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Exploring role-playing as a tool for involving citizens in air pollution mitigation urban policies

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The design of air pollution control policies is a complex decision-making process. Public participation can enhance the legitimacy and effectiveness of environmental urban regulations but does not always occur naturally. This article presents the experience of the use of role-playing in six mid-sized cities in southern Chile to evaluate how residents affected by high concentrations of fine particulate matter perceive the problem and debate possible solutions. For this, the participants were asked to assume the role of advisors. On that premise, they had to prioritize between a series of mitigation measures and reach a consensus with other advisors. The results show the potential of role-playing games, on the one hand, to promote critical thinking and argument skills among the general public and, on the other, to help policymakers in the design of more operative and fair plans of action.

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Introduction

In southern Chile, the use of wood-burning heaters and stoves is particularly common. Although there is no exhaustive registry, it is calculated that approximately 7 in every 10 homes in the south of the country use wood for heating or cooking (Ministerio de Desarrollo Social y Familia, 2017). A large share of wood-burning stove users is in socially vulnerable sectors, for whom it is too expensive to access other sources of energy (Schueftan and González, 2015; Boso et al., 2017; Reyes et al., 2019). The relations between rural and urban areas are narrow, something that favors the ancestral cultural practice of heating and cooking with firewood occurring in cities with tens of thousands of inhabitants. In addition, as happens in other temperate and rainy regions on the planet, like Northern Europe or the Australian continent, the people value fire for comfort or a greater sense of well-being (Hine et al., 2007; Reeve et al., 2013; Boso et al., 2018; 2020a; Sahlberg et al., 2022). Every winter, the substantial use of wood-burning stoves and the climatic conditions of the area generate severe episodes of air pollution due to particulate matter (Jorquera et al., 2018).

Over the past 15 years, authorities have declared non-attainment areas due to high levels of particulate matter in several cities in the country. According to Chilean regulations, non-attainment areas are places where one or more environmental quality standards have been exceeded for at least 3 years[1]. In the case of cities polluted by wood smoke, the declaration of a non-attainment area is a precondition for triggering an Atmospheric Decontamination Plan (ADP), a normative instrument that stimulates the participation of different sectors involved in this environmental problem through programs and incentives intended to: (i) replace old woodstoves with less polluting technologies; (ii) improve the fuel used in domestic heating (promoting the purchase of certified wood); (iii) improve the thermal refurbishment of homes; (iv) restrict firewood burning in health emergency periods; and (v) create educational campaigns. Despite government intervention and efforts, in most cities in the south (with or without ADP), people continue breathing unhealthy air in winter, with $PM_{2.5}$ levels far exceeding the limits recommended by the WHO (IQAir. World Air Quality Report, 2021).

As Poortinga and Darnton (2016) point out, one of the main challenges in designing environmental policies is adjusting action plans to the heterogeneous nature of the public. Universalist environmental policies often tend to produce inefficient results (McKenzie-Mohr, 2011; Campbell and Corley, 2015; Poortinga and Darnton, 2016). For example, a policy restricting the use of a wood-burning stove in critical periods can generate adverse reactions and high levels of non-compliance, given that not all of the public is affected equally in their daily activities (Boso et al., 2018). When an intervention does not recognize the different circumstances of individuals, they tend to react heterogeneously (Poortinga and Darnton, 2016), or even ignore recommendations (Bickerstaff and Walker, 2001).

On the other hand, although air pollution puts people's health at risk, citizen involvement in mitigation policies does not always occur automatically. Certainly, many people can make conscious decisions to protect themselves from environmental risks individually. For example, they can use masks, not open windows, or try not to go out during a critical episode. However, participating in, accepting, and being committed to collective decisions about how to improve air quality are less habitual attitudes. Urban environmental planning occurs in the complexity of changeable contexts and generates social controversies and, sometimes, uncertain futures (Campbell and Corley, 2015). Several studies in southern Chile report that dealing with air pollution requires management of the collective risk (Vallejos-Romero and Oñate-Ñancucheo, 2013; Boso et al., 2020a; 2020b). Individual responses, conditioned by energy

poverty, often lead residents to impasses, where citizens must choose between being cold, breathing clean air, or taking care of other basic needs (Reyes et al., 2019; Boso et al., 2022).

Investigating in detail how to engage society in air quality governance is crucial for several reasons. First, the people affected by the restriction measures or who can opt for certain subsidies to promote behavioral changes must be heard and be able to participate in the decision-making processes. Thus, the ADPs and the institutions in charge of executing them can not only increase their legitimacy but also be more effective. Second, often ADPs are designed by policy-makers who support the opinion of scientists or experts. As a result of this process, the packages of measures applied for air pollution control tend to have an especially technical or engineering approach. This creates knowledge gaps that, often, distance the objectives of the environmental policies from the behavior of the public they wish to affect (Boso et al., 2017). In that sense, the participation of the non-expert public in environmental policies can help improve the quality of the decision-making when providing those in charge with unique information on local knowledge and cultural, social, and economic conditions (Yearley et al., 2003; Dietz and Stern, 2008; Kasymova and Gaynor, 2014).

In recent decades, social sciences have developed a wide variety of methods that involve the public in policy planning, ranging from traditional surveys to more sophisticated and interactive approaches. Scenario construction methods, which include role-playing techniques, have been shown to be especially useful for eliciting alternative realities and possible futures (Thomas et al., 2018). These involvement exercises help to consider multiple perspectives, prioritizing the main concerns of the affected public and generating key recommendations for policy-making. Several authors define role-playing as a situation where participants assume a role, i.e., they interpret a role (their own or another's) in a specific situation/scenario (Steinert, 1993; Alkin and Christie, 2002; Gordon and Thomas, 2018). The role is taken in a game setting, i.e., a safe space (physical or virtual) in which participants can express their opinions freely and creatively (Alkin and Christie, 2002; Gordon and Thomas, 2018).

Role-playing is a technique derived from sociodrama, which is why the focus is not on the participant's individual interpretation or on the culturally defined role they take on (Steinert, 1993). This means participants must represent a character, but they do not have to learn or memorize a script (Steinert, 1993). Although there are different types of role-play exercises within the scope of environmental policy, the most used are those where the scene involves a particular environmental problem that must be confronted by the different actors whose roles the participants have taken on. Role-play games are growing in popularity in environmental sociology (Thomas et al., 2018; Broska et al., 2022) as they permit the structuring of solutions to complex problems or socioecological controversies (Stirling, 2010) while fostering citizen involvement and public governance, specifically to favor citizens' reflection and understanding of the complexity of the rationales, interests and public values which are part of the decision-making process.

In this study, we used role play to analyze the deliberations on possible solutions to the problem of air pollution in southern urban Chile. In addition to investigating how the public hier-archizes and makes decisions on different mitigation measures, we explore the potential of role-playing games to yield insights into a fundamental environmental policy problem and to foster critical thinking and argumentation skills among participants.

Methods and data

Study area. In this study, residents of six mid-sized cities in southern Chile participated, safeguarding the demographic
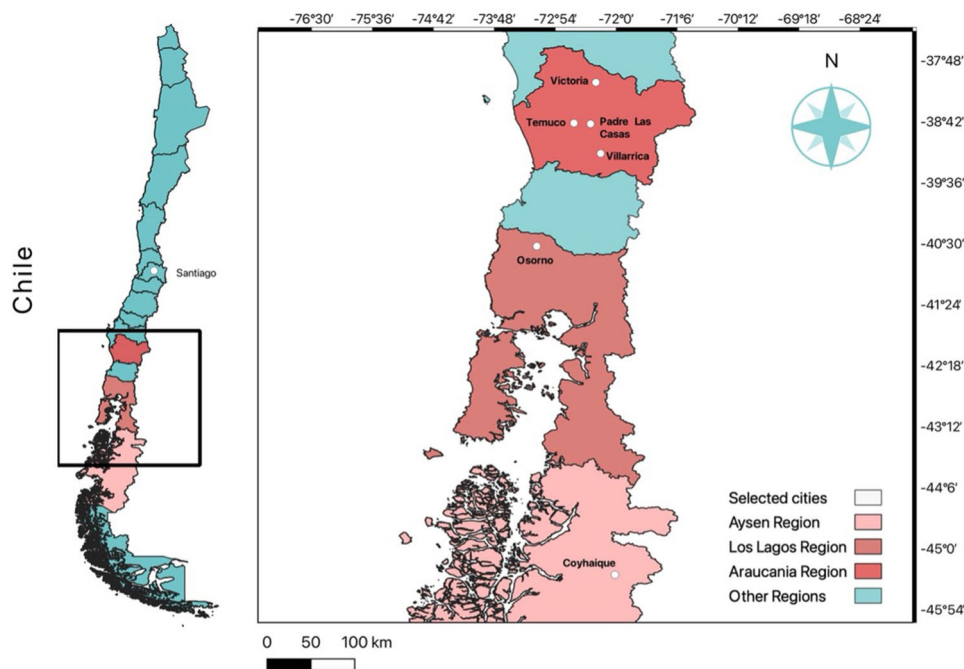
Fig. 1 Map of the study area.

Table 1 Characteristics of selected cities.									
Selected cities	ADP	% IND	% MDP	% ELD	AHI (USD)	Average years of schooling	Heating degrees days annual (°C). Base 15 °C	No. of houses	TP
Temuco	Yes	22.6	15	10.8	676.5	11.7	1250–1500	104,757	282,415
Padre Las Casas	Yes	50	29	9.7	418.8	10.3	1250–1500	26,158	76,126
Villarrica	No	27.5	24.6	12	469.5	10	1250–1500	28,288	55,478
Victoria	No	29	32.6	13.9	350.8	9.7	1000–1250	12,828	34,182
Osorno	Yes	29.8	20.4	12.7	524.2	10.6	1500–2000	60,132	161,460
Coyhaique	Yes	25.5	17.7	9	832.6	11	>2000	23,999	57,818

Source: Prepared by the authors based on data from Instituto Nacional de Estadísticas (2017) and Ministerio de Desarrollo Social y Familia (2017).
Notes: *ADP* does the city have an Atmospheric Decontamination Plan? Yes or No; % *IND* percentage of indigenous people; % *MDP* multidimensional poverty in percentage; % *ELD* Percentage of Elderly people.; *AHI* average household income per month; Annual heating degree days according to "Design guide for energy efficiency in social housing" (MINVU.); *TP* total population.

diversity in the case studies selected. The selected cities are located approximately between the 37°S and 45.5°S parallels. Four are in the Region of La Araucanía, one in the Region of Los Lagos, and the other in the Region of Aysén (see Fig. 1). All share winter with relatively similar climatic conditions according to the Köppen-Geiger climate classification (Sarricolea et al., 2017), considered a "rainy temperate climate" (classifications *csb, cfb(s)* and *cfb*)[2]. By way of comparison, the climate of the study area resembles that of northern France or western Germany, with cold winters and rain distributed throughout the entire year. The cities of Coyhaique, Temuco, Padre Las Casas, and Osorno were chosen for being among the five most polluted in Chile, and among the top twenty in Latin America, due to the high PM2.5 concentrations, which every winter exceed the healthy limits established by the WHO. In addition, Villarrica and Victoria were included in the study because, despite not having an ADP, nor an official system to measure particulate matter, both cities are a good example of what happens in many places in the south of the country, where environmental problems tend to be invisible.

In Table 1 some basic characteristics of the cities that comprise the study area are described. Temuco and Osorno are the two largest cities, followed by Padre Las Casas. This last city, in addition to having a high percentage of indigenous people (50.0%), also has

the highest level in the multidimensional poverty index and the lowest income, together with Victoria. At the opposite end is Coyhaique, the capital of the Region of Aysén, located in the heart of Chilean Patagonia. This city has the highest average income per household since it is relatively small, and in most families, there are people who work as government officials in different types of state services. However, Coyhaique is the city with the coldest recorded winters, given that it is much more to the south than the other cities selected in the study (see Fig. 1). It is for this reason that it has the highest value of heating degree days per year, according to the thermal zoning performed by MINVU in 2009.

Rationale. In our study, a role-play methodology was employed to enable participants to select from a range of six potential measures, with the option to propose additional alternatives, aimed at mitigating air pollution in a fictional city located in urban southern Chile. The study encompassed a dual objective. Firstly, our aim was to assess the perceptions of residents living in urban areas afflicted by severe air quality issues regarding the various measures established by the ADPs. Despite the existence of mechanisms for citizen participation within the ADPs, the responsibility for planning, design, and decision-making tends to

rest primarily with local stakeholders, policymakers, and government technicians. Secondly, our study sought to explore the potential of role-play methods in facilitating citizen engagement within the context of local energy transitions. In recent years, successive administrations in Chile have adopted a progressively decarbonized approach to the nation's energy landscape. This strategic shift encompasses various initiatives, including developing energy scenarios and projections aligned to achieve carbon neutrality by 2050. Central components of this strategy involve expediting the retirement schedule of coal-fired power plants, endorsing renewable energy sources, and advocating for the adoption of electrification systems for residential heating. This contextual backdrop imposes significant challenges on local government officials formulating ADPs. These officials face the intricate task of harmonizing national energy policy objectives with the imperative of alleviating the prevailing energy vulnerability that characterizes urban areas in southern Chile. Role-playing games can serve as a valuable tool to assist urban planners in navigating the complex challenges associated with advancing equitable and sustainable energy transitions.

The citizen participation sessions were structured into four sequential steps as a part of our design. Initially, each participant assumed the role of an advisor within a simulated local emergency committee, tasked with the responsibility of prioritizing and agreeing upon a set of measures. Second, participants were individually required to rank the different options according to their personal preferences. In the subsequent step, participants engage in deliberations aimed at achieving a consensus. Finally, we gathered and analyzed both quantitative and qualitative data derived from these exercises.

Each of the steps taken in the citizen participation exercises obeyed a logic in our study. First, by adopting a fictitious position, the participants not only empathized with the decision-maker's view but also, always starting from their personal experience, tried to orient their opinions towards the public interest. This implies that the participants had to reflect and comprehensively advance on aspects that are not normally so central to their interpretation about air quality, as for example what measures seem most effective to bring about changes in citizens' behavior that contribute to mitigating pollution.

The second element that defined this exercise of citizen involvement was the classification of the different measures to improve air quality in an order of preference. In the context of the governance of natural resources, decision-making requires a choice among various options, since the resources to tackle environmental problems are usually limited. Thus, the preferences of the group are deliberate, condensed, and hierarchized in a work of collective knowledge generation to resolve complex problems. In addition, thanks to this technique, the tensions among the different types of measures, personal experiences, and decisions can be seen, thereby enriching the dialog and the discussion among the participants in the search for solutions.

Third, each group was tasked with reaching a consensus in the prioritization of measures. This third element was not only relevant in the generation of a result, but it promoted debate, and the perceptions of the participants regarding air quality and their ideas about what the most suitable policies would help to solve this environmental problem. Shared understandings were elicited across a continuous process of deliberation and, in all the groups, the different positions and views on urban air pollution were presented and understood.

Sample and participants. Although we recruited a non-representative sample, it reflected the demographic composition of southern urban Chile relatively, recognizing that the statistical representation of the region is unrealistic for a qualitative design. The participant selection tried to be balanced in terms of gender and age, in addition to capturing some key aspects that define local demographic characteristics, which responded to the criterion of density inherent in qualitative approaches. By doing so, we sought to capture a range of perspectives on air quality, energy practical experiences, and local knowledge that were relevant to our research questions. While generalizability may be limited, this approach allowed us to gain valuable insights into the lived realities of individuals within the specific geographical and socio-cultural context under investigation.

As is common in social research, the final composition of the groups was marked by the attendance of the participants to the calls which, to a certain point, is an unpredictable or uncontrollable factor. In each city, recruitment was carried out by neutral third parties. Until they arrived at the meeting place, the participants had no specific information about either the content or the format of the session. Before beginning the activity, all the participants were informed and decided to participate voluntarily and anonymously, signing a consent form, and following the protocols approved by the scientific ethics committee of the university.

In total, 46 participants became involved in the role-playing exercises. Around 65% were women and 35% were men. Participation by city varied between 15% and 19% of participants per city. The education level of the participants was mainly university professionals (complete 22%, incomplete 15%, and other 15% postgraduate) and mean level (complete 9% and incomplete 11%). Belonging to an indigenous people was 29% of the cases and all responded that they were Mapuche. In addition, 26% indicated the presence of people who suffer from chronic respiratory or cardiovascular diseases in their homes. 65% declared the use of a wood-burning stove as the main system to heat the house.

Procedure. Figure 2 summarizes the procedure applied to develop role-playing games. At the beginning of the session, each participant filled out a sociodemographic characterization survey. So that the group would gain a certain trust, they were asked to identify themselves one by one, indicating their name and place of residence. Then, the dynamics of role-playing began. First, the participants were asked to imagine that they were members of a crisis committee in the fictitious city "Salsipuedes". The attributes of this hypothetical city were presented as follows: "Salsipuedes is a city of 100,000 inhabitants in southern Chile. For some years its air quality has been worsened due to the massive use of wood-burning heaters and stoves and the smoke they produce. The WHO ranks this city among the 20 most polluted in Latin America. Each of you has been selected to be part of a Citizens Committee that must implement an action plan to control the problem of air pollution in the city in the coming years".

Once this scenario was set, the participants were given six possible proposals for public intervention:

a. We propose the prohibition of the use of wood-burning stoves and progress in the replacement of pellet or paraffin devices;
b. A policy must be developed that favors the use of electricity as the main source of heating;
c. Substitution of all wood-burning stoves for a district heating system;
d. The Thermal Refurbishment Subsidy Program must be strengthened;
e. We propose supporting companies that sell firewood and the wood-burning stove industry. This is to say, a subsidy for the purchase of certified firewood and the replacement of old woodstoves;
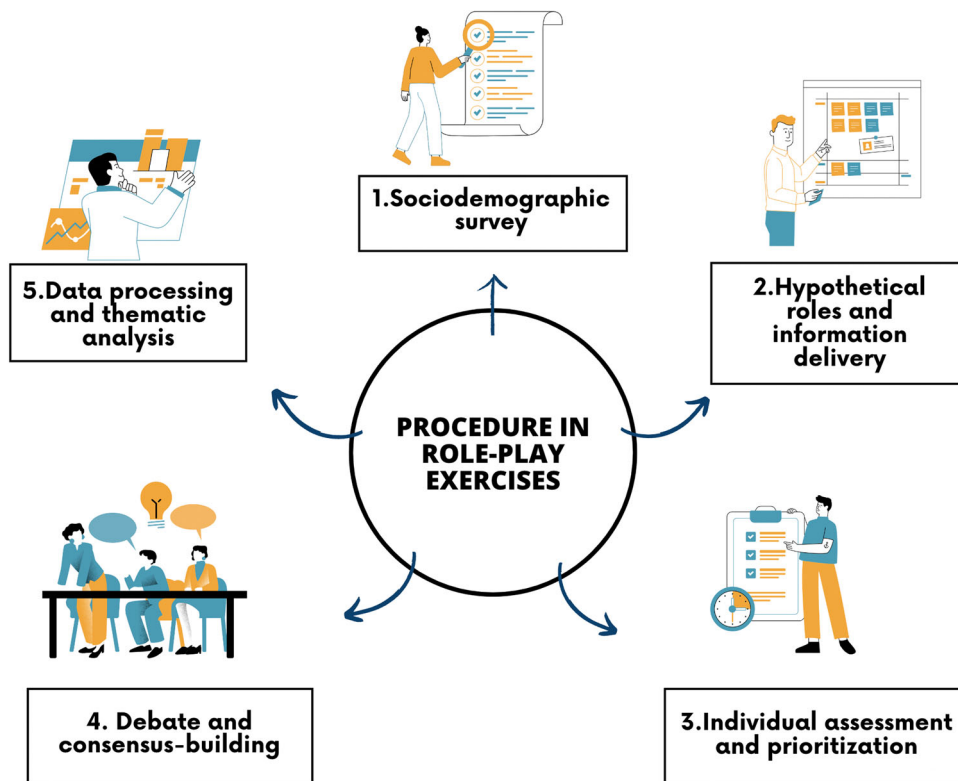f. We propose that a policy be generated that promotes subsidizing gas.

Fig. 2 Procedure.

Next, the participants were asked to assess the different options and, if they thought it necessary, to offer alternative measures as the basis for an action plan to reduce air pollution in the city. Participants based their choices and reflections on their own experiences, so they were not provided with any information on the costs and benefits of the different policy options, or any other factual background. Individually, the participants prioritized those measures where the emphasis was placed through a hierarchical structuring scale. From the choice that each participant made, a debate began, in which the committee members had to argue their decision-making to try and convince their fellow committee members and listen to the proposals of the other members of the group. The objective of the group was to try to reach a consensus of the committee to generate an Action Plan. However, for the researchers, the dialog, the emerging perceptions, and the discourses built around air pollution and possible interventions to mitigate it constituted the most sociologically relevant data.

Role-play groups were conducted in Spanish by a team comprised of three experienced researchers. All the discussions were recorded in audio and transcribed literally before being analyzed with the NVivo software. The transcriptions were anonymized and collated with the audio files by the research team. Following Braun and Clarke (2006), we applied an inductive thematic analysis to the texts obtained from the transcriptions. In the first stage, the main author made a list of the main subjects emerging in the group discussions. Following Graneheim and Lundman (2004), the credibility of the findings was checked by dialog between the co-investigators of the study. Generally, thematic analysis is used as a method that can reduce and systematize information using large descriptive categories, which are supported in specific narrative configurations, constituted in turn by the set of discursive positions expressed in the conversational space (Braun and Clarke, 2006). The

narrative space is constructed from an interpretative analytical exercise of phenomenological reduction, the reliability of which occurs between the consistency of the illustrative verbatims and the central category. Due to the study characteristics, emerging categories were not developed.

Results
Preferences. As observed in Fig. 3, there was a significant variation in the participants' preferences. Thermal refurbishment was the most highly rated option, followed by the focus on electricity, the gas subsidy, the combination between substitution to pellets, and the prohibition of the use of wood-burning stoves. The proposals with the least support were district heating and the promotion of the use of certified firewood. These positions were maintained and reinforced in the subsequent debate.

The subsidy for the thermal refurbishment of the house was the first option in five cities, being Osorno the exception, where participants preferred the gas subsidy. When the hierarchical structuring of proposals by commune is compared (Fig. 4), there are some remarkable differences, in addition to the preference for gas by the Osorno group. In Padre Las Casas and Temuco, for example, the second option reinforces the combination of incentives for the replacement by alternative technologies to firewood and fines for violators which, together with thermal refurbishment, constitutes the focus of the current ADP. However, in the rest of the communes, the participants were more skeptical about this option. In Coyhaique there was strong support for the electrification of the heating systems and district heating which, as is seen next, is linked to a focus on seeking community solutions rather than at the level of the end user. In Villarrica, where there is still no ADP, the focus on improving the quality of the firewood and heaters is rated positively in the search for an energy transition model best suited to the local culture and the social practices of heating ingrained in the territory.
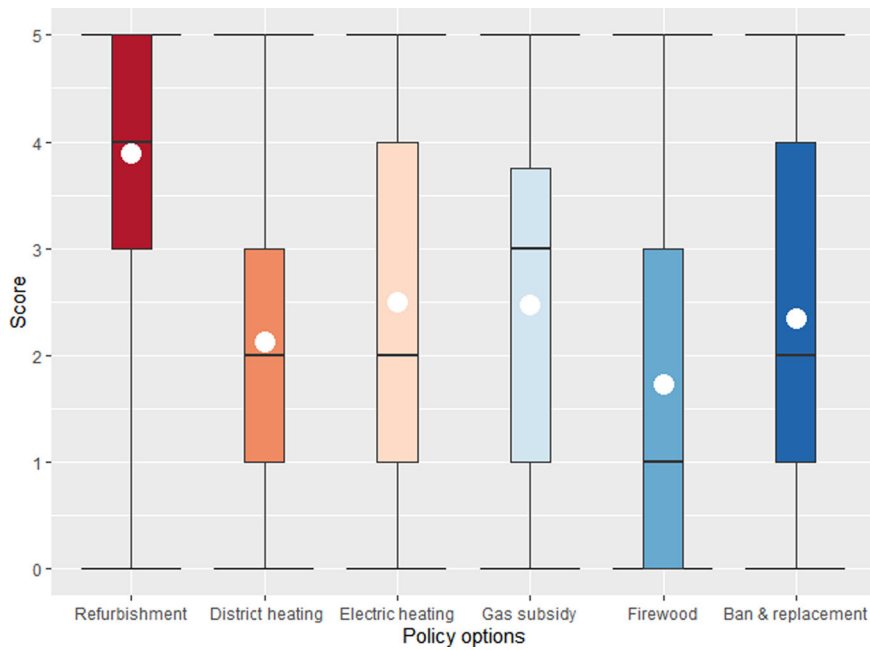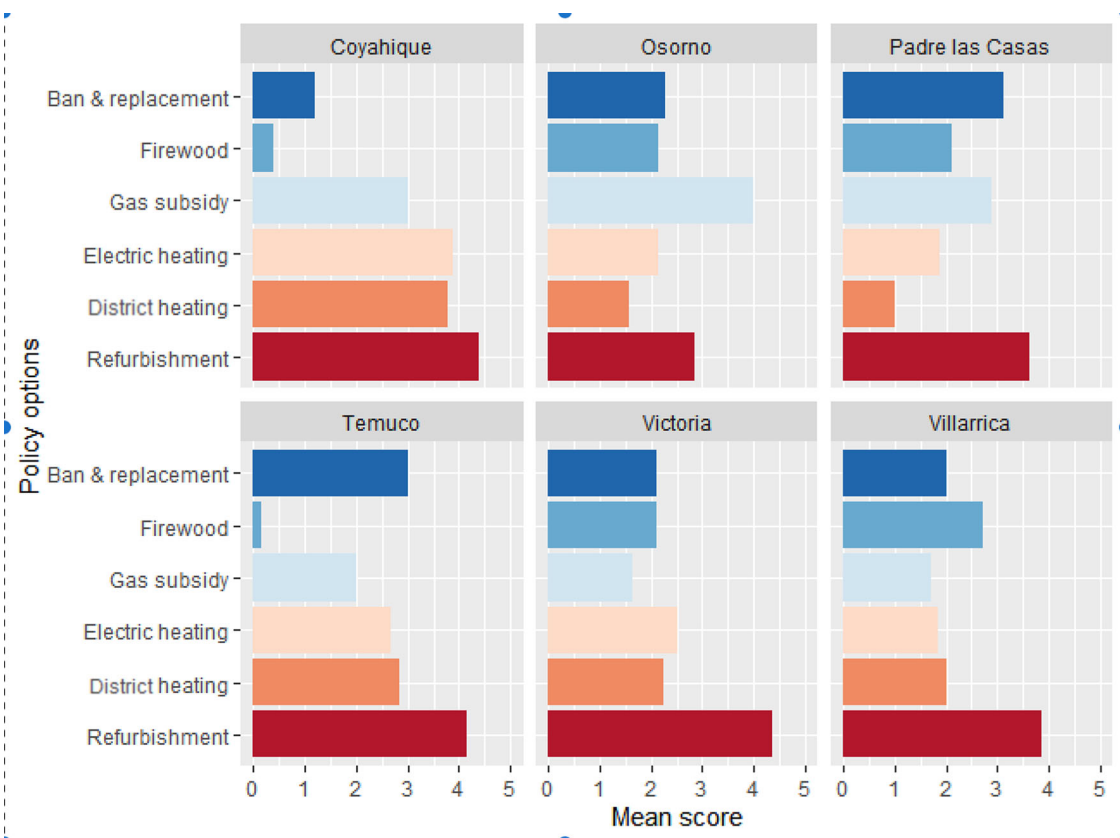
Fig. 3 Policies preferred by participants.

Fig. 4 Prioritization of proposals by commune.

Deliberation

Thermal refurbishment subsidy. The thermal refurbishment of houses was one of the measures for atmospheric pollution control with the most consensus in the discussion. Most of the participants contributed positive arguments in favor of public investment to improve the thermal refurbishment of buildings and, in general, the correct insulation of houses. Based on their personal experiences and practical knowledge, the diagnosis of the groups agreed when indicating that the base of the problem of wood smoke pollution is usually in the uncertainty of the materials and deficiencies of construction of many of the houses.

There was a consensus that it is necessary to improve the energy efficiency of homes to reduce air pollution levels. The thermal refurbishment of houses is seen as a prerequisite for efficiency.

Mod: Of seven participants, there are four who agree with this option. Why? Could you argue why you think it's the best intervention?

V1: It's that… I think it's the main thing. Because if I have a well-insulated house, I'm going to need less firewood for heating. The heat will stay around longer.

V2: and in addition, …

V3: Then, whichever option you choose… you have to combine it with thermal refurbishment. Once the house is refurbished, afterward, uh… after the cost will be minimal.

V2: … and in addition all the other measures, electricity or gas… they're still measures that lead to a certain degree of pollution in a city that is already pretty polluted or they have some other environmental impact (Victoria).

In most groups, the consensus was that opting for thermal refurbishment as an improvement intervention offers several advantages over other options. The primary advantage is the reduction in fuel consumption and the resulting economic savings, which is particularly important for vulnerable families. Participants across different discussion groups agreed that programs should prioritize or be directed towards the most socially disadvantaged sectors. Some groups, including Coyhaique, Temuco, and Osorno, where an ADP is in place, highlighted the issue of subsidies often reaching households that are least in need, as they must meet certain requirements (e.g., financial resources for co-financing thermal covering installation). Consequently, participants felt that a policy targeting houses with the most significant deficiencies would enhance its legitimacy. Furthermore, other positive aspects of thermal refurbishment were emphasized in the groups. These included reduced indoor pollution through improved house air tightness, enhanced esthetics leading to increased comfort and well-being for residents, and the prevention of risks associated with summer heatwaves. However, participants also identified two drawbacks of this measure: the high economic cost of refurbishing houses in older neighborhoods and its long timeframe of implementation.

Electrification of heating systems. The electrification of heating systems has emerged as a highly contentious measure within the studied groups, giving rise to polarized discursive positions. Furthermore, it has been observed that support for this measure is influenced by local historical and cultural factors. For instance, in the case of Coyhaique, participants expressed a positive assessment, drawing upon their experiences with the HidroAysen-Castilla hydroelectric project, which was regarded as a missed opportunity and a failed endeavor according to the prevailing opinion (Boso et al., 2017). The residents of Coyhaique deemed it illogical to endure critical episodes of severe PM pollution every winter or for certain families to endure cold conditions when both issues could have been resolved through the implementation of a hydroelectric power station. In contrast, participants in Villarrica, a city characterized by amenity migration, advocated for this measure due to its alignment with their ecological values. Consequently, they emphasized the need to prioritize renewable energy sources to facilitate the transition toward a decarbonized future while simultaneously improving air quality.

This aspect also was valued in other groups but with less emphasis. From a practical point of view, in almost all the groups it was valued positively that the electrification of heating systems is an extremely comfortable solution. On the one hand, it does not involve tasks associated with its accumulation, storage, or complex maintenance of the equipment, unlike what happens with other alternatives like firewood or paraffin. In addition, it is worth noting that electrical heating systems allow greater control overturning the devices on and off.

Some participants emphasized that it would be a quickly implemented measure. There is an electricity grid in every city, families already have certain habits and practices associated with electricity in their daily routines and, therefore, it seems an option that should not generate great cultural resistance.

V5: Electricity…. I consider it to be the most practical, the easiest to apply. In addition, in the houses you don't need to be tossing wood on the fire… And, for example, with paraffin, you must go out and buy it… However, electricity is something more practical, easier. Although electricity is expensive… it's more practical, I consider that it is the most practical.

V6: I agree with her. In addition, the use of solar panels to generate it could be promoted (Victoria).

Participants also recognized the need for substantial increases in electrical energy generation, improvements in local distribution networks, and upgrades in power supply infrastructure within houses. These requirements imply that the measure would necessitate changes and investments in the city's infrastructure, making it a long-term option. Additionally, they expressed concerns about potential socio-environmental conflicts arising from the measure's impact on the environment and communities, particularly in relation to power generation facilities that could lead to conflicts with local Mapuche communities.

Furthermore, participants conveyed apprehension about energy security and equity in distribution. They emphasized the importance of providing constant and sufficient electrical energy to all, including those in rural areas of the municipalities. Some of them also raised concerns about the fire risk associated with this measure, particularly for houses with poor electrical system conditions. The idea of implementing stringent price regulations to guarantee universal access to energy for heating and cooking purposes in every household emerged consistently across all the groups.

Gas subsidy. The reference to the case of Punta Arenas, the Capital City of the Region of Magallanes, appeared in most of the groups. Despite being in the south of the country and sharing climatic conditions with the rest of the cities of our study, the gas subsidy gives Punta Arenas the best air quality indices. From this experience, it stands out as a solution that does not generate social conflict and that the management and maintenance of the gas heating systems is usually quite simple. However, extending the gas subsidy to other cities is perceived as an option that presents more disadvantages than advantages. In fact, the gas subsidy was one of the worst-evaluated measures in the different groups. First, it is considered that gas is expensive. Therefore, to keep the price low for the population would require strong regulation and public investment. The State would be forced to make large transfers to the gas distributors and, therefore, taxes would have to be increased. In addition, it is not an energy source generated in the country, which is why it also implies energy security problems and dependency on stable supply agreements with third countries.

S5: because it must be borne in mind that gas is a limited resource.

S7: and what happens in Punta Arenas happens to me a bit. So, I think it leads to an excessive use and gas is not sustainable. I feel that policy of gas subsidy can be misrepresented. We need to move towards a more sustainable system (Temuco).

It was also expressed that the use of this energy in the home can entail certain risks, either because a good part of the population in southern Chile is not used to using it or they do not have sufficient infrastructure in the home for its correct use. In

addition, an initial investment in boilers and central heating systems in the houses would be necessary, so they thought that the cost for the end user could be high. In the groups, aspects regarding the characteristics of this technology were also indicated. For example, some participants commented that "the heat doesn't last", or "it's not stable" and that in addition "it's damp", or "uncomfortable".

Support for replacing wood-burning stoves for pellets and restrictions. The combination of two of the most applied measures in the deployment of the ADPs in southern Chile generated debate and, generally, was not the first option. On the one hand, some participants believe the experience of replacing firewood with pellets shows us that the measure is adapted to the local culture. Although there are remarkable differences between how a pellet stove and a wood-burning stove work, pellets are a biomass fuel that, in southern Chile, comes from sawdust and wood. The combustion system is similar and the transition from small wood producers to pellet producers can happen easily to not impact the local economy.

I went for the stove replacement from wood to pellets also thinking a little about, the cultural baggage, so to speak. The population in the south is accustomed to heating with firewood. There are elements that are more custom, tradition… they're symbolic. For example, the idea of seeing the flame or the fire. It gives you much more of a feeling of warmth than electrical systems. I think that with pellets there is less reluctance to change… people keep thinking… or at least keep feeling that the heating is the same, or quite similar (Temuco, S7).

The ban on firewood sparked controversy and debate among groups, leading to disagreement in their final decisions. While recognizing the detrimental impact of poor air quality on public health, the participants found it challenging to reconcile this with their deeply held values and moral principles. They expressed concerns that banning firewood would leave economically vulnerable families without a viable heating option. As firewood is the most affordable fuel in southern Chile, its accessibility plays a crucial role in ensuring thermal comfort for these homes. Instead of a ban, participants favored pollution mitigation policies that incentivize and reinforce positive behaviors. They believed that investing in education, promoting cultural change, and exploring technological alternatives should take precedence over an outright ban on firewood.

V1: […] I see banning as the last option. It doesn't make sense, because people are going to use it all the same, […]. They'll comply in the beginning, when the inspectors start checking, but then later …

V2: Yes, it's true. That's how it was in Temuco. The restriction is put in place, and I believe that later nothing will happen. Now… I have a question: how did they do it in Canada and the northern United States? The families from there used firewood and now they use electrical energy. So, I think it's a cultural change. In other words, we are saying that it's very difficult because Mapuche families in the country use the wood-burning kitchen oven. But there might a cultural change and a shift to using electrical energy (Villarrica).

The existing restrictions on the use of firewood in several cities in southern Chile were criticized for their failure to effectively control air pollution. Participants expressed concerns about irregular compliance with these measures across different cities. They argued that a complete ban on burning firewood would be impractical to enforce, as it would require extensive monitoring of chimneys to detect visible smoke emissions or the use of dry firewood. Consequently, they deemed it unsuitable to focus on a measure that cannot be effectively enforced. During discussions on the ban of firewood, participants emphasized that the real issue lies in the unregulated burning of various fuels, including

waste materials and coal, leading to substantial emissions. They identified factors such as limited economic means, easy access to coal or garbage, the ability to burn these materials in household stoves, and a lack of awareness regarding the environmental and public health implications.

District heating. Little previous knowledge about district heating was observed among the participants. There were few references to this proposal in the group discussions and it tended to be ranked as one of the less high-priority options, which is not strange since it was the only proposal that moved away from the daily social practices of our participants. In the groups from Temuco and Coyhaique, some participants were in favor of ranking this type of heating among the first intervention options. The argument for this modality is that it reduces the users' ability to intervene in the wood-burning stoves, which, in the opinion of the participants, is the source of the problem.

As a first option, I tended toward district heating. Thinking that the city is in a grave state, it is one of the most polluted in the world, and in a context where heating is a need speaking of… southern Chile. I believe that it is a um… [the participant thinks] drastic measure. Having district heating, um… The wood-burning stoves are replaced, and thus the source of the problem is attacked more. […] I would have doubts afterward like… How am I going to pay for this later? Because, clearly, the money can be there to implement the project, but later to be able to heat everyone … (Temuco, S4).

As highlighted in the previous quotation, participants questioned the cost of implementing the heating system, both in terms of economic resources and the time required for its deployment. In addition, they expressed reservations about the operational feasibility, because there is currently no existing network in place, and houses are not adequately prepared for connection. Consequently, it is presumed that the effectiveness of the measure would be confined to the long-term. Additionally, participants acknowledged that the adoption of this heating system could potentially give rise to conflicts, as it necessitates citizen organization for its maintenance and efficient operation. Notably, in southern Chile, households are accustomed to using wood-burning heaters and stoves, predominantly driven by individual preferences.

Support for companies who produce and distribute certified firewood. Generally, the support for the companies that produce certified firewood was the lowest-rated option in the groups. When the participants reflected on possible measures to guarantee thermal comfort in their homes without adversely affecting the air quality, investing in a solution that is at the base of the problem did not seem a reasonable option to them.

Villr3: For me the proposal to support the firewood companies with the certified purchase subsidy is the last option. Because I see it, living in Villarrica and, I am in Temuco. I face the reality of the use of firewood and the air pollution is overwhelming … It is very concerning that it continues to be subsidized, thinking that the subject of firewood use is going to be solved that way…

F: You don't think it works? It isn't an effective measure to control pollution.

Vill3: Clearly because, as has been said, the use of firewood is deep-rooted. It is very difficult to change that. Subsidizing firewood, although it is certified, is how to throw more wood on the fire.

In most of the groups, there was a concern regarding the high cost of certified firewood, considering the limited purchasing power of households in southern Chile, and the resulting emergence of alternative markets for uncertified firewood. Participants observed that certified firewood generally carries a

higher price tag, which led them to argue that public investment in this option could inadvertently stimulate the demand for cheaper, lower-quality firewood through informal channels.

Furthermore, participants highlighted the potential risk associated with promoting certified firewood, namely shifting the responsibility for pollution control onto the end-users. The consumer of firewood bears the responsibility for appropriately storing it, maintaining the stove, flue, and chimney, and ensuring proper combustion to minimize emissions. Participants envisioned a hypothetical scenario in which all firewood was certified, yet pollution levels continued to exceed healthy limits. Additionally, some participants noted negative consequences associated with the focus on firewood, such as the illegal or unauthorized felling of native trees and the risk of fire in households.

The advantages they perceived in this measure focused on subjective, emotional, and cultural aspects. They think that the feeling of comfort being warmed with a firewood fire is far beyond that of other alternative systems. The wood-burning stoves in southern Chile are multifunctional and are linked to the local culture. Most houses are adapted to this heating infrastructure, which is why, in the short term, the option of certified firewood would be the one that could help reduce pollution, thereby avoiding cultural resistance to technological change.

V4: My second option is to propose support for the companies that sell firewood and wood-burning stove industries. The subsidy to buy certified firewood and the replacement of old wood-burning stoves for other wood-burning stoves that are less polluting. I think the use of dry firewood instead of green firewood needs to be encouraged. Retailers often make money by selling green firewood. People buy it out of necessity really; they buy it where it's cheap. But there's already a heating method in this city that's being used, but that pollutes a lot. Why not do it so it pollutes less? (Victoria)

Discussion
Air pollution and the need for transitioning toward cleaner energy sources, driven by the imperatives of addressing environmental issues and the broader challenges of global warming, have intensified the demands and responsibilities of local policymakers. The ADPs applied in the cities in southern Chile are the main instruments to achieve just and clean energy transitions. To date, the results in reducing the levels of particulate matter have been modest, despite the considerable efforts made by the authorities and responsible governmental institutions. One of the possible strategies of improvement consists of the search for mechanisms to involve citizens in solving the problem. This study proposed a series of participants to analyze different alternative intervention scenarios using a role-playing exercise. With this technique, we endeavored to focus attention on the strategies for change and not only on the participants' perceptions. In addition to trying to discover the motivations that orient the environmental behavior of citizens in southern Chile and the factors that constrain it, our intention was to address the case study with a problem-solving approach.

The results show the potential of role-playing games to promote critical thinking and argument skills among the non-expert public, in the same sense as indicated by some previous studies (Rumore et al., 2016; Thomas et al., 2018). In our experience, the participants were able to have a discussion using constructive reflections, starting from personal experience, but leading towards the search for a common goal. Thus, although improving the air quality in southern urban Chile poses numerous challenges, the participants placed particular emphasis on those solutions that address the struggle for energy insecurity. Our participants concluded that urban planning systems should move towards mitigating pollution and relieving the damage that extreme cold and humidity cause houses in situations of multidimensional poverty. From the analysis of the narratives of the different groups, a common idea emerged: breathing clean air and access to a safe and comfortable house are fundamental human rights. Therefore, in the group dialogs, most of the participants oriented their planning decisions towards the goal of increasing energy efficiency, facilitating both access to energy alternatives to firewood, and a far-reaching improvement in the thermal refurbishment of the houses. Thus, a concern shared by most participants is that the ADPs are a useful tool to avoid socially more vulnerable homes experiencing thermal discomfort or having their economic disadvantages exacerbated.

The participants pointed out a view that is commonly noted in the literature, namely that low energy efficiency is a serious problem that affects medium and low-income households (Reyes et al., 2019; Pérez-Fargallo et al., 2020). In the groups, it was indicated that thermal comfort is usually low unless stoves are used that not only consume excessive amounts of firewood but also produce strong $PM_{2.5}$ emissions. This creates a spiral in which the residents use wood-burning stoves to avoid falling to unhealthy low temperatures, reject the adoption of more efficient technologies so that the energy bill does not drastically increase and, consequently, pollute the air they breathe. It was criticized that, in southern Chile, some low-income families cannot even manage the costs of operating a wood-burning stove. Thus, addressing these situations of inequality by improving the ability of the most vulnerable households to access thermal insulation subsidies was considered a fundamental axis of urban planning.

In the field of environmental studies, these exercises have proven valuable in engaging citizens in climate change adaptation measures (Paschall, Wüstenhagen, 2012; Schenk and Susskind, 2014; Sterman et al., 2015; Rumore, Schenk, and Susskind, 2016) or energy transitions (Thomas et al., 2018; Wagner and Gałuszka, 2020). Our research highlights the role-playing's potential to recognize instances of energy injustice. Through dialogs and prioritization exercises, participants unveiled the hidden energy vulnerability present in southern Chile, that is, the propensity of households to experience harm from energy deprivation because their situation is not captured by common or official indicators of energy poverty (Willand, Torabi, and Horne, 2023). Underconsumption that leads to thermal comfort deprivation, inefficient combustion of firewood causing harmful air pollution exposures, and cases where energetically precarious households are unrecognized by institutions due to non-compliance with eligibility criteria for assistance programs, are just some of the situations of hidden energy vulnerability revealed in participants' narratives.

Can these games help urban communities in southern Chile mitigate air pollution? It is evident that participatory exercises cannot in themselves improve air quality or put an end to the problems of energy poverty in the region. However, our study shows that public participation in role-playing exercises could help policymakers design more effective and fair plans of action. Often, urban environmental management plans fail when they connect regulations to the attitudes and behaviors they are attempting to guide (Davis, 2008; McKenzie-Mohr, 2011; Espluga et al., 2016). These games allow for collective reflection on how to prioritize, what to invest resources in, and what strategies are the best to protect the most vulnerable populations. Potentially, the games could also be applied iteratively and include various alternative perspectives. Thus, policymakers, local activists, and business leaders could also participate to raise and debate their points of view with the public. More sophisticated designs could help identify certain common strategies that can signify partial advances toward the objective of clean air in the region.

Insights gleaned from our research findings may be relevant beyond air pollution control policies. Consistent with prior research on street science (Corburn, 2005; Privitera et al., 2021; Smith et al., 2022; Barry, 2022; Corburn et al., 2022), this study provides further evidence supporting the necessity for policymakers and urban planners to relinquish the "deficit" model of citizen participation. Assuming that the public is ignorant and needs to be educated on environmental issues strips urban environmental policy of the "contextual intelligence" that only residents possess (Corburn, 2005). Underprivileged communities facing the highest technological and environmental risks need a more significant role in describing and designing solutions for the hazards they encounter. Undoubtedly, the task of scaling up local knowledge to the levels of generality that public policy requires is intricate, given the wide range of social and cultural contexts influencing socioecological problems. The results of this research show that role-playing games are not only a way to incorporate local knowledge into the practice of policy-making, but they apply to other fields such as urban biodiversity conservation, responsible solid waste management, water saving in drought scenarios, or health protection against heatwaves.

This study is the first approach using role-playing games for the problem of air quality management in cities saturated by firewood smoke. Therefore, from the start, there are two clear limitations that must be considered when assessing the potential of these exercises. First, their design: role-playing games are exercises to stimulate reflection and conversation on the environmental problem posed. They are, however, a simplification of reality, where a limited level of information is dealt with. For that reason, used in isolation, role-playing games are an exercise to initiate social dialog in an organized way, but they cannot result in final decision-making. Second, we believe that a greater internal homogenization of the sociodemographic characteristics of the participants in the exercises is preferable, and a greater inter-group heterogeneity. Although more resources are needed to customize and adapt the exercises, a more precise segmentation and selection of the participants in each group could contribute valuable information to the politicians responsible for how to reorient the existing ADPs or generate new environmental management tools adapted to the social and cultural diversity of the different territories and population groups that coexist in the city. Finally, this is an exploratory study. It does not intend to find causal relationships from its findings. Although the role-playing games produced encouraging results in terms of their potential to elicit deliberate solutions to the problem of air pollution control, future research should contrast and extend their validity to multiple other contexts.

Conclusions

All over the world, air pollution is a key challenge for affected communities. The results of this study show that role-playing games are an interesting way for academics, citizens, and policymakers to reflect, diagnose, and establish priorities in the search for a more effective management of the mitigation and risk prevention plans against air pollution. The promotion and development of such techniques, through the institutions, are an interesting way to rethink the design of public policies with greater effectiveness and social legitimacy. In addition, citizen involvement on a collaborative level is made possible in the search for solutions in that the problem can be understood in its broader dimensions. Therefore, our study demonstrates the usefulness of role-playing games to transfer concern and action from the interests of those involved to a perspective oriented toward the general well-being of the community. In addition, the study documents how role-playing games can be especially useful in trying to reduce the complexity of an environmental problem with multiple actors, perspectives, and conflicts of interest which, up to a certain point, can seem incommensurable.

Notes
1 Law 19,300 on General Bases of the Environment.
2 Victoria, Temuco, and Padre Las Casas: csb climate "Rainy winter Mediterranean". Osorno and Villarrica, cfb(s) climate "Temperate rainy with light summer dryness"; and Coyhaique cfb climate "Rainy temperate".

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Àlex Boso: conceptualization, methodology, investigation, writing—original draft, supervision, funding acquisition. Jaime Garrido: data analysis, writing—original draft preparation. Luz Karime Sánchez: investigation, reviewing, and editing. Ignacio Rodríguez: investigation, data curation. Arturo Vallejos-Romero: writing—reviewing and editing.

Competing interests
The authors declare no competing interests.

Ethical approval
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the Universidad de la Frontera Date: 12/04/2019 Act: 044_19.

Informed consent
All participants sign an informed consent.

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