Renewable vs. conventional energy: which wins the race to sustainable development?

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Abstract. Fossil fuel is no longer a reliable source to meet an increasing energy demand and guarantee a sustainable world in the future. This is because of its known environmental effects linked to climate change, global warming, and severe pollution. The current situation of harnessing energy requires to adjust for the integration of renewable energy into transportation and electricity generation for sustainable development. Throughout the literature, two main trends in energy technology are recognized. One is continuing to use petroleum-based fuel, but with less and wise fuel consumption, increased efficiency of the engines of vehicles and electricity generators, and decarbonizing carbon in the exhaust. Second is technology development in green energy from renewable sources such as sun, wind, and hydropower to reduce in construction and production costs and lessen their environmental effects. This paper firstly presents an overview on green technology in the past and present. Secondly it discusses the adoption of green technology into the current conventional energy industry, challenges and approaches and thirdly how to increase its competitiveness with fossil fuel for the future.

1. Introduction

It is undeniable that scientific discoveries and inventions have revolutionized the human society to a modern age with countless benefits from mass production in the industry, safer and faster transportation, ease and convenience in communication, access to education, better health care and so on. All of these are the driving factors for the economic growth which demands a huge energy source. In addition, the energy demand from 12.5 to 16 billion tons of oil equivalent (btoe) also results from the forecasted increase in the world population from seven to nine billion in 2050 [1]. Unfortunately, fossil fuel is known to be a finite energy source which is projected to be available in the next 104 years only [2].

Heavy dependency on the limited source of fossil fuel obviously results in energy crisis and threat to national security of energy for economic development. Instead, harnessing other energy sources which is not only more abundant in nature but also eco-friendlier is a more effective solution to the current or future shortage of energy. Due to this reason and consideration for long term use of energy, a better approach for this circumstance is sustainability, which is defined as the ability to be sustained, supported, upheld, or confirmed [3]. Economics, politics and culture are the human factor, whereas ecology is the nature factor, which closely relates to energy as one of the subdomains, besides materials, water, air, flora and fauna and many more [4].

The sustainability approach is seriously taken to a further step by the United Nation known as sustainable development - “development that meets the needs of the present without compromising the
ability of future generations to meet their own needs” [5]. Therefore, a sustainable development needs an integration with renewable energy source to secure energy usage, facilitate modernization and mitigate the environmental effects in the long run. This paper discusses the perspective in energy mix situation, improvement in the efficiency of current usage of non-renewable energy, and advance in the renewable energy technology.

2. Current and future situations of energy
Energy plays an important role in the effort to build a sustainable development. According to the United Nation, clean and affordable energy is set as an important goal to achieve [5]. Similarly, four out of 14 grand challenges for engineering are related to efficient energy usage, i.e., making solar energy economical, manage the nitrogen cycle, provide energy from fusion and develop carbon sequestration method [6]. Based on the analysis of energy mix to 2050, the world energy demand continues to increase from 12.5 btoe to 16 btoe and petroleum-based energy sources including coal, oil and natural gas tend to decrease, while an increasing trend in renewable energy such as hydro biofuel and biomass is seen and anticipated to increase its share with non-renewable source to 15% [1]. With the technology development in renewable energy, the global CO₂ emissions was able to remain flat in the past three years (2014 – 2015) [7].

Notably, renewable energy increases its share in the total energy production. From 2004 to 2015, the percentage of energy share from renewable sources increase from 13.61% to 19.3% [8]. This fact implies a positive future for renewable energy in commercialization.

3. Current usage of non-renewable energy
In the US, energy from non-renewable source mainly petroleum contributed 37% of total energy consumption in 2016. In this 37%, 71% consumption of energy went to transportation considered as the main sector [1]. However, the current technology in car design has a large amount of energy loss at 78.5%, and only 21.5% of useful energy to move the car [9]. Therefore, energy efficiency of transportation vehicles can be further improved by improvement in the technology. Using light weight material for vehicles can make a 10% reduction weight, which results in 6 to 8% reduction in fuel consumption [10]. Furthermore, technology in using spark ignition engine, direct injection, lean burn, turbocharge and premium octane rating is able to increase the efficiency of the internal combustion engine [10].

Decarbonizing fossil fuel emission via carbon capture and storage is a potential solution to reduce the greenhouse gas effect. CO₂ gas after being release from the combustion is captured by a system consisting sorbent-based CO₂ separation unit, sorbent generator and CO₂ compressor [10]. However, to achieve 90% of the carbon emitted from coal, capital cost for a carbon capture and storage system is estimated to be equal to the cost of the coal plant itself. Therefore, technology for carbon capture and storage is yet to be mature for commercialisation, and still need more research and development in this area.

4. Advance in the renewable energy technology
Various types of renewable energy are available to harness. In comparison with conventional or non-renewable energy source, renewable energy has more advantages in term of free cost of materials, and less impacts on the environment. However, the challenges of renewable energy are that their technologies are still at the development stage, yet to be well-established to integrate with non-renewable energy generation system. Therefore, production cost of renewable energy is less competitive as non-renewable energy. The following section presents a brief overview of the typical renewable energy sources, its shares in the energy production and the current challenges.

4.1. Hydropower
Hydropower is energy obtained from the flow of water to rotate turbine for electricity generation. In 2015 and 2016, China and Brazil are two largest hydropower generation countries with capacities of
300, 250 gigawatts respectively, contributing 37% of total hydropower capacity of 1096 GW [8] as shown in Figs. 1 and 2.

![Hydropower shares of top 6 countries and rest of the world in 2016](image1)

**Figure 1.** Hydropower shares of top 6 countries and rest of the world in 2016 [8].

![Hydropower capacity and addition of top 9 countries in 2016](image2)

**Figure 2.** Hydropower capacity and addition of top 9 countries in 2016 [8].

The advantages of hydropower as a renewable energy source are high yield and low production cost, long lifespan and able to supply continuously. On the other hand, the disadvantages of hydropower are displacement of local community, high impact on ecosystem at upstream and downstream river, emission of greenhouse gases such as carbon-dioxide, methane and nitrous oxide and high capital investment [11]. Every year, the total amount of CO$_2$ released from hydropower dams to the atmosphere is 48-82 TG and that of CH$_4$ is 3-14 TG [12], [13]. In addition, other concern with construction of hydropower is the impact on the local habitat and biodiversity [11].
4.2. Wind energy
Due to the uneven heating on the Earth’s surface by the Sun, air flow is harnessed to convert from mechanical to electrical energy by wind turbines. In 2016, the expansion of wind energy reached 487 GW [8]. China and the US have the highest capacity of wind power at 224 GW as can be seen in Fig. 3.

![Figure 3. Wind power capacity and additions of top 10 countries in 2016 [8].](image)

Cost of wind energy decreases because of the significant improvement in turbine components such as blades, gearboxes, and increase in height of wind towers [10]. Moreover, integration of wind energy with electricity grid for power distribution is possible by advance in direct-drive wind turbines which convert slow rotation to alternative current using electromagnetic generator [10].

For wind energy, geographical location is the limitation for countries which are unfavoured with windy condition or situated inside continent. Weather-dependent factor results in intermittent supply of energy from wind [10]. In addition, the environmental impact of wind farm is the death of hundred thousand of birds and bats due to the turbine collision [14], [15]. In 2012, it was reported that the number of birds and bats being killed due to collision was estimated at 573,000–888,000 [14–16]. Migration and residence of birds are also affected by the presence of wind farm [17], [18]. An additional effect of wind farm operation on the ambience is the increase in the level of noise and temperature, an example for this is an increase by 0.18 °C at night time reported at a windfarm in Scotland [19].

4.3. Solar energy
Sunlight is captured and turned to electricity via photovoltaic cells installed in solar panels. Solar energy is the fastest growing energy source among renewable energy production. In just one hour, the amount of energy from sunlight reaching the Earth is so huge that it is enough to power the world economic for an entire year [4]

Between 2006 and 2016, global capacity of solar energy continuously increases from below 50 to 300 GW [8] due to innovation in technology (Fig. 4).
Figure 4. Solar PV global capacity and annual addition from 2006 to 2016 [8].

The price of solar energy is getting cheaper around 50-60 USD per MWh without subsides by 2020 [10]. Notably, with the significant improvement in manufacturing solar photovoltaic cells between 2008 and 2012, the price of silicon solar module decreased from 4 to 1 USD per watts [10]. It is expected that the price of solar energy delivered to housing area can reach 0.8-0.5 USD per watts [20].

Challenges of solar energy is weather-dependent and an intermittent energy source with low density and high production cost. In comparison with other energy types like coal, oil and gas, the production cost of solar energy is almost 8 times higher [1]. Besides that, the price of solar energy has to include a high cost for balance system including permit, interconnection, inspection, financing customer acquisition) [10].

4.4. Biofuel energy

Extraction of energy from biomass in food-sources or non-food-sources is biofuel energy. From 2006 to 2016 in Fig. 5, total energy generation from biopower was almost 504 terawatt-hours per year, which were contributed mainly by European countries and North America [8].

Figure 5. Global bio-power generation by region from 2006 to 2016 [8].
Bioenergy technology especially ethanol fuel has attracted an increasing interest as a practical solution to solve environmental pollution caused by fossil fuel usage due to its carbon-neutral process, improvement in national energy security and suitability for agricultural countries. There are two platforms to produce ethanol fuel, i.e., syngas and sugar platforms [21]. Conventionally, food source such as corn, rice, wheat and sugar are used as feedstock for ethanol production. Hence it is call the first-generation ethanol fuel, which results in a controversial issue of using food versus fuel, and other negative impacts on regional water source, biodiversity, soil quality [22], [23]. In contrast, introduction of the second-generation fuel ethanol from cellulosic feedstock originated from agricultural and forestry residuals (corn stovers, sugar bagasse, rice straw and palm empty fruit bunches) is able to not only avoid such issues but create an environmental-friendly way to reuse cellulosic biomass for producing a value-added fuel ethanol product instead of conventional fertilizers, animal feedings.

Although bioenergy is a renewable energy source in the carbon-neutral process, it also poses some challenges which needs to address. Poor land management for biofuel crop can results in some environmental effects as serious as effects of using fossil fuel [24]. Bioethanol from food-source (sugar and starches) induces the increase in feedstock price which has to compete with agriculture and food industry [25].

4.5. Geothermal energy

Geothermal energy - heat released from the Earth’s crust is captured to rotate turbine and be converted to electrical energy. Water is injected in to the production well down the crust to be heated and turn to steam. Steam is then withdrawn to rotate turbines for electricity generation. After heat extraction in the turbine, water steam is turned back to liquid water in the condenser and finally injected back to the well [26]. Two countries leading the world to harness geothermal power are Indonesia and Turkey with the capacities of more than 1500 and 900 megawatts in 2016 as shown in Fig. 6 [8].

![Figure 6](image_url)

**Figure 6.** Geothermal power capacity and additions of top 10 countries in 2016.

Advantages of geothermal energy is a kind of renewable energy with high production yield but low operating cost [26]. The disadvantage similar to hydropower energy are geographical location which not every country is favoured to have, and high capital investment. Furthermore, current process design of producing geothermal energy causes some water and H_2S pollutions [26].
5. Integration of renewable energy with non-renewable energy

With a well-established technology and public policy support, replacement of conventional energy by renewable energy is an overnight process but needs times and goes through different stages from integration to transition. It was identified in the commercialisation journey of the renewable energy, the driving factors are economic benefits in market, research and development in construction of infrastructure, environmental awareness in public and government policies to support [27].

While waiting for renewable energy technology to be mature and fully commercialised, saving the non-renewable energy such as increase its efficiency and hence reducing its consumptions are better solutions to slow down its depletion and give an effective reservation of energy resources for the further generation. According to a study on energy losses in passenger cars due to friction by Anderssona et al., it was found that 33% of energy loss is due to friction, while only 21.5% of the total energy input are useful to move a car [9]. If using electric cars, the frictional loss would be greatly reduced by 50% in comparison with those cars using internal combustion engines [9]. Additionally, by implementing new tribological solutions, it would be possible to make an energy saving of 18% in just five years, which is more effective and faster than the expansion of renewable energy into production taken for 11 years from 2004 to 2015 [8].

Therefore, at the present, integration of renewable energy sector into energy production is more important by increasing its share in production and consumption. Besides that, there are still space for further improvement for technology of using conventional energy (fossil fuel) more efficiently and effectively in order to reduce its consumption and give space for renewable energy to take part in.

6. Conclusion

With the continuous increase in the world population, conventional energy availability becomes obviously unable to sustain a huge energy demand for living, industrialisation, and sustainable development perspective. To meet the energy demand and mitigate the effect of greenhouse gases as a result of using fossil fuel, the renewable energy is an alternative to make contribution.

At the present, an integration of renewable energy with non-renewable energy is a more important step to proceed to not only fully prepare, implement and commercialise the renewable energy firmly in the long term, but also offering effective solution of using and preserving the non-renewable energy resources to attain sustainable development.

- Reduce the consumption of fossil fuel by improvement in engine efficiency, direct saving.
- Promote the use of renewable energy via policy making, economic benefit and increasing public awareness.
- Every energy source has environmental impact, but sustainable development is the pathway to make a wise choice.
- Human plays a key role in creating a culture of utilizing energy effectively and efficiently as a way of saving the non-renewable energy in order to prolong the reservation and stop or decrease the emission of CO2.

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