

Chapter 2

Future Energy Sources

2.1 Introduction

Energy affects all aspects of modern life. Energy sources will play an important role in the world's future. Because of the exponential growth of the world population, demand for energy is increasing at an exponential rate. Current examples of these priorities include: reducing greenhouse gas emissions, improving the energy efficiency of our homes, offices and industries, energy marketing, energy cost, energy management, energy conservation, energy security, finding practical and affordable alternate sources of energy, developing cleaner and more efficient transportation vehicles and systems, energy policy, energy strategy and alternative energy usage. The world is presently confronted with twin crises of fossil fuel depletion and environmental degradation. To overcome these problems, recently renewable energy has been receiving increasing attention due to its environmental benefits. Competition of renewable liquid fuels to the petroleum liquid fuels is important in the near future. Renewable energy is a promising alternative solution because it is clean and environmentally safe. Biomass is the most used renewable energy source now and in future. Geothermal, hydrogen, wind and solar energies will become the most important sources in future.

The promising future transportation fuels are liquid biofuels, hydrogen, biogas, and methane. Biomass will be the most important energy sources. The algae will be one of the important energy sources in the future. Electricity and hydrogen are principle energy carriers and can be produced from all primary energy sources.

2.2 Renewable Energy Scenarios

Renewable energy is a promising alternative solution because it is clean and environmentally safe. They also produce lower or negligible levels of greenhouse gases and other pollutants when compared with the fossil energy sources they replace. Table 2.1 shows global renewable energy scenario by 2030. Approximately, half of the global energy supply from renewables in 2030 according to European Renewable Energy Council (EREC) (2009). The most significant developments in renewable energy production are observed in photovoltaics (from 0.2 to 221 Mtoe) and wind energy (from 4.7 to 542 Mtoe) between 2001 and 2030.

Biomass is the most used renewable energy source now and in future. The potential of sustainable large hydro is quite limited to some regions in the world. The potential for small hydro (<10 MW) power is still significant and more significant in future. Wind energy is a technology with annual growth rates of more than 30 % during the last years that will become more significant in future. Photovoltaics already had impressive annual growth rates of more than 30 % during the last years that will become more significant in future. Geothermal and solar thermal sources are more important energy systems in future.

Using fossil fuels as the primary energy source has led to serious energy crisis and environmental pollution on a global scale. In order to mitigate environmental problems renewable energy especially wind and solar energies at competitive costs resulting from the fast technological development. The limitations of solar power are site-specific, intermittent and, thus, not reliable for instantaneous supply. Using batteries to store any energy surplus for later consumption can resolve the time mismatch between energy supply and demand. The shortcomings of battery storage are low-storage capacity, short equipment life, and considerable solid and chemical wastes generated. A system consisting of photovoltaic (PV) panels coupled with electrolyzers is a promising design to produce hydrogen (Ni et al. 2006).

Table 2.1 Global renewable energy scenario by 2040

	2001	2010	2020	2030
Total consumption (million ton oil equivalent)	10,038	10,549	13,148	15,379
Biomass	1080	1313	1791	2483
Large hydro	22.7	266	309	341
Geothermal	43.2	86	186	333
Small hydro	9.5	19	49	106
Wind	4.7	44	266	542
Solar thermal	4.1	15	66	244
Photovoltaic	0.2	2	24	221
Solar thermal electricity	0.1	0.4	3	16
Marine (tidal/wave/ocean)	0.05	0.1	0.6	5
Total renewable energy sources	1365.5	1745.5	2694.6	4291
Renewable energy sources contribution (%)	13.6	16.6	20.5	27.9

Table 2.2 Growth scenarios for global installed wind power capacity (GW)

Years	Stagnat growth	Moderata growth	Strong growth
2010	63	73	81
2020	132	140	165
2030	166	195	250

The detailed analysis of the technical, economic and regulatory issues of wind power is scanned in the European Wind Energy Association (EWEA) Report: “Large scale integration of wind energy in the European power supply: Analysis, issues and recommendations” published in December 2005. In 2005, worldwide capacity of wind-powered generators was 58,982 MW; although it currently produces less than 1 % of world-wide electricity use, it accounts for 23 % of electricity use in Denmark, 4.3 % in Germany and approximately 8 % in Spain. Globally, wind power generation more than quadrupled between 1999 and 2005 according to the EWEA (2005).

Table 2.2 shows the growth scenarios for global installed wind power (IEA 2004). In 2004, the International Energy Agency (IEA) Reference Scenario projections for wind energy were updated to 66 GW in 2010, 131 GW in 2020 and 170 GW in 2030. The IEA Reference Scenario projections for wind energy were updated to 75 GW in 2010, 145 GW in 2020 and 202 GW in 2030. The IEA advanced strong growth scenario projected a wind energy market of 82 GW in 2010, 165 GW in 2020 and 250 GW in 2030. Figure 2.1 shows the scenarios for global installed wind power.

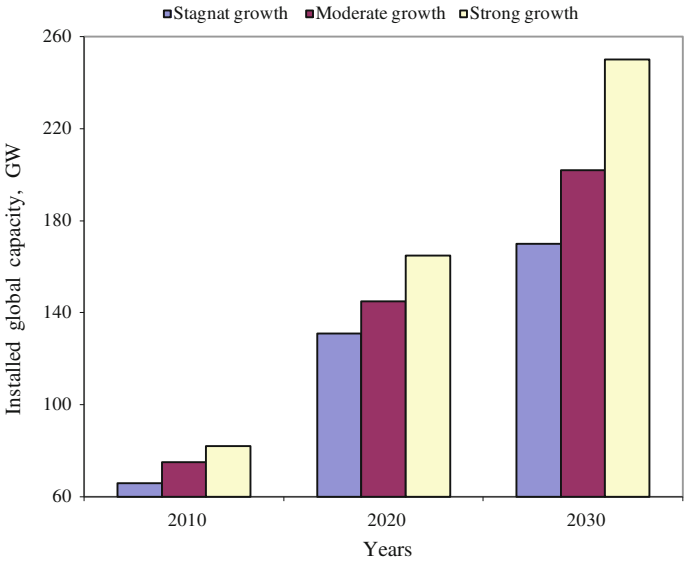


Fig. 2.1 Scenarios for global installed wind power

Geothermal energy can be utilized in various forms such as electricity generation, direct use, space heating, heat pumps, greenhouse heating, and industrial. The electricity generation is improving faster in geothermal energy rich countries. As an energy source, geothermal energy has come of age. The utilization has increased rapidly during the last three decades.

As an energy source, geothermal energy has come of age. Geothermal energy for electricity generation has been produced commercially since 1913, and for four decades on the scale of hundreds of MW both for electricity generation and direct use. In Tuscany, Italy, a geothermal plant has been operating since the early 1900s. There are also geothermal power stations in the USA, New Zealand and Iceland. In Southampton (UK) there is a district heating scheme based on geothermal energy. Hot water is pumped up from about 1,800 m below ground. The utilization has increased rapidly during the last three decades. In 2000, geothermal resources have been identified in over 80 countries and there are quantified records of geothermal utilization in 58 countries in the world.

Geothermal energy is clean, cheap and renewable, and can be utilized in various forms such as space heating and domestic hot water supply, CO₂ and dry-ice production process, heat pumps, greenhouse heating, swimming and balneology (therapeutic baths), industrial processes and electricity generation. The main types of direct use are bathing, swimming and balneology (42 %), space heating (35 %), greenhouses (9 %), fish farming (6 %), and industry (6 %). Geothermal energy can be utilized in various forms such as electricity generation, direct use, space heating, heat pumps, greenhouse heating, and industrial usage. Electricity is produced with geothermal steam in 21 countries spread over all continents. Low temperature geothermal energy is exploited in many countries to generate heat, with an estimated capacity of about 10,000 MW thermal.

World's total installed geothermal electric capacity was 7304 MWe in 1996. In much of the world electricity from fossil fuel-burning electricity plants can be provided at half the cost of new geothermal electricity. A comparison of the renewable energy sources shows the current electrical energy cost to be 2–10 US¢/kWh for geothermal and hydro, 5–13 US¢/kWh for wind, 5–15 US¢/kWh for biomass, 25–125 US¢/kWh for solar photovoltaic and 12–18 US¢/kWh for solar thermal electricity (Demirbas 2006a).

Solar energy is defined as that radiant energy transmitted by the sun and intercepted by Earth. It is transmitted through space to Earth by electromagnetic radiation with wavelengths ranging between 0.20 and 15 μm . The availability of solar flux for terrestrial applications varies with season, time of day, location, and collecting surface orientation. In this chapter we shall treat these matters analytically (Kutz 2007).

One of the most abundant energy resources on the surface of the earth is sunlight. Today, solar energy has a tiny contribution in the world total primary energy. Photovoltaic (PV) systems, other than solar home heating systems, are used for communication, water pumping for drinking and irrigation, and electricity generation. The total installed capacity of such systems is estimated at about 1000 kW. A solar

home heating system is a solar PV system with a maximum capacity of 40 W. These systems are installed and managed by a household or a small community.

Like wind power markets, PV markets have seen rapid growth and costs have fallen dramatically. The total installed capacity of such systems is estimated at about 1000 kW. The PV installed capacities are growing at a rate of 30 % a year. Solar PV system has been found to be a promising energy in future. One of the most significant developments in renewable energy production is observed in PVs. The PV will then be the largest renewable electricity source with a production of 25.1 % of global power generation in 2040 (EWEA 2005).

Solar thermal electricity power system is a device by the use of solar radiation for the generation of electricity through the solar thermal conversion. Solar thermal electricity may be defined as the result of a process by which directly collected solar energy is converted to electricity through the use of some sort of heat to electricity conversion device. The last three decades have witnessed a trend in solar thermal electricity generation of increasing the concentration of sunlight. There are three main systems of solar thermal electricity: solar towers, dishes and the parabolic troughs. Solar thermal power stations based on parabolic and heliostat trough concentrating collectors can soon become a competitive option on the world's electricity market. Table 2.3 shows the economics and emissions of conventional technologies compared with solar power generation.

PV systems convert sunlight directly to electricity. They work any time the sun is shining, but more electricity is produced when the sunlight is more intense and strikes the PV modules directly. The basic building block of PV technology is the solar "cell." Multiple PV cells are connected to form a PV "module," the smallest PV component sold commercially. Modules range in power output from about 10–300 W. A PV system connected to the utility grid has these components: (1) One or more PV modules, which are connected to an inverter. (2) The inverter, which converts the system's direct-current (DC) electricity to alternating current (AC). (3) Batteries (optional) to provide energy storage or backup power in case of a power interruption or outage on the grid.

Small, single-PV-panel systems with built-in inverters that produce about 75 W may cost around \$900 installed, or \$12 per watt. A 2-kW system that meets nearly all the needs of a very energy efficient home could cost \$16,000 to \$20,000 installed, or \$8 to \$10 per watt. At the high end, a 5-kW system that completely

Table 2.3 Economics and emissions of conventional technologies compared with solar power generation

Electricity generation technology	Carbon emissions (g C/kWh)	Generation costs (US¢/kWh)
Solar thermal and solar PV systems	0	9–40
Pulverized coal–natural gas turbine	100–230	5–7

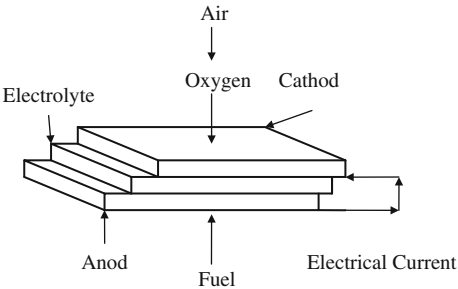


Fig. 2.2 Schematic of a fuel cell

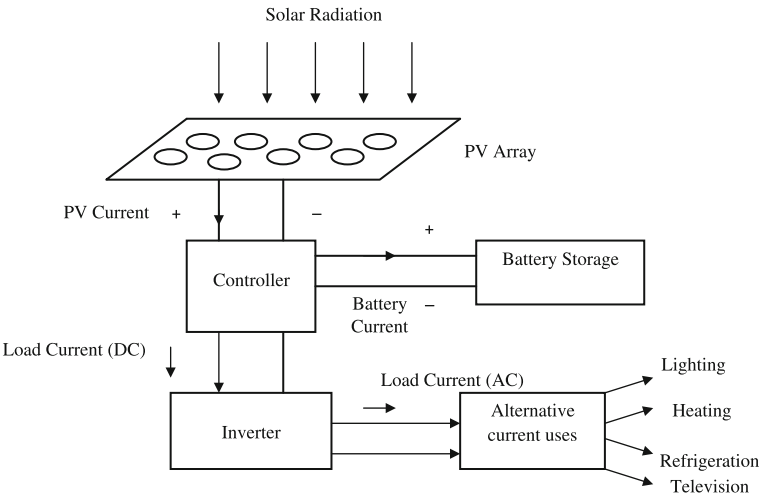


Fig. 2.3 Configuration of PV system with AC appliances

meets the energy needs of many conventional homes can cost \$30,000 to \$40,000 installed, or \$6 to \$8 per watt. Figure 2.2 shows the schematic of a fuel cell.

Figure 2.3 shows the configuration of PV system with AC appliances (e.g., household lighting, heating, refrigeration, television or video).

2.3 Research and Development of Biomass Energy

2.3.1 Introduction

Biomass energy research should include an interdisciplinary approach and includes researchers from various professions such as agricultural, environmental,

mechanical, chemical, electrical engineering, and biology. The group works on the biochemical and thermochemical conversion of different biomass sources into biofuels.

Biomass has historically been a dispersed, labor-intensive, and land-intensive source of energy. By the year 2050, it is estimated that 90 % of the world population will live in developing countries. It is critical therefore that the biomass processes used in these countries are sustainable. In the future, biomass has the potential to provide a cost-effective and sustainable supply of energy. The modernization of biomass technologies, leading to more efficient biomass production and conversion is one possible direction for biomass use in developing countries.

Biomass provides a clean, renewable energy source that could dramatically improve our environment, economy and energy security. Biomass energy generates far less air emissions than fossil fuels, reduces the amount of waste sent to landfills and decreases our reliance on foreign oil. Biomass energy also creates thousands of jobs and helps revitalize rural communities.

In Europe, North America and the Middle East, the share of biomass averages 2–3 % of total final energy consumption, whereas in Africa, Asia and Latin America, which together account for three-quarters of the world's population, biomass provides a substantial share of the energy needs: a third on average, but as much as 80–90 % in some of the poorest countries of Africa and Asia (e.g. Angola, Ethiopia, Mozambique, Tanzania, Democratic Republic of Congo, Nepal and Myanmar). Indeed, for large portions of the rural populations of developing countries, and for the poorest sections of urban populations, biomass is often the only available and affordable source of energy for basic needs such as cooking and heating.

Biomass provides a number of local environmental gains. Energy forestry crops have a much greater diversity of wildlife and flora than the alternative land use, which is arable or pasture land. In industrialized countries, the main biomass processes utilized in the future are expected to be direct combustion of residues and wastes for electricity generation, bio-ethanol and biodiesel as liquid fuels and combined heat and power production from energy crops. The future of biomass electricity generation lies in biomass integrated gasification/gas turbine technology, which offers high energy conversion efficiencies. Biomass will compete favorably with fossil mass for niches in the chemical feedstock industry. Biomass is a renewable, flexible and adaptable resource. Crops can be grown to satisfy changing end user needs.

In the future, biomass has the potential to provide a cost-effective and sustainable supply of energy, while at the same time aiding countries in meeting their greenhouse gas reduction targets. By the year 2050, it is estimated that 90 % of the world population will live in developing countries. Figure 2.4 shows the carbon cycle, photosynthesis, and the steps of biomass fuels formation.

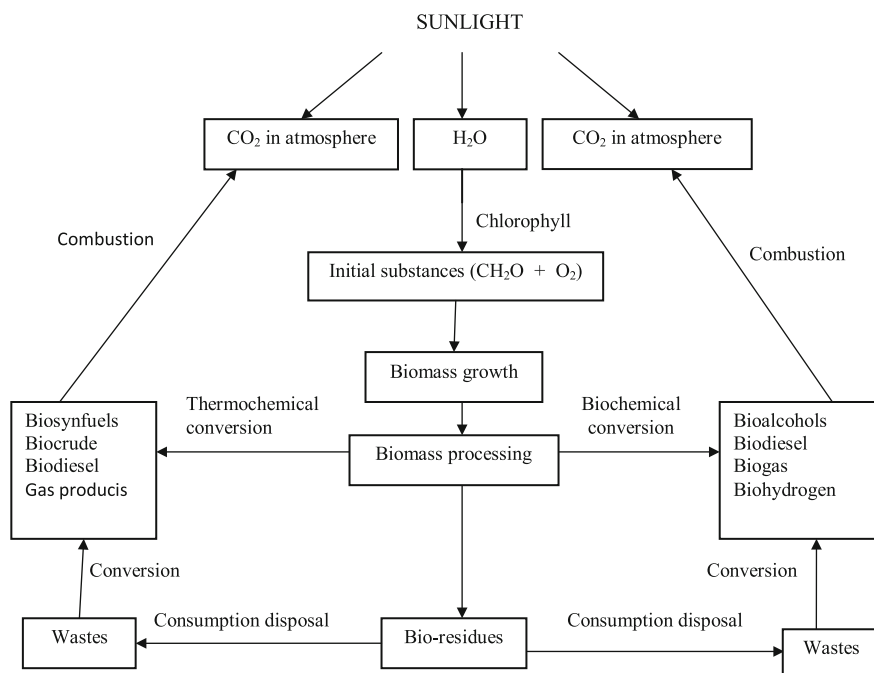


Fig. 2.4 Carbon cycle, photosynthesis, and the steps of biomass fuels formation

2.3.2 *Transportation Biofuels from Biomass*

The term biofuel is referred to as liquid or gaseous fuels for the transport sector that are predominantly produced from biomass. The biofuels mainly include bioethanol, biobutanol, biodiesel, vegetable oils, biomethanol, pyrolysis oils, biogas, and biohydrogen. There are two global biomass based liquid transportation fuels that might replace gasoline and diesel fuel. These are bioethanol and biodiesel. There are several reasons for biofuels to be considered as relevant technologies by both developing and industrialized countries. They include energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector.

Biofuels are important because they replace petroleum fuels. Biofuels are generally considered as offering many priorities, including sustainability, reduction of greenhouse gas emissions, regional development, social structure and agriculture, security of supply (Reijnders 2006).

Biofuels appear to be a potential alternative “greener” energy substitute for fossil fuels. They are renewable and available throughout the world. Biomass can contribute to sustainable development and globally environmental preservation since it is renewable and carbon neutral. Biofuels are currently expensive than conventional

energy sources. There are different technologies presently being practiced to produce biofuels economically from biomass. Biofuel technology will play a major role in future because it can utilize the renewable sources of energy.

The use of liquid biofuels for transport in order to reduce greenhouse gas emissions and the environmental impact of transport, as well as to increase security of supply, technological innovation and agricultural diversification has a strategic important. Biofuels can be burned in such a way as to produce no harmful emissions.

There are several reasons for biofuels to be considered as relevant technologies by both developing and industrialized countries. Due to its environmental benefits, the share of biofuel such as bioethanol and biodiesel in the automotive fuel market will grow fast in the next decade.

Bioethanol is a petrol additive/substitute. It is possible that wood, straw and even household wastes may be economically converted to bioethanol. Biodiesel is an environmentally friendly alternative liquid fuel that can be used in any diesel engine without modification. Biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content and biodegradability. Bioethanol is by far the most widely used bio-fuel for transportation worldwide. Global bioethanol production more than doubled between 2000 and 2005. About 60 % of global bioethanol production comes from sugarcane and 40 % from other crops.

According to International Energy Agency (IEA), scenarios developed for the USA and the EU indicate that near-term targets of up to 6 % displacement of petroleum fuels with biofuels appear feasible using conventional biofuels, given available cropland. A 5 % displacement of gasoline in the EU requires about 5 % of available cropland to produce ethanol while in the USA 8 % is required. A 5 % displacement of diesel requires 13 % of USA cropland, 15 % in the EU (IEA 2006).

The recent commitment by the USA government to increase bio-energy three-fold in 10 years has added impetus to the search for viable biofuels. The advantages of bio-fuels are the following: (a) Bio-fuels are easily available from common biomass sources, (b) They are represent a carbon dioxide-cycle in combustion, (c) Bio-fuels have a considerable environmentally friendly potential, (d) There are many benefits the environment, economy and consumers in using bio-fuels, and (e) They are biodegradable and contribute to sustainability (IEA 2004).

The dwindling fossil fuel sources and the increasing dependency of the USA on imported crude oil have led to a major interest in expanding the use of bio-energy. The recent commitment by the USA government to increase bio-energy three-fold in 10 years has added impetus to the search for viable biofuels. The EU have also adopted a proposal for a directive on the promotion of the use of bio-fuels with measures ensuring that bio-fuels account for at least 2 % of the market for gasoline and diesel sold as transport fuel by the end of 2005, increasing in stages to a minimum of 5.75 % by the end of 2010 (Puppan 2002). Bioethanol is a fuel derived from renewable sources of feedstock; typically plants such as wheat, sugar beet,

Table 2.4 Shares of alternative fuels compared to the total automotive fuel consumption in the world (%)

Fuel	2020	2025	2030	2035	2040	2045	2050
Biofuels	5.0	6.9	9.1	10.2	10.8	11.4	11.8
Natural gas	5.7	9.0	10.2	10.9	9.6	9.3	7.9
Hydrogen	3.4	3.9	10.6	13.2	15.8	17.4	18.5

corn, straw, and wood. Bioethanol is a petrol additive/substitute. Biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content and biodegradability.

If the biodiesel valorized efficiently at energy purpose, so would be benefit for the environment and the local population. Job creations, provision of modern energy carriers to rural communities avoid urban migration and reduction of CO₂ and sulfur levels in the atmosphere. Biofuels include energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector.

Table 2.4 shows the shares of alternative fuels compared to the total automotive fuel consumption in the world as a futuristic view (Demirbas 2006b). Hydrogen is currently more expensive than conventional energy sources. There are different technologies presently being practiced to produce hydrogen economically from biomass. Biohydrogen technology will play a major role in future because it can utilize the renewable sources of energy (Nath and Das 2003).

Bioethanol is a gasoline additive/substitute. Bioethanol is by far the most widely used bio-fuel for transportation worldwide. Global bioethanol production more than doubled between 2000 and 2005. About 60 % of global bioethanol production comes from sugarcane and 40 % from other crops. Biodiesel refers to a diesel-equivalent mono alkyl ester based oxygenated fuel. Biodiesel production using inedible vegetable oil, waste oil and grease has become more attractive recently. The economic performance of a biodiesel plant can be determined once certain factors are identified, such as plant capacity, process technology, raw material cost and chemical costs. Even with today's high oil prices, biofuels cost more than conventional fuels. The central policy of biofuel concerns job creation, greater efficiency in the general business environment, and protection of the environment.

The biggest difference between biofuels and petroleum feedstocks is oxygen content. Biofuels have oxygen levels from 10–45 % while petroleum has essentially none making the chemical properties of biofuels very different from petroleum. All have very low sulfur levels and many have low nitrogen levels. Biofuels are non-polluting, locally available, accessible, sustainable and reliable fuel obtained from renewable sources.

Sustainable biofuel production potential mainly depends on the productivity and the plantation options. A sustainable use of biomass for bioenergy production is expected to reduce environmental contamination. Achieving a solution to environmental problems requires long-term policies for sustainable development. In this

Table 2.5 Availability of modern transportation fuels

Fuel type	Availability	
	Current	Future
Gasoline	Excellent	Moderate-poor
Bioethanol	Moderate	Excellent
Biodiesel	Moderate	Excellent
Compressed natural gas (CNG)	Excellent	Moderate
Hydrogen for fuel cells	Poor	Excellent
Vegetable oil for fuel cells	Poor	Moderate-excellent
Liquefied petroleum gas (LPG)	Moderate-excellent	Moderate
Liquefied natural gas (LNG)	Poor	Moderate
Methane	Poor	Excellent

aspect, renewable energy resources appear to be the one of the most efficient and effective solutions. Sustainability of renewable energy systems must support both human and ecosystem health over the long term, goals on tolerable emissions should look well into the future. The sustainability of biofuels for energy use requires a high efficiency recycling of energy and low emissions of carbon compounds, NO_x , persistent organics and acidifying compounds and heavy metals due to biomass combustion. Electricity generation from biofuels has been found to be a promising method in the nearest future. The electricity costs are in the 6–8 c/kWh range. The future of biomass electricity generation lies in biomass integrated gasification/gas turbine technology, which offers high-energy conversion efficiencies.

Liquid biofuels for transportation have recently attracted huge attention in different countries all over the world because of its renewability, sustainability, common availability, regional development, rural manufacturing jobs, reduction of greenhouse gas emissions, and its biodegradability. Table 2.5 shows the availability of modern transportation fuels. The advantage of biofuel in this aspect is that it is a derivative of natural products. Policy drivers for renewable liquid biofuels have attracted particularly high levels of assistance in some countries given their promise of benefits in several areas of interest to governments, including agricultural production, greenhouse gas emissions, energy security, trade balances, rural development and economic opportunities for developing countries. The European Union is on the third rank of biofuel production worldwide, behind Brazil and the United States. In Europe, Germany is the largest, and France the second largest producer of biofuels. Most biofuels in commercial production in Europe today are based on sugar beet, wheat and rapeseed, which are converted to bioethanol/ETBE and biodiesel.

Ethanol has gained huge interest in both industry and research as a plausible renewable energy source in the future. Bioethanol is a gasoline additive/substitute. Biomass wastes that have high contents of hydrocarbon, such as sugarcane, sugar beets, corn and from molasses, can be good sources of bioethanol. Bioethanol is an

alternative fuel that is produced almost entirely from food crops. Bioethanol represents an important, renewable liquid fuel for motor vehicles. Bioethanol is derived from alcoholic fermentation of sucrose or simple sugars, which are produced from biomass by hydrolysis process. In order to produce bioethanol from cellulosic biomass, a pretreatment process is used to reduce the sample size, break down the hemicelluloses to sugars, and open up the structure of the cellulose component. The cellulose portion is hydrolyzed by acids or enzymes into glucose sugar that is fermented to bioethanol.

The sugars from the hemicelluloses are also fermented bioethanol. Producing and using bioethanol as a transportation fuel can help reduce carbon dioxide buildup in two important ways: by displacing the use of fossil fuels, and by recycling the carbon dioxide that is released when it is combusted as fuel. Using ethanol-blended fuel for automobiles can significantly reduce petroleum use and exhaust greenhouse gas emission. An important advantage of crop based ethanol is its greenhouse benefits. Corn stover consists of the stalks, leaves, cobs, and husk. It is possible that corn stover may be economically converted to bioethanol.

Ethanol can be produced in a culture medium. For this purpose, an alginate-loofa matrix was developed as a cell carrier for ethanol fermentation owing to its porous structure and strong fibrous nature. The matrix was effective for cell immobilization and had good mechanical strength and stability for long-term use (Phisalaphong et al. 2007).

Partly due to the oil crises, biomass-derived syngas (bio syngas) has become an important part of alternative energy since the 1980s. Once clean biosyngas is available, the known process technology can be used produce biomethanol, Fischer-Tropsch diesel oil, and hydrogen. Methanol can be produced from hydrogen-carbon oxide mixtures by means of the catalytic reaction of carbon monoxide and some carbon dioxide with hydrogen. Biosynthesis gas (bio-syngas) is a gas rich in CO and H₂ obtained by gasification of biomass. Mixture of gases from organic waste materials is converted to methanol in a conventional steam-reforming/water-gas shift reaction followed by high-pressure catalytic methanol synthesis.

Biodiesel is known as monoalkyl, such as methyl and ethyl, esters of fatty acids. Biodiesel is produced from triglycerides by transesterification process (Demirbas 2003). Environmental and political concerns are generating a growing interest in alternative engine fuels such as biodiesel. Biodiesel is the best candidate for diesel fuels in diesel engines. Biodiesel refers to a diesel-equivalent, processed fuel derived from biological sources. Biodiesel is the name for a variety of ester based oxygenated fuel from renewable biological sources. It can be made from processed organic oils and fats. Biodiesel production using inedible vegetable oils, waste oil and grease has also become more attractive recently. Biodiesels play an important role in meeting future fuel requirements in view of their nature (less toxic), and have an edge over conventional diesel as they are obtained from renewable sources (Sasthy et al. 2006).

Cottonseed methyl ester was used in a four-stroke, single cylinder, and air-cooled diesel engine as alternative fuel. Engine tests carried out at full

load-different speed range, the engine torque and power of cottonseed oil methyl ester was found to be lower than that of diesel fuel in the range of 3–9 % and specific fuel consumption was higher than that of diesel fuel by approximately 8–10 %. CO₂, CO, and NO_x emissions of cottonseed methyl ester were lower than that of diesel fuel (Yucesu and Ilkilic 2006).

In general, the physical and chemical properties and the performance of the cotton seed oil methyl ester was comparable to diesel fuel. The effects of cotton seed oil methyl ester and diesel fuel on a direct-injected, four-stroke, single-cylinder, air-cooled diesel engine performance and exhaust emissions were investigated. Test quantities of cottonseed oil methyl ester of renewable fuels were processed and characterized, and performance and exhaust gas emissions were tested in various injection pressures. In order to determine emission and performance characteristics, the engine were tested with full load varied injection pressure and constant speed. The results show that engine performance using cottonseed oil methyl ester fuel differed little from engine performance and torque with diesel fuel. As to the emissions, there was an approximate 30 % reduction in CO and approximate 25 % reduction in NO_x.

An engine performance test using sunflower methyl esters exhibited characteristics very similar to regular diesel. The test values obtained from a 2.5 L, 4 cylinder Peugeot XD3p157 engine shows that torque values obtained by the two types of fuels are 5–10 % in favor of regular diesel. Specific fuel consumption, however, is better with biodiesel. This means that a better combustion characteristic is achieved with biodiesel, which compensates for its lower calorific value. Soot emissions are slightly less with biodiesel, as expected, due to the improvement in specific fuel consumption (Kaplan et al. 2006). Physical and chemical properties of methyl ester of waste cooking oil were determined in the laboratory. The methyl ester was tested in a diesel engine with turbocharged, four cylinders and direct injection. Obtained results were compared with No. 2 diesel fuel (Utlü 2007).

A new lipase immobilization method, textile cloth immobilization, was developed for conversion of soybean oil to biodiesel. Immobilized *Candida* lipase sp. 99–125 was applied as the enzyme catalyst. The effect of flow rate of reaction liquid, solvents, reaction time, and water content on the biodiesel yield is investigated. The test results indicate that the maximum yield of biodiesel of 92 % was obtained at the conditions of hexane being the solvent, water content being 20 wt%, and reaction time being 24 h (Lv et al. 2008).

The dynamic transesterification reaction of peanut oil in supercritical methanol media was investigated. The reaction temperature and pressure were in the range of 523–583 K and 10.0–16.0 MPa, respectively. The molar ratio of peanut oil to methanol was 1:30. It was found that the yield of methyl esters was higher than 90 % under the supercritical methanol. The apparent reaction order and activation energy of transesterification was 1.5 and 7.472 kJ/mol, respectively. In this method, the reaction time was shorter and the processing was simpler than that of the common acid catalysis transesterification (Cheng et al. 2008; Demirbas 2016).

The existing biodiesel production process is neither completely “green” nor renewable because it utilizes fossil fuels, mainly natural gas as an input for methanol production. Also the catalysts currently in use are highly caustic and toxic. To overcome the limitation of the existing process, a new method was proposed that used waste vegetable oil and non-edible plant oils as biodiesel feedstock and non-toxic, inexpensive, and natural catalysts. The economic benefit of the proposed method is also discussed. The new method will render the biodiesel production process truly green (Chhetri and Islam 2008).

A four-stroke, 3-cylinder, 30 kW TUMOSAN (Turkish Motor Industry and Trade) diesel engine was used for experimentation of biodiesel. The kinematic viscosity, density, flash point, cloud point, pour point, freezing point, copper strip corrosion values of all biodiesel fuels stayed within the limit values described by DIN-TSE EN 14214. They can readily be used without any need for modifications of the engine. Even though specific fuel consumption for biodiesel fuels tended to be higher than that for normal diesel fuel, the exhaust smokiness values of biodiesel fuels were considerably lower than that for petroleum diesel fuel. On the other hand, there were no significant differences observed for torque, power and exhaust smokiness (Oguz et al. 2007).

Problems to be studied include fuel storage stability, fuel solubility, and oxidative stability of recycled soybean-derived biodiesel was investigated. Unlike newly manufactured soy oils, it was found that this recycled soy oil was not stable in fuels. The question was what in the recycled oil led to the observed fuel degradation (Mushrush et al. 2007).

The oxidative and thermal degradation occurs on the double bonds of unsaturated aliphatic carbons chains in biolipids. Oxidation of biodiesel results in the formation of hydroperoxides. The oxidative and thermal instability are determined by the amount and configuration of the olefinic unsaturation on the fatty acid chains. The viscosity of biodiesel increases with the increase of thermal degradation degree due to the trans-isomer formation on double bonds. The decomposition of biodiesel and its corresponding fatty acids linearly increases from 293 to 625 K. The densities of biodiesel fuels decreased linearly with temperatures from 293 to 575 K. The combustion heat of biodiesel partially decreases with the increase of thermal degradation degree (Arisoy 2008).

The emission-forming gasses, such as carbon dioxide and carbon monoxide from combustion of biodiesel, generally are less than diesel fuel. Sulfur emissions are essentially eliminated with pure biodiesel. The exhaust emissions of sulfur oxides and sulfates from biodiesel were essentially eliminated compared to diesel. The smog-forming potential of biodiesel hydrocarbons is less than diesel fuel. The ozone-forming potential of the speciated hydrocarbon emissions was 50 % less than that measured for diesel fuel (Dincer 2008).

2.4 Water Energy and Power

Water is used in power generation. Hydroelectricity is electricity obtained from hydropower. Hydroelectric power comes from water driving a water turbine connected to a generator. Hydroelectricity is a low-cost, non-polluting, renewable energy source. The energy is supplied by the motion of water. Typically a dam is constructed on a river, creating an artificial lake behind it. Water flowing out of the lake is forced through turbines that turn generators.

Adhesive forces are the attractive forces between unlike molecules. They are caused by forces acting between two substances, such as mechanical forces and electrostatic forces. In the case of a liquid wetting agent, adhesion causes the liquid to cling to the surface on which it rests. When water is poured on clean glass, it tends to spread, forming a thin, uniform film over the glass surface. This is because the adhesive forces between water and glass are strong enough to pull the water molecules out of their spherical formation and hold them against the surface of the glass, thus avoiding the repulsion between like molecules.

When liquid is placed on a smooth surface, the relative strengths of the cohesive and adhesive forces acting on that liquid determine the shape it will take. If the adhesive forces between a liquid and a surface are stronger, they will pull the liquid down, causing it to wet the surface. However, if the cohesive forces among the liquid itself are stronger, they will resist such adhesion and cause the liquid to retain a spherical shape and bead the surface.

According to the second law of Pascal, in a container, pressure acts perpendicular to the boundary. It is dependent on the nature of plane or curved surface. If F is total force, P is hydrostatic pressure and A is total surface:

Hydraulic ram (hydram) pumps are water-lifting or water pumping devices that are powered by falling water. The hydram pumps have been used for over two centuries in many parts of the world. The pump works by using the energy of a large amount of water falling a small height to lift a small amount of that water to a much greater height. Wherever a fall of water can be obtained, the ram pump can be used as a comparatively cheap, simple and reliable means of raising water to considerable heights. The main and unique advantage of hydram pumps is that with a continuous flow of water, a hydram pump operates automatically and continuously with no other external energy source—be it electricity or hydrocarbon fuel. It uses a renewable energy source (stream of water) and hence ensures low running cost (Tessama 2000).

Lifting water from the source to a higher location can be carried out usually through a number of potential water-lifting options, depending on the particular site conditions. One means for lifting water is the hydraulic ram pump or hydram. The hydram is a self-actuating pump operated by the same principle of a water hammer. If correctly installed and properly maintained, it is a dependable and useful device that can lift water to a great height without the use of any other source of energy or fuel other than water itself. The hydram can be used for lifting water from a source lying at

a lower elevation to a point of use located at a higher elevation for domestic use, drinking, cooking and washing, and irrigation of small areas, gardens, and orchards.

Energy that is stored in the gravitational field is called gravitational potential energy, or potential energy due to gravity. If the object is being lifted at constant velocity, then it is not accelerating, and the net force on it is zero. When lifting something at a constant velocity the force that you lift with equals the weight of the object. So, the work done lifting an object is equal to its mass times the acceleration due to gravity times the height of the lift. As the object falls it travels faster and faster, and thus, picks up more and more kinetic energy. This increase in kinetic energy during the fall is due to the drop in gravitational potential energy during the fall. The gravitational potential energy becomes the kinetic energy of the falling object.

Archimedes' principle may be stated thus in terms of forces: Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object. A ship loaded into the sea to the mountain top is removable by using the system of sequential pools installed.

The water energy is converted into electrical energy. Buoyancy of the water can be used as a source of infinite energy by using convenient geometric devices. The "emitting" device can be basically long cylindrical, metallic cavity with a non-metallic outer layer. The geometric energy field around the emitting device can be converted the electricity power.

Buoyancy is an upward force exerted by a fluid that opposes the weight of an immersed object. The buoyancy of the water is a source of infinite energy. Because numerous ship swim in the ocean does not decrease the force. Buoyancy of the water can be converted into electrical energy using suitable geometric devices. It has been operated with OWOAS.

2.5 Hydrogen Energy

Hydrogen is not a primary fuel. It must be manufactured from water with either fossil or nonfossil energy sources. Widespread use of hydrogen as an energy source could improve global climate change, energy efficiency, and air quality. The thermochemical conversion processes, such as pyrolysis, gasification and steam gasification is available for converting the biomass to a more useful energy. The yield from steam gasification increases with increasing water-to-sample ratio. The yields of hydrogen from the pyrolysis and the steam gasification increase with increasing of temperature. The list of some biomass material used for hydrogen production is given in Table 2.6. Hydrogen powered fuel cells are an important enabling technology for the hydrogen future and more-efficient alternatives to the combustion of gasoline and other fossil fuels. Hydrogen has the potential to solve two major energy problems: reducing dependence on petroleum and reducing pollution and greenhouse gas emissions.

Table 2.6 List of some biomass material used for hydrogen production

Biomass species	Main conversion process
Bio-nut shell	Steam gasification
Olive husk	Pyrolysis
Tea waste	Pyrolysis
Crop straw	Pyrolysis
Black liquor	Steam gasification
Municipal solid waste	Supercritical water extraction
Crop grain residue	Supercritical fluid extraction
Pulp and paper waste	Microbiol fermentation
Petroleum basis plastic waste	Supercritical fluid extraction
Manure slurry	Microbiol fermentation
Algae	Pyrolysis
Municipal sewage sludge	Supercritical water extraction
Forest wastes	Microbiol fermentation
Tyre waste	Supercritical fluid extraction

A fuel cell is a device or an electrochemical engine that converts the energy of a fuel directly to electricity and heat without combustion. Fuel cells consist of two electrodes sandwiched around an electrolyte. When oxygen passes over one electrode and hydrogen over the other, electricity is generated. Fuel cells running on hydrogen derived from a renewable source would emit nothing but water vapor. Fuel cells are clean, quiet, and efficient.

Hydrogen is currently more expensive than conventional energy sources. There are different technologies presently being practiced to produce hydrogen economically from biomass. Hydrogen can be produced by pyrolysis from biomass. It can be burned to produce heat or passed through a fuel cell to produce electricity. Biomass represents a large potential feedstock resource for environmentally clean hydrogen production. It lends itself to both biological and thermal conversion processes. In the thermal path hydrogen can be produced in two ways: direct gasification and pyrolysis to produce liquid bio-oil, followed by steam reforming. Hydrogen can alternately be produced by supercritical water gasification of biomass (Byrd et al. 2007).

Biological generation of hydrogen (biohydrogen) technologies provide a wide range of approaches to generate hydrogen, including direct biophotolysis, indirect biophotolysis, photo-fermentations, and dark-fermentation. Biological hydrogen production processes are found to be more environmental friendly and less energy intensive as compared to thermochemical and electrochemical processes. Researchers have started to investigate hydrogen production with anaerobic bacteria since 1980s. Biohydrogen technology will play a major role in future because it can utilize the renewable sources of energy.

There are three types of microorganisms of hydrogen generation: cyano-bacteria, anaerobic bacteria, and fermentative bacteria. The cyano-bacteria directly decompose water to hydrogen and oxygen in the presence of light energy by

photosynthesis. Photosynthetic bacteria use organic substrates like organic acids. Anaerobic bacteria use organic substances as the sole source of electrons and energy, converting them into hydrogen. Biohydrogen can be generated using bacteria such as *Clostridia* by temperature, pH control, reactor hydraulic retention time (HRT) and other factors of the treatment system.

Biological hydrogen can be generated from plants by biophotolysis of water using microalgae (green algae and cyanobacteria), fermentation of organic compounds, and photodecomposition of organic compounds by photo-synthetic bacteria. To produce hydrogen by fermentation of biomass, a continuous process using a non-sterile substrate with a readily available mixed microflora is desirable (Hussy et al. 2005). A successful biological conversion of biomass to hydrogen depends strongly on the processing of raw materials to produce feedstock which can be fermented by the microorganisms.

Hydrogen production from the bacterial fermentation of sugars has been examined in a variety of reactor systems. Hexose concentration has a greater effect on H_2 yields than the HRT. Flocculation also was an important factor in the performance of the reactor.

Hydrogen gas is a product of the mixed acid fermentation of *Escherichia coli*, the butylene glycol fermentation of *Aerobacter*, and the butyric acid fermentations of *Clostridium* spp. It was conducted to improve hydrogen fermentation of food waste in a leaching-bed reactor by heat-shocked anaerobic sludge, and also to investigate the effect of dilution rate on the production of hydrogen and metabolites in hydrogen fermentation.

The combustion products of hydrogen when it is burned completely with air consist of water, oxygen, and nitrogen. In the meantime, it has been suggested, hydrogen is too valuable to burn. Laboratory tests conducted on internal combustion engines burning hydrogen demonstrate good performance (Berry et al. 1996). In comparison with an engine burning gasoline, the emission of nitrogen oxides is far less for the engine-fueled hydrogen. The product of hydrogen combustion with air is water vapor and negligible pollution when the peak temperature is limited. Some oxides of nitrogen (NO_x) are formed at very high combustion temperatures (<2300 K); fortunately, the auto ignition temperature of hydrogen is only 858 K.

Hydrogen has good properties as a fuel for internal combustion engines in automobiles. Some of the characteristic properties of a hydrogen-air mixture that can definitely influence the engine design and performance are low ignition energy, low density, wide range of ignition limits, high diffusion speed, and high flame speed (Plass et al. 1990).

The main disadvantages of using hydrogen as a fuel for automobiles are huge on-board storage tanks, which are required because of hydrogen's extremely low density. Hydrogen may be stored on board a vehicle as compressed gas in ultra-high-pressure vessels, as a liquid in cryogenic containers, or as a gas bound with certain metals in metal hydrides.

Hydrogen is one of the most promising alternative fuel. Hydrogen can be generated in a number of ways, such as electrochemical processes, thermochemical processes, photochemical processes, photocatalytic processes, or photoelectrochemical processes

(Momirlan and Veziroglu 2002). Bio-hydrogen production by anaerobic fermentation of from renewable organic waste sources has been found to be a promising method for the recovery of bio-energy (Han and Shin 2004). In this method, anaerobic bacteria use organic substances as the sole source of electrons and energy, converting them into hydrogen.

The use of hydrogen as a fuel for transportation and stationary applications is receiving much favorable attention as a technical and policy issue (Cherry 2004). Hydrogen gas is being explored for use in combustion engines and fuel-cell electric vehicles. It is a gas at normal temperatures and pressures, which presents greater transportation and storage hurdles than exist for the liquid fuels. Several hydrogen technologies are under development; the most promising of these is the fuel cell. Fuel cells use hydrogen, oxygen, catalyst, and electrolytic solution to produce energy in the form of heat and electricity.

2.6 Biogas Energy

The first methane digester plant was built at a leper colony in Bombay, India in 1859 (Meynell 1976). A methane digester system, commonly referred to as an anaerobic digester is a device that promotes the decomposition of manure or digestion of the organics in manure to simple organics and gaseous biogas products. Anaerobic digestion (AD) is the conversion of organic material directly to a gas, termed biogas, a mixture of mainly methane and carbon dioxide with small quantities of other gases such as hydrogen sulfide. Methane is the major component of the biogas used in many homes for cooking and heating (Kan 2009).

Biogas, a clean and renewable form of energy could very well substitute (especially in the rural sector) for conventional sources of energy (fossil fuels, oil, etc.) which are causing ecological–environmental problems and at the same time depleting at a faster rate. Biogas is a modern form of bioenergy that is derived from the anaerobic digestion of organic matter, such as manure, sewage sludge, municipal solid waste, biodegradable waste and agricultural slurry under anaerobic conditions.

Anaerobic digestion (AD) is a bacterial fermentation process that is sometimes employed in wastewater treatment for sludge degradation and stabilization. The AD is known to occur over a wide temperature range from 283 to 344 K. Anaerobic digestion requires attention to the nutritional needs and the maintenance of reasonable temperatures for the facultative and methanogenic bacteria degrading the waste substrates. The carbon/nitrogen (C/N) ratio of the feedstock is especially important. Biogas can be used after appropriate gas cleanup as a fuel for engines, gas turbines, fuel cells, boilers, industrial heaters, other processes, and the manufacturing of chemicals.

For anaerobic systems, methane gas is an important product. Depending on the type and nature of the biological components, different yields can be obtained for different biodegradable wastes. For pure cellulose, for example, the biogas product

is 50 % methane and 50 % carbon dioxide. Mixed waste feedstocks yield biogas with methane concentrations of 40–60 % (by volume). Fats and oils can yield biogas with 70 % methane content.

For first 3 days, methane yield is almost 0 % and carbon dioxide generation is almost 100 %. In this period, digestion occurred as fermentation to carbon dioxide. The yields of methane and carbon dioxide gases are fifty-fifty at 11th day. At the end of the 20th day, the digestion reaches the stationary phase. The methane content of the biogas is in the range of 63–79 % for the runs, the remainder being principally carbon dioxide. During digestion, the volatile fatty acid concentration is lower and the pH higher.

Digestion is a term usually applied to anaerobic mixed bacterial culture systems employed in many wastewater treatment facilities for sludge degradation and stabilization. Anaerobic digestion is also becoming more widely used in on-farm animal manure management systems, and is the principal process occurring in landfills that creates landfill gas (LFG). Anaerobic digestion operates without free oxygen and results in a fuel gas called biogas containing mostly methane (CH_4) and carbon dioxide (CO_2), but frequently carrying impurities such as moisture, hydrogen sulfide (H_2S), and particulate matter.

Biogas can be used after appropriate gas cleanup as a fuel for engines, gas turbines, fuel cells, boilers, industrial heaters, other processes, or for the manufacturing of chemicals. Before landfilling, treatment or stabilization of biodegradable materials can be accomplished by a combination of anaerobic digestion followed by aerobic composting.

Landfill leachate treatment has received significant attention in recent years, especially in municipal areas. The generation of municipal solid wastes (MSW) has increased in parallel to rapid industrialization. Approximately 16 % of all discarded MSW is incinerated; the remainder is disposed of in landfills. Effective management of these wastes has become a major social and environmental concern. Disposal of MSW in sanitary landfills is usually associated with soil, surface water and groundwater contamination when the landfill is not properly constructed. The flow rate and composition of leachate vary from site to site, seasonally at each site and depending on the age of the landfill. Young leachate normally contains high amounts of volatile fatty acids. MSW statistics and management practices including waste recovery and recycling initiatives have been evaluated. Anaerobic digestion of the organic food fraction of MSW, on its own or co-digested with primary sewage sludge, produces high quality biogas, suitable as renewable energy. The processing of MSW (i.e. landfill, incineration, aerobic composting) secures many advantages and limitations. The greenhouse gas emissions can be reduced by the uncontrolled releasing of methane from improperly disposed organic waste in a large landfill.

Decomposition in landfills occurs in a series of stages, each of which is characterized by the increase or decrease of specific bacterial populations and the formation and utilization of certain metabolic products. The first stage of decomposition, which usually lasts less than a week, is characterized by the removal of oxygen from the waste by aerobic bacteria. In the second stage, which

Table 2.7 Production of biogas components with time in landfill (percent of biogas, by volume)

Time, month	Methane	Carbon dioxide	Oxygen	Nitrogen	Hydrogen
0	0	0	21	78	0
3	0	35.0	0	64.5	0.5
5	0	49.0	0	46.8	4.2
10	0	61.7	0	32.3	
15	–	68.9	0	16.6	14.5
20	–	71.5	0	13.1	15.4
25	0.3	76.6	0	6.4	17.0
37	4.5	76.1	0	4.2	15.2
48	12.7	68.6	0	1.2	7.5
60	33.5	66.5	0	0	0
70	38.0	62.0	0	0	0
90	48.0	52.0	0	0	0
100	53.3	46.7	0	0	0
110	56.0	44.0	0	0	0
120	56.8	43.2	0	0	0

has been termed the anaerobic acid stage, a diverse population of hydrolytic and fermentative bacteria hydrolyzes polymers, such as cellulose, hemicelluloses, proteins, and lipids, into soluble sugars, amino acids, long-chain carboxylic acids, and glycerol. The main components of landfill gas are by-products of the decomposition of organic material, usually in the form of domestic waste, by the action of naturally occurring bacteria under anaerobic conditions. Table 2.7 shows the production of biogas components with time in landfill (Demirbas 2006b).

Methods developed for treatment of landfill leachates can be classified as physical, chemical and biological which are usually used in combinations in order to improve the treatment efficiency. Biological treatment methods used for the leachate treatment can be classified as aerobic, anaerobic and anoxic processes which are widely used for the removal of biodegradable compounds. Biological treatment of landfill leachate usually results in low nutrient removals because of high chemical oxygen demand (COD), high ammonium-N content and the presence of toxic compounds such as heavy metals. Landfill leachate obtained from the solid waste landfill area contained high COD and ammonium ions which resulted in low COD and ammonium removals by direct biological treatment. Typical analysis results of raw landfill gas are given in Table 2.8.

Anaerobic digestion of organic compounds is a complex process, involving several different types of microorganisms. This is the natural breakdown of organic matter, such as biomass, by bacterial populations in the absence of air into biogas, i.e., a mixture of methane (40–75 % v/v) and carbon dioxide. The end products of anaerobic digestion are biogas and digestate, a moist solid which is normally dewatered to produce a liquid stream and a drier solid. During anaerobic digestion,

Table 2.8 Typical analysis of raw landfill gas

Component	Chemical formula	Content
Methane	CH ₄	40–60 (% by vol.)
Carbon dioxide	CO ₂	30–50 (% by vol.)
Nitrogen	N ₂	2–15 (% by vol.)
Oxygen	O ₂	<1 (% by vol.)
Heavier hydrocarbons	C _n H _{2n+2}	<1 (% by vol.)
Hydrogen sulfide	H ₂ S	40–100 ppm
Complex organics	–	1000–2000 ppm

typically 30–60 % of the input solids are converted to biogas; byproducts consist of undigested fibre and various water-soluble substances.

The anaerobic digestion process occurs in the following four basic steps: (1) hydrolysis, (2) acidogenesis, (3) acetogenesis, and (4) methanogenesis.

The first step in anaerobic degradation is the hydrolysis of complex organic compounds such as carbohydrates, proteins and lipids. Organic compounds are hydrolyzed into smaller units, such as sugars, amino acids, alcohols and long-chain fatty acids. During the hydrolysis step both solubilization of insoluble particulate matter and biological decomposition of organic polymers to monomers or dimers take place. Thermal, mechanic and chemical treatment have been investigated as a possible pre-treatment step to accelerate sludge hydrolysis. The aim of the pre-treatment is disintegrate sludge solids to facilitate the release of cell components and other organic matter.

In the second step, acidogenesis, another group of microorganisms ferments the break-down products to acetic acid, hydrogen, carbon dioxide and other lower weight simple volatile organic acids like propionic acid and butyric acid which are in turn converted to acetic acid. Acetate, carbon dioxide and molecular hydrogen can be directly utilised as a substrate by another group of anaerobic microorganisms called methanogens. These organisms comprise a wide variety of different bacterial genera representing both obligate and facultative anaerobes.

During acidogenesis, the freshly fed biomass on the top produced a lot of volatile fatty acids (VFAs) intermediates that accumulated in the bed. A daily sprinkling of the bed once on one side introduced acidogenic organisms onto the upper regions of the biomass bed and it also carried down VFA intermediates to lower regions of the bed. This degradation pathway is often the fastest step and also gives a high-energy yield for the microorganisms, and the products can be used directly as substrates by the methanogenic microorganism.

The third step is the biological process of acetogenesis where the products of acidogenesis are further digested to produce carbon dioxide, hydrogen and mainly acetic acid, although higher-molecular-weight organic acids (e.g., propionic, butyric, valeric) are also produced. The products formed during acetogenesis are due to a number of different microbes, e.g., *Syntrophobacter wolinii*, a propionate decomposer and *Syntrophomonas wolfei*, a butyrate decomposer. Other acid formers

are *Clostridium* spp., *Peptococcus anerebus*, *Lactobacillus*, and *Actinomyces* (Verma 2002). Acetogens are slow-growing microorganisms that are sensitive to environmental changes such as changes in the organic loading rate and flow rate. The microorganisms in the step are usually facultative heterotrophs which function best in a range of pH from 4.0 to 6.5 (Zhang et al. 2005).

Anaerobic digestion can occur over a wide range of environmental conditions, although narrower ranges are needed for optimum operation. The key factors to successfully control the stability and efficiency of the process are reactor configurations, temperature, pH, HRT, OLR, inhibitor concentrations, concentrations of total volatile fatty acid (TVFA) and substrate composition.

Temperature significantly influences anaerobic digestion process, especially in methanogenesis wherein the degradation rate is increasing with temperature. It has been found that the optimum temperature ranges for anaerobic digestion are mesophilic (303–313 K), and thermophilic (323–333 K) (Braun 2007). Based on the temperature chosen, the duration of the process and effectiveness in destroying pathogens will vary. In mesophilic digestion, the digester is heated to 35 °C and the typical time of retention in the digester is 15–30 days, whereas in thermophilic digestion the digester is heated to 328 K and the time of retention is typically 12–14 days (Erickson et al. 2004). It has been observed that higher temperatures in the thermophilic range reduce the required retention time (Verma 2002). However, anaerobes are most active in the mesophilic and thermophilic temperature range. The activities of microorganisms increase with the increase of temperature, reflecting stable degradation of the substrate.

Temperature is a universal process variable. It influences the rate of bacterial action as well as the quantity of moisture in the biogas. The biogas moisture content increases exponentially with temperature. Temperature also influences the quantity of gas and volatile organic substances dissolved in solution as well as the concentration of ammonia and hydrogen sulfide gas.

pH is a major variable to be monitored and controlled. The range of acceptable pH in digestion is theoretically from 5.5 to 8.5. It may be necessary to use a base or buffer to maintain the pH in the biodigester. In general, the pH has been reported as one of the most important parameters for the inhibition of the methanogenic activity in an acid phase reactor, operating in the pH range 4.5–6.5. Maximum propionate degradation and methane production were observed at pH 7.5 and pH 7.0, respectively. Efficient methanogenesis from a digester operating in a steady state should not require pH control, but at other times, for example, during start-up or with unusually high feed loads, pH control may be necessary. pH can only be used as a process indicator when treating waste with low buffering capacity, such as carbohydrate-rich waste (Parawira 2004).

Agricultural residues contain low nitrogen and have carbon-to-nitrogen ratios (C/N) of around 60–90. The proper C/N ratio for anaerobic digestion is 25–35; therefore, nitrogen needs to be supplemented to enhance the anaerobic digestion of agricultural solid residues. Nitrogen can be added in inorganic form such as ammonia or in organic form such as livestock manure, urea, or food wastes. Once nitrogen is released from

the organic matter, it becomes ammonium which is water soluble. Recycling nitrogen in the digested liquid reduces the amount of nitrogen needed.

2.7 Algae Energy

Billions of years ago the earth atmosphere was filled with CO₂. Thus there was no life on earth. Life on earth started with *Cyanobacterium* and algae.

Algae are the fastest-growing plants in the world. Industrial reactors for algal culture are open ponds, photobioreactors and closed systems. Algae are very important as a biomass source. Algae will someday be competitive as a source for biofuel.

Different species of algae may be better suited for different types of fuel. Algae can be grown almost anywhere, even on sewage or salt water, and does not require fertile land or food crops, and processing requires less energy than the algae provides.

Algae can be a replacement for oil based fuels, one that is more effective and has no disadvantages. Algae are among the fastest growing plants in the world, and about 50 % of their weight is oil. This lipid oil can be used to make biodiesel for cars, trucks, and airplanes.

Microalgae have much faster growth-rates than terrestrial crops. the per unit area yield of oil from algae is estimated to be from between 20,000 and 80,000 L per acre, per year; this is 7 to 31 times greater than the next best crop, palm oil. The lipid and fatty acid contents of microalgae vary in accordance with culture conditions. Most current research on oil extraction is focused on microalgae to produce biodiesel from algal-oil. Algal-oil processes into biodiesel as easily as oil derived from land-based crops.

Microalgae can be used for bioenergy generation (biodiesel, biomethane, bio-hydrogen), or combined applications for biofuels production and CO₂ mitigation. Microalgae are veritable miniature biochemical factories, and appear more photo-synthetically efficient than terrestrial plants (Pirt 1986) and are efficient CO₂ fixers (Brown and Zeiler 1993).

The existing large-scale natural sources of algae are: bogs, marshes and swamps—salt marshes and salt lakes. Microalgae contain lipids and fatty acids as membrane components, storage products, metabolites and sources of energy. Algae contain anything between 2 and 40 % of lipids/oils by weight. Growth medium must provide the inorganic elements that constitute the algal cell. Essential elements include nitrogen (N), phosphorus (P), iron and in some cases silicon (Chisti 2007). Minimal nutritional requirements can be estimated using the approximate molecular formula of the microalgal biomass that is CO_{0.48}H_{1.83}N_{0.11}P_{0.01}. This formula is based on data presented by Grobbelaar (2004).

The production of microalgal biodiesel requires large quantities of algal biomass. Macro and microalgae are currently mainly used for food, in animal feed, in feed for aquaculture and as bio-fertilizer. Biomass from microalgae is dried and

marketed in the human health food market in form of powders or pressed in the form of tablets. Aquatic biomass could also be used as raw material for co-firing to produce electricity, for liquid fuel (bio-oil) production via pyrolysis, or for bio-methane generation through fermentation. Bio-methane can be produced from marine biomass.

Microalgae cultivation using sunlight energy can be carried out in open or covered ponds or closed photobioreactors, based on tubular, flat plate or other designs. Closed systems are much more expensive than ponds, and present significant operating challenges, and due to gas exchange limitations, among others, cannot be scaled-up much beyond about a hundred square meters for an individual growth unit.

The concept of using microalgae as a source of fuel is older than most people realize. The idea of producing methane gas from algae was proposed in the early 1950s. Industrial reactors for algal culture are at present. There are:

1. Photobioreactors
2. Open ponds
3. Closed and hybrid systems.

Photobioreactors are different types of tanks or closed systems in which algae are cultivated. Open pond systems are shallow ponds in which algae are cultivated. Nutrients can be provided through runoff water from nearby land areas or by channelling the water from sewage/water treatment plants. Technical and biological limitations of these open systems have given rise to the development of enclosed photoreactors. Microalgae cultivation using sunlight energy can be carried out in open or covered ponds or closed photobioreactors, based on tubular, flat plate or other designs. A few open systems are presented for which particularly reliable results are available. Emphasis is then put on closed systems, which have been considered as capital intensive and are justified only when a fine chemical is to be produced. Microalgae production in closed photobioreactors is highly expensive. Closed systems are much more expensive than ponds. However, the closed systems require much less light and agricultural land to grow the algae. High oil species of microalgae cultured in growth optimized conditions of photobioreactors have the potential to yield 19,000–57,000 L of microalgal oil per acre per year. The yield of oil from algae is over 200 times the yield from the best-performing plant/vegetable oils (Chisti 2007). Figure 2.5 shows the open pond systems or open algae farms.

Large-scale production of microalgal biomass generally uses continuous culture during daylight. In this method of operation, fresh culture medium is fed at a constant rate and the same quantity of microalgal broth is withdrawn continuously (Molina Grima 1999). Feeding ceases during the night, but the mixing of broth must continue to prevent settling of the biomass (Molina Grima 1999). As much as 25 % of the biomass produced during daylight, may be lost during the night because of respiration. The extent of this loss depends on the light level under which the biomass was grown, the growth temperature, and the temperature at night (Chisti 2007).

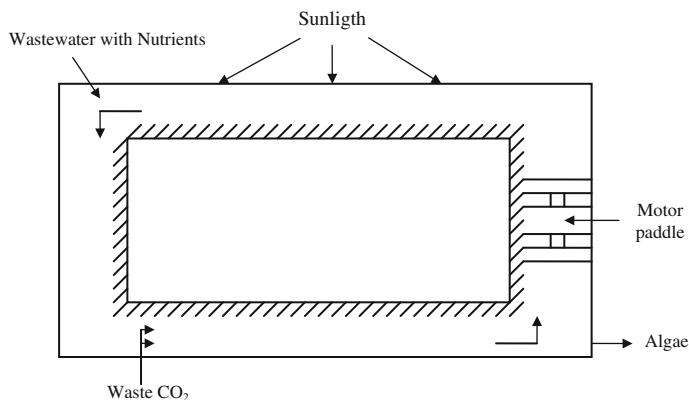


Fig. 2.5 Open pond systems or open algae farms

Algal cultures consist of a single or several specific strains optimized for producing the desired product. Water, necessary nutrients and CO_2 are provided in a controlled way, while oxygen has to be removed (Carlsson et al. 2007). Algae receive sunlight either directly through the transparent container walls or via light fibers or tubes that channel it from sunlight collectors. A great amount of developmental work to optimize different photobioreactor systems for algae cultivation has been carried out and is reviewed in Janssen et al. (2003), Choi et al. (2003), Carvalho et al. (2006), Hankamer et al. (2007).

Bioreactors are the preferred method for scientific researchers, and recently for some newer, innovative production designs. These systems are more expensive to build and operate; however, they allow for a very controlled environment. This means that gas levels, temperature, pH, mixing, media concentration, and light can be optimized for maximum production (Chisti 2007). Unlike open ponds, bioreactors can ensure a single alga species is grown without interference or competition (Campbell 2008).

Algae can be harvested by centrifugation, flocculation or froth flotation. Alum and ferric chloride are chemical flocculants used to harvest algae. Water that is brackish or salty requires additional chemical flocculants to induce flocculation. Harvesting by chemical is a method that is often too expensive for large operations. However, interrupting the carbon dioxide supply to an algal system can cause algae to flocculate on its own, which is called “auto-flocculation”. In froth flotation, the water and algae are aerated into froth and algae are then removed from the water.

2.7.1 Biodiesel Production from Algal Oil

Microalgae contain lipids and fatty acids as membrane components, storage products, metabolites and sources of energy. Algae present an exciting possibility

Table 2.9 Oil contents of some microalgae

Microalga	Oil content (wt% of dry basis)
<i>Botryococcus braunii</i>	25–75
<i>Chlorella</i> sp.	28–32
<i>Cryptocodinium cohnii</i>	20
<i>Cylindrotheca</i> sp.	16–37
<i>Dunaliella primolecta</i>	23
<i>Isochrysis</i> sp.	25–33
<i>Monallanthus salina</i>	>20
<i>Nannochloris</i> sp.	20–35
<i>Nannochloropsis</i> sp.	31–68
<i>Neochloris oleoabundans</i>	35–54
<i>Nitzschia</i> sp.	45–47
<i>Phaeodactylum</i>	20–30
<i>tricornutum</i>	50–77
<i>Schizochytrium</i> sp.	15–23
<i>Tetraselmis sueica</i>	

as a feedstock for biodiesel, and when you realize that oil was originally formed from algae.

In order to have an optimal yield, these algae need to have carbon dioxide (CO₂) in large quantities in the basins or bioreactors where they grow. Thus, the basins and bioreactors need to be coupled with traditional thermal power centers producing electricity which produce CO₂ at an average tenor of 13 % of total flue gas emissions. The CO₂ is put in the basins and is assimilated by the algae. It is thus a technology which recycles CO₂ while also treating used water.

Algae can grow practically anywhere where there is enough sunshine. Some algae can grow in saline water. All algae contain proteins, carbohydrates, lipids and nucleic acids in varying proportions. The oil contents of some microalgae are given in Table 2.9 (Chisti 2007). Microalgae are very efficient solar energy converters and they can produce a great variety of metabolites (Chaumont 2005). The culture of algae can yield 30–50 % oil (Dimitrov 2008). Oil supply is based on the theoretical claims that 47,000–308,000 L/ha/year of oil could be produced using algae. The calculated cost per barrel would be only \$20 (Demirbas 2009a).

Algae are theoretically very promising source of biodiesel. The lipid and fatty acid contents of microalgae vary in accordance with culture conditions. In some cases, lipid content can be enhanced by the imposition of nitrogen starvation or other stress factors. Which is the best species of algae for biodiesel? There is no one strain or species of algae that can be said to be the best in terms of oil yield for biodiesel. However diatoms and secondly green algae were the most promising. *Scenedesmus dimorphus* is a unicellular alga in the class *Chlorophyceae* (green algae). While this is one of the preferred species for oil yield for biodiesel, one of the problems with *Scenedesmus* is that it is heavy, and forms thick sediments if not kept in constant agitation. The strain called as *Dunaliella tertiolecta* has oil yield of about 37 % (organic basis). *Dunaliella tertiolecta* is a fast growing strain and that means it has a high CO₂ sequestration rate as well (Sheehan et al. 1998; Chisti 2007; Ozkurt 2009; Demirbas 2009a). Table 2.10 shows the yield of various plant oils.

Table 2.10 Yield of various plant oils

Crop	Oil in liters per hectare
Algae	100,000
Castor	1413
Coconut	2689
Palm	5950
Safflower	779
Soy	446
Sunflower	952

Certain algae strains also produce polyunsaturated fatty acids (omega-3's) in the form of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) generally found in fish oils. Phototrophic microalgae are used to provide polyunsaturated fatty acids (omega-3 and omega-6) for aquaculture operations. These additional products greatly enhance the overall marketability and economics of producing algae (Volkman et al. 1989; Yaguchi et al. 1997; Vazhappilly and Chen 1998).

The algae that are used in biodiesel production are usually aquatic unicellular green algae. This type of algae is a photosynthetic eukaryote characterized by high growth rates and high population densities. Under good conditions, green algae can double its biomass in less than 24 h. Additionally, green algae can have huge lipid contents, frequently over 50 % (Schneider 2006; Chisti 2007). This high yield, high density biomass is ideal for intensive agriculture and may be an excellent source for biodiesel production.

The annual productivity and oil content of algae is far greater than seed crops. Soybean can only produce about 450 L of oil per hectare. Canola can produce 1200 L per hectare, and Palm can produce 6000 L. Now, compare that to algae which can yield 90,000 L per hectare (Schneider 2006; Chisti 2007; Haag 2007). It is possible that the US demand for liquid fuel could be achieved by cultivating algae in one tenth of the area currently devoted to soybean cultivation (Scott and Bryner 2006).

The process for producing microalgal oils consists of a microalgal biomass production step that requires light, carbon dioxide, water and inorganic nutrients. The latter are mainly nitrates, phosphates, iron and some trace elements. Approximately half of the dry weight of the microalgal biomass is carbon, which is typically derived from carbon dioxide. Therefore, producing 100 tons of algal biomass fixes roughly 183 tons of carbon dioxide. This carbon dioxide must be fed continually during daylight hours. This carbon dioxide is often available at little or no cost (Chisti 2008). Optimal temperature for growing many microalgae is between 293 and 303 K. A temperature outside this range could kill or otherwise damage the cells.

There are three well-known methods to extract the oil from algae: (1) Expeller/Press, (2) Solvent extraction with hexane and (3) Supercritical Fluid extraction. A simple process is to use a press to extract a large percentage (70–75 %) of the oils out of algae. Algal oil can be extracted using chemicals. The most popular chemical for solvent extraction is hexane, which is relatively inexpensive.

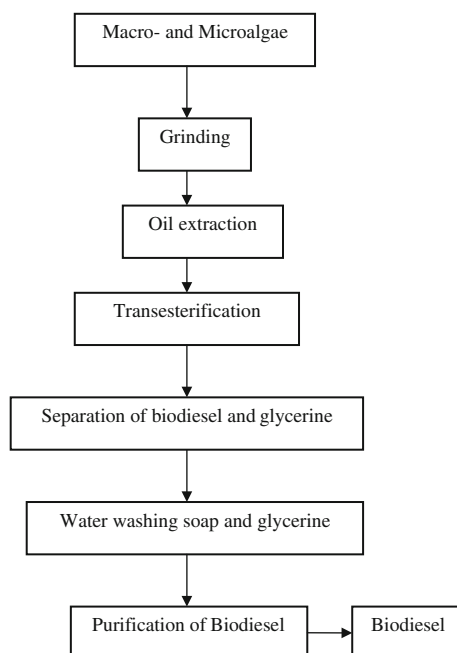
Supercritical fluid extraction is far more efficient than traditional solvent separation methods. Supercritical fluids are selective, thus providing the high purity and product concentrations (Paul and Wise 1971). This can extract almost 100 % of the oils all by itself. In the supercritical fluid carbon dioxide (CO₂) extraction, CO₂ is liquefied under pressure and heated to the point that it has the properties of both a liquid and gas. This liquefied fluid then acts as the solvent in extracting the oil.

The lipid and fatty acid contents of microalgae vary in accordance with culture conditions. Algal oil contains saturated and monounsaturated fatty acids. The fatty acids were determined in the algal oil in the following proportions: 36 % oleic (18:1), 15 % palmitic (16:0), 11 % stearic (18:0), 8.4 % iso-17:0, and 7.4 % linoleic (18:2). The high proportion of saturated and monounsaturated fatty acids in this alga is considered optimal from a fuel quality standpoint, in that fuel polymerization during combustion would be substantially less than what would occur with polyunsaturated fatty acid-derived fuel (Sheehan et al. 1998).

After oil extraction from algae, the remaining biomass fraction can be used as a high protein feed for livestock (Schneider 2006; Haag 2007). This gives further value to the process and reduces waste.

Most current research on oil extraction is focused on microalgae to produce biodiesel from algal oil. The biodiesel from algal oil in itself is not significantly different from biodiesel produced from vegetable oils. Figure 2.6 shows the production of biodiesel from algae.

Fig. 2.6 Production of biodiesel from algae



Oils were obtained by extracting the algae with hexane in a Soxhlet extractor for 18 h. Transesterification of algal oils were performed in a 100-mL cylindrical using supercritical methanol according to earlier methods (Kusdiana and Saka 2001). Fatty acids of the algal oils were fractionated into saturated, monounsaturates, polyunsaturates and free forms by a preparative chromatographic thin layer on a glass plate coating with a 0.25 μm polyethanol succinate.

Xu et al. (2006) used *Chlorella protothecoides* (a microalga) for production of biodiesel. Cells were harvested by centrifugation, washed with distilled water, and then dried by a freeze dryer. The main chemical components of heterotrophic *C. protothecoides* were measured as previous study (Miao et al. 2004). Microalgal oil was prepared by pulverization of heterotrophic cell powder in a mortar and extraction with *n*-hexane.

The optimum process combination was 100 % catalyst quantity (based on oil weight) with 56:1 molar ratio of methanol to oil at temperature of 303 K, which reduced product specific gravity from an initial value of 0.912 to a final value of 0.864 in about 4 h of reaction time (Xu et al. 2006).

The technique of metabolic controlling through heterotrophic growth of *C. protothecoides* was applied, and the heterotrophic *C. protothecoides* contained the crude lipid content of 55.2 %. To increase the biomass and reduce the cost of alga, corn powder hydrolysate instead of glucose was used as organic carbon source in heterotrophic culture medium in fermenters. The result showed that cell density significantly increased under the heterotrophic condition, and the highest cell concentration reached 15.5 g/L. Large amount of microalgal oil was efficiently extracted from the heterotrophic cells by using *n*-hexane, and then transmuted into biodiesel by acidic transesterification (Xu et al. 2006).

Algae biomass cultivation has four important potentials than other sources. First, algae biomass can be produced at extremely high volumes and this biomass can yield a much higher percentage of oil than other sources. Second algae oil has limited market competition. Third, algae can be cultivated on marginal land, fresh water, or sea water. Fourth, innovations to algae production allow it to become more productive while consuming resources that would otherwise be considered waste (Campbell 2008).

Biodiesel derived from oil crops is a potential renewable and carbon neutral alternative to petroleum fuels. Unfortunately, biodiesel from oil crops, waste cooking oil and animal fat cannot realistically satisfy even a small fraction of the existing demand for transport fuels. Microalgae appear to be the only source of renewable biodiesel that is capable of meeting the global demand for transport fuels.

Like plants, microalgae use sunlight to produce oils but they do so more efficiently than crop plants. Oil productivity of many microalgae greatly exceeds the oil productivity of the best producing oil crops. Approaches for making microalgal biodiesel economically competitive with petrodiesel are discussed (Chisti 2007). Biodiesel derived from green algae biomass has the potential for high volume, cost effective production (Campbell 2008).

Laboratory studies, exploring methods to maximize both density and oil content, have demonstrated that there is yet much unrealized potential. Xu et al. (2006) cultivated the algae *Chlorella protothecoids* in a light deprived, heterotrophic environment with inexpensive hydrolyzed corn starch as the sole food source.

Biodiesel from microalgae seems to be the only renewable biofuel that has the potential to completely displace petroleum-derived transport fuels without adversely affecting supply of food and other crop products. Most productive oil crops, such as oil palm, do not come close to microalgae in being able to sustainably provide the necessary amounts of biodiesel. Similarly, bioethanol from sugarcane is no match for microalgal biodiesel (Chisti 2008).

Algae can grow practically anywhere where there is enough sunshine. Some algae can grow in saline water. All algae contain proteins, carbohydrates, lipids and nucleic acids in varying proportions. While the percentages vary with the type of algae, there are algae types that are comprised up to 40 % of their overall mass by fatty acids (Becker 1994). The most significant distinguishing characteristic of algal oil is its yield and hence its biodiesel yield. According to some estimates, the yield (per acre) of oil from algae is over 200 times the yield from the best-performing plant/vegetable oils (Sheehan et al. 1998).

2.7.2 Glycerol from Vegetable Oil for a Promising Carbon Source

Glycerol is present in many applications in the cosmetic, paint, automotive, food, tobacco, pharmaceutical, pulp and paper, leather and textile industries. Glycerol is a by-product from biodiesel and soap industries. The principal by-product of biodiesel production is the crude glycerol, which is about 10 %wt of vegetable oil. Triglycerides from vegetable oils and animal fats can be hydrolyzed or split into its corresponding fatty acids and glycerine. Figure 2.7 shows biodiesel and glycerol from transesterification process.

Direct addition of glycerol to the fuel is not possible; however, derivatives of glycerol such as ethers have potential for use as additives with biodiesel, diesel or biodiesel-diesel blends. Glycerol can be converted into commercially valued

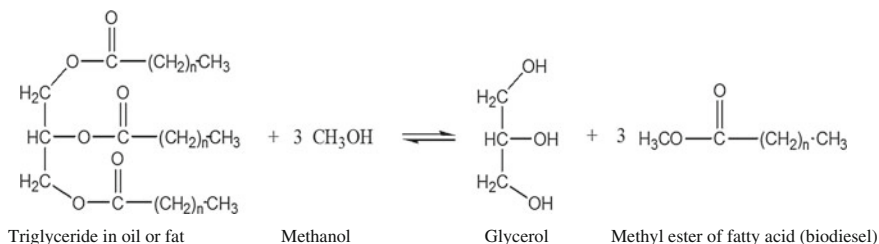


Fig. 2.7 Biodiesel and glycerol from transesterification process

oxygenate products using for the diesel fuel blends. Glycerol alkyl ethers (GAEs) are easily synthesized using glycerol which is reacted with isobutylene in the presence of an acid catalyst. The ethers of glycerol can be effectively added to biodiesel fuels, providing a 5 K reduction in cloud point and an 8 % reduction in viscosity.

The excess glycerol generated may become an environmental problem, since it cannot be disposed of in the environment. One of the possible applications is its use as carbon and energy source for microbial growth in industrial microbiology. Glycerol bioconversion in valuable chemicals, such as 1,3-propanediol, dihydroxyacetone, ethanol, succinate etc. is discussed in this review article (da Silva et al. 2009).

Glycerol must be modified to fuel oxygenates derivatives using as additive in diesel and biodiesel fuel blends. The most obvious derivative of glycerol has an analogy in gasoline reformulation.

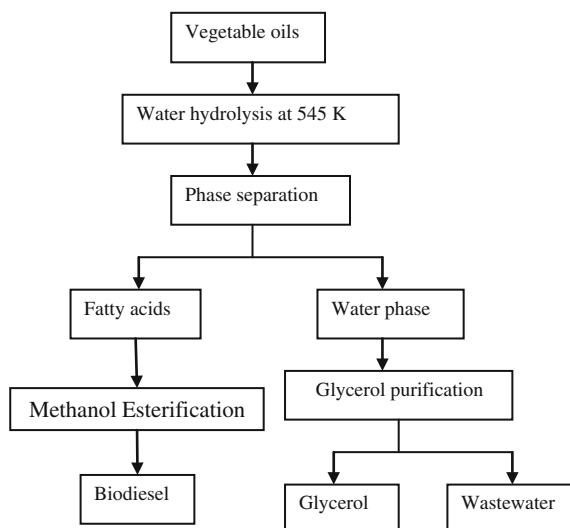
Glycerol alkyl ethers (GAEs) are easily synthesized using glycerol which is reacted with isobutylene in the presence of an acid catalyst, and the yield is maximized by carrying out the reaction in a two-phase reaction system, with one phase being a glycerol-rich polar phase (containing the acidic catalyst) and the other phase being an olefin-rich hydrocarbon phase from which the product ethers can be readily separated (Gupta 1995).

The etherification of glycerol with *tert*-butanol has been studied by Klepacova et al. (2003) at the presence of catex Amberlyst 15 as catalyst. The maximum conversion of glycerol near 96 % was reached at the temperature 363 K and at the molar ratio *tert*-butanol/glycerol = 4:1 after 180 min (Klepacova et al. 2003).

The preparation of the glycerol alkyl ethers (GAE) by etherification (o-alkylation) by alkenes, and preferentially by isobutylene is one of the possibilities of the glycerol usage. The GAEs can be also obtained from alkenes with C₄-fraction from pyrolysis and fluid catalytic cracking at the presence of the acid catalyst. The mixture of mono-, di- and tri- alkyl glycerol ethers can be produced. These ethers (mainly di- and tri- alkyl glycerols) are the main products of glycerol etherification reaction and are excellent oxygen additives for diesel fuel (Jamróz et al. 2007). The addition of these ethers has positive effect on the combustion of diesel fuel (high cetane number, CN) and preferentially ethers are active by reduction of fumes and particulate matters, carbon oxides and carbonyl compounds in exhausts (Klepacova et al. 2003).

Glycerol can be converted to propylene glycol (1,2-propanediol) by dehydration followed by hydrogenation (hydrogenolysis) reaction. Propylene glycol is used in an antifreeze mixture (70 % propylene glycol and 30 % glycerol) that can be produced, refined, and marketed directly by existing biodiesel facilities. The method is based on hydrogenolysis of glycerol over a copper chromite catalyst at 475 K (Pagliaro et al. 2007). Figure 2.8 shows a simple flow diagram of glycerol from continuous biodiesel production process with subcritical water and supercritical methanol stages.

Fig. 2.8 A simple flow diagram of glycerol from a continuous biodiesel production process



2.8 The Next Generation of Hybrid Transportation Vehicles

Internal combustion engines (ICEs) will end in near future and their life until 2040 is estimated. A variety of propulsion technologies and fuels have the promise to reduce petroleum use and greenhouse gas emissions from motor vehicles.

Cars are being developed in many different ways. According to predictions made a few decades ago, current travel should involve self-driving automobiles, jetpacks and flying cars, with space transport a common occurrence. Figure 2.9 shows conventional and future transportation vehicles.

Hybrid electric vehicle (HEV) technology and its various applications, the subject of this paper, have made significant market gains in recent years and form an important part of the fuel economy equation. HEVs are powered with a combination of a combustion engine and an electric motor. A hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle.

Though hybrid cars consume less petroleum than conventional cars, there is still an issue regarding the environmental damage of the hybrid car battery. Today most hybrid car batteries are one of two types: (1) nickel metal hydride, or (2) lithium ion; both are regarded as more environmentally friendly than lead-based batteries which constitute the bulk of gasoline car starter batteries today.

Plug-in hybrids are an evolution from today's so-called "full" hybrid vehicles, such as the Toyota Prius or Ford Escape. A "full" hybrid has the ability to start and accelerate to low speeds without starting the gasoline engine, but the battery pack is charged exclusively from the on-board internal combustion engine and regenerative breaking. A plug-in hybrid operates in the same way but has a larger battery pack

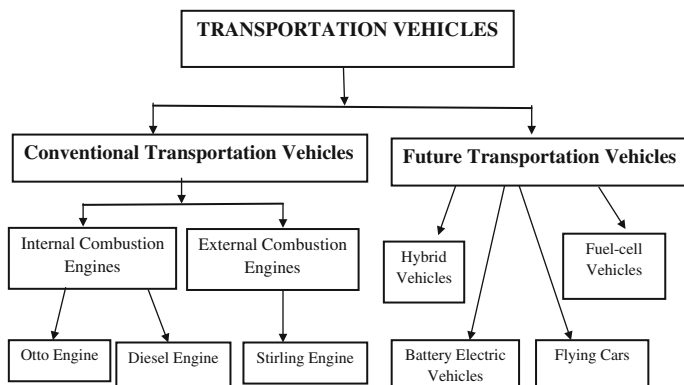


Fig. 2.9 Conventional and future transportation vehicles

and gives the driver the option of charging the battery from a household outlet and then running their vehicle on grid electricity instead of petroleum (NRDC 2007).

Today's popular hybrid vehicles use nickel metal hydride (NiMH) batteries, which can be engineered for relatively short battery-only driving distances in plug-in hybrids. Plug-in hybrids have an advantage over pure battery electric vehicles because drivers don't have to worry about running out of electricity—when the battery runs down, plug-ins operate like conventional hybrids and use the engine and regenerative braking to charge the battery and drive the vehicle.

The purchase price of a hybrid vehicle is higher compared to a conventional vehicle, both for passenger cars, buses, and trucks. However, given the lower fuel consumption, the total cost of ownership or life cycle cost of buying and using a hybrid can be equal to or even lower than buying and using a conventional vehicle—depending on yearly mileage and fuel prices. The life cycle cost does not only include the cost of purchasing the vehicle but also the cost of fueling and maintenance.

Electric vehicles which store electrical energy in a capacitor or battery would not be able to immediately replace all gasoline cars given the available transportation infrastructure. For example, while a gasoline car could undertake a road trip which would require several short (around 5 min) fuel stops to complete, current electric car technology would not be capable of completing the trip in the same length of time; in addition to the limited range of current electric cars, they are not as quick or as practical to recharge.

Proponents of electric cars usually tout an increased efficiency as the primary advantage of an electric vehicle as compared to one powered by an internal combustion engine. The energy efficiency comparison is difficult to make because the two vehicles operate on different principles. Vehicles powered by internal combustion engines operate convert energy stored in fossil fuels to mechanical energy through the use of a heat engine. Heat engines operate with very low efficiencies because heat cannot be converted directly into mechanical energy. Electric vehicles

convert stored electric potential into mechanical energy. Electricity can be converted into mechanical energy at very high efficiencies.

A flying car or roadable aircraft is an aircraft that can also travel along roads. All the working examples have required some manual or automated process of conversion between the two modes of operation.

Flying cars not imagine today. Ground and air traffic, security, speed, convenience fuel with higher heating value and lower weight and low cost are the most important problems for flying cars.

References

- Arisoy K (2008) Oxidative and thermal instability of biodiesel. *Energy Sour Part A* 30:1516–1522
- Becker EW (1994) Microalgae: biotechnology and microbiology. In: Baddiley J et al (ed). Cambridge University Press, Cambridge
- Berry GD, Pasternak AD, Rambach GD, Smith JR, Schock RN (1996) Hydrogen as a future transportation fuel. *Energy* 21:289–303
- Braun R (2007) Anaerobic digestion: a multi-faceted process for energy, environmental management and rural development. Improvement of crop plants for industrial end uses. Springer, Netherlands, pp 335–416
- Brown LM, Zeiler BG (1993) Aquatic biomass and carbon dioxide trapping. *Energy Convers Manage* 34:1005–1013
- Byrd AJ, Pant KK, Gupta RB (2007) Hydrogen production from glucose using Ru/Al₂O₃ catalyst in supercritical water. *Ind Eng Chem Res* 46:3574–3579
- Campbell MN (2008) Biodiesel: algae as a renewable source for liquid fuel. *Guelph Eng J* 1:2–7
- Carlsson AS, van Beilen JB, Möller R, Clayton D (2007) Micro- and macro-algae: utility for industrial applications. In: Bowles D (ed) Outputs from the EPOBIO: realising the economic potential of sustainable resources—bioproducts from non-food crops project. CNAP, University of York
- Carvalho AP, Meireles LA, Malcata FX (2006) Microalgal reactors: a review of enclosed system designs and performances. *Biotechnol Prog* 22:1490–1506
- Chaumont D (2005) Biotechnology of algal biomass production: a review of systems for outdoor mass culture. *J Appl Phycology* 5:593–604
- Cheng J, Li Y, He S, Shen W, Liu Y, Song Y (2008) Reaction kinetics of transesterification between vegetable oil and methanol under supercritical conditions. *Energy Sour Part A* 30:681–688
- Cherry RS (2004) A hydrogen utopia? *Int J Hydrogen Energy* 29:125–129
- Chhetri AB, Islam MR (2008) Towards producing a truly green biodiesel. *Energy Sour Part A* 30:754–764
- Chisti Y (2007) Biodiesel from microalgae. *Biotechnol Adv* 25:294–306
- Chisti Y (2008) Biodiesel from microalgae beats bioethanol. *Trends Biotechnol* 26:126–131
- Choi SL, Suh IS, Lee CG (2003) Lumostatic operation of bubble column photobioreactors for *Haematococcus pluvialis* cultures using a specific light uptake rate as a control parameter. *Enzyme Microbial Technol* 33:403–409
- da Silva GP, Matthias M, Contiero J (2009) Glycerol: a promising and abundant carbon source for industrial microbiology. *Biotechnol Adv* 27:30–39
- Demirbas A (2002) Biodiesel from vegetable oils via transesterification in supercritical methanol. *Energy Convers Manage* 2002(43):2349–2356

- Demirbas A (2003) Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey. *Energy Convers Manage* 44:2093–2109
- Demirbas A (2006a) Biofuel based cogenerative energy conversion systems. *Energy Sour Part A* 28:1509–1518
- Demirbas A (2006b) Biogas production from the organic fraction of municipal solid waste. *Energy Sources Part A* 28:1127–1134
- Demirbas AH (2009a) Inexpensive oil and fats feedstocks for production of biodiesel. *Energy Educ Sci Tech-A* 2009(23):1–13
- Demirbas A (2009b) Production of biodiesel from algae oils. *Energy Sour Part A* 2009 (31):163–168
- Demirbas A (2016) An overview of biodiesel life cycles. *Energy Educ Sci Tech-C* 8:17–48
- Dimitrov K (2008) Green fuel technologies: a case study for industrial photosynthetic energy capture. Brisbane, Australia. Available from <http://www.nanostring.net/Algae/>
- Dincer K (2008) Lower emissions from biodiesel combustion. *Energy Sour Part A* 30:963–968
- EREC (European Renewable Energy Council) (2009) Renewable energy scenario by 2030, EREC Statistics, Brussels
- Erickson LE, Fayet E, Kakumanu BK, Davis LC (2004) Anaerobic digestion. In: Carcass disposal: a comprehensive review (Chap. 7). National Agricultural Biosecurity Center, Kansas State University, Manhattan, pp 1–19
- EWEA (European Wind Energy Association) (2005) Report: large scale integration of wind energy in the European power supply: analysis, issues and recommendations, Paris
- Goldman JC, Ryther JH (1997) Mass production of algae: bio-engineering aspects. In: Mitsui A et al (eds) Biological solar energy conversion. Academic Press, New York
- Grobbelaar JU (2004) Algal nutrition. In: Richmond A (ed) Handbook of microalgal culture: biotechnology and applied phyecology. Blackwell, Oxford
- Gupta VP (1995) Glycerine ditertiary butyl ether preparation. U.S. Patent KO. 5476971
- Haag AL (2007) Algae bloom again. *Nature* 447:520–521
- Han S-K, Shin H-S (2004) Biohydrogen production by anaerobic fermentation of food waste. *Int J Hydrogen Energy* 29:569–577
- Hansen AC, Zhang Q, Lyne PWL (2005) Ethanol–diesel fuel blends—a review. *Biores Technol* 96:277–285
- Hussy I, Hawkes FR, Dinsdale R, Hawkes DL (2005) Continuous fermentative hydrogen production from sucrose and sugarbeet. *Int J Hydrogen Energy* 30:471–483
- IEA (International Energy Agency) (2004) Biofuels for transport: an international perspective. 9, rue de la Fédération, 75739 Paris, cedex 15, France. Available from: www.iea.org
- IEA (International Energy Agency) (2006) Reference scenario projections. 75739 Paris, cedex 15, France
- Jamróz ME, Jarosz M, Witowska-Jarosz J, Bednarek E, Tęcza W, Jamróz MH, Dobrowolski JC, Kijeński J (2007) Mono-, di-, and tri-*tert*-butyl ethers of glycerol: a molecular spectroscopic study. *Spectrochim Acta Part A Mol Biomol Spectrosc* 67(3):980–988
- Janssen M, Tramper J, Mur LR, Wijffels RH (2003) Enclosed outdoor photobioreactors: light regime, photosynthetic efficiency, scale-up and future prospects. *Biotechnol Bioeng* 81:193–210
- Kan A (2009) General characteristics of waste management: a review. *Energy Educ Sci Tech-A* 23:55–69
- Kaplan C, Arslan R, Surmen A (2006) Performance characteristics of sunflower methyl esters as biodiesel. *Energy Sour Part A* 28:751–755
- Klepacova K, Mravec D, Hajekova E, Bajus M (2003) Etherification of glycerol. *Pet Coal* 45:54–57
- Kusdiana D, Saka S (2001) Kinetics of transesterification in rapeseed oil to biodiesel fuels as treated in supercritical methanol. *Fuel* 80:693–698
- Kutz M (ed) (2007) Environmentally conscious alternative energy production. Wiley, Hoboken

- Lv P, Wang X, Yuan Z, Tan T (2008) Conversion of soybean oil to biodiesel fuel with immobilized Candida lipase on textile cloth. *Energy Sour Part A* 30:872–879
- Meynell P-J (1976) Methane: planning a digester. Schocken Books, New York
- Miao XL, Wu QY, Yang CY (2004) Fast pyrolysis of microalgae to produce renewable fuels. *J Anal Appl Pyrolysis* 71:855–863
- Molina Grima E (1999) Microalgae, mass culture methods. In: Flickinger MC, Drew SW (eds) *Encyclopedia of bioprocess technology: fermentation, biocatalysis and bioseparation*, vol 3. Wiley, New York
- Momirlan M, Veziroglu TN (2002) Current status of hydrogen energy. *Renew Sustain Energy Rev* 6:141–179
- Mushrush GW, Wynne JH, Lloyd CT, Willauer HD, Hughes JM (2007) Instability reactions and recycled soybean-derived biodiesel fuel liquids. *Energy Sour Part A* 29:491–497
- Nath K, Das D (2003) Hydrogen from biomass. *Current Sci* 85:265–271
- Ni M, Leung MKH, Sumathy K, Leung DYC (2006) Potential of renewable hydrogen production for energy supply in Hong Kong. *Int J Hydrogen Energy* 31:1401–1412
- NRDC (2007) Natural Resources Defense Council. www.nrdc.org/policy
- Oguz H, Ogut H, Eryilmaz T (2007) Investigation of biodiesel production, quality and performance in Turkey. *Energy Sour Part A* 29:1529–1535
- Ozkurt I (2009) Qualifying of safflower and algae for energy. *Energy Educ Sci Tech-A* 23:145–151
- Pagliaro M, Ciriminna R, Kimura H, Rossi M, Pina CD (2007) From glycerol to value-added products. *Angew Chem Int Ed* 46:4434–4440
- Parawira W (2004) Anaerobic treatment of agricultural residues and wastewater—application of high-rate reactors. Ph.D. thesis, Department of Biotechnology, Lund University, Lund, Sweden, 14 Dec 2004
- Paul PFM, Wise WS (1971) The principle of gas extraction. Mills and Boon, London
- Phisalaphong M, Budiraharjo R, Bangrak P, Mongkolkajit J, Limtong S (2007) Alginate-loofa as carrier matrix for ethanol production. *J Biosci Bioeng* 104:214–217
- Pirt SJ (1986) The thermodynamic efficiency (quantum demand) and dynamics of photosynthetic growth. *New Phytol* 102(1):3–37
- Plass JH Jr, Barbir F, Miller HP, Veziroglu TN (1990) Economics of hydrogen as a fuel for surface transportation. *Int J Hydrogen Energy* 15:663–668
- Puppan D (2002) Environmental evaluation of biofuels. *Periodica Polytech Ser Soc Man Sci* 10:95–116
- Reijnders L (2006) Conditions for the sustainability of biomass based fuel use. *Energy Policy* 34:863–876
- Sastry GSR, Murthy ASRK, Prasad PR, Bhuvaneswari K, Ravi PV (2006) Identification and determination of bio-diesel in diesel. *Energy Sour Part A* 28:1337–1342
- Schneider D (2006) Grow your own?: would the wide spread adoption of biomass-derived transportation fuels really help the environment. *Am Sci* 94:408–409
- Scott A, Bryner M (2006) Alternative fuels: rolling out next-generation technologies. *Chem Week* Dec 20–27:17–21
- Sheehan J, Dunahay T, Benemann J, Roessler P (1998) A look back at the U.S. Department of Energy's aquatic species program—biodiesel from algae. National Renewable Energy Laboratory (NREL) Report: NREL/TP-580-24190. Golden, CO
- Tessema AA (2000) Hydraulic ram pump system design and application. In: ESME 5th annual conference on manufacturing and process industry, Sept 2000
- Utlu Z (2007) Evaluation of biodiesel fuel obtained from waste cooking oil. *Energy Sour Part A* 29:1295–1304
- Vazhappilly R, Chen F (1998) Heterotrophic production potential of omega-3 polyunsaturated fatty acids by microalgae and algae-like microorganisms. *Bot Mar* 41:553–558
- Verma S (2002) Anaerobic digestion of biodegradable organics in municipal solid wastes. Master's thesis, Applied Science Columbia University, New York, NY, USA, May 2002

- Volkman JK, Jeffrey SW, Nichols PD, Rogers GI, Garland CD (1989) Fatty acid and lipid composition of 10 species of microalgae used in mariculture. *J Exper Mar Biol Ecol* 128:219–240
- Xu H, Miao X, Wu Q (2006) High quality biodiesel production from a microalga *Chlorella protothecoides* by heterotrophic growth in fermenters. *J Biotechnol* 126:499–507
- Yaguchi T, Tanaka S, Yokochi T, Nakahara T, Higashihara T (1997) Production of high yields of docosahexaenoic acid by *Schizochytrium* sp. strain SR21. *J Am Oil Chemists Soc* 74:1431–1434
- Yucesu HS, Ilkilic C (2006) Effect of cotton seed oil methyl ester on the performance and exhaust emission of a diesel engine. *Energy Sour Part A* 28:389–398
- Zhang X, Ylikorpi T, Pepe G (2005) Biomass-based fuel cells for manned space exploration. European Space Agency Report: Ariadna AO/1- 4532/03/NL/MV, 31 Oct 2005



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