Recent Trends in Emerging Transportation Fuels and Energy Consumption

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Abstract. Several recent trends indicate current developments in energy and transportation fuels. World trade in biofuels is developing in ethanol, wood chips, and vegetable oil / biodiesel with some countries being exporters and some importers. New drilling techniques, including deep-ocean drilling, extended horizontal drilling, and hydraulic fracturing, are bringing new sources of natural gas and crude oil to market. Resulting increases in natural gas availability have also opened new opportunities in gas to liquids and combined gas, coal, and/or biomass to liquids. The energy landscape is currently undergoing unprecedented change, due to world economics and growth, energy prices, local preferences, and concern about regional air pollution and global warming. Most likely, all options will need to be developed to supply future energy needs, and the energy industry will remain in flux for the foreseeable future.

1 Introduction

Abundance of energy can be improved both by developing new sources of fuel and by improving efficiency of energy utilization, although we really need to pursue both paths to improve energy accessibility in the future. Currently, 2.7 billion people or 38% of the world's population do not have access to modern cooking fuel and depend on wood or dung and 1.4 billion people or 20% do not have access to electricity. It is estimated that correcting these deficiencies will require an investment of $36 billion dollars annually through 2030 [1]. In growing economies, energy use and economic growth are strongly linked, but energy use generally grows at a lower rate due to increased access to modern fuels and adaptation of modern, more efficient technology [2]. Reducing environmental impacts of increased energy consumption such as global warming or regional emissions will require improved technology, renewable fuels, and CO2 reuse or sequestration. The increase in energy utilization will probably result in increased transportation fuel diversity as fuels are shaped by availability of local resources, world trade, and governmental, environmental, and economic policies. The purpose of this paper is to outline some of the recently emerging trends, but not to suggest winners. This paper will focus on liquid transportation fuels, which provide the highest energy density and best match with existing vehicles and infrastructure. Data is

taken from a variety of US, European, and other sources without an attempt to normalize or combine the various data sources.

Liquid transportation fuels can be derived from conventional hydrocarbon resources (crude oil), unconventional hydrocarbon resources (oil sands or oil shale), and biological feedstocks through a variety of biochemical or thermo chemical processes, or by converting natural gas or coal to liquids. The world currently consumes about 90.5 million barrels of crude oil per day (International Energy Agency).

2 Biofuels

The production of biofuels has grown significantly in the last 10 years, driven by environmental concerns, cost incentives, and high oil prices, as shown in Figure 1 [3]. Most of this growth has been in ethanol, mainly in the USA and Brazil. For liquid transportation fuels, biofuels production is only a small percentage of petroleum production, but could grow to 27% of transportation fuels by 2050 [3]. Feedstocks for new biofuels include cane, algae, other cellulosic biomass, energy crops, woody biomass, vegetable oil, animal related waste, and CO2. Conversion processes include biochemical, thermo chemical, esterification, and pyrolysis and related upgrading. This growth is dependent on economically available feedstocks and policies that support investment in the new industries and infrastructure.

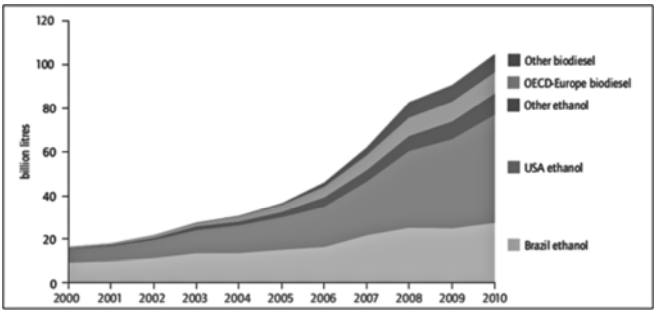

Fig. 1. Growth of biofuels in time period 2000 to 2010 [3]

The US EPA has released a Renewable Fuel Standard which requires increasing amounts of biofuels production and consumption each year through 2022, with targets of 9 billion gallons in 2008 and a gradual increase to 36 billion gallons in 2022 with a cap on the contribution of starch based ethanol at 15 billion gallons. Volume requirements for advanced biofuels (non-starch based) can be adjusted yearly based on evaluation of technology and availability [4]. It is expected that the majority of the increase beyond 15 billion gallons will be composed of cellulosic ethanol and cane derived ethanol.

In the US, ethanol can be used as a 10% blend in gasoline (E10), as an intermediate blend (E15, not currently being sold), and as E85, which actually ranges from E68 to E83, per ASTM D5798. Without the use of intermediate blends and a large increase in flex fuel vehicles, ethanol use will reach a limitation commonly known as the 'blend wall' [5]. Currently of the 840 to 880 thousand barrels of ethanol blended per day in the US, only about 5.6 thousand barrels per day are used for E85 and the remainder is blended at up to 10% [6]. As an example of the changes needed to achieve full ethanol utilization in 2022, it has been estimated that the number of flex fuel vehicles will have to increase from about 8 million presently to 100 million, with the number of pumps offering E85 increasing from about 2,000 to 65,000.

Brazil is the second largest producer of ethanol behind the USA, is the world leader in ethanol exports, and is also a large consumer of ethanol. All gasoline in Brazil contains 20 to 25% ethanol and over half of the vehicles are flex fuel and can run on 100% ethanol or any ethanol-gasoline blend. Ethanol production is in the range of 4000 to 4500 thousand barrels per day. Brazil produces and consumes about 2.5 to 3.0 million barrels of crude oil per day, but must export heavy crude and import both light crude and finished fuels in order to match refining capability. Newly discovered deep off-shore oil fields, known as the 'pre-salt zone', contain up to 8.3 billion barrels of oil equivalent and are being developed for 10,000 barrels per day production in 2010 and 4 million barrels per day by 2020. The depth of these reservoirs is about 18,000 feet and presents significant technical hurtles to achieve this production level [7]. Development of these oil reservoirs will make Brazil a net energy exporter and will also allow for future economic growth. These oil deposits are an example of resources which can be developed with improved drilling techniques.

As can be seen in Figure 2, there is existing world trade in biofuels, mainly for ethanol, biodiesel and vegetable oil, and for wood pellets [3].

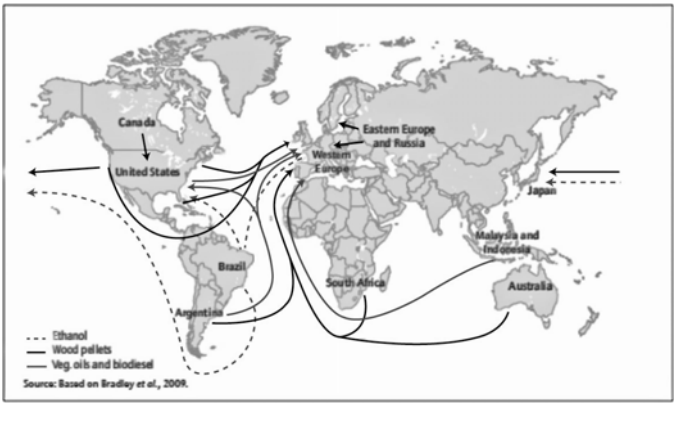

Fig. 2. Existing world trade in biofuels [3]

3 Natural Gas

Natural gas is not a liquid transportation fuel, but can be used in compressed form to fuel fleets, in liquefied form to fuel large engines or power plants, and can be converted to liquid fuels by thermo chemical processes. The proven reserves of natural gas have increased significantly in recent years due to wider use of hydraulic fracturing or *fracking* to shale based deposits containing tightly bound natural gas. Fracking has actually been practiced since 1947 and in North America over 1,000,000 wells have been hydraulically fractured, representing 95% of all gas wells and 43% of all oil wells [8]. Recent application to tightly bound shale assets, combined with improved horizontal drilling techniques, has resulted in a boom in natural gas production and producible reserves in the United States [8]. Much of the controversy related to fracking has resulted in application of these techniques to areas not accustom to energy production and to a rapid growth in the number of wells being drilled. Natural gas asset estimates have increased by a factor of 2 to 3 times in North America and currently the United States is the largest natural gas producer in the world, followed by Russia and Canada. In the US, development of this energy resource is being driven by promises of energy independence and job creation, although other parts of the world are taking a more cautious approach. Examples of recent news headlines include:

- Oil shale resources could help spur economic growth, 204,500 jobs in Ohio, $12 billion economic benefits by 2015 [9].
- Opening of Alaskan National Wildlife refuge to drilling could create hundreds of thousands of jobs [10].
- Study shows that 45% of NY voters support Marcellus drilling [11].
- France to keep fracking ban to protect environment, Sarkozy says [12].Oil shale resources could help spur economic growth, 204,500 jobs in Ohio, $12 billion economic benefits by 2015 [9].
- Opening of Alaskan National Wildlife refuge to drilling could create hundreds of thousands of jobs [10].

The natural gas boom has resulted in wide global price differences for natural gas, due to lack of infrastructure for transportation from new production areas. For example, in January 2011, natural gas prices varied from $4.50 (USA) to $9.50 (UK) to $11.00 per million BTU (Japan) [13]. Figure 3 indicates areas of North America with significant potential for production of natural gas [8].

The market is still under development and areas of low regional prices may not remain. Prices can be affected by development of export infrastructure, growing use for power generation or natural gas vehicles, colder winters, or shifting of drilling emphasis to reservoirs which can produce both crude oil and natural gas. Examples of recent headlines include:

- Dominion seeks exports of Marcellus Shale gas, 1 billion cubic feet per day as liquefied natural gas, to any country not prohibited [14].
- Drilling shift, power demand could hit gas oversupply: Conoco executive [15].

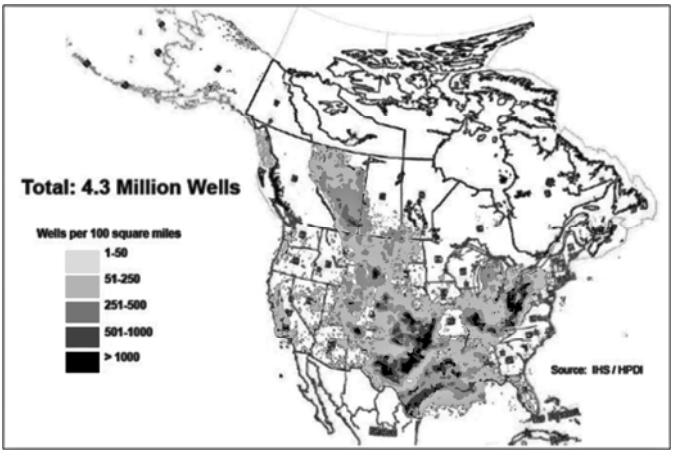

Fig. 3. Areas of North America with potential for natural gas production [8]

Low natural gas prices have also created the opportunity for converting natural gas to liquid hydrocarbons. This technology is well known but capital intensive. Abundant, low cost natural gas combined with high petroleum prices could encourage investment in this area. In a recent Hart's Energy seminar [10], three companies developing natural gas conversion processes were featured. The focus of the seminar was development of lower cost conversion technology and the integration of natural gas conversion with biomass and coal gasification with integrated CO_2 use or sequestration. An example of such a system is shown in Figure 4 for Accelergy Corporation (16), which can produce syngas from a variety of feeds and convert to liquid hydrocarbons. CO_2 is separated before the Fischer Tropsch reactor and used to grow algae, which in turn is used as a bio-fertilizer to

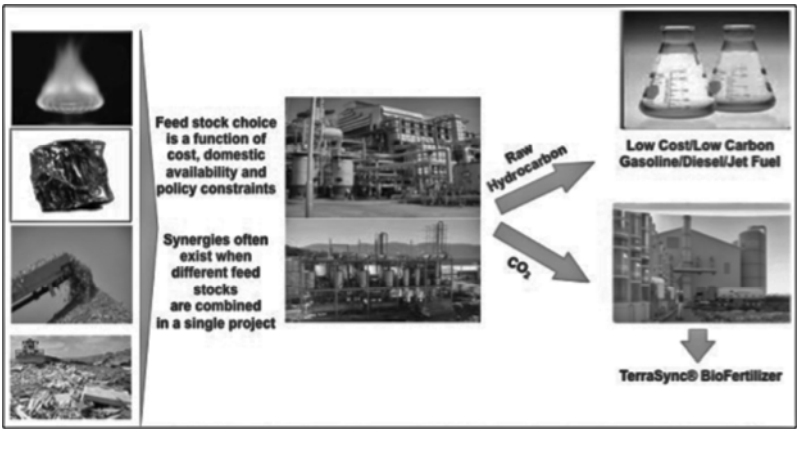

Fig. 4. Accelergy Corporation integration of gasification, thermo chemical conversion, and CO2 reuse [10].

enhance crop production. Although it may be unlikely that 100% CO_2 reuse will be achieved, the overall process can be made less CO_2 intensive by integration of natural gas (a lower carbon fuel), renewable biomass, and CO_2 reuse.

4 Conclusions

World trade in biofuels is currently centered around ethanol, wood chips, and vegetable oil / biodiesel, with the US, Canada, Brazil, Argentina, South Africa, Malaysia, Indonesia, and Australia being exporters and Europe, Japan, and the US as importers. New drilling techniques, including deep ocean drilling, extended horizontal drilling, and hydraulic fracturing are uncovering new sources of natural gas and crude oil, with the US and Eastern Europe leading development of these resources and many other countries following with their own projects and partnerships. Large increases in natural gas availability have also opened new opportunities in gas to liquids and combined gas, coal, and/or biomass to liquids. Overall, the energy landscape is currently undergoing unprecedented change, due to world economics and growth, energy prices, local preferences, and concern about regional air pollution and global warming. Most likely, all options will need to be developed to supply future energy needs, and the energy industry will remain in flux for the foreseeable future.

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