# Development of sustainable energy research and applications

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## Abstract

People relay upon oil for primary energy and this for a few more decades. Other orthodox sources may be more enduring, but are not without serious disadvantages. Power from natural resources has always had great appeal. Coal is plentiful, though there is concern about despoliation in winning it and pollution in burning it. Nuclear power has been developed with remarkable timeliness, but is not universally welcomed, construction of the plant is energy-intensive and there is concern about the disposal of its long-lived active wastes. Barrels of oil, lumps of coal, even uranium come from nature but the possibilities of almost limitless power from the atmosphere and the oceans seem to have special attraction. The wind machine provided an early way of developing motive power. The massive increases in fuel prices over the last years have however, made any scheme not requiring fuel appear to be more attractive and to be worth reinvestigation. In considering the atmosphere and the oceans as energy sources the four main contenders are wind power, wave power, tidal and power from ocean thermal gradients. The renewable energy resources are particularly suited for the provision of rural power supplies and a major advantage is that equipment such as flat plate solar driers, wind machines, etc., can be constructed using local resources and without the advantage results from the feasibility of local maintenance and the general encouragement such local manufacture gives to the build up of small-scale rural based industry. This article gives some examples of small-scale energy converters, nevertheless it should be noted that small conventional, i.e., engines are currently the major source of power in rural areas and will continue to be so for a long time to come. There is a need for some further development to suit local conditions, to minimise spares holdings, to maximise interchangeability both of engine parts and of the engine application. Emphasis should be placed on full local manufacture.

Keywords: Renewable energy technologies, energy efficiency, sustainable development, emissions, environment.

## Introduction

This chapter comprises a comprehensive review of energy sources, the environment and sustainable development. It includes the renewable energy technologies, energy efficiency

systems, energy conservation scenarios, energy savings in greenhouses environment and other mitigation measures necessary to reduce climate change.
The sources to alleviate the energy situation in the world are sufficient to supply all foreseeable needs. Conservation of energy and rationing in some form will however have to be practised by most countries, to reduce oil imports and redress balance of payments positions. Meanwhile development and application of nuclear power and some of the traditional solar, wind and water energy alternatives must be set in hand to supplement what remains of the fossil fuels.
The encouragement of greater energy use is an essential component of development. In the short-term it requires mechanisms to enable the rapid increase in energy/capita, and in the long-term we should be working towards a way of life, which makes use of energy efficiency and without the impairment of the environment or of causing safety problems. Such a programme should as far as possible be based on renewable energy resources.
Large-scale, conventional, power plant such as hydropower, has an important part to play in development. It does not, however, provide a complete solution. There is an important complementary role for the greater use of small-scale, rural based, power plant. Such plant can be used to assist development since it can be made locally using local resources, enabling a rapid built-up in total equipment to be made without a corresponding and unacceptably large demand on central funds. Renewable resources are particularly suitable for providing the energy for such equipment and its use is also compatible with the long-term aims. It is possible with relatively simple flat plate solar collectors (Figure 1) to provide warmed water and enable some space heating for homes and offices which is particularly useful when the buildings are well insulated and thermal capacity sufficient for the carry over of energy from day to night is arranged.

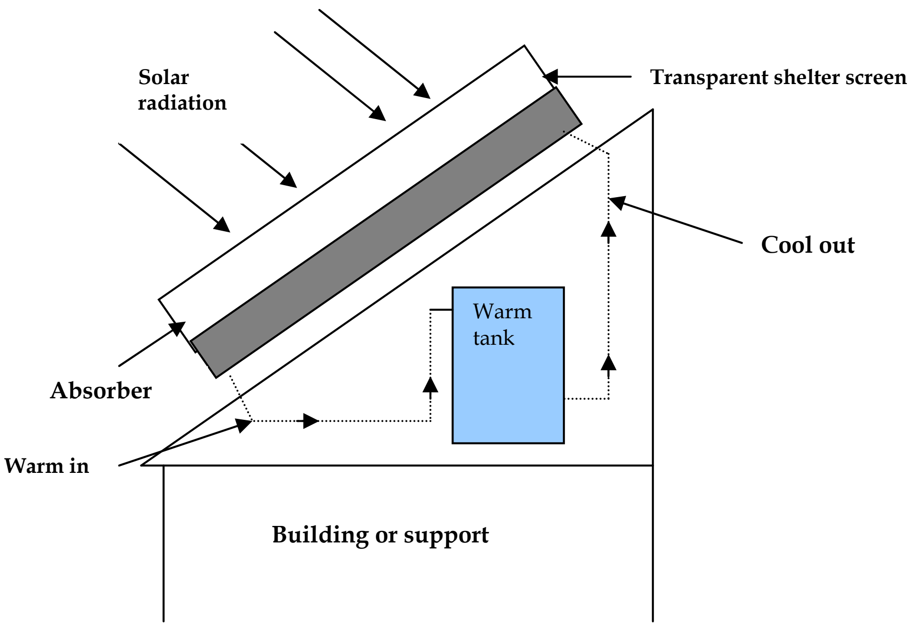


Fig. 1. Solar heater for hot water

In compiling energy consumption data one can categorise usage according to a number of different schemes:

- Traditional sector- industrial, transportation, etc.
- End-use- space heating, process steam, etc.
- Final demand- total energy consumption related to automobiles, to food, etc.
- Energy source- oil, coal, etc.
- Energy form at point of use- electric drive, low temperature heat, etc.

## Renewable energy

The renewable energy resources are particularly suited for the provision of rural power supplies and a major advantage is that equipment such as flat plate solar driers, wind machines, etc., can be constructed using local resources and without the high capital cost of more conventional equipment. Further advantage results from the feasibility of local maintenance and the general encouragement such local manufacture gives to the build up of small scale rural based industry. Table 1 lists the energy sources available.
Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of $CO_2$ and $NO_x$, CFCs emissions and triggered a renewed interest in environmentally friendly cooling, and heating technologies. Under the 1997 Montreal Protocol, governments agreed to phase out chemicals used as refrigerants that have the potential to destroy stratospheric ozone. It was therefore considered desirable to reduce energy consumption and decrease the rate of depletion of world energy reserves and pollution of the environment.

| Energy source | Energy carrier | Energy end-use |
|---|---|---|
| Vegetation | Fuel-wood | Cooking<br>Water heating<br>Building materials<br>Animal fodder preparation |
| Oil | Kerosene | Lighting<br>Ignition fires |
| Dry cells | Dry cell batteries | Lighting<br>Small appliances |
| Muscle power | Animal power | Transport<br>Land preparation for farming<br>Food preparation (threshing) |
| Muscle power | Human power | Transport<br>Land preparation for farming<br>Food preparation (threshing) |

Table 1. Sources of energy

Currently the 'non-commercial' fuels wood, crop residues and animal dung are used in large amounts in the rural areas of developing countries, principally for heating and cooking; the method of use is highly inefficient. Table 2 presented some renewable applications.

| Systems | Applications |
|---|---|
| Water supply | Rain collection, purification, storage and recycling |
| Wastes disposal | Anaerobic digestion ($CH_4$) |
| Cooking | Methane |
| Food | Cultivate the 1 hectare plot and greenhouse for four people |
| Electrical demands | Wind generator |
| Space heating | Solar collectors |
| Water heating | Solar collectors and excess wind energy |
| Control system | Ultimately hardware |
| Building fabric | Integration of subsystems to cut costs |

Table 2. Renewable applications

Table 3 lists the most important of energy needs.
Considerations when selecting power plant include the following:

- Power level- whether continuous or discontinuous.
- Cost- initial cost, total running cost including fuel, maintenance and capital amortised over life.
- Complexity of operation.
- Maintenance and availability of spares.
- Life.
- Suitability for local manufacture.

Table 4 listed methods of energy conversion.

| |
|---|
| Transport e.g., small vehicles and boats |
| Agricultural machinery e.g., two-wheeled tractors |
| Crop processing e.g., milling |
| Water pumping |
| Small industries e.g., workshop equipment |
| Electricity generation e.g., hospitals and schools |
| Domestic e.g., cooking, heating, lighting |
| Water supply e.g., rain collection, purification, storage and recycling |
| Building fabric e.g., integration of subsystems to cut costs |
| Wastes disposal e.g., anaerobic digestion ($CH_4$) |

Table 3. energy needs in rural areas

| | |
|---|---|
| Muscle power | Man, animals |
| **Internal combustion engines** | |
| Reciprocating | Petrol- spark ignition<br>Diesel- compression ignition<br>Humphrey water piston |
| Rotating | Gas turbines |
| **Heat engines** | |
| Vapour (Rankine) | |
| Reciprocating | Steam engine |
| Rotating | Steam turbine |
| Gas Stirling (Reciprocating) | Steam engine |
| Gas Brayton (Rotating) | Steam turbine |
| Electron gas | Thermionic, thermoelectric |
| Electromagnetic radiation | Photo devices |
| Hydraulic engines | Wheels, screws, buckets, turbines |
| Wind engines (wind machines) | Vertical axis, horizontal axis |
| Electrical/mechanical | Dynamo/alternator, motor |

Table 4. Methods of energy conversion

The human wastes (four people) would provide about 280 kWh/a of methane, but with the addition of vegetable wastes from 0.2 ha or wastes from 1 ha growing a complete diet, about 1500 kWh/a may be obtained by anaerobic digestion. The sludge from the digester may be returned to the land. In hotter climates, this efficient could be used to set up a more productive cycle (Figure 2).
There is a need for greater attention to be devoted to this field in the development of new designs, the dissemination of information and the encouragement of its use. International and government bodies and independent organisations all have a role to play in renewable energy technologies.
Society and industry in Europe and elsewhere are increasingly dependent on the availability of electricity supply and on the efficient operation of electricity systems. In the European Union (EU), the average rate of growth of electricity demand has been about 1.8% per year since 1990 and is projected to be at least 1.5% yearly up to 2030. Currently, distribution networks generally differ greatly from transmission networks, mainly in terms of role, structure (radial against meshed) and consequent planning and operation philosophies (Robinson, 2007).

## Energy use

Energy use is one of several essential components for developing countries:

- The overall situation and the implications of increased energy use in the future.
- The problem of the provision of power in rural areas, including the consideration of energy resources and energy conversion.

In addition to the drain on resources, such an increase in consumption consequences, together with the increased hazards of pollution and the safety problems associated with a large nuclear fission programmes. This is a disturbing prospect. It would be equally unacceptable to suggest that the difference in energy between the developed and developing countries and prudent for the developed countries to move towards a way of life which, whilst maintaining or even increasing quality of life, reduce significantly the energy consumption per capita. Such savings can be achieved in a number of ways:

- Improved efficiency of energy use, for example better thermal insulation, energy recovery, and total energy.
- Conservation of energy resources by design for long life and recycling rather than the short life throwaway product.
- Systematic replanning of our way of life, for example in the field of transport.

Energy ratio is defined as the ratio of:

Energy content of the food product/Energy input to produce the food (1)

A review of the potential range of recyclables is presented in Table 5.

Currently the non-commercial fuels wood, crop residues and animal dung are used in large amounts in the rural areas of developing countries, principally for heating and cooking, the method of use is highly inefficient. As in the developed countries, the fossil fuels are currently of great importance in the developing countries. Geothermal and tidal energy are less important though, of course, will have local significance where conditions are suitable. Nuclear energy sources are included for completeness, but are not likely to make any effective contribution in the rural areas.

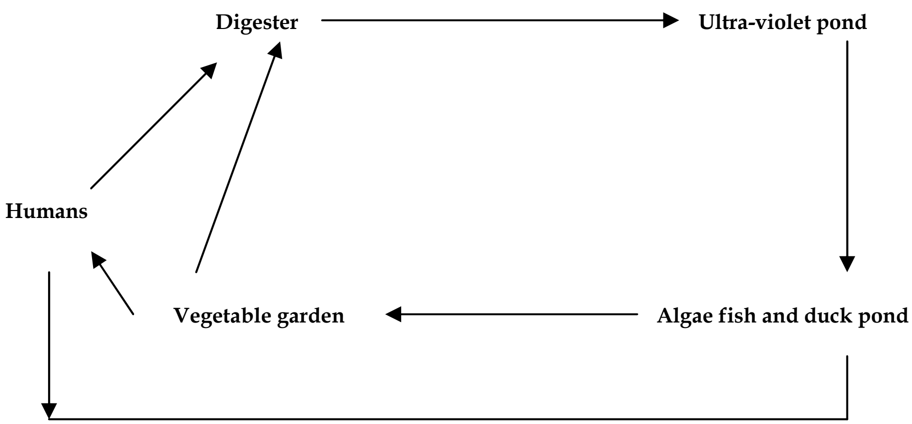


Fig. 2. Biomass energy utilisation cycle

## Biogas

Biogas is a generic term for gases generated from the decomposition of organic material. As the material breaks down, methane ($CH_4$) is produced as shown in Figure 3. Sources that generate biogas are numerous and varied. These include landfill sites, wastewater treatment plants and anaerobic digesters. Landfills and wastewater treatment plants emit biogas from decaying waste. To date, the waste industry has focused on controlling these emissions to our environment and in some cases, tapping this potential source of fuel to power gas turbines, thus generating electricity. The primary components of landfill gas are methane ($CH_4$), carbon dioxide ($CO_2$), and nitrogen ($N_2$). The average concentration of methane is ~45%, $CO_2$ is ~36% and nitrogen is ~18% (Omer, and Yemen, 2001). Other components in the gas are oxygen ($O_2$), water vapour and trace amounts of a wide range of non-methane organic compounds (NMOCs). Landfill gas-to-cogeneration projects present a win-win-win situation. Emissions of particularly damaging pollutant are avoided, electricity is generated from a free fuel and heat is available for use locally.

| Construction and demolition material | Recycling technology options | Recycling product |
|---|---|---|
| Asphalt | Cold recycling: heat generation; Minnesota process; parallel drum process; elongated drum; microwave asphalt recycling system; finfalt; surface regeneration | Recycling asphalt; asphalt aggregate |
| Brick | Burn to ash, crush into aggregate | Slime burn ash; filling material; hardcore |
| Concrete | Crush into aggregate | Recycling aggregate; cement replacement; protection of levee; backfilling; filter |
| Ferrous metal | Melt; reuse directly | Recycled steel scrap |
| Glass | Reuse directly; grind to powder; polishing; crush into aggregate; burn to ash | Recycled window unit; glass fibre; filling material; tile; paving block; asphalt; recycled aggregate; cement replacement; manmade soil |
| Masonry | Crush into aggregate; heat to 900°C to ash | Thermal insulating concrete; traditional clay |
| Non-ferrous metal | Melt | Recycled metal |
| Paper and cardboard | Purification | Recycled paper |
| Plastic | Convert to powder by cryogenic milling; clopping; crush into aggregate; burn to ash | Panel; recycled plastic; plastic lumber; recycled aggregate; landfill drainage; asphalt; manmade soil |
| Timber | Reuse directly; cut into aggregate; blast furnace deoxidisation; gasification or pyrolysis; chipping; moulding by pressurising timber chip under steam and water | Whole timber; furniture and kitchen utensils; lightweight recycled aggregate; source of energy; chemical production; wood-based panel; plastic lumber; geofibre; insulation board |

Table 5. Summary of material recycling practices in construction sector

In the past two decades the world has become increasingly aware of the depletion of fossil fuel reserves and the indications of climatic changes based on carbon dioxide emissions. Therefore extending the use of renewable resources, efficient energy production and the reduction of energy consumption are the main goals to reach a sustainable energy supply. Renewable energy sources include water and wind power, solar and geothermal energy, as well as energy from biomass. The technical achievability and the actual usage of these energy sources are different around Europe, but biomass is seen to have a great potential in many of them. An efficient method for the conversion of biomass to energy, is the production of biogas by microbial degradation of organic matter under the absence of oxygen (anaerobic digestion). It is now possible to produce biogas at rural installation, upgrade it to bio-methane, feed it into the gas grid, use it in a heat demand-controlled CHP and to receive revenues. Biogas is a mixture containing predominantly methane (50-65% by volume) and carbon dioxide and in a natural setting it is formed in swamps and anaerobic sediments, etc., due due to its high methane concentration, biogas is a valuable fuel. Wet (40-95%) organic materials with low lignin and cellulose content are generally suitable for anaerobic digestion. The imporatance and role of biogases in energy production is growing. Nowadays, a lot of countries in Europe promote utilisation of renewable energies by guaranteed refund prices or emission trading systems.

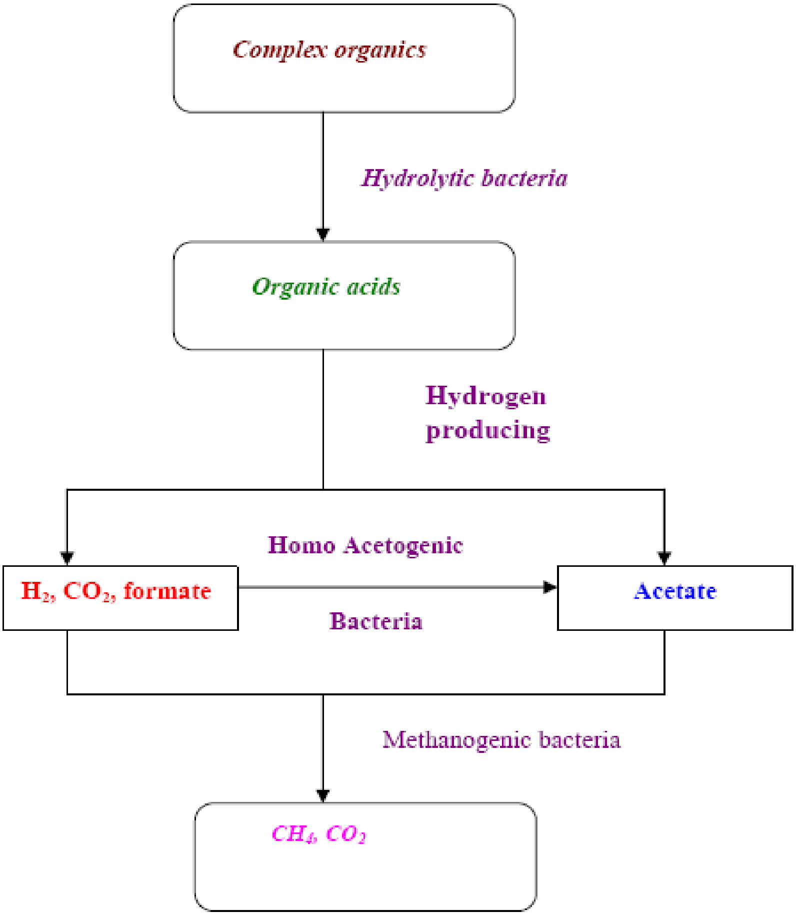


Fig. 3. Biogas production process

## Wave power conversion devices

The patent literature is full of devices for extracting energy from waves, i.e., floats, ramps, and flaps, covering channels. Small generators driven from air trapped by the rising and falling water in the chamber of a buoy are in use around the world (Swift-Hook, et al, 2007). Wave power is one possibility that has been selected. Figure 4 shows the many other aspects that will need to be covered. A wave power programme would make a significant contribution to energy resources within a relatively short time and with existing technology.
Wave energy has also been in the news recently. There is about 140 megawatts per mile available round British coasts. It could make a useful contribution people needs, about twice that of the UK generating system is available provided. Although very large amounts of power are available in the waves, it is important to consider how much power can be extracted. A few years ago only a few percent efficiency had been achieved. Recently, however, several devices have been studied which have very high efficiencies. Some form of storage will be essential on a second-to-second and minute-to-minute basis to smooth the fluctuations of individual waves and wave's packets but storage from one day to the next will certainly not be economic. This is why provision must be made for adequate standby capacity.

The increased availability of reliable and efficient energy services stimulates new development alternatives. This article discusses the potential for such integrated systems in the stationary and portable power market in response to the critical need for a cleaner energy technology. Anticipated patterns of future energy use and consequent environmental impacts (acid precipitation, ozone depletion and the greenhouse effect or global warming) are comprehensively discussed in this paper. Throughout the theme several issues relating to renewable energies, environment and sustainable development are examined from both current and future perspectives. It is concluded that renewable environmentally friendly energy must be encouraged, promoted, implemented and demonstrated by full-scale plan especially for use in remote rural areas.

Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of $CO_2$ and $NO_x$ emissions and CFCs triggered a renewed interest in environmentally friendly cooling, and heating technologies. Under the 1997 Montreal Protocol, governments agreed to phase out chemicals used as refrigerants that have the potential to destroy stratospheric ozone. It was therefore considered desirable to reduce energy consumption and decrease the rate of depletion of world energy reserves and pollution of the environment. One way of reducing building energy consumption is to design buildings, which are more economical in their use of energy for heating, lighting, cooling, ventilation and hot water supply. Passive measures, particularly natural or hybrid ventilation rather than air-conditioning, can dramatically reduce primary energy consumption. However, exploitation of renewable energy in buildings and agricultural greenhouses can, also, significantly contribute towards reducing dependency on fossil fuels. Therefore, promoting innovative renewable applications and reinforcing the renewable energy market will contribute to preservation of the ecosystem by reducing emissions at local and global levels. This will also contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or greenhouse gases. The provision of good indoor environmental quality while achieving energy and cost efficient operation of the heating, ventilating and air-conditioning (HVAC) plants in buildings represents a multi variant problem. The comfort of building occupants is dependent on many environmental parameters including air speed, temperature, relative humidity and quality in addition to lighting and noise. The overall objective is to provide a high level of building performance (BP), which can be defined as indoor environmental quality (IEQ), energy efficiency (EE) and cost efficiency (CE).

## Ethanol production

Alternative fuels were defined as methanol, ethanol, natural gas, propane, hydrogen, coal-derived liquids, biological material and electricity. The fuel pathways currently under development for alcohol fuels are shown in Figure 5. The production of agricultural biomass and its exploitation for energy purposes can contribute to alleviate several problems, such as the dependence on import of energy products, the production of food surpluses, the pollution provoked by the use of fossil fuels, the abandonment of land by farmers and the connected urbanisation. Biomass is not at the moment competitive with mineral oil, but, taking into account also indirect costs and giving a value to the aforementioned advantages, public authorities at national and international level can spur its production and use by incentives of different nature. In order to address the problem of inefficiency, research centres around the world have investigated the viability of converting the resource to a more useful form, namely solid briquettes and fuel gas (Figure 6).
The main advantages are related to energy, agriculture and environment problems, are foreseeable both at regional level and at worldwide level and can be summarised as follows:

- Reduction of dependence on import of energy and related products.
- Reduction of environmental impact of energy production (greenhouse effect, air pollution, and waste degradation).
- Substitution of food crops and reduction of food surpluses and of related economic burdens, and utilisation of marginal lands and of set aside lands.
- Reduction of related socio-economic and environmental problems (soil erosion, urbanisation, landscape deterioration, etc.).
- Development of new know-how and production of technological innovation.

The convention on Biological Diversity set conservation of biodiversity on the world agenda. Gaps in knowledge need to be addressed for actions to be effective and sustainable. Gaps include: species diversity, microorganisms and their ecological roles, ecological and geographical status of species, human capacity to access and forecast bio-ecological degradation. Requirements for global inventories call for worldwide collaboration. Criteria for setting priorities need to be formulated and agreed. Global inventorying needs a collaborative international effort, perhaps under the aegis of the Convention on Biological Diversity. The recently formulated global taxonomy initiatives are a step in the right direction.

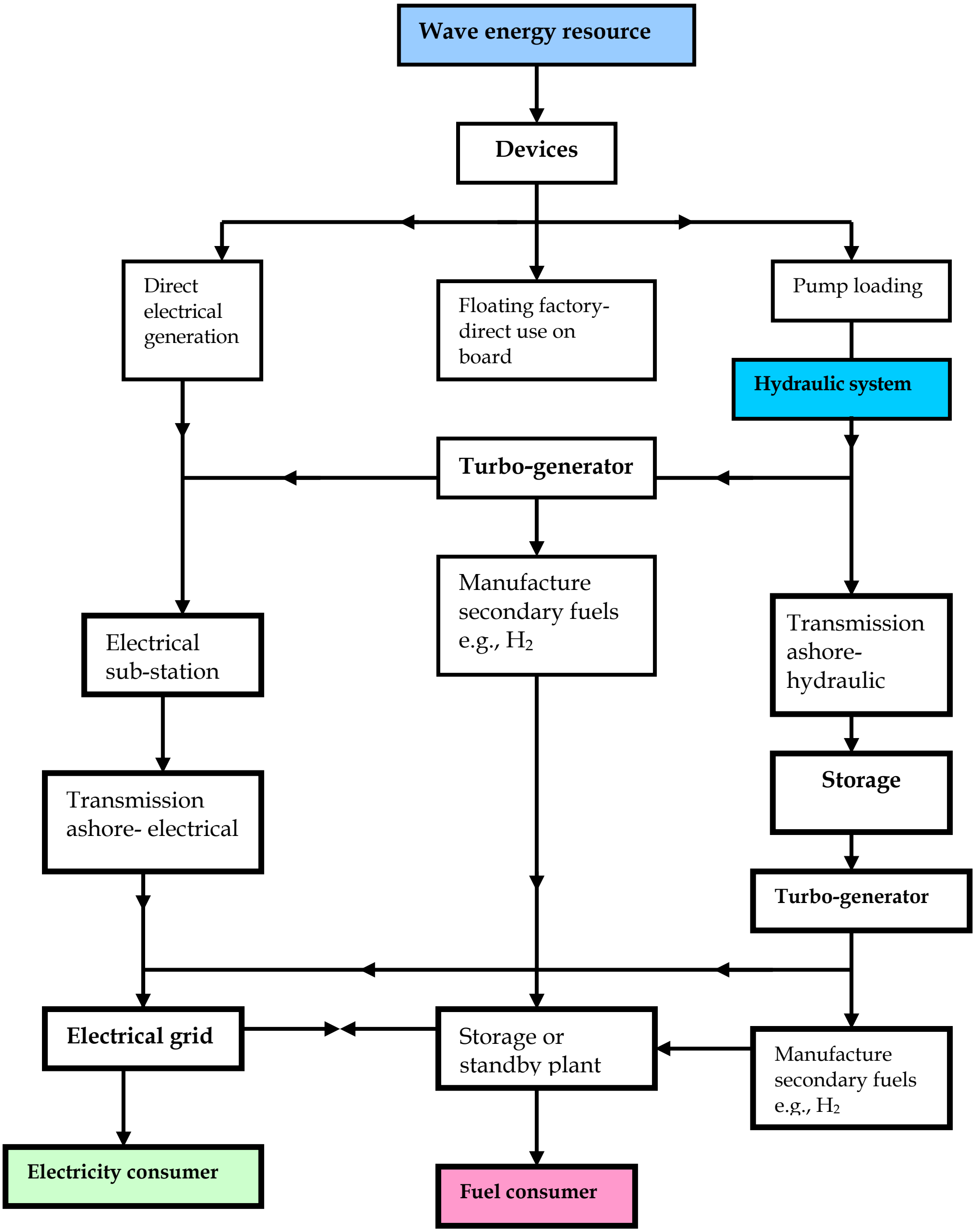


Fig. 4. Possible systems for exploiting wave power, each element represents an essential link in the chain from sea waves to consumer

The debate over an international climate change regime has thus far focused primarily on efficiency concerns in developed countries. In the international negotiations over the control of climate change, the developing countries so far have assumed few obligations. At present, this debate has not progressed very far. There are several reasons for this impasse. First, there is a distinction between cost effectiveness (where in the world should the control be undertaken in order to minimise the global costs of control) and equity (who should bear the costs of mitigation and abatement resulting from climate change) that has not been adequately clarified and agreed upon by the parties to the Protocol. Second, the global control or anthropogenic climate change will require complex cooperative efforts among a large number of individual nations. This cooperative effort will have to be based on a thorough understanding of how the various participating nations contribute to the process of global climate change, and how that process affects them. One of the fundamental principles of environmental policy is that the polluter pays for using the environment and the use of natural resources. This is one way of imposing responsibility for environmental consequences on the party causing the environmental damage. In the context of environmental taxes, it is the polluter who pays, which is one reason why taxes are as suitable as an instrument for environmental policy.

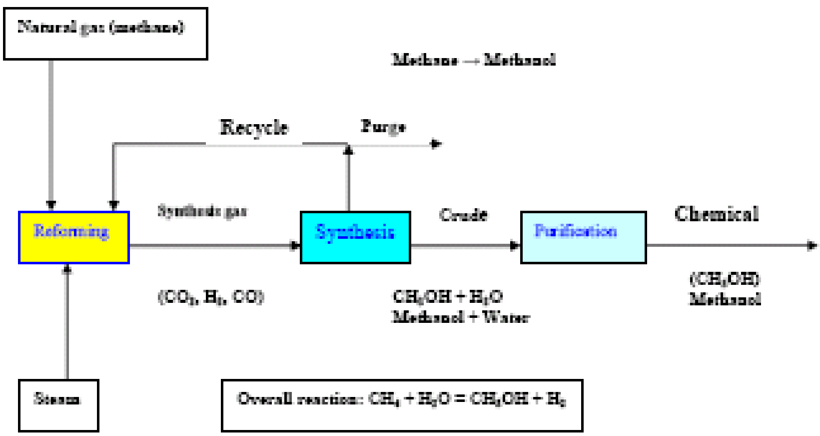


Fig. 5. Schematic process flowsheet

Biomass resources play a significant role in energy supply in all developing countries. Biomass resources should be divided into residues or dedicated resources, the latter including firewood and charcoal can also be produced from forest residues. Ozone ($O_3$) is a naturally occurring molecule that consists of three oxygen atoms held together by the bonding of the oxygen atoms to each other. The effects of the chlorofluorocarbons (CFCs) molecule can last for over a century. This reaction is shown in Figure 7.
It is a common misconception that the reason for recycling old fridge is to recover the liquid from the cooling circuit at the back of the unit. The insulating foams used inside some fridges act as sinks of CFCs- the gases having been used as blowing agents to expand the

foam during fridge manufacture. Although the use of ozone depleting chemicals in the foam in fridges has declined in the West, recyclers must consider which strategy to adopt to deal with the disposal problem they still present each year. It is common practice to dispose of this waste wood in landfill where it slowly degraded and takes up valuable void space. This wood is a good source of energy and is an alternative to energy crops. Agricultural wastes are abundantly available globally and can be converted to energy and useful chemicals by a number of microorganisms. The success of promoting any technology depends on careful planning, management, implementation, training and monitoring. Main features of gasification project are:

- Networking and institutional development/strengthening.
- Promotion and extension.
- Construction of demonstration projects.
- Research and development; and training and monitoring.

## Biomass CHP

Combined heat and power (CHP) installations are quite common in greenhouses, which grow high-energy, input crops (e.g., salad vegetables, pot plants, etc.). Scientific assumptions for a short-term energy strategy suggest that the most economically efficient way to replace the thermal plants is to modernise existing power plants to increase their energy efficiency and to improve their environmental performance. However, utilisation of wind power and the conversion of gas-fired CHP plants to biomass would significantly reduce the dependence on imported fossil fuels. Although a lack of generating capacity is forecasted in the long-term, utilisation of the existing renewable energy potential and the huge possibilities for increasing energy efficiency are sufficient to meet future energy demands in the short-term.

A total shift towards a sustainable energy system is a complex and long process, but is one that can be achieved within a period of about 20 years. Implementation will require initial investment, long-term national strategies and action plans. However, the changes will have a number of benefits including: a more stable energy supply than at present, and major improvement in the environmental performance of the energy sector, and certain social benefits. A vision used a methodology and calculations based on computer modelling that utilised:

- Data from existing governmental programmes.
- Potential renewable energy sources and energy efficiency improvements.
- Assumptions for future economy growth.
- Information from studies and surveys on the recent situation in the energy sector.

In addition to realising the economic potential identified by the National Energy Savings Programme, a long-term effort leading to a 3% reduction in specific electricity demand per year after 2020 is proposed. This will require further improvements in building codes, and continued information on energy efficiency (IEA, 2007).

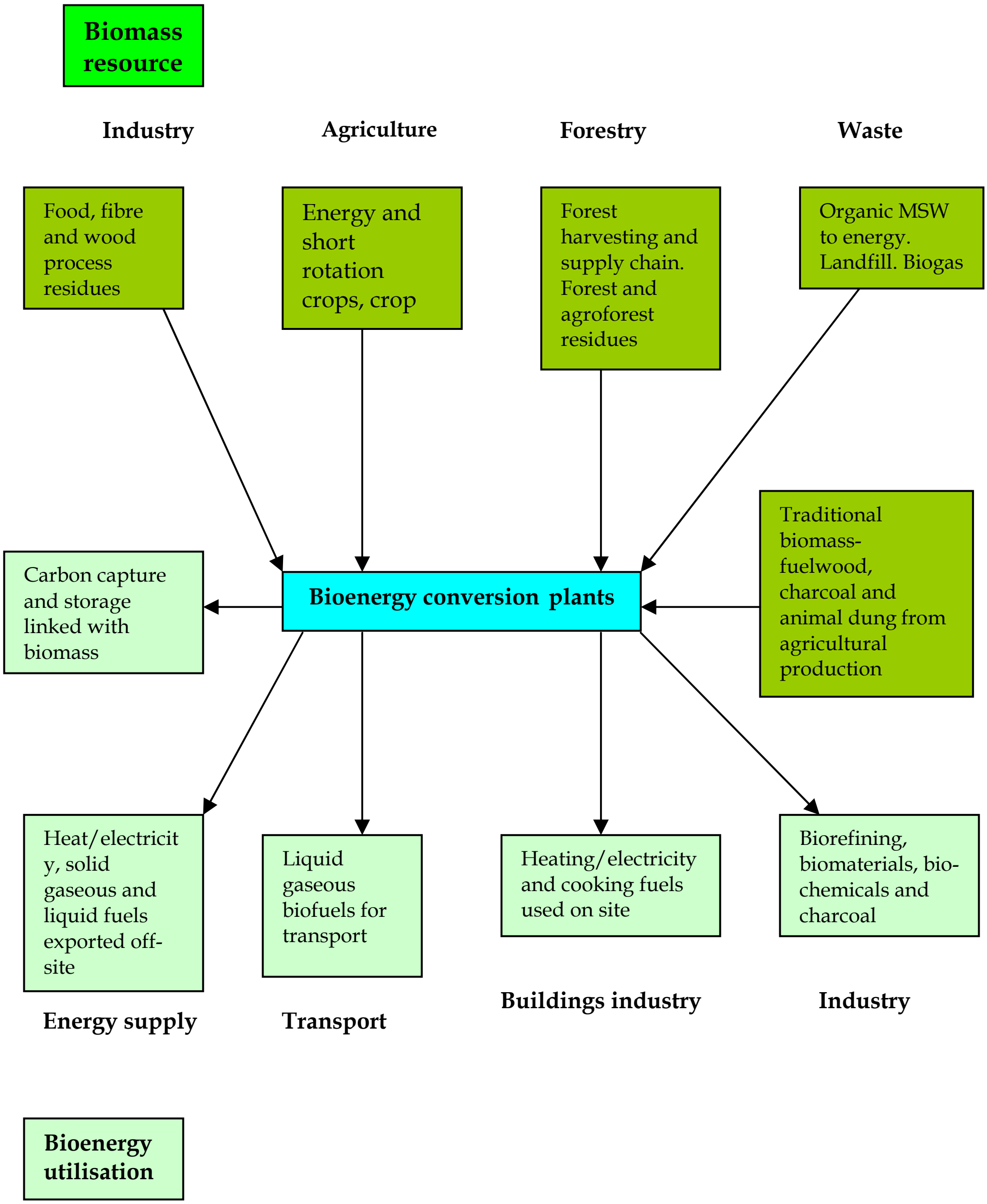


Fig. 6. Biomass resources from several sources is converted into a range of products for use by transport, industry and building sectors

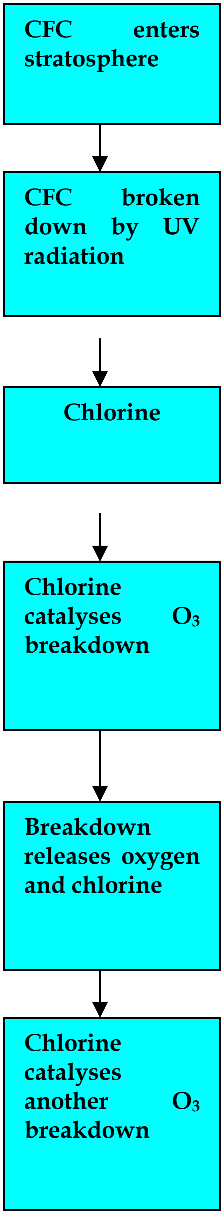


Fig. 7. The process of ozone depletion (Trevor, 2007)

The environmental Non Governmental Organisations (NGOs) are urging the government to adopt sustainable development of the energy sector by:

- Diversifying of primary energy sources to increase the contribution of renewable and local energy resources in the total energy balance.
- Implementing measures for energy efficiency increase at the demand side and in the energy transformation sector.

The price of natural gas is set by a number of market and regulatory factors that include:

Supply and demand balance and market fundamentals, weather, pipeline availability and deliverability, storage inventory, new supply sources, prices of other energy alternatives and regulatory issues and uncertainty.

Classic management approaches to risk are well documented and used in many industries. This includes the following four broad approaches to risk:

- Avoidance includes not performing an activity that could carry risk. Avoidance may seem the answer to all risks, but avoiding risks also means losing out on potential gain.
- Mitigation/reduction involves methods that reduce the severity of potential loss.
- Retention/acceptance involves accepting the loss when it occurs. Risk retention is a viable strategy for small risks. All risks that are not avoided or transferred are retained by default.
- Transfer means causing another party to accept the risk, typically by contract.

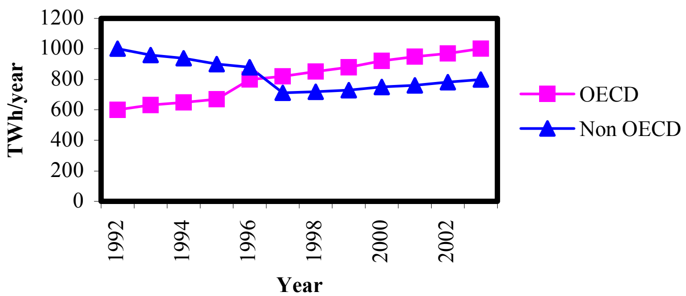


Fig. 8. Global CHP trends from 1992-2003

Methane is a primary constituent of landfill gas (LFG) and a potent greenhouse gas (GHG) when released into the atmosphere. Globally, landfills are the third largest anthropogenic emission source, accounting for about 13% of methane emissions or over 818 million tones of carbon dioxide equivalent ($MMTCO_2e$) (Brain, and Mark, 2007) as shown in Figures 8-10.

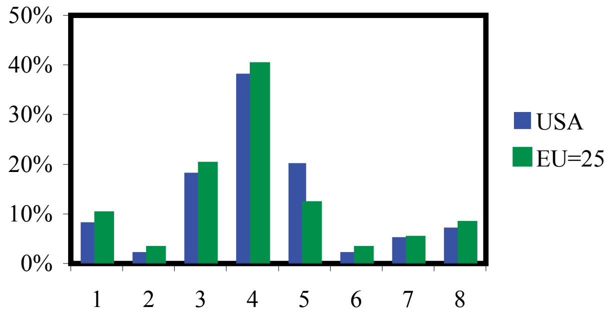


Fig. 9. Distribution of industrial CHP capacity in the EU and USA

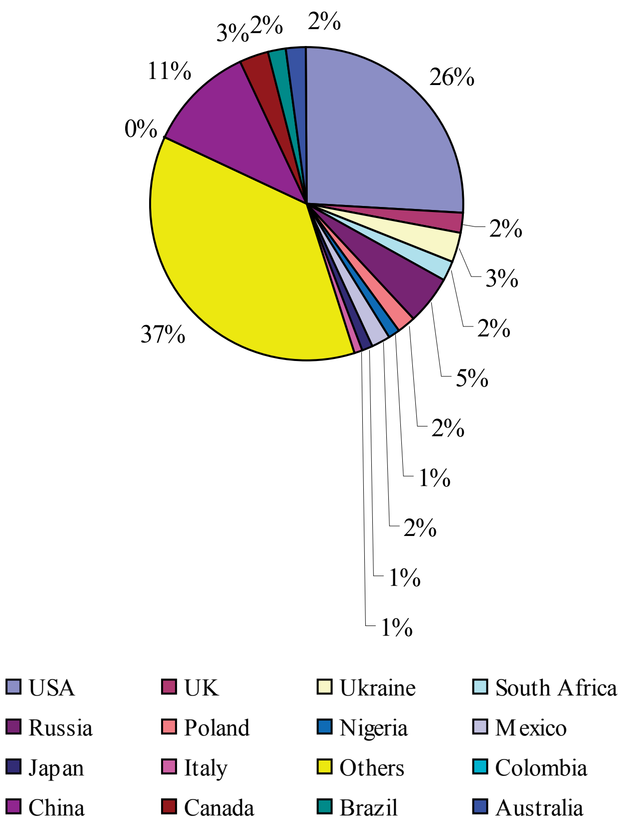


Fig. 10. World landfill methane emissions (MMT$CO_2$e)

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