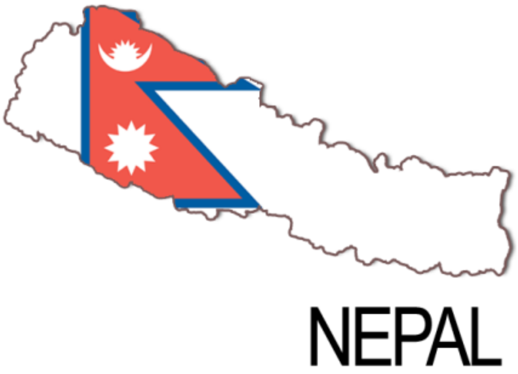
Diesel Power Generation

Inventories and Black Carbon Emissions in Kathmandu Valley, Nepal



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BC	Black Carbon
CO	Carbon Monoxide
DG	Diesel Generator
DoC	Department of Customs
GO	Governmental Organization
IIASA	International Institute for Applied Systems Analysis
INGO	International Nongovernmental Organization
INPS	Integrated National Power Supply
ML	Million Liters
MOE	Ministry of Energy
MoSTE	Ministry of Science, Technology and Environment
NDGES	National Diesel Generators Emission Standard
NEA	Nepal Electricity Authority
NGO	Nongovernmental Organization
NOC	Nepal Oil Corporation
NOx	Nitrogen Oxides
OC	Organic Carbon
PM_{10}	Particulate Matter (<10 mm)
$PM_{2.5}$	Particulate Matter (<2.5 mm)
SO_2	Sulfur Dioxide
TEPC	Trade and Export Promotion Center
TVOCs	Total Volatile Organic Compounds
LCSD	Ultra-low Sulfur Diesel
U.S. EPA	United States Environment Protection Agency

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EXECUTIVE SUMMARY

Air pollution is a major problem in Nepal. The Environment Performance Index (EPI) 2012 has ranked Nepal in the third last position (the 130th) among 132 countries, in terms of air pollution impact on human health[1]. A World Bank study (2007) estimated that urban air pollution in Nepal caused nearly 7,000 premature deaths in 2005 and about 2106 new cases of chronic bronchitis. The total economic costs of urban air pollution in Nepal was estimated at about USD 21 million, or 0.29% of Nepal's GDP.

Particulate matter (PM) is the major air pollutant of concern in Kathmandu Valley. Routine monitoring between September 2007 and May 2008 shows that 24-hour PM_{10} concentrations exceed the WHO guideline value of 50µg/m^3 by a factor of two to six; and $PM_{2.5}$ was approximately five to eight times higher than the WHO guideline value of 25µg/m^3. The fraction of $PM_{2.5}$/$PM_{1.0}$ in PM_{10}, which is the fine fraction where black carbon is typically found, ranged from 80% to 90%,, which means that most of particles are in the fine fraction and therefore particularly dangerous to human health (Stockholm Environment Institute, 2009). This cannot bode well for the city as a tourism gateway, and as an engine of economic growth for the country.

BC emissions have direct adverse impacts on the snow and ice. When deposited on the earth's surface, BC can accelerate the melting of snow and ice; sensitive regions such as the Arctic and the Himalayas are particularly vulnerable to melting. Actions taken now to reduce BC emissions in transport, industries, and power generation, and in domestic/residential sectors, can have local, regional, and global benefits, delivering improved air quality.

BC emissions from diesel generators in Nepal have been rising, as diesel generators (DG) have increased in use due to power shortages. Nepal is facing severe power shortages with the installed capacity significantly below demand. The annual peak power demand of the Integrated National Power Supply (INPS) in FY 2012/13 was estimated to be 1,095 MW; however, only 720 MW was supplied. The almost 35-percent deficit in electricity supply is the primary reason for load shedding (NEA 2013) and the government has been struggling to keep load shedding below 12 hours/day during the driest month. Nepal's dependency on generators has massively increased in order to meet the increased load-shedding hours every day. Distributed generator sets can be very polluting and are contributing significantly to local and regional air pollution, and will remain as one of the key polluting sectors in the short-term before the grid can provide reliable electricity to most of the consumers in the country.

To fill major data gaps of black carbon sources, this study provides a first approximation of emissions from DG sets for the Kathmandu Valley which accounts for 2/3 of the total diesel consumed in the capital city. The study estimates that 221 tons of BC was emitted from diesel generators in FY2012/13 by developing a baseline inventory of DG sets in use in the Kathmandu Valley. The study collates available national and city-level data on diesel consumption, electricity generation and demand, load shedding, and DG sets imports/sales to estimate emissions of BC and co-pollutants, namely - CO, SO_2, NOx, TVOCs, and OC from DG sets use. The data source for the inventory of DG sets is a city-level survey. Although

[1] http://epi.yale.edu/epi2012/countryprofiles

the estimated BC emission may account for a small share of total national emissions, the increasing use of DG sets for power generation places a growing burden on air quality in the capital. Seasonal analysis indicates that around 65 percent of BC emitted by DG sets in FY 2012/13 was released during the winter (December-February) and in the pre-monsoon season (March-May) because of the comparatively prolonged power shortages during these dry seasons.

A baseline inventory of the number, types, and approximate distribution of DG sets shows the commercial sector to be the largest user, contributing about 77 percent of total BC emissions. The balance of BC emissions comes from manufacturing (10 percent), hospitals (6 percent), and government/nongovernmental buildings (6 percent).

Black Carbon emissions estimates can be refined and extended to other areas of the country. The assessment can be improved by additional research on local operating conditions for DG sets, filling data gaps, and extending the sampling beyond the Kathmandu Valley. The initial BC estimates reported in this study were based on emissions factors for diesel engines derived elsewhere and fuel consumption rates provided by manufacturers. Emissions estimates can be improved with local (or comparable) emissions measurements from DG sets; more comprehensive research on the local environment where DG sets are operated, including fuel efficiency, maintenance, and application of emissions control techniques; better understanding of the enforcement and implementation of regulatory policies; and knowledge about the types of DG sets likely to be on the market in the next 10 years and their emissions profiles. In addition, projections of Nepal's electrification pattern will enable better forecasting of DG set use in the future.

1. INTRODUCTION

1.1. Air Pollution in Kathmandu

Air pollution in Nepal is a major problem. The Environment Performance Index (EPI) 2012[2] has ranked Nepal in the third last position (the 130th) among 132 countries, in terms of air pollution impact on human health.[3] A 2007 World Bank study estimated that urban air pollution in Nepal caused nearly 7,000 premature deaths in 2005 and about 2106 new cases of chronic bronchitis. The total economic costs of urban air pollution in Nepal was estimated at about USD 21 million, or 0.29% of Nepal's GDP (World Bank, 2007).

Fine particulate matter (PM2.5) is a major air pollutant of concern in the Kathmandu Valley. The location and topography of the city worsens the situation, with the bowl-shaped Kathmandu valley stopping the pollution from dispersing. Routine monitoring performed at Patan Hospital and Thamel Hospital sites between September 2007 and May 2008 indicated that 24-hour PM10 concentrations exceed the WHO guideline value of 50µg/m3 by a factor of two to six; PM2.5 was approximately five to eight times higher than the WHO guideline value of 25µg/m3. The fraction of PM2.5 /PM1.0 in PM10, which is the fine fraction where black carbon is typically found, ranged from 80% to 90%, which means that most of particles are in the fine fraction and therefore particularly dangerous to human health (Stockholm Environment Institute, 2009). Such high levels of air pollution cannot bode well for Kathmandu as a tourism gateway, and as an engine of economic growth for the country.

Vehicular emissions, re-suspension of street dust, emissions from brick kilns, and refuse burning are among the many sources contributing to increased air pollution in the Kathmandu valley. The latest commonly cited inventory of PM_{10} (Gautam, 2006) highlights vehicles, road dust re-suspension, agriculture, and brick kilns as the top emitters. It did not look into the contribution of diesel generator sets to PM_{10} emissions.

1.2. Black Carbon Emissions and Impacts

Black Carbon is known to have substantial effects on the regional climate through local pollution and the formation of Atmospheric Brown Clouds. It also exerts a strong warming effect through its impact on ice and snow, as it reduces the reflectivity (albedo) and accelerates melting, exposing darker and less reflecting surfaces. Studies indicate that the effect of BC on seasonal snow cover duration in some regions can be substantial. A recent study by the World Bank (2013) shows how addressing BC emissions in the Himalayan region can be good for preservation of snow and ice as well as the health and wellbeing of the local population.

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[2] Yale Centre for Environmental Law and Policy, Yale University and Centre for International Earth Science Information Network and Columbia University

[3] http://epi.yale.edu/epi2012/countryprofiles

1.3. Black Carbon and Diesel-based Power Generation

Nepal is facing severe power shortages with the installed capacity significantly below demand. The annual peak power demand of the Integrated National Power Supply (INPS) in FY 2012/13 was estimated to be 1,095 MW; however, only 720 MW was supplied. The almost 35-percent deficit in electricity supply is the primary reason for load shedding (NEA 2013) and the government has been struggling to keep load shedding below 12 hours/day during the driest month. Nepal's dependency on generators has massively increased in order to meet the increased load-shedding hours every day. From industrial and commercial to non-commercial sectors, the usage of diesel generators is large. However, DG sets are only a short-term solution to load shedding. In the long run, as better generation and transmission capacity is developed, electricity demand will be largely met through the grid. Distributed generator sets can be very polluting and an inefficient method of generating electricity compared to large-scale grid electricity. They are contributing significantly to local and regional air pollution, and will remain as one of the key polluting sectors in the short-term before the grid can provide reliable electricity to most of the consumers in the country.

This study establishes a baseline inventory of the number, types, and approximate distribution of DG sets in use in the Kathmandu Valley of Nepal and estimates air pollution emissions, including black carbon, from these generators. The study collates available national and city-level data on diesel consumption, electricity generation and demand, load shedding, and DG sets imports/sales to estimate emissions of BC and co-pollutants, namely - CO, SO_2, NOx, TVOCs, and OC from DG sets use. The data source for the inventory of DG sets is a city-level survey.

1.4. Structure of the Report

This rest of this report is organized into four chapters. **Chapter 2** describes the methodology and approach for data collection and emissions estimation (BC and other co-pollutants), including consultations with experts and stakeholders, literature reviews, and data collection at the national and city levels. **Chapter 3** provides information on total electricity generation and consumption, load-shedding scenario, and diesel consumption trends for Nepal and Kathmandu Valley. This chapter also provides information on the increasing trend of diesel sales due to the power shortages in Nepal as well as information on the generators that are imported to Nepal (including numbers, fuel types, and capacities). **Chapter 4** presents the results and findings from the city-level survey, including the distribution of DG sets in Kathmandu Valley according to brand, capacity range, and age. It also summarizes the estimated emissions of BC and other pollutants from different sectors derived from annual diesel consumption for electricity generation, installed captive capacity of DG sets, and annual electricity generation. In addition, the last section of this chapter outlines the study's assumption and data limitations. **Chapter 5** presents the conclusions of the overall study on emissions from DG sets in Kathmandu Valley and recommends ways to improve the analysis in future studies.

2. METHODLOGY

This chapter explains the methodology and approach adopted for this study of inventories and black carbon emissions estimation from diesel power generation.

2.1. Schematic Framework of the Study

The methodology followed in this study consisted of several steps described in this chapter and indicated in the schematic shown in Figure 2-1. Prior to initiation of the analysis, consultations with experts and a review of available data were performed as described in the next two sections.

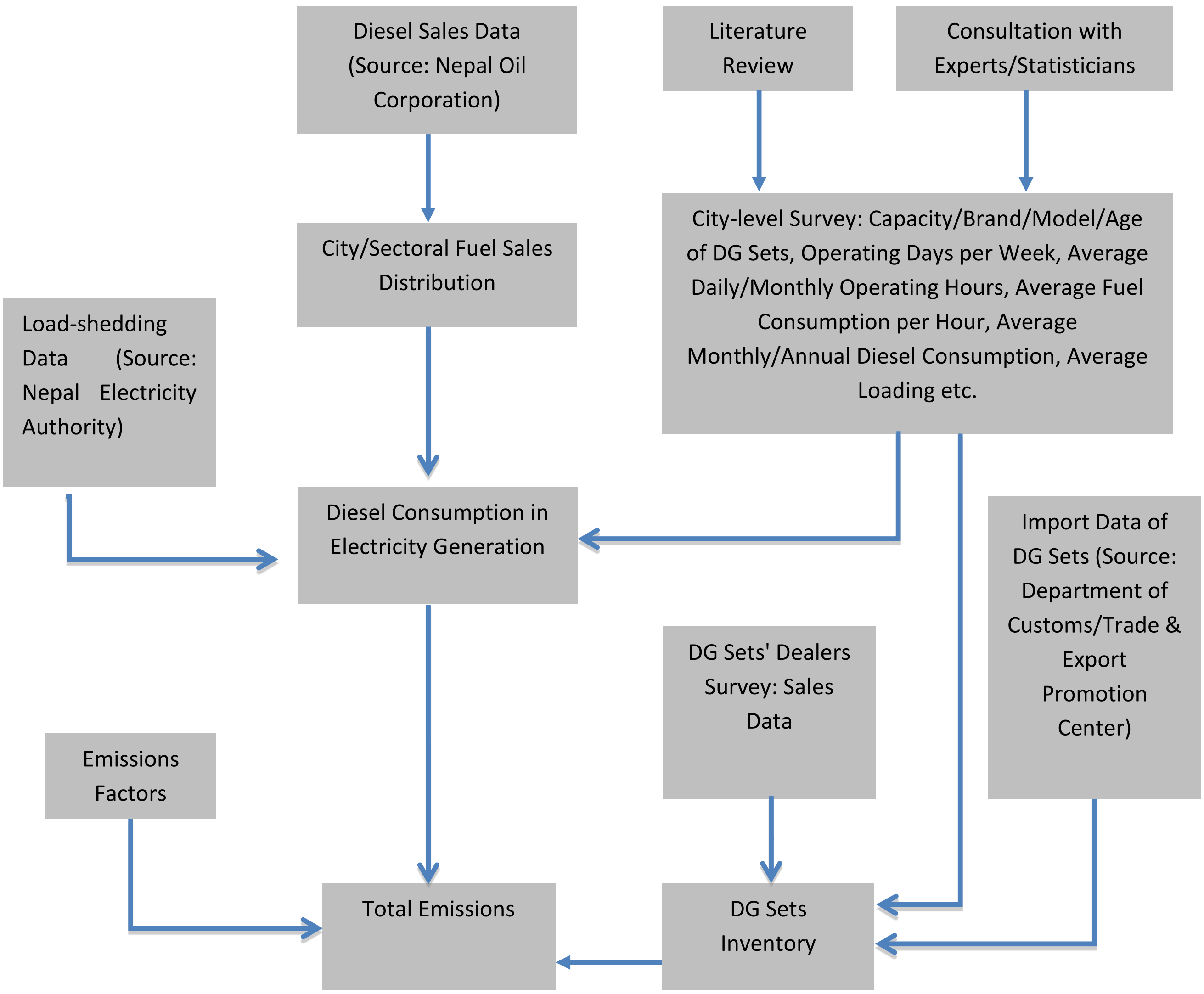


Figure 2-1 Schematic Framework for DG Sets Inventory and Emissions Estimation Study

2.2. Approach

2.2.1. Consultations with Stakeholders

Consultations were held with stakeholders with relevant knowledge of and experience in diesel-based power generation to develop the methodology for estimating the inventory of DG sets in use in Kathmandu Valley and associated emissions of BC and other pollutants.

Two sampling methods were reviewed as a means of gathering information on DG set use in Kathmandu Valley: Generalized Random Tessellation Stratified Random Sampling Method (GTRS) and Simple Random Sampling Method. For the GRTS method, Kathmandu Valley would be divided into 2×2. km^2 grids and the total number of buildings in each grid would be estimated using GIS. Ten percent of all buildings would be sampled in any particular grid. For the simple random sampling method, sample sizes would be calculated based on the population in each sector identified for DG sets use; the samples would then be randomly selected according to the proportional distribution of the populations in three districts of Kathmandu Valley. Stakeholders suggested focusing on city-level data collection and correlating the diesel consumption data with the load-shedding scenario to get a picture of the quantity of diesel consumed for power generation. Since the GTRS sampling method requires a significant time investment (more than 5-6 months), the Simple Random Sampling Method was selected for this study.

Further consultation was held with stakeholders on emerging findings and messaging. The first round of consultations was undertaken with a small group of experts; it provided important comments and suggestions on emissions calculations. After the small roundtable, a workshop was organized on emerging findings. This consultation was held with the broader stakeholders from national and local government agencies, nongovernmental agencies, development agencies, academia, research institutions, the private sector, and members of the media. Workshop participants discussed issues of power shortages and alternatives to address power shortages. Valuable feedback was provided by stakeholders on policy gaps, emissions regulations, and issues regarding fuel quality and emissions standards.

2.2.2. Review of Data and Available Information

A desk review was undertaken to find relevant information:

- Fuel consumption for power generation in Nepal (focusing on Kathmandu Valley).
- Identification of different possible sectors using DG sets.
- Past research studies similar or relevant to the DG sets study.
- Review of existing methodologies for the emissions inventory of DG sets to help in identifying an appropriate methodology.
- Emissions factors for DG sets.

No specific literature related to diesel power generation and emissions in Nepal was found beyond some academic case studies. The literature sources were mostly Internet-based information from research institutions and universities. Other institutions, including Nepal Oil Corporation and Nepal Electricity Authority, were approached during the literature review.

2.2.3. National-level Data Collection

For the national-level data collection on fuel consumption, load shedding, and import/sales of DG sets, the following information was collected:

- Monthly/Annual fuel sales data in Nepal, including Kathmandu Valley, for FY 2007/08-2012/13 (Source: Nepal Oil Corporation).
- Load-shedding data for FY 2008/09-2012/13 (Source: Load Dispatch Center-Nepal Electricity Authority).
- DG sets import data for FY 2009/10-2011/12 (Source: Trade and Export Promotion Center).

2.2.4. City-level Survey

More detailed and corroborative data were collected at the city level in the Kathmandu Valley (Kathmandu, Bhaktapur, and Lalitpur districts), focusing mainly on five municipalities -- Kathmandu Metropolitan City, Lalitpur Sub-metropolitan City, Bhaktapur Municipality, Kirtipur Municipality, and Madhyapur Thimi Municipality -- targeting where and under what circumstances DG sets are used.

Field visits and surveys *(*see Annex B for the questionnaire template*)* were conducted to collect detailed information on the operation of DG sets and fuel consumption. The questionnaire also focused on economic and environmental aspects of generator use. (See Annex C for the details of the sampling design.)

The following information was collected during the survey:

- Capacity/brand/model/efficiency of the generator
- Age of the generator
- Average daily operating hours (dry and wet season)
- Fuel consumption rate (liters/hr)
- Volume of fuel usage per day/month (dry and wet season)
- Average daily/monthly power generation
- Average daily/monthly cost for operating the generator
- Average Loading
- Purpose for the use of the generator
- Application for air pollution devices
- Capital and maintenance costs of the generator
- Source of diesel supply

2.3. Emissions Estimation Methodology

The emissions estimation is based on the emissions factors published by U.S. EPA for stationary diesel engines (AP-42, Sections 3.3 and 3.4), which was also adopted by Central Pollution Control Board, India, for estimating emissions from DG sets. For the emissions inventory, CO, NOx, PM_{10}, TVOCs, CO_2, and SO_2 emissions were estimated using engine power and operating duration.

The equation used for the estimation of the emissions using engine power is given as follows:

$$E_i = P \times OpHrs \times EF_i \times \left(\frac{100 - ER_i}{100}\right) \times AL$$

Where,

E_i	=	Total emissions of substance i from a stationary combustion engine for the reporting year	(kg/y)
P	=	Engine power capacity rating	(kW)
OpHrs	=	Operating hours of engine during the reporting year	(h/y)
EF_i	=	Emissions factor of substance i	(kg/kWh)
ER	=	Emissions reduction efficiency for substance i	(%)
i	=	Substance i	(-)
AV	=	Average Loading[4]	75%

Note: Since the pollution control technology employed in the diesel generator sets are not clearly known, the emissions reduction efficiency is zero; thus, the emissions results are "uncontrolled" emissions values.

The emissions factors used in this study are given in Table 2-1 and are for the engine sizes smaller than 447 kW and larger than 447 kW.

Table 2-1 Emissions Factors for Emissions Estimation

	For Newer Engines < 15 years old		***For Old Engines > 15 years***
	Emissions Factor (g/kWh)		
Substance	**< 447 kW**	**> 447 kW**	**Old engine of all size**
Carbon monoxide	4.06	3.2	
Oxides of nitrogen - uncontrolled	18.8	14	
Oxides of nitrogen –controlled		7.9	
Particulate matter (PM10)	1.34	0.33	4.5
SO_2	0.18	0.18	
Total VOC	1.5	0.43	
Carbon dioxide (CO_2)	704	703	

Note: With a sulphur content of 350 ppm, SO_2 an emissions factor of 0.7 g/kg (i.e., 0.18 g/kWh) is used.
Sources: U.S. EPA 1996; Shah et al. 2007; CPCB 2011.

[4] The Average Loading (AV) used in the formula of this study is the average percentage of the capacity used while a generator is in operation. It is slightly different than the Average Loading of a power plant which has already factored in the operational time.

Emissions Factor for Black Carbon (BC): There are few measurements of emissions from diesel generators. In many cases, BC inventories are calculated from $PM_{2.5}$ or PM_{10} inventories. These calculations divide the direct carbonaceous particle emissions from the PM_{10} inventory into two categories: black carbon (BC) and organic carbon (OC).This study uses a BC factor derived from a set of studies collected by the International Institute for Applied Systems Analysis (IIASA) that derived from, among other studies (Shah 2007). The measurements are from a combination of diesel generators and somewhat similar diesel engines (locomotives). Based on the age of the generators in use, the estimated share of BC and OC in PM_{10} is given below:

Engine Age	BC	OC
For newer engines < 15 years old	0.6*PM10	0.3*PM10
For older engines >15 years old	0.40*PM10	0.45*PM10

Significance of the Measurement of the Emissions: Monitoring of the emissions from the engines as representative emissions can be useful for having confidence in the emissions factors used from various sources. Measurements were not able to be done as a part of this study. In the event that measurements could be done in the future, they should be undertaken using a standard protocol, which should include exhaust dilution systems for particulate measurement and collection bags to sample the exhaust and measure them gravimetrically.

Box 1 summarizes the key assumptions made in estimating fuel consumption and emissions.

Box 1: Key Assumptions for Estimating Fuel Consumption and Emissions

Diesel consumption rate: No accurate information on diesel consumption rate was obtained from respondents beside average monthly or annual diesel consumption data. And, the majority of respondents reported the consumption rate provided by DG sets manufacturers. Thus, the diesel consumption rate is calculated from the information provided by the few major DG sets manufactures at 75% average loading. No local circumstances or environmental factors are considered for calculating the consumption rate.

DG sets operating hours: Since majority of the respondents said that they operated the DG sets according to the load-shedding hours in their business time, the annual DG sets operating hours are assumed to be equivalent to the annual load shedding data provided by Nepal Electricity Authority in the given business hours. For those that don't operate according to the load-shedding schedule, the annual operating hours are simply calculated from the information provided by the respondents. Public holidays and number of business off-days per week are also considered for calculating the annual DG sets operating hours.

Average loading: Few of the respondents who provided the information on average loading said that the DG sets usually operate at 60%-80% of average loading. However no consistent and reliable information is provided by the respondents during the survey. Thus this study assumed that the DG sets are operated at average 75% of their maximum load. The diesel consumption rate used in the calculation as provided by manufacturers is at 75% average loading.

Emission reduction efficiency: As the pollution control technology employed in diesel generator sets is not known, the emissions reduction efficiency is assumed to be zero and the emissions results represent “uncontrolled” emissions values.

3. ELECTRICITY GENERATION AND DEMAND, FUEL SUPPLY, AND GENERATORS FOR POWER GENERATION

This chapter presents the current scenario for electricity generation, demand and consumption, and diesel import/sales in Nepal, including Kathmandu Valley, based on the literature and available secondary data. This chapter also includes information on the import of different fuel type and sizes of generators, including DG sets.

3.1. Electricity Generation and Demand

Nepal is currently facing severe power shortages; the industrial, commercial, and service sectors are being hit the hardest. The country has witnessed up to 18 hours of load shedding[5] per day during the dry season. High demand for electricity and increasing power shortages during the dry season have forced manufacturing, other commercial, and non-commercial sectors to rely on DG sets. Nepal Electricity Authority (NEA) predicts that load shedding will rise to 21 hours if electricity demand keeps increasing without additional action to meet demand. NEA also estimates that the supply-demand gap is likely to remain for at least the next 3-4 years (NEA, 2012).

There was no load shedding before 2000, when the Khimti Project was commissioned, until 2005. The electricity crisis began in 2006 as demand began to outstrip the supply of electricity. In 2008, when floods breached the Koshi embankment and destroyed power transmission lines, the crisis became a lot worse. With power no longer able to be imported from India, and low water levels in the Kulekhani reservoir, load shedding hours increased from four to 16.5 hours a week.[6]

According to NEA, the peak power demand of Integrated National Power Supply (INPS) in FY 2012/13 was estimated to be 1,095 MW, with 375 MW power estimated to have been shed. Out of the 720 MW of power actually supplied, 53 percent was contributed by NEA hydro, 28 percent by Independent Power Producers (IPPs), and the remaining 19 percent imported from India. Compared to the preceding fiscal year's figure (1000 MW), the peak demand of the INPS increased by 9 percent. Figure 3-1 shows that peak demand for electricity increased continuously from 2004-2013, and it will continue to grow. The electricity demand of INPS in fiscal year 2012/13 was estimated at 5400 GWh, of which only 4200 GWh (or 77.5 percent) was met. The remaining 1200 GWh (22.5 percent) resorted to load shedding (NEA 2013).This is depicted in Figure 3-2.. Although available electricity has also been increasing, the increase has not happened fast enough to meet the peak demand for electricity during the driest months.

[5]Power Cut To Go Up from Saturday. ekantipur, December 11, 2009. *http://www.ekantipur.com/2009/12/11/national/power-cut-to-go-up-from-saturday/304289.html*.
[6]Electricity Crisis (Load Shedding) in Nepal. February 17, 2010. *http://www.ratnasansar.com/2010/02/electricity-crisis-load-shedding-in_17.html*.

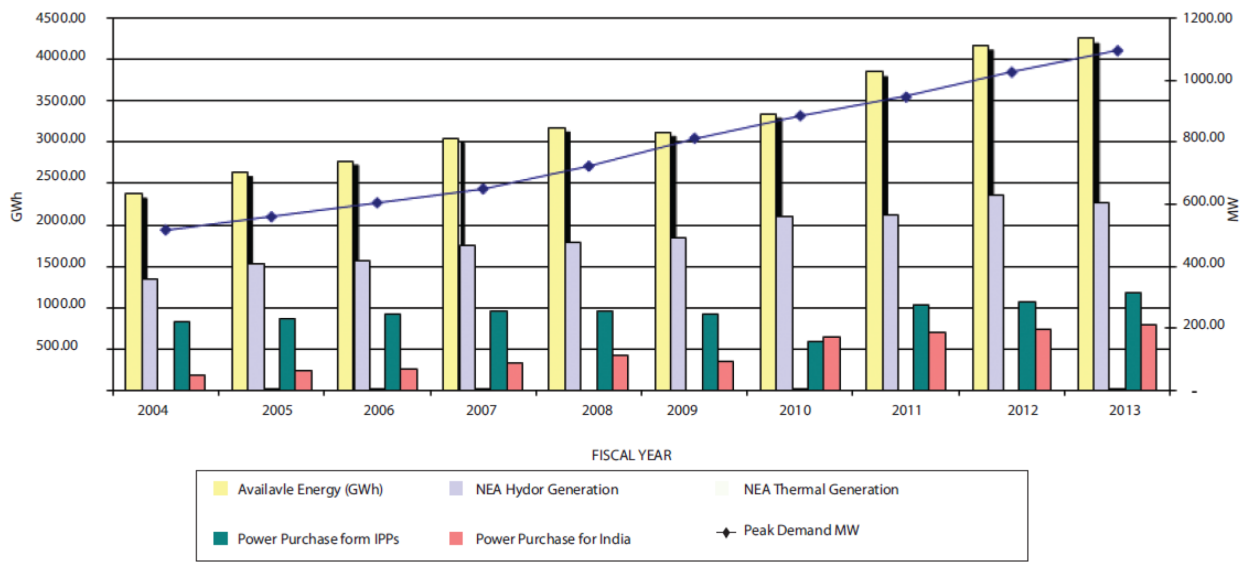


Figure 3-1 Total Electricity Available and Peak Demand for FY 2004-2013 (Source: NEA 2013.)

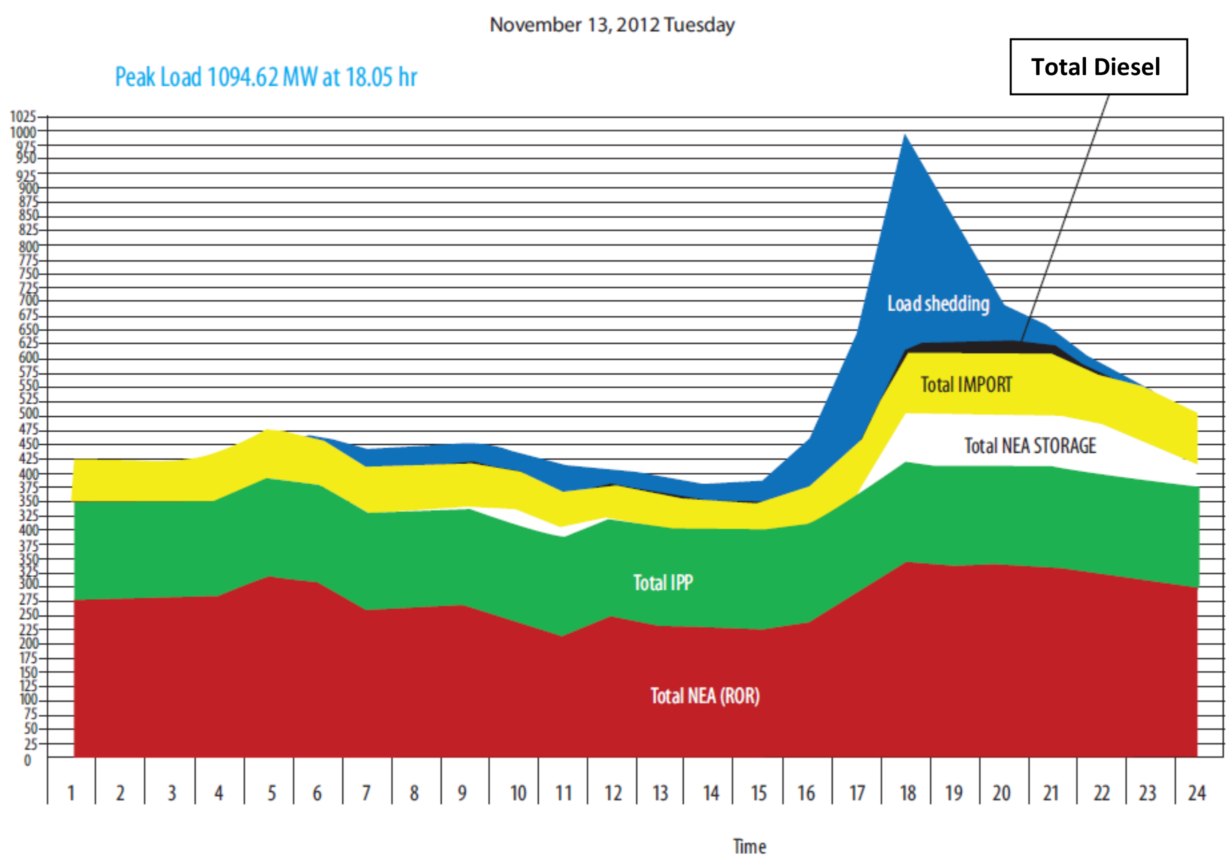
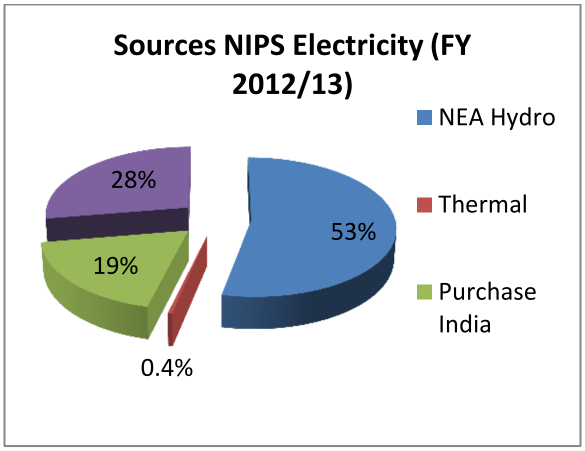


Figure 3-2 System Load Curve of Peak Load Day (Source: NEA 2013.)

The majority of electricity in Nepal comes from hydropower. Figure 3-3 provides the breakdown of sources of electricity connected to the NEA Integrated National Power Supply (INPS) system in FY2012-13. There are only two diesel power stations currently operating and connected to the national grid: Duhabi Multifuel and Hetauda, which have installed capacities of 39,000 kW and 14400 kW respectively. The government had earlier planned to install a new diesel thermal power plant in the country to cut load-shedding hours; due to the huge financial cost and opposition to the plan, the project was called off.



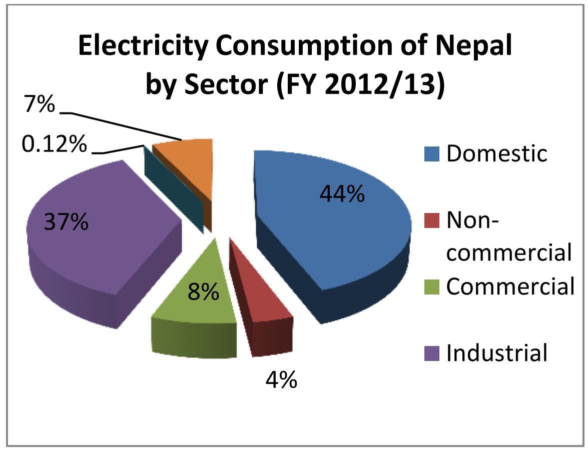


Figure 3-3 Electricity Supply by Source (2012/13) Figure 3-4 Electricity Consumption by Sector (FY 2012/13)

In terms of consumption, around 44 percent of available electricity is consumed in the domestic sector, 37 percent in the industrial sector, 8 percent in commercial sectors, 4 percent in non-commercial sectors, 7 percent in other sectors; the remaining 0.12 percent of available electricity was exported in FY 2012/13.

As hydropower is the major source of electricity, electricity generation largely depends on the amount of river discharge. Given the limited installed capacity and run of the river mode of electricity generation, the load-shedding amount is not evenly distributed throughout the year. During the dry season (December-February), there are maximum load-shedding hours per day as electricity generation significantly decreases due to the decline in river discharge and increase in electricity consumption. During the wet season (June-August), on the other hand, there is minimum load shedding as river discharge reaches its maximum level. The weekly load-shedding hours for FY 2012/13 (June 2012 - May 2013) are given below. The seasonal changes can be clearly seen.

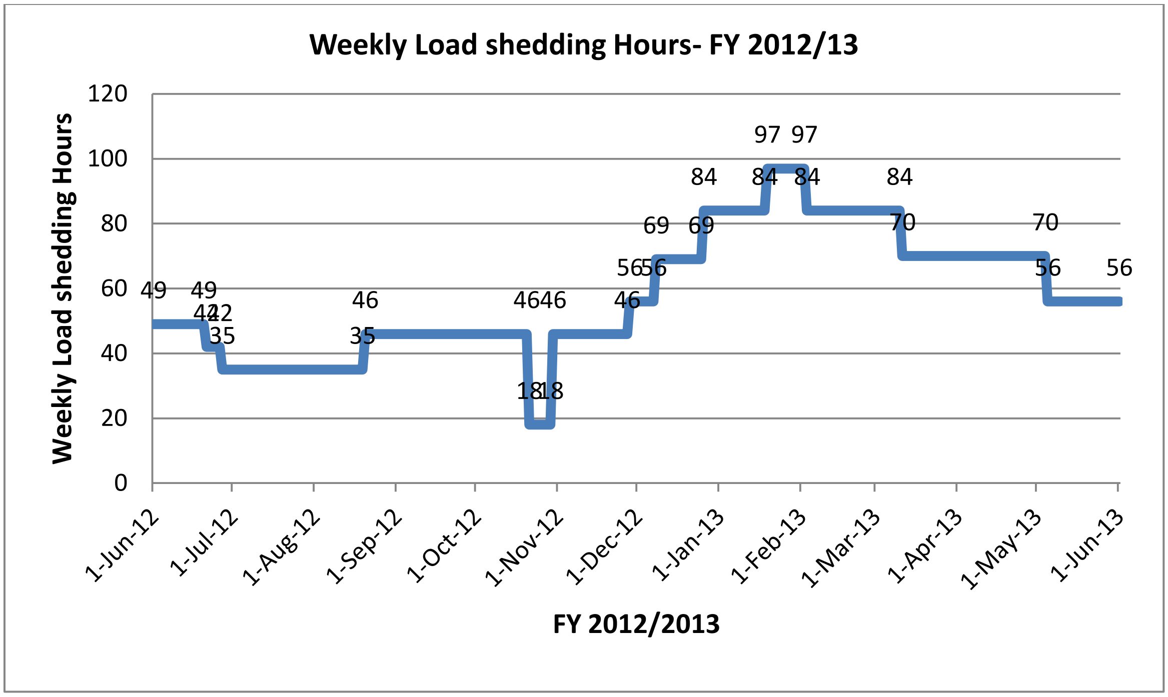


Figure 3-5 Weekly Load Shedding Hours for FY 2012/13 (Source: NEA.)

The future demand for electricity is expected to increase even more rapidly. According to the NEA's load forecast, the annual growth rate of electricity demand for the next 10 years will be about 9 percent. In 2020, electricity demand will increase to 9600 GWh from the current 6000 GWh. Nepal will therefore have to generate substantially more power in order to meet its future demand. The system peak load is expected to double by 2020 and triple by FY 2027/28 (Table 3-1).

Table 3-1 Load Forecast for FY 2013/14-2027/28

Fiscal Year	Electrcity Demand (GWh)	System Peak Load (MW)
2013-14	5,860	1,270
2019-20	9,560	2,050
2027-28	17,400	3,680

Source: NEA 2013

3.2. Diesel Consumption

Nepal relies completely on imports, notably diesel, for petroleum products. Due to increasing load shedding, the usage of DG sets for backup power for industrial and commercial purposes has increased rapidly. According to Nepal Oil Corporation (NOC), around 30-40 percent of the country's total diesel consumption is being used to generate electricity during load shedding. NOC estimates that the country has been generating roughly 531 MW of electricity from diesel.[7]

[7] Diesel provides 531 MW of electricity, 6 May 2012, The Himalayan Times *(See: http://www.thehimalayantimes.com/fullNews.php?headline=Diesel+provides+531+MW+of+electricity&NewsID=330971)*

The data provided by Nepal Oil Corporation show the sharp rise of diesel sales since FY 2007/08 (Figure 3-6). This can be attributed to the severe power shortages that the country has been facing since 2006. In 2008 there was also a sharp increase in the import of electric generators (largely diesel generators). One confounding factor in this increase though is the decline in diversion of kerosene to the diesel market starting in FY 2009, thus boosting the sales of diesel in 2008/09. Diesel sales have more than doubled in last five years, and around 717 million liters in sales were recorded in fiscal year 2012/13. Considering the increasing rate of sales and the load-shedding trends, diesel consumption is likely to grow further.

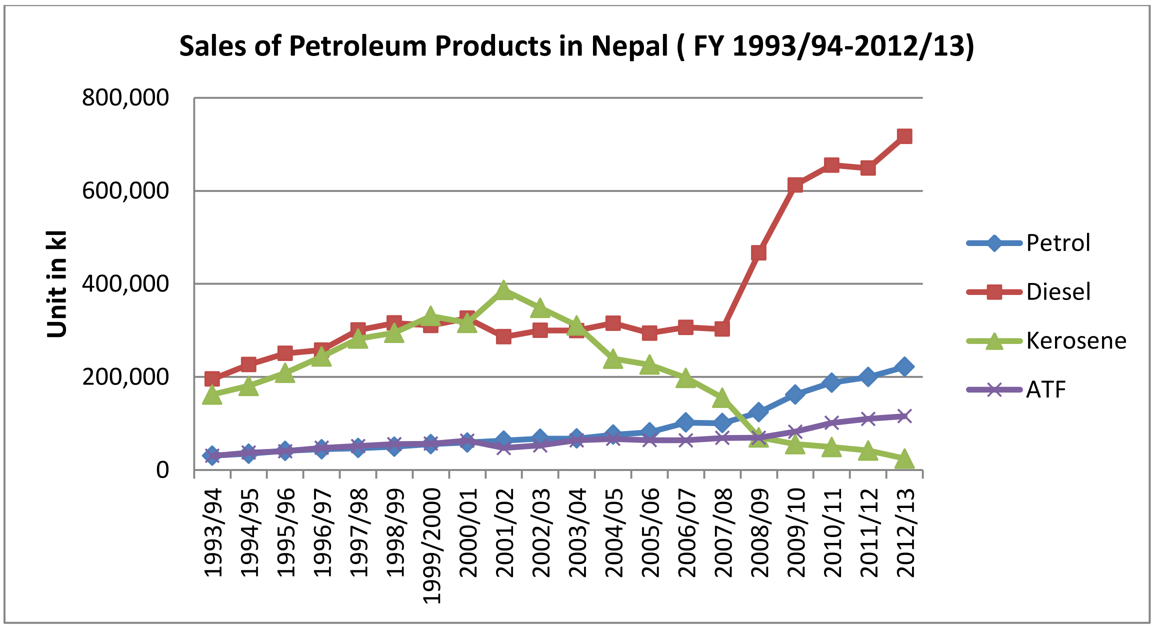


Figure 3-6 Sales of Petroleum Products in Nepal (FY 1993/94-2012/13)

Kathmandu Valley uses about 30 percent of the country's total grid capacity, 15.5 percent of the diesel use, and 31 percent of the total petroleum products used (NRB 2012).

Petroleum products in Kathmandu Valley are supplied by two depots: Thankot (Kathmandu) and Amlekhgunj (Bara). The total quantity of diesel sold in Kathmandu Valley in FY 2012/13 was around 107 ML, which is around 15 percent of total diesel sales in the country. From the monthly sales figure from Thankot Depot, it can be observed that diesel sales peaked during dry seasons (December-February) and the consumption is lowest during wet seasons (June-August) (Figure 3-7); this suggests that the consumption of diesel is linked to the number of load-shedding hours. Contrary to the increasing diesel sales in the whole country, however, the data from NOC show that diesel sales in the Kathmandu Valley (Thankot depot) have decreased in the last two years.

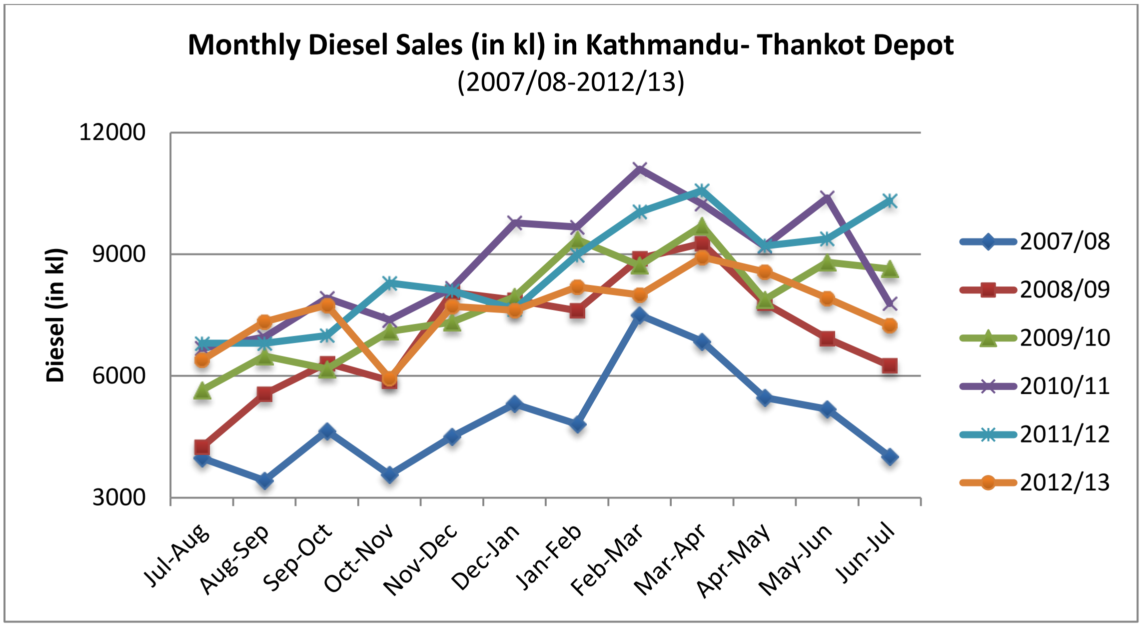


Figure 3-7 Monthly Diesel Sales in Kathmandu Valley-Thankot Depot (FY 2007/08-2012/13)

3.2.1. Fuel Quality

Nepal Oil Corporation is a sole importer and distributor of petroleum oils in Nepal. NOC started importing BS III (Bharat Stage III) fuel quality in 2010, which is regarded as equivalent to the Euro III standard. According to fuel specifications provided by Indian Oil Corporation, the sulfur content of the fuel is less than 350 mg/kg.[8] Before 2010, Nepal imported BS II diesel, which contains <500 mg/kg of sulfur.

3.3. Increasing Generators for Backup Power Generation

The only reason behind the increasing usage of DG sets is the power shortages in the country. Before the power shortages started in Nepal, only a few hospitals and industries were found to have installed generators (primarily for emergency backup during intermittent power outages).

The import data on electric generators for the last three years (FY 2009/10-2011/12) according to fuel type and capacity were obtained from the Ministry of Commerce and Supplies' Trade and Export Promotion Center (TEPC). The Department of Customs, under the Ministry of Finance, also records electric generators imported to Nepal; these are not, however, classified according to fuel type and capacity.

Figure 3-8 shows that diesel generators are the major generators imported into Nepal; imports of generators of other fuel types are comparatively very low. In FY 2009/10, diesel generators made up around 89 percent of total generator imports into Nepal; in FY 2010/11, they accounted for 75 percent; and, in FY 2011/12, 77 percent.

[8] Indian Oil Corporation. http://www.iocl.com/Products/DieselSpecifications.pdf.

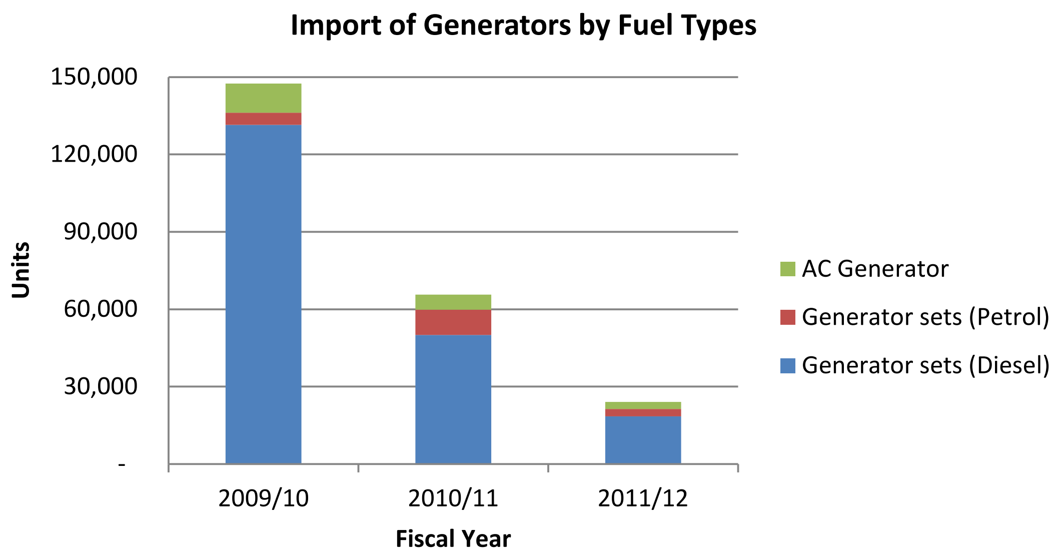


Figure 3-8 Import of Generators in Nepal by Fuel Type (FY 2009/10-2011/12)

Figure 3-9 shows much higher imports of DG sets in 2009/10 than in the following years. The total units of DG sets imported in FY 2009/10, 2010/11, and 2011/12 were 131,000, 50,000, and 18,000 respectively. Of the total DG sets imported into Nepal in the past three years, around 45 percent of had a capacity of less than 75 kW; around 38 percent had a capacity of 75-375 kW; and the remaining DG sets had a capacity greater than 375 kW.

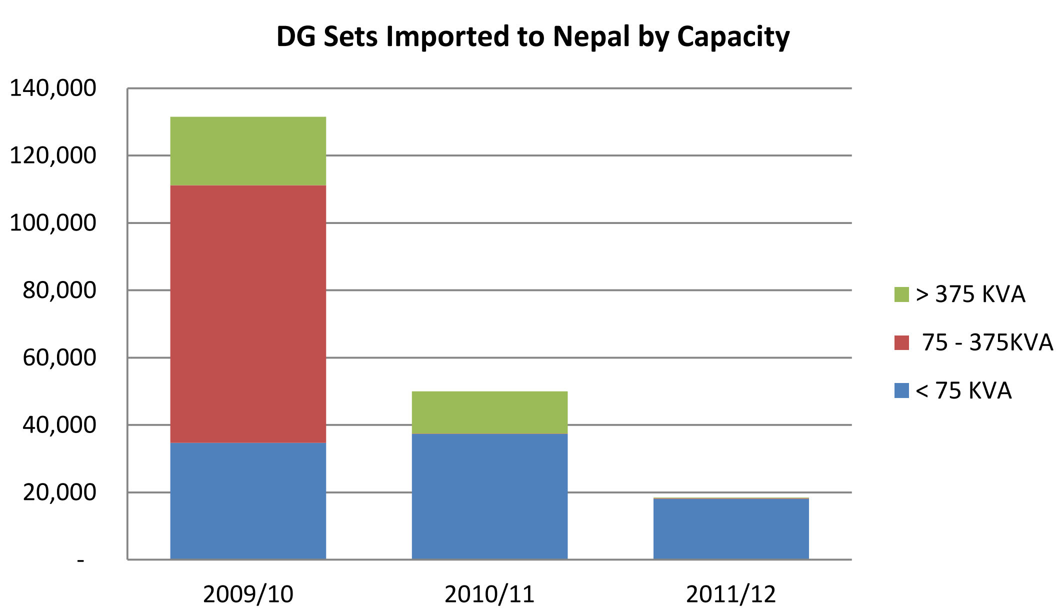


Figure 3-9 Import of DG sets by Capacity in Nepal (FY 2009/10-2011/12)

4. CITY-LEVEL SURVEY IN THE KATHMANDU VALLEY

4.1. Distribution of DG Sets by Brand and Capacity

There are over 50 different brands of DG sets being used in the Kathmandu Valley. The majority of them are manufactured in India. Out of the 766 DG sets sampled, 28 percent of them are Kirloskars. The other major brands used in the Kathmandu Valley are Cummins-Jakson (7 percent), Mahindra (6 percent), Denyo (5 percent), F.G. Willson (4 percent), and Kohler (4 percent).

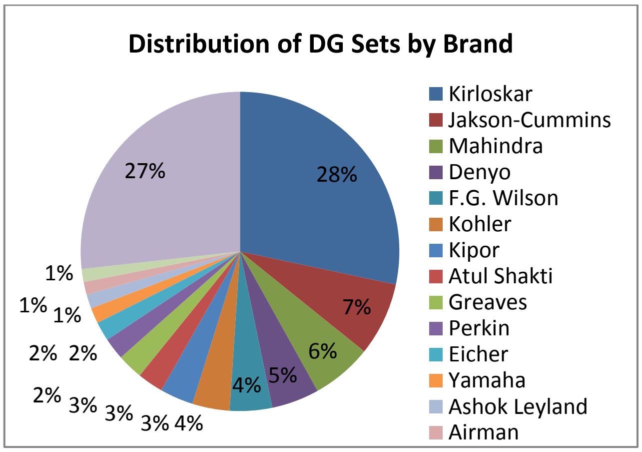


Figure 4-1 Distribution of DG Sets by Brand

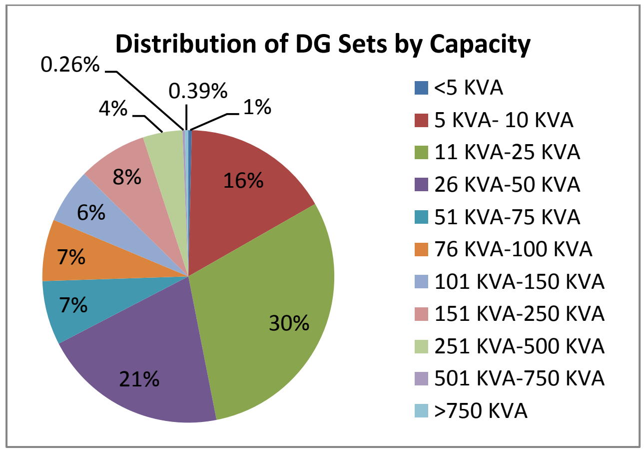


Figure 4-2 Distribution of DG Sets by Capacity

Out of the 776 samples with information on capacity, 67 percent of the DG sets in Kathmandu Valley have a capacity of less than 50 kW; 32 percent range from 50 kW to 500 kW. The highest recorded capacity of a DG set in the survey was 2800 kW; the lowest one was 3.5 kW.

4.1.1. Distribution of DG Sets by Age

Of the 749 samples with information on age/purchase year, 90 percent of the DG sets in Kathmandu Valley were purchased within the last seven years. From this information, it is evident that the use of DG sets has seen unprecedented growth since the power shortages in 2006; the outages have worsened since 2008, with daily outage times as high as 16.5 hours. The distribution of the ages of the DG sets surveyed is provided in Figure 4-3. The survey found that only 2.8 percent of the DG sets are over 15 years old; which were used mainly in hospitals and large industrial facilities for emergency backup.

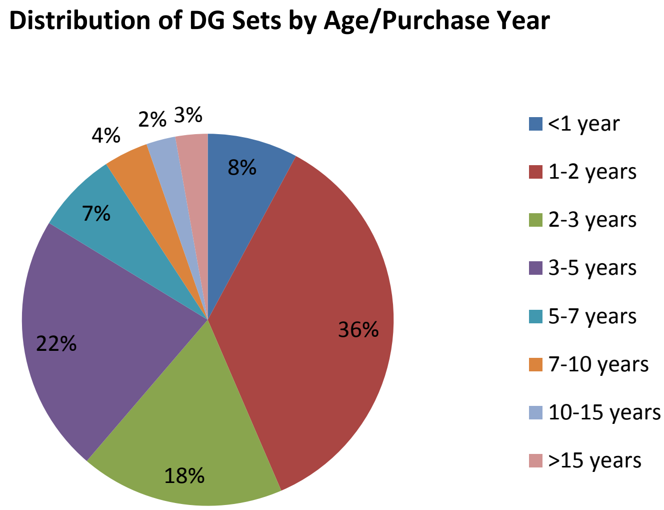


Figure 4-3 Distribution of DG Sets by Age/Purchase Year

4.2. Diesel Consumed and Power Generated

The calculated annual diesel consumption for captive power generation from DG sets in Kathmandu Valley for FY 2012/13 is 72 million liter (ML). Compared to the total diesel sales in FY 2012/13, the share of diesel consumed for power generation is 2/3 of total diesel sales in Kathmandu Valley. Commercial sector has the largest share of diesel consumption which is 82 percent of total consumption followed by manufacturing industries (8 percent), hospitals (6 percent) and combined GOs, NGOs, INGOs and diplomatic mission (4 percent).

The total installed captive capacity of DG sets in Kathmandu Valley is almost 200 MW, and the DG sets provide electricity equivalent to 28 percent of the total electricity consumption of the valley The total electricity generated from DG sets for FY 2012/13 was 340 GWh. Compared to the total electricity supplied by NEA (4,200 GWh in FY 2012/13), the captive electricity generation from DG sets in Kathmandu Valley is almost 8 percent of the total electricity supplied across Nepal. According to Nepal Rastra Bank, around 29 percent of the total electricity distributed by NEA is consumed in Kathmandu Valley, which means Kathmandu Valley consumed around 1200 GWh in 2012/13.

The annual diesel consumption for each diesel generator (DG) set is calculated from the data on diesel consumption rate (Liters per hour or L/h) obtained from Indian DG sets manufacturers and annual DG sets operating hours.

Annual Diesel Consumption (L) = Computed Diesel Consumption Rate $(L/h)_{AL}$ ** Annual DG sets Operating hours*

AL= Average Loading (75%)

The fuel consumption information was obtained from several Indian DG sets manufacturers for different generator sizes. The information used in the current calculation is based on the tests done at 75% engine load. The average of the fuel consumption of three different manufacturers was fitted with the capacity of generators, between 5kW to 100 kW, through a linear relationship (see Fig 4-4). The same regression coefficient was used to compute fuel consumption rate for larger sizes considering the fuel consumption per kW would be more or less the same. Fig 4-5 shows the change in specific diesel consumption (L/kWh) against generator capacity at 75% average loading.

The total annual DG sets operating hours are estimated from the information provided by the respondents. As per the information from respondents, most of the DG sets are operated according to load-shedding schedule during business hours. The annual load-shedding hours are calculated from the load-shedding schedule provided by Load Dispatch Center, Nepal Electricity Authority.

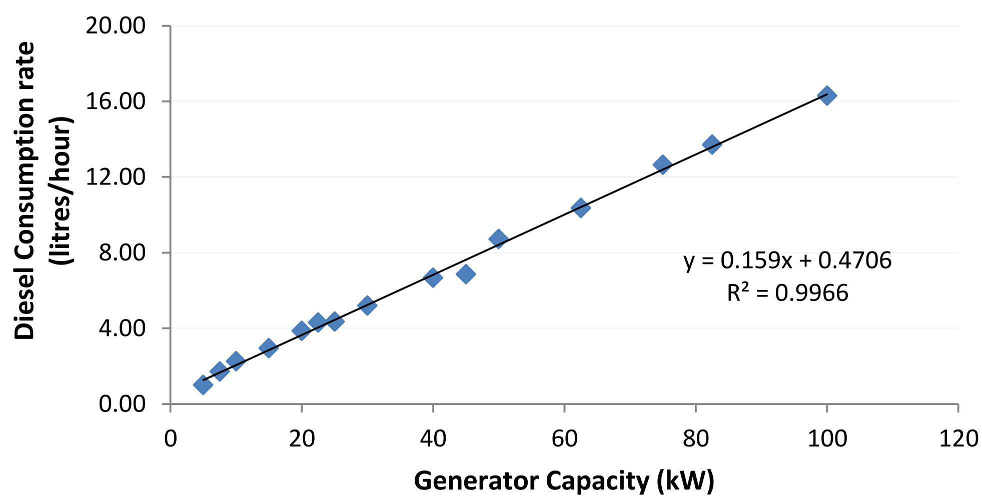


Figure 4-4 Relationship between Diesel Consumption Rate (L/h) and Generator Capacity (kW)

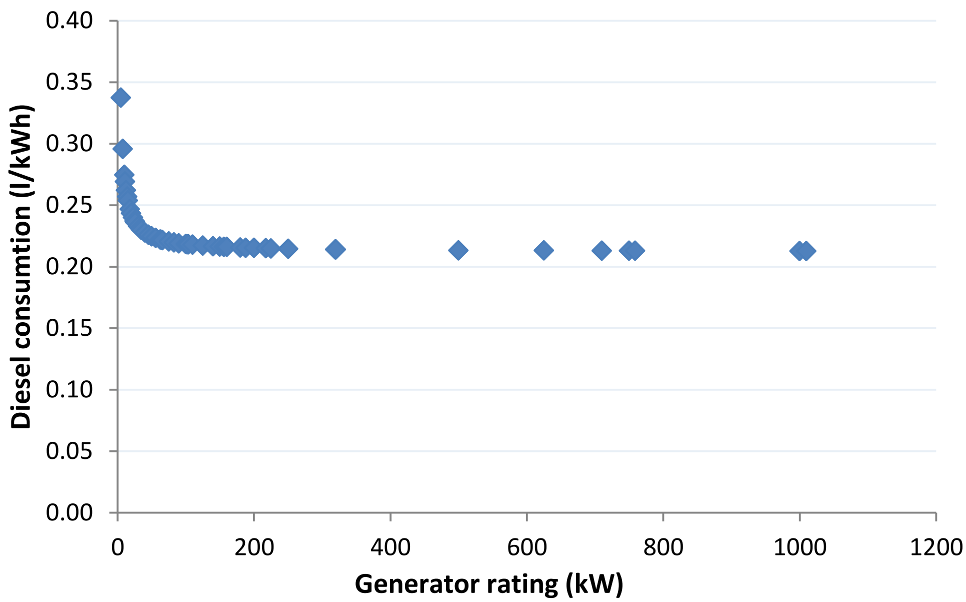


Figure 4-5 Change in Specific Diesel Consumption (L/kWh) with Generator Rating at 75% Load

The annual electricity generation is simply calculated from the generator capacity (in kW), annual DG sets operating hours and average loading.

*Annual Electricity Generation (kWh) = DG set capacity (kW)*Power Factor (0.8)*Annual DG sets operating hours*Average Loading (75%)*

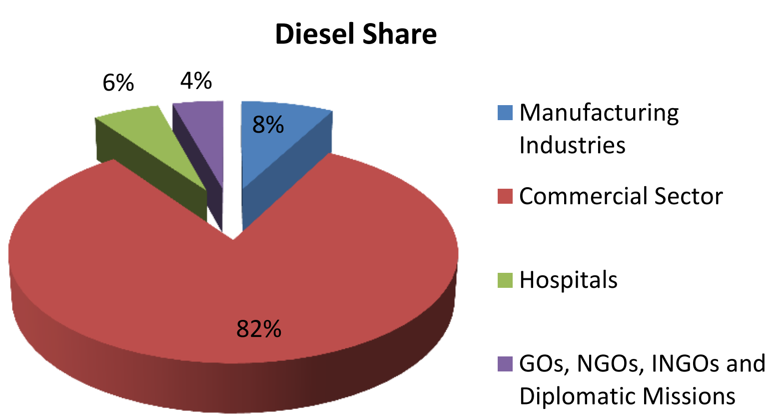


Figure 4-6 Share of Diesel Consumption in Different Sectors

Table 4-1 Annual Fuel Consumption and Power Generation in Various Sectors

SN	Sectors	Annual Fuel Consumption (kl/year)	Annual Electricity Generation (GWh)	Total Generator Installed Capacity (MW)
1	**Manufacturing Industries**	***5,571***	***27***	***19***
1.1	Food Beverages	2,153	11	6
1.2	Textiles	1,922	9	6
1.3	Wood and Wood Products, Furniture	18	0	0
1.4	Paper and Paper Products	2	0	0
1.5	Publishing, Printing, And Reproduction Of Recorded Media	287	1	1
1.6	Rubber and Plastics Products	125	1	1
1.7	Other Non-metallic Mineral Products	902	4	5
1.8	Others	161	1	1
2	**Commercial Sector**	***58,371***	***283***	***151***
2.1	Cinemas /Multiplexes	803	4	2
2.2	Hotels	20,293	101	37
2.3	Restaurants	9,553	44	23
2.4	Communication Service Providers	6,508	32	22
2.5	Financial Institutions (Banks/Cooperatives)	8,199	39	26
2.6	Residential Apartments	1,098	5	3
2.7	Educational Institutions	3,757	17	13
2.8	Shopping Malls, Supermarkets, and Other Commercial/Corporate Office Buildings	8,161	40	24
3	**Hospitals**	***3,995***	***16***	***13***
4	**GOs, NGOs, INGOs, and Diplomatic Missions**	***3,000***	***14***	***12***
4.1	Governmental Organizations (GOs)	1,801	9	7
4.2	International Nongovernmental Organizations (INGOs)	682	3	4
4.3	Nongovernmental Organizations (NGOs)	242	1	1
4.4	Diplomatic/Foreign Missions	276	1	1
	TOTAL	**70,936**	**340**	**196**

4.3. Emissions Inventory

Table 4-2 presents the total emissions for various pollutants (including BC) from DG sets for different sectors and sub-sectors in Kathmandu Valley. As the largest fuel consumer, the commercial sector was found to be the largest source of emissions of pollutants from captive diesel power generation.

Table 4-2 Emissions from Various Sectors (tons/year)

		Emissions (tons/year)							
SN	**Sectors**	**CO**	**NOx**	**PM 10**	**VOC**	**SO2**	**BC**	**OC**	**CO2**
1	**Manufacturing Industries**	***96***	***440***	***39***	***34***	***4***	***23***	***12***	***16,689***
1.1	Food Beverages	36	165	18	12	2	11	6	6,403
1.2	Textiles	34	155	11	12	1	7	4	5,789
1.3	Wood, wood Products, Furniture	0	1	0	0	0	0	0	54
1.4	Paper and Paper Products	0	0	0	0	0	0	0	8
1.5	Publishing, Printing, and Reproduction of Recorded Media	5	23	2	2	0	1	0	858
1.6	Rubber and Plastics Products	2	10	1	1	0	0	0	377
1.7	Other Non-metallic Mineral Products	16	73	5	6	1	3	2	2,719
1.8	Others	3	13	1	1	0	1	0	482
2	**Commercial Sector**	***962***	***4,376***	***295***	***312***	***44***	***171***	***92***	***173,465***
2.1	Cinemas/Multiplexes	14	64	9	5	1	4	4	2,412
2.2	Hotels	305	1,368	77	79	15	44	25	59,102
2.3	Restaurants	168	772	55	62	7	33	17	28,913
2.4	Communication Service Providers	107	486	33	34	5	19	10	19,336
2.5	Financial Institutions (Banks/Cooperatives)	144	659	47	53	6	28	14	24,659
2.6	Residential Apartments	19	88	6	7	1	4	2	3,304
2.7	Educational Institutions	66	303	22	24	3	13	6	11,358
2.8	Shopping Malls, Supermarkets, and Other Commercial /Corporate Office Buildings	139	635	46	48	6	27	15	24,381
3	**Hospitals**	***70***	***320***	***23***	***26***	***3***	***14***	***7***	***11,975***
4	**GOs, NGOs, INGOs, and Diplomatic Missions**	***53***	***241***	***27***	***19***	***2***	***13***	***10***	***9,021***
4.1	Governmental Organizations (GOs)	31	144	19	11	1	9	8	5,389
4.2	International Nongovernmental Organizations (INGOs)	12	55	4	4	1	3	1	2,061
4.3	Nongovernmental Organizations (NGOs)	4	20	1	2	0	1	0	737
4.4	Diplomatic/Foreign Missions	5	22	2	2	0	1	0	835
	Total Emissions (tons/year)	**1,181**	**5,376**	**383**	**391**	**54**	**221**	**121**	**211,150**

4.3.1. Emissions Estimation for Black Carbon

The total estimated amount of BC emissions from various sectors in Kathmandu Valley in FY 2012/13 was 220 tons. There are no BC estimates for Kathmandu Valley in particular and it is difficult to put this in context. However, as part of the MACC/CityZEN EU projects (MACCity), anthropogenic BC emissions for Nepal are estimated at about 13 kilo tons from stoves, self-generation, boilers, fireplaces and vehicles amongst others (Granier et al. 2011; Diehl et al. 2012; Lamarque et al. 2010; van der Werf et al.

2006). This was used to roughly estimate BC emissions from diesel generators in the Valley between 25% and 77% of total BC emissions in the Valley (see Box 2).

In order to provide a reference for the scale of emissions from DG sets in the Kathmandu Valley, the total annual BC emissions estimate from other Asian cities are summarized in Table 4-3. Given that the population of the Kathmandu Valley is between10-20% of these megacities and with much fewer vehicles and industries, around 220 tons of BC per year does not seem to be an insignificant amount.

Table 4-3 Total Annual BC Emissions of Other Mega Cities in Asia (tons/year)

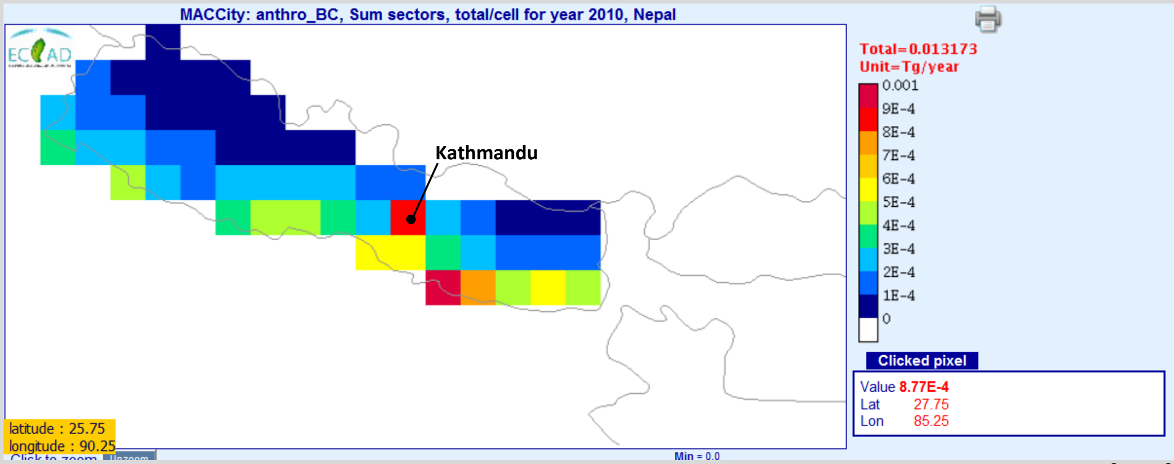
City	BC Emissions (metric tons)	Year of Emission	Reference
Beijing	7,700	2000	Yuan and Shao 2007[9]
Delhi	4,860	2006	Bano et al, 2011[10]
Karachi	6,700	2006-07	Dutkiewicz et al, 2009[11]

[9] YUAN, L. and SHAO, M., 2007, Estimation and prediction of black carbon emissions in Beijing City. *Chinese Science Bulletin*, **52**, pp. 1274–1281

[10] Bano et al, 2011, *Variation in aerosol black carbon concentration and its emission estimates at the mega-city Delhi*, International Journal of Remote Sensing, Volume 32, Issue 21, 2011 http://www.tandfonline.com/doi/abs/10.1080/01431161.2010.512943

[11] Dutkiewicz et al, 2009, *Black carbon aerosols in urban air in South Asia*, Atmospheric Environment Volume 43, Issue 10, March 2009, Pages 1737–1744

Box 2: MACCity (MACC/CityZEN EU projects) anthropogenic BC emissions for Nepal



The MACC/CityZEN EU projects (MACCity) data provides global BC emissions at a resolution of 0.5°x0.5° (equivalent to approximately 2,722km^2). As seen from the map above, the pixel within which Kathmandu is located (the red pixel) has total emissions (in 2010) of 877 tonnes. The distribution of emissions by sector shows that most of the BC emissions are from fuel combustion from the residential, commercial and other public service buildings (approximately 88%) followed by 7% from transport sector and 4% from industries.

The estimated BC emissions from diesel generators only in Kathmandu Valley are about a quarter of total emissions from the red pixel above (about 220 tonnes). This suggests that diesel generators could contribute significantly to BC emissions in the Valley. If it is assumed that all the BC emissions in the red pixel is from the Valley, then the estimated BC emissions from diesel generators is about 25% of total BC emissions. On the other hand, assuming the total BC emissions in the red pixel is evenly distributed within that pixel, total emissions in Kathmandu Valley could be a third of total emissions in the red pixel (about 287 tonnes). This is based on the fact that the land area of the Valley is about a third of the size of the red pixel above. Under these assumptions, estimated emissions from diesel generators could be as high as 77% of total BC emissions in Kathmandu Valley. This range can only be refined, however, following more extensive measurements and a detailed inventory of BC sources in the Kathmandu Valley .

NOTES ON MACCity

The MACCity dataset included all sectors except the combustion of agricultural waste (e.g., burning rice stubble) and biofuels (e.g., cow dung, charcoal). Anthropogenic emissions data were interpolated on a yearly basis between the base years 1990, 2000, 2005 and 2010. For the years 2005 and 2010, the RCP 8.5 emissions scenario was chosen.

MACC (Monitoring Atmospheric Composition and Climate) is a pre-operational atmospheric service of the European Global Monitoring for Environment and Security (GMES) program now known as Copernicus. It provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead (see details here: http://www.gmes-atmosphere.eu/). CityZen was a 3-year (2008-2011) research project funded by the European Union's 7th Framework program about the effects of megacities and emission hot spots on their local, regional and global environment, regarding both air pollution and climate change (see details here http://cityzen-project.eu/).

MACCity data is available from http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_login.jsf .

The share of BC emissions from various sectors is presented in Figure 4-7.The commercial sector, the major contributor of BC from the operation of DG sets, contributes 77 percent of total BC emissions. The share of BC emissions for manufacturing industries is 10 percent, followed by hospitals (6 percent) and GOs, NGOs, INGOs and diplomatic missions (6 percent).

There are slight differences between the sectors' share of diesel consumption and their contribution to the total BC emissions. The emissions factor varies with the engine size which has a sharp transition at the capacity of 447 kW, beyond which the emissions factor becomes very low. On the other hand, the fuel consumption factor – fuel consumption per unit of power generated, is very high for small engines and levels out after the capacity is above 50kW. The BC emissions factor also varies with the ages of the generators, which adds to the complication. The difference between diesel consumption and BC emissions is most likely the result of a combination of the size and the age of the generators.

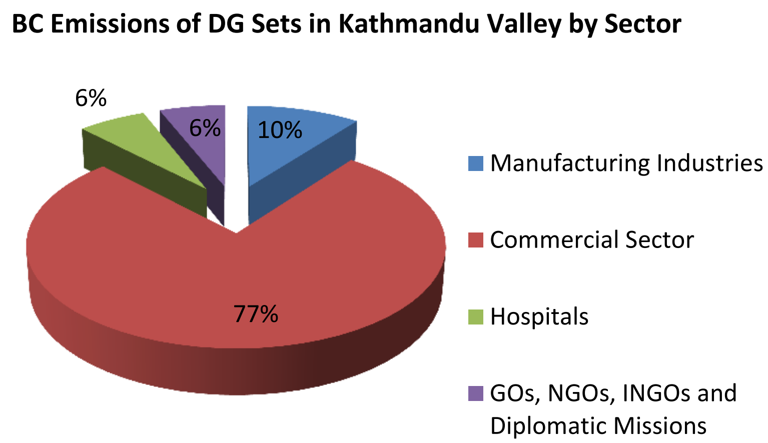


Figure 4-7 BC Emissions from Various Sectors in Kathmandu Valley

The total amount of BC emissions from manufacturing industries was 23 tons in FY 2012/13. The share of BC emissions for food and beverages was 48 percent, followed by textiles (29 percent), non-metallic mineral products (14 percent), publishing, printing, and reproduction of recorded media (4 percent), other (3 percent), rubber and plastics (2 percent), wood and wood products and furniture (0.27 percent), and paper and paper products (0.04 percent).

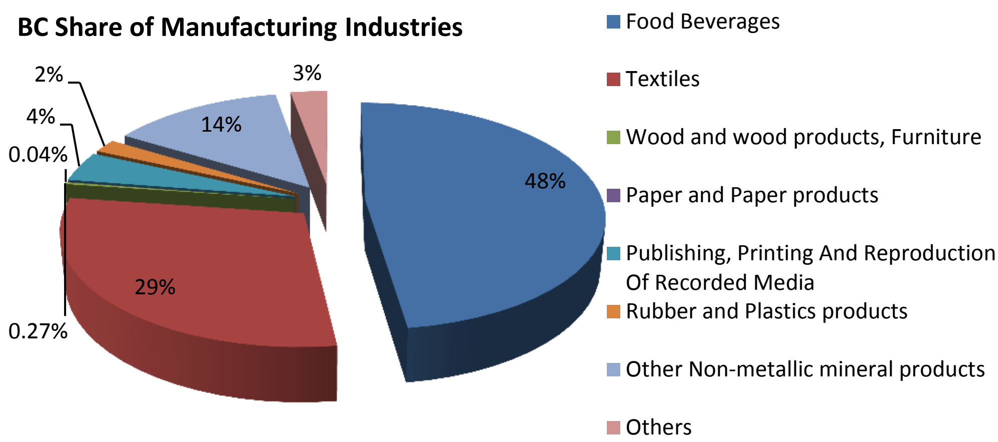


Figure 4-8 BC Emissions from Various Sub-sectors of Manufacturing Industries

The commercial sector is the largest emitter of BC, contributing 171 tons of black carbon per year. Hotels and restaurants account for 25 percent and 19 percent respectively, followed by financial institutions (16 percent), shopping malls, supermarkets, and other commercial/corporate office buildings (16 percent), communication service providers (8 percent), educational Institutions (8 percent), residential apartments (2 percent) and cinemas /multiplexes (2 percent).

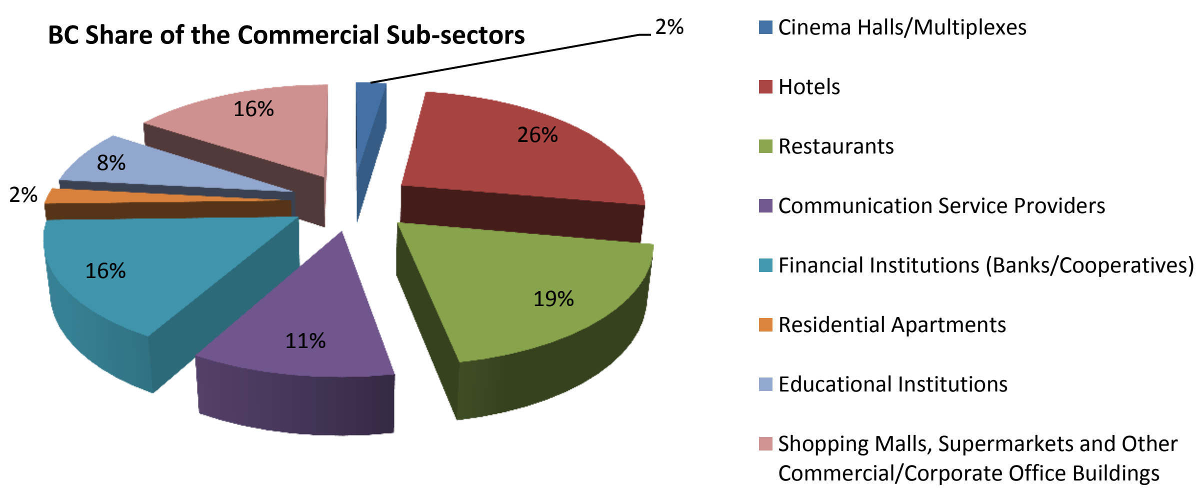


Figure 4-9 BC Emissions from Various Commercial Sub-sectors

The share of BC emissions from various sub-sectors of government/nongovernment buildings is shown in the Figure 4-10. Out of the 13 tons of BC emissions, GOs have the highest share of BC emissions (67 percent), followed by INGOs (19 percent), diplomatic missions (7 percent) and NGOs (6 percent).

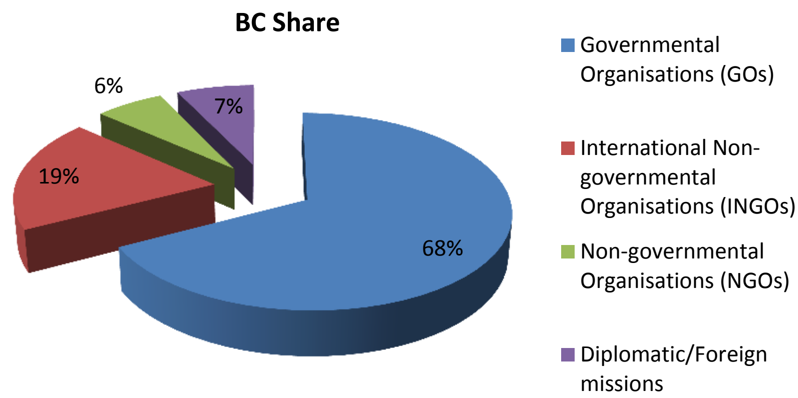


Figure 4-10 BC Emissions from Various Sub-sectors of Combined GOs, NGOs, INGOs, and Diplomatic Missions

Figure 4-11 depicts the seasonal analysis of BC emissions. Around 65 percent of total annual BC emissions in FY 2012/13 were released during the winter and the pre-monsoon season because of the comparatively prolonged power shortages during the dry seasons. The BC emissions were lowest during the monsoon season, accounting to only 17 percent of total annual emissions.

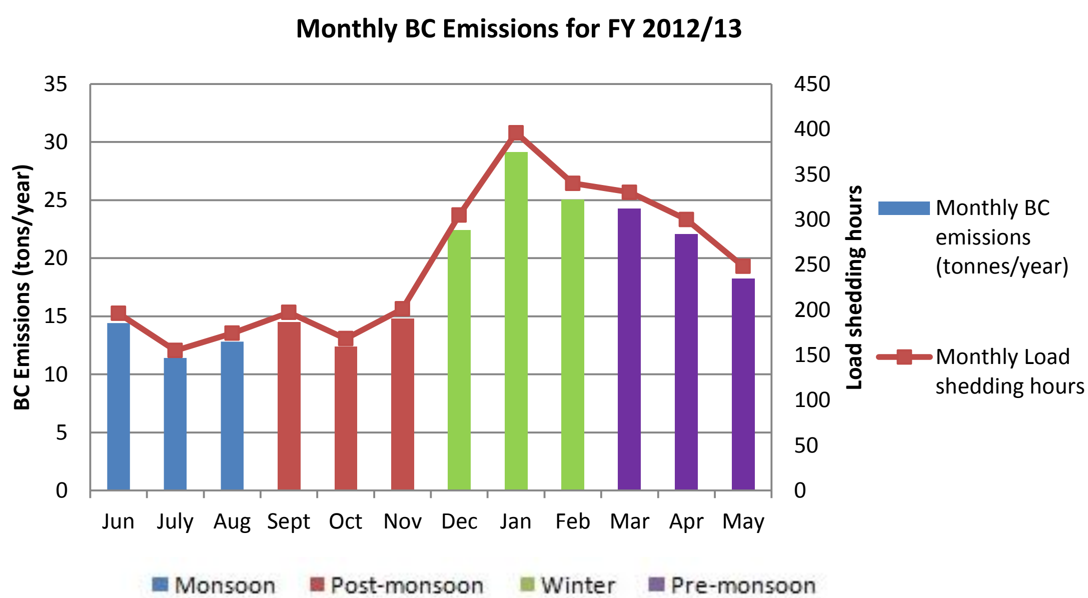


Figure 4-11 Monthly BC Emissions for FY 2012/13[12]

[12] The BC emissions are estimated based on load shedding hours using assumptions about how much generators are in operation during blackout periods.

4.3.2. Emissions Estimation for Other Pollutants

The estimated total annual emissions of CO, NOx, PM_{10}, SO_2, total VOCs, CO_2, and OC in FY 2012/13 were 1,200; 5,400; 380; 54; 390; 210,150; and 120 tons respectively. The proportional shares of the emissions of these polltants for all the sectors and sub-sectors are similar to the share of fuel consumption.

4.4. Assumptions and Data Limitations

This study is a first approximation of an inventory of DG sets in Kathmandu Valley and estimates of black carbon emissions in a data-poor environment. A number of assumptions were made to address the lack of country-specific data:

- The emission estimation is based on emission factors for diesel engines derived elsewhere. This does not represent the actual emissions characteristics of locally operated generators at general operating conditions with the quality of fuel sold in Kathmandu Valley. A better estimation can be obtained with the emission factor determined for the local DG sets and operating conditions.
- The specific fuel consumption rates obtained in the survey were inconsistent. Therefore consumption rates were obtained from the Indian manufacturers and used in the calculations of annual fuel consumption of the DG sets based on annual operating hours. The specific consumption rates obtained from the Indian manufacturers seem to be on the low side which may not be the case of the average specific fuel consumption of the DG sets operating in Nepal. Although real data on specific fuel consumption for each of the generator surveyed would have been ideal, a general fuel consumption characteristics obtained by testing DG sets operating locally could also produce sufficiently accurate results.
- The pollution control technologies employed in diesel generator sets are not known; as a result, the emissions reduction efficiency is set to zero and the emissions results represent "uncontrolled" emissions values. This may not be the actual case because the DGs operating in Nepal are newer with 90 percent of DG sets imported within the last seven years. This can produce significantly less emissions than estimated by the 'uncontrolled' emissions value.
- Recent population data was unavailable for a few sectors and sub-sectors for the year that emissions were estimated. For example the base year population data of manufacturing industries is for 2007/08, and without the information on the growth rate of these industries in Kathmandu Valley, extrapolation for 2012/13 was not possible.
- As this study was undertaken using simple random sampling and not grid-based method of sampling, spatial distribution of the emissions from DG sets could not be estimated.

5. CONCLUSIONS AND RECOMMENDATIONS

This is an initial effort to establish an inventory of DG set use in the Kathmandu Valley and makes a first order estimate of associated black carbon and other air emissions.

The study finds that DG sets are widely used for power generation in industrial, commercial, and non-commercial sectors due to power shortages that began in 2006. DG sets used two-thirds of the diesel sold in Kathmandu Valley in 2012/13, and they supplied 28 percent of the electricity and emitted as much as 220 tons of BC. DG set use and emissions are highest in the drier months of December-April. The commercial sector is the largest DG set user and, accordingly, the largest emitter of black carbon; the sector contributed about 77 percent of total emissions from captive DG sets. Manufacturing industries were the next largest source of BC. DG sets emit a range of other pollutants as well, including CO, NOx, PM_{10}, SO_2, total VOCs, CO_2, and OC.

This growth in DG set use has brought with it an increase in emissions of BC and other pollutants to the Kathmandu Valley, which is likely to continue as long as severe power shortages remain. Other work suggests that BC emissions are a contributing factor in the observed increase in the melting of some glaciers and snowpacks in parts of the Himalayan region, and this has implications for freshwater availability and seasonal droughts (U.S. EPA 2012). BC is likely to be responsible for a considerable part (around 30 percent according to some recent estimates) of the glacial retreat that has been observed in much of the Hindu-Kush-Himalayan region (ICIMOD 2011).

5.1. Recommendations for Future Work

The quality of the DG set inventory and BC estimations could be improved with:

1) Local measurements of BC and other air emissions from DG sets of different ages, operating under similar operating conditions and with similar fuels. Measurements should follow standardized protocols.
2) Better understanding of the fuel efficiency, maintenance, and application of emissions control techniques for DG sets in use in the Kathmandu Valley.
3) Understanding of the relative contribution of DG sets to total BC emissions in the Kathmandu Valley. Some information should be available from other sources (e.g., International Centre for Integrated Mountain Development and Institute for Advanced Sustainable Studies in 2014.)
4) A national DG inventory with calculations of BC and other air emissions. Any future inventory work should improve the spatial allocation of emissions, which can then be used in air quality modeling.

More detailed data that will better inform the role of diesel generators in Nepal's energy mix includes:

1) Types of generators that will be on the market in the next decade, their pollution controls, and the anticipated emissions profiles.

2) Typical and anticipated turnover rates for diesel generators, including projections of DG set that might be expected to be in operation, including and their emissions profiles over the next decade.
3) Alternative back-up power options that may be available in the next decade, delineated by sector.
4) Diesel fuel availability, quality, and market price expectations in the next decade.
5) Regulatory policies likely to be implemented and enforced in the next decade and the implications those of these will have on for both DG use and emissions.
6) Electrification plans and the likelihood of them being carried out, and how this will impact DG set use in the near future.

Annex H summarizes the institutional and regulatory frameworks for DG sets and their emissions. It is important that the government agencies responsible for collecting data on air pollution and energy access (i.e. Department of Environment and Alternative Energy Promotion Center of MoSTE, and Department of Electricity Development of MoE etc.) commit more resources to improving the data quality. With high quality data, policy makers and the general public can be better informed of the real cost of pollution, and viable policies designed and implemented.

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ANNEX A. GENERATOR DEALER SURVEY TEMPLATE

Name of the dealer:

Contact person:

Contact information:

Generator sets sales record:

Year*	**Fuel Type**	**Capacity (kW)**	**Brand**	**Numbers Sold**
	Diesel			
	Petrol			
	Kerosene			
Total				

Remarks:

* Annual sales data for at least the last five years.

ANNEX B. QUESTIONNAIRE FOR CITY-LEVEL SURVEY

General Information

Name of individual/institution/company:	
Type:	
Address:	
Contact information:	Name/Position: Email: Phone no.: Mobile no.:

DG Set and Fuel Consumption Information

Capacity of the DG set: _____kW

Brand: _____

Model: _____

Age/Date of purchase (month, year): _____________.

Operating days in a week: _________________________.

Operation hours of the business: ______-________

Average fuel consumption per hour: _____liters/hour

Average operating hours: Dry season ___________hrs/day Wet season _____hrs/day

Average monthly fuel usage:

Dry season:_____liters/month Wet season: _____liters/month

(*Note: For dry season (Poush-Chaitra): when load shedding at peak; and for wet season (Asar-Ashoj) when season load-shedding at minimum.)*

Electricity generation per liter of fuel: _____kWh or unit

Average Loading [% of the installed capacity]: Peak _____ Non peak _____

Capital cost of the generator: _____NRs.

Monthly operating cost of generator: _____NRs.

Average yearly maintenance cost: _____NRs.

Purpose of usage of generator:

Any application of air pollution control devices?

☐ Yes ☐ No If yes: ………………………………

Key reasons for and concerns of choosing diesel generator for power*

Sources of diesel supply: *

Remarks:

ANNEX C. DETAILS OF THE SAMPLING DESIGN OF THE CITY-LEVEL SURVEY

Sampling Design for City-level Survey: A simple random sampling method was adopted for the city-level survey. Sample sizes for each sector using DG sets) were calculated based on the population size, and samples were randomly selected. Given the different characteristics and power demands, each sector was treated as a separate population for this study. Each sector was further divided into sub-sectors, and representative samples were randomly selected from each sub-sector according to its population size. The population size is unevenly distributed in three districts (Kathmandu, Lalitpur, and Bhaktapur) in Kathmandu Valley. The sample size for each sector and sub-sector was therefore taken in proportion to the population distribution among the three districts.

Based on the preliminary investigation of DG dealers and discussion with key parties, the users of DG sets were broadly categorized into the following sectors:

i. Manufacturing: The population size and the list of manufacturing industries were obtained from the report, Census of Manufacturing Establishment 2006/07, published by the Central Bureau of Statistics. The city-level survey was focused on large manufacturing industries. Small manufacturing industries, which employ fewer than 10 people, are not included in the survey. From observations and a preliminary survey, it was found that small manufacturing industries generally use other alternative sources of electricity (e.g., backup batteries (inverters), solar power, and petrol generators). Food and beverage, textiles, wood products and furniture, paper and paper products, publishing and printing, and rubber and plastic products industries are the dominant manufacturing industries in Kathmandu Valley. Many of these large-scale industries are located in three industrial estates: Balaju, Patan, and Bhaktapur.
ii. Commercial: The commercial sector was further categorized into the following sub-sectors: (i) shopping malls/supermarkets; (ii) cinemas/multiplexes; (iii) hotels; (iv) Restaurants; (v) communication service providers; (vi) financial institutions (e.g., banks/cooperatives); (vii) residential apartments; (viii) education institutions (higher secondary/higher education); and (ix) other commercial/corporate office buildings. The survey on the commercial sector concentrated on the major commercial hubs in Kathmandu Valley, which are mostly within core city areas -- Durbarmarg, Jamal, Thamel, Pulchowk, Kalimati, Jawlakhel, Lagankhel, Baneshwor New Road, and Putalisadak. The commercial hubs of Bhaktapur, Kirtipur, and Madhyapur Thimi were also surveyed.
iii. Government/NGOs/INGOs/Diplomatic Missions: This sector included office buildings of government agencies, NGOs, INGOs, and diplomatic missions.
iv. Hospitals: Data from hospitals in Kathmandu Valley were obtained from the Ministry of Health and Population. The hospitals were further categorized into hospitals with greater than and fewer than 50 beds.

From the preliminary surveys and the discussion with generator set dealers and other key parties, it was found that the backup battery/inverter, solar, and petrol/kerosene generator sets (which are generally less than 5 kW) are generally used in households and small shops. The survey therefore excluded the following small commercial and non-commercial sectors in the city-level sampling:

- Small manufacturing industries (which have fewer than 10 employees).
- Residential buildings (except commercial residential apartments).
- Shops, minimarts, and other small commercial sectors and service providers.
- Small clinics and pharmacies.
- Primary and secondary schools.

Sampling Unit: The sampling unit for the survey was users of generator sets. The respondents were DG sets operators or managers who are directly involved in the operation and procurement of generator sets.

Sample Size: Due to the lack of concrete information regarding the distribution of DG sets and the different characteristics of each categorized sector, each sector was treated as a separate population for sampling purposes (rather than as a strata). The required sample size for each sector was calculated using the following formula:

$$SS = p\,(1-p) * (Z/E)^2$$

Where,
SS = Sample Size, or the number of responses required to be sure that the answers truly reflect the population.
p = Sample Proportion, or the percentage of the sample that uses a generator. The worst case is 50%, and that should be used to determine the level of accuracy for a sample.
Z = Z-value (e.g., 1.96 at the 95% confidence level)
E = Margin of Error, or a measure of the variation within the data. The smaller this value, the more uniform the data.

Confidence level = A percentage representing how often the true percentage of the population that would pick an answer would lie in the confidence interval.

For finite populations, the sample size was estimated as follow:

$$\text{new SS} = SS/(1+((SS-1)/pop))$$

Where,
pop = population

With a 95 percent confidence level and a 5 percent margin of error, the calculated sample size for each sector is provided in Table C-1.

Table C-1 Sample Sizes for the City-level Survey

	Sectors	Population size	Sample size	Sources of population size
1	**Manufacturing Industries**	**798**	**260**	Central Bureau of Statistics (Census of Manufacturing Establishment 2006/07)
1.1	Food Beverages	44	14	
1.2	Textiles	393	128	
1.3	Wood and Wood Products, Furniture	71	23	
1.4	Paper and Paper Products	15	5	
1.5	Publishing, Printing, and Reproduction Of Recorded Media	35	11	
1.6	Rubber and Plastics Products	37	12	
1.7	Other Non-metallic Mineral Products	96	31	
1.8	Others	107	35	
2	**Commercial Sectors**	**3,863**	**350**	
2.1	Cinemas /Multiplexes	22	2	Ministry of Information and Communication/Film Development Board
2.2	Hotels	503	42	Ministry of Culture, Tourism and Civil Aviation
2.3	Restaurants	1,600	134	Restaurant and Bar Association Nepal (Estimated)
2.4	Communication Service Providers	130	11	Ministry of Information and Communication; Nepal Telecommunication Authority; Nepal Cable Network Associations etc.
2.5	Financial Institutions (Banks/Cooperatives)	588	49	Nepal Rastra Bank
2.6	Residential Apartments	35	3	Nepal Land and Housing Developers Association; Department of Urban Development and Building Construction, Kathmandu Division Office
2.7	Educational Institutions	785	66	Ministry of Education
2.8	Shopping Malls, Supermarkets, and Other Commercial/Corporate Office Buildings	200	17	Kathmandu Metropolitan City; Lalitpur Sub-metropolitan City; Kathmandu Valley Town Development Committee (Estimated)
3	**Hospitals**	**129**	**48**	Ministry of Health and Population
3.1	Hospitals with 50 or 50+ beds	86	32	
3.2	Hospitals with fewer than 50 beds	43	16	
4	**Government/NGOs/INGOs/Diplomatic Missions**	**882**	**268**	
4.1	Governmental Organizations (GOs)	188	57	Relevant Ministries; Department of Information
4.2	International Nongovernmental Organizations(INGOs)	206	63	Social Welfare Council

4.3	Nongovernmental Organizations (NGOs)	460	140	Social Welfare Council (only active NGOs)
4.4	Diplomatic/Foreign Missions	28	9	Ministry of Foreign Affairs
	Total	**5,672**	**926**	

Collection of primary data from the city-level survey: A total of 15 people were selected to conduct the survey at the city level. The survey team was mobilized in three different districts to various areas to conduct the survey. Prior to this, the survey team received an orientation on the background and objectives of the study. They were trained on whom to approach for the survey and how to deal with and generate information from respondents. They were also given an orientation and explanation on each question on the survey form. Pilot surveys were also conducted.

ANNEX D. ANNUAL SALES OF PETROLEUM PRODUCTS (IN KL) IN NEPAL (FY 1993/94-2012/13)

Fiscal Year (AD)	Petrol	Diesel	Kerosene	ATF
1993/94	31061	195689	162157	30650
1994/95	34983	226622	180900	37524
1995/96	41193	250500	208715	40619
1996/97	44709	257910	243810	47864
1997/98	46939	300604	282026	51412
1998/99	49994	315780	294982	55549
1999/00	55589	310561	331120	56849
2000/01	59245	326060	316381	63130
2001/02	63271	286233	386592	47452
2002/03	67456	299973.11	348620.07	52839.38
2003/04	67586	299729.65	310826.23	64041
2004/05	75989	315368	239328	66825
2005/06	80989	294329	226637	64335
2006/07	101911.81	306687.21	197849.54	63777.85
2007/08	100841.52	302706.41	155215.47	68938.21
2008/09	124169.37	466467.8	70089.22	69525.17
2009/10	162274.4	612504.98	55788.29	82631.02
2010/11	187640.52	644127.59	49494.77	101314.14
2011/12	199748.62	648512.95	41807.94	109808.25
2012/13	221676	716747	24721	115786

Source: Nepal Oil Corporation

ANNEX E. MONTHLY DIESEL SALES (IN KL) IN KATHMANDU VALLEY-THANKOT DEPOT (FY 2007/08-2011/12)

Fiscal Year (AD)	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13
Shrawan (Jul-Aug)	3976	4245.8	5650	6681	6805	6389
Bhadra (Aug-Sep)	3421	5552.6	6489	6955	6805	7333
Ashoj (Sep-Oct)	4642	6315.5	6174	7918	6997	7744
Kartik (Oct-Nov)	3564	5883	7099	7381	8289	5935
Mangsir (Nov-Dec)	4501	8060.42	7327.1	8165.5	8102.5	7711
Poush (Dec-Jan)	5311	7871.2	7950.2	9772	7638.8	7617
Magh (Jan-Feb)	4807.7	7611.6	9360.4	9668	8981.6	8191
Falgun (Feb-Mar)	7496.44	8900.2	8724	11097	10043.2	7997
Chaitra (Mar-Apr)	6850.6	9270.4	9699.2	10239	10571.5	8926
Baishak (Apr-May)	5466.525	7801.8	7876	9195	9205	8564
Jestha (May-Jun)	5179.74	6921	8803	10390.5	9381	7916
Ashad (Jun-Jul)	4012.84	6257.718	8640	7784.6	10316.6	7243
Total	**59228.845**	**84691.238**	**93791.9**	**105246.6**	**103136.2**	**91565**

Note: There are two depots which supply petroleum products to Kathmandu Valley -- Thankot and Amlekhgunj. This data contains monthly sales figures for the Thankot depot. The Amlekhgunj depot supplies a comparatively small amount of diesel to Kathmandu Valley. (Source: Nepal Oil Corporation.)

ANNEX F. IMPORT DATA OF ELECTRIC GENERATORS (FY 2008/09-2011/12)

[85016100] -- AC Generators of an Output Not Exceeding 75 kW

.	Country	2008-09			2009-10		2010-11		2011-12	
		Qty		Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	Bangladesh	-	-	-	-	-	-	-	1	834,514
2	China	-	-	-	525	12,946,957	981	11,651,249	394	25,807,148
3	China	-	-	3,919,320	-	-	-	-	-	-
4	Germany	-	-	-	-	-	1	241,365	-	-
5	Hong Kong (China)	-	-	44,290	-	-	-	-	-	-
6	India	-	-	-	3,079	34,851,057	3,370	35,602,721	867	44,625,087
7	India	-	-	32,367,777	-	-	-	-	-	-
8	Italy	-	-	-	1	1,006,327	-	-	1	177,311
9	Japan	-	-	-	-	-	8	670,159	5	5,996,111
10	Qatar	-	-	-	-	-	-	-	3	57,119
11	Singapore	-	-	32,382	-	-	-	-	-	-
12	Taiwan (China)	-	-	-	-	-	1	565,094	-	-
13	U.A.E.	-	-	7,332,088	-	-	-	-	-	-
14	U.K.	-	-	-	1	812,168	-	-	-	-
15	U.S.A.	-	-	-	-	-	1	1,529	-	-
	Total :		**-**	**43,695,857**	**3,606**	**49,616,509**	**4,362**	**48,732,117**	**1,271**	**77,497,290**

[85016200] -- AC Generator of an Output Exceeding 75 kW but Not Exceeding 375 kW

.	Country	2008-09			2009-10		2010-11		2011-12	
		Qty		Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	China	-	-	-	346	4,500,738	13	9,647,831	11	1,472,543
2	China.	-	-	20,001	-	-	-	-	-	-
3	India	-	-	-	30	8,310,361	60	10,448,331	53	13,746,064
4	India	-	-	20,351,211	35	1,985,559	-	-	-	-

5	Japan	-	-	2,354,252	-	-	-	-	-	-
	Total :		**-**	**22,725,464**	**411**	**14,796,658**	**73**	**20,096,162**	**64**	**15,218,607**

[85016300] -- AC Generators (Alternators) of an Output Exceeding 375 kW but Not Exceeding 750 kW

.	Country		2008-09		2009-10		2010-11		2011-12	
			Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	China	-	-	2,914,048	-	-	-	-	-	-
2	China	-	-	-	-	-	554	2,180,386	1	874,432
3	Germany	-	-	795,931	-	-	-	-	-	-
4	India	-	-	21,522,805	-	-	-	-	-	-
5	India	-	-	-	21	9,025,619	8	9,489,994	54	6,272,546
6	Japan	-	-	-	1	8,815,046	-	-	-	-
7	U.K.	-	-	-	-	-	1	4,797,488	-	-
	Total :		**-**	**25,232,784**	**22**	**17,840,665**	**563**	**16,467,868**	**55**	**7,146,978**

[85016400] -- AC Generators of an Output Exceeding 750 kW

.	Country		2008-09		2009-10		2010-11		2011-12	
			Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	China	-	-	-	66	3,190,342	-	-	-	-
2	China	-	-	2,289,194	-	-	-	-	-	-
3	Germany	-	-	13,740,393	-	-	-	-	-	-
4	India	-	-	-	7,208	205,046,979	826	82,125,440	1,246	105,257,900
5	India	-	-	18,062,727	-	-	-	-	-	-
6	Japan	-	-	135,162	-	-	-	-	-	-
7	Singapore	-	-	-	-	-	-	-	1	119,791
8	Singapore	-	-	287,294	-	-	-	-	-	-
9	Sweden	-	-	-	-	-	-	-	14	225,771
10	U.A.E.	-	-	925,849	-	-	-	-	-	-
11	U.K.	-	-	44,341	-	-	-	-	-	-
	Total :		**-**	**35,484,960**	**7,274**	**208,237,321**	**826**	**82,125,440**	**1,261**	**105,603,462**

[85021100] -- Generating Sets with Compression Ignition Internal Combustion Piston Engines (Diesel Engines) of an Output Not Exceeding 75kW

.	Country	2008-09			2009-10		2010-11		2011-12	
		Qty		Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	Australia	-	-	5,878,682	-	-	-	-	-	-
2	Brazil	-	-	-	-	-	1	1,294,625	-	-
3	China	-	-	-	8,104	77,343,608	3,498	146,311,168	3,475	130,048,901
4	China	-	-	56,840,194	-	-	-	-	-	-
5	France	-	-	-	-	-	2	1,764,465	-	-
6	Germany	-	-	-	26	23,678,727	20	18,542,504	-	-
7	India	-	-	-	25,845	769,781,400	33,346	949,882,682	14,315	701,536,034
8	India	-	-	869,683,520	23	807,564	-	-	-	-
9	Indonesia	-	-	-	-	-	6	3,095,956	4	2,621,796
10	Italy	-	-	-	-	-	1	1,561,871	-	-
11	Italy	-	-	4,610,100	-	-	-	-	-	-
12	Japan	-	-	-	638	104,464,551	299	62,863,658	173	41,940,313
13	Japan	-	-	106,059,986	-	-	-	-	-	-
14	Korea R	-	-	326,727	-	-	-	-	-	-
15	Korea R	-	-	-	-	-	2	87,356	-	-
16	Singapore	-	-	-	31	3,994,584	-	-	19	102,459
17	Singapore	-	-	3,804,417	-	-	-	-	-	-
18	Switzerland	-	-	-	-	-	1	345,910	-	-
19	Thailand	-	-	-	-	-	-	-	2	11,953,531
20	Turkey	-	-	-	-	-	1	980,080	5	996,810
21	U.A.E.	-	-	2,091,337	-	-	-	-	-	-
22	U.A.E.	-	-	-	-	-	161	96,427,771	-	-
23	U.K.	-	-	22,802,157	-	-	-	-	-	-
24	U.K.	-	-	-	9	5,712,834	3	2,301,119	-	-
25	Vietnam	-	-	22,037,575	-	-	-	-	-	-
26	Vietnam	-	-	-	-	-	12	2,801,178	40	6,356,394
Total :			**-**	**1,094,134,695**	**34,676**	**985,783,268**	**37,353**	**1,288,260,343**	**18,033**	**895,556,238**

[85021200] -- Generating Sets with Compression Ignition Internal Combustion Piston Engines (Diesel or Semi-diesel) of an Output Exceeding 75 kW but Not Exceeding 375kW

	Country	2008-09			2009-10		2010-11		2011-12	
		Qty		Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	China	-	-	14,380,673	-	-	-	-	-	-
2	China	-	-	-	10	9,888,011	7	6,283,256	15	15,171,851
3	Denmark	-	-	-	-	-	1	971,056	-	-
4	Germany	-	-	1,438,800	-	-	-	-	-	-
5	Germany	-	-	-	-	-	3	4,194,676	5	16,646,882
6	India	-	-	-	76,479	209,166,992	98	108,557,164	122	152,022,098
7	India	-	-	294,385,377	-	-	-	-	-	-
8	Italy	-	-	-	-	-	-	-	54	114,414,963
9	Japan	-	-	-	9	15,595,080	1	1,343,732	2	11,321,705
10	Singapore	-	-	-	1	1,712,152	-	-	-	-
11	Singapore	-	-	4,079,580	-	-	-	-	-	-
12	Spain	-	-	952,372	-	-	-	-	-	-
13	Turkey	-	-	-	-	-	5	8,437,437	2	1,871,339
14	U.K.	-	-	-	19	21,802,160	3	5,113,256	4	7,294,650
15	U.K.	-	-	23,718,884	-	-	-	-	-	-
	Total :		**-**	**338,955,686**	**76,518**	**258,164,395**	**118**	**134,900,577**	**204**	**318,743,488**

[85021300] -- Generating Sets with Compression Ignition Internal Combustion Engine of an Output Exceeding 375 kW

S.N.	Country	2008-09			2009-10		2010-11		2011-12	
		Qty		Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	China	-	-	16,303,025	-	-	-	-	-	-
2	China	-	-	-	251	16,688,196	14	9,686,446	10	129,832,960
3	France	-	-	-	-	-	6	70,485,812	-	-
4	Germany	-	-	-	-	-	9	13,957,565	-	-
5	India	-	-	-	19,960	278,788,141	12,432	256,496,158	181	361,843,604
6	India	-	-	265,249,264	-	-	-	-	-	-
7	Italy	-	-	-	-	-	-	-	5	26,121,571
8	Japan	-	-	-	28	2,347,141	14	16,990,731	-	-
9	Japan	-	-	25,310,668	-	-	-	-	-	-
10	Korea,	-	-	-	2	119,811,570	-	-	-	-
11	Malaysia	-	-	2,383,907	-	-	-	-	-	-
12	New Zealand	-	-	-	5	3,385,094	-	-	-	-
13	Singapore	-	-	-	-	-	5	112,063,401	-	-
14	Singapore	-	-	17,451,274	-	-	-	-	-	-
15	Turkey	-	-	-	-	-	2	1,643,465	-	-
16	U.K.	-	-	29,151,943	-	-	-	-	-	-
17	U.K.	-	-	-	29	36,322,705	3	4,964,142	3	12,799,563
18	U.S.A.	-	-	-	1	6,278,515	1	22,145,013	10	238,124,857
19	Vietnam	-	-	15,741,150	-	-	-	-	-	-
20	Vietnam	-	-	-	-	-	1	15,546,700	-	-
Total :			**-**	**371,591,231**	**20,276**	**463,621,362**	**12,487**	**523,979,433**	**209**	**768,722,555**

[85022000] -- Generating Sets Spark Ignition Internal Combustion Piston Engines

S.N.	Country	2008-09			2009-10		2010-11		2011-12	
		Qty		Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)	Qty	Value (NPR)
1	Australia	-	-	6,783,410	-	-	-	-	-	-
2	China	-	-	4,426,876	-	-	-	-	-	-
3	China	-	-	-	4,216	31,092,582	5,132	70,943,305	2,767	29,179,560
4	India	-	-	-	369	53,194,576	4,773	18,720,950	27	5,396,230
5	India	-	-	22,528,331	-	-	-	-	-	-
6	Japan	-	-	333,368	-	-	-	-	-	-
7	Japan	-	-	-	70	13,420,858	-	-	10	1,151,211
8	Switzerland	-	-	366,437	-	-	-	-	-	-
9	Turkey	-	-	-	-	-	-	-	140	3,684,133
10	U.A.E.	-	-	68,331	-	-	-	-	-	-
11	U.K.	-	-	3,020,740	-	-	-	-	-	-
12	U.K.	-	-	-	1	1,328,680	-	-	-	-
Total :			**-**	**37,527,493**	**4,656**	**99,036,696**	**9,905**	**89,664,255**	**2,944**	**39,411,134**

Source: Trade and Export Promotion Center.

ANNEX G. LIST OF MAJOR DG SETS DEALERS IN KATHMANDU VALLEY

	List of Major DG Sets Dealers in Kathmandu Valley			
	Dealers/Sellers	**Address**	**Contact no.**	**Brands**
1	Bhajuratna Agency (P) Ltd., Lazimpat	Lazimpat, Kathmandu	4411786, 4412112	Kubota, Airman
2	Bimal Sparks	Teku, Kathmandu	4228421	Jakson-Cummins
3	BS Trade International	Teku, Kathmandu	4246108, 425884	Mahindra, Robin
4	Buddha Power & Electronics Pvt Ltd	Putalisadak, Kathmandu	4226047	Kirloskar, Ashok Leyland
5	EIS Marketing Pvt. Ltd.	Baneshwor, Kathmandu	4468028, 4467491	Meeraco, Powermate (10 kW- 250 kW)
6	Elemech International P. Ltd.	New Baneshwar, Kathmandu	4780915, 4781874	Kirloskar, Robin
7	Engineering Marketing Concern	Teku, Kathmandu	4260196, 4260728	Ashok Leyland
8	H & O Distributors Pvt. Ltd.	Lazimpat, Kathmandu	4443618	Aksa
10	Himal Refrigeration & Electrical Industries Pvt. Ltd.	Teku, Kathmandu	4215595, 4244023	Kirloskar (12.5 kW-500 kW)
11	Infratech Pvt. Ltd.			Kohler (5 kW-3000 kW)
12	Kathmandu Diesel Concern	Teku, Kathmandu	4262363	Jakson-Cummins (7.5 kW-3000kW)
13	Kirloskar Generators Sterling Sales Co. Pvt. Ltd.	Naxal, Kathmandu	4443950, 4443952	Kirloskar
14	MAW Engineering P. Ltd.	Tripureshwar, Kathmandu	4261160	Yamaha, Integrated DG set controller (GCU 926)
15	New Shrestha Machinery Concern	Sundhara, Kathmandu	4228566, 4255653	Cummins, Perkins, AKSA (0.8 kW to 2500 kW)
16	Omni groups	Teku, Kathmandu	4228529, 4228651	Kipor
17	PowerTec International Pvt. Ltd.	Kamaladi, Kathmandu	4247323, 4246989	Sterling Generators with Perkins engine, PAIKANE with Perkin engine
18	Reliable Tech	Pulchowk , Lalitpur	2042073	Kipor
19	Risik Automobiles Pvt. Ltd.		5555889, 5555890	Yamaha
20	RMS International			Kirloskar, Ashok Leyland
22	Tractors Nepal Ltd (TIL), Caterpillar's Nepal region dealer	Soaltee Mode, Kathmandu	4281749	Caterpillar
23	Universal Trading Center		4255563	Eishin
24	Vishal Tradelink	Balkumari, Lalitpur	4601172, 4600674	Kirloskar

ANNEX H. REGULATIONS, POLICY MEASURES, AND INSTITUTIONAL STRUCTURE

This annex briefly describes the policies and regulations related to the operation of diesel generator sets and emissions control measures. It includes the major regulators and stakeholders concerned with regulating and monitoring the operation of DG sets.

Key Regulators, Stakeholders, and Institutional Structure

Ministry of Science, Technology, and Environment (MoSTE) is the agency responsible for formulating environmental policies/regulations and protection of the environment. It is the focal point to the United Nations Framework Convention on Climate Change (UNFCCC). Nepal ratified the Kyoto Protocol in 2005 and is a party to the UNFCCC.. The Climate Change Management Division in the MoSTE oversees all climate-change-related matters in coordination with other agencies and departments, and oversees the mitigation of greenhouse gases and air pollutants (including black carbon). **The Department of Environment** under MoSTE was established recently by cabinet decision on July 27, 2012, and is primarily mandated to implement and monitor activities that are directly or indirectly related to environmental pollutions. As a result, MoSTE is also an apex agency that formulates emissions standards and monitors emissions for ambient air quality. In 2012, it established the National Ambient Air Quality Standard (NAAQS) and the National Diesel Generators Emission Standard (NDGES).

Figure H-1 outlines MoSTE's organizational structure.

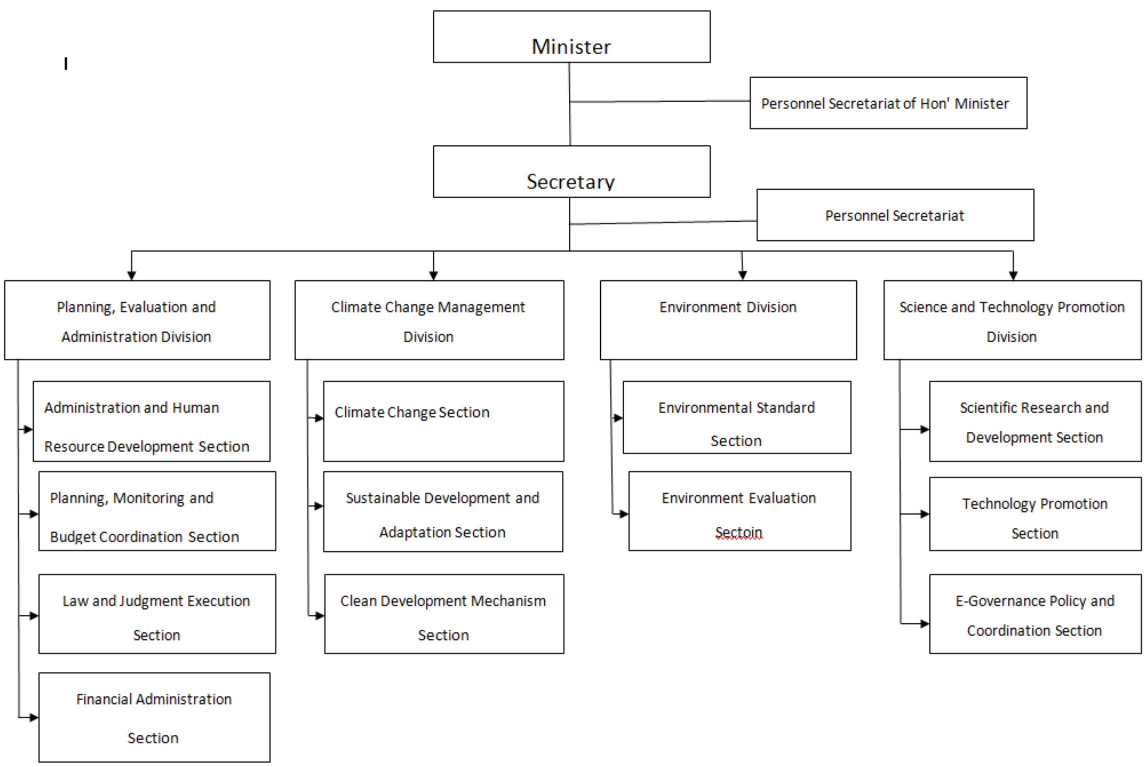

Figure H-1 Organizational Structure of MoSTE[13]

[13]MoSTE website (See*: http://moste.gov.np/ministry/organogram*)

Alternative Energy Promotion Centre (AEPC) is a government institution established in 1996 under the MoSTE with the objective of developing and promoting renewable/alternative energy technologies in Nepal. This is the key agency that explores and promotes alternative source of energy/electricity. Policies formulated at the ministerial level are implemented at the local level by the authorities and departments. Since air quality is linked to different sources (e.g., industry, transport, energy), the formulation of air quality management policies and regulations, and their implementation, requires a coordinated effort among different ministries and departments.

Ministry of Commerce and Supply (MoCS) is responsible for the formulation, implementation, monitoring, and evaluation of policies, plans, and programs relating to commerce, trade, and supply. It is responsible for ensuring the continuous and cost-effective import, storage, and supply of petroleum products. It is also responsible for quality, market, and price controls so that public has effective, efficient, and equitable access to petroleum products. **Nepal Oil Corporation** is a state-owned trading company under MoCS that deals with the import, transport, storage, and distribution of various petroleum products in Nepal. The company is also responsible for regulating and monitoring fuel quality, and for adjusting fuel prices according to international market prices. The **Trade and Export Promotion Center**, meanwhile, promotes trade and exports. It also keeps the records of goods imported into and exported from Nepal.

Ministry of Finance (MoF) is an apex body that formulates economic policy, regulates markets, and is responsible for financial administration. The **Department of Customs** is under the Ministry of Finance; it facilitates trade and industry, ensures compliance, and collects revenues to be paid to the government. It is thus the responsible agency for keeping track of DG sets imported into Nepal and for collecting custom duties on these imports. The department is also responsible for implementing the emissions standards set by MoSTE (i.e., only allowing imports of DG sets that comply with emissions standards).

Ministry of Energy (MoE) is another apex agency; it is tasked with developing policies, plans, and implementation strategies for conservation, regulation, and utilization of energy. The **Department of Electricity Development** is responsible for assisting the ministry in implementing overall government policies related to the power/electricity sector. The **Nepal Electricity Authority (NEA)** is a governmental organization under the ministry with an objective to generate, transmit, and distribute adequate, reliable, and affordable power by planning, constructing, operating, and maintaining all generation, transmission, and distribution facilities in Nepal's power system -- both interconnected and isolated. It also recommends to the long and short- term plans and policies for the power sector.

Leading Manufacturers, Associations, and Importers

There are no manufacturers of diesel generator sets in Nepal. The DG sets are imported from India, China, and other countries.

There are over 60 importers/dealers/sellers of DG sets in the Kathmandu Valley selling over 50 different brands of DG sets. Unlike in other sectors, there is no association of DG sets importers or dealers. The major dealers of DG sets in Kathmandu Valley are listed in Annex F.

Pollution Control Measures and Regulations

The other fuels imported to Nepal include petrol, kerosene, aviation turbine fuel, and liquefied petroleum gas. The quality of petrol imported into Nepal is equivalent to Euro III standards.

National Ambient Air Quality Standard, 2012

The Government of Nepal adopted its first National Ambient Air Quality Standards (NAAQS) in 2003. The Ministry of Science Technology and Environment (MoSTE) recently published the revised NAAQS.

Table H-1 National Ambient Air Quality Standard, 2012

Parameters	Time Weighted Average	Concentration max (μg/m^3)	Test Methods
TSP	Annual	-	
	24-hours*	230	High Volume Sampling and Gravimetric Analysis
PM_{10}	Annual	-	
	24-hours*	120	High Volume Sampling and Gravimetric Analysis, TOEM, Beta Attenuation
SO_2	Annual**	50	Ultraviolet Fluorescence, West and Gaeke Method
	24-Hours*	70	Same as Annual
NO_2	Annual	40	Chemiluminescence
	24-hours*	80	Same as annual
CO	8-hours*	10,000	Non-dispersive Infrared Spectrophotometer
Lead	Annual**	0.5	High Volume Sampling followed by Atomic Absorption Spectrometry
Benzene	Annual**	5	Gas Chromatographic Technique
$PM_{2.5}$	24-hours*	40	PM2.5 Sampling Gravimetric Analysis
Ozone	8-hours*	157	UV Spectrophotometer

Notes:

*The 24-hour and 8-hour values shall be met 95 percent of the time in a year. The standard may be exceeded 18 days per calendar year, but not on two consecutive days.

** Yearly average of any specific area shall be calculated from at least 104 readings taken twice a week for 24 hours, or the same interval of time for a week.

National Diesel Generator Emission Standard, 2012

The MoSTE introduced in October 2012 the National Diesel Generator Emission Standard (NDGES) for new and in-use diesel generators with a capacity of 8 kW-560 kW (under the 1997 Environment Protection Act). In doing so they followed the Indian standards for construction equipment rather than for diesel gensets. Hence the Nepal emission standards for new and in-use diesel gensets are less stringent than in India. The emissions standards set for new diesel generator imports is equivalent to Bharat Stage III standards and, for in-use diesel generators, is equivalent to Bharat Stage II. The emissions limits are set for four major pollutants: CO, HC, NOx, and PM. The emissions limit for PM for new DG sets less than 19 kW is 0.80 g/kWh; for 19 to <37 kW, the emissions limit is 0.60 g/kWh; for 37 to <75, it is 0.40 g/kWh; for 75 to <130 kW, it is 0.30 g/kWh; and for 130 to <560 kW, it is 0.20 g/kWh. MoSTE has not yet been able to monitor the compliance of emissions standards for new and in-use DG sets.

Table H-2 National Diesel Generators Emissions Standard, 2012

1. Emissions Limits (g/kWh) for Imports of New Diesel Generators

Category (kW)	CO	HC+NO_x	PM
kW< 8	8.00	7.50	0.80
8 = kW <19	6.60	7.50	0.80
19 = kW <37	5.50	7.50	0.60
37 = kW <75	5.00	4.70	0.40
75 = kW <130	5.00	4.00	0.30
130 = kW <560	3.50	4.00	0.20

Note: This standard is equivalent to Bharat III standards.

2. Emissions Limits (g/kWh) for In-use DG Sets

Category (kW)	**CO**	**HC**	**NO_x**	**PM**
kW< 8	8.00	1.30	9.20	1.00
8 = kW <19	6.60	1.30	9.20	0.85
19 = kW <37	6.50	1.30	9.20	0.85
37 = kW <75	6.50	1.30	9.20	0.85
75 = kW <130	5.00	1.30	9.20	0.70
130 = kW <560	5.00	1.30	9.20	0.54

Note: This standard is equivalent to Bharat II standards.

a) *Sampling collection point should be located at one-third of the DG set stack height.*
b) *kW= Power Factor * kW*
c) *Testing Methodology: Should be according to ISO 8178 or equivalent to ISO 8178 standard set by the manufacturing country.*

Source: MoSTE

Most of the generators imported into Nepal are manufactured in India. The Central Pollution Control Board of India's Ministry of Environment and Forests formulated amended emissions limits for new diesel engines in 2008 (under the Environment Protection Act of 1987). Manufactures are not obliged to comply with the emissions standards, however, for diesel engines that are manufactured for export. Thus, the DG sets that are imported into Nepal may not necessarily have to comply with Indian emissions standards for diesel gensets.

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