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Author: N. Abas A. Kalair N. Khan

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Review of Fossil Fuels and Future Energy Technologies

N. Abas, A. Kalair, N. Khan*

Department of Electrical Engineering
Comsats Institute of Information Technology
H/Q Campus, Park Road, Islamabad
*nasrullahk@yahoo.com

Highlights

- Oil, gas and coal production rates would continue rising till 2017, 2025 and 2055.
- Energy demand would increase from 12.5 GTOE today to 25 GTOE by 2035.
- CO_2 emissions would increase from 38GtCO_2/yr today to 75GtCO_2/yr by 2035.
- Fischer Tropsch Syncrude, bipolar, hydrogen and nuclear fusion are potential future energy technologies.
- CO_2 and H_2O based fuels may facilitate the energy transition process.

Review of Fossil Fuels and Future Energy Technologies

Abstract:

Fossil fuels production peaks, declines and depletions depend on their proved reserves, exploration and consumption rates. Worldwide proven oil, gas and coal reserves are 1,688 Billion barrels (Bb), 6,558 Trillion Cubic Feet (TCF) and 891 Billion tons (Bt) being consumed at rates of 0.092 Bb, 0.329 TCF and 7.89 BT per day, respectively. The oil, gas and coal reserves are increasing at the rate of 600 Million barrels (Mb), 400 Billion Cubic Feet (BCF) and 19.2 Giga Tons of Oil Equivalents (GTOE) per year. While the rate of annual increase in consumption of oil, gas and coal is 1.4Mb, 4.5BCF and 3.1 Million tons (Mt). Global annual energy demand of over 12 Billion Tons of Oil Equivalent (BTOE) results in the emission of 39.5 Giga tons of carbon dioxide (Gt-CO_2), and the annual CO_2 emission would increase up to 75 Gt-CO_2 when future energy demand will rise to 24 to 25 BTOE. Oil, gas and coal may continue to exist for next several decades, yet the energy transition to low carbon intensity fuels is necessary to cope with rampant climate changes. Renewable and alternative energy sources hold key to the solution of twin problems, energy and climate change, with a high initial investment. Transition from fossil fuels to sustainable and renewable energy resources of 150 Petawatt hours (PWh) requires major investment and innovatory technologies. Perhaps CO_2 and H_2O based fuel systems would facilitate climate change and grand energy transition. An energy mix consisting of fossil fuels, hydrogen, bio-fuels, and renewable energy sources seems to be a good initiative. This paper reviews evidence of hydrocarbons decline scenarios and timelines of future energy technologies.

Keywords: Oil peaking, Climate Change, Energy crisis, Energy transition, Energy futures

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1. Introduction

Oil peaking is the point in time when the rate of petroleum extraction reaches its highest plateau (Laherrère, 2000). Based on local oil and gas production peaking experience, prediction of King Hubbert in 1956 about the production of US oil fields hitting the highest point in the 1960s, proved correct (Hubbert, 1956). Based on the successful prediction of indigenous oil production peak, (Hubbert, 1949), King Hubbert predicted global oil production to reach a peak plateau in 1995 (Hubbert, 1971), however, this timeline was extended due to subsequent oil discoveries (Hirsch, 2007). Global oil reserves were only 500 Bb in 1970 which were predicted to end by 1995 (Hubbert, 1971); yet due to new explorations, after two decades the world had 900 Bb despite consumption of 600 Bb. Oil and gas reserves increase rates were 0.11 Mb and 7.4 Trillion Cubic Meter (TCM) per year in 2010 as shown in Fig.1 and Fig.2 respectively (BP, 2014).

So far global oil, gas and coal reserves are steadily increasing without any immediate depletion threat in sight, yet fossil fuels are finite resources. Despite climate change, population increase and inflation the living standards are rising over time. Human prosperity may substantially be attributed to the discovery and utilization of fossil fuels, the reserves of which, though limited in nature, are increasing to date. Oil peaking has, no doubt, become an academic debate with no concurrence to date (Cheney & Hawkes, 2007). The Optimists believe that the planet earth has an abundant quantity of oil and its production rate will rise to peak in 2100 at the rate of about 105 Million barrels per day (Mbpd) and decline to 40 Mbpd by 2400 (Trendlines, 2012). However, the pessimists trust in the oil era is over (Heinberg, 2005); gas shall be peaking soon (Darley, 2004) marking the end of the hydrocarbon age (Goodstein, 2005). According to pessimistic reports, the peak oil occurred in 2009 at a production rate of 86 Mbpd and global oil production will decline to 40 Mbpd by 2050. A moderate view holds that the oil production will peak in 2025 at the rate of 120 Mbpd but will decline to 40 Mbpd by 2115. The majority of scientists argues that the world oil production has either peaked already or will be peaking in coming few years (Simmons, 2007; Deffeyes, 2002; Cohen, 2008) whilst oil and gas professionals consider the oil peaking as no more a relevant topic now, because it was conceived long ago (Chapman, 2014). The oil depletion scenario may be attributed to supply chain disconnection due to the oil embargo in 1970s and decline in oil demand due to paradigm shift towards energy efficient cars, electricity and gas heating in the late 1970s and early 1980s (Toth & Rogner, 2006). Energy experts have various opinions on the decline rate after the occurrence of peak oil production between 2000 and 2030 with peak production rates varying from 75 to 120 Mbpd. The decline of oil production rate determines the actual decline profile. Several terms like ultimate, ultimate resources (UR) and ultimate recoverable resources (URR) are used to describe total oil and gas reserves in the earth. Normally fossil fuel reserves are expressed by proved (1P), probable (2P) and possible (3P) reserves. Oil and gas resources are called reserves, contingent resources and prospective resources. According to BP statistical review of world energy, proved world oil reserves at the end of 2013 were 1687.9 Bb (BP, 2014). There will be peak oil in the near future, but experts are not aware of the exact date (Andrews & Udall, 2003; EIA, 2013; Gail, 2012; Hook, 2010; Pedro & Pedro, 2009; Tea, 2008; Towler, 2014). Environmentalists advise to minimize the use of fossil fuels due to their adverse effects on nature irrespective of repletion or depletion. Environmentalists relate the peak production of oil and gas with peak emission of CO2, which is so far constantly rising (402ppm in 2014) (Aleklett, 2007). There is no chemical process which can clean ballooning volumes of CO_2 volumes from the atmosphere. Energy experts have started thinking of sustainable hydrocarbon fuels by recycling H_2O and CO_2 with renewable energy resources (Christopher, Sune, Mogens & Klaus, 2011). CO_2 capture and sequestration (CCS) process may help in converting CO_2 back into hydrocarbon fuels in the presence of H_2O as it converted vegetation and dead animals into fossil fuels over tens of millions of years in the past (Hu, Guild & Suib, 2013). Meanwhile, using CO_2 as refrigerant may help mitigate climate change, as discussed in our preceding work (Abas, 2014; Nease & Adamsm, 2014). Solar, wind, geothermal, wood, carbon dioxide and water are being examined to replace oil, but there is no apparent success to date. It is on-time to explore new and efficient energy systems for the post - carbon era (Geer, 2009).

The fossil fuels account for about 86% of the global primary energy demand which is rising gradually. At present, oil, gas, coal, renewable and alternative energy resources have a share of 36%, 27%, 23% and 14% respectively, in the global energy mix.

While solar, wind, geothermal, biomass and hydal accounts for 8% and nuclear power has a just 6% fragment. The situation is likely to worsen after oil peak in 2015 at 30Gb/year, gas in 2035 at 132 TCF/year and coal in 2052 at 4.5GTOE/year (Maggio & Cacciola, 2012). We are consuming fossil fuels at the rate of 0.001Mb per second producing 29Gt of CO_2 per year out of which hardly 6.8Gt absorbs in the natural process and the remaining 10.2Gt enter into the atmosphere (Bilanovic, Angargatchew, Kroeger, & Shelef, 2009).

The world is producing oil, natural gas and coal at the rate of 87.4 Mb (11.92 MTOE), 329 BCF (8.225 MTOE) and 21.63 MT (14.42 MTOE) per day respectively. The global sum of oil, gas and coal production, in terms of equivalent oil yields at the rate of 0.002933 Mb per second, is three times higher than the earlier claim of 0.001 Mb per second (Peter, 2007). Currently, consumption of 87.4 Mb per day is likely to decline to 39 Mb by 2030. World hydrocarbons reserves, production rates and depletion dates assuming no future discoveries are shown in Table 1.

Oil, gas and coal depletion dates, calculated on the basis of current reserves and production rates without including future discoveries, are not defined as the reserves are on the rise today. The rate of rise is declining; therefore, ultimate depletion is unsure. Independent reviews on oil, gas and coal depletion indicate that the decline in terminal fossil fuels will trigger food, water and security crises (Sorrell, Spiers, Bentley, Brandt & Miller, 2010; Friedrichs, 2010; Nel, 2008). Energy experts are afraid of the rise in food price (Chen, Kuo & Chen, 2010) and political instability (Igor, 2009) by fast depletion of oil in the world market. Energy and food crises are likely to start decades before real end of hydrocarbons due to shortage in electricity, fuel and food. The production of oil increased from 77 to 85.6 Mb/day (2002 to 2009) followed by an increase in cost from 26.18 to 149.67 $/barrel. The oil production cost may range from 20 to 25$/barrel, but its price at fuel stations exceeds 159 $/barrel due to processing and transport charges. Global natural growth rates will decline to 1.69% by 2025, 1.30% by 2035 and 1.19% by 2050. The renewable and alternative energy sources may cause variation in the effective global growth rate from 1-2%in different countries. Coal and water based economies will be affected lesser compared to the imported oil based economies (Waisman, Rozenberg Sassi & Houcrade, 2010). Energy experts forecast oil prices to be in the range of 200 $/barrel by 2050 as shown in Fig.3

In 2008, oil prices suddenly went higher up to 149$/barrel, which cannot be justified using any model. Such momentary surges and sags may be attributed to geopolitical instabilities and circulating rumors. Actual oil prices dipped in 2009 from 149$/barrel to 30$/barrel for some time then rebounded again. The current plunge (2015) in oil process is being attributed to fresh restoration of Libyan and Iraqi oil supplies. US oil production has become comparable to Saudi Arabia. Oversupply of oil during global economic recession has led to decline in oil prices. This trend might continue up to 2017 until either shale oil producers fail to compete or economic recovery starts accelerating. Economic benefits derived from the use of fossil fuels have decreased death rates due to increase in health facilities. Economic expansion, climate change and population are the lexis nexus today. Social scientists (Ehrlich, 1968) warned of the potential threat of population explosion due to spiraling food, energy and security issues. Exponential population growth and rising energy demands are shown in Fig.4 (Luiz, & Lima, 2011).

According to statistical data of US Energy Information Administration (EIA) and the International Energy Agency (IEA), the global power consumption, including transportation, industry, residential and commercial use is about 16-17TW in 2006 with exponentially increasing trends.
Machines waste a lot more energy to produce 16-17PW power due to 40 to 50% conversion efficiency. Total energy reserves consist of fossils such as coal (290ZJ), oil (57ZJ) and gas (30ZJ); whilst the rest come from nuclear (uranium) and solar energy as shown in Table 2.

Growing global population (200,000 persons per day) causes an exponential increase in energy demand on limited fossil fuel reserves. It is more painful to have many children dying with hunger and diseases than parenting lesser children. Over 650 children die with curable diseases, shortage of food and clean water every year in the Thar desert in Pakistan. In the Southern Punjab and Northern regions, parents send their children to religious schools (Madrassas) due to fat fees of smart schools. If we express the energy reserves in terms of time of the day, then currently we are experiencing dusk of oil, the high noon of gas, forenoon of coal and dawn of renewable energy sources. The energy reserves in terms of time of day are shown in Fig.5.

2. Twilight in Deserts

Historically, the crude was used for street lighting in Mesopotamia in 5000BC. Vegetable oils were produced commercially thousands of years ago. Conventional petroleum oil was discovered in 1859 during the industrial revolution. Oil peaking discussion was investigated in the light of oil production rates (Aleklett, Hook, Jakobsson, Lardelli, Snowden & Söderbergh, 2010), oil formation theories (Tsatskin & Balaban, 2008), four stages (Ugo, 2011), seven suppositions basis (Sovacool, 2011) and long term forecasts (Mohr & Evans, 2009). Proved global oil reserves were 1065.9 Bb in 1995, 1353.1 Bb in 2005 and 1688.5 Bb in 2014. Oil reserve's history indicates that it is rising at a low rate of 600Mb/yr as shown in Fig.6.

King Hubert's Curve reflects a tentative picture of fossil fuels peaks, declines and depletions using normal distributions, but the actual oil production decline profile would be similar to long tail natural lightning type events. The Oil production rate was 67.99Mb/day in 1995, 82.107Mb/day in 2005 and 87.365 Mb/day currently in 2014. The oil production rate is increasing at a slow rate of 0.557Mb/yr as shown in Fig.7.

The Oil consumption rate was 70.364 Mb/day in 1995, 84.389 Mb/day in 2005 and 92.73 Mb/day currently in 2014. Oil consumption is increasing steadily at a rate of 1.4 MB/yr as shown in Fig.8.

Some 6.8% researchers believe that the oil production has already peaked before 2007 whereas 37.9% are of the opinion the oil peaking to occur between 2008 and 2012, 34.5% believe it's peak between 2012 and 2013, 0.1% guess it will touch the peak between 2013 and 2022 whilst 20.7% claim it will peak in 2023 or later (Pedro & Pedro, 2011). A scatter plot of individual opinion on expected peak year for conventional oil extraction is shown in Fig.9

3. High Noon for Natural Gas

Natural gas was used by the ancient Chinese to transform sea water into salt. Eternal natural gas fires emanating in Azerbaijani and Persian regions were considered Holy Fires in ancient times. Natural gas is the second most popular fossil fuel yet it is subject to peak production, decline and depletion as oil (Bentley, 2002). Mankind started utilizing natural gas soon after oil causing its peak to occur accordingly. Several studies have reviewed production and consumption trends of global gas reserves (Laherrere & Perrodon, 1996) and forecast gas peak within decades of oil peak (Startzman & Barruget, 2004). Oil and gas experts predict the natural gas peaking time line within a decade of oil peaking. Global natural gas demand is rising for space and water heating and electric power production primarily due to the high efficiency of gas turbines (Al-Fattah & Startzman, 2000). Natural gas peaking may delay significantly due to the discovery of shale gas in many countries (Garcia & Mohaghegh, 2004). Worldwide natural gas reserves were 120 TCF in 1995, 156.9 TCF in 2005 and 186.1TCF in 2014. Global proved natural gas reserves are increasing over time at rate of 400BCF/yr as shown in Fig.10.

Natural gas production rate was 204.5 BCF/day in 1995, 268.8 BCF/day in 2005 and 329.4 BCF/day in 2014. The gas production rate has been increasing at a lower rate of 3.4 BCF/yr as shown in Fig.11.

Global gas consumption rate was estimated to be 206.4 BCF per day in 1995, the rate increased 30% in 2005 and reached at 328.4 BCF/day in 2014.At present, the annual consumption rate of gas is 4.5BCF as shown in Fig.12.

Global current natural gas production rate is 3.4 BCF/yr which is quite lower than its increasing consumption rate of 4.5 BCF/yr. We must reduce gas consumption rate to delay gas peaking. American shale gas reduced natural gas demand in the world market (Al-Fattah, 2005). Global ultimate natural gas reserves estimate may vary from 9500 to 15,400 TCF.

4. Forenoon for Coal

Cole played a major role in getting the industrial revolution off the ground. Coal fired steam engines started the industrial revolution, developing earlier rail system. Mankind has been using coal since millennia, yet it was taken as regular fuel after the invention of steam engine. Steam engines were replaced by diesel and electric engines by the middle of the 20th century. There are huge reserves of coal in various parts of the world. China (Tao & Li, 2007; Lin & Liu, 2010) and America (Hook & Aleklett, 2009; Hook & Zittel, 2010) are the largest coal producers and consumers. Coal production and utilization would continue to increase due to decline and depletions of oil and gas in the future (Mohr & Evans, 2009). Coal fired power plants produce 14 to 15Gt of CO_2 every year which is 49% to 50% of global CO_2 emission. Global sum of

anthracite, bituminous, sub-bituminous and lignite coal reserves is 891.531 trillion tons. World coal discoveries increase coal reserves like oil and gas. In 1990, geologists discovered 189 billion tons of coal in the Thar desert in Pakistan. Thar coal reserves were found during drilling holes for hand water pumps at the end of 1980s. There might be yet many similar coal reserves in different developing countries. Global coal production rate was 2.867 GTOE in 2000, 3.548 GTOE in 2010 and is 3.901 GTOE in 2014. World coal production is increasing at a rate of 19.20GTOE/yr as shown in Fig.13.
World coal consumption was 2.2146 GTOE in 1990, 2.3429 GTOE in 2000 and 2.9297 GTOE today in 2014. World coal consumption rate has been rising at an average rate of 103 MTOE/yr as shown in Fig.14.

Global coal consumption rate of 103 MTOE/yr is higher than global coal reserves increase rate of 19.2 MTOE/yr. Thus, coal is also subject to peak, decline and depletion (Patzek & Coft, 2010). Global ultimate coal reserves vary from 550 to 750 GTOE.

In the last decade, global total oil consumption rate was 4000 MTOE which is expected to decline to 1000 MTOE by 2050 due to depletion of most oil reserves. Global oil production has declined from 40 in 2006 to 26Mb/day in 2010 which is likely to further decline in coming decades. Natural gas production has increased from 2300 to 2750 MTOE during 2000 to 2010, and experts believe this rate will be subject to peak at 3200 MTOE in year 2025 decline to 1300 MTOE by 2050.

Coal production has increased from 2400 in 2000 to 3450 MTOE in 2010 and is likely to peak at 3650 MTOE by 2035 and decline to 2700 MTOE in 2050 and 1350 MTOE by 2070 (Rutledge, 2011). Global renewable energy supply was 15 MTOE in 1990, 20 MTOE in 2000 and 45 MTOE in 2010 that is likely to increase to 200MTOE by 2040 and 300MTOE by 2050. Total hydrocarbon demand was 10.70 GTOE in 2005 which is likely to be 12 GTOE by 2015, thereafter fast declining to 10 in 2035. Worldwide gas fields, oil wells and coal mines supply 21Gb/yr (3.066 GTOE), 29 Gb/yr (4.234GTOE), and 27 Gb/yr (3.942GTOE) respectively. Fossil fuel reserves are in a fixed quantity subject to decline in coming decades (Gavin & Andrews, 2010).

Conventional oil and gas reserves may deplete in the second half of this century, yet it is not the final end of oil and gas (Lynch, 1999). Even if the oil is going to peak or decline, it would not deplete in the next fifty to sixty years (Nick, Oliver & David, 2010). Oil and gas depletion would be the next generation problem, not an immediate concern (Renato, 2011. Total recoverable shale gas reserves amount to 7,299 TCF. US hydrofracking has reduced natural gas prices in the world energy market.

A grand energy transition (GET) is underway from solid to gas phase fuels (Robert, 2009). Gas phase fuels can directly be ignited to run internal combustion engines. Inaccessible deep subsurface coal would be converted into water gas using underground coal gasification (UCG) technique. Hydrogen, methane and water gas may be transported through the same pipe like composite AC/DC high voltage transmission systems. World community currently uses 79 to 80% fossil fuels and 20-21% renewable energy resources. The global community has a time period of five decades to increase renewable energy currently from 20% to 50% by 2050 and 80% by 2100. The ultimate energy solution will come from innovatory cold or laser fusion (Edward, 2010) that will continue to exist for long until any new energy source like heat, electricity and light will be invented. Pessimistic notion that lack of energy would lead to the demise of the high-technology countries is a misleading exaggeration which would never happen at all (Bockris, 2007). It is our experience that scarcities, shortages and wars accelerate technological developments. For instance, coal to gas or oil conversion method was developed during WW-II (Gavin & Andrew, 2010).

5. Dawn for Innovatory Energy Technologies

Reviews on solar (Solangi & Islam, Saidur, Rahim, Fayaz, 2011), wind (Herbert, Iniyanb, Sreevalsan & Rajapandian, 2007), hydrogen (Moriarty & Damon, 2009), Bioenergy (Faaij, 2006), artificial photosynthesis (Pearce, 2002), fission (Duffey, 2005) and fusion (NAP, 2013) show that natural and artificial resources other than fossil fuels can meet world energy demand. World energy resources surveys (WEC, 2010) show that hydrogen and nuclear (Shinzo, 2010) energies can play significant role in addition to natural renewable energy sources. Solar power density at the earth’s surface is 125-375 W/m² that is equivalent to 3-9 kWh/m²/day. An average photovoltaic panel, with 15% efficiency, may deliver 15-60 W/m² or 0.45-1.35 kWh/m²/day electricity. The solar cell conversion efficiency has steadily increased from 6% (1954) to 40% (2006) over last 52 years. Based on gross solar power generation less than 0.05GW, the solar power generation capacity was 3.7 TWh (0.6 MTOE) in 2005, 30.5 TWh (6.9 MTOE) in 2010 and 124.8 TWh (28.2 MTOE) in 2013. Global installed accumulative solar power generation capacities were negligible in 1995 which have now grown to over 177 GW today. Installed capacity is limited by solar cell production rates yet still increasing at a rate yet of 37.76GW/yr as shown in Fig.15.

Theoretical wind power intensities vary from 80- 9560 W/m^2 at a speed of 5m/s to 25m/s.
Global wind resource varies from 55 to 1000 PWh/yr (Manwell, Mcgowan & Rogers, 2009). Wind energy was started being harnessed for industrial application five to six decades ago. Worldwide accumulative wind energy capacity was limited to 104.5 TWh (9.4 MTOE) in 1995 which increased to 343.2 TWh (98.6 MTOE) in 2010 and 628.2 TWh (142.2 MTOE) in 2013. Worldwide accumulated installed wind power capacity was 17.93 GW in 2000, 59.18 GW in 2005, 197.72GW in 2010 and 319.91GW in 2013. Global wind power capacity is increasing at a fast rate of 35.42 GW/yr as shown in Fig.16.

Worldwide accumulative geothermal energy capacity was limited to 230.3 TWh (52.1MTOE) in 2003 which increased to 316.2 TWh (71.5 MTOE) in 2008 and to 481.3 TWh (108.9 MTOE) in 2013. Worldwide accumulated installed geothermal power capacity was 6.755 GW in 1995, 9.323 GW in 2005, 11.12 GW in 2010 and 11.71GW in 2013. Worldwide geothermal power capacity is increasing at a slow rate of 0.348 GW/yr as shown in Fig.17.

Hydroelectricity is the second largest existing source for power production. World accumulative hydroelectric capacity was 922.8 TWh in 1965 which increased to 2487.7 TWh by 1995 and 3879.9 TWh today in 2014. Hydroelectricity of 3787 TWh replaces 855.8 MTOE. Developing Hydel power stations requires a large investment, but in the long run such systems have the lowest operating cost. Hydropower capacity is increasing steadily at a rate of 97.9 TWh/Yr as shown in Fig.18

Energy harvested from other renewable sources such as ocean tidal and wave power sources is also on constant rise. Worldwide energy consumption using small scale renewable sources has been just 5 TWh in 1965 which increased to 1404 TWh in 2014. It is increasing steadily at the rate of 170 TWh/yr as shown in Fig.19.

Population and economic growth quest for more electricity. Electric energy generation was 15.41PWh in 2000, 18.33 PWh in 2005, 21.42 PWh in 2010 and 23.62 PWh now in 2014. Electric energy generation is increasing at a fast rate of 492 PWh/yr as shown in Fig.20.

Rampant power and energy demand is supplied by multiple sources. According to Campbell's Peak, now 86% global energy demand is being met by fossil fuels. Nuclear, hydro, geothermal, biomass and combined solar & wind supply 8%, 2.7%, 0.3%, 2.8 and 0.2% of global energy demand. Primary energy consumption by fuels is shown in Table 3.

Oil, gas and coal would remain dominant energy sources in the coming decades. Nuclear energy was 8% to 9% of global demand, but decreased to 4 to 5% after Fukushima Nuclear Catastrophe and surged again after resumption in 2014. Many countries have stopped their under execution and future planned nuclear power projects. Nuclear energy was 25.7 TWh in 1965, 1482 TWh in 1985, 2761 TWh in 2005 and 2489 TWh (563.2 MTOE) in 2013. Nuclear energy is increasing at the rate of 14.6 TWh/yr as shown in Fig.21.

Biotechnology has made possible to convert biomass into gasoline. Biofuels are getting popular worldwide. Brazil has long experience of using ethanol. In view of the food crisis, the biofuels technology faces some limitations. Worldwide total biofuels production capacity was 142 kboe/day in 1990 which has now increased to 1387 kboe/day today in 2014. Global biofuels production of 61.752 Mboe in 2013 replaced 1.237 MTOE in 2013. Biofuels are increasing worldwide at a rate of 75 Kobe/yr as shown in Fig.22.

Primary energy consumption consists of fossil fuels (86.40%) and renewable and alternative energy sources (13.60%). Worldwide total primary energy consumption was 9.342 GTOE in 2000, 10.714 GTOE in 2005, 11.955GTOE in 2010 and 12.730GTOE in 2013. Total primary energy consumption is increasing at a rate of 243 MTOE/yr as shown in Fig.23.

The planet has a huge renewable resource, hundreds time more than our needs, which are awaiting to be harvested. The world has 1700 TW wind, 6500 TW photovoltaic and 4600 TW CSP power potentials out of which we have yet harvested 20, 1.3 and 0.46 GW as shown in Fig.24.

Global energy demands may be met with solar, wind and water watts (Jacobson & Deluchhi, 2011). World power demand is hardly 17TW per year, which can be supplied with sun or wind alone (Perez & Perez, 2009). Discovery of fusion and CO_2 based fuel would be the ultimate answer

All fossil fuel reserves, known to humankind, are equal to 20 days' sunshine. Renewable energy resources have the virtual potential to supply thousands time more energy than the current global demand of 17.12 TW-Yr or 150 PWh (Omar, Haitham & Frede, 2014). The earth receives 89PW solar energy. Sunshine, coal, uranium, petroleum, natural gas and wind are the largest energy sources available to humankind. Abundant renewable energy sources and innovatory technologies, in principle, can facilitate the gradual energy transition over the time.

6. Grand Energy Transition

The term "Energy Transition" refers to the paradigm shift of energy policy and sustainable system development by means of renewable energy phasing out the fossil fuels. A sustainable energy system must be environmentally friendly and economically viable. Significant energy transition policy vision includes German 80-95% GHG emissions reduction by 2050, Japanese nuclear phase out by 2040, French 60% GHG emissions reduction by 2040 and the Danish decision to increase wind power share to 50% by 2020. The committee on transition to alternative vehicles and fuels in USA assessed the potential of alternative fuels and GHG reduction for light duty vehicles (LDVs) fleet. LDVs are responsible for half of total USA's petroleum consumption and 17% GHG emissions. The study was aimed at reduction of petroleum consumption and GHG by 50 and 80%, respectively, by the year 2050. The impact of highly efficient Internal Combustion Engines (ICE), expected to be available by next two decades, Hybrid Electric Vehicles (HEVs), Plug in Electric Vehicles (PHEs), Battery Electric Vehicles (BHEs), Fuel Cell Electric Vehicles (FCEVs) and Compressed Natural Gas Electric Vehicles (CNGVs) was incorporated in the future energy mix fleet. The committee results show that high fractures cost ($2000-$3000) of hydrogen, biofuels and electric vehicles will be a limiting factor as compared to current petroleum based vehicles ($530). Incorporating hydrogen, electricity and bio-fuels options with 10% each in LDVs fleet would require 250,000 kg of platiuium, 28 GW of night time energy and 12 billion gallons of gasoline per year. This entails an investment of $38 billion, $16-$42, $50-$70 billion to run the energy mix fleet system (National Research Council, N., Transition to alternative Vehicles and fuels, 2013).

Energy phases and forms had always been changing in human history. Energy phase has been transformed over time from solids to liquids and gases and energy forms from high emissions and pollutions to low carbon clean technologies. On environmental pollution, China and India in the 21st century, represent the true picture of Europe at the start of the 19th century when coal powered industrial revolution took place.

Hydrogen has a huge market for heating, power generation and transport industries (Will, 2014). Fossil fuels produce 30 to 31Gt of CO_2 out of which half comes from coal power plants (Kathleen, 2014). Mitigation of CO_2 emissions is the basis of grand energy transition which encompasses sustainable energy systems, access to clean energy, energy security, climate change and food chain systems. The polluter pays principle type proposals come, but they are taken as attuned to regional idiosyncratic nuances. The first step should be reduction of CO_2 emissions, which would catapult the overall energy transition process. Environmentalists believe that the idea of fighting climate change through climate engineering would not help without reducing the use of fossil fuels irrespective of their earlier or later depletions (Ming, Renaud, Liu & Caillot, 2014).

The challenges we face today are looming energy crisis and climate change. European energy transition example of catching two birds with one renewable energy stone (Felix, Jan, Paul, Eva, Christian, Blanca, Michael, Brigitte, Stepffen, Tiziana & Konstantin, 2014) and Swedish low carbon district heating attempt (Lorenzo & Karin, 2014) are guidelines for others. Oil heating/cooling plants may be run by waste energy from industry, power houses, fuel gases, biomass, geothermal and municipal waste. If carbon capture and storage facility is integrated with coal, then it can also be used as primary fuel for district heating. Energy experts believe that drawing on CO_2 based business would solve climate change problem (Abas, 2014). Capturing, utilization and storage of CO_2 produced by combustion of fossil fuels and its concentration in the atmosphere may attribute to use of fossil fuels in energy transition period.

Energy efficiency requires a huge sum of $38 trillion amount to augment and renovate the energy infrastructures. Smart grid (Gellings, 2009), energy conservation based negawatt (Gulbinas, Jain & Taylor, 2014) approaches plead efficient use of energy, but the experience has shown that increase in efficiency also increases energy demand by expansion of industries. The decline of oil prices in January 2015 led to petrol crisis in Pakistan. The concept of infinite growth with finite fossil fuel reserves seems obscure (Josh, Reiner & Aseem, 2011). Oil, gas and coal are major sources of CO_2 emissions, which are 86% of our global fuel mix. Worldwide CO_2 emissions were only 11.746 $GTCO_2$ in the 1970s, which increased to 20.34 $GTCO_2$ in 1985, 23.485 $GTCO_2$ in 1995, 29.479 $GTCO_2$ in 2005 and over 35.72 $GTCO_2$ today. CO_2 emissions due to burning fossil fuels and biomasses are steadily increasing at a rate of 630 $MTCO_2$/yr as shown in Fig.25.

There are several ways of optimizing the fuel mix by replacing some fossil fuels with renewable energies and enhancing conversion efficiencies (John, 2011). Current halt in global warming trend may be attributed to exponential growth in renewable, delay in 25th solar cycle and oceans' CO_2 absorptions (Ernest, 2005). Energy experts correlate CO_2 emission peaking with fossil fuel peaking (Robert, 2008) and others relate it to human activities (Hui & Gabriel, 2005). A world community of 7.2 billion persons emits CO_2 from their body about 2.63GtCO2/yr which is easily absorbed by nearby trees and lakes. All power and energy sources emit greenhouse gases, but fossil fuels have higher emissions compared to other sources. We use 86% fossil fuels which is the major cause of rampant CO_2 emissions. Rate of rise in oil, gas and coal demands shows that the CO_2 emissions will continue to rise in future. Keeling curve of CO_2 records shows that the CO_2 concentrations in the air have exceeded 400 ppm and rate of rise is yet increasing. The way we produce and consume energy would lead to high CO_2 concentrations and temperature rise. The world needs an urgent energy transition from high to low carbon fuels. Under 450 ppm Scenario, 65% CO_2 emissions are related to power generation, 16% to transport, 11% to industry, 4% to buildings and 4% to other sources (IEA, 2011).

The IEA believes the current total primary energy supply (TPES) of 12 BTOE may increase to 17BTOE (22.6TW) by 2035 under new policies and to 18.3 BTOE (24.3TW) under the 450 scenarios (IEA, 2011), according to Shell TPES would increase to 14.9 BTOE (19.8 TW) by

2035 and 21BTOE (27.9TW) by 2050 (Shell, 2009). European Commission perceives that the TPES would increase to 22.3BTOE (29.6TW) by 2050 (EC, 2006). A recent Norwegian study claimed the TPES would increase to 19.8BTOE (26.3TW) by 2035 and 24.5BTOE (32.7TW) by 2050 (Narbel & Hansen, 2014). Lighting load used to be 10% of residential electricity loads which declined to 5% after widespread use of energy saving lights. Experience has shown that due to replacement factors the energy efficient lights had exhibited 6% rebound effect in Europe (Schleich, Mills & Dutschke, 2014).

The grand transition is a capital intensive venture as it takes $1600 billions to supply world energy demands today. It would need $24 trillions to meet the new demands to appear in the future from 2014 to 2035. Power sector needs $16.37 trillions to upgrade transmission, distribution, power plants and renewable.

Oil, gas, coal, biofuels sectors need 13.67, 8.77, 1.034, 0.320 trillion dollars respectively. To make a successful transition from 2014 to 2035 it needs more than $8 trillion in efficiency of end user in residential, transport and energy sectors and over $40 trillion on fossil fuels (IEA, 2014). Due to low EROEI and the oil depletion stories, the investors suffer the leverage effect which affects investment in the energy sectors (Ladislav, 22014). New global investments in oil and gas sector increased from 2004 to 2011 but started declining again after 2012 (Omar & Haitham, 2014). The recent plunge in oil prices has discouraged investment in oil and gas exploration. US shale oil producers are biting their nails in competing to cheap crude oil.

Energy storage systems are key components of future sustainable energy systems. The potential benefits include seasonal storage, frequency regulation, load flowing, voltage support, demand shifting, peak reduction, variable supply resource integration and waste heat utilization. The Pumped Storage Hydro (PSH), concentrated thermal storage, electric vehicles, flywheels, Compress Air Energy Storage (CAES), super capacitor and hydrogen are successful practices which may be incorporated with national grid. Currently, 99% of total global energy storage (140 GW) is based on PSH whilst rest 1% includes a mix of battery, CAES, hydrogen and flywheel. Hydrogen storage has a broad potential with existing developed storage system with a promising future of direct use in cars, fuel cells, ICEVs and for power production (European Commission-Director General for Energy, 2012). To-date storage energy systems and their present phase of implementation is expressed in Fig. 26.

Efficient energy storage systems are an integral part of future combined heat and power (CHP) smart grid utilities. Current state-of-the-art solid, liquid and gas phase storage technologies are shown in Table 4.
Hydrogen and electricity are not fuels rather energy carriers. Laser ignited nuclear fusion was perceived as promising future, but the failure of NIF experiment has overshadowed the design of artificial star on earth (NAP, 2013). Wind farms and solar parks are prone to lightning attacks and 34% of damage to wind turbines are attributed to lightning strikes. Lightning may be harnessed to support energy systems (Kozima, 1994) instead of destroying and damaging turbines, and killing humans (Khan, Abas & Kalair, 2014). A few experiments (Shindo, Aihara, Miki & Suzuki, 1993; Xin, Jean, Cai & Juan, 1995) were carried out to harness lightning energies, like storm impeding wind turbines, but none of them could capture and store the wild

static charges. James Graham in MIT has demonstrated crowd farms akin to wind farms to convert human kinetic energy into power at railway stations and airports.

We can grow hardwood forests to sequester CO_2 for several decades. Concrete houses need more energy for cooling in summer and heating in winter compared to wooden buildings. Concrete has positive emissions during manufacturing but negative after recycling (Wu, Xia & Zhao, 2014). Plastic decomposition to 12-20 molecules (diesel), 5-11 molecules (petrol) and 1-4 molecules (combustible gases) may be a good start to reduce pollution as plastics take centuries to decompose and decay naturally. Glowing plants and long fluorescence time phosphors are new interesting research areas to pursue. Piezoelectric roads, shoes, Jims and roadways may be considered. To cope with rampant CO_2 we can capture, utilize and store CO_2. Chemists and physicists are brainstorming utilization of CO_2 as raw material for industrial products and fuels such as methane, water gas and acetylene. Synthetic refrigerants may be replaced by CO_2 for heat transfer and refrigeration. We have successfully designed CO_2 mediated solar water heater shown in Fig.27.

Nature uses sunlight to convert CO_2 and H_2O into biomass using complex biochemical reactions which may be replicated in the laboratory by splitting water using solar electricity. Photosynthesis is a natural process which inspires us to replicate artificial photosynthesis. Old proven electrolysis method may be upgraded to direct photoelectrolysis. Recent research has revealed 67% Faradic yields lead to 1.2% solar to fuel conversion efficiency (James, Jake, Jerry, Paul & Andrew, 2014). Biosolar technologies can play the ultimate role to solve the climate change problems (Lucien, Huib & Bart, 2014). Concepts of super smart grid capable of transmitting AC, DC and hydrogen with storage capacities are being evaluated as integral parts of future energy networks (Ehteshami & Chan, 2014). Energy storage media such as flywheel, pumped hydro, battery, supercapacitor, pressurized air and hydrogen can help shave peak demands.

7. Conclusions

Energy is life, energy gets energy, as life thrives on life. Renewable energy sources depend on fossil fuels to design wind turbines, hydrokinetic and solar cells. The embodied fossil fuel energy is a major fraction of total renewable energy produced. There is no alternative source in sight which can replace the fossil fuels. This paper has reviewed the evidence of peaks, declines and depletions of fossil fuels and transition trends to cope with global climate change. King Hubbert's peak oil theory predicted normal production rise, peak and decline of conventional oil, whereas natural processes usually take fast emergence and slow decay profiles. Lightning rise time is a few microseconds, but decay time is several tens of microseconds long. Oil, gas and coal being finite resources would take a profile that depends upon production rates, which are low at start, high on plateau and moderate in terminal phase due to new technologies. Rate of rise becomes lower than the rate of decline in terminal phase due to higher production rates. If production capacity is high, then the duration of the peak plateau continues until terminal depletion of reserves. The half truth of bottomless oil wells or infinite gas dungeons and paradoxes of the imminent end of Oil Age or Hydrocarbon Era reflect derelict views afar from reality. The truth lies somewhere between fossil fuels deplete and renewable energy repletion.

There is neither any imminent end of oil nor any looming gas crisis in next quite a few decades, yet it may be the beginning of breakpoint sometime in distant future. It is time to fix targets to increase the renewable energy share in the national energy mix to participate grand energy transition.

Continued use of fossil fuel has led to a steady increase of CO_2 concentration in the atmosphere to 400.26 ppm in 2015. To decelerate climate change and develop sustainable energy resources, the world community must support the grand energy transition from fossil fuels to renewable and alternative energy resources. A 20% power from renewable resources by 2020, 50% by 2050 and 100% by 2100 is a good energy transition initiative. According to REN-21 some 91-97% people prefer using hydro, wind and solar energy, 80% like natural gas, 48% coal and 38% nuclear power. The current share of renewable sources include 1,350GW hydel, 336GW wind, 150GW solar and 20GW geothermal energies. Farmers produce 17.5Mt bio-ethanol and 2.45Mt bio-diesel annually. Despite 1856GW of renewable energy from various sources, except hydro, contribute to only 20% of global energy demand and the rest 80% is supplied by fossil fuels. The renewable Energy harvesting rate is hardly equal to the rate of rise of energy demand. Chinese electricity demand has tripled in last one decade and their renewable energy source's contribution has quadrupled in the same period. A policy of continuous increasing renewable energy percentage in the national energy mix is the true way forward.

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Table 1 Global fossil fuel statistics based on proved reserves.

Fuels	**Total Reserves**	**Production/Day**	**End (Date)***
Oil	1.689 Tb	86.81Mb	2066
Gas	6558 TCF	326 BCF	2068
Coal	891.531 BT	21.63 MT	2126

* End dates may shift ahead after new discoveries

Table 2 Natural energy resources available to humankind.

Source	Sun	Fossils	Clathrates*	Uranium
Energy (J)#	$3.8x10^{24}$	$36x10^{21}$	$1.5x10^{24}$	$2.5x10^{24}$
Energy (KWh)	$1x10^{18}$	$10x10^{15}$	$4.17x10^{17}$	$694x10^{15}$

* Methane calathrates; Conversion rate 1kWh = $3.6x10^6$J.

Table 3 Primary energy consumption by fuels today.

Source	2012 (GTOE)	2013 (GTOE)	2014 (GTOE)	% Share
Oil	4.1389	4.1851	4.2313	32.60
Gas	2.9863	3.0204	3.0545	23.53
Coal	3.7237	3.8267	3.9297	30.27
Nuclear	0.5599	0.5632	0.5665	4.36
Hydro	0.8336	0.8568	0.8800	6.78
Renewables	0.2408	0.2793	0.3178	2.45
Total	12.4832	12.7304	12.9798	100%

Table 4 Energy storage technologies (Decourt, 2013; Pakosy, 2013)

Technology	Location	Output	Efficiency (%)	Initial investment cost (USD/kW)	Primary application
PSH	Supply	Electricity	50 - 85	500 - 4 600	Long-term
UTES	Supply	Thermal	50 - 90	3 400 - 4 500	Long-term storage
CAES	Supply	Electricity	27 - 70	500 - 1 500	Long-term storage, arbitrage
Pit storage	Supply	Thermal	50 - 90	100 – 300	Medium temperature applications
Molten salts	Supply	Thermal	40 - 93	400 – 700	High-temperature applications
Batteries	Supply, demand	Electricity	75 - 95	300 - 3 500	Distributed/ off-grid storage, short-term storage
Thermochemical	Supply, demand	Thermal	80 - 99	1 000 - 3 000	Low, medium, and high-temperature applications
Chemical-hydrogen storage	Supply, demand	Electrical	22 - 50	500 – 750	Long-term storage
Flywheels	T&D	Electricity	90 - 95	130 – 500	Short-term storage
Supercapacitors	T&D	Electricity	90 - 95	130 – 515	Short-term storage
Superconducting magnetic energy storage (SMES)	T&D	Electricity	90 - 95	130 – 515	Short-term storage
Solid media storage	Demand	Thermal	50 - 90	500 - 3 000	Medium temperature applications
Ice storage	Demand	Thermal	75 - 90	6 000 - 15 000	Low-temperature applications
Hot water storage (residential)	Demand	Thermal	50 - 90	Negligible	Medium temperature applications
Cold-water storage	Demand	Thermal	50 - 90	300 – 600	Low-temperature applications

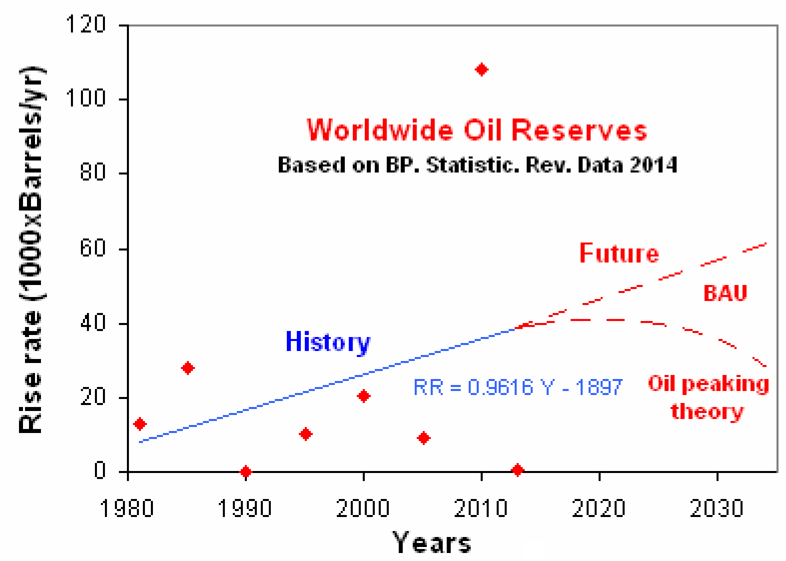

Fig.1 Annual oil reserves increase rates from 1980 to 2013.

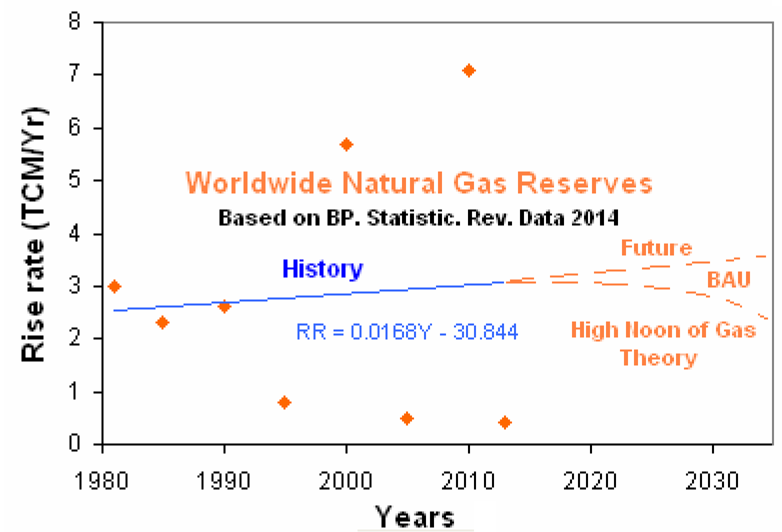

Fig.2 Annual gas reserves increase rates from 1980 to 2013.

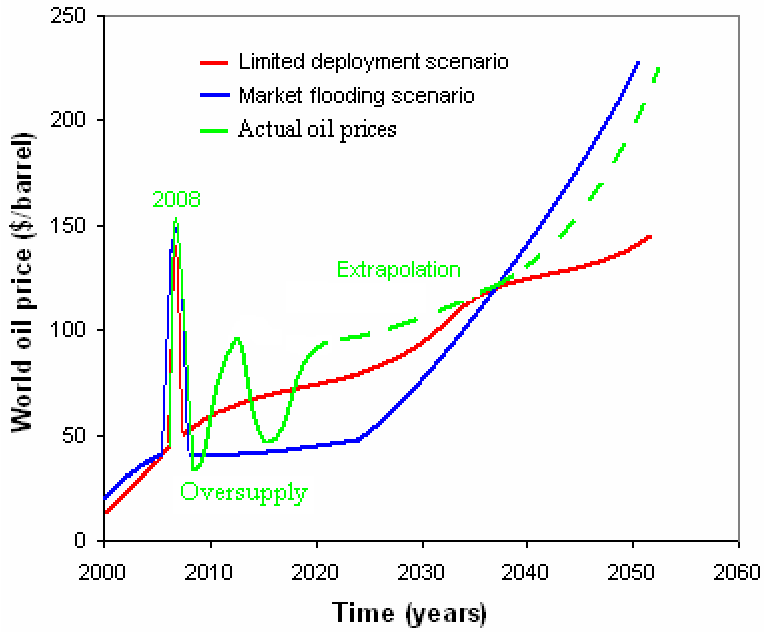

Fig.3 World oil prices and theoretical forecasts.

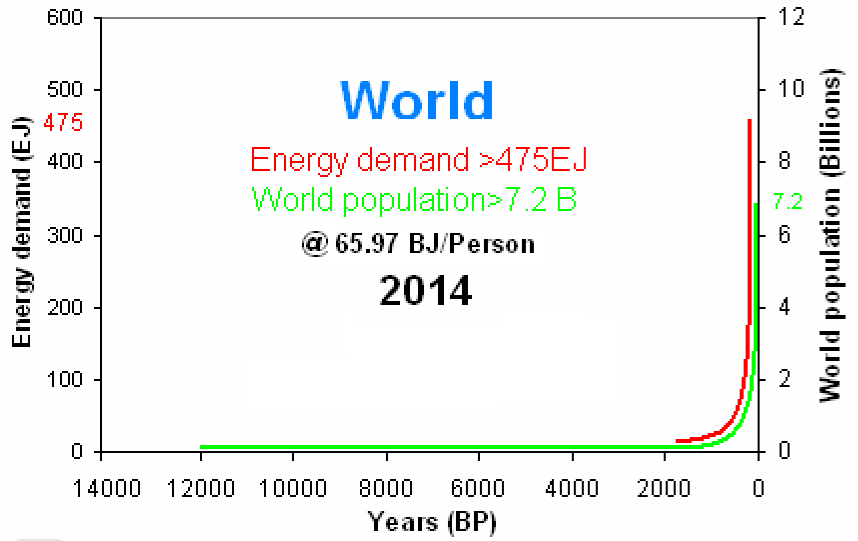

Fig.4 Population and energy demand growth.

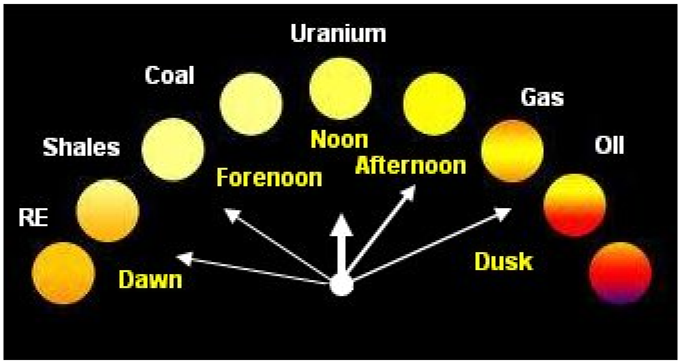

Fig.5 Rise, peak and decline of energy sources

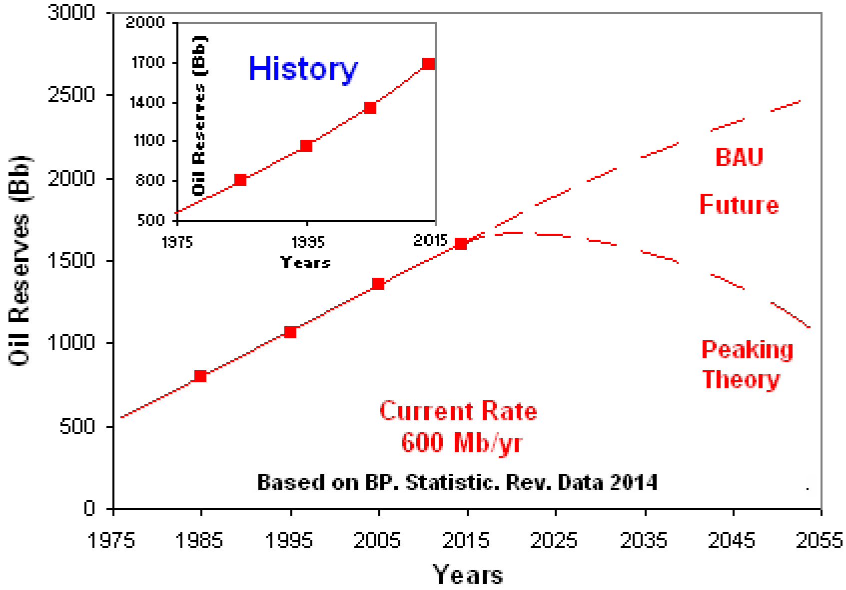

Fig.6 Proved global oil reserves variations with time.

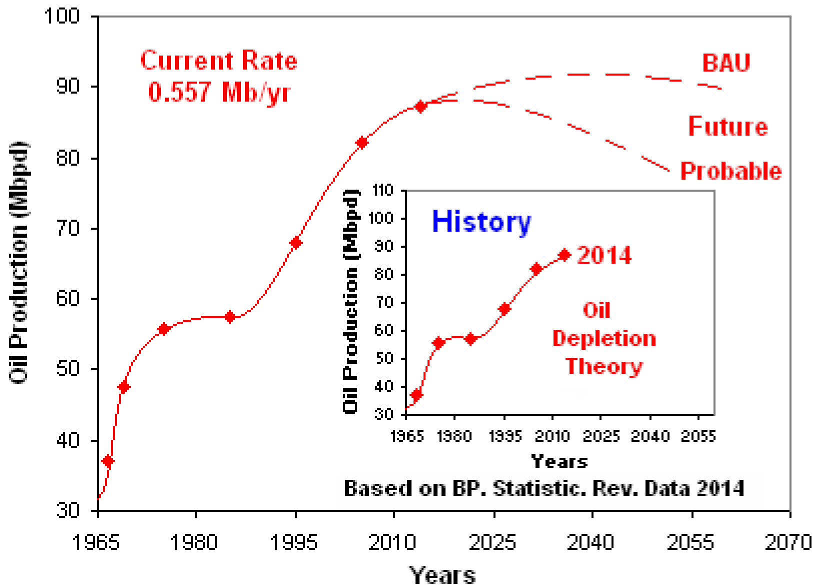

Fig.7 Global oil production variations for last 100 years.

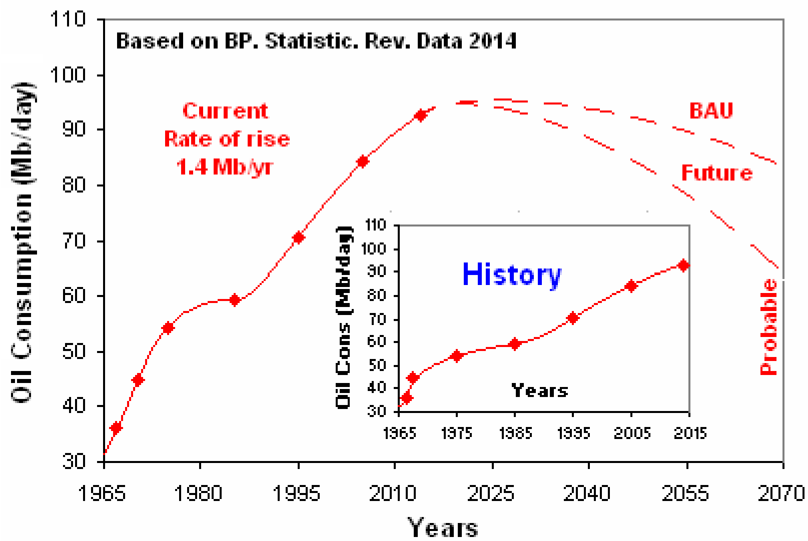

Fig.8 Word oil consumption rate in last 100 years.

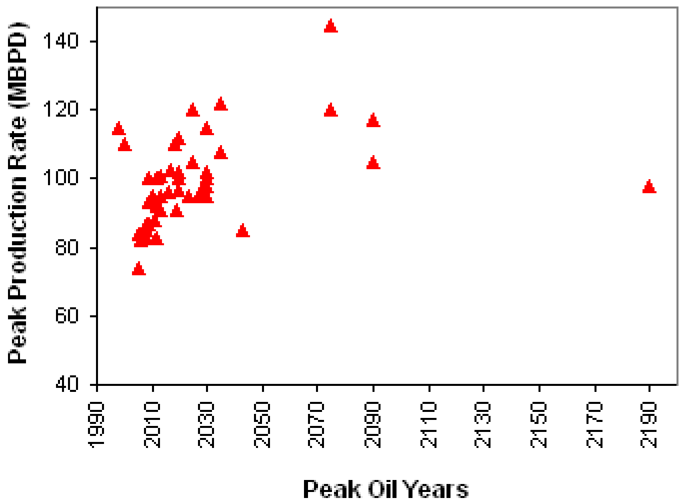

Fig.9 Reported peak oil production years.

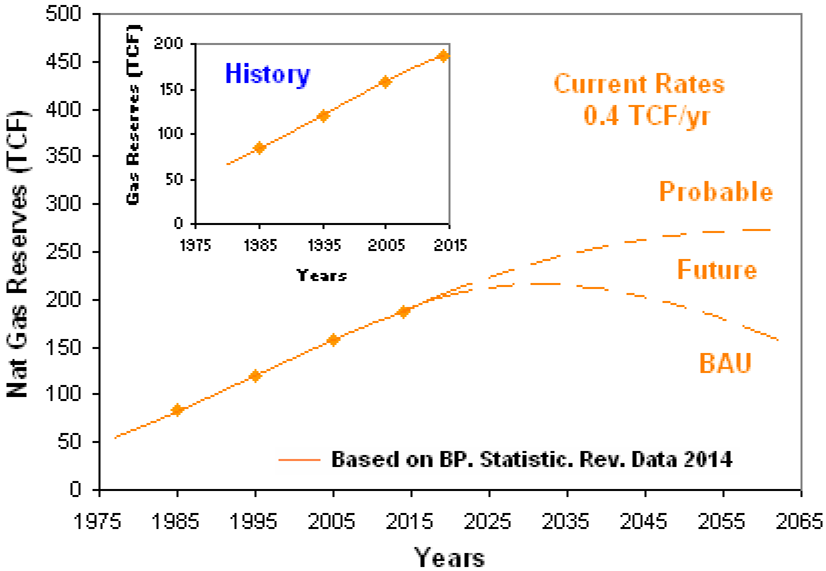

Fig.10 Variation of natural gas reserves over time.

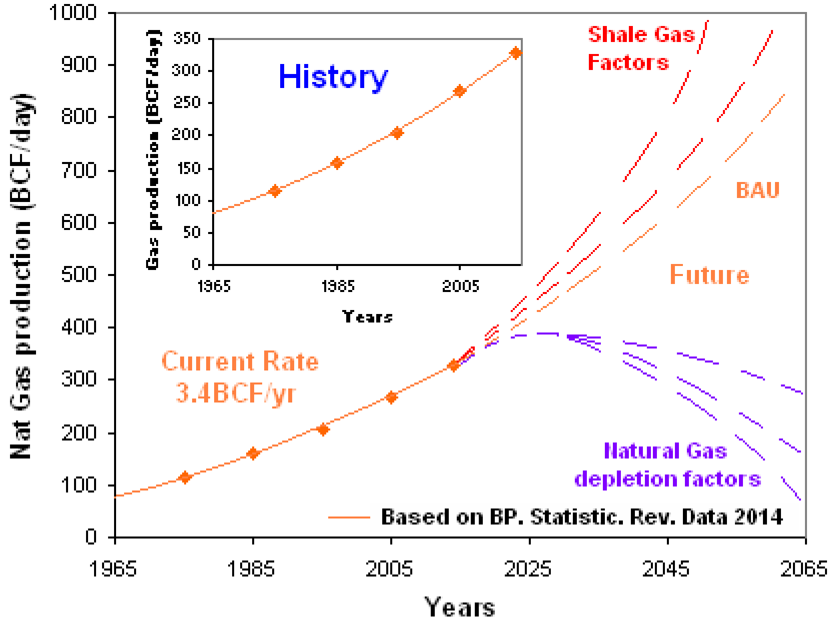

Fig.11 Natural gas production variations over time

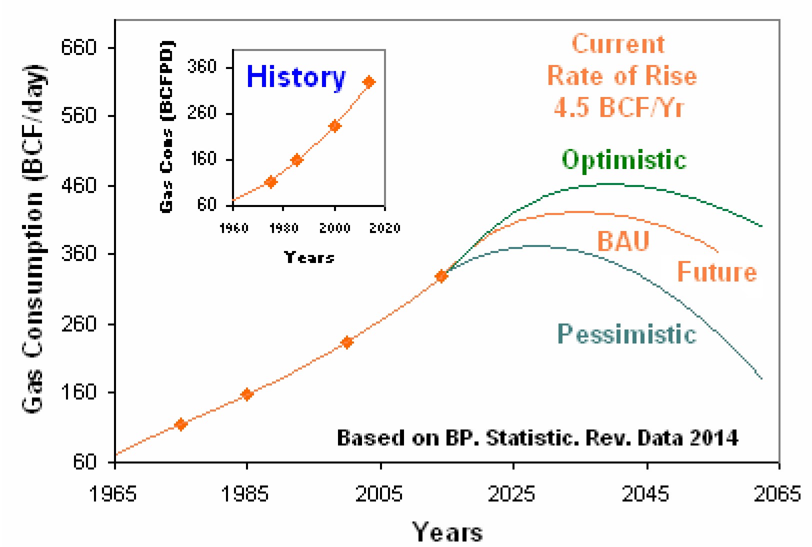

Fig.12 Natural gas consumption rates over time.

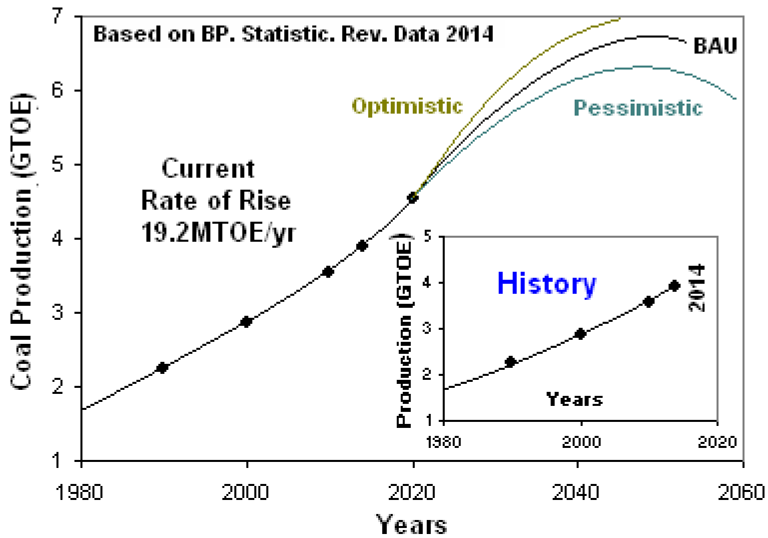

Fig.13 Worldwide coal production over time.

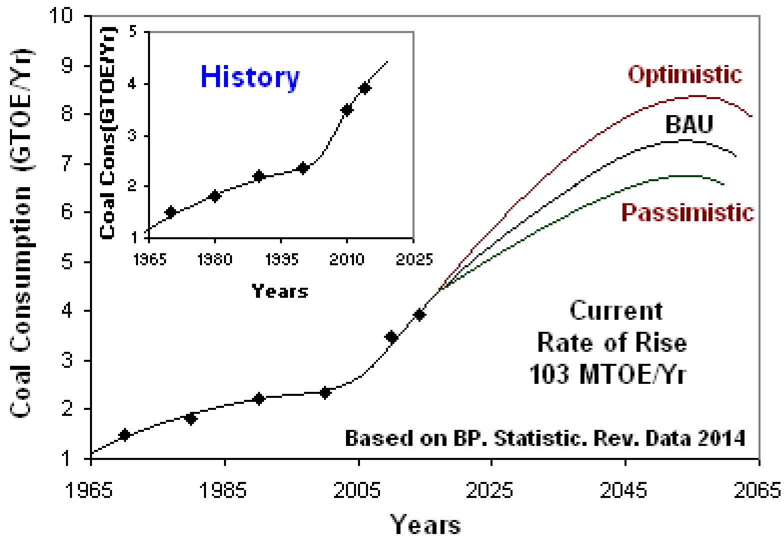

Fig.14 World coal consumption rates over time.

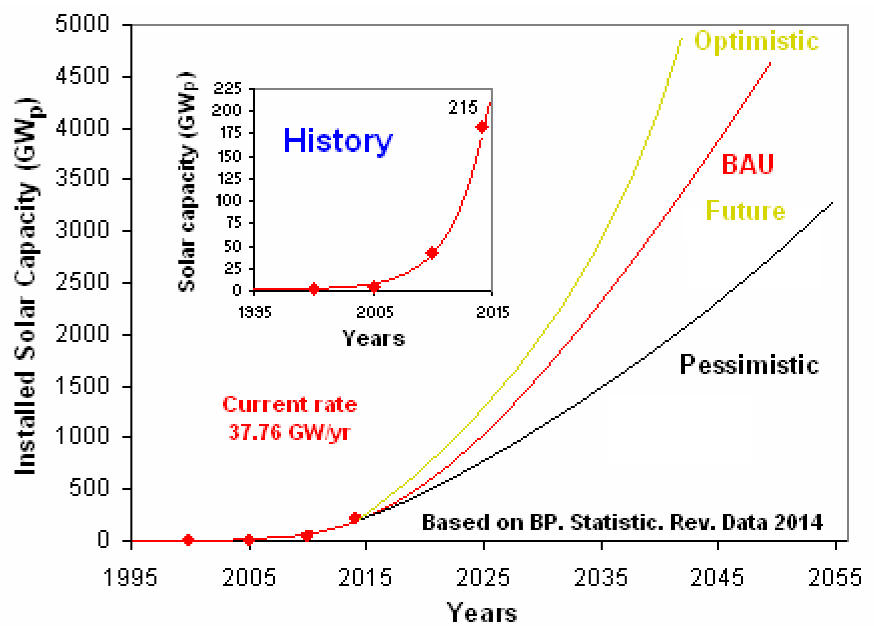

Fig.15 Worldwide accumulative installed solar power capacities over time.

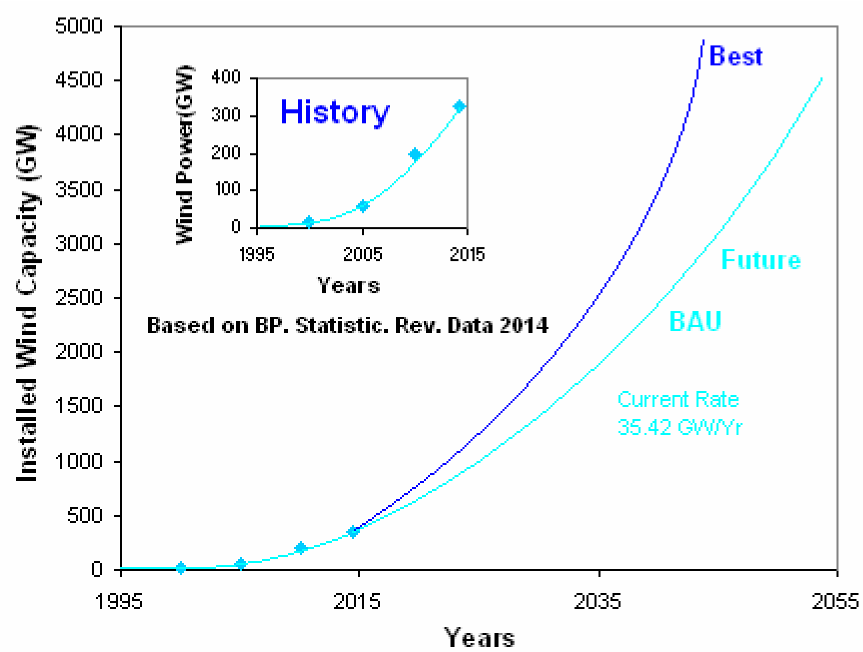

Fig.16 Worldwide accumulative installed wind power capacities over time.

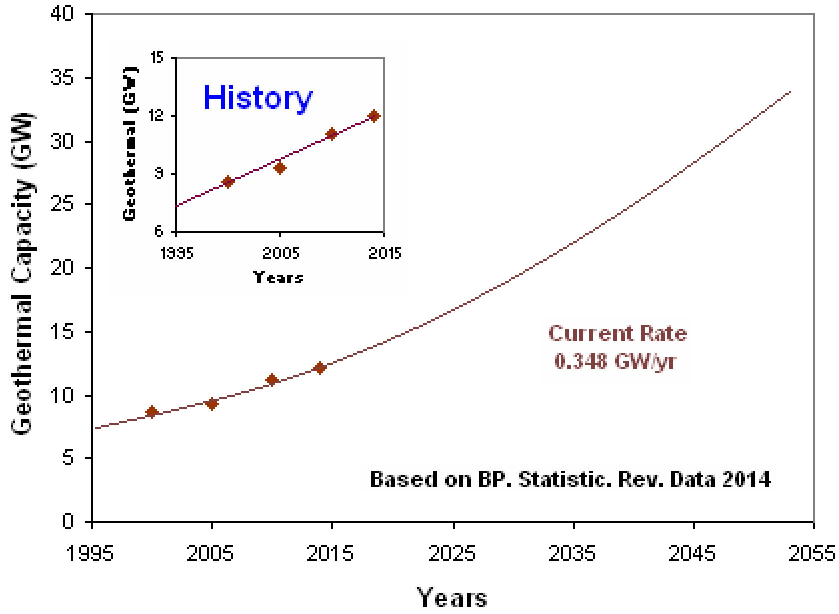

Fig.17 Worldwide accumulative installed geothermal power capacities.

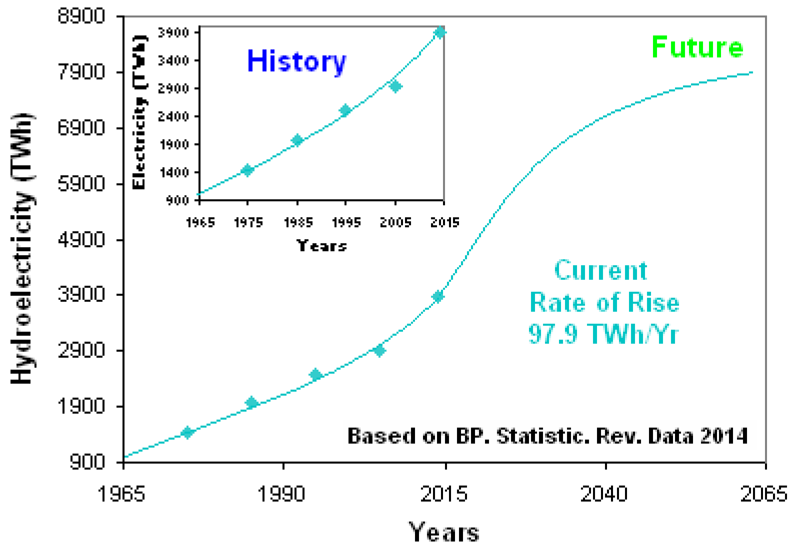

Fig.18 Hydropower increase over times worldwide.

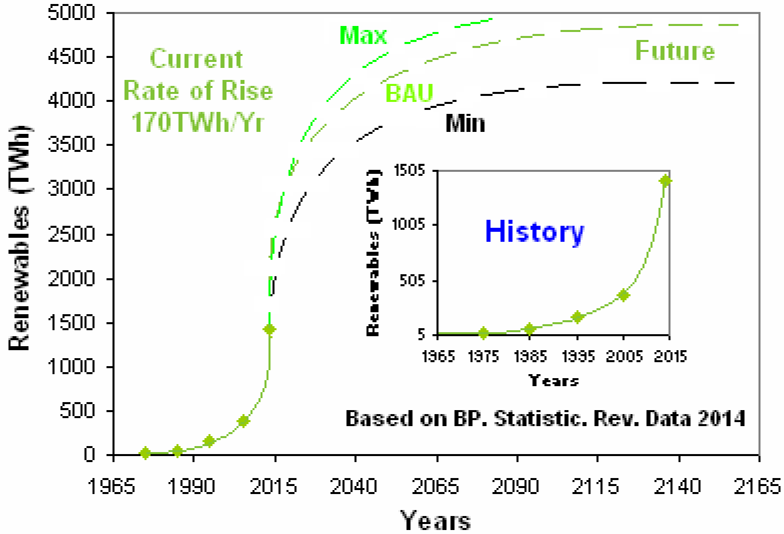

Fig.19 Energy obtained from other renewable energy sources.

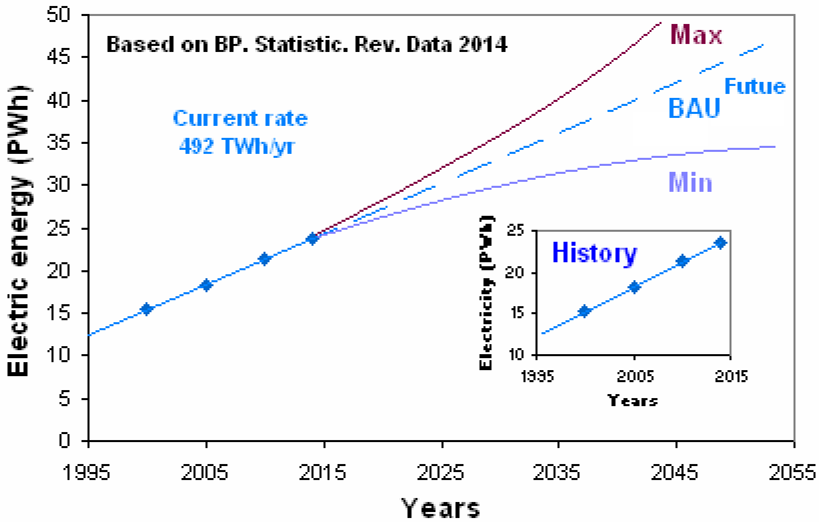

Fig.20 Worldwide accumulative electric energy over time.

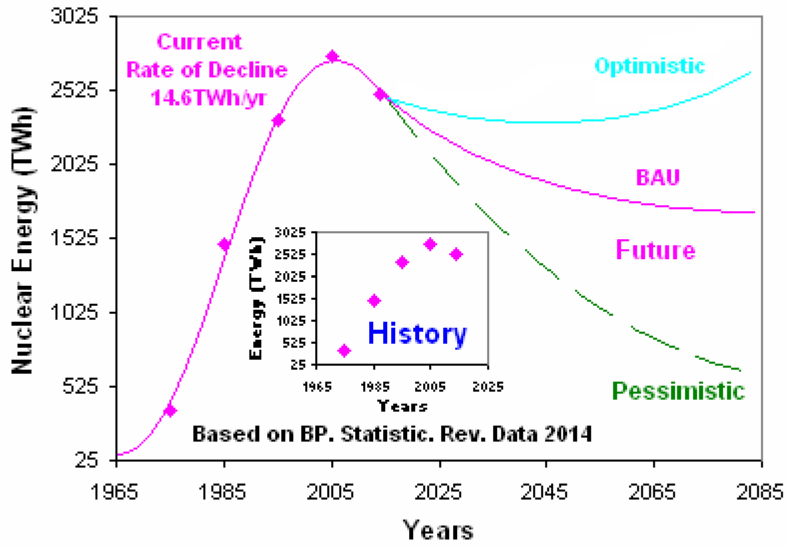

Fig.21 Nuclear energy development over times.

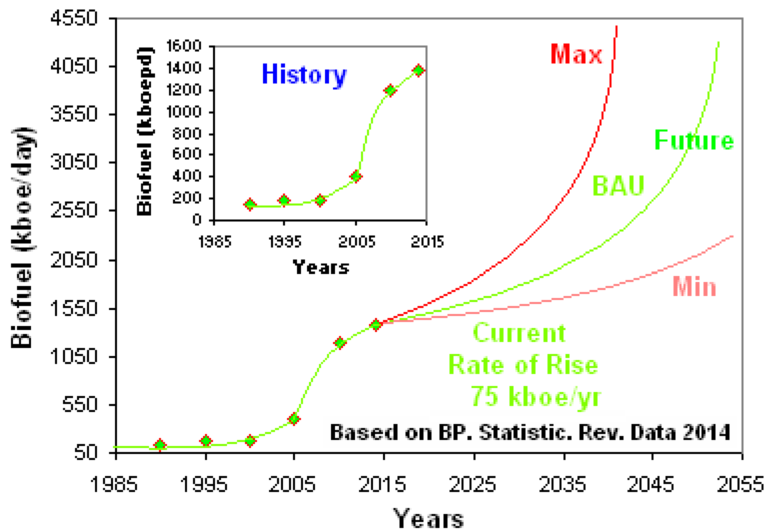

Fig.22 Global biofuels productions over time.

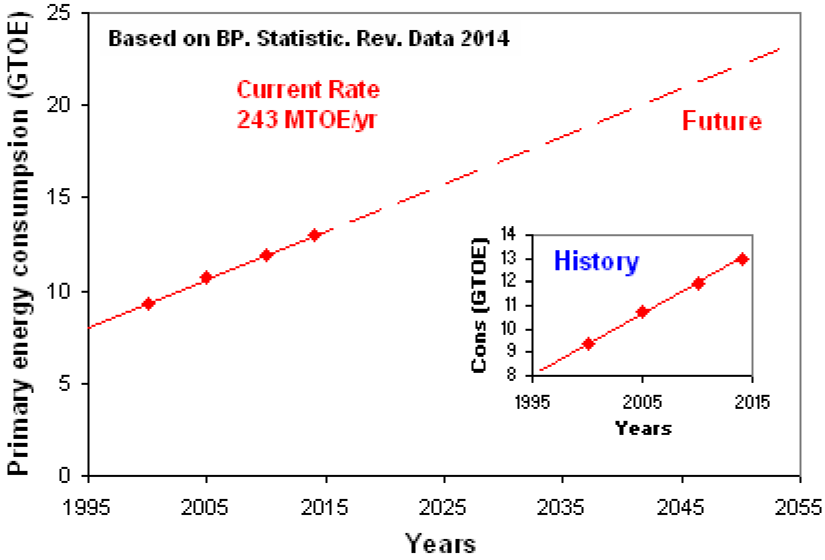

Fig.23 Total primary energy consumption over time.

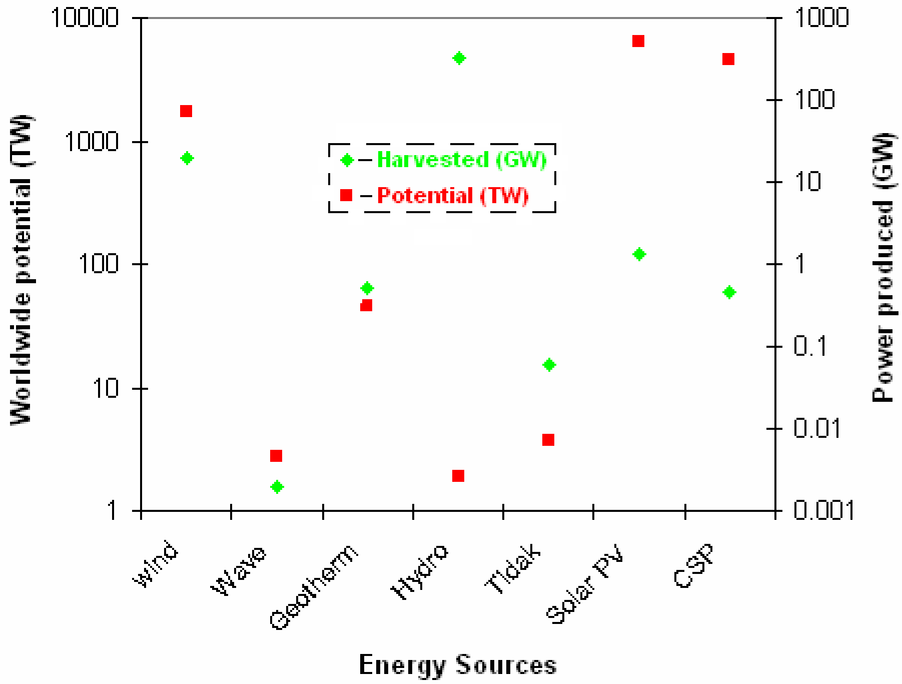

Fig. 24 Global power potential and harvested energies.

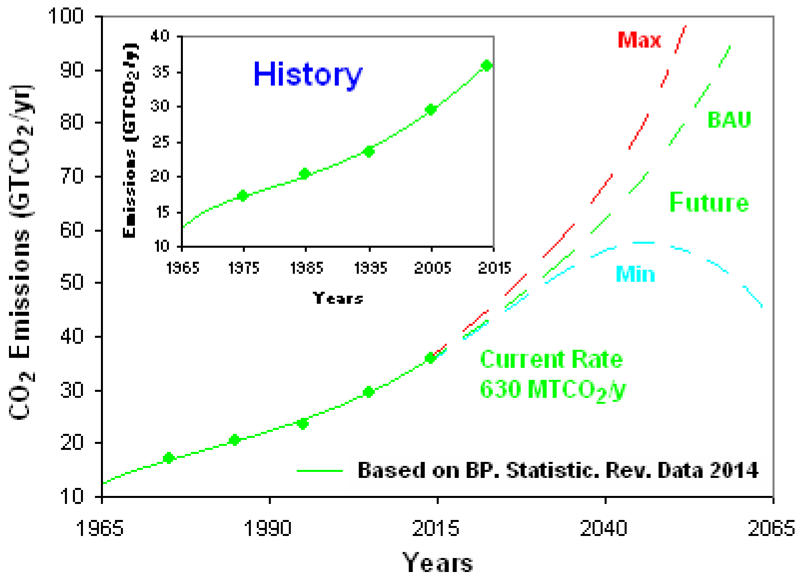

Fig.25 Annual CO_2 emissions by consuming fossil fuels worldwide

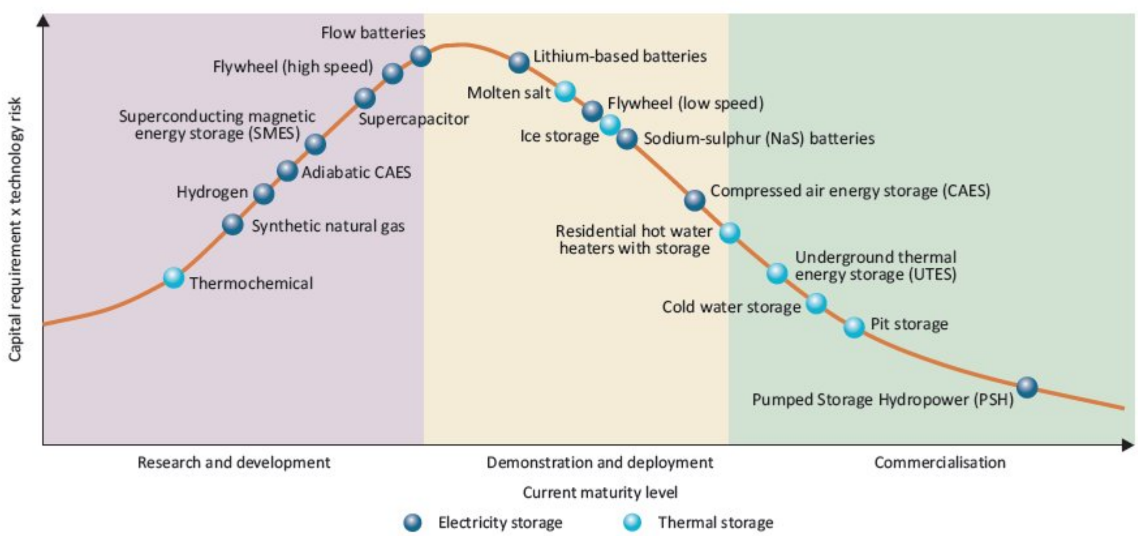

Fig. 26 Maturity phases of future energy systems (Decourt, 2013; Pakosy, 2013).

Fig.27 CO_2 mediated solar water heater