Global Compact Cities Programme and RMIT University

Sustainable Affordable Housing: New Models for Low-Income Housing in Chile

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Abstract
In the context of increasing urbanization in Latin America, UN-Habitat encourages addressing housing issues focusing on housing quality, eliminating slums and the development of market-based approaches to increase affordability and accessibility for low-income households. Chile’s housing policy has been considered successful as it effectively reduced the accumulated deficit. It also enables the involvement of non-government organizations in the development of low-income housing projects. One of these organizations is TECHO, which aims to reduce poverty and precarious settlements through a close community-participation approach. In the context of Chile’s energy insecurity and climate change, TECHO is introducing energy efficiency measures in their housing projects. However, TECHO faces a major barrier: upfront costs and the effect on the affordability of the house, independent of the operating cost savings. This paper assesses the economic benefits of implementing energy efficiency in low-income housing through cost-benefit analysis and examines innovative financing approaches to provide ideas for financing energy efficiency in low-income housing projects in Chile.

Keywords
Energy efficiency • low-income housing • EPC • ESCO
1. Introduction

With a population over 17 million, Chile is one of the fastest growing economies in Latin America with a GDP growth of 5.5% and a per capita annual growth of 3.8% (average for the last 20 years). In 2010, Chile became the first South American country to the OECD (World Bank 2013).

Most of the population in Chile lives in cities, the main ones being Santiago, Concepción, and Valparaiso. Rapid and increasing urbanization has led to the establishment of irregular settlements. Still, the proportion of population living within the poverty line has fallen from 20% in 2000 to 14.4% in 2011, and currently Chile has one of the lowest housing deficits in Latin America. Chile’s housing policies are considered by international agencies such as the World Bank and the Inter-American Development Bank, as a best practice model. Nonetheless, inequality and poverty still prevail (World Bank 2013).

Chile’s current housing policy allows private and social organizations to be involved in the process of providing housing. TECHO, ‘Un Techo Para Chile’ (translated as ‘A Roof for Chile’, Techo) is one of these organizations. Particularly, TECHO develops projects with the lowest-income settlements with a community development strategy centred upon community and volunteers’ engagement and participation.

Although housing developments are funded by government subsidies, TECHO’s philosophy is to provide better housing projects and thus they invite private organizations and companies to invest in the housing developments as part of their corporate social responsibility.

In recent years, to align themselves to the country’s needs and commitments to reduce energy insecurity and impact on the environment, TECHO is developing a strategy to provide housing that is more sustainable. Along with institutions such as the Chilean Energy Efficiency Agency (ACHEE) and the German NGO GTZ, TECHO has carried out studies on household energy use, and technical assessments of design and economic performance of existing housing projects. Lo Espejo housing project was the first type of development from TECHO’s projects to include energy saving features in the design. Results from these studies are contributing to a framework for future housing developments. However, in order to attract further investment in energy efficiency features there is a need to reconcile the costs and benefits of such investments.

This paper reviews relevant literature and assesses the economic benefits of implementing energy efficiency in low-income housing through cost-benefit analysis.

The results provide a basis for energy efficiency investment. TECHO relies on government subsidies and support (donations) from private companies to finance the
housing projects, but energy efficiency is often regarded as a risky investment and is not well understood by traditional finance mechanisms. Relatively new finance mechanisms focused on energy efficiency investments, such as Energy Performance Contracts (EPC), carried out by Energy Service Companies (ESCOs) are growing in importance as a promising strategy for a wider spread adoption of energy efficiency. This paper draws upon such mechanisms to provide ideas for financing energy efficiency in low-income housing projects in Chile.

2. Background

2.1 The Context of Low-income Housing in Chile

The Latin American region contains emerging and growing economics, which has led to a rapid increase in urbanization. According to the Inter-American Development Bank (IADB) and the United Nations Human Settlements Programme (UN-Habitat) the region is also the most urbanized globally, with 75.5% of the population living in cities in 2000. This figure is expected to increase to 85% by 2030 (Bouillon 2012; McBride 2011).

Despite the GDP high performance and high rates of house ownership, economic disparities, the prevalence of slums, and the quantitative and qualitative deficit of the housing stock present challenges for Latin American governments. UN-Habitat encourages governments to address housing issues focusing on housing quality, eliminating slums and the development of market-based approaches to increase affordability and accessibility for low-income households (McBride 2011).

Social housing or low-income housing is defined as “housing that is built for sectors of the population with lower economic resources” (Ceron-Palma 2013). The Inter-American Development Bank (IADB) defines housing as adequate when it involves legal rights, basic infrastructure and services (electricity, water, and drainage), affordability, accessibility, habitability, location and an adequate cultural environment (Bouillon 2012).

Chile’s housing policies are part of a broader evolution and development of housing provision across Latin America. Housing policies have shifted away from a direct government provision system, through a ‘self-help’ approach, to a market-based mechanism. The World Bank, IADB and USAID, consider this policy as best practice model for targeting the poor in a more efficient and effective way (McBride 2011; Posner 2011).

In the 1970’s housing policies in Chile delegated housing finance and construction to the private sector, and state subsidies were awarded through stratifying means-testing which combined one-time subsidy, obligatory savings, and an optional loan component (McBride 2011; Posner 2011). It also allowed social and private organizations to work together with municipalities to provide emergency and permanent housing, as well as to
develop solutions for other neighbourhood social issues (Burgos 2011).

This public financing mechanism allowed for substantial improvement in housing provision, especially for the low-income sector. It reduced the accumulated housing deficit, contributed to informal settlements regularization, slum clearance and replacement, and allowed the improvement of the quality of dwellings (McBride 2011).

Nonetheless, authors have pointed out some of the deficiencies of this policy (Posner 2011; Rodriguez 2011):

- The prevailing low quality and poor design of the dwellings, which lead to dissatisfaction among beneficiary families.
- Benefits accrue to middle-class sectors, intensifying social stratification and isolation among the poorest sectors.
- Competition and distrust in private provision discourages collective action and unity.
- Ongoing social issues such as insecurity, delinquency and drugs and lack of space, are associated with further marginalization and isolation.

One of the most comprehensive housing stock studies in Chile, based on the 2002 census, showed the quantitative and qualitative housing deficit still faced by the country. Chile has included housing statistics in their census since 1952, which include data on the type of dwellings, tenancy, construction materials, lighting and other services and equipment. However, in the 2002 census, the Ministry of Housing and Urbanism (Ministerio de Vivienda y Urbanismo, MINVU) extended the study to better characterize and define the quantitative and qualitative housing deficit.

Dwellings were categorized qualitatively according to the type of dwelling, sanitary facilities, and the condition and type of construction materials of walls, roof and floor (as shown in Figure 1).

![Dwelling categories](image)

**Figure 1:** Dwelling categories. Translated and modified by author from (MINVU 2004, pg 23)

The quantitative deficit was identified based on the level of overcrowding in households, plus the stock needed to replace irreparable dwellings (3.99%). From the 3,899,448
dwellings studied (MINVU 2004):

- Around 12% of households lived in overcrowded condition, either living with other members of the family or with other families;
- Of the overcrowded households 30% of the families are potentially financially independent;
- 46.5% of housing construction requirements are concentrated in the metropolitan areas of Greater Santiago, Greater Valparaiso and Greater Concepcion;
- In contrast, requirements for extension and improvement of dwellings are concentrated in cities with less than 100 thousand inhabitants; and
- Around 40% of housing need is for the lowest income sector.

To address these issues, in 2002 the MINVU made changes to the housing and subsidies policies to allocate almost 70% of the housing resources to the neediest households, which had not been able to access to housing subsidies before (McBride 2011). Further changes to the policies were made after the 2010 earthquake and tsunami (which increased the housing deficit), to improve programme efficiency, simplify the application system and improve incentives for families (CCHC 2011). Nowadays, Chile has one of the largest and most well developed housing finance mechanisms in Latin America representing almost 20% of GDP (Bouillon 2012).

2.2 Climate Change and Energy in Chile

2.2.1 Climate Change

Impacts from climate change in Chile represent social, economic and environmental risks for the country (CNACG 2006).

The projections of the impacts from climate change under the Intergovernmental Panel on Climate Change (IPCC) A2 scenario are (MMA 2011):

- Increased ocean and land temperatures, especially in the Central Valley and the Andes Mountains (where most water resources are stored);
- Susceptibility to natural disasters, droughts in low-lying coastline and desertification in arid, semi-arid and forest ecosystems;
- Major impacts on water resources, greater in south and northern regions, due to changes in precipitation and retreating glacier ice cover (most important source of water source);
- Soil erosion affecting the agriculture, livestock and forestry sectors;
- Effects on biodiversity through the shift in species distribution, although low rate of extinction.

In 2009, Chile contributed 0.22% of global greenhouse gas (GHG) emissions, making it 47th in the global ranking. GHG emissions have increased by 300% over the period 1984 to 2003, mainly due to the growth in the energy sector (CONAMA 2008). Chile is the 6th largest emitter in Latin America after Mexico, Brazil, Venezuela, Argentina and Colombia.
(in 2009) and is also 6th in emissions per capita (World Bank 2013).

Chile is a signatory party to the United Nations Framework Convention on Climate Change (UNFCCC) since 1994 and ratified the Kyoto Protocol in August 2002. It has no binding agreements to reduce its emissions as a developing country; however, the government is highly committed to mitigating and adapting to climate change impacts. Two national communications have been submitted: 2000 and 2011.

The government created the National Advisory Committee on Global Change (Comite Nacional Asesor sobre Cambio Global, CNACG) in 1996. The CNACG has developed: the Strategic Guidelines on Climate Change in 1998; the National Strategy for Climate Change in 2006; and the National Action Plan on Climate Change 2008-2012. These strategies recognize the opportunities to reinforce environmental policies, contribute to sustainable development and alleviate poverty by: incorporating adaptation and mitigation measures in national, regional and local development plans; technology transfer; and generating financial arrangements to promote the necessary investments. The government has also greatly promoted Clean Development Mechanisms (CDL) for which the CDL National Authority was established in 2003 (CNACG 2006).

2.2.2 Energy and Energy Efficiency

The energy sector is the largest contributor to GHG emissions, with significant growth in the transport and energy generation sectors. The energy generation sector, however, is greatly at risk since it is largely dependent on water resources, which, as stated before, are projected to be affected by changes in the climate conditions. This is an important consideration for energy policies (CONAMA 2008).

Chile’s electricity generation mix comprises: Hydropower (42%), coal (25%), gas and diesel (17%), wood (7%), natural gas (6%), and other (3%, non-conventional renewable energies) (IEA 2012). The energy industry is comprised of privatized generation, transmission and distribution activities, with reliance upon private capital to fund increases in installed capacity and productivity.

Over the last decade, severe droughts affecting hydropower production, the rationalization of natural gas supply from Argentina, and more recently, the damages to refineries and electricity grid caused by the 2010 earthquake, have emphasized the deficiencies of the energy system and exacerbated energy insecurity. This situation has led to an increase in energy production from coal and diesel, and since Chile has limited indigenous fossil fuel resources, increasing imports have led to increasing electricity prices. Chile has one of the highest electricity prices in Latin America, above OECD average. Furthermore, electricity demand is projected to increase at 6 – 7% per annum (IEA 2012; MinEnergia 2012).

Given this context of energy insecurity, the government embedded the development of renewable
energy and increased fuel diversity into the energy and climate change strategies. Chile has great potential to develop small and large-scale hydropower and biomass, solar and ocean energy (IEA 2009). The government has also focused on reducing energy demand through energy saving publicity campaigns (IEA 2009; IEA 2012). Programmes related to energy saving and energy efficiency have targeted variously: daylight saving time, peak hour electricity pricing and load limiting (Agostini 2012).

With an overall goal of reducing demand by 12% by 2020 (MinEnergia 2012), the National Energy Strategy recognized as the first key step the necessity to “adopt a commitment to energy efficiency and promote it as public policy to reduce consumption and break the relationship between economic growth and energy demand” (MinEnergia 2012).

Investing in energy efficiency is considered by many authors and governments as the most cost-effective option and policy tool to reduce energy consumption in the short to medium term, as there is a reduced need for energy production and its associated GHG emissions (IEA (b) 2012; Limaye 2011; World Bank 2005).

Government agencies across transport, housing and economic development sectors, are now targeting energy efficiency, and are increasingly developing strategies and action plans to encourage its implementation (APEC 2009; Limaye 2011). According to the Energy Studies and Research Programme (Programa de Estudios e Investigaciones en Energia, PRIEN) at the University of Chile, energy demand could double in the period from 2007 to 2021 nationwide. Yet through a widespread energy efficiency, 20% of energy demand could be reduced (APEC 2009).

The following agencies have been established to target energy efficiency:

• National Energy Commission (Comision Nacional de Energia, CNE): which developed the Energy Efficiency Action Plan 2012 – 2020 (Plan de Accion de Eficiencia Energetica) and the National Energy Efficiency Programme 2005-2010 (Programa País de Eficiencia Energetica, PPEE);

• Chilean Energy Efficiency Agency (Agencia Chilena de Eficiencia Energetica, ACHEE): is a corporation-like designed agency, where decision making is shared by private companies and authorities (APEC 2009).

2.2.3 Energy Efficiency in the Residential Sector

Energy efficiency strategies in Chile span across all energy consumption sectors. As show in figures below, the buildings sector account for almost 30% of total electricity demand in 2009 and for 24% of total gas consumption in 2010 (IEA 2012). In the 2011 statistics this sector accounted for 26%, out of which 77% of the energy consumption corresponds to residential buildings.
The residential sector is clearly a large energy consumption sector, and energy efficiency programmes and campaigns have played a prominent role in energy efficiency policy.

Besides addressing the housing deficit, energy scarcity means there is an urgent need to provide sustainable homes that exert less pressure on natural resources and mitigate and adapt to climate change. This is particularly critical in the case of social housing, which has often resulted in replicated models that disregard climatic conditions and energy consumption, potentially resulting in fuel or energy poverty and/or increased use of energy (Ceron-Palma 2013; Seyfang 2010).

Healy (2004) defines a fuel poor home as the one that “does not have the adequate financial resources to meet these winter home-heating costs, and because the dwelling’s heating system and insulation levels prove to be inadequate for achieving affordable household warmth”. Fuel poverty is directly related to the energy price increase and the level of energy inefficiency of the dwellings, because they consume more energy than necessary. Energy inefficient houses also increase health risk especially for children and elderly people (Healy 2004).

Significant environmental and economic resources savings are achievable through tailored features that take into consideration energy use variables such as technology, housing design and size, and occupants’ behaviours and practices (Ceron-Palma 2013; Dominguez 2012).

In Chile, residential buildings account for 77% of building sector energy use. The residential fuel mix is shown in Figure 3. Firewood is the most commonly used fuel, mainly used for heating and cooking. Oils derivatives include combustible oil, diesel, kerosene and liquefied gas. Consumption of natural gas has increased in recent years, mainly due to environmental and health concerns from the use of firewood and kerosene. It is worth noting that gas and liquid petroleum gas (LPG) figures overlap, since LPG consumed in replacement of natural gas in the form of ‘LPG aire’ during gas

Figure 2: a) Energy consumption by sector; b) Energy consumption by type of building. All types of fuel, 2011 (MinEnergia 2011)
supply shortages (IEA 2012).

Figure 3: Residential energy consumption by fuel, 2011 (MinEnergia 2011)

Residential energy use is a function of the characteristics of the dwellings and household composition and practices, as well as the equipment and services provided, and the frequency and intensity they are used (Agostini 2012).

The MINVU and the Ministry of Energy (ME) have developed various initiatives to reduce energy consumption in the residential sector. Some of the energy efficiency programmes that have had impressive results, especially during the 2008 energy shortages, are (APEC 2009):

- Widespread adoption of compact fluorescent lamps (CFL);
- Energy labelling for appliances;
- Minimum construction standards for envelope insulation (mandatory for new homes since 2007, and retrofit programmes for existing homes);
- Energy certification programme for residential buildings.

2.3 TECHO

“A number of independent initiatives, emerging from NGOs, community groups, and local governments have worked to address housing issues in low-income communities through new housing construction, housing improvements, and infrastructure provision. They represent more than just a method for conveyance of subsidies or delivery of housing, but utilize the process of producing housing as an opportunity to build communities and local organizational capacities” (McBride 2011).

TECHO (Un Techo para Chile translated as ‘A Roof for Chile’) is one of these organizations. Born in 1997 as a youth led voluntary initiative to construct emergency housing for families living in marginal urban settlements in unacceptable conditions, Techo aims to overcome poverty through (Techo undated):

- Encouraging community development – by promoting leadership, organization and participation of habitants to generate solutions to their problems
• Enhancing social conscience and action – among young volunteers and various society actors who work in the settlements in collaboration with habitants

• Influencing decision and public policy making – by exposing exclusion and vulnerability in settlements so that these issues are recognized and become priority in public agenda.

Since 2010, TECHO has been creating partnerships with private organizations for the finance and development of housing projects, such as architectural firms and construction companies, or organizations which are looking to offset their negative externalities by financially contributing to projects.

TECHO is a “Social Real Estate Entity” (Entidades de Gestion Inmobiliaria Social, EGIS) and a Technical Assistance Service Provider (Prestadores de Servicios de Asistencia Tecnica, PSAT). These are “organizations, “for” or “non-for” profit, that advise families in all aspects (technical and social) needed to access and apply for a housing subsidy” (MINVU undated, translated by author). Techo also develops housing design, according to the needs and desires of the community, advises and prepares the application for the subsidy, and once approved, they supervise the construction, until finally the houses are delivered to the community (TECHO 2013).

In the process of providing families with permanent homes, TECHO has a threefold strategy (TECHO undated):

1) Contact with communities. Young volunteers approach vulnerable communities and identify and characterize the conditions of their homes and settlements. Volunteers start building a trust relationship between the community and Techo, and promote organization and a co-responsible participation among members of the community to start generating solutions to their problems.

2) Participative Spaces. Techo generates concrete solutions to the identified needs in the community by setting up working groups or ‘mesas de trabajo’ with members of the community and volunteers. These working groups meet weekly to develop programmes such as: education, employment and self-employment, health, and others. Also, in this phase Techo’s volunteers and members of the community build ‘emergency’ houses as a first step for community development with great impact on the families’ quality of life.

3) Permanent solutions. Staff members from Techo assist the community in developing a permanent housing project and accessing government programmes (e.g. Housing subsidies, regularization and basic services, local development).

Present today in 19 countries in Latin America and the Caribbean, TECHO has worked with more than 89,500 families constructing their homes, delivered 3,310 permanent
homes, and mobilized more than 530,000 volunteers across Latin America (TECHO undated).  

2.3.1 TECHO’s Energy Efficiency Projects  

With the philosophy of always delivering better projects and making homes more sustainable, TECHO is introducing energy efficiency features in houses. Techo considers permanent housing "as a sustainable way to overcome poverty. The goal is to provide a standard that understands housing not just as infrastructure, but as a relevant and formative process to overcome poverty... [] involving families in the process and present designs that optimize the use of resources and allow expansion and consolidation in an easy and safe way" (Fabron 2012).

TECHO and other institutions, such as the Chilean Energy Efficiency Agency (ACHEE) and the German NGO GTZ, have carried out studies on energy use, including technical assessments of design and economic benefits of existing housing projects. Results from these studies are informing a framework for future housing developments.

Particularly, two housing projects served as case studies for EE improvements: Lo Espejo and Emati, both located in Santiago.

Community of Emati. A study conducted for this community (Fabron 2012) evaluated energy flows and recommended future designs. The community comprised 140 families, with an average of 5.5 people per family, occupying 56 m2 apartments. The study analysed the thermal insulation of two selected apartments. The retrofit and future construction recommendations were centred around: increased external walls insulation, energy saving lighting, optimization of solar gains, and variations in the behaviour of habitants.

Community of Lo Espejo. Following recommendations from the ACHEE, the houses had two energy efficient measures implemented: they were constructed with autoclaved
aerated concrete for improved thermal performance and solar hot water systems, with varying results depending on the house orientation (TECHO 2013).

The community of Lo Espejo lives in two storied homes with an attic in the roof, and a net floor area of 53.8 m2. Unit blocks consisting of between five and twelve units per building are constructed in east-west and north-south orientations. The 125 families (average of five people per family) that comprise the community had lived in slums for an average of six years prior to moving to Lo Espejo.

In her thesis, Clara Mazzone (Mazzone 2011) studied the thermal performance and comfort of Lo Espejo houses. The study concluded that the houses design, construction and thermal conform are far higher than the standards expected in social housing, but there is still potential for further thermal improvement. She identified further potential energy savings from following features: external wall insulation, internal wall insulation, roof insulation, windows and glass doors double glazing, ground slab carpet and underlay, and sealing air infiltrations. She also gave recommendations for improvement and retrofit options for future constructions.

Recommendations from these two projects resulted in the following considerations for future projects:

- Solar hot water systems;
- Construction materials with better thermal performance;
- Correct window location and orientation; and
- Floor insulation.

One of the barriers to implementing the energy efficiency measures in housing more broadly is the high upfront cost. The next two sections will analyse the economic benefits of implementing energy efficiency in homes and will also present ideas for alternative energy efficiency financing models.
3. Cost-Benefit Analysis

This section describes a cost-benefit analysis carried out based on economic data from energy study developed for the Emati housing project. Fabron's (2012) study analysed: optimization of solar gains through window and building orientation, external wall insulation (for construction and retrofit), window insulation, air infiltrations, and upgrade of electric equipment (light bulbs).

This analysis took into consideration the amount of energy saved by improving lighting, improving thermal comfort through external wall insulation, and double glazed windows, noted in Fabron's study. Window and building orientation was not considered for this study because the solar gains will be dependent on each particular housing project. Savings from reduced air infiltrations were treated as part of adapted window opening based on occupants’ behaviour, and for this reason it was not considered as part of this analysis.

Although some inconsistencies were found in Fabron’s study (such as the amount and price of bulbs and data regarding energy consumption), energy use and savings and cost of each improvement was used as is as reported in the study. Information about interest rates, inflation, exchange rates, and others were taken from current reliable sources and databases.

Energy consumption and savings was broken down into types of energy sources (electricity and gas) and how each of the improvements would affect energy consumption. The cumulative effect was also analysed.

As recommended by Jakob (2006) the long-lifetime electricity and gas consumption curves were constructed using yearly consumption affected by inflation and energy demand increase. For the case of Chile, an expected inflation rate of 3% and an increase in demand of 6% were used (IEA 2012).

3.1 Results and Discussion

Electricity Consumption. Fabron's (2012) study assessed the energy saving potential of changing incandescent bulbs (IB) to compact fluorescent lamps (CFL). The figure below shows the electricity consumption with traditional incandescent bulbs and with CFL.

It was found that the investment of incandescent bulbs and CFL considered by Fabron (2012) is quite low in terms of bulbs' price and the number of bulbs per home. Hence, the final investment was modified to a more realistic figure considering a larger number of bulbs per home and the price of each type of bulb.

The lifespan of both types of bulbs was considered in the economic analysis and the result indicate that, even though the initial investment for CFL is higher than for incandescent bulbs, it is paid off in the first year. Over the period of 20 years electricity
consumption savings are around 33%. A study made on another of TECHO’s housing projects, reported that 96% of the families used high intensity incandescent bulbs (GTZ 2008). We conclude from this that improving lighting technology is low-cost and easy to implement, and there is significant potential for reducing energy consumption more broadly.

![Electricity Consumption](image)

**Figure 6:** Electricity consumption (lighting) with incandescent bulbs (IB) and compact fluorescent lamps (CFL).

Gas Consumption. For the gas consumption, a base model or business as usual (BAU) model was constructed with data from homes without envelope improvements. Similarly, gas consumption was modelled for homes with double glazed windows and with external wall insulation independently and also the accumulated benefit, as shown in Figure 7. The modelled decrease in gas consumption from both improvements is around 58% in the period of 20 years.

![Gas Consumption](image)

**Figure 7:** Gas consumption (heating), business as usual (BAU), with each improvement and the accumulated benefit.

Regarding the external wall insulation, Fabron’s study analysed the cost and levels of insulating in the phase of construction and as retrofit.
A sensitivity analysis was also conducted to assess the effect of increasing energy price and increases in energy demand on energy consumption, and the effect of discount rate on the investment. For this part of the analysis energy consumption includes electricity and gas.

**Energy price increase.** Chile has had an average of 3.2% increase in energy price in the last decade (Del Campo 2012). Energy price is expected to continue to increase in these next few years and decrease/stabilize afterwards. The expected price increase is around an average of 3.5% for the next decade. For this analysis, increases of 3.5%, 7% and 15% were considered. As shown in the figure below, energy price increase does not have a major effect for dwellings that are energy efficient.

![Energy price increase effect on energy consumption](image)

**Figure 8:** Energy price increase effect on energy consumption

**Energy demand increase.** Even during the energy crises experienced in Chile, energy demand is expected to be around 6% for the next decade (IEA 2012). Additional investments to cope with deficit and an expected increase in wealth result in a continuous increasing demand in the long run (Agostini 2012). Furthermore, as mentioned above, energy consumption is a function of the characteristics of the dwellings, household composition, equipment and services provided. Agostini’s study estimates some of the features that increase energy consumption:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Increase in energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 more person in the household</td>
<td>7.6%</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>32.9%</td>
</tr>
<tr>
<td>Computer</td>
<td>19.8%</td>
</tr>
<tr>
<td>Washing machine</td>
<td>11.5%</td>
</tr>
<tr>
<td>Heating</td>
<td>6.5%</td>
</tr>
<tr>
<td>Additional room/bathroom</td>
<td>6.5%</td>
</tr>
<tr>
<td>Thermal insulation</td>
<td>-2.7%</td>
</tr>
</tbody>
</table>

*Table 1: Increase in energy consumption due to various variables. Adapted from (Agostini 2012).*
High energy consumption features are particularly relevant for low-income communities. GTZ’s (2008) study in the community of Lo Espejo reported that most of the households already possess appliances such as a refrigerator (86% of families), washing machine (81%), and TV (99%), while only 18% of families had a computer. For the purpose of this analysis, the base model assumes that communities working with Techo are in similar conditions and have most of the basic appliances, and that no additional equipment is acquired after moving into the new housing development.

For the whole cost-benefit analysis, 6% demand increase was considered in all calculations, which is factored in the heating consumption. However, in order to represent a more realistic scenario in which there is an expected increase in wealth, out of the above mentioned estimates the following were considered as factors for the sensitivity analysis: two additional rooms, the purchase of a computer, and the combined effect.

Figure 9: Energy demand increase effect on energy consumption

Figure 9 shows that even if residential demand continues to increase, the investment in energy efficiency measures is economically beneficial for families.

Sensitivity to discount rate. A social discount rate of 4.6% was applied to the calculations over a period of 20 years. This value was calculated by Lopez (2008) based on growth bases scenarios. A sensitivity analysis was carried out to assess the risk of investing in energy efficiency, using a lower and a higher discount rate, based on the lower and higher ends of the same study by Lopez (2008).
Figure 10: Net present value (NPV) sensitivity to discount rates

The net present values (NPV) in the three scenarios are positive figures, meaning that the investment is profitable. However, the higher the discount rate and thus lower NPV the riskier the investment is, and it only considers short-run benefits.

Other benefits such as increased level of comfort (e.g. adequate indoor temperature and noise protection), health improvement (less propensity to respiratory diseases) and environmental benefits (reduced GHG emissions), which are often not easily quantifiable, should be taken into consideration and hence justify a lower discount rate (Jakob 2006).

4. Energy Efficiency Finance Models

The cost-benefit analysis in the preceding section indicates that energy efficiency features are a cost-effective investment that also brings health and environmental benefits to households. Such measures are therefore cost-effective to reduce energy consumption and address fuel poverty (Limaye 2011). However, in buildings, particularly residential, one of the barriers is potentially the extra upfront costs of installing energy efficiency.

Therefore, there is a need to find new ways to finance energy efficiency for new constructions. Two options to fund the extra financial resources to implement energy efficiency in the TECHO context are: 1) more partnerships with the private sector; 2) extra vouchers from the Ministry of Energy to cover the additional cost. Techo would also consider retrofitting these measures to past projects, if they could be privately financed or through other organizations (Techo 2013).

Investing in energy efficiency presents many challenges, including vulnerability to international energy prices and macroeconomic conditions (demand, reduced incentives...
and prioritization) (World Bank 2005). Furthermore, inadequate information and technical expertise on energy efficient technologies, the lack of dedicated budgets, limited access to appropriate financing, rigid procurement practices, and subsidized energy prices may hamper widespread adoption of energy efficient technologies (Limaye 2011).

Moreover, services and products related to energy efficiency may fall outside traditional financing mechanisms because of lack of understanding from financing institutions, inherent risks, and/or a view that benefits are small compared to overall operating costs (World Bank 2005). One mechanism to address this issue of financing energy efficiency is Energy Savings Performance Contracts (ESPC or EPC) carried out by Energy Service Companies (ESCOs). This business model was developed in North America to bridge the gap between end-users and economic and technological resources, in both the public and private sector and in large or small scale energy efficiency projects. It is increasingly being used in developing countries and widely accepted by the World Bank (Limaye 2011; World Bank 2005).

The ESCO is a commercial provider that is engaged in a performance contract (EPC) to develop an energy efficiency project. The ESCO provides the products and services to guarantee energy savings at the end-user level, including: development and design of energy efficiency and emission reduction projects, energy efficiency technologies and equipment (procurement, installation and commissioning), energy auditing and monitoring, training, operations and maintaining. The ESCO provides its expertise and capital and assumes all technical, financial, construction and performance risks. This investment is repaid in the form of flexible financing options and from income from the amount of energy saved throughout the EPC. Any type of organization related to energy technologies, equipment or construction can act as an ESCO (Fang 2012; Limaye 2011).

Given the good results and acceptance of micro-finance mechanisms in Latin America, the ESCO model could be adapted to become a promising tool to enhance the uptake of energy efficiency projects. Micro-loans or micro-finance mechanisms have been increasingly used as means for house construction or house improvement, and these activities have considerable potential to grow. Housing micro-finance involves progressive, short-term loans for land acquisition, home improvement or construction, and legal regularization. Micro-finance mainly addresses the affordability issue for low-income households or households that are unable to access traditional loans because of their informal labour situation, and have been increasingly supported by international financial institutions such as IADB, private international and local banks, NGOs and private corporations (Bouillon 2012).

The EPC model could be adapted to a micro-loans context, where households could access microfinance that is specific for energy related projects, in the way EPC works.

A micro-finance – EPC model could benefit housing projects in development, and could also benefit past projects by retrofitting already established housing. This would require
(based on the limitations identified by the World Bank (2005)):

- Appropriate and sufficient information regarding the technical requirements of the housing projects;
- Clear guidelines and a strong legal and taxation framework;
- Appropriate and sufficient energy verification and monitoring techniques;
- Community knowledge and commitment regarding energy use;

5. Conclusion

In conclusion, Chile is one of the fastest growing economies in Latin America that is like many, experiencing rapid and increasing urbanization. Chile has recently achieved a reduction in its housing deficit and the proportion of population living below the poverty line through internationally recognized housing policies that allow private and social sectors to be involved in housing development. TECHO is one of those organisations. As an innovative social housing provider, TECHO aims to reduce poverty and precarious settlements through a community and volunteers' participation centred strategy.

Also requiring consideration in social housing planning is the energy supply crises and resultant energy insecurity which is presenting significant challenges for Chile’s government, especially in the face of imminent climate change.

This paper has drawn on Chile’s housing policies, the need for greater energy efficiency in social housing and the work of TECHO to make recommendations for innovative financial models to support increased energy efficiency models in social housing.

TECHO, in its work to redress poverty is now seeking to develop more energy efficient dwellings which will protect households from fuel poverty and improve their livelihoods. This paper has looked at the findings from the technical assessments of two pilot projects in the Chilean communities of Lo Espejo and Emati. Data from these studies have served as a valuable basis for the cost-benefit analysis presented in this paper.

Our cost-benefit analysis has indicated that relatively low-cost improvements to the house design could provide significant energy savings. The subsequent sensitivity analysis also supports the argument for its cost-effectiveness, even in increasing energy price and energy demand scenarios. Of particular interest is the potential increase of energy demand due to increased wealth. As low-income communities overcome poverty, the acquisition of electronic devices and comfort features will lead to a higher consumption of energy. Energy efficiency awareness campaigns and education will be crucial to avoid a counter-productive impact on the communities that Techo is working with.

Also, to address the need to address the issue of energy efficiency financing, this paper has presented ideas to overcome cost barriers. Aside from government subsidies and private organizations funding, new finance mechanisms, such as micro-finance – energy performance contracts (EPC) model, are presented as alternative options to reduce potential financial barriers and encourage the uptake of energy efficiency in TECHO’s
developments, as well as more broadly.

Nonetheless, the success of implementing energy efficiency measures in housing will also be driven by households’ energy use and practices. The next stage of this research project will conduct primary research to better understand the effect of increasing wealth in energy demand. It will also draw upon the elements of social practice to evaluate the process of community participation in the design of housing project and their practices around energy use in Techo’s housing developments. Previous social and technical assessments, as well as this further research will contribute to a framework for the development of future housing Techo projects and inform best practice more broadly.
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About the Authors

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Sandra is a Project Coordinator and Research Officer with the Global Compact Cities Programme and she has been with the Programme since January 2013. She holds a Master of Environment degree from Melbourne University, focused on Climate Change and Sustainable Community Development, and a Carbon Accounting accreditation from Swinburne University. Sandra's current research is focused on developing in energy efficiency measures for low income housing with the Chilean NGO TECHO. She is working with Professor Ralph Horne. They secured COALAR funding to collaborate with TECHO and present findings internationally, at the World Urban Forum and a seminar on Sustainable Urban Housing in Chile. Sandra is leading the 2014 Global Compact Cities Programme survey of participant cities. She is also involved in research on natural disasters in Australia in RMIT University.

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Ralph Horne is the incoming Director of the Global Compact Cities Programme. Ralph’s expertise is in urban social and policy change for sustainable design and development. He has extensive experience of environmental techniques and sustainability appraisal and has a specific research interest in urban transitions, including socio-technical relations in the context of climate change and resource scarcity. He has led over 100 urban research projects, collaborating with researchers, cities, governments, and commercial organisations across all continents and including specifically studies of housing and development in Europe, Australasia, SE Asia and Latin America. He combines research leadership and participation in research projects concerning the environmental, social and policy context of production and consumption in the urban environment.

He held the positions of Director, Green Building Council of Australia from 2010-13 and Council Member, Built Environment Industry Innovation Council, Commonwealth Government, Australia from 2008-12. He also holds the position of Deputy Pro-Vice Chancellor Research for the College of Design and Social Context at RMIT where he supports research performance through the development of new and existing research Groups and Centres, mentoring future research leaders, and providing strategic leadership in support of research activity across the College.

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