The Economics of Low Carbon Cities

Palembang, Indonesia

Andy Gouldson, Sarah Colenbrander,
Andrew Sudmant and Effie Papargyropoulou

Foreign & Commonwealth Office
UNIVERSITY OF LEEDS
Ministry of Transportation Republic of Indonesia
E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL
Centre for Climate Change Economics and Policy
Centre for Low Carbon Futures 2050

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Today

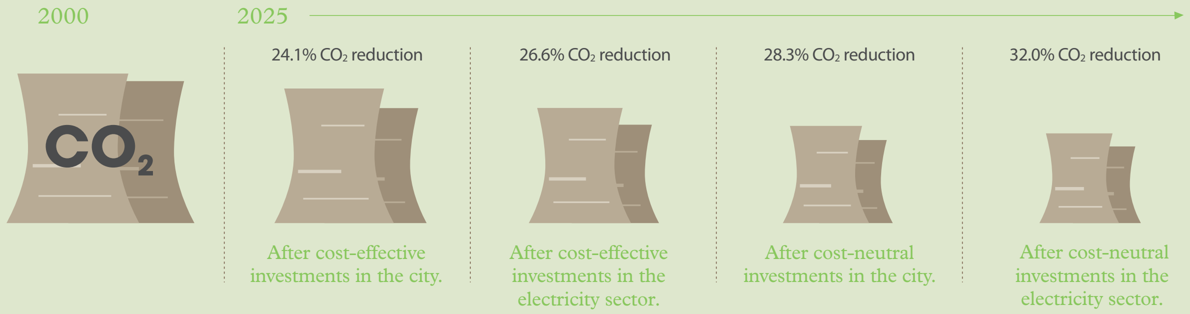
18.7% of city-scale GDP leaves the local economy every year through payment of the energy bill. In 2025, this is forecast to grow to 20.9% of GDP.

Tomorrow

0.9% 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 4.2% of GDP
- **Financial viability**
  less than one year for 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**
  reductions in fuel poverty, improvements in health

Potential to reduce CO_2 emissions



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Foreword

I am pleased to present the study on The Economics of Low Carbon Cities: A Mini-Stern Review for Palembang, Indonesia. This study provides prioritised lists of the most cost and carbon effective measures that could realistically be promoted across the energy, housing, commercial buildings, transport, industry and waste within the city for the city of Palembang.

As we know, the issue of global climate change, especially in Indonesia, presents a variety of challenges in policy making, planning and technology needed in order to tackle it. The Indonesian government has voluntarily committed to reducing carbon emission intensity by 26% by 2020 compared with 2005, and a reduction of 41% with international assistance, as stipulated in Presidential Regulation number 61 of 2011 on National Action Plan – Green House Gas Emission Reduction. Most of the national emission reduction anticipated from agriculture, peat land, forestry, energy, transport, industry and waste management.

In urban areas, as population growth and economic development, energy and transport demand also increases. Activities in the cities of the world generally consume up to 70% of all energy and contribute up to 70% of all carbon emissions. In Indonesia, 51% (125.9 million) from 246.9 million people currently living in the city. Evolving with the rapid urbanization on average 2.45% per year, which means that 32.5 million of Indonesians moved from rural to urban areas between 2000 and 2010. The increase is creating pressure on the urban environment in which the transport sector is a major source of air pollution.

Selection of Palembang as the location of this study felt very appropriate because in addition to being one of the three cities for sustainable transportation, it is also being implemented with a variety of programs through Palembang City Council in an effort to improve institutional capacity and addressing rising energy prices and climate change.

My gratitude and appreciation to the team who have been working to complete this study and look forward to helping the Government of Indonesia, especially the City Council and all stakeholders to understand and identify energy efficiency efforts and a decrease in carbon emissions effectively and realistically can be applied to sectors: transport, energy, housing, commercial buildings, industry and waste

Dr. Elly Sinaga, M.Sc.
Director General of Research and Development Agency
Ministry of Transportation
The Republic of Indonesia

Executive Summary

Introduction

What is the best way to shift a city to a more energy efficient, low carbon development path? Even where there is broad interest in such a transition, there are major obstacles that often prevent cities from acting on such a far-reaching agenda. The absence of a credible and locally appropriate evidence base makes it particularly difficult for decision makers to act.

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

Our Approach

We start the analysis by collecting data on levels and composition of energy use in Palembang. We do this for a range of different sectors including the electricity 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 efficiency, and we develop 'business as usual' baselines that continue these trends through to 2025. These baselines allow us to predict future levels and forms of energy supply and demand, as well as future energy bills and carbon emissions.

Based on extensive literature reviews and stakeholder consultations, we compile lists of the low carbon 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 Palembang in the period to 2025. 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 supply and demand, energy 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 effective measures that could be adopted both in each sector and across the city as a whole.

Palembang's GDP was US$ 4.6 billion in 2014, and the city's energy bill was US$ 857.2 million. This means that 18.7% of all income earned in Palembang is spent on energy.

A continuation of business as usual trends in Palembang will see total energy use increase by 129.2%, energy bills by 155.1% and carbon emissions by 164.6%, relative to 2014 levels, by 2025.

The economic case for low carbon investment

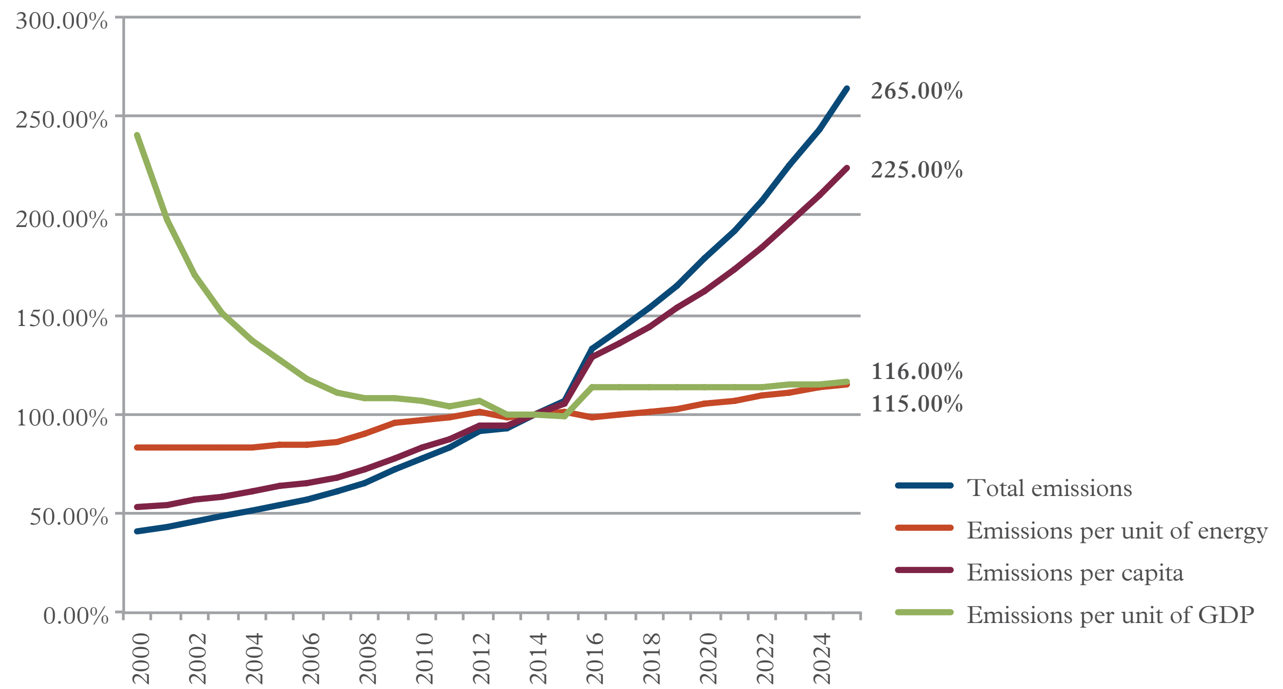
We estimate that Palembang's GDP was IDR 54.00 trillion (US$4.59 billion) in 2014, and if recent trends continue we forecast that GDP will grow to IDR 123.21 billion (US$10.47 billion) by 2025. We also find that the total energy bill for Palembang in 2014 was IDR 10.08 trillion (US$857.22 million), meaning that 18.7% of all income earned in Palembang is currently spent on energy (without including government expenditure on fuel subsidies).

We predict that a continuation of business as usual trends in the period to 2025 would see total energy use in Palembang rising by 129.2% from 2014 levels to 2025 and we forecast that the total energy bill for the city will increase by 155.1% from 2014 levels to IDR 25.73 billion (US$2.19 billion) in 2025. We also predict that under a business as usual scenario, total carbon emissions from Palembang are forecast to increase by 164.6% from 2014 levels by 2025.

After examining the potential costs and benefits of the wide range of energy efficiency, renewable energy and other low carbon measures that could be deployed across different sectors in the city, we find that - compared to business as usual trends – Palembang could reduce its carbon emissions by 2025 by:

— 24.1% through cost effective investments that would more than pay for themselves on commercial terms over their lifetime. This would come from an investment of IDR 4.77 trillion (US$ 405.6 million), generating annual savings by reducing energy bills by IDR 5.14 trillion (US$ 436.80 million), paying back the investment in less than one year but generating annual savings for the lifetime of the measures.

Figure 1.
Indexed total CO_2-e emissions per unit of energy, per unit of GDP and per capita.



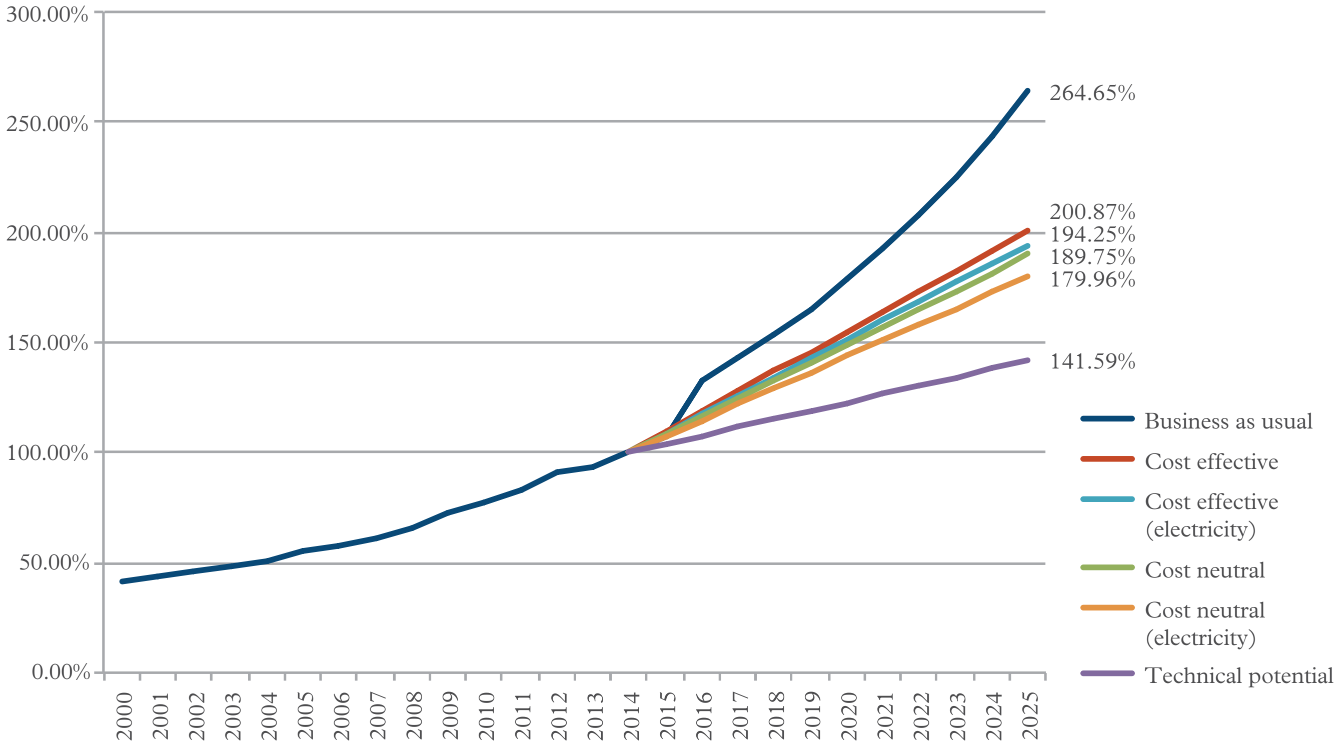
— 26.6% if, as well as the above investments, cost effective investments in the electricity sector were made that could more than pay for themselves on commercial terms over their lifetime. This would require an investment of IDR 34.95 trillion (US$ 2.97 billion), generating annual savings of IDR 2.29 trillion (US$ 195.05 million), paying back the investment in 15.2 years and generating annual savings across South Sumatra for the lifetime of the measures.

— 28.3% with cost neutral measures that could be paid for by re-investing the income generated from all cost-effective measures. This would require an investment of IDR 18.17 trillion (US$ 1.54 billion), generating annual cost savings of IDR 5.50 trillion (US$ 467.4 million), paying back the investment in 3.3 years but generating annual savings for the lifetime of the measures.

— 32.0% with cost neutral measures in the electricity sector that could be paid for by re-investing the income generated from cost-effective measures. This would require an investment of IDR 111.42 trillion (US$ 9.47 billion), generating annual cost savings of IDR 6.50 trillion (US$ 552.25 million), paying back the investment in 17.2 years and generating annual savings across South Sumatra for the lifetime of the measures.

— 46.5% with the exploitation of all the realistic potential of the different measures with carbon saving potential. This would require investment of IDR 4.56 quadrillion (US$ 387.30 billion), generating annual savings of IDR 14.53 trillion (US$ 1.24 billion).

Figure 2.
CO_2-e emissions from Johor Bahru and Pasir Gudang under five different investment scenarios, as a function of 2014 emissions, between 2000 and 2025.



We find that the industry sector contains 46.1% of the total potential for cost-effective low carbon investments, with the remaining potential being distributed among the domestic sector (21.4%), commercial sector (1.2%), transport sector (7.8%), waste sector (14.1%) and the electricity supply sector (9.4%).

While 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 options, by 2025 emissions would be 88.5% above 2014 levels and, With the exploitation of all cost neutral measures, 78.0% above 2014 levels. Investment in all cost effective measures will save IDR 7.18 trillion (US$610.94 million) in energy costs per year, thereby reducing the energy bill in 2025 from 20.9% to 15.0% of GDP. Investment in all cost neutral measures will save IDR 7.85 trillion (US$667.12 million) in energy costs per year, thereby reducing the energy bill in 2025 to only 14.5% of GDP.

Conclusions and Recommendations

This research reveals that there are many economically attractive opportunities to increase energy efficiency and stimulate renewable energy investment, which would in turn improve the economic competitiveness, energy security and carbon intensity of Palembang. The scale of the opportunities demonstrates that accounting for climate change in the early stages of development can be attractive in commercial terms, above and beyond the immense benefits of reducing the future impacts of climate change.

The presence of such opportunities does not mean that they will necessarily be exploited. By providing evidence on the scale and 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 Palembang in particular and Indonesia more broadly to secure the investments and develop the delivery models needed for ambitious climate action. Some of the energy efficiency and low carbon opportunities could be commercially attractive whilst others may only be viable with public investment and/or climate finance. Many of the opportunities would benefit from the support of enabling policies from government.

We also stress that economics is not the only discipline that has something useful to say on the transition to a low carbon development model in Palembang. 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 in the city.

Palembang can reduce its emissions by 24.1% in 2025, relative to business as usual levels, through cost effective investments. These would generate annual savings of IDR 5.14 trillion (US$ 436.80 million) and pay back the investment in less than one year.

Chapter 1. Introduction, Context, Aims and Objectives

Cities, Energy, Carbon and Climate

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.

One of the key issues in the future of cities is energy. 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.[3] Despite its costs and impacts, modern energy is critical to human wellbeing. It enhances quality of life and enables economic activity. Increasing energy supplies and improving energy access facilitate development. The challenge is achieving sustainable and affordable energy provision – how can cities shift to energy efficient, low carbon development paths?

Cities' share of global emissions is high and rising fast, but their institutional capacity and socio-economic dynamism also mean that cities are uniquely positioned to tackle climate change. This is particularly true in fast-growing emerging economies where massive investment in infrastructure provides an opportunity to transition to a less energy and carbon intensive development trajectory. 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 efficiency and low carbon objectives into planning processes has the potential to reduce energy bills, increase energy access, improve air quality, ease congestion, create jobs and mitigate the impacts of climate change.

Focusing on Palembang, this report considers the ways in which the relationship between energy and development in a rapidly growing city with pressing development needs could be changed. 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 Palembang. 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.

The Indonesian Context

Indonesia's energy demand more than tripled between 1990 and 2012, from 52.4 million tonnes of oil equivalent (Mtoe) to 159.4 Mtoe.[4] This means that Indonesia today has the sixteenth largest energy demand in the world, which – considering that it also has the fourth largest population – indicates the low level of energy consumption per capita. The industrial sector's share of total primary energy demand increased from 31% to 40% between 1990 and 2009. Transport has also grown significantly, with an increase from 14% to 18% of energy demand in the same period. The share of energy use by households and services has decreased from 55% to 43% (though absolute energy consumption increased).[5] In 2012, Indonesia's fuel mix comprised 36% oil, 27% biomass and other renewables, 20% coal and 17% natural gas.[6]

Individual energy consumption remains low in Indonesia at 0.85toe per capita, compared to the OECD average of 4.28, China of 1.7 or Africa at 0.67.[7] This is particularly striking considering that Indonesia was formerly a net oil exporter and was the world's largest exporter of coal and fourth largest exporter of liquefied natural gas (LNG) in 2012.[8] Indonesia is seeking to significantly expand domestic energy access to achieve human development goals and eliminate poverty. Even though economy activity in Indonesia is relatively energy intensive, and energy is in turn relatively carbon intensive, the low levels of energy consumption mean per capita emissions in Indonesia are only two fifths of the world average and 18% of the OECD average.[9]

Nonetheless, in its National Action Plan to Combat Climate Change, the national government has committed to emission intensity reduction targets of 26% on 2005 levels by 2020, and 41% reduction with international assistance.[10] The majority of these savings are anticipated to come from the land use, land use change and forestry sector, as rapid deforestation currently positions Indonesia as one of the world's leading greenhouse gas emitters. However, Indonesia's large population, rapid economic growth and carbon intensive energy generation all mean that emissions from other sectors will be increasingly significant.

There are strong social, political and economic incentives for Indonesia to improve the efficiency and sustainability of urban energy consumption beyond its vulnerability to climate change impacts. Low carbon measures have the potential to reduce traffic congestion, improve air quality, create jobs, improve energy access and increase economic competitiveness. Of particular importance in an Indonesian context are the substantial fossil fuel subsidies, which lead to artificially low prices for consumers and encourage preferential investment in these energy sources. The subsidies impose a significant burden on government budgets (7-25% of annual public expenditures between 2005 and 2013)[11], favour the emerging middle classes at the expense of pro-poor expenditure[12] and risk national 'lock in' to high carbon, high cost development paths. Improved energy efficiency and provision of renewable energy has the potential to reduce net consumption of fossil fuels and therefore support government efforts to transition to market prices.

This broader context on energy and climate in Indonesia is directly relevant to cities.[13] Currently, 51% (125.9 million) of the 246.9 million people of Indonesia live in cities. Urbanisation is progressing at the rapid rate of 2.45% per annum,[14] which meant that 32.5 million Indonesians moved from rural to urban areas between 2000 and 2010.[15] Although there are significant inequalities within cities regarding access to modern energy, energy consumption is overwhelming concentrated in cities apart from the resource extraction industry. The inter-relationships between energy and cities are therefore pronounced.

Palembang

Palembang is the capital of South Sumatra and the seventh largest city in Indonesia. With a population of 1.5 million[16] and GDP per capita (Purchasing Power Parity) of US$ 2,940, Palembang exemplifies a medium-sized city in the newly industrialised country.[17] The major industries in the city include textiles and apparel, wood and paper products, chemicals and pharmaceuticals, rubber and plastic products, fabricated metals, and machinery, among others. Palembang is also an important port for the island of Sumatra. The city is increasingly known as a sporting hub, having jointly hosted the Southeast Asian Games in 2011 and the Islamic Solidarity Games in 2013.

The city of Palembang faces significant economic and social challenges. While it is expected to enjoy economic growth rates of 6-7% over the next decade,[18] residents often face income inequality and poor environmental conditions. Industrialisation combined with a growing vehicle fleet mean that air pollution and congestion are widely recognised as problems.[19] While there is some energy poverty in the city, Palembang has a high rate of electrification compared to rural South Sumatra and successfully converted the domestic sector from kerosene to LPG in 2007.[20]

Palembang is served by the South Sumatran grid, which has increased electricity production by 166% between 2000 and 2014. However, electricity use per capita in the state is less than a fifth of that in neighbouring Malaysia. We calculate that the carbon intensity of this grid has increased from 0.80tCO_2-e/MWh in 2000 to 0.84tCO_2-e/MWh in 2014. In this year, 48% of electricity was generated from coal, 19% from natural gas, 14% from hydropower, 9% from diesel and 1% from geothermal resources. With several coal-fired power plants coming online, the carbon intensity of the grid looks likely to increase to 0.94tCO_2-e/MWh unless Indonesia's national electricity company, Perusahaan Listrik Negara (PLN), achieves its ambitious geothermal production targets.

Massive additional investment in urban infrastructure is planned in order to fulfil Indonesia's human development goals. Palembang has been selected by the Indonesian Government as one of three cities to showcase sustainable transport options. A number of related projects are currently being completed under the auspices of the city council, including a Clean Air Initiative in collaboration with GIZ and solid waste management programme in conjunction with JICA. In addition to these sectoral plans, Palembang City Council has joined a number of city networks and programmes in an effort to improve institutional capacity and respond to challenges such as rising energy prices and climate change.

These initiatives are intended to redress historical deficits in infrastructure investment and maintain current economic growth rates. While imposing substantial challenges, the inadequacy of established infrastructure and the high growth rates also offer opportunities to influence the city's development trajectory to ensure that environmental constraints do not curtail human development or economic growth. The proposed spatial distribution and type of infrastructure are key to predicting energy and carbon trends in the city. If Palembang maintains its historical growth rates of 6% a year, half of the urban economy that will exist in 2025 has not been built yet. Integrating energy efficiency and low carbon goals into the city's development therefore offers the chance to shift the city on to a more cost-efficient and sustainable energy trajectory. Initial investment requirements might be higher, but ongoing costs will be lower and the city economy will be more resilient to volatile fuel prices and climate change impacts.

Aims and Objectives

What is the best way to shift a city to a more energy efficient, low carbon development path? Even where there is broad interest in such a transition, there are some major obstacles that often prevent cities from acting on such a far-reaching agenda. The absence of a credible and locally appropriate evidence base makes it particularly difficult for decision-makers to act.

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

We seek to map broad trends in energy use, energy expenditure and carbon emissions in Palembang, and examine the implications of 'business as usual' development in the city. This macro-level context aims to demonstrate the importance of energy efficiency and energy security at the city scale with the goal of mobilising high-level action around these issues.

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-effective measures, we aim to help development agencies, government, industry and civil society organisations to design low carbon strategies that exploit the most attractive opportunities. Notably, this 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 energy efficient, low carbon 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 supply to, and demand in Palembang. We do this for a range of different sectors including the energy sector on the supply side and the housing, commercial buildings, 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 in, for example, economic growth, population growth, consumer behaviour and energy efficiency. We then develop 'business as usual' baselines based on the continuation of these trends through to 2025. These baselines allow us to predict future levels and forms of energy supply and demand, as well as future energy bills and carbon footprints. We then compare all future activities against these baselines.

Identification and assessment of measures

We develop lists of all the energy efficiency, small scale renewables and low carbon 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 then review these to remove any options that are not applicable in the Indonesian context. The outputs then form our shortlists of measures for each sector. These shortlists are not necessarily exhaustive – some measures may have been overlooked, while others may not have been included in the analysis due to the absence of data on their performance.

Again drawing on extensive literature reviews and stakeholder consultations, we assess the performance of each measure on the shortlists. We consider the capital, running and maintenance costs of each measure, focusing on the marginal or extra costs of adopting a more energy efficient or lower carbon alternative. 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 incorporate the changing carbon intensities of energy use and assume an average annual rise of 3% in real prices (including energy).

Some of the measures interact with each other, so their performance depends on whether/to what extent another option is also adopted. For example, the carbon saving from any measure depends on the carbon intensity of electricity supply, and this in turn depends on whether various low carbon measures have been adopted in the electricity supply sector. Similarly, the carbon savings from adopting green building standards depend on whether there are also energy efficiency standards for air conditioners. To take these interactions into account, we calculate the impact of each measure if adopted independently with business as usual conditions in energy supply. These calculations underpin the figures in the league tables, the prioritised menus of different options. When we are determining the potential savings across a sector or across the city economy, we calculate the effect of each measure on the potential energy savings of other measures to develop realistic assessment of their combined impacts. For example, any electricity savings from efficiency improvements in the housing sector are deducted from the emission reductions associated with reducing the carbon intensity of the grid.

In many cases, a single measure has been considered under varying policy conditions: for example, solar photovoltaic panels with and without feed-in tariffs or waste infrastructure with high and low gate fees. When compiling the sector or economy-wide summaries, the cost-effective options which require the least enabling policies have been included (unless these policies are already established at scale). Therefore, the total investment needs, energy savings and payback periods reflect those of solar PV panels without feed-in tariffs and waste infrastructure with low gate fees.

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.

Table 1.
Lists of the low carbon measures considered.

Sector	Mitigation Measures
Electricity	Biodiesel replacing diesel; biomass-fired power plants; coal best available technology; coal retrofit; coal replaced with solar photovoltaic (PV) panels; geothermal power plants; installing smart grids; natural gas best available technology; natural gas retrofit; natural gas replaced by solar PV; non-technical loss reduction programmes; upgrading grid transmission.
Commercial	Air conditioners – energy efficiency standards; banning incandescent light bulbs; computers – energy management; copiers – energy management; elevators and escalators – energy efficiency standards; faxes – turning off; green building standards; monitors – energy management; printers – energy management; raising thermostat 1°C; retrofitting with mineral wool and fibreglass urethane; setting LED targets; solar photovoltaic panels with and without a feed-in tariff (FiT); turning off lights.
Domestic	Air conditioners – energy efficiency standards; banning incandescent light bulbs; biomass boilers; entertainment appliances – standby; green building standards; kitchen appliances – energy efficiency standards; raising thermostat 1°C; retrofitting with mineral wool and fibreglass urethane; setting LED targets; solar lamps for outdoor lighting; solar photovoltaic panels with and without FiT; solar water heaters with and without FiT; turning off lights; washing machines – energy efficiency standards; water heaters – energy efficiency standards.
Industry	Fertiliser industry – ammonia synthesis at lower pressure, hydrogen recovery, improved process control, more efficient CO_2 removal from synthesis gas, process integration, steam reforming (large improvements), steam reforming (moderate improvements); fuel switching – coal replaced with grid electricity, coal replaced with natural gas, coal replaced with solar PV with and without FiT, diesel replaced with biofuel; gasoline replaced with bioethanol, petroleum replaced with grid electricity, petroleum replaced with solar PV with and without FiT, petroleum systems replaced with dual fuel systems; petroleum refinery and petrochemical industry – more efficient compressors, more efficient furnaces and boilers, more efficient heat exchangers, more efficient motors, more efficient pumps, more efficient utilities, monitoring and targeting, process integration; rubber industry – adoption of variable speed drive in electric motors, adoption of variable speed drive in pumps, heat recovery, leak prevention, lowering functional pressure, more efficient nozzles, reduction of excess air in boilers, using outside intake air.
Transport	B100 fuel with and without fuel subsidies and sales tax relief; B5 fuel with and without fuel subsidy; bicycle lanes; Bus Rapid Transport (BRT) system; electric cars; electric motorbikes; fuel efficient private cars (EURO IV); High Occupancy Vehicle (HOV) lanes; hybrid private cars with and without sales tax relief; Liquefied Petroleum Gas (LPG) buses; Light Rail Transit (LRT) system; parking demand management.
Waste	Anaerobic digestion with combined heat and power (CHP); anaerobic digestion with electricity recovery; centralised composting; Energy from Waste (EfW) with CHP; EfW with electricity recovery with and without FiT; home composting; landfill gas flaring; landfill gas utilisation with and without FiT; mass burn incinerator; recycling; waste prevention.

Assessment of the scope for deployment

We evaluate the potential scope for deploying each of the measures in the various sectors in Palembang in the period to 2025. We calculate deployment 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 and forms of energy consumption, or the scope for an option to be adopted in a particular industrial sub-sector.

Based on stakeholder consultations, we develop realistic and ambitious rates 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 with supporting policies and favourable conditions 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/rates of deployment to participatory review in expert workshops to ensure that they are as realistic as possible.

Aggregation, assessment of investment needs and opportunities

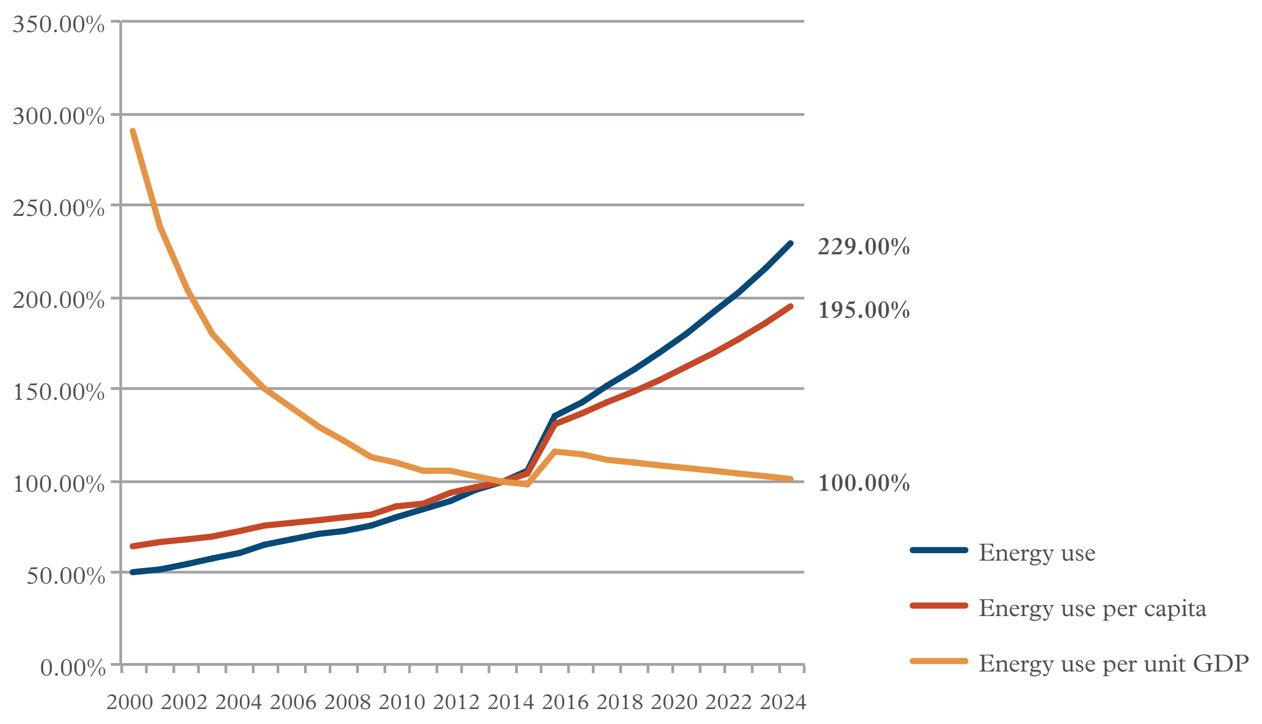
We draw together the results from our assessment of the performance of each measure, and the scope for deploying each measure, to develop aggregations of the potential influence of each measure across the different sectors of the city as a whole. This allows us to understand overall investment needs and paybacks, as well as impacts on energy supply and demand in the different sectors in the city. It also allows us to generate league tables of the most cost and carbon 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 3.
The Key Findings

Business as usual trends in Palembang show some decoupling of economic output and energy use between 2000 and 2025 (see Fig. 3). However, GDP and energy demand per capita are both rising steadily, while the population of Palembang is also growing. These effects are offsetting recent improvements in energy intensity and leading to a net increase in energy use.

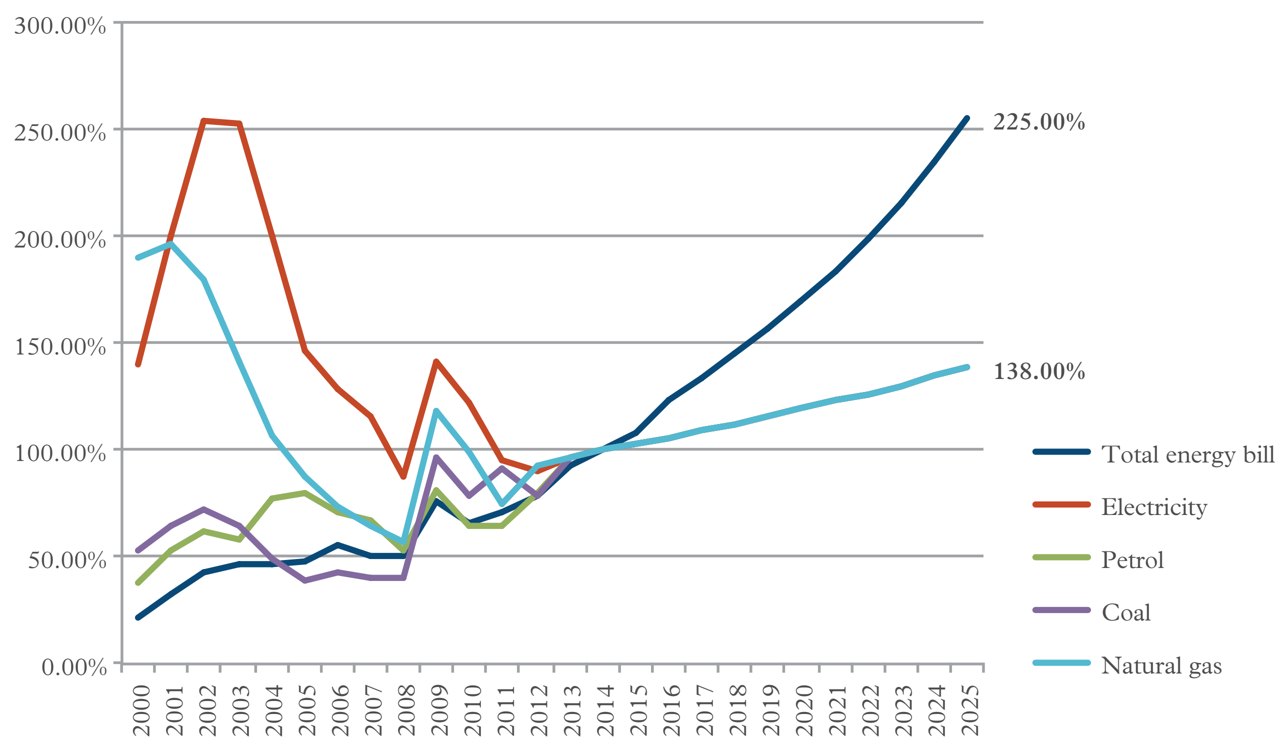
Figure 3.
Indexed energy use per unit of GDP and per capita.



The electricity grid on South Sumatra depends largely on coal for generation, with diminishing contributions from natural gas, hydroelectricity, diesel and geothermal resources. Despite the rising cost of natural gas and diesel in international markets, the real price of electricity in Indonesia has fallen significantly since 2000. This is because prices are set by the national government. The peak in the early 2000s reflects a rise in nominal prices during a period of relatively low inflation, while the subsequent fall in electricity prices reflects the fact that nominal prices were held roughly constant during a period of high inflation. While the real prices of petrol, diesel and kerosene have also risen, the increases are well below those of international market prices.

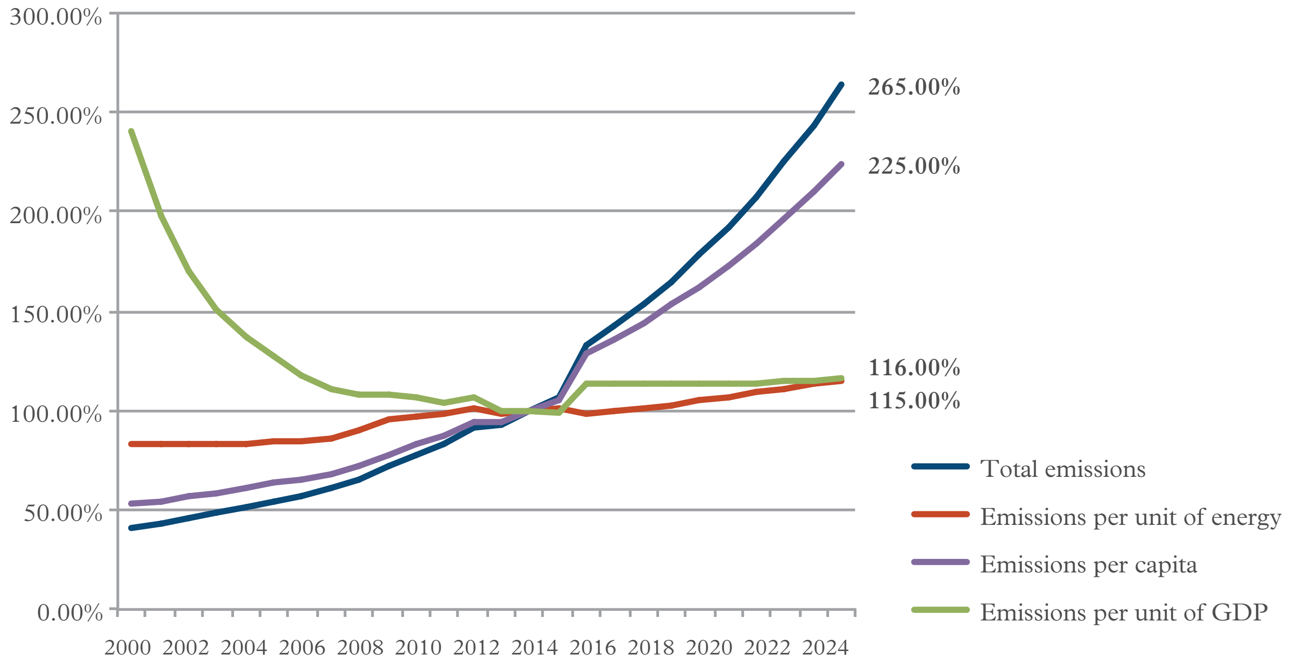
We have assumed an increase of 3% per annum for real energy prices. The rising real energy prices combined with increasing energy consumption means that, under business as usual conditions, the total energy bill for Palembang will more than double from its 2014 level in the period to 2025 (see Fig. 4).

Figure 4.
Indexed energy prices and total energy bill.



The emissions intensity of energy production is projected to increase slightly to 2025. When combined with rapid economic growth driven largely by an expansion of energy-intensive industries, the emissions produced per unit of GDP will remain roughly constant from 2014 to 2025. This is significant because this is the index that Indonesia is using in their national carbon targets in international negotiations. It is important to note that, despite the fact that emission intensity per unit of energy and per unit of GDP remains largely constant, rapid economic and population growth will lead to a rapid rise in emissions per capita and total emissions. In a business as usual scenario, total emissions from Palembang are therefore forecast to more than double 2014 levels by 2025 (see Fig. 5).

Figure 5.
Indexed total emissions per unit of energy, per unit of GDP and per capita.



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

For the city of Palembang, business as usual trends will lead total energy consumption to rise by 129.2% from 15.6 TWh in 2014 to a forecast level of 35.9 TWh in 2025 (see Fig. 6).

When combined with increasing real energy prices, this leads to the total expenditure on energy to increase by 155.1% from IDR 10.08 trillion (US$857.2 million) in 2014 to a forecast level of IDR 25.73 trillion (US$2.19 billion) in 2025 (see Fig. 7).

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 164.6% from 4.6 $MtCO_2$-e in 2014 to a forecast level of 12.3 $MtCO_2$-e in 2025 (see Fig. 8). presented in Appendix B.

Figure 6.
Energy consumption in Palembang (TWh) between 2000 and 2025.

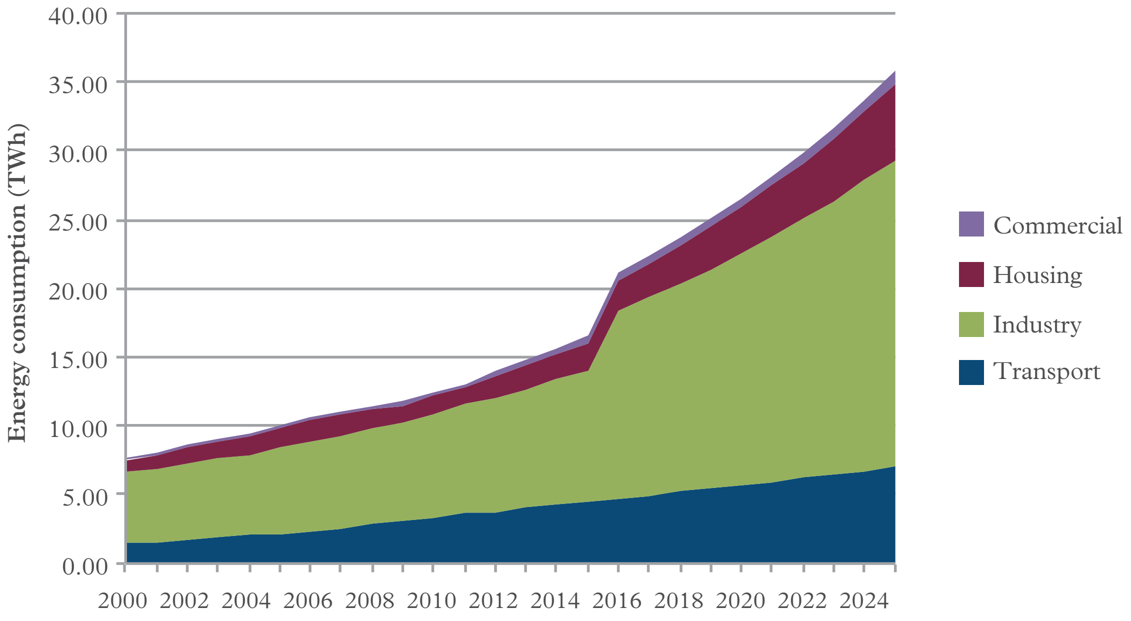


Figure 7.
The energy bill for Palembang (IDR trillions) between 2000 and 2025.

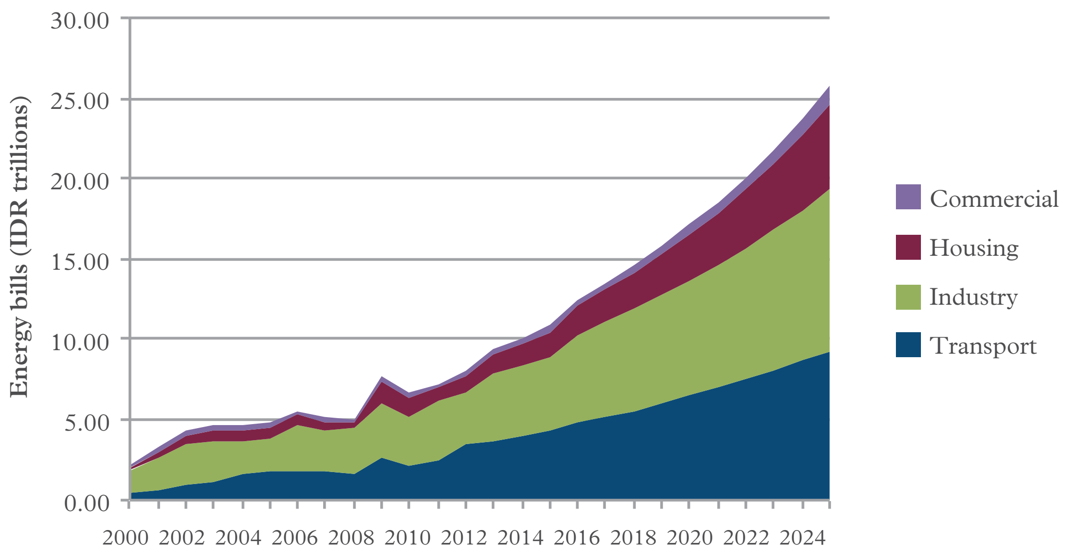
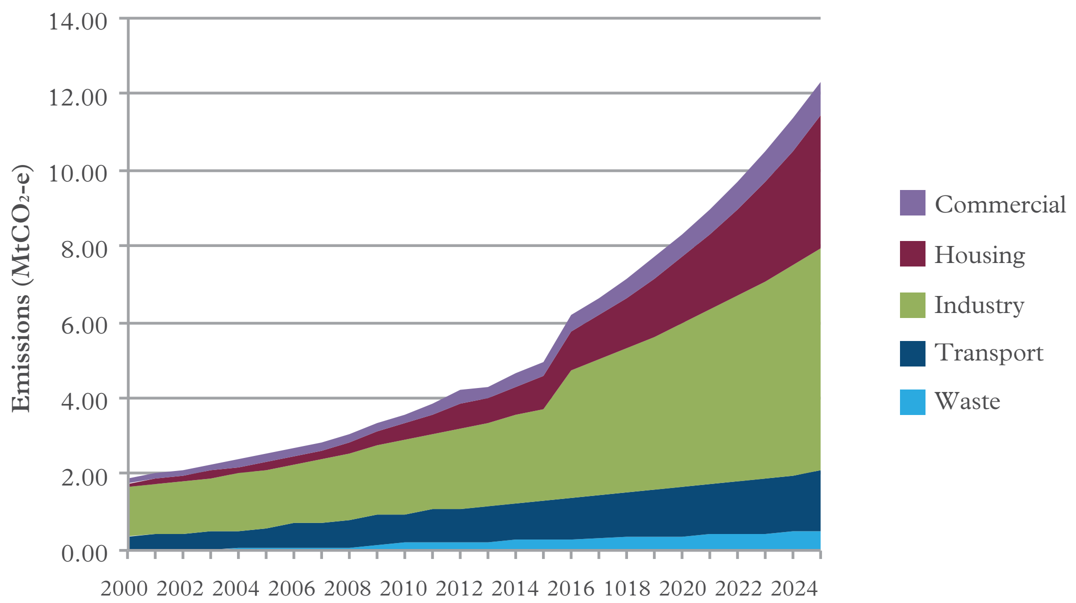


Figure 8.
Emissions from Palembang ($MtCO_2$-e) between 2000 and 2025.

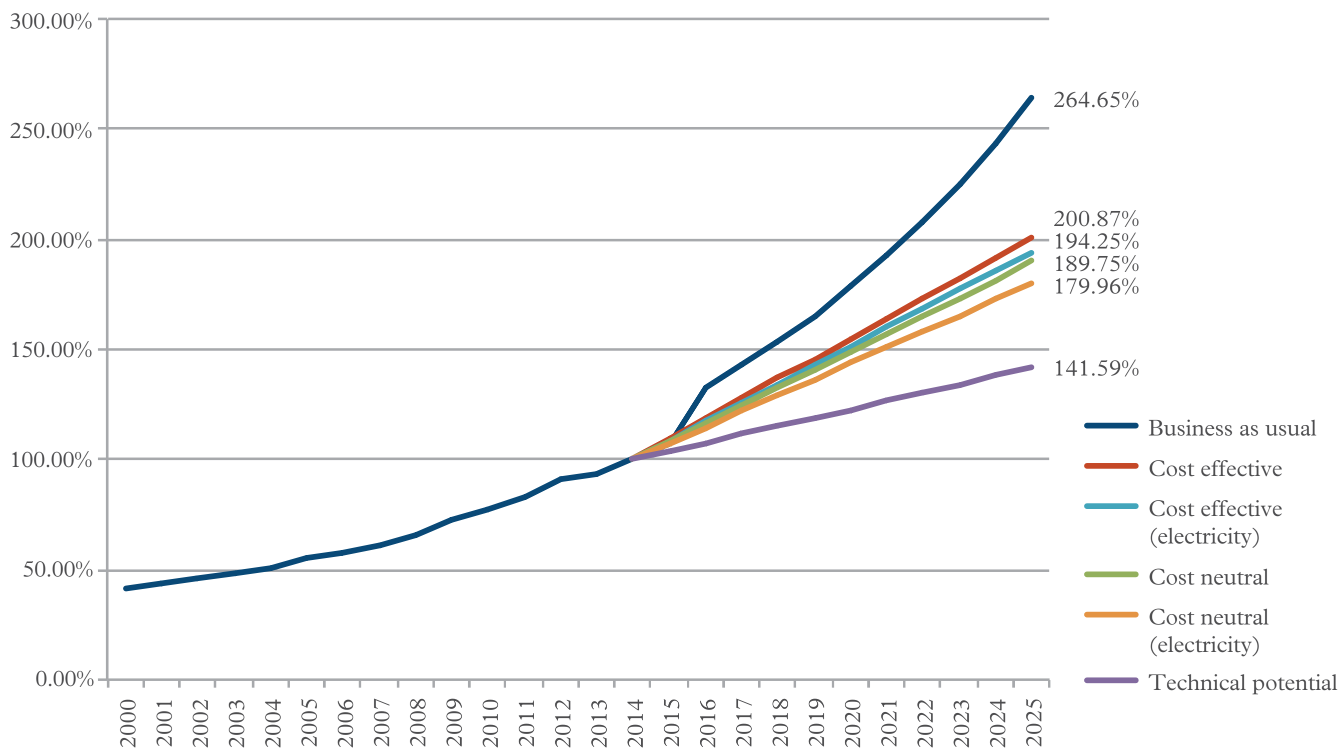


The Potential for Energy Efficient, Low Carbon Development

We find that - compared to business as usual trends – Palembang could reduce its carbon emissions by 2025 by:

- 24.1% through cost effective investments that would more than pay for themselves on commercial terms over their lifetime. This would come from an investment of IDR 4.77 trillion (US$ 405.6 million), generating annual savings by reducing energy bills by IDR 5.14 trillion (US$ 436.80 million), paying back the investment in less than one year but generating annual savings for the lifetime of the measures.
- 26.6% if, as well as the above investments, cost effective investments in the electricity sector were made that could more than pay for themselves on commercial terms over their lifetime. This would require an investment of IDR 34.95 trillion (US$ 2.97 billion), generating annual savings of IDR 2.29 trillion (US$ 195.05 million), paying back the investment in 15.2 years and generating annual savings for the lifetime of the measures.
- 28.3% with cost neutral measures that could be paid for by re-investing the income generated from all cost-effective measures. This would require an investment of IDR 18.17 trillion (US$ 1.54 billion), generating annual cost savings of IDR 5.50 trillion (US$ 467.4 million), paying back the investment in 3.3 years but generating annual savings for the lifetime of the measures.

Figure 9.
Emissions from Palembang under six different scenarios, as a function of 2014 emissions, between 2000 and 2025.

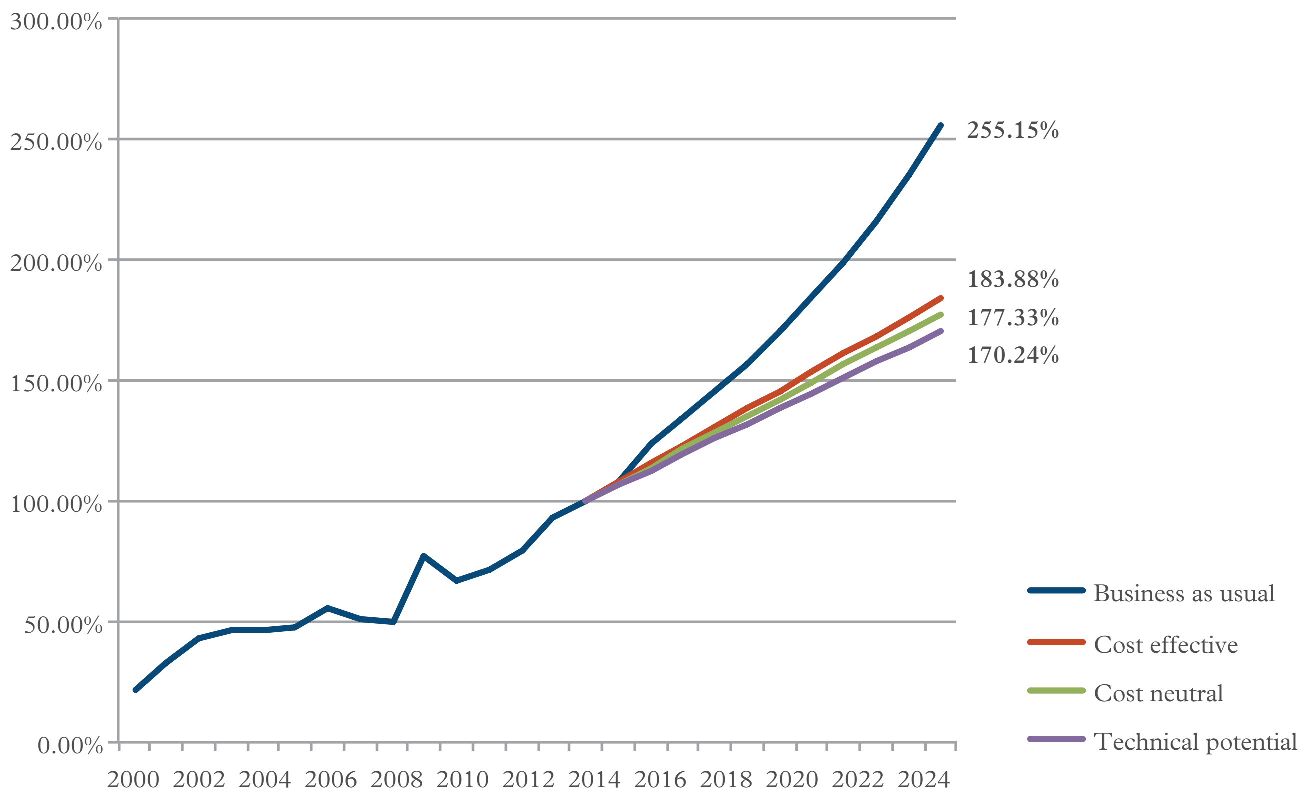


— 32.0% with cost neutral measures in the electricity sector that could be paid for by re-investing the income generated from cost-effective measures. This would require an investment of IDR 111.42 trillion (US$ 9.47 billion), generating annual cost savings of IDR 6.50 trillion (US$ 552.25 million), paying back the investment in 17.2 years and generating annual savings for the lifetime of the measures.

— 46.5% with the exploitation of all the realistic potential of the different measures with carbon saving potential. This would require investment of IDR 4.56 quadrillion (US$ 387.30 billion), generating annual savings of IDR 14.53 trillion (US$ 1.24 billion).

The impacts of all of these levels of change are shown in Figures 9 and 10.

Figure 10.
Energy bills for Palembang under four different scenarios (excluding investment in the electricity sector), as a function of 2014 emissions, between 2000 and 2025.



Chapter 4. Sector Specific Findings

The Electricity Sector

Palembang was connected to the South Sumatran electricity grid in 2004, which was in turn linked to the Northern Sumatran grid in 2006. Until this year, Palembang was serviced entirely by diesel generating units.

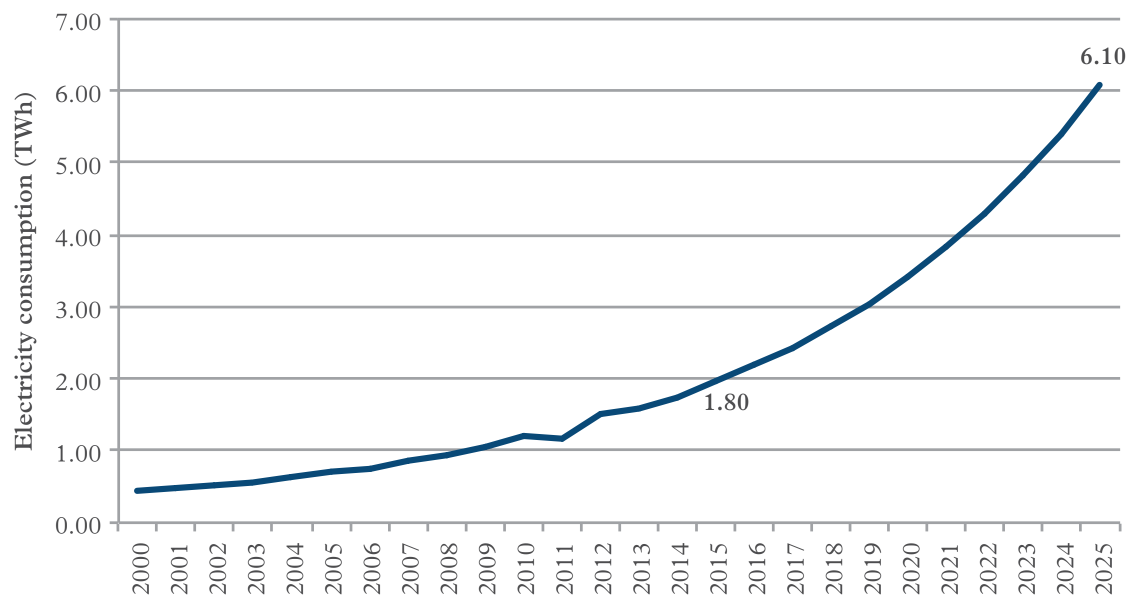
The electricity supply to the Sumatran grids increased by 166% between 2000 and 2014. Electricity usage per capita, however, is less than 20% of that in neighbouring Malaysia. Currently, the South Sumatera grid is 48% coal, 19% natural gas, 14% hydroelectric, 9% diesel and 1% geothermal generation. Looking forward to 2025, Indonesia's national electricity company, PLN, has ambitious plans to develop Sumatra's coal and geothermal resources. This will enable Sumatra to become a net energy exporter when the Java and Sumatra grids are connected in 2017.

The Changing Context and the Impacts of Business as Usual Trends

In the electricity sector, background trends suggest substantial growth in electricity consumption from the residential and industrial sectors. Electricity consumption is projected to rise by 238.9% from 1.8 TWh in 2014 to 6.1 TWh in 2025 (see Fig. 11).

When combined with rising levels of carbon emissions per unit of energy consumed, carbon emissions from electricity consumption in Palembang are projected to increase by 300.0% from 1.3 Mt CO_2-e in 2014 to 5.2 Mt CO_2-e in 2025 (see Fig. 12).

Figure 11.
Electricity consumption (TWh) between 2000 and 2025.



The Potential for Carbon Reduction – Investments and Returns

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

— 12.2% with cost effective measures that would more than pay for themselves on commercial terms over their lifetime. This would require net investment of IDR 35.0 trillion (US$ 2.9 billion), generating annual savings of IDR 2.3 trillion (US$ 175 million), paying back the investment in 15.2 years and generating annual savings for the lifetime of the measure.

— 34.9% with cost neutral measures that could be paid for by re-investing the income generated from cost-effective measures. This would require IDR 111 trillion (US$ 9.5 billion), generating annual savings of IDR 6.5 trillion (US$ 552 million), paying back the investment in 17.1 years and generating annual savings for the lifetime of the measure.

— 42.5% with the exploitation of all of the realistic potential of the different measures with carbon saving potential. This would require IDR 273 trillion (US$ 23.2 billion), generating annual savings of IDR 8.6 trillion (US$ 732 million), paying back the investment in 31.8 years and generating annual savings for the lifetime of the measure.

Figure 12.
Emissions from the electricity sector ($MtCO_2$-e) between 2000 and 2025.

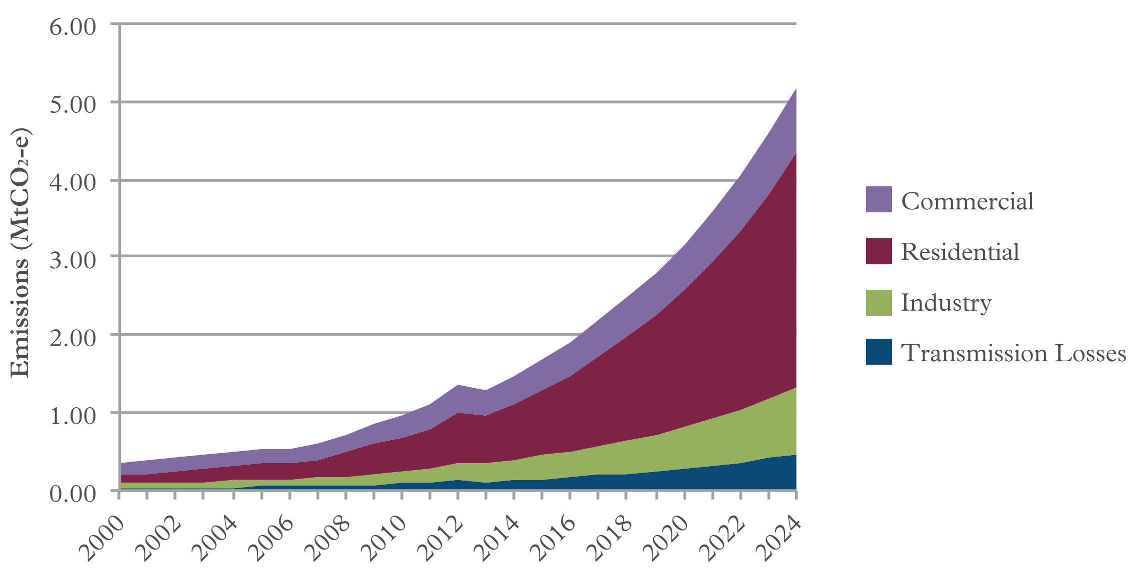


Figure 13.
Emissions from the electricity sector, as a function of 2014 emissions, between 2000 and 2025.

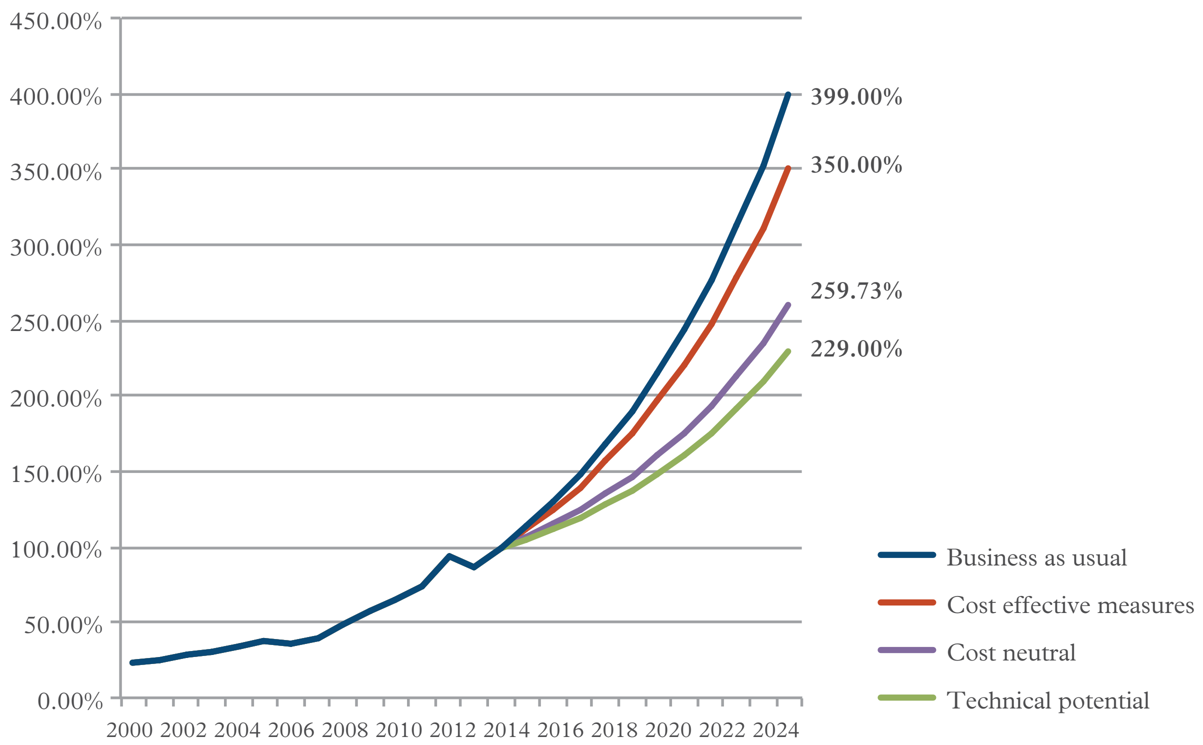
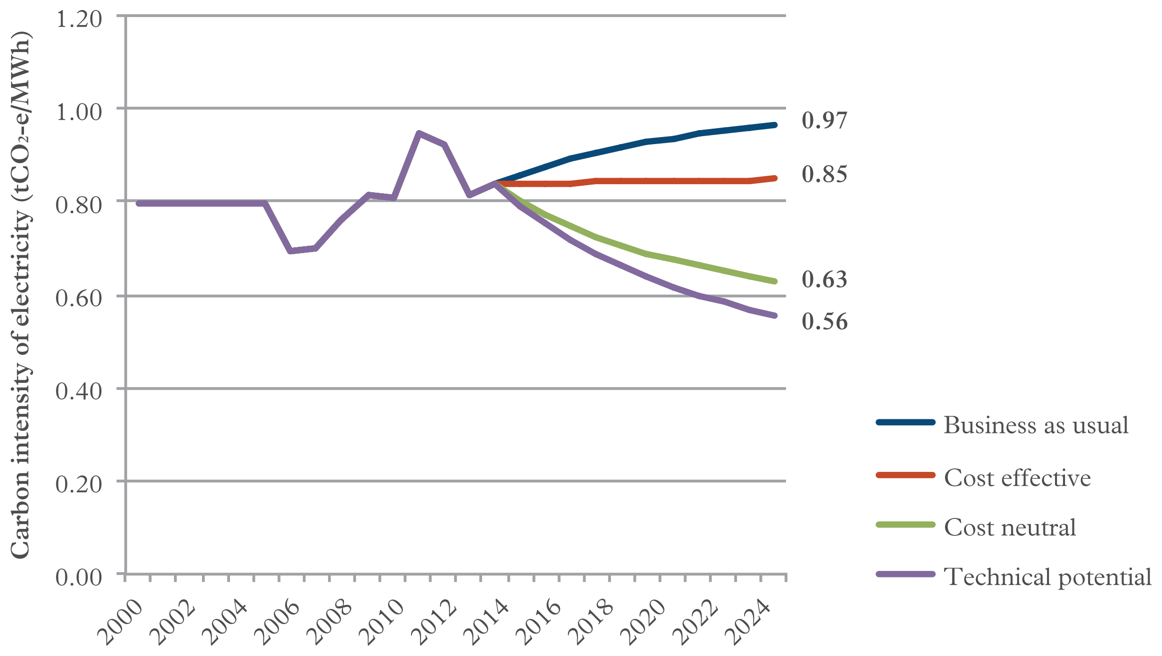


Figure 14.
Carbon intensity of the South Sumatran grid under four investment scenarios between 2000 and 2025.



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

Table 2.
League table of the most cost-effective measures for the electricity sector

Rank:	Measure:	IDR/tCO_2-e	USD/tCO_2-e
1	Natural gas retrofit (514 MW)	-745,193	-62
2	Geothermal 1000MW (replacing coal)	-95,712	-8
3	Geothermal 2000MW (replacing coal)	26,595	2
4	Coal replaced with Solar PV (1200 MW)	593,653	49
5	Natural gas replaced by Solar PV (1200 MW)	1,046,336	87
6	Coal retrofit (2185 MW)	11,053,499	915
7	Coal BAT (3673 MW)	11,053,499	915

Table 3.
League table of the most carbon-effective measures for the electricity sector

Rank:	Measure:	$ktCO_2$-e
1	Geothermal 2000MW (replacing coal)	74,583
2	Geothermal 1000MW (replacing coal)	37,291
3	Coal replaced with solar PV (1200 MW)	13,127
4	Natural gas replaced by Solar PV (1200 MW)	6,092
5	Coal BAT (3673 MW)	4,639
6	Coal retrofit (2185 MW)	2,760
7	Natural gas retrofit (514 MW)	1,233

Sector Focus

The Commercial Sector

The commercial sector uses a relatively small share of total energy in Palembang. Electricity is overwhelmingly the main source of energy. The commercial sector includes electricity sold under the ‘business’, ‘social services’, ‘government office building’ and ‘public street lighting’ tariffs. Businesses are by far the largest users of energy within this sector.

The Changing Context and the Impacts of ‘Business as Usual’ Trends

For 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 trends lead commercial sector energy consumption to rise by 120.0% from 427.6 GWh in 2014 to a forecast level of 940.7 GWh in 2025 (see Fig. 15).

When combined with increasing real energy prices, this leads to the total spend from the domestic sector on energy to increase by 208.7% from IDR 358.9 billion (US$30.5 million) in 2014 to a forecast level of IDR 1.11 trillion (US$94.2 million) in 2025 (see Fig. 16).

When combined with increasing levels of carbon emissions per unit of energy consumed, this leads to carbon emissions attributed to commercial consumption increasing by 154.0% from 357.6 $ktCO_2$-e in 2014 to a forecast level of 908.3 $ktCO_2$-e in 2025 (see Fig. 17).

Figure 15.
Energy consumption (GWh) by the commercial sector between 2000 and 2025.

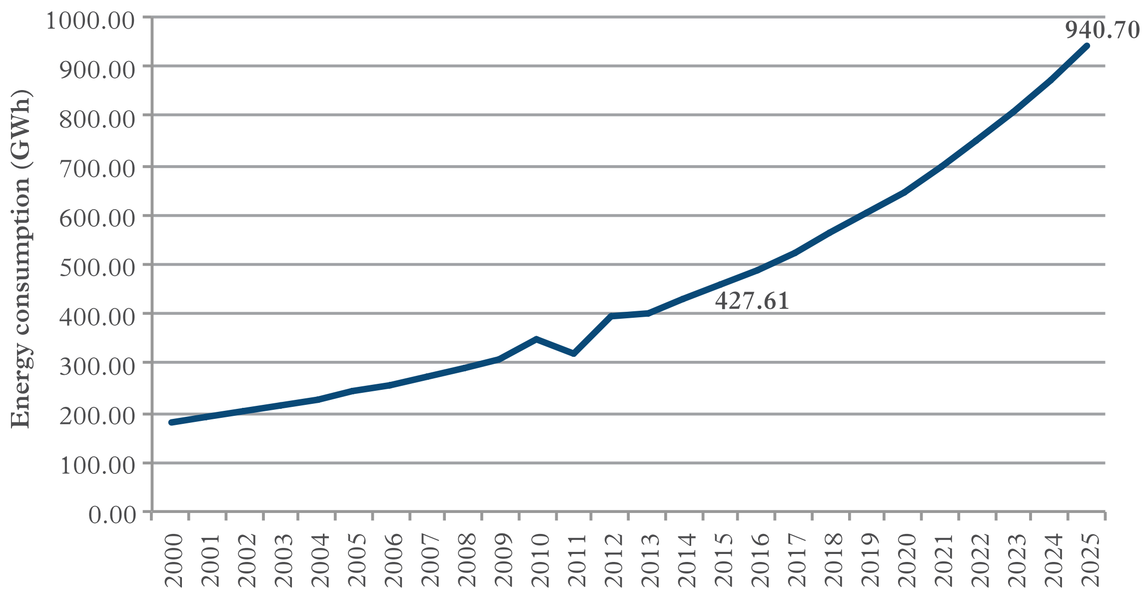


Figure 16.
Energy bills from the commercial sector (IDR billions) between 2000 and 2025.

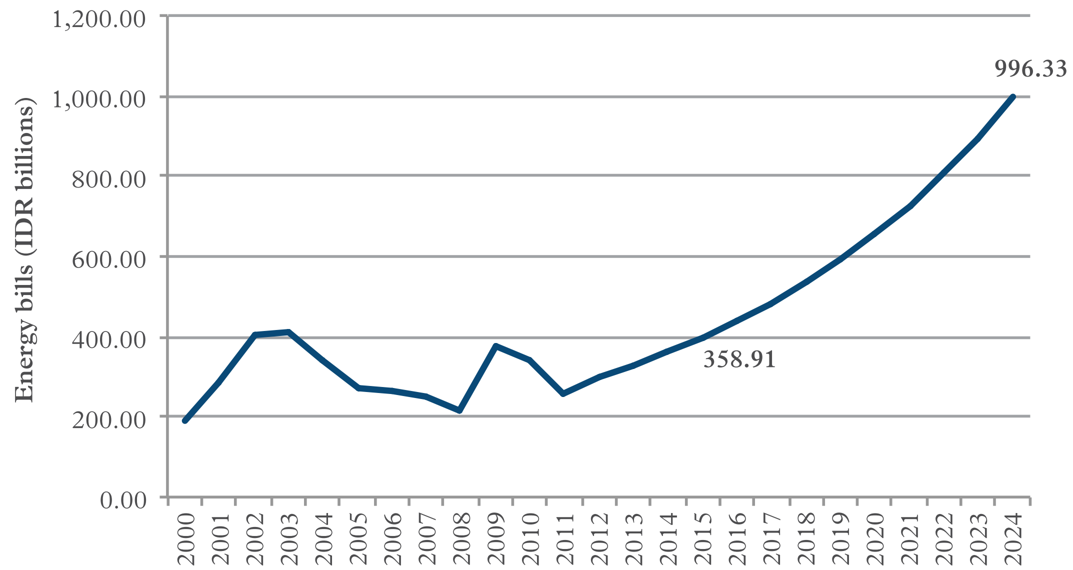
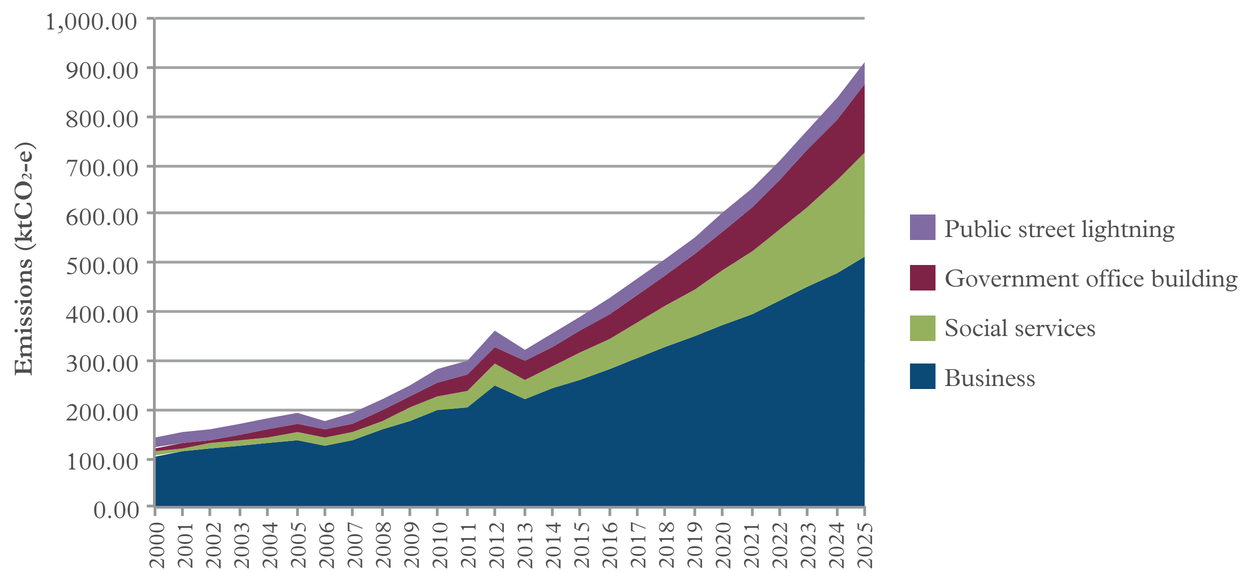


Figure 17.
Emissions from the commercial sector ($ktCO_2$-e) between 2000 and 2025.

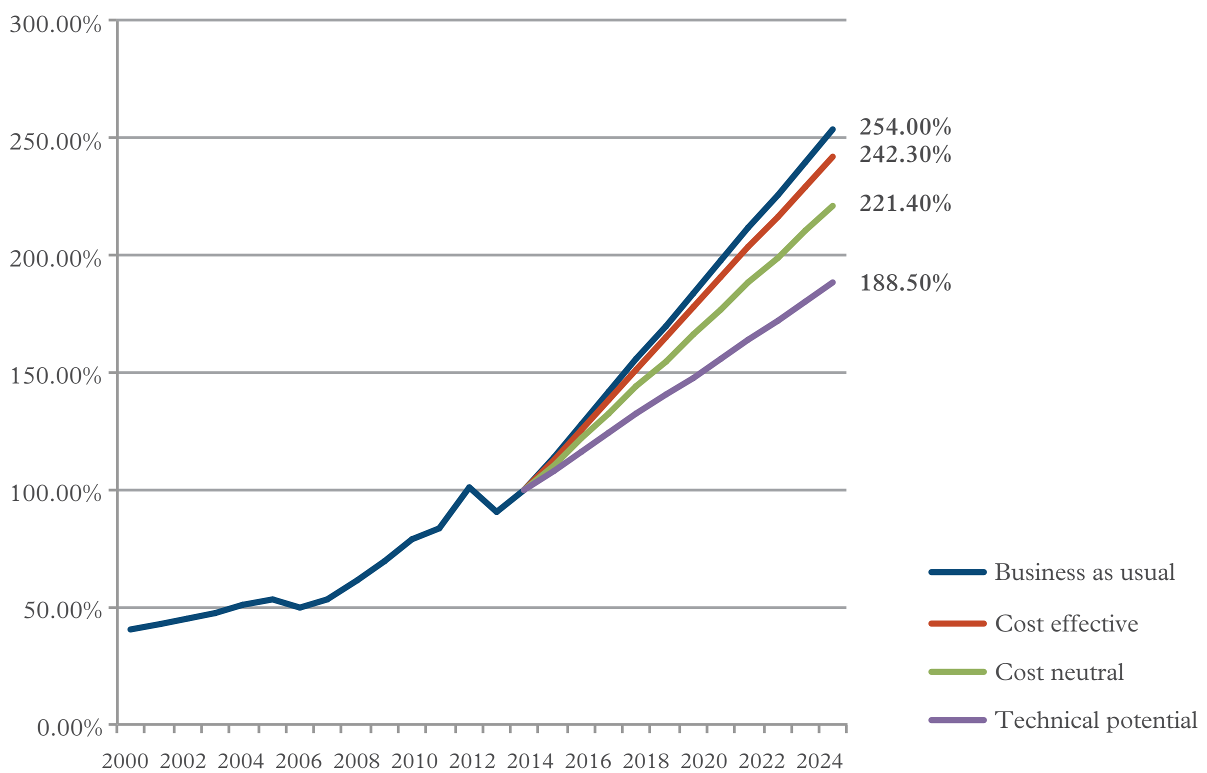


The Potential for Carbon Reduction – Investments and Returns

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

- 4.6% through cost-effective investments that would more than pay for themselves on commercial terms over their lifetime. This would require investment of IDR 55.05 billion (US$4.68 million), generating annual savings of IDR 65.90 billion (US$5.6 million), paying back the investment in less than a year and generating annual savings for the lifetime of the measures. These figures are based on the realistic deployment scenarios and do not include the revenue from feed-in tariff schemes.
- 8.2% through cost-neutral investments that could be paid for by re-investing the income generated from the cost-effective measures. This would require investment of IDR 645.71 billion (US$54.89 million), generating annual savings of IDR 84.61 billion (US$7.19 million), paying back the investment in 7.6 years and generating annual savings for the lifetime of the measures. These figures are based on the realistic deployment scenarios and do not include the revenue from feed-in tariff schemes.
- 12.9% with the exploitation of all of the realistic potential of the different measures with carbon saving potential. This would require an investment of IDR 2.89 trillion (US$246.00 million), generating annual savings of IDR 125.07 billion (US$10.6 million), paying back the investment in 23.1 years and generating annual savings for the lifetime of the measures. These figures are based on the optimistic deployment scenarios and do not include the revenue from feed-in tariff schemes.

Figure 18.
Emissions from the commercial sector under four different scenarios, as a function of 2014 emissions, between 2000 and 2025.



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

Table 4.
League table of the most cost-effective measures for the commercial sector

Rank:	Measure:	IDR/tCO$_2$-e	USD/tCO$_2$-e
1	Substituting grid electricity for diesel generators - shopping centres	-17,973,735.63	-1,527.90
2	Banning incandescent light bulbs	-1,518,490.31	-129.08
3	Computer - energy management	-871,751.30	-74.11
4	Printer - energy management	-871,751.30	-74.11
5	Fax - turning off	-871,751.30	-74.11
6	Copier - energy management	-871,751.30	-74.11
7	Monitor - energy management	-871,751.30	-74.11
8	Raising thermostat 1˚C	-821,538.76	-69.84
9	Elevators and escalators - EE Standard 1	-688,956.66	-58.57
10	Elevators and escalators - EE Standard 2	-688,956.66	-58.57
11	20kWp solar PV panel with FiT	-22,773.60	-1.94
12	20kWp solar PV panel	-4,395.07	-0.37
13	Setting LED target of 25%	-1,162.75	-0.10
14	Turning off lights	-878.14	-0.07
15	Green Buildings Standard 1	-590.68	-0.05
16	Green Buildings Standard 2	-572.71	-0.05
17	Air conditioner - EE Standard 1	804,281.05	68.37
18	Air conditioner - EE Standard 2	2,857,735.77	242.93

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

Table 5.
League table of the most carbon-effective measures for the commercial sector

Rank:	Measure:	$ktCO_2$-e
1	Green Buildings Standard 2 (100% of new commercial buildings)	221.47
2	Air conditioner - EE Standard 2	195.25
3	Turning off lights	121.98
4	Green Buildings Standard 1 (100% of new commercial buildings)	110.73
5	Green Buildings Standard 2 (50% of new commercial buildings)	110.73
6	Air conditioner - EE Standard 1	97.63
7	Banning incandescent light bulbs	66.69
8	Green Buildings Standard 1 (50% of new commercial buildings)	55.37
9	Raising thermostat 1˚C	33.51
10	Setting LED target of 25%	21.87
11	Elevators and escalators - EE Standard 2	19.02
12	Computer - energy management	13.80
13	20kWp solar PV panel – target of 2MW by 2025	9.58
14	20kWp solar PV panel with FiT – target of 2MW by 2025	9.58
15	Elevators and escalators - EE Standard 1	9.51
16	Monitor - energy management	5.21
17	20kWp solar PV panel – target of 1MW by 2025	4.79
18	20kWp solar PV panel with FiT – target of 1MW by 2025	4.79
19	Printer - energy management	4.13
20	Substituting grid electricity for diesel generators - shopping centres	0.12
21	Copier - energy management	0.37
22	Fax - turning off	0.07

Sector Focus

The Domestic Sector

Rapid improvements in living standards are both causing and caused by increasing energy use by the domestic sector in Palembang. Growing demand for electricity is largely driven by increasing ownership of air conditioners and, to a lesser extent, rice cookers, refrigerators and televisions. The demand for non-electricity energy sources is predominately for cooking. The Indonesian government coordinated a very successful kerosene-to-LPG conversion programme across the country, which reached Palembang in 2007-2008. This programme has significantly reduced the emission intensity of cooking in the domestic sector.

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

For the residential sector, background trends suggest substantial growth both in the number of households and in the average levels of energy consumption per household. Domestic sector energy consumption is projected to rise by 193.2% from 1.89 TWh in 2014 to a forecast level of 5.54 TWh in 2025 (see Fig. 19).

When combined with increasing real energy prices, this leads to the total spend from the domestic sector on energy to increase by 284.2% from IDR 1.36 trillion (US$115.4 million) in 2014 to a forecast level of IDR 5.21 billion (US$443.3 million) in 2025 (see Fig. 20).

Rapid increases in household electricity consumption combined with the increasing carbon intensity of the grid leads to carbon emissions attributed to the domestic sector increasing by 310.6% from 1.0 $MtCO_2$-e in 2014 to a forecast level of 3.9 $MtCO_2$-e in 2025 (see Fig. 21).

Figure 19.
Energy consumption (TWh) by the domestic sector between 2000 and 2025.

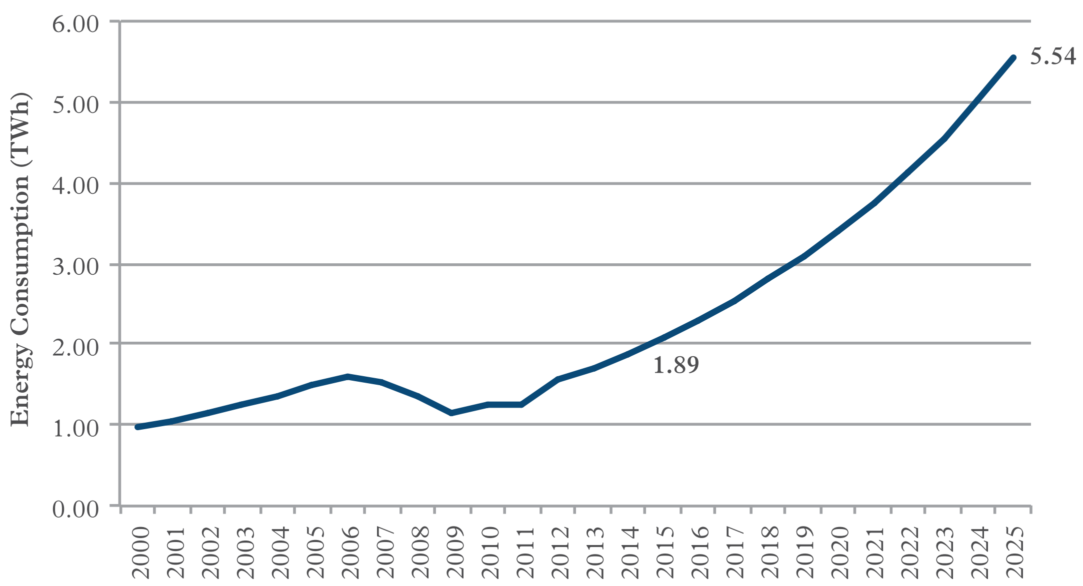


Figure 20.
Energy bills from the domestic sector (IDR trillions) between 2000 and 2025.

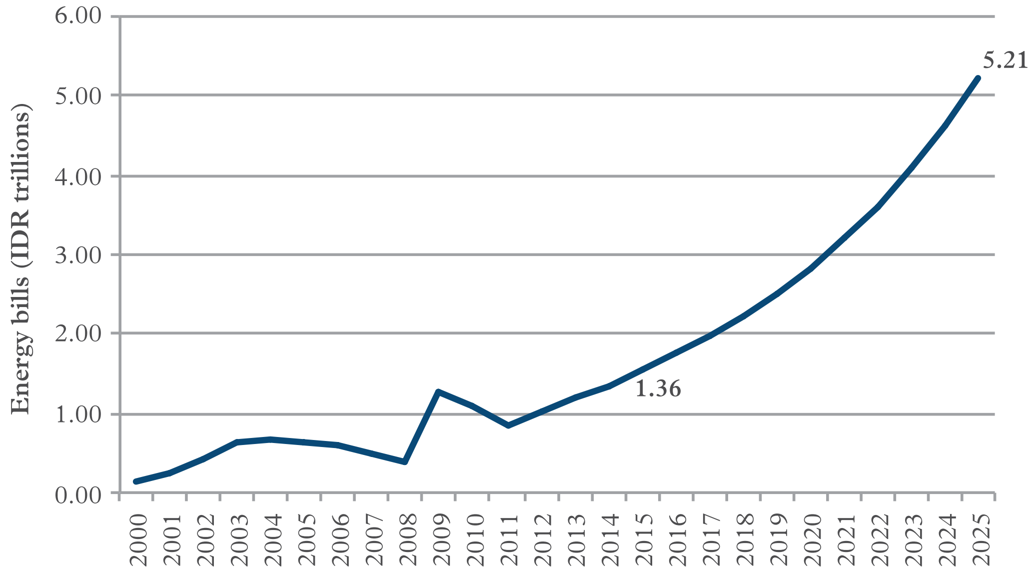
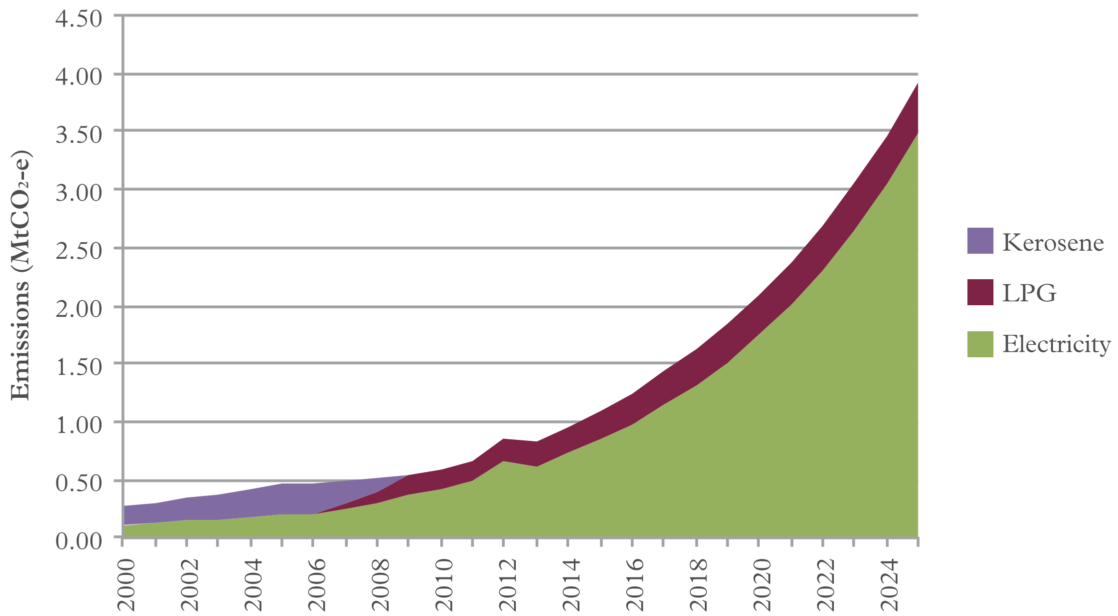


Figure 21.
Emissions from the domestic sector ($MtCO_2$-e) between 2000 and 2025.

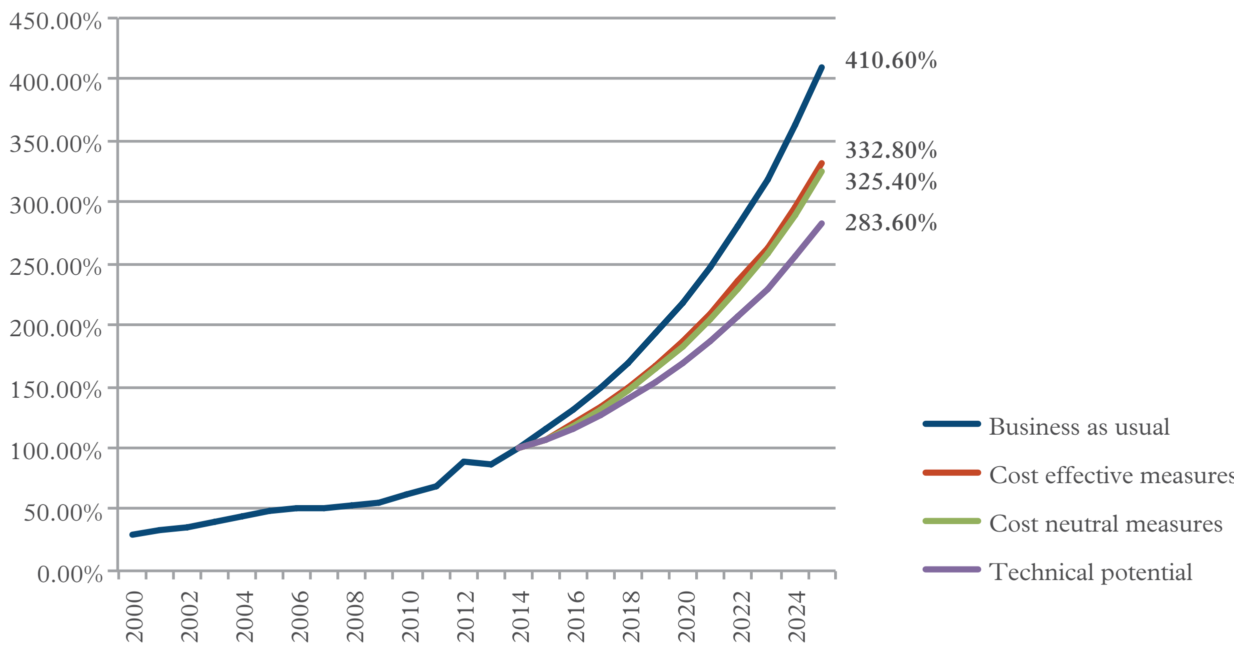


The Potential for Carbon Reduction – Investments and Returns

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

- 18.9% through cost-effective investments that would more than pay for themselves on commercial terms over their lifetime. This would require investment of IDR 1.59 trillion (US$166.11 million), generating annual savings of IDR 231.65 billion (US$19.69 million), paying back the investment in 8.4 years but generating annual savings for the lifetime of the measures. These figures are based on the realistic deployment scenarios and do not include the revenue from feed-in tariff schemes.
- 20.75% through cost-neutral investments that could be paid for by re-investing the income generated from the cost-effective measures. This would require investment of IDR 4.17 trillion (US$354.74 million), generating annual savings of IDR 302.05 billion (US$25.68 million), paying back the investment in 13.8 years and generating annual savings for the lifetime of the measures. These figures are based on the realistic deployment scenarios and do not include the revenue from feed-in tariff schemes.
- 30.9% with the exploitation of all of the realistic potential of the different measures with carbon saving potential. This would require an investment of IDR 15.39 trillion (US$1.31 billion), generating annual savings of IDR 450.14 billion (US$38.27 million), paying back the investment in 34.2 years and generating annual savings for the lifetime of the measures. These figures are based on the optimistic deployment scenarios and do not include the revenue from feed-in tariff schemes.

Figure 22.
Emissions from the domestic sector under four different scenarios, as a function of 2014 emissions, between 2000 and 2025.



- Cost effective
- Cost neutral
- All others (including "cost ineffective" and those mutually exclusive with other measures)

Table 6.
League table of the most cost-effective measures for the domestic sector

Rank:	Measure:	IDR/tCO_2-e	USD/tCO_2-e
1	Solar water heating with FiT	-1,513,224.15	-128.64
2	4kWp solar PV panel with FiT	-1,299,768.44	-110.49
3	Setting LED target of 25%	-967,007.30	-82.20
6	Banning incandescent light bulbs	-892,552.11	-75.87
7	Raising thermostat 1˚C	-535,367.78	-45.51
8	Entertainment appliances - standby	-533,604.54	-45.36
9	4kWp solar PV panel	-467,063.49	-39.70
10	Turning off lights	-458,346.83	-38.96
11	Green Building Standard 1	-422,711.13	-35.93
12	Green Building Standard 2	-422,711.13	-35.93
13	Solar water heating	-354,013.76	-30.09
14	Air conditioner - EE Standard 1	-165,288.45	-14.05
15	Retrofitting mineral wool insulation	-162,571.94	-13.82
16	Retrofitting fibreglass urethane insulation	-419,357.13	-12.27
17	Water heater - EE Standard 1	-92,697.05	-7.88
18	Solar lamps for outdoor lighting	-381.92	-0.03
19	Water heater - EE Standard 2	15,755.36	1.34
20	Kitchen appliances - EE Standard 1	169,062.28	14.37
21	Air conditioner - EE Standard 2	231,853.78	19.71
22	Kitchen appliances - EE Standard 2	571,241.59	48.56
23	Entertainment appliances - EE Standard 2	1,107,634.43	94.16
24	Entertainment appliances - EE Standard 1	1,192,494.68	101.37
25	Washing machine - EE Standard 1	6,727,299.26	571.87
26	Washing machine - EE Standard 2	19,462,440.25	1,654.46

Cost effective

Cost neutral

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

Table 7.
League table of the most carbon-effective measures for the domestic sector

Rank:	Measure:	$ktCO_2$-e
1	Air conditioner - EE Standard 2	2,159.45
2	Air conditioner - EE Standard 1	1,649.27
3	Retrofitting fibreglass urethane insulation (20% of existing households by 2025)	1,213.39
4	Water heater - EE Standard 2	705.26
5	Retrofitting mineral wool insulation (20% of existing households by 2025)	647.14
6	Retrofitting fibreglass urethane insulation (10% of existing households by 2025)	606.69
7	4kWp solar PV panel with FiT (10MW by 2025)	549.97
8	4kWp solar PV panel (10MW by 2025)	549.97
9	Green Building Standard 2 (100% of new households from 2015)	510.91
10	Kitchen appliances - EE Standard 2	457.16
11	Entertainment appliances - EE Standard 2	427.76
12	Raising thermostat 1°C	411.69
13	Entertainment appliances - EE Standard 1	327.63
14	Water heater - EE Standard 1	324.80
15	Retrofitting mineral wool insulation (10% of existing households by 2025)	323.57
16	Entertainment appliances - standby	322.57
17	4kWp solar PV panel (5MW by 2025)	274.99
18	Green Building Standard 1 (100% of new households from 2015)	255.46
19	Turning off lights	251.00
20	Solar water heating with FiT (10% of households by 2025)	239.54
21	Solar water heating (10% of households by 2025)	239.54
22	Green Building Standard 2 (50% of new households from 2015)	129.15
23	Green Building Standard 1 (50% of new households from 2015)	127.73
24	Solar water heating (5% of households by 2025)	119.77
25	Banning incandescent light bulbs	94.15
26	Kitchen appliances - EE Standard 1	75.90
27	Washing machine - EE Standard 2	53.79
28	Washing machine - EE Standard 1	41.83
29	Setting LED target of 25%	34.06
30	Solar lamps for outdoor lighting (100% of outdoor lamps sold)	14.16
31	Solar lamps for outdoor lighting (50% of outdoor lamps sold)	7.08

Sector Focus

The Industrial Sector

Palembang is the industrial centre of southern Sumatra and has seen dramatic growth in industrial activity over the last decade. Major industries in the city include textiles and apparel, wood and paper products, chemicals and pharmaceuticals, rubber and plastic products, fabricated metals, and machinery. From an energy or carbon perspective, the most significant are the petrochemical (fertiliser) and oil refinery industries

Background trends and planned investments suggest an ongoing expansion of industry and consequently, industrial energy use. In particular, the anticipated completion of a new fertiliser factory in 2015 is evident across all the figures as a significant spike in energy use, bills and emissions across the city. Natural gas is the most significant source of energy.

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

Industrial sector energy consumption is projected to rise by 146.7% from 9.05 TWh in 2014 to a forecast level of 22.33 TWh in 2025 (see Fig. 23).

When combined with increasing real energy prices, this leads to the total spend from the domestic sector on energy to increase by 135.5% from IDR 4.30 trillion (US$365.8 million) in 2014 to a forecast level of IDR 10.13 trillion (US$861.4 million) in 2025 (see Fig. 24).

Rapid increases in industrial energy consumption combined with the increasing carbon intensity of the grid leads to carbon emissions attributed to the industrial sector increasing by 152.6% from 2.32 $MtCO_2$-e in 2014 to a forecast level of 5.85 $MtCO_2$-e in 2025 (see Fig. 25).

Figure 23.
Energy consumption (TWh) by the industrial sector between 2000 and 2025.

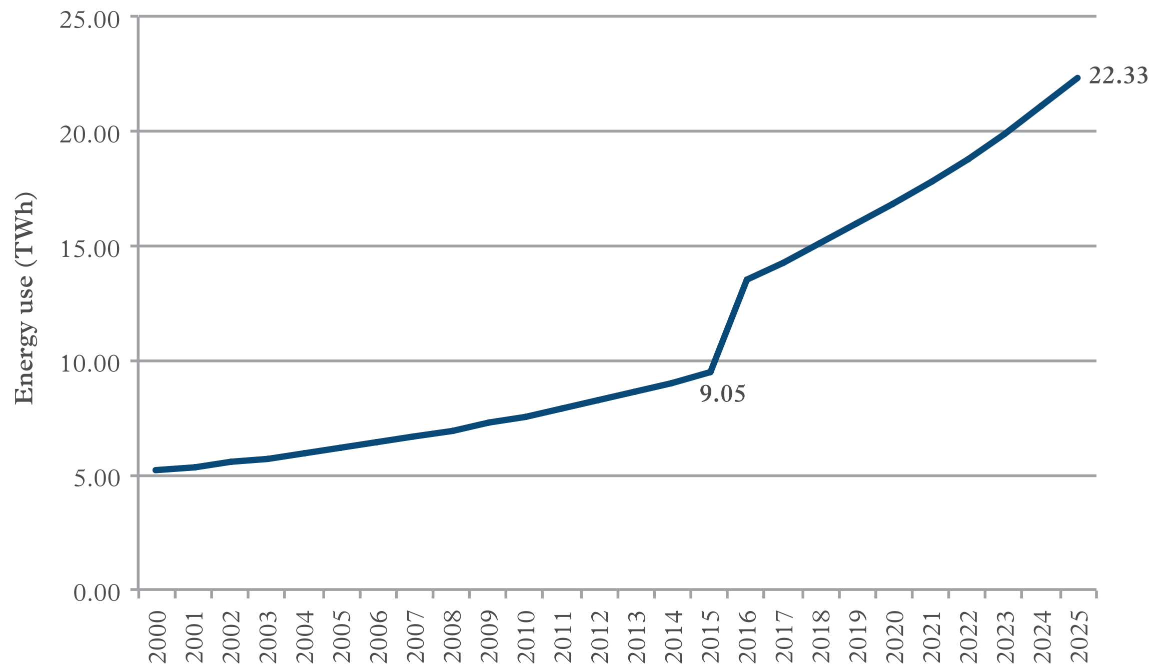
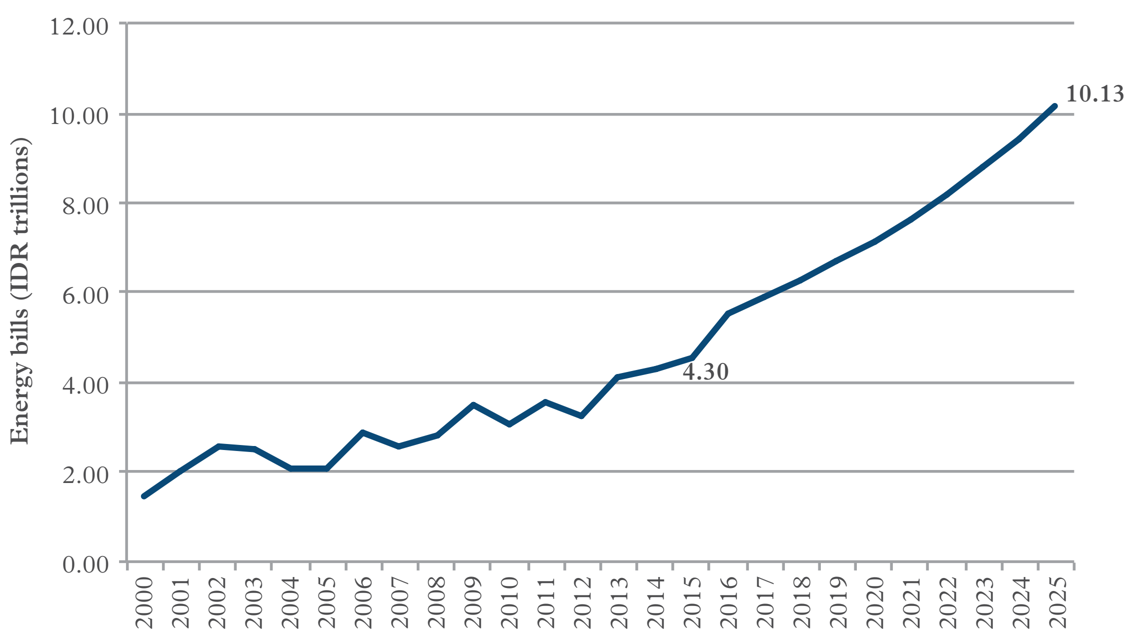


Figure 24.
Energy bills from the industrial sector (IDR trillions) between 2000 and 2025.



The Potential for Carbon Reduction – Investments and Returns

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

— 27.4% through cost-effective investments that would more than pay for themselves on commercial terms over their lifetime. This would require investment of IDR 562.7 billion (US$47.8 million), generating annual savings of IDR 2.98 trillion (US$253.2 million), paying back the investment in less than one year and generating annual savings for the lifetime of the measures.

— 29.4% through cost-neutral investments that could be paid for by re-investing the income generated from the cost-effective measures, which in this case includes all the remaining low carbon measures evaluated for the industrial sector. This would require investment of IDR 1.18 trillion (US$101 million), generating annual savings of IDR 2.67 trillion (US$226.6 million), paying back the investment in less than one year and generating annual savings for the lifetime of the measures.

— 34.2% with the exploitation of all of the realistic potential of the different measures with carbon saving potential. This would require an investment of IDR 4,076.9 trillion (US$346 billion), generating annual savings of IDR 2,913.0 trillion (US$247.6 million) for the lifetime of the measures.

Figure 25.
Emissions from the industrial sector ($MtCO_2$-e) between 2000 and 2025.

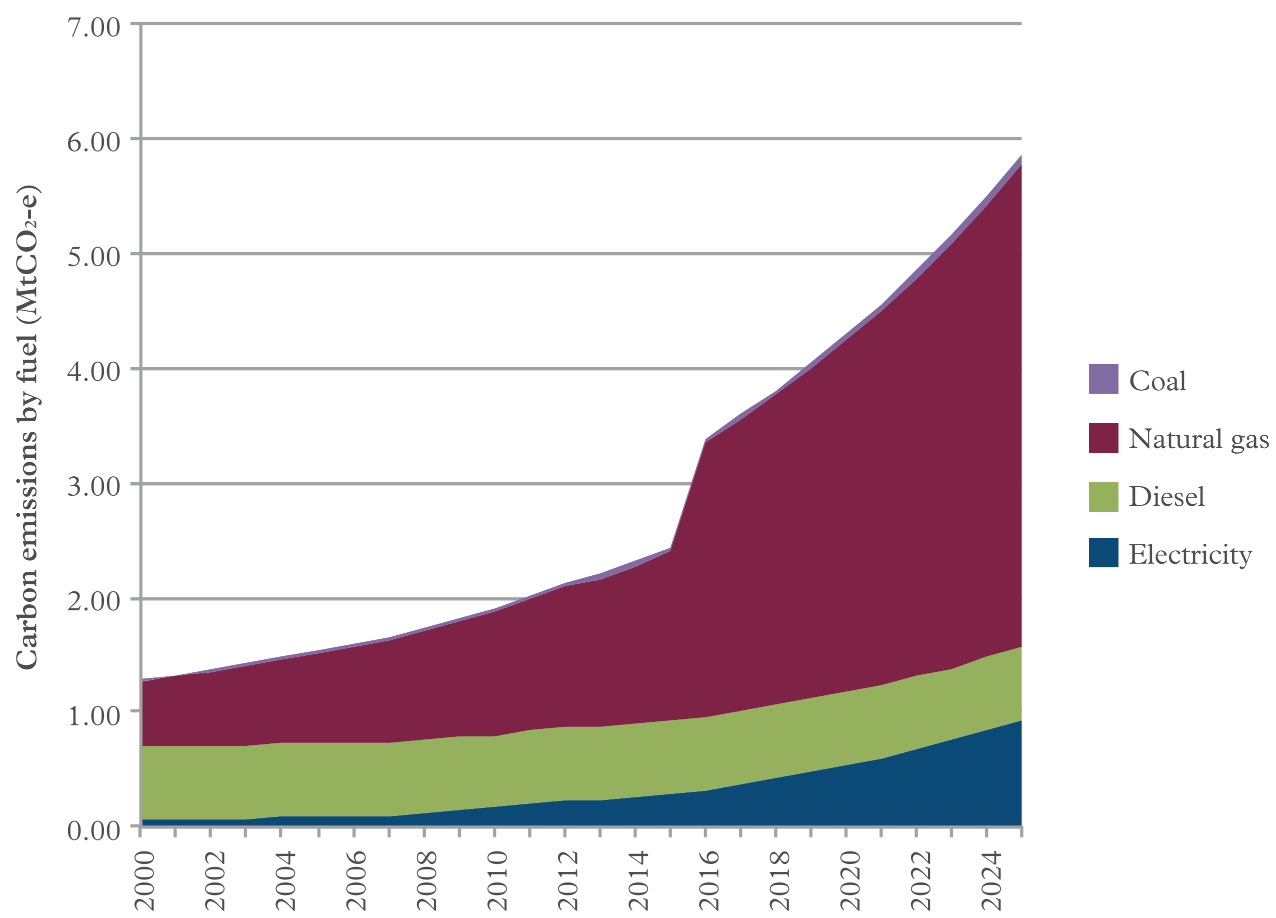
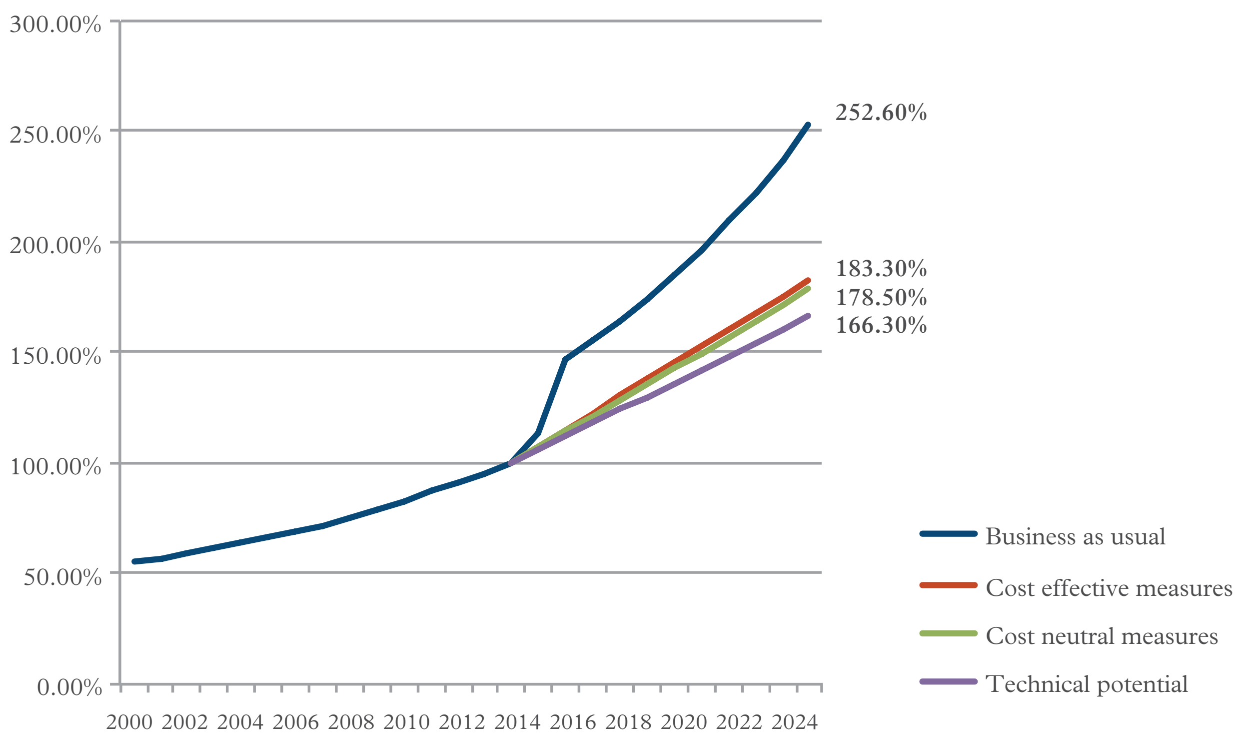


Figure 26.
Emissions from the industrial sector under four different scenarios, as a function of 2014 emissions, between 2000 and 2025



Cost effective

Cost neutral

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

Table 8.
League table of the most cost-effective measures for the industrial sector

Rank:	Measure:	IDR/tCO_2-e	USD/tCO_2-e
1	Fuel switching - diesel to dual fuel systems	-13,972,373.73	-1,187.76
2	Fuel switching - replacing diesel generators with solar PV	-4,392,128.17	-373.36
3	Petroleum refinery - more efficient pumps	-3,689,481.32	-313.63
4	Petroleum refinery - more efficient compressors	-3,637,503.88	-309.22
5	Petroleum refinery - more efficient motors	-3,637,503.88	-309.22
6	Petroleum refinery - more efficient furnaces and boilers	-3,627,108.39	-308.33
7	Petroleum refinery - more efficient heat exchangers	-3,533,548.99	-300.38
8	Petroleum refinery - more efficient utilities	-3,481,571.55	-295.96
9	Petroleum refinery - process integration	-3,460,780.58	-294.19
10	Petroleum refinery - monitoring and targeting	-2,251,453.13	-191.39
11	Fertiliser - steam reforming (moderate improvements)	-1,330,718.44	-113.12
12	Fertiliser - steam reforming (large improvements)	-1,329,327.67	-113.00
13	Pulp and paper - more efficient boilers and furnaces	-1,316,298.30	-111.90
14	Rubber industry - lowering functional pressure	-1,156,916.07	-98.35
15	Rubber industry - heat recovery	-1,128,342.59	-95.92
16	Rubber industry - leak prevention	-1,112,270.00	-94.55
17	Rubber industry - more efficient nozzles	-1,097,090.34	-93.26
18	Pulp and paper - replace pressure reduction valves with steam turbines (1MW)	-1,060,852.54	-90.18
19	Rubber industry - reduction of excess air in boilers	-946,186.61	-80.43
20	Pulp and paper - boiler maintenance	-737,452.40	-62.69
21	Fertiliser - process integration	-732,450.38	-62.26

Cost effective

Cost neutral

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

22	Fertiliser - hydrogen recovery	-731,591.38	-62.19
23	Pulp and paper - shoe press	-730,751.29	-62.12
24	Fertiliser - improved process control	-728,250.79	-61.91
25	Fertiliser - ammonia synthesis at lower pressure	-726,151.00	-61.73
26	Fertiliser - more efficient CO_2 removal from synthesis gas	-723,478.53	-61.50
27	Pulp and paper - boiler process control	-716,393.81	-60.90
28	Pulp and paper - flue gas heat recovery	-700,769.69	-59.57
29	Pulp and paper - steam trap maintenance	-695,335.22	-59.11
30	Pulp and paper - improved insulation of pipes, valves and fittings	-695,335.22	-59.11
31	Pulp and paper - pinch analysis	-677,786.39	-57.62
32	Pulp and paper - optimisation of pump system design	-677,786.39	-57.62
33	Pulp and paper - condensate return to boilers	-632,159.44	-53.74
34	Pulp and paper - optimisation of compressed air systems	-590,042.26	-50.16
35	Renewables - replacing diesel boiler/furnace with solar water heaters	-7,673.47	-0.65
36	Rubber industry - adoption of variable speed drive in electric motors	156,274.19	13.28
37	Fuel switching - diesel to biodiesel	201,392.51	17.12
38	Rubber industry - adoption of variable speed drive in pumps	737,863.27	62.72
39	Rubber industry - using outside intake air	1,314,690.53	111.76
40	Fuel switching - 30% grid electricity replaced by solar PV	1,646,854,141.15	139,995.12

Table 9.
League table of the most carbon-effective measures for the industrial sector

Rank:	Measure:	$ktCO_2$-e
1	Fuel switching - diesel to biodiesel	7,048.24
2	Renewables - replacing diesel boiler/furnace with solar water heaters	6,729.52
3	Fertiliser - steam reforming (large improvements)	3,165.91
4	Fertiliser - process integration	2,374.43
5	Fuel switching - 30% grid electricity replaced by solar PV	1,864.70
6	Fuel switching - diesel to dual fuel systems	1,260.52
7	Fertiliser - steam reforming (moderate improvements)	1,108.07
8	Petroleum refinery - monitoring and targeting	1,055.24
9	Fertiliser - more efficient CO_2 removal from synthesis gas	712.33
10	Fertiliser - hydrogen recovery	633.18
11	Petroleum refinery - more efficient utilities	593.57
12	Fertiliser - improved process control	569.86
13	Rubber industry - adoption of variable speed drive in electric motors	454.69
14	Fertiliser - ammonia synthesis at lower pressure	395.74
15	Petroleum refinery - more efficient furnaces and boilers	395.71
16	Petroleum refinery - process integration	296.79
17	Petroleum refinery - more efficient heat exchangers	296.79
18	Renewables - replacing diesel generators with solar PV	138.18
19	Rubber industry - reduction of excess air in boilers	126.07
20	Rubber industry - heat recovery	100.23
21	Petroleum refinery - more efficient pumps	94.97
22	Pulp and paper - replace pressure reduction valves with steam turbines (1MW)	92.53
23	Rubber industry - adoption of variable speed drive in pumps	84.84

Cost effective

Cost neutral

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

24	Petroleum refinery - more efficient motors	79.14
25	Pulp and paper - pinch analysis	55.94
26	Petroleum refinery - more efficient compressors	23.74
27	Rubber industry - more efficient nozzles	17.62
28	Pulp and paper - optimisation of pump system design	15.85
29	Pulp and paper - steam trap maintenance	13.05
30	Pulp and paper - boiler maintenance	8.48
31	Rubber industry - leak prevention	6.71
32	Pulp and paper - improved insulation of pipes, valves and fittings	3.92
33	Pulp and paper - boiler process control	3.65
34	Pulp and paper - more efficient boilers and furnaces	3.13
35	Rubber industry - using outside intake air	2.73
36	Rubber industry - lowering functional pressure	2.31
37	Pulp and paper - shoe press	2.10
38	Pulp and paper - optimisation of compressed air systems	2.01
39	Pulp and paper - condensate return to boilers	1.96
40	Pulp and paper - flue gas heat recovery	1.70

Sector Focus

The Transport Sector

Palembang has seen tremendous growth in transport demand since 2000, with car and motorcycle numbers growing on average 9.5% and 15.5% per year respectively. This has already led to significant increases in congestion and a deterioration of air quality in the city. A Bus Rapid Transport (BRT) system was launched in 2010, which has had some positive impacts on the energy intensity of travel. Looking forward to 2025, business as usual growth in vehicle numbers will lead to exponential increases in emissions and fuel expenditure, and sharp increases in travel times as Palembang's roads becomes still more gridlocked. To avoid this scenario a number of options for transit infrastructure are available.

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

In the transport sector, background trends suggest a substantial growth in the number of vehicles in Palembang. Growth in vehicle numbers leads transport sector energy consumption to rise by 58.0%, from 4.27 TWh per year in 2014 to a forecast level of 7.0 TWh in 2025 (see Fig. 27).

When combined with increasing real energy prices (3% per year), this leads to total spending on energy from the transportation sector to increase by 128.1% from IDR 4.06 trillion (US$ 345.6 million) in 2014 to a forecast level of IDR 9.27 IDR trillion (US$788.3 million) in 2025 (see Fig. 28).

Although public transportation has recently been added in Palembang with the introduction of a BRT in 2010, rapid growth in vehicle ownership is projected to lead to carbon emissions from the transportation sector increasing by 58.0%, from 1.0 MT in 2014 to a forecast level of 1.58 MT in 2025 (see Fig. 29).

Figure 27.
Energy consumption (TWh) from the transport sector between 2000 and 2025.

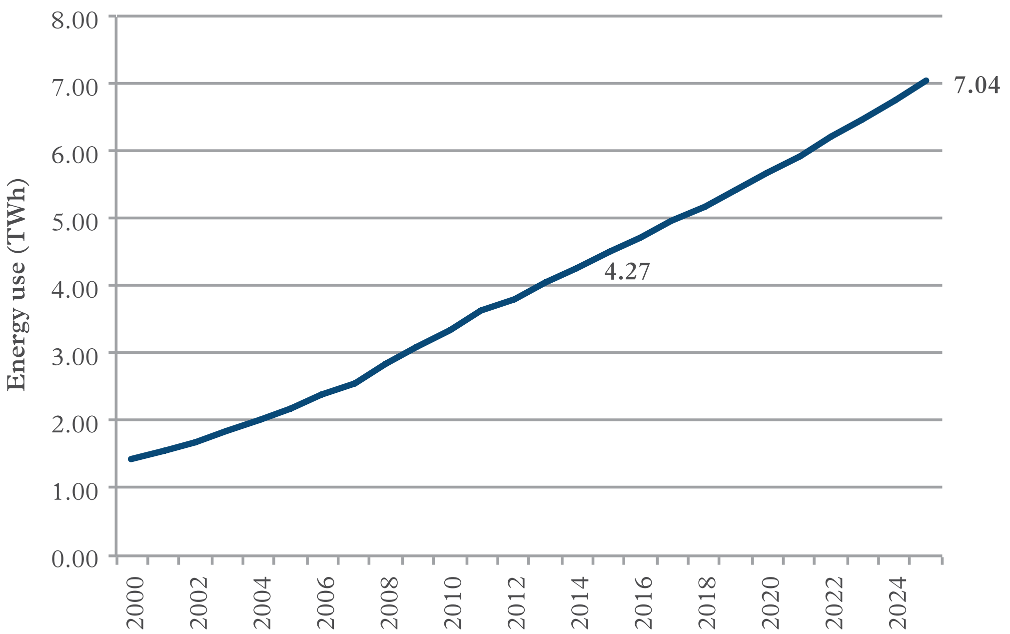


Figure 28.
Energy bills for the transport sector (IDR trillions) between 2000 and 2025.

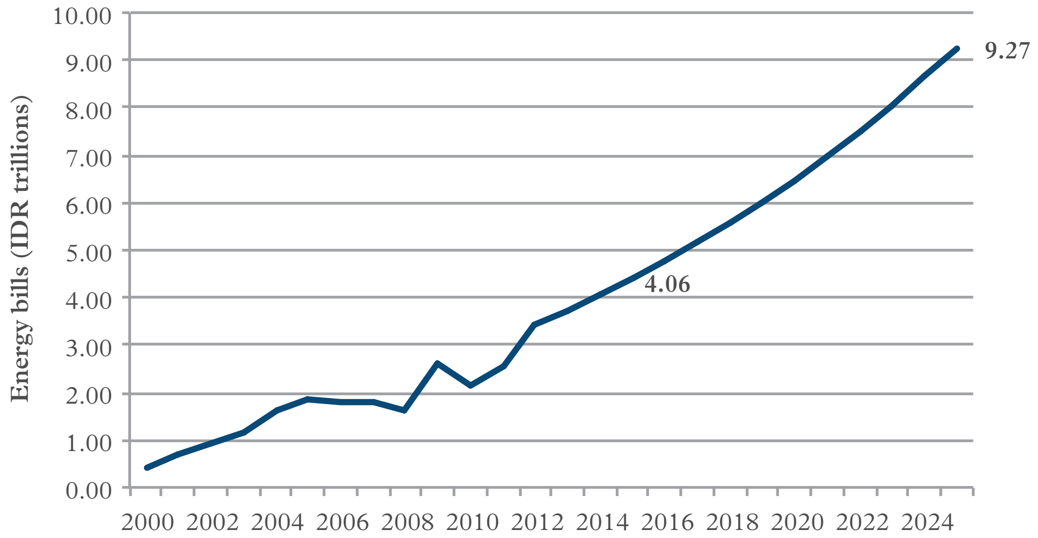
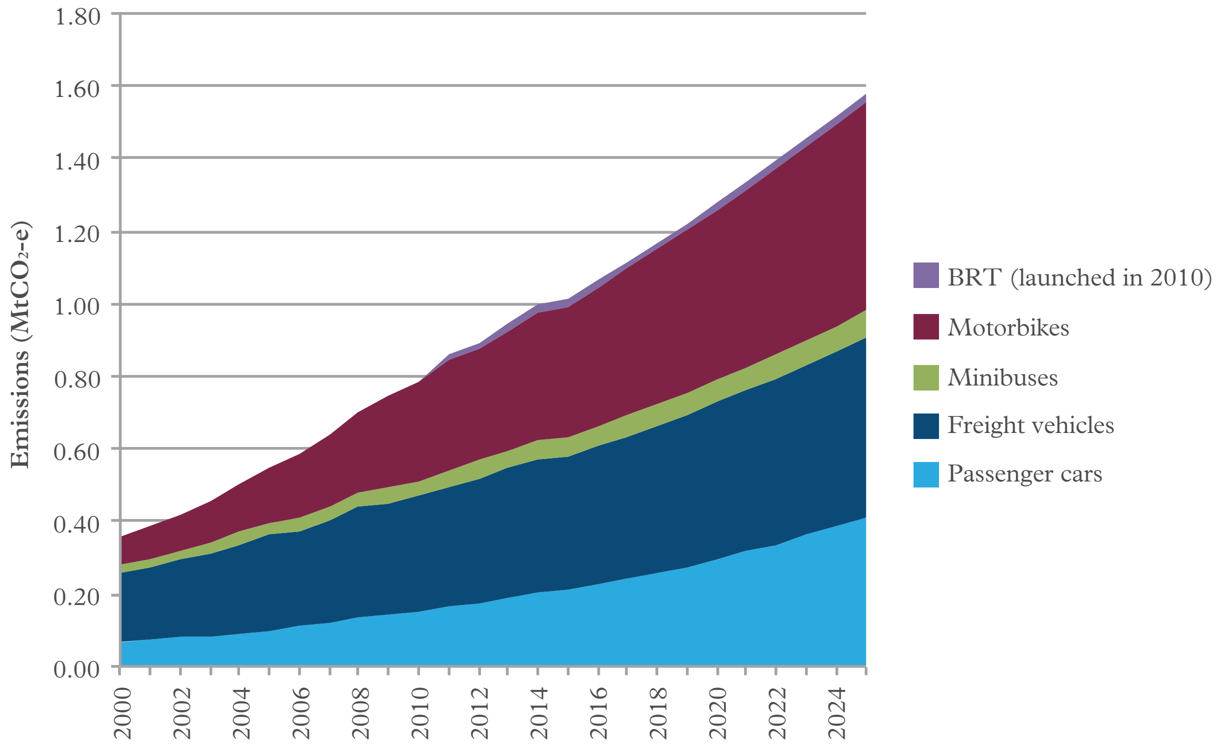


Figure 29.
Emissions from the transport sector ($MtCO_2$-e) between 2000 and 2025.



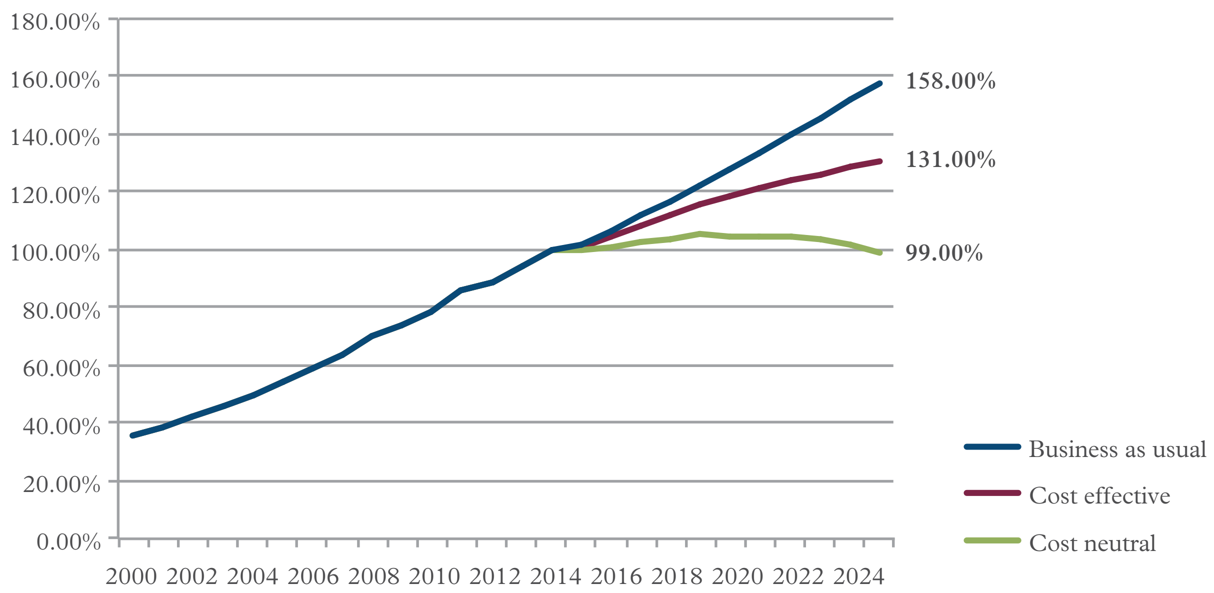
The Potential for Carbon Reduction – Investments and Returns

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

— 17.3% with cost effective measures that would pay for themselves on commercial terms over their lifetime. This would require investment of IDR 39.6 billion (US$ 3.4 million), generating annual savings of IDR 1.3 trillion (US$110.5 million), paying back the investment in less than one year and generating annual savings for the lifetime of the measure.

— 37.1% with cost neutral measures that could be paid for by re-investing the income generated from cost-effective measures, which in this case includes all the remaining low carbon measures evaluated for the transport sector. This would require investment of IDR 7.8 trillion IDR (US$ 663.1 million), generating annual savings of IDR 1.8 trillion (US$ 153.0 million), paying back the original investment in 4.3 years and generating annual savings for the lifetime of the measure.

Figure 30.
Emissions from the transport sector under four different scenarios, as a function of 2014 emissions, between 2000 and 2025.



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

Table 10.
League table of the most cost-effective measures for the transport sector

Rank:	Measure:	IDR/tCO_2-e	USD/tCO_2-e
1	Fuel tax / subsidy reduction of 600 IDR/L	-42,103,073	-3,579.08
2	Fuel tax/ subsidy reduction of 300 IDR/L	-24,034,165	-2,043.09
3	Parking meters	-3,414,465	-290.26
4	Euro IV vehicle standards – motorcycles	-1,428,389	-121.42
5	Euro IV vehicle standards – cars	-1,387,243	-117.93
6	CNG BRT (4x)	502,851	42.75
7	CNG BRT (2x)	756,134	64.28
8	B15 fuel – cars	1,138,284	96.76
9	B15 fuel – motorcycles	1,214,054	103.20
10	BRT upgrade (2x)	1,572,573	133.68
11	2025 biofuel targets – cars	2,374,260	201.83
12	BRT upgrade (4x)	2,616,693	222.44
13	2025 biofuel targets – motorcycles	2,954,863	251.19
14	Bicycle lanes	5,556,359	472.33

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

Table 11.
League Table of the most carbon-effective measures for the transport sector

Rank:	Measure:	$ktCO_2$-e
1	CNG BRT (4x)	2,522
2	BRT upgrade (4x)	2,139
3	CNG BRT (2x)	1,785
4	BRT upgrade (2x)	1,607
5	Euro IV vehicle standards – cars	1,620
6	Euro IV vehicle standards – motorcycles	732
7	B15 fuel - motorcycles	584
8	B15 fuel - cars	394
9	Fuel tax/ subsidy reduction of 600 IDR/L	109
10	Fuel tax/ subsidy reduction of 300 IDR/L	55
11	Parking meters	227
12	2025 biofuel targets - motorcycles	106
13	2025 biofuel targets - cars	83
14	Bicycle lanes	14

Sector Focus

The Waste Sector

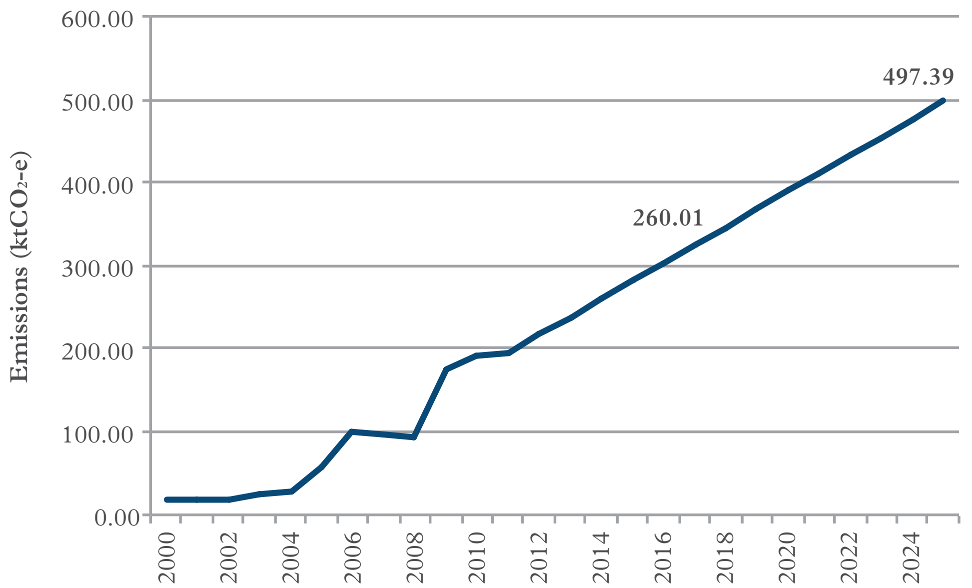
Population growth and the changing consumption patterns in Palembang lead to an increasing waste generation per capita rate. According to Indonesia's Second National Communication to the UNFCCC the waste sector accounted for 11% of the country's greenhouse gas emissions in 2000.[21] Indonesia's landfills, the majority of which operate without a landfill gas capture mechanism, is the main source of methane emissions of the sector.

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

Background trends and the projected population growth lead to a substantial increase in waste generation in Palembang. Waste generation is estimated to increase by 91% between 2014 and 2025 and exceed 0.5 million tonnes per year in 2025.

This rapid growth is projected to lead to carbon emissions from the waste sector increasing by 91%, from 260 $ktCO_2$-e in 2014 to a forecast level of 497 $ktCO_2$-e in 2025 (see Fig. 31).

Figure 31.
Emissions from the waste sector ($ktCO_2$-e) between 2000 and 2025.



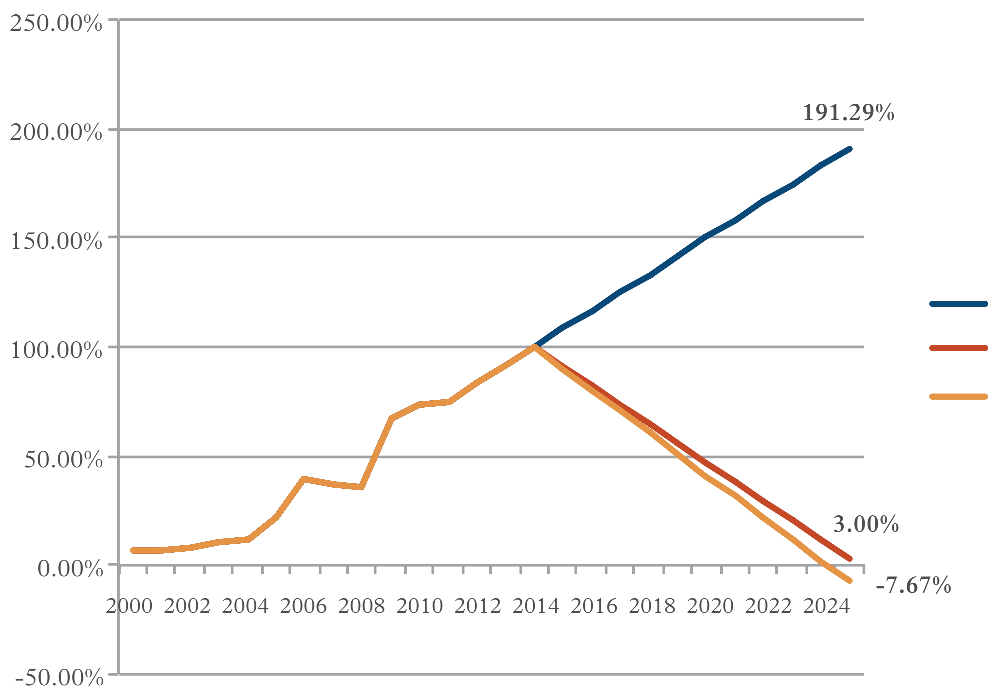
The Potential for Carbon Reduction – Investments and Returns

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

- 98.4% with cost effective measures that would pay for themselves on commercial terms over their lifetime. This would require investment of IDR 2.16 trillion (US$ 183.7 million), generating annual savings of IDR 469.47 billion (US$ 39.91 million) paying back the investment in 4.6 years and generating annual savings for the lifetime of the measures.
- 104.2% with cost neutral measures that could be paid for by re-investing the income generated from cost-effective measures. This would require investment of IDR 2.50 trillion (US$ 212.27 million), generating annual savings of IDR 508.53 billion (US$ 43.23 million), paying back the investment in 4.9 years and generating annual savings for the lifetime of the measures.

In the case of Palembang, the waste sector can deliver substantial emissions savings. This is due to the energy generation potential (in the form of combined heat and power) linked to some of the waste treatment measures. The energy generated in these measures displaces CO_2 emissions that would have otherwise been released in the power generation sector, thus making the waste sector a carbon sink.

Figure 32.
Emissions from the waste sector under four different scenarios, as a function of 2014 emissions, between 2000 and 2025.



Cost effective

Cost neutral

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

Table 12.
League table of the most cost-effective measures for the waste sector

Rank:	Measure:	IDR/tCO_2-e	USD/tCO_2-e
1	Centralised composting – high gate fee	- 789,691	-67.13
2	Waste prevention	- 681,950	-57.97
3	Centralised composting – low gate fee	- 607,678	-51.66
4	Energy from waste (CHP) – high gate fee	- 396,555	-33.71
5	LFG utilisation	- 319,414	-27.15
6	Energy from waste (CHP) – low gate fee	- 66,024	-5.61
7	LFG flaring	4,307	0.37
8	Home composting	57,684	4.90
9	Recycling (20% of household waste)	60,511	5.14
10	Anaerobic digestion (CHP) – high gate fee	181,108	15.40
11	Energy from waste (electricity recovery) – high gate fee	305,497	25.97
12	Anaerobic digestion (electricity recovery) – high gate fee	393,860	33.48
13	Anaerobic digestion (CHP) – low gate fee	543,142	46.17
14	Anaerobic digestion (electricity recovery) – low gate fee	859,615	73.07
15	Energy from waste (electricity recovery) - low gate fee	906,542	77.06
16	Mass burn incinerator – low gate fee	2,186,538	185.87

Table 13.
League table of the most carbon-effective measures for the waste sector

Rank:	Measure:	ktCO_2-e
1	LFG utilisation	3,802
2	Energy from waste (CHP) – high gate fee	3,414
3	Energy from waste (CHP) – low gate fee	3,414
4	Energy from waste (electricity recovery) – high gate fee	1,877
5	Energy from waste (electricity recovery) – low gate fee	1,877
6	Anaerobic digestion (CHP) – high gate fee	1,104
7	Anaerobic digestion (CHP) – low gate fee	1,104
8	LFG flaring	1,059
9	Mass burn incinerator – low gate fee	1,012
10	Home composting	932
11	Anaerobic digestion (electricity recovery) – high gate fee	858
12	Anaerobic digestion (electricity recovery) – low gate fee	858
13	Centralised composting – high gate fee	732
14	Centralised composting – low gate fee	732
15	Recycling	598
16	Waste prevention	118

Chapter 5. Discussion

Business as usual trends in Palembang show that there has been some decoupling of emissions and GDP during the past decade, but that energy use and emissions will outpace economic growth from 2014 to 2025. Palembang is therefore on an increasingly carbon intensive development trajectory in both relative and absolute terms.

Emissions per unit of energy are projected to rise by 15% by 2025 from 2014 levels and emissions per unit of GDP are expected to increase by 16% over the same period. When combined with rapid population and economic growth, the city of Palembang will experience steep increases in energy demand and emissions per capita.

These trends underline the importance of the coming decade. If Palembang maintains growth rates of 6-7%, its economy will more than double in size over the coming decade. Without strategic energy policies and investments during this period, the city risks being locked into high energy bills, high emission intensities and vulnerability to volatile fuel prices.

Absolute levels of energy use are projected to rise at a rate of 6.1% per annum between 2015 and 2025. This will lead to an increase in real energy bills of 8.1% per annum to IDR 25.73 trillion (US$ 2.19 billion) per year and of net emissions of 8.0% per annum to 12.3MtCO_2-e per year over the same period. The major energy costs are associated with the transport sector where fuels are relatively expensive, and the industrial sector where significant growth of energy-intensive industries will drive increasing energy use, energy bills and carbon emissions. These figures suggest that current rates of decoupling between economic output and energy use, while significant, will not realize the city's full potential to enhance economic competitiveness and energy security and to reduce its contribution to climate change.

This study reveals a compelling business case for large-scale investment in energy efficiency, renewable energy and low carbon development in Palembang above and beyond these background trends. By 2025, the city can cut its emissions by 24.1% of projected emissions in the business as usual scenario through cost-effective investments that would pay for themselves on commercial terms in less than a year. If the profits from these investments are re-invested in low carbon measures, Palembang can slash its emissions to 28.3% relative to business as usual trends and recover its investment in 3.3 years. These low carbon measures would continue to generate annual savings throughout their lifetime. At a national or regional level, investments in South Sumatra's electricity sector could reduce the city's emissions a further 3.7% relative to business-as-usual trends (and achieve additional emission reductions across the state) at no net cost.

In addition to the economic case for low carbon investment, many of these measures support broader economic development goals. Apart from fossil fuel subsidy reductions, the list of the most cost-effective options is dominated by energy efficiency measures in the industry sector: widespread adoption of these options would increase the competitiveness of the local economy by reducing input costs, and increase its resilience to rising fuel prices. Renewable energy technologies and more efficient lighting systems also prove to be very attractive in Palembang, with or without incentive schemes. Increased use of these renewable energy technologies would help meet national energy policy objectives of improved energy security and energy access. Measures for the transport and electricity sector, while not quite as profitable in terms of economic savings per tonne of carbon, offer large-scale and commercially attractive opportunities to improve air quality, congestion and mobility in Palembang. The prioritised menus of the most cost-effective measures therefore highlight a wide range of win-win opportunities for different stakeholders across key sectors in Palembang.

In other cases, this research highlights that the most carbon-effective measures are not necessarily attractive to commercial investors. This is most evident in the electricity sectors, where many low carbon measures do not yield significant financial returns with current energy prices but do offer very significant emission reductions. These measures offer opportunities for international climate funds to achieve dramatic improvements in emissions intensity without crowding out private investment.

The transition to a low carbon development path could be accelerated through strategic investments in energy efficiency, renewable energy and other low carbon measures. The massive expansion of infrastructure projected for Palembang – like most cities in fast-growing emerging economies – provides an opportunity to integrate climate considerations into urban planning at a relatively early stage. Such an approach improves both the cost- and carbon-effectiveness of most low carbon options and would significantly enhance Palembang's efforts to transition to a more energy efficient and low carbon city.

Conclusions and Recommendations

Business as usual trends in Palembang show that relative and absolute levels of energy use and emissions are rising. Energy bills are also increasing steadily – which will have significant implications for economic competitiveness and for social equity.

This research reveals that there are many economically attractive opportunities to increase energy efficiency and stimulate renewable energy, which would in turn improve the economic competitiveness, air quality and carbon intensity of Palembang. The scale of the opportunities demonstrates that preparing for climate change at an early stage of development can be attractive in commercial terms, above and beyond the immense benefits of reducing the future impacts of climate change.

Clearly the presence of such opportunities does not mean that they will necessarily be exploited. But we hope that by providing evidence on the scale and the composition of these opportunities, this report will help to build political commitment and institutional capacities for change. We also hope this report will help Palembang to secure the investments and develop the delivery models needed to implement change. Some of the energy efficiency and low carbon opportunities could be commercially attractive whilst others may only be accessible with development assistance. Many of the opportunities would benefit from the support of enabling policies from government.

And fundamentally, we should recognise that economics is not the only discipline that has something useful to say on the transition to a low carbon economy/society. 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 pathways towards a low carbon economy and society in Palembang.

Appendices

Appendix A: Workshop Participants and Expert Consultants

Name	Position	Organisation
Elly Adriani Sinaga	Director-General, Research and Development Agency	Ministry of Transportation
Zulfikri Zamzami	Research and Development Agency	Ministry of Transportation
Doddy Wibowo	Secretariat General	Ministry of Transportation
Tonny AS	Directorate BSTP – Director-General, Land Transport	Ministry of Transportation
Elbriyan S.	Directorate BSTP	Ministry of Transportation
Fita Kurniawati	Planning and Cooperation Division, Research and Development Agency	Ministry of Transportation
Ellenlies	Research and Development Agency	Ministry of Transportation
Dian Irawati	Directorate PBL	Ministry of Public Works
Widya Anantya	Directorate PPLP	Ministry of Public Works
Angelita A.S.	Directorate PBL	Ministry of Public Works
Harris	Directorate EBTKE	Ministry of Energy and Mineral Resources
Elif Doka	Director-General, Electricity	Ministry of Energy and Mineral Resources
Hafizh Khaerudin		Ministry of Environment
Heradi Prabowo	Directorate IATD	Ministry of Housing
Seno S.A.	Director-General, PPI	Ministry of Industry
H. Harnojoyo	Vice-Mayor	City Council of Palembang
Indira Kusuma Dewi	Technical Project Professional	Secretariat RAN-GRK (Secretariat of National Action Plan for GHG Emission Reduction), GIZ

Appendix B: Data sources, methods and assumptions

B1 Baseline development

The baseline emissions inventory has been developed in line with the Greenhouse Gas Protocol for Communities (GPC) v0.9, developed by the C40 Cities Climate Leadership Group and ICLEI Local Governments for Sustainability in collaboration with the World Resources Institute, World Bank, UNEP, and UN-HABITAT.[22] The use of this open, standardised approach for city-scale accounting and reporting is intended to enable effective communication between different levels of government, financing institutions and the private sector, and to allow a comparison of emissions over time.

In summary, the principles underpinning the GPC are:

- Measurability: At a minimum, data required to perform complete emissions inventories should be readily available.
- Accuracy: The calculation of GHG emissions should not systematically overstate or understate actual GHG emissions.
- Relevance: The reported GHG emissions should reflect emissions occurring as a result of activities and consumption from within the community's geopolitical boundaries.
- Completeness: All significant emissions sources included should be accounted for. – Our method does not include long-distance rail, air travel or shipping.
- Consistency: Emissions calculations should be consistent in approach.
- Transparency: Activity data, sources, emissions factors and accounting methodologies should be adequately documented and disclosed.

Details on how the baseline has been developed for each of the sectors are summarised in the table below:

Activity	Projection method	Useful data
Population	Data on Palembang's population in 2010 was obtained from an emissions inventory conducted by the University of Sriwijaya[23] and for 2006-2007 from a CDM design document prepared by PT Gikoko Kogyo Indonesia and the Municipal Government of Palembang.[24] The population growth rate of 2.27% provided in this document to calculate Palembang's population in the remaining years.	The population is estimated to be: 2014: 1,561,250 2025: 1,838,214
GDP	Data on GDP per capita in 2013 was obtained from the IFC and World Bank.[25] This was backcast and forecast using historical and projected economic growth rates for the region of South Sumatra, obtained from the Indonesian Department of Statistics.[26] GDP per capita was multiplied by population to determine the GDP of the city.	GDP per capita is estimated to be: 2014: US$2,940 2025: US$ 5,698 GDP of the city is estimated to be: 2014: US$ 4.6 billion 2025: US$ 10.5 billion
US$: IDR exchange rate	The exchange rate is the average midpoint of bid and ask prices for 2013, using OANDA.[27]	IDR 1.0 = US$ 0.0000850076

Electricity generation	Data on the Sumatran electricity grid was provided by PLN 2009-2012.[28] Looking forward to 2025 our baseline estimates are based on PLN's yearly reports and a forecast of Palembang electricity consumption based on data from the years 2000-2012.[29]	Estimated consumption per capita: 2014: 1125 KWh 2025: 3304 KWh
Commercial sector	Data on residential electricity use in South Sumatra was provided by PLN for 2009-2012.[30] This was scaled to Palembang using data from 2012 the Palembang City Council. We assumed that the share of electricity consumed by Palembang relative to the rest of South Sumatra held constant.[31] The amount in electricity sold to the domestic sector from 2000 to 2025 was backcast and forecast using a growth function, which provided a rate of increase of 6-7% per annum. Data on other fuels used was collected from an emissions inventory conducted by the University of Sriwijaya.[32] This included mainly diesel for boilers and power generators in hospitals and shopping centres. Consumption of these fuels was held constant.	Estimated consumption of electricity per building type in 2014: Business: 288.3 GWh Social services: 56.6 GWh Government offices: 47.2 GWh Street lighting: 34.8 GWh Estimated consumption of electricity per building type in 2025: Business: 529.9 GWh Social services: 219.7 GWh Government offices: 145.9 GWh Street lighting: 44.6 GWh
Domestic sector	Data on residential electricity use in South Sumatra was provided by PLN for 2009-2012.[33] This was scaled to Palembang using data from 2012 the Palembang City Council.[34] We assumed that the share of electricity consumed by Palembang relative to the rest of South Sumatra held constant. The amount in electricity sold to the domestic sector from 2000 to 2025 was backcast and forecast using a growth function, which provided a rate of increase of 13.9% per annum. While high, this is not inconsistent with the fast economic growth rates and human development needs in the region. Data on LPG consumption in 2010 and 2011 was collected from an emissions inventory conducted by the University of Sriwijaya.[35]	Estimated consumption per fuel type: Electricity: 2014: 864.3GWh 2025: 3,610.5GWh LPG: 2014: 77,898.9t 2025: 146,446.0t
Industry	Data on residential electricity use in South Sumatra was provided by PLN for 2009-2012.[36] This was scaled to Palembang using data from 2012 the Palembang City Council[37] and forecast using a growth function, which provided a growth rate of 11.1% per annum. Data on other fuels used within the city boundaries in 2010 was collected from an emissions inventory conducted by the University of Sriwijaya.[38] These figures were held constant from 2000 to 2025 as there was no data on when the boilers, generators, etc had been purchased and there was no data on additional planned investments. The one exception was in the fertiliser industry, as energy data was available on a new plant from the operator, Pupuk Indonesia.[39]	Energy use by fuel type in 2014: Electricity: 3.4% Diesel: 27.5% Natural gas: 67.8% Coal: 1.3% Energy use by fuel type in 2025: Electricity: 4.3% Diesel: 11.2% Natural gas: 83.5% Coal: 1.0%

Transport	Data on number of vehicles based on real data for Palembang for 2006-2008 collected by the University of Sriwijaya.[40] Changes in the number of vehicles was forecast and backcast using national growth rates taken from the Indonesian Department of Statistics.[41] Data on the average fuel efficiency of Indonesian vehicles was collected from analyses conducted as part of the BRT planning process and from academic literature.[42] Average distances travelled were based on expert consultation with the Indonesian Ministry of Transport: an average of 25km/day was assumed for private vehicles and motorbikes, 50km/day for freight vehicles and 150km/day for minibuses.	Number of vehicles in 2014: Passenger cars: 117,635 Freight vehicles: 46,878 Minibuses: 4,270 Motorcycles: 483,085 Fuel efficiency of vehicles in 2014: Passenger cars: 11.8km/L Freight vehicles: 6.0km/L Minibuses: 11.8km/L Motorcycles: 27.0km/L Ratio of petrol to diesel cars: 5:1
Waste	Calculations of waste generation were based on data from GIZ's 'Emission Inventory for the City of Palembang, South Sumatra - Indonesia. Under the Project "Clean Air for Smaller Cities in the ASEAN Region" 2013[43]. Waste composition, average waste collection rate, recycling rate and open burning rate were based on data provided largely by academic literature.[44, 45, 46] Emissions from waste collection vehicles were based on 5% of total waste emissions.[47] 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the GHG Protocol for Community Scale GHG Emissions formed the basis of the calculation of greenhouse gas emissions from the waste sector.[48, 49]	Waste generation in 2014: 269,104 tonnes Waste composition: Organic (food and garden waste): 68% Paper: 9% Textiles: 1% Plastics: 8% Metals: 1% Glass: 1% Others: 11% Average collection rate: 75%
Energy prices	Nominal energy prices were taken from the Indonesian Department of Statistics,[50] PLN[51] and the World Bank.[52] These reflect prices for the consumer, i.e. incorporate government subsidies. Nominal prices were converted into real prices at 2013 levels using the IMF Monthly Consumer Price Index.[53] Real prices are projected to increase at a rate of 3% per annum from 2014 to 2025.	Energy prices in 2014 are: Gasoline: IDR 10,815/L Diesel: IDR 12,566/L LPG: IDR 6,369/L Electricity: Business: IDR 940/kWh Domestic: IDR 612/kWh Public sector: IDR 1,033/kWh Industrial: IDR 824/kWh Public lighting: IDR 772/kWh Natural gas: IDR 51,714/MMBTU Coal: IDR 802/kg Geothermal: IDR 601/kWh
Conversion factors	Conversion factors were taken from the IPCC Guidelines for National Greenhouse Gas Inventories[54] and the UK Department of Environment, Food and Rural Affairs.[55]	The carbon intensity of electricity in South Sumatra is calculated to be: 2014: 0.84tCO_2-e/MWh 2025: 0.97tCO_2-e/MWh

B2 Sectoral approach

The energy sector

The table below presents the key variables and assumptions used for electricity sector mitigation options. A number of sources, including expert consultations, focus group discussion and primary data are included in this data set.[56, 57, 58]

		Operating Ratio	Thermal Efficiency	Overnight Capital Cost Per MW	Yearly Operating and Maintenance ($/MW)	Non Fuel Cost Per MWh ($)
Coal	Existing Standard	0.9	0.38	1,800,000	20,000	2
	Best Available Technology	0.9	0.42	3,246,000	20,000	2
Natural Gas	Existing Standard	0.9	0.48	800,000	15,000	2
	Best Available Technology	0.9	0.52	1,323,000	20,000	2
Oil	Existing Standard	0.90	0.36	800,000	15,000	2
	Best Available Technology	0.90	-	-	-	-
Solar PV	Existing Standard	-	-	-	20,000	-
	Best Available Technology	0.25	-	2,000,000	20,000	4
Geothermal	Existing Standard	0.75	-	-	-	-
	Best Available Technology	0.75	-	4,000,000[59]	10,000	4

The commercial sector

Measure	Summary and key assumptions
Banning incandescent lights	Savings consist of saved energy if a ban on incandescent lights becomes effective in 2015, using data from the Association of Water and Energy Research Malaysia.[60] The model assumes that a transition away from incandescent bulbs would be complete by 2025 irrespective of policy interventions. The average incandescent light bulb is assumed to be 60W, being replaced a compact fluorescent (CFL) bulb of 12W. Costs for CFL light bulb are based on market prices (around RM17 more than incandescent light bulbs in 2014).
Electronic appliances – energy management	The breakdown of small power in offices is drawn from academic literature.[61] The potential savings from energy management are drawn from energy companies' efficiency recommendations.[62]
Energy Efficiency (EE) Standard 1	Savings consist of 10%, 20% and 30% of business-as-usual energy consumption in 2015, 2020 and 2025 respectively. Increase in costs for air conditioners based on current market prices; no increase in costs for more efficient elevators and escalators. Energy savings are calculated over a ten year lifetime for air conditioners and a twenty year lifetime for elevators and escalators.
Energy Efficiency (EE) Standard 2	Savings consist of 20%, 40% and 60% of business-as-usual energy consumption in 2015, 2020 and 2025 respectively. Increase in costs for air conditioners based on current market prices; no increase in costs for more efficient elevators and escalators. Energy savings are calculated over a ten year lifetime for air conditioners and a twenty year lifetime for elevators and escalators.
Green Building Standard 1	Savings consist of 10% of energy consumed by air conditioner and lighting. Building costs increased by 2%. Energy savings are calculated to 2040.
Green Building Standard 2	Savings consist of 20% of energy consumed by air conditioner and lighting. Building costs increased by 5%. Energy savings are calculated to 2040.
Raising thermostat 1°C	Savings consist of 6.14% of the energy used by air conditioners per degree. This figure is drawn from academic literature.[63]
Setting LED target	Savings consist of saved energy if a target of 25% LED lighting is effectively realised by 2025. The model assumes that LED bulbs would achieve10% market penetration irrespective of policy interventions. The average CFL light bulb is assumed to be 12W, being replaced a LED bulb of 7W. Costs for LED light bulb are based on market prices (around IDR 55,000 more than CFL light bulbs in 2014).
Solar PV panel	Data on average size and efficiency of solar panels collected from the Malaysian Sustainable Energy Development Authority[64] and academic literature.[65] An individual commercial building is assumed to have space for four times as many solar panels as an individual domestic building. The FiT is based on 2014 rates with an 8% degression.
Turning off lights	Savings consist of the energy used for one hour of lighting per day. The average light bulb in the commercial sector is assumed to be used for eight hours per day.

The domestic sector

Measure	Summary and key assumptions
Banning incandescent lights	Savings consist of energy not used if a ban on incandescent lights becomes effective in 2015. The model assumes that a transition away from incandescent bulbs would be complete by 2020 irrespective of policy interventions. The average incandescent light bulb is assumed to be 60W, being replaced a compact fluorescent (CFL) bulb of 12W. Costs for CFL light bulb are based on market prices (around IDR 49,780 more than incandescent light bulbs in 2014).
Energy Efficiency (EE) Standard 1	Savings consist of 10%, 20% and 30% of business-as-usual energy consumption in 2015, 2020 and 2025 respectively. Additional costs for efficient air conditioners, entertainment appliances, kitchen appliances, washing machines and water heaters are based on current market prices. Energy savings are calculated over a ten year lifetime for entertainment appliances, microwaves and rice cookers and a fifteen year lifetime for air conditioners, refrigerators, stoves, washing machines and water heaters.
Energy Efficiency (EE) Standard 2	Savings consist of 20%, 40% and 60% of business-as-usual energy consumption in 2015, 2020 and 2025 respectively. Additional costs for efficient air conditioners, entertainment appliances, kitchen appliances, washing machines and water heaters are based on current market prices. Energy savings are calculated over a ten year lifetime for entertainment appliances, microwaves and rice cookers and a fifteen year lifetime for air conditioners, refrigerators, stoves, washing machines and water heaters.
Green Building Standard 1	Savings consist of an improvement of 5kWh/m2 (i.e. 14% of energy) consumed by air conditioner and lighting. There is no increase in building costs. Energy savings are calculated to 2040.
Green Building Standard 2	Savings consist of 10kWh/m2 (i.e. 29%) of energy consumed by air conditioner and lighting. There is no increase in building costs. Energy savings are calculated to 2040.
Raising thermostat 1˚C	Savings consist of 6.14% of the energy used by air conditioners per degree. This figure is drawn from academic literature.[66]
Retrofitting fibreglass urethane insulation	Savings consist of 40% of energy consumed by air conditioner and lighting. Data on the cost and effectiveness of different insulation types is drawn from the academic literature.[67] Energy savings are calculated to 2040.
Retrofitting mineral wool insulation	Savings consist of 75% of energy consumed by air conditioner and lighting. Data on the cost and effectiveness of different insulation types is drawn from the academic literature.[68] Energy savings are calculated to 2040.
Setting LED target	Savings consist of saved energy if a target of 25% LED lighting is effectively realised by 2025. The model assumes that LED bulbs would achieve 10% market penetration irrespective of policy interventions. The average CFL light bulb is assumed to be 12W, being replaced a LED bulb of 7W. Costs for LED light bulb are based on market prices (around IDR 55,000 more than CFL light bulbs in 2014).
Solar lamps for outdoor lighting	Costs for solar lamps are based on market prices (around IDR 95,000 more than non-solar lamps in 2014).
Solar PV panel	Data on average size and efficiency of solar panels collected from the Malaysian Sustainable Energy Development Authority[69] and academic literature.[70] The FiT is based on 2014 rates with an 8% degression.
Solar water heater	Costs for solar water heaters are based on market prices (around IDR 1,900,000 in 2014). It is assumed that households will also need an electric water heater, but that the solar water heater will displace 80% of its electricity consumption. The FiT is based on 2014 rates with an 8% degression.
Turning off lights	Savings consist of the energy used for one hour of lighting per day. The average light bulb in the domestic sector is assumed to be used for four hours per day.

The industrial sector

All academic sources cited in this section were referenced in the IPCC report as examples of the potential efficiency improvements available in their respective industries. Payback periods have been doubled for measures with large capital expenditure in light of low energy costs in Indonesia. The research is typically based on US case studies.

Industry	Measure	Summary and key assumptions
Petroleum refinery and petrochemical industry	More efficient utilities	Delivers energy savings of 4.5%, requiring investment of IDR 170.1 billion (US$14.5 million) with a payback period of 5 years.[71]
	More efficient furnaces and boilers	Delivers energy savings of 3%, requiring investment of IDR 49.8 billion (US$4.5 million) with a payback period of 2.2 years.[72]
	Process integration	Delivers energy savings of 2.3%, requiring investment of IDR 91.8 billion (US$7.8 million) with a payback period of 5.4 years.[73]
	More efficient heat exchangers	Delivers energy savings of 2.3%, requiring investment of IDR 68.0 billion (US$5.8 million) with a payback period of 4 years.[74]
	More efficient motors	Delivers energy savings of 0.6%, requiring investment of IDR 9.1 billion (US$771 thousand) with a payback period of 2 years.[75]
	More efficient pumps	Delivers energy savings of 0.75%, requiring investment of IDR 5.4 billion (US$463 thousand) with a payback period of 1 year.[76]
	More efficient compressors	Delivers energy savings of 0.15%, requiring investment of IDR 2.7 billion (US$231 thousand) with a payback period of 2 years.[77]
	Monitoring and targeting	Delivers energy savings of 8%, requiring investment of IDR 84.7 billion (US$7.2 million) with a payback period of 1.4 years.[78]
Fertiliser industry	Steam reforming – large improvements	Delivers energy savings of 10.3%, requiring investment of IDR 12.0 billion (US$1.0 million) with a capital cost of INR 378,333 per ton of fertiliser.[79]
	Steam reforming – moderate improvements	Delivers energy savings of 3.6%, requiring investment of IDR 2.5 billion (US$212 thousand) with a capital cost of INR 79,027 per ton of fertiliser.[80]
	More efficient CO_2 removal from synthesis	Delivers energy savings of 2.3%, requiring investment of IDR 7.5 billion (US$637 thousand) with a capital cost of INR 237,084 per ton of fertiliser.[81]
	Ammonia synthesis at lower pressure	Delivers energy savings of 1.3%, requiring investment of IDR 3.0 billion (US$254 thousand) with a capital cost of INR 94,833 per ton of fertiliser.[82]
	Hydrogen recovery	Delivers energy savings of 2.1%, requiring investment of IDR 999 million (US$85 thousand) with a capital cost of INR 31,611 per ton of fertiliser.[83]
	Improved process control	Delivers energy savings of 1.9%, requiring investment of IDR 3.0 billion (US$254 million) with a capital cost of INR 94,833 per ton of fertiliser.[84]
	Process integration	Delivers energy savings of 7.8%, requiring investment of IDR 1.5 billion (US$127 thousand) with a capital cost of INR 47,416 ton of fertiliser.[85]

Industry	Measure	Summary and key assumptions
Pulp and paper industry	More efficient boilers and furnaces	Delivers energy savings of 0.84%, requiring investment of IDR 436 million (US$37 thousand) with a payback period of 3 years.[86]
	Boiler process control	Delivers energy savings of 0.98%, requiring investment of IDR 85 million (US$7 thousand) with a payback period of 0.5 years.[87]
	Boiler maintenance	Delivers energy savings of 2.28% with no significant capital costs and a payback period of less than one month.[88]
	Condensate return to boilers	Delivers energy savings of 0.53%, requiring investment of IDR 227 million (US$19 thousand) with a payback period of 2.5 years.[89]
	Flue gas heat recovery	Delivers energy savings of 0.46%, requiring investment of IDR 69 million (US$6 thousand) with a payback period of 0.9 years.[90]
	Improved insulation of pipes, valves and fittings	Delivers energy savings of 1.05%, requiring investment of IDR 182 million (US$15 thousand) with a payback period of 1 year.[91]
	Steam trap maintenance	Delivers energy savings of 3.5%, requiring investment of IDR 606 million (US$51 thousand) with a payback period of 1 year.[92]
	Shoe press	Delivers energy savings of 0.56%, requiring investment of IDR 16 million (US$1 thousand) with a capital cost of US $2.24/ton paper.[93]
	Optimisation of pump system design	Delivers energy savings of 4.25%, requiring investment of IDR 1.0 billion (US$88 thousand) with a payback period of 1.42 years.[94]
	Optimisation of compressed air systems	Delivers energy savings of 0.54%, requiring investment of IDR 327 million (US$29 thousand) with a payback period of 3.5 years.[95]
	Pinch analysis	Delivers energy savings of 1.75%, requiring investment of IDR 3.7 billion (US$312 thousand) with a payback period of 1.4 years.[96]
	Replace pressure reduction valves with steam turbines (1MW)	Capital cost of US$600,000/MW and an operating cost of US$11/MW.[97] Electricity generated is valued at the industrial tariff for electricity.

Industry	Measure	Summary and key assumptions
Rubber industry	Adoption of variable speed drive in motors (30% speed reduction)	Delivers energy savings of 29.3%, requiring investment of IDR 448 billion (US$38 million) with a payback period of 21.2 years.[98]
	Reduction of excess air in boilers	Delivers energy savings of 29.3%, requiring investment of IDR 29.3 billion (US$2.5 million) with a payback period of 2.36 years.[99]
	Leak prevention	Delivers energy savings of 6.3%, requiring investment of IDR 330 million (US$28 thousand) with a payback period of 0.5 years.[100]
	Using outside intake air	Delivers energy savings of 0.3%, requiring investment of IDR 7.4 billion (US$631 thousand) with a payback period of 27.7 years.[101]
	Lowering function pressure	Delivers energy savings of 0.1% with no significant capital costs.[102]
	More efficient nozzles	Delivers energy savings of 0.9%, requiring investment of IDR 3.2 billion (US$268 thousand) with a payback period of 0.67 years.[103]
	Adoption of variable speed drive in pumps (30% speed reduction)	Delivers energy savings of 4.27%, requiring investment of IDR 1.2 billion (US$99 thousand) with a payback period of 21.2 years.[104]
	Heat recovery	Delivers energy savings of 5.0%, requiring investment of IDR 177.2 billion (US$15 million) with a payback period of 0.3 years.[105]
Fuel switching	50% petroleum systems changed to dual fuel systems	Cost of conversion to a dual fuel system based on market prices (RM 9,300 in 2014). Total investment need is IDR 3.2 billion (US$ 282 million).
	30% grid electricity replaced by solar PV	Cost of 1MW solar PV panel based on market prices (US$ 3 million in 2014).[106]
	Diesel replaced with biodiesel	Cost of biodiesel is 5% higher per litre than diesel.

The transport sector

Measure	Summary and key assumptions
Parking Meters	Installation of parking meters along 75 km of Palembang streets. 35 parking meters per km at US$ 1,250 per meter, with maintenance costs of $120 per year. Vehicle travel elasticity of -0.06, fee per hour: 3000 IDR, occupancy rate 50%.[107]
BRT Upgrade 2x and BRT Upgrade 4x	Doubling and quadrupling the number of buses currently operating in Palembang. Cost per km of new BRT (including buses, stops and road reorganization): US$ 2.5 million, load factor 0.7, vehicle life 15 years, cost per ticket: US$ 0.32, vehicle productivity 1000 passengers per day, efficiency of new vehicles: 3.8 km/L.[108]
CNG BRT Upgrade 2x and CNG BRT Upgrade 4x	Doubling and quadrupling the number of buses currently operating in Palembang with a CNG fleet. Cost per km of new BRT (including buses, stops and road reorganization): US$ 2.75 million USD, load factor 0.7, vehicle life 15 years, cost per ticket: $0.32 USD, vehicle productivity 1000 passengers per day, efficiency of new vehicles: 3.7 km/L.[109]
Euro IV Vehicle Standards	Euro IV cars: 17.86 km/L. Euro IV motorcycles: 32.4 km/L. Increase in fuel prices as a result of lower sulphur fuel: 10%. Short run elasticity of fuel demand: -0.16. Long run elasticity of fuel demand: -0.30. Penetration of Euro IV: 3% per annum.[110]
Biofuel Targets (2025 biofuel targets and 15% biofuel target)	Reduction in fuel efficiency: 2%. Increase in fuel price: 4% for 15% target, 5% for 2025 targets. Price elasticity of travel distance with fuel price: -0.07.[111]
Fuel Tax/Subsidy Decrease	Short run elasticity of fuel demand: -0.16. Long run elasticity of fuel demand: -0.30.[112, 113]
Bicycle Lanes	Cost per km: US$147,000. Maintenance cost per km/year: US$325,000. Length of lanes to be built: 20km. Percent of trips made by bike by 2025: 2.5%. Percent of users who would otherwise have used a vehicle: 7%.[114]

Table 14.
2025 Indonesian Biofuel Targets

Fuel	2008	2009	2010	2015	2020	2025
Bioethanol	1%	5%	7%	10%	24%	24%
Biodiesel	0%	1%	3%	7%	20%	20%

It is important to note the broader political economy of biofuel production is critical when considering carbon savings. Bioethanol and biodiesel will only reduce net emissions if they are produced in a way that avoids land use change and environmental degradation. This report assumes sustainable biofuel production in its estimates of potential emission reductions.

The waste sector

Measure	Summary and key assumptions
Landfill gas flaring	Capital and operational costs are based on SE Asian case studies of CDM projects.[115] Savings calculated based on 20% landfill gas collection efficiency[116] and 10% oxidation factor due to landfill cover.[117]
Landfill gas utilisation	This measure assumes 60% landfill gas collection efficiency[118] and 10% oxidation factor due to landfill cover[119]. Electricity generation from LFG, its CO_2-e and carbon emissions saved by energy displaced calculations are based on academic literature[120, 121] and IPCC reports.[122] 10% of the electricity generated in used on site The revenue from electricity generation is based on the current FiT.[123] The capital and operational costs are based on SE Asian case studies of CDM projects.[124]
Energy from Waste (EfW)	Savings from this measure are calculated assuming a 200,000 tonnes/ year thermal treatment plant with energy generation potential. One scenario is based on electricity only recovery and another on Combined Heat and Power (CHP) generation. 'Low gate fee' is equal to the current landfill tipping fee; 'high gate fee' is equal to four times the current landfill tipping fee.[125, 126] Tipping fees in Malaysia and Indonesia are amongst the lowest even between other developing countries. Therefore a gate fee equal to four times the current landfill tipping fee is a realistic option. In the case of CHP, it is assumed that both the heat and electricity recovered will receive current FiT rates.[127] The calculations of electricity and heat generation and the carbon emissions saved by energy displaced are based on IPCC (2006)[128] and European Communities (2001.[129] The capital and operational costs are based on SA Asian case studies of CDM projects.[130]
Anaerobic Digestion (AD)	AD assumes a 120,000 tonnes/year biological treatment plant with energy generation potential. One scenario is based on electricity only recovery and another on a Combined Heat and Power (CHP) option. 'Low gate fee' is equal to the current landfill tipping fee; 'high gate fee' is equal to four times the current landfill tipping fee.[131, 132] In the case of CHP, it is assumed that both the heat and electricity recovered will receive current FiT rates.[133] Calculations of electricity and heat generation and the carbon emissions saved by energy displaced are based on IPCC (2006)[134] and European Communities (2001).[135] It is assumed that the feedstock to the AD plant will comprise good quality, source separated organic waste (food and garden). The participation and capture rates are based on WRAP (2009)[136, 137] Capital and operational costs are based on Se Asian and UK case studies of AD projects.[138]
Mass burn incineration	Mass burn incineration assumes a 200,000 tonnes/year thermal treatment plant without energy generation potential. 'Low gate fee' is equal to the current landfill tipping fee; 'high gate fee' is equal to four times the current landfill tipping fee.[139, 140] The carbon emissions saved by energy displaced are based on IPCC (2006)[141] and European Communities (2001).[142] The capital and operational costs are based on SE Asian case studies of CDM projects.[143]

Measure	Summary and key assumptions
Centralised composting	Centralised composting assumes a 120,000 tonnes/year aerobic biological treatment plant. 'Low gate fee' is equal to the current landfill tipping fee; 'high gate fee' is equal to four times the current landfill tipping fee.[144, 145] The carbon emissions savings calculations are based on IPCC (2006)[146] and European Communities (2001).[147] It is assumed that the feedstock to the composting plant will comprise good quality, source separated organic waste (food and garden). The participation and capture rates are based on WRAP (2009).[148, 149] The capital and operational costs are based on SE Asian and UK case studies of composting projects.[150] The assessments consider a revenue source from the sale of the compost, with current international compost prices and 30% of organic waste to be converted to compost.[151]
Home composting	Home composting assumes aerobic biological treatment of organic waste at home. The carbon emissions savings calculations are based on IPCC (2006)[152] and European Communities (2001).[153] The participation and capture rates are based on WRAP (2009).[154, 155] Costs for home composting bins were included in the assessment. Average costs of home composting campaigns to ensure correct use of composting bins and maintain participation were based on experiences from successful UK based schemes.[156]
Recycling	The recycling scenario is relevant to paper, plastics, metals and glass. It includes a 80,000 tonnes/year Materials Recycling Facility (MRF). This scenario assumes separate collection of comingled recyclables and considers the additional carbon emissions and costs associated with the separate collection. The revenue from the sale of the recyclables was based on prices at international trading sites at the time of the assessment. Capital and operation costs are based on European case studies.[157, 158, 159]
Waste prevention	The waste prevention scenario is relevant to packaging waste (paper and plastic) and assumes a final reduction of packaging by 20%. Costs of waste prevention campaigns and the cost savings from packaging waste prevention are based on successful UK case studies.[160, 161]

Cost effective

Cost neutral

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

Appendix C: League Table of the Most Cost-Effective Measures in Palembang (NPV/tCO_2-e)

Rank	Sector	Measure	IDR/tCO_2-e	USD/tCO_2-e
1	Transport	Fuel tax / subsidy reduction of 600 IDR/L	-42,103,073	-3,579.08
2	Transport	Fuel tax/ subsidy reduction of 300 IDR/L	-24,034,165	-2,043.09
3	Commercial	Substituting grid electricity for diesel generators - shopping centres	-17,973,736	-1,527.90
4	Industry	Fuel switching - diesel to dual fuel systems	-13,972,373	-1,187.76
5	Industry	Fuel switching - replacing diesel generators with solar PV	-4,392,128	-373.36
6	Industry	Petroleum refinery - more efficient pumps	-3,689,481	-313.63
7	Industry	Petroleum refinery - more efficient compressors	-3,637,504	-309.22
8	Industry	Petroleum refinery - more efficient motors	-3,637,504	-309.22
9	Industry	Petroleum refinery - more efficient furnaces and boilers	-3,627,108	-308.33
10	Industry	Petroleum refinery - more efficient heat exchangers	-3,533,549	-300.38
11	Industry	Petroleum refinery - more efficient utilities	-3,481,572	-295.96
12	Industry	Petroleum refinery - process integration	-3,460,781	-294.19
13	Transport	Parking meters	-3,414,465	-290.26
14	Industry	Petroleum refinery - monitoring and targeting	-2,251,453	-191.39
15	Commercial	Banning incandescent light bulbs	-1,518,490	-129.08
16	Domestic	Solar water heating with FiT	-1,513,224	-128.64
17	Transport	Euro IV vehicle standards – motorcycles	-1,428,389	-121.42
18	Transport	Euro IV vehicle standards – cars	-1,387,243	-117.93
19	Industry	Fertiliser - steam reforming (moderate improvements)	-1,330,718	-113.12
20	Industry	Fertiliser - steam reforming (large improvements)	-1,329,328	-113
21	Industry	Pulp and paper - more efficient boilers and furnaces	-1,316,298	-111.9
22	Domestic	4kWp solar PV panel with FiT	-1,299,768	-110.49
23	Industry	Rubber industry - lowering functional pressure	-1,156,916	-98.35

Cost effective

Cost neutral

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

24	Industry	Rubber industry - heat recovery	-1,128,343	-95.92
25	Industry	Rubber industry - leak prevention	-1,112,270	-94.55
26	Industry	Rubber industry - more efficient nozzles	-1,097,090	-93.26
27	Industry	Pulp and paper - replace pressure reduction valves with steam turbines (1MW)	-1,060,853	-90.18
28	Domestic	Setting LED target of 25%	-967,007	-82.2
29	Industry	Rubber industry - reduction of excess air in boilers	-946,187	-80.43
30	Domestic	Banning incandescent light bulbs	-892,552	-75.87
31	Commercial	Computer - energy management	-871,751	-74.11
32	Commercial	Printer - energy management	-871,751	-74.11
33	Commercial	Fax - turning off	-871,751	-74.11
34	Commercial	Copier - energy management	-871,751	-74.11
35	Commercial	Monitor - energy management	-871,751	-74.11
36	Commercial	Raising thermostat 1˚C	-821,539	-69.84
37	Waste	Centralised composting – high gate fee	-789,691	-67.13
38	Electricity	Natural gas retrofit (514 MW)	-745,193	-62
39	Industry	Pulp and paper - boiler maintenance	-737,452	-62.69
40	Industry	Fertiliser - process integration	-732,450	-62.26
41	Industry	Fertiliser - hydrogen recovery	-731,591	-62.19
42	Industry	Pulp and paper - shoe press	-730,751	-62.12
43	Industry	Fertiliser - improved process control	-728,251	-61.91
44	Industry	Fertiliser - ammonia synthesis at lower pressure	-726,151	-61.73
45	Industry	Fertiliser - more efficient CO_2 removal from synthesis gas	-723,479	-61.5
46	Industry	Pulp and paper - boiler process control	-716,394	-60.9
47	Industry	Pulp and paper - flue gas heat recovery	-700,770	-59.57
48	Industry	Pulp and paper - steam trap maintenance	-695,335	-59.11
49	Industry	Pulp and paper - improved insulation of pipes, valves and fittings	-695,335	-59.11

50	Commercial	Elevators and escalators - EE Standard 1	-688,957	-58.57
51	Commercial	Elevators and escalators - EE Standard 2	-688,957	-58.57
52	Waste	Waste prevention	-681,950	-57.97
53	Industry	Pulp and paper - pinch analysis	-677,786	-57.62
54	Industry	Pulp and paper - optimisation of pump system design	-677,786	-57.62
55	Industry	Pulp and paper - condensate return to boilers	-632,159	-53.74
56	Waste	Centralised composting – low gate fee	-607,678	-51.66
57	Industry	Pulp and paper - optimisation of compressed air systems	-590,042	-50.16
58	Domestic	Raising thermostat 1˚C	-535,368	-45.51
59	Domestic	Entertainment appliances - standby	-533,605	-45.36
60	Domestic	4kWp solar PV panel	-467,063	-39.7
61	Domestic	Turning off lights	-458,347	-38.96
62	Domestic	Green Building Standard 1	-422,711	-35.93
63	Domestic	Green Building Standard 2	-422,711	-35.93
64	Domestic	Retrofitting fibreglass urethane insulation	-419,357	-12.27
65	Waste	Energy from waste (CHP) – high gate fee	-396,555	-33.71
66	Domestic	Solar water heating	-354,014	-30.09
67	Waste	LFG utilisation	-319,414	-27.15
68	Domestic	Air conditioner - EE Standard 1	-165,288	-14.05
69	Domestic	Retrofitting mineral wool insulation	-162,572	-13.82
70	Electricity	Geothermal 1000MW (replacing coal)	-95,712	-8
71	Domestic	Water heater - EE Standard 1	-92,697	-7.88
72	Waste	Energy from waste (CHP) – low gate fee	-66,024	-5.61
73	Commercial	20kWp solar PV panel with FiT	-22,774	-1.94
74	Industry	Renewables - replacing diesel boiler/furnace with solar water heaters	-7,673	-0.65
75	Commercial	20kWp solar PV panel	-4,395	-0.37
76	Commercial	Setting LED target of 25%	-1,163	-0.1

Cost effective

Cost neutral

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

77	Commercial	Turning off lights	-878	-0.07
78	Commercial	Green Buildings Standard 1	-591	-0.05
79	Commercial	Green Buildings Standard 2	-573	-0.05
80	Domestic	Solar lamps for outdoor lighting	-381	-0.03
81	Waste	LFG flaring	4,307	0.37
82	Domestic	Water heater - EE Standard 2	15,755	1.34
83	Electricity	Geothermal 2000MW (replacing coal)	26,595	2
84	Waste	Home composting	57,684	4.9
85	Waste	Recycling (20% of household waste)	60,511	5.14
86	Industry	Rubber industry - adoption of variable speed drive in electric motors	156,274	13.28
87	Domestic	Kitchen appliances - EE Standard 1	169,062	14.37
88	Waste	Anaerobic digestion (CHP) – high gate fee	181,108	15.4
89	Industry	Fuel switching - diesel to biodiesel	201,393	17.12
90	Domestic	Air conditioner - EE Standard 2	231,854	19.71
91	Waste	Energy from waste (electricity recovery) – high gate fee	305,497	25.97
92	Waste	Anaerobic digestion (electricity recovery) – high gate fee	393,860	33.48
93	Transport	CNG BRT (4x)	502,851	42.75
94	Waste	Anaerobic digestion (CHP) – low gate fee	543,142	46.17
95	Domestic	Kitchen appliances - EE Standard 2	571,242	48.56
96	Electricity	Coal replaced with Solar PV (1200 MW)	593,653	49
97	Industry	Rubber industry - adoption of variable speed drive in pumps	737,863	62.72
98	Transport	CNG BRT (2x)	756,134	64.28
99	Commercial	Air conditioner - EE Standard 1	804,281	68.37
100	Waste	Anaerobic digestion (electricity recovery) – low gate fee	859,615	73.07
101	Waste	Energy from waste (electricity recovery) - low gate fee	906,542	77.06
102	Electricity	Natural gas replaced by Solar PV (1200 MW)	1,046,336	87
103	Domestic	Entertainment appliances - EE Standard 2	1,107,634	94.16
104	Transport	B15 fuel – cars	1,138,284	96.76
105	Domestic	Entertainment appliances - EE Standard 1	1,192,495	101.37
106	Transport	B15 fuel – motorcycles	1,214,054	103.2
107	Industry	Rubber industry - using outside intake air	1,314,691	111.76
108	Transport	BRT upgrade (2x)	1,572,573	133.68
109	Waste	Mass burn incinerator – low gate fee	2,186,538	185.87
110	Transport	2025 biofuel targets – cars	2,374,260	201.83
111	Transport	BRT upgrade (4x)	2,616,693	222.44
112	Commercial	Air conditioner - EE Standard 2	2,857,736	242.93
113	Transport	2025 biofuel targets – motorcycles	2,954,863	251.19
115	Transport	Bicycle lanes	5,556,359	472.33
116	Domestic	Washing machine - EE Standard 1	6,727,299	571.87
117	Electricity	Coal retrofit (2185 MW)	11,053,499	915
118	Electricity	Coal BAT (3673 MW)	11,053,499	915
119	Domestic	Washing machine - EE Standard 2	19,462,440	1,654.46
120	Industry	Fuel switching - 30% grid electricity replaced by solar PV	1,646,854,141	139,995.12

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

Appendix D: League Table of the Most Carbon-Effective Measures in Palembang ($ktCO_2$-e)

Rank	Sector	Measure	$ktCO_2$-e
1	Electricity	Geothermal 2000MW (replacing coal)	74,583
2	Electricity	Geothermal 1000MW (replacing coal)	37,291
3	Electricity	Coal replaced with solar PV (1200 MW)	13,127
4	Industry	Fuel switching - diesel to biodiesel	7,048
5	Industry	Renewables - replacing diesel boiler/furnace with solar water heaters	6,730
6	Electricity	Natural gas replaced by Solar PV (1200 MW)	6,092
7	Electricity	Coal BAT (3673 MW)	4,639
8	Waste	LFG utilisation	3,802
9	Waste	Energy from waste (CHP) – high gate fee	3,414
10	Waste	Energy from waste (CHP) – low gate fee	3,414
11	Industry	Fertiliser - steam reforming (large improvements)	3,166
12	Electricity	Coal retrofit (2185 MW)	2,760
13	Transport	CNG BRT (4x)	2,522
14	Industry	Fertiliser - process integration	2,374
15	Domestic	Air conditioner - EE Standard 2	2,159
16	Transport	BRT upgrade (4x)	2,139
17	Waste	Energy from waste (electricity recovery) – high gate fee	1,877
18	Waste	Energy from waste (electricity recovery) – low gate fee	1,877
19	Industry	Fuel switching - 30% grid electricity replaced by solar PV	1,865
20	Transport	CNG BRT (2x)	1,785
21	Domestic	Air conditioner - EE Standard 1	1,649
22	Transport	Euro IV vehicle standards – cars	1,620
23	Transport	BRT upgrade (2x)	1,607
24	Industry	Fuel switching - diesel to dual fuel systems	1,261
25	Electricity	Natural gas Retrofit (514 MW)	1,233
26	Domestic	Retrofitting fibreglass urethane insulation (20% of existing households by 2025)	1,213
27	Industry	Fertiliser - steam reforming (moderate improvements)	1,108
28	Waste	Anaerobic digestion (CHP) – high gate fee	1,104
29	Waste	Anaerobic digestion (CHP) – low gate fee	1,104
30	Waste	LFG flaring	1,059
31	Industry	Petroleum refinery - monitoring and targeting	1,055
32	Waste	Mass burn incinerator – low gate fee	1,012
33	Waste	Home composting	932
34	Waste	Anaerobic digestion (electricity recovery) – high gate fee	858
35	Waste	Anaerobic digestion (electricity recovery) – low gate fee	858
36	Transport	Euro IV vehicle standards – motorcycles	732
37	Waste	Centralised composting – high gate fee	732
38	Waste	Centralised composting – low gate fee	732
39	Industry	Fertiliser - more efficient CO_2 removal from synthesis gas	712
40	Domestic	Water heater - EE Standard 2	705
41	Domestic	Retrofitting mineral wool insulation (20% of existing households by 2025)	647
42	Industry	Fertiliser - hydrogen recovery	633
43	Domestic	Retrofitting fibreglass urethane insulation (10% of existing households by 2025)	607
44	Waste	Recycling	598
45	Industry	Petroleum refinery - more efficient utilities	594
46	Transport	B15 fuel - motorcycles	584
47	Industry	Fertiliser - improved process control	570
48	Domestic	4kWp solar PV panel with FiT (10MW by 2025)	550
49	Domestic	4kWp solar PV panel (10MW by 2025)	550
50	Domestic	Green Building Standard 2 (100% of new households from 2015)	510
51	Domestic	Kitchen appliances - EE Standard 2	457
52	Industry	Rubber industry - adoption of variable speed drive in electric motors	455
53	Domestic	Entertainment appliances - EE Standard 2	428

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

54	Domestic	Raising thermostat 1˚C	412
55	Industry	Fertiliser - ammonia synthesis at lower pressure	396
56	Industry	Petroleum refinery - more efficient furnaces and boilers	396
57	Transport	B15 fuel - cars	394
58	Domestic	Entertainment appliances - EE Standard 1	328
59	Domestic	Water heater - EE Standard 1	325
60	Domestic	Retrofitting mineral wool insulation (10% of existing households by 2025)	324
61	Domestic	Entertainment appliances - standby	323
62	Industry	Petroleum refinery - process integration	297
63	Industry	Petroleum refinery - more efficient heat exchangers	297
64	Domestic	4kWp solar PV panel (5MW by 2025)	275
65	Domestic	Green Building Standard 1 (100% of new households from 2015)	255
66	Domestic	Turning off lights	251
67	Domestic	Solar water heating with FiT (10% of households by 2025)	240
68	Domestic	Solar water heating (10% of households by 2025)	240
69	Transport	Parking meters	227
70	Commercial	Green Buildings Standard 2 (100% of new commercial buildings)	221
71	Commercial	Air conditioner - EE Standard 2	195
72	Industry	Renewables - replacing diesel generators with solar PV	138
73	Domestic	Green Building Standard 2 (50% of new households from 2015)	129
74	Domestic	Green Building Standard 1 (50% of new households from 2015)	128
75	Industry	Rubber industry - reduction of excess air in boilers	126
76	Commercial	Turning off lights	122
77	Domestic	Solar water heating (5% of households by 2025)	120
78	Waste	Waste prevention	118
79	Commercial	Green Buildings Standard 1 (100% of new commercial buildings)	111
80	Commercial	Green Buildings Standard 2 (50% of new commercial buildings)	111

81	Transport	Fuel tax/ subsidy reduction of 600 IDR/L	109
82	Transport	2025 biofuel targets - motorcycles	106
83	Industry	Rubber industry - heat recovery	100
84	Commercial	Air conditioner - EE Standard 1	98
85	Industry	Petroleum refinery - more efficient pumps	95
86	Domestic	Banning incandescent light bulbs	94
87	Industry	Pulp and paper - replace pressure reduction valves with steam turbines (1MW)	93
88	Industry	Rubber industry - adoption of variable speed drive in pumps	85
89	Transport	2025 biofuel targets - cars	83
90	Industry	Petroleum refinery - more efficient motors	79
91	Domestic	Kitchen appliances - EE Standard 1	76
92	Commercial	Banning incandescent light bulbs	67
93	Industry	Pulp and paper - pinch analysis	56
94	Commercial	Green Buildings Standard 1 (50% of new commercial buildings)	55
95	Transport	Fuel tax/ subsidy reduction of 300 IDR/L	55
96	Domestic	Washing machine - EE Standard 2	54
97	Domestic	Washing machine - EE Standard 1	42
98	Domestic	Setting LED target of 25%	34
99	Commercial	Raising thermostat 1˚C	34
100	Industry	Petroleum refinery - more efficient compressors	24
101	Commercial	Setting LED target of 25%	22
102	Commercial	Elevators and escalators - EE Standard 2	19
103	Industry	Rubber industry - more efficient nozzles	18
104	Industry	Pulp and paper - optimisation of pump system design	16
105	Domestic	Solar lamps for outdoor lighting (100% of outdoor lamps sold)	14
106	Transport	Bicycle lanes	14
107	Commercial	Computer - energy management	14
108	Industry	Pulp and paper - steam trap maintenance	13

Cost effective

Cost neutral

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

109	Commercial	20kWp solar PV panel – target of 2MW by 2025	9.58
110	Commercial	20kWp solar PV panel with FiT – target of 2MW by 2025	9.58
111	Commercial	Elevators and escalators - EE Standard 1	9.51
112	Industry	Pulp and paper - boiler maintenance	8.48
113	Domestic	Solar lamps for outdoor lighting (50% of outdoor lamps sold)	7.08
114	Industry	Rubber industry - leak prevention	6.71
115	Commercial	Monitor - energy management	5.21
116	Commercial	20kWp solar PV panel – target of 1MW by 2025	4.79
117	Commercial	20kWp solar PV panel with FiT – target of 1MW by 2025	4.79
118	Commercial	Printer - energy management	4.13
119	Industry	Pulp and paper - improved insulation of pipes, valves and fittings	3.92
120	Industry	Pulp and paper - boiler process control	3.65
121	Industry	Pulp and paper - more efficient boilers and furnaces	3.13
122	Industry	Rubber industry - using outside intake air	2.73
123	Industry	Rubber industry - lowering functional pressure	2.31
124	Industry	Pulp and paper - shoe press	2.1
125	Industry	Pulp and paper - optimisation of compressed air systems	2.01
126	Industry	Pulp and paper - condensate return to boilers	1.96
127	Industry	Pulp and paper - flue gas heat recovery	1.7
128	Commercial	Copier - energy management	0.37
129	Commercial	Substituting grid electricity for diesel generators - shopping centres	0.12
130	Commercial	Fax - turning off	0.07

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The Climate Smart Cities Programme

www.climatesmartcities.org

The study has been conducted as part of the Climate Smart Cities programme that has been underway since 2009. The programme is led by Prof Andy Gouldson at the University of Leeds with support from the Centre for Low Carbon Futures and the ESRC Centre for Climate Change Economics and Policy.

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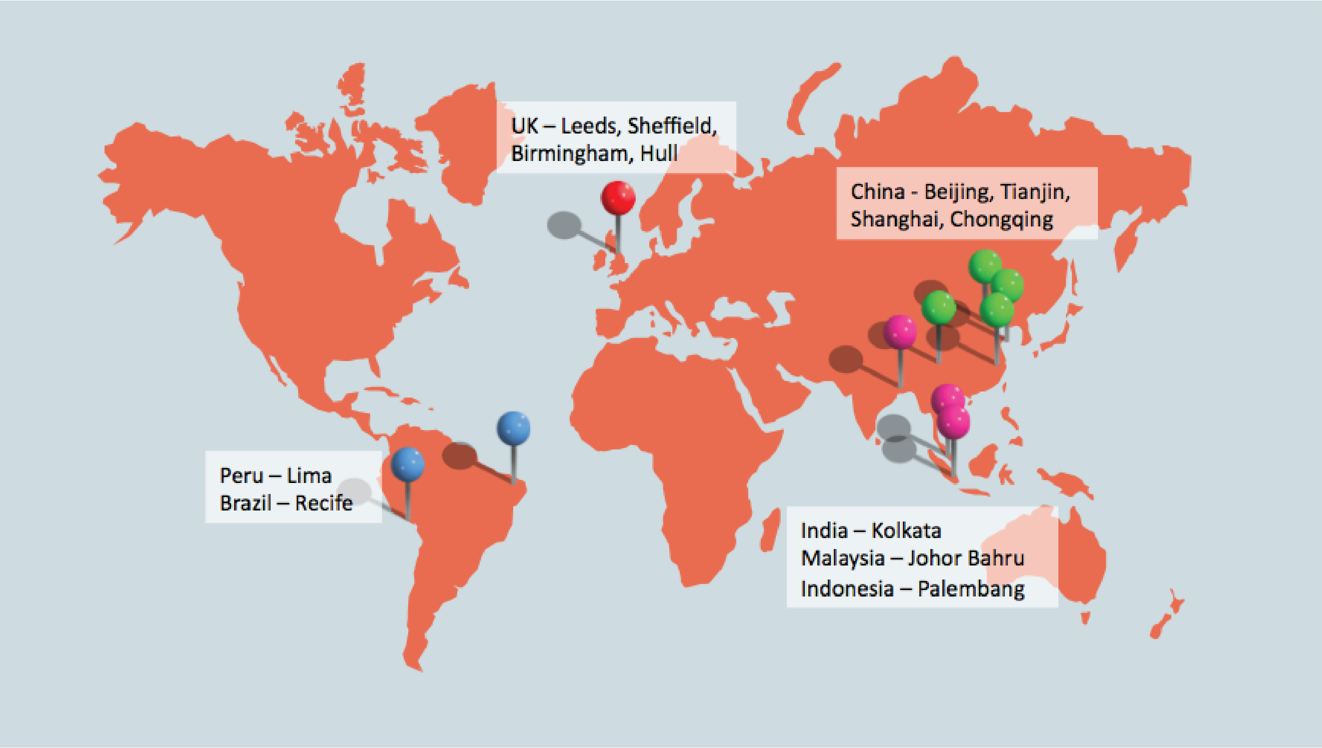

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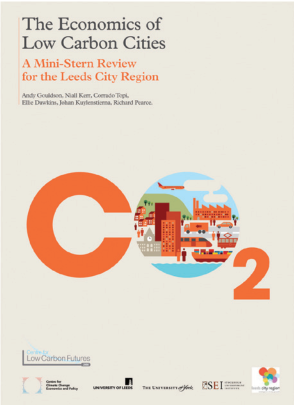

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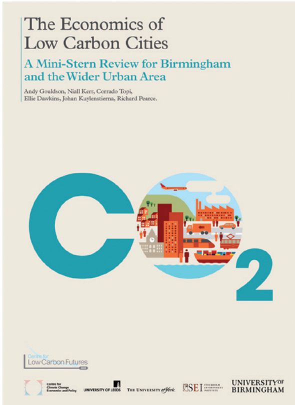

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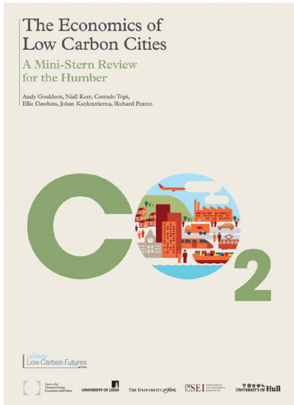

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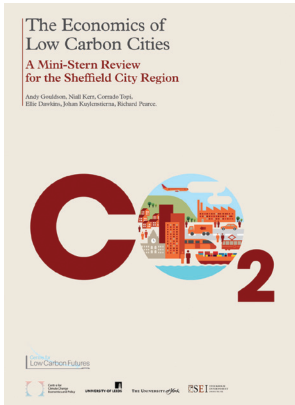

Sheffield City Region

Project Director:

Prof Andy Gouldson
a.gouldson@leeds.ac.uk

UNIVERSITY OF LEEDS

Project Manager:

Sarah Colenbrander
s.colenbrander@leeds.ac.uk

UNIVERSITY OF LEEDS

In-country lead:

Dr Elly Sinaga
ellysinaga@yahoo.com

Ministry of Transportation
Republic of Indonesia