Conclusions and Recommendations

REPORT TO THE NATIONS

The air we breathe: past, present and future

$PM_{2,5}$ air pollution in central and southern Chile

(CR)² Center for Climate and Resilience Research
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Conclusions

Photo: City of Coyhaique

Air quality is a complex issue affected not only by physico-chemical factors, but also by socio-cultural, economic and institutional variables. This report considers all these different factors with a focus on how they relate to pollution from fully inhalable particles ($PM_{2,5}$) in the residential sector.

Characterizing the evolution of air pollution in Chile was made possible by integrating historical and instrumental data and computer tools. Doing so revealed a gradual deterioration in air quality over the last 2,000 years, with a marked increase in air quality deterioration during the 20th century. This trend is directly related to the country's economic, urban and demographic growth. However, there has been a gradual improvement in air quality over recent decades as decontamination plans and public policies for monitoring and controlling emissions have been implemented. Nonetheless, this improvement is still insufficient: the effects of environmental management are spatially and temporally heterogeneous, and there is insufficient evidence of the efficiency and effectiveness of these policies.

Nationwide, the use of firewood for heating and cooking food accounted for 94% of $PM_{2,5}$ emissions in 2017, and these were unevenly distributed throughout the Chilean mainland. In the cities of central and southern Chile, $PM_{2,5}$ emissions come mainly from the residential use of firewood, while in northern Chile they come from transport and industry. Meanwhile in the capital city, Santiago, a combination of these three factors is at play. However, it is impossible to estimate the relative impact of each of these sources on air quality without accurately quantifying the emissions.

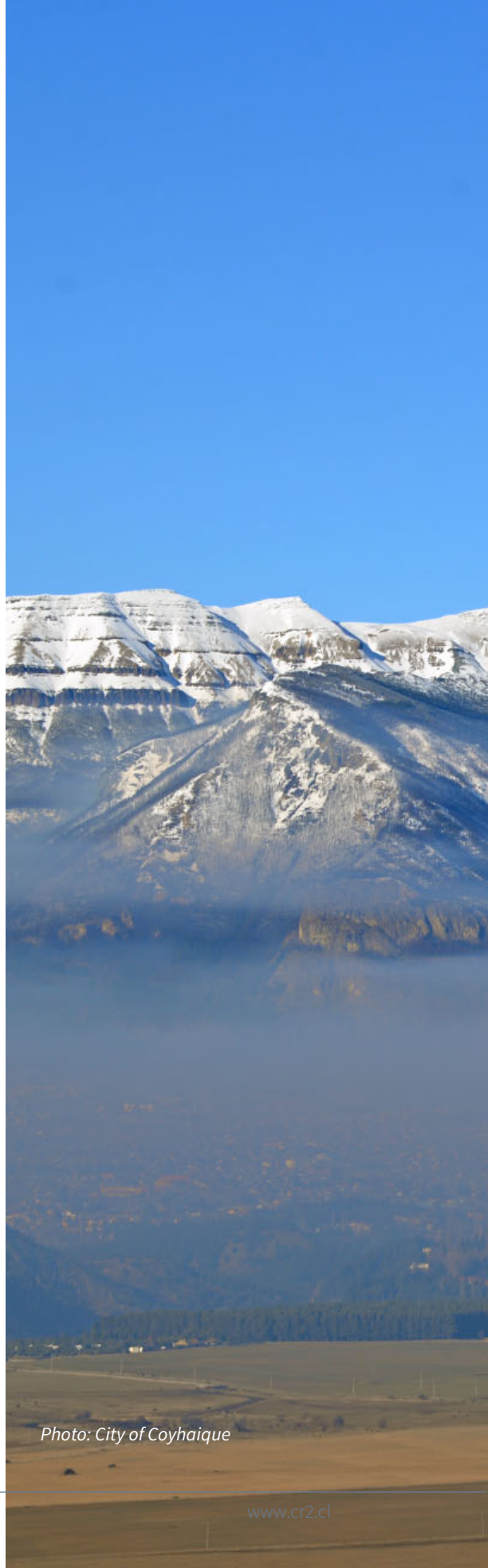
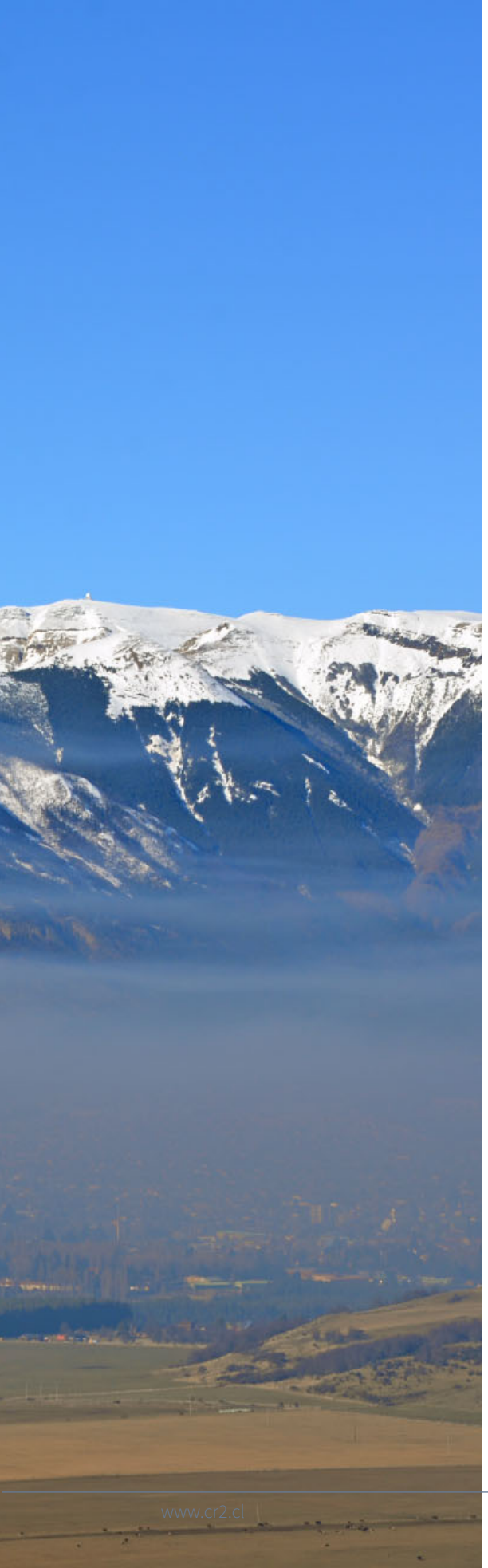


Photo: City of Coyhaique



In addition, although the climate varies significantly across Chile, a common meteorological pattern has been identified during episodes of low atmospheric ventilation and high particle pollution in the cities in the central and southern parts of the country. This situation is especially critical during winter due to low ventilation levels and high $PM_{2,5}$ emissions from residential heating.

A home's energy requirements and heating capacity are determined by the type and affordability of the available fuel, the appliances used for combustion, and the home's thermal insulation. In this context, firewood is valued because it is the cheapest source of energy, because of the type of heat it provides and the multi-functionality of the associated appliances and because it can be obtained relatively easily. It is important to also address the associated problem of energy poverty - that is the difficulty of accessing high-quality energy services - because in this case the intensive use of firewood results in air pollution.

Multiple barriers to energy transition have been identified in the cases studied, including deficient thermal insulation of homes, limited infrastructure for firewood storage, lack of knowledge regarding energy efficiency, cultural attachment to firewood and the associated appliances, high thresholds of thermal comfort and ignorance about indoor pollution. In this context, generational differences were also identified in terms of people's willingness to change heating practices. From the point of view of public policy, the factors hindering energy transition are: the limited decision-making autonomy of regional institutions, the high economic costs of possible structural solutions, the implementation of short-term and limited-scope solutions that do not prioritize scientific-technical criteria, the fragmented manner in which the legal/regulatory framework addresses firewood, the lack of coordination and duplication of policies, the long periods it takes for decontamination plans to be implemented, the low levels of social participation and the lack of legitimacy of public policies, the lack of sufficient oversight, the absence of fuel quality standards and gaps in the regulations related to heating.

Our results indicate that each year in Chile there are approximately 3,000 hospital admissions and around 4,500 preventable deaths in people of all ages due to $PM_{2,5}$ exposure. However, the official estimates of deaths associated with $PM_{2,5}$ air pollution are lower, as they only consider the cardiopulmonary effects on the adult population, excluding the elderly segment, even though Chile is at an advanced stage of the demographic transition towards population ageing. By contrast, our estimates include both cardiopulmonary effects and all natural causes (with the exception of external or non-natural causes, such as accidents, crime, etc.), in accordance with World Health Organization (WHO) recommendations, which suggest including the entire population without age distinction. Our calculations indicate that the annual rate of mortality due to $PM_{2,5}$ could be being underestimated by around 50% if only the cardiopulmonary effects are taken into account.

As for the environmental burdens, these are heterogeneously distributed throughout the country and are related to the distribution of socio-environmental variables, thus reproducing other forms of inequality. Similarly, the level to which people's health is vulnerable to $PM_{2,5}$ pollution varies according to their level of exposure and pre-existing medical conditions.

In turn, the population's vulnerability depends on people's sensitivity and their ability to adapt to the threat of $PM_{2,5}$ pollution. For this report, in estimating the sensitivity of the population to $PM_{2,5}$ pollution we have considered age, health and multidimensional poverty indicators on a district-level basis for 324 municipalities between the Coquimbo and Magallanes regions. This estimate shows a heterogeneous distribution in which the cities in the central and southern parts of mainland Chile are especially vulnerable. This approach makes it possible to prioritize the monitoring of the most vulnerable population groups by identifying first the corresponding municipalities, and then those areas within the municipalities that require most attention.

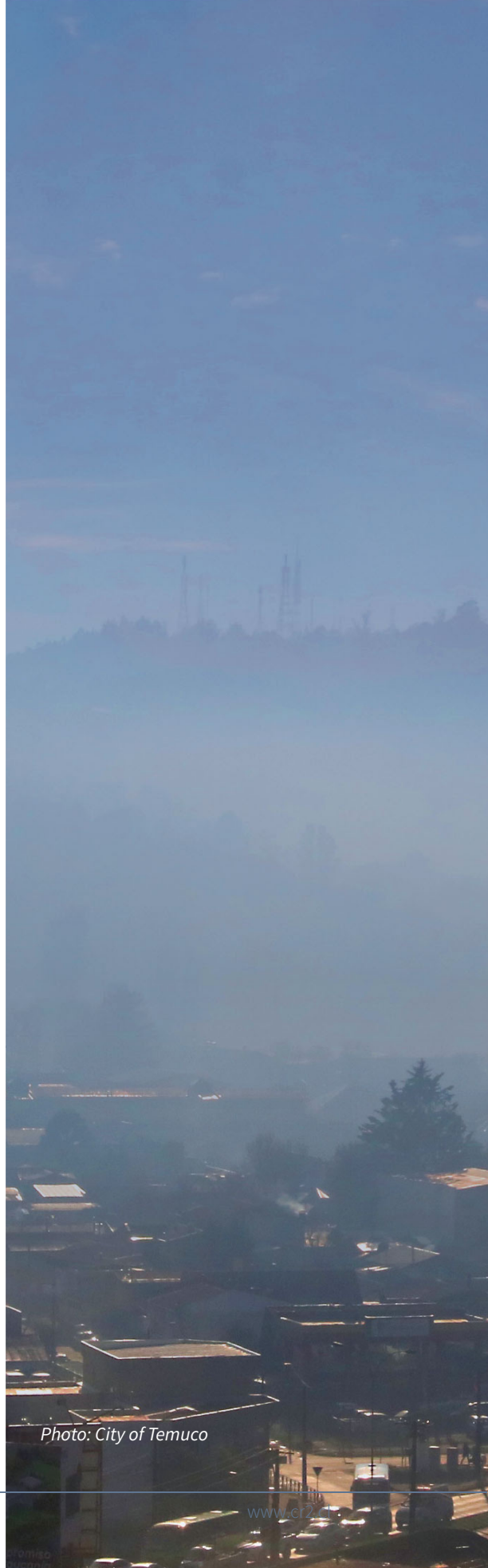
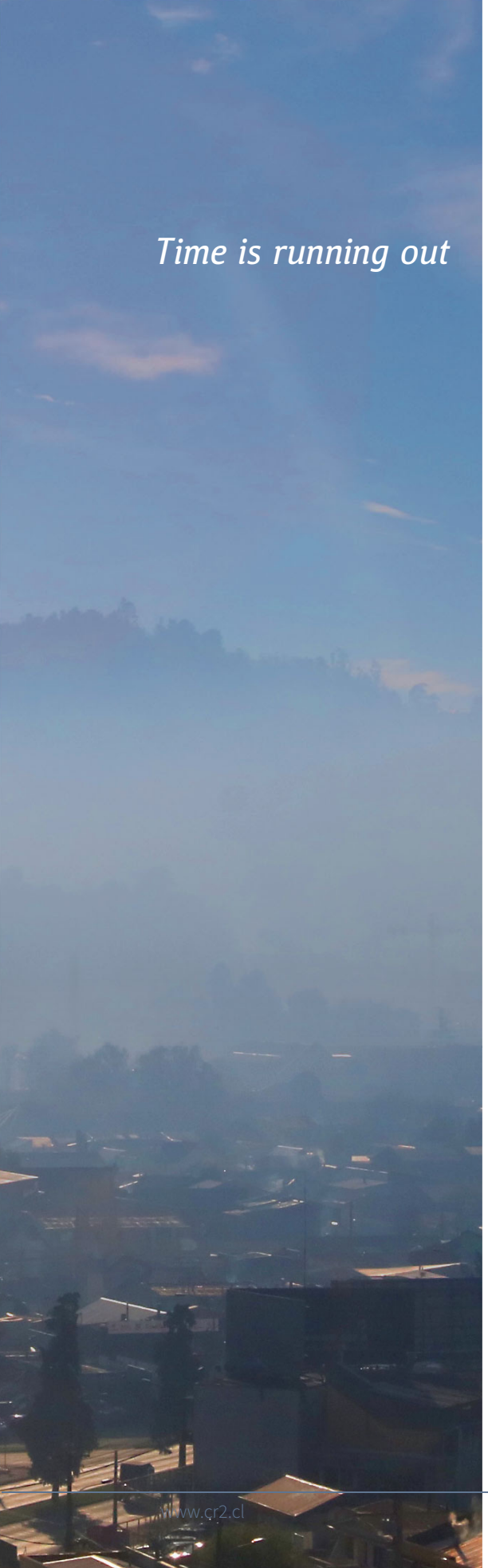


Photo: City of Temuco

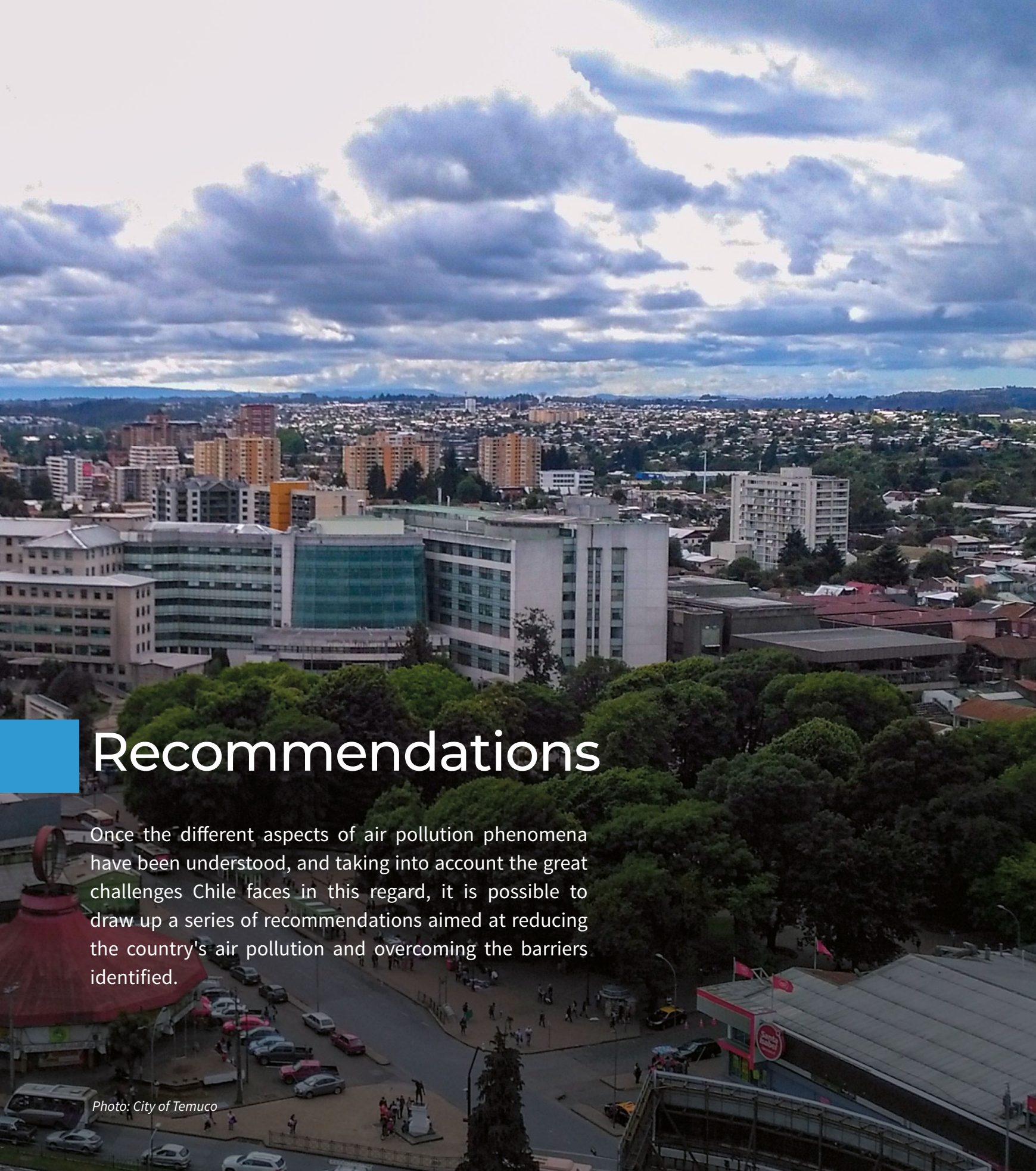


Time is running out

Climate change will also have a bearing on the problem of $PM_{2,5}$ pollution because, among other things, the conditions in which air pollutants are mixed and ventilated will be affected. Our estimates show that climate change will result in favourable, neutral or unfavourable conditions in different parts of mainland Chile. For example, while the frequency of meteorological conditions that are unfavourable to the dispersion of pollutants may increase in the southern regions of the country, their frequency could decrease in the central and northern zones.

In addition, research into the effects of the quarantine measures in Santiago have shown that in order to address the problem of particulate matter pollution there, it is not enough to simply consider primary emissions; the processes occurring in the atmosphere - including the photochemical aspects - must be included too.

As a result, air pollution from particulate matter in the future will be determined, first of all, by the actions and policies that we as a society adopt to reduce both direct emissions and the formation of pollutant precursors in the atmosphere. Based on the emissions projections set out in this report, pollutant dispersion simulations, and the socio-cultural, economic and political barriers, it is clear that current efforts to improve air quality are far from adequate. This, coupled with a generally unfavourable scenario for air quality due to climate change, makes it necessary to speed up efforts to improve the population's quality of life and to move towards more sustainable practices and behaviour.



Recommendations

Once the different aspects of air pollution phenomena have been understood, and taking into account the great challenges Chile faces in this regard, it is possible to draw up a series of recommendations aimed at reducing the country's air pollution and overcoming the barriers identified.

Photo: City of Temuco

More and better information for managing air quality

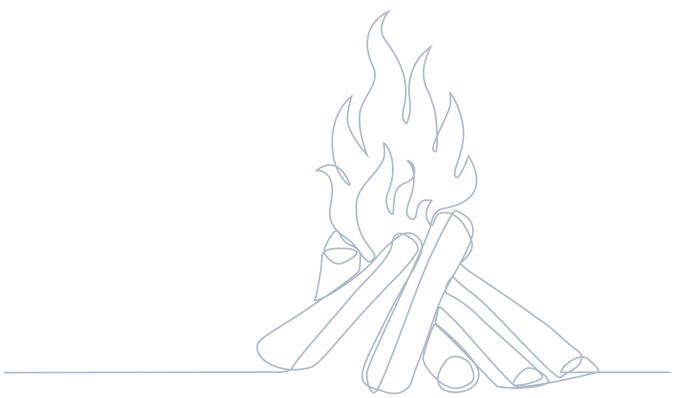
Based on the information presented in this report and our expert opinion, there is ample scope for improving the management of air quality and critical episodes.

With regard to **emissions**, we propose:

- The implementation of a national emissions inventory system – with criterion pollutants and short-lived climate precursors – that is analogous to and consistent with that for greenhouse gases, and that meets the conditions of transparency (methodology, assumptions, replicability, peer-reviewed and open access), correctness (assessment and quantified uncertainty), completeness (temporally and spatially distributed for multiple species and traces) and comparability (allowing for retroactive and prospective analysis).
- A progressive reduction in uncertainty through better characterization of activity levels and the development of emission factors that are representative of local conditions. This is particularly pressing in the case of domestic wood burning.
- The development of high resolution inventories in spatial (1km x 1km grids) and temporal terms (hourly, weekly, seasonal and annual). These inventories would permit efficient, accurate and rapid assessment of the mitigation measures.

With regard to **observations and measurements**, we propose:

- Complementing the National Air Quality Information System by adding - to the already regulated traces - the measurement of gas precursors of secondary pollutants (for example, volatile organic compounds) and the regular measurement of the chemical composition (speciation) and size distribution of particle matter. We propose that this should occur in at least one station per city.
- The integration of atmospheric column measurements to quantify the mixing and stability conditions in at least one representative station in each city.
- The implementation of monitoring, reporting and verification systems that make it possible to follow up on the mitigation measures applied. This will serve to empirically discriminate between those measures that are more effective in reducing emissions from those that are less effective, in order to promote the most efficient ones.



More and better information for managing air quality

With regard to **modelling**, we propose:

- That in order to design successful mitigation policies for the future, we need to understand the impact of climate change on the modulation of air quality. To do so requires the application of regional atmospheric chemistry and transport models forced by different climate scenarios. These simulations must cover at least the period 2020-2050 and should ideally also consider different emission scenarios.

- These simulations are computationally intensive and require a powerful, robust and developed infrastructure to run on. We therefore recommend continuing and reinforcing the processing capacity at the National Laboratory for High Performance Computing (Laboratorio Nacional de Computación de Alto Rendimiento, NLHCP) for carrying out these and other simulations that contribute towards the design of mitigation measures to improve air quality.

With regard to **social indicators**, we propose:

- The inclusion of specific energy use indicators in the National Socio-economic Characterizations Survey (Encuesta de Caracterización Socioeconómica Nacional, CASEN) in order to obtain a thorough diagnosis of contaminating fuel use at the home level.

- Making socio-economical tools (for example, the Family Budget Survey) more representative, in order to obtain disaggregated information - at least at regional level - to account for the diversity of energy sources and uses, and to discover energy consumption habits and access equity thresholds.

- The development of a regular, nationwide tool that provides systematic and comprehensive information on firewood consumption, such as consumption practices, the types of appliances and amount of firewood consumed. This data will contribute towards the design of public policies that are more in line with local circumstances and will also make it possible to better quantify emissions from the residential sector.

Improved prevention and air decontamination plans

The Air Decontamination Plan (PDA) and Air Prevention and/or Decontamination Plan (PPDA) applied in Chile have progressed substantially since they were implemented. However, the air quality in those locations where these plans have been implemented is still at levels that are incompatible with good health according to the national primary care standards and especially with respect to the WHO guidelines.

We recommend:

- Bringing flexibility to the requirements for drawing up prevention plans and incorporating clauses to update the biannual measures based on the results obtained, so as not to exceed 80% of the thresholds in the quality standard. These updates should make it possible to implement stricter measures to control pollution sources, without making it necessary to go through the whole process of developing the instrument again.

- Extending the area in which the PDAs and PPDAs are applied to all the regions reached by the pollutants and pollutant precursors, rather than just to the administrative districts where air quality standards are found to have been exceeded. This implies a spatial scope beyond urban boundaries and considering political and administrative macro-areas as well as many different stakeholders.

- Considering, in the design of PDA and PPDA measures, not only the economic feasibility of implementing certain technologies, but also the social, cultural and economic context where they will be implemented. This will help improve the effectiveness and efficiency of the measures through a greater capacity to foresee uncertain implementation conditions, such as those arising from energy poverty or a highly informal local market.

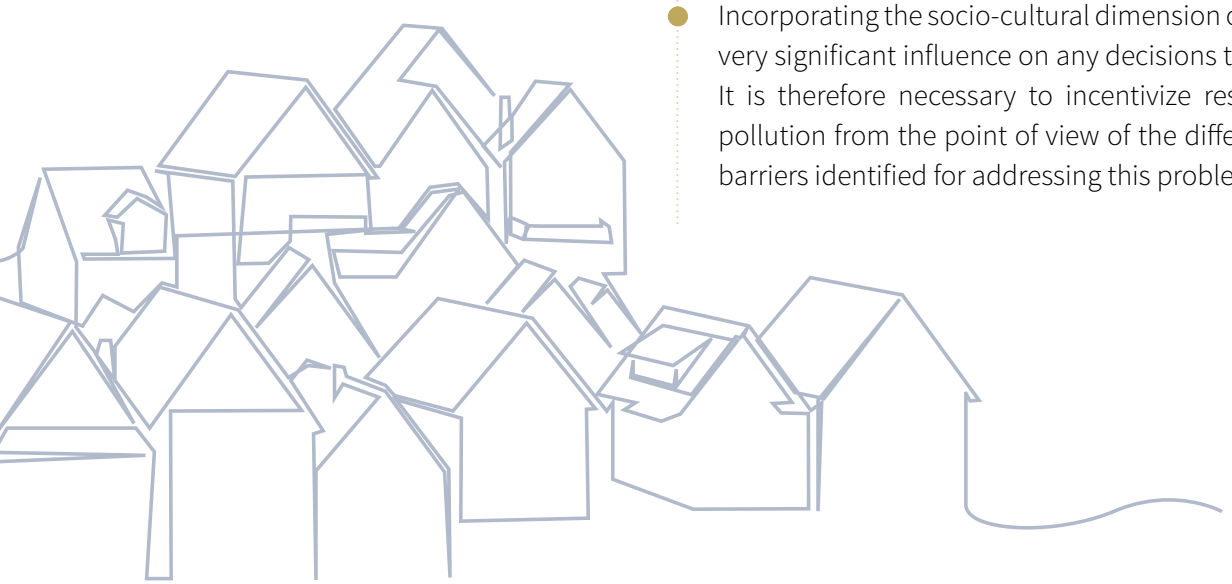
- Making a concerted effort to incorporate scientific and public participation in the design and evaluation of the measures, beyond mere public consultations. Participation is a right, the exercise of which depends on access to information, and is a requisite for environmental justice (Principle 10 of the Rio Declaration and the general terms of the National Environmental Framework Law). Participation also encourages citizens to take ownership of the scope and objectives of the PDAs and PPDAs, and favours cross-sector and public discussion on shared ground.

- The regulation of PDAs and PPDAs through the implementation of quality assessments, including standards for monitoring, reporting and verifying on a regular basis compliance with the measures contained in the PDAs and PPDAs. This would ensure that mitigation targets are met, provide effective oversight and, if needed, make sure that corrections are made in a timely manner.

Overcoming the barriers to energy transition

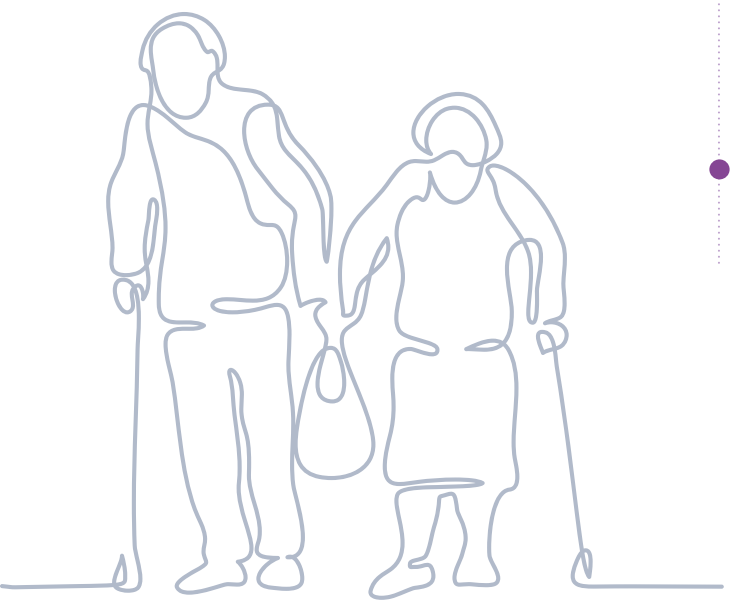
With regard to the barriers to energy transition in southern Chile, we propose:

- The speeding up of the discussion and implementation of a solid biofuel (i.e. firewood) law. This is vital for regulating the firewood market and would speed up the process of atmospheric decontamination and reduce indoor pollution in the south of the country.
- Promoting the urgent discussion and implementation of the Energy Efficiency Law, which provides for mandatory mechanisms for assessing the energy rating of new homes and makes it possible to integrate existing homes into this process. In addition, it facilitates regulation of the firewood market by categorizing it as fuel.
- Improving the standard for the thermal regulation of homes, as appropriate to the different zones of the country, and establishing a clear timeline for progressively improving this regulation, taking into account the energy rating of homes (existing and future housing stock). This is coherent with the energy efficiency assessment and would make it possible to improve the information standards for the real estate market. It would also make it possible to establish a building quality baseline that will permit improvement programmes to be more efficient.
- Incorporating the socio-cultural dimension of air pollution, as this has a very significant influence on any decisions taken to reduce its impacts. It is therefore necessary to incentivize research into understanding pollution from the point of view of the different stakeholders, and the barriers identified for addressing this problem.



Health impacts: much more than national counts

The impacts of air pollution are both acute and chronic. These impacts depend not only on exposure levels and times, but also on age, pre-existing diseases, socio-economic conditions, etc. In other words, health impacts should not only be regarded as additional impacts, but their assessment should also take into account who is affected and where, when and how they are affected.



We propose:

- Complementing health data from the Department of Statistics and Health Information (Departamento de Estadísticas e Información de Salud, DEIS), which is aggregated at the municipal level, with information of the location of cases, obviously while protecting personal data. This would make it possible to better characterize vulnerability to air pollution and to define mitigation measures that are spatially relevant within a municipality.

- Assessing the impacts of air pollution on mortality and morbidity, in terms of both the primary air quality standards and with respect to the WHO guidelines and making the corresponding methodologies transparent and coherent. While the national regulations establish achievable levels within a framework of technical and economic feasibility, the WHO 's regulations identify the effective impact of criteria air pollutants.

- Adopting the WHO guidelines that estimate the vulnerability of the population to air pollution based not only on mortality from cardiopulmonary diseases, but also on the percentage of deaths from any cause that may be attributable to pollution. In addition, the entire population, especially the elderly, should be considered. The justification for this is that health effects of air pollution are systemic and cumulative, and contribute to mortality and morbidity following chronic exposure to pollution.

- Complementing the national focus of the Annual Report on the State on the Environment, prepared by the Ministry of the Environment, with results at sub-national, regional, municipal and urban level.

Finally, addressing the challenges caused by air pollution requires **strengthening the links** between universities, research centres, scientific associations and public policy decision makers. It is therefore essential to **understand** the climatic, geographical, economic, political, legal and cultural components, in order to produce coherent and consistent information that allows **diagnoses to be made** from an inter and cross-disciplinary perspective. This would make it possible to propose feasible solutions to be implemented in the short, medium and long term, favouring evidence-based, relevant and appropriate decision-making at the **national, regional and local levels.**

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