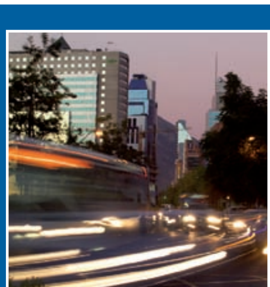
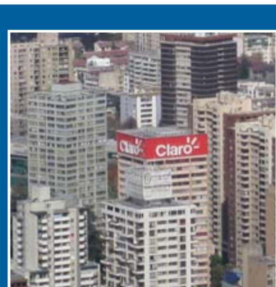
How sustainable is Santiago de Chile?

Current Performance – Future Trends – Potential Measures

Synthesis report of the *Risk Habitat Megacity* research initiative (2007 – 2011)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1 Introduction

(Kerstin Krellenberg, Jürgen Kopfmüller, Jonathan Barton, Dirk Heinrichs)

1.1 The challenge of sustainable urban development in Santiago de Chile

Today, there is a broad consensus that sustainability is the most important common guiding vision of societal development and that justice with respect to present and future generations is at the very heart of this vision. Urbanisation, and in particular mega-urbanisation, is one of the most dramatic phenomena of global development in the 21st century; it requires the definition of sustainable urban development and represents a challenging task for science, policy and society.

Megacities are characterized by extreme size, change dynamics and complexity. They are places with an extreme consumption of resources that can lead to tremendous sustainability deficits, e.g. the unequal distribution of access within the city and across socioeconomic groups. These deficits affect the quality of life of people in the city and in the area of influence to a large extent.

Latin America is by far the most urbanised developing region in the world and has likewise the distinction of being the most inequitable. Although it performs well in sustainability terms compared to other major cities in the region, the city of Santiago de Chile still represents several problems, but also opportunities. Santiago holds a strategic position as a centre of regional development and networking, hosting key international institutions such as the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and it can be seen as a model of integration into global economies and related urban policy making.

Problems in Santiago such as high levels of resource consumption, unequal access to resources and services, air pollution, inadequate housing conditions, inefficient transformation and use of energy, etc. go hand in hand with weak institutional control mechanisms. As the majority of current urban development plans and strategies for Santiago de Chile are based principally on sectoral approaches, they do not sufficiently address the complex interaction of problems and challenges of sustainable mega-urban development. An official sustainable development plan does not exist as yet, but is currently being developed.

1.2 Content and aims of the synthesis report

This report summarises the principal results of a three-year joint German-Chilean research initiative. Its main objective is to provide answers for two questions. First, how sustainable is the Metropolitan Region of Santiago today? Second, what alternative future development options and potential measures are available to increase sustainability performance of the agglomeration until 2030?

The report provides policy makers, practitioners, administrators, planners, and citizens concerned with different policy fields with the main project findings and recommendations. These results are based not only on profound scientific analyses, but also on intensive discussions with these stakeholders. By synthesizing the results, this report addresses the information needs of actors concerned with the overall metropolitan development and also those of the interested public.

The document has four main sections. After this brief introduction, section two introduces the research approach of the *Risk Habitat Megacity* research initiative. It highlights the sustainability concept that is based on indicators and introduces the scenario methodology used for describing future trends. Section two serves as important background information for understand-ing the analytical approach of the work. Readers who are especially interested in results and recommendations for specific urban development fields can refer directly to section three, which focuses on the current performance, future trends and potential measures in selected urban development fields: Transportation and Air quality, Energy, Socio-spatial differentiation, Land-use management, Waste management and Water resources and services. For each field the document provides a summary of current sustainability performance and problems, describes three alternative scenarios for the development until 2030, and outlines potential policy measures. The concluding section four highlights overall findings and their significance for the entire Metropolitan Region of Santiago de Chile in terms of challenges and recommendations.

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2 Risk Habitat Megacity: an integrative research approach and scenarios for Santiago de Chile

(Jürgen Kopfmüller, Kerstin Krellenberg, Jonathan Barton, Dirk Heinrichs)

The *Risk Habitat Megacity* research initiative integrates the joint work of five research centres of the German Helmholtz Association and six partner organisations in Chile. The Helmholtz Centres are the Helmholtz Centre for Environmental Research - UFZ (as coordinator of the project), the Karlsruhe Institute of Technology - KIT, the German Aerospace Centre – DLR, the Helmholtz Centre Potsdam - GFZ (German Research Centre for Geosciences), and the Helmholtz Centre for Infection Research - HZI. The Chilean partner organisations are the Uni-versidad de Chile, the Pontificia Universidad Católica de Chile, the Pontificia Universidad Católica de Valparaíso, the Universidad Alberto Hurtado, the United Nations Economic Com-mission for Latin America and the Caribbean (ECLAC/CEPAL), and the Gobierno Regional Metropolitano de Santiago de Chile (GORE).

The overall objective of this research initiative was to develop and test a methodology that enables a better understanding of the complex urban processes, interactions and feedback mechanisms that turn megacities and large urban agglomerations into habitats of risks and opportunities. The initiative contributes to the specification of sustainable metropolitan development objectives and to developing strategies and policies that can steer the urban system towards more sustainable development. Its basic objective is to provide adequate inter- and transdisciplinary orientation and action knowledge for decision-makers, and to integrate methodological issues and project results into academic curricula and practice.

To implement this interdisciplinary and integrative research approach and to offer a common framework for orientation, the research initiative applies three theory-based analytical concepts and combines them with empirical and application-oriented analysis. The concept of Sustainable Development defines the target dimension of the initiative by analysing the current and the future sustainability situation in Santiago de Chile. The integrative sustainability concept of the Helmholtz Association, adopted for the present research, is based on three general sustainability goals (see Table 1): “Securing human existence”, “Maintaining society’s productive potential”, and “Preserving society’s options

Table 1: The sustainability rules of the integrative concept of the Helmholtz Association

Substantial rules		
General sustainability goals		
Securing human existence	*Maintaining society's productive potential*	*Preserving society's options for development and action*
Protection of human health	Sustainable use of renewable resources	Equal access of all people to information, education and occupation
Ensuring the satisfaction of basic needs (nutrition, housing, medical care etc.)	Sustainable use of non-renewable resources	Participation in societal decision-making processes
Autonomous subsistence based on income from own work	Sustainable use of the environment as a sink for waste and emissions	Conservation of cultural heritage and cultural diversity
Just distribution of chances for using natural resources	Avoiding technical risks with potentially catastrophic impacts	Conservation of the cultural function of nature
Reduction of extreme income or wealth inequalities	Sustainable development of man-made, human and knowledge capital	Conservation of social resources

for development and action" and consists of a set of rules that describe minimum conditions for sustainable development to be guaranteed for all human beings of present and future generations. The Risk concepts focus on the extent of the problems and their severity, and help to analyse the conditions for and impacts of the emergence of risks that pose a potential threat to future sustainability. The Governance concept concentrates on the actions to be undertaken, by analysing current efforts to enhance sustainability as well as by providing knowledge of and recommendations for specific problem solutions and their potential for implementation.

These three concepts are applied to several typical megacity issues (see section 3). These issues illustrate the role of megacities as spaces of intensive resource consumption, and reveal their critical function as major producers of waste, pollution, and other negative externalities. They also point to crucial social aspects of mega-urban development processes.

The implementation of the integrative research approach with respect to the sustainability concept is mainly based on two tools:

(1) the use of selected indicators to describe and assess the current and future sustainability performance, and
(2) the design and analysis of scenarios in order to consider and assess options for potential future development and action.

If the vision of sustainable development is to have any influence on scientific analyses and gain practical relevance in societal and political decision making, first of all it must be adequately formulated. This is usually done in terms of indicators. Such indicators have to fulfil various functions: to provide understandable *information* about complex subjects, to give *orientation* about trends (early warning), to allow for *steering* in political and societal decision processes, to facilitate *communication* in order to support discussion, learning and consciousness processes, and finally to allow for integration in terms of common orientation for different actors or working groups. While a great number of sustainability indicator systems have been developed at international, national or local level, their application has so far been limited in most of the cases to the scientific area, whereas urban policy and planning are still only weakly based on such indicators.

In the case of the Santiago Metropolitan Region, to date there has been no systematic application of sustainability indicators to orient urban and regional policies or to evaluate the effectiveness of planning instruments. Even in the cases where such indicators have been developed in a suitable way, e.g. in the 2006-2010 Regional Development Strategy or in the OTAS initiative 2005, they have not been utilised as a tool for decision-making. In the case of the Strategy, this may be a reason for its underutilization in public decision-making and for the fact that it remains of little relevance as a yard-stick of development processes.

Consequently, one principal goal of the *Risk Habitat Megacity* research initiative is to overcome current deficits by developing a set of sustainability indicators which fulfil the functions mentioned above and which can be used for longer-term strategic urban planning. This planning includes development targets, goal-oriented measures and monitoring systems, and can be distinguished from the current, rather short-term and mainstream, urban management approach.

The results consist of a set of headline indicators for different thematic fields to measure and assess current and future sustainability performance (see chapter 3). Examples of such indicators are *the percentage of overcrowded homes* referring to the satisfaction of basic needs rule, the *proportion of students with higher education qualification* referring to the equal access to information etc. rule, or the *consumption of water resources in relation to water supply* referring to the sustainable use of renewable resources rule.

The work with indicators is complex, normative and involves many concessions, for instance responding to data availability restrictions and a range of inadequacies, such as lack of time series or changing measurement frequencies or methodologies over time. Consequently, the list of indicators applied in this context cannot fully respond to the complexities of systemic interactions. However, it is viable because it serves the purpose of identifying balancing forces that are in tension in the region, and it can be introduced into decision-making processes in its current form.

Furthermore, these indicator sets provided the basis for a comparative sustainability analysis beyond the Santiago case study, the "Regional Panorama Latin America". The objective of this analysis, carried out within the RHM initiative by UN-ECLAC, is to describe and understand the main sustainability issues and challenges in six metropolitan areas in Latin America: Mexico City, São Paulo, Buenos Aires, Lima, Bogotá and Santiago de Chile.

The second tool to implement the integrative research approach of this project is the scenario analysis. It is a well-established tool for appropriately dealing with mega-urban development processes characterised by growing diversity, complexity, interdependencies and dynamics. The basic idea behind scenarios is not to predict future development, but to describe and analyse plausible alternative future development options which allow for if-then statements ("if certain factors develop in a certain way, then certain effects may happen"). The main aim is to provide a framework for creating a shared vision of potential futures and to provide an improved knowledge base for political and societal decision makers and thus for strategic planning.

For the purpose of this project, a five-step approach combining explorative and normative scenario parts is applied: alternative framework scenarios are designed, describing potential future development options for relevant driving factors of societal development (explorative part), within which qualitative and quantitative analyses and evaluations of future sustainability performances are carried out (normative part).

Step 1: Development of explorative scenario frameworks at the global level

For the time horizon 2030, a global framework scenario for a "Business-as-usual" case is defined based on a comprehensive review of relevant global scenario studies for a set of essential driving factors of societal development, such as economic development, institutional frameworks, demographics, technological development, or societal value system.

Step 2: Contextualization to the Santiago / Chile level

To contextualise the framework, particular future development assumptions for the driving factors at the global level are explored in the context of Chile and the Metropolitan Region of Santiago in particular. For this purpose, storylines following the structure of the driving factors for three alternative scenarios: "Business-as usual" (BAU), "Collective responsibility" (CR), and "Market individualism" (MI) are developed.

In essence, the basic "philosophy" of the BAU scenario is characterised by a continuation of liberalisation and privatisation trends, persistence of strong market forces and weak public regulation activities, continuation of existing social protection measures and subsidy schemes for the poorest, and ultimately the persistence of a "twin-track" socio-economy. The essential ideas of the MI scenario are increasing individual freedom and freedom of action, markets as the dominant vehicle for all societal transactions, together with resources and services generation and distribution strongly subject to supply and demand principles. Finally, the CR scenario is characterised by social and environmental justice as principal goals of public regulation, strong regulation of market activities and large public investments, together with the embedding of technologies in society and decoupling of socioeconomic development from resource use.

Additionally, for a set of basic socioeconomic variables – GDP growth rate, population, household income, persons per household, share of economic branches, etc. – development projections until 2030 are estimated based on historic trends. Taking the example of population, starting from the currently 6.5 million inhabitants in the Metropolitan Region (52 municipalities), 8.0 million (consistent with INE projections) are estimated for the BAU scenario, 7.6 million for CR and 8.2 million for MI. These basic

variables guarantee consistency between the different topics and serve as key input data in particular for the model-based quantitative scenario analyses.

Step 3: Translation into the thematic field contexts

Here, the alternative framework storylines designed for Santiago and Chile are translated into each thematic field in the Santiago Metropolitan Region. Specific storylines for the three scenarios are developed for each field, considering previous trends and future estimations for the most relevant driving factors.

Step 4: Scenario analyses

The scenario analysis is carried out in all thematic fields based on the specifically selected sustainability indicators. It consists of firstly, quantitative model-based or qualitative estimations of future indicator performances towards 2030 within the three scenario alternatives (BAU, CR and MI) in order to identify future strengths and problem "hot spots", based for instance on distance-to-target considerations; secondly, the design and analysis of suitable measures ad-dressing the most urgent problems within the scenarios.

The basic conceptual scenario approach and thematic field results have been discussed with civil society stakeholders and political decision-makers of the regional government and national ministries. This conceptually well-founded, systematic and stakeholder-involving scenario work is an essential precondition for producing relevant and broadly acceptable project results which may be used as inputs for current planning and decision-making processes in the Santiago Metropolitan Region. Additionally, it represents an important distinctive feature compared to other projects on Megacity issues.

Working with scenarios is likewise a necessary precondition for considering longer-term perspectives which are essential in the sustainable development context, and thus to provide an important counterbalance to the prevailing short-term thinking and acting in the economic system, in management, and in political decision-making.

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3 Fields of urban development: Current performance – future trends – potential measures

3.1 Thematic field: Transportation, Air quality and Health

(Andreas Justen, Peter Suppan, Francisco Martínez, Cristián Cortés, Ulrich Franck)

3.1.1 Current sustainability of the transport sector

Santiago's urban transport system has changed significantly in recent years. The metro network expanded from 40 km to over 100 km between 2000 and 2010, a total of 155 km urban highways were constructed and finally, in 2007 the new public transport system Transantiago was introduced. As in many other emerging economies, the motorization rate in Santiago is rising rapidly. Number and use of motorized vehicles circulating increased continuously, partly accelerated by the problematic introduction of Transantiago. In 2009 about 1.2 million vehicles were on the streets, representing a motorization rate of 194 vehicles per 1,000 inhabitants. This denotes an absolute increase in vehicle fleet size of more than 40% between 2001 and 2009. Despite the extension of the urban highway system, congestion levels persist and the metro is oversaturated, especially in the morning peak hours.

About 17 million trips occur on a regular working day in the Metropolitan Area of Santiago AMS[1] (Sectra). Against this background air pollution remains a severe problem for the city, with traffic emissions accounting for more than 70% of nitrogen oxide (NOx) and about 37% of particulate matter (PM10) emissions. This ranks Santiago among the world's most polluted cities. Despite significant advances in bringing down air pollution no further reduction of pollutant lev-els could be observed since 2000. Furthermore high traffic densities result in high exposure situations especially in street canyons. The high concentrations of airborne pollutants (NOx, particles, O3) are strongly related to the development of various environmental related diseases. The health impacts of the observed pollution levels attribute more than 1,000 deaths per year to particulate matter (PM). These numbers demonstrate that air pollution – and with it the implied health impact on Santiago's population – remains one of the city's most important environmental problems and challenges.

3.1.2 Likely development trends in the transport sector towards 2030

The analysis focuses on selected city-wide sustainability indicators, namely motorization rate, modal split, congestion levels, accessibility and emission levels. These indicators and their expected development according to the scenarios are used to evaluate the future sustainability situation of Santiago. Besides the demographic and economic development until 2030 (see chapter 2), further assumptions and likely developments regarding e.g. infrastructure and technology are necessary in order to apply the modelling suite (see table 2).

To evaluate the impacts of demographic and economic development and the selected policies by scenario, different models are applied: mathematical-economic models of land use (MUSSA) and transport (ESTRAUS), a traffic emission model (MODEM), a model for the dispersion of air pollutants (GRAL) and statistical tools for the estimation of adverse health effects. The calculations are made for a base year 2010, the BAU scenario 2030 and the respective alternative scenarios of CR and MI.

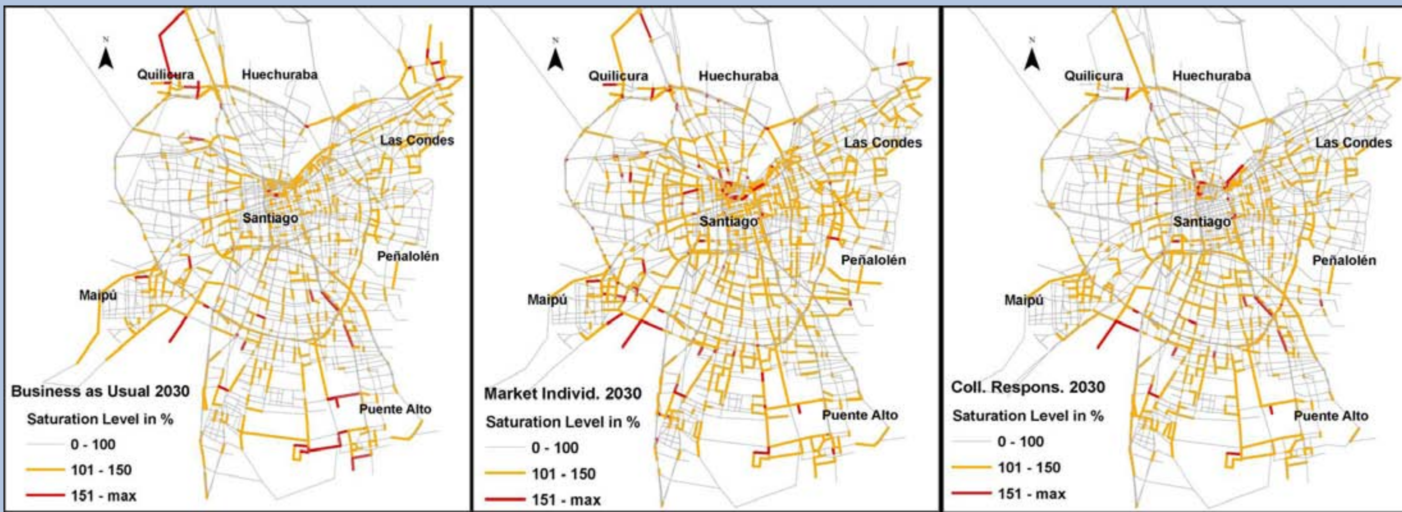
The scenario results show that the motorization rate is expected to increase in the BAU scenario up to 325 vehicles per 1,000 inhabitants (MI: 366, CR: 268) which has a direct impact on travel mode choices. For the

Table 2: main assumptions for the scenario analyses

In 2030 scenarios daily trips made by bicycle are assumed at 7% of daily trips in the BAU, 10% in the CR and 7% in the MI.
General road capacities increase by 5% in all scenarios, and highways by an additional 30% in the BAU, 0% in the CR and 130% in the MI scenario.
A congestion charge in the historical centre and the eastern commercial area is assumed in the CR scenario.
For all scenarios metro line 6 is considered, and the metro line 3 is added in the CR scenario.
Bus frequencies increase by 15% in the BAU, by 25% in the CR and by 10% in the MI scenario.
A suburban train from Estación Central to Melipilla is considered in the CR scenario; integrated public transport tariffs vary between 600 CHP in the BAU, 400 CHP in the CR and 1.000 CHP in the MI scenario.
Vehicle emission standard EURO 5 is introduced in the year 2015 (CR), 2017 (BAU), and 2018 (MI); EURO 6 in 2018 (CR) and 2020 (BAU, MI). 10% of all vehicles in 2030 (BAU) have full or partially electric propulsions (7% PHEV, 3% BEV); 15% in the CR and MI scenarios (10% PHEV, 5% BEV).

1 The Metropolitan Area of Santiago, which provides the spatial background for this study, is constituted of the 32 municipalities of the province of Santiago plus the 6 municipalities of San Bernardo, Puente Alto, Pirque, Calera de Tango, Colina and Lampa.

Figure 1: Estimated congestion levels, measured by the degree of saturation per road link (left: BAU, middle: MI, right: CR), morning peak hour (7.30h-8.30h)



morning peak hour between 07.30h and 08.30h, the share of public transport trips decreases from 44% in the BAU, to 36% in the MI scenario (slight increase for the CR scenario to 45%). The use of private cars increases in all scenarios. Although, in the CR scenario, motorization is at lower levels and substantial improvements in the public transport system are assumed, public transport usage as per cent of total demand is maintained but not expanded. This is partly due to the extension of the road infrastructure and the improvements in public transport, keeping car-use in the CR scenario attractive given the reduced levels of congestion in comparison to the BAU and MI scenarios. An effective measure to reduce congestion in the inner city centres is a congestion charge policy (cordon pricing scheme charging 5.500 CHP) studied in the CR scenario. Figure 1 shows the expected congestion levels for Santiago's urban road network.

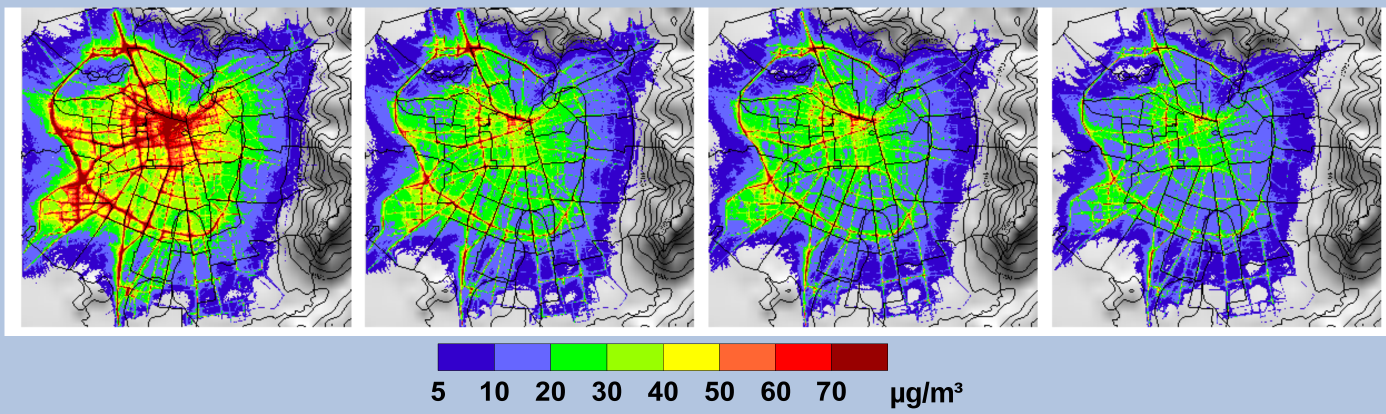
Capacity bottlenecks are most frequent in the periphery where the urban road infrastructure is not adjusted to absorb the increased number of cars in 2030. This is also due to the relatively sparse coverage of road network in the model which is likely to become denser in reality. Although an increase in road capacity was assumed, the historic city centre in particular suffers in 2030 from high congestion levels and a related decrease in average vehicle speed. Most of the centre and eastern districts that concentrate financial and commercial activities are expected to have oversaturated roads in 2030. This is also the case for the roads that connect the southern and south-western municipalities of Maipú, La Florida and Puente Alto with the main employment centres.

Accessibility levels tend to worsen. System-wide accessibility is defined as the average travel time needed to reach any other municipality starting from one of the 38 municipalities considered. On average, for car trips travel time rises from 31.8 minutes in 2010 to 40.4 minutes in the 2030 BAU scenario (CR: 41.9; MI: 45.8). For public transport, accessibility levels improve slightly in the CR scenario, with decreasing average travel times from 51.2 in 2010 to 49.5 minutes in 2030 (BAU: 54.3; MI: 54.2).

The traffic flows (cars, buses, light and high duty vehicles) for each scenario are used as input to estimate the traffic emission levels for Santiago.

Figure 2 represents the annual mean of NOx based on the meteorological situation of 2006. The highest concentrations are found along the Américo Vespucio highway, main access roads and in the central areas of Santiago. In the scenarios a significant decrease of primary pollut-ants (NOx, CO and PM10) can be observed. Despite the increase in motorization and vehicle miles travelled, the decrease in pollution is caused by substantially improved vehicle emission standards. The general decrease of emission levels of about 50% is accompanied by local increases, especially on the northern and southern access roads. These patterns can also be observed in the CR scenario, but with generally higher reduction levels than in the BAU and MI scenarios. The related health assessment resulted in a daily risk increase

Figure 2: Traffic related NOx concentration levels in µg/m³ within the Metropolitan Area of Santi-ago (left: situation 2010, middle left: BAU, middle right: MI, right: CR)



of 5 to 7% per 10 µg/m³ PM10 within time lags of 1 to 4 days. Generally, PM10-exposure risk of premature death from cardiovascular and respiratory diseases for the Metropolitan Area population is increased significantly. According to the decrease of pollutants within the scenarios CR and MI, such re-ductions (based on the target values of the Directives 1999/30/EC and 96/62/EC of 40 (20) µg/m³ as yearly exposure averages) may decrease the associated mortality risks by around 20-35 % in areas of the city with high reduction potentials.

3.1.3 Recommendations of measures

The results confirm some expectations about the future of the city of Santiago, but also yield new concerns. The development of transport needs is strongly fuelled by the combination of demographics – with rising population trends accompanying a reduction in average household size – and improved economic conditions. Despite all the efforts to introduce mitigation policies, the main transport indicators tend to perform negatively, whereas air pollution levels and associated adverse health impacts tend to develop positively thanks to improvements in vehicle technologies. Nevertheless, the high concentrations of air pollutants (far above threshold levels recommended by World Health Organisation) still cause many negative effects on human health. The potential for a future car-based city is strong, and irreversible due to the adjustment of the infrastructure on roads and buildings.

Further policy action seems to be necessary to control more effectively congestion and to main-tain the option of a less car dependent system for future generations. In the CR scenario it is evident that the combination of improved public transport services and road pricing in central parts of the city is an effective policy option, which can be complemented by increased tolls on urban highways. Additional investments are necessary for the construction of exclusive bus lanes that reduce travel times, and a significant improvement of infrastructure for non-motorized transport to alleviate car-based congestion effects and increase competitiveness of public transport and non-motorized modes with car travel. Of high importance seems to be the expansion of information technologies in public transport (real-time information at bus stops and within buses, and the controlling of schedules). The recommendation is to keep a long term balance between the use of cars and public transport in order to control congestion effects as well as the social and visual intrusion caused by the road infrastructure. Non-motorized transport options need to be supported by providing adequate infrastructure and operational means.

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3.2 Thematic field: Energy

(Sonja Simon, Volker Stelzer, Adriana Quintero, Luis Vargas, Gonzalo Paredes, Kristina Nienhaus, Jürgen Kopfmüller)

3.2.1 Current Sustainability performance of the energy sector

From the energy perspective the Metropolitan Region of Santiago is closely interlinked with the national energy system, generating a major share of energy demand and relying primarily on energy supply from outside the region. The Chilean energy system is characterized by its highly privatized structure, concentrated in a limited number of actors and regulated by the National Energy Commission (CNE) and the new Energy Ministry. Another characteristic is the structure of the electric power supply, with four unconnected grids.

As Chile currently imports 90% of its fossil fuels, import dependency poses a risk to energy supply. This effect was experienced in recent years when Argentina restricted gas exports to Chile. Hydro power provides 50% of the power of the Metropolitan Region of Santiago. This high concentration exposes the city to the risk of energy security in the case of droughts and longer-term climate change scenarios.

Nevertheless, Chile has vast potential in renewable energy sources ranging from traditional hydro power, biomass, solar heating and wind to the yet barely developed solar, geothermal and wave power. Developing renewable energies is one of the challenges for a future more sustainable energy system, together with exploiting the vast potential for more efficient energy use in industry, households, commerce, services and transportation.

3.2.2 Future development trends to 2030

The three alternative scenarios are implemented first on the national level and subsequently at the Santiago Metropolitan Region level. Besides the principal input factors from the framework scenarios, the energy scenarios are basically distinguished by different efficiency gains on the demand side and the variation in resource use on the supply side. The table below summarizes the measures within the three scenarios for the energy system.

The main challenges for the future sustainable development of the energy system are the strongly increasing energy demand, induced by population and GDP growth. The following table summarizes the measures assumed for the three scenarios.

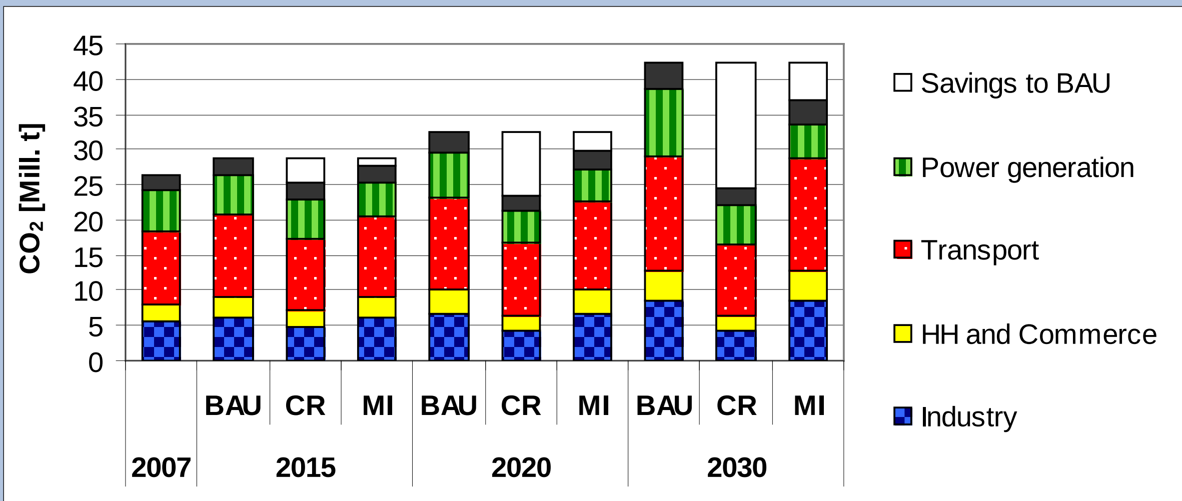
Table 3: Development of energy input factors in the three scenarios for 2030

	BAU	CR	MI
Energy intensity (share of 2008)	72%	52%	64%
Hydro	Incorporating HidroAysen	Focus on small hydro	Incorporating HidroAysen
Non conventional renewable energies	Official target met (extended)	Strong development of combined heat and power, wind, solar, geothermal, biomass	Increasing wind power and solar collectors
Fossil fuels	Investment in coal power plants	Gas as a backup for renewable energies	Investment in coal power plants
Transport	6% electric vehicles of total stock	10% electric vehicles	10% electric vehicles

The energy scenarios are implemented within an energy system model (MESAP/PlaNet). Results indicate that MI follows the BAU scenario, with only few improvements. Hydro power remains the backbone of Santiago's power supply, while in CR non-conventional renewable energies will account for 37% of power supply, presenting a higher share than hydro in 2030. In BAU in particular, the energy system faces the risk of being locked-in with a high amount of installed capacity in coal power plants, retaining high CO_2 emissions. Calculations also show that transport will still remain the major source of CO_2 emissions in all scenarios and over the whole modelling period.

As Figure 3 shows, even if there are major improvements in emissions from the power sector, industry, households and commerce, the transport sector will pose the main challenge for a more sustainable energy future.

Figure 3: development of energy-related CO_2 emissions by sectors in the Metropolitan Region of Santiago in the three scenarios until 2030



3.2.3 Recommendations for the energy sector

In order to reduce the negative impacts of energy use and to secure energy supply, two main strategies are recommended: first, to improve energy efficiency, and second, to increase the use of domestic renewable energy sources.

Well-established and efficient measures to increase energy efficiency are the introduction of energy-use-related taxes on the one hand, and stronger energy standards on the other hand, for instance for new buildings in order to accelerate the construction of low- or zero-emission houses.

To increase the use of renewable energies, a carbon tax on the use of fossil fuels is a suitable measure, accompanied by governmental stimulation of research, for instance on renewable energies potentials in the various regions of Chile. Additionally, it is important to enable free entry for renewables into the energy market, even to the extent of their prioritisation in the grid.

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3.3 Thematic field: Socio-spatial differentiation

(Corinna Hölzl, Kerstin Krellenberg, Juliane Welz, Dirk Heinrichs, Sigrun Kabisch)

3.3.1 Current key problems and major risks of social inclusion

In order to measure the sustainability performance of socio-spatial differentiation, seven indicators are selected: *dissimilarity index of lowly-educated groups per cluster, proportion of household overcrowding per municipality, average years of earning to buy a house or apartment per municipality, proportion of social housing units in municipal housing stock, green area per inhabitant and municipality, proportion of students with higher education entrance qualification per municipality, and proportion of labour force employed in municipality of residence.* The current results clearly reveal that opportunities of social inclusion and risks of not being included are very unevenly distributed across different socio-economic groups and locations. The analysis of these indicators refers to the Greater Metropolitan Area of Santiago (GMAS) of 39 municipalities as well as to five aggregated municipal clusters within GMAS.

» Regarding the sustainability goals, the best results are achieved in the Centre (municipality of Santiago) (cluster I). Here, the availability of green areas, education facilities and jobs is highest.

However, social housing units are scarce and the displacement of lower income residents is expectable.

»The Peri-Centre (II), which includes those municipalities surrounding the Centre, is confronted with either decay or reno-vation. Green areas barely exist and for instance in Lo Espejo, where proportions of overcrowding and low quality of education are striking, tendencies of stigmatization and social isolation can be stated. Other municipalities such as San Miguel are subject to urban renovation projects.

»In the Eastern Peri-Centre (III), which includes Ñuñoa, Providencia, Las Condes, Vitacura, La Reina and Lo Barnechea, an ongoing 'elitisation' process can be observed. Segregation levels are clearly above average.

» The Periphery (IV), which includes the municipalities outside the ring motorway Américo Vespucio, shows two 'extremes': first, a strong risk of social exclusion due to the high concentration of social housing units and predominant disadvantages such as unequal access to labour. Second, a 'new' spatial mix of households from different socio-economic groups calls upon the potential opportunities of social inclusion.

» The Extra-Periphery (V) (Pirque, Lampa, La Colina, Calera de Tango, Padre Hurtado) is confronted with similar key problems as the Periphery, but the labour market offers at least some opportunities for social inclusion.

3.3.2 Sustainability analysis of alternative socio-spatial scenarios for 2030

The analysis of the three alternative scenarios is based on expected scenario trends: strong increase (++), increase (+), stable (0), decrease (-), strong decrease (--). These trends are compared with recommended target values for the selected indicators and evaluated as follows: Target will not be attained , Target will be approached but not attained , Target will be attained (see table 4 for the scenario analysis scheme of two selected indicators).

For the BAU scenario, suggested target values for 2030 will most likely be attained for access to education, creation of local jobs and social segregation, except in the Peri-Centre and the Periphery. Slightly worse are the results for household overcrowding and the prices for housing. At least the Centre is expected to reduce overcrowding to a reasonable level; the Eastern Peri-Centre even eliminates this problem. Above all, green areas and proportions of social housing do not fulfil the proposed sustainability targets. In the Periphery and Extra-Periphery, further social housing construction will maintain high levels. In the Peri-Centre and the Extra-Periphery, green areas remain small.

The CR scenario shows more positive results, particularly for education and prices for housing. Thus, CR appears to have incorporated suitable (political) framework conditions to realize better access to good education and housing in GMAS. Apart from the Eastern Peri-Centre, segregation could be kept stable or even reduced. Overcrowding and social housing are further from sustainability targets. The availability of green areas and local jobs will be improved, but targets will not be met in all clusters. All clusters, except the best performing Centre, show results between target fulfilled and target approached.

The MI scenario is least sustainable for social inclusion. The situation is bad regarding green areas and the years of earning to buy an apartment. Household overcrowding, social housing and access to education are only marginally better. Most likely seems to be the reduction of segregation. Again, the Centre performs best, followed by Eastern Peri-Centre and Extra-Periphery. Prospects are worst for the Peri-Centre. The situation in the Periphery is a little better: the share of labour force will slightly increase and the targets for social housing and the development of house prices will be approached. However, the underlying reasons are – unlike the CR-scenario – shortages of housing subsidies and the decreasing attractiveness of the cluster as place of living.

Table 4: Current performance and scenario results for two selected indicators

	Cluster	Status quo & target value 2030		Alternative future trends			Scenario analysis		
Proportion of social housing units in total housing stock (%)		2002 (%)	target (%)	BAU	CR	MI	BAU	CR	MI
	GMAS	14,7	15	+	0	-	[green]	[green]	[red]
	I	1,1	15	0	+	0	[red]	[orange]	[red]
	II	11,0	15	+	+	-	[green]	[green]	[red]
	III	2,8	15	0	+	0	[red]	[orange]	[red]
	IV	22,7	15	+	-	-	[red]	[orange]	[orange]
	V	18,7	15	+	0	-	[red]	[orange]	[green]
Green area per inhabitant (m²)		2009 (m²)	target (m²)	BAU	CR	MI	BAU	CR	MI
	GMAS	3,9	9	+	+	-	[orange]	[orange]	[red]
	I	12,7	12,7	+	-	0	[green]	[green]	[green]
	II	2,9	9	0	+	0	[red]	[orange]	[red]
	III	7,2	9	+	0	-	[orange]	[red]	[red]
	IV	3,2	9	+	++	--	[orange]	[green]	[red]
	V	1,6	9	0	++	--	[red]	[green]	[red]

All three scenarios show more-or-less that existing sustainability deficits regarding social inclusion will persist and even be aggravated in future. However, the scenarios show increasing sustainability, in particular in the Centre, as well as decreasing sustainability in the Periphery and Peri-Centre. In consequence, spatial discrepancies in sustainability levels are likely to even increase to some extent in future, even though some differences are reduced.

3.3.3 Recommendations for promoting social inclusion

These results call for any policy concerned with social inclusion to be not only selective in terms of target groups but also spatially sensitive regarding location, scale or magnitude of interventions. Two policy fields for which this is of relevance, and in which interventions are likely to have the most significant effect on the indicators described above, are public housing policy and education policy. Both have paid little attention to targeted and location-specific interventions. However, at least social housing policy has started to change more recently and moved towards more qualitative objectives. Another line of interventions currently being tested is the increase of spatial proximity and social diversity (Ciudad Bicentenario).

Measures to stimulate socially mixed housing: To reduce the concentration of poor households, further smaller-scale programs could enlarge opportunities to live in consolidated city areas with higher land values, via subsidies differentiated according to land values and quotas in the municipal regulatory plans (PRC). This would increase immediate direct costs of social housing programs, but save subsequent costs for municipalities in the longer term. Another option would be to enforce housing quotas for low-income households in new development projects, as already implemented in large-scale conditioned projects. However, such 'top-down' measures are difficult to implement and monitor and may harm low-income residents by adverse location effects, such as high transportation costs.

Measures to improve equal access to education: Although the education budget has doubled from 2000 to 2008 in Santiago, it still remains below the OECD average. In order to increase the opportunities, the quality of teaching at public schools and the access to subsidized schools must be improved. This requires stronger public control and subsidies for lower income groups. However, decisive reforms of the education system will not be pushed through until education is acknowledged as a public good with public responsibility.

Further measures that could have an additional impact on social inclusion in the city are

(i) improving access to public transportation, service infrastructure, recreational facilities and work,

(ii) better checking of new green spaces planning regarding just distribution and equal access for all inhabitants, mainly by better civil society involvement from the beginning,

(iii) implementation control of planning instruments, integrated development plans and regulation of housing development projects in order to support multifunctional neighbourhoods, and

iv) policies to support communities in disadvantaged locations in order to improve their social capacity and networks. All these measures would require increased public expenditures.

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3.4 Thematic field: Land use management and flood risk prevention

(Annegret Kindler, Ellen Banzhaf, Annemarie Ebert, Ulrike Weiland, Sonia Reyes)

3.4.1 Current sustainability performance from the land use management perspective

Currently, there are four sustainability strengths in Land Use Management in the Metropolitan Area of Santiago to be mentioned: first, an urban 'compact' city is indicated due to a high degree of imperviousness in the central part, thus contrasting to urban sprawl; second, regional institutions have adopted flood risk management instruments and regulations; third, at least in some municipalities a sufficient amount of green space per inhabitant exists; and fourth, technical measures for flood risk mitigation have been created and are mandatory measures for new infrastructure and residential development.

In contrast, several weaknesses can be stated. The increase of population and building density in peripheral municipalities is not sustainable. As a consequence, impervious surfaces increase and green spaces decrease, resulting in reduced rainwater infiltration and increasing flood risks. Urban expansion has to be rated as unsustainable in cases where residential areas are being created in peri-urban areas far beyond the built-up urban core, thus lacking urban compaction; this phenomenon is known as "spatial leapfrog development". Urban growth in the periphery and areas facing high flood hazard poses new risks. Furthermore, in most municipalities the WHO green spaces threshold value of 9 m^2/inhabitant is not achieved. In addition, a systematic understanding of risks in land use management institutions is lacking. For example, vulnerability is only understood as a physical condition, not as a social phenomenon. As such, the concentration on structural / technical measures dominates over prevention-type thinking. The analysis shows that stable links are missing between land-use management and risk prevention.

3.4.2 Differences between scenario alternatives regarding sustainability goals

With regard to the sustainability indicators presented in table 5, the sustainability goals are to reduce the degree of imperviousness, to increase the amount of green spaces, and to avoid construction permits of new settlements in areas prone to flood risks. Figure 4 shows probable urban development directions until 2030.

For the BAU scenario, the development is rather critical regarding sustainability indicators: in the peripheral areas the degree of imperviousness will increase. The amount of green spaces will tend to stagnate or increase only slightly, with unconnected patches. The proportion of new settlements and infrastructure in areas facing high flood hazard levels will increase strongly in peri-central and peripheral areas.

As in the BAU scenario, the MI scenario has to be rated critically regarding sustainability indicators: the central and peri-central areas are characterised by high imperviousness and will even be built-up further in some of the rare open spaces. In the periphery, the degree of imperviousness will rise dramatically. The amount of green spaces will tend towards insignificance. In peripheral areas, the proportion of new settlements and infrastructure in areas facing high flood hazard levels will increase strongly.

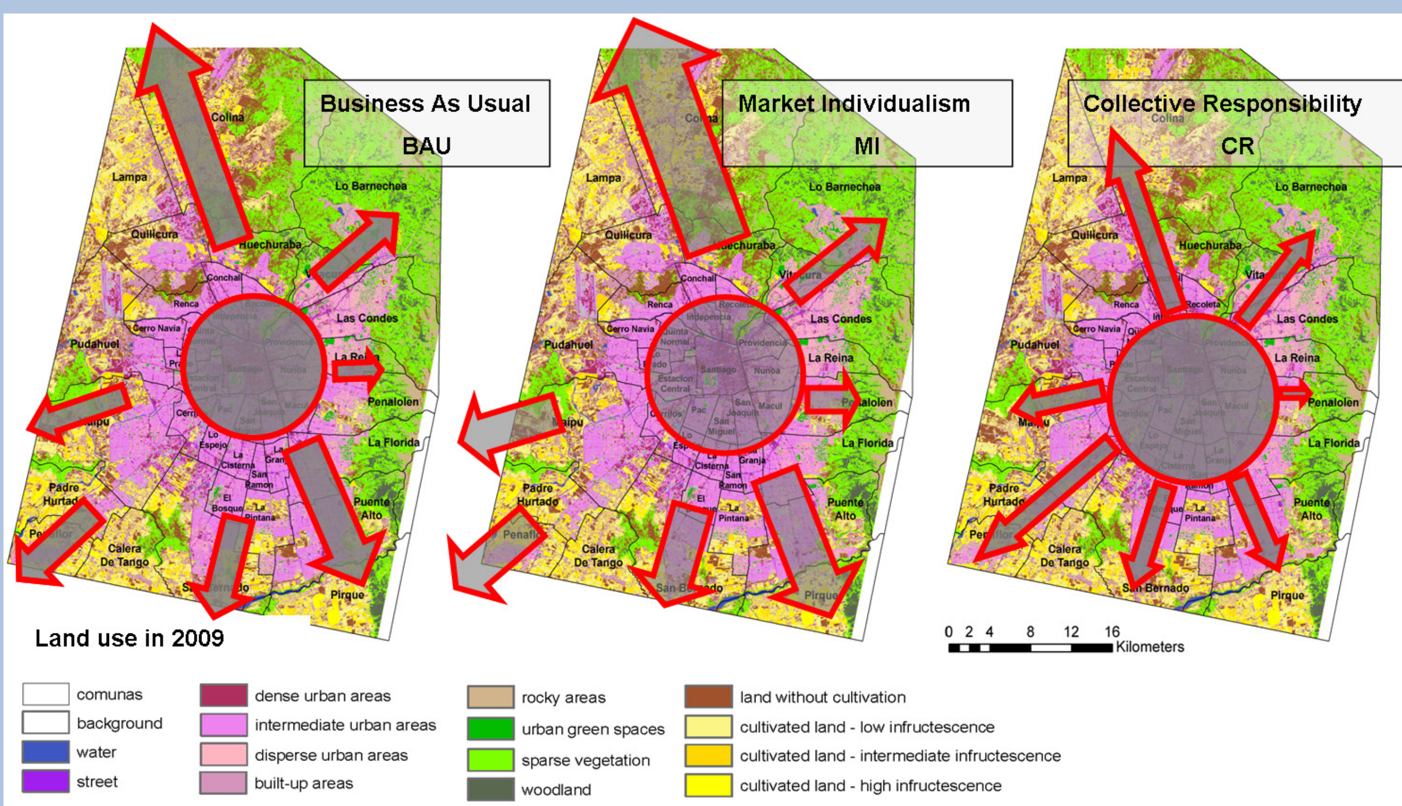
In the CR scenario it is most likely that indicators will approach the above-mentioned sustainability targets.

Table 5: Assumed development trends in Land Use Management until 2030 regarding sustainability indicators for flood risk assessment

	BAU - Business as usual	MI - Market individualism	CR - Collective Responsibility
Degree of imperviousness	Central and peri-central [1] areas: 0 / + [2] Periphery: +	Central and peri-central areas: 0 / + Periphery: + +	Central and peri-central areas: 0 / +Periphery: 0 / +
Amount of green spaces	NE – SW : one green axis, E: media-luna green axis; some additional patches: 0 / +	Small patches in the NE: 0 / -	Green network covering the MAS (large connected patches): + +
Proportion of new settlements and infrastructure in areas facing high flood hazard levels	In peri-central and peripheral areas: + +	In peripheral areas: + +	Amount in the entire urban area: tendency towards 0

1 The peri-central areas are located around the municipality of Santiago. They depend on the distance to the centre of Santiago, the population growth and the socio-economic composition of households.
2 The symbols used in this table stand for the following trends:
0 => stable; + => increase; ++ => strong increase; - => decrease

Figure 4: Probable urban development directions until 2030 for the three scenarios. (The spatial background depicts the land use classes for 2009)



3.4.3 Recommendations of measures addressing flood risks

Land-Use Management in Santiago de Chile should concentrate on prevention and mitigation measures. Prevention measures should consider the updating and coordination of flood risk analysis. Retention areas should be included in new urbanization projects, and a watershed management strategy for the Metropolitan Region should be elaborated. An essential measure is to raise awareness among the responsible institutions and decision-makers. In terms of mitigation, the work of MINVU and MOP should be coordinated better, with better information about risk areas made available to (potential) homeowners, and with a clarification of maintenance responsibilities.

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3.5 Thematic field: Waste management

(Tahnee González, Klaus-Rainer Bräutigam, Helmut Seifert, Marcel Szantó)

3.5.1 Challenges of the current municipal solid waste management

The performance of the municipal solid waste management (MSWM) of Santiago de Chile was evaluated with respect to the overall objectives of waste management: to protect human health, to protect the environment and to preserve natural resources. To perform the assessment, six indicators of sustainability were used.

The total and per capita amount of MSW (indicator 1) has continuously increased during the last decade, which, in addition to low recycling rates (indicator 2), has lead to a deficient management in terms of resource efficiency. The informal sector plays an important role in current recycling. However informal operators are not considered important actors of the system and their monthly earnings are below those of the average household income (indicator 3). Furthermore, MSWM is based on final disposal at sanitary landfills, but without any pretreatment (indicator 4). This results in the anaerobic decomposition of the biowaste, generating leachates and emissions of landfill gas (indicator 5). These emissions may contaminate groundwater or contribute to global warming, having an impact on the environment and public health. Finally, the fraction of gross domestic product spent in MSWM (indicator 6) was used to estimate the potential of Santiago de Chile to choose its MSW treatment technologies.

Target values for these indicators focus on the fulfilment of the objectives of MSWM, based on the priorities and requirements of Santiago de Chile. A comparison of current and target values (Table 6) shows that the most urgent problems are related to the amount of pretreated waste, emissions of greenhouse gases and the amount of MSW recovered. The associated negative impacts of these indicators are irreversible and present an important spatial and temporal range, thus constituting a risk to more sustainable development.

Table 6: Sustainability indicators for the various scenarios

	Indicator	2007	Target	BAU	CR	MI
1	Specific waste arising [kg/person/day]	1.1	Max. 1.6	1.81	1.66	1.91
2	Waste fraction recovered as material or energy [%]	12.5	36	31	43	20
3	Income level of informal workers in relation to average individual household income [%]	76	100	113	154	-
4	Amount of pre-treated waste that is sent to adequate landfills in relation to total waste sent to landfills [%]	0	50	0	21	0
5	Greenhouse gases emitted during waste management [kg. CO_{2eq} /person/year]	143	71	235	153	296
6	Costs of MSW in relation to GDP [%]	0.22	0.30	0.16	0.17	0.16

3.5.2 Future scenarios of municipal solid waste management

In order to evaluate how sustainability deficits of MSWM evolve over time, three alternative scenarios were elaborated, including qualitative descriptions and quantitative calculations.

Table 6 shows the results of the scenario analysis. The MSW arising increases in the three scenarios, exceeding in each case the maximum target value proposed for 2030. Furthermore, the main deficit corresponds, as in the current situation, to the amount of waste that is pre-treated before disposal in landfills and to the associated emissions of greenhouse gases. The fraction of GDP spent on MSWM in the three scenarios suggests that the technologies selected in each case are feasible for implementation.

The BAU scenario shows improvements in the amount of waste recovered, attributable to installation of mechanical sorting plants and segregated collection of biowaste and recyclables through organized informal workers, in addition to energy recovery from landfill gas and biogas. The organization of the informal workers it is also reflected in their improved incomes.

The lowest waste generation value is achieved in the CR scenario; this is attributed to changes in economic and social factors that affect this variable. The CR scenario reaches the target values for the amount of MSW recovered and for the income of the informal workers; it also shows progress in the pretreatment of waste. Nevertheless, the released GHG emissions are still far from the target value. This fact can be attributed, among other reasons, to the large amount of organics still being deposited at landfill sites.

The MI scenario shows large deficits in almost all the indicators. Of special importance is the income level of informal waste workers, which does not improve in comparison with current values, jeopardising their possibilities for securing basic needs.

3.5.3 Policy recommendations for municipal solid waste management

In general, recommendations for sustainable MSW management should integrate, more than at present: government policy, technological development, efficient production and adequate costs calculations. The weight given to each of these factors within each scenario differs according to their specific characteristics.

The large increase of total MSW arising in the three scenarios generates considerable pressure on the current infrastructure of waste management. An obvious measure is the application of MSW prevention strategies. However, the challenge would be to create the legitimacy and support for these policies in a BAU scenario. Another important measure to deal with the amounts of waste arising is the adaptation, i.e. construction of landfills before maximum capacities are reached. Recommendations towards improvement of waste treatment include a larger energy recovery from solid wastes. Additionally, other policy areas such as renewable energy, environment and climate change can give an impulse towards energy recovery from waste; these types of policies could be developed in time within the BAU scenario.

In the CR scenario there is also an increase in the total waste arising, but the trends are lower than in the two other scenarios. Prevention policies are also recommended in this case, in order to decrease pressures occurring at final disposal sites and waste treatment facilities. Prevention policies are likely to be accepted in this scenario, as are those promoting energy recovery from waste. Another related measure corresponds to adequate spatial planning, in order to create markets for the heat produced from waste to energy plants. Moreover, due to the characteristics of this scenario, it is likely that command and control strategies, which involve direct regulation along with monitoring and enforcement, can play an important role in achieving targets to divert wastes from landfills. In order to improve the management of the biogenic waste fraction, supplementary informative instruments to promote home composting can be potentially beneficial in the CR scenario. These recommendations raise the amount of pretreated waste, reducing greenhouse emissions, which correspond to the largest sustainability deficits in this scenario.

The MI scenario presents several sustainability deficits; the creation of prevention and recovery policies in this scenario is a major challenge for policy makers, given the materialist consumption nature characteristic of MI, accompanied by limited interest in environmental issues. Strong pressures occur at final disposal sites, due to the large amount of waste produced and low recycling rates. Even though it is not likely that policies promoting recovery of material and energy from wastes will be made in this scenario, secondary raw materials and energy markets could have an effect on recovery rates. In order to stimulate these markets, economic instruments could be implemented, if there is government commitment. Of special importance are revenue-providing instruments which motivate industries to change manufacturing processes, reducing solid wastes. Some examples are tax incentives for pollution-saving and energy efficiency, or charge reduction based on the use of secondary raw materials in production processes.

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3.6 Thematic field: Water

(Helmut Lehn, James McPhee)

3.6.1 Current situation and trends regarding water resources and services

The status analysis is based on 14 sustainability indicators (out of 64 in total). A core group of these is presented here. From a *resources perspective,* Santiago's contributing watershed has enough water to satisfy current demands from the municipal and industrial as well as the agricultural sectors in normal to wet years. However, the *rate of utilization of available resources* is high (0.8), which is considered a risk to sustainability although it is typical for arid and semi-arid climates. Given the average amount of water resource available and current as well as future population estimates, it can be said that Santiago exemplifies a situation that varies between water stress and severe water scarcity according the Falkenmark-index. The trend towards urbanisation has resulted in *increasing sealed surfaces* which implies reduced recharge of subsurface resources and falling groundwater tables. Water quality in the upper reaches of the Maipo system is adequate, but total metal concentrations are high in some reaches of the Mapocho River. Nevertheless, only a rather small fraction of water bodies in the region are suitable for recreation of any kind, due to either restricted access to riverbanks or diminished water quality. Finally, the *degree of compliance with emission norms to surface and subsurface water bodies* has been increasing steadily in the last few years (70% and 47%, respectively, for the year 2009).

Water services show very good performance since the 1990s, with very high *rate of connection to the distribution and sewage systems* managed by water utilities (today Aguas Andinas, SMAPA). *Water tariffs are within 2% of the average household income*, which satisfies MIDEPLAN guidelines. *Water per capita usage* shows a high variability within the region (150-600 l per person per day, depending on the comuna). The trend towards complete *wastewater treatment* in the last few years is remarkable. Two remaining challenges in the water service sector include

i) ensuring that all inhabitants of the region (including peri-urban localities) receive adequate water supply and sanitation, and
ii) integrating water (bodies and related infrastructure) in territorial planning of the city (e.g. green areas, recreation areas, groundwater recharge areas, green roofs, recycling of used water in the city).

Table 7: Future development trends for selected indicators

Sustainability indicator	BAU	MI	CR
Cost of sanitation services as percentage of average household income	< 2%	3-4%	<3%
Sealing of soil in selected areas due to urbanization	++	+++	+
Degree of compliance with emission norms (surface & subsurface)	60%	50 – 60%	> 80%
Rate of connection to sanitation services	>95%	>95%	>99%
Per capita water demand (including all municipal uses) [l/person-day]	250	200	180
Rate of utilization of available resources (ratio usage/supply)	0.8	0.9	0.6-0.7
Wastewater treatment and reutilization	+	+	++

"+" indicates a strengthening of the characteristic; "–" indicates a weakening of the characteristic.

3.6.2 Future development trends in 2030

According to the general approach explained in section 2, three alternative scenarios for water resources and services development in Santiago de Chile were developed. The main characteristics of these scenarios relative to the sustainability indicators highlighted above are presented, qualitatively or quantitatively, in table 7.

The MI scenario is closely related to the BAU scenario, and as such it is assumed that observed trends persist in terms of: market concentration of water services (one main provider), inefficient water-related practices (urban and agricultural use), and leap-frog urban expansion with associated effects upon groundwater recharge. Therefore, both scenarios result in unsatisfactory answers to the rising gap between water supply and demand as well as insufficient water quality in specific reaches of surface water bodies.
For the CR scenario:
i) increased public awareness results in efficient water use at the domestic, industrial and agricultural levels;
ii) the state guarantees the application of existing norms; and
iii) public participation in decision-making is very active. Some remarkable results include: because of lower water use, de facto ecological flows are left in the streams by water rights holders, thus enabling the restoration of previously degraded water bodies. Increasing stream health is not only positive for ecologic considerations, but also the Santiago population is able to enjoy more intensively the ecosystem services provided by streams close to the city – this is enabled by much better access to, and enhanced quality of, river banks. In summary, the CR scenario entails alleviating the water stress situation in the region and significantly reducing pollution problems affecting water bodies.

3.6.3 Recommendations of measures

Increased sustainability in the water sector requires social and institutional developments including increased environmental education together with an integrative and participative approach to resource management.

Specific measures include
i) Reduce flow speed – keep water longer in the catchment: various alternatives allow for increasing the retention times of storm and meltwater, including decentralized technologies for runoff management and artificial groundwater recharge (augmented groundwater, decrease flooding);
ii) Improve water efficiency in agriculture and domestic use: water efficiency must be addressed from a local and systemic perspective, whereby its goals should include increasing sustainability, as opposed to increasing economic productivity, and should also include both less water use and more water reutilization;
iii) Integrated watershed management: this involves strengthening stakeholder organizations, recognizing environmental services as legitimate water uses, and allowing the state to participate in water markets in order to recover environmental flows in fully allocated rivers.

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4. Prospects for a sustainable future of Santiago de Chile: Overall Findings

(Jonathan Barton, Jürgen Kopfmüller,
Kerstin Krellenberg, Dirk Heinrichs)

The starting point of the project was to answer the questions of how sustainable metropolitan development can be defined, what risks or opportunities are associated with mega-urbanization, which strategies and policies can steer the urban system towards more sustainability, and what institutional and organizational preconditions or changes are required for their effective implementation. In this sense, the project has generated diverse findings across a wide range of themes and disciplines. As with all urban or regional development research exercises, the principal challenge is to translate scientific concepts and results into policy and planning orientation. In the case of the *Risk Habitat Megacity* research initiative, this is done via proposals for strategic planning in Santiago de Chile for 2030 based on analyses of three alternative scenarios. The use of projections and scenarios helps to focus attention on future action and not only on assessment of previous trends and current state in urban and regional development.

As with all exercises in planning of sectors and territories (districts, municipalities, provinces, regions), the goal is first to integrate, i.e. link together various thematic and corresponding policy fields, and second to create positive synergies between diverse components and processes in order to consolidate development towards more sustainable outcomes, defined here by the Helmholtz sustainability concept. The use of indicator sets with desirable targets and the design and analysis of three alternative scenarios for 2030 contribute to this process of envisioning a more sustainable future for the city-region.

The principal findings of the project can be summarised in thematic and synergetic dimensions. The building blocks of scientific enquiry are disciplines, which have their own languages, methods and tools. However, the city-region is a complex "habitat" with multiple dynamic interactions, hence the need to promote the understanding of synergies and feedback mechanisms, as well as engaging with complex phenomena such as equity, access, risk and governance.

The results indicate many positive aspects of Santiago's development over recent decades. Examples include declining poverty levels, improvements in housing conditions and overcrowding, the almost complete coverage of waste-water treatment, and the Transantiago public transport system. Nevertheless, considerable challenges remain on the way towards a more sustainable condition of the metropolitan region, in particular with respect to attaining an improved quality of life for its residents in the medium-term future. Given expected trends in socio-spatial growth, the urban area of today (including 34 municipalities (INE)) will become a Metropolitan Area of 38-40 municipalities. The nature of this change must be understood as clearly as possible in order to ensure both equity and efficiency in this transformation process.

Thematically, problems of socio-spatial segregation remain crucial; these experiences are diverse across the city. The driving factors of access to education and housing policy instruments weigh heavily in producing or changing this situation. Localisation of people and services are also key elements to understanding risks that are generated, such as risk of flooding. Likewise, socioeconomic status is key to people's possibilities for successfully facing these risks. It is evident that urban expansion and even densification have taken place without sufficient attention to socio-ecological risks, whether risks to property damage or adequate investment in storm-water drainage systems, i.e. to environmental justice issues. Localisation decisions also play a role for the shape of transport needs and associated health risks from emissions. Congestion will slow down any future transport system and it would appear to be inevitable that different road pricing instruments will be required in different parts of the city, alongside stronger public transport measures that enable the 'metro and bus' routes to maintain higher capacities and velocities than the private passenger car option.

As incomes rise and demographic trends will generate a Metropolitan Region of 8 million inhabitants in 2030 compared to the 6.5 million of today, waste generation as well as water and energy demand will continue to rise. Because 'dry years' are likely to increase in future due to expected climate change, water stress will increase and new transfers will be required between sectors in order to maintain environmental services. To reduce emissions from waste collection and transfer, and from decomposition, the options for processing the organic fraction of domestic waste need to be explored. Ways in which these options can complement existing collection by informal operators provide an important link to the securing of basic needs for more vulnerable social groups. Energy demand is also expected to rise per capita and in total, therefore there is an urgent need to change the composition of the energy matrix, in order to move from a fossil fuel (carbon emissions) and a big hydro power plant

base (also threatened by climate change since the distribution network will have to be extended). This must be complemented by energy savings achieved by changes in personal life styles, in building design (heating and cooling), and particularly in transport technologies and behaviour.

4.1 Future sustainability trends

The synergies across all themes are evident, and it is here that more integrated, coordinated and consistent government and governance responses are required. Risks need to be identified at early stages of decision-making, and more adaptive governance structures need to be in place in to ensure broadly-based understandings of city-region dynamics and potential impacts, both positive and negative. Across the different scenarios, it is clear that the "Market Individual-ism" option includes more potential longer-term problems than the other two options, and that the "Business-as-usual" option does not meet the demands that lie ahead for 2030 and the 8 million metropolitan inhabitants. Even the "Collective responsibility" option is not a panacea, although it retains more positive outcomes, in particular in terms of reducing socio-spatial segregation and risks, and decoupling demographics from resource demand.

The scenario exercise does reveal, however, the need to explore different options. All options identify and make transparent the current trajectory that the city-region is navigating along, with its associated challenges. Delayed responses, weak preventive measures and the insufficient application of the precautionary principle displace impacts to different social groups across the city in different locations, as well as shifting responsibility and burdens to future generations. The intention to design a new regional long-term development strategy for the period until 2021 (as opposed to the current short-term four-year cycles) is a positive one. However, this exercise should remain the roadmap for the city-region over time and across Regional Administrators (Intendentes) and Regional Councils, in order to fulfil the claim of a longer-term perspective and validity and to ensure consistency in thinking and decision-making towards more sustainable development across the Metropolitan Region of Santiago de Chile.

4.2 Governance for metropolitan sustainable development: challenges and recommendations

Planning with existing tools, such as the regional development strategy, the regional urban development policy, the inter-communal regulatory plan, local regulatory plans and local development plans, will need to link much more clearly with sectoral initiatives from the public and private sectors. They will need to include a strong and binding public participation complementing existing democratic processes of direct local elections. A corresponding use of planning instruments and the guiding of investments requires goal-oriented planning in order to ensure complementarities, synergies and coherence across thematic fields and different actors within the Metropolitan Region, to avoid displacement of problems and to ensure more equitable and more efficient outcomes. Localisation remains a central dimension of this puzzle with respect to access to transport, appropriate land-use and segregation, for example, as well as to water availability, energy demand and waste management. These themes and their interrelation require a more effective and coherent planning that will need to consider medium and longer-term outcomes of current decisions, investments and programmes, and will also need to ensure that goals and targets are met which define a more sustainable development trajectory for the Metropolitan Region of Santiago de Chile. «

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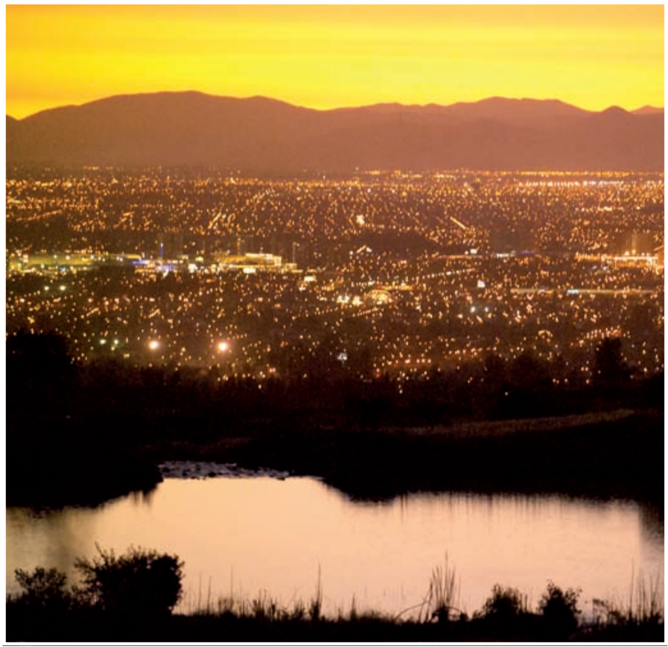

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