Evaluation of Economic Value of Natural Gas in Various Sectors

Final Report

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Executive Summary

This study is conducted to assess the economic value of natural gas in the various economic sectors of Pakistan. It would assist the Government of Pakistan (GoP) in formulating a gas load management policy through which optimal use of natural gas in various economic sectors can be achieved while ensuring highest economic returns for the country.

The economic value of natural gas in each sector was assessed using alternatives for natural gas based on the application in which natural gas is presently utilized. The economic value of gas was determined on the basis of the cost of the best alternative in each sector and end-use. The study took into account near-term and medium-term alternatives to natural gas. The near-term is defined as the period of time during which infrastructure and supply constraints would be present and imported LNG would not be available for the country. Thus, the near-term is defined as a period of 1-2 years from the present. In the medium-term, it was assumed that there would be no infrastructure and supply constraints and imported LNG would be available. The medium-term is defined as a period of 3-5 years from the present. A sectoral comparison of the economic value of natural gas and the contribution of natural gas consumption towards the GDP of the country was performed, based on which directions for the pricing and allocation of natural gas have been suggested. The study is intended as an input into the policy-making process. Additional studies may be required to determine precise recommendations for the efficient utilization of the scarce resource.

The entire analysis was conducted under a base case Brent crude oil price ($ 115/bbl) scenario. Sensitivities were conducted for Brent crude oil prices of $ 100/bbl, $ 130/bbl and $ 145/bbl.

Economic Value of Natural Gas

Consistent with the definition of economic value of gas, the next best alternative to natural gas, in terms of cost per unit of service delivered, was selected as the replacement for natural gas for each sector.[1]

Economic Value of Gas in the Near-term

In the near-term, constraints such as supply and infrastructure will prevent consumers from switching to alternatives that cost less for some end-uses. Also, in the near-term, the use of imported LNG as an alternative to indigenous natural gas was ruled out due to the current absence of regasification facilities and other necessary infrastructure for the import of LNG in the country. Near-term economic values include annualized capacity

[1] The alternatives to natural gas considered in the analysis are listed in **Exhibit 2.8** in **Section 2**.

costs to account for the loss in investments that will occur due to the replacement of natural gas with its alternatives.[2]

Power Generation

For power generation, the economic value of gas was calculated as the replacement cost of generation using replacement fuels for each power generation unit. The power sector in Pakistan has a minimum requirement of 585 MMscfd of gas for the combined cycle gas turbines (CCGT) plants that face technological or contractual constraints in using alternative fuels. However, these plants can operate on HSD and therefore the economic value of gas supplied to these plants was calculated on the basis of replacement cost of HSD. The replacement cost of natural gas supplied to CCGT plants with infrastructure for HSD in place is estimated at $ 26.56/MMBtu under the base case crude oil price scenario.[3]

Residential and Commercial Sector

In the residential and commercial sector, LPG was determined to be the least cost alternative for cooking and space heating, while electricity was determined to be the least cost alternative for water heating. However, availability of additional electricity to replace natural gas for water heating in households cannot be ensured while the country is facing power shortages. Therefore, even though electric water heaters are more economic ($ 13.24/MMBtu) than solar water heaters ($ 17.12/MMBtu for solar-gas geyser hybrids), solar water heating was selected as the alternative energy source.

Fertilizer Industry

For the fertilizer industry, the analysis indicated that in the near-term, the economic value of natural gas for efficient plants in the fertilizer industry is $ 23.86/MMBtu, while the economic value of natural gas for inefficient plants is $ 19.10/MMBtu for the base case.

Industrial Sector

In the industrial sector, FO was considered as the replacement fuel for natural gas in the case of boilers and furnaces. The base case economic value of natural gas for boilers and furnaces was calculated to be $ 18.35/MMBtu. For captive power generation, the analysis indicated that the base case economic value of natural gas was $ 21.67/MMBtu in the near-term, with FO as the least cost alternative.

Transportation Sector

In the transportation sector, for the cars that are presently operating on CNG, the alternative fuel was motor gasoline. In the case of importing motor gasoline to replace

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[2] The near-term economic values of natural gas are presented in **Exhibit 5.1** in **Section 5**.

[3] Until the completion of infrastructure augmentation and contract modifications, not supplying gas to this capacity may further increase the already rampant load shedding in the country. In that case, the economic value of 585 MMscfd of gas demand could be equated to the cost of unserved energy which has been estimated to be around three times higher than the cost of supplying electricity on HSD. The economic cost of power load-shedding is $ 79.13/MMBtu, as reported by a study carried out by International Resources Group for Asian Development Bank (ADB) under ADB TA-4982 PAK: *Pakistan Integrated Energy Model (Pak-IEM) - Policy Analysis Report Volume II (2010)*. The estimate for economic cost of load shedding was $ 0.60 kWh, which was converted to MMBtu using the average thermal efficiency of 45% for the CCGT plants with natural gas commitments. .

CNG, capital costs that would have to be incurred by the existing CNG stations were factored in the near-term analysis. The base case economic value of gas for the transportation sector was calculated to be $ 31.2/MMBtu in the near-term.

Contribution of Natural Gas to Economy

The results of the regression analysis suggest that higher priority for allocation of scarce natural gas resource needs to be given to the sectors that utilize natural gas for productive purposes in comparison to the sectors that utilize natural gas for consumptive purposes. By curtailing natural gas for the productive end-uses, the economy incurs a loss, as the direct and multiplier benefits of productive activities are foregone.[4]

Amongst the sectors that utilize natural gas for productive purposes, the power and commercial sectors use natural gas more productively. The commercial sector, which only forms 3% of total gas consumption, contributes more than 30 times to the total GDP against each MMBtu of natural gas supplied to the sector (Rs 69,267/MMBtu of natural gas valued at its economic value of $ 23.79/MMBtu). The contribution of one MMBtu of natural gas through generation of power to total GDP is five times the economic value of natural gas for power generation.

In case of fertilizer sector, the contribution of fertilizer consumption towards total GDP was evaluated and results of the analysis suggest that fertilizer contributes significantly towards total GDP, which is consistent with the fact that agriculture is the mainstay of the economy. This supply of fertilizer can be met through imports or domestic production of fertilizer. The continuation of natural gas supply to the fertilizer industry was determined through the analysis of the near-term economic values of natural gas.

Economic Value of Natural Gas in the Medium-term

In the medium-term, annualized capacity costs will not be applicable since the government would have the option of declaring in advance that it would not be liable to make any capacity compensations in case gas is not supplied for the specific end uses. Therefore, the capacity components included in the near-term economic value of natural gas for the fertilizer sector, captive generation in industrial sector and transport sector were removed from the medium-term economic values. In addition, in the medium-term, supply constraints will not apply on energy sources and availability of infrastructure and facilities for use of alternatives.[5]

The medium-term economic value of natural gas was compared to the economic cost of delivered natural gas, based on the price of delivered imported LNG, for the various end-uses to evaluate the potential cost of using alternatives to natural gas in the medium-term.

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[4] The results of the regression analysis conducted to assess the contribution of natural gas consumption in each sector towards total GDP are summarized in **Exhibit 5.2** in **Section 5.**

[5] The medium-term economic values of natural gas are presented in **Exhibit 5.4** in **Section 5.**

Suggested Directions for Pricing and Allocation of Natural Gas

Government has the option to regulate the natural gas demand through the following instruments:

- *Price regulation*: demand responds negatively to an increase in price and by increasing the price of natural gas the government can discourage inefficient consumption of the scarce resource as well as promote use of alternatives to natural gas;
- *Allocation*: through allocation and setting of quotas for different consumer segments, the government can promote use of alternatives to natural gas.

Suggested Directions for Management of Supply of Natural Gas in the Near-term

In the near-term, use of pricing mechanisms has the following limitations and repercussions:

- Cost of production will increase thereby reducing demand for goods and services, which will hinder economic growth;
- Production may have to be curtailed in the absence of infrastructure for delivery of alternative fuels and energy forms, thereby hindering economic growth;
- There will be adverse social and political repercussions associated with extreme reaction of the consumers.

Gradual price changes are, therefore, recommended as a regulatory instrument for the medium-term to allow consumers to adjust to price increases and to provide time for construction of infrastructure for delivery and use of alternative fuels. In the near-term, optimal use of natural gas should be achieved through allocation of natural gas on economic basis.[6]

Suggested Directions for Management of Supply of Natural Gas in the Medium-term

In the medium-term, the results of the economic analysis carried out in this study suggest that the following priority should be given to supply of natural gas, as the economic cost of the replacement fuel is higher than the economic cost of natural gas delivered for these end-uses:

- Power generation from CCGT plants;
- Cooking in the households;
- Cooking, water heating and space heating in commercial sector, which only forms 3% of total gas consumption;
- Captive power generation by the industry.

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6 The suggested allocation of natural gas in the near-term, based upon the economic analysis carried out in this study, is presented in **Exhibit 5.3** in **Section 5**.

In the medium-term, natural gas in the following end-uses should be replaced with the alternatives:

- *Domestic production of fertilizer*: Imported fertilizer should replace domestic production of fertilizer as the cost of imports ($ 17.26/MMBtu) is less than the economic cost of delivered natural gas ($ 20.3/MMBtu) for the fertilizer sector. In the long-term, no new fertilizer plants should be set up in the country;
- *Power generation from steam turbine plants*: FO should continue to be used as the power generation fuel for steam turbine plants since the economic cost of FO ($ 17.42/MMBtu) is lower than the economic cost of delivered natural gas for the power sector ($ 20.33/MMBtu);
- *Natural gas utilization by the industry for captive generation and heating use*: The economic value of natural gas for heating use, assuming FO as the replacement fuel, is lower than the economic cost of delivered natural gas. The economic value of natural gas for heating use is $ 18.35/MMBtu, which is lower than the economic cost of delivered natural gas in the industrial sector ($ 20.33/MMBtu). Thus, the industry should switch to FO as the replacement fuel for heating use in boilers and furnaces;
- *Fuel for motor vehicles*: Motor gasoline should be utilized as fuel for vehicles instead of natural gas since motor gasoline is more economical than natural gas delivered to CNG stations. The economic value of natural gas in the transport sector is $ 24.37/MMBtu in comparison to the $ 29.21/MMBtu, which is economic cost of natural gas delivered and compressed for use as CNG. In the medium-term, no new CNG plants should be set up in the country;
- *Residential water heating*: Solar water heating is the economic option in comparison to natural gas for water heating in the residential sector. Thus, solar water heaters should be installed in houses to replace natural gas water heaters, as cost of water heating on solar energy is $ 17.12/MMBtu of natural gas replaced, in comparison to $ 20.33/MMBtu, which is economic cost of delivered natural gas for the residential sector;
- *Residential space heating:* Despite the lower economic cost of delivered natural gas in the residential sector or space heating in the residential sector, solar space heating is suggested towards the medium-term, using solar building design. Using solar building designs windows, walls, and floors can be made to store and distribute solar energy in the form of heat. Solar design techniques can be applied most easily to new buildings, while existing buildings can be adapted or retrofitted.

In the medium-term, the government should gradually increase the price of natural gas to equate it to the economic cost of natural gas delivered to the customers. In sectors where natural gas should be replaced by its alternative, such as fuel oil in the industry and solar water heating appliances in the households, the price of natural gas should be set higher than the medium-term economic value to encourage switching to the alternatives. In areas not connected to the gas network, GoP should facilitate access to LPG. However, the price slabs should be in place for the existing residential consumers to subsidize use of natural gas for cooking. The subsidy can be in the following forms:

- Cross-subsidization within the residential sector where high-income consumers can subsidize the low-income consumers. The tariff for higher-consumption slabs, corresponding to the use of energy for water and space heating, should exceed the economic cost of delivered natural gas for the residential sector to encourage use of solar appliances for water and space heating;
- A direct subsidy by the government.

Abbreviations

AEAI	–	Advanced Engineering Associates International
bbl	–	barrel
CapEx	–	capital expenditure
C&F	–	carriage and freight
CCGT	–	combined cycle gas turbine
CGE	–	computable general equilibrium
CIF	–	carriage, insurance and freight
CNG	–	compressed natural gas
DISCO	–	distribution company
E&P	–	exploration and production
EVTL	–	Engro Vopak Terminal Limited
FO	–	high sulfur fuel oil
FoB	–	freight on Board
FY	–	fiscal year
GDP	–	gross domestic product
GDS	–	gross development surcharge
GENCO	–	generation company
GoP	–	Government of Pakistan
GSA	–	gas sales agreement
GWh	–	gigawatt-hour
HBP	–	Hagler Bailly Pakistan
HESS	–	Household Energy Strategy Study
HIES	–	Household Integrated Economic Survey
HSD	–	high speed diesel
IFEM	–	inland freight equalization margin
IPI	–	Iran-Pakistan-India
IPP	–	independent power producer
IPP	–	import parity price
IRSA	–	Indus River System Authority
JCC	–	Japan Crude Cocktail
KAPCO	–	Kot Addu Power Company
KESC	–	Karachi Electric Supply Corporation
KWh	–	kilowatt-hour

LNG	–	liquefied natural gas
LPG	–	liquefied petroleum gas
MMBtu	–	million British thermal units
MMscfd	–	million standard cubic feet per day
MMscf	–	million standard cubic feet
MMscmd	–	million standard cubic meters per day
MPNR	–	Ministry of Petroleum and National Resources
MTOE	–	million tonnes of oil equivalent
MW	–	megawatt
NEPRA	–	National Electric Power Regulatory Authority
NTDC	–	National Transmission and Dispatch Company
O&M	–	operation and maintenance
OGRA	–	Oil and Gas Regulatory Authority
OMC	–	oil marketing company
OpEx	–	operating expenditure
PEPCO	–	Pakistan Electric Power Company
PPA	–	Power Purchase Agreement
PSO	–	Pakistan State Oil
PQA	–	Port Qasim Authority
PV	–	photovoltaic
SNGPL	–	Sui Northern Gas Pipelines Limited
SSGCL	–	Sui Southern Gas Company Limited
T&D	–	transmission and distribution
Tcf	–	trillion cubic feet
TOE	–	tonnes of oil equivalent
ToR	–	terms of reference
UFG	–	unaccounted-for gas
USAID	–	United States Agency for International Development
W	–	watt
WACC	–	weighted average cost of capital
WAPDA	–	Water and Power Development Authority

Currency Equivalents (As of 30 April 2009)

Currency Units	–	Pakistan rupee/s (Rs) United States Dollar ($) United States Cent (¢)
Rs 1.00	=	$ 0.0117
$ 1.00	=	Rs 85.50

Weights and Measures

GWh	–	gigawatt-hour (1,000 megawatt-hours)
MWh	–	megawatt-hour (1,000 kilowatt-hours)
MMBtu	–	one million (1,000,000) British thermal units
MMscf	–	one million (1,000,000) cubic feet

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1. Introduction

Advanced Engineering Associates International (AEAI) has initiated a study for the Planning Commission to assess the economic value of natural gas in various end-use sectors. Hagler Bailly Pakistan (HBP) was engaged for this purpose through a contract (A012-HB-002) to prepare the study. The objectives of the study as specified in the study terms of reference (ToRs) include:

1. Evaluation of the economic value of gas based on its cost of substitutes in each end-use sector;
2. Estimation of correlation between natural gas consumption and economic growth;
3. Present recommendations on gas price rationalization and allocation priorities, using results of the economic analysis.

The study ToRs are given in **Appendix B** of the report. According to the study deliverables, an inception report, which included details to the approach of the study, was submitted by HBP. The inception report is also included in **Appendix A** of the report.

1.1 Study Rationale: Sector Performance and Problems

Natural gas plays a significant role in Pakistan's economy, meeting about 44% of the country's energy demand (**Exhibit 1.1**). It is preferred over other fuel alternatives in nearly all the sectors of the economy owing to its lower consumer tariffs and cleanliness in use. As of June 2010, Pakistan's total recoverable gas reserves stood at 27.6 trillion cubic feet (Tcf). Meanwhile, the annual gas consumption was 1.27 Tcf during FY2010, with an annual average growth of 2.8% over the last five years. Increasing demand of natural gas coupled with the fact that there have been no major gas discoveries in recent years provides a compelling impetus to reconsider the current natural gas pricing and allocation policies.

Exhibit 1.1: Share of Energy Consumption by Energy Type, FY2010

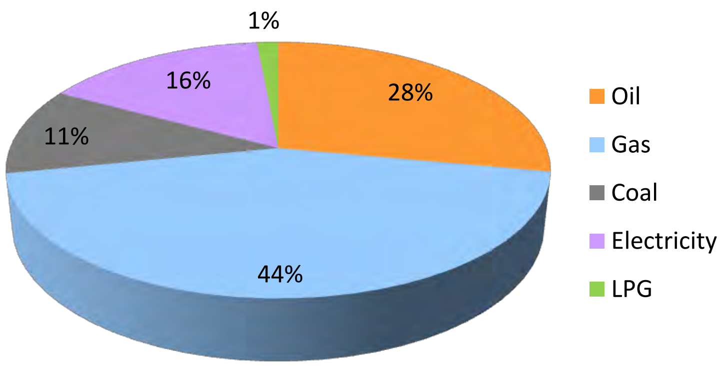
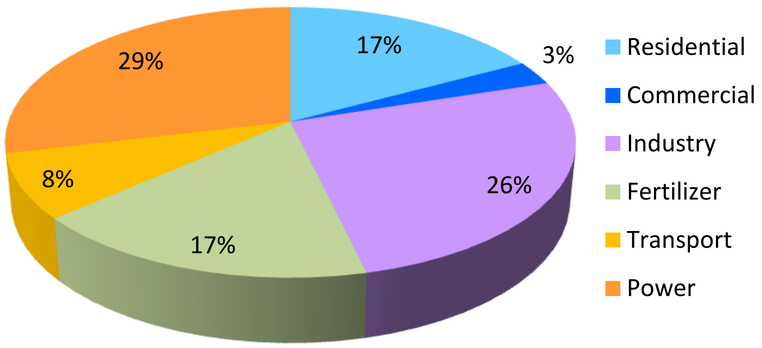


Exhibit 1.2 shows the share of various end-use sectors in natural gas consumption. The demand for natural gas in the power sector forms the largest share in the total natural gas consumption, followed by the industry (which includes captive power generation) and residential sectors.

Exhibit 1.2: Share of Natural Gas Consumption



1.2 Methodology

HBP assessed the economic value of natural gas in each sector using alternatives for natural gas based on the application in which natural gas is used. The economic value of natural gas was considered to be the corresponding end-use cost of the next best alternative. Since the alternative energy source in each sector is different, the economic value of gas substantially varies across sectors. The study took into account near-term and medium-term alternatives to natural gas. The near-term was defined as a period of 1-2 years from present during which infrastructure and supply constraints would be present and imported LNG would not be available for the country. In the medium-term, a period extending from 3 to 5 years from present, it was assumed that there would be no infrastructure and supply constraints and imported LNG would be available.

The determination of economic values of natural gas in each sector was followed by a regression analysis between natural gas consumption in each sector and GDP to assess the indicative contribution of natural gas in the country's national income.

Energy prices (prices of natural gas and its alternatives) were determined for various crude oil price scenarios to account for sensitivity of the economic value of natural gas to the price of crude oil. Brent crude oil prices of $ 100/bbl, $ 130/bbl and $145/bbl were considered for sensitivities, while a price of $ 115/bbl, the average Brent crude oil price for March 2011, was defined as the base case.

1.3 Assumptions

The following assumptions were made for the analysis:

1. An exchange rate of Rs 85.5/US $, which was the average for March 2011, was assumed for the study;
2. Energy prices were computed according to the current pricing mechanisms and determinations issued by Oil and Gas Regulatory Authority (OGRA) and National Electric Power Regulatory Authority (NEPRA). The prices of fuel oil (FO) and liquefied petroleum gas (LPG), which have been deregulated by the government, were based on market data;
3. The analysis was based on the current levels of energy consumption and fuel mix in the economy.
4. The output produced by the sectors was taken at its current level and was assumed constant for the computation of economic values;
5. Margins of suppliers and producers were taken at current levels and were assumed constant for the analysis;
6. The energy prices were linked to the price of Brent crude oil.

1.4 Limitations

Limitations in the analysis conducted are summarized below:

1. Simple linear regression analysis was conducted to determine correlations between natural gas consumption and national income. A more comprehensive and accurate approach for determining these correlations would have been to use computable general equilibrium (CGE) models that utilize extensive economic data to estimate how an economy reacts to changes in policy or other factors by measuring the corresponding change (increase or decrease) in national income. Updated CGE models for Pakistan are not available so this approach was not possible;
2. The analysis assumed that no significant natural gas discoveries would be made in the country in the near and medium-term. In case of significant gas discoveries in the country in the near and medium-term, the recommendations of the study would not hold;
3. In the medium-term, the economic cost of delivered natural gas was based upon the cost of imported LNG for Pakistan. The formula used to determine the cost of imported LNG provides a point of reference, but the cost at which LNG will be imported by Pakistan is subject to negotiations between the Government of Pakistan and the potential suppliers of LNG;
4. Due to lack of availability of the entire supply chain, only sales tax, excise duties and levies were excluded from financial consumer prices to arrive at economic prices;
5. The study is intended as an input into the policy-making process. Additional studies may be required to determine precise recommendations for the efficient utilization of the scare resource.

1.5 Organization of the Report

Section 1 provides an introduction, explaining the rationale and methodology adopted for the study. **Section 2** explains the current pricing mechanism for indigenous gas, imported pipeline gas, imported liquefied natural gas (LNG), and those fuels that can replace natural gas in the different economic sectors. The current allocation policy of natural gas is also explained in **Section 2**. **Section 3** explains the computation of economic value of natural gas in each sector. **Section 4** presents the results of a regression analysis that indicate the amount of national income generated by the natural gas consumption in each sector. **Section 5** interprets and compares the economic values of natural gas calculated in **Section 3** and suggests a policy direction for natural gas allocation and pricing in light of the analysis.

2. Energy Cost and Pricing Framework

This section first explains the current pricing mechanisms for indigenous gas, imported pipeline gas and imported liquefied natural gas (LNG). The price of indigenously produced natural gas was determined as per OGRA's methodology, while the prices of imported pipeline gas and LNG were determined using formulae provided by Interstate Gas Systems (ISGS).

The pricing mechanisms are followed by an overview of the pricing and allocation policies that are presently in effect.

The last sub-section explains the pricing methodologies of energy sources that can replace natural gas in various sectors. For regulated products like kerosene, gasoline and HSD, the pricing methodology was obtained from OGRA, while electricity prices were computed based on NEPRA publications. For unregulated products like FO and LPG, a pricing mechanism was built using market data. All prices were linked to the Brent crude oil price for the purpose of sensitivity analysis.

2.1 Cost of Supplying Indigenous Natural Gas

The consumer price of natural gas in Pakistan comprises of: (a) the 'prescribed price' for utilities and (b) a Gas Development Surcharge (GDS). OGRA fixes the prescribed price for gas utilities. Pursuant to the provision of the OGRA Ordinance, the GoP advises the sale prices for various categories of consumers, after adjustment of GDS in the Prescribed Price determined by OGRA. The consumer prices are notified by the government through OGRA on a biannual basis. Thus, consumer prices notified in January remain effective till June, while those notified in July remain effective till December.

The prescribed prices are determined by OGRA for the gas utilities for various consumer segments. OGRA fixes the prescribed price for the gas utilities through public hearings where relevant stakeholders are consulted. The prescribed price includes the following elements:

1. Producer gas prices, which are linked to international prices of crude oil and high-sulfur fuel oil (FO)
2. Excise duty
3. Allowance for unaccounted-for-gas (UFG)
4. Transmission and distribution costs
5. Depreciation
6. Minimum return to the gas companies as stipulated in the World Bank/ADB loan covenants

2.1.1 Wellhead Gas Prices

Producer gas prices, or wellhead prices, differ for different gas fields. The cost of gas supplied to the SSGCL and SNGPL systems therefore also varies substantially causing a significant variation in the prescribed prices. The GoP, as a policy, has always maintained uniform consumer prices of gas all over the country and to implement this policy it issued a policy guideline on June 18, 2003[7] stating that the cost of gas of SSGCL and SNGPL should be worked out on an overall weighted average basis to keep this major input cost uniform for both utilities. To implement this policy, the two utilities have signed an agreement to make adjustments in the price of gas paid to the producers on the basis of weighted average cost of gas.

Wellhead prices are determined through a pricing formula that links the wellhead prices to international crude oil or fuel oil prices, and depend on when a field commenced production. The wellhead price of fields that declared commercial production before 1985 is set on a 'cost-plus' basis, while those that started producing between 1985 and 1994 have their gas prices linked with the carriage and freight (C&F) price of FO. Those that announced production after 1994 have their prices linked to the C&F price of basket of imported crude oils. The wellhead gas pricing mechanism is summarized in **Exhibit 2.1** and the actual wellhead prices for different Brent oil price scenarios are shown in **Exhibit C.1** of **Appendix C**.

Exhibit 2.1: Wellhead Pricing Mechanism

Year of Commercialization	*Wellhead Pricing Mechanism*
Between 1985 to 1991	Producer prices were linked to 66% of FO price, minus negotiated discounts
Between 1991 to 1992	Linkage increased to 75% of FO price less negotiated discounts
Between 1992 to 1993	Linkage further increased to 100% of FO price, less negotiated discounts
Between 1993 to 1994	Linked to 100% of FO price, with floor price of $ 80/ton and 50% beyond $ 80/ton
1994, 1997, 2001, 2009	Petroleum Policies came into effect. Based on geological prospects and available gas transmission infrastructure network, the country was divided into three prospective zones. Producer prices were linked to 77.5%, 72.5% and 67.5% of the price of a basket of imported crude oil for discoveries in Zones I, II and III respectively. The current practice is to link producer gas prices to the price of crude oil using a sliding-scale discounting formula with a decreasing share of uplift as crude prices increase. Zonal discount is applied in addition to this sliding discount.

Source: Ministry of Petroleum and Natural Resources. *Petroleum Exploration and Production Policy,* 2001

The concession agreements signed after 1994 are governed by the Petroleum Policies of 1994, 1997 and 2001. In December 1999, the GoP modified the gas-pricing framework as spelt out in the previous petroleum policies of 1994 and 1997. A new inflection-point based pricing framework with a discounted price mechanism was defined. This discounted price was applicable whenever the C&F price of a basket of imported

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[7] OGRA. Annual Report: 2009-10

Arabian/Persian Gulf crude oil exceeded $ 15/bbl during the six months prior to price notification. The details of this price-discounting mechanism, also known as a sliding-scale mechanism, have been explained in **Exhibit 2.2**.

Exhibit 2.2: Gas Price Discounting Mechanism

Ruling Price ($/bbl)	*Applicable Price ($/bbl)*
Below $ 10/bbl	Fixed at $ 10/bbl (floor)
$ 10-15/bbl	100% of ruling price
$ 15-20/bbl	$ 15 plus 50% of the amount by which the price exceeds $ 15/bbl
$ 20-25/bbl	$ 17.50 plus 30% of the amount by which the price exceeds $ 20/bbl
Above $ 25/bbl	$ 19 plus 20% of the amount by which the price exceeds $ 25/bbl

Source: Director General Petroleum Concessions, Ministry of Petroleum and Natural Resources.

The producer price mechanism offered in December 1999 was modified again in May 2000 to account for international inflation in oil prices. The discounting mechanism mentioned above is applicable for the first four years from the date of the signing of the Gas Sales Agreement (GSA). After four years, the inflection points of $ 15, 20 and 25/bbl are raised by $ 1. The formula was further modified under the Petroleum Exploration and Production Policy 2001 by adding a ceiling price of $ 36/bbl. According to the policy, the GoP can review floor and inflection points every five years for appropriate adjustments, keeping in view the prevailing conditions in international oil and gas markets.

The sliding discount mechanism was further revised in the Petroleum Exploration and Production Policy 2009. The price floor was removed and inflection points were modified. This discounted price was applicable whenever the C&F price of a basket of imported Arabian/Persian Gulf crude oil exceeded $ 20/bbl during the six months prior to price notification. Details of this mechanism are explained in **Exhibit 2.3**. Since no fields have been discovered since 2009, this policy has not yet become applicable.

Exhibit 2.3: Gas Price Discounting Mechanism According to 2009 Policy

Ruling Price ($/bbl)	*Applicable Price ($/bbl)*
$ 0-20/bbl	100% of ruling price
$ 20-30/bbl	$ 20 plus 50% of the amount by which the price exceeds $ 20/bbl
$ 30-40/bbl	$ 25 plus 30% of the amount by which the price exceeds $ 30/bbl
$ 40-70/bbl	$ 28 plus 20% of the amount by which the price exceeds $ 40/bbl
$ 70-100/bbl	$ 34 plus 10% of the amount by which the price exceeds $ 70/bbl

Source: Ministry of Petroleum and Natural Resources. *Petroleum Exploration and Production Policy: 2009*

2.1.2 Unaccounted-for-Gas

The unaccounted-for-gas (UFG) is a loss incurred during transmission and distribution of natural gas and is valued at the average wellhead price. The utilities are given a UFG target, which in 2010 was 5.5% of the volume of gas purchased from E&P companies. If the utilities are able to stay within this target, i.e. they control their actual T&D losses and keep them below 5.5%, they retain the savings (the difference between the target and actual losses), whereas if the actual T&D losses exceed the UFG allowance, the utilities bear the excess loss.

2.1.3 Transmission and Distribution Costs

The transmission and distribution costs incurred by the utilities comprise expenses such as Human Resource costs (i.e. salaries, wages and benefits), repairs and maintenance of transmission networks, security expenses, and gas bill distribution and collection charges.[8]

2.1.4 Minimum Return to Utilities

OGRA determines the total revenue requirement of the utilities to ensure that they operate prudently and achieve a certain return on their average net fixed assets in operation for each financial year. This return is subject to efficiency related benchmarks imposed from time to time. For FY2011, it is 17.5% and 17% for SNGPL and SSGCL respectively.

To arrive at the prescribed price, the following costs are factored in to the average wellhead price.

1. The cost of gas lost and internally consumed, valued at the wellhead price
2. Transportation and distribution costs
3. Minimum return to utilities
4. Other income is subtracted because it reduces the amount of return required by gas sales.

For Gulf crude and FO prices corresponding to a Brent crude price of $ 115/bbl, the resulting prescribed price is $ 4.15/MMBtu. A brief summary of this build-up of prescribed price for various Brent crude oil price scenarios defined for the study is also shown in **Exhibit 2.4**, and a more detailed calculation of the same is shown in **Exhibit C.2** and **Exhibit C.3** of **Appendix C**.

8 These are reported in Final Revenue Requirement Determinations of the utilities.

Exhibit 2.4: Prescribed Prices of Domestic Gas

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Price of Basket of Imported Crude Oils (C&F Karachi)	$/bbl	112	97	126	141
FO Price (C&F)	$/tonne	662	579	745	828
Average Wellhead Price	**$/MMBtu**	**3.50**	**3.33**	**3.67**	**3.85**
T&D losses and Internal Consumption	$/MMBtu	0.28	0.27	0.30	0.31
Transportation & Distribution Cost	$/MMBtu	0.34	0.34	0.34	0.34
Return on Assets	$/MMBtu	0.19	0.19	0.19	0.19
Less: Other Income	$/MMBtu	(0.16)	(0.16)	(0.16)	(0.16)
Prescribed Price	**$/MMBtu**	**4.15**	**3.97**	**4.34**	**4.52**

2.2 Imported Natural Gas Supply Cost

2.2.1 Liquefied Natural Gas (LNG)

The imported price of LNG was determined using the formula stated below:[9]

Border price of LNG ($/MMBtu) = 0.152 x Brent ($/bbl) + 0.5

The border price of LNG included ocean transportation charges. Re-gasification costs of $ 0.90/MMBtu and average inland T&D cost of $ 0.65/MMBtu were incorporated to calculate the mid-country delivered price of LNG. The mid-country delivered price of LNG was calculated as $ 19.53/MMBtu for the base case crude oil price scenario. **Exhibit 2.5** presents the mid-country delivered price of LNG under various crude oil price scenarios.

[9] This is the GDF Suez formula, which was reported in a Business Recorder new item, 'MoP bent on awarding Mashal LNG Project to GDF Suez' dated November 11, 2010. This formula provides a point of reference, but the cost at which LNG will be imported by Pakistan is subject to negotiations between the GoP and the potential suppliers of LNG.

Exhibit 2.5: Mid-Country Delivered Price of LNG

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
LNG Import Price – Border Price	**$/MMBtu**	**17.98**	**15.70**	**20.26**	**22.54**
Regasification	$/MMBtu	0. 90	0.90	0.90	0.90
LNG Import Price – Re-gasified	**$/MMBtu**	**18.88**	**16.60**	**21.16**	**23.44**
Inland T&D Cost	$/MMBtu	0.65	0.65	0.65	0.65
Mid-country Delivered Price of LNG	**$/MMBtu**	**19.53**	**17.25**	**21.81**	**24.09**

The above cost of imported gas appears high when compared with the average cost of gas delivered to the consumers in the country, which ranges from $ 3.97/MMBtu under the $ 100/bbl crude oil price scenario to $ 4.52/MMBtu under the $ 145/bbl crude oil price scenario. However, keeping in view the limited availability of domestic gas due to depleting reserves and the increasing energy demand, gas import in the form of LNG may be necessary to meet the country's energy needs. An increase in the price of domestic gas will be unavoidable following the commencement of natural gas imports since the cost of imported gas will become part of the prescribed prices for the two gas utilities.

2.2.2 The Iran-Pakistan-India (IPI) and Turkmenistan-Afghanistan-Pakistan-India (TAPI) Gas Pipeline Projects

The ToRs of the study also specified that the cost of imported gas supplied through the IPI and TAPI pipelines be determined in line with the proposed purchase agreements for the two projects. However, the government has not disclosed the IPI and TAPI formulae as they are not yet determined. Thus, the cost of imported piped gas through the IPI and TAPI projects could not be determined.

2.3 Consumer Pricing and Allocation for Natural Gas

Consumer gas prices vary across the economic sectors in the country. The government fixes consumer gas prices and maintains them at a uniform level throughout the country. The two gas utilities, SNGPL and SSGCL, supplying gas to consumers in their operational areas are not required to maintain or provide a breakdown of costs of service delivery for different segments of the transmission and distribution system or for supplying gas to different consumer categories. The cost of supplying gas to customers at various locations is not accounted for and, regardless of the difference in cost due to location, all consumers within the same category pay a uniform price. **Exhibit C.4** of **Appendix C** summarizes the current consumer prices of gas for the various economic sectors of Pakistan.

Currently, gas is supplied to the various sectors under the 'Natural Gas Allocation and Management Policy 2005'. According to this policy, natural gas demand on the system during the peak winter load period or shortfalls in supplies from E&P companies are met as per the order of priority and demand management practices outlined in **Exhibit 2.6** and **Exhibit 2.7**.

Exhibit 2.6: Priority Order for Consumers connected to the System

Sector	*Priority*
Domestic and Commercial Sectors	First
i) Fertilizer Sector; and	Second
ii) Industrial Sector to the extent of their process gas.	
Independent Power Plants as well as WAPDA and KESC's Power Plants having firm gas supply commitments under their GSAs.	Third
General Industrial and CNG Sectors.	Fourth
i) WAPDA's and KESC Power Plants other than those listed above; and ii) Captive Power Sector.	Fifth
Cement Sector.	Sixth

Exhibit 2.7: Priority Order for Consumers on Independent Network

Sector	*Priority*
Fertilizer Plants	First
Power Sector including WAPDA, KESC and IPPs having firm gas supply commitments under GSAs	Second
Power Sector other than those listed above.	Third

The power sector is the largest consumer of gas with a 29% share at present, followed by the industrial (26%), domestic (17%), fertilizer (17%), transportation (8%) and commercial (3%) sectors.[10]

2.4 Consumer Pricing and Allocation for Alternatives to Natural Gas

The alternatives to natural gas considered in the analysis are listed in **Exhibit 2.8**.

10 Ministry of Petroleum & Natural Resources. *Pakistan Energy Yearbook: 2010*.

Exhibit 2.8: Alternatives to Natural Gas in Various Sectors

Sector	*Application/End-Use*	*Alternative*
Power	Power Generation	FO HSD LNG
Residential and Commercial	Cooking	Firewood LPG Kerosene
	Water Heating	Electricity LPG Solar – Hybrid Electric Solar – Standalone Solar – Hybrid Gas Geyser
	Space Heating	Electricity LPG
Agricultural	Domestic Fertilizer Production	Import Urea LNG
Industrial	Captive Generation	Electricity – supplied from utility FO
	Boiler/Heating Use	FO
Transportation	Fuel for Motor Vehicles	Gasoline

This section provides the present pricing mechanism for the alternative fuels to natural gas considered in the analysis. The HBP Energy Pricing Model is used to calculate the prices of the alternative fuels to natural gas in accordance with the pricing mechanism presented in this section.

2.4.1 Petroleum Products

Since March 2006, OGRA has been mandated to determine the prices of petroleum products. OGRA is advised to fix the import parity price (IPP) of kerosene, gasoline and HSD, and the ex-depot sale prices of gasoline and kerosene only. The price computation of FO has been completely deregulated by the GoP; oil marketing companies (OMCs) are allowed to import it directly and fix its sale price based on the average cost of import. The local consumer prices are linked with the international market prices of petroleum products. OGRA notifies the consumer prices on a monthly basis.[11] The consumer price buildup constitutes the following:

[11] Before February 2009, petroleum prices were notified on bimonthly basis.

Carriage and freight (C&F) price, which is computed by adding the premium and ocean transportation cost to the freight on board (FoB) price, where the FoB price is a monthly average of the daily Platts prices for the preceding month.[12]

Import parity price: this is the C&F price plus various import incidentals such as marine insurance, ocean losses, bank charges and wharfage. This is also known as the ex-refinery price.

Ex-depot price: this is calculated by adding the distributors' margin, dealer commission, inland freight equalization margin (IFEM), and sales tax to the ex-refinery price.[13]

For the purpose of this study, the FoB price of petroleum products was determined using an average price relationship of petroleum products with Brent crude oil, using price data of March 2011. Based on this one month period, the resulting price relationships between the different petroleum products and Brent crude oil are shown in **Exhibit 2.9**:

Exhibit 2.9: Relationship of Petroleum Products with Brent Crude Oil

Fuel	*Price Relation with Brent Crude*
Kerosene	121%
Motor Gasoline	105%
High Sulfur Fuel Oil	78%
High Speed Diesel	111%

Diesel fuel meets a large percentage of land transportation requirements in the country, and its production by the local refineries is encouraged through a premium over the international market price. A 7.5% tariff (or deemed duty), included in the IPP price of HSD, is used to protect a minimum level of return to oil refineries. The tariff is computed using the following step-by-step methodology:

1. An insurance cost of 1% of the C&F price is calculated.
2. This insurance cost is added to the C&F price to reach the carriage, insurance and freight (CIF) price.
3. Customs charges (which are 1% of the CIF price) are added to this, and the resulting price is used for tariff computation.
4. Tariff is charged at the rate of 7.5% of this resulting price.

It should be noted that as per OGRA's methodology, the insurance and customs charges are only used for tariff calculation and are not included in the buildup of IPP.

[12] Platts is a division of The McGraw-Hill Companies based in the US, is a leading independent global provider of energy and metals information and is widely used as a reliable source of industry information.

[13] As deemed duty in the calculation of ex-refinery prices of HSD, kerosene, LDO, and JP-4 in the IPP.

In the determination of the IPP,[14] the FoB prices of kerosene, gasoline, HSD and FO are taken from Platts. Previously, the computation of IPP included import incidentals such as, marine insurance, ocean losses, bank charges and wharfage, which formed around 1% of the C&F price. However, on 30 November 2010, OGRA announced that import incidentals would no longer be included in the IPP computation.

In the same order, the mechanism for distributors' margin and dealer commission was also changed and these were fixed at absolute values given in **Exhibit 2.10**. Previously, the distributors' margin and dealer commissions were set at 4% and 5% of the ex-refinery price, respectively. The distributors' margin is the return to the suppliers of OMCs, while the dealer commission is the return to OMCs. OMCs are also allowed an Inland Freight Equalization Margin (IFEM). A petroleum levy as notified by Ministry of Petroleum and National Resources (MPNR) from time to time is also added to the price of motor gasoline and HSD. After the distributors' margin, dealer commission, IFEM and petroleum levy are added to the IPP, the ex-depot price is reached. The OMCs have also been allowed to charge the secondary freight costs from depots to retail outlets over and above the ex-depot prices under the freight pool mechanism. Current consumer prices of the petroleum products are given in **Exhibit 2.11**.

Exhibit 2.10: Distributors' Margin and Dealers Commission of Petroleum Products as of November 30, 2010

		Motor Gasoline	*HSD*	*Kerosene*
Dealer Commission	Rs/Liter	1.87	1.50	0
Distributors' Margin	Rs/Liter	1.50	1.35	1.58

Exhibit 2.11: Consumer Prices of Petroleum Products as of April 1, 2011

Product		*Consumer Price*
Motor Gasoline	Rs/Liter	83.56
Kerosene Oil	Rs/Liter	84.10
HSD	Rs/Liter	92.89
FO	Rs/Tonne	71,446

A detailed computation based on OGRA's and PSO's methodology of calculating the delivered price of Gasoline, Kerosene, FO and HSD is presented in **Exhibit 2.12** for different Brent crude oil price scenarios. The table distinguishes the economic and financial prices for each fuel, as opposed to the ex-refinery and ex-depot prices, because this distinction is more relevant to the analysis.

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[14] Ex-refinery price is the price at which the local refineries sell the petroleum products, which equals the import parity price of the products.

Exhibit 2.12: Detailed Computation of Prices of Gasoline, Kerosene, FO and HSD

		Motor Gasoline				*FO ($/MMBtu)*				*HSD ($/MMBtu)*				*Kerosene ($/MMBtu)*			
Crude Oil Price – Brent	*($/bbl)*	*115*	*100*	*130*	*145*	*115*	*100*	*130*	*145*	*115*	*100*	*130*	*145*	*115*	*100*	*130*	*145*
FoB Price	($/MMBtu)	20.79	18.08	23.51	26.22	15.54	13.51	17.56	19.59	21.88	19.03	24.73	27.59	24	20.87	27.13	30.27
Premium & Ocean Transport	($/MMBtu)	0.41	0.41	0.41	0.41	0.66	0.66	0.66	0.66	0.36	0.36	0.36	0.36	0.39	0.39	0.39	0.39
C&F Price	**($/MMBtu)**	**21.2**	**18.49**	**23.92**	**26.63**	**16.19**	**14.17**	**18.22**	**20.25**	**22.25**	**19.39**	**25.10**	**27.95**	**24.4**	**21.27**	**27.53**	**30.66**
Dealer Commission	($/MMBtu)	0.66	0.66	0.66	0.66	0.57	0.50	0.64	0.71	0.48	0.48	0.48	0.48	–	–	–	–
Distributors' Margin	($/MMBtu)	0.53	0.53	0.53	0.53	–	–	–	–	0.43	0.43	0.43	0.43	0.54	0.54	0.54	0.54
IFEM	($/MMBtu)	1.97	1.97	1.97	1.97	0.71	0.71	0.71	0.71	0.73	0.73	0.73	0.73	0.46	0.46	0.46	0.46
Economic Price	**($/MMBtu)**	**24.37**	**21.65**	**27.08**	**29.79**	**17.47**	**15.38**	**19.57**	**21.67**	**23.88**	**21.03**	**26.73**	**29.59**	**25.4**	**22.27**	**28.53**	**31.67**
Tariff on Import Price (on HSD only)	($/MMBtu)	–	–	–	–	–	–	–	–	1.7	1.48	1.92	2.14				
PDC (on Kerosene only)	($/MMBtu)													(0.58)	(0.58)	(0.58)	(0.58)
Petroleum Development Levy	($/MMBtu)	1.12	1.12	1.12	1.12	–	–	–	–	0.14	0.14	0.14	0.14	–	–	–	–
Sales Tax (17% of delivered Price)	($/MMBtu)	4.33	3.87	4.79	5.26	2.97	2.61	3.33	3.68	4.31	3.79	4.83	5.35	4.22	3.69	4.75	5.28
Financial Price (taxed)	**($/MMBtu)**	**29.82**	**26.65**	**32.99**	**36.17**	**20.44**	**17.99**	**22.90**	**25.35**	**30.03**	**26.44**	**33.62**	**37.22**	**29.04**	**25.38**	**32.70**	**36.37**

2.4.2 Liquefied Petroleum Gas (LPG)

The LPG pricing methodology has been completely deregulated and the prices are determined by LPG marketing companies. In 2006, the GoP linked the LPG base stock price to the FOB Saudi ARAMCO contract price for propane and butane, published in Platts for the previous month, taking a propane-butane ratio of 40:60. However, in December 2007, the GoP decided to use this price as a ceiling for LPG prices in the country, and producers were allowed to offer discounts on these prices in their retail operations. The average local market price of LPG, on 1 April 2011, stood at $ 26.5/MMBtu. [15]

In the summers, producers offer discounts due to lack of demand. Thus, the distributor margin shrinks in the summers and increases in the winters. Under recommended retail prices, the distributor typically earns Rs 50 on average on each domestic 11.8 Kg cylinder transaction.

For the purpose of the study, the Saudi ARAMCO contract price was determined based on a historical relationship with the average Brent crude oil price during March 2011. A freight cost, of around 13% of the base stock price, was added to reach the C&F price. Insurance and landing costs of around 0.2% and 0.5% of the C&F price respectively, were added on to the C&F price to arrive at the CIF price. Wharfage and port incidentals were further added to the CIF price to arrive at the landed cost of imported LPG. Engro Vopak Terminal Limited (EVTL) charges, bulk transport costs and bulk shifting costs were added to the landed cost to arrive at the price at port Qasim. Finally, costs of filling cylinders and transporting them to the market were added to the port Qasim price to arrive at the economic retail price of LPG, which was $ 23.79/MMBtu for the base case scenario. This complete price chain is presented in **Exhibit 2.13** for various price scenarios of Brent crude oil.

Exhibit 2.13: Price Chain of Imported LPG

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Base Stock Price	$/MMBtu	18.74	16.30	21.18	23.63
Freight	$/MMBtu	2.44	2.12	2.75	3.07
C&F Price	$/MMBtu	21.18	18.41	23.94	26.70
Insurance (0.2% of C&F price)	$/MMBtu	0.04	0.04	0.05	0.05
Landing Charges (0.5% of C&F price)	$/MMBtu	0.11	0.09	0.12	0.13
CIF Price	$/MMBtu	21.32	18.54	24.11	26.89
Wharfage	$/MMBtu	0.03	0.03	0.03	0.03

[15] **Source:** *OGRA*. Prices notified by LPG marketing companies. <http://www.ogra.org.pk/images/data/downloads/1304334925.pdf>

		Base Case	Oil Price Scenario 1	Oil Price Scenario 2	Oil Price Scenario 3
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
PQA Royalty	$/MMBtu	0.07	0.07	0.07	0.07
Clearing Charges/Agent Fee (0.45% of C&F price)	$/MMBtu	0.10	0.08	0.11	0.12
Landed Cost	$/MMBtu	21.52	18.73	24.31	27.11
EVTL Charges	$/MMBtu	0.43	0.43	0.43	0.43
Bulk Transportation Rate	$/MMBtu	0.07	0.07	0.07	0.07
Bulk Shifting, EVTL to Plant	$/MMBtu	0.07	0.07	0.07	0.07
Cost at Plant (PQA)	$/MMBtu	22.09	19.29	24.88	27.68
Bulk Transportation Cost to the Market	$/MMBtu	1.10	1.10	1.10	1.10
Cylinder Filling Cost	$/MMBtu	0.03	0.03	0.03	0.03
Distributor Transportation Cost	$/MMBtu	0.57	0.57	0.57	0.57
Economic Price ($/MMBtu)	**$/MMBtu**	**23.79**	**21.00**	**26.58**	**29.38**
Excise and Taxation (0.5% of C&F price)	$/MMBtu	0.11	0.09	0.12	0.13
Sales Tax (17% of total price)	$/MMBtu	4.06	3.59	4.54	5.02
Financial Price ($/MMBtu)	**$/MMBtu**	**27.96**	**24.67**	**31.24**	**34.53**

2.4.3 System Average Cost of Electricity Service

The system average cost of electricity service in the Pakistan Electric Power Company (PEPCO) system was determined by adjusting 2009 data for 2011 prices. Data was taken from the latest NEPRA tariff determination for distribution companies (DISCOs) dated 4 September, 2009, and was adjusted to account for currency inflation and changes in fuel prices, where applicable. The economic costs of all the fuels used for power generation were considered. Since the current price of domestic gas does not reflect its true economic cost, the economic cost of natural gas was taken at parity with FO, which is the next best alternative for power generation. Hence, the total fuel cost for 2011 was determined. All other expenses were adjusted only for currency inflation, and were added to the fuel cost to arrive at the total economic cost of service. A summarized buildup of the total cost of service is shown in **Exhibit 2.14**.

Exhibit 2.14: Cost of Service

	Cost of Supply ($ '000)
Fuel Cost	9,060,302
Other costs	152,169
Capacity Cost	1,241,474
Total Generation Costs	**10,453,945**
Transmission Cost	222,173
Distribution Cost	644,944
Total Cost of Service	**11,321,062**

The total cost of service was divided by the total volume of electricity generated to arrive at the system average economic cost of electricity per unit, as shown in **Exhibit 2.15**.

Exhibit 2.15: Base Case System Average Economic Cost of Service per Unit

		Total Amount
Total Cost of Service	$ '000	11,321,062
Total Electricity Sold	GWh	62,646
Average Economic Cost of Service per Unit	**¢/KWh**	**18.07**

Petroleum products and natural gas are input fuels for electricity generation, and since their prices vary with the price of Brent crude oil, the system average economic cost of electricity also varies with different Brent crude oil price scenarios. The resulting electricity prices for various Brent crude oil price scenarios are shown in **Exhibit 2.16**. The economic prices of natural gas, HSD and FO were used to calculate the system average economic costs of delivered electricity.

Exhibit 2.16: System Average Economic Cost of Service per Unit for Different Brent prices

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Natural Gas Price	$/MMBtu	5.14	4.92	5.36	5.58
HSD Price	$/Liter	0.93	0.82	1.05	1.16
FO Price	$/Tonne	713	627	798	884
Average Economic Cost of Electricity Service per Unit	**¢/kwh**	**18.07**	**16.37**	**19.78**	**21.48**

3. Economic Value of Natural Gas in Various Sectors

This section explains how the economic value of natural gas was computed in each sector based on the alternative energy sources mentioned in **Section 2.4**. The economic value was considered to be the total cost to the economy of replacing natural gas with its next best alternative. Since each sector uses natural gas differently, there is a different cost associated with the replacement of natural gas in each sector.

3.1 Power

Power sector consumed about 15.8 million tonnes of oil equivalent (MTOE) of energy in 2010, of which FO and natural gas accounted for 53% and 45% respectively. Pakistan is an energy deficit country and imports FO for nearly 65% of the electricity produced by thermal power plants. With increasing shortage of natural gas, the country's reliance on FO is rapidly rising. The government is seriously pursuing import of natural gas in the form of LNG or piped gas from gas-rich neighboring counties to meet the demand for natural gas in the country.

The economic value of natural gas for power generation will vary over time as both the fuel and technology mix for power generation will change. The factors that will determine economic value of gas for power generation in the long-term include capital and operating costs as well as operational characteristics of the alternative power generation technologies, resource/fuel availability, the economic costs of natural gas and alternative fuels, forecast of electricity demand, and government policies on development of hydroelectric, renewable energy, and other energy resources.

The economic value of natural gas for power generation in the near and medium-term depends on the replacement cost of alternative fuels for the existing[16] switchable power generation capacity. This study focuses on the near and medium-term perspective to assist the government in formulation of a gas load management policy for optimal use of natural gas in the economy to achieve highest economic returns for a limited supply of gas.

The economic value of natural gas for power generation was calculated on the basis of the cost of replacement fuels for existing gas-based generation capacity. HSD, FO, naphtha and coal could serve as alternatives to natural gas for power generation. In the near and medium-term, the use of naphtha as an alternative to natural gas would require technological modifications in existing gas-based plants. A continuous supply of naphtha would also have to be guaranteed since power plants cannot operate on naphtha and HSD interchangeably. Based on current estimates of the domestic production of naphtha, a continuous supply of naphtha for power generation could not be assumed in the near and

[16] Existing power generation capacity for the purpose of this study includes both the existing plants and those which are committed to be commissioned within 2011.

medium-term. Thus, the use of naphtha as an alternative to natural gas for power generation was ruled out in the near and medium-term. The use of coal as an alternative to natural gas for power generation was also ruled out in the near and medium-term since converting the existing gas-based steam turbines to coal-based steam turbines would require a time period of at least three to four years. At present, Pakistan has a very limited coal-based power generation capacity.[17] In the near and medium-term, HSD and FO were considered as alternatives to natural gas since a number of installed power plants have dual fuel capability and can operate on FO or HSD as alternative fuels to natural gas. These plants fall in three categories:

1. Combined cycle gas turbine (CCGT) plants that can only operate on natural gas due to technological or contractual constraints,
2. Combined cycle plants that can operate on alternative fuels such as HSD and FO, and
3. Steam turbine plants that can switch to FO.

The first category of plants can also operate on HSD with infrastructure augmentation and contract modifications and therefore, were lumped together with plants falling in the second category to calculate the economic value of natural gas. To determine the economic value of gas for power generation, the HBP Power Model, which takes into account seasonality of electricity demand, hydroelectric and thermal plant capabilities, thermal efficiencies and plant availability, was used.[18]

Cost and operational data were obtained from the National Electrical Power Regulatory Authority (NEPRA) and Power System Statistics.[19] These data included the tariff determinations for generation companies. The terms and conditions outlined in the power purchase agreements for IPPs were used as a reference. Operational data related to availability, heat rates, variable operational expenditures and annual power demand and supply patterns was obtained from NEPRA determinations for GENCOs, NTDC and DISCOs. The operational data was fed as input into the HBP power dispatch model to calculate the cost of producing electricity for the power sector as a whole and per unit cost of producing electricity for individual plants. All the existing power plants, as well as those which are to be commissioned by the end of June 2011, were taken into account when calculating the cost and capacity for power generation. The total power generation output of the country was kept constant at its current level. Thus, in present analyses, the economic cost of replacing gas for power generation was based on the additional FO and HSD consumed to maintain the same power generation output.

The scheduled maintenance and forced outage rates and net availability of power plants for plant dispatch simulations were based on average performance indicators for plants in the public sector and on IPP contracts for plants in the private sector. The energy

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17 Lakhra Power Station, with an installed capacity of 150 MW, is the only power plant based on locally produced lignite coal. The effective capacity of the plant has dropped to 30 MW due to technical and operational constraints.

18 HBP has developed and maintains a proprietary analytical model for long-term planning and economic dispatch of power generation capacity in Pakistan.

19 National Transmission and Despatch Company. *Power System Statistics.*

generation from each plant was worked out on the basis of economic dispatch to meet the energy generation requirements of the country. The plant dispatch was simulated on a monthly basis to account for seasonal variations in power demand and availability of hydroelectric resources in the country. The dispatch of hydroelectric units is governed by the water release indents issued by the Indus River System Authority (IRSA) to meet the demand of provinces for irrigation water. The thermal plants, on the other hand, were dispatched on economic merit order. The economic merit order was determined only on the basis of the variable costs of the plants accounting for the fuel cost and variable O&M costs, and plants with lower variable operational costs were dispatched ahead of those with higher costs.

In order to capture the economic value of natural gas supplied to various generation units, the dispatch analysis was performed on an incremental basis by switching gas unit by unit, starting with the most expensive (based on total variable costs) and going down to the least expensive units in the system. Economic prices (prices excluding taxes and subsidies) of gas and alternative fuels were used in the analysis. The total power generated and the total variable costs incurred for one year of operation were calculated for each step of gas switching. Due to prevailing shortages of natural gas in the country, natural gas was supplied in the near-term only to plants that face technological or contractual constraints in use of alternative fuels. These plants could also switch to HSD, but would require installation of HSD storage and handling infrastructure at the plants and revision of IPP agreements that may take years to accomplish. Furthermore, the gas supply contracts of four of the recently commissioned combined cycle IPPs,[20] which were set up under the 2002 Power Policy and are currently receiving gas from the national gas pipeline network,[21] will expire in June 2011. These plants have the infrastructure to use HSD as the alternative fuel in the absence of natural gas. In addition, the combined cycle units of Kot Addu Power Company (KAPCO) also have the capability of using HSD and FO and have been operating on alternative fuels after 2008 due to the shortage of natural gas.

For each power generation unit, the economic value of natural gas was calculated as the replacement cost of generation using replacement fuels. **Exhibit 3.1** shows the economic value of natural gas for each incremental MMscfd supplied to the power sector. **Appendix D** presents the unit-wise calculation of economic value of natural gas under the four crude oil price scenarios considered in this study.

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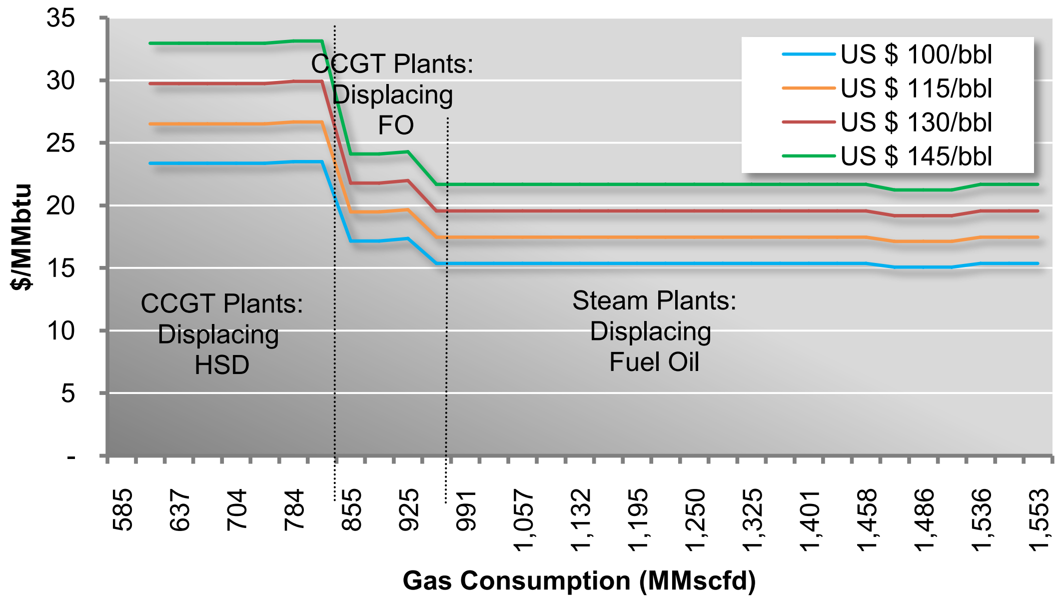
[20] Four IPPs set up under the 2002 power policy, Orient Power Company Limited (229 MW), Saif Power Limited (229 MW), Sapphire Electric Company Limited (225 MW) and Bhiki (Halmore) Power Company Limited (225 MW), have a total average annual demand of gas of 152 MMscfd.

[21] National gas pipeline network of Sui Northern Gas Pipeline Limited (SNGPL) and Sui Southern Gas Company Limited (SSGCL)

Exhibit 3.1: Economic Value of Gas for Power Generation



The power sector in Pakistan has a minimum requirement of 585 MMscfd of gas for the CCGT plants that face technological or contractual constraints in using alternative fuels in the near term.[22] However, these plants can operate on HSD and therefore, the economic value of natural gas supplied to these plants was calculated on the basis of replacement cost of HSD.[23] The economic value of natural gas for HSD-based CCGT units of IPPs was estimated at $ 26.56/MMBtu for the base case crude oil price scenario of $ 115/bbl.

The economic value of natural gas for FO-based CCGT units[24] was calculated to be $ 19.54/MMBtu. However, these CCGT plants are not being supplied natural gas and are fully operational on FO. Thus, the economic value of natural gas for FO-based CCGT plants was excluded from the analysis.

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22 The low/medium Btu gas from independent sources is supplied to Engro Energy Limited, Liberty Power, Uch Power, and TPS Guddu. The pipeline quality gas is supplied to Habibullah Coastal, Fauji Kabirwala, Rousch Power, and GTPS Faisalabad by SNGPL, whereas GTPS Kotri, GTPS Site, GTPS Korangi, and DHA Cogen are supplied through the gas network of SSGCL.

23 Until the completion of infrastructure augmentation and contract modifications, not supplying gas to this capacity may further increase the already rampant load shedding in the country. In that case, the economic value of 585 MMscfd of gas demand could be equated to the cost of unserved energy, which has been estimated to be around 3 times higher than the cost of supplying electricity on HSD. Value of cost of unserved energy was estimated to be $ 0.6/kWh by the study carried out by International Resources Group for Asian Development Bank (ADB) under ADB TA-4982 PAK. *Pakistan Integrated Energy Model (Pak-IEM) - Policy Analysis Report Volume II (2010)*. Pakistan.

24 Block 1 (GT1, GT3, and ST9) and Block 2 (GT2, GT4, and ST10) of KAPCO have one Fiat gas turbine each that can only operate on natural gas and HSD. Rest of KAPCO consists of gas turbines manufactured by Siemens and General Electric, capable of operating on natural gas, FO and HSD. However, these turbines normally operate on FO as the alternative fuel to natural gas because of the cost advantage of FO over HSD.

The economic value of natural gas for steam turbine plants was also calculated. Presently, natural gas is not being supplied to any of the steam turbine plants which can operate on both natural gas and FO. Thus, the calculation of economic value of natural gas for steam turbine plants is a hypothetical case. The economic value of natural gas for steam turbine plants was calculated as $ 17.42/MMBtu based upon the cost of FO as the replacement fuel, under the crude oil price scenario of $ 115/bbl.

Exhibit 3.2 summarizes the economic value of natural gas for power generation under various crude oil price scenarios.

Exhibit 3.2: Economic Value of Gas for Power Generation under Various Crude Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
CCGT Plants with HSD as Replacement Fuel	$/MMBtu	26.56	23.39	29.78	33.01
CCGT Plants with FO as Replacement Fuel	$/MMBtu	19.54	17.22	21.85	24.17
Steam Turbine Plants with FO as Replacement Fuel	$/MMBtu	17.42	15.33	19.52	21.61

3.2 Residential and Commercial Sectors

Natural gas is utilized in the residential and commercial sector of Pakistan for cooking, water heating, and space heating. Alternatives to these three uses of the fuel were considered separately in the study to determine the economic value of gas for each use. The costs of these alternative fuels were calculated based on the amount of energy needed to provide the same level of service as that provided by a specific volume of gas. Thus, the analysis took into account efficiency adjustments, which were determined using industry sources.[25] Detailed assumptions and calculations relating to the analysis are presented in **Appendix E**.

For cooking, LPG, kerosene, and purchased firewood were treated as alternatives to natural gas. Self-gathered firewood was not included in the study since the study only looks at firewood as a commercial fuel. Self-gathered firewood is mainly used in areas where the gas network does not exist and thus, does not serve as an alternative to natural gas in areas with access to the gas network. The HBP Energy Pricing Model (**Section 2.4**), which takes prices notified by OGRA as inputs, was used to determine the economic cost of LPG and kerosene, while the cost of purchased firewood was obtained

[25] End-use efficiencies applying to cooking have been obtained from World Bank estimates, while water heating efficiencies were obtained from a study titled 'Development of Solar Hot Water Systems for Domestic Application in Pakistan' carried out by German Technical Corporation (GIZ). Estimates of space heating efficiencies were based on verbal communication with market sources.

from market sources. The efficiency-adjusted costs of the alternative fuels were then compared to determine the least cost alternative, which was considered as the economic value of natural gas for use in cooking. Conversions were carried out to determine the economic value of natural gas in terms of $/MMBtu. The analysis indicates that LPG is the cheapest of the three alternatives and thus, its cost, on a $/MMBtu basis, was considered to be the economic value of gas for cooking purposes in the residential and commercial sectors. The results of the analysis under the base case Brent crude oil price scenario are tabulated in **Exhibit 3.3**.

Exhibit 3.3: Economic Value of Gas for Cooking

		LPG	*Kerosene*	*Firewood*
Replaced Gas	MMBtu	1.00	1.00	1.00
End-use Efficiency	%	100	66	10
Alternative Fuel	MMBtu	1.00	1.50	10.00
Delivered Economic Price of Alternative Fuel	$/MMBtu	23.79	25.40	7.81
Total Cost of Alternative Fuel	$	23.79	38.49	78.14
Economic Value of Gas	**$/MMBtu**	**23.79**	**38.49**	**78.14**

The analysis was repeated for various crude oil price scenarios. However, the price of firewood remained the same under all the scenarios since no direct linkage between Brent crude oil and firewood prices could be established due to a lack of historical data on firewood prices. The analysis indicates that LPG remains the cheapest of the three alternatives and thus, its cost, on a $/MMBtu basis, was considered to be the economic value of gas for cooking purposes under all the crude oil price scenarios, as shown in **Exhibit 3.4**.

Exhibit 3.4: Economic Value of Gas for Cooking under Various Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Economic Cost of LPG	$	23.79	21.00	26.58	29.38
Economic Cost of Kerosene	$	38.49	33.75	43.23	46.40
Economic Cost of Firewood	$	78.14	78.14	78.14	78.14
Economic Value of Gas for Cooking	**$/MMBtu**	**23.79**	**21.00**	**26.58**	**29.38**

Current consumption patterns of gas, LPG and kerosene in the residential and commercial sector were analyzed to determine the relative consumption of each fuel in the sector. Consumption figures for gas, LPG and kerosene indicate that, at present, natural gas, with a share of 90%, dominates the combined consumption of the three fuels in the residential and commercial sector, with LPG and kerosene contributing 8% and 2% to the mix, respectively. However, these shares account for all possible uses of each fuel in the residential and commercial sector. For instance, the market share of kerosene includes its use for cooking as well as for lighting, for which kerosene is principally used in the absence of ready access to electricity, and space heating.

LPG is primarily used in cooking by those households that do not have access to piped gas, while kerosene is primarily used for lighting in areas with no access to electricity. Kerosene's use, for cooking purposes is restricted to areas where both piped gas and LPG are not available. Kerosene is not the fuel of choice for cooking in areas connected to the gas network or where LPG is available, due to lower end-use efficiency of kerosene in cooking and higher cost of the fuel in comparison to both natural gas and LPG.

Firewood is mainly used in rural households in mountainous and remote areas, such as those in Baluchistan that lack access to alternative fuels, where much of it is gathered by women and children. In such households, it is used for cooking, space heating, water heating and other purposes. For instance, cooking stoves also provide space heating and serve a social function as women huddle around the stoves to talk amongst themselves. Firewood is also used extensively in households and commercial establishments in those areas of Northern Pakistan where access to the gas network is limited. The availability of firewood in comparison to alternatives and available labour (women and children) for collection of firewood determine fuel choice in such areas. The negative environmental impact, in the form of harmful emissions, of firewood in comparison to its alternative is usually ignored by the households when choosing fuels in rural and low-income households.

The share of consumption of firewood was not included in the combined consumption of gas, LPG and kerosene since reliable data was not available for the consumption of purchased firewood in the residential and commercial sector. The only source of reliable firewood consumption data is the Pakistan Household Energy Strategy Study (HESS) and the Household Integrated Economic Survey (HIES). HESS reports firewood, both purchased and gathered, accounting for 54% of the total household energy consumption in Pakistan. However, the data is outdated since the survey was conducted in 1992. HIES, completed in 2005-06, contains data regarding household consumption expenditure on firewood. HIES attributes 20% of the total household expenditure on fuel and lighting to firewood. However, the data for HIES included consumers without access to the gas network. Currently, purchased firewood is not expected to be used by consumers who are connected to the gas network given firewood's high efficiency-adjusted cost, as highlighted in **Exhibit 3.3**.

For water heating, electricity and solar appliances were considered as alternatives to natural gas. In the case of electricity, equivalent amount of heating output was calculated by taking into account the comparative efficiency factors of gas geysers versus electrical water heaters. The cost of heating water using electricity was then calculated for the selected oil price scenarios based upon the average economic cost of electricity delivered to the consumers in the country.

Exhibit 3.5: Cost of Electricity for Water Heating

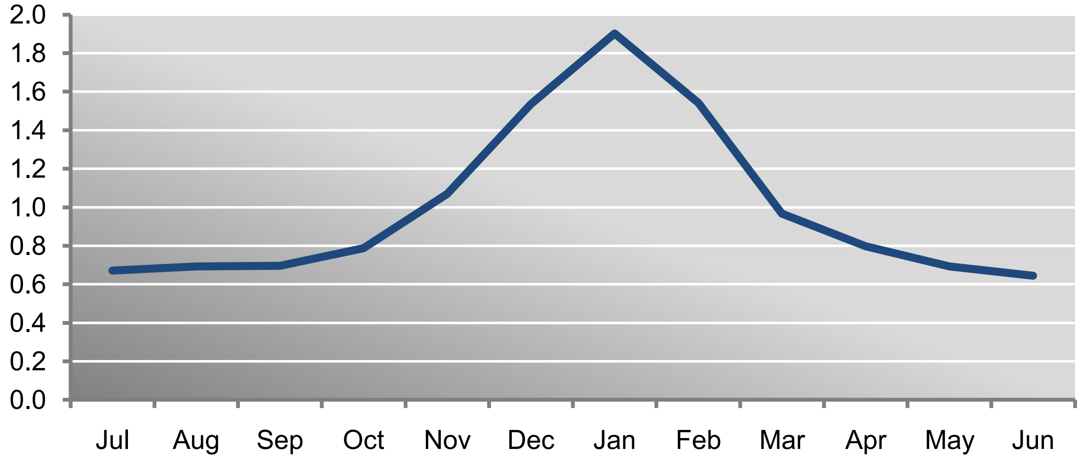
		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Replaced Gas	MMBtu	1.00	1.00	1.00	1.00
Gas Geyser Efficiency	%	20	20	20	20
Equivalent Energy Consumed	MMBtu	0.20	0.20	0.20	0.20

		Base Case	Oil Price Scenario 1	Oil Price Scenario 2	Oil Price Scenario 3
Electric Heater Efficiency	%	80	80	80	80
Equivalent Electricity Required	kWh	73.27	73.27	73.27	73.27
Average Economic Cost of Delivered Electricity	$/kWh	0.18	0.16	0.20	0.21
Cost of Electricity for Water Heating	**$/MMBtu**	**13.24**	**11.99**	**14.49**	**15.74**

The use of solar water heating systems in the country would be affected by convenience of supply issues, particularly among the high income consumers. Solar energy is only available during daylight hours, unless it is stored, which significantly increases the cost of solar water heating, with the investment costs of a standalone solar water heating system being almost double the costs of hybrid systems, as highlighted in **Exhibit 3.7**. Thus, this study considered the use of solar energy not just on a standalone basis, but in hybrid systems as well, which can provide the same level of service as gas-based heating systems. The investment cost of different solar water heating systems was obtained from market sources. These costs were then annualized, using the discount rate of 15% assumed in the study, for the economic life of the equipment. The O&M costs, estimated at 2% of the solar water heating system's investment cost, were added to the annualized capital costs to determine the total annual costs of the systems.

In order to calculate the amount of gas displaced by the solar water heating systems, gas consumption data was obtained from the two gas utilities and estimates of the end-uses (cooking, water heating and space heating) of gas were developed through the analysis of monthly demand profiles for both national gas utilities (**Exhibit 3.6**). Gas demand for cooking is uniform throughout the year, whereas both water and space heating contribute to peak loads during the winter season. The average monthly demand in the summer season (May-September) was considered as demand for cooking, while the difference between the demand for cooking and the average demand during the mild winter period (March, April, October and November) was attributed entirely to water heating. During these months, there is negligible space heating and thus, the incremental demand during the mild winter period can be considered as gas demand for water heating during these months. The difference between the average demand during the mild winter period and the average demand during the peak winter period (December-February) was considered as demand for both water and space heating since gas required for water heating increases during the peak winter period. Thus, the total annual demand for water heating was calculated by adding a proportion of the total incremental demand during peak winter to the gas demand for water heating during mild winter. The remaining incremental demand during peak winter was attributed to space heating.

Exhibit 3.6: Monthly Residential Sector Gas Demand Factors



The proportion of the total annual gas consumed for water heating that would be displaced by solar water heating was estimated by studying the consumption patterns of household energy use and using information collected from market sources. The total annual costs of the different solar systems, for an average household, were calculated in terms of $/MMBtu by using the estimated proportion of the total annual gas consumed for water heating that would be displaced by solar water heating. **Exhibit 3.7** summarizes the costs of solar water heating.

Exhibit 3.7: Costs of Solar Water Heating[26]

		Solar-Electric Hybrid	*Standalone Solar Water Heater*	*Solar-Gas Geyser Hybrid*
Total Investment Cost	$	565.96	1,003.29	578.82
Life	years	15	15	15
Discount Rate	%	15	15	15
Annualized Investment Cost	$	96.79	171.58	98.99
Annual O&M Cost	$	11.32	20.07	11.58
Total Annual Cost		108.11	191.64	110.56
Total Annual Gas Consumed	MMBtu	8.07	8.07	8.07
Proportion Replaced by Solar Water Heating	%	80	100	80
Annual Gas Replaced	MMBtu	6.46	8.07	6.46
Cost of Solar Water Heating	**$/MMBtu**	**16.74**	**23.74**	**17.12**

26 The capacity of the solar water heaters included in the analysis is 210 liters. In the case of a standalone solar water heater, two solar water heaters are used, so that sufficient storage capacity is available and thus, the total capacity of the standalone solar water heating system is 420 liters. The capacity of gas geysers is 130 liters.

A sensitivity analysis, using lower discount rates (10% and 5%), was conducted for solar water heating costs. The lower discount rates resulted in a decrease in solar water heating costs. Under the 10% discount rate scenario, solar water heating costs were in the range of $ 13.0/MMBtu to $ 18.8/MMBtu. Under the 5% discount rate scenario, solar water heating costs were in the range of $ 10.0/MMBtu to $ 14.5/MMBtu. Details of the analysis are presented in **Appendix E**.

The solar water heating costs were then compared to the cost of heating water using electricity under the base case crude oil price scenario to determine the least cost alternative, which was considered as the economic value of natural gas for water heating purposes in the residential and commercial sector. The analysis indicates that electricity is the cheapest of all the alternatives and thus, its cost, on a $/MMBtu basis, was considered to be the economic value of gas for water heating purposes in the residential and commercial sectors. **Exhibit 3.8** summarizes the economic value of gas for water heating under the base case crude oil price scenario.

Exhibit 3.8: Economic Value of Gas for Water Heating

		Electricity	*Solar-Electric Hybrid*	*Standalone Solar Water Heater*	*Solar-Gas Geyser Hybrid*
Replaced Gas	MMBtu	1.00	1.00	1.00	1.00
Cost of Alternative Energy	$	13.24	16.74	23.74	17.12
Economic Value of Gas for Water Heating	**$/MMBtu**	**13.24**	**16.74**	**23.74**	**17.12**

The cost of heating water using a solar water heating system were compared to the cost of heating water using electricity under various crude oil price scenarios. While the costs of heating water using solar water heating systems were assumed to remain the same for various scenarios, the average economic cost of delivered electricity changed under each scenario, as highlighted in **Exhibit 3.5**. The analysis indicates that water heating using electricity remains more economic in comparison to water heating using solar systems for all the crude oil price scenarios. **Exhibit 3.9** summarizes the economic value of gas for water heating under various crude oil price scenarios.

Exhibit 3.9: Economic Value of Gas for Water Heating under Various Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Replaced Gas	MMBtu	1.00	1.00	1.00	1.00
Economic Cost of Electricity	$/MMbtu	13.24	11.99	14.49	15.74
Annualized Cost of Solar-Electric-Hybrid	$/MMbtu	16.74	16.74	16.74	16.74
Annualized Cost of Standalone Solar-Water Heater	$/MMbtu	23.74	23.74	23.74	23.74
Annualized Solar Gas-Geyser Hybrid	$/MMbtu	17.12	17.12	17.12	17.12
Economic Value of Gas for Water Heating	**$/MMBtu**	**13.24**	**11.99**	**14.49**	**15.74**

For space heating, electricity was considered as an alternative to natural gas in the residential and commercial sector. Equivalent amounts of heating output were calculated by taking into account the comparative efficiency factors of gas heaters versus electrical heaters. The cost of space heating using electricity, based upon the average economic cost of delivered electricity for the consumers in the country, was taken as the economic value of gas under the selected oil price scenarios. **Exhibit 3.10** summarizes the economic value of gas for space heating under various crude oil price scenarios.

Exhibit 3.10: Economic Value of Gas for Space Heating under Various Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Replaced Gas	MMBtu	1.00	1.00	1.00	1.00
Gas Heater Efficiency	%	80	80	80	80
Equivalent Energy Consumed	MMBtu	0.80	0.80	0.80	0.80
Electric Heater Efficiency	%	90	90	90	90
Equivalent Electricity Required	kWh	260.51	260.51	260.51	260.51
Average Economic Cost of Delivered Electricity	$/kWh	0.18	0.16	0.20	0.21
Cost of Electricity	$	47.08	42.64	51.52	55.95
Economic Value of Gas for Space Heating	**$/MMBtu**	**47.08**	**42.64**	**51.52**	**55.95**

The ToRs of the study specified the use of LPG as an alternative to natural gas for cooking only. Given that the country is facing power outages, LPG was also considered as an alternative to natural gas for water and space heating. The efficiency of water and space heating appliances remains the same on LPG as on natural gas. The economic value of natural gas considering LPG as an alternative for water and space heating was estimated to be $ 23.8/MMBtu.

The use of photovoltaic (PV) panels for generation of electricity using solar energy as an alternative to natural gas in the residential and commercial sector was also assessed to ascertain if the economic cost of delivered electricity to the residential and commercial consumers needs to be adjusted taking this source into account. The feasibility of switching to PV panels in the residential and commercial sector was analyzed based upon simple payback periods for PV panels of different capacities. The long payback periods suggest that under the present framework of costs and electricity tariffs, the use of PV panels is not feasible in the residential and commercial sector. Detailed assumptions and calculations relating to the analysis are presented in **Appendix E**.

3.3 Fertilizer

The fertilizer industry uses natural gas both as feedstock and fuel for manufacturing fertilizer. Since urea constitutes around 80% of the current domestic fertilizer production,[27] the study focused on economic value of natural gas for production of urea in the country. Detailed assumptions and calculations relating to the analysis are presented in **Appendix F**.

The two alternatives to supplying natural gas to the fertilizer sector are directly importing fertilizer in place of domestic fertilizer production, and using imported LNG both as a replacement feedstock and fuel. In the near-term, the use of imported LNG as an alternative feedstock and fuel in the fertilizer industry was ruled out due to the current absence of regasification facilities and other necessary infrastructure for the import of LNG in the country. Thus, the near-term analysis only considered the direct import of urea as an alternative to supplying natural gas to existing plants. In the case of importing urea in the near-term, simultaneous capacity payments would have to be made to existing plants to account for the cash payments the industry will have to make to the lenders against borrowed capital, return on equity, and fixed O&M costs.

To calculate the economic value of natural gas for existing fertilizer capacity in the near-term, the amount of natural gas required for both feedstock and fuel purposes for a specified level of fertilizer production was first calculated based on information provided by industry sources. Capacity payments, based upon the fixed costs involved in the fertilizer production process, were calculated using the industry data. Natural gas requirements and production costs for both efficient capacity added recently and older inefficient plants were calculated separately. To calculate the cost of importing urea, urea prices in the international market, on a monthly basis from January 2008 to May 2011, were obtained from industry sources. A correlation between urea prices in the international market and Brent crude oil prices was determined by using a simple linear

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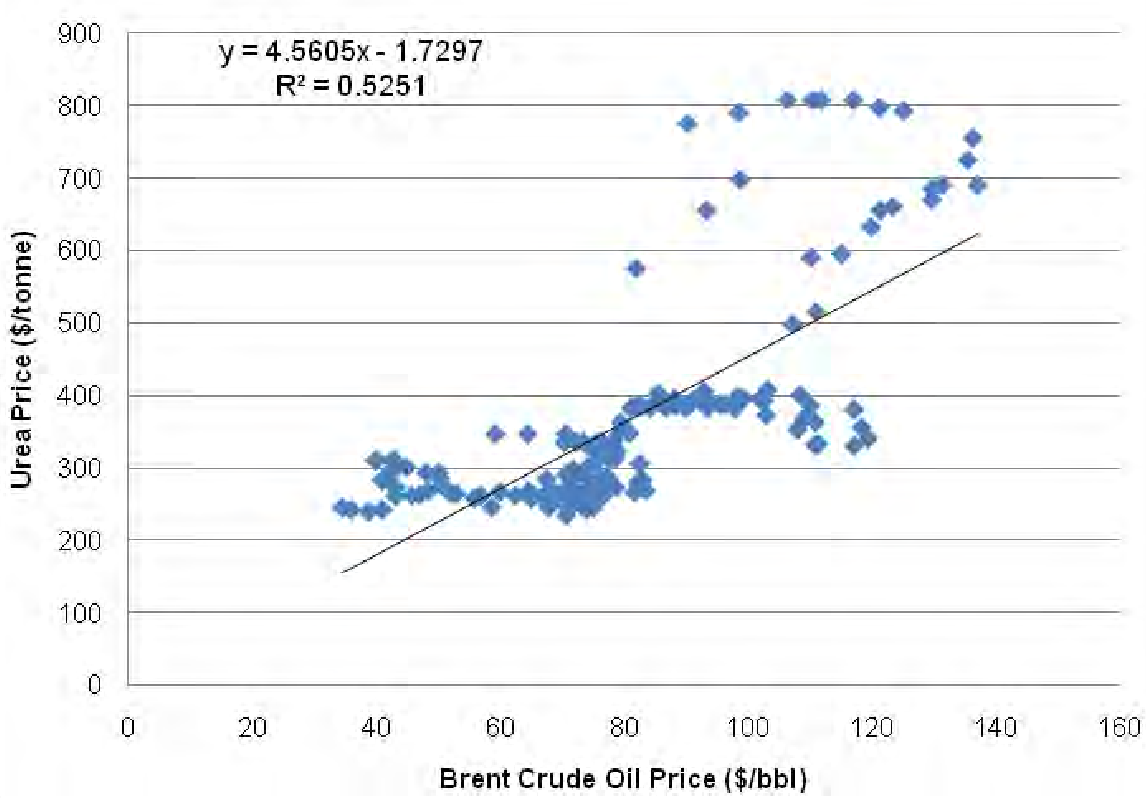
27 National Fertilizer Development Centre. *Fertilizer Review: 2009-10.*

regression analysis. The results of the analysis were insignificant (**Exhibit 3.11**) and a conclusive relationship between urea prices and Brent crude oil prices could not be established. Further analysis is required to determine a reliable relationship between urea prices and that of Brent crude oil. However, an indicative relationship between Brent prices and the price of urea in the international market was established.

Exhibit 3.11: Regression Plot of Urea Prices with Brent Crude Oil Prices



Prevailing prices of urea in the international market were also analyzed. It was determined that the indicative price of urea based upon the regression analysis for the base crude oil price scenario of $ 115/bbl was in line with the urea import tender price of $ 545/tonne at which Pakistan is in the process of importing urea.[28] Thus, recognizing the weakness in the regression analysis, the indicative price of urea in the international market was used for the study. Transportation and wharfage charges were added to the indicative price of urea in the international market to arrive at the indicative landed price of urea for Pakistan. **Exhibit 3.12** presents the indicative landed price of imported urea under various crude oil price scenarios.

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[28] The import tender price was quoted in a Business Recorder news item, '150,000 Tonnes of Urea Import Deals Finalised', dated June 21, 2011.

Exhibit 3.12: Indicative Landed Price of Imported Urea under Various Crude Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Price of Imported Urea	$/tonne	552	484	621	689

The indicative price of imported urea was also determined using a costing model assuming the price of gas being used as feedstock and fuel for fertilizer production in energy-rich fertilizer-exporting countries to be comparable to the price of FO under various crude oil price scenarios. The price of urea determined in this manner was within 10% of the indicative price of imported urea estimated through regression analysis.

Given the similarity between the results of regression analysis and the costing model, the indicative landed price of imported urea based on regression analysis was used to derive a best estimate for the economic value of natural gas in the fertilizer industry. The indicative cost of imported urea was added to the capacity payments to determine the economic value of natural gas for efficient as well as inefficient plants in the fertilizer industry. Conversions were carried out to determine the economic value of natural gas in terms of $/MMBtu under the base case crude oil price scenario. **Exhibit 3.13** presents the indicative near-term economic value of natural gas in the fertilizer industry under the base case crude oil price scenario.

Exhibit 3.13: Near-term Economic Value of Gas in the Fertilizer Industry under Base Case Crude Oil Price Scenario

		Efficient Plants	*Inefficient Plants*
Gas used as Feedstock	MMBtu	22.00	24.00
Gas used as Fuel	MMBtu	2.00	5.00
Capacity Costs	$/MMBtu	6.60	4.81
Cost of Imported Urea	$/tonne	552.73	552.73
Cost of Imported Urea	$/MMBtu	23.03	19.06
Economic Value of Gas	**$/MMBtu**	**29.63**	**23.87**

Exhibit 3.14 presents the indicative economic value of natural gas for the fertilizer industry in the near-term under various crude oil price scenarios.

Exhibit 3.14: Indicative Economic Value of Natural Gas for Fertilizer Industry in the Near-term under Various Crude Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Efficient Plants	$/MMBtu	29.63	26.78	32.48	35.33
Inefficient Plants	$/MMBtu	23.87	21.51	26.23	28.59

A medium-term analysis of the economic value of gas in the fertilizer sector was also performed. The two alternatives that were considered in this case were importing urea, without the burden of capacity payments, and using LNG both as an alternative feedstock and fuel. In the case of importing urea, capacity payments would not be required in the medium-term since the government would have the option of announcing in advance that it would not be liable to make any capacity compensations to the fertilizer industry in case gas was not supplied to plants. In the case of imported LNG, the cost of domestic urea was estimated using the production costs of efficient plants and the cost of imported LNG. The total cost of domestically produced urea using imported LNG was then compared to the cost of imported urea to determine the least cost alternative,. The analysis revealed that importing urea was the cheaper of the two alternatives.

The price of natural gas for the fertilizer industry at which the price of domestically produced urea would equate to that of imported urea was then calculated, in terms of $/MMBtu, by taking into account the amount of natural gas required for both feedstock and fuel purposes. The price of natural gas determined in this manner was considered to be the economic value of natural gas in the medium-term based upon imported urea as the alternative option. The results of the analysis are summarized in **Exhibit 3.15**.

Exhibit 3.15: Price of Natural Gas equating Domestic Urea Price to Imported Urea Price

		Efficient Plants
Cost of Imported Urea	$/tonne	552.73
Fixed Costs	$/tonne	158.31
Variable Costs (excluding feedstock and fuel)	$/tonne	22.50
Gas used as feedstock and fuel	MMBtu	24.00
Price of Natural Gas equating Domestic Urea Price to Imported Urea Price	**$/MMBtu**	**15.50**

Exhibit 3.16 presents the price of natural gas at which the price of domestic fertilizer would equate to that of imported fertilizer under various crude oil price scenarios.

Exhibit 3.16: Price of Natural Gas equating Domestic Urea Price to Imported Urea Price under Various Crude Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Price of Natural Gas equating Domestic Urea Price to Imported Urea Price	$/MMBtu	15.50	12.65	18.35	21.20

The medium-term analysis was hypothetical since committing additional gas supply to new fertilizer plants is not possible given the current gas supply constraints. The economic value of natural gas determined in this case would only come into play if significant gas reserve discoveries were made in the country in the future. The analysis highlighted that in the absence of such discoveries, importing urea would be an economic option in comparison to using imported LNG for producing urea domestically for the country in the medium-term. **Exhibit 3.17** summarizes the economic value of gas for the fertilizer industry in the medium-term.

Exhibit 3.17: Medium-term Economic Value of Gas in the Fertilizer Industry

		Import Urea	*Import LNG*
Gas used as Feedstock	MMBtu	22.00	22.00
Gas used as Fuel	MMBtu	2.00	2.00
Cost of Imported Urea	$/tonne	552.73	–
Cost of Imported LNG	$/MMBtu	–	19.53
Economic Value of Gas	**$/MMBtu**	**15.50**	**19.53**

3.4 Industrial

The industry in Pakistan requires natural gas for two purposes—as an energy source for various production processes and for captive power generation. The industrial sector consists of various energy consuming sub-sectors—namely, textile, cement, sugar, iron and steel, paper and pulp, brick kilns and fertilizer. For the purpose of this study, the fertilizer sub-sector was treated as an independent sector, as highlighted in the ToRs, due to its intensive usage of gas as feedstock. The ToRs of the study also specified that the use of natural gas as feedstock in the petrochemicals industry be considered separately. However, since the use of natural gas as feedstock in the petrochemicals industry is almost negligible in Pakistan, the economic value of natural gas was not calculated separately for the petrochemicals industry, as highlighted in the Inception Report.

The use of natural gas for most of the small and medium-sized industrial units is limited to heating and generation of steam. The large-sized industrial units use gas for a wider range of applications, such as heating, generation of steam for production processes, and cogeneration. For heating and boiler usage, most of the industries possesses dual fuel capacity and are thus capable of operating on natural gas and FO.

Since the mid-1990s, the large-sized industrial units have largely shifted to gas and FO based captive power generation due to unannounced and frequent power outages. However, the significant investment requirements, operational costs and suboptimal use of generation capacity have prevented the small and medium-sized industries from switching to captive power.

For boilers and furnaces, FO was considered as the replacement fuel for natural gas. For captive power generation, electricity supplied by the utilities and FO were considered as alternatives to natural gas. However, a time period of around six months would be required before FO can be used as an alternative since switching to FO-based captive power generation would require machinery to be replaced. The captive power generation analysis took into account capacity payments that would have to be made to industries with gas-based captive generation to compensate for the investment in gas engines. Thus, the economic value of natural gas for captive power generation was the cost of using utility-supplied electricity or FO added to the cost of simultaneous capacity payments to industries in the near-term. In the medium-term, capacity payments would not be required since the government would have the option of announcing in advance that it would not be liable to make any capacity compensations to industries in case gas was not supplied to them. The detailed calculations for determining the economic value of natural gas in the industrial sector are presented in **Appendix G**.

The relative efficiency of FO in comparison to natural gas for industrial applications, such as boilers and furnaces, was estimated to be 95%.[29] The relative efficiency adjustment and the economic price of FO were used to determine the economic value of natural gas for boilers and furnaces in the industrial sector. The economic value of natural gas for boilers and furnaces was calculated to be $ 18.35/MMBtu under the base case ($ 115/bbl) crude oil price scenario. The analysis was repeated for various crude oil price scenarios. The results are summarized in **Exhibit 3.18**.

Exhibit 3.18: Economic Value of Gas for Boilers and Furnaces assuming FO as Replacement Fuel under Various Crude Oil Price Scenarios

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Economic Value of Gas for Boilers and Furnaces assuming FO as Replacement Fuel	$/MMBtu	18.35	16.14	20.55	22.75

29 Heating and generation of steam on FO in the industrial sector is marginally less efficient than on natural gas due to the removal of sludge from FO (1%) and potential drop in boiler efficiency ranging between 4-10% if the boiler has been originally designed to operate on natural gas. In addition, the O&M costs may increase due to frequent boiler and equipment cleaning when operating on FO in comparison to natural gas.

For captive power generation, the economic value of natural gas was determined by applying appropriate efficiency adjustments for each alternative energy supply option. Economic prices of the alternative energy sources were used.

To calculate the economic value of natural gas for captive power generation in the industrial sector, the following information was obtained from the tariff determinations of the National Electric Power Regulatory Authority (NEPRA) and industry sources:

- Average economic cost of delivered electricity by the utilities;
- Capital costs of gas and diesel engine based captive power generation units;
- Thermal efficiencies of gas and diesel engines;
- Operating and fixed costs of gas and diesel engines.

For electricity supplied by the power utilities as an alternative to gas-based captive power generation in the near-term, economic values of natural gas were calculated for B3 and B4 industrial consumers.[30] The economic values of natural gas differed for B3 and B4 consumers since the load factors, used to calculate the annualized capital costs for gas engines, differed for B3 and B4 industrial consumers.[31] The economic cost of electricity[32] delivered to the industrial sector was used to determine the economic value of natural gas. The capital costs associated with establishing gas-based captive power generation capacities were annualized and then calculated, in terms of ¢/kWh, based upon the average annual load factor of the power generation capacity. The capital costs were considered to be the capacity payments that would have to be made to industries and so, added to the economic cost of electricity delivered to the industrial sector to arrive at the economic value of natural gas for captive power generation. Conversion factors were applied to determine the economic value of natural gas in terms of $/MMBtu.
Exhibit 3.19 presents the buildup of the economic value of natural gas for captive power generation in the near-term assuming utility-supplied electricity as the alternative. The analysis indicates that the base case economic value of natural gas for captive power generation in the near-term assuming utility-supplied electricity as the alternative is $ 23.70/MMBtu and $ 22.98/MMBtu for B3 and B4 customers, respectively.

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30 B3 industrial consumers are defined as those whose monthly power load ranges from 500 kW to 5,000 kW, while the monthly power load of B4 industrial consumers exceeds 5,000 kW.

31 Load factor is the ratio of actual power generated and the maximum power that a power generation unit could produce in a given period of time.

32 Based on the NEPRA tariff determinations of September 2009. The economic cost of delivered electricity was updated to adjust for inflation and economic cost of thermal fuels corresponding to various crude oil price scenarios.

Exhibit 3.19: Economic Value of Gas for Captive Power Generation using Electricity as an Alternative in the Near-term

		B3 Industrial Customer	*B4 Industrial Customer*
Economic Cost of Electricity Delivered to the Industrial Sector	¢/kWh	18.07	18.07
Capacity Costs - Capital Costs of Gas Engines	¢/kWh	2.15	1.53
Economic Value of Gas	¢/kWh	20.22	19.61
Economic Value of Gas for Captive Power Generation using Electricity Supplied by Utilities as an Alternative	**$/MMBtu**	**23.70**	**22.98**

Given the frequent power outages in the country, utility-supplied electricity may not be the feasible alternative to gas-based captive power generation. Thus, FO based diesel engines (DE) were also considered as an alternative to gas-based captive power generation capacity in the industry. Due to the higher financial costs of FO in comparison to gas, the use of FO based captive power generation is restricted to large-sized industries. The load factor for large-sized industries was assumed to be the same as that for B4 industrial consumers. Thus, the annualized capital costs of gas engines were the same in the case of B4 industrial consumers using utility-supplied electricity and large-sized industries using FO-based DEs as alternatives to gas-based captive power generation.

In the near-term, the capital costs, in terms of ¢/kWh, for gas-based captive power generation were considered as capacity payments that would have to be made to industries and added to the total generation costs of FO based DEs. The resulting value was considered as the economic value of natural gas for captive power generation in the near-term assuming FO as the alternative fuel, as presented in **Exhibit 3.20**. The analysis indicates that the economic value of natural gas for captive power generation assuming FO as the alternative fuel is $ 21.67/MMBtu.

Exhibit 3.20: Economic Value of Gas for Captive Power Generation Assuming FO as Replacement Fuel in the Near-term

			B4 Industrial Customer
A	**Electricity Generation Cost on DE[1]**		
i.	Capital Cost	¢/kWh	1.12
ii.	O&M Costs	¢/kWh	0.93
iii.	Fuel Cost	¢/kWh	14.90
iv.	Total Cost of Generation on DE	¢/kWh	16.95

			B4 Industrial Customer
B	**Economic Value of Natural Gas**		
i.	Capacity Payments - Capital costs of GE[2]	¢/kWh	1.53
iv.	Economic Value of Gas (A.iv – B. i)	¢/kWh	18.49
	Economic Value of Gas assuming FO as Replacement Fuel	**$/MMBtu**	**21.67**

[1] DE: FO fired Diesel Engines

[2] GE: Gas Engines

Exhibit 3.21 summarizes the economic value of natural gas for captive power generation under various crude oil price scenarios in the near-term.

Exhibit 3.21: Economic Value of Gas for Captive Power Generation under Various Crude Oil Price Scenarios in the Near-term

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Economic Value of Gas for Captive Power Generation assuming Utility-Supplied Electricity for B3 Industrial Consumers as an Alternative	$/MMBtu	23.70	21.71	25.70	27.70
Economic Value of Gas for Captive Power Generation assuming Utility-Supplied Electricity for B4 Industrial Consumers as an Alternative	$/MMBtu	22.98	20.99	24.98	26.98
Economic Value of Gas for Captive Power Generation assuming FO as Replacement Fuel	$/MMBtu	21.67	19.58	23.77	25.87

In the medium-term, the economic value of natural gas for captive power generation was the cost of the alternative energy source without accounting for any capacity payments. **Exhibit 3.22** summarizes the economic value of natural gas for captive power generation under various crude oil price scenarios in the medium-term.

Exhibit 3.22: Economic Value of Gas for Captive Power Generation under Various Crude Oil Price Scenarios in the Medium-term

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Economic Value of Gas for Captive Power Generation assuming Utility-Supplied Electricity for B3 Industrial	$/MMBtu	21.19	19.19	23.18	25.18

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Consumers as an Alternative					
Economic Value of Gas for Captive Power Generation assuming Utility-Supplied Electricity for B4 Industrial Consumers as an Alternative	$/MMBtu	21.19	19.19	23.18	25.18
Economic Value of Gas for Captive Power Generation assuming FO as Replacement Fuel	$/MMBtu	19.88	17.78	21.97	24.07

3.5 Transportation

GoP has maintained a policy of encouraging the use of compressed natural gas (CNG) in automotive vehicles as an alternative to motor gasoline. In 1997, the Government introduced a number of measures to shift consumer preferences towards the use of CNG as an automotive fuel in order to avoid expensive motor gasoline imports, which were $ 44.2 million in 1997.[33] Procedures for the application and grant of licenses, approval of CNG equipment, imports and safety compliance by the CNG stations had been streamlined to facilitate private sector investment. Investment promotion incentives included duties and sales tax exemption on imported machinery, equipment, conversion kits and cylinders for a period of five years since 1997. These measures helped the GoP to completely eliminate Pakistan's import bill of motor gasoline by 2001. This encouragement of the CNG industry has also led to the establishment of up to 3,116 operational CNG stations in the country for approximately 2,400,000 CNG vehicles in 2009, compared to 1,050,000 vehicles in 2004. With an overall investment of up to Rs 70 billion, Pakistan at present is the largest user of CNG in the world.[34]

For the cars that are presently operating on CNG, the alternative fuel is motor gasoline. In the case of importing motor gasoline to replace CNG, consistent with the methodology adopted for calculation of economic price of gas, capital costs that would have to be incurred by the existing CNG stations were factored in. These capital costs include the cash payments the owners of CNG stations would have to make to their lenders against borrowed capital, return on equity, and fixed O&M costs. The cost of installing a CNG kit was also factored in, to account for the investments made by consumers to avoid motor gasoline imports.

To calculate the economic value of CNG, the following information was obtained through industry sources:

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[33] Ministry of Petroleum and Natural Resources. *Pakistan Energy Yearbook: 2002.*

[34] Finance Division, Government of Pakistan. *Economic Survey of Pakistan: 2010.*

- Amount of motor gasoline required by a vehicle to travel one kilometer
- Operating and fixed costs of a CNG station
- Cost of installing a CNG kit in a vehicle

Capital costs, based on the fixed costs involved in setting up a CNG station were calculated using industry data, while investment made by consumers was calculated using the cost of a CNG kit, annualized over 5 years.[35] The import parity price of motor gasoline excluding taxes was used as the replacement cost of CNG. The conversion of prices of CNG and motor gasoline to $/MMBtu factors in the efficiency of the two fuels, because the mileage of a vehicle is constant for one MMBtu unit.

The price of motor gasoline is around $ 24.4/MMBtu against the base case Brent crude scenario, and this would be the economic value of CNG if capacity costs are not to be included. However, if capacity costs and consumers' investment are added to this price, the economic value of gas for the transportation sector would go up to $ 31.2/MMBtu. In the medium-term, the government does not have to make capital payments because it can announce in advance that operators of CNG stations are not liable to receive the same in the event of curtailment of gas from the transport sector. This means that the economic value of CNG in the medium-term would be $ 24.4/MMBtu, while $ 31.2/MMBtu would be the near-term economic value of natural gas. These results are shown in **Exhibit 3.23** for various crude oil price scenarios.

Exhibit 3.23: Economic Value of Gas in the Transport Sector

		Base Case	*Oil Price Scenario 1*	*Oil Price Scenario 2*	*Oil Price Scenario 3*
Crude Oil Price – Brent	*$/bbl*	*115*	*100*	*130*	*145*
Price of Motor Gasoline (Import Parity)	$/MMBtu	21.20	18.49	23.92	26.63
Costs Incurred till Delivery to Consumer	$/MMBtu	3.16	3.16	3.16	3.16
Economic Value of CNG (Price of Delivered Motor Gasoline)	**$/MMBtu**	**24.37**	**21.65**	**27.08**	**29.79**
Capital Costs	$/MMBtu	4.76	4.76	4.76	4.76
Investment made by CNG consumers	$/MMBtu	2.04	2.04	2.04	2.04
Economic Value of CNG (Inclusive of capital Costs)	**$/MMBtu**	**31.17**	**28.45**	**33.88**	**36.59**

35 As per industry data, the cost of a CNG kit for a Suzuki Mehran is Rs 33,000. This is annualized for a required return of 15%. To arrive at a $/MMBtu value, the investment amount is divided by the MMBtus of natural gas required to travel an average of 24,000 km in a year.

4. Contribution of Natural Gas to Economy

In addition to evaluating the economic value of natural gas through the cost of replacement fuels, correlations between economic output and natural gas consumption were determined for each sector to identify the sectors where supply of gas generates highest economic returns for the country. The correlations were established using simple linear regression analysis, the results of which are discussed in this section of the study.

The use of natural gas can be classified as productive and consumptive. Productive use of natural gas includes uses that result in the production of valued goods or services, such as use of natural gas by the industry to produce output. Consumptive uses do not result in production of valued goods or services, such as residential use of natural gas for space heating.

4.1 Composition of Gross Domestic Product

The gross domestic product (GDP) is a measure of a country's overall economic output and represents the market value of all final goods and services produced within the country. Real GDP is adjusted for price changes (inflation) and represents growth in volume of output of final goods and services. The economic returns of the sectors that utilize natural gas were assessed based on their value addition to the real GDP.[36]

It is important to note that a large segment of the Pakistani economy goes unreported in the national accounts due to the existence of an informal sector.[37] Studies indicate that the informal economy could range between 31% and 65% of the formal economy.[38] In the absence of reliable estimates for the informal sector, only published information for the formal economy was used to assess the economic returns of natural gas consumption in various sectors.

The country's economic sectors (sectors that contribute to the economy) can be grouped into the following two categories:

- Commodity producing sectors, which include agriculture and industry;
- Services sectors, which include private, governmental and financial services.

Since the last three decades, the country's GDP mix has been dominated by the services sectors, which have consistently maintained a share of up to 50% in the total GDP. The share of agricultural and industrial sectors for the corresponding period has averaged at 25%. The GDP composition in FY2010 was also the same. A description of each

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36 In national accounts, value-added refers to the contribution of the factors of production, i.e., land, labor, and capital goods, to raising the value of a product and corresponds to the incomes received by the owners of these factors.

37 The informal sector alludes to the exchange of goods and services which are not accurately documented in government figures and accounting. The informal economy, which is generally untaxed, includes goods and services such as domestic employment, tutoring, or black market exchanges.

38 Pakistan Institute of Development Economics. A Fresh Assessment of the Underground Economy and Tax Evasion in Pakistan: Causes, Consequences, and Linkages with the Formal Economy, 2007.

economic sector, its share in GDP and GDP growth, and its use of natural gas in generating the output, is discussed below.

4.1.1 Services

Services sectors include:

1. *Transport, storage and communication*: the economic value addition of various modes of transportation (e.g. road, rail, air and sea), oil storage, and communication services such as postal and courier services, telecommunication and internet, is included in this sector;
2. *Wholesale and retail trade*: the economic activities included in this sector are local and foreign trade of goods, services provided by purchase and sale agents, auctioning, and services provided by hotels and restaurants;[39]
3. *Finance and insurance*: this sector comprises of financial institutions such as banks, depository corporations, financial intermediaries and the State Bank of Pakistan;
4. *Ownership of dwellings*: this sector takes into account all the rent accruing from the ownership of housing units;
5. *Public administration and defense*: this sector consists of the salaries and benefits paid to government employees;
6. *Community, social and personal services*: this includes the income generated by all persons engaged in businesses, private education, social work and recreational services.[40]

The contribution of each of the above sectors in the overall GDP is illustrated in **Exhibit 4.1**. Amongst the services sectors, wholesale and retail trade sector has the largest share in the overall GDP, forming 17.1% of the GDP and 32.1% of the services sectors' value added. Social and private services, and transport, storage and communication services follow next, contributing 11.6% and 10.2%, respectively, to the overall GDP.[41]

The use of natural gas in the services sectors is prominent in the hotels and restaurants, the value added for which is reported under wholesale and retail trade services. Natural gas is utilized in hotels and restaurants for cooking and heating (space and water) purposes and directly contributes to production of the final output (food and lodging services). The Pakistan Energy Yearbook reports natural gas consumption in hotels and restaurants as natural gas consumption in commercial sector, which also includes gas

[39] In this section, the term economic activity refers to an activity related to production of goods and services within the economy.

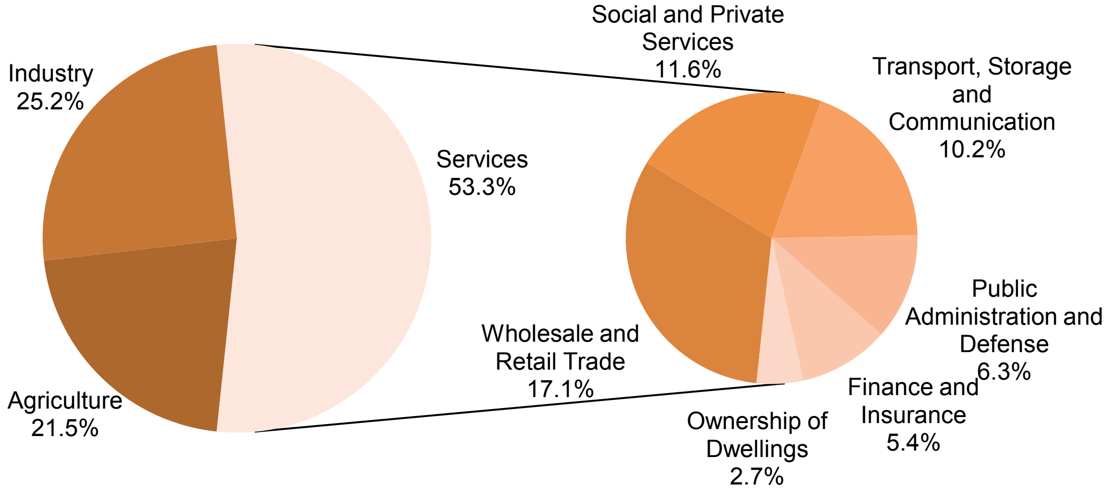
[40] Statistics Division. National Accounts – Exposition of Methodology.

[41] Finance Division. Pakistan Economic Survey.

consumption by other commercial entities.[42] Almost 92% of the natural gas consumption in commercial sector is estimated to be used for cooking purposes.[43]

In the services sectors, natural gas is also utilized in the transport sector in the form of CNG, the value added for which is lumped with storage and communication under the value added in transport, storage, and communication activities. The use of CNG by the vehicles is predominantly a consumptive use by private vehicles.

Exhibit 4.1: Composition of GDP and Services Sector



4.1.2 Industry

The industrial sector includes:

1. *Mining and quarrying industry*: this value addition of this sector is generated from mining of coal, natural gas, crude oil and other mineral resources;
2. *Manufacturing*: this accounts for value addition generated from large scale industries, small scale and household manufacturing industries, and slaughtering industry that relates to sale of skin and meat products from livestock such as camel, cow and goats;
3. *Construction industry*: includes land improvement, construction of buildings and infrastructure such as roads, bridges, railway lines, utility lines and dams, and repair and maintenance work pertaining to such infrastructure;
4. *Electricity and gas distribution sector*: this sector includes the income of power generation and supply companies, and gas transmission and distribution companies.

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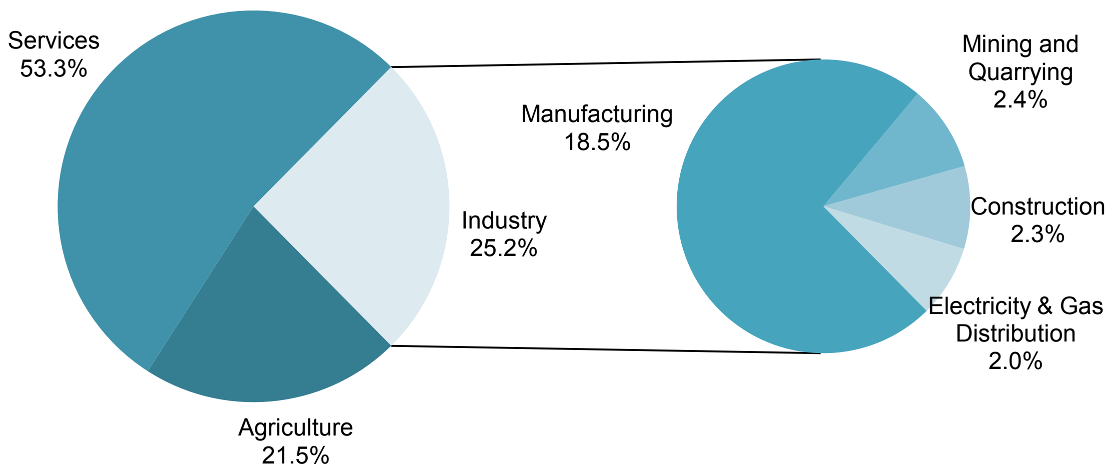
42 Ministry of Petroleum and Natural Resources. *Pakistan Energy Yearbook*.

43 Asian Development Bank. *Pakistan: Sustainable Energy Efficiency Development Program* (2009). Islamabad, Pakistan.

The contribution of each of the above sectors in the overall GDP is illustrated in **Exhibit 4.2**. Amongst the industrial sectors, large and small-scale manufacturing (manufacturing) contributes up to 18.5% in the overall GDP and forms 73.4% of the industrial value added.

Industrial natural gas consumption reported in the Pakistan Energy Yearbook mainly pertains to gas utilized by the manufacturing sector. The supply of natural gas for power generation is reported separately under the power sector, in the Pakistan Energy Yearbook.

Exhibit 4.2: Composition of GDP and Industrial Sector



4.1.3 Agriculture

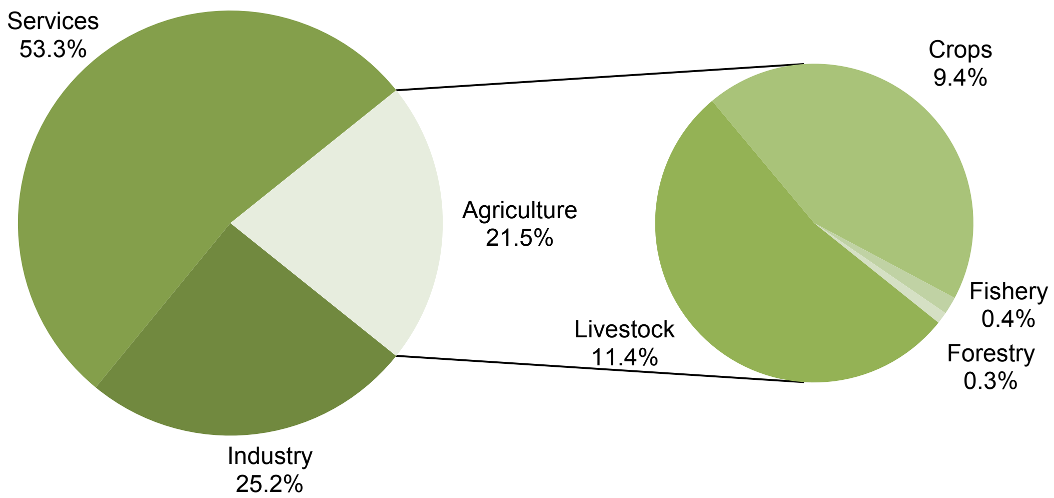
The agricultural sector consists of:

1. *Major and minor crops*: this involves estimation of gross value of crop products and by-products;
2. *Livestock*: the livestock sector includes the value of livestock products and the value of draught power (animals used due to sheer physical strength in tasks such as ploughing or logging);
3. *Fishing*: this sector includes both commercial and subsistence fishing in various water bodies;
4. *Forestry*: the activities of logging and gathering of uncultivated forest products fall into this sector.

Amongst the agricultural sector, livestock and crop production generate the most value addition in the total GDP, forming 11.4% and 9.4% respectively of the total GDP (**Exhibit 4.3**). The agricultural sector is the source of livelihood of 44.7% for the total employed labor force in the country,[44] and is the mainstay of rural livelihoods. Major crops, such as wheat, rice, cotton and sugarcane, account for upto 30% of the agricultural output of the country.

Natural gas is utilized in the agriculture sector for manufacturing fertilizer, which is an essential input in the production of crops. Natural gas is not utilized in any other form in the remaining agricultural sector.

Exhibit 4.3: Composition of GDP and Agricultural Sector



4.2 Correlations between Gas Consumption and Sectoral GDP

In order to determine the contribution of natural gas in the GDP, correlations between natural gas consumption and GDP were determined using a simple linear regression technique. Regression analysis is a statistical modeling technique that helps assess the relationship between a dependent variable and one or more independent variables. The dependent variable responds to changes in the independent variable. For this analysis, GDP was taken as the dependent variable and sectoral natural gas consumption as the independent variable.

4.2.1 Approach for Regression Analysis

The dependent and independent variables that best capture the contribution of natural gas to GDP were selected for the regression analysis.

In economic terms, the total impact of an economic activity exceeds the direct expenditure undertaken to initiate that activity. For instance, the spending by an individual on purchasing goods and services within the economy, forms income of other individuals, who further spend it on purchasing more goods and services. This is termed

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44 Finance Division. Pakistan Economic Survey.

as the multiplier impact of an economic activity. GDP incorporates these multiplier benefits arising from various activities.

Total GDP was taken as the dependent variable to capture the multiplier impacts associated with the use of natural gas in each sector. Thus, by regressing natural gas consumption in the industrial sector against total GDP, the multiplier impacts associated with the production of industrial goods were also accounted for through the regressions. Sectoral consumption of natural gas was correlated with total GDP. In the case of the power sector, consumption of gas indirectly generates value through the final consumption of power in various sectors. At the primary level, total GDP was regressed against power consumption to estimate the economic value-addition generated by power consumption (in Rs Million per GWh). At the secondary level, the contribution of natural gas to GDP through consumption of power in the economy was determined assuming that power (in GWh) is generated by natural gas at 50% and 33% thermal efficiency.

In order to establish correlations that best reflect the current market and gas utilization trends in Pakistan, a relatively recent data set was selected for regressions, while ensuring that sufficient data points were included for larger degrees of freedom in the regression models.[45] Therefore, dataset for the period 1991 to 2010 was used for the regression analysis. In case of the transport sector, the use of natural gas commenced in 1999. Therefore, dataset for the period 1999 to 2010 was used. For the fertilizer sector, fertilizer utilization information was taken from the Fertilizer Review.[46] Data from 1996 to 2010 was available, which was used for regressions.

An approach similar to the power sector was adopted for the fertilizer industry. Fertilizer is an essential input to production of crops. The use of natural gas in the fertilizer industry indirectly generates value addition, through the final use of fertilizer in the crop production process. Therefore, total GDP was regressed against fertilizer consumption (domestically produced and imports). However, in case of fertilizer the least-cost alternative to supplying natural gas to the fertilizer industry is to import fertilizer (**Section 3.3** of the report). Therefore, on establishing the contribution of fertilizer consumption to the economy through the regression analysis, no subsequent determination for indirect contribution of natural gas was made as the country will have to resort to imports of fertilizer.

4.2.2 Results of Regression Analysis

The results of the regression analysis are tabulated in **Exhibit 4.4**. The data set used for regressions and the details of the regression results are provided in **Appendix H**. The analysis provides indicative figures that can be used to establish relative significance of natural gas in each gas-consuming sector.

The results of the regression analysis suggest that for supply of natural gas, higher priority needs to be given to the sectors that utilize natural gas for productive purposes in

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45 The number of degrees of freedom of a linear model is the number of independent observations in a sample of data that are available to estimate the coefficient or parameter of the population.

46 National Fertilizer Development Centre. *Fertilizer Review*.

comparison to the sectors that utilize natural gas for consumptive purposes. By curtailing natural gas for the productive end-uses, the economy incurs a loss, as the direct and multiplier benefits of productive activities are foregone.

Amongst the sectors that utilize natural gas for productive purposes, the commercial and power sectors have a higher productive use of natural gas than the industrial sector, i.e., contribute more to total GDP in terms of each MMBtu of natural gas supplied. The commercial sector contributes 12 times more than the industrial sector.

The contribution of fertilizer consumption towards total GDP was evaluated and results of the analysis suggest that fertilizer supply to the agriculture sector should continue in order to maintain the high contribution of agriculture sector towards GDP. This supply of fertilizer can be met through imports or domestic production of fertilizer, which will be determined based on economic value of natural gas. The high contribution of fertilizer consumption towards total GDP is consistent with the fact that agriculture is the mainstay of the economy. When considered as a single sector, agricultural output contributes the largest share in the total GDP (21.5%). Up to 44.6% of the total employed persons aged 10 years and above, are employed in the agriculture sector. As the largest primary sector of the economy,[47] it contributes to driving other sectors such as manufacturing and wholesale and retail services, by producing the essential input raw materials or final goods (such as cotton and food including meat) required by the other sectors. An assessment of the use of imported fertilizer to replace domestic fertilizer production was presented in **Section 3.3** of the report and the continuation of natural gas supply to the fertilizer industry will be determined through the analysis of the economic values of natural gas.

The regressions were insignificant for residential and transport sectors i.e., it could not be established that the use of natural gas in these sectors generates significant contribution to the GDP. In case of residential sector, the insignificance of the results is consistent with the fact that residential use of natural gas is a nonproductive use. In the transport sector, the analysis suggests that the total GDP is indifferent to the use of natural gas in motor vehicles. This is likely due to the fact that most of the transport sector relies more on the use of HSD (in heavy traffic vehicles), for which natural gas is not an alternative.

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[47] The primary sector of the economy involves changing natural resources into primary products. Most products from this sector are considered raw materials for other industries.

Exhibit 4.4: Results of Regression Analysis

Category	*Sector*	*Variables*	*Coefficient*			*Indicative Contribution to GDP*	*Comments*
			Value	*Unit*	*Significance*		
Economy-wide Productive Utilization	Power	Total GDP regressed against power consumption	72.51	Rs Million/GWh	Yes	Rs 10,626/MMBtu of natural gas supplied, at 50% thermal efficiency Rs 7,013/MMBtu of natural gas supplied, at 33% thermal efficiency	The results were significant and value of coefficient high, indicating that power consumption generates high value-addition in the economy. This is consistent with its economy-wide utility, which contributes to generating output in each economic sector.
Sectoral Productive Utilization	Commercial	Total GDP regressed against gas consumption in commercial sector	65.80	Rs Million/MMscf	Yes	Rs 69,267/MMBtu of natural gas supplied	The results were significant and value of coefficient high, indicating that gas consumption in the commercial sector generates high value-addition in the economy. This is consistent with the high share of the services sectors, in the total GDP (53.3%); especially wholesale and retail services sector that reports the value-addition generated from hotel and restaurants, which utilize natural gas to generate their services.
	Agricultural - Fertilizer	Total GDP regressed against fertilizer consumption	0.64	Rs Million/tonne fertilizer	Yes	Rs 640,399/tonne of fertilizer consumed Rs 26,683/MMBtu of natural gas supplied to efficient plants Rs 22,083/MMBtu of natural gas supplied to efficient plants	The results indicate that consumption of fertilizer generates high value addition in the economy. Therefore, uninterrupted supply of fertilizer is essential to ensure continued value addition to the economy through the use of fertilizer in the agriculture sector.
	Industrial	Total GDP regressed against gas consumption in industry (excluding fertilizer)	5.07	Rs Million/MMscf	Yes	Rs 5,340/MMBtu of natural gas supplied*	The results were significant, indicating that gas consumption in the industrial sector has a meaningful correlation with the total GDP. However, the value of the coefficient was lesser than that of power and commercial sectors, indicating that the use of natural gas in the industrial sector contributes relatively lesser to the total GDP, in comparison to the power and commercial use of natural gas.

Category	*Sector*	*Variables*	*Coefficient*			*Indicative Contribution to GDP*	*Comments*
			Value	*Unit*	*Significance*		
Consumptive Utilization	Transport	Total GDP regressed against gas consumption in transportation sector	5.65	Rs Million/MMscf	No	–	The results were insignificant. Therefore, it could not be established that the use of CNG in the transport sector generates a significant contribution to GDP. This is likely due to the fact that most of the transport sector relies more on the use of HSD (in heavy traffic vehicles), for which natural gas is not an alternative
	Residential	Total GDP regressed against gas consumption in residential sector	1.61	Rs Million/MMscf	No	–	The results were insignificant. Therefore, it could not be established that the use of natural gas in the residential sector has a significant contribution to the GDP This is consistent with the fact that residential use of natural gas is a nonproductive use.

Note: The relative difference of the coefficient values is of significance and can be interpreted for the purposes of this analysis. The absolute figures can only serve as indicative figures.

* The proportion of natural gas in the combined consumption of natural gas, FO and HSD by the industry is presently 89%, and historically has averaged at 70%.

5. Observations and Suggested Directions for Management of Supply of Natural Gas

Government has the option to regulate the natural gas demand through the following instruments:

- *Price regulation*: demand responds negatively to an increase in price and by increasing the price of natural gas, the government can discourage inefficient consumption of the scarce resource as well as promote use of alternatives to natural gas;
- *Allocation*: through allocation and setting of quotas for different consumer segments, the government can promote use of alternatives to natural gas.

This section presents a sectoral comparison of the economic value of natural gas and the contribution of natural gas consumption towards the GDP of the country, based on which directions for pricing and allocation of natural gas are suggested for the consideration of the government. The results of the analysis carried out in this study can serve as inputs for the determination of a comprehensive framework for the allocation and pricing of natural gas, as highlighted in **Section 5.2.5**.

5.1 Near-term Analysis

Consistent with the definition of economic value of gas and the methodology adopted for this study, the next best alternative to natural gas in terms of cost per unit of service delivered was selected as the replacement for natural gas. However, in the near-term, for some end-uses constraints such as supply and infrastructure will prevent consumers from switching to alternatives that cost less. As an example, availability of additional electricity to replace natural gas for water heating in households cannot be ensured while the country is facing power shortages. Therefore, even though electric water heaters are more economical than solar water heaters, solar water heating technology was selected as the alternative energy source. Also in the near-term, the use of imported LNG as an alternative to indigenous natural gas was ruled out due to the current absence of regasification facilities and other necessary infrastructure for the import of LNG in the country. In case of the CCGT plants with natural gas commitments for which infrastructure required for storage and supply of HSD is not in place, it will not be possible to switch these plants to HSD when natural gas is not available; preventing utilization of their capacity (details provided in **Section 3.1**).

5.1.1 Near-term Economic Value of Natural Gas

The near-term economic value of natural gas under the base case crude oil price scenario is presented in **Exhibit 5.1**. The estimates have been placed in descending order, by productive and consumptive end-uses.[48]

Amongst the productive end-uses, the economic value of natural gas is highest at $ 29.63/MMBtu (includes economic cost of capacity payments in case the fertilizer industry is shut down, as explained in **Section 3.3**) for efficient fertilizer plants under the base case crude oil price scenario of $ 115/bbl. Following efficient fertilizer plants, the economic value of natural gas is highest for power generation by CCGT plants. The replacement cost of natural gas supplied to CCGT plants with infrastructure for HSD in place was estimated at $ 26.56/MMBtu under the base case crude oil price scenario of $ 115/bbl.[49]

[48] As defined in **Section 4** of the study, productive use of an input includes uses that result in the production of valued goods or services. Consumptive uses do not result in production of valued goods or services.

[49] The economic cost of power load-shedding is $ 0.60 kWh, as reported by a study carried out by International Resources Group for Asian Development Bank (ADB) under ADB TA-4982 PAK. *Pakistan Integrated Energy Model (Pak-IEM) - Policy Analysis Report Volume II (2010)*. The estimate of $ 0.60 kWh, was converted to MMBtu using the average thermal efficiency of 45% for the CCGT plants. Thus, if natural gas supplied to the CCGT plants with natural gas commitments is valued at the economic cost of power load shedding, the economic value would be $ 79.13/MMBtu. This implies that power load shedding has a significant impact on the economic growth.

Exhibit 5.1: Economic Value of Natural Gas in Near-term, Base Case

Application/End-Use	*Sector*	*Type of End-Use*	*Estimated Gas Consumption by End-Use, FY2010*		*Near-term Economic Value of Natural Gas*			
			MMscf	*% of Total*	*Alternative*	*$/MMBtu*	*$ Million*	*% of Total Value*
Fertilizer Production – Efficient Plants	Agriculture	Productive	44,025	3.4%	Imported Fertilizer	29.63[1]	998	3.6%
Power Generation from CCGT Plants	Power	Productive	299,300	23.4%	HSD	26.56	7,553	27.4%
Fertilizer Production - Inefficient Plants	Agricultural	Productive	176,099	13.8%	Imported Fertilizer	23.87[2]	3,195	11.6%
Cooking, Water Heating and Space Heating[3]	Commercial	Productive	36,955	2.9%	LPG	23.79	835	3.0%
Captive Generation	Industrial	Productive	118,148	9.2%	FO	21.67	2,432	8.8%
Boiler/ Heating Use in Industrial Processes	Industrial	Productive	217,304	17.0%	FO	18.35	3,787	13.8%
Power Generation from Dual Fuel Plants –Steam Turbines[4]	Power	Productive	67,606	5.3%	FO	17.42	1,119	4.1%
Total for Productive Use			**959,437**	**75.1%**			**27,472**	**72.4%**
Fuel for Motor Vehicles	Transport	Consumptive	99,002	7.7%	Motor Gasoline	31.17	2,931	10.7%
Cooking	Residential	Consumptive	138,211	10.8%	LPG	23.79	3,124	11.4%
Space Heating	Residential	Consumptive	35,101	2.7%	LPG	23.79	793	2.9%
Water Heating	Residential	Consumptive	46,070	3.6%	Solar - Hybrid Gas Geyser	17.12	749	2.7%
Total for Consumptive Use			**318,384**	**24.9%**			**7,597**	**27.6%**

Note: [1] This includes capacity costs of $ 6.60/MMBtu for efficient fertilizer plants in case they are shut down. If capacity costs are excluded from the calculation, the economic value of natural gas would be $ 23.30/MMBtu.

[2] This includes capacity costs of $ 4.81/MMBtu for inefficient fertilizer plants in case they are shut down.

[3] Commercial sector forms the smallest proportion in the total natural gas consumption. Therefore, its economic value has not been presented by end-uses.

[4] These plants are not supplied natural gas presently.

Following efficient fertilizer plants and power generation by CCGT plants, the economic value of natural gas is highest for inefficient fertilizer plants at $ 23.87/MMBtu (includes economic cost of capacity in case the industry is shut down, as explained in **Section 3.3**) and for cooking, water heating and space heating use by the commercial sector at $ 23.79/MMBtu. The economic value of natural gas supplied to the industry for captive generation is $ 21.67/MMBtu, which is lower than the replacement cost of natural gas in CCGT plants due to the higher efficiency of CCGT plants in comparison to the FO fired diesel generators installed by the industry. The economic value of natural gas using FO as an alternative for captive power generation factors in the capacity payments for the gas-based power generation capacity presently installed in the industry.[50]

In the near-term, the lowest replacement cost of natural gas is against the following productive end-uses, which have been placed in ascending order according to their economic values of natural gas:

1. Natural gas being supplied to steam turbines. These plants are presently not supplied natural gas. The replacement cost for natural gas using FO as the alternative was determined as $ 17.42/MMBtu;
2. Natural gas being utilized for heating purposes in industry. The alternative is to use FO, which costs $ 18.35/MMBtu.

Amongst the consumptive end-uses, the economic value of natural gas was highest in the transport sector at $ 31.17/MMBtu. This is due to high replacement cost of CNG with motor gasoline, which includes economic cost of capacity payments to be made to the CNG stations and annualized investment costs of the CNG conversion kits installed by the car owners. In comparison, the economic value of natural gas is relatively low for use in the residential sector for cooking and space heating purposes, at $ 23.79/MMBtu, for which the alternative fuel is LPG. However, energy required for cooking is an essential use for households and therefore, carries the highest value for consumers, amongst all the consumptive end-uses. For switching to LPG, the present consumers of natural gas in the residential sector will have to invest in LPG cylinders, which the low-income consumers may not be able to afford. In areas not connected to the existing gas network, GoP should facilitate access to LPG.

For water heating in the residential sector, the economic cost of replacing natural gas with solar-hybrid-gas water heaters is $ 17.12/MMBtu, which is the lowest amongst both productive and consumptive end-uses.[51]

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[50] Efficiency of CCGT plants is up to 48%, which is higher than that of the diesel gensets (40%) installed by industries.

[51] The solar-hybrid-gas water heaters use natural gas as a backup fuel in the absence of solar energy.

5.1.2 Suggested Direction for Management of Supply of Natural Gas in the Near-term

In the near-term, pricing regulations can:

1. Increase the cost of production thereby reducing demand for goods and services, which will hinder economic growth;
2. Result in shutdown of productive activity in the absence of infrastructure for delivery of alternative fuels and energy forms, thereby hindering economic growth;
3. Have adverse social implications in the form of extreme reaction of the consumers.

As a result, gradual price changes, as a regulatory tool, are recommended in the medium-term to allow consumers to adjust to price increases and to provide time for construction of infrastructure for delivery and use of alternative fuels.

The results of the regression analysis conducted to assess the contribution of natural gas consumption in each sector towards total GDP are summarized in **Exhibit 5.2** (presented earlier in **Section 4**). The sectors have been listed in ascending order, according to their indicative contribution to GDP.

Exhibit 5.2: Indicative Contribution of Natural Gas in Total GDP

Sector	*Type of End-Use of Natural Gas*	*Indicative Contribution to GDP, Rs/MMBtu of Natural Gas Supplied*	*Comments*
Commercial	Productive	69,267	Estimated multiplier* of 30/MMBtu of natural gas supplied in near-term.
Power	Productive	10,626	Calculated at 50% thermal efficiency. Estimated multiplier of 5/MMBtu of natural gas supplied in near-term.
		7,013	Calculated at 33% thermal efficiency, Estimated multiplier of 5/MMBtu of natural gas supplied in near-term.
Industrial	Productive	5,340	Estimated multiplier of 3/MMBtu of natural gas supplied.
Transport	Consumptive	It could not be established that the use of natural gas in the transport sector has a significant contribution to the GDP	
Residential	Consumptive	It could not be established that the use of natural gas in the residential sector has a significant contribution to the GDP	

Note: *Multiplier refers to the ratio between total economic benefit, measured as the contribution in total GDP, to economic value of natural gas supplied.

The results of the regression analysis suggest that for supply of natural gas, higher priority needs to be given to the sectors that utilize natural gas for productive purposes in comparison to the sectors that utilize natural gas for consumptive purposes. By curtailing natural gas for the productive end-uses the economy incurs a loss, as the direct and multiplier benefits of productive activities are foregone.

Amongst the sectors that utilize natural gas for productive purposes, the commercial and power sectors use natural gas more productively. The commercial sector contributes more than 30 times to the total GDP against each MMBtu of natural gas supplied to the sector (Rs 69,267/MMBtu of natural; gas valued at its economic value $ 23.79/MMBtu). The contribution of one MMBtu of natural gas through generation of power to total GDP is five times the economic value of natural gas for power sector. The contribution of the industrial sector is comparatively lesser than commercial and industrial sectors, adding up to 3 times the value of natural gas for that sector.

In case of fertilizer sector, the contribution of fertilizer consumption towards total GDP was evaluated and results of the analysis suggest that fertilizer contributes significantly towards total GDP, which is consistent with the fact that agriculture is the mainstay of the economy (details given in **Section 4**). This supply of fertilizer can be met through imports or domestic production of fertilizer. The continuation of natural gas supply to the fertilizer industry will be determined through the analysis of the near-term economic values of natural gas.

The results of the regression analysis are in line with the near-term economic values of natural gas. Both suggest that the use of natural gas should be prioritized in the power and commercial sectors. In case of fertilizer sector, supply of fertilizer should be ensured through either imports of fertilizer or domestic production of fertilizer.

The allocation of natural gas in the near-term, based on the results of the economic analysis, is presented in **Exhibit 5.3**.

Exhibit 5.3: Allocation of Natural Gas in the Near-term

End-Use	*Type of End-Use*	*Sector*	*Economic Value of Natural Gas ($/MMBtu)*	*Priority*	*Comments*
Fertilizer Production - Efficient Plants	Productive	Agricultural	29.63	First	▶ The replacement cost of natural gas is highest in efficient fertilizer plants, followed by CCGT plants. The economic returns of natural gas supply to power sector are also high. ▶ Energy use for cooking is an essential use for every household and therefore carries the highest value for consumers. In areas not connected to the existing gas network, GoP should facilitate access to LPG.
Power Generation from CCGT Plants	Productive	Power	26.56		
Cooking	Consumptive	Residential	23.79		
Fertilizer Production - Inefficient Plants	Productive	Agricultural	23.87	Second	▶ Amongst the productive end-uses, use of natural gas for fertilizer production in inefficient fertilizer plants and for cooking, water heating and space heating purposes in the commercial sector has the second highest economic value. These end-uses should be given priority in allocation as they generate high value addition in the economy as well.
Cooking, Water Heating and Space Heating	Productive	Commercial	23.79		
Captive Generation	Productive	Industrial	21.67	Third	▶ Natural gas used for captive power generation has a high economic value and should be given the third highest priority in allocating natural gas.
Boiler/ Heating Use in Industrial Processes	Productive	Industrial	18.35	Fourth	▶ Natural gas should be diverted from these end-uses towards end-uses with a higher economic value for natural gas. Lowest priority should be given to natural gas based power generation from steam turbines, followed by natural gas supply for heating use in industrial processes.
Power Generation from Dual Fuel Plants –Steam Turbines	Productive	Power	17.42		
Fuel for Motor Vehicles	Consumptive	Transport	31.17	Fifth	▶ Natural gas should be diverted from the transport sector and in the residential sector from space heating and water heating uses, towards productive end-uses. For space heating use in areas not connected to the existing gas network, GoP should facilitate access to LPG.
Space Heating	Consumptive	Residential	23.79	Sixth	
Water Heating	Consumptive	Residential	17.12		

5.2 Medium-term Analysis

In the medium-term, constraints in switching to alternative fuels and forms of energy will not be applicable, as the infrastructure required to ensure a reliable supply of energy sources can be established.

5.2.1 Medium-term Economic Value of Natural Gas

Near-term economic values include annualized capacity costs to account for the loss in investments that will occur due to the replacement of natural gas with its alternatives. In the medium-term, it was assumed that these capacity costs will not be applicable since the government would have the option of declaring in advance that it would not be liable to make any capacity compensations to the affected consumers in case gas is not supplied to them. Therefore, the capacity components included in the near-term economic value of natural gas for the fertilizer sector, captive generation in industrial sector and transport sector were removed from the medium-term economic values. Under the base case crude oil price of $115/bbl, the economic value of natural gas for the fertilizer industry reduced from $ 29.63 for the near term to $ 15.50/MMBtu for the medium-term and that for the captive generation use by the industry reduced from $ 21.67/MMBtu in the near term to $ 19.88/MMBtu for the medium term.. For the transport sector, the economic value decreased from $ 31.17 for the near term to $ 24.37/MMBtu for the medium term under the base case crude oil price scenario. In addition, as explained earlier, in the medium-term, supply constraints will not apply on energy sources, such as the availability of electricity for water heating in the residential sector. However, despite lower cost of water heating for residential sector based on electricity, solar water heating is suggested as the economic option in the medium-term, as electricity should be supplied for productive end-uses.

5.2.2 Medium-term Economic Cost of Delivered Natural Gas

The medium-term economic value of natural gas was compared to the economic cost of delivered natural gas for the various end-uses, to evaluate the potential cost of continuing the use of alternatives to natural gas in the medium-term. The economic cost of natural gas was determined at its import parity price, based on the price of LNG (explained in **Section 2.2.1**).[52] The economic cost of delivered natural gas for each end-use was determined after all the costs incurred to deliver natural for specific end-uses were added to the price of re-gasified LNG. Since the technology for utilization of natural gas varies in the economic sectors, operational costs across the sectors will vary as well. In the transport sector, compression costs were added to arrive at the delivered cost of CNG. In the remaining sectors, the economic cost of gas was the price of re-gasified LNG including T&D costs, as no additional costs are incurred to make natural gas useable by the end-user. The economic cost of delivered natural gas was $ 19.53/MMBtu for all end-uses, except for use in motor vehicles, where the cost was calculated as $ 28.41/MMBtu.

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[52] Pakistan already has a shortage of natural gas, and currently there are no expectations in the foreseeable future for firm pipeline gas import agreements; so the economic cost is considered to be the import parity price of re-gasified LNG.

Exhibit 5.4 summarizes the medium-term economic value of natural gas against each end-use.

Exhibit 5.4: Economic Value of Natural Gas in Medium-term, Base Case

Application/End-Use	*Sector*	*Type of End-Use*	*Least-Cost Alternative to Natural Gas*		*Economic Cost of Delivered Gas*	*Medium-term Incremental Economic Cost*
			Alternative	*$/MMBtu*	*$/MMBtu*	*$/MMBtu*
Power Generation from CCGT Plants with Natural Gas Commitments	Power	Productive	HSD	26.56	19.53	7.03
Power Generation from CCGT Plants with Infrastructure for HSD in Place	Power	Productive	HSD	26.56	19.53	7.03
Cooking, Water Heating and Space Heating	Commercial	Productive	LPG	23.79	19.53	4.26
Captive Generation	Industrial	Productive	FO	19.88	19.53	0.35
Boiler/ Heating Use in Industrial Processes	Industrial	Productive	FO	18.35	19.53	(1.18)
Power Generation from Dual Fuel Plants–Steam Turbines	Power	Productive	FO	17.42	19.53	(2.11)
Fertilizer Production - Efficient Plants	Agricultural	Productive	Natural Gas*	15.50	19.53	(4.03)
Cooking	Residential	Consumptive	LPG	23.79	19.53	4.26
Space Heating	Residential	Consumptive	LPG	23.79	19.53	4.26
Water Heating	Residential	Consumptive	Solar - Hybrid Gas Geyser	17.12	19.53	(2.41)
Fuel for Motor Vehicles	Transport	Consumptive	Motor Gasoline	24.37	28.41	(4.04)

*Natural gas supplied at the price that would equate the cost of domestically produced urea to that of imported urea was used to determine the economic value of natural gas in the medium-term, as explained in **Section 3.3**.

5.2.3 Suggested Direction for Management of Supply of Natural Gas in the Medium-term

Based on the medium-term economic values presented in **Exhibit 5.4**, the following end-uses of natural gas are suggested, as the cost of replacing natural gas with its alternative is higher than the economic cost of delivered natural gas for these end-uses:

1. *Power generation from CCGT plants using natural gas*: the cost of power generation on HSD, which is the next best alternative to natural gas for CCGT plants, is $ 26.56/MMBtu. This exceeds the economic cost of natural gas delivered at $ 19.53/MMBtu to the power sector;
2. *Commercial use of natural gas for cooking, water heating and space heating*: the economic value of natural gas using LPG as an alternative is $ 23.79/MMBtu, which exceeds the economic cost of natural gas delivered to the commercial sector ($ 19.53/MMBtu);
3. *Residential use of natural gas for cooking*: similar to commercial sector, the cost of cooking on LPG is $ 23.79/MMBtu. This exceeds the economic cost of natural gas delivered to the residential sector at $ 20.33/MMBtu;
4. *Captive power generation by the industry:* the economic value of natural gas for captive power generation by the industry, assuming FO as the replacement fuel, is $ 19.88/MMBtu, which is lower than the economic cost of delivered natural gas ($ 19.53/MMBtu) for captive power generation by the industry.

For space heating in the residential sector, solar space heating is suggested towards the medium-term, using solar building design. Under solar building designs, windows, walls, and floors can be made to store and distribute solar energy in the form of heat. Solar design techniques can be applied most easily to new buildings, while existing buildings can be adapted or retrofitted.

In the medium-term, natural gas in the following end-uses should be replaced with the alternatives:

1. *Domestic production of fertilizer*: Imported fertilizer should replace domestic production of fertilizer as the cost of imports ($ 15.50/MMBtu) is less than the economic cost of delivered natural gas ($ 19.53/MMBtu) for the fertilizer sector. In the medium-term, no new fertilizer plants should be set up in the country;
2. *Power generation from steam turbines plants*: FO should continue to be used as the power generation fuel for steam turbine plants since the economic cost of FO ($ 17.42/MMBtu) is lower than the economic cost of delivered natural gas for the power sector ($ 19.53/MMBtu);
3. *Natural gas utilization by the industry for captive generation and heating use*: The economic value of natural gas for heating use, assuming FO as the replacement fuel, is lower than the economic cost of delivered natural gas. The economic value of natural gas for heating use is $ 18.35/MMBtu, which is lower than the economic cost of delivered natural gas in the industrial sector ($ 19.53/MMBtu). Thus, the industry should switch to FO as the replacement fuel for heating use in boilers and furnaces;

4. *Fuel for motor vehicles*: Motor gasoline should be utilized as fuel for vehicles instead of natural gas since motor gasoline is more economical than natural gas delivered to CNG stations. The economic value of natural gas in the transport sector is $ 24.37/MMBtu in comparison to the $ 28.41/MMBtu, which is economic cost of natural gas delivered and compressed for use as CNG. In the medium-term, no new CNG plants should be set up in the country.
5. *Residential water heating*: Solar water heating is the economic option in comparison to natural gas for water heating in the residential sector. Thus, solar water heaters should be installed in houses to replace natural gas water heaters, as cost of water heating on solar energy is $ 17.12/MMBtu of natural gas replaced, in comparison to $ 19.53/MMBtu, which is economic cost of delivered natural gas for the residential sector.
6. *Residential space heating*: solar space heating is suggested towards the medium-term, using solar building design.[53]

In the medium-term, the government should gradually increase the price of natural gas to equate it to the economic cost of delivered natural gas in sectors where use of natural gas is economic. In sectors where natural gas should be replaced by its alternative, the price of natural gas should gradually be set higher than the medium-term economic value to encourage use of alternative fuels. This should be coupled with promotional campaigns to encourage use of alternatives that are new to the consumers, such as use of solar appliances for water and space heating. In the residential sector, the price slabs should be in place to subsidize use of natural gas for cooking, which is an essential use and in comparison to water and space heating uses in the residential sector, carries a higher social value for the consumers. The subsidy can be in the following forms:

- Cross-subsidization within the residential sector, where high-income consumers can subsidize the low-income consumers. The tariff for higher consumption slabs, corresponding to the use of energy for water and space heating, should exceed the economic cost of delivered natural gas for the residential sector to encourage alternative use of solar energy for water and space heating;
- A direct subsidy by the government.

5.2.4 Sensitivity to Prices of Crude Oil

The economic value of natural gas for various end-uses was determined under the crude oil price scenarios of $ 100/bbl, $ 115/bbl, $ 130/bbl and $ 145/bbl, as specified in the Inception Report. **Exhibit 5.5** presents the near-term economic value of natural gas for various end-uses under the crude oil price scenarios studied. The economic value of natural gas for water heating in the residential sector remains unchanged for all crude oil price scenarios, as highlighted in **Section 3.2**.

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[53] A separate study, analyzing the economics of solar space heating, needs to be conducted to evaluate this option further.

Exhibit 5.5: Economic Value of Natural Gas in Near-term Under Various Crude Oil Price Scenarios

Application/End-Use	*Sector*	*Type of End-Use*	*Alternative*	*Near-term Economic Value of Natural Gas*			
			Crude Oil Price-Brent	*$ 100/bbl*	***$ 115/bbl***	*$ 130/bbl*	*$ 145/bbl*
				$/MMBtu	***$/MMBtu***	*$/MMBtu*	*$/MMBtu*
Fertilizer Production-Efficient Plants	Agricultural (Fertilizer)	Productive	Imported Fertilizer	26.78	**29.63**	32.48	35.33
Power Generation from CCGT Plants	Power	Productive	HSD	23.39	**26.56**	29.78	33.01
Fertilizer Production-Inefficient Plants	Agricultural (Fertilizer)	Productive	Imported Fertilizer	21.51	**23.87**	26.23	28.59
Cooking, Water Heating and Space Heating*	Commercial	Productive	LPG	21.00	**23.79**	26.58	29.38
Captive Generation	Industrial	Productive	FO	19.58	**21.67**	23.77	25.87
Boiler/ Heating Use in Industrial Processes	Industrial	Productive	Fuel Oil	16.14	**18.35**	20.55	22.75
Power Generation from Dual Fuel Plants–Steam Turbines**	Power	Productive	Fuel Oil	15.33	**17.42**	19.52	21.61
Fuel for Motor Vehicles	Transport	Consumptive	Motor Gasoline	28.45	**31.17**	33.88	36.59
Cooking	Residential	Consumptive	LPG	21.00	**23.79**	26.58	29.38
Space Heating	Residential	Consumptive	LPG	21.00	**23.79**	26.58	29.38
Water Heating	Residential	Consumptive	Solar-Hybrid-Gas Geyser	17.12	**17.12**	17.12	17.12

Note: * Commercial sector forms the smallest proportion in the total natural gas consumption. Therefore, its economic value has not been presented by end-uses.

** These plants are not supplied natural gas presently.

Based on the economic values of gas listed in **Exhibit 5.5**, the allocation of natural gas recommended under the base case crude oil price scenario would also hold under the crude oil price scenarios of $ 100/bbl, $ 130/bbl and $ 145/bbl.

The economic value of natural gas was compared to the economic cost of delivered natural gas under various crude oil price scenarios to determine the economic option for various end-uses in the medium-term. The conclusions remain unchanged under all crude oil price scenarios in the medium-term.

5.2.5 Recommendations for Further Analysis

Further research and analysis, building upon the results presented in this study, need to be carried out to develop a comprehensive natural gas allocation and pricing policy for the country. The following areas, in particular, require detailed analysis through a follow-up study:

1. Demand-supply analysis of natural gas: Projections for natural gas demand in the country should be developed based upon economic forecasting models. The economic models would use historical consumption patterns of natural gas as a basis for developing future forecasts. The economic models would take into account GDP growth rates and the expansion of sectors that consume natural gas. The projections should be compared to the estimated supply of indigenous natural gas in the future to calculate the shortfall of natural gas in the near and medium-term, which would have to be met through imports or the use of alternatives. Supply-side constraints, such as infrastructure limitations, for alternatives to natural gas should also be analyzed in order to ensure that the country's future energy needs are met;
2. Price elasticity of natural gas demand: While the present study suggested that natural gas demand could be managed through price regulations, the study did not measure the quantitative impact of pricing changes on natural gas demand. Further analysis is required to estimate the price elasticity of natural gas demand in various sectors, so that changes in prices can be proposed accordingly. The data required for estimating the price elasticity of natural gas demand might not be available in the case of Pakistan. However, data for comparable developing countries can be obtained and used to estimate the indicative price elasticity of natural gas demand for Pakistan;
3. Incremental cost analysis of supplying natural gas to various sectors: The costs to the economy of supplying natural gas, on a marginal basis, to various sectors should be analysed for each of the allocation decisions, particularly with reference to determining the quantity of natural gas which should be diverted from one sector to another;
4. Social and environmental externalities: The economic values of natural gas determined in this study did not take into account social and environmental costs. These costs should be analysed and taken into account in order to develop a comprehensive natural gas allocation and pricing policy;
5. Impact of utilization of natural gas in various sectors on economic output : For this study, the correlations were established using simple linear regression

analysis. Techniques and tools more comprehensive and thorough than regression analysis will be required to establish a more accurate correlation between economic output and natural gas consumption in various sectors. Such tools include economic input-output models, social accounting matrices or computable general equilibrium models, which capture the inter-sector linkages through extensive data on transactions and flow of capital from one sector to others. For any representative year, these models can estimate the impact of a change in input (such as natural gas) on the economic output more accurately than the regression technique, which assumes a simple linear relationship between variables and does not take in to account the cross-sectoral linkages that exist within the economy.

Following the completion of the multi-stage analysis recommended above, an analytical framework for the allocation and pricing of natural gas will be developed, which can be used to develop a comprehensive natural gas allocation and pricing policy. The policy would outline an allocation priority, taking into account economic, social and environmental factors. It would also outline how the desired allocation of natural gas, in quantitative terms, can be achieved through both the direct management of the supply of natural gas and the rationalization of natural gas prices.

The preliminary observations, with reference to solar water heating, presented in this report should also be expanded upon. The analysis of solar water heating in the residential sector in this study relied upon broad assumptions and best available estimates due to the absence of an established market for solar water heating in the country. Thus, the results of the analysis are indicative and need further verification. Further opportunities for the use of solar energy as an alternative to natural gas in the residential and commercial sector should be explored through studies such as detailed market surveys and pilot projects to determine the feasibility of solar energy in Pakistan.

Appendix A: Inception Report

See following pages.

March 28, 2011

Evaluation of Economic Value of Natural Gas in Various Sectors

Inception Report

Evaluation of Economic Value of Natural Gas in Various Sectors

Inception Report

March 28, 2011

Contents

Annexure

1 Introduction

Natural gas plays a significant role in Pakistan's economy, meeting about 44% of the country's energy needs. Natural gas is preferred over other petroleum-based alternatives in nearly all the fuel-consuming sectors of the economy as it is generally a cheap, clean and convenient fuel. As of June 2009, Pakistan's total recoverable gas reserves stood at 28.9 trillion cubic feet (Tcf). Meanwhile, annual gas consumption reached 1.5 Tcf during FY09 and is expected to continue growing. This, coupled with the fact that there have been no major gas discoveries in recent years, is resulting in a widening demand-supply gap in the country. In order to begin to redress this gas shortage—by establishing an environment conducive to balancing demand with supply—it is essential that the gas pricing and allocation policy be reframed.

Advanced Engineering Associates International (AEAI) has initiated a study to assess the economic value of natural gas in the various economic sectors of Pakistan. Hagler Bailly Pakistan (HBP) has been engaged for this purpose through a contract (A012-HB-002) dated March 7, 2011.

This Inception Report summarizes the basic objectives, approach, methods, timelines, and outputs to be adopted or produced for addressing the study's Terms of Reference.

The purpose of this document is to outline the broad parameters and the methodology to be adopted for the study, and to list specific requirements or issues relevant to its initiation and implementation. As a working document, it is therefore subject to change, as deemed appropriate, from time to time based on mutual agreement amongst the parties concerned.

2 Study Objective

The objective of the study is to assist the Government of Pakistan (GoP) in formulating a gas load management policy through which optimal use of natural gas in various economic sectors can be achieved while ensuring highest economic returns for the country. HBP will assess the economic value of natural gas in each sector, and determine the corresponding cross-sectoral energy consumption and economic growth correlations. Under varying oil price scenarios, the impact of changes in crude oil price on the economic value of natural gas in each sector will be assessed. Overall, the analysis will foster policy debate and allow the government to make informed policy choices with respect to gas pricing and allocation by providing a viable and sustainable approach to the issue.

3 Scope of Work

The study aims to focus on the following areas, central to the rationalization of gas policies:

- Cost of supplying indigenous gas, under current pricing regime.
- Cost of imported gas, both liquefied natural gas (LNG) and pipeline imports.
- Existing mechanism for determining the sale price of gas.
- The economic value of gas, using the cost of alternatives approach.
- Comparison of the economic value of gas between various sectors.
- Present recommendations on gas price rationalization and allocation priorities with respect to competing end-use sectors.

4 Study Approach

The approach adopted to address each of the above aspects is outlined below.

4.1 Cost of Supplying Indigenous Gas

Pakistan's gas supply system can be divided into two distinct stages: exploration and production, and transmission and distribution (T&D). Thus, for various sectors, the average delivered price of indigenous gas will be calculated on the basis of the weighted-average wellhead price of natural gas plus the T&D cost of the gas utilities: Sui Northern Gas Pipelines Limited (SNGPL) and Sui Southern Gas Company Limited (SSGCL). Latest tariff determinations and gas price notifications of the Oil and Gas Regulatory Authority (OGRA) will be used to determine the delivered price of gas. Taxes and subsidies will be extracted, to the extent possible, from this price to arrive at the economic delivered cost of indigenous gas.

4.2 Cost of Supplying Imported Gas

The cost of imported LNG and gas supplied through prospective cross-border pipelines, i.e., the Turkmenistan-Afghanistan-Pakistan-India (TAPI) and Iran-Pakistan-India (IPI) pipeline projects, will be determined according to the proposed purchase agreements for each option. Latest pricing formulas will be obtained to determine the border-price of imported LNG and piped gas. T&D costs will be added to this price to arrive at the final delivered price of imported gas. In the case of LNG, regasification costs will also be included. These pricing formulas and cost estimates will be obtained from Inter State Gas Systems Limited (ISGSL).

4.3 Sale Price of Gas

The study will provide an overview of the existing pricing mechanism for gas in the various economic sectors under consideration. It will set out a general pricing framework for the determination of domestic gas prices, including the basis for and frequency of revisions. For this purpose, publicly available documents, such as existing policy guidelines, latest gas price notifications issued by OGRA and the Authority's annual reports, will be consulted.

4.4 Economic Value of Gas

In each sector, alternatives for natural gas are determined according to the purpose or application for which it is utilized. The economic value of gas will be determined on the basis of the cost of the best alternative in each sector and end-use. Using this as a basis for developing gas pricing recommendations will help address existing anomalies, with respect to inter-fuel pricing, in the current gas pricing structure. The approach to be adopted for estimating the economic value of gas in various economic sectors is outlined in the sections below.

Power Sector

In the case of the power sector, fuel oil (FO) and high-speed diesel (HSD) shall be considered as alternatives to natural gas. To determine the economic value of gas for this sector, the HBP Power Model, which takes into account seasonality of electricity demand, hydroelectric and thermal plant capabilities, thermal efficiencies and plant availability, will be used.[1] The analysis will factor in existing gas-based generation capacity. This will include dual-fuel (gas and HSD for combined cycle and gas and FO for steam turbine) power plants. Some of these plants have been committed gas through supply contracts with the utilities, while others have not been guaranteed such supply. Within the former category, there are plants whose supply contracts will be expiring during the period under consideration (one year) in the study. There are also some plants that can only operate on gas due to technological constraints. Thus, economic dispatch of the power plants could be performed under the following three natural gas supply scenarios:

- **Zero Gas Case:** This assumes that no gas is supplied to the power sector whatsoever. Instead, all plants, including those which have been committed gas or which are configured to operate on gas only, will be hypothetically assumed to run on alternative fuels;
- **Essential Gas Case:** This takes into account both contractual and technological constraints. It assumes that gas is only supplied to those plants which have been committed gas supply or cannot operate on other fuels due to technological constraints, or both. Thus, dual-fuel power plants, which have not been guaranteed gas supply or the commitment periods of which are expiring, will be assumed to run on alternative fuel, as will plants without technological constraints;
- **Unconstrained Gas Case:** This assumes that gas is supplied to all plants which have the option of running on it. Thus, all dual-fuel plants, regardless of whether they have been committed gas or not and whether they are able to run on alternative fuels or not, can be supplied gas on demand. This assumes zero

[1] HBP has developed and maintains a proprietary analytical model for long-term planning and economic dispatch of power generation capacity in Pakistan.

constraints on the supply of natural gas in the country, whether indigenous or imported.

For the purpose of the study, the 'zero gas' case will not be considered since it is hypothetical and cannot be implemented in reality. Instead, the two scenarios that will be simulated are the 'essential' and 'unconstrained gas' supply cases. The differential cost of alternatives (HSD and FO) for one operational year under the essential and unconstrained gas cases will define the economic value of natural gas in the power sector. Economic prices (prices excluding taxes and subsidies) of the alternative fuels will be used.

The total power generated and the total variable costs incurred for one operational year will be calculated for both cases using the HBP Power Model. The difference between the total variable costs will be added to the total value (in monetary terms) of gas utilized in the unconstrained case to arrive at the economic value of gas.

Cost and operational data will be obtained from the National Electrical Power Regulatory Authority (NEPRA) and Power System Statistics.[2] These data will include the tariff determinations for generation companies. The terms and conditions outlined in the power purchase agreements for independent power producers (IPPs) will be used as a reference. Assumptions related to availability, heat rates, variable operational expenditures and annual power demand and supply patterns will be made in order to calculate the per unit cost of electricity generation for various plants. For calculating the cost and capacity of power generation, existing power plants, as well as those which are to be commissioned by the end of June 2011 will be taken into account. Meanwhile, the total power generation output of the country will be kept constant at its current level. Thus, in later analyses, the economic cost of pulling gas from the power sector will be the additional FO and HSD consumed to maintain the same power generation capacity, rather than having no power at all.

Residential and Commercial

Natural gas is utilized in the residential and commercial sectors for heating (space and water) and cooking purposes. Alternatives to the two uses of the fuel will be considered separately. The costs of these alternatives will be calculated based on the amount of energy needed to provide the same level of service as that provided by a specific volume of gas. Efficiency adjustments and technology investments will be accounted for while determining the economic value of gas for this sector.

In the case of space and water heating, electricity and solar appliances will be considered as alternatives to natural gas. Electricity tariff notifications by the Ministry of Water and Power will be used to calculate the cost of using electricity as an alternative to gas for heating purposes.

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[2] National Transmission and Despatch Company. *Power System Statistics.*

Using grid-supplied electricity as a direct substitute would require calculating the equivalent amounts of heating output (using comparative conversion efficiencies of gas versus electrical space and water heaters) and assessing the alternative costs involved based on utility retail electricity tariffs for the residential sector. This would provide the first approximation to the economic value of gas for space and water heating in the residential sector.

However, solar heating systems could viably supplement some of the utility-provided energy for such applications as well. Calculating the potential for displacement of gas by solar energy in the residential sector would be a slightly complicated exercise, but could help further refine the economic value of gas in this sector to the extent that such an option could be a viable alternative to both gas and grid-supplied electricity.

The approach adopted to evaluate the use of solar energy in the residential and commercial sector will look into the feasibility of switching to solar appliance and draw results based upon the energy savings caused by the switch. Solar energy is only available during daylight hours, unless it is stored, which is a rather expensive option. Thus, the study would consider its use in hybrid systems instead, which can provide the same level of service as gas-based heating systems. Solar thermal water geysers will be considered for household use. To determine the gas substitution potential in the residential sector, residential consumers will be segmented into three groups based on their consumption levels. The cumulative gas consumption in each of the three categories for water heating purposes will be estimated using data from the gas utilities and/or reasonable usage estimates. More expensive solar-gas hybrid systems will be considered for the highest consumption and income category, as these consumers would be willing to switch to only an equivalent, on-tap hot water system. The percentage of consumers, termed the 'solar penetration' percentage, who would be willing to switch to hybrid systems in the higher-income category of consumers will be estimated based on the payback period involved, assuming ready availability of such alternative technology and services in the country. It would be assumed that the remaining consumers in this category will continue to use natural gas. The costs of hybrid systems will be calculated to include both the investment cost of the solar systems and the cost of integrating them with the existing heating systems in the residential sector. These costs will be obtained from market sources. Proportionately lower penetration rates will be assumed for the consumers belonging to the middle income bracket (in the absence of direct subsidies for solar heating systems).

In the case of lower income consumers, convenience of supply is not a determining factor in deciding on a heating source, as cost assumes a much greater priority. Thus, direct replacement of gas with standalone solar water heating systems would be possible in this segment, costs notwithstanding. However, large subsidies will have to be provided to this class of consumers in order to make solar energy affordable. Such subsidies might also be evaluated for the middle income segment in order to encourage the penetration of solar heating. A cost-benefit analysis would have to be carried out to determine if a subsidy program makes economic sense. The benefits accruing from this subsidy program would be measured in terms of the gas saved if solar energy were to be partially or completely used instead of gas.

On the basis of the above mentioned assumptions and estimates, the total savings, accruing in the form of gas available for other sectors or future consumption, would be determined. However, the analysis would ignore factors such as the current unavailability of services required to integrate the solar system with the ones being used in the residential sector at present, foreign exchange impacts of solar technology imports, etc.

The use of photovoltaic (PV) panels for providing electricity may be the only renewable alternative to gas-based space heating in the urban residential sector. For such an application, only a fraction of the electricity produced would actually be used for space heating, as the electricity produced would have multiple household uses. As such, the amount of solar electricity that can be viably produced by solar home PV systems will be estimated, from which the amount of gas thus displaced for space heating purposes may be arrived at based on reasonable assumptions.

Solar PV prices, although steadily declining, are still prohibitively expensive as a direct alternative to grid-supplied power. Apart from the initial cost of the PV panels themselves, various ancillary components, such as invertors and batteries, are required to enable them to provide a steady AC current and voltages, which further add to their costs. The least costly solar PV home solution relies on the concept of 'net metering', in which unutilized solar power can be sold back to the grid directly by the household. This has many cost efficiency benefits for the consumer: it does away with the otherwise substantial battery storage requirements and costs; it helps reduce the household's utility bills, thereby increasing the payback of the solar option; it ensures that the full output potential of the solar panels is utilized, either in the household itself or through supply back to the utility, so that the PV panels always operate at their maximum efficiency. The success of net metering depends critically on the prevailing utility retail tariff rates (at which the 'net' transactions take place), and countries such as Germany and Japan, where consumer tariffs are already high, have achieved remarkable success in such residential PV applications. The potential for PV penetration in Pakistan's residential sector, based on net metering arrangements with the utilities (for which the relevant provision already exists in the GoP's 2006 Renewable Energy Policy) will be assessed based on a cost-benefit analysis, especially for the higher domestic tariff categories where its economics would be most viable. Based on this assessment, the fraction of the electricity generated that would displace gas used for residential space heating will be calculated, and the associated costs and savings presented to determine the economic value of the gas displaced. All configurations of solar PV home systems other than those relying on net metering would be correspondingly more expensive and therefore not considered as viable alternatives.

For the purpose of cooking, liquefied petroleum gas (LPG), kerosene, and firewood will be treated as alternatives to natural gas. OGRA price notifications will be used to determine the cost of LPG and kerosene, while market sources will be utilized in the case of firewood, although the proportion of firewood use is expected to be almost negligible amongst consumers who are connected to the gas network.

Fertilizer

The fertilizer industry uses natural gas for two purposes—as feedstock and as fuel for the fertilizer manufacturing process. Imported LNG will be considered as an alternative feedstock in the fertilizer industry, while both LNG and FO will be considered as the alternative fuels. To calculate the economic value of gas for feedstock purposes, the amount of LNG required for a specified level of fertilizer output will first be calculated, based on information provided by industry sources. Using this amount and the cost of LNG supply, the per-unit cost of LNG as feedstock for the fertilizer industry will be determined. This will serve as the economic value of gas for the purpose of feedstock supply in the fertilizer industry. Similarly, the amount of LNG and FO required as fuel for a specified level of fertilizer output will be determined and their costs calculated. These costs will be compared and the lower of the two will serve as the economic value of the amount of gas required for an equivalent output of fertilizer. During the calculation process, a few necessary conversions will be carried out to determine the economic value of gas in terms of Rs/MMBtu.

Based on the economic value of gas determined using LNG as feedstock, the cost of domestically produced fertilizer will be calculated. This will take into account domestic production costs, which will be obtained from local industry players. Discussions concerning fuel (gas and FO) generation options in the industry will be held with industry players to determine if there are any additional costs to be incurred for using FO as an alternative fuel to gas. In case there are additional conversion costs involved, these will be factored into the analysis. The cost of domestically-produced fertilizer will be compared to the cost of imported fertilizer in order to determine the more economical option for the country.

Industry

General industry relies on natural gas as an energy source for various production processes and for captive power generation. The Terms of Reference of the study also mentioned that the use of natural gas as a feedstock in the petrochemicals industry be considered separately. However, since this is almost negligible in the case of Pakistan, the economic value of gas will not be calculated separately for this purpose.

HSD and FO will be considered as alternative energy sources for general industry. The economic value of gas will be determined by applying appropriate efficiency adjustments for each alternative fuel. Economic prices of the alternative energy sources will be used. Technology-related information will be obtained from local industry sources in this case.

The share of gas-based captive power generation in the industry will be estimated separately. The alternative to this will be electricity supplied by the power utilities. Prevailing industrial electricity tariff rates for B3 and B4 industrial consumers will be used to calculate the cost of using the alternative source of energy. Capital (unit-based) and operational expenditures will be subtracted from the cost to arrive at the economic value of gas for the purpose of captive power generation within the industrial sector.

Transportation

Natural gas, in the form of compressed natural gas (CNG), is used as fuel in a very large number of motor vehicles in Pakistan. The alternatives to this are motor spirit (gasoline) and HSD. Thus, a comparison with the price of motor spirit and HSD, while accounting for engine efficiencies and compression costs, will be drawn. OGRA price notifications will be used as an information source in the case of motor spirit, while Pakistan State Oil (PSO) price notifications will be utilized for HSD.

4.5 Economic Analysis

The estimation of economic values of gas in each sector will be followed by an assessment of sectoral contribution to national GDP to understand the value addition represented by each sector to the economy. Correlations will be established between energy consumption and economic value addition of each sector to determine the contribution of energy in producing a unit of income. These correlations will be established using historical data for the following variables:

- **Power Sector:** Power consumption per capita and GDP per capita;
- **Residential and Commercial:** Gas consumption per capita and GDP per capita;
- **Fertilizer:** Gas consumption in fertilizer sector and agricultural value-added;
- **Industry:** Gas consumption in industry and manufacturing value-added;
- **Transportation:** Gas consumption in transportation sector and GDP.

At the primary level, the use of gas as fuel, feedstock and for power generation will be assessed. At the secondary level, the use of gas in each sector, in terms of contribution to the economy, will be evaluated. For the power sector, existing pricing policies and allocation practices will be assumed.

The entire analysis will be conducted under a base case crude oil price scenario and three additional scenarios since a change in oil prices will impact the economic value as well as the cost of imported gas. Base case results will be based upon a crude oil price of US$ 115/bbl, as agreed upon with the client. Sensitivities will be conducted for the following cases:

- Crude oil price of US$ 100/bbl;
- Crude oil price of US$ 130/bbl;
- Crude oil price of US$ 145/bbl.

4.6 Recommendations to GoP

Recommendations with reference to the allocation and pricing of gas will be made based on the economic value of natural gas in various sectors and keeping in view the contribution of each sector to the overall economic growth. The recommendations will aim to rationalize the consumer price of gas, which in turn, may influence the producer price due to the linkages between the two. Recommendations for natural gas pricing will be based on the following characteristics of an economic price:

- The price will balance the supply with demand. A lower price than the equilibrium price would result in consumers demanding more than the quantity that producers are willing to supply at that price, and vice versa.
- It will discourage inefficient consumption.
- It will optimize the use of natural gas and its alternatives in each sector.
- In the long run, it will allow the market to operate freely and reduce need for government intervention.

Thus, the recommended gas price must not be so high as to discourage consumption in sectors where consuming gas provides net economic benefit, nor so low as to promote inefficient consumption.

In light of these recommendations, a load management program for natural gas will be outlined, highlighting priority sectors for gas allocation, and an allocation framework developed. Recommendations will also be made with reference to the possible allocation of any additional gas acquired through imports that are secured for the country and the social implications of proposed changes in gas load management.

5 Assumptions and Data Limitations

During the course of the study, HBP will seek information from various sources, including government regulatory bodies, such as OGRA, and state-owned gas utilities. In order to gain inputs and experience from such bodies, HBP will request the GoP, principally through the office of the Planning Commission, to facilitate the process to the extent possible. However, in cases where information is not provided within a reasonable timeframe, the best available estimates would be utilized. For instance, in case the latest field-wise gas formulas and prices are not provided by OGRA in a timely manner, HBP would utilize the best available, latest estimates of these to determine the cost of indigenous gas supply under the crude oil price scenarios agreed upon with AEAI.

Some required information might not be readily available or necessary data might not be systematically collected regularly in Pakistan. In the case of calculating the economic value of gas in the residential and commercial sectors, firewood is to be considered as one of the alternatives to natural gas for cooking purposes. However, due to the lack of a proper commercial market governing the supply and demand, and thus, the price, of firewood, cost figures for this alternative are not necessarily verifiable or properly consolidated and, thus, the analysis would have to rely upon estimates. Similarly, while solar energy is to be considered as an alternative to gas in the residential sector, it would be difficult to obtain accurate figures to determine feasible solar penetration rates in the country. While there would not be sufficient time during the study to undertake reasonably detailed market surveys or data collection exercises, preliminary information gathering efforts, banking upon any related alternative energy feasibility studies already carried out in Pakistan or other similar countries, could provide useful direction and estimates to draw upon.

When calculating the economic value of gas, it might not be possible to extract all applicable taxes, particularly those applied at the production stage, because such figures are not easily and readily accessible. In addition, it might not be possible to conduct a detailed analysis of balance of payment (BoP) and foreign reserve impacts.

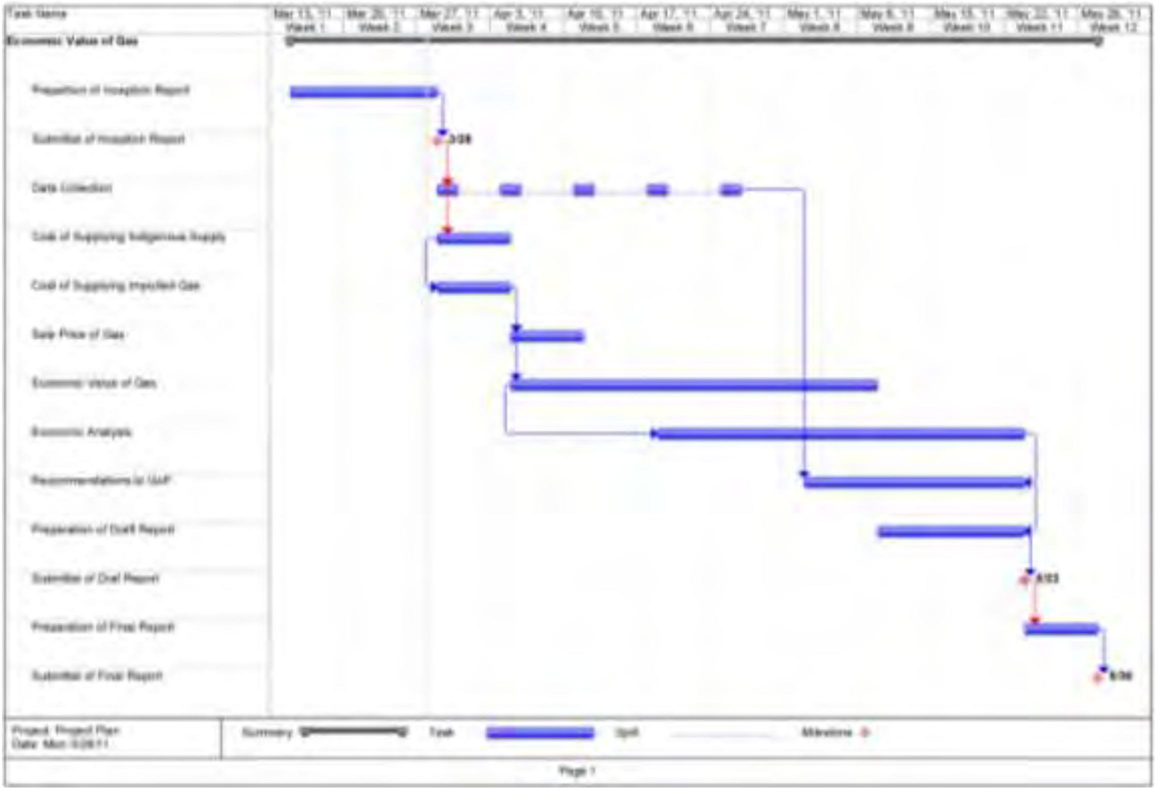
The analysis will require the assumption of a US dollar to Pakistan rupee exchange rate, which will be agreed upon with the client at the inception stage. This will be used for calculating the cost of supply of indigenous gas, the cost of importing both LNG and piped gas, and the cost of some alternative fuels.

The study is expected to rely, to some extent, on consultations with key stakeholders in framing an effective gas pricing and allocation policy for the future. These would include, amongst others, various relevant government agencies and regulatory bodies, gas utilities, power producers, private industry, sector experts, and representatives from key gas consuming categories.

6 Outputs and Schedules

A proposed study work plan, showing the different tasks and milestones, is shown in **Exhibit 1**.

Exhibit 1: Tentative Project Work Plan



A timeline for key milestones, as agreed upon in the contract between HBP and AEAI, is given in **Exhibit 2** below.

Exhibit 2: Study Timeline

Milestone	**Date**
Contract Negotiations	February 2011
Contract Signing	March 9, 2011
Receipt of Mobilization Advance and Study Initiation	March 15, 2011
Inception Report	March 28, 2011
Draft Report	May 23, 2011
Final Report	One week after the receipt of comments from AEAI

6.1 Project Reports

Based on the results of the study, a set of reports will be produced for broad stakeholder dissemination and discussion. These will consist of:

- Inception Report (March 2011)
- Draft Report (May 2011)
- Final Report (June 2011)

The draft report will be submitted for stakeholder and AEAI comments, which will be incorporated in the final versions to be prepared within one week of their receipt by the consultant.

Annexure A

Project Terms of Reference

1. Study Objectives

The objective of this study is to facilitate the government in formulating gas load management policy as follows:

- Assess the financial and economic value of natural gas for specific economic sectors.
- Identify and prioritize the sectors where supply of gas can generate highest economic return for the country.

2. Proposed Outline

The proposed outline for the study is provided below:

Cost of Supply of Indigenously Produced Gas

a. Wellhead price of gas: Price of gas charged by the E&P Companies as per the Gas Sales Agreement with the Distribution Companies (SSGCL & SNGPL)

b. Transmission and distribution (T&D) cost charged by SSGCL and SNGPL

c. Any other cost of supply

Cost of Supply of Gas through LNG

a. Pricing formula assumption for Pakistan in case of long-term contracts b. Spot prices of LNG + Freight rates

b. Capitalized costs of re-gasification and storage terminal(land based or floating ship)and additional pipelines

c. Any other infrastructure costs (draught enhancement at port etc.)

Cost of Supply of Gas through Pipeline Imports

- Turkmenistan Afghanistan Pakistan India (TAPI) pipeline
  a. Formula price of gas and capitalized costs of pipeline and other infrastructure
- Iran Pakistan India (IPI) Project:
  a. Formula price of gas and capitalized costs of pipeline and other infrastructure

Sale Price of Gas

a. Sector wise tariffs charged by SSGCL and SNGPL respectively

b. Time-frame of applicable tariffs

Sector Wise Analysis of Economic Value of Gas and Cost of Substitutes

a. Power Sector:

   i. Fuel substitution through alternative fuel: (Fuel oil and HSD)
   ii. Loss in efficiencies and deterioration of plants incapable of running only on alternative fuel
b. Residential/Commercial Sector:
   i. Alternate use of LPG for cooking
   ii. Alternate use of Kerosene and firewood (pre-dominantly in the rural areas)
   iii. Alternate use of electricity for heating (space and water)
   iv. Alternate use of solar appliances
c. Fertilizer Sector:
   i. No fuel substitution for gas primarily used to manufacture ammonia for urea in this sector
   ii. Product substitution of domestically produced urea and phosphates, with imported product
   iii. Loss of exports in case of net export capability
d. Industrial Sector:
   i. Industrial sector uses three types of power generation modes: (1) gas engines on natural gas; (2) diesel engines based on RFO; and (3) dual fuel fired steam power plants providing cogeneration outputs in the form of electricity and steam. Fuel substitution through RFO and HSD.
   ii. Petrochemicals: Similar to the fertilizer sector, the netback value for use of gas as an input in the production process will be computed from the delivered cost of imported petrochemical products
e. Transportation Sector:
   i. Fuel substitution of CNG through HSD and gasoline

Economic Analysis

a. Sector wise contribution to GDP (of sectors discussed above)
b. GNI per capita correlation with consumption of gas per capita in each sector
c. Calculation of economic value of gas
d. Analysis based on the following three crude price scenarios:
   i. Current: Current price of crude oil
   ii. High: Current price + 20 $/bbl scenario
   iii. Low: Current price -20 $/bbl scenario

Conclusion and Recommendation

a. Optimization of resources through allocation of gas across the portfolio of sectors
b. Proposed gas load management mechanism based on results from economic analysis
c. Brief outline of the social impact of proposed changes in gas load management

Appendix B: Project Terms of Reference

See following pages.

Project Terms of Reference

1. Study Objectives

The objective of this study is to facilitate the government in formulating gas load management policy as follows:

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c. Any other cost of supply

Cost of Supply of Gas through LNG

a. Pricing formula assumption for Pakistan in case of long-term contracts b. Spot prices of LNG + Freight rates

b. Capitalized costs of re-gasification and storage terminal(land based or floating ship)and additional pipelines

c. Any other infrastructure costs (draught enhancement at port etc.)

Cost of Supply of Gas through Pipeline Imports

- Turkmenistan Afghanistan Pakistan India (TAPI) pipeline
  a. Formula price of gas and capitalized costs of pipeline and other infrastructure
- Iran Pakistan India (IPI) Project:
  a. Formula price of gas and capitalized costs of pipeline and other infrastructure

Sale Price of Gas

a. Sector wise tariffs charged by SSGCL and SNGPL respectively

b. Time-frame of applicable tariffs

Sector Wise Analysis of Economic Value of Gas and Cost of Substitutes

a. Power Sector:

    i. Fuel substitution through alternative fuel: (Fuel oil and HSD)
    ii. Loss in efficiencies and deterioration of plants incapable of running only on alternative fuel

b. Residential/Commercial Sector:
    i. Alternate use of LPG for cooking
    ii. Alternate use of Kerosene and firewood (pre-dominantly in the rural areas)
    iii. Alternate use of electricity for heating (space and water)
    iv. Alternate use of solar appliances

c. Fertilizer Sector:
    i. No fuel substitution for gas primarily used to manufacture ammonia for urea in this sector
    ii. Product substitution of domestically produced urea and phosphates, with imported product
    iii. Loss of exports in case of net export capability

d. Industrial Sector:
    i. Industrial sector uses three types of power generation modes: (1) gas engines on natural gas; (2) diesel engines based on RFO; and (3) dual fuel fired steam power plants providing cogeneration outputs in the form of electricity and steam. Fuel substitution through RFO and HSD.
    ii. Petrochemicals: Similar to the fertilizer sector, the netback value for use of gas as an input in the production process will be computed from the delivered cost of imported petrochemical products

e. Transportation Sector:
    i. Fuel substitution of CNG through HSD and gasoline

Economic Analysis

a. Sector wise contribution to GDP (of sectors discussed above)
b. GNI per capita correlation with consumption of gas per capita in each sector
c. Calculation of economic value of gas
d. Analysis based on the following three crude price scenarios:
    i. Current: Current price of crude oil
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Conclusion and Recommendation

a. Optimization of resources through allocation of gas across the portfolio of sectors
b. Proposed gas load management mechanism based on results from economic analysis
c. Brief outline of the social impact of proposed changes in gas load management

Appendix C: Indigenous Natural Gas Pricing

Exhibit C.1: Wellhead Prices

Field Name	*Quantity (MMBtu)*	*Base Case*	*Oil Scenario 1*	*Oil Scenario 2*	*Oil Scenario 3*
Crude Oil Price – Brent		*$ 115/bbl*	*$ 100/bbl*	*$ 130/bbl*	*$ 145/bbl*
Adhi	16,123	1.47	1.47	1.47	1.47
Badar	2,054	2.37	2.37	2.37	2.37
Badin Deep	71,617	4.37	4.02	4.72	5.07
Bhit	113,376	4.79	4.42	5.17	5.54
Chachar	2,274	2.60	2.60	2.60	2.60
Chanda	2,969	2.74	2.74	2.74	2.74
Dakhni	20,669	1.47	1.47	1.47	1.47
Daru	357	1.29	1.29	1.29	1.29
Dhodak	139	2.94	2.94	2.94	2.94
Dhullian Meyal	514	1.29	1.29	1.29	1.29
Dhurnal	12	0.27	0.27	0.27	0.27
Hasan	2,839	2.44	2.44	2.44	2.44
Kadanwari	16,036	8.50	8.50	8.50	8.50
Kandhkot	14,892	2.18	2.01	2.36	2.53
Khipro Mirpur Khas Block	3,526	2.64	2.64	2.64	2.64
Makori	9,851	2.74	2.74	2.74	2.74
Manzalai	92,070	2.84	2.84	2.84	2.84
Mela	7,102	2.67	2.67	2.67	2.67
Miano	19,125	4.46	4.11	4.81	5.16
Pindori/ Pariwali/ Turkwal	5,890	4.79	4.42	5.17	5.54
Pirkoh/Loti	5,438	1.38	1.38	1.38	1.38
Qadirpur	196,660	2.70	2.70	2.70	2.70
Ratana	1,158	3.91	3.91	3.91	3.91
Rehmat	3,139	2.64	2.64	2.64	2.64
Sadkal	498	9.37	9.37	9.37	9.37
Salsabeel (Rodho)	10,388	2.84	2.84	2.84	2.84
Sari Hundi	646	9.11	9.11	9.11	9.11
Sawan	106,457	4.46	4.11	4.81	5.16

Field Name	*Quantity (MMBtu)*	*Base Case*	*Oil Scenario 1*	*Oil Scenario 2*	*Oil Scenario 3*
Crude Oil Price – Brent		*$ 115/bbl*	*$ 100/bbl*	*$ 130/bbl*	*$ 145/bbl*
Sui	145,506	2.18	2.01	2.36	2.53
Zamzama SNGPL	55,431	4.37	4.02	4.72	5.07
Zamzama SSGCL	85,138	4.37	4.02	4.72	5.07
Hassan - Rustam	45	4.48	4.48	4.48	4.48
Ghotki Town	349	4.48	4.48	4.48	4.48
Ubaro Town	333	4.48	4.48	4.48	4.48
Mari	185	0.58	0.58	0.58	0.58
Choundio	6	2.19	2.19	2.19	2.19
Adam / Hala	5,194	2.37	2.37	2.37	2.37
Pakhro	389	2.28	2.28	2.28	2.28
Bobi	5,384	4.62	4.62	4.62	4.62
Latif	8,997	2.37	2.37	2.37	2.37
Mazarani	3,690	2.18	2.01	2.36	2.53
Mirpurkhas block - Kausar	7,405	2.37	2.37	2.37	2.37
Haseeb	6,787	2.64	2.64	2.64	2.64
Sinjhoro	25	2.60	2.60	2.60	2.60
Loti	1,431	1.38	1.38	1.38	1.38
Saqib	7,112	2.74	2.74	2.74	2.74
Tajjal	5,208	2.74	2.74	2.74	2.74
Nashpa	7,164	2.70	2.70	2.70	2.70
Maran Zai	12,447	2.74	2.74	2.74	2.74
Koonj	2,051	2.74	2.74	2.74	2.74
Mami Khel	7,149	2.74	2.74	2.74	2.74
Weighted Average Price		**3.50**	**3.33**	**3.67**	**3.85**

Exhibit C.2: Gas Purchased and Sold

('000 MMBtu)

Sector	*SNGPL*	*SSGC*	*Total*
Gas Purchased	687,704	405,541	1,093,245
Losses	68,083	43,312	111,394
Total Gas sold	619,621	362,229	981,851

Exhibit C.3: Calculation of Prescribed Price

(Rs Millions)

Sector	*SNGPL*	*SSGC*	*Total*
Revenues other than gas sales			
Rental & service charges	1,050	605	1,655
Surcharge and interest on arrears	1,501	575	2,076
Amortization of deferred credit	1,281	378	1,659
Sale of gas condensate		599	599
Meter manufacturing profit		127	127
Gas transportation charges		573	573
Revenue from JJVL		3,377	3,377
Royalty income from JJVL		2,674	2,674
Other operating income	518	247	765
Total other income "A"	**4,350**	**9,155**	**13,505**
Expenses			
Cost of gas sold	206,068	121,519	327,587
UFG (disallowance) / allowance	(8,215)	(3,974)	(12,189)
Transmission and distribution cost	8,652	7,196	15,848
Cost of Reinstated Employees	553		553
Gas Internally Consumed	2,555	146	2,701
Depreciation	8,069	3,206	11,275
Workers Profit Participation Fund	116	435	551
Total expenses "B"	**196,585**	**117,024**	**313,609**
Costs to be recovered (A-B)	192,235	107,869	300,104
Amount of return required	8,533	7,326	15,860
Revenue requirement	200,768	115,195	315,964
Average Prescribed Price (Rs/MMBtu)	**358.25**	**349.78**	**355.13**

Exhibit C.4: Consumer Gas Prices

	Gas Sale Price notified by OGRA On June 30, 2010	
	(Rs/MMBtu)	*($/MMBtu)*
Domestic		
Up to 100 cubic meter per month	95.00	1.11
101 – 300 cubic meter per month	190.00	2.22
300 – 500 cubic meter per month	800.00	9.35
over 500 cubic meter per month	1,006.00	11.76
Commercial	463.76	5.42
Special Commercial		
Up to 100 cubic meter per month	95.00	1.11
101 to 300 cubic meter per month	190.00	2.22
over 300 cubic meter per month	463.76	5.42
Industrial	382.37	4.47
CNG	503.64	5.89
Cement	536.42	6.27
Fertilizer		
Pak American Feedstock	102.01	1.19
Pak American Fuel	382.37	4.47
Daud Hercules Feedstock	102.01	1.19
Daud Hercules Fuel	382.37	4.47
Pak Arab Feedstock	102.01	1.19
Pak Arab Fuel	382.37	4.47
Pak China Feedstock	102.01	1.19
Pak China Fuel	382.37	4.47
Hazara Feedstock	102.01	1.19
Hazara Fuel	382.37	4.47
Engro Fertilizer Feedstock	59.29	0.69
Engro Fertilizer Fuel	382.37	4.47
Fauji Fertilizer Feedstock	102.01	1.19
Fauji Fertilizer Additional Feedstock	59.29	0.69
Fauji Fertilizer Fuel	382.37	4.47
Power Stations	393.79	4.60
IPPs	332.36	3.89
Captive	382.37	4.47

Appendix D: Detailed Calculations for Power Sector

The following table summarizes the calculations pertaining to the economic value of gas in the power sector in the near-term:

Fuel	Unit	Heat Rate	Economic Prices, $/MMBtu			
			$ 100/bbl	$ 115/bbl	$ 130/bbl	$ 145/bbl
Fuel Pricing Assumptions for Plant Dispatch Analysis						
Gas	Btu/scf	950	4.85	5.07	5.29	5.51
RFO	Btu/Tonne	40.79	15.38	17.47	19.57	21.67
HSD	Btu/Tonne	44.05	22.31	25.34	28.41	31.48

No.	Power Plants	Alternate Fuel	Heat Rate of Generation Units			Annual Fuel Consumption			Total Annual System Costs, $ Million				Economic Value of Gas, $/MMBtu			
			Gas	FO	HSD	Gas	RFO	HSD	Base Case	Oil Scenario 1	Oil Scenario 2	Oil Scenario 3	Base Case	Oil Scenario 1	Oil Scenario 2	Oil Scenario 3
			Btu/kWh			MMscfd	000' Tonnes	000' Tonnes	$ 115/ bbl	$ 100/bbl	$ 130/bbl	$ 145/bbl	$ 115/ bbl	$ 100/bbl	$ 130/bbl	$ 145/bbl
	Essential Gas					**585**	**10,987**	**2,002**	**11,944**	**10,693**	**13,200**	**14,455**				
1	Bhikhi Power (Halmore)	HSD	7,086		7,417	604	10,987	1,844	11,801	10,570	13,037	14,272	26.52	23.35	29.74	32.95
2	Muridke Power	HSD	7,086		7,417	637	10,987	1,571	11,555	10,358	12,757	13,958	26.52	23.35	29.74	32.95
3	Orient	HSD	7,086		7,417	670	10,987	1,294	11,305	10,142	12,472	13,638	26.52	23.35	29.74	32.95
4	Sahiwal Power (Saif)	HSD	7,086		7,417	704	10,987	1,021	11,059	9,930	12,191	13,323	26.52	23.35	29.74	32.95
5	Korangi New CC 1	HSD	7,086		7,417	733	10,987	782	10,843	9,743	11,945	13,047	26.52	23.35	29.74	32.95
9	KAPCO 1	HSD	7,363		7,751	784	10,987	355	10,457	9,410	11,505	12,553	26.67	23.49	29.90	33.14
10	KAPCO 2	HSD	7,363		7,751	819	10,987	62	10,193	9,182	11,203	12,214	26.67	23.49	29.90	33.14
6	KAPCO 3	FO	7,363	8,124		855	10,656	62	10,016	9,031	11,001	11,987	19.48	17.16	21.79	24.10
7	KAPCO 4	FO	7,363	8,124		890	10,325	62	9,840	8,880	10,799	11,759	19.48	17.16	21.79	24.10

No.	Power Plants	Alternate Fuel	Heat Rate of Generation Units			Annual Fuel Consumption			Total Annual System Costs, $ Million				Economic Value of Gas, $/MMBtu			
			Gas	FO	HSD	Gas	RFO	HSD	Base Case	Oil Scenario 1	Oil Scenario 2	Oil Scenario 3	Base Case	Oil Scenario 1	Oil Scenario 2	Oil Scenario 3
			Btu/kWh			MMscfd	000' Tonnes	000' Tonnes	$ 115/ bbl	$ 100/bbl	$ 130/bbl	$ 145/bbl	$ 115/ bbl	$ 100/bbl	$ 130/bbl	$ 145/bbl
8	KAPCO 5	FO	7,363	8,124		925	9,993	62	9,661	8,727	10,595	11,529	19.66	17.35	21.97	24.29
11	Bin Qasim Steam 6	FO	9,098	9,098		959	9,710	62	9,518	8,605	10,430	11,342	17.47	15.38	19.57	21.67
12	Bin Qasim Steam 5	FO	9,098	9,098		991	9,433	62	9,378	8,487	10,269	11,160	17.47	15.38	19.57	21.67
13	Bin Qasim Steam 2	FO	9,478	9,478		1,024	9,156	62	9,237	8,367	10,107	10,977	17.47	15.38	19.57	21.67
14	Bin Qasim Steam 1	FO	9,478	9,478		1,057	8,878	62	9,097	8,248	9,945	10,794	17.47	15.38	19.57	21.67
15	Muzaffargarh Steam 4	FO	9,982	9,982		1,101	8,498	62	8,904	8,085	9,724	10,543	17.47	15.38	19.57	21.67
16	Muzaffargarh Steam 3	FO	10,482	10,482		1,132	8,241	62	8,774	7,975	9,574	10,374	17.47	15.38	19.57	21.67
17	Muzaffargarh Steam 2	FO	10,530	10,530		1,165	7,961	62	8,633	7,855	9,411	10,189	17.47	15.38	19.57	21.67
18	Muzaffargarh Steam 1	FO	10,553	10,553		1,195	7,701	62	8,501	7,743	9,260	10,018	17.47	15.38	19.57	21.67
19	Guddu Steam 4	FO	11,090	11,090		1,222	7,472	62	8,386	7,645	9,126	9,867	17.47	15.38	19.57	21.67
20	Guddu Steam 3	FO	11,138	11,138		1,250	7,232	62	8,264	7,542	8,987	9,709	17.47	15.38	19.57	21.67
21	Bin Qasim Steam 4	FO	11,373	11,373		1,287	6,917	62	8,105	7,406	8,803	9,501	17.47	15.38	19.57	21.67
22	Bin Qasim Steam 3	FO	11,373	11,373		1,325	6,601	62	7,945	7,271	8,619	9,293	17.47	15.38	19.57	21.67
23	Jamshoro Steam 4	FO	11,452	11,452		1,361	6,287	62	7,786	7,136	8,436	9,087	17.47	15.38	19.57	21.67

No.	Power Plants	Alternate Fuel	Heat Rate of Generation Units			Annual Fuel Consumption			Total Annual System Costs, $ Million				Economic Value of Gas, $/MMBtu			
			Gas	FO	HSD	Gas	RFO	HSD	Base Case	Oil Scenario 1	Oil Scenario 2	Oil Scenario 3	Base Case	Oil Scenario 1	Oil Scenario 2	Oil Scenario 3
			Btu/kWh			MMscfd	000' Tonnes	000' Tonnes	$ 115/ bbl	$ 100/bbl	$ 130/bbl	$ 145/bbl	$ 115/ bbl	$ 100/bbl	$ 130/bbl	$ 145/bbl
24	Jamshoro Steam 2	FO	11,584	11,584		1,401	5,952	62	7,616	6,992	8,241	8,865	17.47	15.38	19.57	21.67
25	Muzaffargarh Steam 6	FO	11,694	11,694		1,425	5,749	62	7,514	6,905	8,123	8,732	17.47	15.38	19.57	21.67
26	Muzaffargarh Steam 5	FO	11,744	11,744		1,458	5,465	62	7,371	6,783	7,958	8,545	17.47	15.38	19.57	21.67
27	Korangi St 1	FO	11,766	11,530		1,467	5,394	62	7,335	6,753	7,917	8,498	17.12	15.07	19.18	21.23
28	Korangi St 2	FO	11,766	11,530		1,486	5,236	62	7,256	6,686	7,825	8,395	17.12	15.07	19.18	21.23
29	Korangi St 3	FO	11,766	11,530		1,505	5,078	62	7,176	6,619	7,734	8,292	17.12	15.07	19.18	21.23
30	Jamshoro Steam 3	FO	12,410	12,410		1,536	4,809	62	7,040	6,503	7,577	8,114	17.47	15.38	19.57	21.67
31	Faisalabad SPS 2	FO	12,477	12,477		1,546	4,724	62	6,997	6,467	7,528	8,058	17.47	15.38	19.57	21.67
32	Faisalabad SPS 1	FO	12,886	12,886		1,553	4,668	62	6,969	6,443	7,495	8,021	17.47	15.38	19.57	21.67

Appendix E: Economic Value of Natural Gas for the Residential and Commercial Sector

E.1 Analysis of Gas Consumption Patterns in the Residential Sector

The amounts of gas used for cooking, water heating and space heating in the residential sector were determined by studying the gas consumption patterns in the residential sector. Estimates of monthly gas consumption data were obtained from SNGPL and SSGC. These estimates were combined to determine the total monthly gas consumption in the residential sector. The total monthly gas consumption for each month was divided by the annual average monthly gas consumption in the residential sector to determine monthly gas demand factors in the residential sector, as presented in **Exhibit E.1**.

Gas demand for cooking is uniform throughout the year, whereas both water and space heating contribute to peak loads during the winter season. The average monthly demand in the summer season (May-September) was considered as demand for cooking, while the difference between the demand for cooking and the average demand during the mild winter period (March, April, October and November) was attributed entirely to water heating. During these months, there is negligible space heating and thus, the incremental demand during the mild winter period can be considered as gas demand for water heating during these months. The difference between the average demand during the mild winter period and the average demand during the peak winter period (December-February) was considered as demand for both water and space heating since gas required for water heating increases during the peak winter period. Thus, the total annual demand for water heating was calculated by adding a proportion of the total incremental demand during peak winter to the gas demand for water heating during mild winter. The remaining incremental demand during peak winter was attributed to space heating. The average gas consumption figures for cooking, water heating and space heating are presented in **Exhibit E.2**.

The total annual gas consumption for cooking, water heating and space heating was calculated separately based upon the average gas consumption figures for the three purposes in the residential sector. The number of gas-connected households in the country was obtained from the annual reports of SNGPL and SSGC and OGRA's public documents. The total annual gas consumption figures for cooking, water heating and space heating were divided by the number of gas-connected households individually to calculate the average amount of gas consumed per household for the three purposes, as presented in

Exhibit E.3.

Exhibit E.1: Monthly Gas Consumption Patterns for Residential Sector

		Jul-10	*Aug-10*	*Sep-10*	*Oct-10*	*Nov-10*	*Dec-10*	*Jan-11*	*Feb-11*	*Mar-11*	*Apr-11*	*May-11*	*Jun-11*	*Total*	*Average*
Gas Consumption in SNGPL System	MMscf	9,438	9,507	9,280	11,293	15,382	23,909	30,517	22,629	13,920	11,262	9,518	8,435	175,091	14,591
Gas Consumption in SSGC System	MMscf	4,529	4,901	5,212	5,088	6,887	8,004	9,058	9,431	6,204	5,336	4,901	4,964	74,453	6,204
Gas Consumption inTotal System	MMscf	13,968	14,409	14,492	16,381	22,269	31,912	39,576	32,060	20,124	16,598	14,419	13,399	249,606	20,801
Monthly Seasonal Demand Factors		0.67	0.69	0.70	0.79	1.07	1.53	1.90	1.54	0.97	0.80	0.69	0.64	12.00	1.00

Exhibit E.2: Average Gas Consumption for Cooking, Water Heating and Space Heating in Residential Sector

Proportion of Incremental Gas Consumption for Water Heating in Peak Winter		40%
Proportion of Incremental Gas Consumption for Space Heating in Peak Winter		60%
Average Monthly Gas Consumption in Peak Winter	MMscf	34,516
Average Monthly Gas Consumption in Mild Winter	MMscf	18,843
Average Monthly Gas Consumption in Summer	MMscf	14,137
Average Monthly Gas Consumption for Cooking	MMscf	14,137
Average Monthly Gas Consumption for Water Heating in Mild Winter	MMscf	4,706
Average Incremental Monthly Gas Consumption for Water Heating in Peak Winter	MMscf	6,269
Average Monthly Gas Consumption for Space Heating in Peak Winter	MMscf	15,673

Exhibit E.3: Average Gas Consumption per Household

		Cooking	*Water Heating*	*Space Heating*
Total Annual Gas Consumption	MMscf	169,647	51,747	28,211
Total Annual Gas Consumption	MMBtu	161,165,001	49,159,974	26,800,767
Number of Households	Million	6.1	6.1	6.1
Average Gas Consumption per Households	MMBtu	26	8	4

E.2 Analysis of Solar Water Heating Systems

The costs of different solar water heating systems were obtained from industry sources. A study titled ‘Development of Solar Hot Water Systems for Domestic Application in Pakistan’ carried out by German Technical Corporation (GIZ) in October 2010 was used as a reference source. Both standalone solar water heating systems and hybrid systems were considered. The storage capacity (420 liters) of standalone systems was higher than the storage capacity (210 liters) of hybrid systems since the standalone systems would require hot water to be stored in the absence of sunlight and a backup heating option. **Exhibit E.4** summarizes the investment costs of different solar water heating systems.

Exhibit E.4: Investment Costs of Solar Water Heating Systems

		Solar-Electric Hybrid	*Standalone Solar Water Heater*	*Solar-Gas Geyser Hybrid*
Storage Tank Capacity	**Litres**	**210**	**420**	**210**
Cost of Heater	$	450.2	771.8	385.9
Piping Cost	$	90.0	128.6	141.5
Insulation Cost	$	–	51.5	25.7
Installation Cost	$	25.7	51.5	25.7
Total Investment Cost	**$**	**566.0**	**1,003.3**	**578.8**

The costs of the solar water heating systems were annualized, using the discount rate of 15% assumed in the study, for the economic life of the equipment. The annualized investment costs of solar water heating systems were added to the O&M costs, estimated at 2% of the solar water heating system's investment cost, to determine the total annual costs of the system. To calculate the cost of solar water heating, in terms of $/MMBtu, the proportion of the total annual gas consumed for water heating by an average household that would be displaced by hybrid solar water heating systems was estimated at 80%. The 80% estimate would be affected by factors such as the household's geographic location and climatic conditions as well as lifestyle habits.[54] The total annual costs of solar water heating were divided by the amount of gas that would be displaced by solar water heating to arrive at the economic value of natural gas for water heating. **Exhibit E.5** summarizes the economic value of natural gas for water heating assuming solar water heating as an alternative.

Exhibit E.5: Economic Value of Natural Gas for Water Heating
Assuming Solar Water Heating as an Alternative

		Solar-Electric Hybrid	*Standalone Solar Water Heater*	*Solar-Gas Geyser Hybrid*
Total Investment Cost	**$**	**566.0**	**1,003.3**	**578.8**
Economic Life	years	15	15	15
Discount Rate		15%	15%	15%
Annualized Investment Cost	$	96.8	171.6	99.0
Annual O&M Costs	$	11.3	20.1	11.6

54 Lifestyle habits influence the amount of hot water required as well as the time of the day during which it is required. For instance, showering at night in the absence of solar energy would result in increased utilization of the backup fuel option (electricity or gas) and decreased utilization of solar energy. This would reduce the savings that can be accrued from the use of solar energy. Thus, the cost of solar water heating would increase.

		Solar-Electric Hybrid	*Standalone Solar Water Heater*	*Solar-Gas Geyser Hybrid*
Total Annual Costs	**$**	**108.1**	**191.6**	**110.6**
Total Annual Gas Consumed for Water Heating per Average Household	MMBtu	8.1	8.1	8.1
Proportion Replaced by Solar Water Heating	%	80	100	80
Annual Gas Replaced by Solar Water Heating	**MMBtu**	**6.5**	**8.1**	**6.5**
Economic Value of Natural Gas for Water Heating assuming Solar Water Heating as an Alternative	**$/MMBtu**	**16.7**	**23.7**	**17.1**

The total investment costs of solar water heating systems were also annualized using lower discount rates of 10% and 5%. The analysis to determine the economic value of natural gas for solar water heating was then repeated with the revised annualized investment costs. The analysis indicates that the annualized investment cost decreases with a lower discount rate and thus, the economic value of natural gas for water heating is lower. **Exhibit E.6** summarizes the economic value of natural gas for water heating under the 10% discount rate scenario.

Exhibit E.6: Economic Value of Natural Gas for Water Heating Assuming Solar Water Heating as an Alternative under a 10% Discount Rate Scenario

		Solar-Electric Hybrid	*Standalone Solar Water Heater*	*Solar-Gas Geyser Hybrid*
Total Investment Cost	**$**	**566.0**	**1,003.3**	**578.8**
Economic Life	years	15	15	15
Discount Rate		10%	10%	10%
Annualized Investment Cost	**$**	**74.4**	**131.9**	**76.1**
Annual O&M Costs	$	11.3	20.1	11.6
Total Annual Costs	**$**	**85.7**	**152.0**	**87.7**
Total Annual Gas Consumed for Water Heating per Average Household	MMBtu	8.1	8.1	8.1
Proportion Replaced by Solar Water Heating	%	80	100	80
Annual Gas Replaced by Solar Water Heating	**MMBtu**	**6.5**	**8.1**	**6.5**
Economic Value of Natural Gas for Water Heating assuming Solar Water Heating as an Alternative	**$/MMBtu**	**13.3**	**18.8**	**13.6**

Exhibit E.7 summarizes the economic value of natural gas for water heating under the 5% discount rate scenario.

Exhibit E.7: Economic Value of Natural Gas for Water Heating Assuming Solar Water Heating as an Alternative under a 5% Discount Rate Scenario

		Solar-Electric Hybrid	*Standalone Solar Water Heater*	*Solar-Gas Geyser Hybrid*
Total Investment Cost	**$**	**566.0**	**1,003.3**	**578.8**
Economic Life	years	15	15	15
Discount Rate		5%	10%	10%
Annualized Investment Cost	**$**	**54.5**	**96.7**	**55.8**
Annual O&M Costs	$	11.3	20.1	11.6
Total Annual Costs	**$**	**65.8**	**116.7**	**67.3**
Total Annual Gas Consumed for Water Heating per Average Household	MMBtu	8.1	8.1	8.1
Proportion Replaced by Solar Water Heating	%	80	100	80
Annual Gas Replaced by Solar Water Heating	**MMBtu**	**6.5**	**8.1**	**6.5**
Economic Value of Natural Gas for Water Heating assuming Solar Water Heating as an Alternative	**$/MMBtu**	**10.2**	**14.5**	**10.4**

The analysis of solar water heating in the residential and commercial sector relied upon broad assumptions and best available estimates due to the absence of an established market for solar water heating in the country. Thus, the results of the analysis are indicative and need further verification.

E.3 Analysis of Photovoltaic (PV) Panels in the Residential and Commercial Sector

The use of photovoltaic (PV) panels for generation of electricity using solar energy as an alternative to natural gas in the residential and commercial sector was also assessed to ascertain if the economic cost of delivered electricity to the residential and commercial consumers needs to be adjusted taking this source into account. The electricity produced by PV panels would have multiple end-uses (such as space and water heating, lighting and power supply for various household appliances). Solar PV panel prices, although steadily declining, are still prohibitively expensive as a direct alternative to grid-supplied power. Apart from the initial cost of the PV panels themselves, various ancillary components, such as inverters and batteries, are required to enable the PV system to provide a steady AC current and voltages. These ancillary components further add to the costs of PV panels. The least expensive solar PV solution relies in the concept of 'net metering', in which unutilized solar power can be sold back to the grid directly by the household. This has many cost efficiency benefits for the consumer: it does away with the otherwise substantial battery storage requirements and costs; it helps reduce the household's utility bills, thereby increasing the payback of the solar option; it ensures that the full output potential of the solar panels is utilized, either in the household itself or through supply back to the utility, so that the power generated by the PV panels is not wasted.

The feasibility of switching to PV panels in the residential and commercial sector was analyzed based upon simple payback periods for PV panels of different capacities. Net metering arrangements with the utilities were assumed. The costs of PV panels and inverters, as well as installation costs, were based upon information obtained from market sources and combined to calculate the total investment cost. Annual savings accruing from the PV panels, in the form of a reduction in the household's electricity bill, were calculated based upon an average daily solar insolation value of six hours for Pakistan.[55] The total amount of electricity generated by the PV system was calculated and the PV system generation was assumed to be compensated at the corresponding retail slab tariff. The annual savings were then compared to the total investment cost of the PV system to calculate the simple payback periods of the PV system. Financial costs were used since the consumer's decision to opt for PV panels would be based upon the financial feasibility of the PV system. The simple payback periods of the PV systems were lower for high-usage consumers in comparison to low-usage consumers since a higher retail tariff applies to high-usage consumers, resulting in greater utility bill savings. Nevertheless, the payback periods for even the high-usage consumers were significantly high. Thus, under the present framework of costs and electricity tariffs, the use of PV panels is not feasible in the residential and commercial sector. **Exhibit E.8** summarizes the simple payback periods for PV panels in the residential and commercial sector.

55 The average daily solar insolation value of six hours is based upon information obtained from market sources.

Exhibit E.8: Simple Payback Periods for Various PV Panels

		0.5 kW PV Panel	*1.0 kW PV Panel*	*2.0 kW PV Panel*	*3.0 kW PV Panel*
Total System Cost[56]	$	2,370.3	4,740.6	9,481.2	14,221.8
Average Daily Solar Insolation	hours	6.0	6.0	6.0	6.0
Daily Electricity Generated	kWh	3.0	6.0	12.0	18.0
Annual Electricity Generated	kWh	1,095.0	2,190.0	4,380.0	6,570.0
Electricity Tariff Rate[57]	$/kWh	0.06	0.09	0.15	0.18
Annual Savings	$	65.3	197.8	638.2	1,194.6
Simple Payback Period for PV Panel	**years**	**36**	**24**	**25**	**12**

The analysis of PV panels in the residential and commercial sector relied upon broad assumptions and best available estimates due to the absence of an established market for PV panels relying upon net metering arrangements with the electric utilities in the country. Thus, the results of the analysis are indicative and need further verification.

56 The total system costs did not include the costs of integrating the PV systems with the local electricity grid since the integration costs could not be estimated since net metering arrangements using PV panels are not currently implemented in the residential sector in Pakistan. The payback periods for PV panels will increase once the costs of integrating the PV systems with the local electricity grid are included in the total system costs.

57 The electricity tariff rates were obtained from the consumer tariff notifications of electric supply utilities.

Appendix F: Economic Value of Natural Gas for the Fertilizer Sector

To calculate the economic value of natural gas for existing fertilizer capacity in the near-term, the costs of importing urea and making capacity payments were taken into account. Fixed O&M costs, in terms of $/tonne, were calculated by dividing the total annual fixed O&M costs by the annual plant capacity. The fixed O&M costs as well as other plant data were obtained from industry sources. The fixed O&M costs were then added to the other cash outflows necessary to account for the investment made by the industry as well as the interest payments to be made to lenders. The combined costs were considered as the capacity payments to be made to the industry. The total amount of natural gas, in terms of MMBtu, required as feedstock and fuel for a specified level (1 tonne) of fertilizer output was obtained from industry sources. The capacity payments were divided by the total amount of natural gas required for fertilizer production to calculate the capacity payments in terms of $/MMBtu. **Exhibit F.1** summarizes the capacity payments to be made to the fertilizer industry in the near-term if urea is imported.

Exhibit F.1: Capacity Payments for Existing Fertilizer Plants in the Near-Term

		Efficient Plants	*Inefficient Plants*
Annual Plant Capacity	Million tonnes	1.9	1.9
Annual Fixed O&M Costs	Million $	49.1	62.1
Annual Fixed O&M Costs	**$/tonne**	**25.6**	**32.3**
Cash Outflows to account for Investment and Interest Payments	$/tonne	132.8	107.2
Total Fixed Costs	**$/tonne**	**158.3**	**139.5**
Amount of Gas required as Feedstock	MMBtu/tonne	22.0	24.0
Amount of Gas required as Fuel	MMBtu/tonne	2.0	5.0
Total Amount of Gas required as Feedstock and Fuel	**MMBtu/tonne**	**24.0**	**29.0**
Capacity Payment for Existing Fertilizer Plants in the Near-Term	**$/MMBtu**	**6.6**	**4.8**

The indicative international price of urea was determined under various crude oil price scenarios based upon regression analysis. Transportation and wharfage charges of $ 30/tonne were added to the indicative international price of urea to arrive at the indicative landed price of imported urea for Pakistan. The indicative landed price of imported urea, in terms of $/tonne, was divided by the amount of natural gas required for the production of 1 tonne of urea to calculate the cost of imported urea in terms of $/MMBtu.

Exhibit F.2: Cost of Imported Urea under Base Case Crude Oil Price Scenario

		Efficient Plants	*Inefficient Plants*
Indicative Landed Price of Imported Urea	$/tonne	522.7	522.7
Transportation and Wharfage Costs	$/tonne	30.0	30.0
Average Landed Price of Urea	**$/tonne**	**552.7**	**552.7**
Amount of Gas required as Feedstock	MMBtu/tonne	22.0	24.0
Amount of Gas required as Fuel	MMBtu/tonne	2.0	5.0
Total Amount of Gas required as Feedstock and Fuel	**MMBtu/tonne**	**24.0**	**29.0**
Cost of Imported Urea	**$/MMBtu**	**23.0**	**19.1**

The capacity payments for existing fertilizer plants were added to the cost of imported urea, in terms of $/MMBtu, to calculate the near-term economic value of natural gas in the fertilizer industry. **Exhibit F.3** summarizes the results of the analysis.

Exhibit F.3: Near-Term Economic Value of Gas

		Efficient Plants	*Inefficient Plants*
Capacity Payments	$/MMBtu	6.6	4.8
Cost of Imported Urea	$/MMBtu	23.0	19.1
Near-Term Economic Value of Gas	**$/MMBtu**	**29.6**	**23.9**

The medium-term analysis of the economic value of natural gas considered two alternative—the import of urea without the burden of capacity payments and the import of LNG to produce domestic urea. Fertilizer plants were assumed to be efficient in the medium-term. In the case of LNG, the cost of domestic urea was estimated using the production costs of efficient plants and natural gas priced at the delivered cost of imported LNG. Variable (excluding feedstock and fuel) and fixed production costs were obtained from industry sources. **Exhibit F.4** summarizes the cost of domestic urea using LNG as feedstock and fuel under the base case crude oil price scenario.

Exhibit F.4: Cost of Domestic Urea using Imported LNG as Feedstock and Fuel under Base Case Crude Oil Price Scenario

		Efficient Plants
Delivered Cost of Imported LNG	$/MMBtu	19.5
Amount of Gas Required as Feedstock and Fuel	MMBtu/tonne	24.0
Total Cost of Gas Required as Feedstock and Fuel	**$/tonne**	**468.7**
Variable Costs (excluding feedstock and fuel)	$/tonne	22.5
Total Variable Costs	**$/tonne**	**491.2**
Fixed Costs	$/tonne	158.3
Cost of Domestic Urea using Imported LNG as Feedstock and Fuel	**$/tonne**	**649.5**

The price of natural gas at which the cost of domestically produced urea would equate the cost of imported urea and the cost of delivered imported LNG, in terms of $/MMBtu, were compared to determine the medium-term economic value of natural gas in the fertilizer sector. **Exhibit F.5** summarizes the medium-term economic value of natural gas.

Exhibit F.5: Medium-term Economic Value of Gas

Price of Natural Gas equating Domestic Urea Price to Imported Urea Price	$/MMBtu	15.5
Cost of Imported LNG	$/MMBtu	19.5
Economic Value of Gas	**$/MMBtu**	**15.5**

Appendix G: Detailed Calculations for Industrial Sector

The following table summarizes the calculations pertaining to the economic value of gas in the Industrial sector in the near-term:

	Description	*Units*	*Near-Term Value*	
1	**Assumptions**			
1.a	General Assumptions			
	Exchange Rate	Rs/ $	85.52	
	Crude Oil Price Scenario	$/bbl	115.00	
	Sales Tax		17%	
	WACC		15%	
	Heating Value of Natural Gas	Btu/Scf	950	
	Gas Tariff for Captive Power	$/MMBtu	4.94	
	RFO Price	$/MMBtu	17.47	
	Fuel for Boiler/Heating Use			
	Efficiency Drop in Switching from Gas to RFO		5%	
	Load Factors for Industrial Customers			
	B3 Industrial Customer		50%	
	B4 Industrial Customer		70%	
1.b	**Power Generation Costs and Operational Parameters**			
			Gas Engine	*Diesel Engine*
	Capital Cost of Power Plant	$/kW	550	400
	Engine Efficiency	%	40.0%	40.0%
	Economic Life	Years	15	15
	Total Fixed O&M	$/kW/Year	14.32	15.76
	Total Variable O&M	¢/kWh	0.56	0.68
2	**Calculation of Economic Value of Gas in the Base Case Scenario (Crude oil Brent 115/bbl)**			
2.a	Economic Value of Gas for Industrial Boiler/Heating Use			
	Economic Value of Gas in Boiler/ Heating Use	$/MMBtu	18.35	

	Description	*Units*	*Near-Term Value*		
2.b	Economic Value of Gas for Industrial Captive Power Use				
	Cost of Power Supplied by DISCOs[1]				
	B3 Industrial Customer (Current Tariff)	¢/kWh	13.11		
	B4 Industrial Customer (Current Tariff)	¢/kWh	12.33		
	Average Economic Cost of Service	¢/kWh	18.07		
	Cost of Electricity for large Industrial Customers from Captive Generation				
			Gas Engine		*Diesel Engine*
			B3 Industrial Customer	*B4 Industrial Customer*	*Large Industries (B4 Equivalent)*
	Load Factor	%	50%	70%	70%
	Capital Cost				
	Power Plant Capex	$/kW	550	550	400
	Annualized Capex	$/kW/Yr	94	94	68
	Capital Cost	¢/kWh	2.15	1.53	1.12
	O&M Cost				
	Variable O&M	¢/kWh	0.56	0.56	0.68
	Fixed O&M	$/kW/Yr	14	14	16
	Fixed O&M	¢/kWh	0.33	0.23	0.26
	Total O&M Cost	¢/kWh	0.89	0.80	0.93
	Fuel Cost				
	Thermal Efficiency	%	40%	40%	40%
	Heat Rates	Btu/kWh	8,530	8,530	8,530
	Fuel Cost	$/MMBtu	4.94	4.94	17.47
	Fuel Cost	¢/kWh	4.21	4.21	14.90
	Total Cost of Generation	¢/kWh	7.25	6.54	16.95
	Economic Value of Gas for Industrial Captive Customers				
	A: For Industries taking Power from Utilities/National Grid				
	Replacement Cost of Gas based Captive Power for Electricity Supplied by Utilities/National Grid				
	Cost of Power from Utility	¢/kWh	18.07	18.07	
	Capital costs	¢/kWh	2.15	1.53	
	Economic Value of Gas	¢/kWh	20.22	19.61	
	Economic Value of Gas	$/MMBtu	23.70	22.98	

Description	*Units*	*Near-Term Value*
B: For Large Industries Generating Power from RFO based Captive Power Plants		
Replacement Cost of Gas based Captive Power for RFO based captive Power		
Cost of Power from Diesel Engine	¢/kWh	16.95
Capital costs	¢/kWh	1.53
Economic Value of Gas	¢/kWh	18.49
Economic Value of Gas	$/MMBtu	21.67

[1] Based on notified customer electricity tariff as of November 2010 by the GoP

Appendix H: Regression Analysis

Simple linear regression analysis is an approach to economic modeling that assesses the relationship between a dependent and a single independent variable. For example, in the following equation, variable y depends on x_1, and m_1 measures the response of y to changes in x_1:

$$y = m1 \;\; x1 \;\; \pm c$$

Regression analysis estimates the value and significance of the coefficient m_1, and of the whole equation.

Exhibits H.1 tabulates the results of the regression analysis conducted to estimate the correlations between sectoral consumption of natural gas and GDP. As a rule of thumb, the coefficient m_1 is statistically significant if the probability value is less than or equal to 0.05 or equally, if the t-statistic is greater than 2.0.[58] The R-squared provides an indication of the 'goodness of fit' of a regression equation. In time series regression, this is an important indicator of the regression equation as it tests that how well a regression line approximates real data points. **Exhibit A.2** contains the data used for the regression analysis.

Exhibit H.1: Correlation between GDP and Power Consumption

Dependent Variable: GDP,Rs. Million					
Independent Variable	*Sample*	*Coefficient*	*t-Statistic*	*P-Value*	*R-squared*
Electricity Consumption, GWh	1991 to 2010	72.5146	27.1567	0.0000	98.9%
Natural Gas Consumption in Commercial Sector, MMscft	1991 to 2010	65.8036	2.3929	0.0285	99.3%
Fertilizer Production and Imports, tonnes	1996 to 2010	640.3993	8.5344	0.0000	83.7%
Natural Gas Consumption in Industrial Sector, MMscft	1991 to 2010	5.0726	4.9626	0.0001	99.6%
Natural Gas Consumption in Residential Sector, MMscft	1991 to 2010	1.6120	0.5666	0.5794	99.2%
Natural Gas Consumption in Transport Sector, MMscft	1999 to 2010	5.6517	0.5356	0.6068	98.9%

[58] t-statistic is the estimated coefficient divided by its standard error. Thus, it measures the number of standard deviations from zero the estimated coefficient has, and it is used to test the hypothesis that the true value of the coefficient is non-zero, in order to confirm that the independent variable belongs in the equation or model. The p-value is the probability of observing a t-statistic. If the p-value is greater than 0.05, which occurs roughly when the t-statistic is less than 2, this means that the coefficient's significance cannot be established.

Exhibit H.2: Data Set Used for Regressions

	GDP at Factor Cost[59]	Electricity Consumption[60]	Fertilizer Production and Imports[61]	Natural Gas Consumption[2]			
				Commercial Sector	Industrial Sector	Domestic Sector	Transport Sector
	Rs. Million	GWh	Tonnes	MMscft	MMscft	MMscft	MMscft
1991	2,427,570	31,360	–	465,338	101,845	66,797	–
1992	2,615,121	34,467	–	486,606	107,397	70,741	–
1993	2,672,316	37,058	–	511,526	114,905	75,783	–
1994	2,794,119	37,850	–	550,769	110,818	82,461	–
1995	2,939,827	39,780	–	546,788	110,828	97,045	–
1996	3,142,324	42,151	4,899	582,868	118,771	110,103	–
1997	3,203,866	42,936	4,895	597,798	119,083	115,488	–
1998	3,254,107	44,662	5,171	607,916	127,342	134,500	–
1999	3,395,448	43,223	5,853	635,887	129,419	131,656	2,178
2000	3,562,020	45,500	6,200	658,897	144,842	132,088	2,026
2001	3,632,091	48,492	6,087	718,620	145,235	135,063	4,454
2002	3,745,118	50,593	6,200	771,649	157,977	144,748	7,310
2003	3,922,307	52,596	6,493	813,061	168,084	151,190	11,196
2004	4,215,582	57,467	6,811	993,250	195,002	155,408	15,516
2005	4,593,230	61,247	7,342	1,120,909	239,604	172,168	24,312
2006	4,860,476	67,604	8,479	1,223,385	294,180	171,109	38,885
2007	5,191,709	72,712	7,379	1,221,995	321,286	185,533	56,446
2008	5,383,012	73,400	7,684	1,275,212	335,299	204,035	72,018
2009	5,448,037	70,372	7,511	1,269,432	326,307	214,113	88,236
2010	5,670,768	74,348	9,411	1,277,821	335,452	219,382	99,002

59 Finance Division. Pakistan Economic Survey.

60 Ministry of Petroleum and Natural Resources. Pakistan Energy Yearbook.

61 National Fertilizer Development Centre. Fertilizer Review. Data before 1996 not available.