World Applied Sciences Journal 8 (7): 900-905, 2010
ISSN 1818-4952

Energy Demand and Emission Analysis of Islamabad Industrial Area Using Energy Model

Summra Erum and Sheikh Saeed Ahmad

Department of Environmental Science, Fatima Jinnah Women University, Rawalpindi, Pakistan

Abstract: Study was conducted for the projection of energy demand and emission analysis for the next thirty years, taking the 2000 as a base year. This has been determined with the help of the Long Range Energy Alternative planning system (LEAP). It forecasted the energy consumption and environmental emissions in industrial area of Islamabad. All available energy consumption activities and socio-economic data have been collected for input to the model to obtain results based on different scenario. Initially, a reference scenario was created based on the current energy situation. This uses the base year situation and the expected future changes based on the likely plans and growth trajectories. It is "Business-as-usual" scenario with implementation of anticipated and likely to be carried out projects and policies. Then alternative scenario that simulates new policy measure was developed to meet the energy demand and reduce environmental emissions. Different alternative scenarios were Fuel efficiency Improvement (FEI) and Oil to Natural Gas (OTN). These scenarios were then evaluated to check the validity of different scenarios, which resulted in maximum emission reduction. The prime objective was to arrive at an optimal policy, which limits the future growth of fuel consumption as well as air pollution.

Key words: Emissions, Energy Consumption · Long range Energy Alternative Planning system · Scenario Analysis · Islamabad

INTRODUCTION

In many areas of Pakistan especially in big cities, the industrial units are established without Environment Impact Assessment (EIA) and Environmental Management and Planning (EMP). Islamabad which was formerly considered as one of the beautiful city in the world now got enough pollution both in the air and water due to increase in number of industries. The industrial pollution is a major problem in all big cities of Pakistan. However, severe problems arising in Karachi, Lahore, Faisalabad, Sheikhupura, Multan, Hyderabad, Peshawar, Rawalpindi and Islamabad [1]. Industrial Estate Islamabad (IEI) was established in early sixties. It houses more than 200 industries. The Capital Development Authority (CDA) is managing the industrial estate Islamabad. IEI is spread over 625 acres of land on the border of cities of Rawalpindi and Islamabad. Islamabad IEI was isolated from residential area through a buffer zone, but now residential area has developed very close to it to the south and west due to elimination of buffer zone by CDA. IEI therefore is posing a pollution threat to the residents of the I-9 and I-10 sectors. Industry at IEI has been categorized into eight segments i. e. steel melting furnaces, re-rolling mills, flour mills, oil and ghee, marble cutting and polishing, pharmaceuticals, galvanizing and metal working and engineering [2].

Ecologically sound development of the region is possible when energy needs are integrated with the environmental concerns at the local and global levels. Energy planning entails preparation of area based decentralized energy plans for meeting energy needs for subsistence and development with least cost to the environment and the economy. A large number of models have been developed for energy system analysis till date and which are based on different fundamental approaches and concepts [3].

In present study energy model LEAP was used to analyze the energy demand and emissions associated to industrial estate of Islamabad. LEAP has had a significant impact in shaping energy and environmental polices worldwide. For example in California, LEAP is used for energy forecasting and identifying alternative fuels [4]. In Mexico it is used

Corresponding Author: Sheikh Saeed Ahmad, Department of Environmental Science, Fatima Jinnah Women University, Rawalpindi, Pakistan, 00923215167726, 0092519271168

to determine the feasibility of future scenarios based on moderate and high use of biofuels in the transportation and electricity generation sectors [5]. In Lebanon mitigation options were assessed to reduce emissions from electricity generation with emphasis on the usage of renewable energy resources [6]. The energy consumption and various types of emissions in consumption sectors in Iran were analyzed by using LEAP model [7]. Up till now LEAP had been successfully used in more than 150 countries worldwide for different purposes.

This study was undertaken with following objectives:

- To create an up-to-date database of various factors governing emissions from industries.
- Collection of up-to-date qualitative information related to industrial emissions.
- Analyze and project by what factor energy demand and its emission would rise without any new policy measure.
- Recommend measures with the anticipated impacts on the energy demand and emission for industrial policies

MATERIAL AND METHODS

The present study was carried out for forecasting the possible ailments which the industrial sector of Islamabad may came across in coming future. The study was focused on two main factors i.e.

- Fuel Consumption
- Total Emissions

In this study, the industrial sector was broadly classified into two manufacturing sub-sectors,

- Steel melting furnaces
- Other industries

Others industries include, re-rolling mills, flour mills, oil and ghee mills, marble cutting and polishing units, pharmaceuticals, galvanizing, metal working and engineering units.

The Model Framework: To meet the main objective of this research, the LEAP model was used to analyze and forecast energy demand and its related emissions under alternative strategies in the industrial sector of Islamabad for the planning period of 2000-2030. The central concept in LEAP is an end use driven scenario analysis. The LEAP framework is disaggregated in a hierarchical tree structure of f our levels: sector, sub-sector, end-use and device (Fig. 2.1). The model contains two main modules: the energy demand module and the TED module. In the energy demand module, the energy intensity values along with the type of fuel used in each device are required to estimate the energy requirements at sector, sub-sector and end-use level. The emission factors of different pollutants in the TED module are linked to the device level to appraise the environmental emission from the energy utilization during the planning horizon [8].

The LEAP model requires data for at least the base year and any of the future years. Then, using the function such as interpolation or extrapolation or the growth rate method, the future energy demand and emissions are estimated for the other years. However, in this study some parameters, which will be described below, were prepared and then input to the model. Taking into account the projected parameters in the LEAP model, the energy demand and their emissions were also evaluated. In this study, the emission factors were based on values recommended by the Intergovernmental Panel on Climate Change [9].

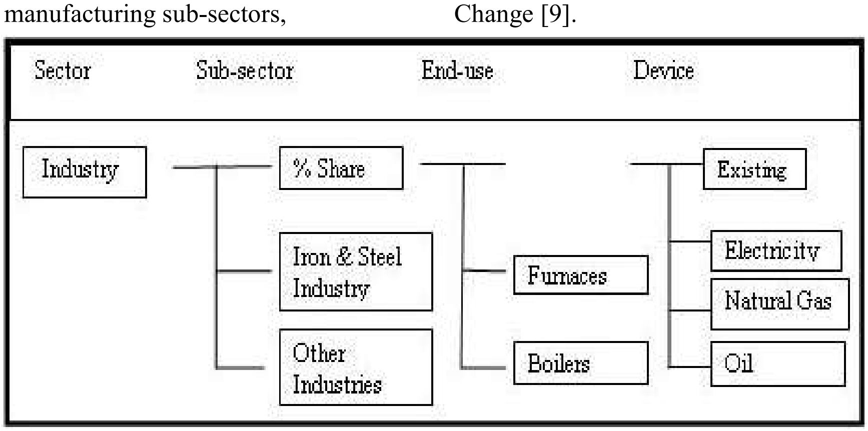

Fig. 2.1: Structure of analysis using LEAP

Data Collection: The model of energy demand in each sector was formulated and disaggregated based on the format of the LEAP model. The historical data were the secondary data collected from several reports of the government and non-government agencies.

Data was collected from national statistical publications, economic survey of Pakistan, energy year books, local and international research studies and different research reports. Previous energy and other studies were used for projections of energy use in industrial sector, where appropriate. Where data were lacking or particularly weak, local data were supplemented with data from similar countries. Different institutes and research centers were visited for data collection and guidance are:

- Pak-EPA (Pakistan Environmental Protection agency)
- FBS (Federal Bureau of Statistics)
- Hagler Bailly Pakistan

The energy demand projection in the industrial sector was formulated as a function of gross domestic product (GDP), proportion of utilized energy, device efficiency and useful energy intensity.

The historical data of GDP were taken from the economic survey of Pakistan and used to project the future GDP by using the average annual growth rate of 3%. The proportions of GDP in the industrial sub-sectors are assumed to be constant during time horizon. The proportions of energy utilized in end-use and device levels were derived from the energy consumption in 2000 and were also assumed to be constant during the planning period, as presented in Table 2.1. The average efficiencies of industrial equipment are taken from the energy audits reports. However, it was too difficult to classify types of devices with a specific energy because of the variety of devices and also the limitation of data in the industrial sector. So, it was assumed that each type of energy in each manufacturing sub-sector was used in a specific device. The useful energy intensity was estimated by the following equation:

$$UEI_{j} = \frac{\Sigma\,(EnU_{i\,j} \times \varsigma_{i\,j})}{GDP_{j}} \tag{1}$$

where UEIj denotes the energy intensity in industrial sub-sector j (ktoe/106 Baht), EnUi,j denotes the energy type i utilized in industrial sub-sector j (ktoe), η_{ij} denotes the efficiency of equipment using fuel type i utilized in industrial sub-sector j and GDPj denotes the gross domestic products of industrial sub-sector j (106 Baht).

The average useful energy intensity in each sub-sector is presented in Table 2.2.

Scenario Construction: Imagining the future was a challenging task. One method widely used to foresee the future consists of setting a baseline, usually a business-as-usual scenario and then evaluating alternative strategies by comparing them to that baseline. This study also followed this strategy in which three scenarios were considered to study the fuel consumption and different policy initiatives that would reduce total emissions in the industrial sector of Islamabad. These scenarios are defined below:

Table 2.1: Proportion of energy utilization in industrial sub-sectors

	Proportion of energy utilization %	
Fuel Type	Steel melting furnaces	Other industries
Oil	96.1	88.4
Natural gas	2.6	10.7
Electricity	1.1	0.9

Table 2.2: Average useful energy intensities in Industrial sub-sectors

Sub-sectors	Average useful energy intensity (k toe/10^3 Baht)
Steel melting furnaces	0.033
Other industries	0.015

Table 2.3. Emissions factors used in the LEAP model

	Emissions factors (kg/TJ energy consumed)			
Fuel Types	CO	NO_x	SO_x	PM_{10}
Natural gas	30	150	-	-
Oil	10	200	994.26	-
Electricity	-	-	-	-

Business-as-Usual (BAU) Scenario: In the BAU scenario, 2000 was selected as the base year and this scenario was selected as base scenario. The current trends of parameters in industrial sector were assumed to be increasing continuously. By extrapolating these trends, values were projected to 2030 without any change. In the industrial sector, the proportion of energy utilization in industrial sub-sectors and average useful energy intensities are shown in Tables 2.1 and 2.2. In the BAU scenario, the present efficiency of any appliances and technologies and the pattern of energy utilization for different appliances and technologies are unchanged in the future. The ongoing projects were not implemented. The environmental emissions were also evaluated using TED of the LEAP model Table 2.3.

Alternative Scenarios

Fuel Efficiency Improvement (FEI): In this scenario, it was assumed that the fuel efficiency would be increased by 1%. This could be achieved by increasing the efficiency of appliances. Then the values were projected to 2030.

Oil to Natural gas (OTN): The industrial sector consumes 16% of the total oil consumption (23.14 million toe) and generates approximately 285 tonnes CO, 162 tonnes NO_x, 378 tonnes SO_2 and 4400 tonnes PM_{10}. This scenario considers the substitution for oil in the industrial sector. The substitution rate of oil was assumed to be 2%. After the construction of scenarios these were analyzed and results were compared between different scenarios.

RESULTS AND DISCUSSIONS

Results of the BAU Scenario: As mentioned earlier, this scenario was continuation of values from base year to end year without any change. In Business-as-usual scenario time period was extended from 2000 to 2030 to forecast future increase in energy consumption and in total emissions of CO, NO_x, SO_2 and PM_{10}.

In the BAU scenario, results from the LEAP model reveal that the total energy demand is estimated to be about 6.1 thousand tonnes and 14.7 thousand tonnes in 2000 and 2030, respectively, as presented in Table 3.1. The energy requirement in 2030 was more than two times the energy demand in 2000. In the industrial sector, the projected demand increases from 6.1 thousand tonnes to 12.5 thousand tonnes.

In addition, the CO and other harmful emissions are estimated by using the emission factors in the TED of the LEAP model. The CO emissions are increased by 480 thousand tonnes in 2030 which was higher than two times the CO in 2000. The NO_x, SO_2 and PM_{10} emissions in 2030 were estimated to be approximately 280 thousand tons, 48 thousand tonnes and 1200 thousand tons which were higher than those in 2000 by approximately three times and two times, respectively (Table 3.2).

Comparison of different scenarios for fuel consumption was shown in Table (3.1). The maximum reduction was for OTN i.e. 26.5% and for FEI, the reduction was 15%.

Table 3.1. Estimated energy demand in different industrial sub-sectors under different scenarios

	Energy demand (thousand tonnes)				
Scenarios	2000	2015	2020	2025	2030
Business-as-Usual	6.1	9.5	10.9	12.8	14.7
Fuel Efficiency Improvement	6.1	8.7	9.8	10.9	12.5
Oil to Natural Gas	6.1	8	8.9	9.7	10.8

Table 3.2. Estimated environmental emissions under different scenarios

	Estimated environmental emissions (10^3 tonnes)				
Scenarios	2000	2015	2020	2025	2030
BAU scenario					
CO	1.80	2.90	3.40	3.80	4.30
NO_x	116	175	200	230	280
SO_2	21.3	43	37	33	48
PM_{10}	540	810	920	1008	1200
FEI scenario					
CO	1.80	2.60	2.90	3.20	3.60
NO_x	116	160	180	200	220
SO_2	21.3	35	33	28	40
PM_{10}	540	700	800	880	1000
OTN scenario					
CO	1.80	2.60	2.70	2.90	3.20
NO_x	116	140	160	180	200
SO_2	21.3	28	30	32	36
PM_{10}	540	680	750	820	900

Scenarios Analysis: In order to analyze the potential of alternative scenarios to reduce the emissions in industrial estate, the BAU was taken as a reference, because the present efficiencies or technologies remain unchanged in future and then the three alternative scenarios were compared with the baseline scenario. The purpose of the comparison was to check that which scenario gave the minimum emissions.

In FEI scenario, the total emissions were found to be 3.6 thousand tonnes, 220 thousand tonnes, 40 thousand tonnes and 1000 thousand tonnes respectively. In OTN scenario, the values were 3.20 thousand tonnes, 200 thousand tonnes, 36 thousand tonnes and 900 thousand tonnes respectively. In the above study it can be seen that among all the selected four pollutants PM_{10} were high. With the help of above study, in the end, it could be concluded that all the alternative scenarios resulted in emission reduction, but the Oil to Natural gas (OTN) offers the better solution to the important issues such as reducing emissions fuel consumption.

Table (3.2) showed the comparison of three different scenarios for total emissions of pollutants i.e. CO, NO_x, SO_2 PM_{10}.it showed that maximum reduction in emissions was occurred in oil to natural gas scenario that was 41.7% while in FEI scenario it was 30.5%.

The study showed among all the scenarios Oil to Natural Gas proved to be better. An analysis of emission factors for fuels showed that natural gas was the least polluting fuel with respect to magnitude of emissions per heat unit. By reducing the use of oil, it contributes to reductions in energy consumption as well as reductions in emissions of air pollutants and greenhouse gases. In order to forecast the energy demands and the emissions and to analyze the potential of scenarios for saving energy demands and reducing emissions, various studies have been carried out all over the world. In a similar study an inventory of greenhouse gas emissions from various economic sectors was conducted in Lebanon. The inventory indicated that the energy sector is the major contributor (74%) to greenhouse gas emissions. This research assesses mitigation options to reduce emissions from electricity generation with emphasis on the usage of renewable energy including biomass, hydropower, solar and wind resources [6].

Concerns about energy consumption and environmental impact in Iran has been raised in recent years [7]. This research presented the energy consumption and various types of emissions in consumption sectors in Iran. LEAP was used to present the assessment of energy efficiency improvement and renewable energy substitution in the three main economic sectors i.e. the residential, small commercial building and industrial sectors, in Thailand [10]. The energy sector is the single largest source of greenhouse gas emissions as detailed in the inventory developed for Pakistan. As such, it is also the sector which is believed to have the greatest potential for development of mitigation options.

The assessment of energy demand along with the environmental emissions can help the energy planner to develop an energy plan in a sustainable manner. In this study measures were expressed with the anticipated impacts on energy demand and emission, with out analyzing the reduction costs of these measures. Therefore, the study needs future development work focusing on the reduction costs of these measures. The mitigation scenarios developed and applied are few and limited due to limited availability of detailed data for energy use by end use in the industry. Therefore, future analysis needs to be done in these sectors too. In this study, default emission factors were used as a result of absence of country specific emission factors. There is also a need to have further work to develop local specific factors. There is also an important need to improve the reliability and availability of data through active cooperation between various organs of the State, private sector, academia and civil society.

REFERENCES

1. Ambreen, S., 1993. Environmental pollution (ed.) Pakistan Book Foundation, Lahore, Pakistan, pp: 60-80.
2. Pakistan environmental Protection Agency, 2006. Environmental Survey of Industrial Estate (I-9 and I-10) Islamabad. Survey report, Islamabad, Pakistan.
3. Hiremath, R.B., S. Shikha and N.H. Ravindranath, 2007. Decentralized energy planning; modeling and application-a review. Renewable and Sustainable Energy Reviews, 11: 729-752.
4. Ghanadan, R. and J.G. Koomey, 2005. Using energy scenarios to explore alternative energy pathways in California. Energy Policy, 33: 1117-1142.
5. Islasa, J., F. Manzini and O. Masera, 2007. A prospective study of bioenergy use in Mexico. Energy, 32: 2306-2320.
6. El-Fadel, M., M. Zeinati, N. Ghaddar and T. Mezher, 2001. Mitigating energy-related GHG emissions through renewable energy. Energy Policy, 29: 1031-1043.

7. Awami, A. and B. Farahmandpour, 2008. Analysis of environmental emissions and greenhouse gases in Islamic Republic of Iran. International Institute for Energy Studies (IIES), 4(4).
8. Stockholm Environment Institute (SEI), 2001. Long-range Energy Alternative Planning System (LEAP) Version 2000, Stockholm Environment Institute, Boston Center, USA. http://www.seib.org.
9. Intergovernmental Panel on Climate Change (IPCC), 1996. IPCC Guideline for National Greenhouse Gas Inventories. http://www.ipcc.ch.
10. Tanatvanit, S., B. Limmeechokchai and S. Chungpaibulpatana, 2003. Sustainable energy development strategies: implications of energy demand management and renewable energy in Thailand. Renewable and Sustainable Energy Reviews, 7: 367-395.