Fuel for Economic Growth: Forecasting the Energy Mix of Pakistan using TIMES

Syed Atif Rafiq Shah

NUST-2013-61506-MCES-64113-F

Session 2013 – 2015

Supervised by

Dr. Muhammad Bilal Khan

This thesis is submitted to the Center for Advanced Studies in Energy in partial fulfillment of the requirements for the degree of

MASTERS of SCIENCE in

ENERGY SYSTEMS ENGINEERING

Center for Advanced Studies in Energy (CAS-EN)

National University of Sciences & Technology (NUST)

H-12, Islamabad, 44000, Pakistan

September, 2015

Fuel for Economic Growth: Forecasting the Energy Mix of Pakistan using TIMES

Syed Atif Rafiq Shah

NUST-2013-61506-MCES-64113-F

Session 2013 – 2015

Supervised by

Dr. Muhammad Bilal Khan

This thesis is submitted to the Center for Advanced Studies in Energy in partial fulfillment of the requirements for the degree of

MASTERS of SCIENCE in

ENERGY SYSTEMS ENGINEERING

Center for Advanced Studies in Energy (CAS-EN)

National University of Sciences & Technology (NUST)

H-12, Islamabad, 44000, Pakistan

September, 2015

Certificate

This is to certify that the work in this thesis has been carried out by **Mr. Syed Atif Rafiq Shah** and completed under my supervision in Center for Advanced Studies in Energy, National University of Sciences & Technology, Islamabad, Pakistan.

Supervisor	Dr. M. Bilal Khan Center for Advanced Studies in Energy NUST, Islamabad
GEC Member # 1	Dr. Ehsan Ali Center for Advanced Studies in Energy NUST, Islamabad
GEC Member # 2	Dr. Faisal Jamil School of Social Sciences and Humanities NUST, Islamabad
GEC Member # 3	Mr. Ghazi Alam Lahore
HoD–CAS-EN	Dr. Zuhair S. Khan Center for Advanced Studies in Energy NUST, Islamabad
Principal/Dean	Dr. M. Bilal Khan Center for Advanced Studies in Energy NUST, Islamabad

Dedicated to my father, Dr. Muhammad Rafiq Shah (Late) & mother, Mah-e-Talat, without whom nothing in this world would have been possible

For Sir Nadeem Anwar (Late)

Acknowledgements

I would like to extend my sincerest gratitude to my thesis supervisor, Dr. Muhammad Bilal Khan, whose technical knowledge has been a cornerstone in completing my work in a timely manner. His advice and suggestions have been a constant source of motivation and learning during my research period.

I am very much thankful to Mr. Ghazi Alam for providing me an opportunity to work under his tutelage and guidance, along with helping me in laying the foundation for my work.

I would also like to extend my gratitude to Dr. Zuhair Khan, Dr. Ehsan Ali, Dr. Adeel Waqas, Dr. Majid Ali, Sir Fawad Kashan, Sir Rashid Wazir and Sir Amin Durrani, Center for Advanced Studies in Energy (CAS-EN), NUST for their continuous support and encouragement during the entire course of Master's degree. I would like to mention the effective cooperation of Dr. Faisal Jamil, School of Social Sciences and Humanities, NUST, as well, along with all the faculty members of CAS-EN, NUST.

Finally, I owe my deepest gratitude to my friends and family members whose unconditional love, absolute affection, infinite trust and endless confidence inspired me to complete my work.

Abstract

Pakistan is blessed with an abundant stock of indigenous energy resources. Despite the availability of these sources, there is a widening gap between supply and demand. The following research work presents a quantitative and analytical study on the current energy situation of Pakistan, along with a methodology to reduce the gap. The work also emphasizes on the urge for a need to use energy models in order to forecast an increase in demand. Using TIMES, a model which allows the input of several variables, enables to predict and optimize the energy mix, in order to forecast the most beneficial solutions to create a more extensive depiction of the country's existing energy system under varying scenarios and policies.

This methodology helps in developing an applicable reference energy system, thereby solving for the least cost energy solution to create a more comprehensive picture of the country's energy system under varying policies and possibilities. The results will portray future demand projections along with strategies necessary to meet growing demand.

Keywords: Pakistan; Energy Mix; Energy System Models; TIMES

Table of Contents

List of Figures

List of Tables

List of journal/conference papers from this work

1. **Syed Atif Rafiq Shah**, Muhammad Mubassir Saleem, Hafiz-ur-Rehman, Dr.Muhammad Bilal Khan
   "The Cost for Economic Growth: A study on the Energy Demand of Pakistan using TIMES"
2. **Syed Atif Rafiq Shah**, Dr.Muhammad Bilal Khan

   "Fueling the Future: Forecasting the Oil demand of Pakistan using TIMES"
3. Hafeez-ur-Rehman, Haris Mushtaq, **Syed Atif Rafiq Shah**, Dr.Muhammad Bilal Khan
   "Pakistan's Natural Gas forecast and management using TIMES"

Chapter 1
Introduction

1.1. Global Energy Outlook

Energy is one of the fundamental pillars for the development of any country. According to Newton's third law of motion, "*Energy can neither be created nor destroyed but can be converted from one form to the other*". From power generation to heating our homes to transportation, energy is used in different forms and makes the world go round. Circumstances leading to disruptions in the hoard of energy result not only curtailing economic growth, but adversely affect commercial and social activities as well. The 21st century as we see it today wouldn't have been possible without innovations in the field of energy.

Increase in population and greater industrial, agricultural and transportation needs has resulted in an increase in the global energy demand. Figure 1 summarizes the global increase in energy demand up to the year 2040 as a result of the aforementioned reasons.

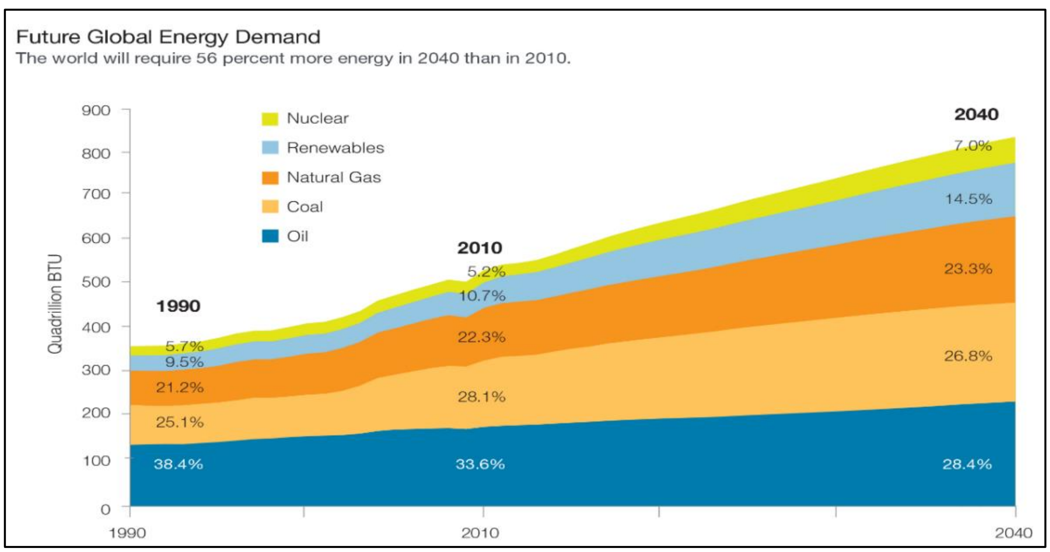

Figure 1.1: Global Energy Outlook – 2040 [14]

Finite fossil fuel reserves, in the form of oil, coal and natural gas govern the energy mix at the global stage as well, but with depleting reserves, amends need to be made in order to increase energy efficiency and alter the existing mix and utilize alternative energy resources, in order to minimize the gap between supply and demand.

The year 2015 has witnessed a major turnaround in global crude oil prices, declining from $110 a barrel in June 2014 to 49.34 as of June 2015 [1]. The approximately 41% plunge in oil prices has been primarily due to a slow-moving global economy, as a result of geopolitical tensions and the competitiveness between Organization of the Petroleum Exporting Countries (OPEC) and USA. shale oil producers. These shale companies have drilled 20,000 wells since 2010, which is 10 times more than Saudi Arabia's tally (the leading oil producer of the world) [2]. This global imbalance of a surplus of oil in the market has resulted in China being the largest oil importer [3]. However, the overall economic effect of cheaper oil has been clearly positive. LNG has been the beneficiary as a result of the decline in oil prices. Countries are able to purchase LNG on a sport market agreement and with contracts linked with oil prices, governments have readily welcomed a cheaper energy commodity.

1.2. Energy Outlook of Pakistan

The key objective of this section is to provide an assessment of the energy supply and demand of Pakistan. The current situation with respect to all major fuels, namely natural gas, oil, liquefied petroleum gas (LPG), liquefied Natural Gas (LNG), coal, hydel, and renewable sources will be presented in this section.

Reliable, clean and cost-effective availability of energy, for now and the future is indispensable in ensuring sustainable economic growth and development. The stability of developing countries like Pakistan depends upon the growth of the energy sector to influence social prosperity and long-term planning. With a population greater than 180 million [4] and a developing economy, Pakistan's energy needs are huge.

Pakistan has been facing an acute energy crisis since 2006 [5]. This predicament is assuming alarming proportions in its severity with each passing day. The current shortfall in the supply of energy has resulted in a negative impact, both on a societal as well as economic wellbeing, reflected by an estimated 4-7% loss to the country's GDP [5]. Factors contributing to adverse effects include:

- Absence of a coordinated energy utilization and infrastructure framework
- Excessive reliance on expensive imported oil
- Rapid increase in population
- Dilapidated power plants and distribution infrastructure
- Weak governance and management skills
- Lack of investments for the development of indigenous resources for power generation
- Nonexistent focus towards energy management and conservation

The tremors emanating from the aforementioned problems have severely jolted the power generation sector as well, with the population across the country witnessing 8-10 hours of load shedding in urban areas and 12-20 hours in rural areas.

Pakistan's energy demand has grown at an annual consumption growth rate of 4.8 percent in the past five years [6]. In the coming years, it is expected to grow at a rate of 8 to 10 percent per annum[6]. As a result there is a need for an urgency to create an environment where an energy supply and infrastructure capacity grows at the rate of 7 to 8 percent per year in order to support the steady growth in the state's GDP [6]. Hence, despite being blessed with an abundant stock of indigenous energy resources, the inability to adhere the utilization of the existing energy mix and formulate an integrated energy policy has been one of the primary shortcomings in the lack of growth in this sector.

1.2.1 Natural Gas

Natural gas is the main indigenous supply source of the country, meeting approximately half of the country's energy requirements. The share of natural gas in the primary energy supply mix has been increasingly rapidly and reached a high 49.5 percent in FY 2011-12 [7]. However, during FY 2013-14, the natural gas share stood at 48.2 percent [8]. As of 30th June 2013, total gas recoverable reserves were 24.7 trillion cubic feet (TCF) [9]. Natural gas consumption in the country has been increasing rapidly in the last ten years, primarily due to the addition of two newly added gas consuming sectors namely captive power and CNG for transport. The increasing growth of these sectors has resulted in a natural gas availability constraint. As a result, the supply of gas to other sectors is being curtailed.

The sector-wise consumption of natural gas is shown in the figure below.

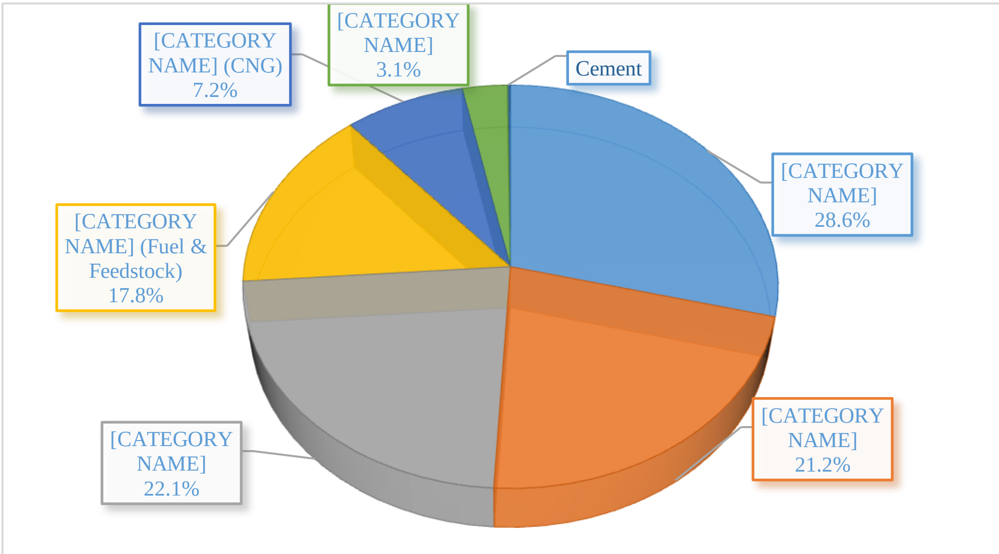

Figure 1.2- Sector-wise Consumption of Natural Gas [8]

At the moment there are 15 gas producing companies operating in Pakistan, both foreign and local, producing a total of little over 4,000 million cubic feet per day (MMCFD) [8]. Oil and Gas Development Company Limited (OGDCL) has the largest share, contributing 1,179 MMCFD [8]. Table 1. Shows the major E&P companies contributing to the production of natural gas in the country.

Name of Company	**Production (MMCF)**
OGDCL	427,579
BHP	104,570
Dewan Petroleum	6,684
ENI	178,612
Hycarbex	4,063
MPCL	216,448
MOL	104,838
OMV	112,980
OPL	3,431

PEL	7,133
OMV Maurice	6,515
POL	5,358
PPL	236,445
Tullow	-
UEPL	75,126
Total	**1,493,508**
Total (MMCFD)	**4,092**

Table 1.1- Company-wise Production of Natural Gas [8]

It needs to be mentioned that in Table 1.1, Unaccounted for Gas (UFG) and other losses result in current production of about 3,600 MMCFD. These companies have been able to increase their production as a result of the exploitation of large gas fields in the country, namely Sui, Qadirpur, Zamzama, Sawan, Bhit, Badin and Miano. Gas production is from independent systems as well, particularly from gas fields in Mari, Uch and Kandhkot and other small gas fields. Pakistan has a well-developed and integrated infrastructure network of transmission and distribution of natural gas for domestic, industrial, commercial and transport sectors. The two main gas utilities are Sui Northern Gas Pipeline Limited (SNGPL) and Sui Southern Gas Company Limited (SSGCL). SNGPL is responsible for the distribution of gas to the northern regions of the country, including the provinces of Khyber-Pakhtunkhwa and Punjab. SSGCL caters to the southern part of the country including the provinces of Sindh and Balochistan. As of June 2014, SSGCL and SNGPL's cumulative transmission and distribution network is summarized in Table 1.2 below.

Transmission and Distribution Network	SSGCL (km)	SNGPL (km)
Transmission	3,551	7,733
Distribution	43,090	96,587
TOTAL	**46,641**	**104,320**

Table 1.2- Transmission and Distribution Network of Pakistan [10]

With the increase in demand of natural gas set to amplify further in the next few years, amends need to be made in order to initiate various measures to bridge the gap between demand and supply which includes rapid and excessive indigenous exploration and production, import of natural gas in the form of Liquefied Natural Gas (LNG) etc.

1.2.2. Oil

Pakistan's economy has been able to become stable as a result of crippling global crude oil prices. This has resulted in an economic growth of approximately 4 percent. With fuel oil being mainly used for power generation, the fall in crude prices has led to a rapid expansion in industrial progression. As of June 2013, recoverable reserves of crude oil in country stand at 371 million barrels (MMBBL) [9]. The current production in the country is more than 85,000 barrels per day (BBL/d) [8], with almost 13 E&P companies involved in carrying out day to day exploration and production activities. At this existing rate of production, the country's indigenous oil reserves are expected to last for no longer than 15 years in case a major development is made.

The country is therefore dependent on importing fuel to meet the demand of petroleum products and bridge the gap between supply and demand. In 2012, 24,573 thousand barrels of crude oil were produced locally while almost double of it i.e. 47,104 thousand barrels were imported. [11] Like the gas sector, the main consumers of petroleum products are the transport and power sectors respectively.

The supply chain of oil consists of upstream, refining and marketing activities. In the upstream sector, OGDCL and Pakistan Petroleum Limited (PPL) are the pioneers, followed by international companies including ENI (Italy), United Energy Pakistan Limited (UEPL) (China), OMV (Austria), MOL (Hungary), KUFPEC (Kuwait), and Polish Oil & Gas Company (Poland).

Operator/Company	**Production (US bbl./day)**
BHP	1,393
POL	1,943
ENI	353
MOL	17,293
MPCL	642
OGDCL	42,969
OPL	616
OMV	46
UEPL	13,464
Dewan Petroleum	136
OMV Maurice	1,259
PPL	6,420
Total	**86,534**

Table 1.3- Production of Oil in Pakistan [8]

The total refining capacity as on 30th June 2014 was 18.79 Million tonnes per year, while the total crude oil processed in the refineries of the country was 12 Million tonnes [8]. The company with the largest refining capacity is Pak Arab Refinery (PARCO), processing a total of 4.50 million tonnes per year, followed by the National Refinery and Attock Refinery, with the former having a capacity of 2.71 million tonnes per year and the latter 1.96 million tonnes per year [8].

The refining capacity of the country only caters to half the demand, and thus sectoral reforms need to be made in order to convert crude into more refined petroleum products.

The major oil marketing companies (OMC's), which are responsible for supplying oil across all sectors of the country include Pakistan State Oil (PSO), Shell, Caltex (now a part of TOTAL) and Total-PARCO. PSO enjoys a market share dominance of more than 70 percent [8]. As per rules and policy directives, these companies are free to import oil to meet the local demand.

1.2.3 Liquefied Petroleum Gas

Pakistan meets about 87% of LPG demand through local production, whereas the rest is imported [9]. Currently, there are three main sources of LPG supply i.e. refineries, gas producing fields and imports.

In areas where natural gas is not available, LPG plays an essential in meeting energy needs by providing a more viable alternative to bio related sources. As of today, approximately 1000 tons/day of LPG is being domestically produced, resulting in a contribution of less than 1 percent in the existing energy mix of Pakistan [9].

The total production of LPG during FY 2013-14 was 541,685 tonnes.[8] OGRA is the focal authority for regulating the LPG sector. In total, 15 licenses have been issued by OGRA for the construction of LPG auto refueling stations across the country [9].

Natural gas and LPG are more expensive alternatives to coal but are cheaper than oil. It is for this reason that the Government of Pakistan is carrying out a multi-pronged strategy in order to bridge the natural gas demand gap via transnational pipelines and LNG import projects.

1.2.4. Coal

Despite having dearth of coal reserves in the country, the commodity has been a neglected energy source in the country. This has been primarily due to the discovery of large gas fields across the provinces in the country. This led to the formation of gas infrastructure services, thereby resulting in ignoring the utilities of coal as a major fuel. With natural gas being a cheaper and more environmental friendly alternative, it proved to be a primary fuel for the next three to four decades, curtailing the growth of any other category of fuel. However, with gas reserves declining rapidly, alternatives need to be found quickly in order to overcome the gap between demand and supply and produce cheaper electricity.

Globally coal is considered as one of the most sustainable and probably the cheapest source for power generation as opposed to other fuels. With over 186 billion tonnes of coal reserves [8], it is essential that Pakistan utilizes its potential in order to find a cheaper alternative for power generation. Coal reserves have been discovered in all four provinces of the country. The coal deposits in Sindh are greater in number as opposed to any other province, with a total of 185,456 million tonnes, followed by Punjab, Balochistan and Khyber Pakhtunkhwa, having reserves of 235, 217 and 91 million tonnes respectively [8].

The category of Thar coal primarily lies in the lignite to sub-bituminous range. The deposits in the area of Thar were discovered towards the late 1980's and early 1990's. The other major fields in Sindh are Lakhra, Sonda-Jherruck, Indus East, Ongar, Meting-Jhimpir and Badin.

Irrespective of the vast domestic reserves, 3 million tonnes of coal are imported as well [8]. The reason being that the quality of domestic coal is not of the highest standard i.e. has a low BTU value and a high sulfur content, and therefore large quantities have to be imported. The figure below shows the consumption of coal across different sectors.

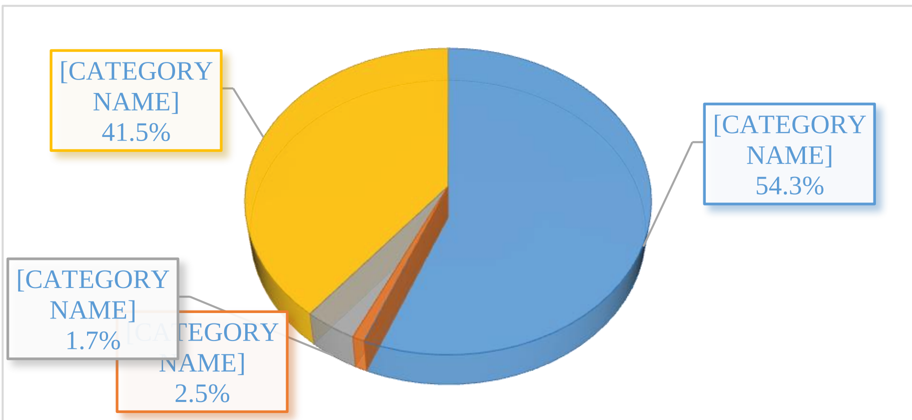

Figure 1.3- Sector-wise Coal Consumption [8]

It can be seen that the power sector consumes only approximately 2.5% percent of coal for electricity generation. If the share of coal utilization is increased, then load shedding in the country can be curbed to a certain extent.

Following the commencement of the 18th Amendment, coal exploration and development activities have been on the rise, as a result of continuous backing and support by the federal and provincial governments. The federal government has been striving hard for optimum development and utilization of indigenous coal resources and pursuing the policy of promoting coal based power generation. Some of the salient efforts include:

- Evaluation of Thar coal deposits
- Development of Infrastructure for carrying out mining activities
- Joint Ventures between local and foreign coal mining companies for expediting and promoting coal exploration
- The Finance Division has sponsored under PSDP a pilot project for Underground Coal Gasification at Thar Coal Block- V [9]
- Formation of Sindh ENGRO Coal Mining Company (a joint venture between the Provincial Government of Sindh and ENGRO) for the development and installation of a 600-1000 MW coal based power plant [9]
- Underground coal gasification projects, in accordance with the Planning Commission of Pakistan and under the tutelage of Dr. Samarkand Mubarak [9]

The invest initiatives is shown in Table.

Block	Investment Firm	Exploitable Coal Reserves (MM Tonnes)	Power Projects	Year of Operation
I.	SSRL (China – Pak)	3,657	2 x 660 = 1,320	2018
II.	SECMC Pakistan	1,584	2 x 330 = 660	2017-18
			2 x 330 = 660	2019
			4 x 660 = 2,640	2021
III.	Asia Power UK.	2,007	2 x 660 = 1,320	2021-22
IV.	Harbin Electric China	2,572	2 x 660 = 1,320	2020-21
V.	UCG Project – Pakistan	1,394	2 x 5 = 10	2021

VI.	Oracle (China – UK)	1,423	2 x 330 = 660	2019
VII.	FFC Pakistan	2,176	2 x 660 = 1,320	-

Table 1.4 – Coal Investment Projects [8]

With the ongoing efforts of both the federal and provincial governments, it is expected that the share of coal in the primary energy mix be increased, resulting in a cheaper alternative fuel for power generation.

1.2.5. Liquefied Natural Gas (LNG)

Worldwide, total LNG supply is expected to grow by an average of 6.4 percent per year, doubling production levels from 245 million tonnes per year in 2014 to 484 million tonnes per year in 2025[12].

Foreseeing the current energy crisis in the country, the Government of Pakistan introduced two LNG policies, one in 2006 and the other in 2011 for potential investors to facilitate the successful implementation of LNG import projects [11]. One of the important links in the LNG supply chain is to provide access to natural gas pipelines for taking Re-gasified Liquefied Natural Gas (RLNG) from import terminals to the end user. For this purpose, OGRA has hired an independent expert to prepare Third Part Access (TPA) Rules. These rules aim at establishing industry vide transparent and uniform principles for allowing entities to allow access to the Natural Gas Transmission and Distribution Pipeline networks.

The government of Pakistan has approved LNG import projects which include a proposal to import 400 MMCFD of RLNG from Qatar [9].

1.2.6. Hydel Energy

Electricity generated from hydel sources are dependent of hydrological variations and irrigation released requirements. During the 7 to 8 months of summer, levels of the reservoirs are relatively lower than their original values, and turbines operate at relatively low heads with consequently low power output. During the months of monsoon, where the country witnesses torrential flooding, the reservoir levels increase and are high enough to release large discharges which can then be passed through turbines for maximum power generation. In winters, the irrigation requirements are low and the discharges for power generation are limited resulting in lower power output. This is one of the primary reasons for why the country is unable to utilize its complete hydropower potential. Table 1.4 presents the hydro power potential of the country.

Source	**Power Plant Name**	**Location**	**Source and Type**	**Commissioning Year**	**No. x Unit Capacity**	**Installed Capacity**	**Available Capacity**	
							Summer	Winter
						(MW)	(MW)	(MW)
WAPDA Hydel (Existing)	Tarbela	Indus River, KPK	Daily - base, Regulating	1977 - 85 (1992 - 1993)	10 x 75 (4 x 432)	3,478	3,702	1,874
	Warsak	Kabul River, Peshawar	Daily - base, Regulating	1960 - 81	4 x 40 ; 2 x 41.5	243	200	20
	Mangla	Jhelum River, Mirpur	Daily - base, Regulating	1967 - 1994	10 x 100	1,000	1,120	450
	Ghazi Barotha	Indus River, Attock	Power Channel	2003 - 04	5 x 290	1,450	1,030	1,160
	Chashma	Indus River, Chashma	Power Channel	2001	8 x 23	184	157	67
	Khan Khwar	Shangla, KPK	Run of River	2010	2 x 34 ; 1 x 4	72	72	15
	Allai Khwar	Shangla, KPK	Run of River	2013	2 x 60.5	121	121	60
	Dubair Khwar	Shangla, KPK	Run of River	2013	1 x 130	130	130	65
	Jinnah	Mianwali, KPK	Power Channel	2012-14	8 x 120	96	96	40
	Small Hydro (< 25 MW)		Run of River	-		128	81	26
	Sub Total					6,902	6,709	3,777
Hydel (IPP)	Jagran (AJK)	Jagran, AJK	Run of River	2000	5 x 6	30	30	10
	Malakan - III	Malakand, KPK	Run of River	2008	4 x 20.25	81	81	20
	Laraib/New Bong etc.	Laraib, AJK	Run of River	2013	4 x 21	84	84	34
	Sub Total					195	195	64

Table 1.5- Installed Hydel Capacity [8]

1.2.6. Nuclear Energy

Nuclear is a clean energy source which can be used for cheap production of electricity. Unfortunately, due to political tensions, Pakistan has been unable to utilize this particular medium of energy.

The planning, construction, and operation of Nuclear Power Plants in the country is carried out by the Pakistan Atomic Energy Commission (PAEC). At the moment, there are three primary operating plants, Karachi Nuclear Power Plant (KANUPP), having a gross capacity of 100 MW, and Chashma Nuclear Power Plants (C-1 & C-2), each having a capacity of 325 MW and 330 MW respectively [9]. The GoP is putting its efforts to produce more electricity from nuclear energy, and the table below shows the commitments made for the development of this sector.

Plants	Gross Capacity (MW)	First Concrete Pour Date	Target Completion Operation Date
C – 3	340	4 – March – 2011	30 – April - 2016
C – 4	340	18 – Dec – 2011	31 – Dec – 2016

Table 1.6- Proposed Expansion Plan of Nuclear Power Plants [9]

1.2.7. Renewable Energy

In view of the aforementioned energy resources, there is a need diversify the existing energy mix by introducing different sources of energy. Pakistan is fortunate to witness all four seasons in a year. This makes it ideal for investors to invest heavily in solar and wind projects. The wind corridor at Gharo-Keti Bandar has a potential of 50,000 MW. In addition, several solar projects in the form of the “Bahawalpur Solar Park” have been setup, with a capacity to generate up to 100 MW. Biomass is readily used as the primary fuel in rural areas, where access to pipeline gas is not easily accessible.

1.3. Primary Energy Supplies of Pakistan

The primary energy supplies of Pakistan stand at 67 MTOE. The figure below shows a heavy dependence on oil and natural gas.

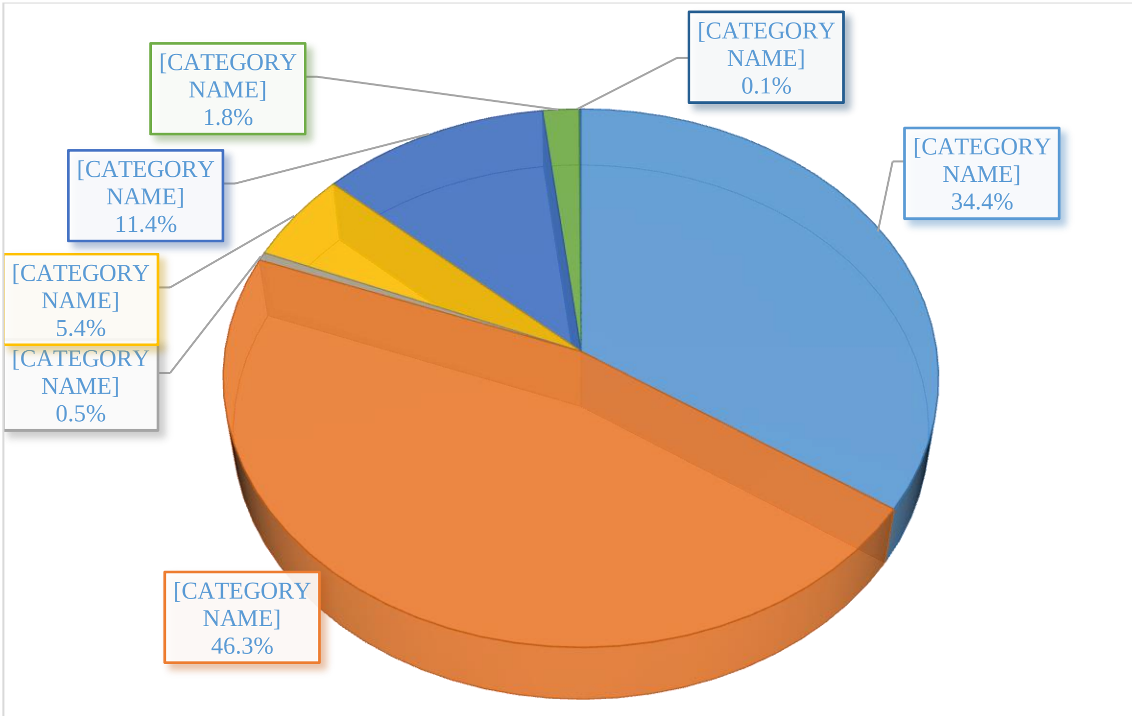

Figure 1.4- Primary Energy Supplies

Summary

In view of the above, there is an urgent need to develop an integrated energy development plan that addresses the merits of our energy imports, the development of indigenous energy resources, a more diversified energy mix, and initiatives to achieve better energy efficiency.

Pakistan has a very attractive petroleum policy where special incentives are offered for tight gas, offshore discoveries, and for exceeding certain production target thresholds.

Strategies to meet our natural gas shortfall (2 BCF constrained) through imports include pipelines from Turkmenistan – (TAPI project) - and a pipeline from Iran (I.P project). Additionally, gas is to be imported through liquefied natural gas or LNG.

The first LNG regasification terminal became operational this March in record time. A second LNG terminal is planned at Gwadar with support from China. This will include a pipeline linking the terminal at Gwadar to Nawabshah. Investment opportunities exist for the setting up of additional LNG terminals. There are also opportunities for companies and investors to participate in the supply of LNG to Pakistan.

Over the coming years Pakistan needs to significantly enhance its gas transmission capacity by over 2 BCF per day. The government of Pakistan has also entered into a government to government agreement with the Russian Federation for the development of a North – South pipeline to carry about 1.2 BCF gas per day.

Pakistan while being a major importer of crude oil and finished petroleum products is exporting around $800 million per annum of naphtha. Most of the refineries in Pakistan are based on hydro-skimming technology. The missing element in our refining footprint is a deep conversion refinery. Special incentives are available for setting up refineries with minimum 100,000 bpd capacity in the coastal belt of Balochistan province. These incentives include a twenty-year tax holiday and waiver of five percent workers participation fund. Pakistan has only two domestic pipe manufacturers, Sui Northern Gas Pipeline Limited (SNGPL) and Sui Southern Gas Company Limited (SSGCL), both of which have limited capacity. Given the very substantial upcoming demand of pipes for our pipeline projects opportunities exist for investing in pipeline manufacturing capacity.

The aim of this study is to identify the gaps in our systems, in order to allow an integrated examination of the various resource options, both on a supply and demand side.

References

[1] "No Title." [Online]. Available: http://www.bloomberg.com/energy.

[2] "Sheikhs vs Shale," *The Economist*, p. 128, Dec-2014.

[3] T. Morgan, "China Now World's Largest Oil Importer; Effect on Global Market," 2015.

[4] W. Bank, "No Title," 2015. [Online]. Available: https://www.google.com.pk/publicdata/explore?ds=d5bncppjof8f9_&met_y=sp_pop_totl&idim=country:PAK:BGD&hl=en&dl=en.

[5] E. Sector, "Chapter 10 Energy Security and Affordability," pp. 119–130, 2014.

[6] M. Arifeen, "Can Pakistan meet its energy needs?," 13-Jul-2013.

[7] HDIP, "Pakistan Energy Yearbook," 2012.

[8] HDIP, "Pakistan Energy Yearbook," 2014.

[9] M. Shoaib and Hammad, "Energy - Economic Survey of Pakistan."

[10] "Transmission and Distribution - SSGCL and SNGPL."

[11] M. Shoaib, "Energy - Economic Survey of Pakistan," Islamabad.

[12] M. MacDonald, "Elengy Terminal Project Technical Due Diligence - Final Report," 2014.

[13] S. Alam, A. Fatima, and M. S. Butt, "Sustainable development in Pakistan in the context of energy consumption demand and environmental degradation," *J. Asian Econ.*, vol. 18, no. 5, pp. 825–837, Oct. 2007.

[14] "No Title," 2014. [Online]. Available: http://www.energytomorrow.org/energy-101/global-energy-demand.

Chapter 2

Literature Review

2.1. Energy Models

The energy deficiencies of Pakistan have been well documented. Factors often contributing to these short-comings have already been highlighted in Chapter 1.

All these aforementioned points have an impact, a socio-economic one. As mentioned earlier, this has led to shortfalls across all sectors, from power to commercial to the transport sector, resulting in a necessity to optimize the existing energy mix with regard to their economic feasibility, indigenousness, risk assessment, and environmental impact.

Studying the policies governing the energy sector of Pakistan play an integral part in understanding the energy mix of Pakistan. These include Pakistan's Petroleum Policies, with the last one being published in 2012 [1]. The policy provides incentives for foreign companies to enhance their exploration and production activities in the country. "The State of Industry Report" [2], is an annual report published by NEPRA which provides insights into the electricity sector of Pakistan. The report also explains the detailed, sector-wise consumption of electricity in the country and highlights the performances of the electricity distribution companies (DISCO's) as well. "The Pakistan Energy Yearbook" [3] is another annual report which provides the reader with detailed facts and figures of the resource potential of the energy sector of Pakistan. It needs to be mentioned that the report does not account for any losses i.e. values indicated are showing the true potential of the source. In addition, other informative reports include "Census of Mining" [4], "Census of Electricity" [5], and a recently published journal by Woodrow Wilson titled "Pakistan's Interminable Energy Crisis – Is there a way out?" [6].

In order to access different situations at hand, energy models have been developed to formulate strategies that could prove to be beneficial for the development of any country. The model takes into account aspects pertaining to different factors, from energy efficiency and conservation, to monetary indicators such as financial investments, costs etc. These models help bridge ideological gaps, as leading planning institutions have a working framework, enabling them to carry out integrated energy planning strategies, in cohesion with developing national policy options.

The range of benefits provided by energy modelling include:

- Proposing a better understanding of current and future markets with respect to fuel supply, demand and their respective prices.
- Designing an energy supply system for short, medium and long term usage.
- Ensuring sustainable exploitation of indigenous energy resources.
- Creating a viable network between past and future energy demands.
- Providing implications of utilizing energy resources in accordance with their environmental impact.

These models are created on the basis of different approach and theoretical foundations, from engineering to economics to other sectors of sciences. The figure below shows the classification of different types of energy models.

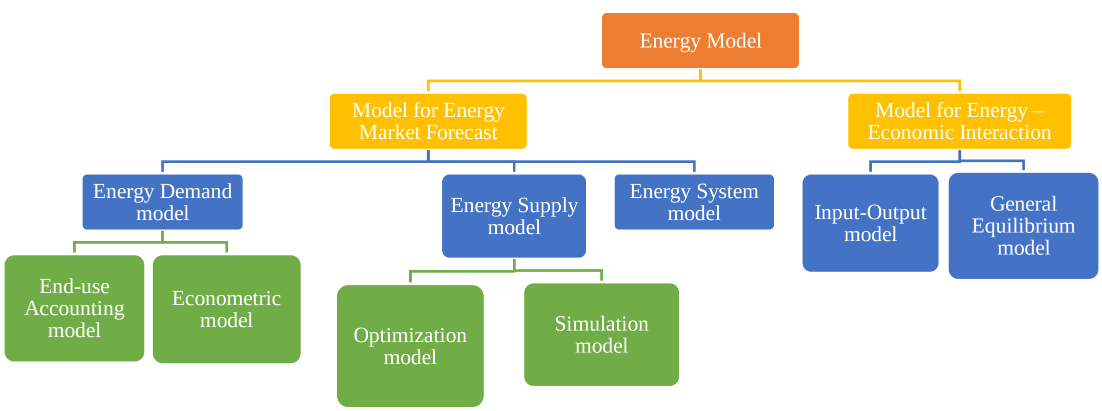

Figure 2.1- Classification of Energy Models

Energy System Models are one category of models which formulate results by taking into account both, supply and demand projections. When compared with other models, they provide the following advantages:

- An in-depth analysis on energy policy
- Insights into existing market applications
- Projections of Environmental elements i.e. GHG
- Employ different methodologies for both, supply and demand blocks

The table below provides a comparison of energy system models used globally.

Criteria	**RESGEN**	**EFOM**	**MARKAL**	**TIMES**	**MESAP**	**LEAP**
Approach	Optimization					Accounting
Geographical coverage	Country	Local - national	Country - multi-country		National	Local - global
Activity coverage	Energy			Energy & Trading	Energy	
Sector	Pre-defined	User defined			Pre-defined	
Technology	Good	Extensive				
Data need	Variable	Extensive				Variable
Skill requirement	Limited	High				Limited
Documentation	Limited	Good	Extensive	Good		Extensive

Table 2.1 - Classification of Different Types of Models

The TIMES model has been incorporated in over 70 countries, formulating policies and strategies in order to determine the least cost solution for an applicable reference energy system [7]. In China, the model has been used to study China's energy demand from 2010 to 2050 [8]. The results show that China's energy demand is expected to maintain a sustained and rapid growth before 2020, and then gradually slow down as a result of strict policies, particularly with regard to population growth. Oil-rich Canada has also made use of the model, where it has been used to analyze the introduction of a new technology-rich and multi-regional energy structure to analyze possible futures for the Canadian integrated energy system through 2050 [9]. The results have shown a significant penetration of renewables in the electricity mix after 2035.

Summary

Energy Modelling has a long history, dating back to the early 1970s, where a wide variety of models became available for analysing energy systems or sub-systems, such as the power system. These energy models had an array of purposes which include providing a better understanding of existing and futuristic markets from a supply, demand and pricing perspective; facilitation of a better design of energy supply systems in short, medium and long term horizons along with guaranteeing the sustainable exploitation of scarce energy resources.

The understanding of the present and future interactions energy and the rest of the economy is of prudent importance in order to channel the policy framework of a country. Energy models have been developed in order to access the best situation at hand. TIMES is a category of energy system models which can be used to provide the least-cost energy solution.

Globally the use of energy models have been a success as they are able to provide a framework for formulating policies on the basis of different sensitivities.

References

[1] “Pakistan Petroleum Policy,” 2012.

[2] “State of Industry Report,” 2014.

[3] HDIP, “Pakistan Energy Yearbook,” 2014.

[4] S. Division, “Census of Mining and Quarrying Industries (CMQI),” 2005.

[5] S. Division, “Census of Electricity Establishments,” no. September, 2007.

[6] M. Kugelan, “Pakistan’s Interminable Energy Crisis - Is there a way out?,” 2015.

[7] “No Title.” [Online]. Available: http://www.iea-etsap.org/web/Times.asp.

[8] LIU Jia, “Scenario analysis of China’s future energy demand based on TIMES model system,” *Energy Procedia*, vol. 5, 2010.

[9] J.-P. W. Kathleen Vaillancourta, Yuri Alcocera, Olivier Bahnb, Camille Fertela, Erik Frenettea, Hichem Garbouja, Amit Kanudiac, Maryse Labrietd, Richard Louloue, Mathilde Marcya, Yosra Nejia, “A Canadian 2050 energy outlook: Analysis with the multi-regional model TIMES-Canada,” *Appl. Energy*, vol. 132, 2014.

Chapter 3

TIMES

3.1. The Integrated Markal Efom System (TIMES)

TIMES is a category of energy system models, developed by the Energy Technology System Analysis Program (ETSAP) of the International Energy Agency (IEA) [1]. The model requires a core set of data to characterize the energy system that the model is intended to represent. Once constructed, the model will solve for the least-cost solution that utilizes available energy carriers (fuels, electricity, heat) and technologies (power plants, refineries, end-use devices) to meet the energy service demands (e.g., space conditioning, industrial process heat, lighting, passenger kilometers traveled), subject to physical limitations (e.g., resource availability, hydro/solar/wind potential), targets (e.g., energy independence and diversity in the terms of imports, renewables share of electricity generation) and policies (e.g., greenhouse gas (GHG) limits, emission caps, nuclear), and other constraints imposed on the system. Advantages provided by the model include:

- Provide a collated assessment between energy efficiency and renewable energy, along with carbon emissions.
- Insights into economic indicators.
- Ability to make long-term policy decisions by taking near-term implications into account.
- Provide scenarios which are favorable by policy maker’s i.e. least-cost scenarios.

All TIMES model are incorporated using 4 basic entities. These include:

Commodities: These are assets which satisfy demands and needs. For e.g. crude oil and natural gas are “Energy” commodities, SO2 is an “Environmental” commodity. They can either be produced or consumed from one or more technologies.

Processes: They are the technologies which are required in order to acquire a particular commodity. These include "Mining", which may be used to extract a fossil fuel based energy resource such as coal. "Import" and "Export" is another category of processes.

Commodity Flows: The link between a commodity and a process is created via a commodity flow. The figure below shows a representation of the types of commodities and processes accessible in the TIMES model.

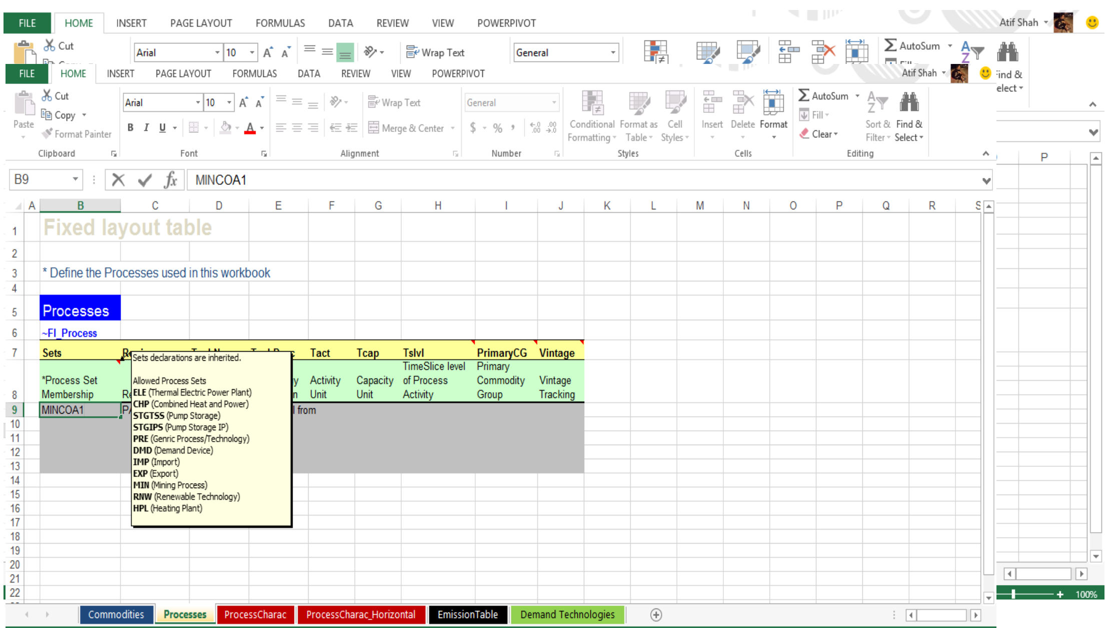

Figure 3.1 - Option of Commodities in TIMES

Figure 3.2- List of Processes in TIMES

Scenarios: They are defined in order to analyze the TIMES model from different principle insights. An example includes formulating a policy which results in the maximum utilization of Pakistan's coal reserves. The first scenario of the model, also known as the reference energy scenario is running without any specific policies i.e. in the absence of any policy constraints. Other scenarios which the model executes takes into account different assumptions in order to solve for the one least cost solution.

3.2. Functionality

The components of the TIMES framework includes [2]:

a) Versatile Data Analyst- Front End (VEDA-FE): It relies on templates in Excel. It manages the input data and submits model runs.

b) Versatile Data Analyst- Back End (VEDA-BE): It manages the results.

c) General Algebraic Mathematical Solver (GAMS): serves as a calculator and performs the necessary calculations.

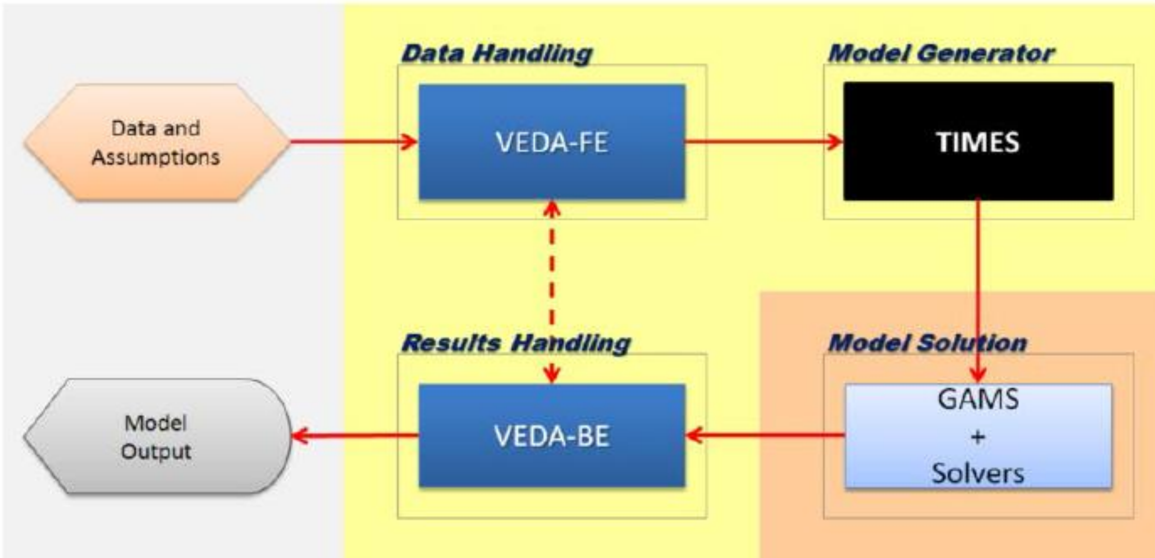

Figure 3.3 - Overview of the operating framework of TIMES [1]

VEDA-FE consists of a “Navigation Manager” and a “Case Manager”, as shown in the Figures 3.4 and 3.5. The “Navigation Manager”, comprises of four basic entities. These include “B-Y Templates”, which defines the settings of the model for the entire base year i.e. start year of the model is calibrated in the base year. In these excel sheets, we define the commodities, processes, commodity flows, demand technologies, import and export processes etc. Each sheet is filled according to a particular sector. The syntax of these sheets is “VT_<region>_<sector>_<model version>”.

The terminology “SysSettings” stands for System Settings and is used to declare the settings of the very basic model structure including regions, time slices, start year, time horizon etc. The “SubRES” takes in to account any new innovations which are not part of the base year. For example, if a technology comes into practice from 2016 onwards and has not been mentioned in the base year (which has been set at 2013), the model will run and take into account all new technological initiatives from that particular year. The declarations of the “B-Y Templates” are very similar to that of the “SubRES” templates. The “Demand Scen” solves the different scenarios which a user can enter from the demand perspective. These are usually economic indicators which are used in accordance with the region driver allocation. The “ScenTrade” provides scenarios specifically for trade technologies. “Scenarios” or policies allows the modeler to execute the model under different circumstances. The “Case Manager” is shown in Figure 3.5.

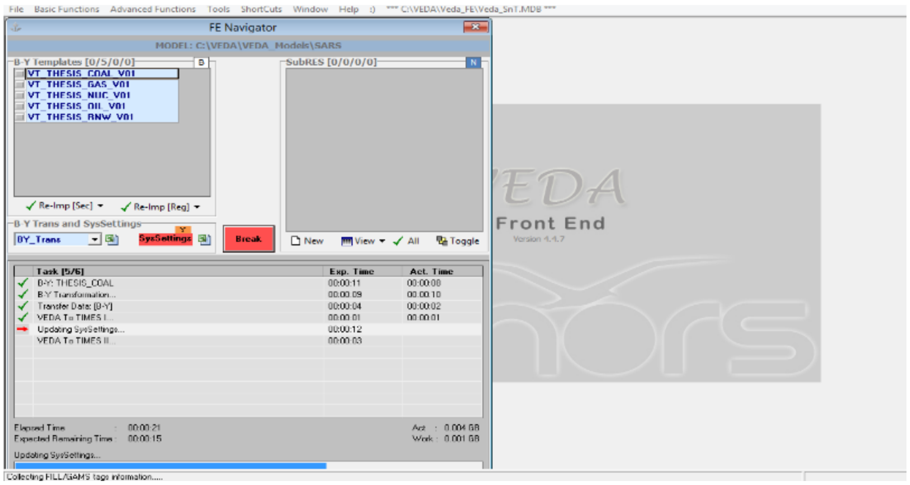

Figure 3.4 - FE Navigation Manager

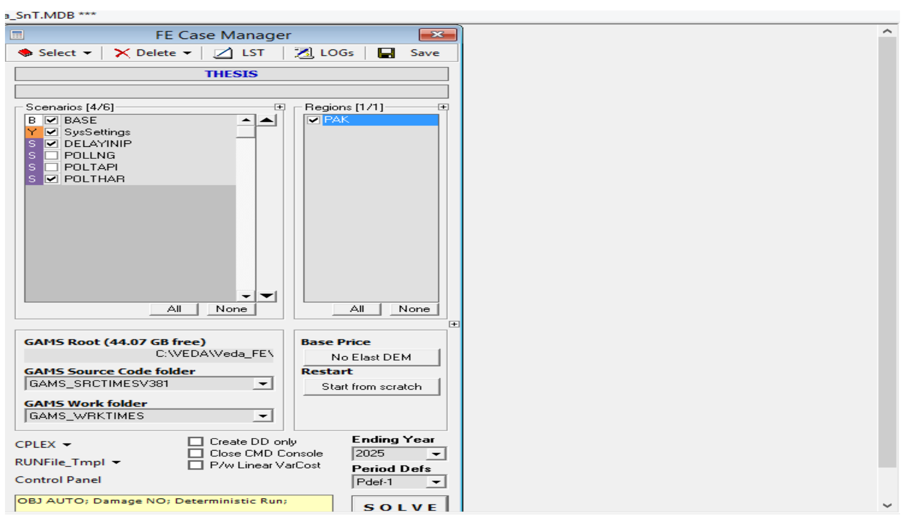

Figure 3.5 - FE Case Manager

The “Case Manager” includes options to select which type of Scenario to use. In case multiple regions are being used in the model, it even gives an option to select the type of region.

Once all the commodities, processes and scenarios have been defined, the model will make an attempt to solve and determine the energy system that meets the desired energy demands over a time horizon, which can either be yearly, seasonal and even daily, at the lowest cost. This is achieved by simultaneously defining the region (e.g. Pakistan, India, China etc.) and making infrastructure investment decisions, in accordance with the defined primary energy supplies, along with energy trade decisions. TIMES provides results with full knowledge of future events as defined in the time horizons.

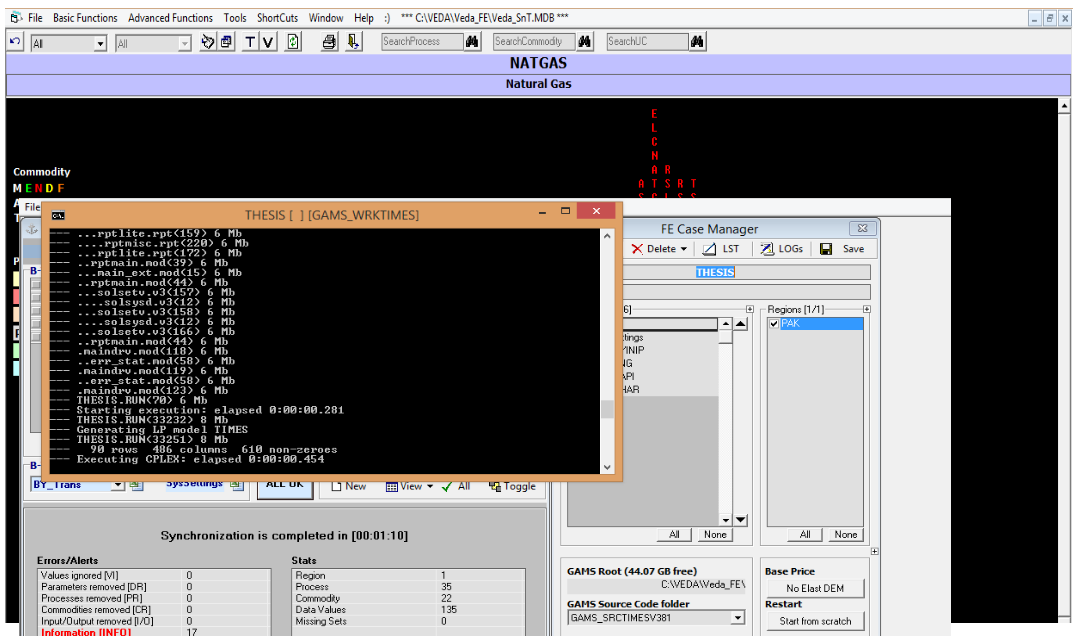

Figure 3.6 - Reference Energy System (TIMES View)

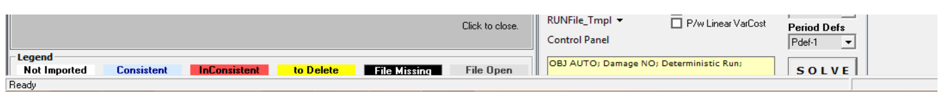

Figure 3.7 - GAMS evaluating the model

When the model reaches a situation where it is able to meet the supply options with the demand requirements i.e. producers of energy with the consumers, the model configures the production and consumption of commodities and their prices and will thereby be said to be in equilibrium. Mathematically, this means that model maximizes the producer and consumer surplus [15]. The model has been designed in such a way that the price of producing any commodity affects the demand for that commodity, while at the same time the demand affects the commodity's price. This is optimized as shown in the figure below.

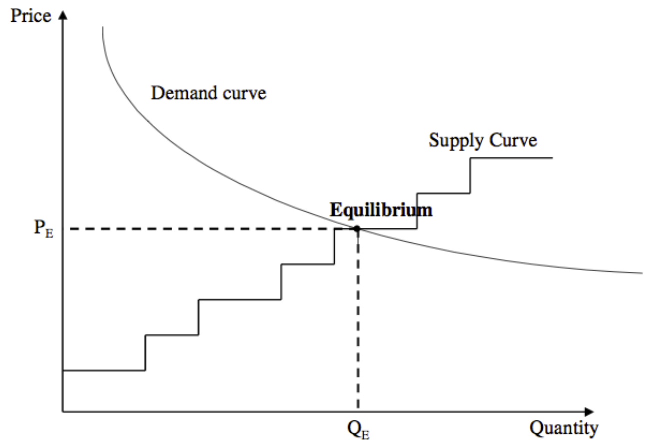

Figure 3.8 - Calculating the Best Solution [2]

3.3. Outputs

The primary output of the model are to formulate an energy system configuration, which meets demand requirements under various policy constraints for e.g. increasing the share of coal utilization up to 25% in the energy mix of Pakistan. A summary of some of the questions which the model addresses to include:

- Is a particular energy source feasible?
- What will be the cost?
- What will be the environmental implications?
- Time period for executing an project
- Effect of different policies on executing that particular project

The model runs will then be imported from VEDA-FE to VEDA-BE, whose interface is shown in the Figure 3.8.

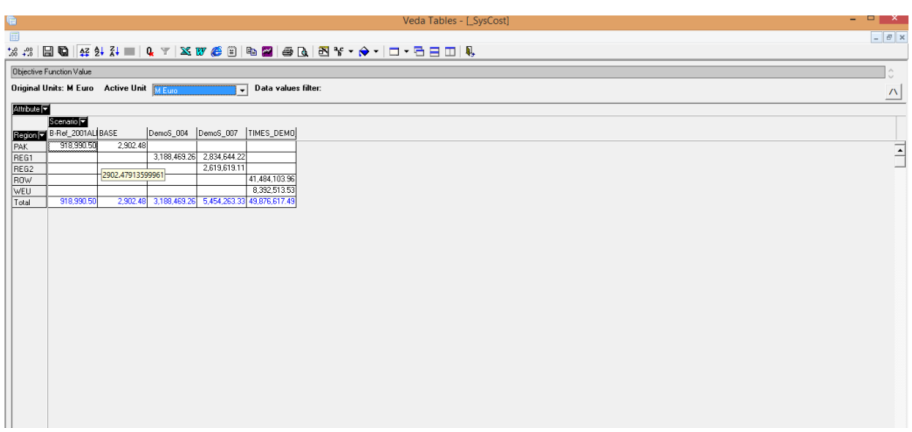

Figure 3.9 - VEDA-BE View

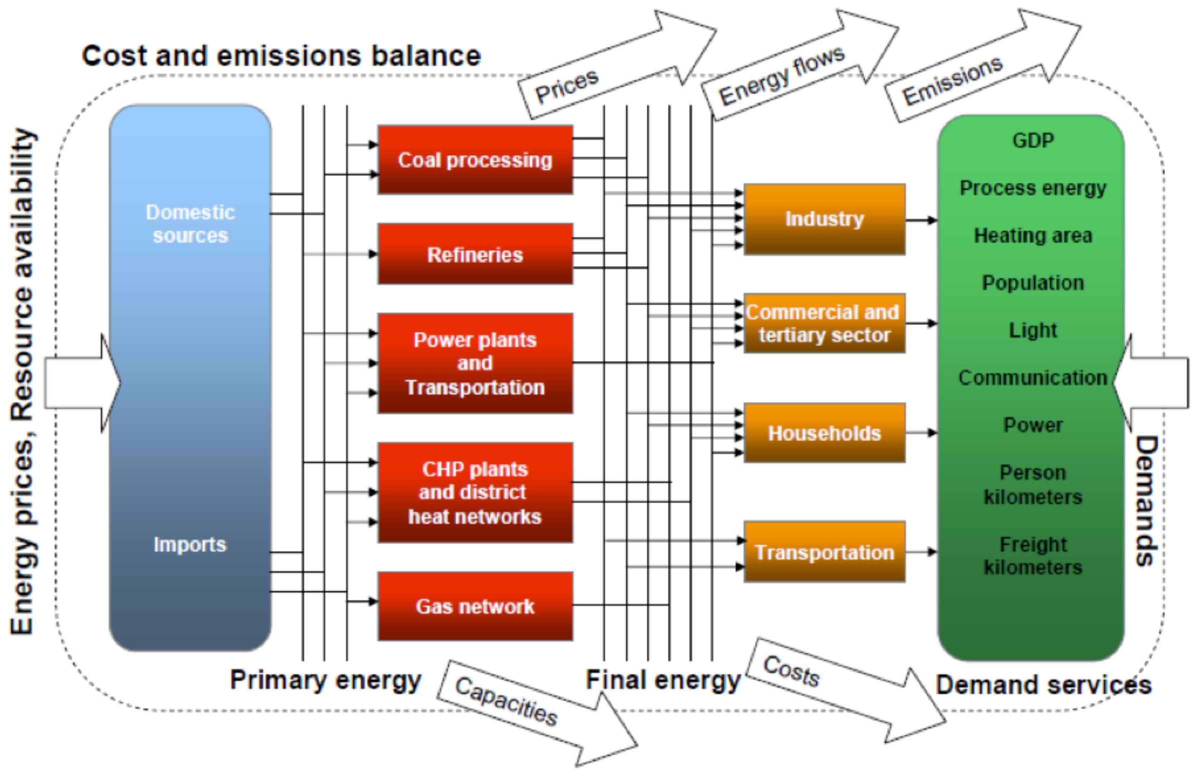

Figure 3.10 - Range of Outputs provided by the Model [2]

Summary

In Pakistan, the Pakistan Integrated Energy Model (PAK-IEM) was developed with the assistance of the Asian Development Bank. The project was initiated in 2008-2009 and was completed in 2011. Unfortunately, the model has not been updated in order to carry out policy formulation activities. The model would prove to be useful had it been updated with a scenario which includes crude oil prices at $40-45 a barrel.

References

[1] "VEDA User Guide." 2010.

[2] "No Title." [Online]. Available: http://www.iea-etsap.org/web/Times.asp.

Chapter 4

Policies and Strategies - Forecasting the Energy Mix of Pakistan

4.1. Forecasting the Energy Mix of Pakistan

Pakistan's total energy need during 2013-14 was 67 Million Tonnes of Oil Equivalent [1]. The details of the energy mix of Pakistan have already been portrayed in Chapter 1. With energy being classified as a fundamental of the Government of Pakistan's Vision 2025[2], the total energy demand is expected to double by the year 2022. This however needs to be achieved with a GDP at a constant rate of 4.5% to 6%.

The TIMES model gives the flexibility of analyzing results based on different scenarios. As discussed in previous chapters, the "Business as Usual" approach will result in Pakistan facing a large and growing energy shortfall in the next 10 years. With Brent oil currently trading at $50 a barrel [3], a large portion of the gap between supply and demand would have to be filled through importing hydrocarbons. Although it does not present a bad option, but with global environmental constraints, Pakistan will have to find a cleaner solution. Therefore it is necessary to carry out scenarios where Pakistan is focused more on self-reliance in order to diversify its energy mix. This can be achieved by exploiting its coal reserves in Thar along with utilizing its solar, biomass, wind, hydel and nuclear energy potential. In neighboring countries such as China and India, the power generation cost is low due to their reliance on coal for power generation [4]. The table below reflects the different scenarios for fuel supply which have been analyzed in TIMES.

Base Case	Scenario 1	Scenario 2	Scenario 3
- Business as Usual	Domestic Coal has not been exploited	TAPI gas from 2014 onwards	Increase in Domestic Crude Oil Production
	Reliance on Imported Coal	I – P Gas from 2015 onwards	Increase in utilization of domestic coal increase
	Increase in domestic Natural Gas Production	LNG from 2014 onwards	Imports reduced
	TAPI instead of IP Gas (from 2015 onwards)	Utilization of Thar Coal	Increase in Domestic Gas due to shale and offshore breakthroughs
	LNG Delayed i.e. no imports in 2015	Decline in Domestic Crude Oil Production	No LNG/TAPI and IP are already under Production

Table 4.1- Possible Options of Scenarios in TIMES

From the above table, it can be seen that the "Business as Usual" scenario yeilds the policy decisions on which the country is heavily relying on in order to meet growing demand. These include importing LNG, utilziation of Thar coal, Transnational Pipelines in the form of TAPI and Iran – Pakistan Pipelines, exploiting shale oil/gas reserves etc. It should be noted that for all scenarios the region has been set for "PAK", an annual discount rate of 7% has been assumed, and the base year has been set at 2013.

From the base case, the supply of fossil fuels is approximately 56 MTOE, with only 5 primary fuels contributing to the energy mix as compared with seven of the same case but for the year 2025. For the year 2013, the fuel mix is heavily dominated by natural gas, as it was the year in which our domestic natural gas reserves peaked. The supply from fields such as Sui and Qadirpur stood at approximately 1200 MMCFD [1]. With around $15 billion being spent on the import bill, a high percentage of it is occupied by imported petroleum which as of 2013, prices stood at $112 a barrel [5]. Liquefied

Natural Gas was supposed to be added into the grid by 2011, but due to unfornutae circumstances, the fuel has been successfully made part of the mix with effect from 26th March, 2015. The Engro Elengy Pakistan Limited (ETPL) terminal was constructed in a record time of 11 months and has the capacity to regasify 400 MMCFD of liquefied gas [6]. As of today, 10 cargoes have already been regasified at the terminal, with the gas being utilized by the power, CNG and fertilizer sectors. LNG will prove to be a game changer in the energy market because of the rapidly declining domestic gas reserves. It should be mentioned that the declining gas reserves do not take into account shale or any other major offshore breakthrough. The second terminal for LNG is under bidding process, with Government Holdings Private Limited (GHPL) pivoted to setup the terminal. Questions are often raised as to why LNG is being imported in a market where oil prices are as low as $50 a barrel. The reason being that Pakistan does not have a quick fix solution to its depleting resrves. The LNG is purchased on a spot market agreement. In addition, natural gas is a clean fuel as compared to the harmful emissions released by petroleum products in the form of high sulfur furnace oil (HSFO), diesel etc. Kerosene and LPG are alternatives, but they do not provide a practical usage for both transportation or domestic purposes.

The other fuel options discussed in the scenarios include Turkmenistan-Afghanistan-Pakistan-India (TAPI) Pipeline and the Iran – Pakistan Pipeline (IP) which will collectively inject upto 2000 MMCFD of gas. Unfortunately, due to the politcial tensions in Afghanistan and sanctions on Iran, the pipelines are yet to see fruition. Other alternatives for Pakistan include exploiting the resereves of Thar, which have already been discussed in “Chapter 1”.

In the base case, it can be seen that in the year 2025, Pakistan will have a slightly more diversified fossil fuel supply mix. The reason being that supplies from LNG, TAPI and IP will augment the exisitng supply of natural gas. The energy supply will be over 95 MTOE, a little less than the predicted 122 MTOE by the government of Pakistan. So what must the Pakistan energy strategists do? The answer lies with “Scenarios 1, 2 and 3”. Had any of the sources been added to the national grid a lot earlier, the energy landscape of the country would have been a lot more different. For example, the RLNG which is going to be added to the grid will be supplied for power generating stations. These include Orient Power, Saphire, Saif Power etc. These stations will generate a total of 3600 MW, resulting in reducing the load-shedding deficit by a significant factor [7]. The government will be saving upto $300 million. But due to delays in improvising these fuel supply projects, the domestic, commercial, industrial, and commuter sectors, have to pay the price in one form or the other. It should be mentioned that all these fuel supply projects need to be carried out simultaneously along with infrastructure augmentation projects. These include the SNGPL – SSGCL system augmentation programmes, North – South Pipeline, Gwadar – Nawabshah Pipeline etc.

Through Scenario 3, we are able to meet our energy requirments. The reason being that we are heavily relying on our own domestic production. Though LNG will not be taken into account, the I-P and TAPI pipelines, to which Pakistan has already made commitments, will provide sufficient back-up to the natural gas sector. The natural gas sector will be boosted due to exploiting the country's shale gas reserves, in accordance with making sufficient offshore breakthroughs in the Indus Block – G. Oil prices are expected to take a tumble, but are expected to recover to prices at $60 a barrel after falling to as low as $20 a barrel. This however, needs to be carried out in conjuntion with the country increasing its storage capacity and the refineries improving their production quality for e.g. most refineries in the country operate on hydro-skimming units i.e. not all the crude is converted into white products. With the GoP having already taken steps to improve the existing operating framework of refineries and PARCO leading the line by setting up Isomerization units, Pakistan may have sufficient reserves of petroleum products, both in the form of imports and domestic production.

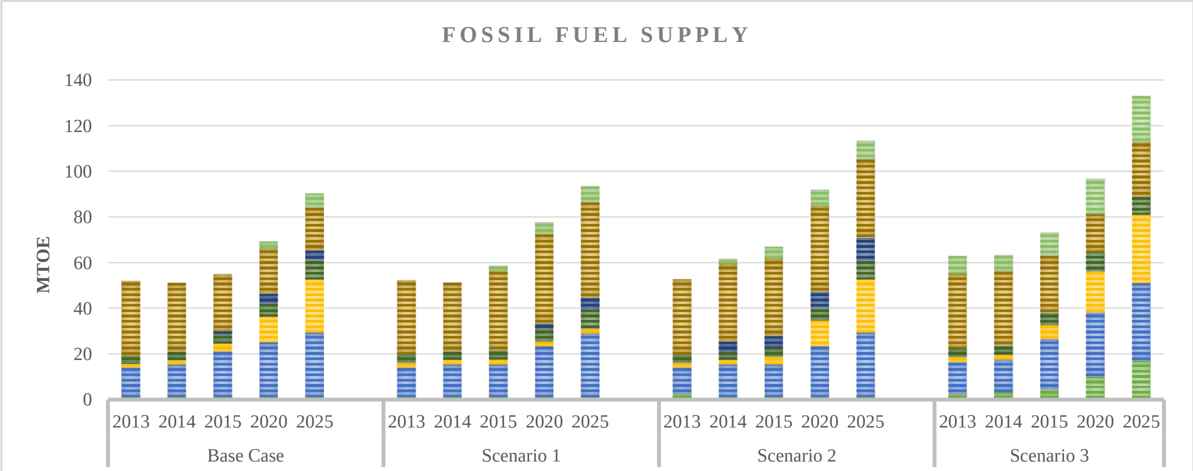

Figure 4.1 - Projection of Fossil Fuel Mix of Pakistan

Thar has coal reserves of 175 billion tonnes, but the quality of the coal i.e. lignite makes it difficult for the commodity to be transported across country. The solution lies in carrying out underground coal gassification and setting up combined cycle power plants in the vicinty of the region so that the reserves can be exploited to the fullest. In this way, the reliance on imported coal can also be decreased.

In summary, the future projections reveal that the fuels which show the most growth are domestic coal (keeping in view a cheaper alternative for producing electricity) and as a result of the decline in international oil prices, imported crude.

The supply chain of all energy products needs to also be taken into account, with potential bottlenecks in the energy supply chain of Pakistan indicated in Figure 4.2.

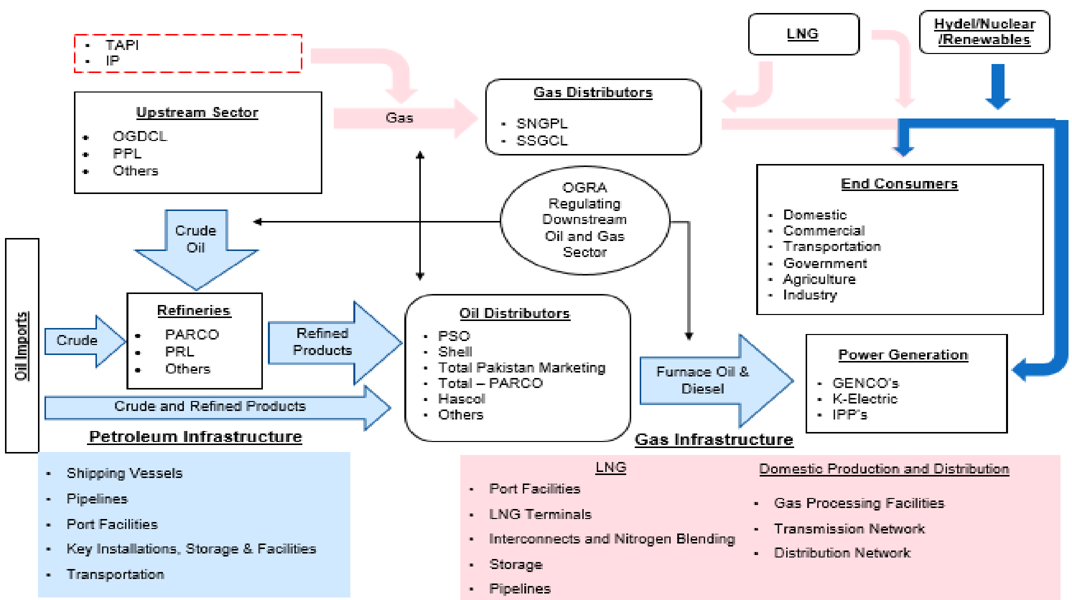

Figure 4.2 - Potential Bottlenecks in the Energy Supply Chain of Pakistan

Figure 4.3 shows the additional system costs required to enhance the existing infrastructure of Pakistan. For all three scenarios, there is an increase in cost because with the addition of each energy source, the required technological instrumentation and equipment will increase. Due to the increase in the influx of crude oil, more and more refineries will be needed to setup in order to get quality petroleum products. Whether these refineries are installed in KPK or at the ports is a matter of debate, but their neccessity is of immense importance. The best energy scenarios will be needing more system augmentation requirements, but the efficient utilization of those sources will result in fewer losses by the power sector. It should be noted that in all cases, as the energy supply source increase, the country heavily invests on power plants and refineries. This is because of the lack of having sufficient enegy resources has led to an increase in loadshedding. With the addition of having more gas and oil, the primary fuel on which most of the country's power plants operate, the electricity shortfall would also be controlled to a certain extent.

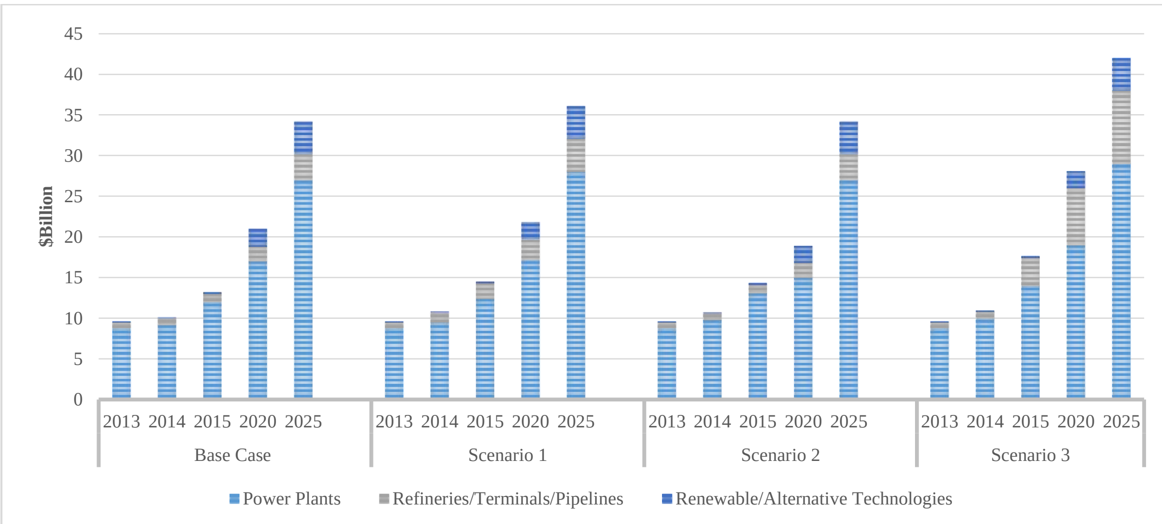

Figure 4.3- Energy Investment Cost

The final probable energy mix of Pakistan is shown in the Figure 4.4. By the year 2025, the energy mix of Pakistan still shows a heavy reliance on Petroluem Products and Natural Gas. This however needs to be taken into account with the fact that the share of coal, nuclear and hydel electricity and renewables has simultaneously increased as well. This is useful as the burden on oil and gas will be reduced to a certain extent. The share of electricity produced by hydel and nuclear energy will also increase due to the micro-hydel projects being set up in the northern regions of Pakistan. Many nuclear projects have also been proposed, which will result in production of a cheaper form of electricity. These figures need to be accounted with a strong increase in GDP.

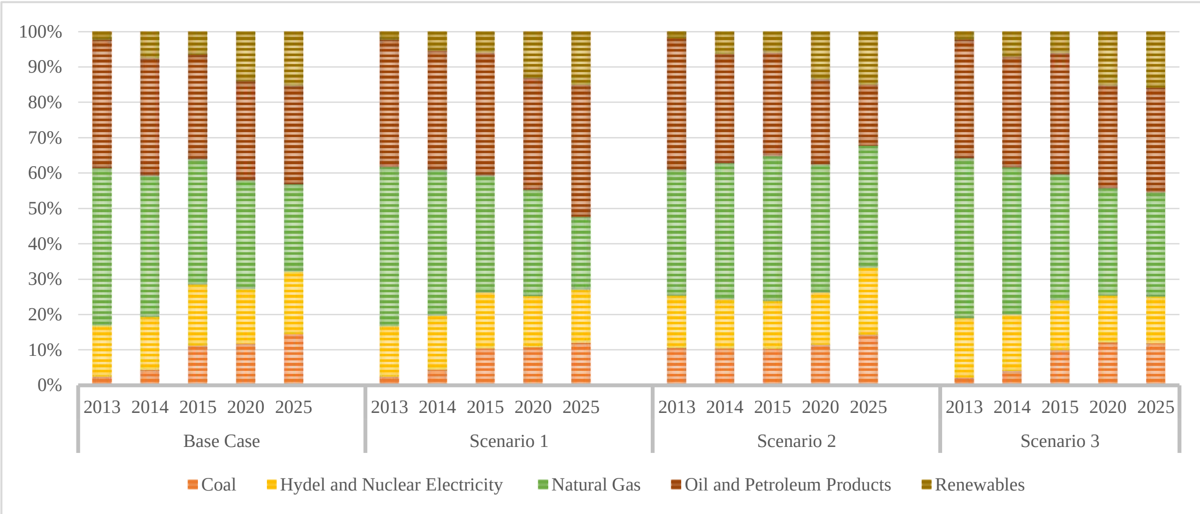

Figure 4.4- Possible Final Energy Mix of Pakistan

Summary

The governing body of Pakistan needs to come up with an attractive energy policy in order to bridge the gap between supply and demand. The dearth of indigenous resources within the basins of the country have been well documented, but despite the presence of these reserves, the country still faces an energy shortfall. Energy system models can be used to forecast for as to how a specific commodity varies under different prices and policies so that the least-cost solution for the utilization of that commodity can be achieved.

References

[1] HDIP, “Pakistan Energy Yearbook,” 2014.

[2] “Chapter 10 - Energy Security and Affordability.”

[3] “Crude Oil and Commodity Prices.” [Online]. Available: http://www.oil-price.net/.

[4] M. Ahmad, “Coal accounts for 6.5pc of Pakistan’s energy mix,” 18-Jun-2014.

[5] M. Shoaib and Hammad, “Energy - Economic Survey of Pakistan.”

[6] “the lng terminal – a step towards resolving the energy deficit,” 2015.

[7] APP, “LNG power plants to generate 3,600 MW of electricity: PM,” 17-Oct-2015.

Chapter 5

Policies and Strategies for Ensuring Economic Growth

5.1. The Way Forward

With an abundant stock of energy resources in the form of both fossil fuels and renewables, Pakistan needs to find a more convenient way in order to utilize its energy reserves so that growing gap between supply and demand can be bridged to a certain extent. The interests of the country rely best in utilizing its very own indigenous resources including exploiting Thar coal reserves, carrying out major offshore exploration activities and deploying advanced technological equipment's for utilizing nuclear energy. It also needs to be mentioned that the diverse supply of energy resources will only cater to half of the job. Pakistan needs to invest heavily in its infrastructure in order to ensure that the end user is able to get access to these sources. This is due to the fact that only 20% of the country is able to get access to pipelined gas. The country has 3 ports, namely Port Qasim Authority (PQA), Karachi Port Trust (KPT) and the Gwadar Port. However, these ports have limited acreage and cargoes, resulting in congestion during most parts of the year. This can be emphasized by the oil crisis at the start of the year where demand increased by 25%. If Pakistan is to fully take advantage of the decline in international crude oil prices, it needs to heavily invest in its infrastructure in the form of storages and pipelines.

5.2. Policy for Energy Efficiency and Conservation

Pakistan also needs to effectively carry out a study so that its energy sources are utilized and conserved in the best possible manner. From digital media to billboards, vigorous and robust initiatives need to be carried out in order to make the public aware about the effective utilization of energy resources. Training centers need to be established so that more manpower is equipped with the toolset to carry out effective operation and maintenance of new and existing technological equipment. As of today, there is no concrete energy conservation policy. With transmission and distribution losses at over 25%, Pakistan can conserve most of its unaccounted energy losses by passing strict laws with regard to electricity and gas theft.

5.3. Safe Haven for Foreign Investors

Pakistan has not been able to attract foreign investors due several reasons. The existing energy mix of Pakistan is heavily dominated by oil and natural gas. But it needs to be mentioned that the Exploration and Production (E&P) sector is a very expensive, high risk and technology intensive business. Policies need to be revised on an annual basis in order to attract foreign investors so that the entire process of carrying out E&P activities can be carried out in the most transparent of manners.

5.4. Contemplate the execution of Solar and Wind Energy Projects

The current decline in oil prices has put a halt in investing in the fields of Solar and Wind Energy. This has been advocated on two occasions where first, the government imposed a ban on initiating any new projects in the fields of both solar and wind energy, and second, by reducing the tariff of electricity produced by photovoltaic panels [1] [2]. With China having approximately 44,000 dams, Pakistan needs to invest heavily in hydel energy. Pakistan has an agriculture based economy (Agro-economy), but due to a lack of dams, the country faces losses of billions of dollars due to floods, eroding all the crops at the same time. This has been a trend for a long time, hitting the economy in the worse possible manner. Going forward, Pakistan needs to invest in micro-hydel projects so that it cannot only store the excess water during the monsoon period, but also generate electricity.

5.5. LNG and Transnational Pipelines

Pakistan has also been hit hard by the unfortunate delays in transnational pipelines. This gap can be to some extent be bridged by importing LNG on a sport market basis. Global LNG trade stands at 249.1 MTPA [3]. With the commencement dates of TAPI and IP still to be finalized, Pakistan must utilize RLNG in order to mitigate the growing natural gas gap between supply and demand [4].

The consistent use of energy system models can pay the way for countries such as Pakistan to analyze and strategize energy resources under varying policies. Such a methodology has proved to be successful in countries across the world, including the likes of Argentina, Kazakhstan, China and the UAE. Models based on TIMES have not been used extensively globally as compared with its predecessor MARKAL. The primary differences between the two models is shown in the table below.

S.#	MARKAL	TIMES
1	Fixed time periods	Variable time periods
2	No Data Decoupling	Data Decoupling
3	Rigid Definition of Time Slices	Flexible Definition of Time Slices
4	Each Investment Cost needs to entirely be made at the beginning of each time period	More accurate depiction of Investment Cost Payments i.e. more detailed
5	Environmental parameters are not detailed	More useful for showcasing environmental constraints
6	Few Commodity Related Variables	Large Number of Commodity related Variables

Table 5.1 - Comparison between MARKAL and TIMES

5.6 Alternative Energy Modelling Tools

Apart from these two models, LEAP, the Long Range Energy Alternatives Planning System, is a tool which can be used for both energy policy analysis and climate change alleviation assessment. It is an integrated modeling tool that can be used to track energy consumption, production and resource extraction across all sectors of an economy.

LEAP has been adopted by thousands of organizations in more than 190 countries worldwide [5]. The model was created in the mid 1980's as a mainframe tool for organizations including the USAID. However, it was not until late 1990's when the model was updated and had the ability to account for environmental emissions as well. It has been used across all forums, with users from numerous agencies, academia, non-profit organizations, and energy consulting companies. It has been used at many different scales ranging from cities and states to national, regional and global applications. The working function of the model is shown in figures 1 and 2.

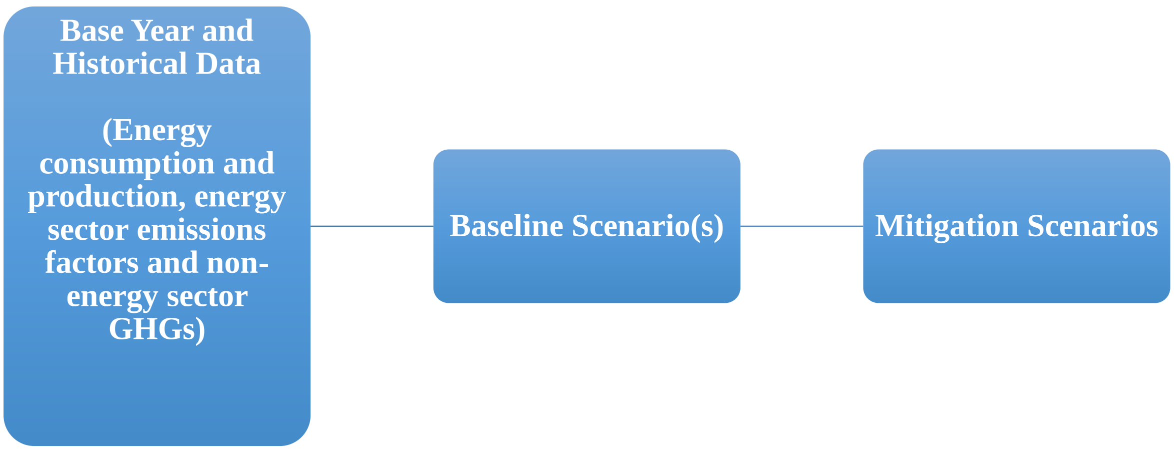

Figure 5.1 - Operation of LEAP

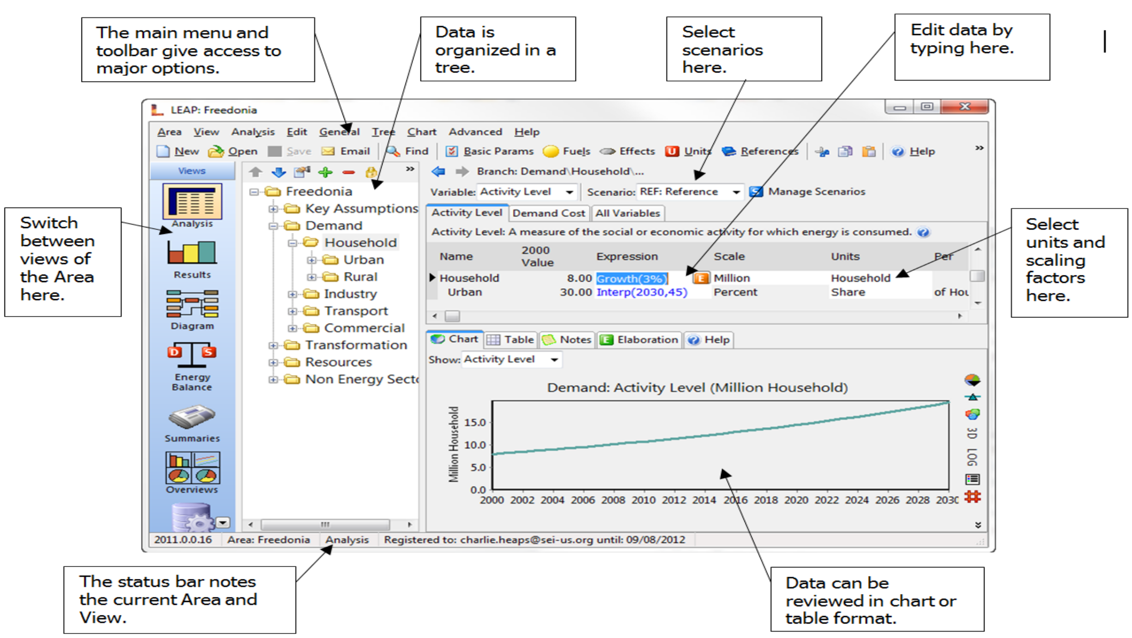

Figure 5.25- User Interface of LEAP

LEAP supports a wide range of different modeling methodologies: on the demand side these range from bottom-up, end-use accounting techniques to top-down macroeconomic modeling. LEAP also includes a range of optional specialized methodologies including stock-turnover modeling for areas such as transport planning

LEAP’s modeling capabilities operate at two basic conceptual levels. At one level, LEAP's built-in calculations handle all of the "noncontroversial" energy, emissions and cost-benefit accounting calculations. At the second level, users enter spreadsheet-like expressions that can be used to specify time-varying data or to create a wide variety of sophisticated multi-variable models, thus enabling econometric and simulation approaches to be embedded within LEAP’s overall accounting framework.

Summary

The Government of Pakistan recognizes that sufficient and reliable, clean and cost-effective availability of energy is indispensable in ensuring sustainable economic growth and development. It is therefore mandated to ensure availability and security of sustainable supply of energy resources for economic development and strategic requirements of Pakistan and to coordinate development of natural resources.

Oil and gas constitute over 70% of Pakistan's energy demand. Pakistan has a natural gas demand-supply gap of over 2 billion cubic feet per day (BCFD), which has developed over decades of reliance on cheap gas and limited planning in the past for future requirements.

Pakistan however has been working hard to reduce the natural gas demand-supply balance through the following channel which include encouraging domestic hydrocarbon production through various policy incentives and license awards; importing liquefied natural gas (LNG) which is the most effective way to bridge the natural gas demand-supply in the near term; launching projects to develop our natural gas transmission network to allow for the movement of re-gasified LNG; continued progress on pipeline import projects; enhancing exploration and activities in the country; various gas efficiency initiatives directed at reducing unaccounted for gas; and, while giving priority to domestic households making natural gas available to all sectors through market based concepts.

The strategy for maximizing indigenous production includes exploring our significant shale resources and encouraging investment in Enhanced Oil Recovery (EOR) technology.

Pakistan needs policy implications for enhancing energy security along with diversifying its energy mix by promoting the using of coal, micro hydel, nuclear etc. For existing power plants, the Government should take steps to enhance the efficiencies of both the generation companies (GENCOs) and distribution companies (DISCOs). Energy models have been used to forecast the best possible solution under an array of scenarios. Such a methodology can be useful when formulating policies in order to create a better future for tomorrow.

References

[1] Z. Bhutta, “Taking a new line: Focusing on LNG, govt bans new solar and wind projects,” 21-Apr-2015.

[2] “Nepra reduces wind power tariff by 20 per cent,” 27-Jun-2015.

[3] I. G. Union, “World LNG Report,” 2015.

[4] H. Khalid, “Pak-Qatar deal on LNG purchase to be signed on November 15,” 01-Nov-2015.

[5] “Introduction to LEAP.”

Annexure I

The Cost for Economic growth: A study on the Energy Demand of Pakistan using TIMES

Syed Atif Rafiq Shah[1], Muhammad Mubassir Saleem[1], Hafeez-ur-Rehman[1], Dr. Bilal Khan[1]

[1]Centre for Advance Studies in Energy (CAS–EN), National University of Sciences & Technology (NUST), H–12, Islamabad, 44000, Pakistan.

Abstract

Pakistan is blessed with an abundant stock of indigenous energy resources. Despite the availability of these sources, there is a widening gap between supply and demand. The following paper presents a quantitative and analytical study on the current energy situation of Pakistan, along with a methodology to reduce the gap. The paper emphasizes the urge for a need to use energy models in order to forecast an increase in demand. This can be achieved by using TIMES, a model which shows a detailed relationship between energy commodities and the relevant processes required to achieve those particular commodities. This methodology helps in developing an applicable reference energy system, thereby solving for the least cost energy solution to create a more comprehensive picture of the country's energy system under varying policies and possibilities. The results will portray future demand projections along with energy marketing strategies necessary to meet growing demand.

Keywords: Pakistan; Energy; TIMES

1. Introduction:

Energy is one of the fundamental pillars for the development of any country. Globally, energy is used in different forms for different purposes, from power generation to heating our homes to transportation. Circumstances leading to disruptions in the hoard of energy result not only in curtailing economic growth, but adversely affect commercial and social activities as well. The 21st century as we see it today wouldn't have been possible without energy.

An increase in the global energy demand has been fueled as a result of increasing population and greater industrial, agricultural and transportation needs. Figure 1 summarizes the regional increase in global energy demand up to the year 2040 as a result of the aforementioned reasons. Finite fossil fuel reserves, in the form of oil, coal and natural gas govern the energy mix at the global stage, but with depleting reserves, amends need to be made in order to alter the existing mix and utilize alternative energy resources, in order to minimize the gap between supply and demand.

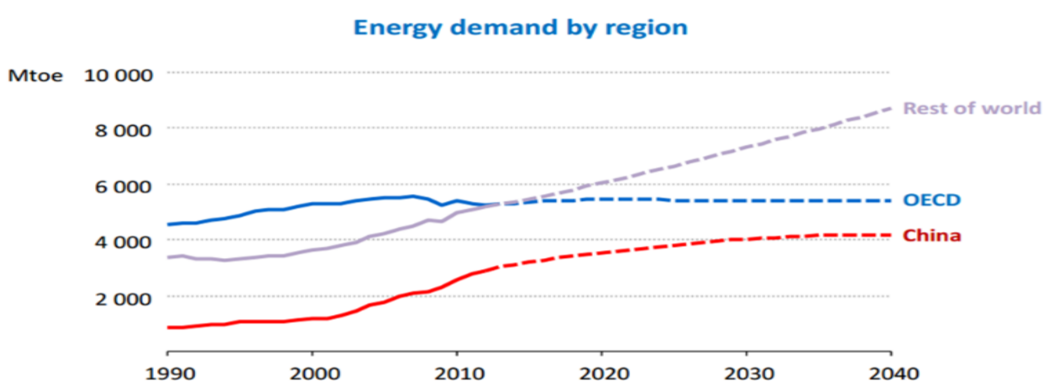

Figure 1 - IEA Energy Outlook – 2014

2. Energy Outlook of Pakistan

The growth of a nation is measured in terms of economic indicators such as GDP, energy consumption per capita etc. Unfortunately, Pakistan has been facing a GDP loss of 7% annually as a result of an acute energy crisis since 2006 [1]. From the time of independence, there has always been a variation in the supply of major sources in the primary energy mix of Pakistan. As of 2013, indigenous energy availability was 65,539 thousand tonnes of oil equivalent (TOE) [2].

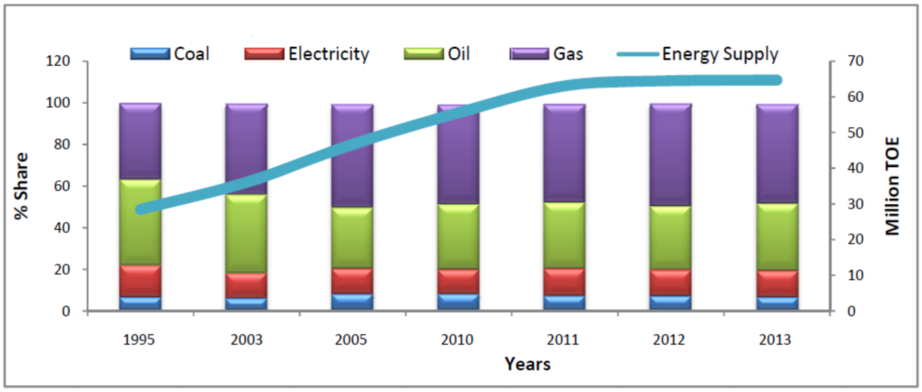

Figure 2 - Primary Energy Supply by Source [2]

Electricity is being considered as a secondary source, as shown in figure 2, produced by utilizing primary fuels such as coal, oil, natural gas etc. The existing correlation between GDP and growth rate in energy consumption can be seen in figure 3. It is evident that periods of an increase in GDP lead to an increase in the rate of energy consumption and vice versa.

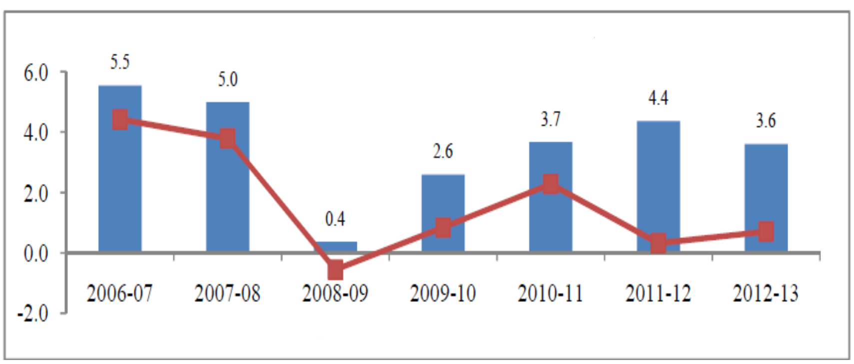

Figure 3- Relationship between growth rate of GDP and energy consumption [3]

3. Energy Models

Pakistan's energy demand has grown at an annual consumption growth rate of 4.8 percent in the past five years [4]. In the coming years, it is expected to grow at a rate of

8 to 10 percent per annum [4]. As a result there is a need for an urgency to create an environment where an energy supply and infrastructure capacity grows at the rate of 7 to 8 percent per year [4] in order to support the steady growth in the state's GDP. Hence there is a need to optimize the energy mix with reference to its economic feasibility.

So in order to access the different situations at hand, energy models have been developed, to predict the sustainable progress of a nation from different aspects. These models are developed using different macro or micro-economic variables, giving the very basic knowledge of the working of an energy system across short and long term horizons. Such a methodology is necessary to formulate a framework in order to select technologies to meet future energy demands in a least-cost way, improving energy security and at the same time contributing to the country's economic growth.

Energy system models, such as TIMES, are a category of models which can be used to forecast both demand and supply projections.

4. TIMES

It is the acronym for "The Integrated MARKAL-EFOM System" [5]. Some of the advantages of the model include providing a joint assessment between energy efficiency, renewable energy and low carbon emissions, along with an ability to create a link between supply and demand commodities over a short to long term time period.

By providing insights into economic drivers, results obtained will be favorable for both investors and policy makers, allowing them to make short term policy decisions by keeping long term implications at hand. Such type of a framework has been missing when it comes to formulating energy policies of Pakistan.

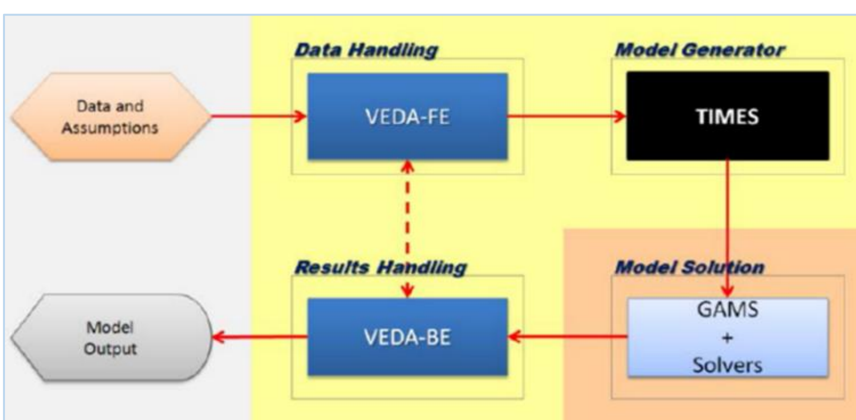

Figure 4 - Working function of TIMES [5]

5. Methodology

The model relies on 2 working groups i.e. VEDA-Front End (VEDA-FE) and VEDA-Back End (VEDA-BE) [5]. VEDA-FE relies on templates in excel sheets, which manage the input data and assess different policy scenarios in order to execute model runs. In these files, different commodities and processes are outlined. Commodities are the elements we define according to their role in the energy system, for e.g. “Crude Oil” is an energy commodity (NRG), “CO2” is an environmental commodity (ENV) etc. Processes indicate the nature of a procedure. In order to create a network between commodities and processes, we create a “Reference Energy System” (RES) as shown in figure 5.

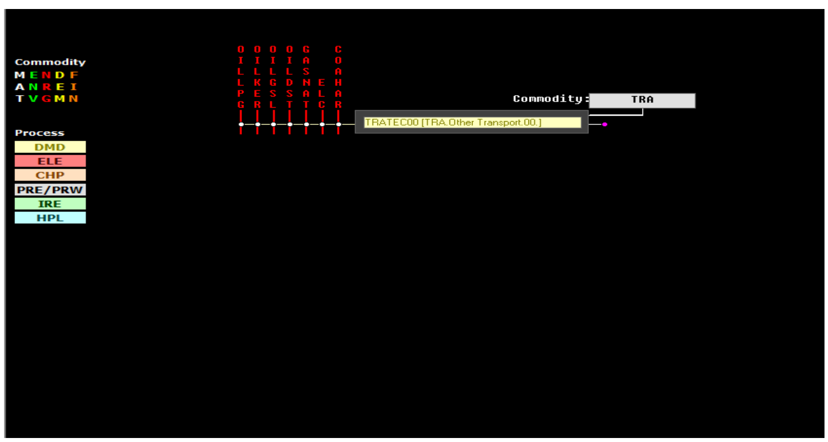

Figure 5- An Example of the RES - TIMES View

VEDA-BE manages the results.

The TIMES model has been used to project the energy demand requirements of Pakistan up to the year 2025. Using the reference case of “PAK-IEM” and a commodity set of energy (NRG), the favorable energy mix of Pakistan will be used to project the cost for growth in terms of GDP.

Once the RES has been developed, we export our model runs to VEDA-BE in order to filter our results according to different policy scenarios. 2 policy scenarios have been used, the first showing an impact of growth in GDP and the second, a decline. The discount rate has been set at a constant 7%, and the base year has been selected for the year 2010, for the region PAKISTAN.

6. Results

As mentioned earlier, the cost for growth is reflected by a country's GDP, so 2 scenarios have been depicted to forecast the energy demand of Pakistan, one in which we are diversifying our mix, and the other in which we are continuing to rely on our existing energy resources.

A need for a road map is mandatory, where an economic ascendance is linked with a versatile energy mix, as shown in figure 6. It can be seen that in the years to come, up to 2025, it is essential that the energy mix be diversified by exploiting more indigenous energy resources in the form of renewable energy. This will reduce the dependence on conventional fuels in the form of oil and natural gas, resulting in a cheaper power generation mix, coupled with a more affordable mix to fuel progress across the transportation, agricultural and industrial sectors, thereby reducing inflation and improving lifestyles. By implementing such a scenario, the country's GDP escalates from a mere 4.0 to around 7.0 by 2025. Heavy investments in LNG by the exchequer will help in countering the depletion in Natural Gas reserves. However, it should be kept in mind that apart from investing in new technologies, several marketing strategies need to be accounted for. This is essential in order to conserve energy resources in a more efficient way. Some of the measures necessary for a continued growth in GDP include a robust drive for emphasizing the importance of energy conservation, from putting up large billboards to newspaper advertisements to social media notifications; training centers for increasing the number of skilled manpower to ensure effective operation and maintenance of new and existing technological developments; promoting the use of energy efficient equipment's; encourage building owners to invest heavily on ensuring proper heating and cooling insulations etc.

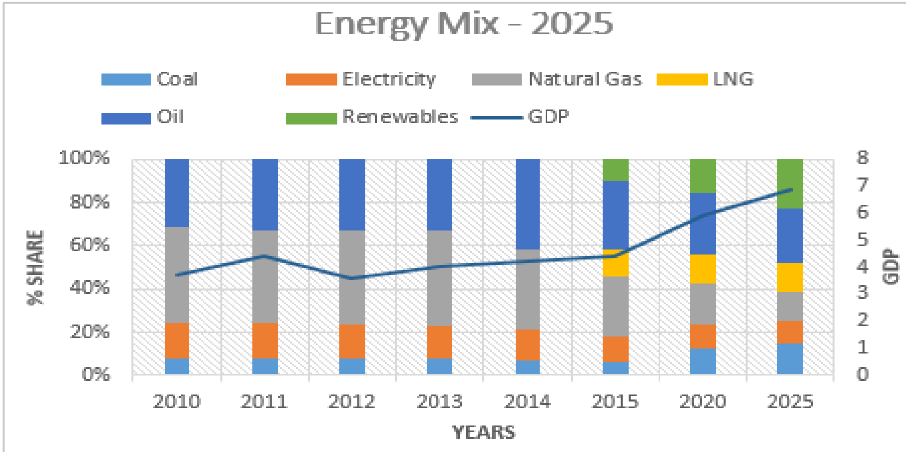

Figure 6 - Energy Mix (High GDP)

The results for not diversifying the energy mix can be seen in figure 7. The high dependence on fossil fuels leads to a minimal growth in GDP. By not making investments in LNG, it is seen that the country's natural gas reserves will deplete, resulting in widespread unavailability of a fuel which once contributed to approx. 40% of the mix. In the year 2015, it can be seen that as a result of a decline in worldwide oil prices, there was an increase in the demand of oil. The GDP did increase due to a decline in inflation, but a lack of supply and an over-reliance on one fuel commodity led to disruptions in meeting the demands, thereby preventing a sustained growth.

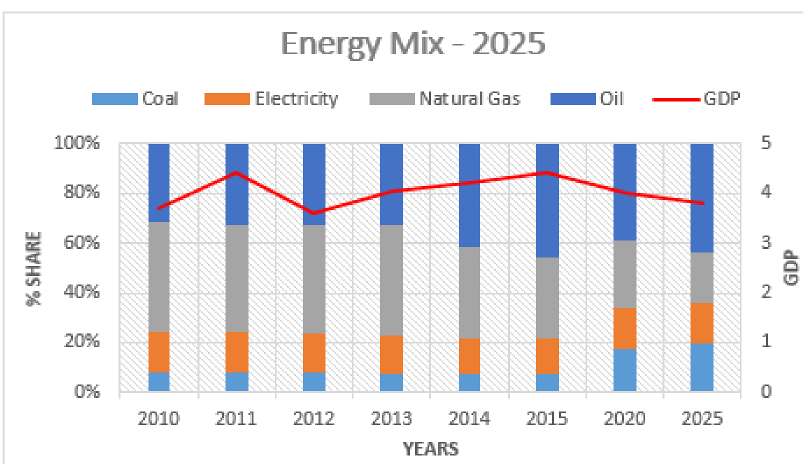

Figure 7 - Energy Mix (Low GDP)

By comparing both graphs, it can be devised that by restricting the progression in energy development leads to a poor economic performance which consequently mirrors a negative impact on the GDP.

7. Conclusion

With the energy sector already declared as one of the seven pillars of Vision 2025 [1], it is essential to diversify our energy mix for enhancing productivity across different sectors. The results show that an energy expansion leads to a higher growth rate, which can catapult the progress of an economy, whereas a lack of it may slow it down.

In today's day in age where modernization and industrialization are moving at a fast pace it is essential that improvements in the energy sector be implemented. The impact of having a successful energy scheme brings about improvements in the quality of life styles, improving environmental prospects as well. With several marketing strategies mentioned earlier, efficient deliveries in social services can also be achieved.

Hence it can be concluded that a progression in energy development, especially catering to the demand aspect, leads to implications in not only implementing alternative energy services, but also on the eradication of day to day economic stumbling blocks. Thus the use of an energy commodity input is expected to have a proportional yet, positive impact on the resulting output, while at the same time complementing an improved corroboration in poverty alleviation and the quality of life through employment generation.

8. REFERENCES

[1] Ministry of Planning, Development and Reform, Government of Pakistan, "Chapter 10 - Energy Security and Affordability," Annual Plan 2014 - 2015, pp. 119 - 130.

[2] M. Shoaib, "Chapter 14 - Energy," Economic Survey of Pakistan, pp. 217 - 230, 2013 - 2014.

[3] M. Shoaib, "Chapter 14 - Energy," Economic Survey of Pakistan, pp. 187 - 202, 2012 - 2013.

[4] M. Arifeen, "Can Pakistan meet its energy needs?" The Nation, Lahore, 2013.

[5] I. R. Group, "Pakistan Integrated Energy Model (Pak-IEM)," Final Report, vol. 3, pp. 1 - 202, 2010.

Annexure II

Fueling the Future: Forecasting the Oil Demand of Pakistan using TIMES

Syed Atif Rafiq Shah[1], Dr. Bilal Khan[1]

[1]Centre for Advance Studies in Energy (CAS–EN), National University of Sciences & Technology (NUST), H–12, Islamabad, 44000, Pakistan.

Abstract

Despite Pakistan being blessed with an abundant stock of indigenous energy resources, especially in the form of crude oil, there still exists a widening gap between supply and demand. The following paper presents a quantitative and analytical study on the existing crude oil situation of Pakistan, along with a methodology to reduce the gap. While taking into account mandatory amendments necessary for carrying out infrastructural initiatives and formulating policies, using energy system models, it is possible to project future oil demands. This can be achieved by using TIMES (The Integrated MARKAL EFOM System), a model which shows the detailed relationship between energy commodities, such as crude oil, and the relevant processes required to attain such commodities. In order to create a more comprehensive picture of the country's existing energy system under varying policies and possibilities, such a modelling framework proves helpful in creating a compliable reference energy system. The results will portray future demand projections along with strategies necessary to meet growing demand.

Keywords: Pakistan; Oil; Energy System Models; TIMES

1. Global Energy Outlook

Energy is the fundamental pillar for growth of any nation. From fuelling our homes to powering our electricity generating plants, energy resources have been of critical importance. However, as of late, the global energy outlook is portraying a gloomy picture. This has been due to the growth of the transportation, industrial and agricltural sectors, coupled with an increase in population demands. Figure 1 portrays the increase in global energy demand up to the year 2040 as a result of the aforementioned reasons. Oil and natural gas dominate the energy mix at the global stage as well, but with oil prices expected to drop to $20 (Randall, 2015) a barrel, it is predicted that the finite reserves are to exhaust sooner rather than later. However along with taking environmental standards into account, energy resources in the form of renewables and nuclear will play a key role to minimize the gap between supply and demand, resulting in a more stabilized economic situation and catering to a better future for tomorrow.

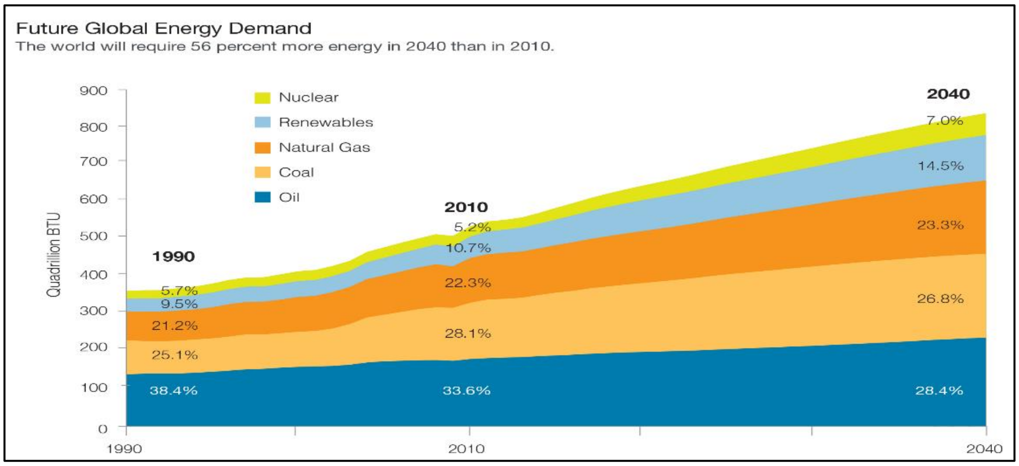

Figure 6: Future Global Energy Demand (Energy Tomorrow, 2015)

2. Oil Outlook of Pakistan

Pakistan's energy demand has risen at a Compound Annual Growth Rate (CAGR) of six percent during the financial year 2011 to 2015. The energy mix of Pakistan is heavily dependent on fossil fuels, as shown in figure 2. Due to technological shortcomings, Pakistan has been unable to fully utilize the coal reserves in Thar, which stand at 175 billion tonnes. (Wikipedia, n.d.)

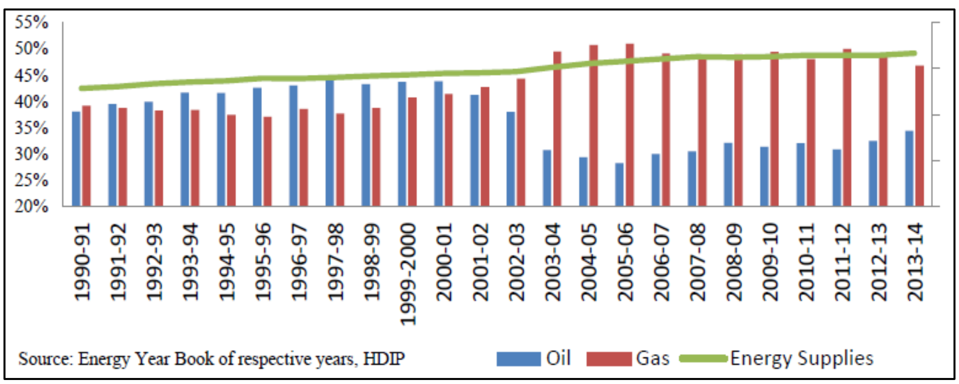

Figure 7: Primary Energy Supplies by major sources (Shoaib, Economic Survey of Pakistan, Energy, 2014-15)

Primary energy supplies during 2013-14 show natural gas dominating the mix with 49.5%, followed by oil (30.5%), hydel electricity (10.9%), coal (9.2%), nuclear electricity 1.2%, LPG (0.7%) and imported electricity 0.1% (Shoaib, Economic Survey of Pakistan, Energy, 2013-14). Figure 2 shows the over-reliance of Pakistan's energy mix on fossil fuels.

The power generation cost is also high as a result of an over-reliance on oil and natural gas. Load shedding has been hurting our economy from periods dating several decades ago. This has been largely due to shifting our energy mix from 70:30 in the favor of hydel to 60:40 in the favor of oil dependent thermal powered plants. The efficiencies of some thermal based power plants as low as below 30 percent. Coupled with depleting gas reserves, the existing circumstances have led to an inadequate and expensive power generation cost. Pakistan needs to find a route by which they can project a more formidable policy framework for securing a better future.

Being a non-OPEC country (Organization of the Petroleum Exporting Countries), consumers in Pakistan have benefited hugely from the glut in oil prices. With motor gasoline rates as low as Rs.67.79 (Shoaib, Economic Survey of Pakistan, Energy, 2014-15) for the first time since 2009, demand increased by 25%, resulting in a fuel shortage during the early months of 2015. The increase in demand had a trickle-down effect and there are several reasons to it.

Firstly, there are infrastructural constraints in the country. Pakistan has 3 ports, Port Qasim (PQA), located in the South-Eastern region of Karachi, Karachi Port Trust (KPT), and the Gwadar Port. All these ports have infrastructural constraints, such that a surge in demand limits and hinders timely delivery of imported petroleum products to the shore because of congestion at the ports.

Secondly, Pakistan has refineries which have insufficient storage capacities. The table below shows the production and configuration of each refinery in Pakistan.

In addition, they lack the technology requirements to produce quality products as well. The Research Octane Number (RON) of motor gasoline found in Pakistan is 87. Apart from Pakistan, Somalia is the only country which utilizes motor gasoline of such low quality (Hasan, 2015).

	Configuration	Local	Imported	Total
PARCO	CCR/ Diesel Max//Visbreaker	529,090	4,083,699	4,612,789
NRL	Hydro-skimming/Lubes	539,560	1,819,518	2,359,078
PRL	Hydro-skimming	321,771	1,316,785	1,638,556
ARL	Hydro-skimming	1,956,869	-	1,956,869
BPL	Hydro-skimming	182,328	734,767	917,095
Total		**3,529,618**	**7,954,769**	**11,484,387**

Figure 8: Configuration of Refineries in Pakistan

Thirdly, the transportation sector of petroleum products is heavily controlled by road tankers. Due to a lack of pipelines to transport these products across the country, curtailing the supply chain of these tankers as a result of internal or external circumstances leads to delays of several days, resulting in losses of millions of rupees.

With all the aforementioned reasons kept into view, it is evident that there needs to be a framework where the need for energy demands need to be met in a timely manner.

3. Energy Models

In order to access the sustainable growth of a country from different polciy perspectives, energy models have been developed for forecasting the best case scenario. The primary working of these models are developed using fundamental macro and micro-economic variables, giving the very best solution under various policy scenarios, across short to medium to long-term horizons. The category of models is shown in the figure below.

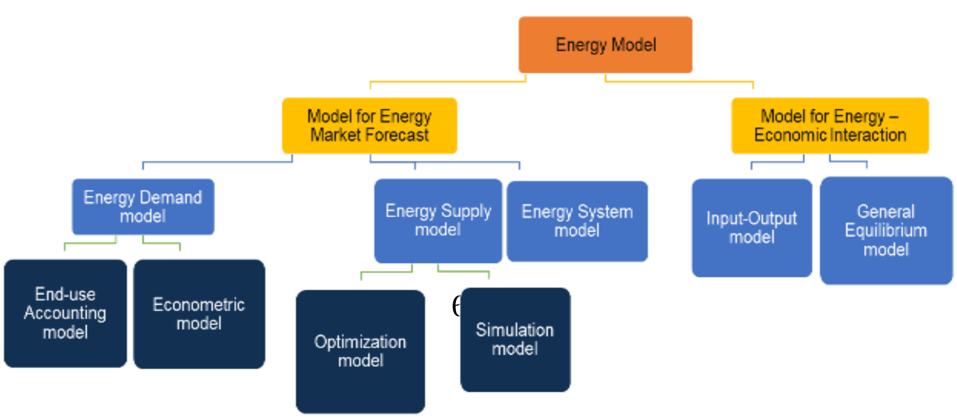

Figure 9: Different Types of Energy Models

A concrete methodology is thereby necessary to formulate a framework in order to select the best technological advancements, in accordance to their feasibility for fueling the future oil demands, resulting in economic growth across corridors of the country.

TIMES is a category of energy system models which can be used to forecast both demand and supply projections under an array of policy scenarios.

3.1 TIMES

TIMES is the ancronym for "The Integrated MARKAL EFOM System" (IEA-ETSAP, n.d.). It is an improvement on its previous edition, formerly known as MARKAL. Some of the advantages provided by TIMES include providing a joint assessment between energy productivity, green house gas emissions, and at the same time formulating a link between commodities supply and demand.

4. Methodology

The TIMES model comprises of two working groups namely VEDA – Front End (VEDA – FE) and VEDA – Back End (VEDA – BE) (IEA-ETSAP, n.d.). All TIMES models are developed with 3 entities:

1. Commodities: They are categorized according to the role they are going to play in the energy system. For e.g. crude oil is an energy commodity, SO2 is an environmental commodity etc.

2. Processes: They need to be defined so that the commodity can be achieved or extracted via a procedure for e.g. mining of coal, imports and exports etc.

3. Scenarios: They are the different policy situations on which we determine the feasibility of the energy system.

The workings of the TIMES framework is shown in the figure below

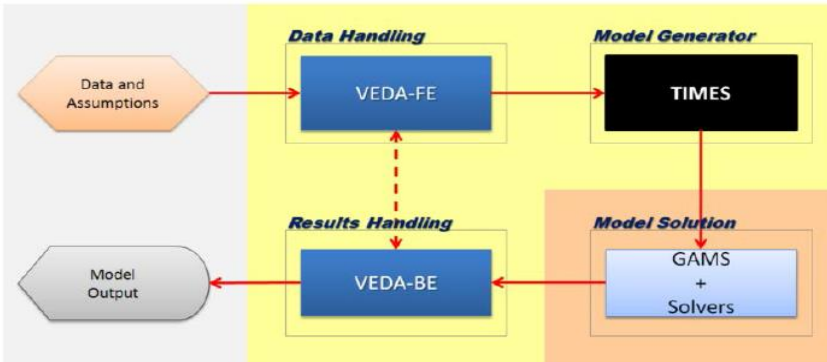

Figure 10: Working Framework of the TIMES model

VEDA – FE comprises of excel sheets which lay the workings of the model. While executing model runs, it takes into account different policy situations in accordance with mandatory inputs in order to determine the best possible energy solution. The link between commodities and processes is created by the Reference Energy System (RES), as shown in the figure below.

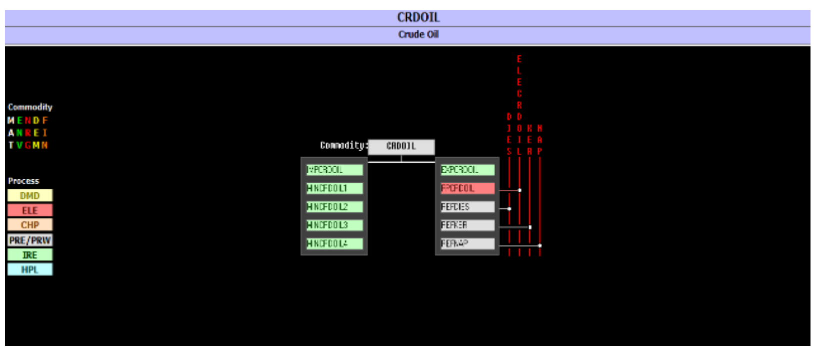

Figure 11: Crude Oil "RES"

VEDA – BE manages the results. The General Algebraic Modeling System (GAMS) is a high-level modeling system for mathematical programming problems (GAMS, n.d.).

The TIMES model has been built to project the crude oil demand requirements of Pakistan up to the year 2025. The base year has been set at 2010 for the region "PAK", and the discount rate a constant 7%.

5. Results

As previously mentioned about the shortcomings of the crude oil supply in the country, two policy scenarios have been shown.

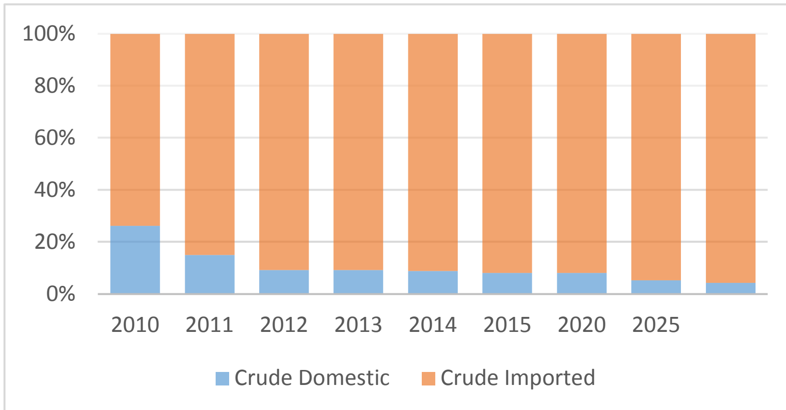

Figure 12: Pakistan Dependence on Imported Crude Oil

The first case reflects a business as usual scenario where the cost of a barrel of crude has been kept at an average of $50 from 2015 onwards up till 2020. The price of a barrel has been assumed at an increased cost $75 from 2020 onwards. It can be seen that as a result of a lack of major breakthroughs in the Exploration and Production (E&P) of oil fields, there is a huge dependence on imported crude oil.

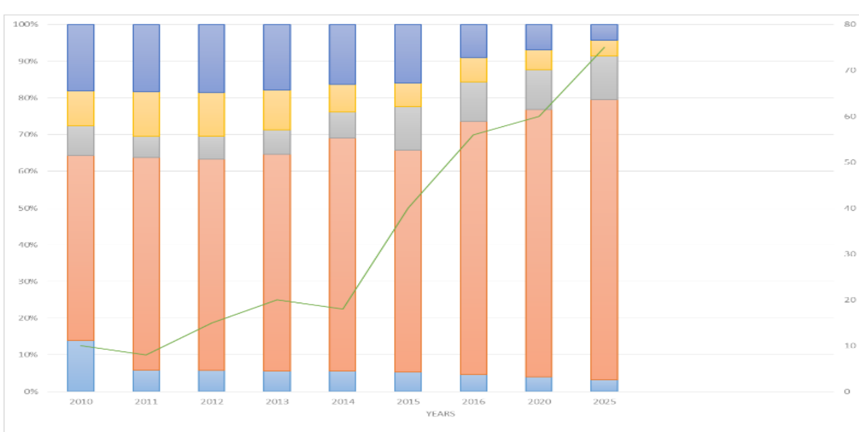

Figure 13: Scenario -1 Increase in Import Bill

The supply of gasoline is also marginal as the RON 87 will no longer be useful to the commuters. The business as usual also takes into account a lack of infrastructural and technological initiatives in the form of increasing the number of oil tankers at the ports along with a lack of upgrading refineries.

However, by importing less crude oil and increasing domestic E&P activities, the import bill of Pakistan can be decreased to a certain extent.

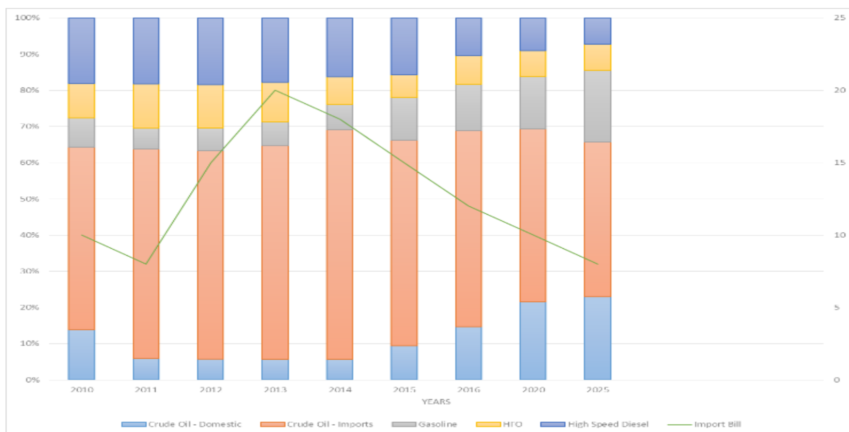

Figure 14: Reduction in import bill by enhancing domestic E&P activities.

This can however only be achieved by introducing policies which are beneficial from an investment perspective. It's not only the E&P sector that needs attention, upgrading the existing infrastructure shows that it will be beneficiary for the greater good of the progress of the nation.

6. Conclusion

Oil is the weapon for empowering any nation. The current decline in oil prices clearly shows how oil dependent the economies of several countries are. For Pakistan, it too needs to take advantage of the current fall in prices by increasing their storage reserves.

It also needs to upgrade its existing refineries so that a lot more white oil products can be produced from raw crude.

Apart from increasing reserves, the country also needs alter its existing energy mix. Investments in coal, hydel, nuclear and renewables need to be made at a fast pace so that the reliance on crude oil is reduced. The fuel load on power plants operating on oil will be reduced once coal from Thar becomes more accessible and viable. However, with greenhouse gas emissions on the rise, renewables in the form of wind, solar and biomass need to be promoted so that not only is the energy mix a lot more balanced, but electricity shortcomings of the country be curtailed to a certain extent.

7. References

(n.d.). Retrieved from Organization of the Petroleum Exporting Countries: http://www.opec.org/opec_web/en/about_us/24.htm

(n.d.). Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Thar_Desert

(n.d.). Retrieved from IEA-ETSAP: http://www.iea-etsap.org/web/Times.asp

(n.d.). Retrieved from http://www.gams.com/

(n.d.). Retrieved from GAMS: http://www.gams.com/

(2015). Retrieved from Energy Tomorrow: http://www.energytomorrow.org/energy-101/global-energy-demand

Hasan, S. (2015, September 7). Retrieved from Express Tribune: http://tribune.com.pk/story/951855/looking-higher-abbasis-new-found-hate-for-current-fuel/

Randall, T. (2015, February 9). Retrieved from Bloomberg Business: http://www.bloomberg.com/news/articles/2015-02-09/citi-oil-could-plunge-to-20-and-this-might-be-the-end-of-opec-

Shoaib, M. (2013-14). *Economic Survey of Pakistan, Energy*.

Shoaib, M. (2014-15). *Economic Survey of Pakistan, Energy*.

Annexure III
Pakistan's Natural Gas Forecast and Management using TIMES

Hafeez-ur-Rehman[1], Haris Mushtaq[1], Syed Atif Rafiq Shah[1], Dr. Muhammad Bilal Khan[1]

[1]*Centre for Advance Studies in Energy (CAS–EN), National University of Sciences & Technology (NUST), H–12, Islamabad, 44000, Pakistan.*

Abstract

Pakistan, like many other developing countries, is experiencing an acute energy crisis due to a continual and ever increasing mismatch between supply and demand. Political disputes, rapidly growing population, insecurity and mismanagement of energy resources in the past has resulted in a large gap between supply and demand of energy in the country. Meeting the energy requirements of the country in the future would become even more severe with an intermittent nature and excessive consumption of resources in the current energy mix. This situation calls for a better and proper forecasting of existing energy resources, which is deeply necessary for more accurate planning and policy formulation in the energy sector. With respect to the economic and energy constraints in the country, this work highlights the subsequent energy demand and supply in terms of natural gas forecast using Pakistan integrated energy model (Pak-IEM) based on the TIMES model. Under the given circumstances, the paper features the importance of implying an array of different demand scenarios in order to minimize the gap between supply and demand. This approach will equip decision-makers to formulate effective policies to meet the ever-rising demand for natural gas

Keywords: Natural gas; forecasting; management; Pakistan; Pakistan integrated energy model (Pak-IEM)

1. Introduction

Energy plays a vital and fundamental role in our daily day life. It is the keystone of a country’s economy. A country with a robust energy sector has a strong GDP and economic prosperity. Energy modeling has a long history for analyzing entire energy systems or sub-systems such as commercial or power sectors. It has earned substantial strength over the last couple of years, for optimum utilization and management of the energy resources in the world. [1] Energy modeling is essential from economic as well as the environmental point of view. According to International Energy Outlook projection, natural gas is the rapidly expanding primary energy source. In future natural gas is anticipated to be the best optimal fuel for several countries [2]. Natural gas plays a very important role in the energy sector of Pakistan because it is clean, cheap and environment-friendly compared to other fossil fuels. It is poorly managed in the country which leads to a mismatch between its supply and demand, especially in highly populated areas. The need now is to properly manage the natural gas reserves and forecast its production in future in order to control its shortage in the country. In addition, policy recommendations also need to be suggested as guidelines for improved energy planning approach. This paper presents the impact of GDP growth on the production of natural gas and provides a road map for future production and management of natural gas up to 2040 as well. TIMES model has been selected with reference to PAK-IEM. In collaboration to Asian development bank, planning commission Government of Pakistan, has developed an integrated entire energy system development model using the least cost optimization scheme i.e. TIMES. The model is termed as Pakistan integrated energy model (PAK-IEM) that covers the entire energy system comprising resource supplies, refineries, power plants, and transmission and distribution networks for electricity and fuels and end-use devices that deliver the energy services in a reliable and economical way.

2. Pakistan Gas Sector

Pakistan is a gas-rich country. The first gas field was discovered in 1952 at Sui Baluchistan. The total transmission and distribution network is 9,843 kilometers and 71,863 kilometers respectively. PPL and OGDCL are the main natural gas production companies in the country [3]. In Pakistan’s energy sector, natural gas is considered as a key indigenous resource. On June 2013, the actual domestic recoverable stock of natural gas was 55.6 trillion cubic feet (TCF) while total production and recoverable stock was

30.9 TCF (56%) and 24.7 TCF (44%) respectively [4]. Pakistan's regular gas demand is about 6.5 billion cubic feet per day (BCFD) while its present inventory is about 4 BCFD with an apparent shortage of 2.5 BCFD. Furthermore, during the coming 10 years, the gas requirement is calculated to be approximately 8.58 BCFD. As the gas supplies exhaust, household supplies are anticipated to stretch the level of 2.11 BCFD, and, as a result, a mismatch of 6.47 BCFD will be noticed in demand and supply in the year of 2022 [5].

Figure 1 shows the sector wise consumption of natural gas demonstrating that the power sector, industrial sector, and domestic sector have dominant utilization. Most of the electricity in the power sector is generated from thermal means. According to (NEPRA (National Electric Power Regulatory Authority), in the financial years of 2010-11, the share of natural gas and oil in the thermal electricity generation was 44.7% and 55.1% respectively [6].

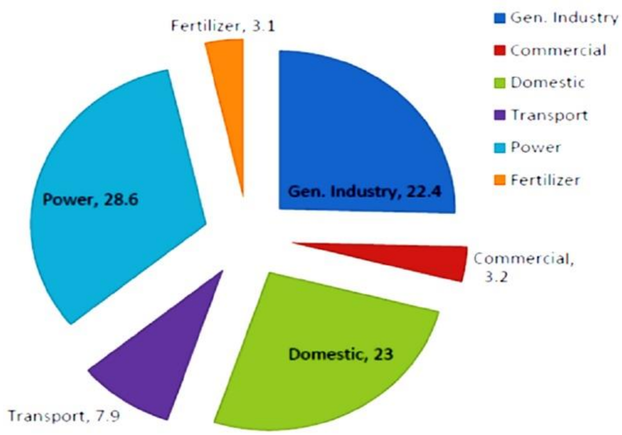

Figure 15: Natural Gas consumption by Sector 2012-13 [6].

Natural gas ‘chemical energy is used to produce electrical energy in the power sector. Natural gas in power plants is generally utilized as a fuel to run gas alternators, steam engines, gas turbines, etc. In industrial and manufacturing sector, it is utilized as a source of power to run large looms and to process the raw material.

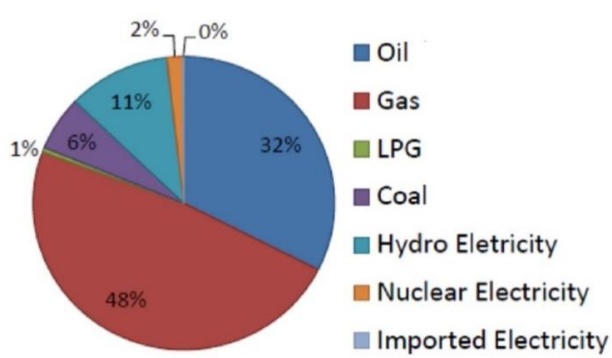

Figure 16: Primary energy supplies by source 2012-13 [7]

In the fertilizer industry, gas is utilized as a vital constituent for fertilizer production. Residential users utilize natural gas for cooking and space heating purposes [1]. Fig 2 illustrates the primary energy supplies by a source in the financial years 2012-13 showing that the natural gas contribution has a major role in the energy mix of the country.

3. Natural Gas Forecast and Management

Forecast and Management tool

TIMES has been used as the tool, with reference to PAK-IEM, for carrying out the forecast and management of natural gas production against the GDP growth in the country. TIMES (an acronym for "The Integrated MARKAL-EFOM System") is an economic model generator for single-sectorial, national or multi-sectorial energy systems and provides a technology-rich environment for upcoming energy dynamics over a long-term and multi-period time frame [7]. It follows the principal of (RES) reference energy system and finds a least-cost set of technologies to satisfy end-use energy service demands and user-specified constraints.

Figure 3 shows the working environment of TIMES modeling.

A model illustrated in Fig. 4, is developed to figure out the forecast of natural gas using the TIMES model. TIMES model has two major components i.e. VEDA-Front end in which data is input to the model directly or through excel sheets and VEDA-Back end in which results are analyzed and studied.By putting the input data into the VEDA-Front end, it submits the data to generate the model in TIMES. After generating the model in TIMES, it is solved mathematically in General Algebraic Modeling System (GAMS) using the solver CPLEX. In the VEDA-Back end, the model results are analyzed and studied [8].

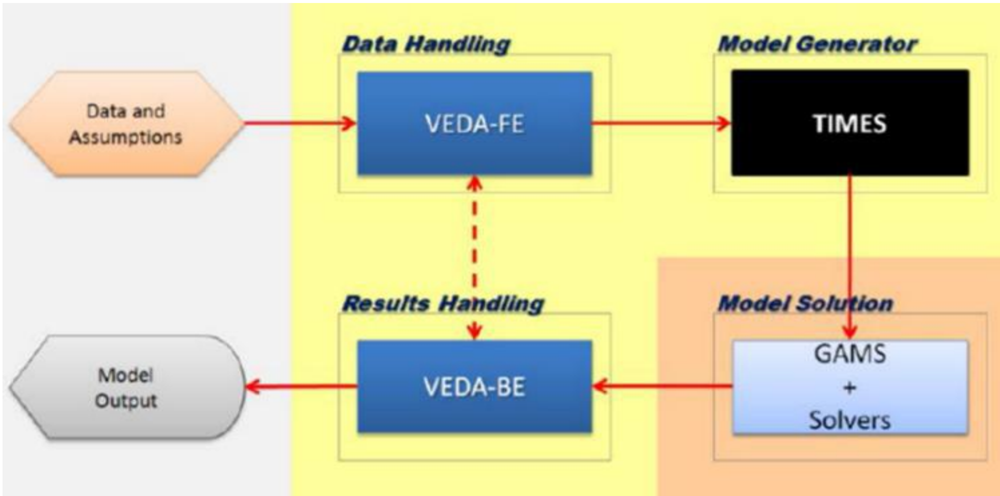

Figure 17: Working of components of TIMES [8].

4. Methodology

A forecast model, Fig. 4, is developed to study the production of natural gas. Proper management and suitable policies can play a vital role to describe the importance of such a model by keeping the core concern as the cheap and environment friendly energy usage .The model uses the production of natural gas, selection of three cases based on GDP growth. The production is calculated on provincial level in parallel with import of natural gas from neighbor countries. Input data has been managed and handled through excel sheets into the VEDA-FE. The Model is being generated in TIMES and solved mathematically in GAMS. Three specific cases have been defined based on GDP growth i.e. low, medium and optimal demand. The results for production of natural gas, generated by the model, have been examined and analyzed for each case in VEDA-BE.

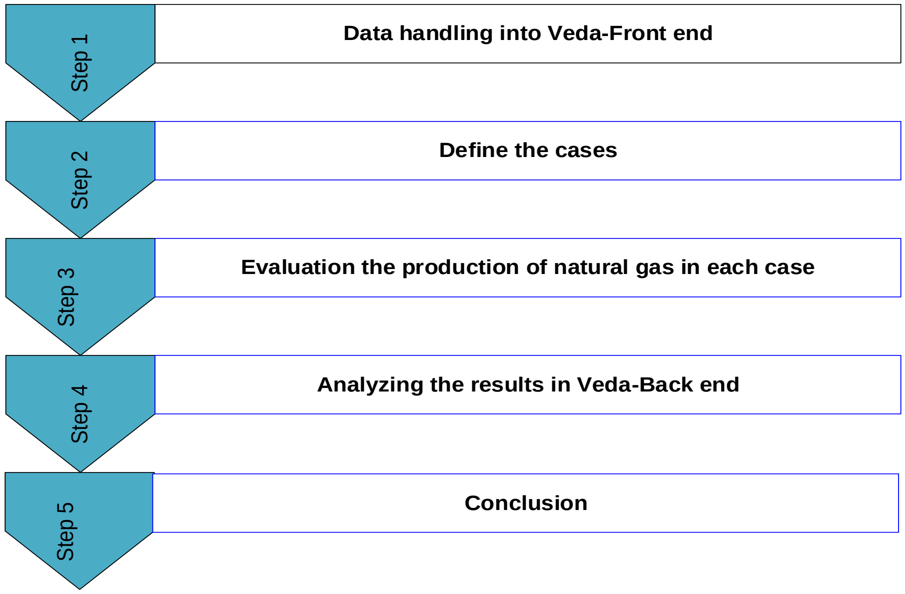

Figure 18: Proposed model for Natural Gas Forecast

5. Forecast and Management Cases

Three cases have been considered to figure out and estimate the future natural gas production forecast using TIMES with reference to PAK-IEM.

i. Low demand
ii. Medium demand
iii. Optimal demand

Low demand:

Production of natural gas for the low demand case in PAK-IEM has been analyzed at 4.2% average GDP growth.

Medium demand:

For the medium demand, the production of natural gas in PAK-IEM has been analyzed at 5%, average GDP growth.

Reference demand:

Natural gas production for optimal demand case has been analyzed at 5.6% average GDP growth in PAK-IEM.

Energy efficiency, renewable contribution plus transmission and distribution losses of gas have also been included in carrying out the evaluation.

6. Results and Discussion

Figure 5 shows the results for low demand case, analyzed at 4.2% GDP, representing the production of Gas in MTOE versus years. Low demand accounts for the fewer economic activities and less development in the industrial sector and leads to a lower economic growth and per capita energy consumption. Literature stands a testimony to the fact that the instability in energy consumption has distorted massive scale industrial growth that consecutively affected the actual GDP growth [4].

The forecast results for low demand case indicate that the indigenous natural gas resources production will be exhausted in the year 2030. Therefore, some strategic planning and policy regulations are needed to cater the gap between supply and demand for the uninterrupted supply up to the year 2040. For this, on the management side, the results show that some amount of LNG will have to be imported in the years 2030-2040.

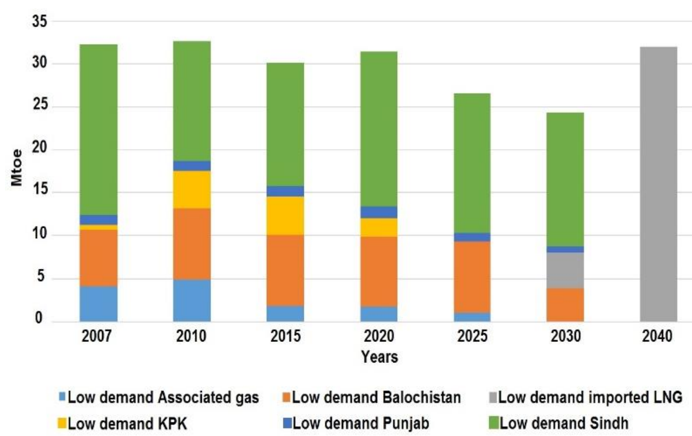

Figure 19: Gas Production at Low Demand

Figure 6 shows the results for medium demand case, analyzed at 5% GDP, representing the production of Gas in MTOE versus years. Medium demand case accounts for the reasonable expansion in economic activities and leads to the increased economic growth and energy per capita as compared with the low demand case. The forecast results for medium demand case indicate that the indigenous natural gas resources production will be exhausted somewhere in the years 2020-2030. For the uninterrupted supply of natural gas up to the year 2040, some strategic planning and policy regulations have to be introduced in order to cater the gap between supply and demand. For this purpose, the management side results show that the import of LNG will have to be started from the year 2015 and will continue up till the year 2040. Also, some share from the Iranian gas pipeline will have to be incorporated in the year 2040, along with the import of LNG, in the supply.

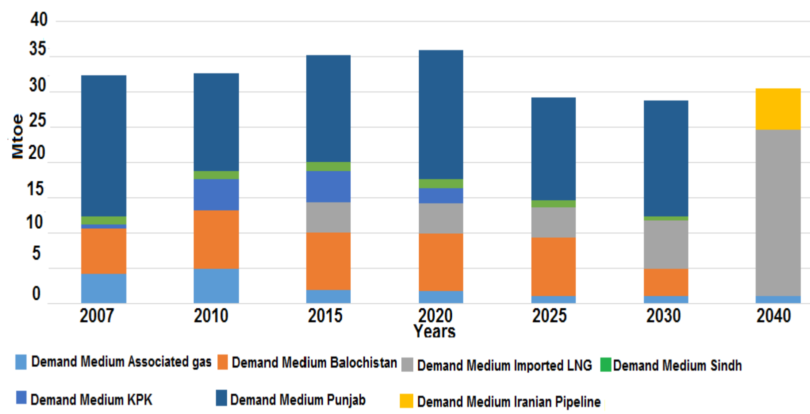

Figure 20: Gas Production at Medium Demand

Figure 7 shows the results for the high demand case, analyzed at 5.6% GDP, representing the production of Gas in MTOE versus years. The forecast results for high demand case indicate that the indigenous natural gas resources production will be exhausted somewhere in the years 2020-2030. For the uninterrupted supply of natural gas up to the year 2040, some strategic planning and policy regulations have to be introduced in order to cater the gap between supply and demand in the country. For this purpose, the management side results show that the import of LNG will have to be started from the year 2025 and continue up to the year 2040. Also, to cater the high demand, shares from Iranian gas pipeline and central Asian pipelines, along with the LNG import, will have to be incorporated in the supply in the year 2040.

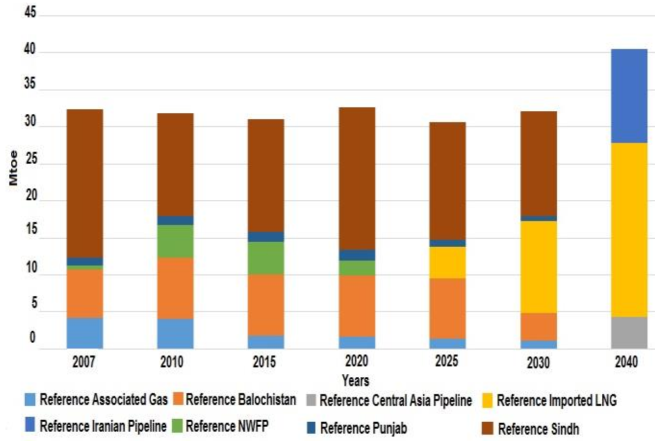

Figure 21: Gas Production at Reference demand

7. Conclusion and Recommendations

The Energy crisis is a worldwide phenomenon. Nations are considering all potential resolutions for proper energy resource management. In this regard, the need of the hour is to handle and properly manage present resources of energy and search for novel technologies to utilize renewable and non-renewable resources. Energy planners should implement strategic alternatives and energy efficient technologies for future energy production and consumption. Pakistan is blessed with a generous amount of natural resources but due to lack of proper management and poor policies these resources are not being utilized effectively which has led to the acute energy shortage in the country. The troublesome issue is that our gas assets are diminishing day by day taking into account its ever-increasing consumption, the current recoverable reserves will mostly be tired by 2025 or 2030.

Using PAK-IEM, forecast of the natural gas production in Pakistan was performed up to the year 2040. Three cases based on demand size, (i.e. low demand, medium demand and reference demand) were studied and solutions to compensate for the natural gas shortage in each case were suggested to achieve the null mismatch between supply and demand up to the year 2040. In this scenario, the role LNG import and importance of Asian gas pipeline & Iranian gas pipeline was also highlighted.

8. References

[1] H. S. Dey, M. A. Kabir, Z. Wadud, S. I. Khan, and M. A. K. Azad, "Econometric modeling and forecasting of natural gas demand for power sector in Bangladesh," *IEEE Reg. 10 Annu. Int. Conf. Proceedings/TENCON*, pp. 1383–1386, 2011.

[2] *Natural Gas in Pakistan and Bangladesh : current issues and trends Ieda Gomes*, no. June. 2013.

[3] G. A. S. Sector, "By : Absar Saleh."

[4] N. P. Policy, M. W. New, B. Hydropower, M. W. Gas, B. Davis, E. Project, M. W. I. Coal, P. Project, P. Qasim, S. Features, N. P. Policy, T. Ministry, and P. Policy, "Chapter 14 ›," 2013.

[5] "Energy SDPI NG.com." [Online]. Available: https://energysdpi.wordpress.com/. [Accessed: 20-Mar-2015].

[6] I. N. Kessides, "Chaos in power: Pakistan's electricity crisis," *Energy Policy*, vol. 55, pp. 271–285, 2013.

[7] R. Loulou, U. Remme, A. Kanudia, A. Lehtila, and G. Goldstein, "Documentation for the TIMES Model Part I," *IEA Energy Technol. Syst. Anal. Program.*, no. April, pp. 1–78, 2005.

[8] U. Guide, "Pakistan Integrated Energy Model (Pak-IEM) Users ' Guide," vol. III, no. December, 2010.