# CITY ENERGY EFFICIENCY REPORT

# Combined Analysis for Colombo, Dehiwala, Kotte and Kolonnawa Municipal Council

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# EXECUTIVE SUMMARY

## Overview of TRACE

Tool for the Rapid Assessment of City Energy (TRACE) has been developed as a part of World Bank's Energy Efficient Cities Initiative to present a quick, first-cut sectoral analysis on the city energy use. This assessment framework prioritizes sectors with significant energy savings potential and identifies contextualized and reasoned energy efficiency interventions. It covers energy efficiency across six sectors – transport, waste, water & wastewater, power & heat, public lighting, and buildings, as well as organizational management.

TRACE consists of three principal components:

(i) a city energy benchmarking tool ,

(ii) a process for prioritizing sectors which offer the greatest potential with respect to energy efficiency

(iii) a 'playbook' of tried and tested energy efficiency recommendations.

It provides a benchmarking tool for Key Performance Indicators (KPIs) identified in the 6 sectors mentioned above with other peer cities around the world. Based on the spending on a sector, its relative energy intensity and the control of the city council over the sector, a list of prioritized sectors with the greatest energy savings potential is determined. The final output of TRACE is a tailored set of recommendations for Energy Efficiency measures that can be implemented in the city along with an estimation of its first cost, the time of implementation, speed of implementation and a of implementation of the recommendation in other cities.

## Summary of city background context

This report does a combined analysis for the municipalities of Colombo, Dehiwala, Kotte and Kolonnawa. This approach is unique to the assessment carried out in Sri Lanka. The project team comprising of the World Bank staff and consultants developed this combined analysis technique given the fact that data available for 3 out of 4 municipalities was not too different given their size and homogeneity of the governance structures.


**Colombo**

Colombo is the largest city in Sri Lanka and the commercial, industrial and financial capital of Sri Lanka. It is located on the west coast of the island country. The population of the city is 506,720 people spread over 38 $km^2$ area. It has a tropical climate and the major religions followed are Buddhists, Muslims, Hindus and Christians. It has an HDI of 0.715, per capita energy consumption of 1330.8 kWh/annum and generates a GDP of US$[1] 3.9 billion within the city limits. Colombo has a 97% employment rate. The Colombo Municipal Council governs the city. It overlooks the major functions like street lighting, garbage management public health, water supply and sewage management.

**Dehiwala-Mount Lavinia**

Dehiwala is the largest suburb of capital Colombo in Sri Lanka's Western Province and is situated immediately south of the Colombo city centre. It has a population of 224,102 people spread over an area of 21 $km^2$. It experiences tropical climate. The HDI of the city is 0.715 with per capita electricity consumption of 766.07 kWh/annum. It generates a GDP of US$ 1.7 billion.

[1] *Exchange rate: 1US$ = 130.62 LKR on 29th April, 2014*

**Kolonnawa**

Kolonnawa is also a suburb of Colombo in Sri Lanka's Western Province. It has a population of 55,285 over a land area of 10 $km^2$. It has a HDI of 0.715 with per capital energy consumption of 766.07 kWh/annum. It generates a GDP of US$ 422 million.

**Kotte**

Sri Jayawardenepura Kotte, also known as Kotte, is the parliament site and official capital of Sri Lanka. It is the largest suburb of Colombo city and is located to the South East of Colombo city centre. It has a population of 121,831 and a land area of 17 $km^2$. It has an HDI of 0.715, generates a GDP of US$ 932 million and has a per capita energy consumption of1117.8 kWh/annum.

The overarching body of power sector in Sri Lanka (including the city of Colombo) is Ceylon Electricity Board (CEB). It is the largest electricity establishment in Sri Lanka with a market share of nearly 100%, it controls all major functions of electricity generation, transmission and distribution and retailing in Sri Lanka. It is one of the only two on-grid electricity establishments in the country; the other being Lanka Electricity Company (LECO). The National Water Supply and Drainage Board (NWSDB) is the principal authority in providing safe drinking water and sanitation in the country. The Ministry of Transport is responsible for the National Policy Framework and enactment on all matters pertaining to transport within Sri Lanka. The Sri Lanka Sustainable Energy Authority established under the purview of Ministry of Environment and Renewable Energy (MoE&RE) aims to make Sri Lanka energy secure.

## Energy Efficiency Issues being faced and list of prioritized sectors

The TRACE module prioritizes sectors by assigning them with scores for Relative Energy Intensity, Sector Spending and the City Authority Control and multiplying them. The high priority sectors in all the 4 suburbs combined with the maximum potential for energy saving are Transportation (both Public and Private transportation), Solid Waste, Municipal Buildings and Street Lighting. The transportation sector has the highest spending and thus makes it into the prioritized sector list in spite of low city authority control. The sectors of street lighting and municipal buildings, in spite of a lower spending, make it into the priority list owing to a high degree of city authority control.

## Principal Recommendations

TRACE recommendations for the prioritized sectors were discussed with the local authorities. Post-discussion, the following most promising projects (in the order of importance) were proposed by the local authorities:

1. Municipal Buildings sector - Renewable energy integrated energy efficient buildings
2. Public Transportation sector - Mode integration in public transport
3. Street Lighting sector - Standardizing of street lighting system
4. Waste Sector - Waste to energy

# 1. INTRODUCTION

The duration of the project undertaken was 8 months (August 2013 to March 2014). The project was split into pre-mission, mission and post-mission phases. The pre-mission phase involved getting background information related to the city in general and the energy sector by interviewing various stakeholders across different departments of the 4 municipalities. The data collected was used in the benchmarking module of TRACE to evaluate the relative position of Colombo from an energy efficiency viewpoint across 6 sectors (transport, municipal buildings, waste, potable and sewage water, street lighting, power and heat) with respect to its peer cities. Data about the energy efficiency measures implemented and underway in the city was also collected during this phase. During the mission, the TRACE team visited the city, engaged and interviewed stakeholders (municipal engineers) across all the TRACE sectors in the municipalities, the local consultants and the local government. Detailed data was requested for each sector for the sector prioritization and the energy savings assessment modules of TRACE. Sectors were prioritized based on the data input and a list of relevant recommendations for the 4 municipalities from the shortlisted sectors was selected.

The major challenge faced during the mission was obtaining the detailed and granular data required for the Savings Assessment Calculator of TRACE module.

Colombo is the largest city and the commercial, industrial and financial capital of Sri Lanka. It is located on the west coast of the island and adjacent to Sri Jayawardenapura Kotte suburb or the parliament capital of Sri Lanka. Colombo is also the administrative capital of Western Province, Sri Lanka and the district capital of Colombo. Colombo is often referred to as the capital since Sri Jayawardenapura Kotte is a satellite city of Colombo. Colombo is a busy and vibrant place with a mixture of modern life and colonial buildings and with a population of about 506,720 in the city limits. It was the political capital of Sri Lanka, before Sri Jayawardenapura Kotte. Some important demographic, economic and energy details about the city are mentioned in the table below:

*Table 1: Key Statistics – Colombo City*

| Particulars | Value |
|---|---|
| **Population** | 506,720 |
| **Climate** | Tropical |
| **Total Area** | 38 $km^2$ |
| **Density** | 17,400/ $km^2$ |
| **Religion(s)** | Buddhists, Muslims, Hindus and Christians |
| **Main Industries & Services** | Colombo is the main commercial and administrative hub of Sri Lanka and there exist ministries of the Government, head offices of most of the companies and banks, industries such as tea packing, tobacco processing, garments, large hotels, major hospitals, etc. |
| **Gross Domestic Product - US$** | US$ 3,876.7 million |
| **Human Development Index (HDI)** | 0.715 |
| **Employment Rate (%)** | 97.1% |
| **Energy Consumption per Capita (kWh/capita/annum)** | 935.8 |
| **Electricity Consumption per Capita** | 1330.8 |

| Particulars | Value |
|---|---|
| **(kWhe/capita/annum)** | |
| **Energy Consumption per GDP (kWh/$)** | 0.027 |
| **Energy Supply Cover (% population with access to electricity and heat, as applicable)** | 100% |

The key statistics for Dehiwala-Mt Lavinia Municipality are:

*Table 2: Key Statistics – Dehiwala-Mt Lavinia Municipality*

| Particulars | Value |
|---|---|
| **Population** | 224,102 |
| **Climate** | Tropical |
| **Total Area** | 21 km2 |
| **Density** | 10,626/ km2 |
| **Gross Domestic Product - US$** | US$ 1,714.5 million |
| **Human Development Index (HDI)** | 0.715 |
| **Energy Consumption per Capita (kWh/capita/annum)** | 766.07 |

The key statistics for Kolonnawa Municipality are:

*Table 3: Key Statistics – Kolonnawa Municipality*

| Particulars | Value |
|---|---|
| **Population** | 55,285 |
| **Climate** | Tropical |
| **Total Area** | 10 $km^2$ |
| **Density** | 5,495/ $km^2$ |
| **Gross Domestic Product - US$** | US$ 422.9 million |
| **Human Development Index (HDI)** | 0.715 |
| **Energy Consumption per Capita (kWh/capita/annum)** | 766.07 |

The key statistics for Kotte Municipality are:

*Table 4: Key Statistics – Kotte Municipality*

| Particulars | Value |
|---|---|
| **Population** | 121,831 |
| **Climate** | Tropical |
| **Total Area** | 17 $km^2$ |
| **Density** | 7,150/ $km^2$ |
| **Gross Domestic Product - US$** | US$ 932.1 million |
| **Human Development Index (HDI)** | 0.715 |
| **Energy Consumption per Capita (kWh/capita/annum)** | 1117.8 |

*Table 5: Key Statistics – All*

| | Combined | Colombo | Dehiwala | Kolonnawa | Kotte |
|---|---|---|---|---|---|
| **Population** | 907,938 | 506,720 | 224,102 | 55,285 | 121,831 |
| **Climate** | Tropical | Tropical | Tropical | Tropical | Tropical |
| **Total Area** | 86 $km^2$ | 38 $km^2$ | 21 $km^2$ | 10 $km^2$ | 17 $km^2$ |
| **Density** | 10,534/ $km^2$ | 17,400/ $km^2$ | 10,626/ $km^2$ | 5,495/ $km^2$ | 7,150/ $km^2$ |
| **Gross Domestic Product - US$** | 6,946,238,580 | 3,876,694,237 | 1,714,506,890 | 422,961,750 | 932,075,970 |
| **Human Development Index (HDI)** | 0.715 | 0.715 | 0.715 | 0.715 | 0.715 |
| **Energy Consumption per Capita (kWh/ capita/ annum)** | 1128.5 | 935.8 | 766.07 | 766.07 | 1117.8 |

The Colombo Municipal Council oversees the activities in the city. Its organizational and functional framework has been given in the picture below. It does not have complete control over all of the 6 sectors, as there are national authorities, which regulate them. The power sector is controlled by the Ceylon Electricity Board, the potable and waste water programs fall under the purview of National Water Supply and Drainage Board and the transport sector is controlled by the national Ministry of Transport.

The split of primary energy by source over the past 5 years has been provided in the table below.

*Figure 1: Split of primary energy by source*

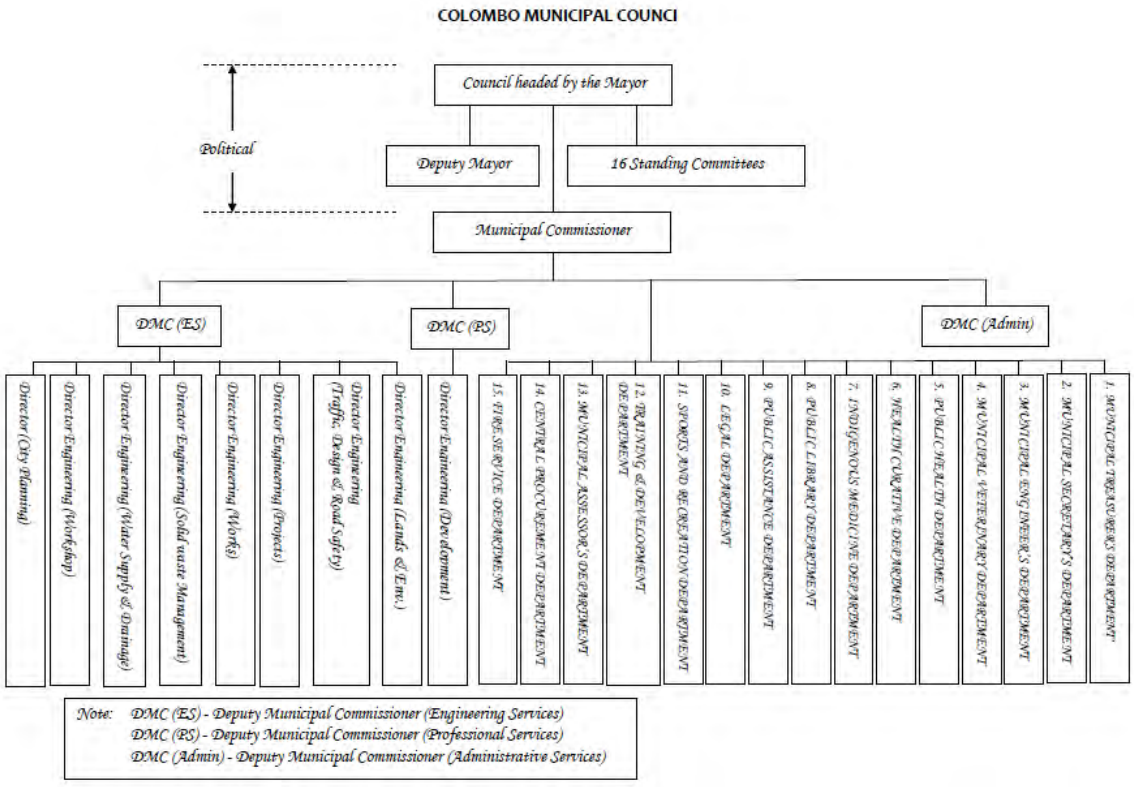



*Table 6: Split of primary energy by source*

| Source | Year | | | | |
|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 |
| **Biomass** | 4712.77 | 4688.52 | 4652.53 | 4762.41 | 5042.05 |
| **Petroleum** | 4002.44 | 4237.98 | 3928.97 | 3896.53 | 4543.87 |
| **Hydro** | 1112.17 | 947.26 | 991.06 | 931.46 | 1532.28 |
| **Non Conventional** | 4.08 | 4.28 | 4.88 | 4.88 | 4.91 |

## 1.1. ENERGY SCENARIO IN CITY

The main primary energy sources used in Sri Lanka are hydro resources, petroleum and biomass. Hydro resources are used for electricity generation for the national grid; fuel oil and coal are used for transportation and power generation, and industrial requirements of thermal energy. Biomass is used for domestic cooking and industrial heating.

Present maximum demand (Based on the 2012 data) for electricity is around 2,150 MW and the total annual electricity generation is around 11,800 GWh. About 70% of the electricity generation is with thermal power plants running on diesel furnace oil and coal, 1.4% from NCRE (Non-Conventional Renewable Energy) and the balance 28.6% with hydropower.

As a consequence of the high share of oil-based generation, the average electricity costs are higher when compared with other countries in the region. The daily load curve is highly skewed, with a high evening peak lasting for about three hours. This has been an additional burden to the utilities, whereas a flatter load curve would have made existing plants operate more evenly reducing the necessity to add new capacity to serve the high peak. Lighting, TV and other domestic appliances contribute to the peak period, and the efficiencies of the equipment used by customers are not at satisfactory levels. In this background, it is of paramount importance to devise effective modalities to ensure the optimum use of available resources, and to popularize better means of using energy efficient equipment and technologies.

## 1.2. ENERGY POLICY FRAMEWORK

National energy policy and strategies published in 2008 is providing comprehensive framework for implementation of energy activities in the country. This document, spells out the implementing strategies, specific targets and milestones through which the Government of Sri Lanka and its people would endeavor to develop and manage the energy sector in the coming years in order to facilitate achieving its millennium development goals. Specific new initiatives are included in this policy to expand the delivery of affordable energy services to a larger share of the population, to improve energy sector planning, management and regulation, and to revitalize biomass as a significant resource of commercial energy. The main elements of the policy are presented below.

1. Providing Basic Energy Needs

2. Ensuring Energy Security

3. Promoting Energy Efficiency and Conservation

4. Promoting Indigenous Resources

5. Adopting an Appropriate Pricing Policy

6. Enhancing Energy Sector Management Capacity

7. Consumer Protection and Ensuring a Level Playing Field

8. Enhancing the Quality of Supply

9. Protection from Adverse Environmental Impacts of Energy Facilities

The main policy statement in the document is: 'Energy supply systems will be efficiently managed and operated while also ensuring efficient utilization and conservation of energy' and is further elaborated as follows, "Efficient management and operation of the energy sector utilities are vital to ensure minimum cost of supply to consumers. Efficient utilization of energy by all concerned, from utilities (supply-side management) to final consumers (demand-side management) not only saves valuable resources of the country but also reduces the overall cost of energy to the consumer. Meaningful conservation of energy will be pursued at all times."

Sustainable energy development has been identified in the "Mahinda Chinthanaya Vision for the Future" – the national action plan of the Government. It describes *"By 2020, about 20 percent of electricity supply is expected to be generated by the renewable energy. For this purpose, sufficient investment will be made on development of renewable energy sector with wind, dendro, solar and mini hydro power plants. With the long-term objective of reducing 8.7 percent of energy consumption by the year 2020, under the power conservation and management programme, energy conservation activities will be implemented at household as well as industrial and commercial levels. A comprehensive mechanism to deliver energy efficiency services will be developed to curtail energy waste in industrial and commercial sectors"*

In line with the above, Government has implemented several activities during past and considering further acceleration of such initiatives, National Energy Management Plan (EnMAP) has been developed by Sri Lanka Sustainable Energy Authority (SLSEA), covering a period of 5 years (from 2012 to 2016) with the objectives of assisting Sri Lanka to retain the energy intensity of the economy at present levels, assisting the country to meet the energy requirements at a constant or progressively lower level of specific energy use.

# 2. BACKGROUND TO THE RAPID ASSESSMENT FRAMEWORK

The rapid urbanisation of developing countries over the last fifty years has led to challenges in achieving environmental, social and economic sustainability. While cities in developing countries continue to face significant environmental challenges, they remain the primary engines of economic growth. The challenge is thus to achieve economic growth while minimising it's associated environmental externalities. In this context, improving energy efficiency is essential. However, the lack of city-specific, disaggregated data has been a major impediment to assessing the overall energy implications of different urbanization patterns and to guiding improved energy, economic and environmental analysis, especially in cities of the developing world.

The Tool for Rapid Assessment of City Energy (TRACE) is a central component of the Energy Efficient Cities Initiative (EECI), launched by the Energy Sector Management Assistance Program (ESMAP) in collaboration with the Urban Anchor in 2008.

The purpose of TRACE is to identify technical and institutional measures that will improve the energy efficiency of the municipal infrastructure across the following sectors:

1) Transportation (public and private)
2) Waste
3) Potable water supply and waste water treatment
4) Power and heat
5) Public Lighting
6) Municipal Buildings

The organizational management practices with respect to energy efficiency of the City Authority (CA) that span all of the sectors above are also considered. The ultimate aim of TRACE is to identify ways in which energy efficiency can be improved by the CA and therefore reduce their expenditure on energy. However, in some cases it is clear that there are city-wide activities that cut across all sectors. Sectors that will directly save the CA money and over which it has direct control are labelled as 'City Authority'; while sectors that do not necessarily affect the CA's energy expenditure, relate to energy use principally in the private sector, and which the CA may have limited influence are labelled as 'City Wide.' In such instances, the TRACE process identifies how these issues may be addressed through engagement, representation and other means.

## 2.1. PRE-MISSION, MISSION AND POST-MISSION ACTIVITIES

The project duration was of 8 months from August 2013 to March 2014. The pre-mission phase involved getting background information related to the city in general and the energy sector by interviewing various stakeholders across different departments of respective Municipal Corporations. The data collected was used in the benchmarking module of TRACE to evaluate the relative position of municipalities from an energy efficiency viewpoint across sectors of transport, municipal buildings, waste, potable and sewage water, street lighting, power and heat with respect to its peer cities. Data

about the energy efficiency measures implemented and underway in the city was also collected in this phase. During the mission, the TRACE team visited the city, engaged and interviewed stakeholders across all the TRACE sectors in the municipalities (municipal engineers), the local consultants and the local government. Detailed data was obtained for each sector for the sector prioritization and the energy savings assessment modules of TRACE. Sectors were prioritized based on the data input and a list of relevant recommendations for all the 4 municipalities combined from the shortlisted sectors was selected.

## 2.2. OVERVIEW OF THE 6 TRACE SECTORS

The specific status of energy efficiency in the 6 sectors is provided below.

### 2.2.1 Transport

*Table 7: Key Statistics - Transportation (Combined)*

| Parameter | Value |
|---|---|
| **Current Modal Split (motorized and non-motorized)** | Negligible non-motorized transport. Motorized vehicles include Motor Cycle, 3 Wheelers, Cars, Vans, Lorry, Bus |
| **Private Vehicle Ownership** | 90% |

Since the Colombo city is the commercial and administration centre of the country, about 1.6 million [Greater Colombo traffic management report 2009] of passengers are come to the city daily in the morning and go back in the evening using different mode of transport. The share of mode of transport is approximately Motor Cycle 24%, 3 Wheelers 19.0%, Cars 25.0%, Vans 20.0%, Lorry 7.0%, Bus 5.0% and others 1.0%. The use of passenger kilometres in different types of vehicles are approximately buses 56.9%, motor cycle 13.4%, three wheelers 9.3%, vans 11.6% and cars 8.8%. Passengers who use train services are not accounted in this calculation. The other 3 suburbs of Kotte, Kolonnawa and Dehiwala have a similar split in transportation, as described by the local authorities.

The city authorities have low control over the transportation sector. The public transportation is under the purview of the Ministry of Transport at the National Government level. As such, any intense changes in the standards, etc. would have to be driven by the central agencies.

### 2.2.2 Waste

Colombo Municipal Council is responsible for the collection and disposal of solid waste in the area coming under their preview. The governing legislations related to the three types of Local Authorities i.e. Municipal Councils Ordinance, Urban Councils Ordinance, and Pradheshiya Sabha Act have made necessary provisions for management of waste. The Western Province shares more than 59% of the country's daily generated waste, and the amount generated within the Colombo Municipal Council is in the range of 640 MT per day. Further the provincial waste management authority (WMA)

of Western Province has the sole authority to provide guidance, directions and assistance for better management of the SW (eg. Implement power generation projects, sanitary land filling, etc).

Lack of national approach in solid waste management has brought about tremendous negative environmental consequences. In order to remedy this situation a program named "Pilisaru Waste Management Programme" has been initiated by the Ministry of Environment and Renewable Energy to establish Integrated Solid Waste Management (ISWM) program in the country. Through this programme the Ministry has established a platform to bring all relevant stakeholders together to implement a cohesive national programme to address waste management issues in the country.

The following table shows the total waste generated annually and the per capita waste for the 4 municipal areas. Most of the generated waste goes to landfills and a very tiny fraction is recycled (in Dehiwala and Kolonnawa):

*Table 8: Waste generated annually*

| Region | Waste Generated Annually ('000 tons) | Per capita waste (kg/capita/yr) | % |
|---|---|---|---|
| **Colombo** | 255.4 | 504 | 59.7% |
| **Dehiwala** | 73.0 | 326 | 17.0% |
| **Kolonnawa** | 12.0 | 218 | 2.8% |
| **Kotte** | 87.6 | 719 | 20.5% |
| **Combined** | **428** | **471** | **100.0%** |

### 2.2.3 Potable and Waste Water

Water supply scheme and the waste water management system of the Colombo municipal council area is operated and managed by National Water Supply & Drainage Board (NWS&DB). Almost 95 % of the areas in Colombo city are covered with pipe water supply. However due to variation in line pressure, the availability of water varies in time to time in certain areas [ADB Project data sheet]. Water is taken from three main resources viz. River Kelani at Ambatale, Kalatuwawa reservoir and Labugama reservoir and after treating the water at Labugama and Kalatuwawa, it takes to the user point under gravity. There is a separate treatment plant at Ambathale and water get to the respective user points through mechanical pumping after treating. Water quality at each treating plant is maintained at applicable level.

The total amount of water sold in Colombo and Dehiwala annually is 106.6 and 37.7 million m3. There haven't been any significant energy efficiency measures implemented in the potable or sewage water networks. The municipalities do not have any control over this network. The following table shows the water consumption in the four municipalities per capita per day. The average consumption is 563 liters/capita/day. On an average, all the 4 municipalities have a very high percentage of non-revenue water viz. 49%.

*Table 9: Water consumption and non-revenue water*

| Municipality | Water Consumption (liters/capita/day) | Percentage of non revenue water |
|---|---|---|
| **Colombo** | 332 | 49% |
| **Dehiwala** | 462 | NA |
| **Kolonnawa** | 331 | NA |

| Municipality | Water Consumption (liters/capita/day) | Percentage of non revenue water |
|---|---|---|
| **Kotte** | 1127 | NA |
| **Combined** | 563 | 49%[2] |

### 2.2.4 Power and Heat

Colombo being in the tropical belt does not have significant heating requirement. The power sector is under the purview of the Ceylon Electricity Board and not the city municipalities. The following table gives some important statistics about the power consumption in the Colombo. The total T&D losses in all the municipalities is about 5%.

*Table 10: Key Statistics – Power and Heat*

| Parameter | Value |
|---|---|
| **Total Transmission & Distribution Losses ($kWh_e$/annum)** | 14,833,571 |
| **Number of houses with authorized electrical service** | 65,051 |
| **Total Electricity Produced (kWh/annum)** | 103,835,000 (Consumption) |

### 2.2.5 Street Lighting

All the roads in the Colombo city are provided with street lights in different scale with more emphasis on congested and public areas. Special lighting system has been introduced in Galle road from Bambalapitiya to Kolpity with sophisticated control system. Baseline road, the gateway to most of the areas of the city is illuminated with LED lamps. Independent square is one of the public places in the city and the pathways in the area are illuminated with LED lamps.

Lighting system in the city is owned by Colombo municipals council and road development authority. Operation and maintenance of the lighting system is also done by the council. The following table gives key statistics about street lighting in the 4 municipalities. 100% of the 366 kms long roads are lit in all the regions.

*Table 11: Key Statistics – Street Lighting*

| Municipality | Total length of roads (km) | % of city roads lit | Number of light poles |
|---|---|---|---|
| **Colombo** | 480 | 100% | 11,657 |
| **Dehiwala** | 286 | 100% | 8,000 |
| **Kolonnawa** | 72 | 100% | 1,808 |
| **Kotte** | 127 | 100% | 3,733 |
| **Combined** | 366 | 100% | 25,198 |

[2] *This parameter value is expected to be similar to Colombo*

### 2.2.6 Public Buildings

Municipal Buildings (apart from those owned by other government agencies) come under the purview of the city authority. The table below lists the types of municipal buildings under their purview. 60% of the buildings are air-conditioned. Refurbishments and construction of building are done according to the building regulation of Colombo municipal council.

Code of practice for energy efficient buildings published by Sri Lanka Sustainable Energy Authority in 2008 is applicable to the entire country and being practiced on a voluntary basis. Directives have been given by the Government to reduce the energy consumption by 20% in Government offices and it is being practiced now. Regulation was published in 2011 requesting to appoint an energy manager in major energy consuming establishments and implement energy conservation program through him/her. One of the obligations of energy managers is to send the energy consumption and the production data to the SLSEA and SLSEA which is used to establish benchmarks. If an institution is consuming over and above the benchmark, three year energy conservation action plan has to be developed by that institution and has to be implemented.

The following table lists some details about public buildings average consumption:

*Table 12: Key Statistics – Public Buildings*

| Municipality | Floor Area (m2) | Electricity Consumption per month (kWhe) | Average power tariff for municipal buildings ($/kWh) |
|---|---|---|---|
| **Colombo** | 19,100 | 71,000 | 0.19 |
| **Dehiwala** | 5,700 | 16,000 | 0.2 |
| **Kolonnawa** | NA | 20,000 | 0.2 |
| **Kotte** | NA | 6,000,000[3] | 0.2 |

[3] *Kotte is the parliament site of Sri Lanka. This could be the reason for the significantly high value of Kotte*

# 3. CURRENT ENERGY PERFORMANCE

## 3.1. INTRODUCTION TO ENERGY PERFORMANCE BENCHMARKING

The benchmarking component of the TRACE tool is intended to assess the energy performance of a city compared to other peer cities. Peer cities are defined using similar climate, population or human development index (HDI) score. These can be reviewed and selected in the TRACE tool. For each sector, a number of Key Performance Indicators (KPIs) have been derived to indicate energy performance either across the sector or with respect to components of the sector. KPI data for the chosen peer cities is used as a principal factor in sector prioritization in the TRACE tool.

3 sets of peer cities are defined based on similarity in climate, population and HDI. The population of Colombo (with the municipal boundary) is 506,720 according to the 2012 census report. The peer cities having similar population are Sangli (India), Skopje (Republic of Macedonia), Zarqa (Jordan), Sarajevo (Bosnia and Herzegovina), Bratislava (Slovakia) and Tallinn (Estonia). Colombo has a tropical climate and it has an HDI of 0.715. The cities of counties like India, Brazil, Singapore, Malaysia which are located in the tropical belt are Colombo's peers based on climate. The peer cities based on HDI are Rio de Janeiro, Sao Paulo and Brasillia (Brazil), Baku (Azerbaijan), Odessa (Ukraine), Sarajevo (Bosnia and Herzegovina) and Skopje (Republic of Macedonia).

KPIs were obtained through the country consultants and interviews with various authorities in the municipal corporation. The data for all the KPIs were populated barring the public transport modal split and the municipal buildings energy spend as a percentage of the municipal budget. Almost all the data was available for the Key Performance Indicators (KPIs) of the cities.

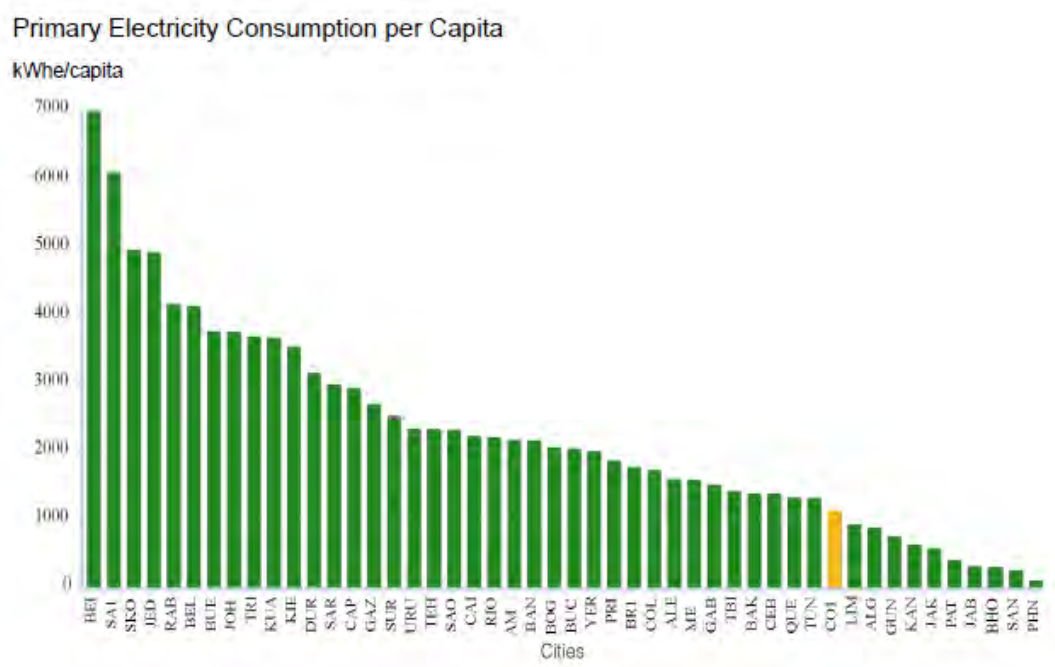
The following sections graphically present the data collected and give a benchmarking comparison to other cities around the world.

## 3.2. CITY WIDE ENERGY EFFICIENCY BENCHMARKING

The graphs below have been generated from the Benchmarking tool of the TRACE module. They depict the standing of Colombo with respect to the other cities across the world. The bar in yellow in the graph shows the position of Colombo.

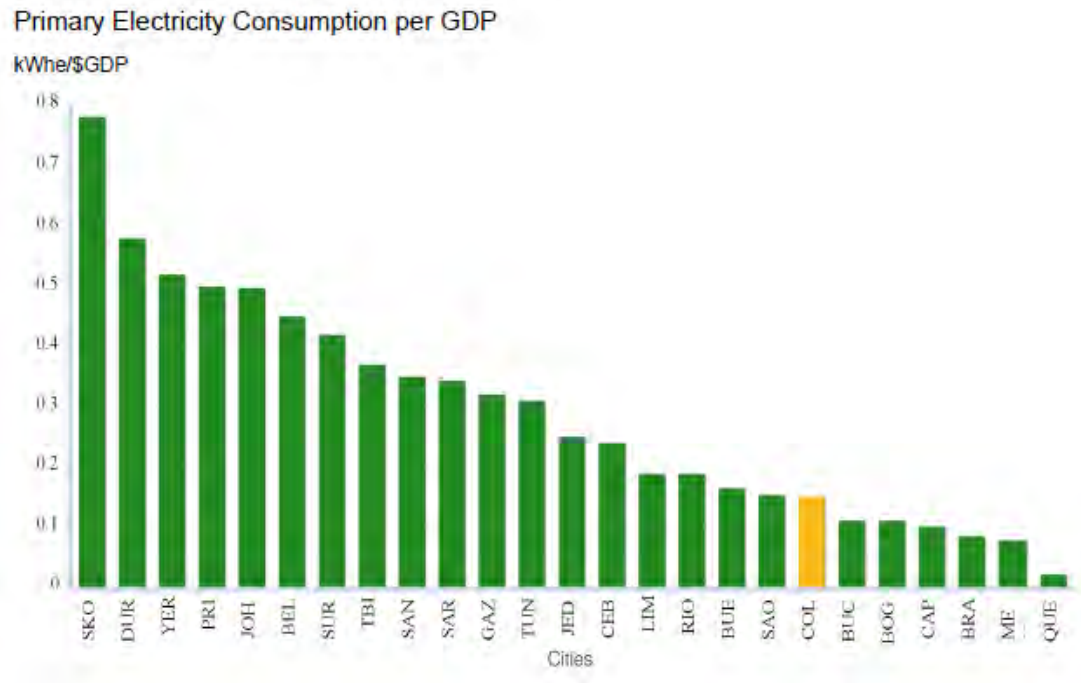
The graphs below are for the KPIs of Electricity Consumption per capita and per GDP and Primary Energy Consumption per capita and per GDP.

*Figure 2: Primary Energy Consumption per capita*




The above plot compares the per capita electricity consumption for cities having a similar HDI to Colombo. As can be seen here, the value is still relatively lower compared to its peer cities.

*Figure 3: Primary Energy Consumption per GDP*



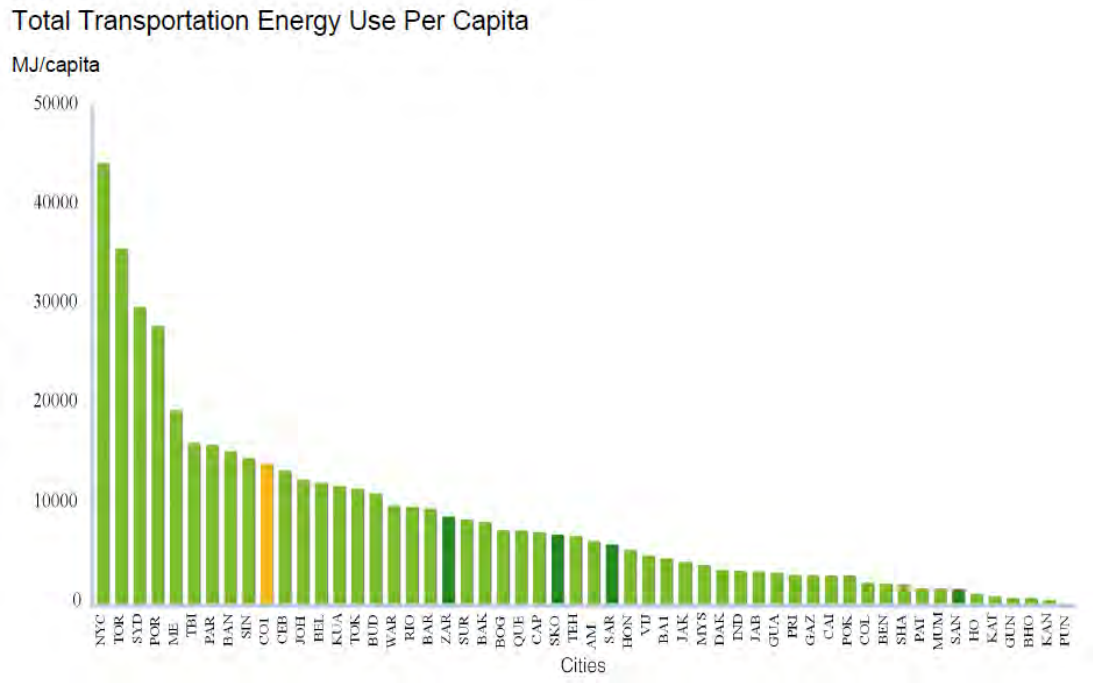
In the above plot, the combined data for the 4 municipalities is compared with cities with similar HDI. It can be seen that the energy intensity of its electricity consumption is relatively low. This implies that the economy, for the same set of GDP-comprising economic activities, is more energy efficient; and in comparison with diverse economies, the data points to focus on non-energy intensive economy.

## 3.3. TRANSPORTATION BENCHMARKING

In terms of energy efficiency of public and private transport measured by transport MJ/passenger km, Dehiwala is the most inefficient with a public transport value of 0.42 MJ/passenger-km and private transport value of 2.10 MJ/passenger-km. The average public transport value for the 4 municipalities is 0.33 MJ/passenger-km and for private transport, the value is 1.16 MJ/passenger-kms. The total transport energy consumption per person for all the 4 municipalities is 14,070 MJ.

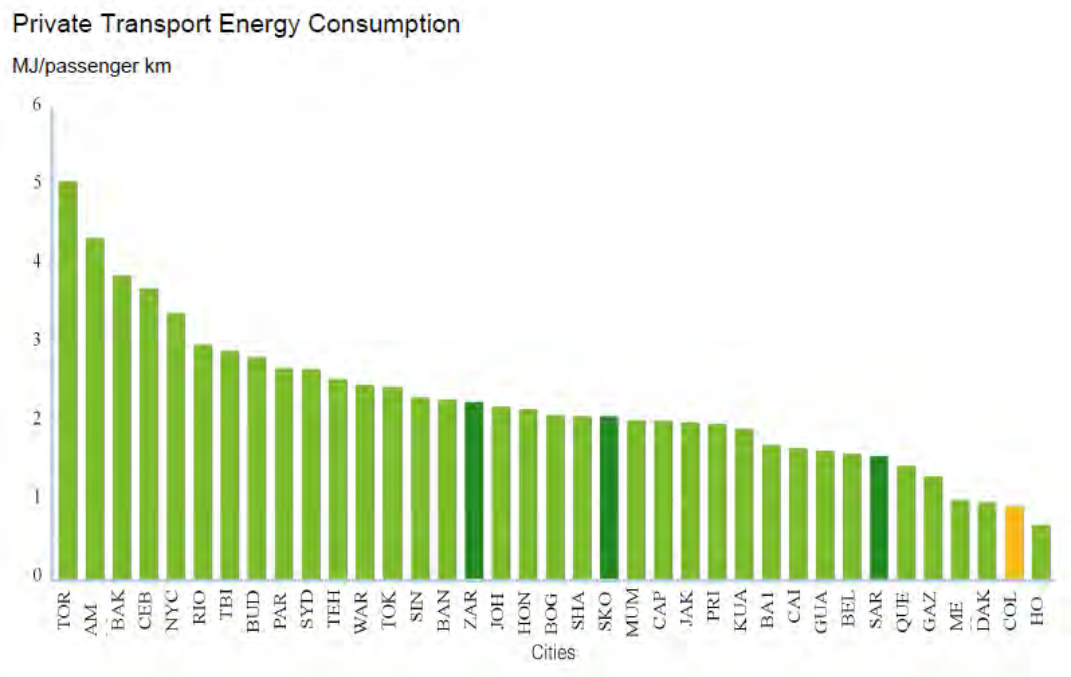
The graphs below are for the KPIs of Total Transport Energy Use in MJ per capita, Public Transport Energy Use in MJ per passenger km, Private Transport MJ / passenger km and Transportation non-motorized Mode Split (%).

*Figure 4: Total transportation energy use per capita*



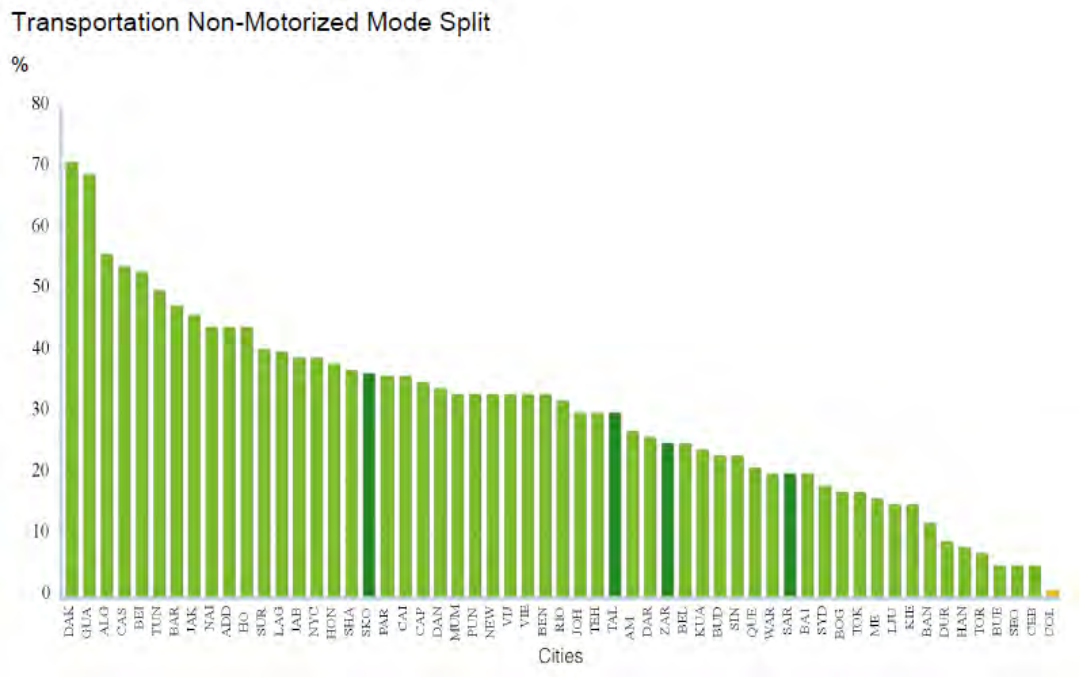

The yellow bar denotes the combined data of the 4 municipalities. The dark green columns denote peer cities based on population. Colombo and the surrounding municipalities have a relatively more energy intensive transportation sector. This can be because of an almost negligible non-motorized vehicular percentage and low public transport percentage.

*Figure 5: Private transport energy consumption*




The combined municipalities have a very low energy efficiency of transport. It is measured by the fuel (energy) required to travel a certain distance.

*Figure 6: Transportation non-motorized mode split*



The above graph shows the negligible non-motorized mode split of Colombo and its surrounding municipalities. This is the cause of the higher energy consumption per capita.

## 3.4. SOLID WASTE BENCHMARKING

The graphs below are for the KPIs of Waste per Capita (kg / capita), Capture Rate of Solid Waste, Percentage of Solid Waste Recycled and Percentage of Solid Waste That Goes to Landfill.

*Figure 7: Waste per capita*

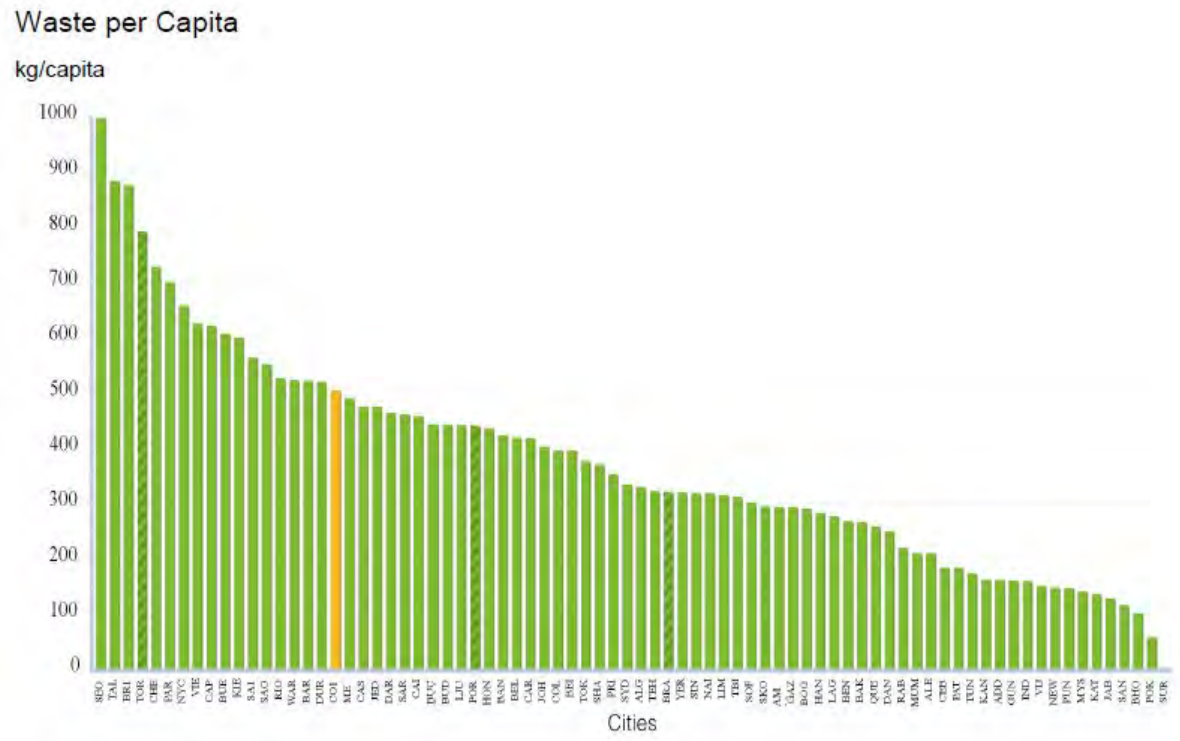
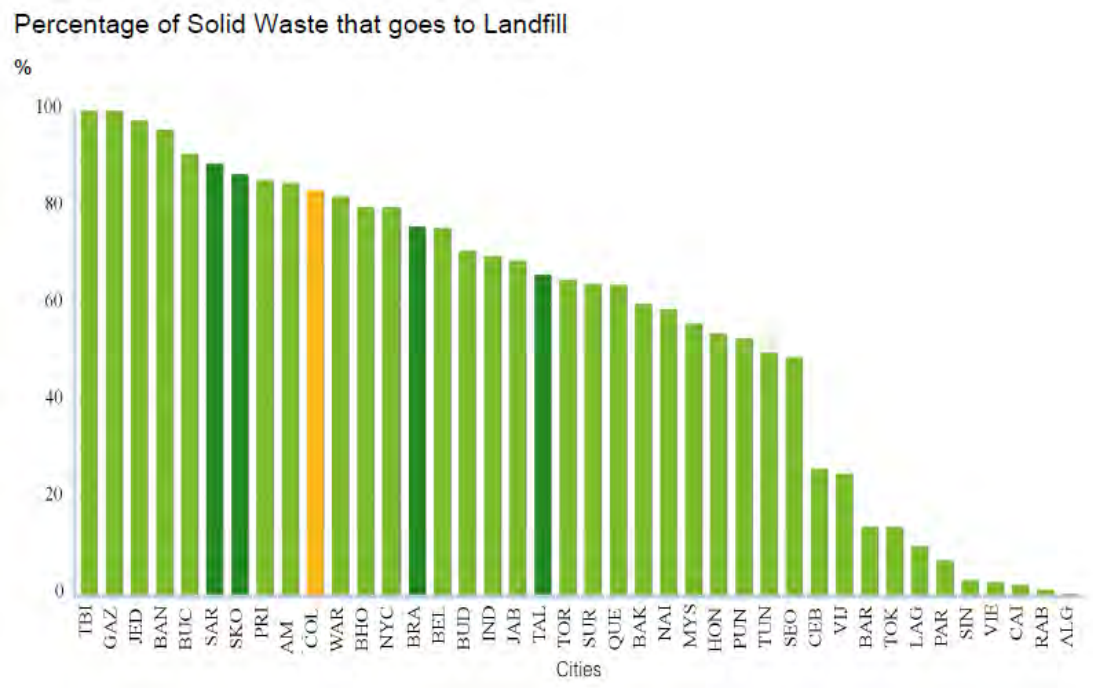


*Figure 8: Percentage of solid waste that goes to landfill*



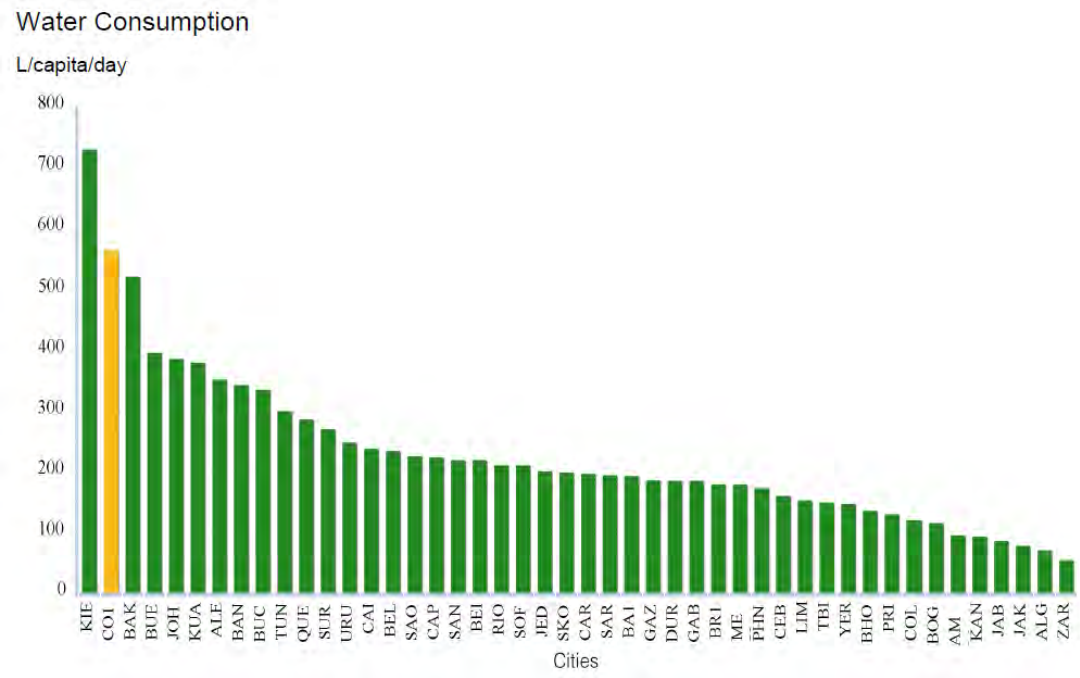

We can infer from the table below and the graphs above that, overall, the municipalities lag in energy efficiency in Waste sector. Out of 84% waste that gets captured, close to 81% goes to landfills and only 3% gets recycled. Kolonnawa is the only region with significant recycling capacity, whereas there is no recycling done in Colombo and Kotte.

*Table 13: Percentage solid waste recycled and percentage solid waste that goes to land fill*

| Region | Waste Generated Annually ('000 tons) | % of solid waste recycled | % of solid waste that goes to landfill |
|---|---|---|---|
| **Colombo** | 255.4 | 0.00% | 83.53% |
| **Dehiwala** | 73.0 | 2.25% | 71.75% |
| **Kolonnawa** | 12.0 | 90.91% | 0.00% |
| **Kotte** | 87.6 | 0.00% | 91.00% |
| **Combined** | 428 | 3.11% | 80.70% |

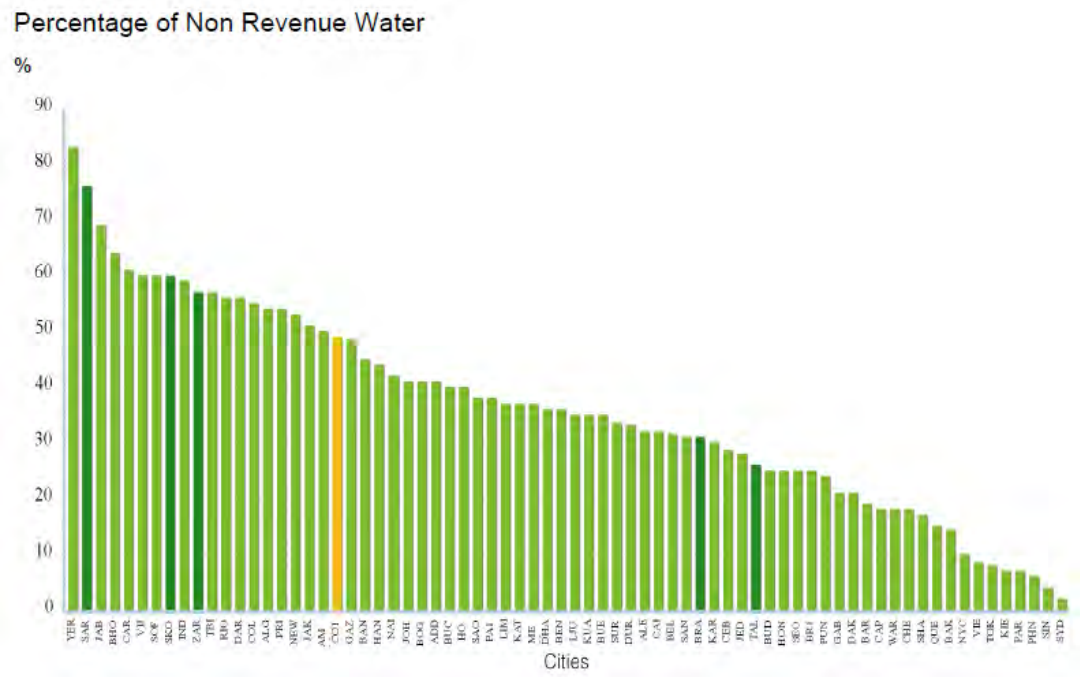
## 3.5. WATER & WASTEWATER BENCHMARKING

*Figure 9: Water consumption per capita per day*



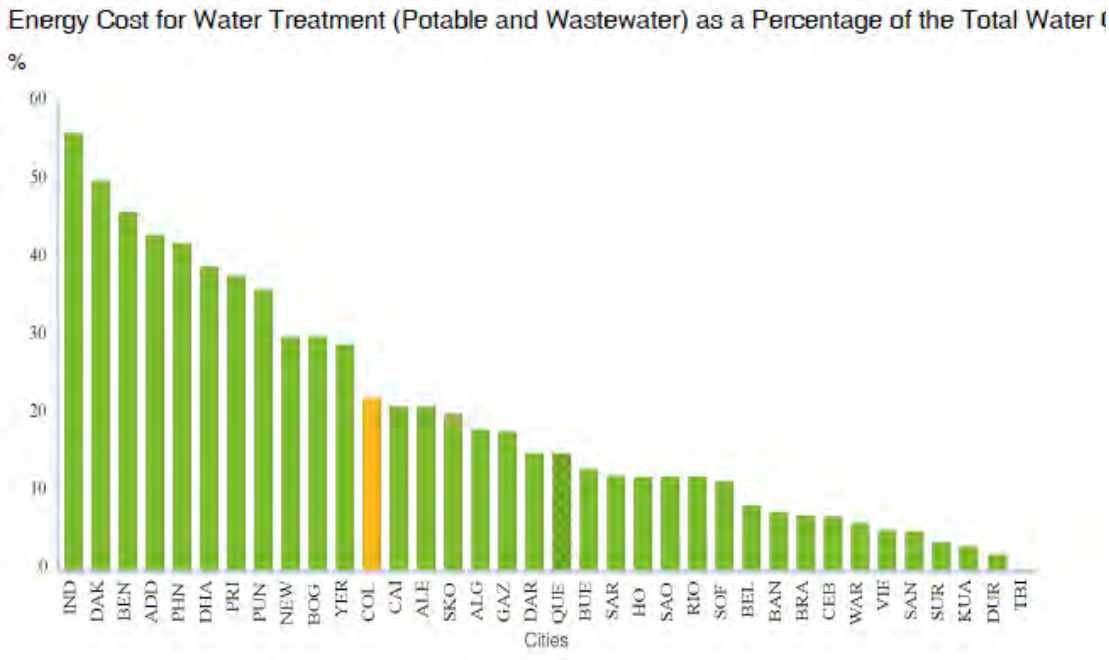

Upon comparison with peer cities based on HDI, Colombo and its surrounding municipalities have a higher per capita water consumption.

*Figure 10: Percentage of non-revenue water*




Colombo still has significant improvements to make to reduce the percentage of non-revenue water

*Figure 11: Energy cost for water treatment*



The above graph shows that, among its peer cities, Colombo is very efficient in both drinking and wastewater treatment which leads to its lower percentage of water treatment costs among total operating costs.

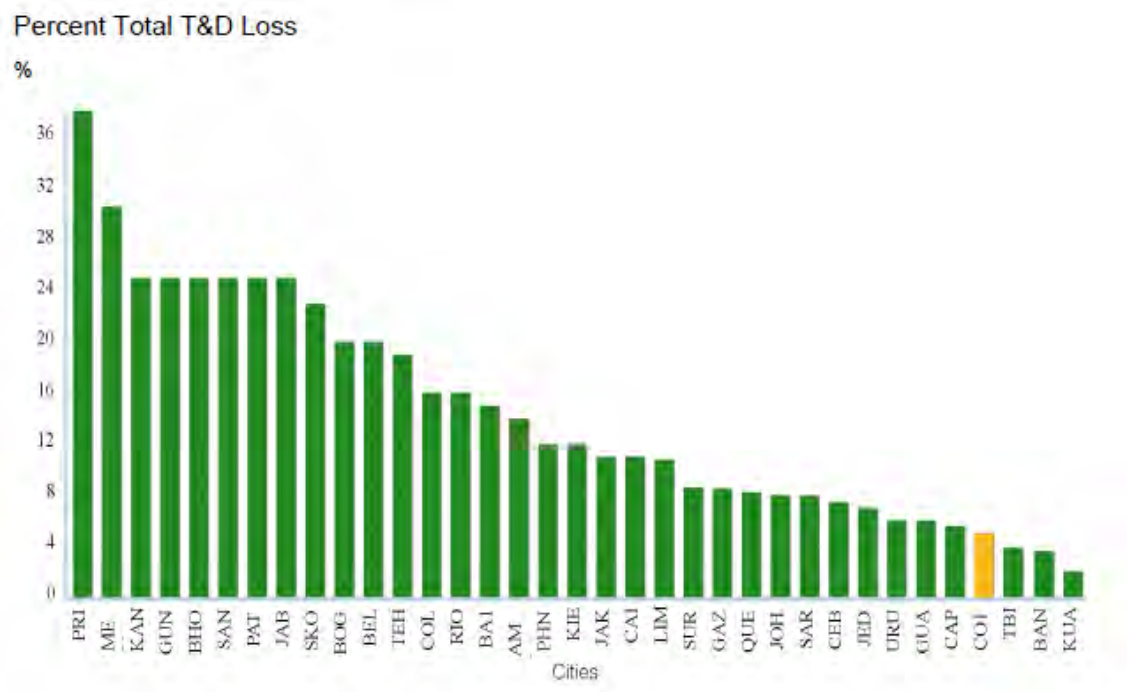
*Table 14: Energy density (potable water treatment and wastewater treatment) and electricity cost for water treatment*

| Municipality | Energy density of potable water production (kWhe/m3) | Energy density of wastewater treatment (kWhe/m3) | Electricity cost for water treatment as % of the total water utility expenditures |
|---|---|---|---|
| **Colombo** | 0.32 | 0.3 | 22% |
| **Dehiwala** | 0.32 | 0.3 | 22% |
| **Kolonnawa** | 0.32 | 0.3 | 22% |
| **Kotte** | 0.32 | 0.3 | 22% |
| **Combined** | 0.32 | 0.3 | 22% |

## 3.6. POWER & HEAT BENCHMARKING

Colombo being a tropical country has higher temperatures throughout the year, thus there is no need for a dedicated heat network for provision of heat to residents. The total T&D losses in all the municipalities is about 5% from the electricity network.

*Figure 12: T&D losses*




Colombo and the other municipalities have a very low T&D loss of just 5%, which is better than most of its peer companies by HDII

## 3.7. PUBLIC LIGHTING BENCHMARKING

*Figure 13: Electricity consumed per km of lit roads*

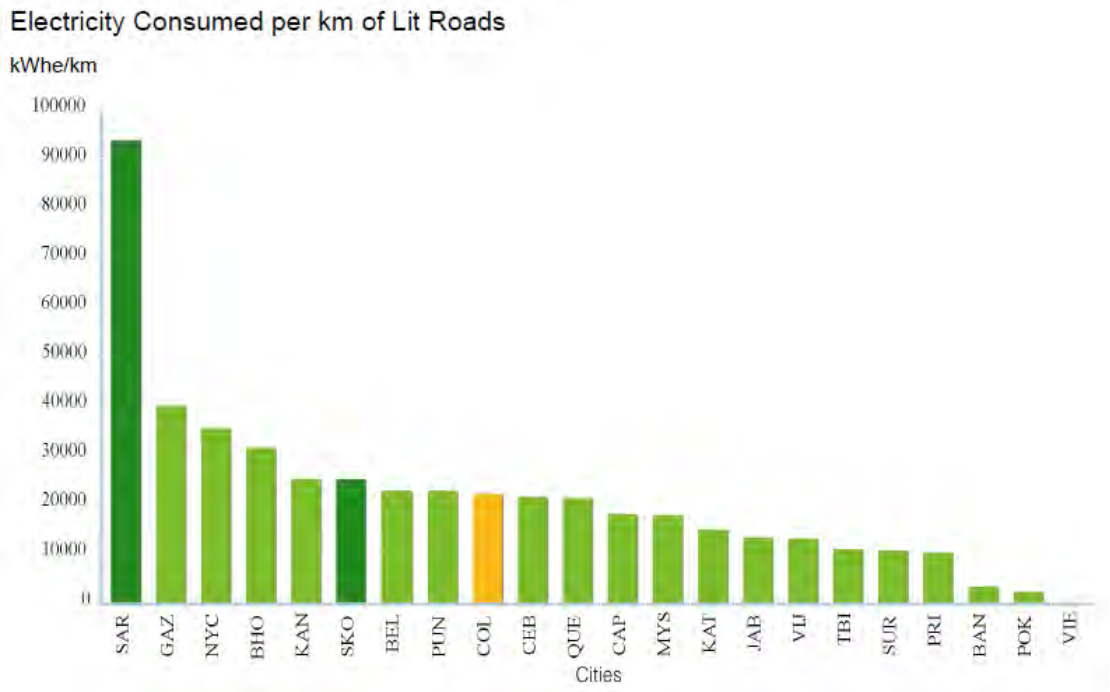
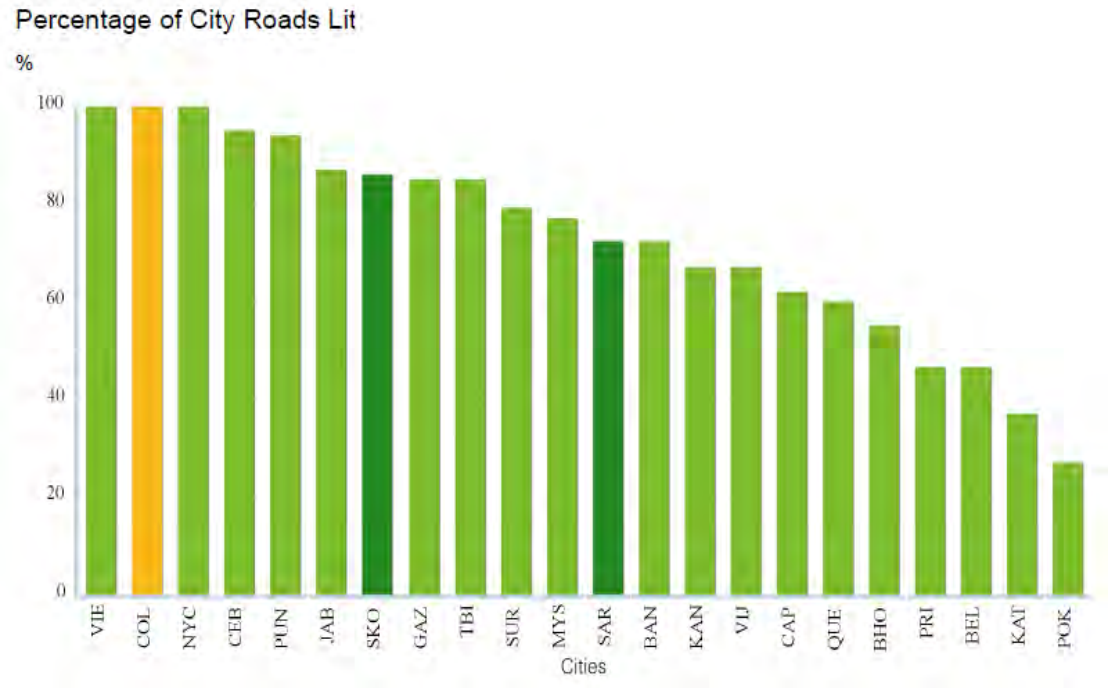



*Figure 14: Percentage of city roads lit*



100% of the roads in the all the 4 municipalities are lit

*Figure 15: Electricity consumed per light pole*

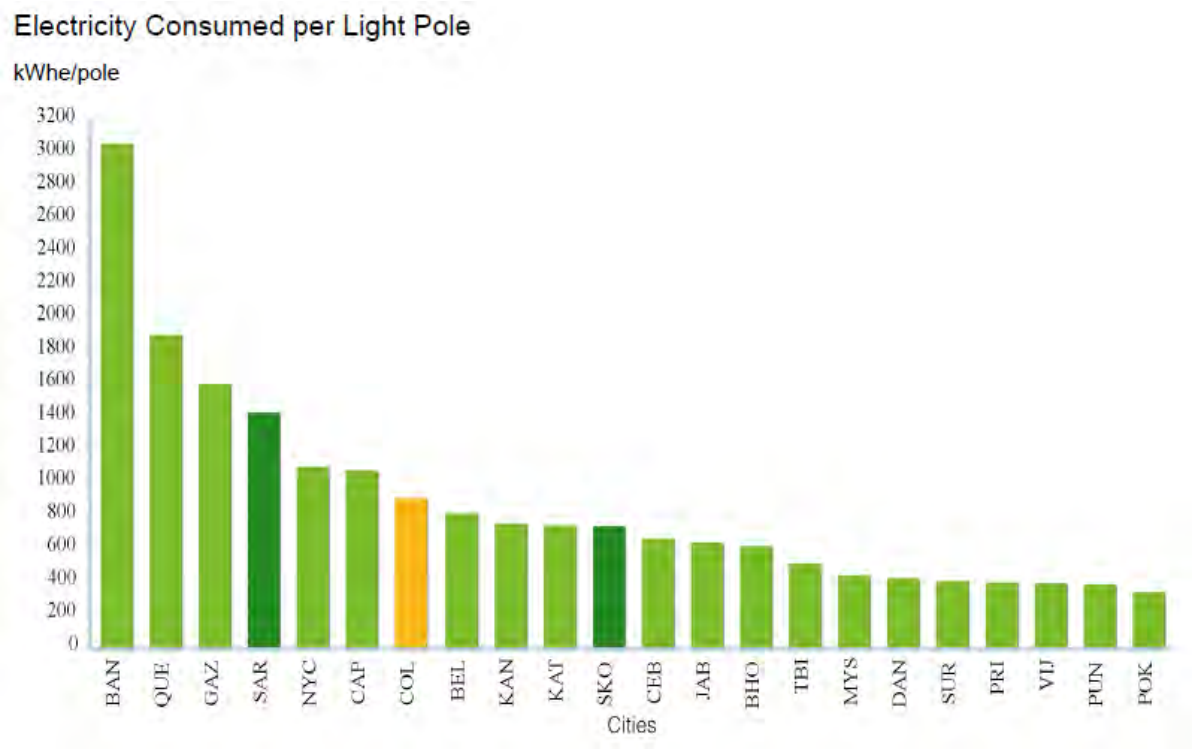
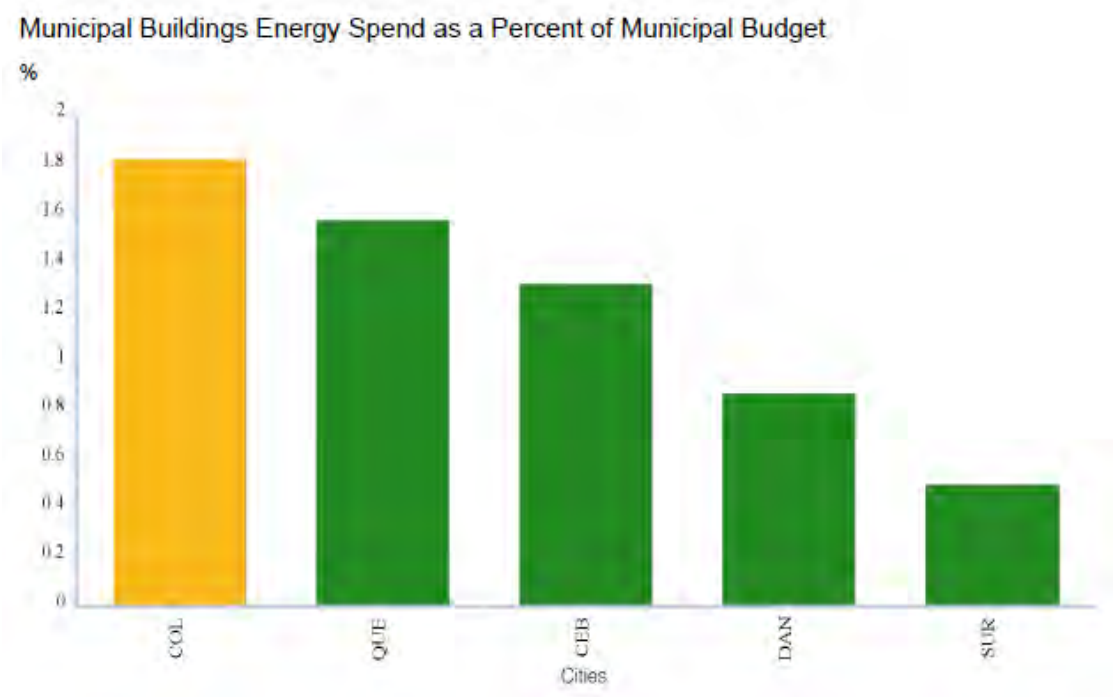



*Table 15: Electricity consumption – street lighting*

| Municipality | Electricity consumed per km of lit roads (kWhe/km) | Electricity consumed per light pole per year (kWhe) | Total energy expenditure for street lights per year (million $) |
|---|---|---|---|
| **Colombo** | 21,920 | 902.5 | 1.6 |
| **Dehiwala** | 1,920 | 416.1 | NA |
| **Kolonnawa** | 14,960 | 598.6 | 1 |
| **Kotte** | 12,200 | 416.1 | 6 |
| **Combined** | 14,190 | 543.8 | 8.6 |

## 3.8. MUNICIPAL BUILDINGS BENCHMARKING

*Figure 16: Municipal buildings energy spend*




The above chart presents a comparison between Colombo and its peer cities based on climate; climate being one of the most important drivers in a building's energy consumption. There is sufficient scope for Colombo to improve on this front.

*Table 16: Municipal buildings energy spend*

| Municipality | Municipal buildings electricity (kWhe/m2) | Municipal buildings energy spend a percent of municipal budget |
|---|---|---|
| **Colombo** | 150 | ~0% |
| **Dehiwala** | 150 | ~0% |
| **Kolonnawa** | 150 | ~0% |
| **Kotte** | 150 | 7.3%[4] |
| **Combined** | 150[5] | 1.8% |

[4] Kotte is the parliament site of Sri Lanka. This could be the reason for the significantly high value of Kotte

[5] *The annual kWh/m$^2$ value of 150 is assumed because of anomalous value received*

# 4. IDENTIFYING PRIORITY SECTORS

The purpose of TRACE is to rapidly assess energy use in a city in order to identify and prioritise sectors, and indicate specific energy efficiency interventions. It is necessary, therefore, to distinguish at an early stage which sectors are most likely to offer the most potential with respect to energy efficiency savings that are both achievable and financially viable.

In the early part of the mission, the consultant had the opportunity to review each sector covered by TRACE through interviews, site visits and review of information provided. This process is designed to provide the consultant with a robust overview of energy use and potential efficiencies in each sector. This information is used alongside the results of the benchmarking data to assess which of the sectors should be focused upon during the remaining part of the mission, ultimately leading to selection of energy efficiency recommendations for the city.

At this point, therefore, certain sectors are set aside and not pursued further. This does not necessarily mean that no energy efficiencies are to be developed in these sectors. It simply indicates that, when compared to other sectors, they are unlikely to produce as compelling energy efficiency savings potential or are unlikely to be achievable by the CA.

The process for identifying priority sectors considers three main issues:

- the proportionate spend on energy in each sector either at a municipal level or for the entire city (public and private);
- the relative energy intensity of the sector, based upon the results of the benchmarking exercise and the consultant's professional opinion having reviewed each sector; and
- the degree of control or influence that the city government has over each sector or components of a particular sector, budgetary control being considered the most important factor.

The tables below serve as a framework for the identification of priority sectors

*Table 17: City Government Energy Spend*

| Parameter | Value |
|---|---|
| **Annual Budget** | NA |
| **Energy Spend** | $ 158,000 |
| **Energy Spend as Percentage of Annual Budget** | NA |

| Sector | Energy Spend[6] | Energy Savings Potential | City Energy Use (%)[7] | Mayor's Influence | Comments |
|---|---|---|---|---|---|
| **Public Transportation** | $7,156.46 mn | 30% | | Low | |
| **Private Vehicles** | $1,789.11 mn | 25% | | Low | |
| **Waste** | $113.51 mn | 40% | | Very high | Lack of national approach in solid waste management has brought about tremendous negative environmental consequences. In order to remedy this situation a program named "Pilisaru Waste Management Programme" has been initiated by the Ministry of Environment and Renewable Energy to establish Integrated Solid Waste Management (ISWM) program in the country. Through this programme the Ministry has established a platform to bring all relevant stakeholders together to implement a cohesive national programme to address waste management issues in the country |
| **Potable Water** | $0.56 mn | 40% | | Low | |
| **Wastewater** | $0.09 mn | 5% | | Low | |
| **Electricity** | $25.78 mn | 40% | | Very low | |
| **Heating** | NA | NA | | NA | |
| **Street Lighting** | $2.83 mn | 40% | | Moderate | |
| **Municipal Buildings** | $37.39 mn | 25% | | Very HIgh | |

[6] *Colombo spending data extrapolated for the other municipalities based on population as their spending data was not available*

[7] *Data not available*

# 4.1. REVIEW OF SECTORS

## 4.1.1 Public Transportation

The public transport fleet consists of 3-wheelers (75%) and 4-wheeled taxis. Most of the taxis are less than 10 years old. All the vehicles come under the purview of emission standards, which is a national government requirement. 3-wheelers used to previously come with 2-stroke engines. All of them have now been banned and a very few 2-stroke vehicles remain on the street. High capacity transit includes a railway network. Dehiwala, Kolonnawa and Kotte have about 14, 8 and 4 kms of railway lines. The fuel efficiency of public transport is around 0.33 MJ/passenger-km. The public transport sector is not under the City Authority. It is under the control of Ministry of Transport at the National Government level. Thus the city council has a very low control and influence over this sector. The city-wide energy spend on this sector is $7,156.46 mn; one of the highest across all the sectors.

The level of competency for implementation of any energy efficiency measure in this sector is low across areas of finance, human resources (CA has few technically skilled staff, but they can be trained as per requirement), data and information (very little reliable data is available and CA does not have any transportation modelling and planning capabilities), policy and regulation (CA has limited capacity to regulate traffic, draft policies and enforce them) and infrastructure (none of the modes of public transport are owned by the CA).

## 4.1.2 Private Vehicles

Private vehicles are governed by Ministry of Transport, which decides the norms for emissions and vehicle clearances. "Commissioner of Motor Traffic" is responsible to governing permits to new types of vehicles. The private vehicle fleet is majorly less than 10 years old and there aren’t any major traffic problems except traffic jams in busy hours in the morning, evening and school closing time in the afternoon. The private transport energy efficiency is about 1.16 MJ/passenger-km.

The level of competency for implementation of any energy efficiency measure in this sector is low across areas of finance, human resources (CA has few technically skilled staff, but they can be trained as per requirement), data and information (very little reliable data is available and CA does not have any transportation modelling and planning capabilities), policy and regulation (CA has limited capacity to regulate traffic, draft policies and enforce them) and infrastructure (none of the modes of public transport are owned by the CA).

## 4.1.3 Waste

The city of Colombo and the surrounding 3 municipalities generate about 428,000 tonnes of waste annually which amounts to about 471 kgs per capita. Waste is captured at an efficiency of 84%. Most of the waste generated, about 80.7% goes to the landfill and only 3% is recycled. The waste sector is under control of the CA. It operates the entire

waste collection and processing systems. There have been a few unsuccessful attempts at converting waste-to-energy and waste composting programs but none of them are in place as of now. There haven't been any energy efficiency improvement programs in this sector. The CA spends about $113.5 mn on this sector annually.

The CA is moderately competent to implement EE recommendations in the waste sector. It has experience of PPP and commercial funding and has the freedom to regulate elements in the waste system. However, enforcement needs to be strengthened. The main low competency areas are lack of reliable data availability and lack of technically qualified staff.

### 4.1.4 Potable Water

The responsibility for potable water rests with the National Water Supply and Drainage Board, a central authority. The distribution is also done by the central authority. Energy density of potable water production is about 0.32 kWh/m3 of potable water. This energy cost accounts for 22% of the total water operating costs. As the CA is not responsible at all for the water distribution, there is no scope for EE improvements in the sector which can be done under the purview of the CA.

### 4.1.5 Wastewater

Wastewater comes under the purview of the National Water Supply and Drainage Board, a central authority. Sewage disposal is done by the CA. Energy density of wastewater treatment is about 0.3 kWh/m3 of waste water. As the CA is not responsible for the water network, there is no scope for EE improvements in the sector which can be done under the purview of the CA.

### 4.1.6 Electricity

Electricity supply comes under the purview of Ceylon Electricity Board and the CA has no control over it.

### 4.1.7 Heat

NA

### 4.1.8 Public Lighting

All the 4 municipalities have a total of 25,198 light poles covering 100% of their 966 km roads. The total electricity consumed by street lights is 13.7 GWh annually. The electricity consumed per light pole is about 543.77 kWh.

The maintenance of the lighting infrastructure falls in the purview of the CA, but it does not bear the electricity costs of the lights. The CA has high level of competency in implementing EE programs in the sector driven by availability of reliable data and information, freedom in regulating the public lighting system and ownership of all street lighting infrastructures. The areas of low competency are a lack of strong enforcement ability, lack of experience in commercial funding in the sector and limited availability of technical staff.

### 4.1.9 Municipal Buildings

The electricity consumption efficiency, per m2 of floor space, is 3.72 kWh. There is tremendous opportunity for improvement as most of the buildings are more than 10 years old and have old and inefficient electricity fixtures. Most of the public buildings, barring those owned by other government departments, come under the purview of the CA. The Colombo Municipal Corporation (CMC) even has a dedicated energy manager.

The CA spends $37 mn in this sector. It also has a high level of competency driven by availability of reliable data and ownership of the buildings. However it lacks competency in the finance, human resources and policy (CA does not have the power to draft and enforce building codes) domains.

## 4.2. PRIORITIZATION CONCLUSIONS

The prioritization module, based on scores allotted to Relative Energy Intensity, CA control and Sector Energy Spend, computes high priority sectors with respect to potential of implementation of EE programs. Based on the influence The World Bank can have over various sectors through the central/city authorities, we define 2 scenarios:

- Scenario 1 is the current scenario where the city authority has control over some sectors and no control over many others
- Scenario 2 is an ideal scenario where we have full control over all sectors

The following table summarizes the control the City Authority has over each sector in both the scenarios:

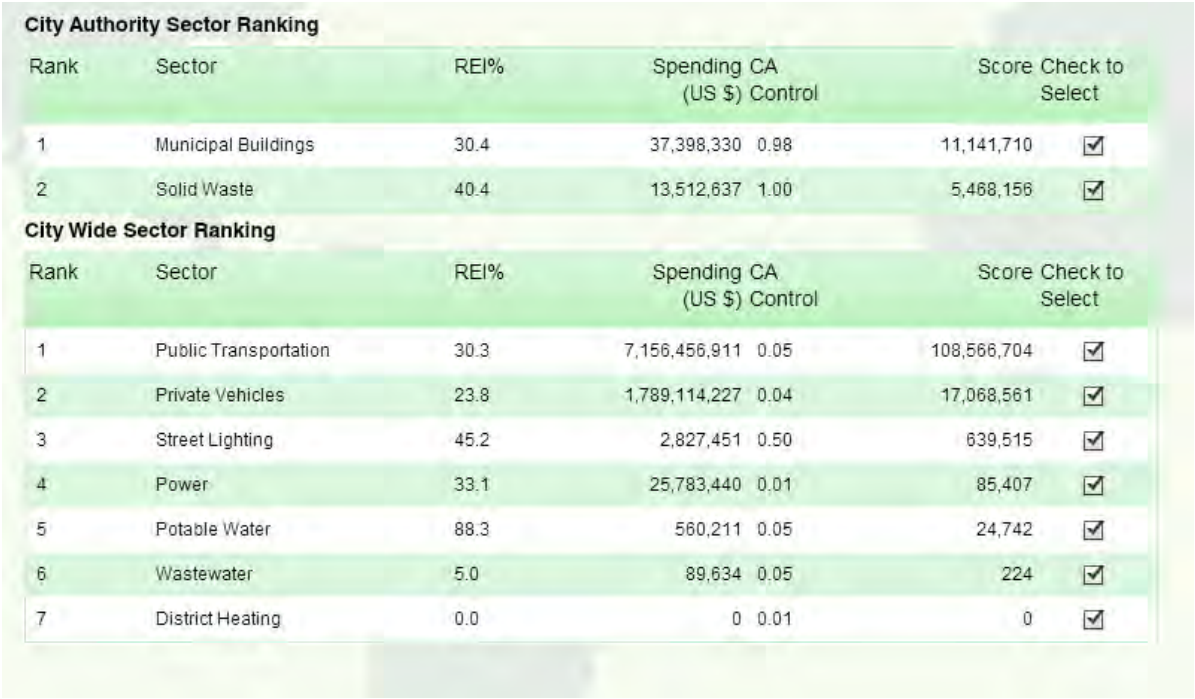
| Sectors | CA control –Scenario 1 (Present Limited Control scenario) | CA control – Scenario 2 (Full Control Scenario) |
|---|---|---|
| Solid waste | 100% | 100% |
| Municipal Buildings | 98% | 100% |
| Public Transport | 5% | 100% |
| Private Vehicles | 4% | 100% |
| Street Lighting | 50% | 100% |
| Power | 1% | 100% |
| Potable Water | 5% | 100% |
| Wastewater | 5% | 100% |

In scenario 1, the following sectors have been prioritized:

1. **Public and Private Transportation** – very high level of spending inspite of low CA control
2. **Municipal Buildings** – very high level of CA control and high spending
3. **Solid waste** - very high potential of improvement and high level of CA control
4. **Street Lighting** – very high level of CA control and high potential of improvement

The following screenshot of the TRACE module shows the results of the Sector Prioritization calculations

*Figure 17: Screenshot – results of Sector Prioritization calculations – Scenario 1*



**City Authority Sector Ranking**

| Rank | Sector | REI% | Spending (US $) | CA Control | Score | Check to Select |
|---|---|---|---|---|---|---|
| 1 | Municipal Buildings | 30.4 | 37,398,330 | 0.98 | 11,141,710 | ☑ |
| 2 | Solid Waste | 40.4 | 13,512,637 | 1.00 | 5,468,156 | ☑ |

**City Wide Sector Ranking**

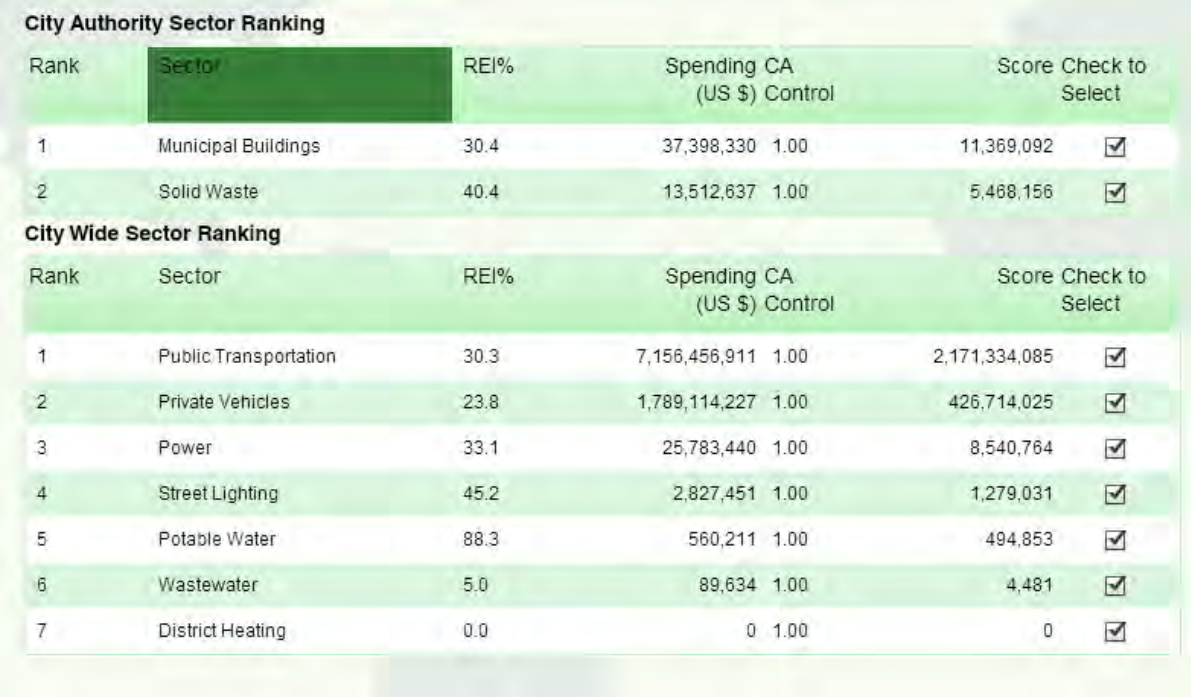
| Rank | Sector | REI% | Spending (US $) | CA Control | Score | Check to Select |
|---|---|---|---|---|---|---|
| 1 | Public Transportation | 30.3 | 7,156,456,911 | 0.05 | 108,566,704 | ☑ |
| 2 | Private Vehicles | 23.8 | 1,789,114,227 | 0.04 | 17,068,561 | ☑ |
| 3 | Street Lighting | 45.2 | 2,827,451 | 0.50 | 639,515 | ☑ |
| 4 | Power | 33.1 | 25,783,440 | 0.01 | 85,407 | ☑ |
| 5 | Potable Water | 88.3 | 560,211 | 0.05 | 24,742 | ☑ |
| 6 | Wastewater | 5.0 | 89,634 | 0.05 | 224 | ☑ |
| 7 | District Heating | 0.0 | 0 | 0.01 | 0 | ☑ |

In scenario 2, the following sectors have been prioritized:

1. Public and Private Transportation – very high level of spending
2. **Municipal Buildings** – very high spending
3. **Power –** Significant spending and moderate potential of improvement
4. **Solid waste** - very high potential of improvement\

The following screenshot of the TRACE module shows the results of the Sector Prioritization calculations

*Figure 18: Screenshot – results of Sector Prioritization calculations – Scenario 2*



**City Authority Sector Ranking**

| Rank | Sector | REI% | Spending (US $) | CA Control | Score | Check to Select |
|---|---|---|---|---|---|---|
| 1 | Municipal Buildings | 30.4 | 37,398,330 | 1.00 | 11,369,092 | ☑ |
| 2 | Solid Waste | 40.4 | 13,512,637 | 1.00 | 5,468,156 | ☑ |

**City Wide Sector Ranking**

| Rank | Sector | REI% | Spending (US $) | CA Control | Score | Check to Select |
|---|---|---|---|---|---|---|
| 1 | Public Transportation | 30.3 | 7,156,456,911 | 1.00 | 2,171,334,085 | ☑ |
| 2 | Private Vehicles | 23.8 | 1,789,114,227 | 1.00 | 426,714,025 | ☑ |
| 3 | Power | 33.1 | 25,783,440 | 1.00 | 8,540,764 | ☑ |
| 4 | Street Lighting | 45.2 | 2,827,451 | 1.00 | 1,279,031 | ☑ |
| 5 | Potable Water | 88.3 | 560,211 | 1.00 | 494,853 | ☑ |
| 6 | Wastewater | 5.0 | 89,634 | 1.00 | 4,481 | ☑ |
| 7 | District Heating | 0.0 | 0 | 1.00 | 0 | ☑ |

The following table presents a comparison of the prioritized sectors in the 2 scenarios.

*Table 18: Comparison of prioritized sectors*

| Prioritization | Scenario 1 (Present Limited control Scenario) | Scenario 2 (Full control over all sectors) |
|---|---|---|
| 1st Priority | Public and Private Transport | Public and Private Transport |
| 2nd Priority | Municipal Buildings | Municipal Buildings |
| 3rd Priority | Solid Waste | Power |
| 4th Priority | Street Lighting | Solid Waste |

If we assume the present limited control scenario, the sectors of Public and Private transport, Municipal Buildings, Solid Waste and Street Lighting should be the top priorities over the other sectors for designing and implementing energy efficiency policies/recommendations. These conclusions have been based on the benchmarking of energy efficiency with peer cities, the CA spending and the authority CA has over the sector. If The World Bank can influence the national agencies to support the energy efficiency initiatives, in addition to Public and Private Transport, Municipal Buildings and Solid Waste, Power sector should also be prioritized. This is because the Power sector has a very high CA spending. The 2nd scenario bases its conclusions on just energy efficiency benchmarking with peer cities and CA spending.

# 5. ENERGY EFFICIENCY RECOMMENDATIONS

TRACE contains a playbook of energy efficiency recommendations applicable across the six individual sectors and subsectors. Following on from the sector prioritization process, each individual recommendation was reviewed to establish its applicability in the city context. This review or filtering process is necessary so that time is spent effectively, focusing on those recommendations that are both viable and practicable.

Recommendations suitable to the 4 municipalities, segregated by the sector, are mentioned below:

**Public and Private Transport**

1. Development of non-motorized modes through pedestrianization, dedicated cycling and walking routes and cycle renting schemes
2. Development of public transport through quality improvement in the bus system (easily available information, well planned operations and routes) and subsidies and incentives to promote public transport
3. Controlling growth rate of private cars through parking restraint measures (like high parking fees), park and ride facilities (making it easier for customers to avail a public transport from the outskirts of the city where they can park their cars) and congestion pricing.

**Municipal Buildings**

1. Buildings benchmarking program -
2. Audit programs of municipal buildings (schools, offices, residential and hospitals)
3. Setting up of energy efficiency task force to monitor and implement energy efficiency in municipal buildings
4. Green building guidelines for new buildings (through green building codes and a robust incentive mechanism) and strict energy efficiency codes for existing buildings

**Solid Waste**

1. Waste composting program at multiple levels (household, community and city-level) through robust incentive and tax systems
2. Waste to energy program
3. Increasing the recycling capacity

**Street Lighting**

1. Street lighting audit and retrofit program

2. Procurement guide for new street lights

The potential implementation activities and attributes of each of the recommendations are presented in detail in the following section. The rationale for selecting specific energy efficiency recommendations is summarised below. A full list of all TRACE recommendations including the reasoning behind their inclusion or exclusion from the final Recommendations list is included in the Appendix

The following table lists the generic recommendations across all the sectors that can be implemented in the city. The recommendations are shown in separate tables based on their speed of implementation (<1 year, 1-2 years and >2 years). In each of the table, the projects have been classified based on their first cost and the energy savings potential.

*Table 19: Implementation Speed of less than 1 year*

| | First Cost | | | |
|---|---|---|---|---|
| Energy Savings Potential | Recommendations | > $1,000,000 | $1,000,000 - $100,000 | <$100,000 |
| | >200,000 kWh | | Solar Hot Water Program | 1. Fuel-efficient waste vehicle operations<br>2. Procurement Guide for new street light installations<br>3. Lighting timing program<br>4. Municipal vehicle fleet efficiency program |
| | 100,000 – 200,000 kWh | | 1. Energy efficiency municipal task force<br>2. Energy efficiency strategy and action plan<br>3. Capital investment planning<br>4. Purchasing and service contracts<br>5. Energy performance contracting<br>6. Awareness-raising campaign | 1. Municipal building energy efficiency task force<br>2. Citywide integrated public lighting assessment program<br>3. Water efficient fixtures and fittings |
| | <100,000 kWh | | | 1. Computer PowerSave project<br>2. Educational Measures |

*Table 20: Implementation Speed of 1-2 years*

| | First Cost | | | |
|---|---|---|---|---|
| Energy Savings Potential | Recommendations | > $1,000,000 | $1,000,000 - $100,000 | <$100,000 |
| | >200,000 kWh | | 1. 2-stroke engine replacement of retrofit<br>2. Public spaces lighting audit and retrofit<br>3. Transformer upgrade program<br>4. Power factor correction program<br>5. Improve performance of system networks<br>6. Improve efficiency of pumps and motors<br>7. Auditing and retrofit of treatment facilities | |
| | 100,000 – 200,000 kWh | 1. Municipal offices audit and retrofit program<br>2. Municipal residential audit and retrofit program<br>3. Municipal hospitals audit and retrofit program<br>4. Sludge beneficial reuse program | 1. EE sorting and transfer facilities<br>2. Traffic restraint measures<br>3. Street lights audit and retrofit program<br>4. Non-technical loss reduction program<br>5. Active leak detection and pressure management program<br>6. Travel planning | 1. Waste composting program<br>2. Buildings benchmarking program |
| | <100,000 kWh | | 1. Municipal schools audit and retrofit program<br>2. Traffic signals audit and retrofit program<br>3. Improve efficiency of pumps and motors<br>4. Water meter program | 1. Waste vehicle fleet audit and retrofit program<br>2. Street signage audit and retrofit program |

*Table 21: Implementation Speed of >2 years*

| | First Cost | | | |
|---|---|---|---|---|
| **Energy Savings Potential** | **Recommendations** | **> $1,000,000** | **$1,000,000 - $100,000** | **<$100,000** |
| | **>200,000 kWh** | 1. Landfill gas capture program<br>2. District cogeneration thermal network | 1. Taxi vehicle replacement program | 1. Mandatory building energy efficiency codes for new buildings<br>2. Green building guidelines for new buildings |
| | **100,000 – 200,000 kWh** | 1. Intermediate transfer stations<br>2. Waste to energy programs<br>3. Non-motorized transport modes<br>4. Public transport development<br>5. Congestion pricing<br>6. Formation of ring main | 1. Enforcement of vehicle emission standards<br>2. Traffic flow optimization<br>3. Prioritizing energy efficient water resources | 1. Water infrastructure planning<br>2. Parking restraint measures |
| | **<100,000 kWh** | Power generation plant maintenance and upgrade program | | |

# 6. IMPLEMENTING ENERGY EFFICIENCY RECOMMENDATIONS

*Table 22: Implementing energy efficiency recommendations*

| Recommendation | Activity | Key Stakeholders | Implementation Timeframe | Performance Measurement |
|---|---|---|---|---|
| **Transport** | | | | |
| Development of non-motorized modes | Pedestrianization, dedicated cycling and walking routes and cycle renting schemes | Mayor, Ministry of transport | >2 years | |
| Development of public transport | Quality improvement in the bus system (easily available information, well planned operations and routes), subsidies and incentives to promote public transport | Mayor, Ministry of transport | >2 years | |
| Controlling growth rate of private cars | Parking restraint measures (like high parking fees), park and ride facilities (making it easier for customers to avail a public transport from the outskirts of the city where they can park their cars) and congestion pricing | Mayor, Ministry of transport | >2 years | |
| Solid Waste | | | | |
| Waste composting program at multiple levels (household, community and city-level) | Robust incentive and tax systems | Mayor, Colombo Municipal Council | 1-2 years | |
| Waste to energy program | Feasibility study, procurement, operation and regulations/taxes | Mayor, Colombo Municipal Council | >2 years | |
| Increasing the recycling capacity | Setting up of recycling plants and transport network to uit | Mayor, Colombo Municipal Council | 1-2 years | |
| Public Lighting | | | | |
| Street lighting audit and retrofit program | | Mayor, road authority of Srl Lanka and Colombo government | 1-2 years | |
| Procurement guide for new street lights | Putting clauses to ensure energy efficient procurement | Mayor, Road authority of Srl Lanka, Colombo government | <1 year | |

| Municipal Buildings | | | | |
|---|---|---|---|---|
| Buildings benchmarking program | | Road authority of Sri Lanka | 1-2 years | |
| Audit programs of municipal buildings (schools, offices, residential and hospitals) | | Road authority of Sri Lanka | 1-2 years | |
| Setting up of energy efficiency task force to monitor and implement energy efficiency in municipal buildings | | Road authority of Sri Lanka | <1 year | |
| Green building guidelines for new buildings (through green building codes and a robust incentive mechanism) and strict energy efficiency codes for existing buildings | | Road authority of Sri Lanka | >2 years | |

# 8. APPENDIX: LIST OF CASE STUDIES

## 8.1. WASTE TO ENERGY PROGRAMS

### Recycling of waste and generation of electricity, Yokohama, Japan

ECO2 Cities: Waste Use and Recycling in Yokohama, available online from http://www.esmap.org/esmap/node/1229

Yokohama is the largest city in Japan. It reduced waste by 38.7 percent between fiscal years 2001 and 2007, despite the growth of 165,875 people in the city's population. This reduction in waste is attributable to the city's success in raising public awareness about environmental issues and the active participation of citizens and businesses in Yokohama's 3Rs program (reduce, reuse, and recycle).

Yokohama has been able to shut down two incinerators because of the significant reduction in waste. The incinerator closures have saved US$6 million4 in annual operating costs and US$1.1 billion that would have been needed to renovate the incinerators (City of Yokohama 2006). Around 5 percent of the fiscal year 2008 budget of the Resources and Wastes Recycling Bureau, the city's waste management entity, was derived from the sale of recycled material (US$23.5 million). In addition, the city raises US$24.6 million annually by selling the electricity generated during the incineration process.

### Abidjan Municipal Solid Waste-To-Energy Project, Abidjan, Ivory Coast

UNFCC (2010) "Abidjan Municipal Solid Waste-To-Energy Project"http://cdm.unfccc.int/Projects/Validation/DB/WMCZWV34G1WDMVMQGPB2AXI3CZXQXF/view.html

The municipal solid waste treatment plant in Bingerville was developed under a Clean Development Mechanism (CDM) project to manage 200,000 tons of municipal solid waste/year. After sorting, the project treats the waste by anaerobic fermentation. The resultant biogas is captured and used to produce renewable electricity for on-site consumption as well as for sale to a state-owned electricity company under Power Purchase Agreement (at US$ 25.66/MWh). Residual waste from the fermentation process is also transformed into compost and sold to local farmers. The project was set to avoid 583,965 tCO2 equivalent over the first 7 years crediting period, create more than 180 jobs, and generate 3MW of electricity per year at full operation in October 2009.

A key success factor to the project is the adoption of technology from an Italian-based company (PROMECO Spa) specialised in engineering, planning and turnkey building of urban and industrial waste treatment plants. The Ivorian project developer (SITRADE) receives trainees from the technology provider, benefiting the project from know-how transfer. Due to the reliance on imported components and equipment, the project requires special assistance in the first months of operations to alleviate the risk of technological failure. Lack of public funding and difficulties in attracting investors in a high-risk business climate are a barrier to success, resulting in project developers taking out loans from local banks.

### Singapore Waste Management Project, Singapore

"9.5 MW Food Waste Based Grid Connected Power Project implemented by IUT Singapore Pte Ltd., Singapore"http://cdm.unfccc.int/Projects/Validation/DB/OFKVAJIKYTB05GUR4JXMRLC0DREF3G/view.html

IUT Global Pte Ltd., a Singapore-based waste management company has implemented a 9.5 MW grid connected power project produced by bio-methanisation of food waste generated in Singapore, using the ADOS (Anaerobic Digestion of

Organic Slurry) technology. An additional benefit of this project is that it increases energy efficiency of solid waste incinerators, especially as food wastes have high moisture content (around 80%) and consume more energy to incinerate. The electricity generated is sold in the wholesale electricity market and residual material is processed for bio-compost for commercial use as an organic soil conditioner. At full capacity, the waste-to-energy plant will process more than half of the food waste being delivered to local incineration plants for disposal in 2008. Phase 1 of the project was expected to produce 10,599 MWh net incremental power per year and reduce emissions by 5,088 tCO2 equivalent per year.

As Asia's first major organic bio-methanisation power plant based on food wastes, the project presents high operating and performance risks, requires training man-power with new skill sets, and incurs high capital costs for relatively small installed power capacity. An additional disadvantage in Singapore is that, because of the absence of a long-term Power Purchase Agreement, the tariff of power is determined by the open wholesale market, which means that the revenue brought in by the sale of electricity is inconsistent. The advantage of this project is that the design, implementation and operational experience of the state-of-the-art technology involved in the project can lead to its replication across Asia and the Middle East with Singapore as a base for export of such skills and technological advances.

## Gothenburg Waste Management Project, Gothenburg, Sweden

Clinton Climate Initiative, Climate Leadership Group, C40 Citieshttp://www.c40cities.org/bestpractices/waste/gothenburg_system.jsp

In Sweden, there is a tax on all landfill and a further tax on incineration, with tax benefits if electricity is produced. This encourages landfill operators to generate power from waste through gas capture or incineration.

Gothenburg uses an integrated waste system to collect, sort and burn the city's rubbish. Waste incineration is used to provide energy for heating and electricity through a highly efficient system at 3.3MWh/ton of waste. The project involves the coordination of city authority planners and waste management service companies in the sorting of wastes. Waste management services are contracted out to private companies such as Renova (Sweden's largest waste management company) and IL Recycling who bid for tenders to collect, treat and dispose of industrial and business waste, whilst the local authority is responsible for the collection and treatment of household waste.

Renova incinerates the waste in the Savenas plant, which provides 27% of the 3,970 GWh required for the district heating system. As a result of the construction of new boilers, flue gas condensers, other technologies and increased efficiency in sorting and separation of waste, the energy produced by the plant has increased by sixfold between 1974 and 2006 whilst incinerated waste volumes have only doubled. The waste-to-energy program reduces landfill reliance (of all the waste that is collected, only 8% remains for landfill) and the production of electricity reduces Renova's incineration taxes.

## Durnrohr EfW Facility, Austria

"Delivering Key Wate Management Infrastructure: Lessons Learned from Europe"http://www.wasteawareness.org/mediastore/FILES/12134.pdf

Durnrohr Energy From Waste facility is situated in Lower Austria. The project was conceived by EVN (a power supplier in the Region of Lower Austria) in 1995 in response to the requirements of the Landfill Ordinance and the increasing rate of landfill tax. EVN subsequently formed AVN, which although representing a partnership with the Region of Lower Austria, is made up of entirely private shareholders.

EVN financed the plant using both its own equity and private investment, which was raised on the back of securing two key contracts, one for 154kTpa of MSW from a network of waste management associations and another from a private contractor collecting non-hazardous industrial wastes from sources across Lower Austria. Gate fees charged by the facility are typically in the region of Euro 100 / tonne on both public and private contracts.

## 8.2. MODE INTEGRATION FOR PUBLIC TRANSPORT

### Integrated urban planning and efficient resource use, Singapore

Good practices in City Energy Efficiency: Eco$^2$ Cities - Land and Resource Management in Singapore, available onlinehttp://www.esmap.org/esmap/node/1230

Singapore is an island city-state at the southern tip of the Malay Peninsula. With a limited land area of 700 square kilometers and a population of 4.8 million, Singapore has become developed because of innovative urban planning integrated with the efficient use of land and natural resources. Singapore's small size poses challenges related to the availability of land and natural resources. To optimize land use, Singapore promotes high-density development not only for businesses and commercial entities, but also for residential structures. High density lends itself to higher economic productivity per unit of land and facilitates the identification of green spaces and natural areas for preservation.

Furthermore, high-density development has translated into greater use of public transportation as major business, commercial, and residential areas are well connected to an integrated public transportation network. In 2004, public transportation as a share of all transportation modes during morning peak hours reached 63 percent. The significant use of public transportation helps reduce greenhouse gas emissions. High public transportation ridership also means Singapore has been able to recover all public transportation operating costs from fares, a feat achieved only by Hong Kong, China, and by Singapore among modern, highly developed cities.