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The Current Situation and Perspectives of Electricity Demand and Estimation of Carbon Dioxide Emissions and Efficiency

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***Abstract*—**This article presents a current and future energy situation in Libya. The electric power efficiency and operating hours in power plants are evaluated from 2005 to 2010. Carbon dioxide emissions in most of power plants are estimated. In 2005, the efficiency of steam power plants achieved a range of 20% to 28%. While, the gas turbine power plants efficiency ranged between 9% and 25%, this can be considered as low efficiency. However, the efficiency improvement has clearly observed in some power plants from 2008 to 2010, especially in the power plant of North Benghazi and west Tripoli. In fact, these power plants have modified to combine cycle. The efficiency of North Benghazi power plant has increased from 25% to 46.6%, while in Tripoli it is increased from 22% to 34%. On the other hand, the efficiency improvement is not observed in the gas turbine power plants. When compared to the quantity of fuel used, the carbon dioxide emissions resulting from electricity generation plants were very high. Finally, an estimation of the energy demand has been done to the maximum load and the annual load factor (i.e., the ratio between the output power and installed power).

***Keywords*—**Power plant, Efficiency improvement, Carbon dioxide Emissions.

I. Introduction

TODAY global warming has become the subject of considerable public debate and the concern over the potential effect of CO_2 emissions from fossil fuel power plants contribution to global warming, which is now a key issue for the future of power generation worldwide. Gas and oil playa key role in ensuring a sustainable future for Libya as this energy source is used for electricity to the end of 2010, therefore any strategy to reduce CO_2 emission levels must address the efficiency of power stations based electricity in the main cities and the province centers.

This part of the study deals with the assessment of energy efficiency in the electric power stations in Libya in the context of sustainable development and greenhouse gas (GHG) mitigation strategies for steam power plants, although not specifically pointed the importance of demand-side.

II. Libya Energy Supply and Demand

A. The Country

The Libyan territories are located extensively between 18°45 and 32° 57 North. The Libyan desert covers the entire range of Libyan longitude 11° 44' to 23° 58'E and a latitude range of 24° 17' through to 30° 3'N.

Libyan lands consist of a plateau which is an extension of the African plateau and of coast area on the Mediterranean. Total area is 17,590,540 km^2 and length ofbordersis4383 km, and a coast of around 2000 km length on the Mediterranean.

Libya has a population of 6 million, mostly located along a thin strip along the coastline. The annual population growth is 2.5%. Population intensity is high in the northern coastal area with average of 50 capita/km^2 when in the south is 1capita/km2 [1].

B. Hydrocarbon Supply and Export

According to studies and research work Libya is one of the countries producing and exporting Oil and Natural Gas, the stock guarantee of the energy demand to long term as shown in the Table I below [1]. Fig. 1 shows Libya location map-oil and natural gas.

TABLE I
Statistic of Hydrocarbon Supply and Export

Statistic	Amount
Proven Oil Reserves (2007E)	41.5 Gbbl (6.60×109 m^3)
Oil Production	1.8 Mb/d.(290×103 m^3/d) (95% crude)
Oil Consumption	284,000 barrels per d. (45,200 m^3/d)
Net Oil Exports	1.5 million barrels / d (240×103 m^3/d)
Crude Oil Distillation Capacity	378 k bbl/d (60.1×103 m3/d)
Proven Natural Gas Reserves	52.7×1012 cu ft (1.49×1012 m^3)
Natural Gas Production	399×109 cu ft (1.13×1010 m^3)
Natural Gas consumption	206×109 cu ft (5.8×109 m^3)

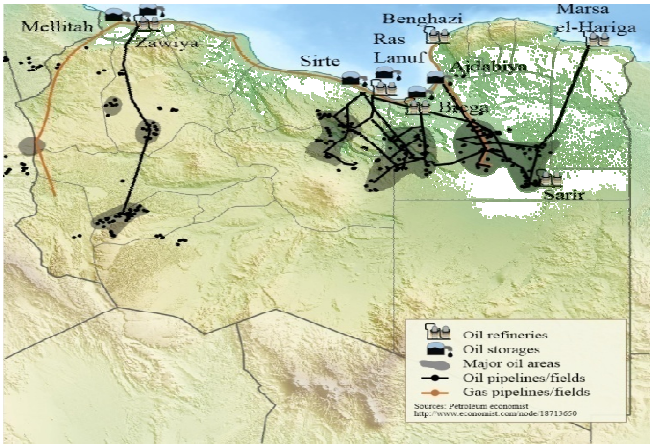

Fig. 1 Libya Location Map-Oil &Gas 2011

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C. Current Situation of Energy Generation in Libya

The General Electric Company of Libya (GECOL) is totally government owned and is responsible for the operation of the entire power sector in the country. All power plants in Libya have been installed by GECOL since it was established in 1984. Fig. 2 shows the location of the installed power plants in Libya.

Libya has a total installed power generation capacity of 6.3GW. The national electric grid consists of an ultra-high voltage capacity of 400kV with a total circuit length of 442km, and a high voltage transmission level of 220kV with a total circuit length 13,677km. The sub transmission voltage level is 66kV, with a total circuit length of 13,973km. The distribution network's voltage level is 30kV with a total circuit length of 6,583km [2].

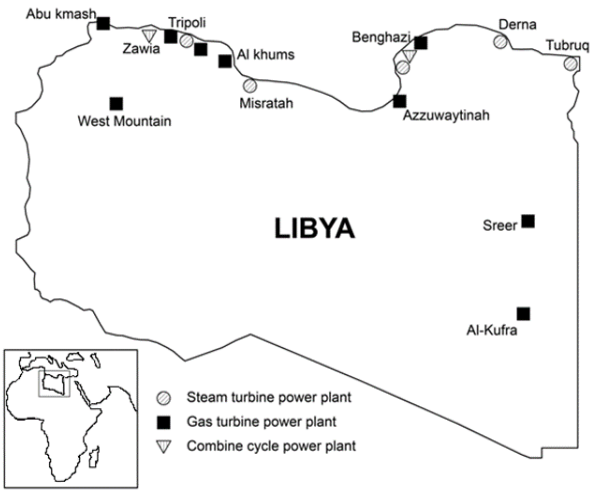

Fig. 2 Installed power plants in Libya

The electric energy production in Libya is provided by gas-turbine, steam-turbine and combined cycle power plants, which use heavy oil, light oil and natural gas respectively. Gas turbine and combined cycle power plants have a share of 30% and 20% respectively in total installed power capacity; the share of steam power plants is 50% in total. Furthermore, some small diesel power plants are also used to contribute to the energy supply, especially in remote areas [2], [3].

The electrical energy consumption per capita has increased from 2276kWh in 2000 to 4000kWh in 2008. The electric energy consumption per capita in UK was 6055kWh in 2008. In contrast the world-average consumption for the year 2008 was 2876kWh [4].

The national electric network is accessible to 99% of the population. Most of the electric network is concentrated on the coast, where most of the inhabitants live [5].

Fossil fuel-fired thermal power plants are used to meet all of the electrical energy demand. In Libya all of the electrical energy demand comes from fossil-fuelled power plants. Libya's power demand is growing rapidly (around 6%-8% annually) and is therefore expected to reach 8GW by 2015 (see Fig. 3).

The growth in electricity power demand will out-strip production capacity and so GECOL plans to build new combined cycle and steam cycle power plants. As well as increasing generation capacity, GECOL also plans to upgrade and expand the country's power transmission grid [5], [6].

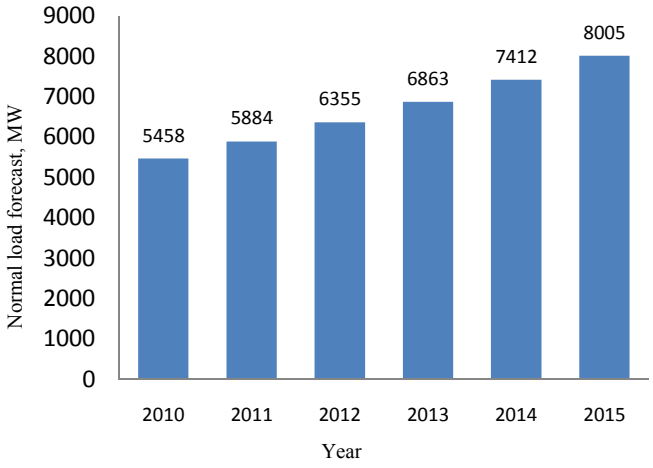

Fig. 3 Libyan peak load growth to 2015

III. Energy Use by Fuel Type

Overall consumption of energy is increased from 2007, 2008 to 2009 by 11.6%, 11%, 6% respectively. Total energy use rises from 22,450 GWh in 2005 to 25,415 GWh in 2007 to 28,666 GWh in 2008 then to 30374 GWh in 2009 (see Fig. 4).

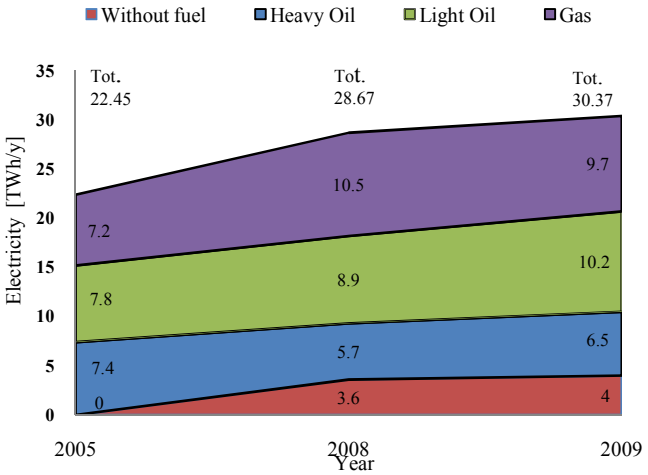

Fig. 4 Development of electricity (TWh) in Libya

A. Energy Produced According to Fuel Type

Liquids and Gas are expected to remain the main energy source in Libya, with mitigation strategies for steam power plants. The liquids consumption (Heavy fuel-Light fuel) decreased from 68% in 2005 (33%HF, 35%LF) to 52% in 2010 (18% Heave Fuel, 34% Light Fuel).

The Natural gas consumption increases from 32% in 2005 to 37% in 2010, natural gas stay a key energy source for electricity generation in Libya in the future (see Fig. 5).

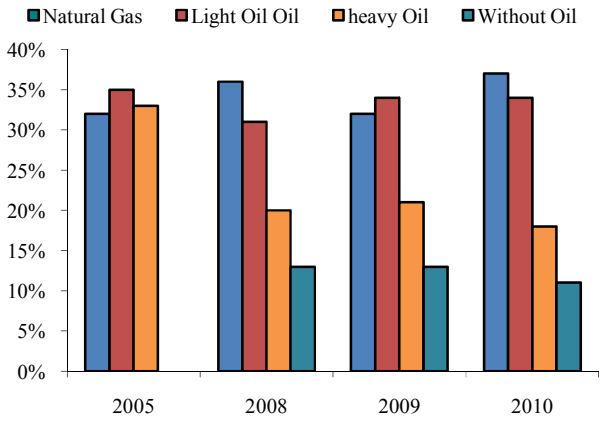

Fig. 5 Development of electricity produced according to fuel used

IV. Energy Demand Outlook and Balance of Demand with Available Power Capacity

Overall consumption of the energy in Libya is projected to increase by (21%, 16%, 19%, 8%, 6%) foreseen respectively, from 2010 to 2014, with use rises from 6706 MW in 2010 to 11298 MW in 2014, while from 2015 to 2020 increase by 3% yearly, to arrive 13714 MW in 2020 [7].

A. Maximum Load and Annual Load Factor

The load factor is calculated for the period from 2007 to 2020. One can see from Fig. 8, that the load factor (i.e., the ratio between the output power and the installed power) was low in the time zone from 2007-2010. It has a mean value of 1.2 with a percentage difference of about 11% due to the quick growth of the Peak load without the corresponding growth of the produced energy. At the beginning of 2013, this value will be improved to 1.6 with a percentage difference of 37%. This percentage can be considered as good when compared with the most electrical networks in the world. They take into consideration a safe rate of 20%-40% from the maximum loading by the long time planning to secure the electrical energy demand in case of the programmed maintenance for any working units or its emergency recovery or by the sudden increase of the demand, especially during the maximum loading hours of the electrical network [8].

B. Balance of Demand with Available Power Capacity

In the last years, the consumption of the electrical energy in Libya has increased, especially due to the development of all life sections as a result of the quick economic growth and the improvement of the living standard. So, it is necessary to study the electrical systems for the future. TheGECOL began to build new power plants which produce 5416 MW. It is also investigated to build other plants with the capacity of 4520 MW (see Figs. 7, 8 and Table II) [8].

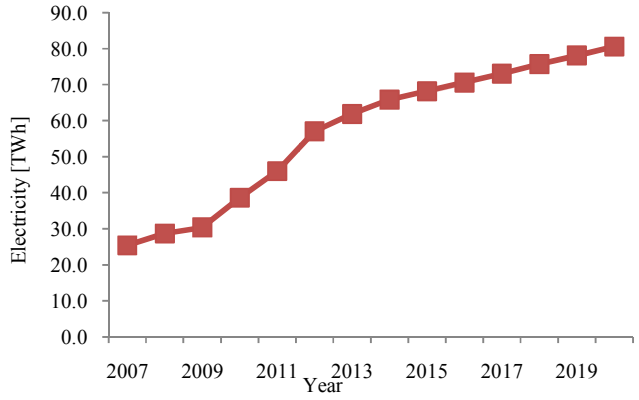

Fig. 6 Electricity demand outlook

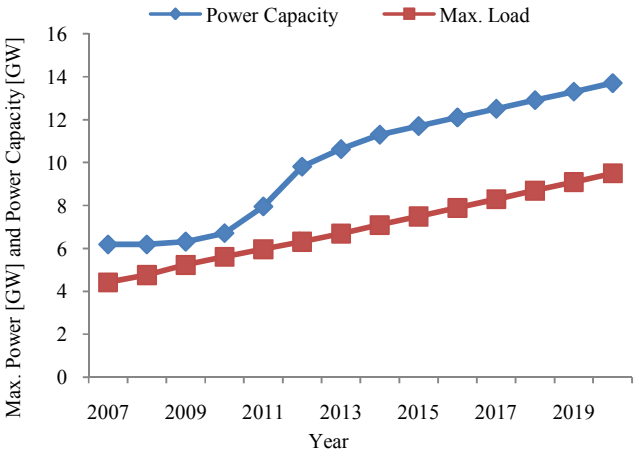

Fig. 7 Power capacity demand outlook

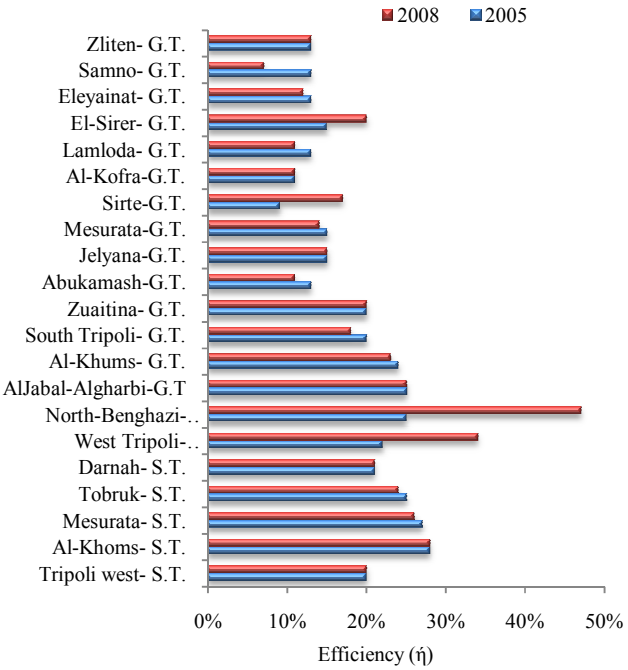

Fig. 8 Efficiency of power plants in Libya

TABLE II
THE BALANCE OF DEMAND WITH AVAILABLE POWER CAPACITY IN LIBYA 2020

Under construction and the contracted upon			
Type of generation	**Units**	**MW**	**Start-Up**
(S.T.P.S)-Alkhalij	4ST	1400	2010
Gas T. power station			
Expansion of W.iljabal	2GT	250	2010
South of Elserer	3GT	684	2011
West of Tripoli	2GT	400	2012
Sabha	3GT	685	2012
Combine cycle			
Mesurata1	2GT	456	2010
	1ST	200	2011
North of Benghazi-2	2GT	456	2010
	1ST	200	2011
Al Zuyaitina-1	2GT	456	2010
	1ST	230	2013
Power (MW)at 2020		5416	
Suggested			
(S.T.P.S)KhalijBumba	3ST	1050	2015
West of Benghazi	4ST	1400	2015
combine Meleta-1	2GT	460	2012
	1ST	230	2013
Meleta-2	2GT	460	2012
	1ST	230	2013
East of Tripoli	2GT	460	2012
	1ST	230	2014
Power (MW)at 2020		4520	

V. CALCULATION THE EFFICIENCY OF POWER STATION

The efficiency of a power station is defined as follows [9]:

$$\eta = \frac{\text{Energy produced (MWh)}}{\text{Fuel.heat (MWh)}} \quad (\%) \tag{1}$$

A. Analysis of the Results of the Stations Efficiency

The efficiency for all power stations in Libya in 2005 and 2008 were calculated. As it is shown from Fig. 9 in year 2005, the efficiency of the steam power plants achieved the range of 20% to 28% and the best one was Al-Khums power plant which reached in limit of 28%. However, for the gas turbine power plants had efficiency range from 9% to 25%, which can be relatively considered as low efficiency.

While in the year 2008, the efficiency improvement has been clearly observed in some power plants, especially in the power plants of north Benghazi and west Tripoli. In fact, these power plants have been modified to combine cycle. For the power plant of north Benghazi, the efficiency was improved from 25% to 46.6% while for the power plant of west Tripoli, the efficiency was improved from 22% to 34%. On the other hand, the efficiency improvement was not observed in the gas turbinate power plants [9], [10].

Another important improvement of the efficiency can be carried out through the examining and improving of the power plants properties, including the use of gas fuel instead of heavy fuel because Libya produces large quantities of gas and have a huge inventory.

VI. CALCULATION OF THE HOURS OF OPERATING OF THE POWER STATIONS

The equation below can be used to calculate the operating number of hours of the power station [9], [11]:

$$h = \frac{\text{Electricity (MWh)}}{\text{Power Capacity (MW)}} \tag{2}$$

It equals the load factor (h/y) [9].

TABLE III
ELECTRIC POWER PLANTS IN LIBYA (CAPACITY AND OPERATING HOURS)

Name of Power stations & Start-time	**Power MW**	**Operation hours**
Tripoli west (1976)	500	2212
Khoms steam (1982)	480	4999
Musrata steel (1990)	507	4810
Tubruk steam (1985)	130	4858
Derna steam (1985)	130	5315
Zauya station (00-05-07)	1440	4675
North Beng-zi(95-02-07)	915	5230
Mountain West (05-06)	624	5176
Khums Gas (1995)	600	4810
South Tripoli (1994)	500	3646
Zuyitina Gas (1994)	200	4290
Bokhamach (1982)	45	3288
Khofra station (1982)	50	2860
Another Power Plants	75	

VII. DETERMINATION OF CARBON DIOXIDE EMISSIONS IN POWER PLANTS IN LIBYA

In the course of the various processes of electric energy generation from the sources, the carbon contained in the fuel is completely converted into carbon dioxide through the reaction with the oxygen contained in the air.

Therefore to various fuel, they are correspond various (CO_2 factor), that they represent how much CO_2 form the complete conversion of a fuel unit (Table IV).

TABLE IV
CO_2 EMISSIONS FOR VARIOUS FUELS

Fuel	**Factor -CO_2(kg/MWh)**
Natural Gas	205
Oil	255
Coal	340
Biomasses	0

From the CO_2 factor it can be calculate the approximate emissions of a system. Simply dividend this value of the efficiency, simply by dividing this value for energy efficiency, according to the following expression [9], [11]:

$$ECO_2 = FCO_2 / E_{ff} \tag{3}$$

where:
Eff = Electrical Efficiency,
ECO_2 = Emissions (kg/MWhe),
FCO_2 = CO_2 factor of the fuel (kg/MWht).

From the obtained data of the GECOL of electricity generation, the CO2- Emissions for all power stations in Libya in 2005 and 2008 were calculated, as shows in Figs. 9-11. The total emissions of CO2 in years 2005 and 2008 were 21.9*106 t/y and 22.1*106 t/y respectively. This shows that with very small increase in CO2-Emissions, but a rapid increase in the electricity generation was achieved from 22.45 TWh to 28.666 TWh in years 2005 - 2008 respectively.

For the steam power stations, Fig. 10 shows that the CO2emissions decreased from 42% in 2005 to 31% in 2008. The improvement of North Benghazi Combine cycle and West Tripoli Combine cycle resulted in the stability of CO_2-Emissions. It was about 25%, with significantly increased electricity generation from 3 TWh in 2005 to 4.7 TWh in 2008 and from 3.6 TWh in 2005 to 6.7 TWh in 2008 respectively.

This indicates strategy of (GECOL) in reducing whenever possible from CO_2-Emissions, with the mitigation strategies for steam power plants and expansion of electricity generation from combine cycle and gas turbine power stations.

Fig. 9 shows CO_2-Emissions outlook up to 2020, which was calculated from the results of the electricity demand outlook with improvement of the efficiency.

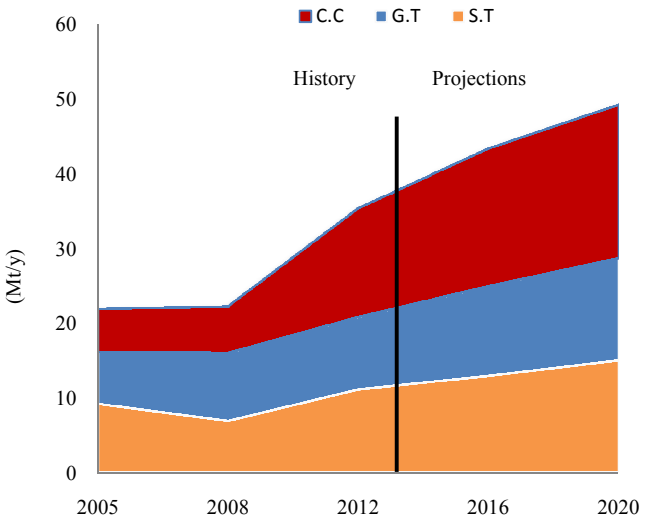

Fig. 9 CO_2 Emissions outlook in Libya

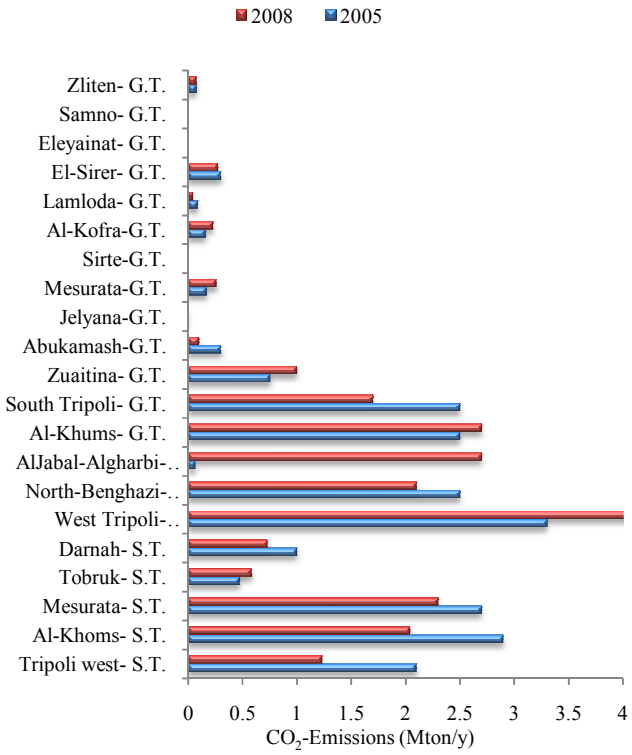

Fig. 10 CO_2Emissions in Libya

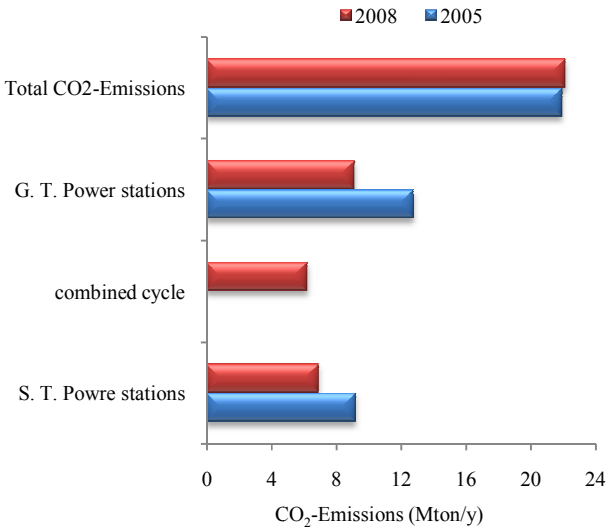

Fig. 11 CO_2 Emission Libya according to production techniques

VIII. Conclusions

The electric power efficiency in power stations in Libya is very low, except at North Benghazi station, which has a good efficiency of 47%. It was noticed that the general electricity company of Libya (GECOL) is concentrated its work on the decrease of the steam power stations. The current and the future quantities of CO_2-Emissions due to the fuel used in the electricity generation in Libya were studied. It could be advised to:

- Improve the efficiency of the most power stations, specially the steam power plants.
- Use the light fuel and the natural gas instead of using the heavy fuel.
- Depend on the renewable energy to cover a part of the energy demand in the future, at least with 15%. Libya has a huge amount of solar energy, especially in the southern zone. Moreover the costal sites have medium wind speeds.

From these conclusions, large quantities of CO_2-Emissions can be decreased, high fuel percentage can be saved, and respectively the resulting kWh cost can be decreased.

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