ENVIRONMENT IMPACTS OF ENERGY SECTOR (NON-RENEWABLE)

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Training schedule for environment audit of infrastructure and renewable energy projects (9th to 13th March, 2015)
Non-renewable energy sources

- Non-renewable energy is energy from fossil fuels such as **coal**, **crude oil**, **natural gas** and **uranium**.
- Fossil fuels are mainly made up of Carbon.
Usage of non-renewable energy resources

Top 10 Petroleum Consumers:

1. United States
2. China
3. Japan
4. India
5. Russia
6. Brazil
7. Saudi Arabia
8. Canada
9. Germany
10. South Korea

Source: November 15, 2014: www.globalpost.com
Usage of non-renewable energy resources

Top 10 Natural Gas Consumers:

1. United States
2. Russia
3. Iran
4. China
5. Japan
6. Saudi Arabia
7. Germany
8. Canada
9. Italy
10. United Kingdom

Usage of non-renewable energy resources

Top 10 Coal Consumers:

1. China
2. United States
3. India
4. Russia
5. Germany
6. South Africa
7. Japan
8. Australia
9. Poland
10. South Korea

The energy sector is the major contributor to economic and industrial accomplishments as well as a pre-requisite for providing the basic human needs.

In India, the main source of electricity generation is coal, which contributes to about ~56% of the electricity generation, whereas natural gas also contributes a significant ~10% towards electricity generation.
## Overview of installed generation capacity of power in India

<table>
<thead>
<tr>
<th>REGION</th>
<th>Installed capacity (MW)</th>
<th>Thermal</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>COAL</td>
<td>GAS</td>
<td>DSL</td>
<td>TOTAL</td>
<td>Nuclear</td>
<td>HYDRO</td>
<td>RES*</td>
<td>TOTAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern</td>
<td></td>
<td>29924</td>
<td>4671</td>
<td>13</td>
<td>34608</td>
<td>1620</td>
<td>15424</td>
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<td>56089</td>
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</tr>
<tr>
<td>Western</td>
<td></td>
<td>42479</td>
<td>8255</td>
<td>17</td>
<td>50752</td>
<td>1840</td>
<td>7448</td>
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<td>68186</td>
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<td>Southern</td>
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<td>23032</td>
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<td>939</td>
<td>28935</td>
<td>1320</td>
<td>11338</td>
<td>11769</td>
<td>53362</td>
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<tr>
<td>Eastern</td>
<td></td>
<td>22338</td>
<td>190</td>
<td>17</td>
<td>2254</td>
<td>0</td>
<td>3882</td>
<td>411</td>
<td>26838</td>
<td></td>
<td></td>
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<tr>
<td>N. Eastern</td>
<td></td>
<td>60</td>
<td>824</td>
<td>143</td>
<td>1027</td>
<td>0</td>
<td>1200</td>
<td>228</td>
<td>2455</td>
<td></td>
<td></td>
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<tr>
<td>Islands</td>
<td></td>
<td>-</td>
<td>-</td>
<td>70</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>76</td>
<td></td>
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<tr>
<td>All India</td>
<td></td>
<td>117833</td>
<td>18903</td>
<td>1199</td>
<td>117646</td>
<td>4780</td>
<td>39291</td>
<td>24998</td>
<td>207006</td>
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</tr>
</tbody>
</table>

*RES - Renewable Energy Sources includes Small Hydro Project(SHP), Biomass Gas(BG), Biomass Power(BP), Urban & Industrial waste Power(U&I), and Wind Energy categorized by Ministry of New and Renewable Energy, Govt. of India.

Source: CEA, 2012
Overview of installed generation capacity of power in India

- COAL: 57%
- Hydro: 19%
- RES: 12%
- GAS: 9%
- Nuclear: 2%
- DSL: 1%
Classifying the impacts of energy use

- By source
  - For example, oil, natural gas, coal, nuclear power, biomass, hydroelectricity etc.

- By pollutant
  - Pb, CO, Nox, SOx, RSPM (PM$_1$, PM$_{2.5}$ and PM$_{10}$), SPM, HC, VOC, CH4 etc.

- By scale
  - Household scale
    - wood burning in developing countries
  - Workplace scale
    - Biomass harvesting and forestry
    - Hydro and wind power
    - Coal, oil and gas
    - Nuclear power
  - Community scale
    - Sulphur dioxide, NOx, CO, Dioxins etc.
  - Regional scale
    - Acid deposition
  - Global scale
    - Global climate change
Impact on human health
The impact pathway approach

EMISSIONS
(e.g. tonnes/year of SO$_2$)

DISPERSION
Increase in ambient concentrations
(e.g. ppb SO$_2$ for all affected regions)

IMPACT
(e.g. change in crop yield)

COST
Examples from thermal power

Case study
Life cycle assessment - a case study of thermal power plant
Methodology

- The CML 2001 and Eco-Indicator 99 (H) methods have been used for midpoint and endpoint impacts, respectively using life cycle analysis (LCA).
- This study uses ISO 14040 methodology along with ‘cradle to gate’ approach which includes upstream and power generation processes.
- The primary data collected by personal visits for air emissions, wastewater, fuel used, and technical specifications.
- The impacts category comprised of global warming, acidification, eutrophication, ecotoxicity, carcinogens, respiratory organics, respiratory inorganics and climate change.
Environmental impact assessment

Source: Eco indicator 1999-H method would be used for environmental impact assessment using LCA approach.
LCA framework used to estimate the life cycle environmental impacts from NGCC thermal power plant

Boundary conditions

Up-stream processes

- Natural gas extraction
  - Waste

- Natural gas treatment
  - Wastewater

- Natural gas transmission (not included in analysis)

Combustion Process

- Air Emissions
  - CH₄, CO₂, NOₓ, SO₂, PM₁₀

- Air Emissions
  - CH₄, CO₂, NOₓ, CO, PM₁₀, PM₂.₅

Power generation

- Wastewater
Boundary conditions

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- Natural gas extraction
  - Waste

- Natural gas treatment
  - Wastewater

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Combustion Process

- Air Emissions
  - CH₄, CO₂, NOₓ, SO₂, PM₁₀

- Air Emissions
  - CO₂, NOₓ, CO, PM₁₀, PM₂.₅

Power generation

- Wastewater
Global warming and climate change potential - NGCC thermal power plant

(a) Global Warming Potential (CML)

(b) Climate Change potential (Eco-Indicator)
Human health damage potential - NGCC

(a) Human Toxicity potential (CML 2001)

(b) Carcinogens potential (Eco-Indicator-99)

(c) Respiratory Inorganics potential (Eco-Indicator-99)

(d) Respiratory Organics potential (Eco-Indicator-99)
Global warming and climate change potential of 1 kWh electricity generation – Imported coal vs. natural gas
Human health damage potential

(a) Human Toxicity Impacts (CML 2001)

(b) Respiratory Inorganics Impacts (Eco-Indicator 99-H)

(c) Respiratory Organic Impacts (Eco-Indicator 99-H)

(d) Carcinogenic Impacts (Eco-Indicator 99-H)
(a) Acidification Impacts (CML 2001)

(b) Eutrophication Impacts (CML 2001)

(c) Acidification/ Eutrophication Impacts (Eco-Indicator 99-H)
(a) Fresh Water Aquatic Toxicity Impacts (CML 2001)

(b) Marine Water Aquatic Toxicity Impacts (CML 2001)

(c) Ecotoxicity impacts (Eco-Indicator 99-H)
Uncertainty analysis for imported coal with FGD vs. without FGD technology

Uncertainly analysis of 1 kWh ‘Electricity, hard coal, at power plant with FGD’ (A) minus 1 kWh ‘Electricity, natural gas, at power plant/CENTREL U’ (B),

Method: Eco-indicator 99 (H) V2.08/Europe El 99H/H, confidence interval: 95%
## Cost analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Coal based TPP</th>
<th>Gas based TPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Cost</td>
<td>Rs/kWh</td>
<td>1.55</td>
<td>1.54</td>
</tr>
<tr>
<td>Variable Cost</td>
<td>Rs/kWh</td>
<td>2.11</td>
<td>3.09</td>
</tr>
<tr>
<td>Total Cost</td>
<td>Rs/kWh</td>
<td>3.66</td>
<td>4.63</td>
</tr>
</tbody>
</table>


Bibliography

- http://www.eia.gov/todayinenergy/detail.cfm?id=18491
Case study

Impacts from transport sector
Energy demand and CO$_2$ emissions from urban on-road transport in Delhi: current and future projections under various policy measures

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**Abstract**

This work presents an analysis of road transportation in Delhi region with focus on energy demand and carbon dioxide (CO$_2$) emissions. The study has considered five scenarios for the year 2021: one business as usual, and four future alternative scenarios, with 2007 as the reference year. The alternative scenarios have been developed by considering the introduction of six policy interventions, namely: construction of integrated mass rapid transit system (IMRTS), fixed bus speed, hike in parking fees, fuel efficiency, stringent emission norms, and increase in the occupancy of private vehicles. An integrated Activity-Structure-Energy Intensity-Fuel Mix (ASIF) framework has been used to model, energy demand and CO$_2$ emissions. The outcome from the study shows that 2021-ALT-IV scenario gives the best-estimate results, which translated to ~32% reduction in annual energy demand than projected in 2021-BAU scenario. This reduces the daily per-capita energy requirement to 53 MJ in 2021-ALT-IV scenario, contributing to about 2.9 million tons of CO$_2$ emissions. This scenario further reduces fossil fuel demand by ~48% compared to 2021-BAU scenario; however, Delhi Metro will require a huge amount of electrical energy by the year 2021 making it inevitable to adopt cleaner electricity generation options in the near future. Therefore, the current study shows that shift to public transport use would not merely be sufficient to reduce energy demand, oil use and carbon emissions from passenger transport in urban areas of developing countries.
Introduction

Urbanization & transportation in Delhi

• Nine districts spread in an area of 1483 square kilometers (in 2011)
• Population is 16.75 million (2011) and projected to grow up to 23 million by 2020
• Largest road network with 7.49 million registered vehicles
• Current traffic volume 182.7 million PKM and projected to increase up to 280.9 million by 2021

Energy demand and CO₂ emissions

• Automobiles cause 66% of total transport-based carbon emissions in Delhi
• Ambient air pollutants from automobile violates NAAQS reflecting poor air quality and deteriorating human health
• Policy interventions till date focus more on controlling the ambient air emissions; while, the impact of urban transport on climate remains unrecognized (Aggarwal and Jain, 2014)
Scope of work & objectives

To assess the impact of transport policy interventions on energy demand and carbon emission in Delhi region; using ASIF energy modelling and scenario analysis approach

- Inventorizing and characterizing on-road vehicle activity
- Energy demand modeling
- Carbon emission accounting
- Future policy intervention using Scenario Analysis
Study area
ASI and ASF framework for estimation of energy demand and CO$_2$ emissions

Where, $E_{\text{Energy}}$ is energy demand from all modes of transport; $E_{\text{CO}_2\text{-emission}}$ is CO$_2$ emission load from all modes of transport; ‘$k$’ represents mode-type (scooter, motorcycle, cars, auto, bus and Delhi metro); ‘$j$’ represents vehicle technology (2/4 stroke); ‘$i$’ represents fuel type (gasoline/diesel/CNG); represents travel demand activity (in km); represents modal structure (in percentage); represents vehicle mileage by mode and fuel type (km/kg or km/l); represents fuel-based calorific value (MJ/kg or MJ/l); represents CO$_2$ emission factor (g/km).
ASF framework for estimation of air emissions
According to the ASIF framework

- \( E = A \times S \times I \times F \)
  - **A** is activity level expressed as total travel demand in passenger-kilometers (PKM). Passenger-kilometer demand by each mode has been estimated using vehicle kilometers (VKM) travelled and occupancy of each mode.
    - \( VKM = \text{Total number of vehicles in each mode} \times \text{Average vehicle utilization} \)
    - **Travel demand** = \( \sum PKM = \sum VKM \times \text{Occupancy} \)
  - **S** stands for structure, which is the modal split of travel demand.
  - **I** is energy intensity i.e. energy consumed per passenger kilometer. Energy intensity depends upon occupancy and fuel efficiency of the mode.
    - \( I = \frac{1}{(\text{Mileage} \times \text{occupancy})} \)
  - **F** is emission factor of the fuel used.
    - **Energy consumed in passenger transport** = \( \sum \text{Total passenger kilometers} \times \text{Share of each mode} \times \text{Energy intensity of each mode} \)
    - **Total emissions resulting from passenger transport** = \( \sum \text{Energy consumed in passenger transport} \times \text{emission factors for each of the fuels used in different modes} \)
## Scenario analysis

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description and Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-REF</td>
<td>Lines 1 to 3 of the Delhi metro (part of IMRTS), covering a distance of 65 km are taken as operational</td>
</tr>
<tr>
<td>2021-BAU</td>
<td>No policy interventions except covered under 2007-REF year BS IV was introduced in the year 2010 and others have been have been assumed in accordance to BS III norms, respectively.</td>
</tr>
<tr>
<td>2021-ALT-I</td>
<td>Full phase of IMRTS implementation, which includes 4 phases of Delhi metro and Bus Rapid Transit (BRT) system, has been considered by the year 2021 (see SI Table S.3), in addition to the assumptions taken in 2021-BAU.</td>
</tr>
<tr>
<td>2021-ALT-II</td>
<td>Two interventions have been added to the 2021-ALT-I scenario, in addition to the assumptions taken in 2021-BAU – (i) bus speed has been regulated to 25 km h⁻¹ because of new infrastructural development for dedicated bus corridors, and (ii) parking fees has been hiked (from Rs. 10-20 to Rs. 60-200) for private vehicles.</td>
</tr>
<tr>
<td>2021-ALT-III</td>
<td>One intervention have been added to 2021-ALT-II scenario, in addition to the assumptions taken in 2021-BAU – (i) Fuel economy standards have been implemented for gasoline and diesel cars in India, by 2017 (as proposed by EU).</td>
</tr>
<tr>
<td>2021-ALT-IV</td>
<td>One intervention have been added to 2021-ALT-II scenario, in addition to the assumptions taken in 2021-BAU – (i) Occupancy for two-wheelers has been increased from 1.2 to 1.5 and for car will increase from 1.8 to 3.</td>
</tr>
</tbody>
</table>
Energy and CO₂ emission in 2021 (BAU & ALT)

- Energy demand reduced from 65.4 billion MJ to 44.6 billion MJ (32% reduction)
- CO₂ emission reduced from 4.1 million tons to 2.9 million tons
Private and public share in 2021 (ALT scenario)
Fuel and CNG usage in 2007 and 2021 (All scenario)

- 48% reduction in fuel demand in 2021-ALT-IV
- Demand for electricity increased by 71%
Annual emissions from passenger transport under different scenarios