Dr. Norbert Cheung's Series in Electrical Engineering

Level 5 Topic no: 27

Energy and the Environment

Contents

Reference:

C.C. Chan and K.T. Chau, Modern Electric Vehicle Technology, London: Oxford, University Press, 2001

Email: norbert.cheung@polyu.edu.hk **Web Site:** www.ncheung.com

1. Energy

Energy plays a very important role in the evolution of our society. Among various energy resources, oil is the major one. The exclusively wide acceptance of ICEVs for road transportation has created a vast market for oil business. Any disruption of oil supply will definitely cause a large turbulence in our society.

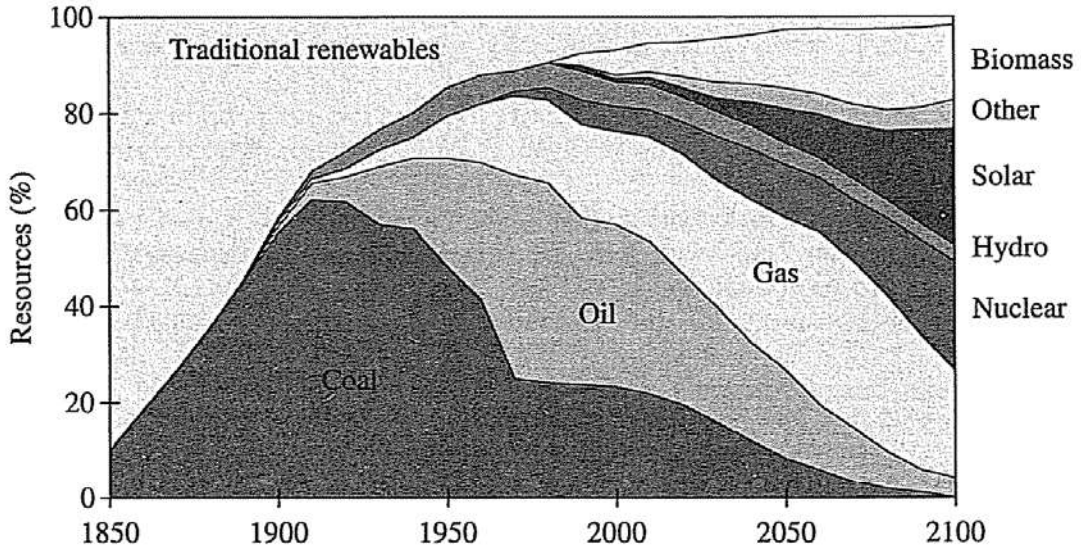

Fig. 10.1. Global energy consumption.

Deriving from oil, petrol and diesel are essentially the exclusive fuels for ICEVs. So, our present transportation means are heavily dependent on oil. EVs are an excellent solution to regulate this unhealthy dependence because electricity can be generated by almost all energy resources in the world. Figure 10.2 illustrates the merit of energy diversification for EVs in which electrical energy can be obtained from thermal power generation, nuclear power generation, hydropower generation, tidal power generation, wave power generation, wind power generation, geothermal power generation, solar power generation, chemical power generation, and biomass power generation.

Thermal power generation is to combust fossil fuels, hence producing heat energy, heating up water to form steam, driving the steam turbine, and finally generating electricity. Three common fossil fuels for this power generation are coal, oil and natural gas. Coal is the most abundant fossil fuel. As shown in Fig. 10.3, coal contributes about 91% of global fossil reserves, whereas oil and natural gas are only of 4% and 5%, respectively. Currently, mineable coal reserves exceed one trillion tonnes which are expected to be large enough to last over 200 years while the current reserves of oil may last 45 years and natural gas 70 years

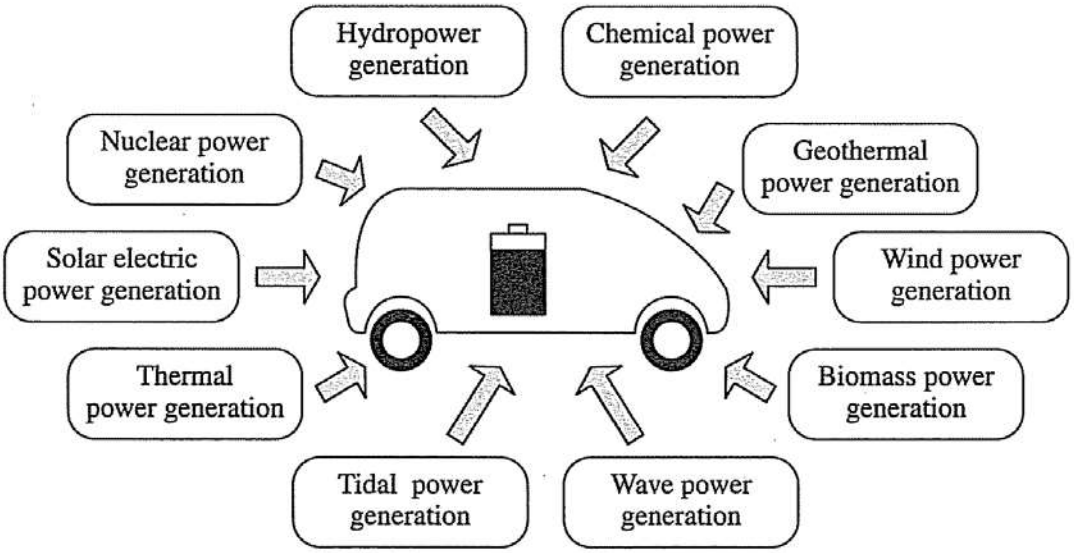

Fig. 10.2. Energy diversification for EVs.

Nuclear power generation is similar to thermal power generation except that the heat energy is resulted from nuclear reactions rather than fossil-fuel combustion. At present, all commercial nuclear power is obtained by fission of very heavy atoms, which are generally extracted from uranium or thorium ores. Nuclear power is a main source for electricity generation. In 1996, nuclear power plants supplied about 23% of the electricity production for countries with nuclear units, and about 17% of the total electricity generated worldwide. Global and regional

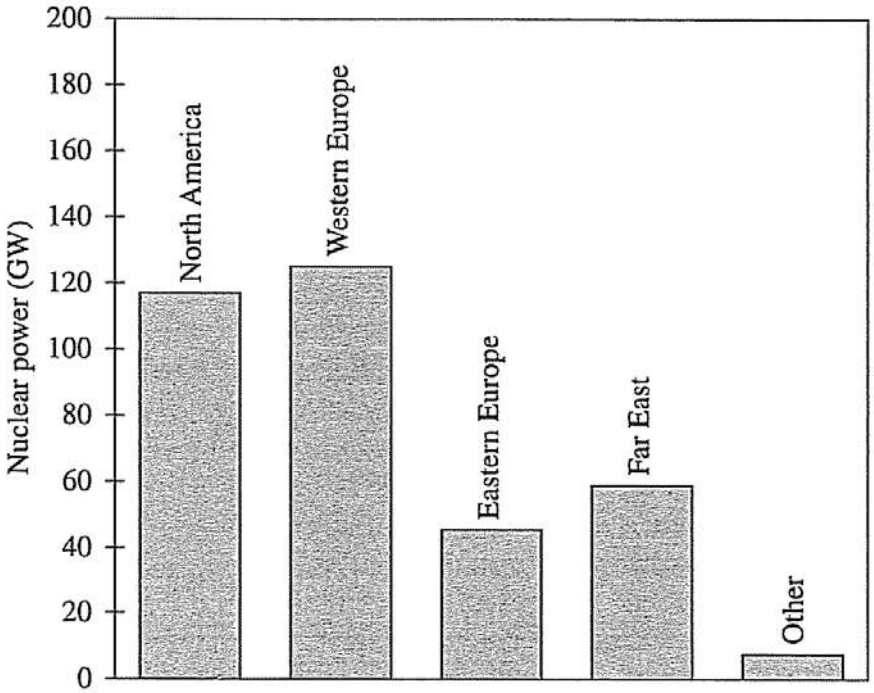

Fig. 10.4. Nuclear power generation.

Hydropower generation is basically the conversion from potential energy to kinetic energy of falling water, hence driving the water turbine and finally generating electrical energy. The operation of hydropower plant is clean, produces no emissions nor greenhouse gases, and leaves behind no wastes. Because of simple operation and no combustion, hydropower can generate electricity with an efficiency as high as 90% which is much higher than that of combustion thermal power generation. In general, the production cost of hydropower is about one-third the cost of using fossil fuels or nuclear. Moreover, hydropower does not experience rising or unstable fuel costs.

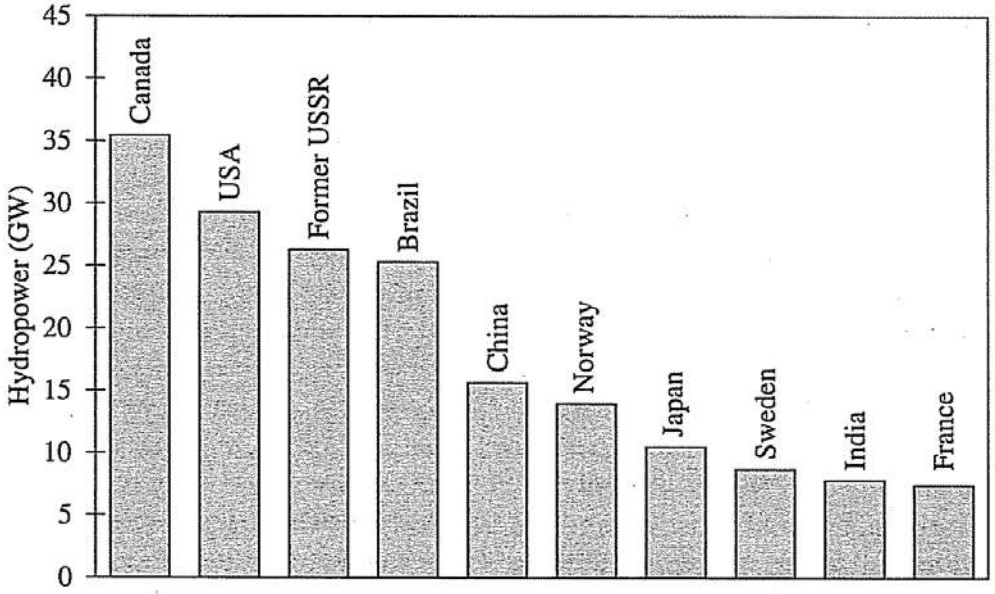

Fig. 10.5. Hydropower generation.

Tidal power generation is the most well developed technology to extract ocean power. It operates on similar principles to hydropower generation. Tidal power is governed by weather conditions, slope of the continental shelf and the coast. The total potential tidal power of the world has been estimated to be about 64 GW.

Wave power, similar to tidal power, is a kind of ocean power as it takes the advantage of ocean waves caused primarily by interaction of winds with the ocean surface. Since wave power is an irregular and oscillating low-frequency energy resource, many types of wave energy converters have been developed to extract energy from surface waves, from pressure fluctuations below the water surface, or from the full wave. It has been estimated that the wave power along California coastline is of 4–10 MW/km. The technology is still at the experimental stage.

Wind power generation basically employs wind turbine technology to generate electricity. It is economical and pollution free, but its security is constrained by intermittence and unreliability. It has been estimated that the total physical potential of wind power may accommodate 20% of the global electricity demand.

Geothermal power is heat energy contained within the Earth, such as hot springs, fumaroles, geysers and volcanoes that can be recovered and put to useful work. Geothermal power generation is to convert those high-temperature (above 150 °C) geothermal resources to electricity using steam or organic vapour turbines. Similar to other power generation using renewable resources, it is economical and pollution free.

Solar power generation is generally classified into two categories, namely solar-thermal and solar-electric (photovoltaic). Solar-thermal power generation makes use of the solar radiation incident on the collector to heat a fluid, commonly water, to its boiling point so that the resultant steam drives a turbine to generate electricity.

Chemical power generation is generally based on fuel cell technologies. A fuel cell is the chemical system in which a fuel (commonly hydrogen) combines with oxygen to produce electricity with pure water as by-product.

Biomass power refers to the energy created by firewood, agricultural residues, animal wastes, charcoal and other derived fuels. Biomass can be used as a substitute for conventional fossil fuels for thermal power generation. The corresponding heat is generated by direct combustion of biomass or biomass-derived products. Those gaseous or liquid biofuels are derived by using thermal conversion, biological conversion and biochemical conversion. Biomass power generation usually operates on a small to medium scale (under 100 MW), and those biomass power plants are likely installed in rural locations that are connected to the distribution network close to the final consumers.

2. Energy Efficiency

Besides the definite merit of energy diversification resulting from the use of EVs, another advantage is the high energy efficiency offered by EVs. In order to compare the overall energy efficiency of EVs with ICEVs, their energy conversion flows from crude oil to road load are illustrated in Fig. 10.6, where the numerical data are only for indicative purposes and may have deviations for different refineries, power plants, power transfers, batteries, EV types, ICEV types or driving cycles. By taking crude oil as 100%, the total energy efficiencies for EVs and ICEVs are 18% and 13%, respectively. Therefore, even when all electricity are generated by oil-fuelled power plants, EVs are more energy efficient than ICEVs by about 40%.

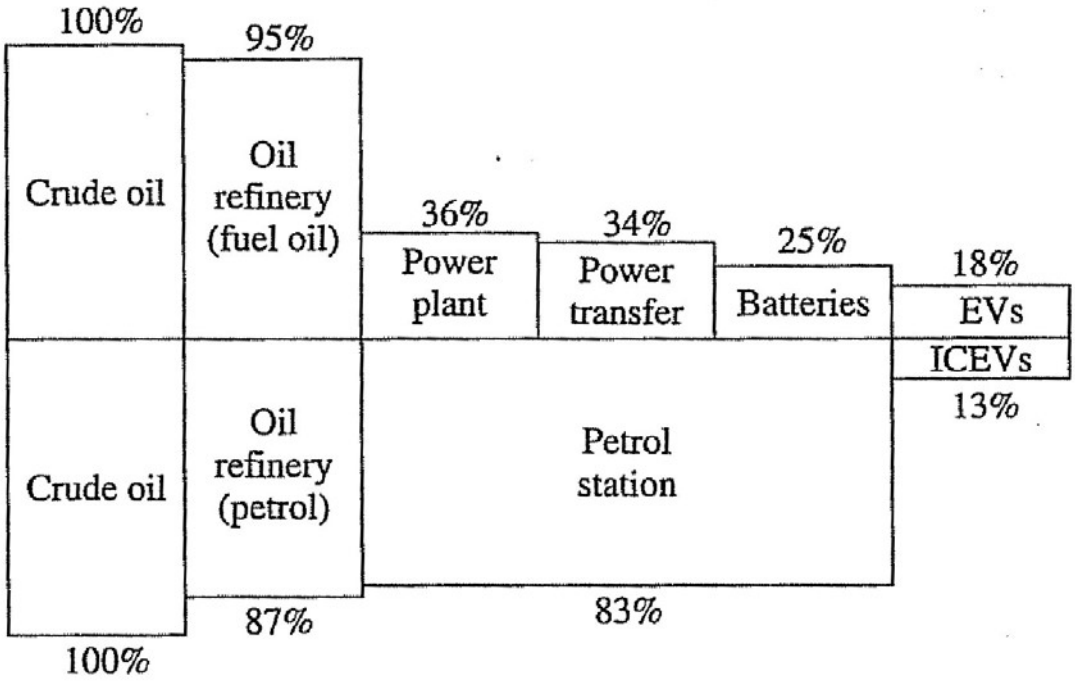

Fig. 10.6. Energy efficiencies of EVs and ICEVs.

3. Transportation Pollution

- CO is odourless, colourless and highly toxic gas which can reduce the oxygen-carrying capability of haemoglobin in our blood, thus causing unconscious death.
- NO_2 and SO_2 gases are harmful to our respiratory passages and lung. When dissolving in water or forming acid rain, they cause the impairment of forest as well as the contamination of lakes and rivers.
- VOCs such as benzene, ethylene, formaldehyde, methyl chloroform and methylene chloride are cancerogenic substances, thus very harmful to human and plants.
- Lead molecules in our environment are very harmful to human, especially the children, because they cause permanent damages to our brain, nervous and digestive systems. In some countries or cities, leaded petrol is becoming prohibited.

Smog is a mixture of fog, smoke and other pollutants, which can be easily realized whenever there is a reduction in visibility. The influence of smog is not restricted to urban areas, but also spreads to rural areas

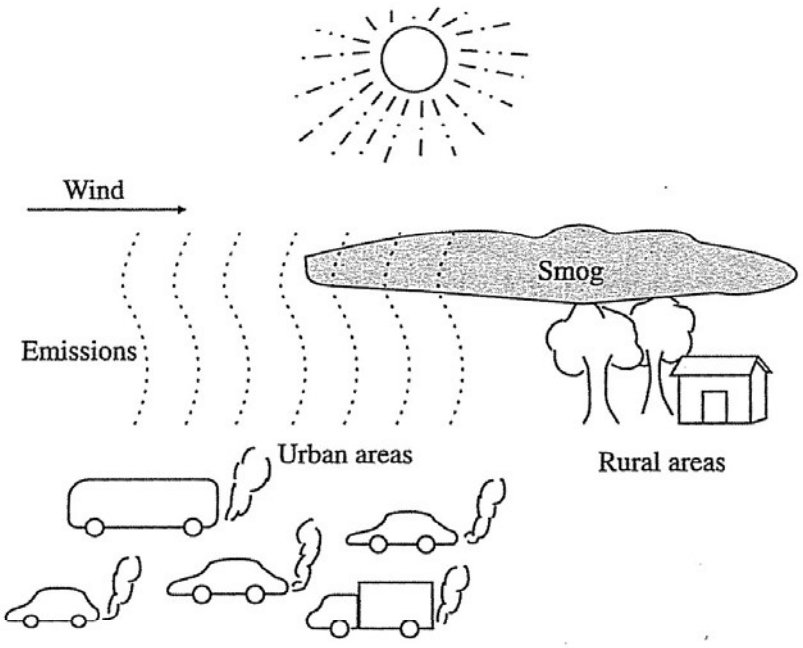

Fig. 10.8. Principle of smog formation.

Nowadays, in many metropolises, ICEVs are responsible for over 50% of hazardous air pollutants and smog-forming compounds. Although the engine of ICEVs is continually improved to reduce the emitted pollutants, the increase in the number of ICEVs is much faster than the reduction of emissions per vehicle. Hence, the total emitted pollutants due to ICEVs continues to grow in a worrying way.

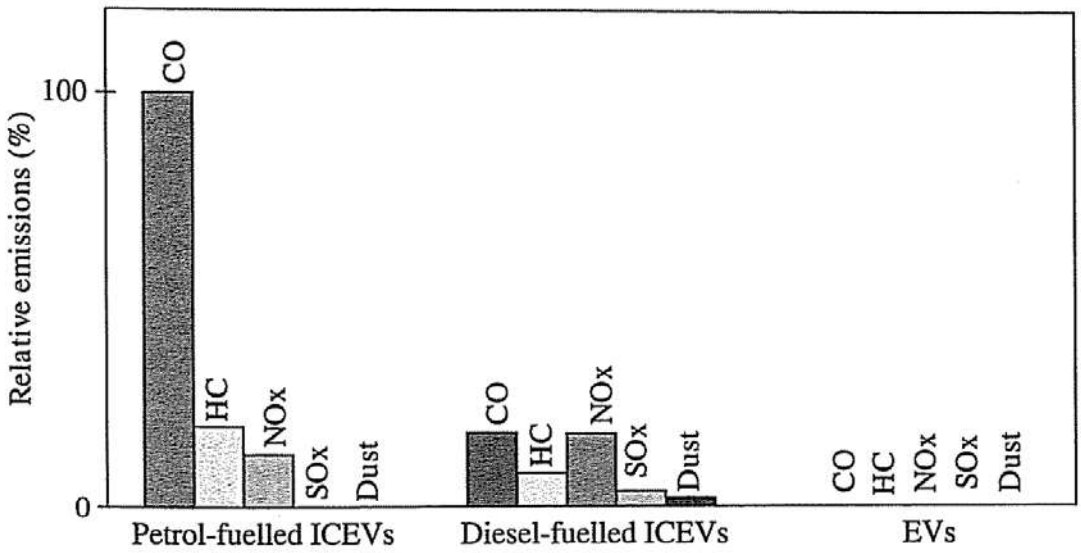

Fig. 10.9. Comparison of local harmful emissions.

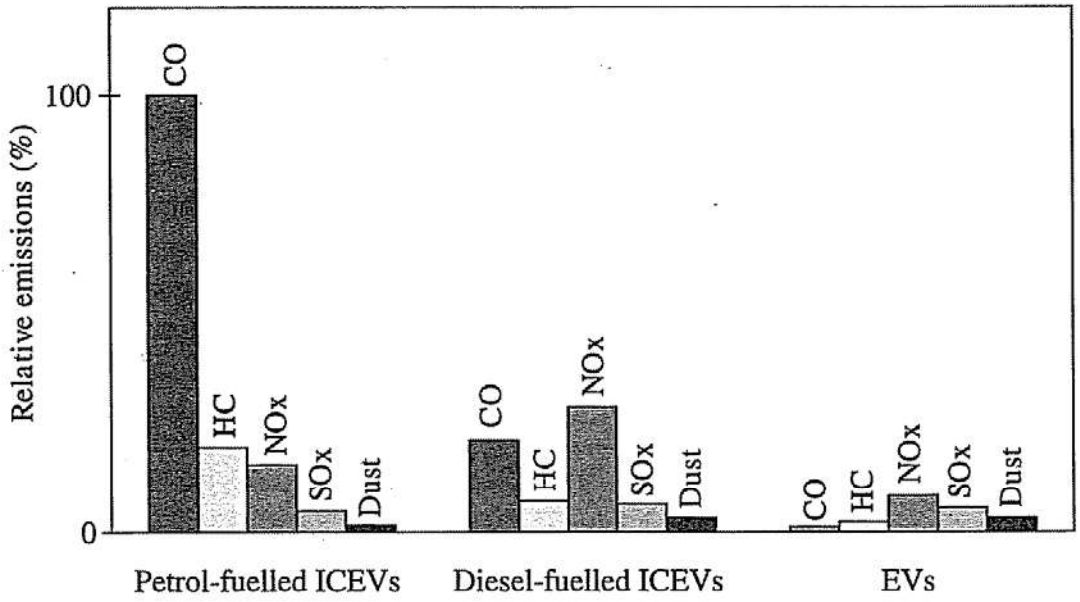

Fig. 10.10. Comparison of global harmful emissions.

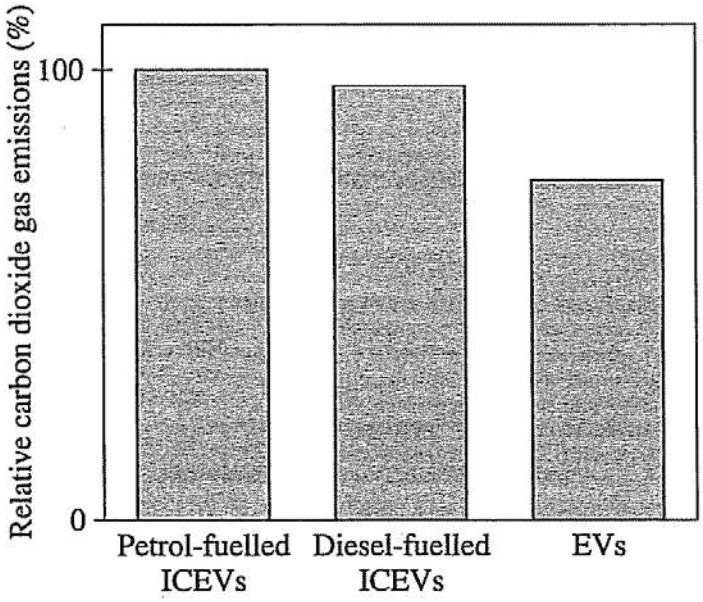

Fig. 10.11. Comparison of global carbon dioxide emissions.

As shown in Fig. 10.12, a CO_2 recycling system has been adopted by Kansai Electric Power in Japan. Firstly, CO_2 gas is recovered from the power plant flue gas by chemical absorption method. It can be extracted with a recovery rate of about 90%. The collected CO_2 gas is then liquefied for storage and transportation. Secondly, it is experimentally used to synthesize methanol (CH_3OH) by the catalytic hydrogenation method as described by:

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O.$$

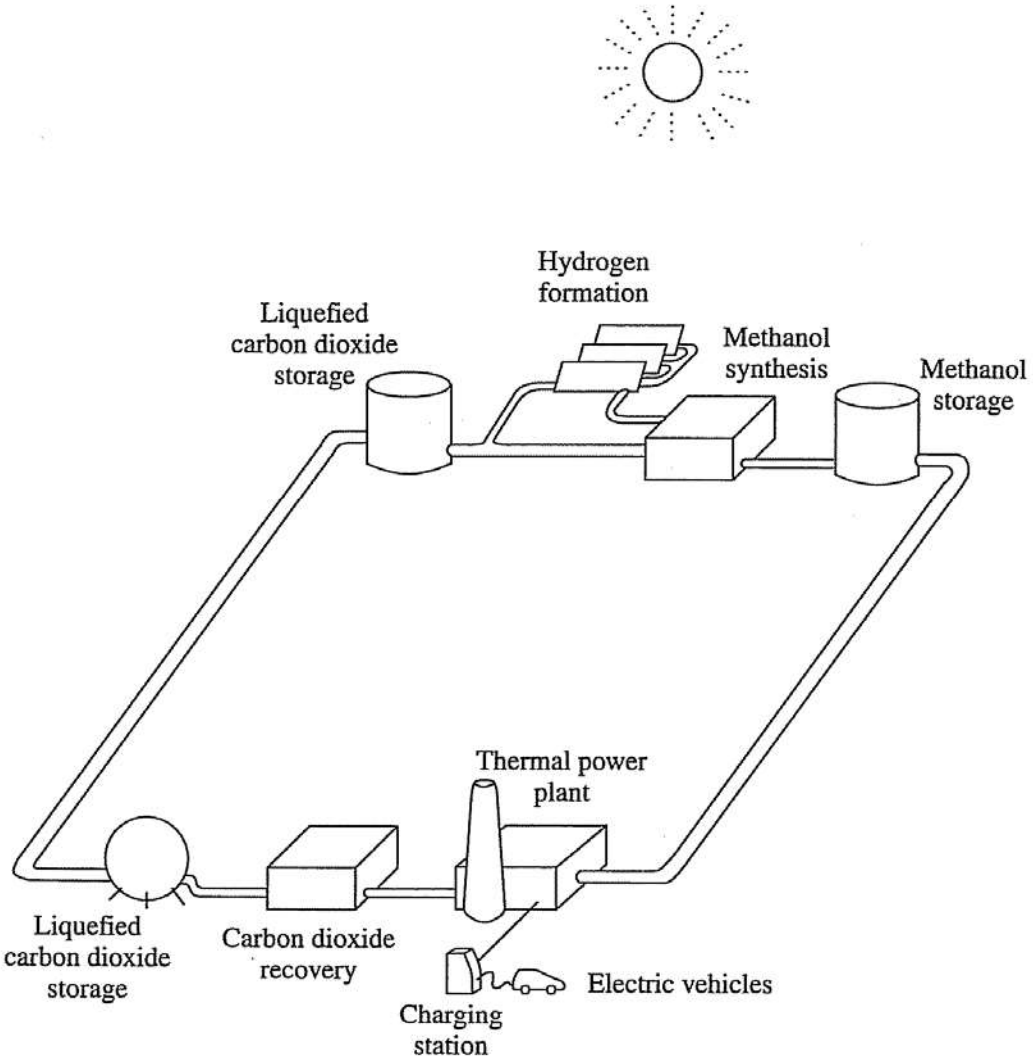

Fig. 10.12. Carbon dioxide recycling system.

The required hydrogen (H_2) gas can be produced by utilizing micro-organisms existing in the natural environment. As illustrated in Fig. 10.13, green algae produces starch from CO_2 by photosynthesis in cultivation vessels, then the resulting starch is decomposed to form organic acid in dark anaerobic fermentation vessels, hence H_2 gas is generated when the organic acid is decomposed by photosynthetic bacteria in the presence of sunlight. Finally, CH_3OH resulting from the whole CO_2 recycling process is used as an alternative fuel for thermal power generation.

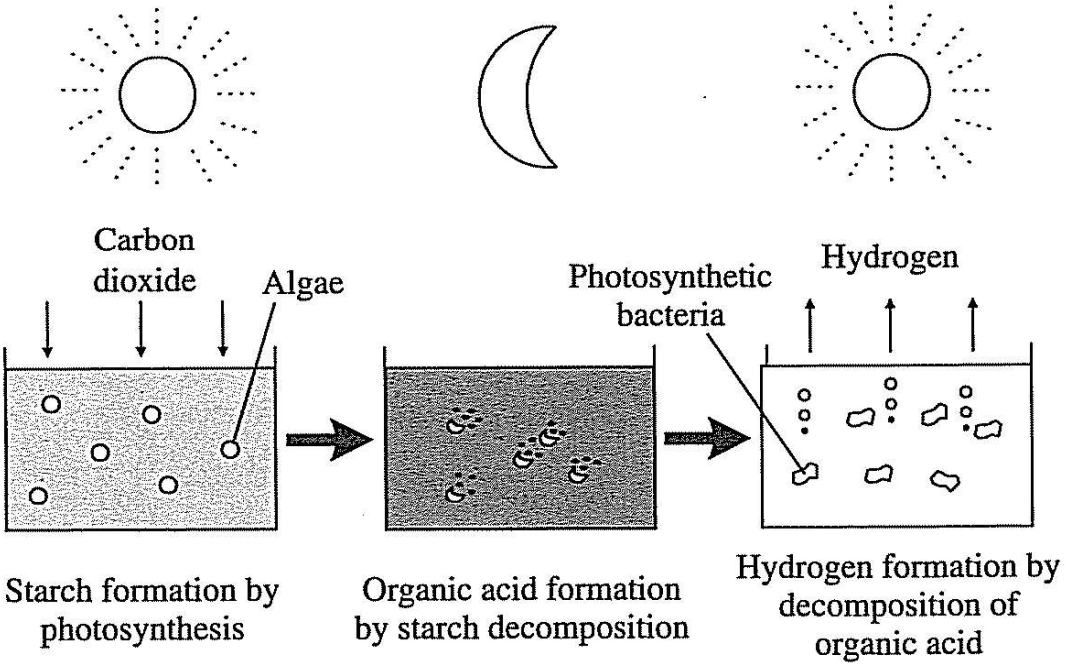

Fig. 10.13. Hydrogen production by micro-organisms.

4. Noise

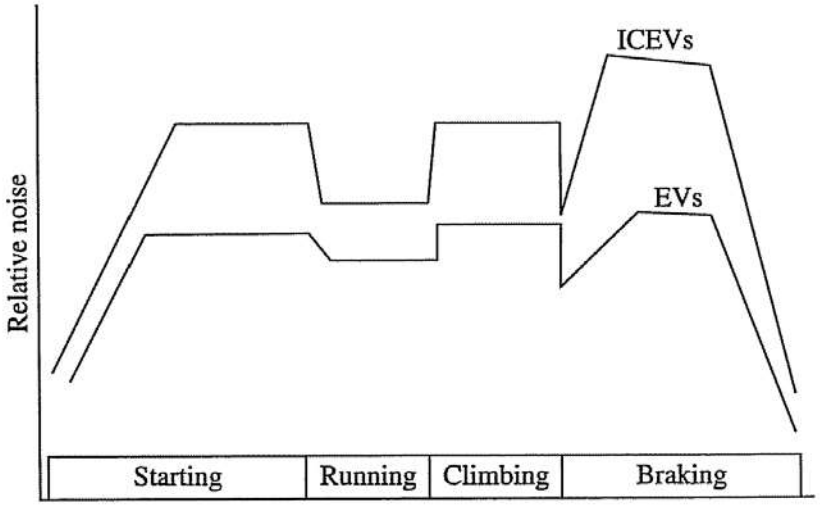

Fig. 10.14. Comparison of noise by ICEVs and EVs.

EVs have another definite advantage over ICEVs, namely the suppression of noise pollution. Different from ICEVs that their combustion engine and complicated mechanical transmission produce severe noise problems to our surroundings, EVs are powered by electric motors operating with very low acoustic noise.

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