The Economics of Low Carbon, Climate Resilient Cities

Lima-Callao, Peru

British Embassy Lima

PERÚ Ministerio del Ambiente

Municipalidad Metropolitana de Lima

IDB

Centre for Low Carbon Futures

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E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Centre for Climate Change Economics and Policy

The Economics of Low Carbon, Climate Resilient Cities

Lima-Callao, Peru

Today

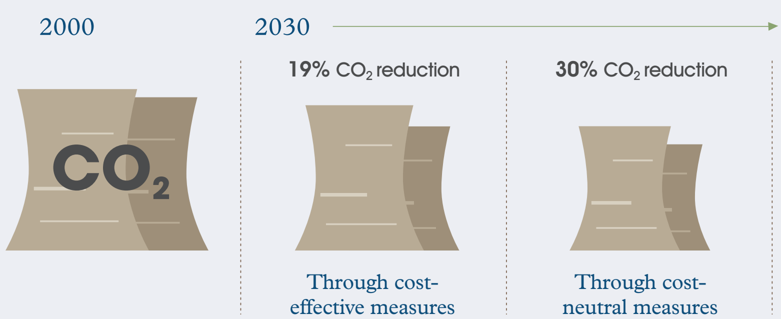
8% of city-scale GDP leaves the local economy every year through payment of the energy, water and waste bill. This is forecast to grow significantly by 2030.

Tomorrow

0.8% of GDP could be profitably invested, every year for ten years, to exploit commercially attractive energy efficiency and low carbon opportunities.

- **Energy**
  reductions in the energy bill equalling 1.6% of GDP
- **Financial viability**
  just under 2.5 years for cost effective measures to pay for themselves and just under 4.5 years for cost neutral measures to pay for themselves
- **Employment**
  more jobs and skills in low carbon goods and services
- **Wider economic benefits**
  energy security, increased competitiveness, extra GDP
- **Wider social benefits**
  better air quality, better health, less noise, better public transport

Potential to reduce CO_2 emissions



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List of Acronyms/Glossary

AIC	Average incremental cost
AMI	Advanced metering infrastructure
APEC	Asia-Pacific Economic Cooperation
BAT	Best available technology
BAU	Business as usual
BRT	Bus rapid transit
Carbon Effective	The level of carbon savings made by a measure
CDM	Clean Development Mechanism
CE	Cost Effective – measures that have a positive Net Present Value
CFL	Compact Fluorescent Lamp
CN	Cost Neutral – measures that when considered as part of a wider group of measures have an overall Net Present Value of greater than zero (**by definition these include cost effective measures**)
CNG	Compressed natural gas
COES	Comité de operación económica del Sistema Interconectado Nacional
EE	Energy efficiency
ENCC	National Strategy for Climate Change
GDP	Gross Domestic Product
GPC	Global Protocol for Community Scale Greenhouse Gas Emissions
Gwh	Gigawatt hour
IPCC	Intergovernmental Panel on Climate Change
LED	Light-Emitting Diode
LFGTE	Landfill gas capture for energy generation
LiWA	Lima-Callao Water project
LPG	Liquid Petroleum Gas
MCA	Multi-criteria analysis
MINAM	Ministry of Environment
MINEM	Ministry of Energy and Mines
MWh	Megawatt hour
NAMA	Nationally Appropriate Mitigation Actions
NPV	Net present value – the sum of the present values of cash flows associated with a project
PEN	Peruvian New Soles
PUCP	Pontifical Catholic University of Peru
PV	Photovoltaic
REDD	Reducing Emissions from Deforestation and Forest Degradation
SEIN	National Interconnected System
TWh	Terawatt hour
UNALM	Universidad Nacional Agraria La Molina
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change

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The study was coordinated by Patricia Iturregui and Karinna Berrospi from the British Embassy in Lima and Carlos Ludena and Jaime Fernandez-Baca from the Inter-American Development Bank (IDB), in collaboration with the Ministry of Environment of Peru (MINAM) and the Municipality of Lima.

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Forewords

Every country in the world is currently evaluating how to mitigate greenhouse effect gases with domestic measures, but also showing their will to do so within the framework of a global agreement, so that climate change will not affect global economy and development, food security and ecosystems in the future. The aim should be a carbon-neutral world for 2050, if we are to honour the decision that global temperature should not increase above 2°C.

Peru partakes in this process and has defined targets, has proposed actions and has been executing them, so that the foundation for a low-carbon sustainable development is laid, and the country becomes adapted to the adverse effects and opportunities brought about by climate change.

The preliminary proposal towards the global agreement to be adopted in Lima at the end of this year -pursuant to international and regional community mandate- depends on the collaboration by all countries and cities in the world to assume their responsibility according to their means. More than ever before, the pressure for a definitive solution will come from bottom to top, with a different approach from that in the Kyoto Protocol. To do so, national legislation, and particularly, city plans and efforts, are a key factor. Therefore, they should clearly show the benefits to be attained and the risks that can be prevented.

The Peruvian Government has created a Multi-sector Commission in charge of preparing the "Plan Perú-Compromiso Climático" (Peru's climate plan and commitment), which will express and confirm Peru's political will this year -2014 has been called "Year to promote Responsible Industry and Climate Commitment"- and will also contain strategic frameworks, concrete and cost effective measures with positive social and environmental effects and sectorial actions, as well as multi-sector coordination, highlighting public and private investment in goods and services that are climate-friendly. In this regard, if all sectors and actors in our society work together, we will identify and assume specific commitments to attain low-carbon sustainable growth, underpinned by clean and inclusive technologies, based on acknowledging the foundation for our development, our natural resources stock. At the same time, we trust that individual and collective commitments will continue being generated to increase the impact already achieved in the "Pon de tu parte" campaign launched together with the Municipality of Metropolitan Lima.

Conceiving and proposing sustainable cities is one of the emblematic topics in Peru's internal agenda on climate change. It will receive special treatment and development during the COP20/CMP10, together with other significant topics in the country such as forests, mountains, water, ocean and energy.

Within this context, the study presented in this document is an important initial technical and scholar contribution for a wider debate on the economy of cities and their role in climate change, a debate that should involve all national authorities, local governments, the private sector and civil society at large, including families and individuals.

The study is particularly interesting in that it shows the relevance of promoting the most profitable investments to reduce GHG emissions and the potential of future financing of climate objectives by the Peruvian government with its own resources and by the international cooperation through the Green Climate Fund.

We salute the authors and promoters –the University of Leeds (UK), Pontificia Universidad Católica del Perú and Universidad Nacional Agraria de La Molina (Peru)- for their commitment and interest in developing this document, as well as the Municipality of Metropolitan Lima and the British Embassy for their commendable efforts of coordination and consensus building.

The Ministry of the Environment, as collaborator and co-facilitator of this initiative, proposes to continue producing studies, and fine-tuning methodologies and approaches to guide policies and urgent actions in the road towards environmental sustainability and climate resilience in our cities.

Manuel Pulgar-Vidal
Minister of the Environment

Climate change is the great challenge of our time. Its current and future repercussions in the economy, society and environment are a huge issue and require our redefining the sense of development, as well as our designing, articulating and implementing public policies that will enable us to face its impacts.

Cities have a fundamental role to play in this regard, not only because they concentrate most activities that generate greenhouse effect gases, but also because, as hubs of economic and political power, they can lead the way required to face the climate challenge.

Therefore, I am pleased to present this report which analyses, from an economic perspective, the most efficient measures for managing carbon and water that could be adopted concerning energy, housing, trade, transportation, industry, waste and water in Lima-Callao.

This research shows there are many economically attractive opportunities for Lima-Callao to take a low-carbon and climate resilience development path that will be more efficient in energy and water management. These investments might equal 7.7% of Lima-Callao's GDP in 2014 and might have not only significant economic repercussions, but also provide a wider range of social and environmental benefits.

From the beginning of this administration, the Municipality of Lima-Callao has tackled with climate change from a cross-cutting approach in municipal policies.

Regarding Adaptation, we are promoting a number of initiatives to manage risk in vulnerable areas, recover the Rímac River, expand green areas in the city, and preserve ecologic infrastructure, aiming at harmonizing human settlements with management of urban ecosystems to foster the development of resilient communities.

Concerning Mitigation, Lima-Callao's agenda's priority is transportation reform. Such reform –expected for more than 30 years- is enabling promotion of orderly, clean and efficient public massive transportation through re-organization of routes, renovation of the vehicle fleet, use of clean fuels and planning of an integrated system to connect the entire city.

This report confirms that we are on the right track and that we need to continue already undertaken actions. Lima will host the COP 20, a conference that will become an extraordinary opportunity to reinforce and coordinate action of all sectors and players around a vision of our future.

Susana Villarán de la Puente
Mayor of Lima

We are glad to show the result of a joint effort: a study produced by Pontificia Universidad Católica and Universidad Agraria La Molina, on the Peruvian side, and by the University of Leeds, which is part of a British consortium of universities at the Centre for Low Carbon Futures, on the British side.

This first analytic effort has implied an important transfer of knowledge and, most of all, collaboration among specialists charged with the task. I would like to congratulate those responsible for the document presented here for their patience and dedication, as well as for having it ready at a very timely moment, looking ahead to the UN Climate Change Conference – COP20, to take place in Lima in December this year.

The relevance of the information contained in this study has earned it the nickname “mini-Stern study for Lima-Callao” (in reference to the decisive 2007 work on climate change published in the United Kingdom by Lord Nicholas Stern, who is preparing a second publication for September). Among much data, the study stands out in that it has gathered evidence that shows how the gross domestic product of Lima-Callao would increase by 8% with the cost effective investments identified by the study. At the same time, gas emissions would decrease by 19% to 2030. Calculations estimate that a five billion dollar investment (without taking the metro into account) would generate economically effective measures that would be paid in less than three years. Undoubtedly, quantitative evidence, research and generation of knowledge are essential for a low-carbon future with high growth and economic development for metropolitan areas such as Lima-Callao.

We hope this study may drive at least two important processes:

- A wide and constructive debate that will institutionalize regular research on this issue with PUCP and UNALM in coordination with the Municipality of Metropolitan Lima and the Ministry of the Environment.

- The preparation of an implementation plan and feasibility studies to undertake identified investments, especially in what regards transportation investments and a carbon-neutral pilot urban development project.

This year, Lima will be in the global limelight as host of COP20. Just a few months before such an important conference, this information becomes more relevant to attract investments and feed other studies about to be completed, such as the Plan for Climate Change (Plan CC). Moreover, international debates in Lima bring a very important novelty since -aiming at making global emission reduction more ambitious before 2020- the agenda includes for the first time the exchange of experiences of some cities in the world that have been able to control their emissions and to adapt to climate change impacts, as well as those that have identified opportunities to prevent or reduce emissions and become adapted to climate change impacts. This report advances substantial recommendations in this regard.

We hope Lima-Callao will take advantage of these recommendations to take steps towards their ambition of being a low-carbon city with high economic growth and which offers its inhabitants a high quality of life.

James Dauris
British Ambassador to Peru

Climate change is not a polar question anymore. It is a matter of how strong and how harmful will the changes be. With more than half of the world population living in cities and urban energy consumption and GHG emissions exceeding 70%, cities are essential to answering these questions. Historically, economic growth of cities has often come at the cost of higher resource demand and unplanned urban sprawl. Lima-Callao, by far the largest agglomeration and economic hub in Peru, has traced this path of resource-intensive growth in the past years. Built in a very arid area along the coastline, Lima-Callao is likely to be exposed to climate change-induced disasters as flooding and droughts. This report makes a case for the economic effectiveness of actions to be undertaken in the metropolitan region that will allow Lima-Callao to take a different trajectory on the emission and resource path and to improve its own climate-resilience.

The report focuses on the analysis of six sectors for emission mitigation in Lima-Callao: electricity, residential, commercial building, industry, transportation, and waste sector. It further examines the possibility to cost effectively minimize the risk of water stress in the future by analyzing a large set of water supply and demand projects and policies. By ranking each hard and soft measure within the different sectors against its cost- and carbon-effectiveness, the report provides reliable evidence for the economic case of low-carbon and climate-resilient investments. The multi-criteria analysis of the measures acknowledges that investment decisions are often taken beyond the isolated economic case.

The "Economics of Low-Carbon, Climate-Resilient Cities: Lima-Callao, Peru" makes an important contribution by providing a readily available argument for sustainable investments. The menu of most suitable options as well as the investment and financing plan constitute valuable guidance for domestic policy makers and other stakeholders. In addition, it presents an indication on the commercial viability of measures, the necessity for publicly driven investments, as well as a reliable document to source additional financing, including climate finance.

The Inter-American Development Bank cherishes the contribution done by the report as it aligns with the Bank's agenda - a lending target of 25% dedicated to climate change-related activities by 2015. The IDB is ready to serve as a partner in financing a resilient and low carbon future, by supporting sustainable investment decisions like those presented in this report.

Fidel Jaramillo

Peru Country Representative,
Inter-American Development Bank

Executive Summary

Introduction

What is the best way to shift Lima-Callao to a low carbon, climate resilient development path that is more energy and water efficient? Even where there is broad interest in such a transition, there are some major obstacles that often prevent action on such a broad agenda. The absence of a credible and locally appropriate evidence base makes it particularly difficult for decision makers to act and for investors to invest.

This study aims to provide such an evidence base for Lima-Callao, and to use this to examine whether there is an economic case that can be used to secure investments in energy and water efficiency and in low carbon, climate resilient development in the city. The more specific aim is to provide prioritized lists of the most cost and carbon/water effective measures that could realistically be adopted across the energy, housing, commercial, transport, industry, waste and water sectors within the city.

The total energy bill for Lima-Callao in 2014 was US$4.7 billion and the bill for waste and water was US$0.5 billion. This means that 8% of all income earned in Lima-Callao is spent on energy, water and waste.

Our Approach

We start the analysis by collecting data on levels and composition of energy and water use in Lima-Callao. We do this for a range of different sectors including the electricity and water sectors on the supply side and the housing, commercial, transport and industry sectors on the demand side. We also evaluate the waste sector as it both generates greenhouse gas emissions and has the potential to generate energy.

For each of these sectors, and for the city as a whole, we examine the influence of recent trends, for example in economic growth, population growth, consumer behaviour and energy and water efficiency, and we develop 'business as usual' baselines that continue these trends through to 2030. These baselines allow us to predict future levels and forms of energy and water supply and demand, as well as future energy and water bills and carbon emissions. Taking into account different scenarios on climate impacts, we forecast trends for water under both a high supply, low demand (optimistic) scenario, and a low supply, high demand (pessimistic) scenario.

Based on extensive literature reviews and stakeholder consultations, we then compile lists of many of the energy and water efficiency measures that could potentially be applied in each of the different sectors in the city. We assess the performance of each measure by conducting a realistic assessment of its costs and likely lifetime savings, and we consider the scope for deploying each one in Lima-Callao in the period to 2030. These appraisals were subjected to a participatory review in expert workshops to ensure that they are as realistic as possible and to consider the key factors that shape the potential for their deployment.

We then draw together the results from our assessment and the expert review to determine the potential impact of the combined measures across the different sectors of the city as a whole. This allows us to understand the scale of the development opportunity, the associated investment needs and paybacks, as well as impacts on energy and water supply and demand, energy and water bills and carbon emissions in the different sectors in the city. These aggregations also allow us to generate league tables of the most cost and carbon/water effective measures that could be adopted both in each sector and across the city as a whole.

The Case for Investment in Energy Efficiency and Low Carbon Development

We estimate that Lima-Callao's GDP was US$66 billion in 2014, and if recent trends continue we forecast that GDP will grow to US$136 billion by 2030. We also find that the total energy bill for Lima-Callao in 2014 was US$4.7 billion and that the bill for waste and water was US$0.5 billion. This means that 8% of all income earned in Lima-Callao is currently spent on energy, water and waste, (without including current subsidies).

We predict that a continuation of business as usual trends in the period to 2030 would see total energy use in Lima-Callao rising by 78% from 2014 levels to 2030 and we forecast that the total energy bill for Lima-Callao will increase from US$4.7 billion to US$10.7 billion in 2030. We also predict that under a business as usual scenario, total carbon emissions from Lima-Callao are forecast to increase by 82% from 2014 levels by 2030.

After examining the potential costs and benefits of the wide range of energy efficiency and low carbon measures that could be deployed across different sectors in the city, we find that – compared to business as usual trends – Lima-Callao could reduce its carbon emissions by 2030 by:

- 19% through cost effective[i] investments that would more than pay for themselves on commercial terms over their lifetime. This would require investment of US$5.1 billion, which by 2030 would generate annual savings in energy bills of US$2.1 billion (at 2014 prices), meaning that investments in these cost effective measures would pay back in 2.4 years whilst generating annual savings over the lifetime of the measures.
- 30% through cost neutral[ii] investments that would cover their costs over their lifetime. This would require investment of US$12.2 billion, which by 2030 would generate annual savings in energy bills of US$2.7 billion (at 2014 prices), meaning that investments would pay back in 4.5 years whilst generating annual savings over the lifetime of the measures.

We find that the transport sector contains 38% of the total potential for cost effective low carbon investments, with the remaining potential being in the industry sector (24%), the domestic sector (16%), the commercial sector (12%), the waste sector (8%) and the electricity supply sector (2%).

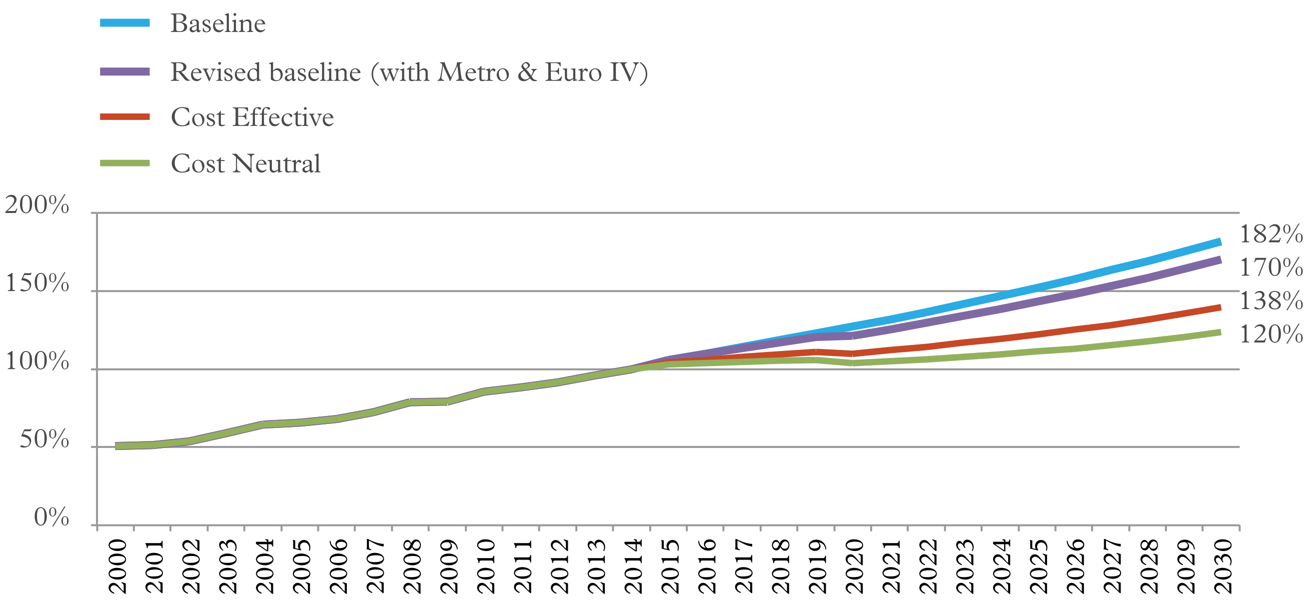
Whilst the impacts of cost effective and cost neutral changes will reduce overall emissions relative to business as usual trends, they do not stop overall emissions from rising in absolute terms. With exploitation of all cost effective, by 2030 emissions would be 38% above 2014 levels, and with all cost neutral measures exploited they would be 20% above 2014 levels. Investment in all cost effective measures will save US$2.1 billion in energy costs per year, thereby reducing the 2030 energy bill from 7.9% to 6.4% of GDP, whilst investment in all cost neutral measures will save US$2.7 billion in energy costs every year, thereby reducing the 2030 energy bill from 7.9% to 5.9% of GDP.

Business as usual to 2030 will see the total energy bill increasing from US$4.7 billion to US$10.7 billion and carbon emissions increasing by 82%.

[i] Cost effective investments are those where the costs of purchasing, installing and running a more energy efficient or lower carbon option are more than offset by the value of the energy savings that the measure generates over its lifetime. In economic terms, these are investments that have a positive net present value.

[ii] Cost neutral investments are those where the costs of purchasing, installing and running a more energy efficient or lower carbon option are not offset by the value of the energy savings that the measure generates over its lifetime, but where the extra costs can be met through the savings generated by other cost effective measures. In economic terms, this means that a blend of cost effective and non-cost effective measures could be adopted at no net cost over the lifetime of the measures.

Figure ES1:
Indexed emissions from Lima-Callao under three different scenarios, 2000-2030 (2014 = 100%).



Lima-Callao could invest US$5.1 billion in cost effective low carbon measures that would generate annual savings in energy bills of US$2.1 billion, meaning investments would pay back in 2.4 years.

Table ES1: Cost effective and cost neutral mitigation measures identified.

Sector	Cost Effective
Transportation	Teleworking campaign; Petrol taxis CNG retrofit; Scrapping cars greater than 20 years old for petrol cars; Replacing Combis with Omnibuses; CNG cars refrofit; Development of cycle lanes; Bus Rapid Transit; Congestions tolls for petrol and diesel private cars.
Waste	Portillo Grande landfill gas capture for energy generation.
Industry	Installing advanced metering infrastructure - industrial (75% deployment); Petroleum refining sector carbon reduction programme; Switch boilers to natural gas; Electricity conservation in other industrial sectors; Ethylene sector carbon reduction programme; Steel sector carbon reduction programme; Cement sector carbon reduction programme.
Commercial	Green building standards - commercial buildings; Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings; Commercial sector electricity retrofit programme; Public sector electricity retrofit programme; Street lighting - conversion to LEDs; Malls sector electricity retrofit programme; Solar PV for commercial sector (with FIT); Hospital electricity retrofit programme; Traffic lights - conversion to LED; Solar hot water for commercial sector; AMI meters - commercial (75% deployment).
Residential	Liquid petroleum gas to natural gas: 50% of households connected by 2020 (860,000 connections); High efficiency (EE1) water heaters; Incandescent lighting phase out and 50% LED by 2020; Installing advanced metering infrastructure - residential (75% deployment); Electricity conservation education; Solar hot water 10% by 2030 (BAU); High efficiency (EE1) refrigerator; Green residential buildings (20% of buildings built 2015-2030).
Electricity	Diesel replaced by solar PV (~160 MW by 2030).

Sector	Cost Neutral*
Transportation	Traffic management investments; Diesel taxis replaced with CNG; Hybrid scheme - $2,000 subsidy for 10% new cars.
Waste	Waste to electricity - 1,000 tonnes per day; Waste windrow composting - 100,000 tonnes per year; Zapallal landfill gas flaring; Recycling plant - 261kt of paper, wood and industrial waste; Taboada sluge to energy incinerator.
Residential	Solar photovolatics: target of 10MW per year (BAU); High efficiency (EE1) kitchen appliances (excluding the refrigerator); High efficiency (EE1) air conditioning; High efficiency (EE1) entertainment appliances; High efficiency (EE1) washing machines; Green roofs on residential apartment buildings (10% of new builds); Green roofs on semi-detached residential buildings(10% of new builds).
Electricity	Coal replaced with wind (200MW by 2030); Natural gas BAT (~3,500MW by 2030); Coal retrofit (~80MW by 2030); Natural gas retrofit (1,000MW by 2030).

*Cost neutral measures include cost effective measures. All mutually inclusive measures have been excluded.

Top 10 carbon effective measures by sector

Commercial	1. Solar hot water for commercial sector; 2. Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings; 3. Green building standards - commercial buildings; 4. AMI meters - commercial (75% deployment); 5. Commercial sector electricity retrofit programme; 6. Malls sector electricity retrofit programme; 7. Street lighting - conversion to LEDs; 8. Public sector electricity retrofit programme; 9. Solar PV for commercial sector (with FIT); 10. Hospital electricity retrofit programme.
Transport	1. Replacing Combis with Omnibuses; 2. Congestions tolls for petrol and diesel private cars; 3. Hybrid scheme - $2,000 subsidy for 10% new cars; 4. Traffic management investments; 5. Bus Rapid Transit; 6. Petrol taxis CNG retrofit; 7. Scrapping cars greater than 20 years old for hybrid cars; 8. CNG cars refrofit; 9. Scrapping cars greater than 20 years old for petrol cars; 10. Diesel taxis replaced with CNG.
Waste	1. Portillo Grande landfill gas capture for energy generation; 2. Taboada sluge to energy incinerator; 3. Waste to electricity - 1,000 tonnes per day; 4. Waste windrow composting - 100,000 tonnes per year; 5. Recycling plant - 261kt of paper, wood and industrial waste; 6. Zapallal landfill gas flaring.
Industry	1. Electricity conservation in other industrial sectors; 2. Switch boilers to natural gas; 3. Ethylene sector carbon reduction programme; 4. Installing advanced metering infrastructure - industrial (75% deployment); 5. Cement sector carbon reduction programme; 6. Petroleum refining sector carbon reduction programme; 7. Steel sector carbon reduction programme.
Residential	1. Incandescent lighting phase out and 50% LED by 2020; 2. Incandescent lighting phase out; 3. High efficiency (EE1) kitchen appliances (excluding the refrigerator); 4. High efficiency (EE1) refrigerator; 5. High efficiency (EE2) kitchen appliances (excluding the refrigerator); 6. High efficiency (EE2) refrigerator; 7. Solar photovolatics: target of 20MW per year (BAU); 8. Solar hot water 10% by 2030 (BAU); 9. High efficiency (EE1) air conditioning; 10. High efficiency (EE2) air conditioners.
Electricity	1. Geothermal 2,000MW (replacing natural gas); 2. Geothermal 1,000MW (replacing natural gas); 3. Coal replaced with wind (200MW by 2030); 4. Natural gas BAT (~3,500MW by 2030); 5. Coal replaced with solar PV (200MW by 2030)); 6. Gas generation replaced by wind (200MW by 2030); 7. Gas generation replaced by solar PV (200MW by 2030); 8. Diesel replaced by wind by 2030 (~130MW by 2030); 9. Diesel replaced by solar PV (~160 MW by 2030); 10. Natural gas retrofit (1,000MW by 2030).

The Case for Investment in Water Efficient, Climate Resilient Development

Climate change poses major uncertainties and risks for water supply and demand in Lima-Callao. Given these uncertainties, it seems prudent to hope for the best but to plan for the worst. We predict that the worst case scenario for Lima-Callao – which involves a 21% growth in water demand coupled with an 7% drop in rainfall for the rivers that feed Lima-Callao due to climate change – would see a 29% water deficit by 2030.

To consider the possible responses, we assess the potential of both supply side and demand side measures to address the 29% water deficit that could occur under the worst case scenario.

- The supply-side strategy. If investments are made in the lowest cost options, then we predict that the potential water deficit could be avoided through US$856 million of investment in supply side measures. This investment, which would increase costs but would generate no net savings, would have a payback period of 10.8 years. It could be financed entirely through a 18% increase in water tariffs for domestic, commercial and industrial water users.
- The demand-side strategy. If we prioritise demand side measures, to reduce the wider social and environmental impacts of increasing supply, then we predict that the potential water deficit could be avoided through US$2.0 billion of investment, 95% of which would be spent on reducing water demand, and 5% of which would be spent on increasing water supply. This investment, which would increase costs but would also generate savings through reduced water bills, would have a payback period of 7.4 years. It could be financed through a 15% increase in water tariffs for domestic, commercial and industrial water users and through the savings that the measures would generate.

We note that in the longer term, if the impacts of climate change on water supply to Lima-Callao grow, then it is likely that both the supply and demand side strategies will need to be adopted.

On water, the worst case scenario for Lima-Callao – which involves a 21% growth in water demand and a 7% drop in rainfall for the rivers that feed Lima-Callao due to climate change – would see a 29% water deficit by 2030.

The 2030 water deficit could be addressed through US$2 billion of investment, 95% of which could be invested in reducing demand and 5% in increasing supply. The investment would have a payback period of 7.4 years.

Figure ES2: Impacts of supply and demand side investments on the worst case (high demand, low supply) scenario.

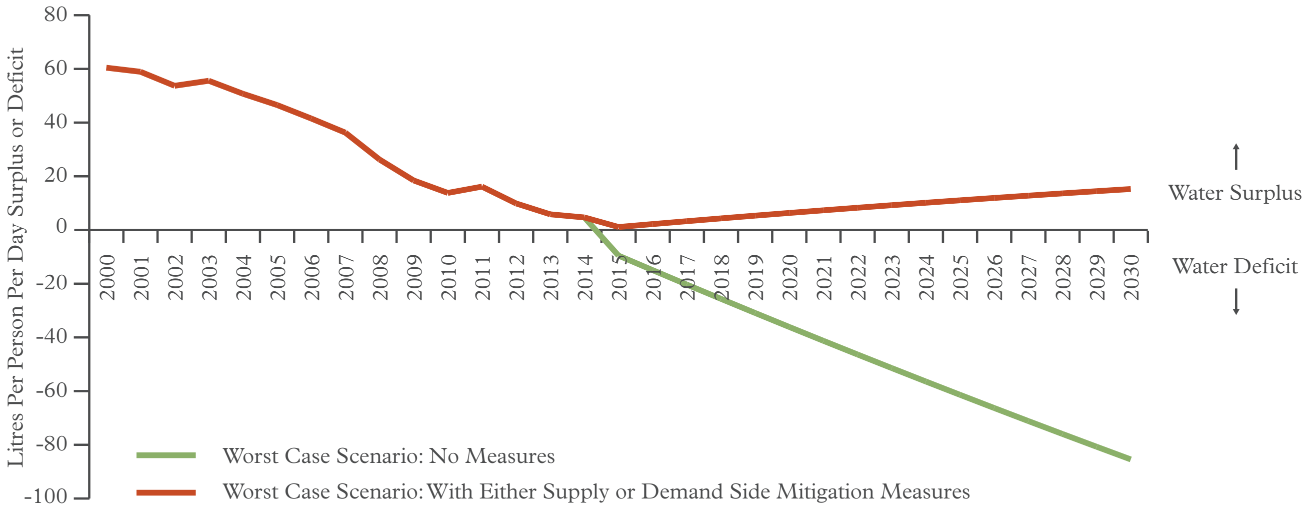


Table ES2: Supply side and demand side water mitigation measures identified in the respective supply side and demand side scenarios.

Supply Side
18% increase in commercial water tariffs; 15% increase in domestic tariff price; Rio Chillon Reservoir; Damming of the Casacancha in Conjunction with Marca III; Autisha Reservoir; Pomacocha - Rio Blanco.
Demand Side
15% increase in commercial water tariffs; 100% metering of serviced units by 2020; 15% increase in domestic tariff price; Commercial Green Building (25% of new builds 2015-2030); Low Flow Showers (50% deployment across all houses); Domestic Green Building (25% of new builds 2015-2030); Commercial Greywater retrofit (25,000 by 2030); Low Flow Toilets (50% deployment across all houses); Rehabilitation of Primary Network; Low Flow Kitchen Faucets (50% deployment across all houses); Rio Chillon Reservoir ; Residential Greywater Retrofit (50,000 by 2030); Domestic Greywater Toilets (100,000 by 2030) ; Low Flow Bathroom Faucets (50% deployment across all houses); 15% increase in industrial water tariffs; Water Conservation Education Programme; High Efficiency Washing Machines (25% deployment across all houses); High Efficiency Dishwashers (25% deployment across all houses).

Conclusions and Recommendations

This research therefore reveals that there are many economically attractive opportunities for Lima-Callao to shift to a low carbon, climate resilient development path that is more energy and water efficient. We estimate that these investments could generate wider economic benefits equivalent to 8% of Lima-Callao's 2014 GDP ($10.2 billion) for the cost effective measures, or 16% for the cost neutral measures ($22.2 billion). We note though that in practice these investments would be spread over the period to 2030 and that the economic impact would not be restricted to Lima-Callao. We also note that exploiting these opportunities could also have a wider range of social, economic and environmental benefits.

But the presence of such opportunities does not mean that they will necessarily be exploited. By providing evidence on the scale and the composition of these opportunities, we hope that this report will help to build political commitment and institutional capacities for change. We also hope this report will help Lima-Callao to secure the investments and to develop the capacities needed to implement change. Some of the energy and water management opportunities could be commercially attractive whilst others may only be accessible with public investment and/or development assistance. Many of them would benefit from the support of enabling policies from government.

But we also stress that economics is not the only discipline that has something useful to say on the transition to a low carbon, climate resilient Lima-Callao. A wider analysis should also consider the social desirability of the different options, as well as issues relating to the equity, inclusivity and broader sustainability of the different development pathways that could be pursued.

Chapter 1. Introduction, Context, Aims and Objectives

Cities and Climate Change

The influence and impact of cities cannot be overstated. More than half of the world's population lives in cities, and up to 70% of production and consumption takes place in cities[1]. Cities are the places where many of the world's institutions and much of its infrastructure are located, and where many of the world's major social, economic and environmental challenges are created, experienced and sometimes tackled. Cities are also the places where many international and national policies and plans must ultimately take effect. Global action frequently relies on urban action – our common future depends to a large degree on the way that we develop, organise, live and work in cities.

Issues relating to energy and water are central in the future development of cities. Currently, activities in cities consume up to 70% of all energy and are responsible for up to 70% of all carbon emissions[2]. Some estimates suggest that around 10% of all income that is earned in cities is spent on energy. Although cities directly consume only 11% of world water supplies, their water footprints are hugely significant, and they are expected to increase at a faster rate than national averages due to their increasing levels of population, income and consumption[3]. This implies that cities will impose larger pressures on water reserves, not only in their immediate hinterlands, but also from water sources located further away. Access to energy and water are obviously critical to human wellbeing and development. But many cities face the challenge of how to shift low carbon, climate resilient development paths that provide sustainable and affordable access to energy and water.

Whilst these are very significant challenges, the institutional capacities and socio- economic dynamism of many cities can make them well placed to respond. This is particularly true in fast-growing emerging economies where massive investment in infrastructure provides an opportunity to change the energy/carbon and water intensity of development. It is often suggested that preparing for climate change at an early stage of development is more effective and economically attractive than replacing or upgrading established infrastructure. Mainstreaming energy and water efficiency into planning processes has the potential to reduce bills and increase access whilst also managing the positive and negative spill-over effects of energy and water provision.

Focusing on Lima-Callao, this report considers the ways in which the relationship between energy, water and development in a rapidly growing city with pressing development needs could be changed. On energy, although the report considers energy supply, the main aim is to review the cost and carbon effectiveness of a wide range of energy efficient, renewable energy and low carbon options that could be applied in different sectors in Lima-Callao. It then considers whether there is an economic case for major investments in these options across the city, and whether these investments have the potential to shift the city on to a more energy efficient, low carbon development path. On water, the report considers the interactions between supply and demand, and the ability of the city to adapt to some of the risks associated with climate change. It assesses the direct costs and benefits of a wide range of options that could be deployed both to increase water supply and to reduce water demand, but it is aware that some of the indirect costs and benefits of changes to water supply and demand could be very significant. It considers whether there is an economic case for major investments in water supply and demand, and it presents different options based on expansions in supply (which could have significant indirect costs – socially, economically and environmentally) and reductions in demand (which could avoid some of these indirect costs).

The Peruvian Context

By land area, Peru is the third largest country in South America, and its population of nearly 30 million people makes it the fourth most populous in the region. During the last ten years, Peru's economy has grown at an average rate of 6.8% p.a., according to World Bank figures[4], just registering a temporary slowdown during the financial crisis. This expansion has been accompanied by a gradual increase in industrial activities, which accounted for 29.9% of the total gross domestic product (GDP) in the year 2000 and reached 34.6% in 2012. Peru has also intensified its openness to trade. The volume of its traded goods rose on average by 10.1% annually during the same period. Peru's solid macroeconomic performance has led to an improvement in standards of living of its population. According to the World Bank, income per capita rose more than 50% during the last decade, managing to halve poverty rates, which declined from 48.5% in 2004 to 25.8% in 2012.

Peru's economic growth has been accompanied by rapidly increasing demand for energy. Demand for energy has grown at 9% per year, roughly equivalent to bringing online a new 500 MW generation plant each year[5]. Per capita energy consumption has grown from 667 KWh in 2000 to 1149 KWh in 2013[6]. Per capita energy demand in Peru remains low at 23% of the OECD average and 53% of the Central and South American average[7]. Around 60% of electric power production in Peru comes from hydroelectric plants; these are complemented by gas generation plants when demand surpasses the hydroelectric generation capacity and when there are water shortages. As demand grows, natural gas is increasing its share of the energy matrix.

This economic growth, however, has been linked to greater pressures on the environment, including through the supply and consumption of energy and water. Increasing energy demands and changes in the energy mix as well as inefficiencies in energy use have seen Peru's greenhouse gas (GHG) emissions increase by 15% from 120 to 138 $MTCO_{2e}$ in the period from 2000 to 2009[8]. Peru itself is particularly exposed to the impacts of increased GHG emissions. It is classified as one of the world's 10 mega-diverse nations[9], and it possesses four of the five types of geographical areas identified by the UNFCCC as the most vulnerable to climate change, from low-lying coastal areas prone to flooding, drought and desertification to fragile mountain ecosystems. According to the 2013 UNDP Human Development report for Peru, the country is already being severely affected by the effects of climate change, derived from its exposure to extreme weather events and an acceleration of creeping long-term trends. It is said that Peru has lost approximately 39% of its glaciers[10] and significant proportions of the country's population rely on climate dependent activities, such as farming and fishing, to make a living.

Figure 1 below shows the composition of Peru's emissions by sector. It is notable that forestry and agriculture make up over 50% of emissions over the period 2000-2009, with other emissions from other sectors (including energy, process industry and waste) making up 33 and 40% in 2000 and 2009 respectively.

In 1992, Peru became a member of the United Nations Framework Convention on Climate Change (UNFCCC); arguably the country's first notable action on an international environmental issue. As a member of the UNFCCC, the country is obliged to produce and consistently update a national GHG inventory[11] . In 2002, Peru signed up to the Kyoto Protocol, thus aligning it with the objective of the convention to "stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference[12]." Peru now has in place a National Environmental Policy that also obliges the country to pursue the adaptation of the population and its activities to climate change and the establishment of adaptation measures aimed at sustainable development[13].

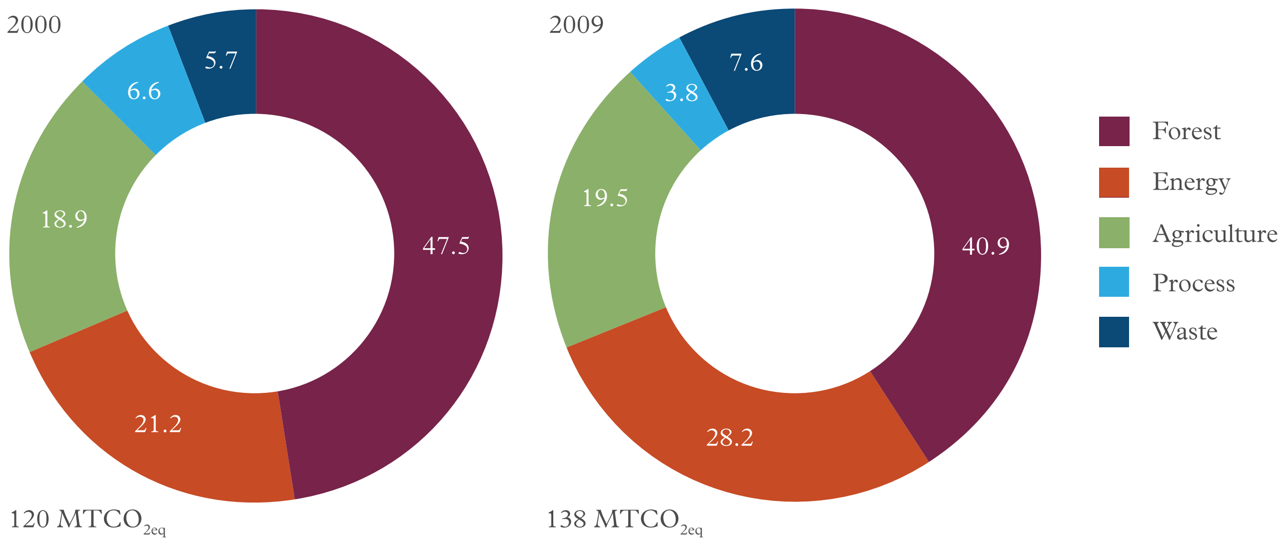
On 9 July 2011, the Government approved a national plan of environmental action for 2010–2021[14], which established goals and actions including the following commitments to achieve a national low-carbon economy:

(a) Using non-conventional renewable energies and hydropower to provide at least 40 per cent of the total energy mix. Together with energy efficiency, this initiative will result in a total emission reduction of 28 per cent compared with the emission level in 2000, with potential avoided emissions of up to 7 Mt CO_2 eq;

(b) Capturing and using CH_4 from urban solid waste: a national programme to build landfills in 31 large and medium-sized cities, with the potential to achieve an emission reduction of 7 Mt CO_2 eq.

The Peruvian Ministry of the Environment (MINAM) heads the National Commission for Climate Change (CNCC) with the responsibility to coordinate the implementation of the UNFCCC principles across Peru's various emission contributing sectors and to design and promote the National Strategy for Climate Change (ENCC). National scale efforts in Peru with the ambition of safeguarding the environment include schemes such as the CDM (Clean Development Mechanism), REDD (Reducing Emissions from Deforestation and forest Degradation) and NAMAs (Nationally Appropriate Mitigation Actions). Peru is still undoubtedly a long way off from securing a sustainable future. However, its recent efforts to harmonize environmental issues with national policy and related institutional frameworks are surely the first steps in doing so. Since 2012, the Peruvian government has supported a climate mitigation programme called Plan CC[15] with the initial activity focused on looking at "long-term scenarios to identify the most economically, socially and environmentally profitable mitigation trends in which the Peruvian society should invest". The longer-term objective of the programme is to catalyse transformation and enable low-carbon investments for Peru.

Figure 1: Sectorial shares in Peruvian GHG emission inventory in 2000 and 2009 in %.[16]



Lima-Callao

Within Peru, the Lima-Callao Metropolitan Zone[17] is home to 9.5 million people, making it the 5th largest city in South America and by far the largest metropolitan area in Peru. Although Lima-Callao is home to 30% of Peru's population, it represents the country's commercial and financial centre. Most of Peru's exports and imports pass through the port of Callao, which, located just 15 km from Lima-Callao's city centre and is one of the largest hubs in the region[18]. In total Lima-Callao accounts for 51% of Peru's GDP and 84% of its taxes[19].

Lima-Callao has grown rapidly in recent years – from 2000 to 2014 its population grew by 28% from 7.4 to 9.5 million. Lima-Callao's growth is at times unplanned – with the expanding population moving up the surrounding valleys where informal settlements are constructed on the hillsides. These settlements – which are home to approximately 12% of the total population - tend to have limited access to water (an estimated 10% of Lima-Callao's population is without direct access to water)[20], sanitation and electricity. Informal water use accounts for 4% of Lima-Callao's overall water use, with informal users getting most of their water from water trucks which charge up to 9 times as much as the rate charged through a formal connection[21]. Informal electricity use accounts for 3% of Lima-Callao's total electricity consumption, with electricity supplied through clandestine connections to the grid.

As Lima-Callao has grown, so some of its environmental challenges have increased. In terms of energy use, the use of hydroelectric power and gas has made the carbon emissions of electricity generation lower than in many other cities. However, increasing demand for electricity, led both by a growing population and rising GDP, has led to higher overall carbon emissions from the energy sector. Based on our work in this report, we find that energy use in Lima-Callao has risen by 82% since 2000, and that carbon emissions from the city have increased by 98% over the same period. More broadly, Lima-Callao accommodates over 70% of Peru's transport fleet, and emissions from transport have a significant impact not only on carbon emissions but also on urban air quality. Pollution from the approximately 1.2 million vehicles in the capital[22], including 60,000 public buses with an average age of 16 years, is said to be amongst the worst in South America[23].

In terms of water use, with less than 10mm of rain falling in Lima-Callao each year, the city is among the world's largest municipal areas situated in a desert. As a result, Lima-Callao is largely dependent for water resources on the Rimac, Chillon and Lurin rivers, whose watersheds originate in the Andes mountains[24]. However, supplies from these sources are close to being fully exploited, and forecasts of the impacts of climate change suggest that there is a real risk of significant reductions in water supply, with forecasts predicting that precipitation across the Mantaro basin could decrease 19% by 2050[25]. Meanwhile, demand for water in Lima-Callao is increasing rapidly, largely because of an increasing population within the city. We find that water use in Lima-Callao increased by 21% in the period from 2000 to2014.

The key environmental policy that has been adopted in Lima-Callao is 'La Agenda Ambiental Metropolitana.' This policy, which prioritizes the rational use of natural resources and improving the quality of the city's environment, is a tool for environmental management in Lima-Callao. It incorporates specific objectives such as, 'optimizing the disposal of solid waste throughout the city' which has been addressed with the launch of 20 city-wide recycling programmes[26]. Other specific objectives include the reorganization and strengthening of environmental management in Lima-Callao, the improvement of the tools to monitor air quality and the promotion of non-motorized transport, along with several others. A 2025 Roadmap for Sustainable Transportation in Lima-Callao has been recently been developed[27] and national plan for the integration of urban transport has also been considered recently which has the goals of shortening journey times, improving transport efficiency and enhancing the health of urban settlers[28].

Aims and Objectives

Given the issues raised above, we explore the best way to shift Lima-Callao to a low carbon, climate resilient development path that is both energy and water efficient. Even where there is broad interest in such a transition, there are some major obstacles that often prevent cities from acting on such a broad agenda. The absence of a credible and locally appropriate evidence base makes it particularly difficult for decision makers to act and for investors to invest.

This study aims to provide such an evidence base for Lima-Callao, and to use this to examine whether there is an economic case that can be used to secure large-scale investments in energy and water efficiency and in low carbon, climate resilient development in the city. The more specific aim is to understand the implications of a continuation of business as usual development trends, and to evaluate how these trends could be changed by providing prioritized lists of the most cost and carbon/water effective measures that could realistically be adopted across the energy, housing, commercial, transport, industry, waste and water sectors within the city.

On energy, the aim is to identify and review the cost and carbon effectiveness of a wide range of energy efficient and low carbon measures that could be applied in different sectors in Lima-Callao. Similarly on water, the aim is to identify and review the cost and water effectiveness of a range of the supply and demand side options that could be applied to help Lima-Callao avoid the major water shortages that could occur as the city grows and as climate change impacts on its water resources. On this basis, the aim is to consider whether there is an economic case for major investments in these energy and water related measures across the city, and whether these investments have the potential to shift the city on to a more low carbon, climate resilient development path.

The evidence base is intended to inform policymaking and programme design both within individual sectors and at the city scale. By identifying the most cost- and carbon/water effective measures, we aim to help government, industry and civil society organisations and development agencies to design low carbon, climate resilient development strategies that exploit the most attractive opportunities. Notably, the evidence base has the potential to underpin national applications to international climate funds, development banks and other financial organisations, thereby helping to unlock and direct large-scale investment into low carbon, climate resilient development.

Chapter 2. Approach to the Analysis

Our analysis has a number of key stages:

Baseline analysis

We start by collecting data that enables us to understand the levels and composition of energy and water supply to, and demand in, Lima-Callao. We do this for a range of different sectors including the energy and water sectors on the supply side and the housing, commercial, transport and industry sectors on the demand side. We also evaluate the waste sector as it both generates greenhouse gas emissions, and has the potential to generate energy. We use 2014 as a baseline year throughout the report with data being forecasted based on the most recently available data. A short summary of how the baseline has been prepared for each sector is given in Appendix B.

For each of these sectors, and for the city as a whole, we examine the influence of recent trends, for example in economic growth, population growth, consumer behaviour and energy or water efficiency, and we develop business as usual baselines based on the continuation of these trends through to 2030. Table B1 in Appendix B summarises the main process for forecasting (and where necessary back casting) for each sector. These baselines allow us to predict future levels and forms of energy and water supply and demand, as well as future energy and water bills and carbon and water footprints. We then compare all future activities against these baselines.

Identification and Assessment of Measures

We then develop lists of all the energy efficient, low carbon and water efficient, climate resilient measures that could potentially be applied in each of the different sectors in the city. We include both technological and behavioural measures. We first develop long lists of all potential measures, based on extensive literature reviews and stakeholder consultations, and we then review these to remove any options that are not applicable in the Lima-Callao context and to add in any other measures that we may have missed. The outputs then form our shortlist of measures for each sector. These shortlists are not necessarily exhaustive – some measures may have been overlooked, others may not have been included in the analysis due to the absence of data on their performance.

Again based on extensive literature reviews and stakeholder consultations, we then assess the performance of each measure on the shortlist. We consider the capital, running and maintenance costs of each measure, focusing on the marginal or extra costs of adopting a more energy efficient, lower carbon or water efficient, climate resilient alternative to construct a Net Present Value for each measure[29]. We then conduct a realistic assessment of the likely savings of each option over its lifetime, taking into account installation and performance gaps. As each measure could be in place for many years, we take into account the changes that are predicted to occur over its lifetime, i.e. in energy prices, carbon intensities, climate impacts, so that we can calculate the energy use that has been avoided or the water that has been saved through the adoption of each measure. In order to calculate energy savings we use the first year after the project has been fully installed to estimate energy savings and therefore derive a payback period

These appraisals and scenarios are then subjected to a participatory review in expert workshops to ensure that they are as realistic as possible. Lists of all of the measures considered in the analysis are presented in Table 1. Lists of all of the participants in the expert workshops are presented in Appendix A.

Finally, a summary of the key assumptions made in developing the individual measures along with the key data sources is provided in Appendix B.

Project Scope

The project looks at measures that we have drawn from previous low carbon city studies, international best practice and from stakeholder workshops within Lima-Callao. Given the nature of the study we have not looked at some specific options. For example, we have not considered the impact of a significant change in land use planning or in the spatial distribution of activities within the city. Whilst such changes have the potential to contribute significant reductions in greenhouse gas emissions, they are outside of the scope of this project. We do however comment below on the impact of an eco-zone within Lima-Callao (see Appendix E). We have also not been able to consider measures such as improvements to the electricity grid to allow significant expansions in the contribution of renewable energy to the grid or the management of the wider river basins to allow more sustainable and effective use of water resources.

Deployment of Mitigation Options

The speed at which mitigation options can be applied across the city depends on a number of factors, such as the time taken to build or distribute the measure, the sequencing of multiple projects, time for public sector changes to be implemented, uptake by the general public, etc. All measures begin at the earliest in 2015, however we have selected appropriate build rates or uptake rates depending on the individual measure. For example green new buildings are spread across the time-period 2015-2030, whereas incandescent lighting phase out is scheduled to take place entirely in 2015 and the water supply measures are completed in a specific order based on Lima-Callao water utility company master plan.

Mutual Exclusivity of Measures

As some of the measures interact with each other, one measure's performance can impact on a second measure. For example, the carbon saving from solar water heating depends on the energy efficiency of the water heaters being replaced and the effectiveness of car-related transport measure depends on the fuel and carbon efficiency of the vehicle stock being considered. We have therefore designed our measures to be mutually exclusive of one another. In the case of electricity, the savings for other sectors assume our baseline scenario for electricity and savings for the electricity sector are kept within that sector.

Table 1: Lists of the low carbon measures considered.

Sector	Mitigation Measures
Electricity Generation	Natural gas BAT (3,500MW by 2030); Natural gas retrofit (1,000MW by 2030); Coal BAT (130MW by 2030); Coal retrofit (80MW by 2030); Coal replaced with wind (200MW by 2030); Gas generation replaced by wind (200MW by 2030); Diesel replaced by wind by 2030 (130MW by 2030); Coal replaced with Solar PV (200MW by 2030); Gas generation replaced by solar PV (200MW by 2030); Diesel replaced by Solar PV (160 MW by 2030); Geothermal 1,000MW (replacing natural gas); Geothermal 2,000MW (replacing natural gas); Natural gas BAT + retrofit (5,700MW by 2030); Coal BAT + retrofit (210MW by 2030); Coal and natural gas retrofit (2,280MW by 2030); Coal and natural gas BAT (3,630MW by 2030); All wind scenarios (530MW by 2030); All solar PV scenarios (560MW by 2030).
Domestic*	Green residential buildings (20% of buildings built 2015-2030); High efficiency (EE1) entertainment appliances; High efficiency (EE1) kitchen appliances (excluding refrigerators); High efficiency (EE1) air conditioning; High efficiency (EE1) washing machines; High efficiency (EE1) water heaters; High efficiency (EE2) entertainment appliances; High efficiency (EE2) kitchen appliances (excluding refrigerators); High efficiency (EE2) air conditioners; High efficiency (EE2) washing machines; High efficiency (EE2) water heaters; Electricity conservation education; Solar photovoltaics: Target of 10MW per year (BAU); Solar photovoltaics: Target of 20MW per year (BAU); Solar hot water 5% by 2030 (BAU); Solar hot water 5% by 2030 (EE1); Solar hot water 5% by 2030 (EE2); Solar hot water 10% by 2030 (BAU); Solar hot water 10% by 2030 (EE1); Solar hot water 10% by 2030 (EE2); High efficiency (EE1) refrigerator; High efficiency (EE2) refrigerator; Incandescent lighting phase out; Incandescent lighting phase out and 50% LED by 2020; Green roofs on semi-detached residential buildings (10% of new builds); Green roofs on residential apartment buildings (10% of new builds); Installing advanced metering infrastructure – domestic (75% deployment); Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections).
Commercial Sector	Green building standards – commercial buildings; Public sector electricity retrofit program; Commercial sector electricity retrofit program; Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings; Street lighting – conversion to LEDs; Malls sector electricity retrofit program; Traffic lights – conversion to LED; Hospital electricity retrofit program; Solar PV for commercial sector (with FIT); Solar hot water for commercial sector; Advanced meter infrastructure – commercial (75% deployment).

Sector	Mitigation Measures
Industry**	Switch boilers to natural gas; Electricity conservation In other industrial sectors; Installing advanced meters – industrial (75% deployment); Ethylene sector carbon reduction programme; Cement sector carbon reduction programme; Petroleum refining sector carbon reduction programme; Steel sector carbon reduction programme.
Transport	Teleworking campaign; Petrol taxis CNG retrofit; Scrapping cars greater than 20 years old for petrol cars; Scrapping cars greater than 20 years old for hybrid cars; Replacing combis with omnibuses; CNG cars refrofit; Development of cycle lanes; Bus Rapid Transit; Congestion tolls for petrol and diesel private cars; Traffic management investments; Diesel taxis replaced with CNG; Diesel taxis replaced with hybrid; Hybrid scheme – US$2,000 subsidy for 10% new cars.
Waste	Recycling plant – 261kt of paper, wood and industrial waste; Waste windrow composting – 100,000 tonnes per year; Waste in-vessel composting – 100,000 tonnes per year; Portillo grande landfill gas capture for energy generation; Zapallal landfill gas flaring; Waste to electricity – 1,000 tonnes per day; Taboda sludge to energy incinerator.
Water	Water conservation education programme; 15% increase in domestic tariff price; 18% increase in domestic tariff price; 18% increase in industrial water tariffs; 15% increase in industrial water tariffs; 18% increase in commercial water tariffs; 15% increase in commercial water tariffs; Aquifer recharge; Condensate catchers; Rehabilitation of primary network; Basin wells of river Chancay (2040); Rio Chillon resevoir; Pomacocha – Rio Blanco; Desalination of the sea water of the south sea; Damming of the Casacancha in conjunction with Marca III; Extension of Graton tunnel; Autisha resevoir; Aquifer recharge for Lurin river; Re-channelling Rimac river; 100% metering of serviced units by 2020; Low flow bathroom taps (50% deployment across all houses); Low flow showers (50% deployment across all houses); Low flow toilets (50% deployment across all houses); Low flow kitchen taps (50% deployment across all houses); High efficiency dishwashers (25% deployment across all houses); High efficiency washing machines (25% deployment across all houses); Domestic greywater toilets (100,000 by 2030); Residential greywater retrofit (50,000 by 2030); Commercial greywater retrofit (25,000 by 2030); Domestic green building (25% of new builds 2015-2030); Commercial green building (25% of new builds 2015-2030).

* *EE1 and EE2 relate to two different performance levels for domestic appliances. For full details see Appendix B – Domestic sector.*

** *Full details of how the industrial measures were developed are included in Appendix B.*

Assessment of the Scope for Deployment

We then consider the scope for deploying each of the measures in each of the sectors in Lima-Callao in the period to 2030. We do this based on the baselines which include an evaluation of the size and composition of energy and water supply and demand in different sectors. We do this not only for the sectors as a whole, but also for sub-sectors, taking into account for example the scope for change in households with different income levels and levels and forms of energy and water consumption, or the scope for an option to be adopted in a particular industrial sub-sector.

Based on stakeholder consultations, we develop likely levels of deployment through to 2030. In some cases we develop both realistic and ambitious levels of deployment, with realistic rates being based on readily achievable levels of up-take, and ambitious rates assuming rates of deployment or take-up that could be achieved if supporting policies and favourable conditions were in place. These assessments take into account the lifespans and rates of renewal of existing measures that could be replaced with more energy efficient or lower carbon alternatives, and also rates of change and growth in the relevant sectors of the city.

Again, we subject our assessments of the scope for and rates of deployment to participatory review in expert workshops to ensure that they are as realisticas possible.

Aggregation, Assessment of Investment Needs and Opportunities

We then draw together the results from our assessment of the performance of each measure, and the scope for deploying each measure, to develop aggregations of the potential influence of each measure across the different sectors of the city as a whole. This allows us to understand overall investment needs and paybacks, as well as impacts on energy and water supply and demand in the different sectors in the city. It also allows us to generate league tables of the most cost and carbon/water effective measures that could be adopted both in each sector and across the city as a whole.

More detailed explanations of the data sources, methods and assumptions used for each sector are presented in Appendix B.

Chapter 3a – The Key Findings for Lima-Callao: Energy and Low Carbon Development

The Changing Context and the Impacts of Business as Usual Trends

We find that Lima-Callao's GDP in 2014 is predicted to be US$66.1 billion[30] (see Appendix B for more details on data sources, methods and assumptions for this and other projections), if recent trends continue we forecast that they will grow to US$136 billion by 2030. We therefore find that per capita incomes in Lima-Callao were US$7,000 in 2014 and that with projected rates of economic and population growth they will grow to US$12,100 by 2030. We also find that the total energy, waste and water bill for Lima-Callao in 2014 was US$5.2 billion, which equates to 7.9% of Lima-Callao's GDP. In other words, 7.9% of all income earned in Lima-Callao is currently spent on energy, water and waste.

We find business as usual trends in Lima-Callao show a limited decoupling of economic output and energy use between 2000 and 2030 (see Fig. 2). However, GDP and energy demand per capita both rise overall from 2000 to 2030, while the population of Lima-Callao is also growing. These effects are offsetting the limited improvements in energy intensity and leading to a net increase in energy use.

Figure 2: Indexed energy use – total, per unit of GDP and per capita, 2000-2030 (2014 = 100%).

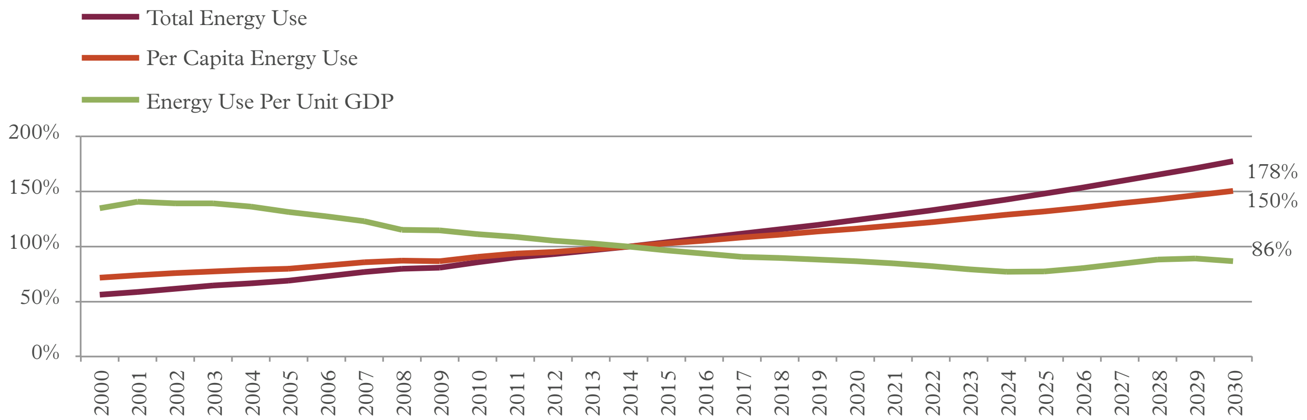
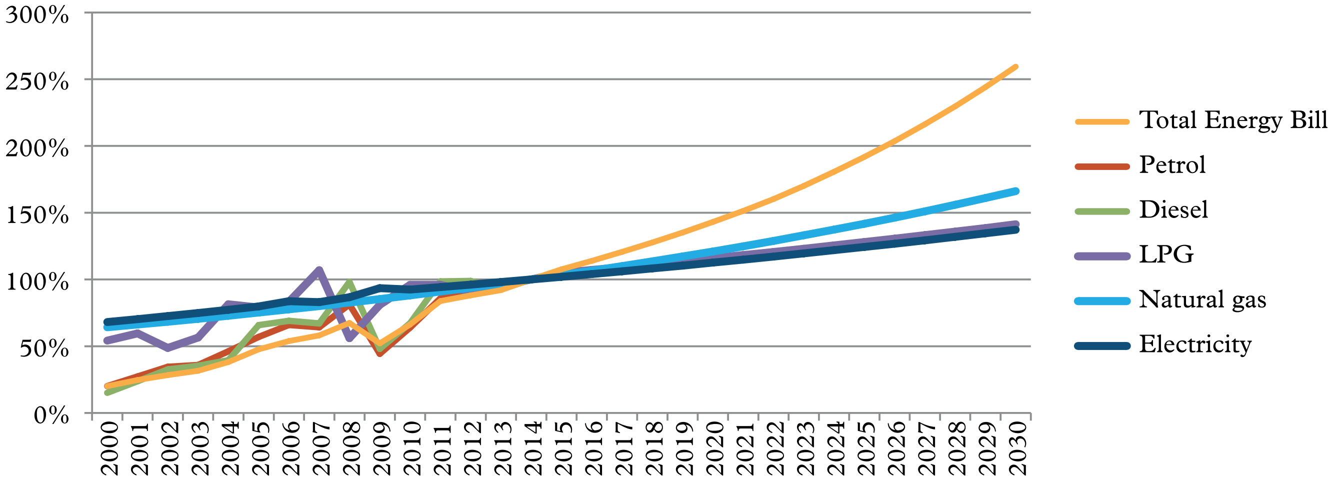


Figure 3: Indexed total energy bill and energy prices, 2000 -2030 (2014 = 100%).



Real energy prices (and before considering the impact of the planned Metro and EuroIV standards) have increased, with volatility, from 2000 to 2014. For most of the energy sources we have assumed a 2% increase in prices each year from 2014 to 2030. We find that the overall rise in real energy prices combined with increasing energy consumption means that the total energy bill for Lima-Callao will be 2.6 times its 2014 level by 2030 in a business as usual scenario.

Our analysis finds that the emissions intensity of energy production is projected to remain largely constant until 2030, and coupled with only a limited improvement in energy efficiency in the wider economy means that the emissions produced per unit of GDP will fall slightly until 2025[31]. Furthermore emissions per capita and total emissions are predicted to rise probably due to increasing individual wealth leading to higher energy use. In a business as usual scenario, total emissions from Lima-Callao are therefore forecast to increase by 82% on 2014 levels by 2030.

When combined with increasing real energy prices, this leads to the total expenditure on energy to increase by 160% from US$4.7 billion in 2014 to a forecast level of US$12.3 billion (before accounting for changes due to the Metro II and Euro IV standards) in 2030 (see Fig. 6). When combined with relatively stable levels of carbon emissions per unit of energy consumed, this leads to carbon emissions increasing by 82% from 15.8 $MtCO_{2e}$ in 2014 to a forecast level of 28.7 $MtCO_{2e}$ in 2030 (see Fig. 7).

Figure 4: Indexed total emissions, per unit of GDP, per capita, and per unit of energy, 2000-2030 (2014 = 100%).

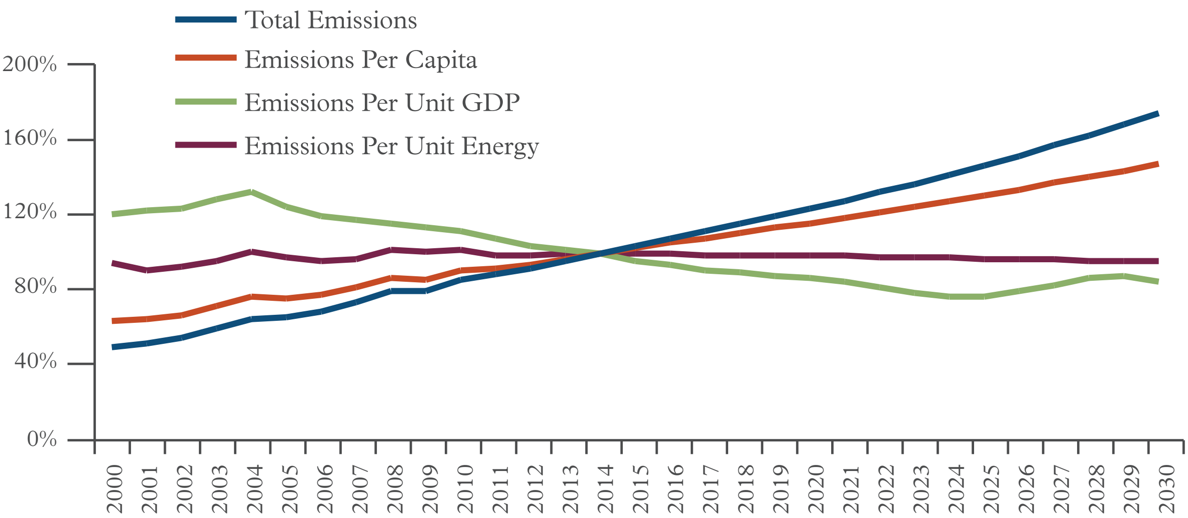


Figure 5: Energy use in Lima-Callao by energy source 2000-2030 (Millions of MWh).

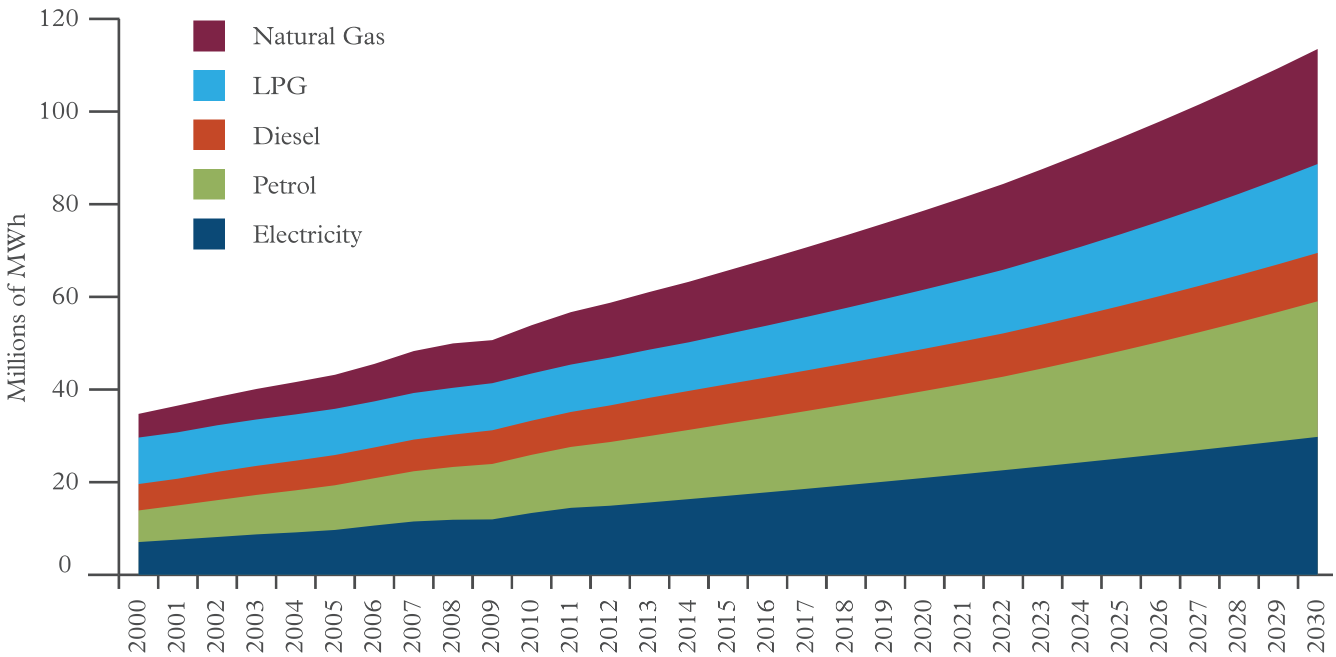


Figure 6: Energy Expenditure by sector in Lima-Callao, 2000-2030 (billions of US$).

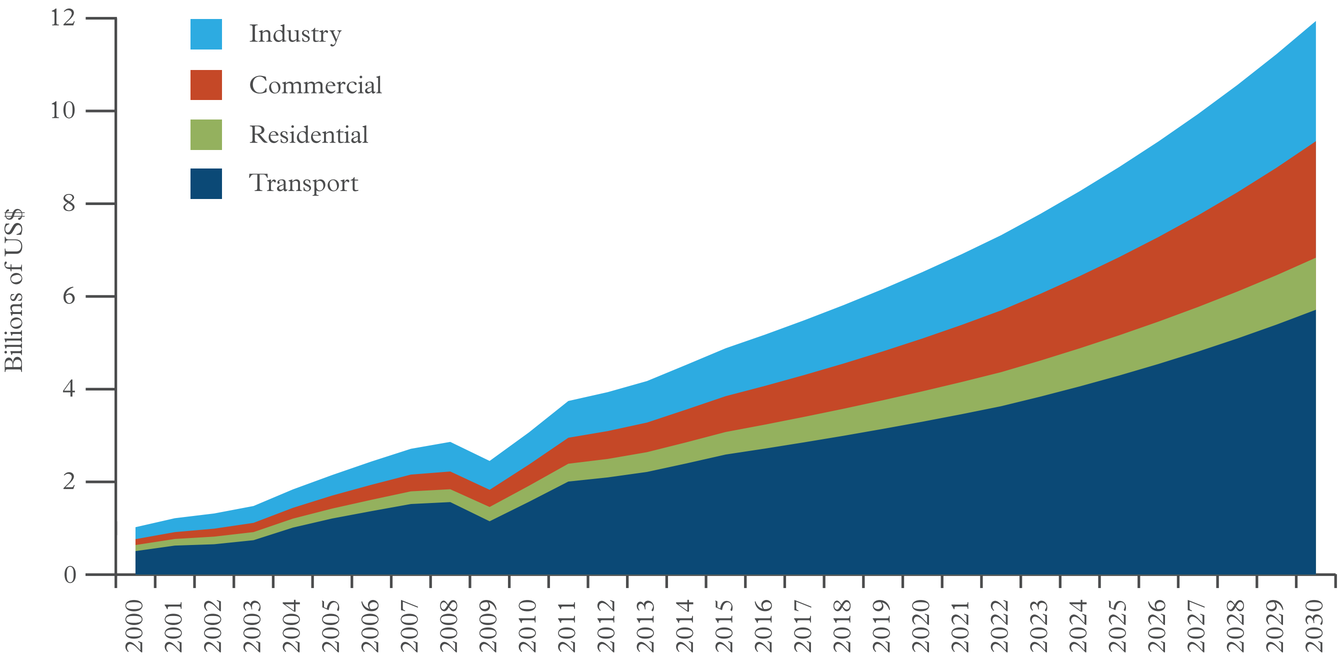
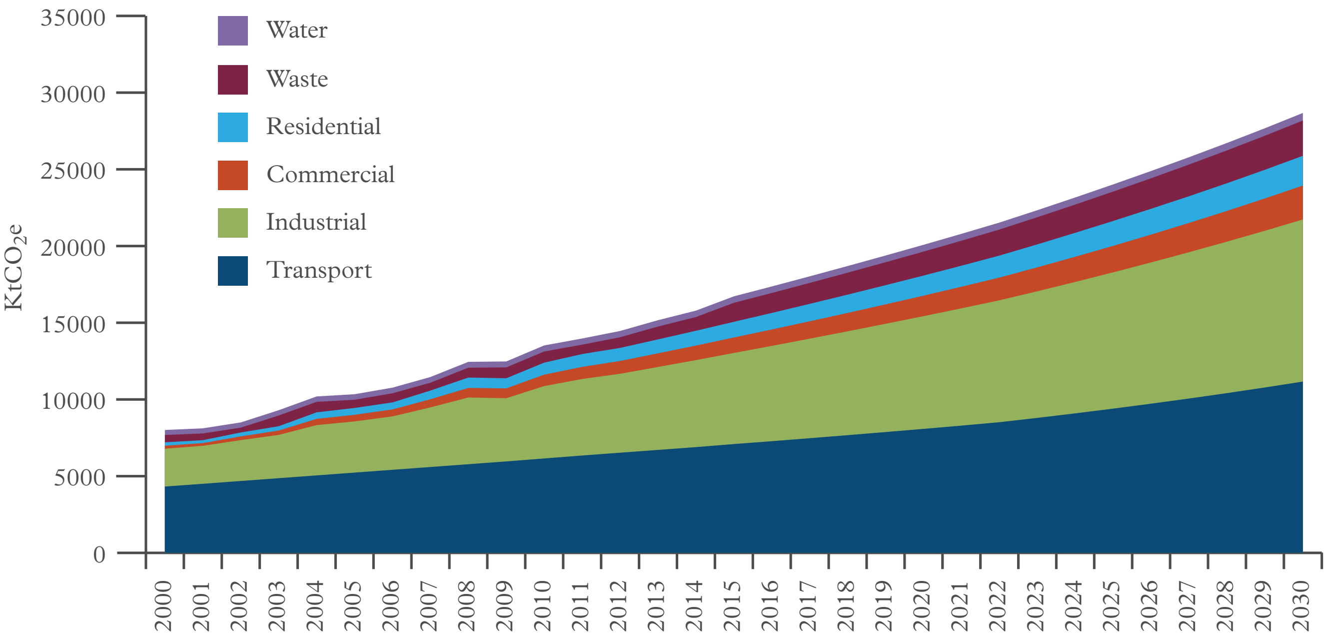


Figure 7: Emissions by end use in Lima-Callao, 2000-2030 ($KtCO_{2e}$).



The Potential for Energy Efficient, Low Carbon Development

We find that – compared to business as usual trends – Lima-Callao could reduce its carbon emissions by 2030 by:

- 19% through cost effective investments that would more than pay for themselves on commercial terms over their lifetime. This would require an investment of US$5.1 billion, which by 2030 would generate annual savings in energy bills of US$2.1 billion (at 2014 prices), meaning that investments in these cost effective measures would pay back in 2.4 years whilst generating annual savings the lifetime of the measures.
- 30% through cost neutral investments that would cover their costs over their lifetime. This would require an investment of US$12.2 billion, which by 2030 would generate annual savings in energy bills of US$2.7 billion (at 2014 prices), meaning that investments would pay back in 4.5 years whilst generating annual savings the lifetime of the measures.

The impacts of all of these levels of change are shown in Figure 8 below which shows that whilst the impacts of cost effective and cost neutral changes will reduce overall emissions relative to business as usual (and assuming Metro II and Euro IV standards will be implemented) trends, they do not stop overall emissions from rising in absolute terms. With exploitation of all cost effective, by 2030 emissions would be 38% above 2014 levels, and with all cost neutral measures exploited they would be 20% above 2014 levels. Investment in all cost effective measures will save US$2.1bn in energy costs per year, thereby reducing the 2030 energy bill from 7.9% to 6.4% of GDP, whilst investment in all cost neutral measures will save US$2.7bn in energy costs every year, thereby reducing the 2030 energy bill from 7.9% to 5.9% of GDP. In addition, the impact on energy expenditure is shown in Figure 9 below.

If the cost effective levels of investment were treated as public infrastructure investments, then using the economic multipliers suggested by Blanchard and Daniel would suggest that they would generate economic impacts equivalent to 8% of Lima-Callao's 2014 GDP. Individual sectors are discussed in more detail in the following chapter and summaries of the cost effective and carbon effective measures are given in Appendix C and D respectively. On the same basis, the cost neutral levels of investment would generate economic impacts equivalent to 16% of Lima-Callao's 2014 GDP. We note though that in practice these investments would be spread over the period to 2030 and that the economic impact would not be restricted to Lima-Callao.

Figure 8: Indexed emissions from Lima-Callao under three different scenarios, 2000-2030 (2014 = 100%).

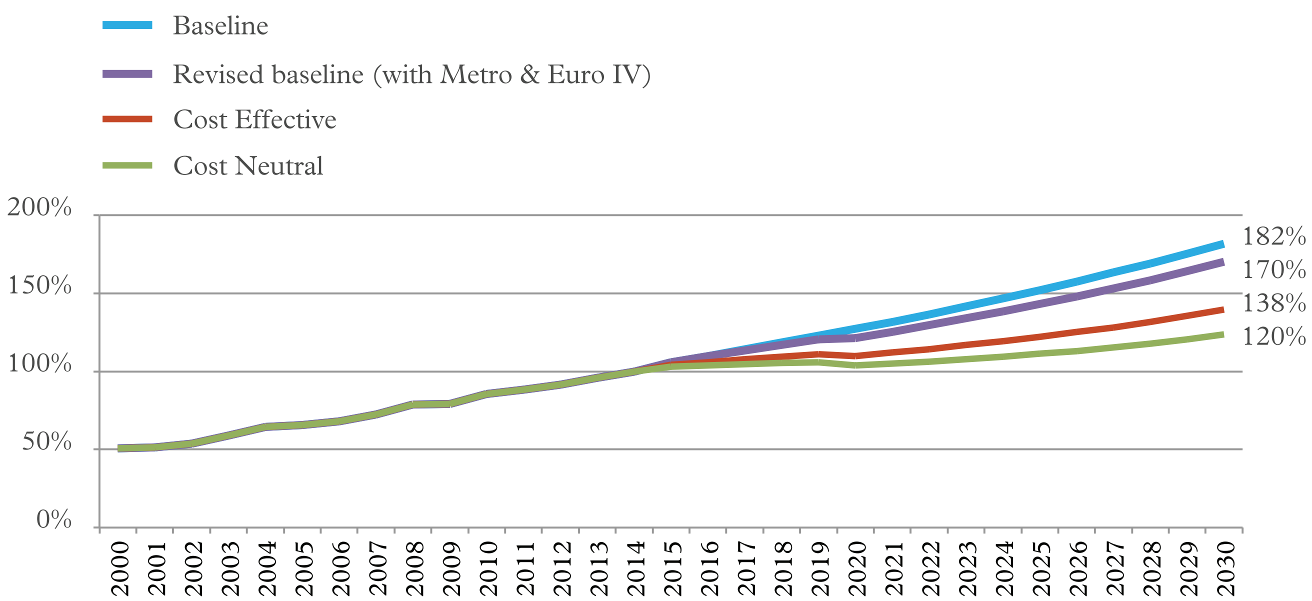
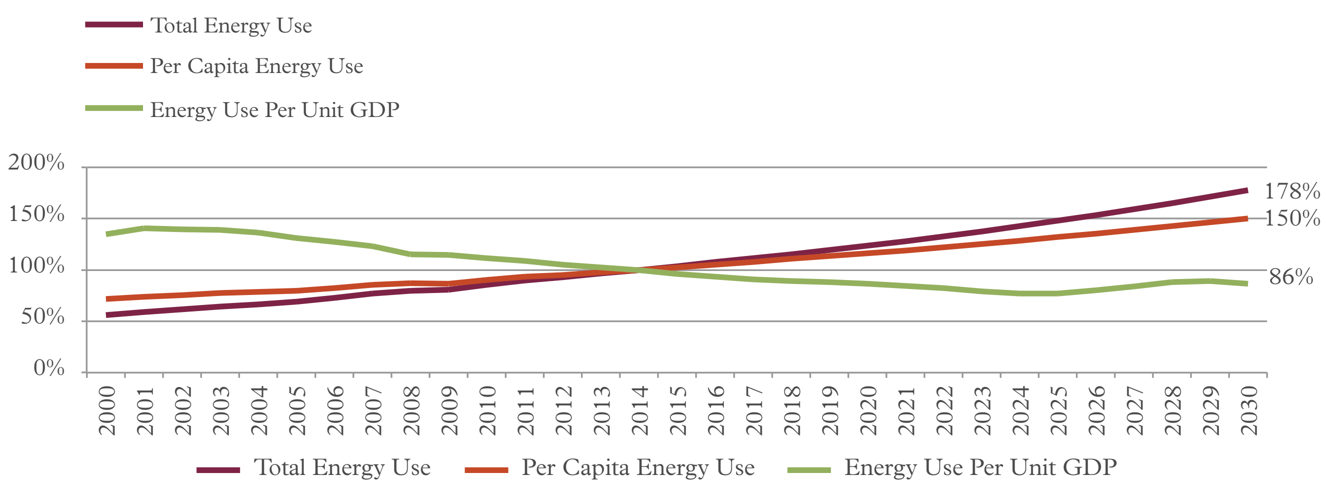


Figure 9: Indexed total energy use, per capita and per unit of GDP, 2000-2030 (2014 = 100%).



Chapter 3b – The Key Findings for Lima-Callao: Water and Climate Resilient Development

The Impacts of Business as Usual Trends and Climate Change on Water

On the demand side, water use in Lima-Callao increased by 21% in the period from 2000 to 2014. For the future, there are both optimistic and pessimistic forecasts for future water demand in Lima-Callao. Building on the LiWa project[32], we forecast that high levels of growth in demand will see water use grow by 21% between 2014 and 2030, but low levels of growth in demand will see water use will fall by 2% over the same period.

On the supply side, water supply to Lima-Callao comes almost exclusively from the Rimac, Chillon and Lurin rivers and the associated aquifers. Supply to these rivers has been supplemented by water which is transferred through a trans-Andean tunnels. An additional trans-Andean tunnels is planned for completion by 2040, and water could be diverted from neighbouring watersheds and catchments. Most options to increase water supply carry significant social, economic, political and ecological risks and therefore we look at alternative options to meet Lima-Callao's water demand.

Climate change poses major uncertainties and risks for water supply to Lima-Callao. While there is a great deal of variablility in estimates of changes in percipitation in the watersheds feeding Lima-Callao, the majority of estimates suggest somewhere between a 6% increase and a 14% decrease over the period until 2050. If we assume that these impacts will be felt steadily over the period to 2030, then we forecast that total supply could increase by 3% or fall by 7% from 2014 levels.

Given these uncertainties in both water supply and demand and the critical role that water plays in Lima-Callao's future, it seems prudent to hope for the best but to plan for the worst. We predict that the best scenario (i.e. a 2% fall in water demand coupled with a 3% increase in rainfall for the rivers that feed Lima-Callao due to climate change) would see a 13% surplus of supply over demand by 2030. We also predict that the worst scenario (i.e. a 21% growth in water demand[33] coupled with an 7% drop in rainfall for the rivers that feed Lima-Callao due to climate change) would see a 29% deficit in meeting the demand in 2030.

For more details see http://www.lima-water.de/index.html

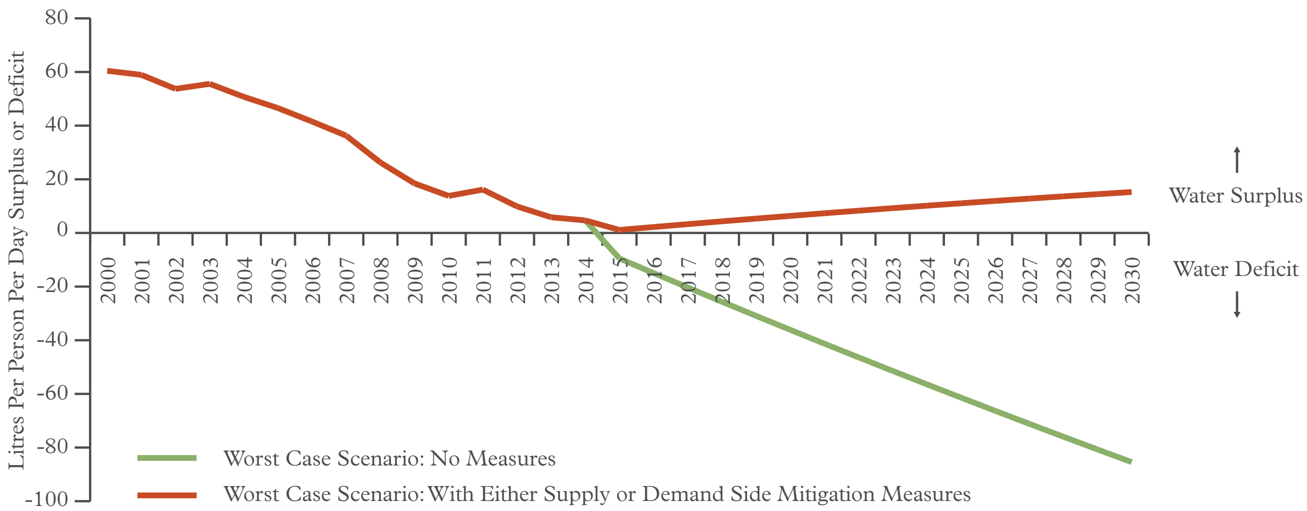
The Potential for Climate Resilience through Water Efficiency

To consider the possible responses, we assess the potential of both supply and demand side measures to address the 29% water deficit that could occur under the worst case scenario.

- **The supply-side strategy.** If investments are made in the lowest cost options, then we predict that the potential water deficit could be avoided through US$856 million of investment in supply side measures. This investment, which would increase costs but would generate no net savings, would have a payback period of 10.8 years. It could be financed entirely through a 18% increase in water tariffs for domestic, commercial and industrial water users.
- **The demand-side strategy.** If we prioritise demand side measures, to reduce the wider impacts of increasing supply, then we predict that the potential water deficit could be avoided through US$2.0 billion of investment, 95% of which would be spent on reducing water demand, and 5% of which would be spent on increasing water supply. This investment, which would increase costs but would also generate savings through reduced water bills, would have a payback period of 7.4 years. It could be financed through a 15% increase in water tariffs for domestic, commercial and industrial water users and through the savings that the measures would generate.

The impact of supply and demand side investments on worst case (high demand, low supply) scenario is shown in Figure 10.

Figure 10: Impacts of supply and demand side investments on the worst case (high demand, low supply) scenario.



In the longer term, if the impacts of climate change on water supply to Lima-Callao grow, then it is likely that both the supply and demand side strategies will need to be adopted.

Sector Focus

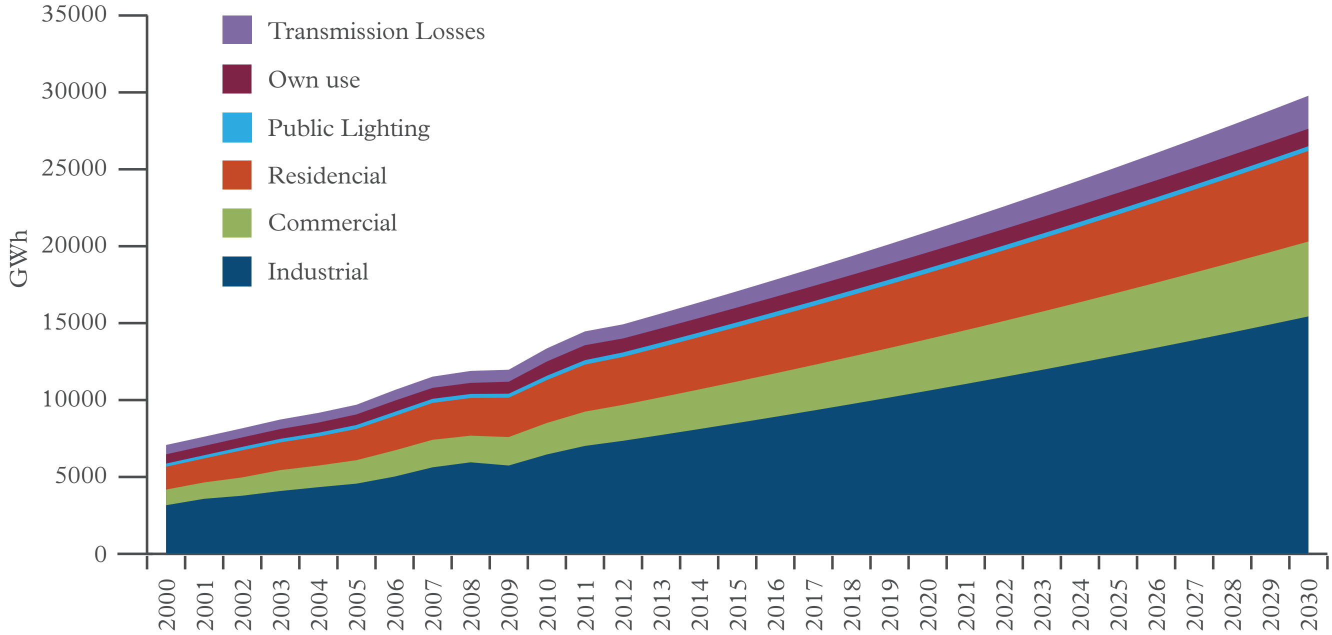
The Electricity Sector

The Changing Context and the Impacts of Business as Usual Trends

In 2014, the national grid electricity mix is 1% diesel, 44% natural gas, 2% coal, 1% bagasse and 52% hydro. In 2030, we are projecting a 91% increase in electricity production to the grid. We also predict that the energy mix used to generate this electricity will be[34] <1% diesel, 55% natural gas, coal 2%, bagasse 4%, hydro 39%, therefore increased amounts of all of these electricity sources are assumed as part of our baseline projections. Furthermore, in making an assessment of mitigation options we have assumed that the grid supplying Lima-Callao is upgraded to enable renewable energy to be used within Lima-Callao[35].

Electricity consumption per capita in the Lima-Callao area is estimated to be 7.0TWh in 2000, rising to 16.3TWh in 2014 and reaching 29.8TWh by 2030. Current data (2014) shows consumption to be split, 49% industrial, 16% commercial, 21% residential and the remainder public lighting (2%), transmission losses (6%) and industry own use (7%). Industrial consumption is projected to show the largest gains, to 15.1TWh by 2030 from 7.3TWh in 2014, reflecting the significant industrial growth expected in the city, however commercial and residential sectors are also projected to increase significantly. When combined with rising levels of carbon emissions per unit of energy consumed, carbon emissions from the electricity sector are projected to increase from 3972 kt CO_{2e} in 2014 to 8216 kt CO_{2e} in 2030, an increase of 107% of 2014 emissions under a business as usual scenario.

Figure 11: Electricity usage in Lima-Callao by sector, 2000-2030 (GWh).



We find that – compared to 2014 – these business as usual trends in carbon emissions from the electricity sector could be reduced by:

- 2% with cost effective measures: This would require net investment of US$261 million, generate US$74 million in annual savings, generating a payback period of 3.5 years but providing savings for the lifetime of the measures.
- 12% with cost neutral measures. This would require investment of US$1.2 billion, generate US$106 million in annual savings, generating a payback period of 11.2 years but providing savings for the lifetime of the measures.
- 53% including all technically possible mitigation measures. This would require investment of US$9.1 billion, generating US$307 million in annual savings, paying back the original investment in 29.5 years but providing savings for the lifetime of the measures.

The impact of these measures on projected emissions is shown in Figure 12 below with cost effective measures giving a 104% increase in emissions, cost neutral giving an 81% increase and technical potential having an overall 3% reduction compared to 2014 levels.

Figure 12: Indexed emissions from the electricity sector, 2000-2030 (2014 = 100%).

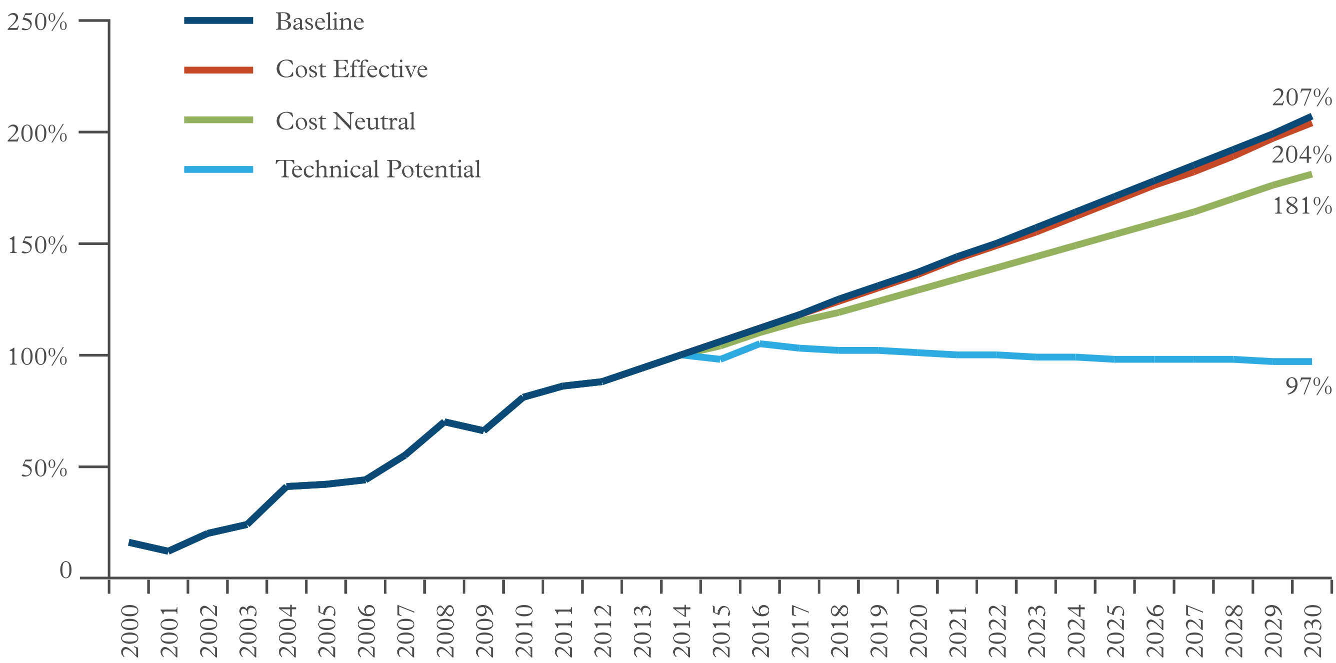
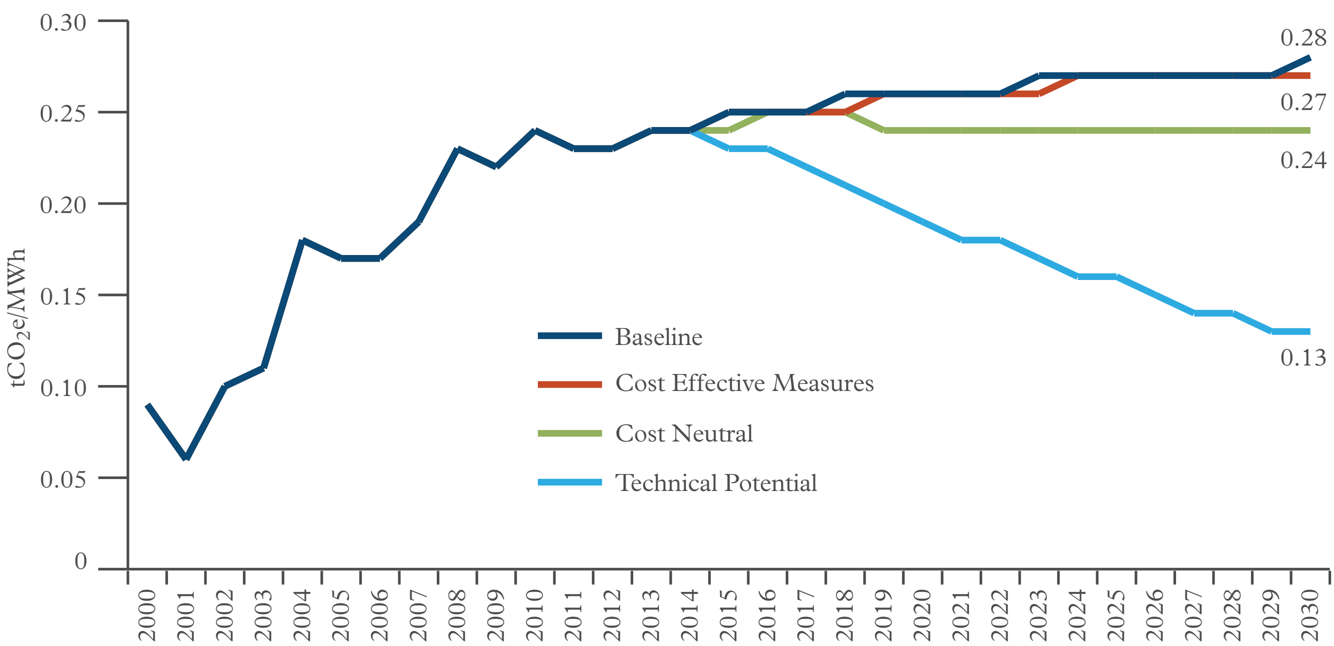


Figure 13: Carbon intensity of electricity from the SEIN grid, 2000-2030 (tCO_{2e} per MWh).



Cost effective

Cost neutral

All others including ("cost ineffective" and those mutually exclusive with other measures)

Table 2: Electricity sector mitigation options ranked by cost effectiveness (2014 US$ & Sol per tCO_{2e}).

Rank	Description	Cost Effectiveness	
		2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}
1	Diesel replaced by solar PV (~160 MW by 2030)	-64	-179
2	Diesel replaced by wind by 2030 (~130MW by 2030)	-48	-136
3	Coal replaced with solar PV (200MW by 2030)	11	31
4	Coal replaced with wind (200MW by 2030)	7	20
5	Natural gas BAT (~3,500MW by 2030)	7	20
6	Natural gas retrofit (1,000MW by 2030)	15	42
7	Geothermal 2,000MW (replacing natural gas)	17	48
8	Coal retrofit (~80MW by 2030)	14	40
9	Geothermal 1,000MW (replacing natural gas)	16	45
10	Gas generation replaced by solar PV (200MW by 2030)	43	120
11	Gas generation replaced by wind (200MW by 2030)	36	100
12	Coal BAT (~130MW by 2030)	99	278

Cost effective

Cost neutral

All others including ("cost ineffective" and those mutually exclusive with other measures)

Table 3: Electricity sector mitigation options ranked by carbon effectiveness (ktCO_2 2015-2025).

Rank	Description	Carbon Effectiveness ktCO_2 2015-2025
1	Geothermal 2,000MW (replacing natural gas)	16,818.7
2	Geothermal 1,000MW (replacing natural gas)	8,409.3
3	Coal replaced with wind (200MW by 2030)	4,507.2
4	Natural gas BAT (~3,500MW by 2030)	3,773.7
5	Coal replaced with Solar PV (200MW by 2030)	3,004.8
6	Gas Generation replaced by wind (200MW by 2030)	1,344.6
7	Gas Generation Replaced by Solar PV (200MW by 2030)	1,344.6
8	Diesel replaced by wind by 2030 (~130MW by 2030)	916.2
9	Diesel replaced by Solar PV (~160 MW by 2030)	916.2
10	Natural Gas Retrofit (1,000MW by 2030)	509.9
11	Coal Retrofit (~80MW by 2030)	355.4
12	Coal BAT (~130MW by 2030)	116.4

Sector Focus

The Domestic Sector

The Changing Context and the Impacts of Business as Usual Trends

For the domestic sector, background trends suggest substantial growth both in the number of households and in the average levels of energy consumption per household. These combined trends lead domestic sector energy consumption to rise by 83% from 4,035 GWh in 2014 to a forecast level of 7,349 GWh in 2030 (see Fig. 13). When combined with changing real energy prices, this leads to the total spend from the domestic sector on energy to increase by 147% from US$458 million in 2014 to a forecast level of US$1.1 billion in 2030 (see Fig. 14). When combined with relatively stable levels of carbon emissions per unit of energy consumed, this leads to carbon emissions attributed to domestic consumption increasing by 101% from 0.96MtCO_{2e} in 2014 to a forecast level of 1.9 MtCO_{2e} in 2030 (see Fig. 15).

The Potential for Carbon Reduction – Investments and Returns

We find that for the domestic sector business as usual trends in carbon emissions can be reduced by:

- 60% with cost effective measures that would pay for themselves on commercial terms over their lifetimes. This would require investment of US$1.5 billion, generate annual savings of US$490 million and payback the original investment in 2.9 years but provide savings for the lifetime of the measures.
- 77% with cost neutral measures that would require investment of US$3.9 billion, generate annual savings of US$720 million and payback the original investment in 5.4 years but provide savings for the lifetime of the measures.

Figure 14: Indexed domestic sector energy use, energy bills, and emissions, 2000-2030 (2014 = 100%).

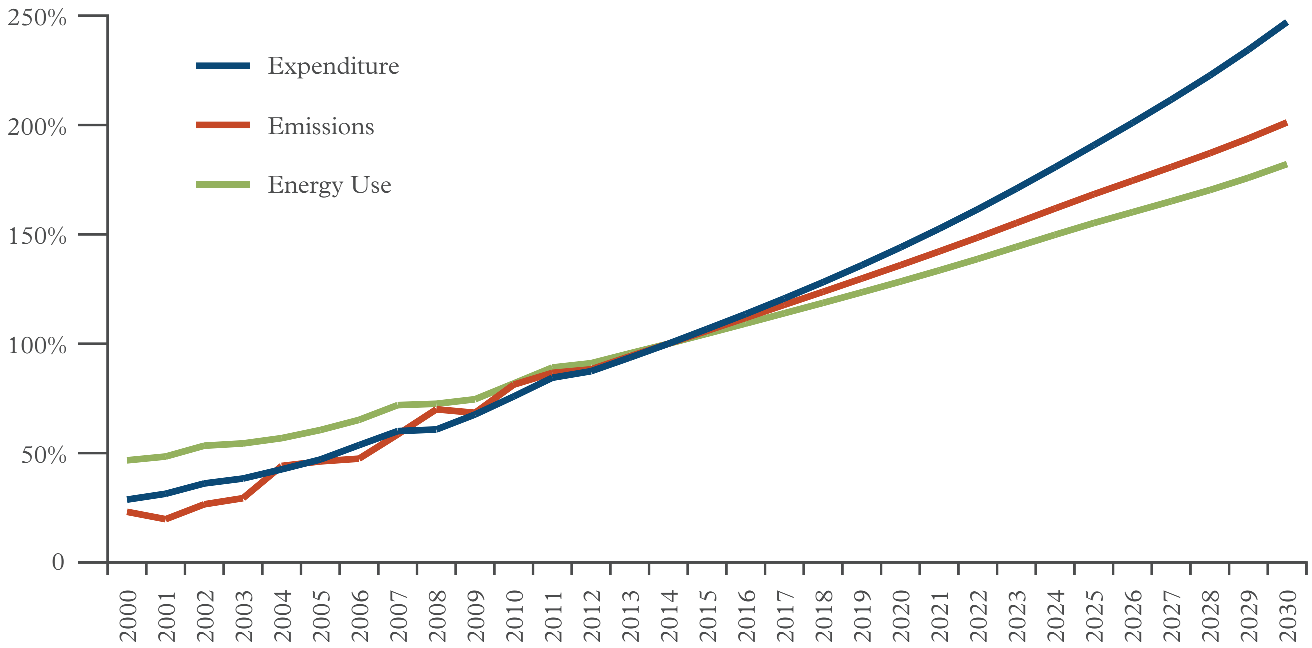
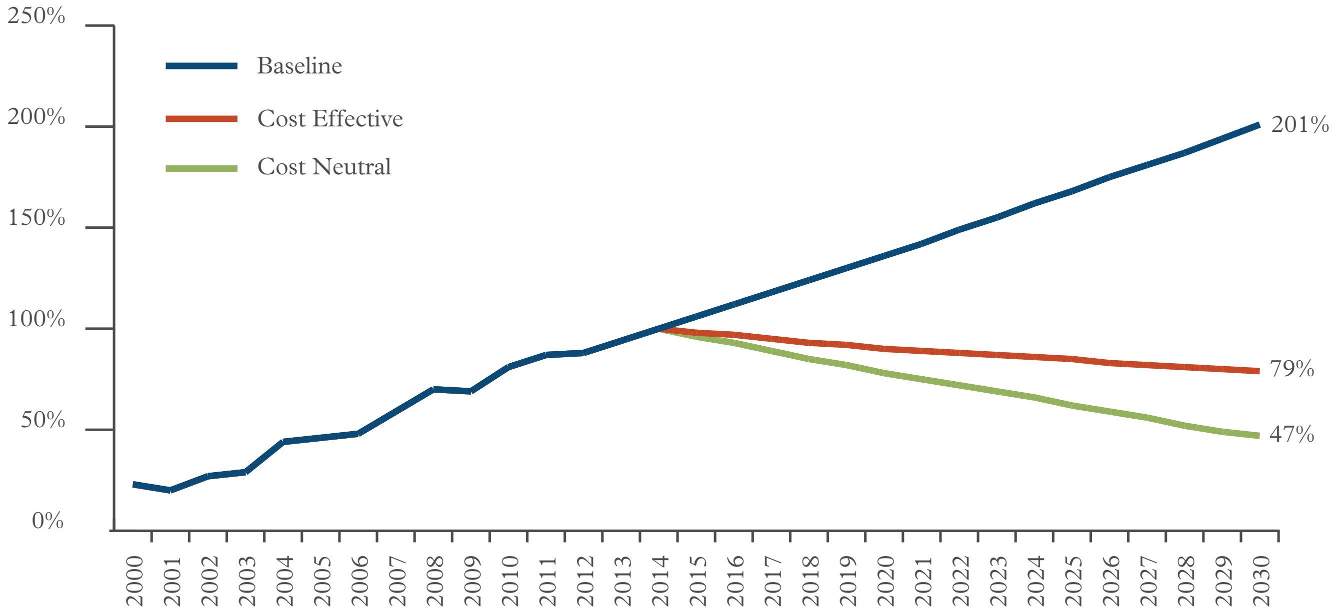


Figure 15: Indexed emissions from the domestic sector in two different scenarios, 2014-2030 (2014 = 100%).



Cost effective

Cost neutral

All others including ("cost ineffective" and those mutually exclusive with other measures)

Table 4: Mitigation measures for the domestic sector ranked by cost effectiveness (2014 US$ & Sol per tCO_{2e}).

Rank	Description	Cost Effectiveness	
		2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}
1	Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections)	-3,301	-9,242
2	High efficiency (EE1) water Heaters	-437	-1225
3	Incandescent lighting phase out	-378	-1059
4	Electricity conservation education	-310	-867
5	Installing Advanced Metering Infrastructure - Domestic (75% deployment)	-282	-791
6	Incandescent lighting phase out and 50% LED by 2020	-237	-664
7	High efficiency (EE2) water heaters	-230	-644
8	Solar hot water 5% by 2030 (BAU)	-221	-618
9	Solar hot water 10% by 2030 (BAU)	-221	-618
10	Solar hot water 5% by 2030 (EE1)	-203	-569
11	Solar hot water 10% by 2030 (EE1)	-203	-569
12	Solar hot water 5% by 2030 (EE2)	-189	-530
13	Solar hot water 10% by 2030 (EE2)	-189	-530
14	High efficiency (EE1) refrigerator	-163	-456
15	Green buildings standards (20% of buildings built 2015-2030)	-110	-308
16	Solar photovoltaics: Target of 10MW per year (BAU)	5	14
17	High efficiency (EE1) kitchen appliances (excluding refrigerators)	11	30
18	Solar photovoltaics: Target of 20MW per year (BAU)	20	57
19	High efficiency (EE1) air conditioning	35	99
20	High efficiency (EE2) kitchen appliances (excluding refrigerators)	105	294
21	High efficiency (EE1) entertainment appliances	289	810
22	High efficiency (EE2) refrigerators	321	898
23	High efficiency (EE2) air conditioners	692	1,938
24	High efficiency (EE2) entertainment appliances	1,283	3,593
25	High efficiency (EE1) washing machines	4,507	12,621
26	Green roofs on residential apartment buildings (10% of new builds)	6,460	18,088
27	High efficiency (EE2) washing machines	8,097	22,670
28	Green roofs on semi-detached residential buildings (10% of new builds)	14,462	40,494

Negative figures represent a saving per unit of emissions saved, whereas positive figures represent a cost per unit of emissions saved.

Cost effective

Cost neutral

All others including ("cost ineffective" and those mutually exclusive with other measures)

Table 5: Mitigation measures for the domestic sector ranked by carbon effectiveness ($ktCO_2$ 2015-2030).

Rank	Description	Carbon Effectiveness $ktCO_2$ 2015-2030
1	Incandescent lighting phase out and 50% LED by 2020	4,268
2	Incandescent lighting phase out	2,409
3	High efficiency (EE1) kitchen appliances (excluding refrigerators)	1,180
4	High efficiency (EE1) refrigerators	1,142
5	High efficiency (EE2) kitchen appliances (excluding refrigerators)	992
6	High efficiency (EE2) refrigerators	960
7	Solar photovoltaics: Target of 20MW per year (BAU)	856
8	Solar hot water 10% by 2030 (BAU)	593
9	High efficiency (EE1) air conditioners	575
10	High efficiency (EE2) air conditioners	484
11	Solar hot water 10% by 2030 (EE1)	469
12	Installing Advanced Metering Infrastructure – Domestic (75% deployment)	439
13	Solar hot water 10% by 2030 (EE2)	404
14	Solar photovoltaics: Target of 10MW per year (BAU)	341
15	High efficiency (EE1) entertainment appliances	326
16	Solar hot water 5% by 2030 (BAU)	296
17	High efficiency (EE2) entertainment appliances	274
18	Solar hot water 5% by 2030 (EE1)	235
19	Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections)	205
20	Solar hot water 5% by 2030 (EE2)	202
21	High efficiency (EE1) water heaters	181
22	Green buildings standards (20% of buildings built 2015-2030)	160
23	High efficiency (EE2) water heaters	152
24	High efficiency (EE1) washing machines	61
25	High efficiency (EE2) washing machines	52
26	Electricity conservation education	49
27	Green roofs on semi-detached residential buildings (10% of new builds)	10
28	Green roofs on residential apartment buildings (10% of new builds)	3

Sector Focus

The Commercial Sector

The Changing Context and the Impacts of Business as Usual Trends

The commercial sector includes commercial and public sector energy use (by natural gas, petrol, diesel, LPG and electricity use) and therefore includes public sector and commercial sector buildings as well as public sector operations such as street lighting.

In the commercial sector, background trends suggest substantial growth both in commercial floor space and in the average levels of energy consumption in each commercial building. These combined trends lead commercial sector energy consumption to rise by 147% from 5,512 GWh in 2014 to a forecast level of 13,590 GWh in 2030 (see Fig. 16). This leads to the total expenditure on energy by the commercial sector to increase by 258% from US$732 million in 2014 to a forecast level of US$2.6 billion in 2030 (see Fig. 17). When combined with relatively stable levels of carbon emissions per unit of energy consumed, this leads to carbon emissions attributed to commercial consumption increasing by 133% from 0.95 $MtCO_{2e}$ in 2014 to a forecast level of 2.2 $MtCO_{2e}$ in 2030 (see Fig. 18).

The Potential for Carbon Reduction – Investments and Returns

We find that for the commercial sector, compared to the business as usual trends in carbon emissions, they could be reduced by:

— 26% through cost effective measures that would more than pay for themselves on commercial terms over their lifetime. This would require capital investment of US$564 million, generate US$338 million in annual savings and payback the original investment in 1.7 years but provide savings for the lifetime of the measures.

— 30% through cost neutral measures that would more than pay for themselves on commercial terms over their lifetime. This would require capital investment of US$699 million, generate US$375 million in annual savings and payback the original investment in 1.9 years but provide savings for the lifetime of the measures.

Figure 16: Indexed commercial sector energy use, energy bills, and emissions, 2000-2030 (2014 = 100%).

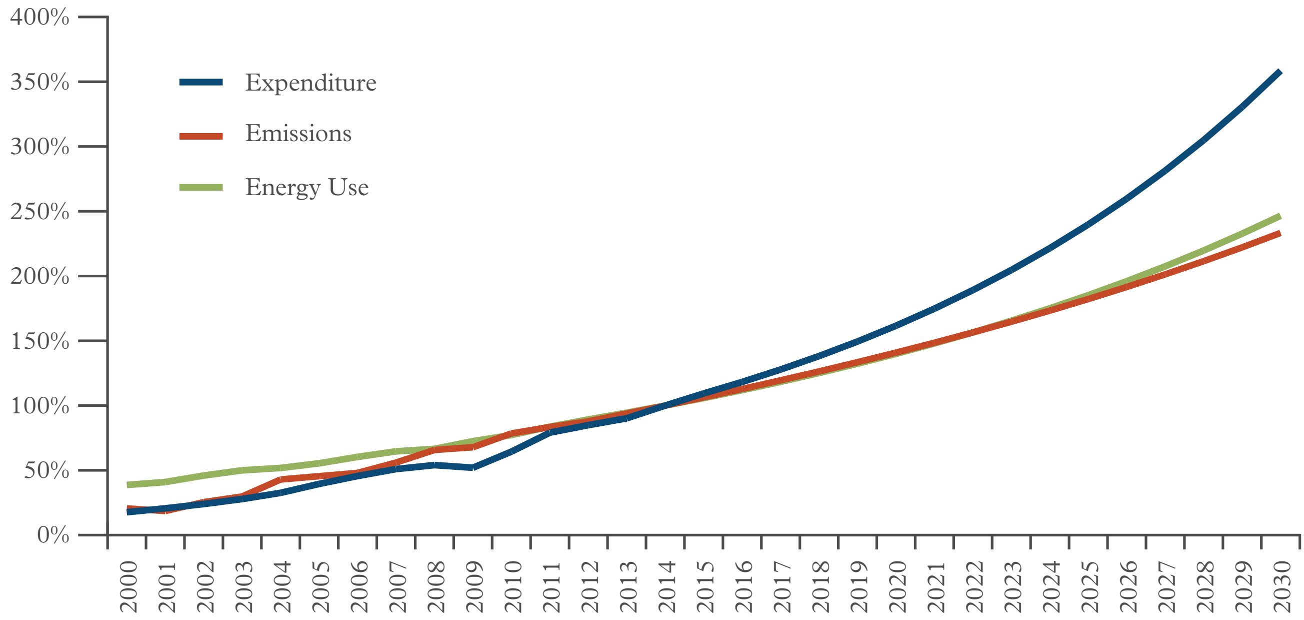


Figure 17: Indexed emissions from the commercial sector in two different scenarios, 2014-2030 (2014 = 100%).

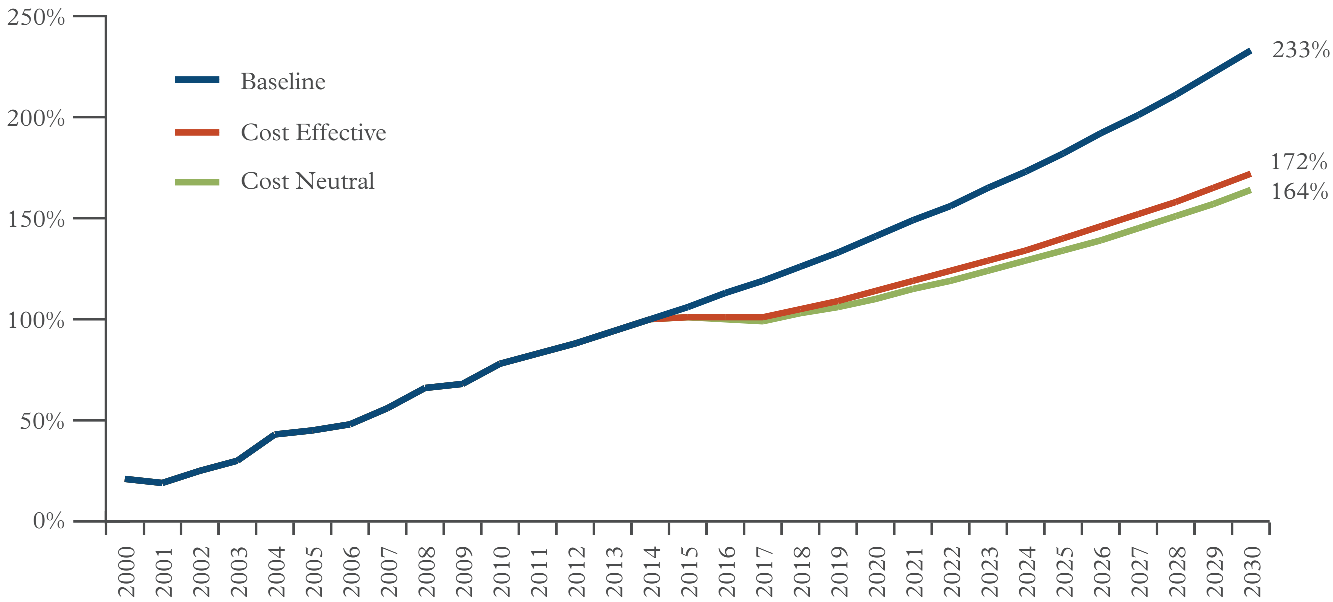
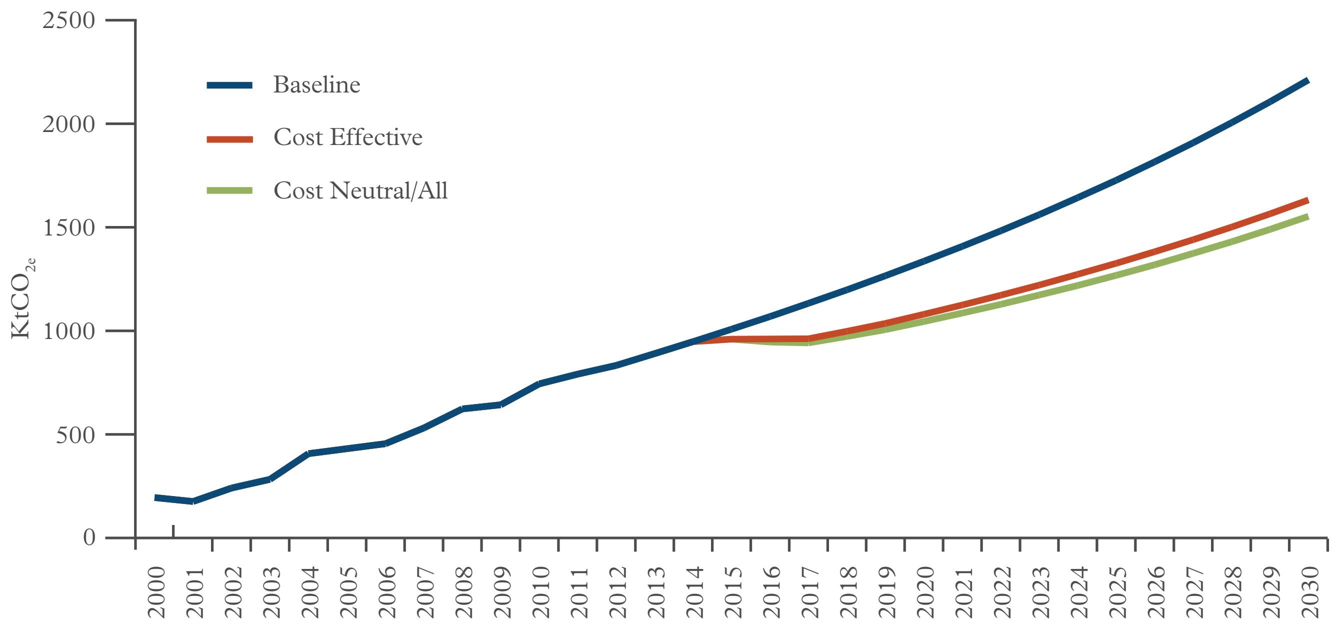


Figure 18: Projected emissions under two scenarios, 2000-2030 ($KtCO_{2e}$).



Cost effective

Cost neutral

Table 6: Mitigation measures for the commercial sector ranked by cost effectiveness (2014 US$ & Sol per tCO_{2e}).

Rank	Description	Cost Effectiveness	
		2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}
1	Green building standards – Commercial buildings	-1,104	-3,090
2	Public sector electricity retrofit program	-862	-2,413
3	Commercial sector electricity retrofit program	-555	-1,555
4	Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings	-484	-1,355
5	Street lighting conversion to LEDs	-361	-1,012
6	Malls sector electricity retrofit program	-204	-571
7	Traffic Lights conversion to Led	-174	-488
8	Hospital electricity retrofit program	-155	-435
9	Solar PV for commercial sector (with FIT)	-145	-405
10	Solar hot water for commercial sector	-35	-99
11	AMI meters - commercial (75% deployment)	12	33

Cost effective

Cost neutral

Table 7: Mitigation measures for the commercial sector ranked by carbon effectiveness ($ktCO_2$ 2015-2025).

Rank	Description	Carbon Effectiveness
		$ktCO_2$ 2015-2025
1	Solar hot water for commercial sector	2,008
2	Thermal (natural gas, LPG, diesel, petrol) retrofit	951
3	Green building standards – commercial buildings	451
4	AMI meters – commercial (75% deployment)	388
5	Commercial sector electricity retrofit program	352
6	Malls sector electricity retrofit program	352
7	Street lighting conversion to LEDs	294
8	Public sector electricity retrofit program	90
9	Solar PV for commercial sector (with FIT)	57
10	Hospital electricity retrofit program	56
11	Traffic lights conversion to LEDs	35

Sector Focus

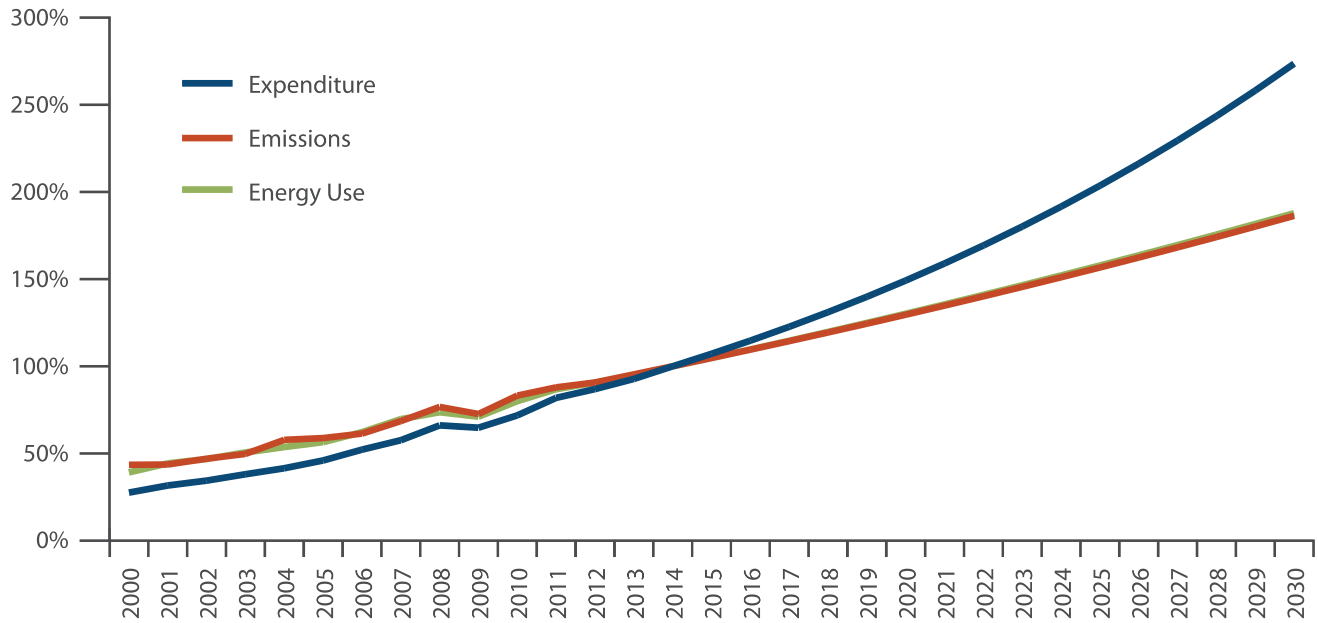
The Industrial Sector

The Changing Context and the Impacts
Business as Usual Trends

For the industrial sector we have looked at industrial sub-sectors with the potential for carbon mitigation based mainly on the Intergovernmental Panel on Climate Change's 2008 report[36]. The report suggests a large number of mitigation options which are relevant to the individual sectors, but we do not look at specific measures for each sub-sector in this report, due to the lack of information we were able to gather for Lima-Callao.

For the industrial sector, background trends show that industrial energy use is predicted to increase from 23,800GWh in 2014 to 44,647GWh by 2030, an increase of 87%. This leads to the total spend from the industrial sector on energy to increase by 174% from US$1.1 billion in 2014 to a forecast level of US$2.9 billion in 2030 (see Fig. 19). This leads to carbon emissions attributed to industrial consumption increasing by 86% from 5.67 $MtCO_{2e}$ to 10.6$MtCO_{2e}$ (see Fig. 20).

Figure 19: Indexed industry sector energy use, energy bills, and emissions, 2000-2030 (2014 = 100%).



The Potential for Carbon Reduction – Investments and Returns

We find that for the industrial sector, compared to the business as usual trends in carbon emissions, emissions could be reduced by:

— 13% with cost effective measures. This would require investment of US$261 million which would produce savings of US$115 million, paying back the original investment in 2.3 years but generating savings for the lifetime of the measures.

Figure 20: Indexed emissions from the industry sector in baseline and cost-effective scenarios, 2014-2030 (2014 = 100%).

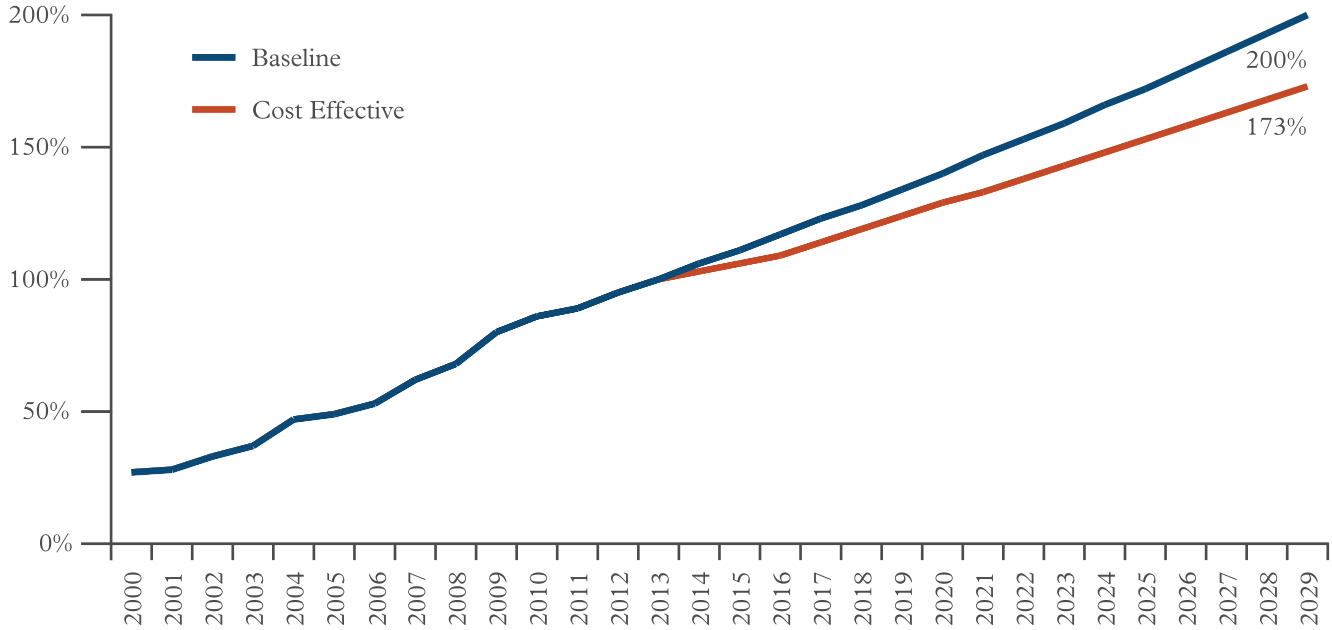


Table 8: Mitigation measures for the industry sector ranked by cost effectiveness (2014 US$ & Sol per tCO_{2e}).

Rank	Description	Cost Effectiveness	
		2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}
1	Installing AMI – Industrial (75% deployment)	-186	-521
2	Petroleum refining sector carbon reduction programme	-179	-502
3	Electricity conservation In other industrial sectors	-133	-372
4	Ethylene sector carbon reduction programme	-129	-361
5	Switch boilers to natural gas	-143	-402
6	Steel sector carbon reduction programme	-50	-139
7	Cement sector carbon reduction programme	-45	-126

Negative figures represent a saving per unit of emissions saved, whereas positive figures represent a cost per unit of emissions saved.

Table 9: Mitigation measures for the industry sector ranked by carbon effectiveness ($ktCO_2$ 2015-2030).

Rank	Description	Carbon Effectiveness
		$ktCO_2$ 2015-2030
1	Electricity conservation In other industrial sectors	3,393
2	Switch boilers to natural gas	3,063
3	Installing AMI Meters – Industrial (75% deployment)	1,121
4	Ethylene sector carbon reduction programme	1,232
5	Cement sector carbon reduction programme	924
6	Petroleum refining sector carbon reduction programme	421
7	Metals sector carbon reduction programme	275

Sector Focus

The Transport Sector

The Changing Context and the Impacts of 'Business as Usual' Trends

Lima-Callao has seen tremendous growth in transportation demand since 2000, with vehicle numbers increasing by on average 4.6% per year. Looking forward to 2030, continued growth at these rates will lead to dramatic increases in emissions, fuel expenditure and travel times as Lima-Callao's vehicle infrastructure becomes gridlocked. To avoid this scenario, a number of options for transit infrastructure investment are available. There are a very large number of possible mitigation measures within the transport sector, a large proportion of which overlap with each other and are difficult to evaluate individually. Therefore, we have considered a number of measures that cover both the public and private sector, many of which are already under consideration within Lima-Callao and therefore have data available on their likely impact. Many of these are in line with the Lima-Callao 2025 roadmap[37] which has the objectives of reducing travel lengths, switching to (or retaining) the use of low carbon modes of transport and decarbonising the energy used for transportation in Lima-Callao. Furthermore, in Appendix E we explore the effectiveness of an Eco-Zone within Lima-Callao.

In the transport sector, background trends suggest that energy consumption will rise by 64%, from 29,400 GWh per year in 2014 to 47,700 GWh per year in 2030 (see Fig. 22). When combined with increasing real energy prices (2% per year), this leads to total spending on energy increasing by 137%, from US$2.4 billion in 2014 to US$5.7 billion in 2030. Concurrently, CO_{2e} emissions are anticipated to rise 61%, from 6,893 Kt in 2014 to 11,165 Kt in 2030.

Figure 21: Total expenditure on fuel in the transport sector, 2000-2030 (billions of US$).

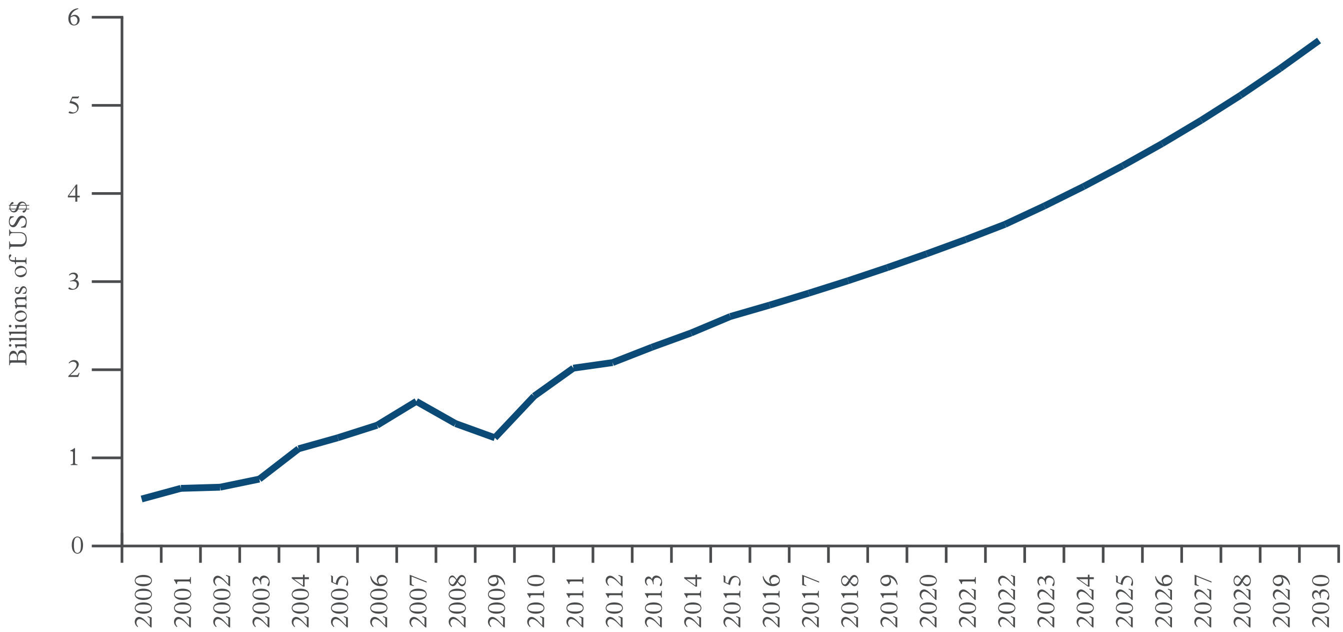


Figure 22: Total energy use in the transportation sector, 2000-2030 (in millions of MWh).

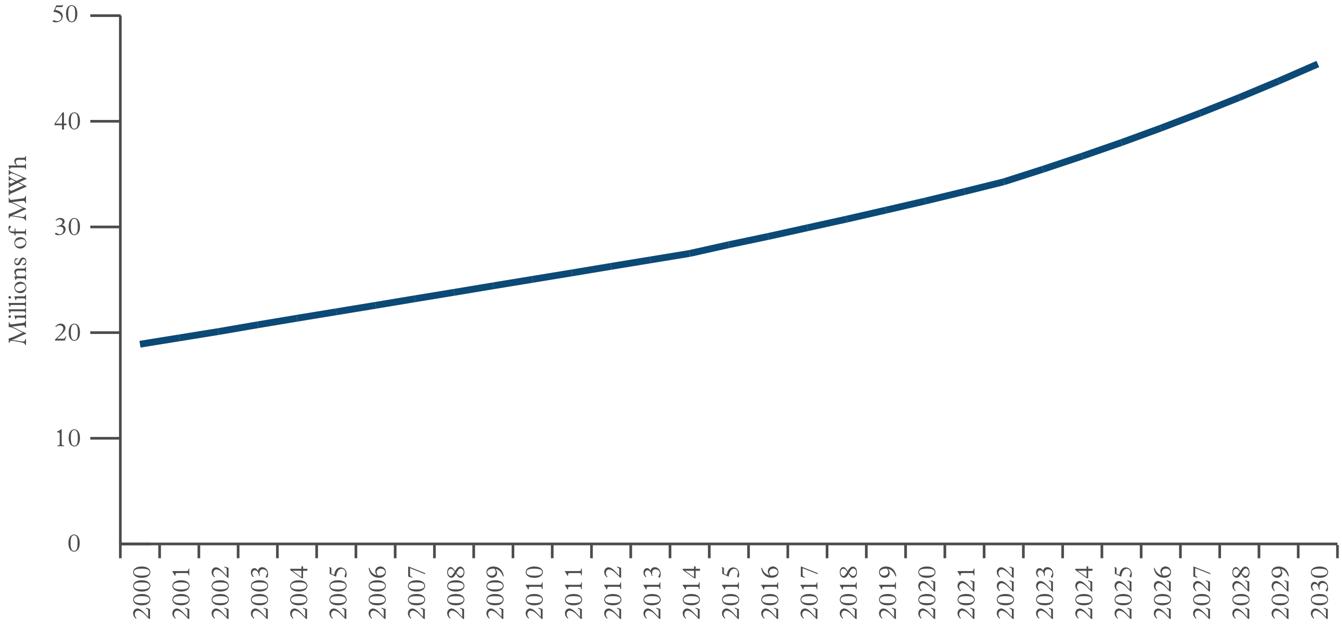
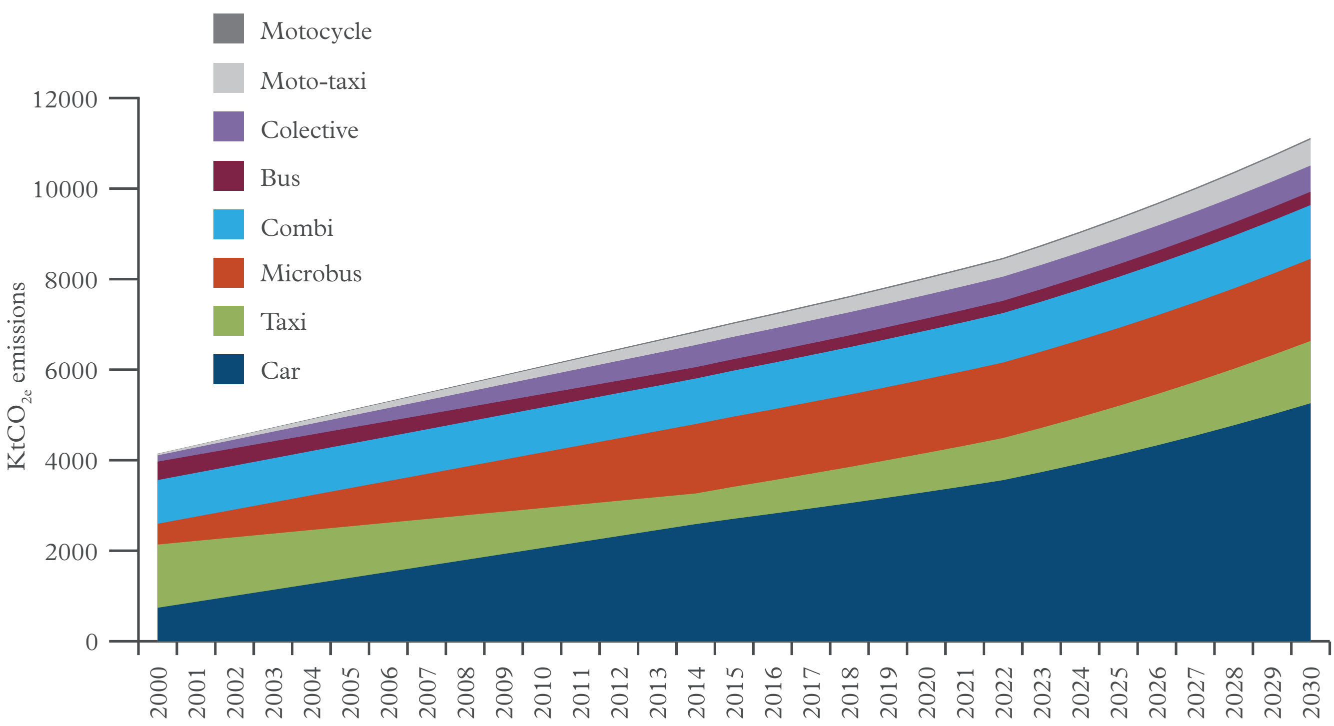


Figure 23: Emissions from the transportation sector by transport mode, 2000-2030 ($KtCO_{2e}$).



The Potential for Carbon Reduction – Investments and Returns

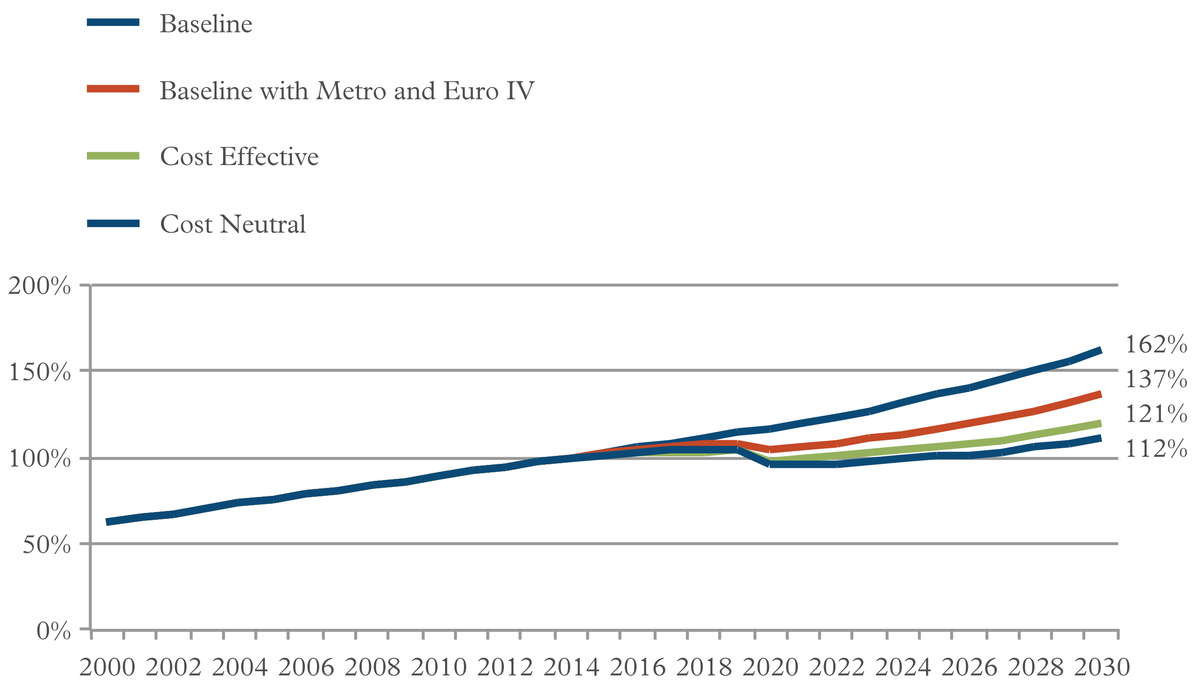
We find that for the transport sector, compared to the business as usual trends, carbon emissions could be reduced by:

— 15% with the implementation of anticipated, but as yet not complete, transportation measures. These include Lima-Callao's Metro Line II (Ate-Callao) and Euro IV fuel efficiency standards[38].

— 26% through cost effective investments that would more than pay for themselves over their lifetime. This would require investment of US$1.1 billion, generating annual energy savings of US$832 million, paying back the investment in 2.6 years but generating annual savings for the lifetime of the measures.

— 31% with the exploitation of all of the realistic potential of the different measures with carbon saving potential. This would require an investment of US$4.9 billion, generating annual savings of US$1.3 billion, paying back the investment in 3.6 years, but generating annual savings for the lifetime of the measures.

Figure 24: Emissions from the transportation sector under three different scenarios, 2000-2030 (2014 = 100%).



Cost effective

Cost neutral

All others including ("cost ineffective" and those mutually exclusive with other measures)

Table 10: Mitigation measures for the transportation sector ranked by cost effectiveness (2014 US$ & Sol per tCO_{2e}).

Rank	Description	Cost Effectiveness	
		2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}
1	Teleworking campaign	-2,380	-6,665
2	Petrol taxis CNG retrofit	-1,837	-5,144
3	Scrapping cars >20 years old for petrol cars	-1,076	-3,013
4	Scrapping cars >20 years old for hybrid cars	-1,073	-3,003
5	Replacing combis with omnibuses	-1,045	-2,926
6	CNG cars retrofit	-755	-2,114
7	Development of cycle lanes	-600	-1,680
8	Bus Rapid Transit	-206	-576
9	Congestions tolls for petrol and diesel private cars	-154	-4,340
10	Traffic management investments	33	92
11	Diesel taxis replaced with CNG	49	137
12	Diesel taxis replaced with hybrid	136	382
13	Hybrid scheme - $2,000 subsidy for 10% new cars	164	459

Negative figures represent a saving per unit of emissions saved, whereas positive figures represent a cost per unit of emissions saved.

Cost effective

Cost neutral

All others including (“cost ineffective” and those mutually exclusive with other measures)

Table 11: Mitigation measures for the transportation sector ranked by carbon effectiveness ($ktCO_2$ 2015-2030).

Rank	Description	Carbon Effectiveness $ktCO_2$ 2015-2030
1	Congestions tolls for petrol and diesel private cars	6,860
2	Replacing Combis with Omnibuses	5,485
3	Hybrid scheme – $2,000 subsidy for 10% new cars	2,755
4	Traffic management investments	1,672
5	Bus Rapid Transit	1,780
6	Petrol taxis CNG retrofit	838
7	Scrapping cars >20 years old for hybrid cars	683
8	CNG cars retrofit	560
9	Scrapping cars >20 years old for petrol cars	557
10	Diesel taxis replaced with CNG	551
11	Diesel taxis replaced with hybrid	428
12	Teleworking campaign	111
13	Development of cycle lanes	101

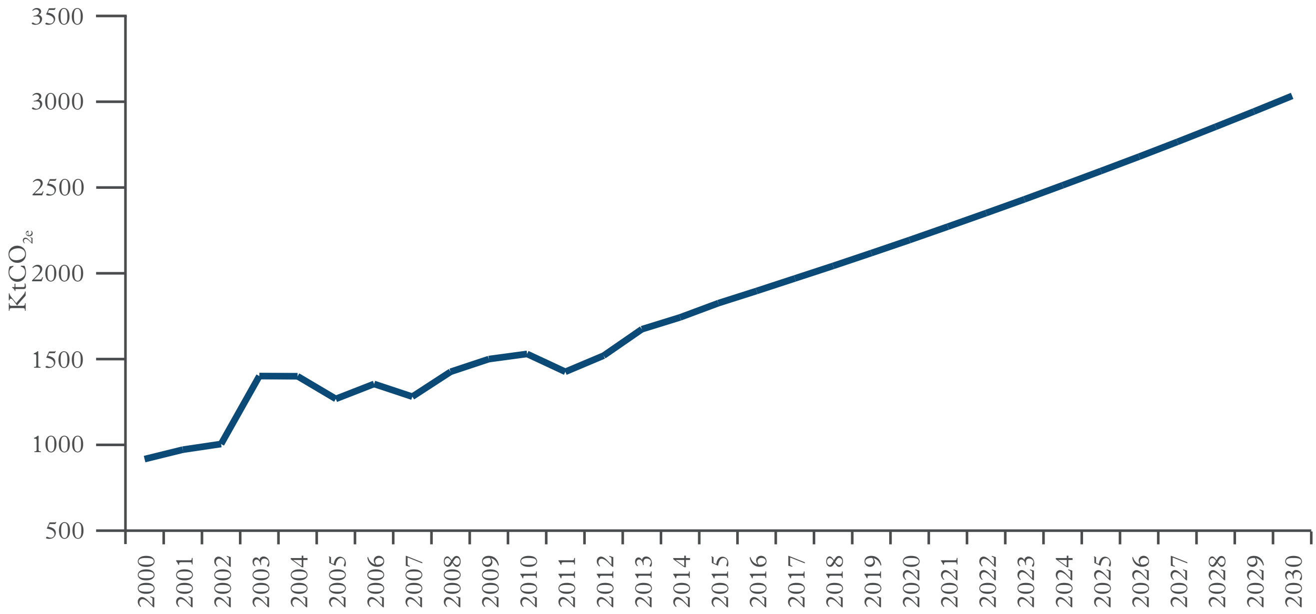
Sector Focus

The Waste Sector

The Changing Context and the Impacts of Business as Usual Trends

In the waste sector, a steady increase in waste production per capita, from 0.19 tonnes per year per capita in 2000 to 0.32 tonnes per capita in 2014, combined with the population growth, has seen waste emissions grow 90% since 2000. Although growth in population and per capita waste production are diminishing, we project that emissions from the waste sector will rise by 75%, from 1.7 $MtCO_{2e}$ in 2014 to 3.0$MtCO_{2e}$ in 2030 (see Fig. 25).

Figure 25: Emissions from the waste sector, 2000-2030 ($KtCO_{2e}$).



The Potential for Carbon Reduction – Investments and Returns

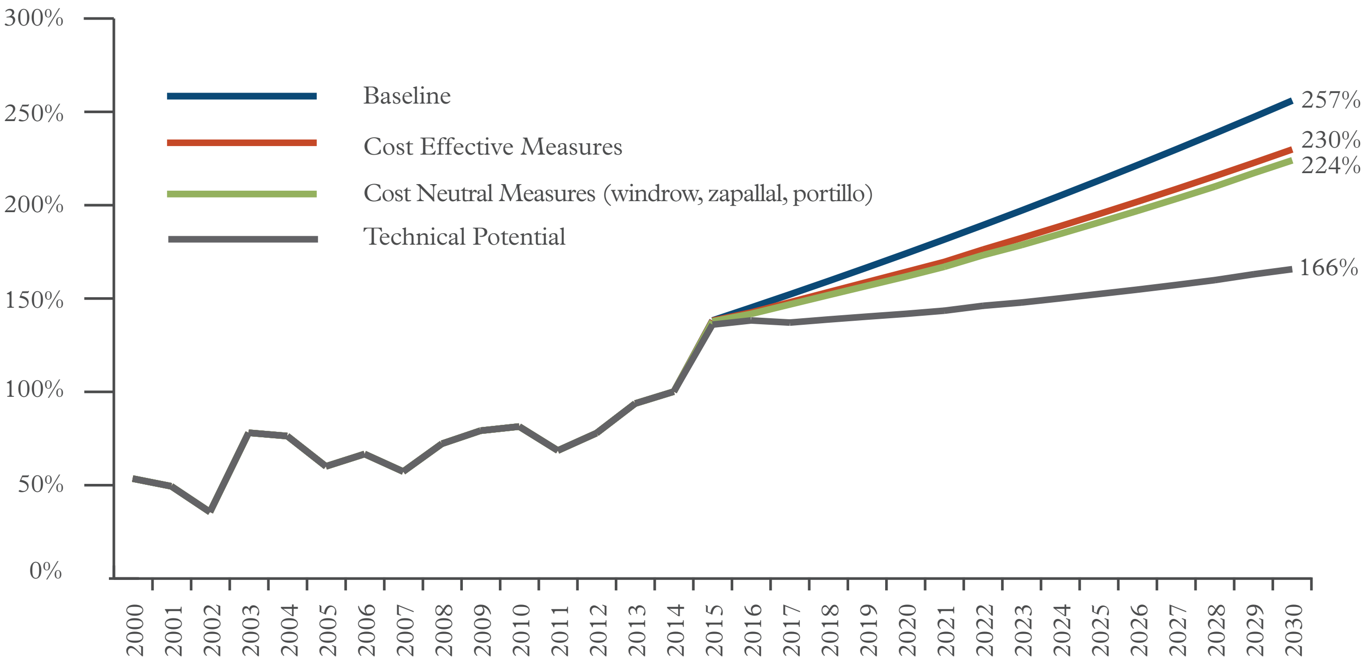
We find that for the waste sector, compared to the business as usual trends, emissions could be reduced by:

— 10% through cost effective investments that would more than pay for themselves over their lifetime. This would require an investment of US$8.9 million, generate annual energy savings of US$2.9 million and pay back the investment in 3.1 years but generate annual savings for the lifetime of the measures.

— 13% through cost neutral measures financed with the proceeds from cost effective measures. This would require investment of US $14.3 million, generate US $3.1 million in savings and payback in 4.7 years but generate annual savings for the lifetime of the measures.

— 35% with the exploitation of all of the realistic potential of all measures with carbon saving potential. This would require an investment of US $792 million, generate annual energy savings of US $45.7 million and pay back the investment in 17.4 years but generate annual savings for the lifetime of the measures.

Figure 26: Emissions from the waste sector under three different scenarios, 2000-2030 (2014 = 100%).



Cost effective

Cost neutral

All others including (“cost ineffective” and those mutually exclusive with other measures)

Table 12: Mitigation measures for the waste sector ranked by cost effectiveness (2014 US$ & Sol per tCO_{2e}).

Rank	Description	Cost effectiveness	
		2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}
1	Portillo Grande Landfill Gas Capture for Energy Generation	-3	-7
2	Waste to Electricity – 1,000 tonnes per day	0	0
3	Waste Windrow Composting – 100,000 tonnes per year	3	7
4	Zapallal Landfill Gas Flaring	6	17
5	Recycling Plant – 261kt of paper, wood and industrial waste	21	59
6	Taboada Sluge to Energy Incinerator	27	77
7	Waste In-Vessel Composting – 100,000 tonnes per year	81	226

Table 13: Mitigation measures for the waste sector ranked by carbon effectiveness (2015-2030).

Rank	Description	Carbon Effectiveness
		$ktCO_2$ 2015-2030
1	Portillo Grande Landfill Gas Capture for Energy Generation	3,443
2	Taboada Sluge to Energy Incinerator	3,276
3	Waste to Electricity – 1,000 tonnes per day	3,079
4	Waste In–Vessel Composting – 100,000 tonnes per year	965
5	Waste Windrow Composting – 100,000 tonnes per year	772
6	Recycling Plant – 261kt of paper, wood and industrial waste	683
7	Zapallal Landfill Gas Flaring	134

Sector Focus

The Water Sector

The Impacts of Business as Usual Trends and Climate Change on Water Supply and Demand

For this sector, we have not been able to consider the impacts related to the wider use of water within the basin, particularly water use by mining and agriculture upstream of Lima-Callao which is both using available water and leading to a reduction in water quality reaching Lima-Callao. A key measure here is the establishment of a basin-wide water management strategy to ensure water is being used fairly across the population and industry located in the basin. Furthermore we have not looked at wastewater treatment options, however there are a number of wastewater treatment processes that can break down wastewater residues and produce energy.

Baseline trends have seen water use in Lima-Callao increase by 21% in the period from 2000 to 2014, leading to a situation where supply and demand are near balanced in 2014. For the future, forecasts of both increases in water demand and the impacts of climate change suggest a best case scenario where there is a 13% surplus of supply over demand by 2030 and a worst case scenario where there is a 29% deficit and demand substantially exceeds supply. If we plan for the worst, the 29% deficit that is possible by 2030 could be met either by increasing supply (with some measures for increased supply already planned) or by decreasing demand. We note, however, that in the longer term, if the impacts of climate change on water supply to Lima-Callao grow, then it is likely that both the supply and demand side strategies will need to be adopted.

The supply-side strategy[39]

— As stated above, the potential water deficit could be avoided through US$856 million of investment in supply side measures, including US$259 million in water treatment facilities. This investment, which would have a payback period of 10.8 years, could be financed through an 18% increase in water tariffs for domestic, commercial and industrial water users. These measures are drawn from SEDAPAL planning reports and therefore align closely with SEDAPAL's current approach to meeting future water demand in Lima-Callao.

As is depicted in Fig. 27, the most cost effective measures to increase water supply include building resevoirs for the Chillon, Casacancha and Autisha rivers, with the Casacancha resevoir feeding into the existing Marca IV trans-Andean pipeline. Of the overall technical potential to increase water supply to Lima-Callao, 28% could come from a resevoir for the Pomacocha river with the Marca II trans-Andean tunnel, 14% from a resevoir on the river Chillon, 13% from diverting the Rimac river, 9% from a resevoir on the Casacancha river, 6% from the Autisha river and the remainder through a variety of smaller projects.

The demand-side strategy.

— If we prioritise demand side measures, to address concerns with the wider impacts of supply side measures, then we predict that the potential water deficit could be avoided through US$2.0 billion of investment, 95% of which would be spent on reducing water demand, and 5% of which would be spent on increasing water supply. This investment, which would have a payback period of 7.4 years, could be financed through a 15% increase in water tariffs for domestic, commercial and industrial water users. Compared to the supply-side strategy, the demand-side strategy has a shorter payback period and requires a smaller increase in water tariff since there is a larger return on investment from demand-side measures.

As is depicted in Fig. 28, the most cost effective measures to reduce water demand include the rehabilitation of the distribution network, the promotion of low flow showers, taps and toilets and small increases in water tariffs. Of the total technical potential to reduce water demand, 56% could come from the rehabilitation of the distribution network, 30% from the promotion of low flow showers, taps and toilets and 5% from the effects of small increases in water tariffs.

Tables of the most cost effective and water-effective supply and demand side measures for reducing the water deficit are shown below.

Figure 27: Relative contribution of different measures under the supply-side strategy, 2014-2030 (m^3/s).

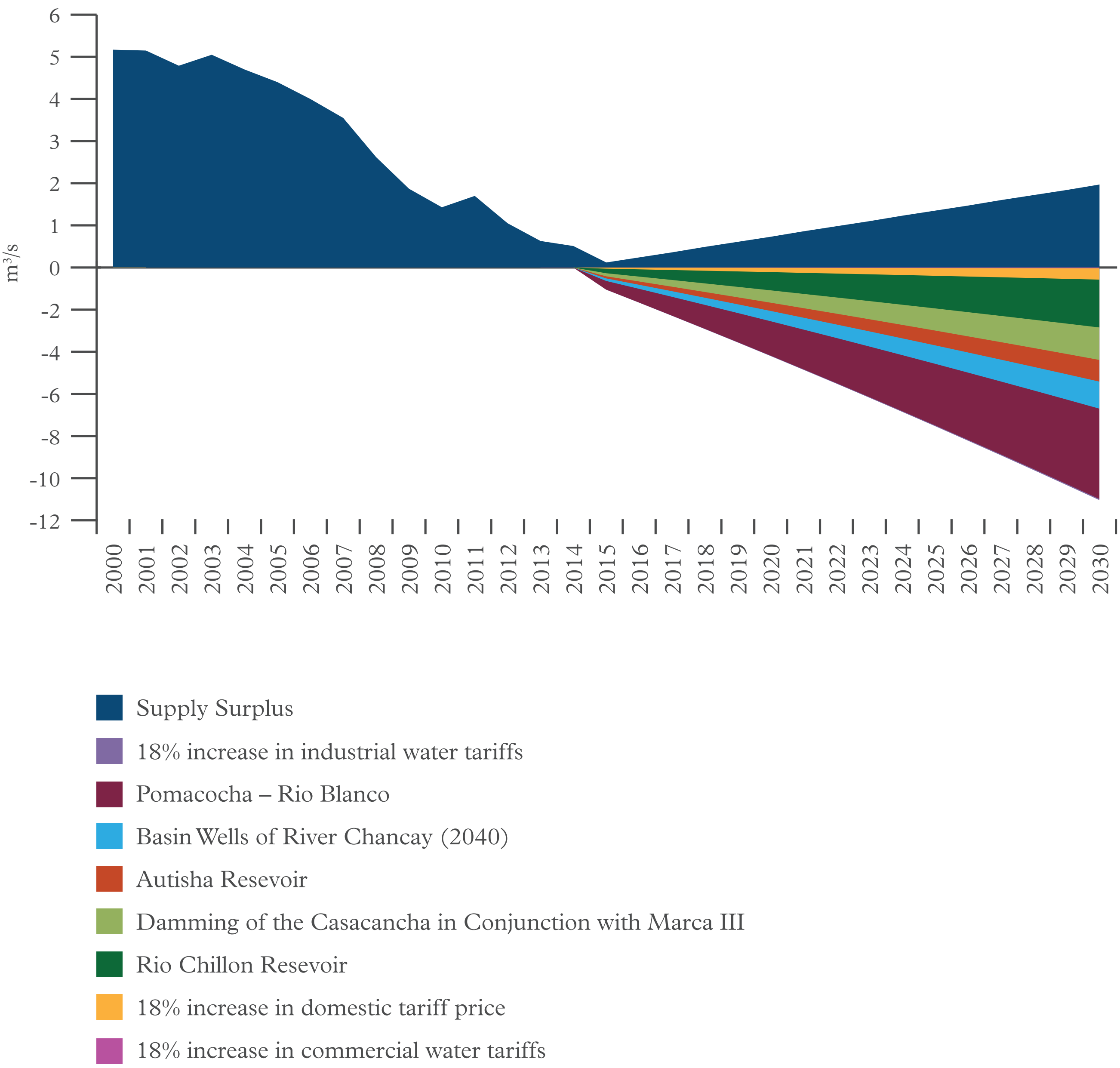
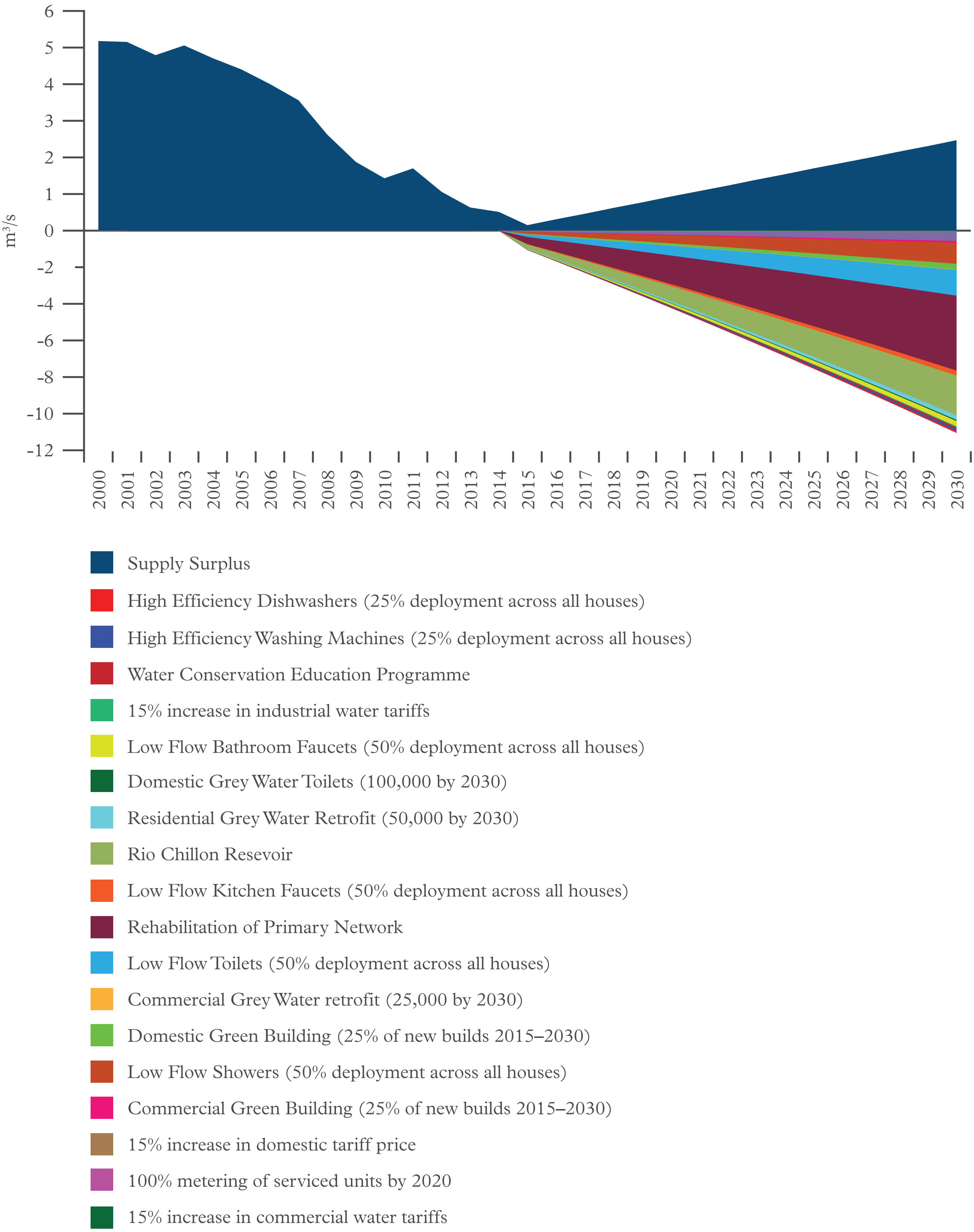


Figure 28: Relative contribution of different measures under the demand-side strategy, 2014-2030 (m³/s).



Cost effective

Cost ineffective

Table 14: Water savings by measure, 2015-2030 (million m³).

Rank	Type	Measure	million m³ 2015-2030
1	Demand	Rehabilitation of primary network	1,734
2	Supply	Pomacocha – Rio Blanco	1,734
3	Supply	Rio Chillon reservoir	919
4	Supply	Re-channelling Rimac River	867
5	Demand	Low flow toilets (50% deployment across all houses)	793
6	Demand	Low flow showers (50% deployment across all houses)	649
7	Supply	Damming of the Casacancha in conjunction with Marca III	624
8	Supply	Desalination of the sea water of the South Sea	520
9	Supply	Extension of Graton tunnel	520
10	Supply	Aquifer recharge	442
11	Supply	Autisha resevoir	416
12	Demand	18% increase in domestic tariff price	392
13	Demand	15% increase in domestic tariff price	327
14	Supply	Basin wells of River Chancay (2040)	237
15	Demand	Low flow bathroom taps (50% deployment across all houses)	161
16	Demand	Low flow kitchen taps (50% deployment across all houses)	157
17	Demand	Residential greywater retrofit (50,000 by 2030)	147
18	Supply	Aquifer recharge for Lurin River	139
19	Demand	Domestic green building (25% of new builds 2015-2030)	103
20	Demand	High efficiency washing machines (25% deployment across all houses)	71
21	Demand	Water conservation education programme	52
22	Demand	High efficiency dishwashers (25% deployment across all houses)	51
23	Demand	18% increase in industrial water tariffs	42
24	Demand	Domestic greywater toilets (100,000 by 2030)	38
25	Demand	15% increase in industrial water tariffs	35
26	Demand	18% increase in commercial water tariffs	28
27	Demand	15% increase in commercial water tariffs	23
28	Demand	Commercial green building (25% of new builds 2015-2030)	23
29	Demand	100% metering of serviced units by 2020	15
30	Demand	Commercial greywater retrofit (25,000 by 2030)	12
31	Supply	Condensate catchers	3

Cost effective

Cost ineffective

Table 15: Water measures ranked by cost effectiveness (2014 US$ & Sol per m³)

Rank	Type	Description	2014 US$/m³	2014 Sol/m³
1	Demand	15% increase in commercial water tariffs	-7.83	-21.94
2	Demand	18% increase in commercial water tariffs	-7.79	-21.82
3	Demand	100% metering of serviced units by 2020	-1.67	-4.68
4	Demand	15% increase in domestic tariff price	-1.40	-3.93
5	Demand	18% increase in domestic tariff price	-1.39	-3.89
6	Demand	Commercial green building (25% of new builds 2015-2030)	-0.52	-1.46
7	Demand	Low flow showers (50% deployment across all houses)	-0.16	-0.46
8	Demand	Domestic green building (25% of new builds 2015-2030)	-0.14	-0.40
9	Demand	Commercial greywater retrofit (25,000 by 2030)	-0.08	-0.23
10	Demand	Low flow toilets (50% deployment across all houses)	-0.05	-0.13
11	Demand	Rehabilitation of primary network	0.03	0.08
12	Demand	Low flow kitchen taps (50% deployment across all houses)	0.05	0.13
13	Supply	Rio Chillon resevoir	0.07	0.21
14	Demand	Residential greywater retrofit (50,000 by 2030)	0.08	0.23
15	Supply	Damming of the Casacancha in conjunction with Marca III	0.09	0.24
16	Supply	Autisha resevoir	0.09	0.26
17	Supply	Basin wells of River Chancay (2040)	0.14	0.40
18	Supply	Pomacocha – Rio Blanco	0.15	0.42
19	Demand	Domestic greywater toilets (100,000 by 2030)	0.15	0.42
20	Supply	Re-channelling Rimac River	0.19	0.52
21	Supply	Extension of Graton tunnel	0.24	0.68
22	Demand	Low flow bathroom taps (50% deployment across all houses)	0.29	0.82
23	Demand	15% increase in industrial water tariffs	0.41	1.15
24	Demand	18% increase in industrial water tariffs	0.42	1.19
25	Supply	Desalination of the sea water of the South Sea	0.43	1.22
26	Demand	Water conservation education programme	0.49	1.39
27	Supply	Aquifer recharge for Lurin River	0.52	1.46
28	Supply	Condensate catchers	0.66	1.86
29	Supply	Aquifer recharge	0.73	2.04
30	Demand	High efficiency washing machines (25% deployment across all houses)	4.63	12.95
31	Demand	High efficiency dishwashers (25% deployment across all houses)	6.33	17.72

Negative figures represent a saving per unit of water saved, whereas positive figures represent a cost per unit of water saved.

Chapter 4. Multi-Criteria Analysis

Introduction

Thus far in this report we have assessed different mitigation measures on the basis of both their cost and carbon effectiveness. However, decisions on the adoption of the different measures cannot be taken on the basis of these criteria alone. The presence of an economic case is a sometimes a necessary but should never be a sufficient condition for action; other factors are also critically important. For this reason, a multi-criteria decision analysis (MCA) was conducted with the aim of assessing the measures according to their political and public acceptability, the capacities for their implementation, their contribution to human development and their wider impacts on the environment. In this section we describe how this multi-criteria evaluation was done, we present the results and we provide some conclusions and recommendations based on these.

Method

Key experts from each sector (energy, domestic, commercial, transport, industry, waste and water) were identified through suggestions made by members of the project steering committee. Semi-structured interviews were conducted with these experts (approximately 3 interviews were conducted for each sector) before the formal MCA was conducted. The objective of the interviews was to secure inputs from the experts about the main results on each of the mitigation options that could guide the MCA process. The experts and a range of other stakeholders were later invited to attend the MCA workshops. A total of seven facilitated workshops, one for each of the sectors under study, were organised with inputs from 48 stakeholders coming from academia, NGOs, local and federal governments, international organisations and international experts working in Peru.

The facilitation of the workshops was impartial and the process was structured. As an introduction, the participants were presented with a brief background of the corresponding sector, followed by a description of the baseline and main projections. The goals to be achieved with the MCA were then explained. Each mitigation option was subsequently presented (some mitigation measures were packaged together in order to reduce the overall number of measures being reviewed). The participants were then provided with a performance matrix, in which the different mitigation options were grouped in clusters. These constituted the rows of the matrix, while the columns represented five broad criteria: political acceptability, public acceptability, capacity for implementation, positive impacts on human development and positive impacts on the environment.

Participants were then asked to provide a score from 1 to 5 to each cluster of options (see table below), where 5 represents the maximum value, according to the prevailing levels of political/social acceptability, the capacity for implementation and the extent to which the options can positively impact human development or the environment. For example, if the attendees thought that a certain cluster of options currently has the potential of enjoying high political acceptability, they could assign it a score of 5. In contrast, if they thought that a cluster currently faces many difficulties to be implemented, they could assign it a value of 1. In this sense, they were prompted in an iterative manner with questions such as: Which measures are more acceptable from the policy/public point of view under the current conditions? Are there currently structures available that can help implementing the mitigation measures? Do you think that the measures will produce positive impacts on the quality of life or on the environment?

Participants were then asked to think about the potential social, economic, political and environmental barriers that must be addressed if the mitigation options were to be implemented under the current conditions. They were instructed to write down the specific aspects they thought should be taken into account when implementing the measures. Those crucial aspects for the sector and for the mitigation options were then discussed as a group. This exercise was helpful to confirm the relevance of the five broad criteria, contextualise the current situation of the sectors, and identify barriers and areas of opportunity.

Participants were then instructed to rank the measures once more, but this time considering that the barriers identified previously during the discussions had been overcome; that is, in the context of a hypothetical situation where current conditions in Lima-Callao have improved. In this sense, they were asked if their initial scores would change. If so, they were asked to assign new scores to the clusters in relation to the criteria.

Results: Ranking of the options under current conditions

The individual scores assigned by the participants to each criterion were averaged. The total score for each cluster of options was then calculated by adding all the average individual scores associated with each criterion. The clusters were finally ranked according to their total scores. These are presented in the Table 19 overpage.

Table 16: Rankings of mitigation measures for a range of wider sustainability issues

Sector	Cluster	Measure	Political acceptability	Public acceptability	Capacity for implementation	Impact on human development	Impact on the environment	Ranking under current conditions
Energy	A	BAT natural gas	**4.7**	3.7	3.0	2.0	2.3	2
	B	BAT coal	3.3	2.3	2.7	3.7	1.7	4
	C	Wind Power	3.3	3.0	2.7	**4.0**	**2.0**	3
	D	Solar power	3.7	**3.7**	**3.7**	3.7	**2.0**	1
Domestic	A	Green Building Standards	3.3	2.7	2.9	2.3	1.7	4
	B	EE Appliances	**3.6**	**3.7**	3.1	2.7	2.0	2
	C	Incandescent Phase Out	**3.6**	3.4	3.1	**3.1**	**3.7**	1
	D	Behavioural change	**3.6**	3.4	**3.4**	2.0	2.1	3
	E	Solar hot water	2.7	2.6	2.6	2.7	2.3	4
Commercial	A	Electricity Retrofit Program	3.2	3.2	2.8	3.7	4.0	2
	B	Green Building certifications	3.2	2.7	2.3	3.3	3.3	4
	C	Solar Hot Water	3.0	3.0	2.8	3.3	3.5	3
	D	Street Lighting	3.3	3.5	3.0	3.7	3.7	1

Note: Last column shows the rankings of the clusters for each sector, where 1 represents the highest ranking. Bold numbers represent the highest values obtained by each criterion in each sector. Underlined values represent the lowest scores.

Sector	Cluster	Measure	Political acceptability	Public acceptability	Capacity for implementation	Impact on human development	Impact on the environment	Ranking under current conditions
Transport	A	Vehicle Emissions Standards, Biofuels	2.7	2.2	2.5	3.0	2.7	5
	B	Alternative technologies (CNG, hybrid)	3.2	3.7	**3.3**	3.0	2.2	2
	C	Increase Metro, BRT	**3.7**	**4.3**	2.5	3.7	1.7	1
	D	Efficient Driver Project, Teleworking, Cycling	2.7	3.4	3.0	**4.0**	2.0	3
	E	Combis replacement, scrapping old cars	3.0	2.8	2.2	3.0	3.0	4
	F	Coron toll in the city centre	2.2	1.8	1.8	2.8	**3.3**	6
Waste	A	Recycling Facility	2.5	**2.5**	**3.0**	2.0	2.0	1
	D	Composting	2.5	**2.5**	2.0	**2.5**	**2.5**	1
	E	Landfill management	**3.0**	2.0	1.5	**2.5**	2.0	2
Water	A	Management of river basin	3.4	3.0	2.4	3.6	4.4	5
	B	System losses reduction	3.6	3.4	3.2	3.8	3.0	4
	C	Water saving educational programme	3.4	**3.8**	2.4	**4.5**	**4.5**	1
	D	Retrofit and efficient use of water	3.4	2.8	2.6	3.3	3.3	9
	E	Increase underground water	3.4	3.6	3.4	2.5	2.8	8
	F	Alternative technologies	3.8	3.2	2.8	3.5	2.5	7
	G	New source of superficial water	**4.4**	**3.8**	3.2	3.3	3.3	2
	H	Improvements in quality and water availabilty	3.8	3.3	3.0	3.3	3.0	6
	I	Tariff modification	3.0	3.0	**3.5**	4.0	4.0	3

Electricity

In the last column of the table above, it can be seen that for the electricity sector the cluster with the highest ranking was solar (cluster D), obtaining the highest scores in public acceptability and capacity for implementation. Cluster A, best available technology (BAT) for natural gas, came in second place, turning out to be the most accepted politically and publicly. It obtained, however, the lowest score in relation to positive impacts on human development. In contrast, wind (cluster C) was deemed as having the highest impact on human development, but was seen as having the lowest political acceptability, being thus placed in the third position. The lowest overall score corresponded to the BAT for carbon (B), which was the lowest in public acceptability, lowest in terms of capacity for implementation, and deemed as producing the greater negative impacts on the environment.

Attendees mentioned that coal is not widely used for the production of electricity in Peru, but that it is mainly utilised when technical problems are experienced in the grid or when there are urgent deficits to be covered. The experts agreed that current trends will force this energy source to disappear in the future.

Domestic sector

Moving to the domestic sector, the highest ranking cluster was for the phase out of incandescent light bulbs (C). It scored highly in the political sphere, as well as in relation to positive impacts on human development and the environment. The second position corresponds to energy efficient appliances (B), which is the option most accepted by the public, but has negative impacts on the environment. The cluster that encompasses behavioural-change measures (D) was placed third. According to the results, it has the highest capacity for implementation of all the measures, but contributes the least to human development.

The last two options were green building standards and solar hot water. This last option got the lowest score in terms of political and public acceptability, as well as regarding the capacity for implementation. Participants mentioned that implementing solar hot water might be a problem, since this option usually demands installing the technology on roofs. However, it is very common that people continue to gradually build additional floors as the size of their families expand, and this would require removing the installations. In addition, no adequate technology is still broadly available in Lima-Callao.

Figure 29: Clusters that scored highest in each criterion by sector.

Political acceptable	Public acceptable	Capacity for implement	Human develop	Impact on the environment
BAT Natural Gas	Solar power	Solar power	Wind power	BAT natural gas
Incandescent Phase out	EE Appliances	Behavioural Change	Incandescent Phase out	Incandescent Phase out
Green building Certifications	Street lighting	Street lighting	Street lighting	Electricity Retrofit Program
Increase Metro BRT	Increase Metro BRT	Alternative technologies (CNG, hybrid)	Efficient Driver Project, Teleworking, Cycling	Cordon toll in city centre
Landfill management	Recycling Facility	Recycling Facility	Composting	Composting
New source of superficial water	Water Conservation Education	Tariff modification	Water	Management of river basin

Commercial sector

In the commercial sector, which also involves the public sector, the highest ranking cluster was street lighting. According to the results, it is the most accepted by politicians and the public. It is also the one with the higher capacity for implementation and is believed to produce high positive impacts on human development. The electricity retrofit program (A) obtained the second place. Its scores show that it is the cluster with the highest positive impacts on the environment. Solar hot water is the cluster that was placed third, being the least accepted politically and also scoring low in relation to positive impacts on human development. Green building certifications came last, being the cluster with the lowest public acceptability. The scores also reveal that it is the most difficult cluster to implement and produces the lower positive impacts on human development and the environment.

Transport sector

Participants in the transport workshop regarded the development of metro and BRT lines (C) as the highest ranking cluster. The scores reveal that it is the one with more political and public acceptability. The second cluster is the promotion of cars with cleaner technologies (CNG, hybrid). According to the scores, this cluster of options can be regarded as the easiest to implement. The cluster that ranked third is the one involving behavioural changes (D). The scores reveal that projects, such as efficient driving, teleworking and encouraging the use of bicycles, have the highest impacts on human development. The fourth cluster was the replacement of combis with omnibuses and scrapping old cars.

Attendees highlighted that some of the problems in Lima-Callao are the age of the existing vehicle fleet and the great amount of combis. Next to last is cluster A (vehicle emission standards, promotion of biofuels). Participants mentioned that the use of biofuels is not only a contested issue in terms of real environmental benefits, but also that the available technologies cannot handle higher levels of biofuels in the fuel mix. Cluster F (cordon toll) came in the last position, as it is the least accepted in political and public terms. It also has the lowest capacity for implementation and is believed to produce the lowest positive impacts on human development. However, it got the highest score on positive impacts on the environment.

Waste sector

In the waste workshop, two clusters occupied the first position: recycling facilities and composting. The former is believed to have the highest capacity for implementation and is highly accepted by the public. However, it was regarded as having a low level of political acceptability and is the option with the lowest positive impacts on human development. In contrast, composting achieved the highest score in relation to positive impacts on the environment and contributes highly to human development. It was mentioned that composting could be a good way of restoring Lima-Callao's arid landscapes. However, the compost market needs to be developed and regulated. Landfill management (E) was placed at the end of the spectrum, despite being the cluster with higher political acceptability. It received the lowest scores for public acceptability, capacity for implementation and for positive impacts on the environment.

Water sector

Water is the sector with the largest number of clusters. The highest ranking cluster in this case is C, water saving educational programmes. This measure got a high score on public acceptability and the highest on positive impacts on human development and the environment. Participants mentioned that it is a necessary action to raise awareness and promote a real behavioural shift. They recognised, however, that this would not be easy to implement and, as can be seen, it thus received the lowest score for the capacity for implementation. Finding new sources of superficial water was placed in the second position. According to the results, it is the most accepted in political terms and highly accepted by the public. According to the attendees, the reason is perhaps that measures oriented towards guaranteeing a secure water supply are more easily favoured by both politicians and the public. The third position belongs to the modification of tariffs. According to the results, raising tariffs has the highest score for capacity of implementation, but the lowest for political acceptability. The need to assign a higher monetary value to water was mentioned by the participants, even though it is not politically attractive.

This measure was followed by reducing system losses and then by the management of the river basin, which is ranked in the fifth place. It scored highly in relation to positive impacts on the environment. Although this measure has an important potential for water savings, it scored low on capacity for implementation. Attendees mentioned that there are yet no institutions capable of carrying out this measure, and that several preliminary steps are needed to implement it. Improvements in quality and water availability (H) were placed in the 6th position, followed by alternative technologies (F) and by increasing the supply of underground water. Retrofit and efficient use of water (D) came last, having the lowest acceptability in the public sphere.

Chapter 5.
Outline Financing and Implementation Plan

Introduction

The study has highlighted the presence of a wide range of measures that could be adopted in Lima-Callao as it moves towards a low carbon, climate resilient development path. Many of these options could be adopted cost-effectively, with the initial costs being more than offset through the savings that would be generated over the lifetime of the measures. However, to exploit these lifetime savings, and to secure the improvements in energy and water efficiency that they would generate, very substantial levels of investment will be required.

For energy efficiency and low carbon development, investments of US$5.1 billion would need to be made to exploit the potential of the cost-effective low carbon measures, whilst US$12.2 billion would need to be invested to reach the cost-neutral (no net cost) level of adoption. These are equivalent to investments of 0.8% and 1.6% of GDP each year for 10 years – and as such are well within the range of investment costs predicted by global studies such as the Stern Review on the Economics of Climate Change[40] (Stern, 2007). Although we have demonstrated that these investments would pay for themselves within 2.4 and 4.5 years respectively, very significant levels of investment capital still need to be raised if these benefits are to be realized.

For water efficiency and climate resilient development, investments of US$856 million would be needed to exploit all supply-side responses to potential the water shortages that could stem from growth in water demand and the risk of drops in water supply due to climate change, whilst investments of US$2.0 billion would be needed to exploit all demand-side responses. In theory, these investments could be met by increasing the water tariffs paid by formal water users by less than 2% a year each year for the next 10 years. This is not to say that they should be funded in this way - merely to point out that they could be funded in this way.

This chapter reviews the different ways in which these investment costs could be met – both through new forms of finance and through new approaches to policy intervention. And based on the results of the economic assessment, the multi-criteria evaluation and a workshop considering financing and implementation issues, we highlight some key areas where early actions might be taken.

Access to Finance

There are many ways of funding investments, and stimulating investments, into low carbon, climate resilient development. As is depicted in Figure 30, each option has the potential to contribute a proportion of the required investment and it is likely that all options have a role to play in securing the required levels of investment.

- *Commercial investments* - A significant proportion of the low carbon, climate resilient investment opportunities identified could be attractive enough to secure commercial investments. These are the investments with, for example, significant returns, short payback periods and low levels of risk and uncertainty.
- *Incentivised investments* – Where the criteria for commercial investment are not strong enough, government can play a temporary role by offering additional incentives for commercial investment. These can come in the form of, for example, feed in tariffs for renewables or tax breaks for the purchase of more efficient vehicles.
- *Informed investments* – As well as providing additional incentives, government and other actors can help to stimulate investment by raising awareness and providing access to information. Awareness raising can take place for example through broad information campaigns, through initiatives such as the energy labeling of vehicles and buildings and through assurance schemes that recognize for instance particular suppliers or technologies that meet different criteria.
- *Enabled investments* – Government and other actors such as trade bodies can also help to create conditions that are more conducive to investment. They can do this by for example supporting feasibility studies, running pilot exercises, building technical capabilities and helping to establish supply chains and networks. They can also do this by minimizing risks – for instance by establishing clear and stable policy targets or acting as an anchor client in purchasing particular technologies.
- *Induced investments* – Government policy can also require different actors to invest in some options. Governments can require new buildings to meet higher levels of energy or water efficiency, or for new vehicles to meet tougher emissions limits. By adopting such standards, government policy forces suppliers to provide and purchasers to buy options that cost a little more in the short term but that easily recoup any extra costs over the life time of the measure.

— *Recovered investments* – Governments can also make some forms of investment viable through different forms of cost recovery. Investments in state owned or regulated utilities in the electricity or water sectors can be enabled through some forms of cost plus pricing. Infrastructure developments can be financed through initiatives such as tax increment financing (where up-front costs are met through the increases in tax revenue they generate) or through planning gain (where permission to build is given on the condition that new infrastructure is provided). Other investments – for example in establish urban congestion zones – can be self financing over time through the revenues they generate.

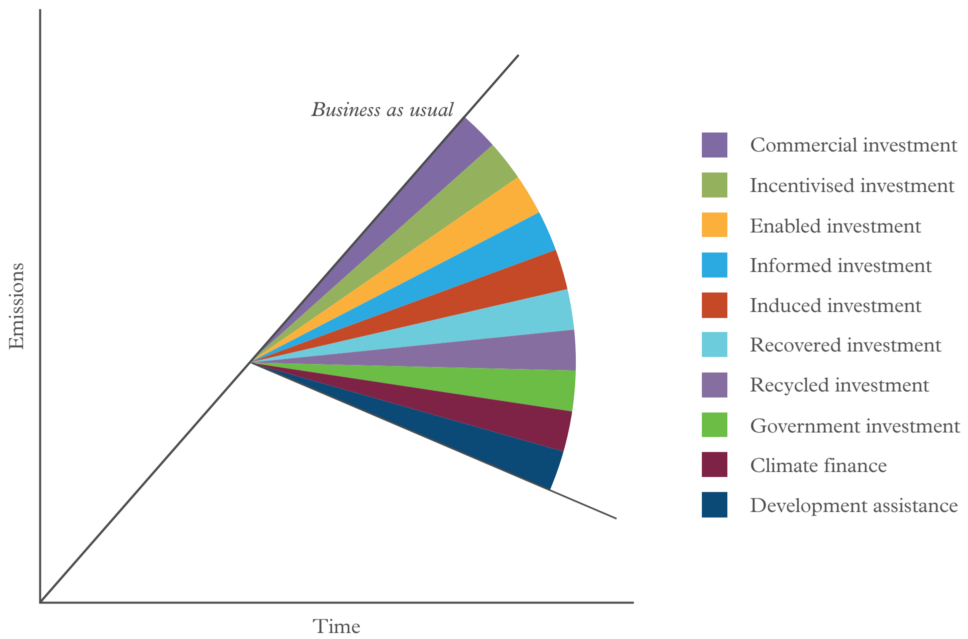
— *Recycled investments* – Some forms of investment can be funded through the savings that they generate. This model has been the basis for both Energy Service Companies (ESCOs) and retrofit schemes that fund investments in energy efficiency from the savings that these investments make and that the schemes capture and use to service loans and for reinvestment.

— *Government investments* – As the public sector typically owns, uses or controls a very large estate, governments have substantial scope to invest in improving their own energy or water efficiency. Through their purchasing policies, governments can also act as cornerstone clients for other investments, for example by guaranteeing a market for a proportion of renewable energy or for particular technologies.

— *Development assistance* – Multi-lateral and bi-lateral development donors are increasingly seeking to promote measures that are compatible with the goals of for example inclusive green growth (e.g. Inter-American Development Bank, World Bank) and climate compatible development (e.g. UK Aid). Such development assistance can fund investments in low carbon, climate resilient measures that have wider development benefits and that would not be funded through private sector finance.

— *Climate finance* – Support for some forms of low carbon development has been available through the Clean Development Mechanism (CDM), through Joint Implementation (JI) mechanisms and through the voluntary carbon markets. Stemming from commitments made during UN climate negotiations, and through initiatives such as the International Climate Funds, new forms of climate finance are emerging based on Nationally Appropriate Mitigation Actions (NAMAs) and Nationally Adaptation Programmes of Action (NAPAs).

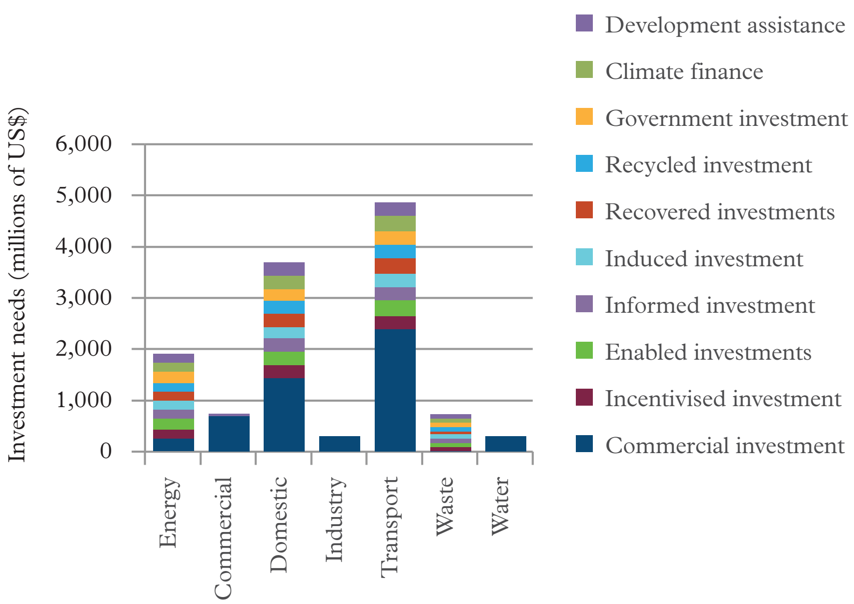
Figure 30: Conceptual diagram showing how different forms of investment can contribute to emissions reductions over time on a city scale.



Understanding Investment Needs and Options for Lima-Callao

Our analysis shows that investment needs/opportunities are spread unevenly across the different sectors in Lima-Callao – both in terms of aggregate investment needs and the proportion of these that are commercially attractive. Figure 31 below shows investment needs to exploit cost effective options in each sector – all coloured blue – and investment needs for cost neutral options that, in the absence of knowledge on how much each financing option might contribute, we have divided investment need equally amongst all other financing options.

Figure 31: Investment needs by sector with potential sources of investment types (millions of US$).



The workshop run to develop an outline financing and implementation plan considered the financing options for each sector in Lima-Callao. A summary of the main points made for each sector is as follows:

— *Water* projects can be either supply-side or demand-side. Supply-side investments could be funded through external loans, Public-Private-Partnerships, concessions or via payments for ecosystem services. Demand-side investments can be funded through incentivised private investment and progressive use of water bills for consumers.

— For the *waste* sector, some measures can be implemented via city government contracts with waste management companies, however this will take time and is dependent on the contractual arrangements and schedules. Public-Private-Partnerships are also possible in this sector.

— The *energy and industry* sectors could finance investments through funds from the carbon markets, carbon finance (e.g. NAMAs), the private sector (including venture capital) and public sector support. Regulation could also be used to stimulate or induce investment (e.g. for PVs).

— In the *transport* sector, financial support for a number of cost effective measures is already available - for example taxis have access to support for fuel switching. However, further incentives are needed – for example to promote the take-up of hybrid vehicles- and taxation could be used to encourage the wider use of a range of low carbon options. Public-Private-Partnerships are already being used to develop the Metro system. Further support for some public transport options could come through NAMAs.

— In the *residential and commercial* sectors, a range of financing options is already available. For example, there is experience within Peru of banks providing finance to install solar water heaters. For other forms of renewable energy, incentives to households could be provided via payments for the production of green energy that is then sold back to the grid. Other tax incentives could also be used to promote domestic generation of renewable energy. Banks could also provide finance for domestic sector energy efficiency projects, however these may need to be developed and advertised within Lima. The mandatory or voluntary adoption of green building standards could also lead to further induced investment, and the public sector could also drive market development by purchasing renewables directly.

Overcoming Barriers to Implementation

The multi-criteria evaluation (MCE) and financing and implementation workshops also identified some key barriers that need to be overcome to create conditions that are more conducive to low carbon, climate resilient development. These barriers can be categorized as:

— *Social* – where there may be a lack of public trust or acceptance of particular measures or approaches and a lack of skills within the employment base to allow a particular measure to be implemented.

— *Political* – where there may be a lack of a strategic vision or targets or a lack of regulation and/or enforcement.

— *Technological* – where there may be a lack of enabling infrastructure (e.g. a smart grid), a lack of awareness of a particular technology or where available technologies may not be applicable in the proposed setting.

— *Financial* – where it may be difficult or impossible to find sufficient finance due to high levels of risk or low levels of knowledge.

— *Institutional* – where the supporting infrastructure needed to allow a project to be implemented may be lacking or absent.

A summary of key barriers and suggested changes required by sector is presented in Appendix G. Based on these findings, we propose the following as priority areas that could help to overcome these barriers, and to build confidence and momentum and that could therefore generate positive feedback and a further strengthening of the capacity for low carbon, climate resilient development in Lima-Callao:

1) *Subsidised feasibility studies* for measures with high potential that are not currently well understood by relevant stakeholders to generate support for new measures. These could be supported and/ or undertaken by development banks, national or municipal government, the private sector, academia or NGOs.

2) *Commercial demonstration schemes* – these could allow the investment community and other relevant stakeholders to gain confidence and experience in new forms of financing for cost-effective low carbon measures.

3) *Policy workshops for national and municipal government* to identify new policy approaches and instruments and to build the institutional capacities needed to facilitate the implementation of low carbon, climate resilient policy frameworks.

4) *Educational campaigns* to encourage behavioural changes and the switching to lower carbon and climate resilient options.

Identifying Priority Mitigation Areas for Action in Lima-Callao

Given all of the above, we have attempted to identify those measures that are both cost and carbon effective, that perform best against wider criteria such as social and political acceptance, and that have the best developed conditions for implementation. As presented in Appendix F, we have done this by assigning a rank for each measure according to its carbon effectiveness, cost effectiveness and rank in the multi-criteria evaluation. These different rankings are then combined to give an overall rank for each measure.

The ten most attractive measures that appear to perform well against all of these criteria are shown in Table 17. A significant number of these are transport measures, as they generally perform well in terms of both cost effectiveness and the multi-criteria evaluation. Other sectors represented include the residential and electricity sectors with measures related to the phase out of incandescent lighting and the introduction of geothermal energy. Table 18 shows the top two measures per sector.

Table 17: Top 10 most attractive greenhouse gas measures based on ranking by overall cost effectiveness (US$/t$CO_2$), overall carbon effectiveness (tCO_2 saved) and sectoral multi-criteria evaluation ranking.

Sector	Measure	Overall Cost Effectiveness Rank	Overall Carbon Effectiveness Rank	Sectoral MCA Rank	Overall Attractiveness Rank
Transportation	Replacing Combis with Omnibuses	4	4	4	1
Residential	Incandescent lighting phase out and 50% LED by 2020	18	6	1	2
Electricity	Geothermal 2,000MW (replacing natural gas)*	57	1	n/a	3
Residential	Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections)*	1	61	n/a	4
Transportation	Petrol taxis CNG retrofit	3	33	2	5
Residential	Incandescent lighting phase out	14	15	1	6
Electricity	Geothermal 1,000MW (replacing natural gas)*	56	2	n/a	7
Transportation	Bus Rapid Transit	22	17	1	8
Transportation	Teleworking Campaign	2	68	3	9
Transportation	Congestions tolls for petrol and diesel private cars	33	3	6	10

See Appendix F for the scoring criteria. NB the industry sector was not included in the multi-criteria evaluation and some measures were bundled together. Where possible these measures have been assigned a value of a comparable measure or they have been given a score of 0.5 for the MCA(marked with a *).

Table 18: Top 2 most attractive measures per sector, sorted by overall attractiveness ranking.

Sector	Measure	Overall Cost Effectiveness Rank	Overall Carbon Effectiveness Rank	Sectoral MCA Rank	Overall Attractiveness Rank
Transportation	Replacing Combis with Omnibuses	4	4	4	1
Residential	Incandescent lighting phase out and 50% LED by 2020	18	6	1	2
Electricity	Geothermal 2,000MW (replacing natural gas)*	57	1	n/a	3
Residential	Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections)*	1	61	n/a	4
Transportation	Petrol taxis CNG retrofit	3	33	2	5
Electricity	Geothermal 1,000MW (replacing natural gas)*	56	2	n/a	7
Commercial	Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings	8	28	2	11
Commercial	Solar hot water for commercial sector	43	16	1	13
Industry	Electricity conservation in other industrial sectors*	36	9	n/a	15
Industry	Switch boilers to natural gas*	35	12	n/a	21
Waste	Waste to electricity - 1000 tonnes per day*	46	11	n/a	23
Waste	Taboada sluge to energy incinerator*	60	10	n/a	26

See Appendix F for the scoring criteria. NB the industry sector was not included in the multi-criteria evaluation and some measures were bundled together. Where possible these measures have been assigned a value of a comparable measure or they have been given a score of 0.5 for the MCA(marked with a *).

For water we have undertaken a similar assessment based on the water saving, cost effectiveness and multi-criteria ranking of individual measures. The results for this analysis are given in Table F2 in Appendix F. The top ranking measure is rehabilitation of the primary network, which scored highly in water savings and the multicriteria analysis as well as relatively high in the cost effectiveness ranking. Of the other top 10 measures identified they can be broadly categorised as being supply side measures which increase water entering Lima, tariff related measures for both the commercial and domestic sectors and metering of water. In order to meet the potential water shortage in Lima a large number of the complete set of measures needs to be implemented and given that the majority of the supply side measures are likely to be undertaken by SEDAPAL (the main water company in Lima) we recommend a water NAPA for the city to encourage improved distribution and demand side water management (see below).

Table 19: Top 10 most attractive water measures based on ranking by overall water effectiveness (million m^3 saved), overall cost effectiveness (US$/$m^3$), and sectoral multi-criteria evaluation ranking.

Type	Measure	Water Effectiveness Rank	Cost Effectiveness Rank	MCA Rank	Overall Attractiveness Rank
Demand	Rehabilitation of Primary Network	1	11	4	1
Supply	Pomacocha - Rio Blanco	2	18	2	2
Supply	Rio Chillon Resevoir	3	13	2	3
Demand	15% increase in commerical water tariffs	27	1	3	4
Demand	18% increase in commerical water tariffs	26	2	3	5
Demand	15% increase in domestic tariff price	13	4	3	6
Supply	Re-channelling Rimac River	4	20	2	7
Demand	18% increase in domestic tariff price	12	5	3	8
Supply	Damming of the Casacancha in Conjunction with Marca III	7	15	2	9
Demand	100% metering of serviced units by 2020	29	3	4	10

See Appendix F for the scoring criteria. NB Measures were bundled together for the multi-criteria assessment.

Based on these findings, we propose the following as priority areas for greenhouse gas mitigation and water management in Lima-Callao:

1) *A transport NAMA* to exploit the transport measures identified as being attractive against all criteria. This would be an effective way to reduce emissions in the sector that is responsible for the highest proportion of emissions in a coordinated manner.

   This measure could support implementation of the measures with the following attractiveness rankings: 1; 5; 8; 9; 10; 12; 14; 16; 27; 30; 40; 54, and; 60.

2) *A water NAPA* (National Adaptation Programmes of Action) to promote a city-wide programme for the promotion of water efficiency. This would promote the adoption of cost-effective and socially beneficial water management measures in the domestic sector and also in the public and private sectors.

3) *Green building standards* could be developed and promoted to allow the range of commercial and domestic water and energy efficiency measures to be effectively implemented.

   This measure could support implementation of the measures with the following attractiveness rankings: 19 and 71. Also indirectly supports the development of the following measures: 2; 4; 6; 9; 22; 31; 35; 36; 38; 39; 42; 44; 46; 48; 56;57; 62; 64-70; 72; 74; 77, and; 78.

4) *Vehicle efficiency standards* could be adopted and promoted to reduce emissions from the different vehicle types operating within Lima-Callao.

   This measure is assumed as part of the Lima-Callao baseline.

5) *A public sector energy and water efficiency scheme* could be adopted and promoted to demonstrate public sector leadership in this area and to allow demonstration of measures that would generate economic and environmental benefits for the public sector. This could cover a wide range of the public sector's operations (including buildings, waste management, vehicles, green spaces etc.).

   This measure could support implementation of the measures with the following attractiveness rankings 19; 28; 38; 43; 50, and; 53.

   It could also be used (alongside sector specific information and examples) to encourage commercial and industrial sectors to undertake change, with measures such as: 11; 13; 15; 19; 21; 22; 33; 37; 38; 41, and; 45.

6) Incentivisation and enablement of *greener energy use (both large scale and small scale)*.

   This measure could support implementation of the measures with the following attractiveness rankings: 3, 4, 7, 17, 18, 19, 20, 24, 25, 36, 38, 44, 52, 55, 61, 71, 73, 76

7) *Regulation on incandescent lighting phase out*

   This measure could support implementation of the measures with the following attractiveness rankings: 2 and 6.

Chapter 6. Discussion, Conclusions and Recommendations

From a climate perspective, the analysis in this report suggests that Lima-Callao can reduce its carbon emissions by 30% from a business as usual scenario by exploiting the range of cost-effective and cost-neutral measures. Reducing emissions by this amount is highly feasible. The technological and behavioural options identified in this research are currently available, the energy and financial savings are clear (and are based on conservative estimates), the investments show real economic returns and feasible payback periods and the assumptions – regarding costs, implementation rates and impacts – have been reviewed by stakeholder committees, focus groups and a formal review process and found to be realistic and achievable.

The economic returns on these investments could be very significant. Many measures would pay for themselves over short periods of time and at competitive interest rates. The measures we have suggested have the potential to significantly change future levels of energy use, energy bills and carbon emissions in Lima-Callao.

However, the presence of an economic case for investment should be seen as a necessary but not a sufficient condition for action. The economic case needs to be supplemented with political will, social support and institutional capacities – and it is critically important that any investments made are also more broadly sustainable. By ranking measures and groups of measures against these broader criteria, some measures seem to be attractive politically, socially, institutionally and environmentally, even under current conditions.

We recognise that implementation of any particular measure, or set of measures, will require a more in-depth financial analysis than we have been able to provide. Importantly, individual measures will need to be adopted in a way that considers their effect on different socio-economic groups and their wider sustainability issues. If initiatives are designed and delivered in the right way, there is clear potential for investments to provide significant co-benefits for example so that they benefit the poorest communities, improve air quality and public health, enhance employment and the economy, improve energy security and access and enhance the quality of life in Lima-Callao.

Transition, however, requires political and social as well as financial capital. The levels of ambition, foresight and activity needed to exploit the opportunities available are substantial. New investment and financing models are needed to enable measures to be exploited. Stimulating the supply of and demand for low carbon, climate resilient investment is likely to require new forms for cost recovery and benefit sharing, and new approaches to managing risk. Furthermore, significant institutional capacity building is likely to be required to allow the implementation of many of these measures, particularly those that require public sector finance or an enabling policy environment.

It is clear that the list of energy and water efficiency measures identified in this report may not be complete. New measures could contribute to a lower cost transition to a low carbon, climate resilient economy and enable the further or deeper decarbonisation of Lima-Callao post-2030.

And fundamentally, we should recognize that economics is not the only discipline that has something useful to say on the transition to a low carbon economy/society. The multi-criteria analysis in this report considers issues of social and political acceptability as well as issues relating to social equity and the broader sustainability of alternative paths to a low carbon economy/society. It highlights the need for international support, governmental leadership, better coordinated cross-sectoral policies, improved environmental impact assessment, enhanced legal enforcement, better stakeholder engagement and increased public awareness building.

Finally, we note that this project was undertaken in parallel with a number of other projects focused on Lima-Callao's current carbon footprint and future emissions strategy . For Lima-Callao to make clear progress with its emissions, a detailed accounting methodology needs to be implemented within the city and the availability of data needs to be improved to allow a clear and consistent comparison of emissions performance across the city.

Appendices

Appendix A: Participants

A list of organisations consulted to develop the baseline is given below:

Table A1: Baseline data inputting organisations.

Organisation	Role/Involvement
SEDAPAL	Lima-Callao based water company, supplying most of Lima-Callao. Provided relevant water data
Pontifical Catholic University of Peru (PUCP)	Leading on greenhouse gas emissions in country
Universidad Nacional Agraria La Molina	Leading on water footprinting in country http://www.lamolina.edu.pe
Pacifico University	(Bruno Seminario) Provided assistance on GDP and population forecasts
MINAM	Provided relevant electricity data
UNDP	Provided assistance on reviewing the greenhouse gas baseline and suggesting additional data sources
Ministry of Environment	Provided assistance on reviewing the greenhouse gas baseline and suggesting additional data sources
PGLRM/Lima-Callao Municipality	Provided relevant solid waste and transport data
OSINERGMIN	Provided assistance on electricity data and fuel prices
Plan CC	Compared Plan CC's emission projection for Peru 2050 to ours for 2030
Huella – Servicios Ambientales	Consultancy working on carbon footprinting projects in Lima-Callao as well as La Paz and Quito
LiWa	Provided assistance on water data and scenarios. Previous detailed study of future supply and demand of water in Lima-Callao, http://www.lima-water.de/index.html
Proinversion	Government body working on public-private investment projects in Peru

We conducted a number of interviews and workshops throughout the study. A list of participants and their organisation is given below.

Table A2: Workshop participants.

Name	Role	Organisation
Dirk ten Brink	Professional	ANA
Fernando Chiock	Responsible for conservation and planning of water resources	ANA
Janet Quevedo Soldevilla	Specialist General Secretariat	ANA
Maria del Pilar Acha	Specialist General Secretariat	ANA
Nancy Tello de la Cruz	Specialist International Cooperation	ANA
Victor Guevara	Technical Secretary	Aquafondo
Peter Davis	Technical Director	ARAPER
Jaime Fernández-Baca	Climate change specialist	BID
Dante Lagatta	Energy Issues	Biopower
Luis Yamada	President of Sustainable Construction Committee	CAPECO
Alvaro Freddy Apaza Ríos	Consultant	CENERGIA
Jorge Aguinaga Diaz	General Manager	Cenergia
José Mesa Segura	Consultant	Cenergia
Denisse Cotrina	Carbon/Eco-efficiency	CER/Grupo GEA
Mariana Alegre	General Coordinator	Lima Cómo Vamos
Eduardo Neira	Specialist	Foro ciudades para la vida
Ana Acevedo	Specialist	FOVIDA
Alfonso Flórez	Manager	Fundación Transitemos
Jorge Vega	Specialist	Fundación Transitemos
Augusto Gutiérrez Zuzunaga	Project Manager	G&G/ARUP
Jimmy Mendoza	Specialist	GTU-MML
Gianina Nuñez		IFC
Inés Gutiérrez		IFC
Aditi Maheswari	Policy Officer	IFC- Climate Business Department

Dulia Araóz	**Consultant**	**IPES**
Alejandra Sota	Consultant	Libélula
Alfonso Cordova	Specialist	MINAM
Jaime A. Cabrera V.	Specialist in International Cooperation	MINAM
Julio Apaza	Specialist	MINEM- DGE
Cecilia Castro	Environmental Advisor	MML
Jenny Quijano	Engineer II	MML
Rodolfo Bracamonte	Consultant	MML
Guisselle Castillo	Climate Change Specialist	Municipalidad Metropolitana de Lima (MML)
Kibutz Agui	Specialist	Municipalidad Metropolitana de Lima (MML)
Jan Janssen	NIRAS Consultant	NIRAS
Claudia Monsalve	Director	ONCE
Lorenzo Eguren	Consultant	ONCE
Ingrid Muñoz	Technical Committee	Peru Green Building Council
Andrea Ruiz de Somocurcio	Technical Committee	Perú Green Building Council
Sebastián Dañino	Director Peru GBC	Perú Green Building Council
Carlos Rueda	Researcher	Plan CC
David Garcia	Consultant	Plan CC
Elizabeth Culqui	Consultant	Plan CC
David García	Specialist	PlanCC
Rodrigo Cabrera	Professional	PUCP
Hector Miranda	Manager	Red regenerativa
Eduardo Bauer	Planning	Sedapal
Elmer Quinteros	Specialist	SEDAPAL
Patricia Tord	Regional Coordinator	Swisscontact
Eusebio Ingol	Professor	UNALM
Christian D. León	Project LiWa Coordinator	Universidad de Stuttgart
Richard Valdivia	Specialist	URP
Gladis Macizo	Advisor	Ministerio de Vivienda-Oficina de Medio Ambiente

Finally the study was supported by a steering committee made up of a wide range of stakeholders. A list of participants is given below.

Table A3: Steering Committee representatives.

Name	Organisation	Name	Organisation
Jaime Fernandez-Baca	BID	**Sofia Hidalgo**	MML
Roberto de la Torre	CCL	**Guisselle Castillo**	MML
Mauricio Rosas	CCL	**Ricardo Alejos García**	OSINERGMIN
Oscar Chávez	CCL	**Eric Cosio Caravasi**	PUCP
Yosith Vega	CCL	**Sofia Castro**	PUCP
Mauricio Rosas	CCL	**Ivan Rodriguez**	SEDAPAL
Oscar Chavez	CCL	**Alvaro Torres**	SEDAPAL
Karinna Berrospi	Embajada Británica	**Orlando Valverde**	UNALM
Patricia Iturregui	Embajada Británica	**Cayo Ramos**	UNALM
Regina Ortega	MINAM	**Paola Hernandez Montes de Oca**	Univ. De Leeds
Mariana Alegre Escorza	Lima como vamos	**Faye McAnulla**	University of Leeds
Alfonso Cordova	MINAM	**Andy Gouldson**	University of Leeds

Appendix B: Data sources, methods and assumptions

B1 Greenhouse gases

B1.1 Baseline development

The Greenhouse Gas emissions for Lima-Callao (current and historical) were calculated in line with the Global Protocol for Community based Emissions (GPC) Guiding Principles (2014). In summary these are:

— Measurability: At a minimum, data required to perform complete emissions inventories should be readily available. – where possible we have obtained data from government departments, institutions and local universities.

— Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions. – our calculations use best available data and most realistic predictions.

— Relevance: The reported GHG emissions should reflect emissions occurring as a result of activities and consumption from within the community's geopolitical boundaries, – where possible we have gathered data for the whole of Lima-Callao.

— Completeness: All significant emissions sources included should be accounted for. – Our method does not include long-distance rail, air travel or shipping. Furthermore at present we have no data on non-electricity based industrial emissions.

— Consistency: Emissions calculations should be consistent in approach. A consistent approach has been taken. Emission factors ideally should be made Lima-Callao specific where possible.

— Transparency: Activity data, sources, emissions factors and accounting methodologies should be adequately documented and disclosed. – This report sets out the project methodology. Appendix C includes a list of key data sources. The accompanying spreadsheet includes all relevant data.

We have projected greenhouse gas emissions for the sectors we have analysed using a range of methods as summarised in the table below. More details on how we have measured and projected population and GDP are given below and individual sector projections and assumptions on their mitigation measures are given in Appendix B2.

Table B1: Methods of projection for various parts of the Lima-Callao Baseline

Activity	Projection Method	Useful Data
Population of Lima-Callao	Actual data extrapolated past 2014 using a growth factor equal to that given by the UNDP[41]. We assume that the growth rate for Peru is the same for Lima-Callao. In this case, our estimations is very near to the Minister of Economy's when they consider an intermediate scenario.	We estimate Lima-Callao's population to be 9.4million in 2014 and predict a rise to 11.2 million by 2030.
GDP	We calculated GDP per capita of Peru by dividing total GDP with population of Peru (see above box). With this, we calculated GDP of Lima-Callao by multiplying GDP per capita of Peru with the population of Lima-Callao. Our main assumption is the economic growth rate of Lima-Callao is the same as Peru[42].	We find that Lima-Callao's GDP in 2014 is predicted to be US$66.1 billion, and if recent trends continue we forecast that GDP will grow to US$135 billion by 2030. This means that the average per capita income in Lima-Callao was US$6,989 in 2014 and that with projected rates of economic and population growth we predict that this will grow to US$12,148 by 2030.
Sectoral GDP	We used elements of Lima's Regional GDP data to develop industrial and service sector growth rates for Lima-Callao. This data is used to predict the commercial sector fuel use, where limited data and other methods of projection were available.	
US$: Peruvian Soles Exchange Rate	Held constant at 2014 exchange rate.[43]	US$: PEN 1: 2.8 for 1 Jan 2014.
Waste water emissions	Downscaled from national emissions and linked to population growth. This figure is then split between industrial, commercial and residential end users based on water usage data provided by SEDAPAL.	2014 estimate 417ktCO_{2e}.
Process emissions	Based on linear extrapolation of 2nd National Communication 2000 and 2009 data and then scaled using Lima-Callao and national population ratio. Assumed only 50% of the figure as other data covers some liquid fuel use. Data held constant from 2009.	Estimates: 2014 791KtCO_{2e}; 2030 791 KtCO_{2e}.
Electricity generation	Linear projection based on figures for electrical energy generation per capita (and therefore also linked to population growth).	Estimated consumption per capita: 2014 1,729Kwh; 2030 2,666Kwh.
Electricity emission factor	Post 2014: APEC electricity projections used to calculate fuel used using constant 2014 specific fuel consumption factor (i.e. no technological improvements). 2000-2012: fuel use and emissions calculated from true data.[44]	Emission Factor Calculated 2014: 0.24tCO_{2e}/MWh; 2030: 0.28tCO_{2e}/MWh (higher proportion of gas on grid increases the overall emission factor).
Activity	**Projection Method**	**Useful Data**

Electricity consumption by sector	Exponential growth and backcasting linked to 1995-2011 sectoral consumption figures.	2014 split: 58.0% industrial; 18.4% commercial; 24.3% residential; 2.1% public lighting; 6.7% own use generation. 2014 Use: Industry 8.1TWh; Commercial 2.6TWh; Residential 3.4TWh; Public Lighting 300GWh; Own Use 944 GWh; Transmission Losses: 1.1GWh. 2030 Use: Industry 15.4TWh; Commercial 4.8TWh; Residential 5.8TWh; Public Lighting 305GWh; Own Use 1.1TWh; Transmission Losses: 2.1GWh.
Transmission losses	Held constant at 7.9% of electricity generated (2014 figure) out to 2030.	2014: 262KtCO_{2eq}; 2030: 725KtCO_{2e}.
Landfilled and composted waste	Using actual data and linear projection to 2030.	Amount produced: 2014: 3.0Mt; 2030: 5.0Mt. Related Emissions: 2014: 896KtCO_{2e} 2030: 2,299KtCO_{2e}.
Transport	Using actual data on transport distances by vehicle type 2005-2011 and applied an exponential growth factor for projecting to 2030 and backcasting to 2000.	Emissions 2014: 6,893KtCO_{2eq}; 2030: 11,165KtCO_{2e}.
Fuel prices	Actual data used for 2003 to 2013[45]. We have assumed prices have increased at 2% per annum to 2030.	2014: Petrol 2.37soles/litre Diesel 2.5137soles/litre and LPG 1.2337soles/litre. 2030: Petrol 2.4337soles/litre, Diesel 2.6637soles/litre and LPG 1.0937soles/litre.
	Electricity prices have been based on data for 2006-2010 and we have assumed a 2% increase per annum to 2030.	Average electricity prices: 2014: 9.98US cents/kwh 2030:16.55 cents/kwh.
	Natural gas prices are based on index data and actual data from OSINERG[46] and we have assumed a 2% price rise to 2030.	2014: 10.5US$/GJ; 2030: 17.4US$/TJ.

Gross Domestic Product

Using Peru's predicted GDP[47] and scaled to Lima-Callao using predicted population, our analysis has found GDP to have increased rapidly since 2000 from US$27.5 billion to an estimated US$58.3 billion by 2012, to US$135.7 billion by 2030 and the predicted rise from 2012 to 2030 is a factor of 2.3. It is predicted to continue increasing at an average annual rate of 4.80% from 2012 to 2030.

When we projected the GDP by sector[48], as can be seen from the table below, the structure of Lima Region's economy (note this is the wider region of Lima-Callao) has been changing and will continue to do so. Value added in agriculture activities will have a lower share, while industry and service sectors will continue growing. This structural change is happening also at a national level[49] , as the percentage share of industry and services are predicted to continue to grow in Peru, transforming Peru into an industrial and urban economy.

Population

For our analysis we used the population calculated by Bruno Seminario from 1990-2011[50], and then we projected with the population annual growth rate of 1.05% from the United Nations[51].

We calculate the population since 2012, multiplying the population the previous year with the factor (1+r), where r is the average annual growth rate. Then, the population of 2012 onwards is multiplied by (1+r), and we get the population of 2013, and so on. Data calculated shows Lima-Callao's population to have grown rapidly between 2000 (7.4 million inhabitants) and 2012 (9.2 million inhabitants), and we predict is likely to continue to grow to 2030 (estimated population of 11.1 million) albeit at a slightly lower rate than the previous decade[52].

Table B2: Average GDP share by sector 2001-2030 (%).

	Agriculture	Industry	Services
2001-2005	5.2%	25.0%	69.8%
2006-2010	4.6%	25.4%	70%
2011-2015	4.0%	25.8%	70.2%
2016-2020	3.5%	26.1%	70.4%
2021-2025	3.1%	26.3%	70.6%
2025-2030	2.7%	26.4%	70.9%

B1.2 Sectoral approach

This section summarises the approaches taken to measuring the baseline for each of the sectors. It also provides the key assumptions for each of the mitigation measures. Data to develop the mitigation measures has been taken from a mixture of best practice and workshop discussions (the use of workshop discussions and reasonable estimates has been used in areas where there was limited or no best practice information available).

The Energy Sector

Mitigation measures for the National Interconnected System (SEIN) grid were formulated from a combination of expert consultations, academic papers and industry data. Baseline projects for the SEIN grid were based on APEC's 2013 projections for electricity production in Peru through 2035[53] and primary data from the Committee of Economic Operation of the National Interconnected System (COES-SINAC). Mitigation scenarios were developed through consultation with stakeholders in Lima-Callao, and with guidance from COES-SINAC. All scenarios result in the same volume of electricity production in 2030. The key values used to estimate electricity scenarios are listed below:

Table B3: Key electricity sector variables.

		Operating Ratio	Thermal Efficiency	Overnight Capital Cost Per MW	Yearly Operating and Maintenance (US$/MW)	Non Fuel Cost Per MWh (US$)
Coal	Existing Standard	0.85	0.37	2,000,000	20,000	-
	Best Available Technology	0.85	0.40	3,246,000	-	-
Natural Gas	Existing Standard	0.90	0.47	800,000	15,000	-
	Best Available Technology	0.90	0.53	1,023,000	-	-
Oil	Existing Standard	0.92	-	800,000	15,000	-
	Best Available Technology	0.92	-	-	-	-
Wind	Existing Standard	0.30	-	-	-	-
	Best Available Technology	0.30	-	1,800,000	-	10
Solar PV	Existing Standard	0.25	-	-	-	-
	Best Available Technology	0.25	-	1,600,000	20,000	10
Geothermal	Existing Standard	0.75	-	-	-	-
	Best Available Technology	0.75	-	3,000,000	20,000	-

The Domestic Sector

Residential emissions are made up of electricity based emissions, waste, water and direct combustion (see industry above for an explanation of how the direct combustion element has been calculated). The electricity related emissions are based on data on energy consumption per capita in the city of Lima-Callao and subsequently scaled across electricity using sectors (including residential use) based on Peruvian data and corrected for transmission losses.

For the domestic sector we have developed two different energy efficiency scenarios for a range of measures which dictate the energy performance improvement on BAU for 2015, 2020 and 2030 as shown in the table below.

The electricity cost of the residential sector has been valued at US$700 million in 2014 and is predicted to grow to US$1550 million by 2030 (See Figure 34).

Table B4: Assumed performance standards for the two energy efficiency scenarios selected.

	Minimum energy performance (% improvement on BAU)		
	2015	2020	2025
Energy Efficiency Scenario 1	10%	20%	30%
Energy Efficiency Scenario 2	10%	25%	50%

Table B5: Key assumptions for mitigation measures in the domestic sector.

Measure	Summary and key assumptions
Green building standards for new buildings	The green building measure was assumed to apply to 20% of new residential buildings, with new average build cost US$75. Extra cost to build 5%, energy saving 25%. Buildings get built each year from 2015 to 2030. CO_2 and energy savings are calculated for 40 years after building (i.e. for 2030 build to 2070).
Adoption of energy efficiency standards for household appliances (entertainment appliances, kitchen appliances, air conditioning, washing machines, water heaters, refrigerators, air conditioning) – EE1	Energy saving of 10, 20, 30% by 2015, 2020 and 2025 respectively. Appliance costs are assumed to be 25% higher under this scenario and depending on the appliance have a life expectancy varying between 10 and 15 years.

Adoption of energy efficiency standards for household appliances (entertainment appliances, kitchen appliances, air conditioning, washing machines, water heaters, refrigerators, air conditioning) – EE2	Energy saving of 10, 25, 50% by 2015, 2020 and 2025 respectively. Appliance costs are assumed to be 50% higher under this scenario and depending on the appliance have a life expectancy varying between 10 and 15 years.
Lighting: incandescent phase out, replacement with CFLs	BAU-change 100% of all the incandescent lightbulbs to CFL. Assumes 3 lightbulbs per household, five hours use per day and incandescent lights are 100w and cost US$1 per bulb and have a lifetime of 1,000 hours. CFLs are 23w and cost US$11 per bulb and have a lifetime of 10,000 hours[54]. 50% uptake across Lima-Callao. No. of households are from Poblacion y hogares según distritos 2014, CPI (julio, 2014), market report, Nª6.
Lighting: incandescent phase out, replace with CFLs and one with LEDs by 2020	BAU-Change 100% of all the incandescent lightbulbs to CFL in 2015 (see above). Then replace one with LED in 2020. LEDs are 15w and cost US$50 and have a lifetime of 50,000 hours. 50% uptake across Lima-Callao
Behavioural change/educational programs on stand by use, washing machine use, use of fridges, etc	Cost of programme based on Water for Life programme using Lima-Callao and national population to scale to Lima-Callao. 5% of population reached per week, 5% electricity reduction per person reached.
Solar hot water program	Scenario 1: Target of 10% of organisations (38,141 by 2030) with SWH by 2030, EE1. Collector size 100ft2, installation cost US$13,400[55]. Assume displacing a water heater and that water would be heated by 30 degrees with a boiler efficiency of 70%. Solar systems have a lifetime of 30 years.
Solar photovoltaics	Scenario 1: Target of additional 10MW per year (390 organisations per year, assuming 4m^2 per household). 2.5m^2 panel operates at 1kw and produces US$2,000. 20% efficiency. Price for electricity sold back to the grid 20% higher than sale rate and assume 20% sold back, 80% displaces electricity purchased by organisation.
Apartment green roofs	Green roof construction costs average US$135 per m^2 and full coverage reduces air conditioning costs 15%. Apartment buildings are estimated to have 3 floors on average ad units to average 92.9 m^2. 10% of new buildings are included in the scenario.
Semi-detached green roofs	10% of new builds include a green wall. 15% reduction in air conditioning use; roof costs average US$90/m^2 to construct. Average apartment size.
Switch from GLP to natural gas	Connections cost US$769.2 each. GLP use in households without natural gas estimated at 180GJ per annum. Household natural gas use post connection estimate at 255.60GJ. 304,294 connections added per year through 2019.
Installing AMI Meters	Meter cost, US$50 per household. Electricity use reduction post meter installation, 2.5%. Portion of electricity purchase that previously was stolen, 75%.[56, 57, 58]

The Commercial Building Sector

Commercial emissions are made up of electricity based emissions for the commercial sector, an estimate of direct fugitive emissions and public lighting and water related emissions for the commercial and government sectors (both process and electricity related emissions). The electricity data is based on energy consumption per capita in the city of Lima-Callao[59] and subsequently scaled across electricity using sectors (including commercial and public lighting use) based on Peruvian data[60] and corrected for transmission losses.

The cost of the commercial sector has been valued at US$180m in 2000 and is predicted to grow to US$1,080m by 2030.

In order to develop mitigation measures for the electricity emissions associated with the commercial sector we used a series of guides by MINAM for the public sector[61], malls[62], commercial sector[63] and hospitals[64] which detail possible emission reductions and payback periods for each of these sub-sectors. For non-electricity related emissions (those related to the use of petrol, diesel, LPG and natural gas in the commercial sector) we used the savings identified in the commercial sector guide (ibid) and applied them to all of the non-electricity related emissions (excepting public lighting and water use). The green building measure was assumed to apply to 20% of new commercial buildings, with new commercial buildings based on figures from 2009 to 2011[65] and an average build cost of US$2,000/$m^2$[66]. The additional build cost was assumed to be 5%[67] and energy saving estimated at 25%[68]. For the street lighting measure we assumed 50% of street lights were converted to LED and that LEDs save 60% of energy compared to incandescent lights and had an installation cost of US$562.

Table B6: Key assumptions for mitigation measures in the commercial sector.

Measure	Summary and key assumptions
Green building certifications – Commercial Sector	20% of new buildings are built with green certification. Average build cost US$2,000/m². Extra cost to build 5%, energy saving 20%. Buildings get built each year from 2015 to 2030. CO_2 and energy savings are calculated to 2050 for all buildings – this is reflected in total NPV and total CO_2 figures.
Public sector electricity retrofit program	Electricity: Makes up 7% of commercial electricity; 15% saving possible with payback of 2 years.
Commercial electricity retrofit program	Electricity: Makes up rest of commercial electricity (61%) – after public sector, malls and hospital measures; 8.5% saving possible with payback of 3 years.
Commercial thermal retrofit	All thermal emissions (petrol, diesel, GLP, natural gas) have the same reduction potential as that for commercial sector report i.e. payback 3 years and average savings of 13%
Street lighting – conversion to LEDs	Half of estimated 2015 street lights switched to LED (375,561). Street light composition same as 2005 data. Average lightbulb use of 12 hours per day; Lightbulb wattage of 60% 70W; 30% 150W and 10% 250W for incandescent bulbs. Assumes LEDs save 60% energy. Installation cost 562US$.
Malls electricity retrofit program	Electricity: Makes up 28% of commercial electricity; 6.5% saving possible with payback of 3 years.
Led traffic lights	6,000 new light emitting diode (LED) traffic lights across Lima-Callao. LEDs 90% more efficient than incandescent lights, and can last over 10 years. Reduce the city's energy use by 5,200 megawatt hours, and save over 4.5 million soles – approx. US$1.5 million annually – and reduce more than 2,500 tons of carbon dioxide. We've assumed programme takes 5 years to fit and each retrofit costs US$500. Source: Clinton Foundation (http://buildyourworld.clintonfoundation.org/answer.php?c=1&an=10&lang=en).
Hospital electricity retrofit program	Electricity: Makes up 3.7% of commercial electricity; 7.5% saving possible with payback of 3 years.
Solar PV – commercial sector	Target of additional 10MW per year (390 organisations per year, assuming 4m² per household). 2.5m² panel operates at 1kw and costs US$2,000. 20% efficiency. Price for electricity sold back to the grid 20% higher than sale rate and assume 20% sold back, 80% displaces electricity purchased by organisation.
Solar hot water – commercial sector	Target of 10% of organisations (38,145 by 2030) by 2030, saves 200KwH/month/system, installation cost US$2,500.[69] Assume displacing electricity of 200kwh/month/system. Solar systems have a lifetime of 20 years.
Advanced metering installation	Conversion of 75% of commercial meters to smart meters by 2030. Cost per meter, US$350[70].

The Industrial Sector

Industrial data was particularly difficult to reconcile at the city level. Our baseline for emissions is therefore made up of a mixture of a number of different activities. These comprise:

— Electricity use. This data is split into industrial use, transmission losses and industry own use for this sector. It is based on energy consumption per capita in the city of Lima-Callao and subsequently scaled across electricity using sectors (including industry electricity use) based on Peruvian data and corrected for transmission losses[71].

— Natural gas[72], diesel[73] and petrol emissions are based on data from OSINERGMIN and MINEM. As only one year of data was available this data was scaled to industrial electricity use within the city for which data was available from 2000-2011.

— Industrial process related emissions. These represent the emissions generated in the production and transformation of mineral, chemical and metal products. Data on process emissions was taken from the National inventories provided in 2000 and 2009. The data was downscaled by using population data and a trend established between the two years. The data was held constant after 2009. Some process related data was found available at the city level including the use in industry of natural gas, diesel and petrol (see above point). Emissions relating to other process related emissions, such as cement production and use of other fossil fuels, was not found at the city level, therefore we have halved the calculated emissions to represent the missing data based on the likely split of the process emissions between these different sources.

For the mitigation options for the industrial sector we found limited availability of data on greenhouse gas emissions or energy use relating to individual sectors (e.g. cement production, metals, etc.) of the industrial sector of Lima-Callao. We therefore used information from the Intergovernmental Panel on Climate Change for the 7 most important sectors in terms of greenhouse gas emissions in developing nations under the B2 Climate Change Scenario. These sectors were: metals; primary aluminium; cement; ethylene; ammonia; petroleum refining; and; pulp & paper. In addition we included a sector for electricity conservation in all other industrial sub-sectors. We took data on production levels, likely greenhouse gas intensity, mitigation potential and mitigation cost from the IPCC report[74]. As these are the key sectors for emission reduction in the industrial sector as identified by IPCC we applied this data to Lima-Callao assuming the 7 key sectors made up 50% of total industrial emissions and apportioned emissions according to the national GDP for equivalent industry sub-sectors[75]. In addition we removed aluminium and pulp & paper from our sectors as we did not consider them to be prevalent in Lima-Callao based on our expert groups. We were then able to use the IPCC data to produce data on likely emission savings and costs for Lima-Callao.

The Transportation Sector

To calculate the CO_2 emissions and fuel use IPCC distance-based methodology was used[76]. We included both the first Metro line[77] and Euro IV standards within the baseline. Activity data was gathered from the Plan Maestro 2004 and Plan Maestro 2012[78]. Average travel times and speeds can be found in the table below.

In terms of the emission factors, here it is acknowledged that they depend on fuel characteristics for geographical regions, but without customised factors for Lima-Callao we decided to use different sources, depending on fuel type (petrol[79], DEFRA's conversion factors for gas[80], diesel and KWh). The table below shows the fuel efficiencies used by type of vehicle.

Table B7: Key variable data used in the transport sector.

Average travel time (mins)	
Walking	12.4
Motorcycle	10.8
Car	24.9
Bus	44.7
Others	29.8
All models	31.4

Travel speed km/hr	
2004	33.4
2010	22.7
2015	17.9
2020	16.4
2025	17.3
Metropolitano	23.5
Metro line	33

Table B8: Data used for different transport modes in the transport sector

Type of vehicle	Type of fuel used	Km/litre	gCO_{2e}/km	Emissions per passenger Km (gCO_{2e}/km)	Average occupancy rate (persons per vehicle)
Motorcycle and mototaxi	Petrol	26.67	87	76	1.14
Car (petrol)	Petrol	10.31	224	117	1.91
Car (CNG)	CNG	11.01	180	94	1.91
Private others	Petrol	10.31	224	145	1.55
Taxi (petrol)	Petrol	9.50	243	228	1.07
Taxi (diesel)	Diesel	13.20	202	188	1.07
Taxi (CNG)	CNG	8.10	180	168	1.07
Combi (petrol)	Petrol	2.97	484	25	19.50
Combi (diesel)	Diesel	2.85	484	25	19.50
Combi (CNG)	CNG	4.81	484	25	19.50
Microbus or bus (petrol)	Petrol	3.20	1,400	23	61.75
Microbus or bus (diesel)	Diesel	3.34	1,500	25	61.75
Microbus or bus (CNG)	CNG	3.71	1,500	393	6
New BRT Euro 6	CNG	1.67	820	8.2	100
BRT (CNG)	CNG	1.67	393	3.93	100
Metro	Electricity		63.17	0.05	1200
New car	Petrol	15.8	146	77	1.91

Sources: CDM Project Bus Rapid Transit (BRT) TransMilenio 2nd Crediting Period. Document prepared by Jurg M. Grutter, Version 08.06.2012.; MINEM (2009) Plan referencial en el uso eficiente de la energía 2009-2018. p. 77; Lima cómo vamos (2010). Evaluando la gestión en Lima al 2010. Primer informe de resultados sobre la calidad de vida; http://www.mantruckandbus.no/no/presse_og_media/press_details_230082.html; http://www.skyscrapercity.com/showthread.php?t=1167911&page=214; Shigemi et al. (2013) Better cars or older cars?: Assessing CO_2 emission reduction potential of passenger vehicle replacement programs. Global Environmental Change, 23:1807-1818; US-EPA 2001 Guide; Perfil Nama transport Peru; New conversion factors published by Defra 2013.

Mitigation measures

Increase the bus rapid transit (BRT)

This option aims to build another BRT system. To calculate emissions we considered that 46% of all trips to work were done by some kind of motorised vehicle. Using the share of motorised private vehicles[81], we consider that 23% of those trips were done by a motorised private vehicle. We assume that with the new BRT, 10% of the trips to work that were done by a car now are done by BRT. We assume that the BRT buses have a low-emission vehicle technology (Euro VI), CNG, so the emission factor is 94 gCO_2 per Km[82] . As recommended by the UNFCCC, we considered the amount of CO_2 emitted while constructing this project –the leakage. We consider 125.37 Kt CO_2 split on one third per year, as leakages from the project due to diverting of traffic, the construction of the system etc.[83]. In terms of the costs, we consider a capital cost of US$262 million, which is the cost that the Institute for Transportation and Development Policy reported as the cost the 1st BRT system in Lima-Callao[84], and we consider the fuel cost of running the system. To calculate the cash inflow, we projected the current price of the Metropolitano (S/.2 , ~US$0.70) and a 75% capacity rate on the BRT.

Build the Metro line 2

To build a new metro line (line 2). We assume that the project begins construction in 2015 finishes in 2020. The line will carry 647,000 journeys/day and 2% passenger growth per year. We estimate emissions based on 0.56 KWh per passenger km[85]. We consider leakages from this project of around 675 $KtCO_2$ distributed across the 62 months of construction works[86]. According Proinversion, construction, operation and maintenance of 35 kms of the Metro line is estimated in US$5.701 billion[87]. We considered operational costs of US$0.07 per passenger[88]. We assume a standard price of ~S/.2.

Enforcement of light vehicle Emissions Standards

The current Lima-Callao car fleet emits 224 gCO_{2e} per kilometre, with a fuel efficiency of 9.7 liters per 100 kms. We consider that manufacturers and importers will have a fleet of new cars emitting 130 g CO_2 per Km travelled[89], and a penetration rate of 5% starting in 2015[90]. As new vehicles are more likely to be driven further, a 10% rebound effect in distance travelled in assumed[91].

Promotion of hybrid private vehicles

A US$2000 subsidy program is suggested to increase hybrid uptate. We assume that a hybrid vehicle consumes 34 KWh/100 miles[92], and an average price of US$17,187. We use a conversion factor of 130 gCO_{2e} per km[93]. A 10% rebound effect on vehicle distance travelled is assumed and a 5% penetration rate.

Retrofit of private vehicles to CNG

To convert 25% of the car's fleet powered by petrol to gas in 5 years. The penetration rate would be 5% each year. The price of the compressed natural gas conversion kits range according the type of motor, but we consider an average of US$2,500 per retrofitting kit[94].

Convert of all taxis to CNG

We assume that taxis currently have the following fuel distribution: 16.81% petrol, 9.20% Diesel and 73.99% gas[95]. This mitigation option proposes to retrofit the taxis that run by petrol and to scrap the taxis run by diesel replacing them with new gas taxis. For the part of retrofitting the taxis (around 47,000 taxis), we considered a similar methodology and the same parameters of the price of the retrofit than the above option. We consider that taxis with gas have a fuel efficiency of 8.10 Km per litre[96] and an emission factor of 58 gCO_2 per kilometre. Following Shigemi[97], we assume 580 gCO_{2e} per vehicle disposed of. In terms of the costs, we consider that the cost to scrap a vehicle is US$128, and an average price of US$14,000 for a taxi. A 10% rebound effect on distance travelled is assumed.

Promotion of Teleworking

To reduce the number of people and vehicles on the street, this option encourages working from home 1 day per week. According to IEP[98], the penetration rate in Lima-Callao of teleworking could be 26%[99]. After consultation we assume that 5%, or 19% of this potential, could be achieved over the time period we are considering. 23% of those trips could have been made by private transportation and 77% by public transportation[100]. We consider an emission factor for the former as 224 gCO_{2e} and for the latter 630 gCO_{2e}. In terms of the costs, we consider a TV campaign of US$600,000 per year.

Cycleway development

This option proposes not only constructing cycle ways, but also aims to create the necessary infrastructure to encourage cycling in the city. It considers the construction of 300 kms of cycle ways in 5 years to have similar levels as in Bogotá [101]. We assume that with the current infrastructure (118 kms) there are 77,000 trips per day[102]. We assume that 1km of cycle way could attract 653 new trips per day[103]. We propose to build 180 km of cycle ways, 20% each year for 5 years, parking lots, cycleway maintenance, and informative TV and radio campaigns. We assume that just the people that currently use public transport will use the bike development at first. However, we assume a behavioural shift of people that use private motorised vehicles towards cycling (5%/yr, up to 30%) after 5 years as a consequence of the infrastructure and campaings. We assume costs of US$2,368,600 plus the savings made by avoiding the use of public transport and cars.

Replace combis with omnibuses

We propose the scrapping of 50% of the total combis and replacing them with omnibuses in 5 years 10% every year. We assume that combis have an emission factor of 1,035 gCO_2 per Km[104], contrasting with a new gas bus of 128 gCO_2 per Km. We assume similar figures of the cost and CO_2 emissions of scrapping the combis as the option of "scrapping old cars" (US$128, 58 gCO_{2e} per vehicle). We consider an average price of a new omnibus (Euro IV) of US$670,000 plus their fuel costs (3.61 Km/Lt) and the savings made of fuel by avoiding the use of combis.

Scrapping old cars and buy new hybrid cars

This mitigation option proposes to scrap 15% of the cars that are more than 20 years old in 2 years. We assume that those cars are replaced for small and high efficient hybrid cars. To calculate the emissions, we consider two leakages: the emissions associated with the disposal of old cars (580 gCO_{2e} per vehicle)[105]. The second is the rebound effect, where it is likely that new vehicles would travel longer distances, so we discounted 10% of the total savings in the first year and 20% from the second year to reflect this issue (ibid). In terms of the costs, we consider an average price of US$17,187 for a hybrid car. We assume that a hybrid vehicle consume 34 KWh per 100 miles and 2.6 gallons per 100 miles[106].

Cordon tolls for petrol and diesel private cars

This option aims to reduce the traffic in the city centre of Lima-Callao by building a cordon toll that private cars run by petrol will pay to drive in this area. We propose payment exempts: hybrid private cars, combis, omnibuses, microbuses, and taxis. We assume that 51% of private cars are used to go to the city centre [107]. We also assume that in 2004 the number of travels in and to the city centre in motor mode were 5,286,000 and has remained the same[108]. We consider that the potential percentage of vehicle reduction is 21% by implementing a cordon toll [109]. We suppose that those travels that will be reduced in cars will be now done by omnibus run by diesel[110]. We assume a toll like the one Lima-Callao has for the highway US$1.42 (S/.4). We assume similar figures as the London initial costs for setting up the scheme US$265 million, with an annual operating cost of about US$180 million[111]. Following other experiences, we also propose here that the money that will be get from the congestion charge will be spend on improvements of the public transport. In that way, equity for poor people will be improved and this would be a progressive rather than regressive scheme[112].

Traffic Management Investments

Rapid population growth in Lima-Callao over the past decade has outpaced development of Lima-Callao's road network. In this mitigation option a number of road efficiency measures are considered as a single mitigation option. Cost is US$700 million and the build time is 5 years. The reduction in travel times, including a rebound effect, is 20% upon completion of the project. Construction is anticipated in increase travel times 5%. The rebound effect long term is estimated to be 15% and the road efficiency is anticipated to increase 30%.

Waste Sector

To calculate the waste baseline IPCC methodology was followed[113]. Waste generation data was obtained from Lima-Callao Municipality[114] and comprises domestic, commercial and public waste. Data on waste composition was gathered from various sources: 2010-2011[115]; 2008[116]; 2005[117]; 2004[118]. We used the waste production trends to make the forecast up to 2030 -a decadal waste production growth rate of 2%. We assume that after the year 2000, 93% of all generated waste is landfilled. The remainder is composted. We take into account both the Ancon, Huaycoloro and Modelo Callao methane saving projects that are already in place. The following table shows the waste composition used for estimating landfill greenhouse gas emissions.

Table B9: Waste share by type (%)

Type of waste	Share
Food	46.10%
Garden waste	0.80%
Paper	14.20%
Wood	0.80%
Textiles	0.00%
Industrial Waste	3.00%

Table B10: Shares of Lima-Callao's landfills, ownership and prices.

Landfill	Location	Ownership	Proportion of the total	Ton/month	Cost US$
Casren	Ancón	Private	20.5%	41,055	3.4
Huaycoloro	Huarochirí	Private	42.6%	85,319	4.5
Portillo Grande	Lurín	Public	20.0%	40,026	3.7
Zapallal	Carabayllo	Public	2.5%	5,107	3.7
Modelo Callao	Ventanilla	Public	14.4%	28,825	5.3
Total/Averages			**100%**	**200,332**	**4.12**

Source: Data taken from MINAM 2007, and IPES 2005

Mitigation measures

The mitigation measures identified are as follow:

Recycling Plant – 261kt of paper, wood and industrial waste

This measure aims to build 3 recycling facilities with a combined capacity to process 261,000 tonnes per year. We assume that for each ton of waste 26% can be recycled[119]. The average price of recycled material in Lima-Callao is US$178.57 per ton[120]. The project assumes a capital cost of US$25,395,000, which includes 1.5 has of land (US$554 per hectare), machinery, equipment and a value of infrastructure of US$465,000 and a variable cost of US$25 per tonne[121].

Waste Windrow Composting Program

This programme aims to build 500 tonne per day composting plant at cost of US$5 million. A similar programme in Ecuador has taken place as part of the CDM mechanism. We adapted the parameters to be applied in Lima-Callao and followed the same methodology. We assume that the plant has the capacity to process 100,000 tonnes of waste per year by 2030. We consider that 35% of the waste can be turned into compost with an estimated production of 13,200 tonnes of compost per year. The life span is 18 years. In contrast to current prices (~S/.10 per 35 Kg Source: La Molina), we took a conservative price of .5 soles per Kg of compost.

Waste In-Vessel Composting Program

This option involves producing compost out of waste. Considering the volume of waste produced in Lima-Callao, 5 plants could be built with a maximum capacity by 2030 of 63,000 tonnes of waste per year, and an annual capacity increase of 0.05%. We followed the methodology and similar parameters as a CDM applied in Bolivia[122]. The percentage of waste that could generate compost is similar to the above option (35%), and the same applies to the price of compost (US$0.07 /ton). This method, however, considers a higher production of 23,760 tonnes of compost per year. The costs per plant are also higher. The initial costs are US$3,500,000, while maintenance costs are of US$1,217,820 per year.

Landfill Gas Capture for energy generation (LFGTE)

Huaycoloro is one of Lima-Callao's landfills, which already houses gas capturing and combustion facility to produce energy[123]. We propose to install a similar project in Portillo Grande, a municipal landfill that shares similar characteristics as Huaycoloro. We assume that Portillo Grande has a methane content of 0.5, and 20% of landfilled waste can be used for this measure. The project will capture landfill gas and transform it into energy, while the LFG that is not fed into the generator will be flared. We assume an initial gross capacity of 5.74 MW, with an annual power production of 42,101 MWh. The plant's capacity factor to capture methane is 0.9%, and will have a recovery potential of 3.3%. We assume that the electricity consumption from the grid for the project is ~362 MWh/year, emitting 471 tCO_{2e} per year with an electricity emission factor of 1.3 tCO_{2e}/MWh. The nature of this project allows generating CERs in the context of the CDM mechanism, which could be used to finance the project. As this mechanism is on standby, we do not calculate here the CERs).

Landfill Gas flaring

We propose to install 2 projects that will flare the gas produced in the landfills. We applied the same methodology and similar figures as the CDM project called: Ancon Ecomethane Landfill Gas[124].

Waste water

Baseline: Wastewater is downscaled from national data using population levels. This was also supplemented with information from SEDAPAL and waste water processing plant data.

Mitigation: Taboada Sluge to Energy Incinerator

Incineration of waste from the newly completed Taboada waste water treatment facility can both eliminate methane emissions and generate energy for the waste water treatment facility. For a facility to incinerate 1200 tons sludge per day capital costs are estimated at US$40 million and operation and maintenance costs are estimated at US$3.9 million per annum.[125, 126]

B2 Water

Water Supply

Lima-Callao receives less than 10mm of rain each year, making the city among the world's largest municipal areas situated in an arid region. As a result, Lima-Callao is entirely dependent for water resources on the Rimac, Chillon and Lurin rivers, whose watershed's originate in the Andes mountains.

Of these rivers, the Rimac provides more than 75% of all water used in Lima-Callao , including both surface waters and withdrawals from the Rimac aquifer. Water from the Mark I, III IV and V trans-Andean tunnels supplement the Rimac's natural flow with water from the Marcapomacocha watershed and an additional Andean tunnel, Mark II, is planned for for completion by 2040. The Chillon provides approximately 15-20% of water to Lima-Callao, both from surface waters and from the Chillon aquifer. The Chillon is also an important resources for agricultre in the Chillon valley, the most significant agricultural lands surrounding Lima-Callao. Lastly, the Rimac contributes approximately 5% of water resources to Lima-Callao, exclusively through extraction from the Lurín aquifer.

A challenge for the estimation of water supply and demand are an estimated 2,000 informal wells tapping groundwater across the three aquifers. SEDAPAL estimates that the proportion of informal groundwater use accounts for 20% of extaction from the Chillon, 30-35% from the Rimac and 20% from the Lurin aquifers. These percentages are calculated from the difference between actual and estimated aquifer levels and suggest that informal wells supply approximately 1.125 m^3/s.[127]

In calculating our water baseline water supply is based on data provided by SEDAPAL and comprises supply available from relevant rivers, groundwater, underground lakes and the Trans-Andean pipeline. Under the baseline scenario, water supply between 2014 and 2030 includes all existing water supply infrastructure and the soon to be completed Mark IV – Huascacocha (2.63 m^3/s).

Water Demand

We found water use in Lima-Callao has increased dramatically, from 22m^3/s in 2000 to 28 m^3/s in 2014. This growth is largely a function of a growing population as per capita usage rises from 258 litres/per capita/day in 2000 to 262 litres/per capita/day in 2014.

The domestic sector accounts for approximately 60% of all use while the commercial (6%), industrial (1%) and government (4%) sectors, collectively account for approximately 11% of consumption. Losses and informal use account for approximately 28% with losses accounting for 25% and informal use accounting for approximately 3% of usage.

Lima-Callao has seen significant gains in the proportion of the population with access to water resources from SEDAPAL and in the proportion of water resources being metered. From 2000, the proportion of serviced residents increased from approximately 75% in 2000 to 86% in 2014 even as the number of residents in the SEDAPAL service area grew 25%. Even more strikingly, the proportion of Lima-Callao's population that with metered water grew from 47% in 2000 to 70% in 2014. As a proportion of residents with service there was an increase from 62.8% in 2000 to 81.5% in 2014, demonstrating that metering has increased both within the existing service area and among new users.

Rising per capita consumption and a rising population, combined with a rising water prices have underpinned a dramatic increase in Lima-Callao's total and per capita water bills. Across Lima-Callao the water bill has risen approximately 300%, while on a per capita basis costs have more than doubled. The increase in total bills have outpaced per capita bills as a result of population growth outpacing the growth of per capita water usage by a wide margin.

One of the most significant effects of rising water prices and per capita usage has been the impact on domestic users, who account for approximately 60% of all water use. Using an average family size of 5, and converting expenditure to 2013 US$, average household annual water bills have risen from US$ 61 to US$112.

Total waste water treated has risen from approximately 4% to 18.5% in 2014, however the volume of wastewater collected has risen from approximately 16 m^3/s to 18 m^3/s. This implies that total waste water collected, but not treated, remained at approximately 16m^3/s in 2014.

A rising tariff for wastewater collection, coupled with rising waste water production, lead to rising expenditure on wastewater collection. In 2000 we estimate that total expenditure on wastewater fees amount to 924 million PEN while in 2014 that number more than doubled to 2206 million PEN. Similarly, per capital expenditure only rose from 125 to 238 PEN per annum.

In calculating our baseline water demand was calculated with the methodology outlined in the PMO 2005 and 2009, and is based on projections of population, per capita water usage by sector, leakage, metering coverage and water infrastructure coverage. In summary, water demand has the following components:

— Domestic demand: demand from households (60% of total city demand).

— Non domestic demand: industrial demand, commercial and public, including the irrigation of parks and agricultural demand (12% of total city demand)[128].

— Leaks and system losses: composed of various components that result in the need for increased water production (24% of city demand).

— Informal Use: Unmetered water use not accounted for by system losses (4% of total city demand)

Figure B1: Projected water balance for Lima-Callao, 2000-2030 (m^3/s).

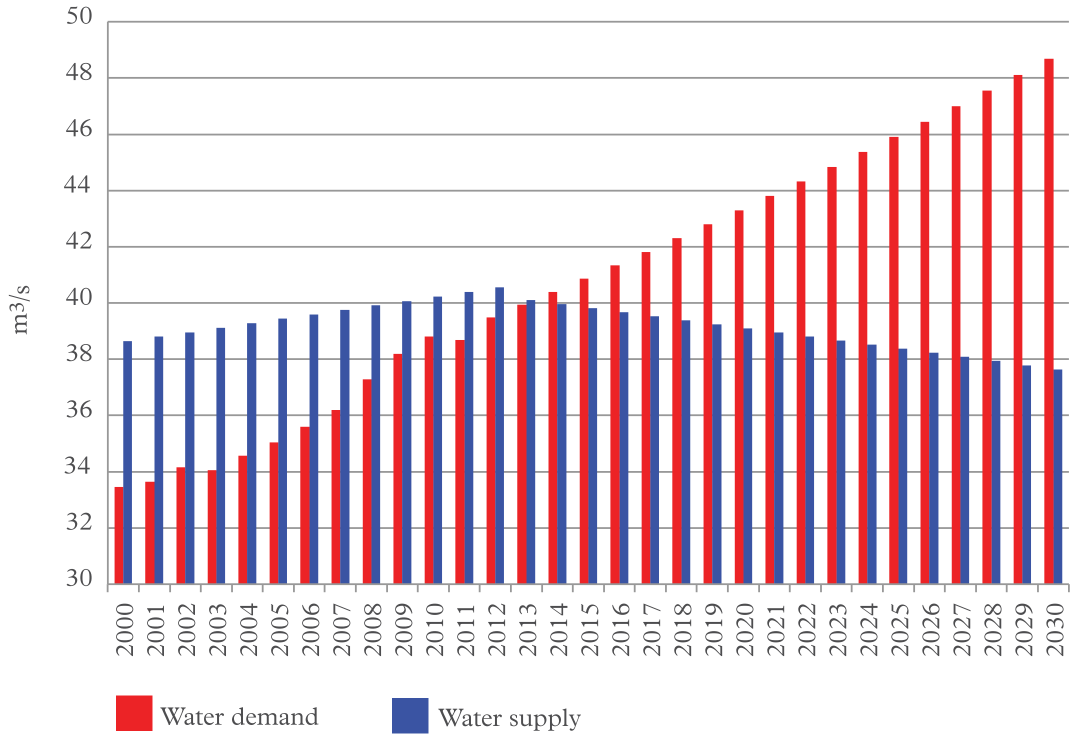


Table B11: Key assumptions for mitigation measures in the water sector.

Measure	Summary and key assumptions
Water conservation education	Based on the 'Culture of Water' Campaign developed by the World Bank, Grupo Agua and the Radio Broadcoaster RPP, a US$900,000 radio broadcast program is assumed to reach 20% of the Lima-Callao population on a weekly basis and produce a 10% reduction in water usage per person reached.[129]
12% or 15% increase in the domestic, commercial and industrial water tariffs	12% and 15% increases in the average domestic tariff were determined as feasible through consultation. Price elasticities of demand for the domestic, commercial and industrial sector of, -0.25, -0.17 and -1.11 are drawn from a survey of academic literature.[130, 131, 132, 133]
Aquifer recharge	Capital costs of US$152 million, operational costs of 20 million, build time of 2 years, increased supply of $1m^3/s$.
Condensate catchers	150 litres for every 10 square meters of Atrapaniebla at a cost of 500 soles. Operating costs are assumed to be 10% of capital cost. 3,500 are operational by 2030.
Rehabilitation of Primary Network	Rebuilding sections of the primary distribution network at a cost of 33.2 million USD. $5m^3/s$ in savings achieved by 2030.
Basin wells of River Chancay (2040)	Water extraction from the Chancay River aquifer located north of Lima-Callao. US$2 million capital costs, US$1.1 million in operational costs, $1.5m^3/s$ by 2030. 5 year build time.
Rio Chillon Reservoir	Damming the River Chillon to improve year round water availability. US$45 million capital cost, operational cost of US$.45 million per year, 5 year build time, 2.65 m^3/s by 2030.
Pomacocha - Rio Blanco	Construction of reservoirs associated with the river Yali to increase storage capacity and water availability to Lima-Callao via the Rimac and the trans-Andean Mark II tunnel. US$216 million capital cost, operational cost of US$4.32 million per year, build time 5 years, 5 m^3/s.
Desalination of the sea water of the South Sea	A reverse osmosis desalination plant. Capital cost of US$149 million, operational cost of US$14.9 million, 5 year build time, $1.5m^3/s$
Damming of the Casacancha in conjunction with Mark III	Improvements to the Casacancha Reservoir. Capital costs of US$45.49 million, operational costs of US$0.91 million, $1.8m^3/s$
Extension of Graton Tunnel	Extension of the Graton Tunnel. Capital cost: US$106.33 million, operational costs: US$2.12 million per year in operational costs, 5 year build time, $1.5m^3/s$
Autisha Reservoir	Improvements to the Autisha Canal and Reservoir. Capital cost of US$1.2 million, operational costs of 0.33million per year, build time of 5 years, 1.2 m^3/s.
Aquifer recharge for Lurin River	Construction of a reservoir to improve drought regulation. US$52 million in capital costs, US$8 million in operational costs,5 year build time, $.4m^3/s$

Measure	Summary and key assumptions
Rechannelling Rimac River	Bypassing the area of greatest contamination in the Rimac, thereby reducing treatment costs and water losses. Potential for 48 MW of electricity generation. US$135.43 in capital costs, US$2.71 million in operational costs per year, 5 year build time, 2.5m^3/s.
100% metering of serviced units by 2020	Expansion of the metering network to cover ~200,000 individuals in 2015 with service but without a meter by 2030. Cost of meter and installation US$435. Reduction in water usage upon receiving a meter assumed to be 11%.[134]
Low flow bathroom faucet (50% deployment)	Cost per unit, US$90. Water savings, 25%. 50% deployment across Lima-Callao. 15 year lifetime.
Low flow shower (50% deployment)	Cost per unit, US$150. Water savings, 40%. 50% deployment across Lima-Callao. 15 year lifetime.
Low flow toilet (50% deployment)	Cost per unit, US$300. Water savings, 50%. 50% deployment across Lima-Callao. 15 year lifetime.
Low flow kitchen faucet (50% deployment)	Cost per unit, US$120. Water savings, 15%. 50% deployment across Lima-Callao. 15 year lifetime.
High efficiency dishwasher (25% deployment)	Cost per unit, US$500. Water savings, 20%. 50% deployment across Lima-Callao. 15 year lifetime.
High efficiency washing machine (25% deployment)	Cost per unit, US$525. Water savings, 15%. 10% deployment across Lima-Callao. 15 year lifetime.
Domestic greywater toilets (100,000 by 2030)	Capital cost US$300, water reduction index 9%[135], 100,000 by 2030. 15 year lifetime.
Residential greywater retrofit (100,000 by 2030)	Average capital cost, US$1,685, water reduction index 35%. 50,000 retrofits by 2030.
Commercial greywater retrofit (25,000 by 2030)	Capital costs of US$660, water reduction index 10%. 25,000 retrofits by 2030.
Domestic green building (25% of new builds 2015-2030)	Incremental capital cost of US$500, water savings of 40%. 25% of new builds 2015-2030.[136]
Commercial green buildings (25% of new builds 2015-2030)	Incremental capital cost of US$500, water savings of 20%. 25% of new builds 2015-2030.[137]
Domestic green buildings (25% of new builds 2015-2030)	Incremental capital cost of $500, water savings of 40%. 25% of new builds 2015-2030.[138]

Appendix C:

League table of the most cost effective measures in Lima-Callao (NPV in US$/$tCO_{2e}$)

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Residential	Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections)	205.04	-3,300.71	-9,241.98	676.79	575.75	138.84	-2,881	4.15
Transportation	Teleworking campaign	110.99	-2,380.29	-6,664.82	264.18	40.45	7.65	34,305	5.29
Transportation	Petrol taxis CNG retrofit	837.94	-1,836.99	-5,143.58	1,539.29	122.88	123.25	273,112	1.00
Transportation	Replacing Combis with Omnibuses	5,485.22	-1,735.60	-4,859.68	9,520.16	372.14	574.11	79,038	0.65
Commercial	Green building standards - commercial buildings	450.63	-1,103.69	-3,090.32	497.35	91.98	60.10	160,239	1.53
Transportation	Scrapping cars >20 years old for petrol cars	557.45	-1,075.93	-3,012.60	599.78	1,030.10	116.82	15,756	8.82
Transportation	Scrapping cars >20 years old for hybrid cars	683.01	-1,072.65	-3,003.43	732.63	1,471.57	157.34	19,283	9.35
Commercial	Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings	951.16	-861.69	-2,412.74	819.61	139.70	186.86	286,021	0.75
Transportation	CNG cars refrofit	559.88	-755.01	-2,114.02	422.72	150.83	58.57	51,765	7.22
Transportation	Development of cycle lanes	100.84	-599.83	-1,679.51	60.49	42.08	5.27	33,626	7.98
Commercial	Commercial sector electricity retrofit programme	352.27	-555.30	-1,554.85	195.62	44.41	36.76	244,728	1.21
Commercial	Public sector electricity retrofit programme	90.25	-483.89	-1,354.89	43.67	6.16	7.62	50,739	0.81
Residential	High efficiency (EE1) water heaters	180.52	-437.42	-1,224.78	78.97	37.45	15.54	88,606	2.41
Residential	Incandescent lighting phase out	2,408.59	-378.39	-1,059.50	673.72	41.17	107.89	615,088	0.38
Commercial	Street lighting - conversion to LEDs	294.27	-361.48	-1,012.14	106.37	182.97	14.02	7,369	13.05
Residential	Electricity conservation education	49.21	-309.76	-867.34	15.24	3.08	2.54	14,465	1.21
Residential	Installing advanced metering infrastructure - domestic (75% deployment)	438.76	-282.36	-790.61	123.89	58.57	50.80	220,827	1.15
Residential	Incandescent lighting phase out and 50% LED by 2020	4,268.31	-237.12	-663.93	738.67	103.54	126.57	721,596	0.82
Residential	High efficiency (EE2) water heaters	151.74	-229.99	-643.97	34.90	62.95	13.06	74,480	4.82
Residential	Solar hot water 5% by 2030 (BAU)	296.44	-220.77	-618.16	133.58	42.36	22.59	128,772	1.88
Residential	Solar hot water 10% by 2030 (BAU)	592.88	-220.77	-618.16	267.16	84.71	45.17	257,544	1.88

NB: Those measures highlighted overlap with other measures which have been identified to be more cost effective. Figures in red are negative.

Appendix C Continued

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Transportation	Bus Rapid Transit	1,779.80	-205.62	-575.73	365.96	355.57	40.64	545,617	8.75
Commercial	Malls sector electricity retrofit programme	352.27	-203.93	-571.01	71.84	16.34	13.49	76,895	1.21
Residential	Solar hot water 5% by 2030 (EE1)	234.61	-203.23	-569.05	95.03	42.36	17.05	97,210	2.48
Residential	Solar hot water 10% by 2030 (EE1)	469.21	-203.23	-569.05	190.06	84.71	34.10	194,421	2.48
Residential	Solar hot water 5% by 2030 (EE2)	202.01	-189.28	-530.00	72.95	42.36	13.42	76,508	3.16
Residential	Solar hot water 10% by 2030 (EE2)	404.02	-189.28	-530.00	145.89	84.71	26.84	153,016	3.16
Industry	Installing advanced metering infrastructure - industrial (75% deployment)	1,121.05	-186.02	-520.85	208.54	7.20	59.03	578,841	0.12
Industry	Petroleum refining sector carbon reduction programme	421.10	-179.46	-502.49	75.57	13.52	0.95	957,774	14.16
Commercial	Solar PV for commercial sector (with FIT)	56.50	-174.27	-487.97	9.85	13.55	2.72	17,520	4.97
Residential	High efficiency (EE1) refrigerator	1,142.37	-162.68	-455.51	185.84	552.34	98.89	563,821	5.59
Commercial	Hospital electricity retrofit programme	55.51	-155.39	-435.10	8.63	5.30	2.09	13,918	2.54
Transportation	Congestions tolls for petrol and diesel private cars	6,860.38	-153.50	-429.81	1,053.10	265.00	130.66	1,731,095	2.03
Commercial	Traffic lights - conversion to LED	35.00	-144.74	-405.26	5.07	2.60	0.99	5,200	2.63
Industry	Switch boilers to natural gas	3,062.75	-143.48	-401.73	439.43	110.22	49.14	-	2.24
Industry	Electricity conservation in other industrial sectors	3,392.85	-132.82	-371.89	450.64	107.50	3.69	1,624,503	29.14
Industry	Ethylene sector carbon reduction programme	1,231.94	-129.08	-361.41	159.01	15.82	1.87	2,669,372	8.47
Electricity	Diesel replaced by solar PV (~160 MW by 2030)	916.16	-63.92	-178.98	471.60	261.11	73.38	1,212,231	3.56
Residential	Green residential buildings (20% of buildings built 2015-2030)	160.62	-109.84	-307.55	120.41	30.10	12.79	62,474	2.35
Industry	Steel sector carbon reduction programme	274.81	-49.74	-139.28	13.67	7.06	0.19	394,716	37.91
Electricity	Diesel replaced by wind by 2030 (~130MW by 2030)	916.16	-48.42	-135.57	357.21	212.80	54.00	1,212,231	3.94
Industry	Cement sector carbon reduction programme	923.99	-44.95	-125.87	41.54	23.73	0.67	758,468	35.41

NB: Those measures highlighted overlap with other measures which have been identified to be more cost effective. Figures in red are negative.

Appendix C Continued

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Commercial	Solar hot water for commercial sector	2,007.91	-35.36	-99.01	71.00	61.28	13.75	91,540	4.46
Commercial	AMI meters - commercial (75% deployment)	387.97	-11.90	-33.32	-4.62	134.35	37.47	182,605	3.59
Waste	Portillo Grande landfill gas capture for energy generation	3,443.47	-2.53	-7.09	8.72	8.92	2.88	31,012	3.10
Waste	Waste to electricity - 1000 tonnes per day	3,079.39	0.05	0.13	-142.34	149.00	2.78	300,000	53.56
Waste	Waste windrow composting - 100,000 tonnes per year	772.10	2.57	7.19	-1.98	4.95	0.19	-	26.00
Residential	Solar photovoltaics: Target of 10MW per year (BAU)	340.60	5.13	14.36	-3.58	216.76	26.16	139,818	8.29
Waste	Zapallal landfill gas flaring	133.94	5.98	16.74	-0.80	0.45	-	-	-
Electricity	Coal replaced with wind (200MW by 2030)	4,507.21	7.04	19.71	-255.49	774.21	28.98	4,529,712	26.72
Electricity	Natural gas BAT (~3,500MW by 2030)	3,773.71	7.12	19.92	-216.24	601.30	27.96	6,669,036	21.50
Residential	High efficiency (EE1) kitchen appliances (excluding the refrigerator)	1,180.26	10.70	29.97	-12.63	587.94	101.69	579,776	5.78
Electricity	Coal replaced with solar PV (200MW by 2030))	3,004.81	11.15	31.22	-269.82	756.14	24.45	4,529,712	30.92
Electricity	Coal retrofit (~80MW by 2030)	355.39	14.12	39.53	-40.40	102.23	5.21	535,744	19.63
Electricity	Natural gas retrofit (1,000MW by 2030)	509.95	15.16	42.45	-62.26	173.00	8.04	1,917,434	21.52
Electricity	Geothermal 1,000MW (replacing natural gas)	8,409.34	16.14	45.18	-1,092.80	2,460.00	59.64	14,861,270	41.25
Electricity	Geothermal 2,000MW (replacing natural gas)	16,818.67	17.11	47.90	-2,317.20	5,420.00	141.63	34,415,432	38.27
Residential	Solar photovoltaics: Target of 20MW per year (BAU)	856.47	20.32	56.89	-28.17	433.51	52.32	279,636	8.29
Waste	Recycling plant - 261kt of paper, wood and industrial waste	682.52	20.99	58.77	-14.33	513.70	37.01	-	13.88
Waste	Taboada sluge to energy incinerator	3,275.78	27.45	76.85	-89.91	40.03	-	-	-
Residential	High efficiency (EE1) air conditioning	575.47	35.41	99.16	-20.38	378.45	45.47	259,228	8.32
Electricity	Gas generation replaced by wind (200MW by 2030)	1,344.57	35.64	99.80	-385.93	950.49	28.86	9,249,608	32.94
Electricity	Gas generation replaced by solar PV (200MW by 2030)	1,344.57	42.82	119.90	-463.68	993.66	18.67	9,249,608	53.23

NB: Those measures highlighted overlap with other measures which have been identified to be more cost effective. Figures in red are negative.

Appendix C Continued

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 $US\$/tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Waste	Waste in-vessel composting - 100,000 tonnes per year	965.13	80.89	226.49	-78.07	80.13	3.00	-	26.71
Electricity	Coal BAT (~130MW by 2030)	116.38	99.34	278.15	-93.10	158.76	1.71	175,443	93.07
Residential	High Efficiency (EE2) Kitchen Appliances (excluding the refrigerator)	992.10	105.10	294.28	-104.27	991.78	85.48	487,348	11.60
Transportation	Traffic management investments	1,672.45	117.97	330.30	-197.29	700.00	150.01	796,973	4.67
Transportation	Hybrid scheme - $2,000 subsidy for 10% new cars	2,755.17	164.82	461.49	-454.10	1,706.50	152.76	1,381,952	11.17
Transportation	Diesel taxis replaced with CNG	551.23	187.45	524.87	-103.33	80.65	2.27	189,113	35.51
Residential	High Efficiency (EE1) entertainment appliance	325.97	289.13	809.57	-94.25	291.10	23.86	136,029	12.20
Transportation	Diesel taxis replaced with hybrid	428.16	314.84	881.57	-134.80	161.29	6.13	147,009	26.33
Residential	High Efficiency (EE2) refrigerator	960.25	320.82	898.30	-308.07	928.57	83.13	473,936	11.17
Residential	High Efficiency (EE2) air conditioners	483.73	692.23	1,938.23	-334.85	515.61	38.22	217,902	13.49
Residential	High Efficiency (EE2) entertainment appliances	274.00	1,283.17	3,592.88	-351.59	504.71	20.06	114,343	25.17
Residential	High Efficiency (EE1) washing machines	61.37	4,507.44	12,620.84	-276.63	316.29	5.31	30,302	59.51
Residential	Green roofs on residential apartment buildings (10% of new builds)	3.14	6,460.02	18,088.06	-2.40	64.10	0.19	1,073	340.54
Residential	High Efficiency (EE2) washing machines	51.59	8,096.57	22,670.40	-417.68	460.83	4.47	25,471	103.15
Residential	Green roofs on semi-detached residential buildings(10% of new builds)	9.55	14,462.17	40,494.09	-26.74	389.72	0.57	3,262	681.08

NB: Those measures highlighted overlap with other measures which have been identified to be more cost effective. Figures in red are negative.

Appendix D:

League table of the most carbon effective measures in Lima-Callao ($ktCO_2$-e)

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Electricity	Geothermal 2,000MW (replacing natural gas)	16,818.67	17.11	47.90	-2,317.20	5,420.00	141.63	34,415,432	38.27
Electricity	Geothermal 1,000MW (replacing natural gas)	8,409.34	16.14	45.18	-1,092.80	2,460.00	59.64	14,861,270	41.25
Transportation	Congestions tolls for petrol and diesel private cars	6,860.38	-153.50	-429.81	1,053.10	265.00	130.66	1,731,095	2.03
Transportation	Replacing Combis with Omnibuses	5,485.22	-1,735.60	-4,859.68	9,520.16	372.14	574.11	79,038	0.65
Electricity	Coal replaced with wind (200MW by 2030)	4,507.21	7.04	19.71	-255.49	774.21	28.98	4,529,712	26.72
Residential	Incandescent Lighting Phase Out and 50% LED by 2020	4,268.31	-237.12	-663.93	738.67	103.54	126.57	721,596	0.82
Electricity	Natural gas BAT (~3,500MW by 2030)	3,773.71	7.12	19.92	-216.24	601.30	27.96	6,669,036	21.50
Waste	Portillo Grande landfill gas capture for energy generation	3,443.47	-2.53	-7.09	8.72	8.92	2.88	31,012	3.10
Industry	Electricity conservation in other industrial sectors	3,392.85	-132.82	-371.89	450.64	107.50	3.69	1,624,503	29.14
Waste	Taboada sluge to energy incinerator	3,275.78	27.45	76.85	-89.91	40.03	-	-	-
Waste	Waste to electricity - 1,000 tonnes per day	3,079.39	0.05	0.13	-142.34	149.00	2.78	300,000	53.56
Industry	Switch boilers to natural gas	3,062.75	-143.48	-401.73	439.43	110.22	49.14	-	2.24
Electricity	Coal replaced with solar PV (200MW by 2030))	3,004.81	11.15	31.22	-269.82	756.14	24.45	4,529,712	30.92
Transportation	Hybrid scheme - $2,000 subsidy for 10% new cars	2,755.17	164.82	461.49	-454.10	1,706.50	152.76	1,381,952	11.17
Residential	Incandescent lighting phase out	2,408.59	-378.39	-1,059.50	673.72	41.17	107.89	615,088	0.38
Commercial	Solar hot water for commercial sector	2,007.91	-35.36	-99.01	71.00	61.28	13.75	91,540	4.46
Transportation	Bus Rapid Transit	1,779.80	-205.62	-575.73	365.96	355.57	40.64	545,617	8.75
Transportation	Traffic Management Investments	1,672.45	117.97	330.30	-197.29	700.00	150.01	796,973	4.67
Electricity	Gas generation replaced by wind (200MW by 2030)	1,344.57	35.64	99.80	-385.93	950.49	28.86	9,249,608	32.94
Electricity	Gas generation replaced by solar PV (200MW by 2030)	1,344.57	42.82	119.90	-463.68	993.66	18.67	9,249,608	53.23
Industry	Ethylene sector carbon reduction programme	1,231.94	-129.08	-361.41	159.01	15.82	1.87	2,669,372	8.47

NB: Figures in red are negative.

Appendix D Continued

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Residential	High efficiency (EE1) kitchen appliances (excluding the refrigerator)	1,180.26	10.70	29.97	-12.63	587.94	101.69	579,776	5.78
Residential	High efficiency (EE1) refrigerator	1,142.37	-162.68	-455.51	185.84	552.34	98.89	563,821	5.59
Industry	Installing advanced metering infrastructure - industrial (75% deployment)	1,121.05	-186.02	-520.85	208.54	7.20	59.03	578,841	0.12
Residential	High efficiency (EE2) kitchen appliances (excluding the refrigerator)	992.10	105.10	294.28	-104.27	991.78	85.48	487,348	11.60
Waste	Waste in-vessel composting - 100,000 tonnes per year	965.13	80.89	226.49	-78.07	80.13	3.00	-	26.71
Residential	High efficiency (EE2) refrigerator	960.25	320.82	898.30	-308.07	928.57	83.13	473,936	11.17
Commercial	Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings	951.16	-861.69	-2,412.74	819.61	139.70	186.86	286,021	0.75
Industry	Cement sector carbon reduction programme	923.99	-44.95	-125.87	41.54	23.73	0.67	758,468	35.41
Electricity	Diesel replaced by wind by 2030 (~130MW by 2030)	916.16	-48.42	-135.57	357.21	212.80	54.00	1,212,231	3.94
Electricity	Diesel replaced by solar PV (~160 MW by 2030)	916.16	-63.92	-178.98	471.60	261.11	73.38	1,212,231	3.56
Residential	Solar photovoltaics: target of 20MW per year (BAU)	856.47	20.32	56.89	-28.17	433.51	52.32	279,636	8.29
Transportation	Petrol taxis CNG retrofit	837.94	-1,836.99	-5,143.58	1,539.29	122.88	123.25	273,112	1.00
Waste	Waste windrow composting - 100,000 tonnes per year	772.10	2.57	7.19	-1.98	4.95	0.19	-	26.00
Transportation	Scrapping cars >20 years old for hybrid cars	683.01	-1,072.65	-3,003.43	732.63	1,471.57	157.34	19,283	9.35
Waste	Recycling plant - 261kt of paper, wood and industrial waste	682.52	20.99	58.77	-14.33	513.70	37.01	-	13.88
Residential	Solar hot water 10% by 2030 (BAU)	592.88	-220.77	-618.16	267.16	84.71	45.17	257,544	1.88
Residential	High efficiency (EE1) air conditioning	575.47	35.41	99.16	-20.38	378.45	45.47	259,228	8.32
Transportation	CNG cars refrofit	559.88	-755.01	-2,114.02	422.72	150.83	58.57	51,765	7.22
Transportation	Scrapping cars >20 years old for petrol cars	557.45	-1,075.93	-3,012.60	599.78	1,030.10	116.82	15,756	8.82
Transportation	Diesel taxis replaced with CNG	551.23	187.45	524.87	-103.33	80.65	2.27	189,113	35.51
Electricity	Natural gas retrofit (1,000MW by 2030)	509.95	15.16	42.45	-62.26	173.00	8.04	1,917,434	21.52

NB: Figures in red are negative.

Appendix D Continued

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 $US\$/tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Residential	High efficiency (EE2) air conditioners	483.73	692.23	1,938.23	-334.85	515.61	38.22	217,902	13.49
Residential	Solar hot water 10% by 2030 (EE1)	469.21	-203.23	-569.05	190.06	84.71	34.10	194,421	2.48
Commercial	Green building standards - commercial buildings	450.63	-1,103.69	-3,090.32	497.35	91.98	60.10	160,239	1.53
Residential	Installing advanced metering infrastructure - Domestic (75% deployment)	438.76	-282.36	-790.61	123.89	58.57	50.80	220,827	1.15
Transportation	Diesel taxis replaced with hybrid	428.16	314.84	881.57	-134.80	161.29	6.13	147,009	26.33
Industry	Petroleum refining sector carbon reduction programme	421.10	-179.46	-502.49	75.57	13.52	0.95	957,774	14.16
Residential	Solar hot water 10% by 2030 (EE2)	404.02	-189.28	-530.00	145.89	84.71	26.84	153,016	3.16
Commercial	AMI meters - commercial (75% deployment)	387.97	-11.90	-33.32	-4.62	134.35	37.47	182,605	3.59
Electricity	Coal retrofit (~80MW by 2030)	355.39	14.12	39.53	-40.40	102.23	5.21	535,744	19.63
Commercial	Commercial sector electricity retrofit programme	352.27	-555.30	-1,554.85	195.62	44.41	36.76	244,728	1.21
Commercial	Malls sector electricity retrofit programme	352.27	-203.93	-571.01	71.84	16.34	13.49	76,895	1.21
Residential	Solar photovoltaics: target of 10MW per year (BAU)	340.60	5.13	14.36	-3.58	216.76	26.16	139,818	8.29
Residential	High efficiency (EE1) entertainment appliances	325.97	289.13	809.57	-94.25	291.10	23.86	136,029	12.20
Residential	Solar hot water 5% by 2030 (BAU)	296.44	-220.77	-618.16	133.58	42.36	22.59	128,772	1.88
Commercial	Street lighting - conversion to LEDs	294.27	-361.48	-1,012.14	106.37	182.97	14.02	7,369	13.05
Industry	Steel sector carbon reduction programme	274.81	-49.74	-139.28	13.67	7.06	0.19	394,716	37.91
Residential	High efficiency (EE2) entertainment appliances	274.00	1,283.17	3,592.88	-351.59	504.71	20.06	114,343	25.17
Residential	Solar hot water 5% by 2030 (EE1)	234.61	-203.23	-569.05	95.03	42.36	17.05	97,210	2.48
Residential	Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections)	205.04	-3,300.71	-9,241.98	676.79	575.75	138.84	-2,881	4.15
Residential	Solar hot water 5% by 2030 (EE2)	202.01	-189.28	-530.00	72.95	42.36	13.42	76,508	3.16
Residential	High efficiency (EE1) water heaters	180.52	-437.42	-1,224.78	78.97	37.45	15.54	88,606	2.41

NB: Figures in red are negative.

Appendix D Continued

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 US$/$tCO_{2e}$	2014 Sol/tCO_{2e}	NPV	Capital cost (NPV) US$M	Energy saving 2030, US$M	Energy saving (MWh)	Payback
Residential	Green residential buildings (20% of buildings built 2015-2030)	160.62	-109.84	-307.55	120.41	30.10	12.79	62,474	2.35
Residential	High efficiency (EE2) water heaters	151.74	-229.99	-643.97	34.90	62.95	13.06	74,480	4.82
Waste	Zapallal landfill gas flaring	133.94	5.98	16.74	-0.80	0.45	-	-	-
Electricity	Coal BAT (~130MW by 2030)	116.38	99.34	278.15	-93.10	158.76	1.71	175,443	93.07
Transportation	Teleworking campaign	110.99	-2,380.29	-6,664.82	264.18	40.45	7.65	34,305	5.29
Transportation	Development of cycle lanes	100.84	-599.83	-1,679.51	60.49	42.08	5.27	33,626	7.98
Commercial	Public sector electricity retrofit programme	90.25	-483.89	-1,354.89	43.67	6.16	7.62	50,739	0.81
Residential	High efficiency (EE1) washing machines	61.37	4,507.44	12,620.84	-276.63	316.29	5.31	30,302	59.51
Commercial	Solar PV for commercial sector (with FIT)	56.50	-174.27	-487.97	9.85	13.55	2.72	17,520	4.97
Commercial	Hospital electricity retrofit programme	55.51	-155.39	-435.10	8.63	5.30	2.09	13,918	2.54
Residential	High efficiency (EE2) washing machines	51.59	8,096.57	22,670.40	-417.68	460.83	4.47	25,471	103.15
Residential	Electricity conservation education	49.21	-309.76	-867.34	15.24	3.08	2.54	14,465	1.21
Commercial	Traffic lights - conversion to LED	35.00	-144.74	-405.26	5.07	2.60	0.99	5,200	2.63
Residential	Green roofs on semi-detached residential buildings (10% of new builds)	9.55	14,462.17	40,494.09	-26.74	389.72	0.57	3,262	681.08
Residential	Green roofs on residential apartment buildings (10% of new builds)	3.14	6460.02	18088.06	-2.40	64.10	0.19	1,073	340.54

NB: Figures in red are negative

Appendix E:

Low carbon urbanisation

Drawing on the measures outlined in the main section of the report, the information below considers the impact of an eco-zone similar to the currently planned Villa El Salvador[139]. This type of development could lead to a large number of mitigation options implemented in a single concentrated area. In addition to complementary impacts between measures, green buildings supporting LED penetration for example, a development of this scale would be large enough to produce economies of scale in implementation, reducing costs.

While estimating the overall impact of the Eco-Zone is challenged by significant overlaps between measures, assuming the site covers 500 hectares and has an estimated 33,500 inhabitants, implementation of the mitigation measures listed below would result in:

- Emissions reductions of 0.54tCO_{2e} per capita and 17.9 KtCO_{2e} across the Eco-Zone
- Energy savings of US$324 per inhabitant per year or US$10.9 million per year across the Eco-Zone
- Water savings of 115m^3 per year per inhabitant, or more than 3.8 million m^3 across the Eco-Zone

A set of the key measures from this report that should be considered for an Eco-Zone are listed below:

Table E1: Key carbon mitigating Eco-Zone measures with carbon savings from 2015 - 2030 (KtCO_2), cost effectiveness (USD/tCO_{2e}), capital cost (NPV in $M) and payback period (years).

Sector	Measure	ktCO_{2e} 2015-2030	2014 US$/ t$CO_{2e}$	Capital cost (NPV) $M	Payback
Transportation	Teleworking campaign	111.0	-2380.3	40.5	5.3
Transportation	Replacing Combis with Omnibuses	5485.2	-1735.6	372.1	0.6
Commercial	Green building standards - commercial buildings	450.6	-1103.7	92.0	1.5
Transportation	Development of cycle lanes	100.8	-599.8	42.1	8.0
Residential	High Efficiency (EE1) water heaters	180.5	-437.4	37.4	2.4
Residential	Electricity conservation education	49.2	-309.8	3.1	1.2
Residential	Incandescent lighting phase out and 50% LED by 2020	4268.3	-237.1	103.5	0.8
Residential	Solar hot water 10% by 2030 (BAU)	592.9	-220.8	84.7	1.9
Transportation	Bus Rapid Transit	1779.8	-205.6	355.6	8.7
Commercial	Solar PV for commercial sector (with FIT)	56.5	-174.3	13.5	5.0
Residential	High efficiency (EE1) refrigerator	1142.4	-162.7	552.3	5.6
Residential	Green residential buildings (20% of buildings built 2015-2030)	160.6	-109.8	30.1	2.4
Commercial	Solar hot water for commercial sector	2007.9	-35.4	61.3	4.5

Energy Measures for the proposed Eco-Zone as identified for Lima as a whole. NB: Figures in red are negative.

Table E1 Continued

Sector	Measure	$ktCO_{2e}$ 2015-2030	2014 US$/ tCO_{2e}	Capital cost (NPV) $M	Payback
Residential	High efficiency (EE1) kitchen appliances (excluding the refrigerator)	1180.3	10.7	587.9	5.8
Residential	Solar Photovolatics: target of 20MW per year (BAU)	856.5	20.3	433.5	8.3
Residential	High efficiency (EE1) air conditioning	575.5	35.4	378.4	8.3
Residential	High efficiency (EE1) entertainment appliances	326.0	289.1	291.1	12.2
Residential	High efficiency (EE1) washing machines	61.4	4507.4	316.3	59.5
Residential	Green roofs on residential apartment buildings (10% of new builds)	3.1	6460.0	64.1	340.5
Residential	Green roofs on semi-detached residential buildings(10% of new builds)	9.5	14462.2	389.7	681.1

Energy Measures for the proposed Eco-Zone as identified for Lima as a whole. NB: Figures in red are negative.

Table E2: Key water Eco-Zone measures with water savings from 2015-2030 (million m^3), cost effectiveness (2014 USD/ m^3), capital cost (NPV in $M) and payback (years).

Measure	million m^3 2015-2025	2014 US$/$m^3$	Capital Cost	Payback
Low flow bathroom faucets (50% deployment across all houses)	161	0.29	131.3	28.1
Low flow showers (50% deployment across all houses)	649	-0.16	218.9	11.7
Low flow toilets (50% deployment across all houses)	793	-0.05	364.8	15.9
Low flow kitchen faucets (50% deployment across all houses)	157	0.05	87.5	19.3
High efficiency dishwashers (25% deployment across all houses)	51	6.33	364.8	247.0
High efficiency washing machines (25% deployment across all houses)	71	4.63	383.0	185.3

Water Measures for the proposed Eco-Zone as identified for Lima as a whole.

Appendix F:

Ranking of most attractive measures

Table F1: Overall measure rankings for carbon savings according to cost effectiveness, carbon effectiveness and multi-criteria ranking.

Sector	Measure	Cost effective		Carbon effective
		Rank	A (cost effective rank/ total no of measures)	Rank
Transportation	Replacing Combis with Omnibuses	4	0.05	4
Residential	Incandescent lighting phase out and 50% LED by 2020	18	0.23	6
Electricity	Geothermal 2,000MW (replacing natural gas)*	57	0.73	1
Residential	Liquid Petroleum Gas to Natural Gas: 50% of households connected by 2020 (860,000 connections)*	1	0.01	61
Transportation	Petrol taxis CNG retrofit	3	0.04	33
Residential	Incandescent lighting phase out	14	0.18	15
Electricity	Geothermal 1,000MW (replacing natural gas)*	56	0.72	2
Transportation	Bus Rapid Transit	22	0.28	17
Transportation	Teleworking campaign	2	0.03	68
Transportation	Congestions tolls for petrol and diesel private cars	33	0.42	3
Commercial	Thermal (natural gas, LPG, diesel, petrol) retrofit in buildings	8	0.10	28
Transportation	CNG cars retrofit	9	0.12	39
Commercial	Solar hot water for commercial sector	43	0.55	16
Transportation	Scrapping cars >20 years old for petrol cars	6	0.08	40
Industry	Electricity conservation in other industrial sectors*	36	0.46	9
Transportation	Scrapping cars >20 years old for hybrid cars	7	0.09	35
Electricity	Coal replaced with solar PV (200MW by 2030))	53	0.68	13
Electricity	Natural gas BAT (~3,500MW by 2030)	51	0.65	7
Commercial	Green building standards - commercial buildings	5	0.06	45
Electricity	Coal replaced with wind (200MW by 2030)	50	0.64	5
Industry	Switch boilers to natural gas*	35	0.45	12
Commercial	Commercial sector electricity retrofit programme	11	0.14	52
Waste	Waste to electricity – 1,000 tonnes per day*	46	0.59	11
Electricity	Diesel replaced by solar PV (~160 MW by 2030)	39	0.50	30

	Carbon effective	MCA			Rating	Overall Attractiveness Rank
	B (carbon effective rank/ total no of measures)	Rank	Number in sector	C (MCA ranking/total number in sector)	=A*B*C	
	0.05	4	6	0.67	0.002	1
	0.08	1	4	0.25	0.004	2
	0.01	n/a	n/a	0.50	0.005	3
	0.78	n/a	n/a	0.50	0.01	4
	0.42	2	6	0.33	0.01	5
	0.19	1	4	0.25	0.01	6
	0.03	n/a	n/a	0.50	0.01	7
	0.22	1	6	0.17	0.01	8
	0.87	3	6	0.50	0.01	9
	0.04	6	6	1.00	0.02	10
	0.36	2	4	0.50	0.02	11
	0.50	2	6	0.33	0.02	12
	0.21	1	5	0.20	0.02	13
	0.51	4	6	0.67	0.03	14
	0.12	n/a	n/a	0.50	0.03	15
	0.45	4	6	0.67	0.03	16
	0.17	1	4	0.25	0.03	17
	0.09	2	4	0.50	0.03	18
	0.58	4	5	0.80	0.03	19
	0.06	3	4	0.75	0.03	20
	0.15	n/a	n/a	0.50	0.03	21
	0.67	2	5	0.40	0.04	22
	0.14	n/a	n/a	0.50	0.04	23
	0.38	1	4	0.25	0.05	24

Electricity	Gas generation replaced by solar PV (200MW by 2030)	63	0.81	19
Waste	Taboada sludge to energy incinerator*	60	0.77	10
Transportation	Hybrid scheme - $2,000 subsidy for 10% new cars	68	0.87	14
Commercial	Public sector electricity retrofit programme	12	0.15	70
Industry	Installing advanced metering infrastructure - industrial (75% deployment)*	28	0.36	24
Transportation	Development of cycle lanes	10	0.13	69
Residential	High efficiency (EE1) refrigerator	31	0.40	23
Waste	Portillo Grande landfill gas capture for energy generation	45	0.58	8
Industry	Ethylene sector carbon reduction programme*	37	0.47	21
Residential	Installing advanced metering infrastructure - domestic (75% deployment)*	17	0.22	46
Residential	High efficiency (EE1) water heaters	13	0.17	63
Residential	Solar Photovoltaic: target of 20MW per year (BAU)	58	0.74	32
Commercial	Malls sector electricity retrofit programme	23	0.29	53
Commercial	Solar PV for commercial sector (with FIT)	30	0.38	72
Residential	High Efficiency (EE1) kitchen appliances (excluding the refrigerator)	52	0.67	22
Transportation	Traffic management Investments*	67	0.86	18
Industry	Cement sector carbon reduction programme*	42	0.54	29
Residential	High efficiency (EE2) water heaters	19	0.24	65
Commercial	Traffic lights - conversion to LED	34	0.44	76
Residential	Solar Photovoltaic: target of 10MW per year (BAU)	48	0.62	54
Industry	Petroleum refining sector carbon reduction programme*	29	0.37	48
Residential	Solar hot water 10% by 2030 (BAU)	20	0.26	37
Waste	Waste windrow composting - 100,000 tonnes per year	47	0.60	34
Residential	High efficiency (EE2) kitchen appliances (excluding the refrigerator)	66	0.85	25
Waste	Waste in-vessel composting - 100,000 tonnes per year	64	0.82	26
Commercial	Street lighting - conversion to LEDs	15	0.19	57
Residential	Electricity conservation education	16	0.21	75
Electricity	Gas generation replaced by wind (200MW by 2030)	62	0.79	20

	0.24	1	4	0.25	0.05	25
	0.13	n/a	n/a	0.50	0.05	26
	0.18	2	6	0.33	0.05	27
	0.90	2	5	0.40	0.06	28
	0.31	n/a	n/a	0.50	0.06	29
	0.88	3	6	0.50	0.06	30
	0.29	2	4	0.50	0.06	31
	0.10	2	2	1.00	0.06	32
	0.27	n/a	n/a	0.50	0.06	33
	0.59	n/a	n/a	0.50	0.06	34
	0.81	2	4	0.50	0.07	35
	0.41	1	4	0.25	0.08	36
	0.68	2	5	0.40	0.08	37
	0.92	1	4	0.25	0.09	38
	0.28	2	4	0.50	0.09	39
	0.23	n/a	n/a	0.50	0.10	40
	0.37	n/a	n/a	0.50	0.10	41
	0.83	2	4	0.50	0.10	42
	0.97	1	4	0.25	0.11	43
	0.69	1	4	0.25	0.11	44
	0.62	n/a	n/a	0.50	0.11	45
	0.47	4	4	1.00	0.12	46
	0.44	1	2	0.50	0.13	47
	0.32	2	4	0.50	0.14	48
	0.33	1	2	0.50	0.14	49
	0.73	5	5	1.00	0.14	50
	0.96	3	4	0.75	0.15	51
	0.26	3	4	0.75	0.15	52

Commercial	Hospital electricity retrofit programme	32	0.41	73
Transportation	Diesel taxis replaced with CNG	69	0.88	41
Electricity	Diesel replaced by wind by 2030 (~130MW by 2030)	41	0.53	31
Residential	High efficiency (EE2) refrigerator	72	0.92	27
Residential	Solar hot water 10% by 2030 (EE1)	24	0.31	44
Waste	Recycling plant - 261kt of paper, wood and industrial waste	59	0.76	36
Commercial	AMI meters - commercial (75% deployment)*	44	0.56	50
Transportation	Diesel taxis replaced with hybrid	71	0.91	47
Electricity	Natural gas retrofit (1,000MW by 2030)	55	0.71	42
Residential	High efficiency (EE1) air conditioning	61	0.78	38
Industry	Steel sector carbon reduction programme*	40	0.51	58
Residential	Solar hot water 5% by 2030 (BAU)	21	0.27	56
Residential	Solar hot water 10% by 2030 (EE2)	26	0.33	49
Residential	Solar hot water 5% by 2030 (EE1)	25	0.32	60
Residential	High efficiency (EE2) air conditioners	73	0.94	43
Residential	Solar hot water 5% by 2030 (EE2)	27	0.35	62
Residential	High efficiency (EE1) entertainment appliances	70	0.90	55
Residential	High efficiency (EE2) entertainment appliances	74	0.95	59
Residential	Green residential buildings (20% of buildings built 2015-2030)	38	0.49	64
Residential	High efficiency (EE1) washing machines	75	0.96	71
Electricity	Coal retrofit (~80MW by 2030)	54	0.69	51
Residential	High efficiency (EE2) washing machines	77	0.99	74
Waste	Zapallal landfill gas flaring	49	0.63	66
Electricity	Coal BAT (~130MW by 2030)	65	0.83	67
Residential	Green roofs on residential apartment buildings (10% of new builds)	76	0.97	78
Residential	Green roofs on semi-detached residential buildings(10% of new builds)	78	1.00	77

NB the industry sector was not included in the multi-criteria evaluation and some measures were bundled . Where possible these measures have been assigned a value of a comparable measure or they have been given a score of 0.5 for the MCA (marked with a *).

	0.94	2	5	0.40	0.15	53
	0.53	2	6	0.33	0.15	54
	0.40	3	4	0.75	0.16	55
	0.35	2	4	0.50	0.16	56
	0.56	4	4	1.00	0.17	57
	0.46	1	2	0.50	0.17	58
	0.64	n/a	n/a	0.50	0.18	59
	0.60	2	6	0.33	0.18	60
	0.54	2	4	0.50	0.19	61
	0.49	2	4	0.50	0.19	62
	0.74	n/a	n/a	0.50	0.19	63
	0.72	4	4	1.00	0.19	64
	0.63	4	4	1.00	0.21	65
	0.77	4	4	1.00	0.25	66
	0.55	2	4	0.50	0.26	67
	0.79	4	4	1.00	0.28	68
	0.71	2	4	0.50	0.32	69
	0.76	2	4	0.50	0.36	70
	0.82	4	4	1.00	0.40	71
	0.91	2	4	0.50	0.44	72
	0.65	4	4	1.00	0.45	73
	0.95	2	4	0.50	0.47	74
	0.85	2	2	1.00	0.53	75
	0.86	4	4	1.00	0.72	76
	1.00	4	4	1.00	0.97	77
	0.99	4	4	1.00	0.99	78

Table F2: Overall measure rankings for water savings according to water saving effectiveness, cost effectiveness and multi-criteria ranking.

Sector	Measure	Water Effectiveness		
		million m^3 2015-2025	Rank	Ratio A (Rank/No in sector=31)
Demand	Rehabilitation of Primary Network	1734.5	1	0.03
Supply	Pomacocha - Rio Blanco	1734.5	2	0.06
Supply	Rio Chillon Resevoir	919.3	3	0.10
Demand	15% increase in commerical water tariffs	22.9	27	0.87
Demand	18% increase in commerical water tariffs	27.5	26	0.84
Demand	15% increase in domestic tariff price	326.6	13	0.42
Supply	Re-channelling Rimac River	867.2	4	0.13
Demand	18% increase in domestic tariff price	391.9	12	0.39
Supply	Damming of the Casacancha in conjunction with Marca III	624.4	7	0.23
Demand	100% metering of serviced units by 2020	14.8	29	0.94
Supply	Autisha Resevoir	416.3	11	0.35
Demand	Low flow showers (50% deployment across all houses)	648.6	6	0.19
Supply	Extension of Graton Tunnel	520.3	9	0.29
Demand	Low flow toilets (50% deployment across all houses)	793.1	5	0.16
Demand	Water conservation education programme	52.4	21	0.68
Demand	Domestic green building (25% of new builds 2015-2030)	103.5	19	0.61
Supply	Desalination of the sea water of the South Sea	520.3	8	0.26
Demand	Commercial green building (25% of new builds 2015-2030)	22.7	28	0.90
Demand	18% increase in industrial water tariffs	42.2	23	0.74
Demand	15% increase in industrial water tariffs	35.2	25	0.81
Demand	Low flow kitchen faucets (50% deployment across all houses)	156.5	16	0.52
Supply	Basin wells of River Chancay (2040)	236.5	14	0.45
Demand	Residential greywater retrofit (50,000 by 2030)	147.0	17	0.55
Supply	Aquifer recharge	441.5	10	0.32

	Cost Effectiveness			MCA		Overall Attractiveness	
	2014 US$/m³	Rank	Ratio B (Rank/No in sector=31)	Rank	Ratio C (Rank/No in sector=9)	Rating =A*B*C	Rank
	0.03	11	0.35	4.00	0.44	0.005	1
	0.15	18	0.58	2.00	0.22	0.008	2
	0.07	13	0.42	2.00	0.22	0.009	3
	-7.83	1	0.03	3.00	0.33	0.009	4
	-7.79	2	0.06	3.00	0.33	0.018	5
	-1.40	4	0.13	3.00	0.33	0.018	6
	0.19	20	0.65	2.00	0.22	0.018	7
	-1.39	5	0.16	3.00	0.33	0.021	8
	0.09	15	0.48	2.00	0.22	0.024	9
	-1.67	3	0.10	4.00	0.44	0.040	10
	0.09	16	0.52	2.00	0.22	0.041	11
	-0.16	7	0.23	9.00	1.00	0.044	12
	0.24	21	0.68	2.00	0.22	0.044	13
	-0.05	10	0.32	9.00	1.00	0.052	14
	0.49	26	0.84	1.00	0.11	0.063	15
	-0.14	8	0.26	9.00	1.00	0.158	16
	0.43	25	0.81	7.00	0.78	0.162	17
	-0.52	6	0.19	9.00	1.00	0.175	18
	0.42	24	0.77	3.00	0.33	0.191	19
	0.41	23	0.74	3.00	0.33	0.199	20
	0.05	12	0.39	9.00	1.00	0.200	21
	0.14	17	0.55	8.00	0.89	0.220	22
	0.08	14	0.45	9.00	1.00	0.248	23
	0.73	29	0.94	8.00	0.89	0.268	24

Demand	Commercial greywater retrofit (25,000 by 2030)	12.2	30	0.97
Demand	Low flow bathroom faucets (50% deployment across all houses)	161.1	15	0.48
Supply	Aquifer recharge for Lurin River	138.8	18	0.58
Demand	Domestic greywater toilets (100,000 by 2030)	37.8	24	0.77
Demand	High efficiency washing machines (25% deployment across all houses)	71.4	20	0.65
Supply	Condensate catchers	2.9	31	1.00
Demand	High efficiency dishwashers (25% deployment across all houses)	51.0	22	0.71

NB Measures were bundled for the multi-criteria assessment to allow the measures to be assessed in a stakeholder meeting

-0.08	9	0.29	9.00	1.00	0.281	25
0.29	22	0.71	9.00	1.00	0.343	26
0.52	27	0.87	8.00	0.89	0.450	27
0.15	19	0.61	9.00	1.00	0.475	28
4.63	30	0.97	9.00	1.00	0.624	29
0.66	28	0.90	7.00	0.78	0.703	30
6.33	31	1.00	9.00	1.00	0.710	31

Appendix G:

Current barriers and proposed changes by sector

Table G1: Key barriers and proposed changes to low carbon development on a sectoral basis

Sector	Barriers	Proposed Changes
Transport	— Lack of vehicles that meet international emission standards — Lack of cleaner fuels — Vehicle taxation system does not currently support low carbon vehicles or fuels — Lack of long-term planning to allow an effective city-wide transport network to be developed (including linkages between public transport infrastructure) — Availability of parking supports private car use in the city — Lack of suitable institutions to manage city-wide transport network and public transport systems. Currently coordination across the 50+ municipalities is difficult	— Educational campaigns to encourage use of low carbon transportation methods — Vehicle and fuel taxation that supports lower carbon transportation methods — Consider future infrastructure developments and review current traffic regulations to prioritise low carbon and public transport options where possible — Creation of a city-wide transport authority with responsibility for managing transport systems and networks across the whole city.
Water	— Lack of understanding of importance of minimising water use — Limited finance sources available to the sector to make required investments — Political issues associated with access to water (and the informal use of water), particularly for the urban poor — Lack of trust by the public of the companies involved	— Educational programme on the efficient use of water in the city — Ensure effective water management upstream by the establishment of a basin wide management approach — Further enable public private partnerships to increase financing (also consider users contributing to costs via tariff increases or payment for ecosystem services) — Create a stakeholder community to allow relevant stakeholders to be involved in the decision making process
Waste	— Informality of waste collection and recycling systems — Issues related to delays in payment of city taxes to operators — Waste management across the city is fragmented across the 50+ municipalities — Lack of political will to make significant changes in this sector — Lack of understanding regarding the need to recycle and acceptance of waste disposal costs	— Establishment of a city-wide waste management authority and strategy with representation of key stakeholders. — Strengthen waste management regulation — Education and awareness raising of ways to minimise waste production and waste treatment options for the city
Energy/ Industry	— New entrants to the sector need to be managed differently to current large, incumbent organisations — Lack of regulation and enforcement of the sector — Lack of knowledge of key renewable options within Peru hinders their use — Weak renewables targets and associated incentives for individuals or organisations. Furthermore there is an issue regarding how much renewables the grid is capable of accepting — Lack of feasibility studies to encourage investment	— Facilitation of transition to low carbon energy generation options via public policy and use of incentives for generators — More effective stakeholder engagement on energy decision making — Improve efficiency and innovation within the industrial sector via knowledge transfer — Upgrade network to reduce transmission losses, enable greater renewable use and reduce connectivity problems

Sector	Barriers	Proposed Changes
Residential	— Lack of a smart grid and payment for home energy production — lack of demonstration projects — Lack of energy education and information on energy use of appliances — Lack of information on green credit lines available from banks — Lack of information on green building materials — Lack of available cash from consumers	— Development of green building standards relevant to Peru/Lima and current (under development) — Support the establishment of a low carbon residential sector via encouragement of knowledge transfer, support for organisations in this sector — Undertake educational campaigns and information dissemination (e.g. of electrical appliance efficiency) — Incentivise action by, for example, use of feed-in-tariffs, easier planning for low carbon developments — Encourage banks to finance green technologies (e.g. solar water heaters) — More detailed studies on suitability of measures (e.g. green roofs)
Commercial	— Lack of a smart grid inhibits take up of renewable energy options by the commercial sector — Lack of green building standards relevant to Peru/ Lima-Callao — Lack of example projects (public sector should act as example) — Lack of energy education and information on energy use of appliances	— Demonstrate public sector leadership by implementing low carbon measures — Provide financial incentives to companies that invest in low carbon measures (e.g. feed in tariff, lower taxes, etc) — Educational campaigns to encourage uptake of low carbon measures — Review current regulation and revise to facilitate low carbon options — Support professional training of relevant personnel to facilitate uptake of low carbon measures

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The Climate Smart Cities Programme
www.climatesmartcities.org

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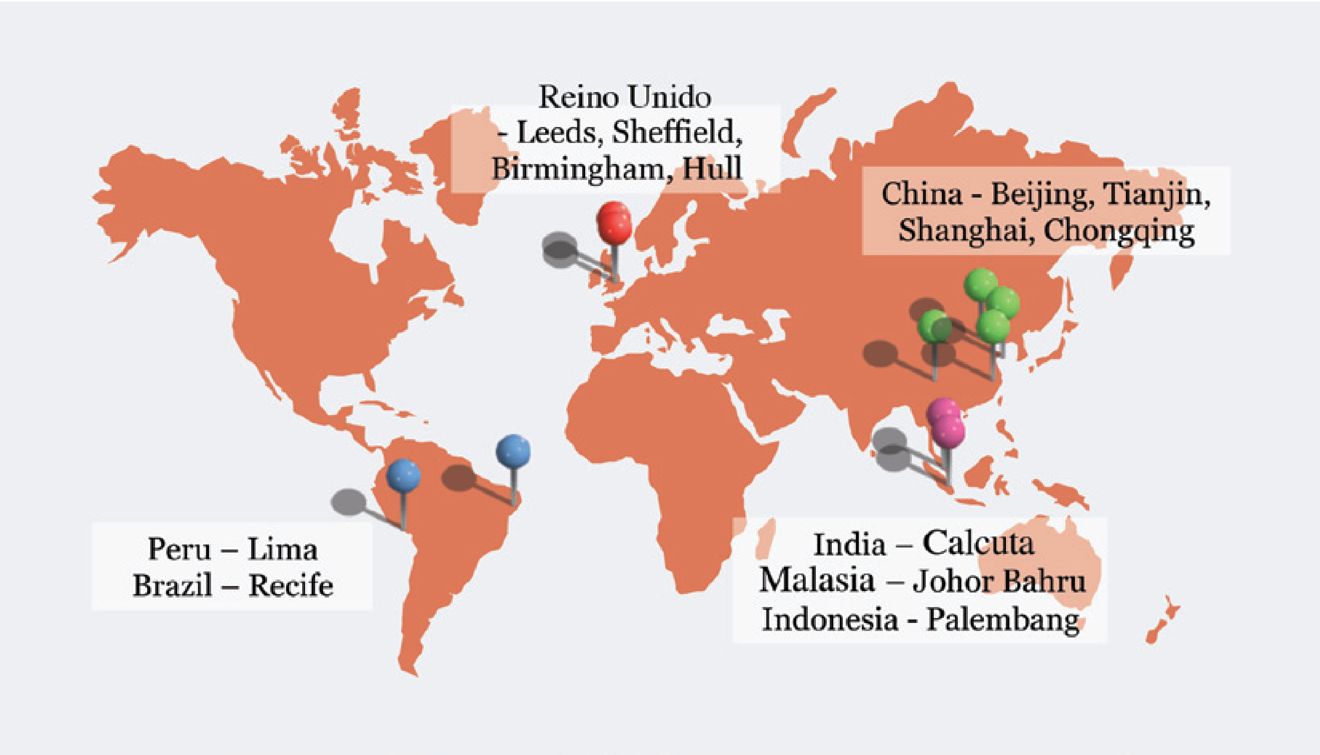

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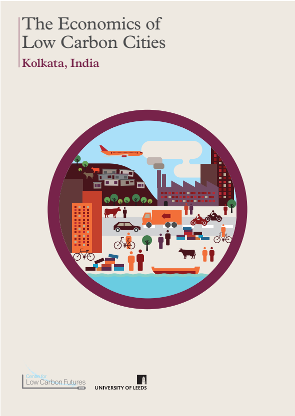

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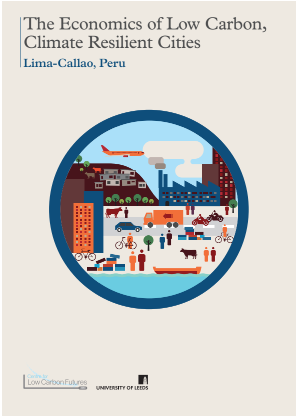

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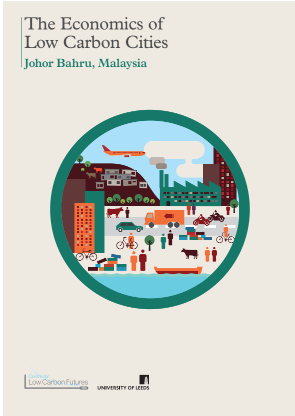

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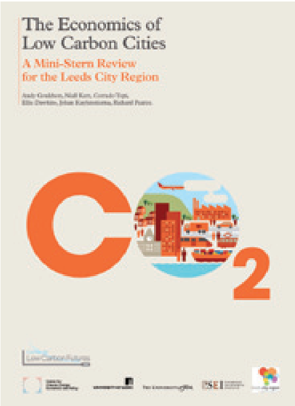

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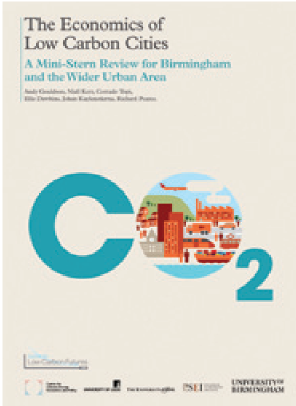

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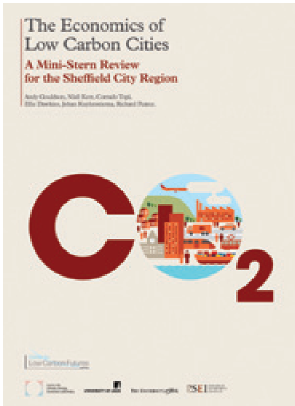

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