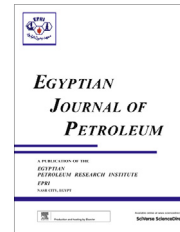




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FULL LENGTH ARTICLE

Liquid fuel resources and prospects for ligno-cellulosic ethanol: An Egyptian case study

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Abstract Fossil fuels (oil, natural gas and coal) presently represent about 90% of the world's total commercial primary energy demand. Yet, they are depletable sources of energy. Growth in the production of easily accessible oil, the main source of high energy liquid transportation fuels, will not match the projected rate of demand growth, especially in developing countries. In the transport sector, today, the only alternative to non-sustainable fossil fuels is biofuels that are produced from biomass, a stored environmentally neutral solar energy. These fuels are compatible with current vehicles and blendable with conventional fuels. Moreover, they share the long-established distribution infrastructure with little, if any, modification of equipment. The main biofuels presently in commercial production are bioethanol and biodiesel. Industrial countries started production of the 1st generation bioethanol and biodiesel from food products (grains and edible oil) since a few decades and these fuels are currently available at petrol stations. Second generation bioethanol from ligno-cellulosic materials is on the research, pilot and/or demonstration stage. This paper discusses the current situation regarding liquid fuels in Egypt which are experiencing imbalance between total production and demand for gasoline and diesel fuels. The quantified need for nonconventional sources is presented. Based on a thorough assessment of current and prospective generated agriculture residues as distributed over the political areas, mapping of the number and capacity of plants to be installed for production of bioethanol from available residues namely rice straw, sugar cane residues and cotton stalks has been developed. Annual capacities of 3000, 10,000 and 20,000 tons ethanol/year until year 2021 have been proposed. Capital and operating requirements and economic indicators have been estimated. It has been concluded that at current price of ethanol of about \$0.6/kg, the simple rate of return on investments is about 2.8%, 11% and 16% for the 3000, 10,000 and 20,000 tons annual capacity ethanol respectively.

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1. Introduction

1.1. Background

The main energy sources worldwide are oil, natural gas, coal and hydro-power. According to recent statistics there is an



annual decrease worldwide in the major sources of fossil fuels. With the depletion of these fuels, efforts are being directed to revert to renewable sources such as solar, wind and biomass. Specifically for the transport sector, which is one of the most important sectors that have direct impact on the economy, candidate fuels comprise biofuels (liquid or gaseous), hydrogen and fuel cells, battery electric and hybrid electric vehicles with plug-in.

Egypt's proven oil reserves stand at 4.4 billion barrels, an increase from 2010 reserve estimates of 3.7 billion barrels. Egyptian oil production comes from five main areas: primarily the Gulf of Suez [1]. Natural gas production exceeds 60 billion m³ per year as for the same year. Oil and gas account for about 95% of total commercial energy productions, while hydropower represents the remaining 5%. Egypt has also limited coal reserves estimated at about 27 MT [2].

Egypt primary energy demand is expected to grow from 62 Mtoe in 2006 to approximately 88 Mtoe in 2020 and 109 Mtoe in 2030 at an average rate of 2.6% per year [3].

In addition to its commercial energy resources, Egypt has potential in renewable resources including, solar, wind and biomass such as fuel wood, agricultural wastes and dried animal dung, which are used in some rural areas to meet part of the energy demand.

In the transport sector, today, the only alternative to non-sustainable fossil fuels is biofuels that are produced from biomass. These fuels are compatible with current vehicles and blendable with conventional fuels. Moreover, they share the long-established distribution infrastructure with little, if any, modification of equipment. The main biofuels presently in commercial production are bioethanol and biodiesel. Industrial countries started production of the 1st generation bioethanol and biodiesel from food products (grains and edible oil) since a few decades and these fuels are currently available at petrol stations. Second generation bioethanol from ligno-cellulosic materials under research, pilot and/or demonstration stage.

This paper is concerned with the prospects for the production of ethanol from ligno-cellulosic materials. Current and prospective energy situation are first highlighted. The current situation regarding biofuel production is briefly outlined. Prospects for the production of ethanol from agricultural residues are then presented.

1.2. World energy consumption for transportation (Mtoe)

Transportation is one of the major energy consuming sectors worldwide. Current and projected world energy consumption for this sector in major regions is presented in Table 1. Over the next 25 years, world demand for liquid fuels is projected to increase more rapidly in the transportation sector than in any other end-use sector. In the IEO2009 reference case, the

transportation share of total liquid fuel consumption increases from 51% in 2006 to 56% in 2030. Over the 2006–2030 period, transportation accounts for nearly 80% of the total increase in world liquid consumption.

1.3. Historical and projected trends for energy consumption and demand for various applications in Egypt

Table 2 presents the evolution of energy sectoral consumption (Mtoe) share, and growth rate in the period 95/96 – 2004/2005 [2] while Table 3 compiles the historical and projected energy demand among the various sectors as projected by the International Energy Agency [4].

In Egypt, there were about 38 vehicles per 1000 capita in 2002; projections for 2030 reached 142 vehicles per 1000 capita with a 6% yearly increase. As of 2007, the total number of vehicles in Egypt is in the order of 3 million of which more than 2 million are passenger cars. The car stock is expected to grow twice as rapidly as per-capita income [5] which has been observed in all industrialized countries during the 20th century.

Thus, transport energy demand poses a particular burden on Egypt's oil demand in the future as public transport is relatively underdeveloped and capital-intensive investments in public transport are difficult to realize.

1.4. Historical and estimated prices for crude oil

Fig. 1 provides the annual average prices calculated from weekly Egypt Suez blend spot price (dollar/barrel) published by Energy Information Administration for the period 1971–2009 [6].

1.5. Subsidies for petroleum products and natural gas

The energy sector is strongly subsidized by Governmental funds. Figs. 2 and 3 depict the petroleum products and natural gas subsidies respectively as a proportion of opportunity cost prices for the period 2007/2008–2010/2011 [7]. Energy subsidies, substantially from Governmental funds, exceeded 60 billion in 2007/2008 [7].

2. Current trends for the production/research of biofuels

The three major biofuels currently under consideration are ligno-cellulosic ethanol, biodiesel from oil resources and biooil from ligno-cellulosic materials.

2.1. International level

Extensive R&D and investments to face the decrease of fossil fuels' resources and the fluctuations in oil prices, which has

Table 1 World energy consumption in transportation Mtoe.^a

Region	2006	2010	2015	2020	2025	2030	Average annual growth rate
OECD	1390	1330	1368	1411	1450	1500	0.3
Non-OECD	821	974	1099	1253	1404	1565	2.7
Total world	2211	2304	2467	2664	2854	3065	1.4

^a Source International Energy Outlook 2009 (in quadrillion BTU).

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