

Research article

Energy culture and the dynamics of energy poverty in south Chile: a blind spot for decontamination energy efficiency policies

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Abstract

While energy poverty has received increasing policy focus in Europe, in Latin America, energy poverty has only recently emerged in the public agenda. Although energy efficiency policies have been implemented in some countries in the region, these typically lack an understanding of the complexities related to energy poverty. In southern Chile, the case study of this article, energy efficiency interventions have been focussed on tackling air pollution from residential firewood combustion. This approach fails to consider the energy poverty condition of households such as the lack of equitable access to high-quality energy services and the cultural aspects of firewood use and preference. This not only hinders efforts around energy efficiency but also in overcoming the environmental problem (i.e. air pollution). Therefore, the concept of energy poverty in middle-developed countries such as Chile needs reframing to have a better context-sensitivity and cultural understanding of this phenomenon.

The concept of energy poverty in this article is understood as a context-sensitive three-dimensional approach that considers quality, access, and equity giving special importance to local energy cultures. This understanding is fundamental to foster a just energy transition and re-scope the air pollution problem. To do so, we examined the economic and political backdrop of energy poverty in south Chile to discuss the site-specific sociocultural factors that must be recognised and included in the energy efficiency policies for developing effective and more responsive local solutions to energy poverty and air pollution. We argue that local energy culture has turned into an air pollution problem that is being tackled by policies that do not consider, for example, the multifunctionality of heating and cooking appliances, the habits related to indoor thermal comfort and the whole culture around firewood use embedded in the everyday life in southern Chile.

Keywords: energy poverty, energy culture, energy efficiency policies, air pollution, just energy transition.

Introduction

In south Chile, residential energy efficiency interventions are typically focused on decontamination to reduce particulate matter emissions from firewood combustion used for heating and cooking. The main factors driving residential firewood combustion are affordability of the firewood and the comparatively high prices of other energy sources, the availability of firewood in formal and informal markets, limited housing energy efficiency, a cold climate that increases heating demand, and cultural factors, such as preference and habits for heating and cooking practices (MINEN, 2020; MMA, 2014). Chile has made significant public investments to reduce heating demand and fine particle emissions by providing retrofit subsidies for improving thermal insulation and upgrading heating appliances. As with other jurisdictions, social housing is a location for energy poverty in central-south Chile and retrofit subsidies could help this situation. However, energy efficiency policies tackling air pollution do not include considerations of equitable access to quality energy services or include a sustainable path to energy transition, ignoring the cultural dimension of energy use and focusing only on the air quality target. This paper begins to address this gap.

Various definitions of energy poverty have been adapted by different countries. For this article the definition provided by the Energy Poverty Network in Chile (further explained in a later section) was considered the most appropriate to analyse the cultural dimension unpinning energy poverty in south Chile. This definition understands energy poverty as a context-sensitive three-dimensional approach that considers access, equity, and quality (RedPE, 2019; Urquiza *et al.*, 2019). This understanding is fundamental to foster a just energy transition and reposition the environmental problem of air pollution as an energy poverty problem, where energy culture plays an important role. To explore this, the historical, economic, and political backdrop of energy poverty in south Chile are examined in this paper to identify sociocultural site-specific factors that should be recognised and included in decontamination energy efficiency policies which could lead to more effective and localised solutions.

This article explores the role of energy culture on the dynamics of energy poverty and the impact on decontamination energy efficiency policies, analysing south Chile as a case study. It is organised into four sections. The first section presents an overview of energy poverty traditional approaches and related policies in the European Union and Latin America. The second section introduces the historical, economic, and political background in which energy poverty is embedded in Chile. The third section presents a context-sensitive approach to energy poverty that guides a literature review discussion on studies related to energy poverty in Chile. The fourth section discussed the lack of understanding of local energy culture in relation to energy poverty and air pollution in central-south Chile. Finally, the main conclusions are presented.

Overview of Energy Poverty and Policies

Energy Poverty Origins as a Concept and Metrics

The first formal definition of fuel poverty was presented by Boardman in 1991 as: a household would be poor when it is unable 'to have adequate energy services for ten per cent of income' (Boardman, 1991: 227). Since emerging in England during the 1990s, the recognition of energy poverty by policy makers and researchers has increased and spread to many countries, mainly European (Rademaekers *et al.*, 2014). This has

resulted in an increasing number of studies that involve defining metrics and indicators for measuring energy poverty and evaluating consequences. In more recent years the definition of energy poverty has evolved in European research and is now commonly understood as the inability to attain a socially and materially necessitated level of domestic energy services (Bouzarovski and Petrova, 2015; Sareen *et al.*, 2020; Simcock *et al.*, 2018).

Traditional approaches to energy poverty definitions are related to affordability and other economic thresholds, or maximum proportions of the income of each household covering energy services according to the minimum lifestyle considered acceptable in their country of residence. These indicators include methodologies such as the “Ten-percent Rule” (TPR) (Boardman, 1991), the Low-Income/High-Cost indicator (LIHC) (Hills, 2012) and the Minimum Income Standard (MIS) (Moore, 2012); all of which present different approaches for calculating the effective energy expenditure of households. Other indicators have emerged to measure energy poverty focused on technology access and/or users perception of energy deprivation, such as the Energy Poverty Multidimensional Index (EPMI) (Bollino and Botti, 2017), the Meeting of Absolute Energy Needs Index (García-Ochoa and Graizbord, 2016), the Multidimensional Energy Poverty Index (MEPI) (Nussbaumer *et al.*, 2012), the Energy Access Ecosystem Index (PPEO, 2014), the Multi-Tier Framework (Bhatia and Angelou, 2014) and the Tridimensional Energy Poverty Index (RedPE, 2019). These various ways of defining and measuring energy poverty have different emphasis’ according to the economic thresholds, access to technologies and energy users’ perceptions.

Rates and indicators of energy poverty are overwhelmingly expressed in the number or percentages of households. The representativeness of datasets used to calculate energy poverty indicators are constrained by factors often related to the design and implementation of surveys (Herrero, 2017). Some authors have stated that metrics and indicators being used have practical barriers linked to limited databases (coverage and disaggregation), lack of contextualised energy use issues, and the need for methodological innovation (Sareen *et al.*, 2020). This article is based on the Chilean Energy Poverty Network approach (RedPE, 2019; Urquiza *et al.*, 2019), as will be detailed in a later section. Regardless of the definition and indicators chosen, energy poverty can be understood as the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development (González-Eguino, 2015; Reddy, 2000).

Over ten per cent of households in the United Kingdom, 14 per cent in Europe and 25 per cent in New Zealand cannot afford to keep their houses adequately warm in winter (McKague *et al.*, 2017). Previous research finds that high energy prices, low incomes and energy inefficient houses are part of the drivers of energy poverty in Europe. The Green Deal launched by the European Commission (2019), states that the risk of energy poverty must be addressed for households that cannot afford adequate energy services to ensure a basic standard of living. The European Commission declared that effective programmes, such as financing schemes for households’ energy retrofits and other energy efficiency improvements, must be addressed by European Union member countries to alleviate energy poverty (European Commission, 2019). Boardman (2012) stated that lessons learned in the United Kingdom from energy policies suggest that investing in demand reduction is much cheaper than providing new forms of energy supply. Research has found that energy retrofit actions are typically concerned with the interaction of building components and technical aspects, often neglecting the environmental and sociocultural ones (Sibilla and Kurul, 2020).

Wood burning for residential heating in Scandinavian and alpine regions have been long recognised as a significant source of air pollution. Recent evidence suggests that

this is becoming a widespread issue in other European cities as well (Fuller *et al.*, 2014). In Sweden, small-scale biomass combustion is responsible for 34 per cent of the heat demand of small houses. In Norway, more than 40 per cent of the biomass used for energy purposes comes from wood log combustion, and there is a national strategy to increase the bioenergy use in wood stoves. In Germany, approximately 50 per cent of residential heat is provided by wood fuel in furnaces and biomass boilers (Karlsson *et al.*, 2020). Residential wood burning is becoming an increasingly popular alternative energy source to fossil fuels since the announcement of carbon neutral policies, higher taxes in heating diesel and the reduction on average household income resulting from various financial crisis (Titos *et al.*, 2017). Therefore, the causes of energy poverty are underpinned and driven both by wider-scale processes and site-specific conditions related to the historical, cultural, material, economic and political context in each country (Simcock *et al.*, 2018).

On the other hand, some authors have identified the significant role of households' particular needs and everyday practices in determining how energy poverty emerges and is experienced (Simcock *et al.*, 2018). Such research highlights the importance of identifying the cultural aspects of energy poverty. The study of energy culture is gaining interest among scholars. Culture can complicate or catalyse efforts to promote more efficient and affordable forms of energy use in homes. It can operate as both a barrier and an enabler to low-carbon transitions, which is often not acknowledged (Sovacool and Griffiths, 2020). Stephenson and colleagues (2010, 2015) have provided a framework to understand energy behaviours and defined three core components that allow a better understanding of energy culture: cognitive norms, energy practices and material culture. Rau *et al.* (2020), using Stephenson's framework, distinguished between energy-cultural elements that are rather sticky, so more resistant to change and those that proved to be relatively malleable. Therefore, energy efficiency interventions and technological implementation do not always have a straightforward adoption by households. While numerous studies on residential energy efficiency interventions seek to address occupant perception, preferences and behaviour in the adoption of new technologies (DellaValle *et al.*, 2018; Galvin, 2013; Michelsen and Madlener, 2012; Schleich, 2019), domestic energy culture remains relatively underexplored and therefore poorly understood in the context of energy poverty.

The relationship between air pollution due to domestic wood burning, energy poverty and energy culture has been underexplored in developed countries. This is due to wood burning being typically associated with a lack of domestic access to clean energy sources in the Global South. In this context, the case presented in this article explores the connection between these three aspects – energy poverty, energy culture and air pollution– and contributes to an improved understanding the role of energy culture on energy poverty dynamics for the development of more adequate and successful decontamination energy efficiency interventions.

Energy Poverty in the Latin American Context

Energy poverty in Latin America has only recently started to be included in the public agenda as part of policy efforts to promote affordable, reliable, sustainable and modern energy access for all in meeting the United Nations Sustainable Development Goal N°7¹. However, the region lacks an authority – like the European Commission (2019) from the European Union – that can guide and enforce levels of energy efficiency in the region to alleviate energy poverty. However, several countries are starting to implement energy efficiency measures. An overview of energy efficiency policies in Latin America Southern Cone countries – Argentina, Brazil, Chile, and Uruguay – shows that building thermal performance standards have had a significant impact on achieving those nation's

objectives to reduce energy consumption and improve energy efficiency (Silvero *et al.*, 2019). However, the introduction of technical standards has often occurred without laws and decrees to support them. These voluntary measures need to be regulated to ensure wider, and equitable uptake. Silvero *et al.* (2019) concluded that each country must analyse its history, politic, economic and culture to develop policies that can be adequately and effectively implemented. Furthermore, these energy efficiency policies are not connected to the energy poverty discussion.

In Latin America, Carvajal *et al.* (2020) have emphasised the relation between (un)affordability of energy services and low per capita energy consumption (2.156 kWh/person), regardless of the high access to electric infrastructure (around 97 per cent of households had access to electricity in 2018). This low per capita energy consumption is not related to energy efficiency but is due to high energy costs and gaps in technology access. In this context, the researchers identified key energy access gaps related to gender, income level, indigenous and afro descendants (Carvajal *et al.*, 2020). In addition to considering affordable access, Urquiza *et al.* (2019) have identified the importance of adjusting energy poverty measures to include the quality of equitable energy access, posing quality as a hidden dimension concerning access and equity in middle-development countries.

According to Urquiza and Billi (2020), in Latin America and the Caribbean (LAC), national energy strategies are focussed on the lack of access to electricity consumption, leaving behind the importance of energy efficiency in dwellings and other energy services like air conditioning. Only 12 of 33 LAC countries consider the affordability of energy expenditure among their policy orientations (Urquiza and Billi, 2020). The quality of dwellings plays a fundamental role in air conditioning demand, energy consumption and energy expenditure, but there is a lack of available data regarding this topic in these countries. However, as a proxy, Calvo *et al.* (2021) identified that 20 countries in the region have thermal regulations for buildings, but only seven countries define these instruments as mandatory requirements.

This first section aimed to provide wider-scale processes influencing local trajectories in the matter of energy poverty. However, it is necessary to better understand the site-specific conditions related to the historical, economic, and political background of energy poverty in Chile before analysing how these aspects are related to energy culture in the local energy poverty dynamics.

Historical, Economic and Political Background of Energy Poverty in Chile

This section discusses the historical, economic, and political backdrop in which energy poverty is embedded in south Chile and introduces the housing deficit and policy model, the residential energy use and energy policy, and air pollution and decontamination energy efficiency policies in the residential sector as factors that contribute to create, shape, and shift respectively local energy cultures. Acknowledging the importance of this context is key to overcome the air pollution problem caused by domestic firewood combustion. The fragmentation of different initiatives to tackle the air pollution problem lacks a comprehensive analysis of heating systems in everyday households' life, failing in accomplishing their objectives.

Housing Qualitative Deficit and Policy Model

Chile is known for its unique geography and diverse climate, but also for its extreme socioeconomic inequality embodied with high urban segregation (United Nation, 2018).

The country's socioeconomic structures reflect a neo-liberal model developed during 17 years of dictatorship (1973-1990), which profoundly affected democratic discourse and social participation (United Nations, 2018). The current market-based housing policy has gradually improved and modified over the years, but the original model developed in the 1980s can be recognised still in existing programs and financial models of homeownership, and the State never intended to play the role of landlord or administrator of public housing (Salvi del Pero, 2016).

It is possible to characterise the development of housing policy in Chile across two important periods: 1) between 1980-2000, and 2) 2000 onwards. During the first period, a large number of social housing units were built, significantly reducing Chile's historical housing deficit (Fariás, 2014). This policy reflected strong support for a homeownership model that was focused more on quantity of housing rather than on its quality. Building quality and amenities were often substandard, and social housing from that period has been noted for its poor material quality, either in terms of leaks, sewage, acoustic insulation, and energy efficiency (Rodríguez and Sugranyes, 2005).

The second period is attributed with a focus on improving the quality, integration, and equity of housing support, following a new housing policy suite launched in 2000. This policy development included thermal regulations in the residential building code, which has been compulsory since 2007. Although energy efficiency guidelines and performance certificates are available for public and commercial buildings, they are not yet mandatory. Improving the quality of housing (or qualitative deficit) has become a more prominent national goal and is now a key housing policy objective in Chile (Salvi del Pero, 2016).

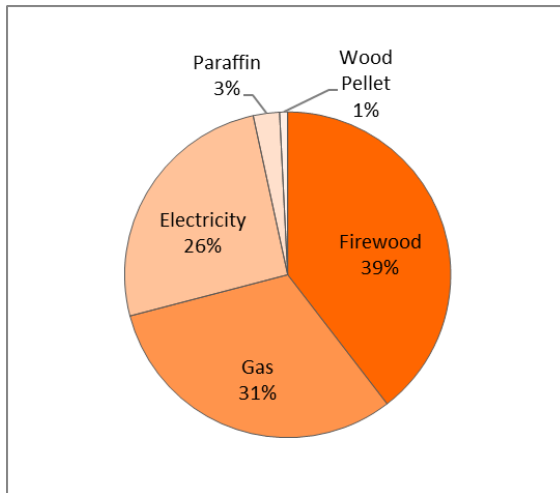
The qualitative deficit identifies the total of private homes that must be improved, repaired, or conditioned to bring them up to an acceptable quality standard (Salvi del Pero, 2016). According to the Ministry of Housing and Planning (MINVU²) reports, the lowest household income quintile has a higher qualitative deficit (MINVU, 2017). This can be explained by the rapid deterioration of the social housing stock built in the first period due to their lack of design and material quality. Additionally, housing in the lowest income quintiles (especially in the first) display the worst conservation and materiality standards and the highest deterioration rates (Simian, 2010). These conditions negatively impact the wealth generation objective of Chile's housing policy (OECD, 2013). The qualitative deficit of the housing stock is also an indicator of rapid deterioration represented in the number of dwellings built without thermal insulation that need a thermal upgrade to achieve the thermal insulation standard, compulsory since 2007. Furthermore, deterioration is produced by a culture of self-construction to extend the housing floor area when the dwelling does not meet the family needs in terms of, for example, the number of bedrooms. Extensions are normally built without compliance with the building code and therefore are substandard.

The housing's qualitative deficit and policy model has led to a housing stock that lacks energy efficiency, causing high energy demand for heating in southern Chile, as further south, the climate tends to be colder. Furthermore, the building code does not require a heating system to be included in social housing projects delivered by the State, and households have to solve their heating needs by their own means. The lack of minimum heating system standards, energy efficiency requirements and the high energy prices in Chile has created a culture of solving the heating and cooking needs through the most available and affordable energy source in southern Chile: firewood. The use of firewood is attached to everyday life energy use and has created and shaped a local culture embedded in how firewood is traded, handled, and valued.

Residential Energy Use and Energy Policy

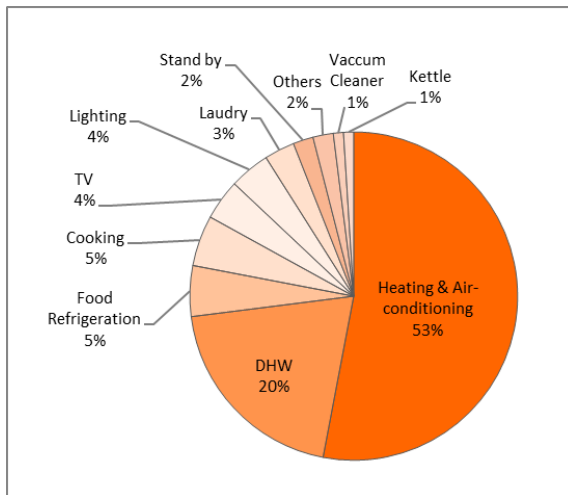
The residential fuel consumption in Chile is characterised by the intensive use of firewood, representing 39 per cent of consumed fuel, followed by gas and electricity (Fig. 1). The energy consumption is mainly used for heating and air conditioning and Domestic Hot Water (DHW) (Fig 2). Residential gas consumption (59%) is mainly used for DHW (CDT & In-Data, 2019).

Figure 1: Residential Energy Consumption by Fuel



Source: CDT & In-Data, 2019

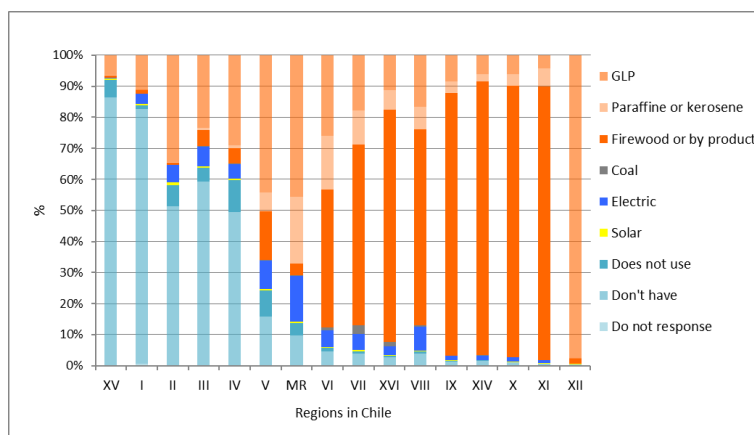
Figure 2: Residential Energy Consumption by Use



Source: CDT & In-Data, 2019

The energy used for heating changes in different regions of the country. Figure 3 shows the regions ordered from north to south (left to right). Firewood consumption starts progressively increasing in region VI (O'Higgins) until region XI (Aysén). Region XII (Magallanes) is an exception to this trend because it is the only region that has a state subsidy for natural gas consumption (CASEN, 2017). These statistics on energy use for heating are directly related to the climate condition and housing energy efficiency.

Figure 3: Energy Use for Heating by Region



Source: CASEN, 2017

The further south, the colder the climate. Therefore, housing energy efficiency becomes a key factor in the energy demand for heating. However, as a consequence of the first period of housing policy detailed above, more than 66 per cent of the current housing stock of the country lack thermal insulation (RedPE, 2019). Historically, families in south Chile have used firewood creating local firewood markets run by small and medium peasants (Álamos *et al.*, 2021).

Despite this historical context, in terms of energy policy, the interventions of the Ministry of Energy (MINEN³) have been focused in the last mile on electricity access, incentivising the change to electricity through a discount on the electricity rate for domestic heating in most polluted cities. Currently, there are no specific energy policies focussed on ensuring equitable access to safe and clean heating systems for central-south households, leaving some dimensions of energy poverty unattended. More recently, it has been possible to observe a shift towards equitable access to high-quality energy services in the national energy policy (MINEN, 2020). However, the effects of this shift are yet to be seen.

All these factors have historically shaped the local energy culture, and inhabitants are used to heating individually with firewood. Specifically, the lack of housing energy efficiency increases heating demand, and low-income families cannot afford to pay for clean energy sources. Even though since 2020 there is a policy for electricity rates discounts, many inhabitants still use dry firewood for heating. As a result, southern cities are still highly polluted by particulate matter 2.5 (PM2.5) (Huneus *et al.*, 2020).

Air Pollution and Decontamination Energy Efficiency Policies in the Residential Sector

The Ministry of Environment in Chile (MMA⁴) has declared that over ten million people are exposed to concentrations of PM2.5 that exceed healthy levels⁵ (MMA, 2014). This has effects on national mortality estimated by Huneus *et al.* (2020) as 1,800 annual deaths. More than 1,500 hospital admissions for respiratory and cardiovascular causes could be avoided if air pollution were kept below the national standard, and more than 4,000 if considering the WHO standard (Huneus *et al.*, 2020). Air pollution is affecting the most vulnerable population, especially young people and the elderly, people with health problems and those living in multidimensional poverty (Huneus *et al.*, 2020).

Today in Chile, air pollution is measured in more than 25 cities through the National Air Quality Information System⁶, considering both coarse particles (PM10) and fine

particles (PM_{2.5}). At a national level, in 2017, the residential sector represented 94 per cent of total PM_{2.5} emissions due to the use of firewood for heating and cooking (Huneus *et al.* 2020).

When the national limits of pollutant concentration are exceeded after three years of measures, a city is declared a saturated zone. A slow process follows in which regional representatives of the Ministry of Environment design and approve an Atmospheric Decontamination Plan (ADP⁷). The ADP usually contains a diagnostic of the main pollutant emission sources and various policies to be implemented. Even though there is a local process to make an ADP for each city, they had the same diagnostic and policies to be implemented in all southern region. Even more, ADPs lack an adequate citizen involvement in the policy-making process: less than five per cent who lived in polluted areas have participated during the citizen participation processes to create ADPs (Huneus *et al.* 2020).

The ADPs have had the same prescriptive policies along the southern cities of the country, focusing mainly on implementing two decontamination energy efficiency interventions: one for improving the insulation of the housing stock through thermal retrofits to reduce the energy demand for heating, especially related to the housing quality deficit mentioned above, and the other one for replacing old and inefficient firewood appliances, related to residential energy uses seeking to shift energy culture.

Thermal Retrofit Programme

The MINVU began enforcing an Energy Building Code in 2000 for new residential constructions, based on seven thermal zones defined according to location and altitude⁸. Zone 7 corresponds to the most extreme south area of the country and has the uppermost thermal insulation requirements. At the first stage, the Code covered only roof insulation. Since 2007, the Code has been extended to a second stage to cover exposed floors, external walls, and windows. The regulations specify maximum thermal transmittance (U values as W/m²K) of the building envelope but do not yet specify values for ground heat transfer, air infiltration, ventilation or heating; all key variables to improve the energy efficiency performance of a building. However, all these variables are considered in the thermal retrofit programme implemented in cities with an ADP (Cortes and Rismanchi, 2020). In 2009, the thermal retrofit programme was launched, aiming to reduce 30 per cent of the housing stock heating demand. The programme addresses rural and urban social housing homeowners located in the southern area of the country (Fissore and Colonelli, 2013). In cities with an ADP, the subsidy can be allocated to middle-income families⁹ whose dwellings have less than 140m² with the objective of improving the energy efficiency of the housing stock beyond social housing. The thermal retrofit programme aims to reach the building code standard; however, in cities with an ADP, the standard has been improved for both new and thermal retrofit houses. The cities with an ADP have specific calls for the thermal retrofit programme, and the socioeconomic rating can vary in line with the regional needs. For example, the public call for Coyhaique city in 2019 (MINVU, 2019) established that at least 80 per cent of the subsidy resources should be allocated to families up to the 70% tranche of Socioeconomic Rating (CSE); the remaining 20 per cent could be allocated into families between 70 per cent to 100 per cent socioeconomic tranches. This call included a novel pilot to make compulsory the replacement of wood-burning heaters in homes. The MMA funds the new heating appliance through the Heating Appliance Replacement programme in a different application process.

Heating Appliance Replacement Programme

The Ministry of Environment (MMA) implemented this programme in 2011, aiming to reduce particulate matter emissions in cities with an ADP. Through this programme, beneficiaries obtain a new heater, and their old heater or cookstove appliance is removed from the dwelling. The programme does not include a socioeconomic evaluation of households and works through an online application platform. The requirements for applicants are: 1) to have a firewood heating system installed at home, 2) to live in the area declared as a saturated zone, and 3) to undertake a co-payment to the installer company. The model, fuel, and power of the new heating appliance are specified in each public call, and applicants choose the technology they prefer when applying (MMA, 2020). In Chile, between 2011 and 2019, 40,256 heating appliances have been replaced in all the southern cities declared saturated zones and between 2017 and 2019 the predominant fuel of the new appliances is pellet followed by kerosene.¹⁰

Although the Housing Thermal Retrofit Programme and the Heating Appliance Replacement Programme can be implemented in the same dwelling, they are led by two different government ministries (MINVU and MMA) and involve two separate processes. The process of subsidies allocation does not recognise households' differences in terms of size, design, family members, and energy use habits. Despite the positive achievements, the heating appliance replacement programme does not consider the change of all household's firewood appliances, resulting in many households changing just their heating system and keeping their firewood cookstoves. The consequences include that households improve their technologies (through new appliances and thermal retrofit) to achieve their thermal comfort standards more efficiently but might increase the indoor pollutants concentrations. Researchers have shown that there is a higher risk of increasing the concentration of indoor air pollutants if households keep their firewood cookstoves, given the improved airtightness and hermeticity of the building envelope achieved with the insulation after the thermal retrofit (Cortés and Ridley, 2014). Therefore, even though the programmes might shift the energy culture, they lack a comprehensive approach to dwellings' energy efficiency requirements, the heating and cooking system preferences and all energy needs that are satisfied with them. As a consequence, air pollution remains high, and energy poverty is not addressed.

In Summary, this section aimed to illustrate different factors that have contributed to creating, shaping and shifting local energy cultures, given by the historical, economic, and political national context. Although there are policies focused on improving access to fuel¹¹, upgrading heating appliances and enhancing housing' thermal performance in cities with an ADP, these initiatives are fragmented. Energy efficiency policies lack a thorough analysis of heating and cooking systems in everyday households' life. These programmes are focused on tackling the air pollution problem, neglecting the energy poverty problem that underlies air pollution.

A Territorialised and Sociocultural Approach to Energy Poverty

This section introduces the context-sensitive approach proposed by Urquiza *et al.* (2019), using it to analyse what the scientific literature has to say about energy poverty in Chile and its relation to decontamination energy efficiency policies and energy culture.

For middle-development countries like Chile, mainstream indicators fail to recognise the particularities of energy poverty. According to Urquiza *et al.* (2019), both access-based indicators and equality-based measures fail to account for energy poverty in

middle development countries. The authors explained a lack of an adequate adjustment of quality standards and thresholds: too low for access dimension, so there are almost no energy poverty issues, and too high for affordability dimension; so almost all the population is in this condition. To face this problem, the authors proposed a three-dimensional context-sensitive approach to energy poverty in middle-development countries, recognising the arbitrary nature of thresholds definition and the need to complement different sources of knowledge (top-down and bottom-up) to define these standards.

Context-sensitive Approach to Energy Poverty

In this paper, we use the context-sensitive approach to energy poverty proposed by Urquiza *et al.* (2019) that emphasises the importance of reviewing and redefining the implicit standard of 'energy quality' behind access-based and equity-based measures. This standard is usually 'imported' with mainstream energy poverty measures, without questioning it and it fails to acknowledge territorial and sociocultural variations on defining the quality standards in middle-development countries like Chile. These standards are the basis for defining thresholds of energy poverty, both for access and equity indicators.

The context-sensitive approach has been developed through a transdisciplinary process led by the Energy Poverty Network in Chile (RedPE). RedPE has proposed a definition adapted to the national reality considering three complementary dimensions: access, equity, and quality (RedPE, 2019). The definition states that "a household is in an Energy Poverty (EP) condition when it lacks equitable access to high-quality energy services (adequate, reliable, secure, and non-pollutant) to cover its fundamental and basic needs, allowing it to sustain human and economic development of its members. Fundamental energy needs imply direct impacts on human health, while basic needs are those energy requirements whose pertinence depends on territorial or sociocultural particularities" (RedPE, 2019: 10).

Territorial variations are mainly related to ecological, geographical, climatical, technical, infrastructural, and sociocultural conditions (Calvo, Amigo, *et al.*, 2021). These conditions determine the availability and variability of energy sources and technological appliances in a territory, making energy poverty highly dependent on context conditions. This territorial-dependency condition affects equitable energy access to high-quality energy. To complement the three-dimensional context-sensitive energy poverty framework, the RedPE proposed a complementary framework of Territorial Energy Vulnerability (TEV) (RedPE, 2020), understood as "propensity of a territory to not guarantee equitable access – in quantity and quality – to resilient energy services that allow the sustainable human and economic development of its population" (Calvo, Amigo, *et al.*, 2021: 7). This expands the scale of the problem from household to territory. Both frameworks acknowledge the importance and weight of the sociocultural dimension, but in this 'big sociocultural box' are commonly mixed political, economic, and regulatory studies, lacking a proper cultural lens to observe this problem.

So, how to consider sociocultural variations? Research has revealed some clues, but there remains a lack of an understanding of how energy cultures shape the dynamics of energy poverty in south Chile and how it is connected with energy efficiency policies. We will discuss this below, but first, we will review through this EP-TEV lens the current scientific literature about energy poverty in Chile.

The Study of Energy Poverty in Chile

Through a systematic literature review¹² of research conducted in Chile, we found 160 papers that were analysed and classified. The main content of the paper was categorised considering if the focus was on EP – mainly related to access, equity and/or quality – or TEV (mainly focused on ecological, geographical, climatical, technical, infrastructural, political and market conditions related to energy). Findings show an increasing interest in energy poverty topics in the scientific literature over the last 11 years (2010-2021), achieving more than ten publications per year in the last four years.

Seventy-one EP papers were analysed using the access, equity and/or quality categories proposed by Urquiza *et al.* (2019), excluding the latter article from the analysis. Not surprisingly, most of the scientific research in Chile is related to quality dimension (54 papers) and strongly attached to case studies in central-south Chile (36 papers) and air pollution.

The access dimension of EP in Chile is related, for example, to research focused on improving households access to renewable energy sources for domestic hot water and heating (Correa and Cuevas, 2018; Vega and Cuevas, 2018), electricity consumption increasing analysis (Yoo and Kwak, 2010), solar photovoltaic generation at domestic level (Walters *et al.*, 2018), access to new technologies and appliances, and considering energy efficiency criteria (Dieu-Hang *et al.*, 2017). Furthermore, the relationship between the lack of equitable access to energy and gender has been studied, highlighting how its consequences increase the burden of unpaid domestic work for women (Amigo-Jorquera *et al.*, 2019).

The equity dimension in relation to energy expenditure has been widely studied. For example, the study of the role of subsidies on energy expenditure in the adoption of new technologies to tackle air pollution (Gómez *et al.*, 2017), the impacts on household's savings of policy interventions such as Net Metering, Net Billing, daylight saving time, replacing biomass with PV systems, among others (Cansino *et al.*, 2019; Verdejo *et al.*, 2016; Watts *et al.*, 2015). Besides, scholars have assessed energy poverty with national data, using different international metrics and indicators. One study estimated the TPR while proposing and measuring a multidimensional energy poverty index (PMEP). Both economic measures show that the energy-poor households represent about 15 per cent of Chile's population. However, energy poverty levels vary significantly across the population, depending on the territory and the measure employed (Villalobos *et al.*, 2021). A second study estimated the energy poverty rate of households in Chile at around 15.7 per cent with the MIS-based approach (Cerdeña and González, 2017). From both studies (Table 2), it is possible to infer that around 15 per cent of the national population is under an energy poverty condition, rising up to 25 per cent in the southern territory. Furthermore, these estimations suggest that in Chile, energy poverty is not only related to acute poverty but may also be a problem for middle-income families (Villalobos *et al.*, 2019). A third study to the equity dimension is the characterisation of the context-sensitive approach proposed by RedPE (2019). In this indicator, results about expenditure are higher due to the adjustment of the thresholds to national reality and the low energy expenditure related to hidden energy poverty. In this scenario, urban energy poverty in Chile is understood as the lack of equitable access to high-quality energy services (both high and low expenditure) and is estimated at around 34,3 per cent of households.

Table 2: Energy Poverty Measured through Equity dimension in Chile

Authors	Indicator	Households in EP	Scale
Villalobos <i>et al.</i> , 2019	Multidimensionally Energy Poor Households	15.5%	National
		25%	South Macrozone
	Ten Percent Rule Index (TPR)	15.5%	National
		19.6%	South Macrozone
Cerde and González, 2017	Ten percent rule	12.9%	National
	Minimum Income Standard (MIS)	15.7%	National
	Low Income-High Cost (LIHC)	5.2%	National
RedPE, 2019	High energy expenditure (MIS-adaptation)	22,6%	National
	Low energy expenditure (Hidden Energy Poverty-adaptation)	16,9%	National
	Lack of equity access to high-quality energy services	34,3%	National

In the intersection between equity and quality, researchers have developed the Fuel Poverty Potential Risk Index, considering energy expenditure (as the household capacity for paying bills) and social housing quality. The index is not only related to the existing structural conditions of dwellings but aims to predict the risk of EP in the future by considering climate change scenarios (Bienvenido-Huertas *et al.*, 2021; Pérez-Fargallo *et al.*, 2017; Pérez-Fargallo, Rubio, Pulido, and Guevara, 2018). Moreover, the same scholars have proposed a new adaptative comfort model to adjust thermal comfort standards to lower Chilean thresholds in social housing in central-south Chile (Pérez-Fargallo, Rubio, Pulido, Trebilcock, *et al.*, 2018). This opens up the debate about how to define thermal comfort standards. Other studies have confirmed the inequality related to indoor thermal comfort, asserting a significant difference between socioeconomic groups, where households with the lowest income live in colder and more polluted (CO₂) houses (Becerra *et al.*, 2018). Porrás-Salazar (2020) demonstrated through a case study that, in Concepción, a third of households are below the thermal comfort threshold at least 20 per cent of the time they are at home; and the ones that are in thermal comfort more than 90 per cent of the time, usually expend more than ten per cent of the minimum salary in energy bills. The researchers also analysed the relationship between thermal comfort and respiratory health impacts, and health expenses. Another key discussion in the equity-quality intersection is the environmental justice approach taken by Boso, Hofflinger, *et al.* (2020) that posed the dilemma that southern Chilean households have to face: breath clean air or heat at low cost.

At least half of the articles about thermal comfort and dwellings belong to the quality dimension (27 papers), followed by indoor environmental quality (IEQ) – especially indoor air pollution – and related health impacts (ten papers). IEQ research has been focused on the impacts on sensible population exposure to pollutants sources such as coal and firewood, especially newborns and children (Barría *et al.*, 2016; Burgos *et al.*, 2015). IEQ papers also focus on the association between hospital admissions and mortality (Paredes *et al.*, 2020).

Scholars have identified that 68% of indoor air pollution (PM2.5) in Temuco city is related to severe outdoor pollution and lack of energy-efficient dwellings. This fact is relevant because energy poverty is not only associated with indoor emissions (related to the intensive use of humid firewood and/or inefficient appliances) but also with dwellings' infiltrations of PM2.5 of outdoor pollution (Jorquera *et al.*, 2018). However, Boso, Garrido *et al.* (2020) have identified a *home halo* effect, where residents tend to diminish indoor air pollution awareness as they feel safer inside their homes and neighbourhoods.

Research on housing energy efficiency programmes and relation to firewood consumption asserts that thermal retrofitting has led to energy poverty alleviation – not only improving dwelling capacity to maintain heat inside but also keeping pollutants outside –, whereas heating appliances upgrades alone do not alleviate energy poverty (Reyes *et al.*, 2019; Schueftan *et al.*, 2016; Schueftan and González, 2013, 2015). A study done in Concepción city questioned the homogeneity of the public policy, considering the diversity of building conditions and showing a wide variety of energy requirements related to historical residential evolution (García Alvarado *et al.*, 2013).

Scholars have made an ex-post evaluation of the thermal retrofit programme in Temuco city, concluding that it has not been effective in reducing air pollution, but it has improved the thermal comfort and life quality associated with the rebound effect (Mardones, 2021a). The ex-post evaluation of the heater replacement program shows a significant waste of public resources (Mardones, 2021b). Only recently have public policies combined both programmes, so no studies have evaluated the joint impact to date. Some studies have modelled different scenarios of pollutants emission, stressing a lack of information regarding the specific impacts that each policy of the ADPs has on residential emission (Cortés and Ridley, 2014; Cortes and Rismanchi, 2020). Notwithstanding the scientific evidence, the air pollution problem remains.

Risk perception, individual behaviour, and willingness to pay have been studied from a psychological and sociological perspective. Álvarez *et al.* (2021) identify individual factors for (not) buying certified firewood (humidity less than >25). These factors are related to price, time, convenience, availability, presence of old persons at home, air quality awareness, information level, and concern about health impacts regarding air pollution. Risk perception has been identified as another key factor, and a study exploring occupants' perception using indoor environmental quality sensors suggests that this technology can improve households' awareness of air pollution levels (Boso Garrido, *et al.*, 2020).

Rojo *et al.* (2018) compared the differences between theoretical models about energy consumption in domestic heating and field measures. Results showed almost double consumption in models, questioning the ability of theoretical models to estimate the energy consumption of residential buildings. These findings are significant, considering that most public policies are based on these theoretical models. The main gap in knowledge is the assumptions regarding how people use energy, especially when there is no automatic control of ventilation and heating systems, like firewood use in central-south Chile. Other authors have acknowledged the importance of behavioural factors in energy consumption. Ruiz-Tagle and Schueftan (2021) argue that some behaviours related to the use of efficient firewood heaters, such as 'choking' the damper¹³, needs to be faced through better information campaigns to induce a behavioural change that can potentially, according to authors, reduce ten per cent of the pollutant emissions.

Despite the increasing research in Chile and the fact that many scholars recognise the importance of culture, the socio-material and cultural underpinnings of energy culture remain poorly studied, and even less in its relation to energy poverty.

Discussion: Lack of Understanding of Local Energy Culture in Chile

It is acknowledged that the four factors contributing to emissions of residential firewood combustion as the main source of pollution are a) the commercialisation and use of firewood that does not comply with the minimum humidity standards; b) the use of wood in old and inefficient appliances with lack of appropriate technology; c) the high demand of firewood for heating due to poor building insulation; and d) the behaviour of firewood consumers (burning preferences, opening-closing air flow, volume of wood combusted, etc.) (Huneus *et al.* 2020; Cortes and Rismanchi, 2020). However, there is one crucial blind spot: energy culture in relation to heating systems as a barrier for residential energy transition.

Undoubtedly, the energy poverty problem in south Chile is related to territorial energy vulnerability conditions (Calvo, Álamos, *et al.*, 2021; RedPE, 2020). There are policies in conflict with regards to the particular characteristics of the firewood market (Álamos *et al.*, 2021), the institutional lock-in mechanisms related to the high institutional density and a lack of coordination (Boso *et al.*, 2017), instability of electrical service and infrastructural conditions related to energy markets. This context-dependency of energy poverty expression has been described recognising the importance of cultural dimension, but without tackling it.

On the other hand, few studies about energy transition from sociotechnical perspectives have recognised the importance of domestic heating practices. Boso *et al.* (2017) identified two cultural lock-ins to advance on energy transition: the changes in domestic 'practice ecologies'—later called heating ecologies (Ariztia *et al.*, 2019)—and practices related to maintenance and care of appliances; moving from daily practices for users to the need of expert knowledge and networks with new technologies. The same authors have emphasised how the heater appliance replacement programme redefines a whole complex set of practices that constitute everyday domestic life, reconfiguring daily activities. Another research evaluating the heating upgrade programme in Coyhaique city surveyed 351 beneficiaries who had changed their heating appliance. Results showed that recipients who had a negative evaluation of the appliance replacement reported perceiving less heating capacity of the new appliance and higher fuel costs. The study also identified that some people had sold the new appliance returning to firewood consumption (DICTUC, 2018). Research in the same city conducted through 400 surveys showed that when households were asked about their willingness to change the heating or cooking appliance 45 per cent responded no and the main reason to continue using firewood was the price, availability and habits (MORI, 2015). As discussed earlier, there is a historical, economic and political context that has created and shaped an embedded energy culture in relation to firewood use, that goes beyond individual preferences, constituting a structural condition on these territories, strongly related to territorial memory.

Lastly, Amigo (2019) has highlighted the link between air pollution, energy poverty and culture related to cold temperatures in Coyhaique city. Cold climate is a territorial risk that households in Coyhaique have been historically facing resulting in different coping strategies. The author's findings showed that households have a wide variety of practices to deal with this climate condition, demonstrating resilience and a local energy culture with higher thermal comfort thresholds and a high intolerance to cold inside their

homes. In contrast, households still lack responses to air pollution, which is mostly observed as a hazard of the environment, 'out of their hands' and always 'other people's responsibility' (Amigo, 2019). Along with this, firewood cookstoves are highly valued as multifunctional appliances that are not only embedded in a traditional way of cooking but they are used for satisfying multiple energy needs such as heating, baking bread (an important daily meal in Chile), boiling water for domestic and hygienic uses, drying clothes and, from users' perspective, 'drying' the dwelling itself. Finally, this appliance is also associated with the social attachments of families, memories, and emotive feelings around the idea of a warm and cosy home ("*calor de hogar*" expression used in Chile) (Amigo, 2019). These results are aligned with research conducted in Sweden, suggesting that watching a fire is linked to an enjoyable emotion, provide a pleasant atmosphere for socialisation, and provides beautiful light, comfortable warmth, and a sense of cosiness (Karlsson *et al.*, 2020). These cultural elements vary along with the generations in south Chile, and it has been more clearly identified in senior citizens regarding technological changes mainly because the cookstove represents part of their daily historical routines (Amigo, 2019).

Photo: Traditional firewood cookstove in Coyhaique



Source: Catalina Amigo

The literature shows that contemporary uses of energy are intimately connected with people's social values, and images of energy and its associated technologies; how people use energy is related to how people value it, and how people value energy is related to what it enables them to accomplish not only materially but also socially and culturally (Strauss *et al.*, 2013). Therefore, energy policies and programmes need to recognise the territorial characteristics and the traditions, beliefs, and understandings of households' energy value. Despite Chile being a relatively small country, only its southern territory has site-specific energy cultural elements that are different from the rest of the country, and that should be identified and integrated into public policies.

Historically, these site-specific cultural elements have been created and reinforced by a housing policy that led to a) an energy-inefficient housing stock, b) a housing stock that lacks a heating system integrated into the design required by the building code, c) a social housing offer that does not meet family needs regarding space and quality d) a State that has limited capability to improve the energy efficiency of the social housing stock, as it has never played the role of landlord, and has promoted mainly homeownership policies. Therefore, the housing policy has forced households to solve their heating needs by their own means and to adapt their homes to solve the space requirements according to their necessities, often through a substandard self-construction process. The historical housing policy pursuing homeownership and particularly self-built housing or extensions reinforces an emotional bond of many people with their own dwellings, which can operate as another cultural barrier to energy efficiency policies (Amigo, 2019). In southern Chile, some cultural elements have been shaped by the territory, such as the cold climate and the low price and availability of firewood in both formal and informal markets, with implications in energy demand and fuel preferences, respectively. As firewood has been traditionally used in this territory, today represents an embedded culture in households' heating and cooking habits, and there is a positive value given to firewood heat capacity and sense of warmth.

While policies tackling the air pollution problem aims to shift the energy culture of firewood use by replacing old appliances with new technologies, they fail in understanding the cultural aspects of energy use that are beyond just a behavioural change. Furthermore, the heating upgrade programme does not consider the housing characteristics, and the same heating appliances are installed regardless of the dwelling size, family members, household income, energy performance and energy use habits. It is urgent that public policies incorporate the heating system as an integrated component of housing energy efficiency programmes in the building code. On the other hand, thermal retrofits have been proved that reduce the energy demand and, as Boardman (2012) explains, is cheaper than providing new forms of energy supply as they cannot deliver warmer houses more cheaply. This is clearly the case in southern Chile, as when firewood is replaced, the new fuel in place is always more expensive (pellet or kerosene nowadays). Both programmes, heating upgrade and thermal retrofit, have been implemented separately in two different application processes. Studies have shown that households that changed their heating appliances without having thermal retrofits have a negative perception of the heating capacity of the new appliance (DICTUC, 2018) and in many cases, they return to firewood use. Moreover, despite the energy demand reduction for heating caused by the thermal retrofit, currently research conducted by Author shows that some households cannot cope with the price of the new fuel in place, even after implementing both programmes. Preliminary results suggest the accomplishment of the thermal building standards may not be achieved given the lack of technical supervision of the construction process (research in progress).

Local energy culture has turned into an air pollution problem that is being tackled by policies that do not consider, for example, the multifunctionality of heating and cooking appliances, the habits related to indoor thermal comfort and the whole culture around firewood use embedded in the everyday life in southern Chile. As previously mentioned, the ADPs lack an adequate citizen's involvement in the policy-making process as less than five per cent of the population that live in polluted areas have participated in creating the ADPs (Huneeus *et al.* 2020). Participatory decision-making and policy-making are essential to design bottom-up policies that can recognise and integrate citizens' energy culture and to better understand their willingness to participate in energy efficiency programmes. International experiences show that thermal retrofits and replacing old stoves would be culturally acceptable, cost-effective, reduce fuel use, improve indoor and outdoor air quality, and lead to improved health outcomes, only if

solutions are compatible with heating practices and traditions, and if community members and leaders are integrated into the process (Champion *et al.*, 2017). Finally, the air pollution problem can be understood as an energy poverty problem, but it must recognise how local energy culture is embedded in it.

Conclusion

The review of policies and research presented in this article shows a lack of understanding of local energy culture in the decontamination energy efficiency interventions in the southern territory of Chile. While the ADP policies continue to be implemented throughout the country, only a few recent studies are grasping the role of energy culture in the dynamics of energy poverty and its impact on thermal retrofit and appliance replacement policies in southern Chile. As a result, policies fail to meet the decontamination target. This site-specific and deeply embedded energy culture has turned into an air pollution problem that is being tackled by policies without considering, for example, the multifunctionality of these appliances, the habits related to indoor thermal comfort and the whole culture around firewood in south Chile.

This environmental problem can be observed through the energy poverty lens, allowing to link the decontamination target with just energy transition to clean energy, but it must recognise how local energy culture is embedded in it and can cope with it. This case is an example of how standardised and homogeneous energy efficiency interventions have led to a tension between decontamination policies and the cultural dimension of energy poverty, failing to accomplish their objectives while people, especially the most vulnerable, are still suffering health impacts.

This article aimed to articulate local energy culture with a context-sensitive three-dimensional notion of energy poverty, emphasise and give some insights about the importance of developing adequate and contextualised policies and programmes that can mitigate energy poverty in Chile and at the same time reduce air pollution. Even though it is hard and timely to produce interdisciplinary knowledge about energy culture, it is a key input to design adequate policies to reduce both energy consumption and emissions. Site-specific sociocultural factors must be recognised and included in the energy efficiency policies to develop effective and responsive local solutions. Maybe it would take longer but promises improved results.

Notes

1 <https://sdgs.un.org/goals>

2 MINVU is the acronym in Spanish that means 'Ministerio de Vivienda y Urbanismo'

3 MINEN is the acronym in Spanish that means 'Ministerio de Energía'

4 MMA is the acronym in Spanish that means 'Ministerio del Medio Ambiente'

5 According to the air quality national primary norm (N° 39.955, 2011) limits of pollutant concentration for PM10 and PM2.5 are exceeded when 50 µg/m³ and 20 µg/m³ annual concentration respectively, being more flexible than the 20 µg/m³ and 10 µg/m³ suggested by WHO for the same contaminants.

6 More information available at: <https://sinca.mma.gob.cl/>

7 PDA is the acronym in Spanish that means 'Plan de Descontaminación Atmosférica'

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8 More information at: <https://catalogo.minvu.cl/cgi-bin/koha/opac-detail.pl?biblionumber=1386>

9 More information at: <https://www.minvu.cl/postulacion/llamado-nacional-pppf-2019>

10 Information sent by the Ministry of Environment to researchers: Transparencia Pública.

11 Such as subsidies on electricity, gas only in Magallanes region and direct money transfer only in Aysén region.

12 Search was made on September 20th, 2021. Query at WOS+Scielo was TS=((energy OR fuel OR firewood) AND (poverty OR household* OR domestic) AND Chile) ALL YEARS. DATA BASE: WOS, KJD, RSCI, SCIELO. Query at SCOPUS was TITLE-ABS-KEY (((energy OR fuel OR firewood) AND (poverty OR household* OR domestic) AND Chile)). From 235 registers, 160 articles were selected after erasing duplicates, conference papers, and non-related papers through title analysis.

13 Common practice in south Chile where people cut the air flow to increase the burning time of the firewood. This is also related to higher pollutant emissions because of the slow and incomplete combustion.

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