Summary for policymakers

REPORT TO THE NATIONS

The air we breathe: past, present and future

$PM_{2.5}$ air pollution in Central and Southern Chile

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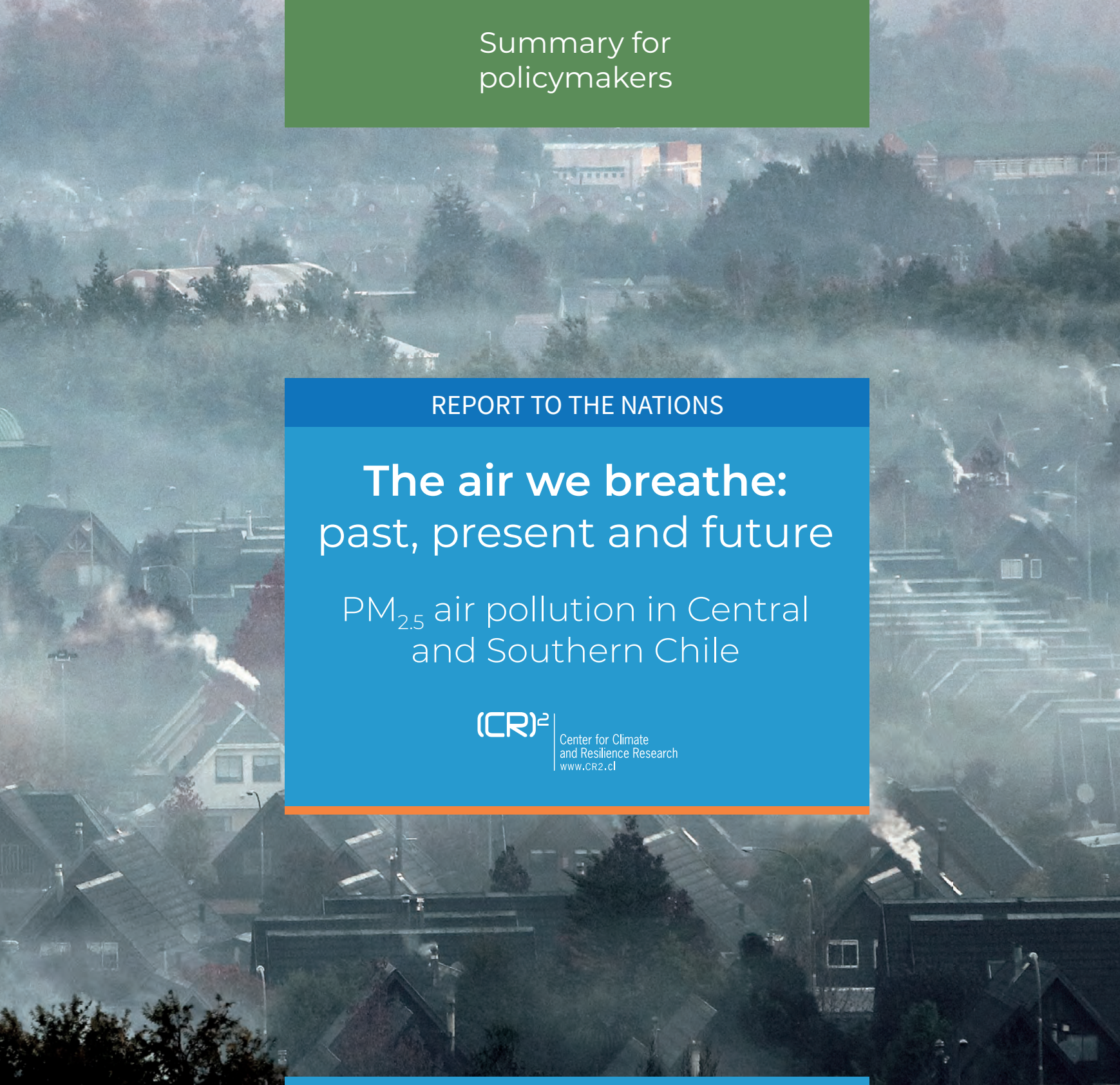

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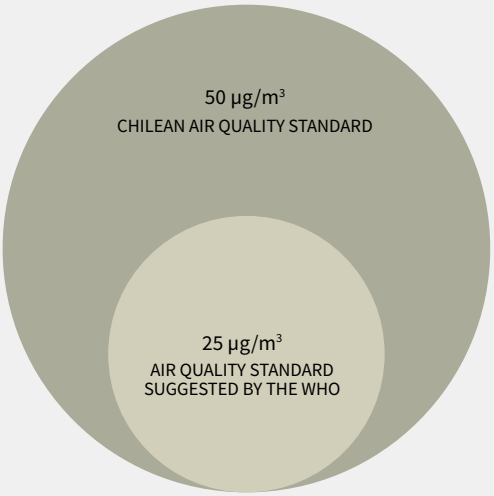
(De)contaminating the air in Chile: a pathway towards the future

(De)contaminating the air in Chile: a pathway towards the future

Air quality is a complex problem involving not only physical-chemical factors, but also sociocultural, economic, and institutional variables. The report *"The air we breathe: past, present and future – PM2.5 air pollution in Central and Southern Chile"* focuses on the impacts and the role played by the residential sector and its $PM_{2.5}$ emissions, taking the above factors and variables into account. This interdisciplinary research integrates information from multiple databases, numerical simulations, and interviews and workshops with diff erent stakeholders in order to characterize not only current air quality but also the evolution of air pollution since pre-Colombian times, and the factors influencing its future evolution.

$PM_{2.5}$ consists of fine, fully inhalable particulate matter; in other words, particles smaller than 2.5 microns. Every winter, it leads to a deterioration of air quality in cities in central and southern Chile. According to estimates from the Environment Ministry (MMA), in 2018 around 10 million citizens were exposed to average daily $PM_{2.5}$ concentrations higher than those allowed under current Chilean law (50 µg/m³) and far above the 25 µg/m³ limit suggested by the World Health Organization (WHO). These levels of $PM_{2.5}$ have serious impacts on human health and, according to MMA estimates, caused nearly 3,600 premature deaths that year.

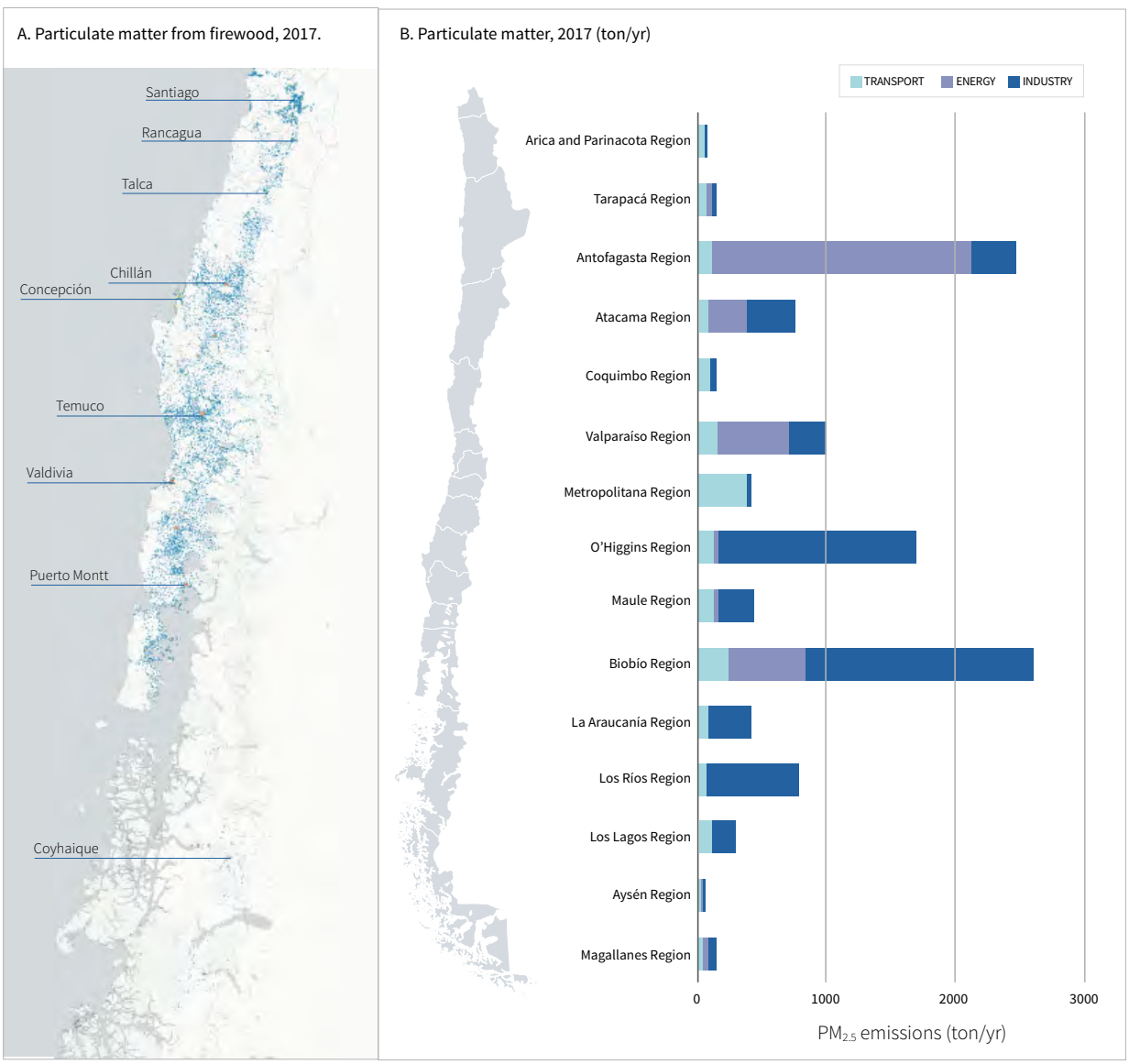


Average daily $PM_{2.5}$ concentration limit

The air quality in Chile has gradually deteriorated over the last 2,000 years, and this deterioration has increased rapidly over the last century, in direct association with population growth, urban expansion, and economic growth in Chile. 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 and there is a lack of evidence of the efficiency and effectiveness of these policies.

In order to assess mitigation policies and quantify the impact of pollutants on air quality and human health, we need to understand the magnitude of human emissions, the relative contribution of each sector to those emissions, and how they are geographically distributed. To that end, the Center for Climate and Resilience Research (CR)2 used publicly available information to compile and develop an emissions inventory for the principal pollutants affecting air quality in Chile. The study involved estimating the emissions from key sectors (residential, transport, industry and energy) for the 2015-2017 period and locating these emission sources on high-resolution maps (approximately 1-km resolution). The inventory revealed that in central and southern Chile, $PM_{2.5}$ emissions come primarily 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. Nationwide, the use of firewood for heating and cooking food accounted for 94% of $PM_{2.5}$ emissions in 2017.

Distribution of total anual $PM_{2.5}$ emissions in 2017 for: (A) residential sector in central and southern Chile with 0.01º degrees resolution, and (B) transport, energy and other industry sectors at a regional scale.



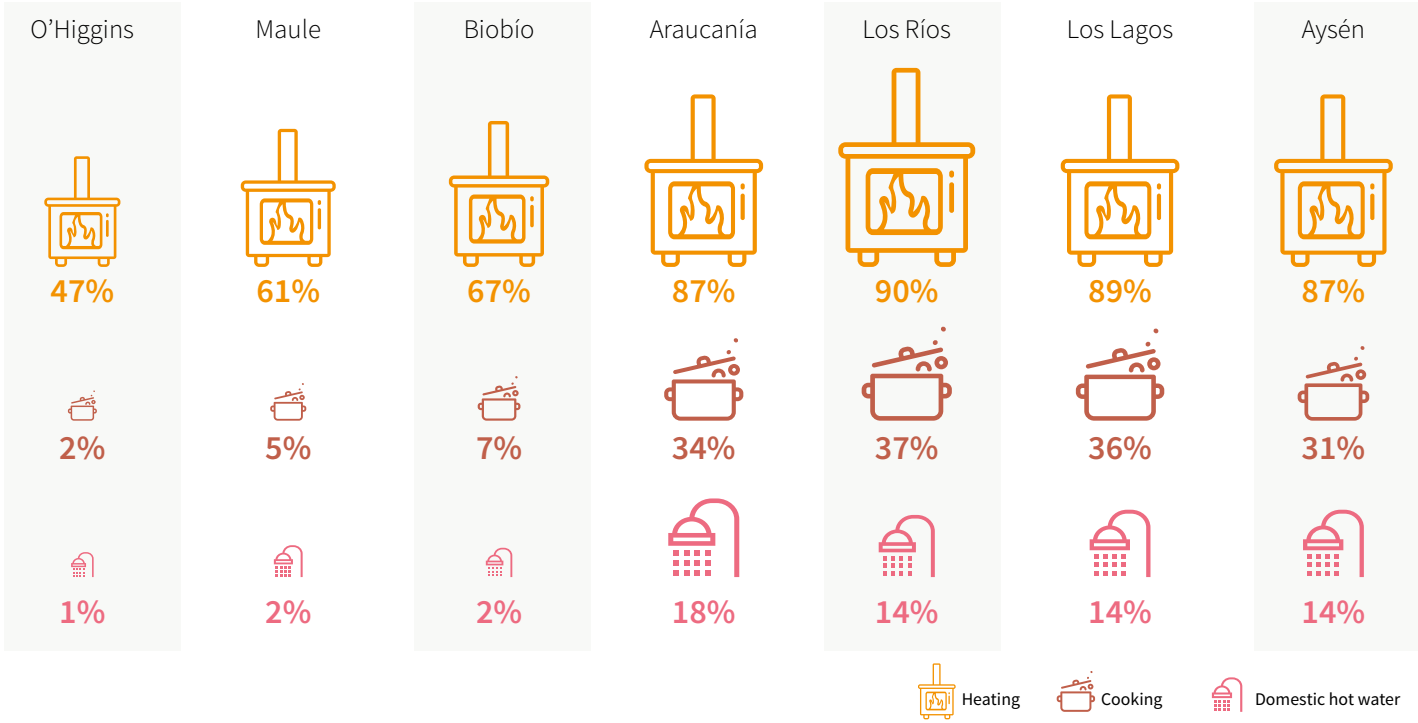
Firewood use and energy poverty

Firewood use and energy poverty

Air pollution from firewood combustion in the cities of central and southern Chile is closely linked to energy poverty, due to the diff i culty in accessing quality energy services and deficient thermal insulation in homes. Firewood is not only valued for being the lowest-cost fuel; the multi-functional nature of wood-burning appliances, the type of heat they provide, and the varied sources of firewood also make wood burning attractive.

Improving air quality to the level of current air quality standards will therefore require an energy transition towards less polluting fuels, with due consideration for sociocultural conditions and how they vary throughout Chile. The *(CR)2 report* identifies multiple sociocultural and sociotechnical barriers to achieving that transition, namely: (a) the poor quality of dwellings, which do not retain heat; (b) limitations in the availability and storage of dry firewood; (c) the lack of knowledge on energy efficiency and proper operation of wood-burning appliances; (d) the cultural attachment to firewood and to multi-functional appliances such as wood-burning cookstoves; (e) high thermal comfort thresholds; and (f) the "programmed forgetfulness" of the problem, as it becomes relevant only in winter. All of this is accompanied by *territorial energy vulnerability* related to the limited availability of other fuels, the unregulated and informal nature of the firewood market, and the fragmentation of legal and political-institutional actions combined with low social participation.

Percentage of households, per region, that use firewood for heating, cooking and/or heating water. Source: CASEN 2017.



The impact of $PM_{2.5}$ on health

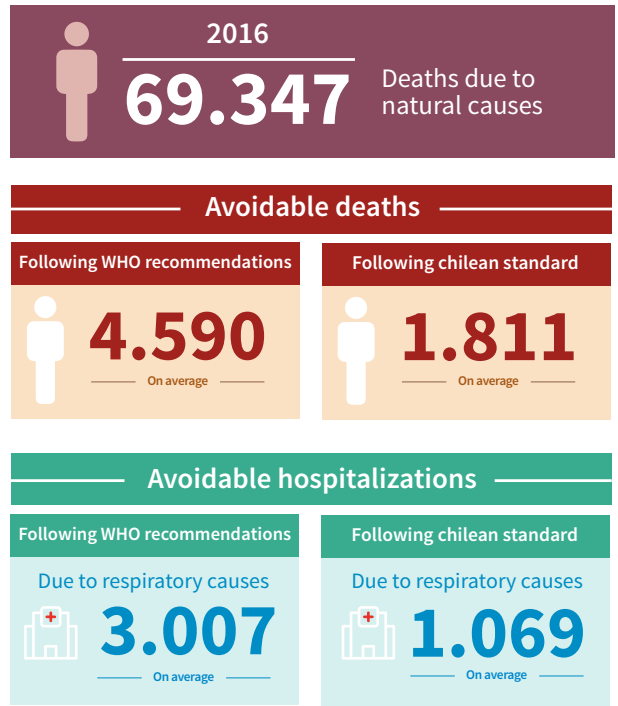
Temuco and pollution

The impact of $PM_{2.5}$ on health

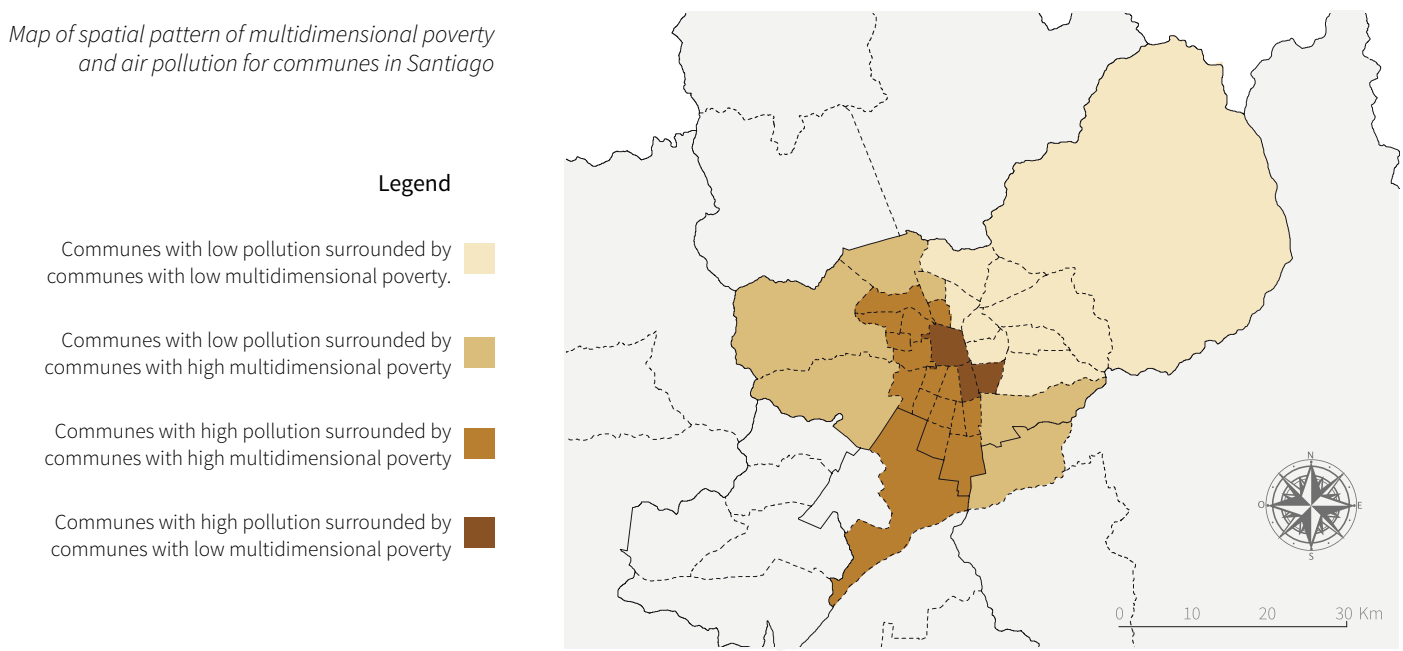
The sensitivity of the population to the health impacts of $PM_{2.5}$ is distributed unequally across the country, with people in the cities of central and southern Chile being especially vulnerable to these eff e cts. That sensitivity is strengthened further by socioeconomic, demographic, and pre-existing medical conditions, thereby reproducing other forms of inequality.

The *(CR)2 report* estimates around 4,500 deaths associated with PM2.5 air pollution each year, higher than the off icial estimated death count, which only considers cardiopulmonary eff ects on adult population under 80 years of age. In contrast, the estimated mortality calculated for this report, following World Health Organization (WHO) recommendations, includes the entire population, regardless of age, and all natural causes (except external or non-natural causes such as accidents, crime, etc.), rather than just those associated with cardiopulmonary eff ects. According to our calculations, these methodological diff erences suggest that the off icial estimate could be underestimating mortality by around 50%.

Avoidable deaths and hospitalizations, according to this study, following WHO recommendations and chilean standard.



Map of spatial pattern of multidimensional poverty and air pollution for communes in Santiago



Pollution in the future

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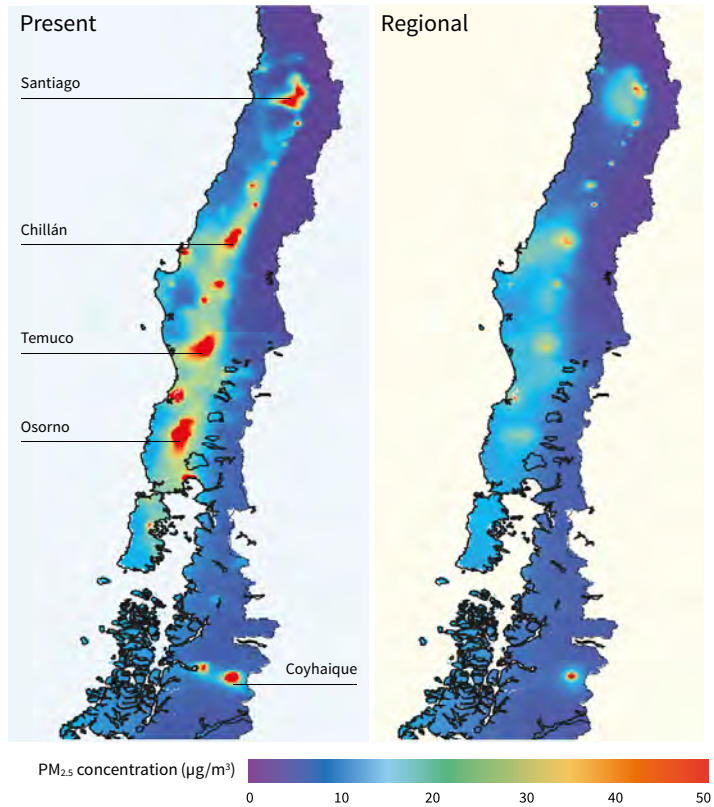
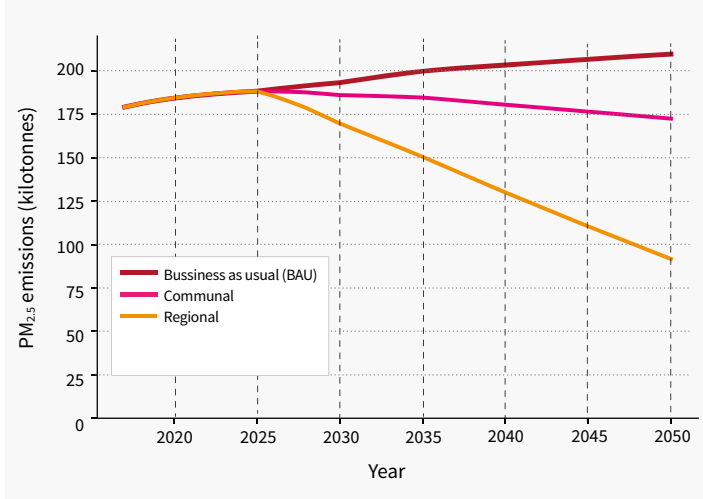
Pollution in the future

In the future, air quality will be determined, first, by actions and policies designed to reduce emissions. The research therefore developed a series of emissions scenarios resulting from different mitigation measures that range from currently planned reductions to higher emission reduction rates. The results suggest that the greatest reduction is achieved when these measures are applied simultaneously in every municipality in central and southern Chile. However, the results of the numerical modelling of pollutant transport based on these scenarios show that the principal cities of this area, already affected by air pollution problems, will continue to exceed the daily air quality standard. This will remain the case even if all the emission reductions up to 2050 considered under the most promising scenario are applied today. These results suggest that more ambitious measures need to be developed than those currently envisioned.

Secondly, air quality will also be influenced, among other factors, by climate change, because conditions in which air pollutants are mixed and ventilated will be affected. Our analysis shows that around the year 2050 the meteorological conditions that favour the occurrence of pollution events could increase in southern Chile, while central and northern Chile may experience conditions more conducive to higher ventilation, reducing the likelihood of such pollution events.

Average $PM_{2.5}$ winter concentration for the period 2015-2017, calculated from presente emissions and based on projections for the year 2050 according to the Regional Mitigation Scenario.





Trajectory of PM2.5 residential emissions according to the scenarios: Current policy "Business as usual" (BAU), Communal and Regional for the years 2017 to 2050.

Recommendations

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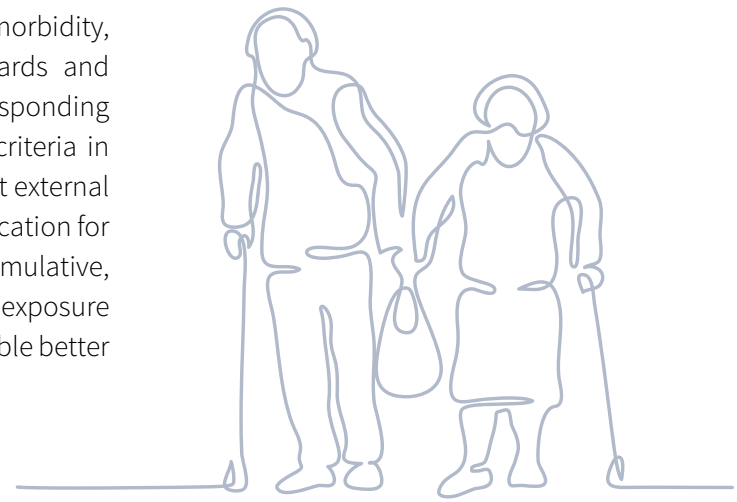
Recommendations

In light of the above and taking into account (a) emissions projections, (b) pollutant dispersion simulations, and (c) sociocultural, economic, and political barriers, it is clear that current efforts to improve air quality are insufficient. All of the above, when coupled with a climate change scenario that is generally unfavourable to air quality, makes it necessary to accelerate efforts to improve the quality of life of the population, reduce preventable deaths, and shift towards more sustainable energy behaviour.

Based on the results presented, the *(CR)2 Report* offers a series of recommendations aimed at improving air quality management in Chile and overcoming the identified barriers. Among those recommendations, we highlight the following:

- Better quantify the emissions associated with wood burning in the residential sector, firstly, by developing emission factors that are representative of local conditions and secondly through the development of a regular and nationwide tool that provides **systematic and comprehensive** information about firewood consumption, such as consumption practices, the types of appliances and amount of consumed firewood. Improving the estimates of emissions in this way, particularly for the residential sector, will contribute to the design of policies that are more in line with local conditions. This will also be beneficial for monitoring Chile's commitment to **mitigate black carbon** under the Paris Agreement.

- Assess the health impacts of air pollution on mortality and morbidity, in terms of both the national primary air quality standards and with respect to the WHO guidelines and making the corresponding methodologies transparent and coherent. Adopt the WHO criteria in estimating mortality, **considering all natural causes** (except external and non-natural causes), for the entire population. 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. Estimating these impacts more precisely will enable better decision making.



- Extend Air Pollution Prevention and/or Decontamination Plans to all cities with high levels of air pollution, developing public policies **with a regional scope**, strengthening public participation, and establishing protocols for effective oversight and inspection.

Lastly, it is essential to improve the standard for the thermal regulation of homes for all newly built dwellings, taking into account local conditions in different climatic zones, and at the same time promote widescale improvements to the insulation of existing dwellings and formalize the firewood market.

It is crucial to understand that air pollution is a highly complex environmental problem; one that requires more ambitious and integrated measures that necessarily seek to improve the quality of housing and make clean fuels and technologies **affordable**.

Padre Las Casas, Temuco

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