COMPREHENSIVE ASSESSMENT OF FUTURE ENERGY NEEDS AND THE ROLE OF ALTERNATIVE ENERGY SOURCES

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Abstract

In this paper the potential future energy demand is evaluated based on the newest results, and is matched with our available energy reserves. Emphasis is placed on the possible role of biofuels and non-conventional fossil energy sources, which among others, include shale gas, tar sand, oil shale, and methane-hydrates. The concept of energy return on energy invested (EROI) is briefly presented to provide a methodological background for comparative assessment of different energy sources, and a comparison is given for the respective energy sources. Afterwards the energetical potential of non-conventional energy sources is assessed by their availability and other characteristics.

Keywords

energy supply, alternative energy sources, renewables

Introduction

Growing global energy needs and the oil production peak

Evolution of future energy demand shows rising tendency according to various forecasts (IEA, EIA, Shell). The future energy mix incorporates significant amount of fossil energy sources, thus underlining European energy dependence. According to a wide range of renowned experts a serious plunge in oil supply and/or soaring energy prices is expected in the near future. This is of key importance, as crude oil is the most important energy source in a global perspective. About 35 percent of the world's primary energy consumption is supplied by oil, followed by coal with 25 percent and natural gas with 21 percent (WEO, 2010). Transport relies to well over 90 percent on oil, be it transport on roads, by ships or by aircrafts. Therefore, the economy and the lifestyle of industrialised societies relies heavily on the sufficient supply of oil, moreover, probably also on the supply of cheap oil (Molnár M., 2010). Fig. 1. demonstrates the growing gap between existing crude oil reserves and reserves yet undeveloped or not explored.

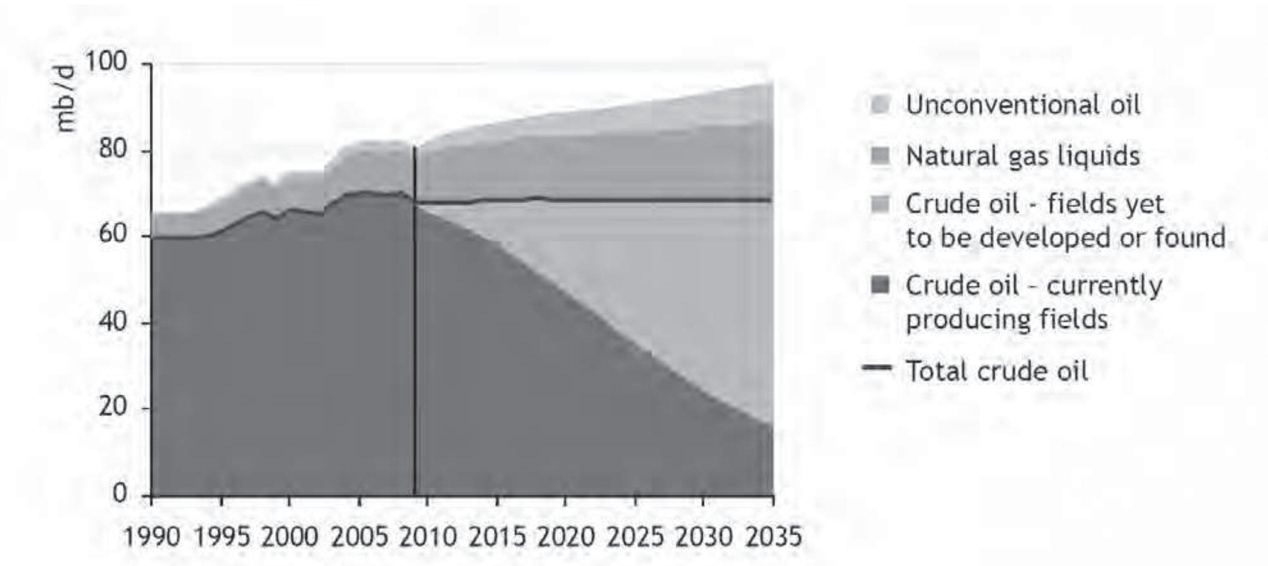


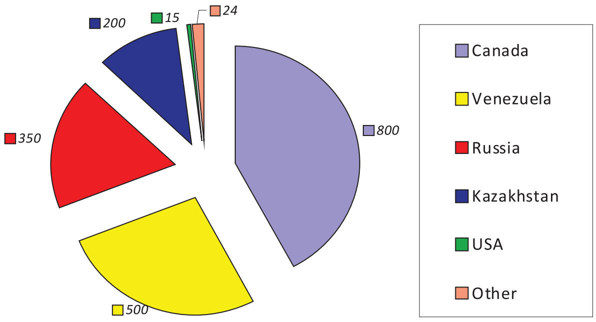
Figure 1. World oil production by type, source: WEO, 2010

Thus, there is a growing market demand towards alternative sources of energy. Renewable and non-conventional energy sources can provide an alternative, yet the extent they can enter the picture is not clear.

What is unconventional oil?

No simple definition exists, however one can define unconventional oil either based on its API gravity, or its geological setting in its reservoir. Here we follow the IAE's definition, which simply enlists these resources as bituminous and extra heavy oils from Canada, Venezuela, or oil shales and distillations from coal-to-oil and coal-to-gas processes. The common attribute of these fossil sources is that unconventional oil resources are huge, multiple times larger than conventional resources, but projects require large upfront capital investments, and expected greenhouse gas emissions are higher per barrel produced on a well-to-wheels basis. The overall scale of bituminous and heavy oil resources exceed 1900 billion barrels in terms of ultimately recoverable resources (as a comparison, the estimated oil consumption of mankind to date is in the range of 1000 billion barrels). Fig. 2a-2b. presents the breakdown of these resources per country.

As it is clear from the above, unconventional oil can play a significant role in providing for future energy demand. Yet, as with oil shales and oil sands the environmental costs can be significant: land and water usage plays a key role in projects. This underlines the relatively slow evolution of expected production trend, show for oil shale in Fig. 2b.



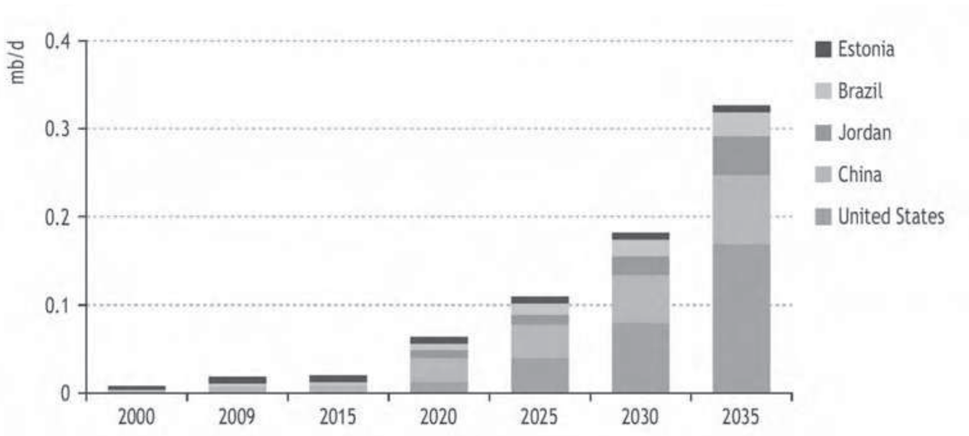


Figure 2a-2b. Reserves in billion barrels and expected production trends of unconventional oil resources (extra heavy and bituminous), source: WEO, 2010

Definition of eroi

For an energy process to be feasible, the energy it provides must be higher than the energy it requires. When the energy cost of recovering a barrel of oil becomes greater than the energy content of the oil extracted, production will be discontinued, no matter what the monetary price may be. This requires the definition of the "energy cost" of energy, and the introduction of the so-called EROI (Energy Return on Investment, Cleveland et al., 1984; Cleveland, 2005). In short, the EROI is defined as the ratio of the energy that is obtained as output of a given energy extraction process to the total energy that is invested for its extraction, processing, and delivery, including the energy embodied in the goods and machinery used. The lower the EROI, the smaller the net advantage provided by a given energy source.

Biofuels and concerns of energetical returns

Fossil sources provided high EROI's in the past, up to 100:1, but values have been declining down to the present 20:1, as shown by Cleveland (2005), due to the exploitation of the most favourable and higher quality fossil reservoirs, and are expected to decrease further. Table 1a-1b. gives an overview of the energetical benefit of certain energy sources.

Table 1a. Energetical return on energy invested for various energy sources, source: theoildrum.com

	EROI (v:1)	*Year*		*EROI (v:1)*	*Year*
Oil and Gas	>100	1930	**Hydropower**	>100	n/a
Oil and Gas	30	1970	**Wind turbines**	18	n/a
Oil and Gas	11-18	2005	**Geothermal**	n/a	n/a
Global oil production	35	1999	**Tidal energy**	n/a	n/a
Natural gas	30	2005	**Flat Plate Solar**	1,90	n/a
Coal	80	1950	**Concentrating Collector Solar**	1,60	n/a
Coal	80	2000	**Solar PV**	6,80	n/a
Bitumen from Tar Sands	2-4	2008	**Ethanol (sugarcane)**	0,8-10	n/a
Shale Oil	5	2008	**Corn-based ethanol**	0,8-1,6	n/a
Nuklear	5-15	2008	**Biodiesel**	1,30	n/a

Table 1b. Efficiency of biomass usage in biofuel production, source: Pimentel, 2008

Energy efficiency	**Corn**	**Sunflower**	**Wood**
Energy output/(direct and indirect) energy input for substrate	3.82	2.59	4.24
Energy output/(direct and indirect) energy input for biofuel	**Ethanol**	**Biodiesel**	**Methanol**
(a) Use of residues as energy source, credit for feedstock	1.5	1.21	(*)
Net-to-gross energy ratio	**0.33**	**0.17**	(*)
(b) Use of residues as energy source, no credit for feedstock	1.15	0.98	1.1
Net-to-gross energy ratio	**0.13**	**<0**	**0.09**
(c) No residues as energy source, credit for feedstock use	0.65	1.51	(*)
Net-to-gross energy ratio	**<0**	**0.34**	**(*)**
(d) No residues as energy source, no feedstock credit	0.58	1.16	(*)
Net-to-gross energy ratio	**<0**	**0.14**	**(*)**

As the above figures show, there is a large extent of uncertainty coupled with biofuels. Table 1b. shows very alarming results from a compilation of a biofuel assessment study (Pimentel, 2008). The analysis shows that biofuels are, essentially, not yet a viable alternative based on economic, energy and environmental aspects. The constraints are not simply technological, but also based on the large scale consequences of biofuel programmes, although improved efficiency in the conversion process and reduced use of fossil fuels in agricultural production might slightly improve the present figures. In particular, when crop production and conversion to fuel are supported by fossil fuels in the form of chemicals, goods and process energy, the fraction of the fuel energy that is actually renewable (i.e. the net energy available) is negligible. On the other side, if a fraction of the biofuel is fed back to the process, in order to make it independent of fossil fuel inputs, the demand for land, water, fertilizers and labour is amplified accordingly, thus increasing the competition with other uses for the same resources. In fact, the growing population of the planet, coupled with the demand for better nutritional quality in developing countries is likely to increase the demand for water and high quality land, even without cropping for energy. Similarly, the decrease of carbon dioxide emissions per unit of fuel delivered is negligible when the process is supported by biofuels in alternative to fossil inputs. For these reasons, biofuels should not be regarded as a contribution to the solution of the problems related to Europe's strong dependency on fossil fuels. In fact, fossil fuels are used in all phases of the biofuel production chain, with the consequence that the energy yield is very low. Therefore, the real fossil fuel savings of a large scale biofuel production, the reduction of the anthropogenic greenhouse emissions and the increase of energy security would be very modest.

Conclusions

Future challenges of energy supply can be met in many alternative ways. There are nevertheless portentous signs that the unconventional oil production can bring about significant environmental harm if undertaken on a large scale. Examining biofuel production, the disadvantages of a large scale biofuel production in terms of land requirement, environmental impact (deforestation, loss of wild and agricultural diversity, over use and contamination of water, etc.) and economic impact (increase in the price of cereals) would be relevant. Pessimistic though the present situation may sound, a margin of hope remains in the advent of second-generation biofuels derived from ligno-cellulosic biomass as these are expected to raise the energy yield by almost one order of magnitude.

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