growth.

1.2.2 Fuel Poverty

The concept of fuel poverty was defined by by Lewis (1982) in the National Right to Fuel Campaign in Bradford UK as "the inability to afford adequate warmth in the home". This definition was revised by Healy (2004) to one that related specifically to housing design as "The inability to heat ones home to an adequate (safe and comfortable) temperature owing to low income and poor (energy inefficient) housing." The term refers to households that must spend over 10% of their annual income on fuels in order to achieve satisfactory indoor heating. This calculation is based on the theoretical value that a household would need to spend and not their actual expenditure. In many cases the required cost escapes the financial means of the household and so satisfactory indoor heating is not achieved. Therefore a household suffering from fuel poverty either spends too much on heating fuel and/or suffers poor hygrothermal comfort. A study by Márquez et al. (2006) showed that all but the richest two fifths of the Chilean population suffer fuel poverty.

1.2.3 Urban Planning

Since the 1930s Chilean urban planning has been dominated by the North American modernist model of single use zoning which discourages or actively prohibits mixed use developments. Large areas of cities are developed as purely residential neighbourhoods with no requirement for the associated infrastructure such as schools, preschool nurseries, convenience stores and workplaces. This obliges the residents to use motorized transport even for simple everyday tasks. Despite government initiatives, such as Transantiago in Santiago which intended to improve public transport, both buses and metros continue to be overcrowded and run with no fixed timetable. Due to a shortage of new buses, many old, highly polluting buses were reintroduced to Santiago streets during the first year to meet the passenger demand. Outside of Santiago public transport remains based on small diesel buses that in general lack regular maintenance. At the same time the drive for meeting social housing targets has lead to the selection of sites based on their low economic value as apposed to the convenience of their location, almost always being located on the city limits far from work opportunities. This has lead to ever increasing commuting times and costs for those who have the least income. Even for the wealthy the desire to live in a detached house with individual garden has lead to urban sprawl and a reliance on the private car. Isolated attempts at regulations to promote mixed use developments have been unsuccessful due to conservative developers who resist innovation. In addition mixed tenure has not been possible due to regulations related to social housing grants. The current government in its manifesto proposed changes to housing policy which would allow the purchase with government subsidies of existing or new-build dwellings not located within social housing blocks. This may pave the way for a market in mixed tenure residential projects, however to date the government has made no changes to the existing laws.

To summarise the study of the context of Chilean housing we can conclude that all Chilean dwellings, both rich and poor, do not provide good hygrothermal conditions; that the current thermal building regulations are insufficient; that all but the highest socioeconomic strata suffer fuel poverty; that heating systems are inefficient and that mono-functional planning policies augment dependence on motorized transport both public and private. As a result of all these factors airborne pollution is elevated to the point of saturation, impinging on the health of the cities inhabitants. Well designed, thermally insulated, mixed use residential buildings would suggest a possible component, which along with other measures such as upgrading of existing building stock and cleaner fuels, could provide the first steps towards resolving some of these problems. There follows a study of some international examples of mixed use residential buildings which aim to provide the building block for sustainable communities.

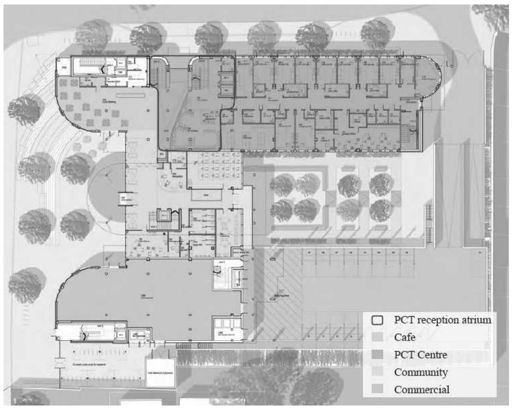
2. International Case Studies of Mixed Use Buildings

2.1 Stonebridge Hillside Hub, Harlesden, London, Southeast England UK

Stonebridge Hillside Hub designed by Edward Cullinan Architects (2009) is a mixed-use residential project which forms the civic focus of the reconstruction of the 1960s Stonebridge housing estate in northwest London. The project was originally envisaged as a series of distinct buildings. These included a health centre, a supermarket, a community centre and housing. The architects proposed that these functions be combined in one single building with the aim of forming the “social glue” of the community. The community functions of the building were in turn designed to pivot around a cafe space that was intended to tie these functions together. Unfortunately to date no tenant has been found for this cafe however different community groups use the space for annual events such as the Older people’s Forum’s “Time of your life” day which enables the local community to gather together for speeches, dinner, dancing and talking (Cullinan 2012). The project includes 25 apartments with government subsidies and 34 for the private market, in addition to: a community centre; computer centre; multi-purpose hall; offices; healthcare trust; café; supermarket; parking and bicycle parking; and a community garden. The housing has received Eco-Homes Very Good” certification and has won the What House Silver Award for Best Starter Home 2009. In addition the overall project was shortlisted for the Best Housing project in the Building Awards 2009 and in 2011 received a Special Civic Trust Award for Community Impact & Engagement.

The thermal insulation exceeds British building regulations by 20% with a calculated energy demand of 73kWh/m2/year. The social centre has rainwater harvest and solar panels for hot water. Provision for separation at source for recycling is provided with individual waste bins below the kitchen sinks and centralized storage facilities for municipal collection.

The group that owns the community centre also owns the café space and adjoining supermarket. The rental received from these spaces allows them to provide a continuous and varied program of community activities.



Figures 1 and 2 Stonebridge Hillside Hub main elevation and ground floor plan.

2.2 Sonnenschiff, Vauban, Freiburg, Southwest Germany

Sonnenschiff which is German for “Solar Ship” was designed by the German architect Rolf Ditch (2004). The project located in the sustainable neighbourhood of Vauban comprises of 59 dwellings of which 9 are two story “penthouses” situated within roof gardens (fig.3); 3600m^2 of offices, studios and clinical practices on the second and third floors; 1200m^2 shops and cafes at street level; and 138 parking spaces in the basement. Public transport links Vauban to the centre of Freiburg 4km away, this combined with the car-sharing system significantly reduces private car use and associated emissions. The dwellings are designed to “Pasivhaus” and “Plusenergyhaus” standards with the PV arrays mounted on their roofs providing more energy than the dwelling requires. When operation and construction costs are included in the calculation, these house are cheaper than normal German market homes. The architect claims a primary annual energy saving of about 1 million kWh (Disch 2006).The innovative technical items included are: PV roofs, use of geothermic energy, rainwater reuse, high standards of external thermal insulation, vacuum insulation, and controlled ventilation with heat recovery.

Considering these factors one would expect that the Sonnenschiff has become a standard role model for German housing. However it has been argued that the project was only made possible by the architect Rolf Disch taking on the role as social entrepreneur as well as architect and with much perseverance over a long period of time (Wüstenhagen 2011).

Figure 3. Roof plan showing 9 “penthouse” dwellings.

2.3 One Brighton, Brighton, Southern England UK

Commissioned by BioRegional, the same developers behind the iconic Bedzed project in London, One Brighton was designed by Feilden Clegg Bradley Architects (2009). For the project BioRegional teamed up with one of the UK’s largest housing developer Crest Nicholson to build a project that appeals to the general housing market rather than a specific “green clientele” whilst still embodying the 10 principals of One Planet Living; zero carbon; zero waste; sustainable transport; sustainable materials; local and sustainable food; sustainable water; land and wildlife; culture and community; equity and local economy; and health and happiness. In the two blocks the project provides 172 residential units with a mixture of private and social ownership. In addition it includes commercial units and 929m^2 of community spaces, including a community cafe. The tenant for the community spaces is The Ethical Property Company. The company buys properties and develops them as centres that bring charities, cooperatives, community and campaign groups together, where they can share skills and ideas. Groups in The Ethical Property Company’s centres benefit from reasonable rents, flexible tenancy terms and office space and facilities designed to meet their needs.

Figures 4 and 5. One Brighton rear elevation and roof top allotments.

Just as with Bedzed, the project has centralized heating fuelled by a biomass boiler; a car club; PVs and solar thermal panels. The walls are clad with an external insulation of rigid cellulose fibre panels, which provide U-values 25% better than British thermal building regulations, the U-value of walls being 0.21W/m^{2}K. The windows achieve a thermal conductivity of 0.80W/m^{2}K with triple glazing and laminated pine internal frames and aluminium external frames with “warm-edge” technology by the company Swedish timber Products. On the roof terraces there are allotments in raised bed timber planters which allow residents to grow some of their own food and at the same time encourage interaction between neighbours.

3. National Context

3.1 Mixed Use Residential Buildings in Chile

In Chile the majority of new residential buildings of all scales are mono-functional. From houses to high-rise apartment blocks there is little attempt to integrate a mix of functions within one built form. Isolated cases of residential buildings above a 2 storey commercial podium are rare and are rarely encountered in projects within the last decade. Developers have become specialized in residential or commercial buildings and rarely cross from one typology to the other (Schlack 2012).

3.1.1 Plaza Lyon, Providencia, Santiago de Chile, Central Valley, Chile

The Plaza Lyon complex by Murtinho & Asociados Arquitectos (1980-82) was designed under the planning policy of “conjunto armónico” which permits a greater density provided that public space and communal functions are incorporated within the design. The design is influenced by post-modern thinking, reinterpreting historical typologies of Santiago such as the city block, the gateway, the continuous facade, the square and the patio (Fernández 1991). The building of 70.000m^2 incorporates residential apartments, offices, retail (department store, shops and supermarket), public spaces and underground car parking, in addition to being directly connected to an underground metro station. Interviews with the building’s administration have reported problems arising due to the complicated mix of functions and related security issues (Schlack 2012).

With walls of 200mm uninsulated reinforce concrete with a typical u-value of 2.2W/m^2K and single glazing the building is far from being an energy efficient model. However it should be considered that the thermal conductivity of the walls is only slightly higher than the current Chilean thermal building regulations of 1.9 W/m^2K, a fact that reflects the low requirements of the regulations.


Figures 6 and 7 Plaza Lyon mixed use development, Providencia, Santiago de Chile

3.2 Energy Efficiency in the Chilean Residential Market

Whilst there do not exist many examples of Chilean mixed use residential buildings, energy efficiency is slowly beginning to play a role in the Chilean residential market. The concept "Full Electric" of Chilectra, the electricity distribution company of the metropolitan region, has been promoted in new residential projects promising dwellings free from intradomicilliary air pollution coupled with greater efficiency with the use of off peak electricity. According to information published by Chilectra in 2009 44% of the new residential apartments built in Santiago included this concept, an increase from 2008 when the same statistic was 30.5% (Prieto 2009). Whilst true that electric heating systems do not produce intradomicilliary air pollution and using off-peak electricity reduces peak demand and therefore the national energy demand, it should be considered that in 2009 59% of the electricity was generated with greenhouse gas emitting fossil fuels (Ministerio de Energía 2010). Therefore this concept still has a long way to go before it can really be considered sustainable.

Another novelty in the Chilean housing market is the installation of thermal solar panels for hot water. The first apartment building in Chile that included thermal solar panels was the Edificio Al Ras, located in Sucre 1900, Ñuñoa, Santiago. In this project of 96 apartments 21 evacuated tube collectors were installed on the roof, providing 10.800 litres per day of hot water or 112.5 litres per apartment. Many other apartment buildings soon followed suit labelling their buildings as "ecological" based solely on the inclusion of thermal solar energy. In the emblematic building Edificio GEN, Portugal 415, Santiago, the architect Felipe Assadi has attempted to integrate flat plate thermal solar panels with the architecture of the building. The panels are located in the north facade with one panel per flat forming part of the balcony balustrade. Despite the insurmountable problem of overshadowing from the pre-existing 20 storey building located directly to the north, it is interesting to see that solar panels have become a key selling point in the private Chilean residential market. In August 2009 the Chilean government passed the law N° 20.365 that established a range of tax rebates for developers for the installation of thermal solar panels for dwellings with a build cost of up to 4,500UF (approximately US$212.000). Although it took a year before the law was put in force, in the last two years the sale of thermal solar panels has increased 292% (Antunovic 2012). The law was only originally intended to last until December 2013 but in 2011, following criticism over the delays in its implementation, the Minister of Energy announced a possible extension of this time frame. As yet this extension has not been confirmed.

Another government program related to energy efficiency came into being as a specific response to problems faced by the cities declared saturated by airborne pollution arising from firewood. This program for thermal reconditioning of existing dwellings was annexed to the existing program knows as PPPF (Programa de Protección del Patrimonio Familiar) the Program for the Protection of Family Assets. The program consist of subsides for the installation of thermal insulation and double glazing. One example of the application of this subsidy is the case of Edificio Barros Arana located in Temuco one of the cities declared saturated. Built in 1959 the two social housing blocks have recently been renovated with the application of 50mm of expanded polystyrene External Insulated Façade system (EIFS) achieving a u-value of 0,56W/m^{2}K. Due to limited funds fenestration was only upgraded from steel framed single glazing to aluminium framed single glazing. However some residents, at their own cost, have installed secondary glazing but only on bedroom windows. Even so, residents of the building interviewed by the authors reported greatly improved thermal comfort and one resident reported 50% reduction in their firewood consumption. In addition to these saving the authors noted how well informed and enthusiastic the residents were with regards to energy efficiency following the renovation process.

3.2.1 Chilean Energy Efficient dwellings

To date there yet to be built in Chile a sustainable mixed use residential project. The cutting edge projects that have aimed for energy efficiency have been limited to houses; either detached such as in the case of the gated community of Condominio Frankfurt Temuco (fig 8); or terraced in the case of Lo Espejo II in Santiago (fig 9); or in a few exceptional cases purely residential apartment blocks such as Edificios Rotterdam (fig 10), la Haya and Brandenburg also in the city of Temuco. In all of these projects the major aim is to improve the thermal properties of the building envelope but none of them innovate with the building form or mix of building program. All are purely residential projects which continue the reliance on motorized transport for even simple daily tasks.



Figures 8, 9 and 10 Condominium Frankfurt, Lo Espejo II and Edificio Rotterdam

4. Conclusion

The cities of Chile's Central Valley face a serious problem regarding airborne pollution with many already declared saturated in terms of PM10. This pollution in many cases is directly related to the poor quality housing stock that is thermally inadequate and the use of inefficient wood burning heating appliances. Transport is also cited as a major contributing factor, with a high dependency on private cars and an overcrowded, highly polluting, public transport system. It would therefore appear that an energy efficient mixed use residential project could provide a key building block for a sustainable future for these cities. This would reduce the emissions related to wood burning heating through lowering heating demands by improved thermal envelope, providing an efficient volume to surface area ratio and allowing low emission centralized heating systems to be implemented. The mixture of uses would also reduce the emissions related to transport by allowing walkable neighbourhoods where the majority of daily needs are met in neighbouring or even the same building. In Chile rare examples of mixed use residential developments have existed in the past. Energy efficiency is an emerging market in Chile but as yet is limited to a few key projects predominantly focused on the individual house rather than residential housing blocks. International examples show that it is possible to combine complex programs in visually pleasing architecture and that sufficient technical knowledge exists to create energy efficient sustainable buildings. The review of the national situation concludes that although there exists an emerging energy efficiency market, developers are unwilling to innovate and take a risk on the as yet unproved market of the mixed use residential building. Time is therefore required to allow research and the development of a strong business plan for a prototype that can form a building block for a sustainable future for Chile's contaminated cities.

References

Ambiente Consultores (2007) Programa de Inversión Pública para Fomentar el Reacondicionamiento Térmico del Parque Construido de Viviendas. Resumen Ejecutivo. Santiago de Chile.

Antunovic C (2012) Desarrollo Solar Térmico, *La Tercera,* 1st November 2012, p.26

Bustamante W, Cepeda R, Martínez P and Santa María H (2009) "Eficiencia energética en vivienda social: un desafío posible." In *Propuestas para Chile: Concurso Políticas Públicas 2009* . Universidad Católica de Chile, Santiago de Chile: p. 253-282

Caldera Sánchez A (2012) "Building Blocks for a Better Functioning Housing Market in Chile", OECD Economics Department Working Papers, No. 943, OECD Publishing. (available online: http://www.oecd-ilibrary.org/ [accessed on 22/03/2012])

Condominios Frankfurt (2011) (available online: http://www.condominiosfrankfurt.cl/contacto.html [accessed on 04 May 2012])

Congreso Nacional de Chile (2010) Plan de Prevención y Descontaminación Atmosférica para la Región Metropolitana, Biblioteca del Congreso Nacional, Santiago de Chile: p. 60

Congreso Nacional de Chile (2010) Plan de Prevención y Descontaminación Atmosférica para la Región MetropoTemuco y Padre las Casas, Biblioteca del Congreso Nacional de Chile, Santiago de Chile: p. 10

Comisión Nacional del Medio Ambiente, CONAMA Temuco (2009), Plan de Descontaminación Atmosférica Temuco – Padre Las Casas (available online: http://www.pdatemucopadrelascasas.cl/ [accessed on 20/03/2012])

Cullinan Studio (2012) Cullinan Studio, London. (available online: http://issuu.com/amyglover/docs/cullinanstudioanthology?mode=window [accessed on 14/11/2012])

Disch, R. (2006) Presentation to the Technological Mission of the Camara Chilena de la Construcción. Freiburg, Germany, November 2006. Unpublished.

Fernández T (1991) La oficina Murtinho & Asociados Arquitectos. Santiago de Chile: Editorial ARQ.

Healy JD (2004) Housing, fuel poverty, and health: A Pan-European Analysis, Ashgate Publishing, Ltd., England

Instituto Nacional de Estadistica (2012) “Resultados Preliminares Censo de Población y Vivienda 2012” Santiago de Chile, (available online: http://www.censo.cl/2012/08/resultados_preliminares_censo_2012.pdf [accessed on 12/11/2012])

Kottek M, Grieser J, Beck C, Rudolf B, and Rubel F, (2006) World Map of the Köppen-Geiger climate classification updated. Meteorologische Zeitschrift, Vol. 15, No. 3, 259-263. (available online: http://koeppen-geiger.vu-wien.ac.at/present.htm [accessed on 20/03/2012])

Márquez M and Miranda R, (2007) Una estimación de los impactos en los presupuestos familiares derivados del sostenido aumento en los precios de la energía, Universidad Austral, Valdivia, Chile.

Ministerio de Energía (2010) Balance Nacional de Energía 2009, Santiago de Chile. Anexo 1. Balance Electrico. (available online: http://antiguo.minenergia.cl/minwww/opencms/14_portal_informacion/06_Estadisticas/Balances_Energ.html [accessed on 15/11/2012])

Prieto M (2009) “El 44% de los departamentos en Santiago son Full Electric.” Veoverde. (available online: http://www.veoverde.com/2009/07/el-44-de-los-departamentos-en-santiago-son-full-electric/ [accessed on 13/11/2012])

Russo H, Rodríguez G, Behm H, Pavez H, MacDonald J, and Testa M, (2008) Climatic Dwellings for Chile and Recommendations for Architectural Design, Chilean Standard NCh 1079 of 77 (2008)”, Institución Nacional de Normalización, Chile

Scheile y Werth (2012) Constructora Schiele y Werth Ltda (available online: http://www.constructorasw.cl/ [accessed on 04/05/ 2012])

Schlack E (2012) Interview with researcher of Centro de Investigaciones Territoriales y Urbanas. Interviewed by Christopher J. Whitman, Universdiad Andrés Bello, 28/08/2012

SINIA Sistema Nacional de Información Ambiental (2009) (available online:http://www.sinia.cl/1292/w3-propertyvalue-15480.html [accessed on 04/05/ 2012])

Sustainability Hub, Case Studies, RIBA (2009) (available online http://www.architecture.com/SustainabilityHub/Casestudies/7-TheStonebridgeHillsideHub.aspx [accessed on 09/01/2013])

Wüstenhagen R (2011) “Rolf Disch´s Solarsiedlung am Schlierberg: a solar housing estate in Freiburg: from an architectural vision to entrepreneurial reality” in S. Lahlou, *Case Studies in sustainable Consumption and Production: Energy Use and the built Environment.* Sheffield: Greenleaf Publishing p.65-74