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Impact of Egypt's Energy Demand on Oil and Gas Power Systems Environment

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***Abstract*—**This paper will explore the influence of energy sector in Arab Republic of Egypt which has shared its responsibilities of many environmental challenges as the second largest economy in the Middle East (after Iran). Air and water pollution, desertification, inadequate disposal of solid waste and damage to coral reefs are serious problems that influence environmental management in Egypt. The intensive reliance of high population density and strong industrial growth are wearing Egypt's resources, and the rapidly-growing population has forced Egypt to breakdown agricultural land to residential and relevant use of commercial ingestion. The depletion effects of natural resources impose the government to apply innovation techniques in emission control and focus on sustainability. The cogeneration will be presented to control thermal losses and increase efficiency of energy power system.

***Keywords*—**Cogeneration, energy indicators, power plant, electricity, environmental loads, environmental impact assessment.

I. Introduction

ENERGY in Egypt is nearly economic indicator to measure or evaluate consumption rate as tripled over the past two decades, from 0.7 quadrillion Btu (British thermal unit) (Quads) in 1980 to 2.04 Quads in 2000. Industrial demands tapped more than half of the nation energy (53.6%) in 1997 while one quarter each went to the transportation (24.7%) and residential use (22.1%) [1]. A historical summery of Egypt's total primary energy production (TPEP) and consumption (TPEC) is shown in Table I [2].

TABLE I
EGYPT'S TPEP AND TPEC, 1990-2000 (IN QUADS) [2]

	1990	**1991**	**1992**	**1993**	**1994**	1995
TPEP	2.36	2.4	2.44	2.55	2.59	2.67
TPEC	1.44	1.43	1.43	1.51	1.55	1.58
	1995	**1996**	**1997**	**1998**	**1999**	2000
TPEP	2.67	2.73	2.61	2.58	2.69	2.66
TPEC	1.58	1.73	1.80	1.87	1.91	2.04

II. Main Energy Sources in Egypt

Egypt exports fuel oil and naphtha, but imports kerosene and diesel. So, thermal power plant mainly depends on gas turbine rather than diesel generators. The production and consumption are mentioned in Table II [3].

***Crude Oil Prices*:** The average price of domestic crude oil at the wellhead was $23.37 per barrel in November 2002, 43% above the level of November 2001. The refiner acquisition cost of imported crude oil in November 2002 was $23.68 per barrel [3]

Natural gas is destined to become more and more important to energy future in Egypt. There are vast reserves of natural gas with a potential for more discoveries, especially in the western desert, the Nile delta and under the Mediterranean Sea. Proven reserves stand at 42.5 trillion cubic feet (tcf) with probable reserves estimated at 120 tcf, based on seismic offshore data [3].

TABLE II
PETROLEUM PRODUCTION AND CONSUMPTION IN EGYPT 1990-2000 (IN THOUSAND B/D) [3]

	1990	**1991**	**1992**	**1993**	**1994**	**1995**
Production (total)*	914	920	927	946	955	981
Production (crude Oil only)	873	874	881	890	896	920
Consumption	465	456	444	450	448	458
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Production (total)*	981	988	928	910	928	851
Production (crude Oil only)	920	922	856	834	852	748
Consumption	458	501	531	555	550	540

* includes crude oil, natural gas plant liquids, and refinery processing gas

TABLE III
DRY NATURAL GAS PRODUCTION AND CONSUMPTION IN EGYPT, 1990-2000 (IN TCF) [3]

	1990	**1991**	**1992**	**1993**	**1994**	**1995**
Production	0.29	0.32	0.35	0.4	0.42	0.44
Consumption	0.286	0.321	0.349	0.399	0.423	0.439
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Production	0.44	0.47	0.48	0.49	0.52	0.65
Consumption	0.439	0.473	0.477	0.485	0.518	0.646

Note: "dry" gas means gas with condensates removed.

Egypt has been increasing domestic gas demand by converting its power plants to run on gas. Thermal power plants account for about 65% of Egypt's total gas consumption. Large industrial consumers have also been switching to gas including large industrial projects (e.g. petrochemical, fertilizers and steel) in Suez, Alexandria and south of Aswan. Some 20,000 vehicles in Cairo have been modified to run on CNG as of a pilot program. This encourages the government in construction 17 CNG service stations for supporting the project. Egypt is trying to improve the availability of natural gas for residential customers by

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allocating service areas to several private companies, beginning in 1998. British Gas head a group that includes Orascom (an Egyptian construction firm), and Edison International SpA will invest $220 million in a distribution network facility to serve Upper Egypt up to Assyout, that area with no existing gas service. The network may be expanded as far south as Aswan [5]. Natural gas consumption in Egypt by sector is shown in Table IV [6], [7]

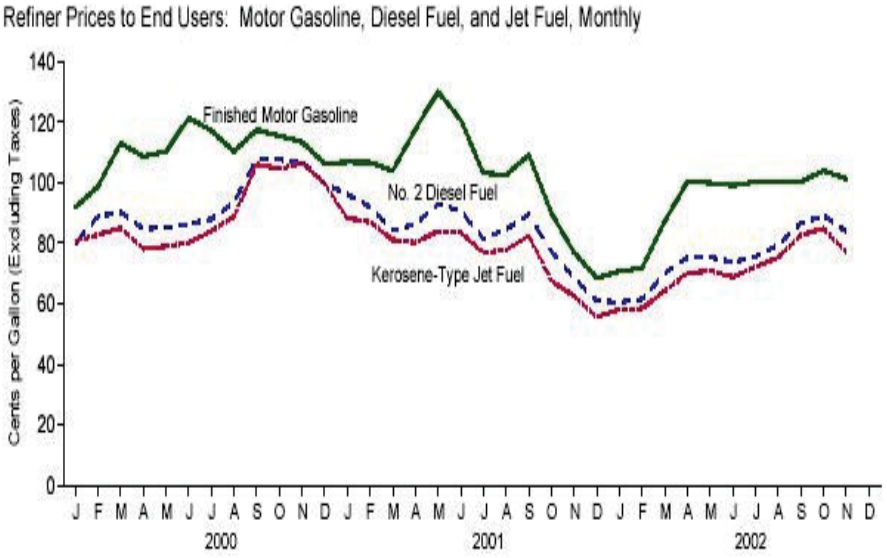

Fig. 1 Refiner prices in cent per gallon [3]

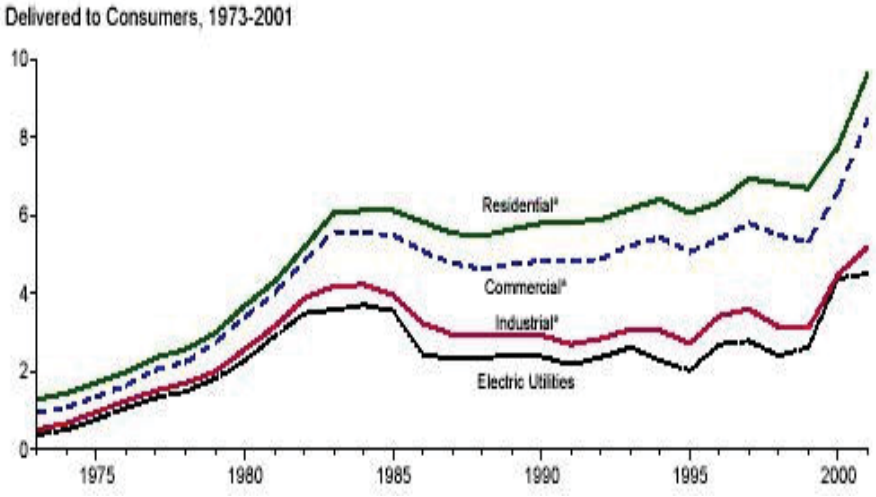

Fig. 2 Natural gas prices (dollars per thousand cubic feet) [4]

TABLE IV
NATURAL GAS CONSUMPTION IN EGYPT BY SECTOR [8]

Sector	Percent of Total
Industrial	59.7
Non-Energy Petrochemical	34.5
Residential	1.6
Transportation	1.4
Other	2.8
Total	**100**

Natural Gas Prices: The average wellhead prices of natural gas for October 2002 were estimated as $3.35 per thousand cubic feet, 40% higher than the October 2001 price [9]. The average price of natural gas delivered to electric utility plants was $3.75 per thousand cubic feet in September 2002 (latest date for which data are available), 19% higher than September 2001 price [9]. The average price of natural gas used by residential consumers in October 2002 was $4.46 per thousand cubic feet, 3% higher than the October 2001 price. The average price of natural gas used by commercial consumers in October 2002 was $6.74 per thousand cubic feet, 5% higher than the October 2001 price. The average price of natural gas used by industrial consumers in October 2002 was $4.11 per thousand cubic feet, 26% above the October 2001 price [9].

Nuclear power in Egypt does not generate commercial amount of electricity from nuclear power source but it does have one 2 MWe nuclear reactor the ET-RR-1 research

reactor, for scientific research and making radioactive isotopes [10], [11].

Coal in Egypt has begun mining in 1995 at El Maghara in the Sinai Peninsula but in the present time Egypt imports a large number of coal to cover the shortage in production natural gas [12].

Hydroelectric power is an important source of energy in Egypt and represent one quarter of total energy production and it is mainly in Aswan [13].

Other renewable energies in Egypt rarely dominate commercial sector but government is looking to expand its renewable energy capacity. Renewable energy generation from solar and wind power are increased by 10% in 1997 to 176 trillion Btu. One example of Egypt's increased commitment to the development of solar power is the Noor Al Salam ("light of peace"), plant to be built near the red sea, which will generate electricity via solar power during the day and natural gas at night. The United States, Israel and Egypt have worked together to develop the design of the plant and the world environmental agency will contribute $65 million [14].

TABLE V
COAL PRODUCTION AND CONSUMPTION IN EGYPT, 1990-2000 (IN MILLIONS OF SHORT TONS) [14]

	1990	1991	1992	1993	1994	1995
Production	0.00	0.00	0.00	0.00	0.00	0.00
Anthracite	n/a	n/a	n/a	n/a	n/a	n/a
Bituminous	n/a	n/a	n/a	n/a	n/a	n/a
lignite	n/a	n/a	n/a	n/a	n/a	n/a
consumption	**1.60**	**1.29**	**1.25**	**1.63**	**1.72**	**1.18**
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Production	0.00	0.11	0.39	0.41	0.43	0.44
Anthracite	n/a	n/a	n/a	N/a	n/a	n/a
Bituminous	n/a	0.11	0.39	0.41	0.43	0.44
lignite	n/a	n/a	n/a	N/a	n/a	n/a
consumption	**1.18**	**1.75**	**1.92**	**2.12**	**2.15**	**2.16**

Note: "n/a" not applicable

III. ENERGY GENERATION AND CONSUMPTION

Egypt's demand for electricity increased dramatically during the decade of the 1990s. to meet that demand, generation from both hydroelectric (16% - mostly from Aswan High Dam) and thermal electric power sources (84% - generated by gas turbine) also increased. An historical summery of electricity generation and consumption is shown in Table VI [15].

Thermal power plants can burn various fuels. These power facilities use natural gas, heavy oil and coal as fuel sources in nearly close prices as shown in Fig. 3 [15].

TABLE VI
ELECTRICITY GENERATION AND CONSUMPTION IN EGYPT, 1990-2000 (IN BILLION (kw/hr)) [15]

	1990	1991	1992	1993	1994	1995
Net Generation	41.4	42.6	43.5	47.8	50.1	52.1
Hydroelectric	9.9	8.5	8.5	10.4	10.6	10.7
Nuclear	n/a	n/a	n/a	n/a	n/a	n/a
Geo/solar/wind/biomass	n/a	n/a	n/a	n/a	n/a	n/a
Conventional thermal	31.5	34.0	35.0	37.4	39.4	41.4
Net Consumption	**38.5**	**39.6**	**40.5**	**44.4**	**46.6**	**48.4**
Import	0.00	0.00	0.00	0.00	0.00	0.00
Export	0.00	0.00	0.00	0.00	0.00	0.00
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Net Generation	52.1	51.8	54.8	59.2	64.7	69.6
Hydroelectric	10.7	11.4	11.9	12.1	15.1	15.9
Nuclear	n/a	n/a	n/a	n/a	n/a	n/a
Geo/solar/wind/biomass	n/a	n/a	n/a	n/a	n/a	n/a
Conventional thermal	41.4	40.3	43.0	47.1	49.5	53.7
Net Consumption	**48.4**	**48.1**	**51.0**	**55.1**	**60.2**	**64.7**
Import	0.00	0.00	0.00	0.00	0.00	0.00
Export	0.00	0.00	0.00	0.00	0.00	0.00

Note: "n/a" not applicable

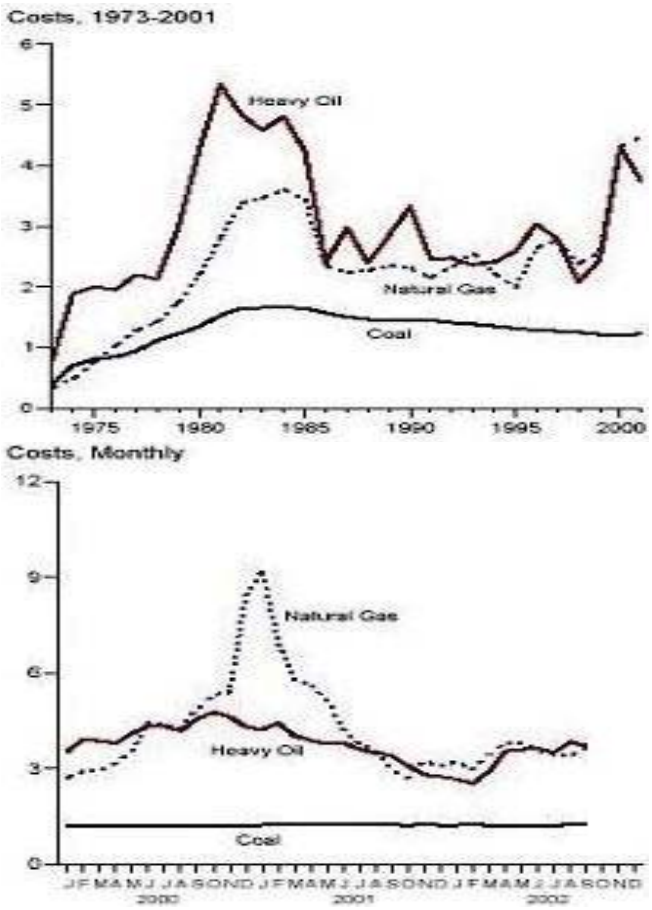

Fig. 3 Cost of Fossil-Fuel Receipts at Steam-electric Utility Plant (Dollars per Million Btu) [15]

IV. AIR POLLUTION

Air pollution is a serious problem in Egypt cities and industrial areas. Concentrations of sulphur dioxide are four

times, smoke and lead levels are three times, and nitrogen oxides are two times worse than world health organization (WHO) guidelines [16]. The sandy storms increase the level of particulate matters and concentrate total suspended particulate matter from 5-10 times than the minimum acceptable standards from WHO. In some areas of the city, lead levels can climb to more than 20 times the maximum WHO exposure levels. Between 10,000 and 25,000 deaths a year in Cairo can be attributed to air pollution [16]

A. Greenhouse Gas Emissions

Egypt's carbon emissions increased 170% from 11.7 million metric tons in 1980 to 31.6 million tons in 1998, mostly due to increased energy consumption. Emission levels have risen 21% since 1990. As the baseline for Kyoto Protocol of the United Nations Framework Convention on Climate Change, as a non-Annex I country under the Convention, Egypt is not required to cut its carbon emissions. Although Egypt has not yet ratified the Protocol, it is a signatory, and Egypt stands to benefit from the Protocol's implementation.

Egypt's carbon emissions per capita are significantly lower than most developed countries. At a rate of 0.5 metric tons of carbon emitted per person in 1998, Egypt's emissions were substantially below the U.S. value of 5.5 metric tons of carbon per capita. Petroleum accounts for 72% of carbon emissions in Egypt, natural gas 25%, and the coal is responsible for 3%. The increasing reliance on natural gas should work to lower carbon emissions. An historical summary of carbon dioxide emission in Egypt is shown in Table VII [17].

TABLE VII
FOSSIL FUEL-RELATED CARBON DIOXIDE EMISSION IN EGYPT, 1990-2000 (IN MILLIONS OF METRIC TONS OF CARBON [17]

(a)	1990	1991	1992	1993	1994	1995
CO_2 from coal	1.02	0.81	0.72	0.87	0.83	0.54
CO_2 from natural gas	4.90	6.01	6.39	6.66	6.98	7.19
CO_2 from petroleum	19.61	19.18	18.59	18.75	19.3	19.09
Total CO_2 from all fossil fuel	**25.54**	**25.99**	**25.69**	**26.28**	**27.10**	**26.82**
(b)	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
CO_2 from coal	0.54	0.95	1.02	1.11	1.12	1.13
CO_2 from natural gas	7.19	7.68	7.71	7.77	8.27	10.17
CO_2 from petroleum	19.09	20.75	21.89	22.86	22.28	21.88
Total CO_2 from all fossil fuel	**26.82**	**29.38**	**30.62**	**31.74**	**31.67**	**33.18**

B. Power Plant Air Pollutant Emissions Factors

Emission factors are used for a variety of purposes at the energy commission; electric system simulation modeling (modeling; mass-of-emission per unit-energy output-input or time), power plant licensing (siting; units of mass-of-emission per unit time) and other related applications. Mainly, emission levels for most emission types depend upon the type of fuel that is being consumed. Burning coal will release more CO_2 and SO_2 into the atmosphere than will burning natural gas for example, NO_x and VOC_s are much depended on combustion sources and technology type or equipment used than other emission types. Modeling work involves forecasting and back casting to evaluate the effects on emissions (primarily NO_x and SO_x) of various strategies or trends in electricity demand and its supply by generation industry [18].

TABLE VIII
THE EMISSION FACTOR FOR NATURAL GAS [18]

Emission Type	Emission Factor		
	lbs. per million Btu	**lbs. per 1000 cf^3**	**lbs. per Therm**
CO_2	117.080	119.423	11.708
NOx	0.150	0.153	0.015
N_2O	0.00216	0.00220	0.00022
SO2	0.00060	0.00061	0.00006
PM10	0.00186	0.00190	0.000186
VOC	0.00539	0.00550	0.000539
CO	0.0240	0.0245	0.0024
Hg	0/negligible	0/negligible	0/negligible

V. ENERGY AND CARBON INTENSITY

Egypt's energy-intensive oil extraction has resulted in a high level of energy intensity compared to Western Europe, yet squarely in the middle of the oil-producing Middle East region. Egypt's 1998 energy intensity was 31,000 Btu/$1990, which is significantly higher than countries such as Germany (7,300 Btu/$1990) and France (7,400 Btu/$1990), but right on par for the region: Egypt's energy intensity level is slightly higher than Iran's (26,900 Btu/$990) and Libya's (22,600 Btu/$1990), but below Saudi Arabia's (35,100 Btu/$1990). In comparison, U.S. energy intensity in 1998 was 13,400 Btu/$1990 [19].

Egypt's energy intensity should fall as the country implements more energy efficiency and conservation programs. Since 1998, the U.S. Agency for International Development's "Energy Conservation and Environment Program," (ECEP) has provided technical assistance and $19 million plus worth of equipment to over 150 industrial and commercial facilities toward improving energy efficiency in Egypt. The project has overseen the completion of over 30 demonstrations of different energy efficient technologies in industries, resulting in annual energy cost reductions for participating companies of around $14 million. ECEP, which now is in its final phase focusing on sustainability, also estimates that it avoided emissions of thousands of tons of greenhouse gases, including 6,000 tons of carbon monoxide (a 48% reduction), 3,000 tons of nitrogen (a 22% reduction), 17,000 tons of sulfur dioxide (a 28% reduction), and 700,000 tons of carbon dioxide (a 7% reduction) [20].

The reduction in carbon emissions growth, combined with a shift of Egypt's energy mix to more natural gas, should help reduce the country's carbon intensity in coming years. In 1998, Egypt's carbon intensity level was 0.53 metric tons of carbon/thousand U$1990. Although this level compares favorably with other countries in the region--Saudi Arabia's carbon intensity was also 0.53, while Iran's was 0.47, and Libya's was 0.44--it is still several times higher than European averages: France's 1998 energy intensity was 0.08, while Germany's was 0.12. As Egypt begins to use more natural gas

and hydropower, its carbon intensity should fall, perhaps coming closer to the level of the United States (0.21 metric tons of carbon/thousand $1990) or Turkey (0.23) [20].

VI. Conclusion

Egypt's energy power system is concern to estimate factors relevant to quantification impact of fuel combustion. The applied US EPA method of emission factors predict emission loads on environment for assessment energy efficiency to extend control programs in Egypt's power plants.

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References

[1] Egypt Energy Policy Laws and Regulations Handbook, Volume (1), Strategic Information and Developments, International Business Publication, Washington DC USA – Egypt, 2015.
[2] Global Trade Information Services, Egypt's Central Agency for Public Mobilization and Statistics, accessed May 2015.
[3] Arab Republic of Egypt Ministry of Petroleum last checked online at http://www.petroleum.gov.eg/en/Pages/default.aspx.
[4] U.S. Energy Information Administration, "Country Analysis Brief: Egypt," 2014.
[5] Business Monitor International (BMI) Research, "*Egypt Power Report Q2 2015"* and Ventures Onsite, "Orascom, IPIC to build 3000 MW coal fired power plant in Egypt, Red Sea coast," March 17. 2015.
[6] Reuters, "Egypt to begin LNG imports as floating terminal arrives," April 2, 2015.
[7] Batsheva Sobelman, "Israel: Egypt Gas Pipeline Explosion Raises Energy Concerns," Los Angeles Times, February 5, 2011.
[8] Financial Time internet site http accessed in March 19, 2016 at: http//www.ft.com/cms/s/0/1d1e00fe-28a2-11e5-8db8-c033edba8a6e.html#axzz4CG8sT4ZI
[9] U.S. EPA E-GRID2002 Version 1.0 Released January 2003. (http://www.epa.gov/airmarkets/egrid/index.html)
[10] Nuclear Threat Initiative, "*Egypt country profile*", accessed May 2015.
[11] Company Brief - Russia and Egypt sign nuclear power plant deal, February 16, 2015.
[12] Middle East Economic Survey (MEES), "Egypt Outlines 2015-16 Budget Guidelines," (March 27, 2015), volume 58, issue 13
[13] Ministry of Electricity and Energy, New and Renewable Energy Authority (NREA) Annual Report 2012/ 2013
[14] U.S. DOE / EIA 1605 Voluntary Reporting of Greenhouse Gases Appendix G. Adjusted Electricity Emission Factors by State, February, 2016
[15] Lloyd's List Intelligence (APEX), accessed April 2015
[16] WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide - Global update 2005 - Summary of risk assessment, World Health Organization Regional Office, (WHO Regional Publications, European Series No. 91), 2005.
[17] EPA's National Emission Trends (NET) database, October 2001 version, EPA Office of Air and Radiation – AIRDATA website (http://www.epa.gov/air/data/geosel.html)
[18] U.S. EPA Office of Air Quality Planning & Standards, AP - 42 Emission Factors Supplement Documents, Update 2002, Website (http://www.epa.gov/ttn/chief/ap42/ap42supp.html)
[19] U.S. National Renewable Energy Laboratory, "*Concentrating Solar Power Projects*", accessed May 2015.
[20] Energy Intelligence Group, "Egypt Makes Aggressive pitch to IOCs to help sustain oil output," (May 20, 2014), page 3.