

The mixed use residential building: A solution for Mediterranean Chilean cities declared saturated in terms of airborne Pollution.

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ABSTRACT: In Chile the architectural design of all types of residential developments, and their related services, occurs with no significant consideration of sustainability, energy efficiency or environmental comfort. This lack of consideration not only results in low standards of habitability, connectivity, social integration and health problems but also in the associated ever increasing operational costs, where the greatest impact is felt by the lowest strata. These problems are compounded in Chile's central valley, a climatic region with cold winters and hot summers, where many cities have been declared saturated in terms of airborne pollution. This contamination is a direct result of the thermally inadequate housing stock, intensive use of poor quality wood for heating and the use of inefficient stoves. The study of the mixed use residential building typology presented in this paper incorporates the assessment of sustainable design at every scale from urban placement to construction details and building management. Although there exists sufficient international theoretical knowledge, and national political will, architects are faced by timeframes too tight to apply and validate these theories. Further research is therefore required to provide a prototype applicable to the Chilean reality upon which Chilean architects and society can build.

Keywords: Housing, mixed-use, energy efficiency, airborne contamination, sustainable neighbourhood.

INTRODUCTION

The housing stock in Chile consists of around 4.4 million dwellings, of which only 0.8 million have been constructed following the introduction of basic thermal building regulations in 2000 [1]. Of the 3.6 million dwellings built prior to the regulations, very few could be considered as adequately insulated considering the heating demand of their climatic location. The burden of household energy costs exacerbates already low incomes, health problems, fabric decay and environmental problems. These costs and problems could finally end in a depreciation of the scarce family assets, averting any hope of breaking the poverty cycle.

In some southern urban areas over 80% of households rely on firewood. Air pollutants coming from inefficient and contaminant stoves and poor quality wood have deteriorate air quality to such an extent that health problems have become a major threat, in addition to diseases related to cold exposure and stoves with no external flue [2]. This fact made imperative the improvement in the energy performance of housing in order to reduce wood burning.

Furthermore, 60% of Chilean homes have an average winter internal dry bulb temperature of less than 15°C,

and 30% a summer dry bulb temperature of over 30°C [3]. This fact implies low standards of habitability, such as low comfort levels, unacceptable indoor air quality and mold growth. These difficulties are aggravated in the central – southern part of Chile, where over 50% of the Chilean population live [4]. This climatic zone has cold winters and hot – dry summers [5]. In addition the majority of the region's cities have been declared saturated in terms of airborne pollution [6]. The pollutants involved are mostly small carbon particles, resulting from inefficient wood stove heating [7].

To compound all these facts, high costs associated to heating systems affect more and more the domestic household budget. The concept of 'fuel poverty' was first defined by Lewis (1982) in the National Right to Fuel Campaign in Bradford UK as "the inability to afford adequate warmth in the home" [8]. This definition was revised by Healy (2004) to one more closely related to housing design, "The inability to heat ones home to an adequate (safe and comfortable) temperature owing to low income and poor (energy inefficient) housing." [8] More specifically it refers to households that would need to spend over 10% of their annual income on fuels in order to achieve a satisfactory indoor heating. The concept refers to the theoretical value that people 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. In other terms, a fuel poor household either spends too much and/or suffers poor hygrothermal comfort. In Chile, a study showed that during 2006 all but the richest two quintiles of the population could be considered as suffering from fuel poverty [9].

In addition to being affected by the general global energy crisis Chile suffers from a high energy dependency with over 75% of its primary energy being imported in 2010 [10]. All of this imported primary energy is in the form of fossil fuels. In 2010 the National Energy Commission determined that built environment consumes 27% of the energy produced, and that transport, itself directly related to the design and planning of the built environment, consumes an additional 34% [10].

To date there exist few examples of sustainable residential buildings in Chile. Of the studies and built projects that do exist the majority are detached single family dwellings. Given their high surface to volume ratio and low land use efficiency, this housing typology is not an adequate solution for achieve high environmental standards.

ANALYSIS OF INTERNATIONAL MIXED USE RESIDENTIAL BUILDINGS

During the 20th century energy was cheap and abundant and mainly from fossil fuel. Buildings were designed without consideration for their energy efficiency. The use of non-renewable natural resources was common place and the capacity of users to pay operational costs during the whole life cycle of the building was not calculated. At the same time, urban design has been dominated by the modernist concept of zoning, with mono-functional districts: residential, cultural, industrial, business, etc. Based on the ideas of protagonists such as Le Corbusier with his Ville Radieuse and Ebenezer Howard with his garden city, modernist city planning produced cities where a large proportion of the inhabitants have to commute ever increasing distances. This results in a dependence on private car ownership and an overloading of both public transport and urban road networks.

At the beginning of the 1990s there began a growing consciousness, originating in the oil crisis of 1973, that it was neither viable nor desirable to continue to develop cities according to these old tendencies. Stricter energy efficient regulations for building began to be applied. Publications began to appear such as “The Compact City: A Sustainable Urban Form?” [11] “Cities for a small planet” [12] and “Towards an Urban Renaissance”, [13]. These publications developed the ideas of integrated

urban land use and the inclusion of mixed used buildings. In doing so they avoided single function zoning, promoting walkable neighbourhoods reducing the need for private transport and inner urban journeys. These concepts have at times been misunderstood as a call for increased density, whereas in reality they call for an increase in urban intensity with the inclusion of active neighbourhoods. Neighbourhoods designed using a human scale, where single and married people, families and pensioners live, work and socialize together.

The following case studies were developed following the concepts of energy efficiency, mixed used programming and sustainability, in order to achieve buildings with low carbon emission, low energy and water demands and the use of low impact materials, whilst promoting a high standard of living and environmental comfort.

INTERNATIONAL CASE STUDIES: SONNENSCHIFF

The Sonnenschiff or Solar Ship Building (2004, Freiburg, Germany) is the most important building of Vauban sustainable borough in Freiburg, Germany’s “Solar City.” Vauban is a new concept of neighbourhood, finished in 2001, with 5000 inhabitants and houses built under the concepts of “Pasivhaus” and “Plusenergyhaus.” The latter of these not only have an annual heating demand of $\leq 15\text{kWh/m}^2$ per annum, but produce more energy than they consume due to the incorporation of photovoltaic panels on their roofs. All of the houses are of super insulated timber framed construction, built using only healthy building materials [14]. The Sonnenschiff, designed by architect Rolf Ditch in 2004, comprises of 9 “penthouse” two story dwellings, situated within roof gardens on the rooftop; offices, studios and clinical practices on the second and third floors; shops and cafes at street level; and parking in the basement. Public transport links Vauban to the centre of Freiburg 4km away, thereby reducing private car use, congestion and carbon dioxide emissions. Users also are organized with a car-sharing system. Together these measures leave public spaces car free. When operation and construction costs are included in the calculation, these house are cheaper than normal German market homes [15]. The innovative technical items included in the Sonnenschiff are: PV roofs, use of geothermic energy, rainwater reuse, high standards of external thermal insulation, vacuum insulation, and controlled ventilation with heat recovery.

ONE BRIGHTON

One Brighton (2009, Brighton, UK) is the latest project of the BioRegional company and the first One Planet Living Community project to reach completion [16]. One Planet

Living was developed by BioRegional in conjunction with the World Wildlife Fund WWF under 10 concepts: Zero Carbon; Zero Waste; Sustainable Transport; Sustainable Materials; Local and Sustainable Food; Sustainable Water; Land Use and Wildlife; Culture and Heritage, Equity and Local Economy; and Health and Happiness [17]. It provides 172 residential units with a mixture of private and social ownership. In addition it includes community spaces and mixed business uses. It was designed by Feilden Clegg Bradley Architects. It is a high density, mixed use, 8 storey building. Bioregional worked with the developer Crest Nicholson in order to realize this project. One Brighton is not only a sustainable building, but was designed to look similar to any normal residential building on the market at that time. Given that the sustainable features are not so apparent; the project could compete in the normal house market in the UK, rather than being marketed at a specific “green” clientele [18]. Today every apartment is sold [16].

Technological features include: biomass boiler; car club; rooftop allotment gardens; PVs and solar thermal panels; external insulation is of rigid panels of cellulose fibres, which provide U-values 25% better than British thermal building regulations. The U-value of walls being 0,21W/m²K and 0,8W/m²K for windows; windows from Swedish Timber Products are triple glazed, laminated pine interior frames and aluminium exterior frame with “warm edge” technology [18].

STONEBRIDGE HILLSIDE HUB

Stonebridge Hillside Hub (2009, London, England) is a mixed-use residential building that belongs to the last reconstruction stage of the Stonebridge housing estate located in northwest London [19]. The mixed tenure residential project includes 25 apartments with government subsidy and 34 for the private market. In addition the building contains: a community centre; computer centre; multi-purpose hall; offices; a healthcare centre for the Brent Primary Care Trust; a café; a supermarket; parking, including bicycle parking; and a community garden. It has received the “Eco-Homes Very Good” certification. The thermal insulation of the building envelope exceeds British building regulations with an energy demand of 73kWh/m²/year. The social center also has rainwater harvest and solar panels.

HEMICICLO SOLAR

The “Hemiciclo Solar” (2009, Mostoles, Madrid, Spain) is a 92 apartment social housing building designed under sustainable criteria [20]. Its orientation and form make full advantage of passive solar energy. Moreover there are also solar protections and geothermal heating and cooling with solar chimney for cooling warm air during

summer. The building has shops and common areas on the ground floor, located in front of a public space also designed under sustainable concepts. A microclimate is created in open spaces through green areas and water ponds.

COVI COOPERATIVE

The Covi Cooperative (2000, URUGUAY) [21] is a residential community providing 50 duplex apartments with a total built area of 3.800 sq.m. including green areas and children playgrounds. It began as an ordinary project in 2000 but between 2007 and 2009 was adapted by a government office to become a more sustainable project. Sustainable features include a thermal envelope; rain water harvesting and recycling using roof top evaporative pools; solar thermal panels; natural lighting through clerestories; natural ventilation through wind towers; construction materials with low embodied energy; and recycling and management of waste. It is claimed that this project can reduce CO₂ emissions by 47 tons per annum, reduce water consumption by a half and at the same time raise living standard of its residents [21].

NATIONAL STUDY CASES:

LO ESPEJO II

Lo Espejo II (2009, Lo Espejo, Metropolitan Area of Santiago) [22], is currently probably the most emblematic new build social housing project in Chile. This experimental Project consists of 125 semi-detached houses built as part of a project to eradication slums with housing subsidies from the “Fondo Solidario de Vivienda” (Solidarity Housing Fund) and managed by the charitable foundation “Un Techo para Chile” (A Roof for Chile). The main objective, above and beyond those normally included in government social housing, was to thermally improve the household envelopes. Energy simulation programs were used and energy, design and material improvements were set out.

According to TAS simulations, with walls constructed of autoclave cellular concrete blocks the heating demand would be 48kWh/m² per annum. This signifies an average energy saving of 45% in winter and reduced overheating in summer. Despite the fact that thermal insulation material was of good quality, the building system had serious problems with thermal bridges caused by concrete floors and pillars required to meet seismic building regulations.

The second phase of this Project, Lo Espejo II, was coordinated by the “Casa de la Paz” foundation and financially supported by the Environment Protection Fund of “CONAMA Metropolitana” (today the Ministry of the Environment). These funds aim to promote

participative environmental management. Consequently the residential development's facilities are related to environmental and sustainable activities such as community allotments for household consumption, organic waste treatment through composting, dedicated recycling bins and community tree planting (Fig. 10).



Figure 1: Lo Espejo II project objective image [23].

Unfortunately it would appear that the project will not form the basis for future projects. In an interview with the director of the foundation “Un Techo para Chile” for the newspaper “El Mercurio” [23], Daniel Garcia said, *“This neighborhood is a project that cannot be replicated as social housing development model. Instead the lifestyle will be studied for a year and its benefits will serve to generate debate on social housing policies.”*

CONDOMINIOS FRANKFURT

Condominios Frankfurt (2008, Temuco, Región de la Araucanía/IX Región) is a gated community of 5600m² containing 34 detached houses [24]. It was designed according to European energy efficiency standards and financed by the government program “CORFO Innova”. The increased thermal standards of the building envelope allow the show house to achieve an electrical energy consumption for heating of 27 kwh/m² year as measured by the Universidad Mayor de Temuco in collaboration with “Chile Consultores”. It is the first gated community in the country that has a district geothermal system for hot water supply. This project shows that it is possible to apply international standards to the Chilean reality.

EDIFICIO ROTTERDAM

This 12 storey housing project (2007, Temuco) of 12 floors was completed in October 2007 [25] (Fig. 17). The development by the developer Schiele y Werth won the National Energy Efficiency Award in 2009 for its building envelope that exceeded the current thermal building regulations. The building has PVC double glazing windows and an air source heat pump heating system. The developer has since completed other housing developments of the same profile, “Edificio Brandenburg” and “Edificio Haya.” A further project “Condominio Valle del Sol” is under construction this time with a ground source heat pump.



Figure 2: Condominio Frankfurt (100% sold) [24] Figure 3: Rotterdam building. Author's photo

According to an unpublished study by the Chilean Agency of Energy Efficiency, the building would obtain a B classification under the, as yet not in use, certification system of the Ministry of Housing. The study also indicates a lack of energy efficiency in the building's mechanical plant. Furthermore, issues like environmental and energy impacts of construction materials, promotion of sustainable lifestyles, renewable energy or sustainable landscaping and urban planning are not considered.

EDIFICIO BARROS ARANA

Built in 1959 in Temuco the two social housing blocks of Edificio Barros Arana have recently been renovated using government funds under the program PPPF (Programa de Protección de Patrimonio Familiar). The renovation focused on the improvement of thermal comfort and the reduction of heating demand with the express purpose of reducing the contamination produced by the wood burning stoves. To achieve these goals, 50mm of expanded polystyrene was applied externally as an External Insulated Façade system (EIFS) achieving a u-value of 0,56W/m²K (figure 4). Due to limited funds improved fenestration was not included. 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.



Figure 4&5: Edificio Barras Aranas before and after.

SUMMARY OF CASE STUDIES

All projects reviewed have a building envelope insulated above and beyond that required by local building

regulations (Table 1). However the effectiveness of this measure is directly related to the stringency of the local building regulations. Given that the Chilean regulations have been criticized both nationally [27] and internationally [28] for their weakness, the improved u-values are not as low as their international counterparts. Despite this, the example of Edificio Barros Arana shows that improvements to the thermal envelope have produced a significant reduction in their fuel consumption and as a result the associated airborne contamination.

Table 1: Summary of international and national building and their features. (X-included and O-not included)

	Building Typology	Mixed use	Thermal Building Envelope ¹	Low impact materials specified	Sustainable Management ²
Sonnenschiff	building	X	X	X	X
One Brighton	building	X	X	X	X
Stonebridge	building	X	X	X	O
Hemiciclo solar	building	X	O	O	O
Coop. COVI	terraced	O	X	O	O
Lo Espejo II	terraced	O	X	O	X
Condo.Frankfurt	detached	O	X	O	O
Edificio Rotterdam	building	O	X	O	O

¹Additional to current building regulation requirements

²In use, following building completion

The application of active systems is less common in the national examples with none of the projects including on-site renewables. This may well change with the introduction of the new net metering law 20.571 [29], however the low feed in tariffs included in the law will probably inhibit the rapid boom in the introduction of these technologies as seen in countries such as Germany.

Within the buildings studied there can be identified two distinct groups, those that have a distinctive architectural style such as Sonnenschiff and those whose external appearance is no different from other projects in the local residential market, such as One Brighton. The “normal” appearance of the latter has been identified in the project’s success [18]. Given that the Chilean market is relative conservative, this approach would appear the best option to pursue.

The most marked difference between the international and Chilean case studies is the absence of mixed use schemes. Since the 1930s Chilean urban planning has been dominated by the modernist model of single use zoning which discourages or actively prohibits mixed use developments. 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 [30].

CONCLUSIONS

More than 50% of Chilean population live in the Central valley of Chile, where dwellings fail to respond to the cold winters and hot summers. Of the fifteen most frequent housing typologies that exist in the Central Valley, ten are variants of the one or two floor detached or semidetached single family house [31] a typology with a greater exposed surface area to volume ratio than any other type of residential development. The thermal quality of dwellings building envelope is very poor, leading to high heating demands and uncertified wood is burn in inefficient stoves and wood burning cookers resulting in most of the central valley cities being saturated with airborne pollution.

Meanwhile, research related to both social and environmental management of projects, and the required high standard technologies applied to mixed use residential buildings, has not been developed at a national level. The case studies presented in this paper show that the design and construction of this building typology has succeeded in Europe and has proved to become integrated in the housing market. All of them show a wide range of sustainable features successfully incorporated in one project, alongside complex building programs (Table 1), a goal that Chilean political and research funding authorities have informed the authors is “unachievable” [32].

The introduction of this building typology in Chile’s Central Valley could contribute in part to providing a solution for the contaminated cities, providing homes where people suffer neither cold nor overheating. Improved thermal building envelopes could reduce heating demand and associated airborne contamination. Mixed use developments would reduce unnecessary car journeys further reducing air pollution.

Summarizing, although there exists sufficient international theoretical knowledge, and national political will, architects are faced by timeframes too tight to apply and validate these theories. Research is therefore required

to provide sufficient time and in addition challenge the reluctance of developers to innovate. In doing so it should be possible to build mixed-use residential projects that not only succeed in the residential market but also instil in their inhabitants an environmentally responsible way of living. Thereby providing the first step to resolving the problems faced by Chile's contaminated cities.

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