Clean and Green Energy Technologies: Sustainable Development and Environment

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Abstract: The move towards a de-carbonised world, driven partly by climate science and partly by the business opportunities it offers, will need the promotion of environmentally friendly alternatives, if an acceptable stabilisation level of atmospheric carbon dioxide is to be achieved. This requires the harnessing and use of natural resources that produce no air pollution or greenhouse gases and provides comfortable coexistence of human, livestock, and plants. This article presents a comprehensive review of energy sources, and the development of sustainable technologies to explore these energy sources. It also includes potential renewable energy technologies, efficient energy systems, energy savings techniques and other mitigation measures necessary to reduce climate changes. The article concludes with the technical status of the ground source heat pumps (GSHP) technologies.

Key words: Renewable energy resources, technologies, sustainable development, environment.

1. Introduction

Over millions of years ago, plants have covered the earth converting the energy of sunlight into living plants and animals, some of which was buried in the depths of the earth to produce deposits of coal, oil and natural gas [1-3]. The past few decades, however, have experienced many valuable uses for these complex chemical substances and manufacturing from them plastics, textiles, fertiliser and the various end products of the petrochemical industry. Indeed, each decade sees increasing uses for these products. Coal, oil and gas, which will certainly be of great value to future generations, as they are to ours, are however non-renewable natural resources. The rapid depletion of these non-renewable fossil resources need not continue. This is particularly true now as it is, or soon will be, technically and economically feasible to supply all of man's needs from the most abundant energy source of all, the sun. The sunlight is not only inexhaustible, but, moreover, it is the only energy source, which is completely non-polluting [4].

Industry's use of fossil fuels has been largely blamed for warming the climate. When coal, gas and oil are burnt, they release harmful gases, which trap heat in the atmosphere and cause global warming. However, there had been an ongoing debate on this subject, as scientists have struggled to distinguish between changes, which are human induced, and those, which could be put down to natural climate variability. Notably, human activities that emit carbon dioxide (CO_2), the most significant contributor to potential climate change, occur primarily from fossil fuel production. Consequently, efforts to control CO_2 emissions could have serious, negative consequences for economic growth, employment, investment, trade and the standard of living of individuals everywhere.

1.1 Energy Sources and Uses

Scientifically, it is difficult to predict the relationship between global temperature and greenhouse gas (GHG) concentrations. The climate system contains many processes that will change if warming occurs. Critical processes include heat transfer by winds and tides, the hydrological cycle involving evaporation, precipitation, runoff and groundwater and the formation of clouds, snow, and ice, all of which display enormous natural variability. The equipment and infrastructure for energy supply and use are designed with long lifetimes, and the premature turnover of capital stock involves significant costs. Economic benefits occur if capital stock is replaced with more efficient equipment in step with its normal replacement cycle. Likewise, if opportunities to reduce future emissions are taken in a timely manner, they should be less costly. Such a flexible approach would allow society to take account of evolving scientific and technological knowledge, while gaining experience in designing policies to address climate change [4].

The World Summit on Sustainable Development in Johannesburg in 2002 [4] committed itself to ‘‘encourage and promote the development of renewable energy sources to accelerate the shift towards sustainable consumption and production’’. Accordingly, it aimed at breaking the link between resource use and productivity. This can be achieved by the following:

- Trying to ensure economic growth does not cause environmental pollution.
- Improving resource efficiency.
- Examining the whole life-cycle of a product.
- Enabling consumers to receive more information on products and services.
- Examining how taxes, voluntary agreements, subsidies, regulation and information campaigns, can best stimulate innovation and investment to provide cleaner technology.

The energy conservation scenarios include rational use of energy policies in all economy sectors and the use of combined heat and power systems, which are able to add to energy savings from the autonomous power plants. Electricity from renewable energy sources is by definition the environmental green product. Hence, a renewable energy certificate system, as recommended by the World Summit, is an essential basis for all policy systems, independent of the renewable energy support scheme. It is, therefore, important that all parties involved support the renewable energy certificate system in place if it is to work as planned. Moreover, existing renewable energy technologies (RETs) could play a significant mitigating role, but the economic and political climate will have to change first. It is now universally accepted that climate change is real. It is happening now, and the GHGs produced by human activities are significantly contributing to it. The predicted global

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temperature increase of between 1.5 and 4.5°C could lead to potentially catastrophic environmental impacts [5]. These include sea level rise, increased frequency of extreme weather events, floods, droughts, disease migration from various places and possible stalling of the Gulf Stream. This has led scientists to argue that climate change issues are not ones that politicians can afford to ignore, and policy makers tend to agree [5]. However, reaching international agreements on climate change policies is no trivial task as the difficulty in ratifying the Kyoto Protocol and reaching agreement at Copenhagen have proved.

Therefore, the use of renewable energy sources and the rational use of energy, in general, are the fundamental inputs for any responsible energy policy. However, the energy sector is encountering difficulties because increased production and consumption levels entail higher levels of pollution and eventually climate change, with possibly disastrous consequences. At the same time, it is important to secure energy at an acceptable cost in order to avoid negative impacts on economic growth. To date, renewable energy contributes only as much as 20% of the global energy supplies worldwide [5]. Over two thirds of this comes from biomass use, mostly in developing countries, and some of this is unsustainable. However, the potential for energy from sustainable technologies is huge. On the technological side, renewables have an obvious role to play. In general, there is no problem in terms of the technical potential of renewables to deliver energy. Moreover, there are very good opportunities for RETs to play an important role in reducing emissions of GHGs into the atmosphere, certainly far more than have been exploited so far. However, there are still some technical issues to address in order to cope with the intermittency of some renewables, particularly wind and solar. Nevertheless, the biggest problem with relying on renewables to deliver the necessary cuts in GHG emissions is more to do with politics and policy issues than with technical ones [6]. For example, the single most important step governments could take to promote and increase the use of renewables is to improve access for renewables to the energy market. This access to the market needs to be under favourable conditions and, possibly, under favourable economic rates as well. One move that could help, or at least justify, better market access would be to acknowledge that there are environmental costs associated with other energy supply options and that these costs are not currently internalised within the market price of electricity or fuels. This could make a significant difference, particularly if appropriate subsidies were applied to renewable energy in recognition of the environmental benefits it offers. Similarly, cutting energy consumption through end-use efficiency is absolutely essential. This suggests that issues of end-use consumption of energy will have to come into the discussion in the foreseeable future [7].

However, RETs have the benefit of being environmentally benign when developed in a sensitive and appropriate way with the full involvement of local communities. In addition, they are diverse, secure, locally based and abundant. In spite of the enormous potential and the multiple benefits, the contribution from renewable energy still lags behind the ambitious claims for it due to the initially high development costs, concerns about local impacts, lack of research funding and poor institutional and economic arrangements [8]. Hence, an approach is needed to integrate renewable energies in a way that meets the rising demand in a cost-effective way.

1.2 Role of Energy Efficiency System

The prospects for development in power engineering are, at present, closely related to ecological problems. Power engineering has harmful effects on the environment, as it discharges toxic gases into atmosphere and also oil-contaminated and saline waters into rivers, as well as polluting the soil with ash and slag and having adverse effects on living things on account of electromagnetic fields and so on. Thus there is an urgent need for new approaches to provide an ecologically safe strategy. Substantial economic and ecological effects for thermal power projects (TPPs) can be achieved by improvement, upgrading the efficiency of the existing equipment, reduction of electricity loss, saving of fuel, and optimisation of its operating conditions and service life leading to improved access for rural and urban low-income areas in developing countries through energy efficiency and renewable energies.

Sustainable energy is a prerequisite for development. Energy-based living standards in developing countries, however, are clearly below standards in developed countries. Low levels of access to affordable and environmentally sound energy in both rural and urban low-income areas are therefore a predominant issue in developing countries. In recent years many programmes for development aid or technical assistance have been focusing on improving access to sustainable energy, many of them with impressive results. Apart from success stories, however, experience also shows that positive appraisals of many projects evaporate after completion and vanishing of the implementation expert team. Altogether, the diffusion of sustainable technologies such as energy efficiency and renewable energy for cooking, heating, lighting, electrical appliances and building insulation in developing countries has been slow. Energy efficiency and renewable energy programmes could be more sustainable and pilot studies more effective and pulse releasing if the entire policy and implementation process was considered and redesigned from the outset [9]. New financing and implementation processes, which allow reallocating financial resources and thus enabling countries themselves to achieve a sustainable energy infrastructure, are also needed. The links between the energy policy framework, financing and implementation of renewable energy and energy efficiency projects have to be strengthened and as well as efforts made to increase people's knowledge through training.

1.3 Energy Use in Buildings

Buildings consume energy mainly for cooling, heating and lighting. The energy consumption was based on the assumption that the building operates within ASHRAE-thermal comfort zone during the cooling and heating periods [10]. Most of the buildings incorporate energy efficient passive cooling, solar control, photovoltaic, lighting and day lighting, and integrated energy systems. It is well known that thermal mass with night ventilation can reduce the maximum indoor temperature in buildings in summer [11]. Hence, comfort temperatures may be achieved by proper application of passive cooling systems. However, energy can also be saved if an air conditioning unit is used [12]. The reason for this is that in summer, heavy external walls delay the heat transfer from the outside into the inside spaces. Moreover, if the building has a lot of internal mass the increase in the air temperature is slow. This is because the penetrating heat raises the air temperature as well as the temperature of the heavy thermal mass. The result is a slow heating of the building in summer as the maximal inside temperature is reached only during the late hours when the outside air temperature is already low. The heat flowing from the inside heavy walls could be reduced with good ventilation in the evening and night. The capacity to store energy also helps in winter, since energy can be stored in walls from one sunny winter day to the next cloudy one. However, the admission of daylight into buildings alone does not guarantee that the design will be energy efficient in terms of lighting. In fact, the design for increased daylight can often raise concerns relating to visual comfort (glare) and thermal comfort (increased solar gain in the summer and heat losses in the winter from larger apertures). Such issues will clearly need to be addressed in the design of the window openings, blinds, shading devices, heating system, etc. In order for a building to benefit from daylight energy terms, it is a prerequisite that lights are switched off when sufficient daylight is available. The nature of the switching regime; manual or automated, centralised or local, switched, stepped or dimmed, will determine the energy performance. Simple techniques can be implemented to increase the probability that lights are switched off [13]. These include:

- Making switches conspicuous and switching banks of lights independently.
- Loading switches appropriately in relation to the lights.
- Switching banks of lights parallel to the main window wall.

There are also a number of methods, which help reduce the lighting energy use, which, in turn, relate to the type of occupancy pattern of the building [13]. The light switching options include:

- Centralised timed off (or stepped)/manual on.
- Photoelectric off (or stepped)/manual on.
- Photoelectric and on (or stepped), photoelectric dimming.
- Occupant sensor (stepped) on/off (movement or noise sensor).

Likewise, energy savings from the avoidance of air conditioning can be very substantial. Whilst day-lighting strategies need to be integrated with artificial lighting systems in order to become beneficial in terms of energy use, reductions in overall energy consumption levels by employment of a sustained programme of energy consumption strategies and measures would have considerable benefits within the buildings sector. The perception is often given however is that rigorous energy conservation as an end in itself imposes a style on building design resulting in a restricted aesthetic solution. It would perhaps be better to support a climate sensitive design approach that encompasses some elements of the pure conservation strategy together with strategies, which work with the local ambient conditions making use of energy technology systems, such as solar energy, where feasible. In practice, low energy environments are achieved through a combination of measures that include:

- The application of environmental regulations and policy.
- The application of environmental science and best practice.
- Mathematical modelling and simulation.
- Environmental design and engineering.
- Construction and commissioning.
- Management and modifications of environments in use.

While the overriding intention of passive solar energy design of buildings is to achieve a reduction in purchased energy consumption, the attainment of significant savings is in doubt. The non-realisation of potential energy benefits is mainly due to the neglect of the consideration of post-occupancy user and management behaviour by energy scientists and designers alike. Calculating energy inputs in agricultural production is more difficult in comparison to the industry sector due to the high number of factors affecting agricultural production, as Table 1 shows. However, considerable studies have been conducted in different countries on energy use in agriculture [14] in order to quantify the influence of these factors.

2. Technology Description

Geothermal energy is the natural heat that exists within the earth and that can be absorbed by fluids occurring within, or introduced into, the crystal rocks. Although, geographically, this energy has local concentrations, its distribution globally is widespread. The amount of heat that is, theoretically, available between the earth's surface and a depth of 5 km is around (140 x 10^{24} joules). Of this, only a fraction (5 x 10^{21} joules) can be regarded as having economic prospects within the next five decades, and only about (500 x 10^{18} joules) is likely to be exploited by the year 2020. Three main techniques are used to exploit the heat available: geothermal aquifers, hot dry rocks and ground source heat pumps.

2.1 Goals

Determine the suitability of ground source heat pumps (GSHPs) for heating and cooling. Verify and document the savings in energy use and demand that GSHPs may be expected to achieve.

2.2 Energy and Population Growth

Urban areas throughout the world have increased in size during recent decades. About 50% of the world's population and approximately 7.6% in more developed countries are urban dwellers [15]. Even though there is evidence to suggest that in many 'advanced' industrialised countries there has been a reversal in the rural-to-urban shift of populations, virtually all population growth expected between 2000 and 2030 will be concentrated in urban areas of the world. With an expected annual growth of 1.8%, the world's urban population will double in 38 years [15].

With increasing urbanisation in the world, cities are growing in number, population and complexity. At present, 2% of the world's land surface is covered by cities, yet the people living in them consume 75% of the resources consumed by mankind [16]. Indeed, the ecological footprint of cities is many times larger than the areas they physically occupy. Economic and social imperatives often dictate that cities must become more concentrated, making it necessary to increase the density to accommodate the people, to reduce the cost of public services, and to achieve required social cohesiveness. The reality of modern urbanisation inevitably leads to higher densities than in traditional settlements and this trend is particularly notable in developing countries.

Generally, the world population is rising rapidly, notably in the developing countries. Historical trends suggest that increased annual energy use per capita, which promotes a decrease in population growth rate, is a good surrogate for the standard of living factors. If these trends continue, the stabilisation of the world's population will require the increased use of all sources of energy, particularly as cheap oil and gas are depleted. The improved efficiency of energy use and renewable energy sources will, therefore, be essential in stabilising population, while providing a decent standard of living all over the world [16]. Moreover, energy is the vital input for economic and social development of any country. With an increase in industrial and agricultural activities the demand for energy is also rising. It is, however, a well-accepted fact that commercial energy use has to be minimised. This is because of the environmental effects and the availability problems. Consequently, the focus has now shifted to non-commercial energy resources, which are renewable in nature. This is bound to have less environmental effects and also the availability is guaranteed. However, even though the ideal situation will be to enthuse people to use renewable energy resources, there are many practical difficulties, which need to be tackled. The people groups who are using the non-commercial energy resources, like urban communities, are now becoming more demanding and wish to have commercial energy resources made available for their use. This is attributed to the increased awareness, improved literacy level and changing culture [16]. The quality of life practiced by people is usually represented as being proportional to the per capita energy use of that particular country. It is not surprising that people want to improve their quality of life. Consequently, it is expected that the demand for commercial energy resources will increase at a greater rate in the years to come [17]. Because of this emerging situation, the policy makers are left with two options: either to concentrate on renewable energy resources and have them as substitutes for commercial energy resources or to have a dual approach in which renewable energy resources will contribute to meet a significant portion of the demand whereas the conventional commercial energy resources would be used with caution whenever necessary. Even though the first option is the ideal one, the second approach will be more appropriate for a smooth transition [17].

Direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, interculture, threshing, harvesting and transportation of agricultural inputs and farm produce. It is seen that direct energy is directly used at farms and on fields. As the name implies, indirect energy is not directly used on the farm. Major items for indirect energy are fertilisers, seeds, machinery production and pesticides (Table 1).

Table 1 Energy equivalent of inputs and outputs [18]

Energy source	Unit	Equivalent energy (MJ)
Input		
1. Human labour	h	2.3
2. Animal labour		
Horse	h	10.10
Mule	h	4.04
Donkey	h	4.04
Cattle	h	5.05
Water buffalo	h	7.58
3. Electricity	kWh	11.93
4. Diesel	Litre	56.31
5. Chemicals fertilisers		
Nitrogen	kg	64.4
P_2O_5	kg	11.96
K_2O	kg	6.7
6. Seed		
Cereals and pulses	kg	25
Oil seed	kg	3.6
Tuber	kg	14.7
Total input	kg	43.3
Output		
7. Major products		
Sugar beet	kg	14.7
Tobacco	kg	5.04
Cotton	kg	0.8
Oil seed	kg	11.8
Fruits	kg	25
Vegetables	kg	1.9
Water melon	kg	0.8
Onion	kg	1.9
Potatoes	kg	1.6
Olive	kg	3.6
Tea	kg	11.8
8. By products	kg	0.8
Husk	kg	13.8
Straw	kg	12.5
Cob	kg	18.0
Seed cotton	kg	25.0

Energy use in the agricultural sector depends on the size of the population engaged in agriculture, the amount of arable land and the level of mechanisation.

To calculate the energy used in agricultural production or repair of machinery, the following formula is used:

$$ME = (G \times E) / (T \times Ca) \quad (1)$$

Where:
ME is the machine energy (MJ/ha)
G is the weight of tractor (kg)
E is the constant that is taken 158.3 MJ/kg for tractor
T is the economic life of tractor (h), and
C_a is the effective field capacity (ha/h)
For calculation of C_a, the following equation is used:

$$C_a = (S \times W \times E_f) / 10 \quad (2)$$

where:
W is the working width (m)
S the working speed (km/h), and
E_f the field efficiency (%)

Agricultural greenhouses have a very poor efficiency of thermal conversion of the received solar energy. This is particularly evident in Europe, where, in a cycle of 24 h, and in the winter period, the following constraints are observed:

- During the day: It is essential to maintain through ventilation to guarantee an inside temperature at a level lower than the excessive temperatures harmful for the growth and the development of the cultures.
- At night: It is required to assure, by a supply of heating energy, an optional temperature higher than the crucial level of the culture.

This low thermal efficiency is due to the fact that the only usable thermal support in a classic greenhouse is the greenhouse soil, which has a weak thermal inertia. This renders the storage of most of the daily excess energy, in order to reuse it during the night when the temperature is low, virtually impossible. The inside air temperature in contact with the aerial part of the plant, constitutes a dominant representative factor, among other climatic factors, contributing to the development of greenhouse cultivation. The impact of heating on the increase of the inside air temperature is very important, because a significant increase of agronomic efficiency in the experimental greenhouse.

Explanations for the use of inefficient agricultural-environmental polices include: the high cost of information required to measure benefits on a site-specific basis, information asymmetries between government agencies and farm decision makers that result in high implementation costs, distribution effects and political considerations [19]. To achieve the aims of agric-environment schemes was must:

- Sustain the beauty and diversity of the landscape.
- Improve and extend wildlife habitats.
- Conserve archaeological sites and historic features.
- Improve opportunities for countryside enjoyment.
- Restore neglected land or features, and
- Create new habitats and landscapes.

3. Renewable Energy

Sustainable energy is energy that, in its production or consumption, has minimal negative impacts on human health and the healthy functioning of vital ecological systems, including the global environment [19]. It is an accepted fact that renewable energy is a sustainable form of energy, which has attracted more attention during recent years. A great amount of renewable energy potential, environmental interest, as well as economic consideration of fossil fuel consumption and high emphasis of sustainable development for the future will be needed. Nearly a fifth of all global power is generated by renewable energy sources, according to a book published by the OECD/IEA [20]. ‘‘Renewables for power generation: status and prospects’’ claims that renewables are the second largest power source after coal (39%) and ahead of nuclear (17%), natural gas (17%) and oil (8%). From 1973-2000 renewables grew at 9.3% a year and it is predicted that this will increase by 10.4% a year to 2015. Wind power grew fastest at 52% and will multiply seven times by 2015, overtaking biopower and reducing GHGs by production of environmental technology (wind, solar, fuel cells, etc.). The challenge is to match leadership in the GHG reduction and production of renewable energy with developing a major research and manufacturing capacity in environmental technologies.

More than 50% of the world’s area is classified as arid, representing the rural and desert part, which lack electricity and water networks. The inhabitants of such areas obtain water from borehole wells by means of water pumps, which are mostly driven by diesel engines. The diesel motors are associated with maintenance problems, high running cost, and environmental pollution. Alternative methods are pumping by photovoltaic (PV) or wind systems. At present, renewable sources of energy are regional and site specific (Appendix 1). It has to be integrated in the regional development plans.

3.1 Solar Energy

The availability of data on solar radiation is a critical problem. Even in developed countries, very few weather stations have been recording detailed solar radiation data for a period of time long enough to have statistical significance. Solar radiation arriving on earth is the most fundamental renewable energy source in nature. It powers the bio-system, the ocean and atmospheric current system and affects the global climate. Reliable radiation information is needed to provide input data in modelling solar energy devices and a good database is required in the work of energy planners, engineers, and agricultural scientists. In general, it is not easy to design solar energy conversion systems when they have to be installed in remote locations. First, in most cases, solar radiation measurements are not available for these sites. Secondly, the radiation nature of solar radiation makes difficult the computation of the size of such systems. While solar energy data are recognised as very important, their acquisition is by no means straightforward. The measurement of solar radiation requires the use of costly equipment such as pyrheliometers and pyranometers. Consequently, adequate facilities are often not available in developing countries to mount viable monitoring programmes. This is partly due to the equipment cost as well as the cost of technical manpower. Several attempts have, however, been made to estimate solar radiation through the use of meteorological and other physical parameter in order to avoid the use of expensive network of measuring instruments [21-24]. Renewable energy, combined with energy efficiency, offers a viable and potent solution to countering the effects of global warming.

Two of the most essential natural resources for all life on the earth and for man's survival are sunlight and water. Sunlight is the driving force behind many of the RETs. The worldwide potential for utilising this resource, both directly by means of the solar technologies and indirectly by means of biofuels, wind and hydro technologies is vast. During the last decade interest has been refocused on renewable energy sources due to the increasing prices and fore-seeable exhaustion of presently used commercial energy sources. The most promising solar energy technology are related to thermal systems; industrial solar water heaters, solar cookers, solar dryers for peanut crops, solar stills, solar driven cold stores to store fruits and vegetables, solar collectors, solar water desalination, solar ovens, and solar commercial bakers. Solar PV system: solar PV for lighting, solar refrigeration to store vaccines for human and animal use, solar PV for water pumping, solar PV for battery chargers, solar PV for communication network, microwave, receiver stations, radio systems in airports, VHF and beacon radio systems in airports, and educational solar TV posts in villages. Solar pumps are most cost effective for low power requirement (up to 5 kW) in remote places. Applications include domestic and livestock drinking water supplies, for which the demand is constant throughout the year, and irrigation. However, the suitability of solar pumping for irrigation is uncertain because the demand may vary greatly with seasons. Solar systems may be able to provide trickle irrigation for fruit farming, but not usually the large volumes of water needed for wheat growing.

The hydraulic energy required to deliver a volume of water is given by the formula:

$$E_w = \rho_w \, g \, V \, H \qquad (3)$$

Where: E_w is the required hydraulic energy (kWh day^{-1}); ρ_w is the water density (kg m^{-3}); g is the gravitational acceleration (ms^{-2}); V is the required volume of water (m^3 day^{-1}); and H is the head of water (m).

The solar array (Appendix 2) power required is given by:

$$P_{sa} = E_w / E_{sr} \, \eta \, F \qquad (4)$$

where: P_{sa} is the solar array power (kW$_p$); E_{sr} is the average daily solar radiation (kWhm^{-2} day^{-1}); F is the array mismatch factor; and η is the daily subsystem efficiency.

Substituting Equation (3) in Equation (4), the following equation is obtained for the amount of water that can be pumped:

$$V = P_{sa} \, E_{sr} \, \eta \, F / \rho_w \, g \, H \qquad (5)$$

PV consists of 32 modules P_{sa} = 1.6 kW$_p$, F = 0.85, η = 40%.

A further increase of PV depends on the ability to improve the durability, performance and the local manufacturing capabilities of PV. Moreover, the availability of credit schemes (e.g., solar funds) would increase the annual savings of oil and foreign currency and further improve the security of energy supply and further employment could be created.

Table 2 Classifications of data requirements

Criteria	Plant data	System data
Existing data	Size Life Cost (fixed and variation operation and maintenance) Forced outage Maintenance Efficiency Fuel Emissions	Peak load Load shape Capital costs Fuel costs Depreciation Rate of return Taxes
Future data	All of above, plus Capital costs Construction trajectory Date in service	System lead growth Fuel price growth Fuel import limits Inflation

Table 3 Effective biomass resource utilisation

Subject	Tools	Constraints
Utilisation and land clearance for agriculture expansion	Stumpage fees Control Extension Conversion Technology	Policy Fuel-wood planning Lack of extension Institutional
Utilisation of agricultural residues	Briquetting Carbonisation Carbonisation and briquetting Fermentation Gasification	Capital Pricing Policy and legislation Social acceptability

3.2 Efficient Bio-Energy Use

The data required to perform the trade-off analysis simulation of bio-energy resources can be classified according to the divisions given in Table 2, namely the overall system or individual plants, and the existing situation or future development. The effective economic utilisations of these resources are shown in Table 3, but their use is hindered by many problems such as those related to harvesting, collection, and transportation, besides the photo-sanitary control regulations. Biomass energy is experiencing a surge in interest stemming from a combination of factors, e.g., greater recognition of its current role and future potential contribution as a modern fuel, global environmental benefits, its development and entrepreneurial opportunities, etc. Possible routes of biomass energy development are shown in Table 4. However, bio-energy usage can generally be divided into the following three categories.

Table 4 Agricultural residues routes for development

Source	Process	Product	End use
Agricultural residues	Direct	Combustion	Rural poor Urban household Industrial use
	Processing	Briquettes	Industrial use Limited household use
	Processing	Carbonisation (small scale)	Rural household (self sufficiency)
	Carbonisation	Briquettes Carbonised	Urban fuel
	Fermentation	Biogas	Energy services Household Industry
Agricultural, and animal residues	Direct	Combustion	(Save or less efficiency as wood)
	Briquettes	Direct combustion	(Similar end use devices or improved)
	Carbonisation	Carbonised	Use
	Carbonisation	Briquettes	Briquettes use
	Fermentation	Biogas	Use

A. Biomass Energy for Petroleum Substitution

1 Oil price increase.
2 Balance of payment problems, and economic crisis.
3 Fuel-wood plantations, and residue utilisation.
4 Wood based heat and electricity.
5 Liquid fuels from biomass.
6 Producer gas technology.

B. Biomass Energy for Domestic Needs

1 Population increase.
2 Urbanisation.
3 Agricultural expansion.
4 Fuel-wood crisis, and ecological crisis.
5 Fuel-wood plantations, and agro-forestry.
6 Community forestry.
7 Improved stoves, and improved charcoal production.
8 Residue utilisation.

C. Biomass Energy for Development

1 Electrification.
2 Irrigation and water supply.
3 Economic and social development.
4 Fuel-wood plantations.
5 Community forestry.
6 Agro-forestry.
7 Briquettes.
8 Producer gas technology.

The use of biomass through direct combustion has long been, and still is, the most common mode of biomass utilisation (Table 4). Examples for dry (thermo-chemical) conversion processes are charcoal making from wood (slow pyrolysis), gasification of forest and agricultural residues (fast pyrolysis – this is still in demonstration phase), and of course, direct combustion in stoves, furnaces, etc. Wet processes require substantial amount of water to be mixed with the biomass. Biomass technologies include:

- Briquetting.
- Improved stoves.
- Biogas.
- Improved charcoal.
- Carbonisation.
- Gasification.

3.2.1 Briquette

Briquetting is the formation of a charcoal (an energy-dense solid fuel source) from otherwise wasted agricultural and forestry residues (Appendix 3). One of the disadvantages of wood fuel is that it is bulky with a low energy density and therefore requires transport. Briquette formation allows for a more energy-dense fuel to be delivered, thus reducing the transportation cost and making the resource more competitive. It also adds some uniformity, which makes the fuel more compatible with systems that are sensitive to the specific fuel input.

Charcoal stoves are very familiar to African societies. As for the stove technology, the present charcoal stove can be used, and can be improved upon for better efficiency. This energy term will be of particular interest to both urban and rural households and all the income groups due to its simplicity, convenience, and lower air polluting characteristics. However, the market price of the fuel together with that of its end-use technology may not enhance its early high market penetration especially in the urban low income and rural households.

3.2.2 Improved Cook Stoves

Traditional wood stoves are commonly used in many rural areas. These can be classified into four types: three stone, metal cylindrical shaped, metal tripod and clay type. Indeed, improvements of traditional cookers and ovens to raise the efficiency of fuel saving can secure rural energy availability, where woody fuels have become scarce. However, planting fast growing trees to provide a constant fuel supply should also be considered. The rural development is essential and economically important since it will eventually lead to a better standard of living, people's settlement, and self-sufficiency in the followings:

- Food and water supplies.
- Better services in education and health care.
- Good communication modes.

3.2.3 Biogas

Biogas technology cannot only provide fuel, but is also important for comprehensive utilisation of biomass forestry, animal husbandry, fishery, agricultural economy, protecting the environment, realising agricultural recycling, as well as improving the sanitary conditions, in rural areas. However, the introduction of biogas technology on a wide scale has implications for macro planning such as the allocation of government investment and effects on the balance of payments.

Hence, factors that determine the rate of acceptance of biogas plants, such as credit facilities and technical backup services, are likely to have to be planned as part of general macro-policy, as do the allocation of research and development funds [25].

3.2.4 Improved Forest and Tree Management

Dry cell batteries are a practical but expensive form of mobile fuel that is used by rural people when moving around at night and for powering radios and other small appliances. The high cost of dry cell batteries is financially constraining for rural households, but their popularity gives a good indication of how valuable a versatile fuel like electricity is in rural areas (Table 5). However, dry cell batteries can constitute an environmental hazard unless they are recycled in a proper fashion. Tables (5-6) further show that direct burning of fuel-wood and crop residues constitute the main usage of biomass, as is the case with many developing countries.

In fact, biomass resources play a significant role in energy supply in all developing countries. However, the direct burning of biomass in an inefficient manner causes economic loss and adversely affects human health. 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.

Accordingly, biomass resources should be divided into residues or dedicated resources, the latter including firewood and charcoal can also be produced from forest residues (Table 6).

The key factors to reducing and controlling CO_2, which is the major contributor to global warming, are the use of alternative approaches to energy generation and the exploration of how these alternatives are used today and may be used in the future as green energy sources.

Table 5 Energy carrier and energy services in rural areas

Energy carrier	Energy end-use
Fuel-wood	Cooking Water heating Building materials Animal fodder preparation
Kerosene	Lighting Ignition fires
Dry cell batteries	Lighting Small appliances
Animal power	Transport Land preparation for farming Food preparation (threshing)
Human power	Transport Land preparation for farming Food preparation (threshing)

Table 6 Biomass residues and current use

Type of residue	Current use
Wood industry waste	Residues available
Vegetable crop residues	Animal feed
Food processing residue	Energy needs
Sorghum, millet, and wheat residues	Fodder, and building materials
Groundnut shells	Fodder, brick making, and direct fining oil mills
Cotton stalks	Domestic fuel considerable amounts available for short period
Sugar, bagasse, and molasses	Fodder, energy need, and ethanol production (surplus available)
Manure	Fertiliser, brick making, and plastering

3.2.5 Gasification

Gasification is based on the formation of a fuel gas (mostly CO and H_2) by partially oxidising raw solid fuel at high temperatures in the presence of steam or air. The technology can use wood chips, groundnut shells, sugarcane bagasse, and other similar fuels to generate capacities from 3 kW to 100 kW.

Three types of gasifier designs have been developed to make use of the diversity of fuel inputs and to meet the requirements of the product gas output (degree of cleanliness, composition, heating value, etc.). These are French, Thai, and Chinese designs [25].

3.2.6 Bio-Energy

There are many emerging biomass technologies with large and immediate potential applications, e.g., biomass gasifier/gas turbine (BGST) systems for power generation with pilot plants, improved techniques for biomass harvesting, transportation and storage.

Gasification of crop residues such as rice husks, groundnut shells, etc., with plants already operating in China, India, and Thailand.

Treatment of cellulosic materials by steam explosion which may be followed by biological or chemical hydrolysis to produce ethanol or other fuels, cogeneration technologies, hydrogen from biomass, striling energies capable of using biomass fuels efficiently, etc.

However, a major gap with biomass energy is that research has usually been aimed at obtaining supply and consumption data, with insufficient attention and resources being allocated to basic research, to production, harvesting and conservation process. Biomass has not been closely examined in terms of a substitute for fossil fuels compared to carbon sequestration and overall environmental benefits related to these different approaches. To achieve the full potential of biomass as a feedstock for energy, food, or any other use, requires the application of considerable scientific and technological inputs [25]. The aim of any modern biomass energy systems must be:

1 To maximise yields with minimum inputs.
2 Utilise and select adequate plant materials and processes.
3 Optimise use of land, water, and fertiliser.
4 Create an adequate infrastructure and strong research and development (R&D) base.

The afforestation programme appears an attractive option for any country to pursue in order to reduce the level of atmospheric carbon by enhancing carbon sequestration in the nation's forests, which would consequently mitigate climate change.

However, it is acknowledged that certain barriers need to be overcome if the objectives are to be fully achieved. These include the following:

- Low level of public awareness of the economic/environmental benefits of forestry.
- The generally low levels of individual income.
- Pressures from population growth.
- The land tenural system, which makes it difficult (if not possible) for individuals to own or establish forest plantations.
- Poor pricing of forest products especially in the local market.
- Inadequate financial support on the part of governments.
- Weak institutional capabilities of the various Forestry Departments as regards technical

manpower to effectively manage tree plantations.

However, social policy conditions are critical. This is still very much lacking particularly under developing country conditions. During the 1970s and 1980s different biomass energy technologies were perceived in sub-Saharan Africa as a panacea for solving acute problems.

On the account of these expectations, a wide range of activities and projects were initiated. However, despite considerable financial and human efforts, most of these initiatives have unfortunately been a failure. Therefore, future research efforts should concentrate on the following areas:

- Directed research and development (R&D) in the most promising areas of biomass to increase energy supply and to improve the technological base.
- Formulate a policy framework to encourage entrepreneurial and integrated process.
- Pay more attention to sustainable production and use of biomass energy feedstocks, methodology of conservation and efficient energy flows.
- More research aimed at pollution abatement.
- Greater attentions to interrelated socio-economic aspects.
- Support (R&D) on energy efficiency in production and use.
- Improve energy management skills and take maximum advantage of existing local knowledge.
- Closely examine past successes and failures to assist policy makers with well-informed recommendations.

3.3. Combined Heat and Power CHP

District Heating (DH), also known as community heating can be a key factor to achieve energy savings, reduce CO_2 emissions and at the same time provide consumers with a high quality heat supply at a competitive price. Generally, DH should only be considered for areas where the heat density is sufficiently high to make DH economical.

In countries like Denmark for example, DH may today be economical even to new developments with lower density areas, due to the high level of taxation on oil and gas fuels combined with the efficient production of DH.

Most of the heat used for DH is produced by large CHP plants (gas-fired combined cycle plants using natural gas, biomass, waste or biogas) as shown in Table 7.

DH is energy efficient because of the way the heat is produced and the required temperature level is an important factor. Buildings can be heated to a temperature of $21^{o}C$ and domestic hot water (DHW) can be supplied at a temperature of $55^{o}C$ using energy sources that are most efficient when producing low temperature levels ($<95^{o}C$) for the DH water [26].

Most of these heat sources are CO_2 neutral or emit low levels. Only a few of these sources are available to small individual systems at a reasonable cost, whereas DH schemes because of the plant's size and location can have access to most of the heat sources and at a low cost. Low temperature DH, with return temperatures of around 30-40°C can utilise the following heat sources:

- Efficient use of CHP by extracting heat at low calorific value (CV).
- Efficient use of biomass or gas boilers by condensing heat in economisers (Table 8).
- Efficient utilisation of geothermal energy.
- Direct utilisation of excess low temperature heat from industrial processes.
- Efficient use of large-scale solar heating plants.

Heat tariffs may include a number of components such as: a connection charge, a fixed charge and a variable energy charge. Also, consumers may be incentivised to lower the return temperature. Hence, it is difficult to generalise but the heat practice for any DH company no matter what the ownership structure can be highlighted as follows:

- To develop and maintain a development plan for the connection of new consumers.
- To evaluate the options for least cost production of heat.
- To implement the most competitive solutions by signing agreements with other companies or by implementing own investment projects.
- To monitor all internal costs and with the help of benchmarking, and improve the efficiency of the company.
- To maintain a good relationship with the consumer and deliver heat supply services at a sufficient quality.

Installing DH should be pursued to meet the objectives for improving the environment through the improvement of energy efficiency in the heating sector. At the same time DH can serve the consumer with a reasonable quality of heat at the lowest possible cost.

The variety of possible solutions combined with the collaboration between individual companies, the district heating association, the suppliers and consultants can, as it has been in Denmark, be the way forward for developing DH in the United Kingdom.

3.4 Fuel Cells

Platinum is a catalyst for fuel cells and hydrogen-fuelled cars presently use about two ounces of the metal. There is currently no practicable alternative. Reserves are in South Africa (70%), and Russia (22%). In South Africa there are sufficient accessible reserves to increase supply by up to 5% per year for the next 50 years, but there are significant environmental impacts associated with its mining and refining, like groundwater pollution and atmospheric emissions of sulphur dioxide ammonia, chlorine and hydrogen chloride.

The carbon cost of platinum use equates to 360 kg for a current fuel cell car, or 36 kg for a future car, with the target platinum loading of 0.2 oz, which is negligible compared to the CO_2 currently emitted by vehicles. The metal is almost completely recyclable.

At current prices and loading, platinum would cost 3% of the total cost of a fuel cell engine. The likely resource costs of hydrogen as a transport fuel are apparently cheapest if it is reformed from natural gas with pipeline distribution, with or without carbon sequestration. However, this is not as sustainable as using renewable energy sources. Substituting hydrogen for fossils fuels will have a positive environmental impact in reducing both photochemical smog and climate change.

Table 7 Sources of renewable energy

Energy source	Technology	Size
Solar energy	Domestic solar water heaters	Small
	Solar water heating for large demands	Medium-large
	PV roofs: grid connected systems generating electric energy	Medium-large
Wind energy	Wind turbines (grid connected)	Medium-large
Hydraulic energy	Hydro plants in derivation schemes	Medium-small
	Hydro plants in existing water distribution networks	Medium-small
Biomass	High efficiency wood boilers	Small
	CHP plants fed by agricultural wastes or energy crops	Medium
Animal manure	CHP plants fed by biogas	Small
Combined heat and power (CHP)	High efficiency lighting	Wide
	High efficiency electric	Wide
	Householders appliances	Wide
	High efficiency boilers	Small-medium
	Plants coupled with refrigerating absorption machines	Medium-large

Table 8 Final energy projections including biomass (Mtoe) [27]

Region (2011)				
	Biomass	Conventional Energy	Total	Share of Biomass (%)
Africa	205	136	341	60
China	206	649	855	24
East Asia	106	316	422	25
Latin America	73	342	416	18
South Asia	235	188	423	56
Total developing countries	825	1632	2456	34
Other non-OECD countries	24	1037	1061	1
Total non-OECD countries	849	2669	3518	24
OECD countries	81	3044	3125	3
World	930	5713	6643	14
Region (2020)				
	Biomass	Conventional Energy	Total	Share of Biomass (%)

Africa	371	266	631	59
China	224	1524	1748	13
East Asia	118	813	931	13
Latin America	81	706	787	10
South Asia	276	523	799	35
Total developing countries	1071	3825	4896	22
Other non-OECD countries	26	1669	1695	1
Total non-OECD countries	1097	5494	6591	17
OECD countries	96	3872	3968	2
World	1193	9365	10558	11

There could be an adverse impact on the ozone layer but this is likely to be small, though potentially more significant if hydrogen was to be used as aviation fuel.

3.5 Hydrogen Production

Hydrogen is now beginning to be accepted as a useful form for storing energy for reuse on, or for export off, the grid. Clean electrical power harvested from wind and wave power projects can be used to produce hydrogen by electrolysis of water. Electrolysers split water molecules into its constituent parts: hydrogen and oxygen. By installing any of the available renewable energy technologies, one will be making a major personal contribution to the well-being of future generations and could also benefit from lower fuel bills.

These are collected as gases; hydrogen at the cathode and oxygen at the anode. The process is quite simple. Direct current is applied to the electrodes to initiate the electrolysis process. Production of hydrogen is an elegant environmental solution. Hydrogen is the most abundant element on the planet, it cannot be destroyed (unlike hydrocarbons) it simply changes state (water to hydrogen and back to water) during consumption. In its production and consumption there are no CO or CO_2 production and depending upon methods of consumption, the production of oxides of nitrogen can be avoided too.

However, the transition will be very messy, and will take many technological paths to convert fossil fuels and methanol to hydrogen, building hybrid engines and so on, but the future will be hydrogen fuel cells. Hydrogen is already produced in huge volumes and used in a variety of industries. Current worldwide production is around 500 billion Nm^3 per year [27]. Most of the hydrogen produced today is consumed on-site, such as at oil refineries, and is not sold on the market. From large-scale production, hydrogen costs around $0.70/kg if it is consumed on-site [28]. When hydrogen is sold on the market, the cost of liquefying the hydrogen and transporting it to the user adds considerably to production cost.

The energy required to produce hydrogen via electrolysis (assuming 1.23 V) is about 33 kWh/kg. For 1 mole (2 g) of hydrogen the energy is about 0.066 kWh/mole [28]. The achieved efficiencies are over 80%

and on this basis electrolytic hydrogen can be regarded as a storable form of electricity.

Hydrogen can be stored in a variety of forms:

- Cryogenic; this has the highest gravimetric energy density.
- High-pressure cylinders; pressures of 10,000 psi are quite normal.
- Metal hydride absorbs hydrogen, providing a very low pressure and extremely safe mechanism, but is heavy and more expensive than cylinders, and
- Chemical carriers offer an alternative, with anhydrous ammonia offering similar gravimetric and volumetric energy densities to ethanol and methanol.

Hydrogen can be used in internal combustion engines, fuel cells, turbines, cookers gas boilers, road-side emergency lighting, traffic lights or signalling where noise and pollution can be a considerable nuisance, but where traffic and pedestrian safety cannot be compromised.

3.6. Hydropower

Hydropower has a valuable role as a clean and renewable source of energy in meeting a variety of vital human needs. Water resources management, benefit sharing and among other points (safe drinking water and sanitation, water for food and rural development, water pollution and ecosystem conservation, disaster mitigation and risk management). The recognition of the role of hydropower as one of the renewable and clean energy sources and that its potential should be realised in an environmentally sustainable and socially acceptable manner. Water is a basic requirement for survival for drinking, for food, energy production and for good health. As water is a commodity, which is finite and cannot be created, and in view of the increasing requirements as the world population grows, there is no alternative but to store water for use when it is needed. The major challenges are to feed the increasing world population, to improve the standards of living in rural areas and to develop and manage land and water in a sustainable way. Hydropower plants are classified by their rated capacity into one of four regimes: micro (<50kW), mini (50-500 kW), small (500 kW-5 MW), and large (>5 MW) [29].

The total world installed hydro capacity today is around 730 GW, and 1500 GW more will be built during this century, principally in developing countries in Asia, Africa and South America. Table 9, which is reproduced from [29], classified hydro plants in the world. The present production of hydroelectricity is only about 18 per cent of the technically feasible potential (and 32 per cent of the economically feasible potential); there is no doubt that a large amount of hydropower development lies ahead [29].

3.7 Wind Energy

Water is the most natural commodity for the existence of life in the remote desert areas. However, as a condition for settling and growing, the supply of energy is the second priority.

The high cost and the difficulties of mains power line extensions, especially to a low populated region can divert attention to the utilisation of more reliable and independent sources of energy like renewable wind energy.

Table 9 World hydro potential and development [29]

Continent	Africa	Asia	Australia and Oceania	Europe	North and Central America	South America
Gross theoretical hydropower potential ($GWhy^{-1}$)	$4x10^6$	$19.4x10^6$	$59.4x10^6$	$3.2x10^6$	$6x10^6$	$6.2x10^6$
Technically feasible hydropower potential ($GWhy^{-1}$)	$1.75x10^6$	$6.8x10^6$	$2x10^6$	10^6	$1.66x10^6$	$2.7x10^6$
Economically feasible hydropower potential ($GWhy^{-1}$)	$1.1x10^5$	$3.6x10^6$	$90x10^4$	$79x10^4$	10^6	$1.6x10^6$
Installed hydro capacity (MW)	$21x10^3$	$24.5x10^4$	$13.3x10^4$	$17.7x10^4$	$15.8x10^4$	$11.4x10^4$
Production by hydro plants in 2002 or average ($GWhy^{-1}$)	$83.4x10^3$	$80x10^4$	$43x10^3$	$568x10^3$	$694x10^3$	$55x10^4$
Hydro capacity under construction (MW)	> 3024	$>72.7x10^3$	>177	$>23x10^2$	$58x10^2$	$>17x10^3$
Planned hydro capacity (MW)	$77.5x10^3$	$>17.5x10^4$	>647	$>10^3$	$>15x10^3$	$>59x10^3$

Accordingly, the utilisation of wind energy, as a form of energy, is becoming increasingly attractive and is being widely used for the substitution of oil-produced energy, and eventually to minimise atmospheric degradation. Indeed, utilisation of renewables, such as wind energy, has gained considerable momentum since the oil crises of the 1970s. Wind energy is non-depleting, site-dependent, non-polluting, and a potential source of the alternative energy option.

Wind power could supply 12% of global electricity demand by 2020, according to a report by European Wind Energy Association and Greenpeace [30]. Wind energy can and will constitute a significant energy resource when converted into a usable form (see Figure 1).

As Figure 1 illustrates, information sharing is a four-stage process and effective collaboration must also provide ways in which the other three stages of the 'renewable' cycle: gather, convert and utilise, can be integrated. Efficiency in the renewable energy sector translates into lower gathering, conversion and utilisation (electricity) costs. A great level of installed capacity has already been achieved. Figure 2 clearly shows that the offshore wind sector is developing fast, and this indicates that wind is becoming a major factor in electricity supply with a range of significant technical, commercial and financial hurdles to be overcome.

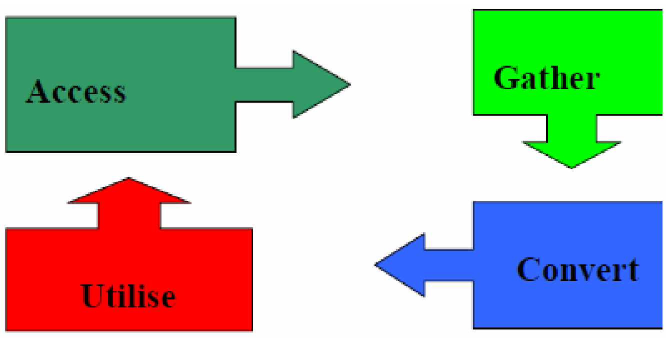


Fig. 1 The renewable cycle

Economic projections are difficult at the best of times, when economies are relatively stable and a reference 'business as usual' case can be used. However, there are numerous signals that the world faces very turbulent economic conditions for a while - a credit crunch may make some project finance difficult and the shortage of raw materials could lead to supply chain difficulties.

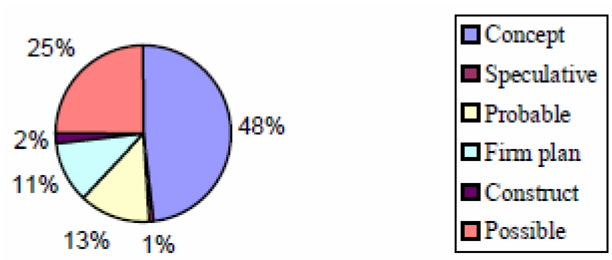


Fig. 2 Global prospects of wind energy utilisation by 2003-2010

The offshore wind industry has the potential for a very bright future and to emerge as a new industrial sector, as Figure 3 implies. The speed of turbine development is such that more powerful models would supersede the original specification turbines in the time from concept to turbine order.

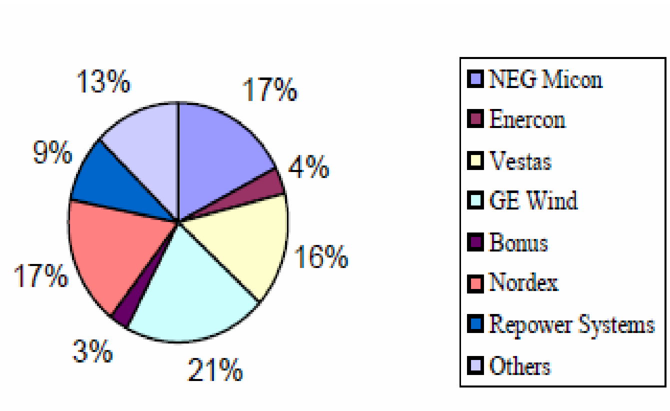


Fig. 3 Turbines share for 2003-2010

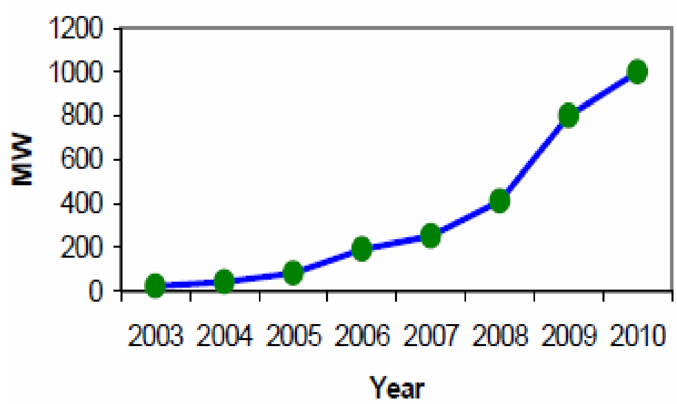


Fig. 4 Average windfarm capacity 2003-2010 (Mega watts, MW)

Levels of activities are growing at a phenomenal rate (Figure 4), new prospects developing, new players entering, existing players growing in experience, technology evolving and political will appears to support the sector. The provision of pumped clean water is one of the best ways to improve health and increase the productive capacity of the population. Rural access to clean water is best achieved through pumping from underground water aquifers rather than using surface water sources, which are often polluted.

4. Energy and Sustainable Development

Sustainability is defined as the extent to which progress and development should meet the need of the present without compromising the ability of the future generations to meet their own needs [31]. This encompasses a variety of levels and scales ranging from economic development and agriculture, to the management of human settlements and building practices.

This general definition was further developed to include sustainable building practices and management of human settlements. Tables (10-12) indicate energy conservation, sustainable development and environment.

Table 10 Energy and sustainable environment

Technological criteria	Energy and environment criteria	Social and economic criteria
Primary energy saving in regional scale	Sustainability according to greenhouse gas pollutant emissions	Labour impact
Technical maturity, and reliability	Sustainable according to other pollutant emissions	Market maturity
Consistence of installation and maintenance requirements with local technical known-how	Land requirement	Compatibility with political, legislative and administrative situation
Continuity and predictability of performance	Sustainability according to other environmental impacts	Cost of saved primary energy

Table 11 Classification of key variables defining facility sustainability

Criteria	Intra-system impacts	Extra-system impacts
Stakeholder satisfaction	Standard expectations met Relative importance of standard expectations	Covered by attending to extra-system resource base and ecosystem impacts
Resource base impacts	Change in intra-system resource bases Significance of change	Resource flow into/out of facility system Unit impact exerted by flow on source/sink system Significance of unit impact
Ecosystem impacts	Change in intra-system ecosystems Significance of change	Resource flows into/out of facility system Unit impact exerted by how on source/sink system Significance of unit impact

The following issues were addressed during the Rio Earth Summit in 1992 [32]:

- The use of local materials and indigenous building sources.
- Incentive to promote the continuation of traditional techniques, with regional resources and self-help strategies.
- Regulation of energy-efficient design principles.
- International information exchange on all aspects of construction related to the environment, among architects and contractors, particularly non-conventional resources.
- Exploration of methods to encourage and facilitate the recycling and reuse of building materials, especially those requiring intensive energy use during manufacturing, and the use of clean technologies.

Table 12 Positive impact of durability, adaptability and energy conservation on economic, social and environment systems

Economic system	Social system	Environmental system
Durability	Preservation of cultural values	Preservation of resources
Meeting changing needs of economic development	Meeting changing needs of individuals and society	Reuse, recycling and preservation of resources
Energy conservation and saving	Savings directed to meet other social needs	Preservation of resources, reduction of pollution and global warming

Also, the following action areas for producers were recommended:

- Management and measurement tools- adopting environmental management systems appropriate for the business.
- Performance assessment tools- making use of benchmarking to identify scope for impact reduction and greater eco-efficiency in all aspects of the business.
- Best practice tools- making use of free help and advice from government best practice programmes (energy efficiency, environmental technology, and resource savings).
- Innovation and ecodesign- rethinking the delivery of 'value added' by the business, so that impact reduction and resource efficiency are firmly built in at the design stage.
- Cleaner, leaner production processes- pursuing improvements and savings in waste minimisation, energy and water consumption, transport and distribution, as well as reduced emissions.
- Supply chain management- specifying more demanding standards of sustainability from 'upstream' suppliers, while supporting smaller firms to meet those higher standards.
- Product stewardship- taking the broadest view of 'producer responsibility' and working to reduce all the 'downstream' effects of products after they have been sold on to customers.

- Openness and transparency- publicly reporting on environmental performance against meaningful targets; actively using clear labels and declarations so that customers are fully informed; building stakeholder confidence by communicating sustainability aims to the workforce, the shareholders and the local community (Figure 5).

This is the step in a long journey to encourage a progressive economy, which continues to provide people with high living standards, but at the same time helps reduce pollution, waste mountains, other environmental degradation, and environmental rationale for future policy-making and intervention to improve market mechanisms. This vision will be accomplished by:

- ‘Decoupling’ economic growth and environmental degradation. The basket of indicators illustrated shows the progress being made (Table 13). Decoupling air and water pollution from growth, making good headway with CO_2 emissions from energy, and transport. The environmental impact of our own individual behaviour is more closely linked to consumption expenditure than the economy as a whole.
- Focusing policy on the most important environmental impacts associated with the use of particular resources, rather than on the total level of all resource use.
- Increasing the productivity of material and energy use that are economically efficient by encouraging patterns of supply and demand, which are more efficient in the use of natural resources. The aim is to promote innovation and competitiveness. Investment in areas like energy efficiency, water efficiency and waste minimisation.
- Encouraging and enabling active and informed individual and corporate consumers.

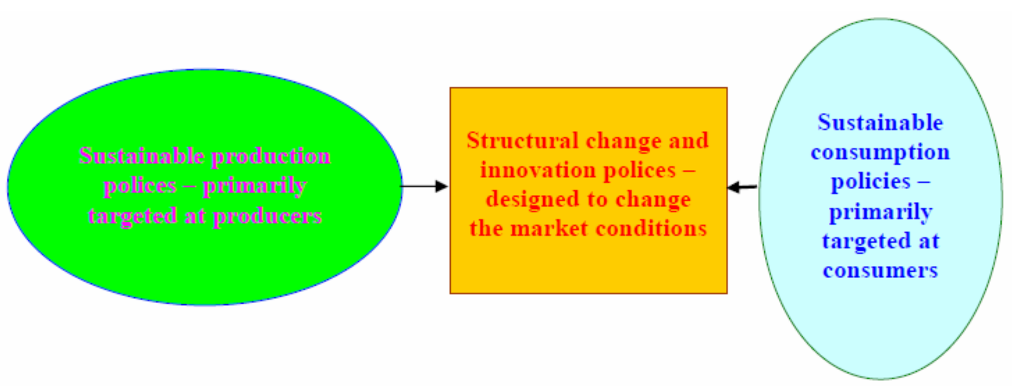


Fig. 5 Link between resources and productivity

5. Global Warming

With the debate on climate change, the preference for real measured data has been changed. The analyses of climate scenarios need an hourly weather data series that allows for realistic changes in various weather parameters.

By adapting parameters in a proper way, data series can be generated for the site (Appendix 4). Weather generators should be useful for:

- Calculating energy consumption (no extreme conditions are required).
- Design purposes (extremes are essential), and
- Predicting the effect of climate change such as increasing annually average of temperature.

Table 13 The basket of indicators for sustainable consumption and production

Economy-wide decoupling indicators
1. Greenhouse gas emissions
2. Air pollution
3. Water pollution (river water quality)
4. Commercial and industrial waste arisings and household waste not cycled
Resource use indicators
5. Material use
6. Water abstraction
7. Homes built on land not previously developed, and number of households
Decoupling indicators for specific sectors
8. Emissions from electricity generation
9. Motor vehicle kilometres and related emissions
10. Agricultural output, fertiliser use, methane emissions and farmland bird populations
11. Manufacturing output, energy consumption and related emissions
12. Household consumption, expenditure energy, water consumption and waste generated

This results in the following requirements:

- Relevant climate variables should be generated (solar radiation: global, diffuse, direct solar direction, temperature, humidity, wind speed and direction) according to the statistics of the real climate.
- The average behaviour should be in accordance with the real climate.
- Extremes should occur in the generated series in the way it will happen in a real warm period. This means that the generated series should be long enough to capture these extremes, and series based on average values from nearby stations.

On some climate change issues (such as global warming), there is no disagreement among the scientists. The greenhouse effect is unquestionably real, it is essential for life on earth. Water vapour is the most important GHG; next is carbon dioxide (CO_2). Without a natural greenhouse effect, scientists estimate that the earth's average temperature would be –18°C instead of its present 14°C [33].

There is also no scientific debate over the fact that human activity has increased the concentration of the GHGs in the atmosphere (especially CO_2 from combustion of coal, oil and gas). The greenhouse effect is also being amplified by increased concentrations of other gases, such as methane, nitrous oxide, and CFCs as a result of human emissions. Most scientists predict that rising global temperatures will raise the sea level and increase the frequency of intense rain or snowstorms. Climate change scenarios sources of uncertainty and factors influencing the future climate are:

- The future emission rates of the GHGs (Table 14).
- The effects of this increase in concentration on the energy balance of the atmosphere.
- The effect of these emissions on the GHGs concentrations in the atmosphere, and
- The effects of this change in energy balance on global and regional climate.

It has been known for a long time that urban centres have mean temperatures higher than their less developed surroundings. The urban heat increases the average and peak air temperatures, which in turn affect the demand for heating and cooling.

Higher temperatures can be beneficial in the heating season, lowering fuel use, but they exacerbate the energy demand for cooling in the summer times.

Table 14 EU member states GHG emissions [34]

Country	1990	1999	Change 1990-99	Reduction target
Austria	76.9	79.2	2.6%	-13%
Belgium	136.7	140.4	2.8%	-7.5%
Denmark	70.0	73.0	4.0%	-21.0%
Finland	77.1	76.2	-1.1%	0.0%
France	545.7	544.5	-0.2%	0.0%
Germany	1206.5	982.4	-18.7%	-21.0%
Greece	105.3	123.2	16.9%	25.0%
Ireland	53.5	65.3	22.1%	13.0%
Italy	518.3	541.1	4.4%	-6.5%
Luxembourg	10.8	6.1	-43.3%	-28.0%
Netherlands	215.8	230.1	6.1%	-6.0%
Portugal	64.6	79.3	22.4%	27.0%
Spain	305.8	380.2	23.2%	15.0%
Sweden	69.5	70.7	1.5%	4.0%
United Kingdom	741.9	637.9	-14.4%	-12.5%
Total EU-15	4199	4030	-4.0%	-8.0%

In temperate climates neither heating nor cooling may dominate the fuel use in a building, and the balance of the effect of the heat is less. As the provision of cooling is expensive with higher environmental cost, ways of using innovative alternative systems, like the mop fan will be appreciated. The solar gains would affect energy consumption.

Therefore, lower or higher percentages of glazing, or shading devices might affect the balance between annual heating and cooling loads. In addition to conditioning energy, the fan energy needed to provide mechanical ventilation can make a significant further contribution to energy demand.

Much depends on the efficiency of design, both in relation to the performance of fans themselves and to the resistance to flow arising from the associated ductwork. Figure 6 illustrates the typical fan and thermal conditioning needs for a variety of ventilation rates and climate conditions.

Building design has traditionally assumed an unchanging climate. However, the comfort of building occupants is dependent on many environmental parameters (air temperature, relative humidity, air quality, lighting and noise) including those provided by the building envelope, building environmental services and control systems.

Control of indoor environmental conditions in the winter and summer months is often relatively straightforward as only heating or cooling are required respectively, as there is often a large difference between the required indoor conditions and the outdoor conditions, e.g., temperature.

However, during the mid-seasons opportunity often exists to take advantage of phase and value differences between indoor and outdoor environments to enable improvements in the energy efficiency of building environmental services. Consequentially, opportunity sometimes exists to increase fresh air ventilation rates and reduce indoor air temperatures without the need for mechanical cooling. Simultaneously, the benefit of improved indoor air quality is realised as a result of increased fresh air ventilation rates.

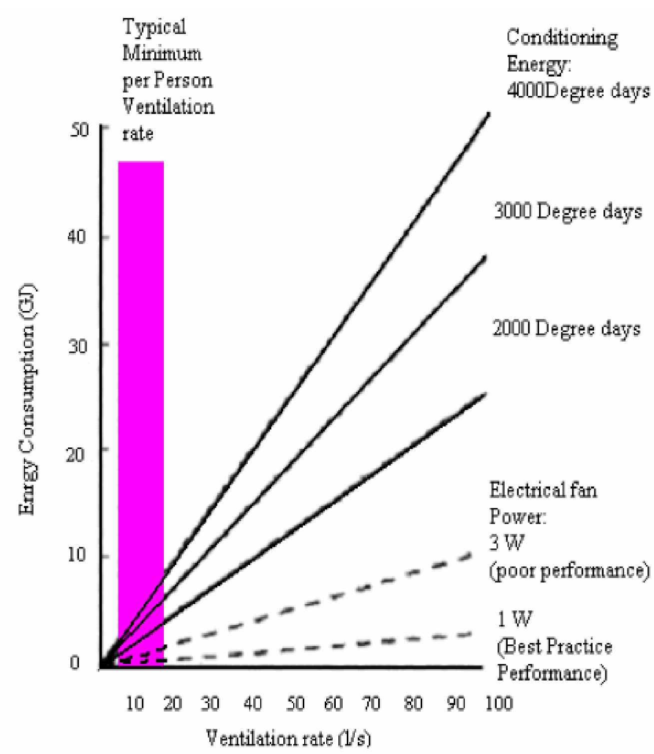


Fig. 6 Energy impact of ventilation

It was also decided that cost efficiency was to be taken into account and should not be compromised in favour of energy efficiency as this would have a negative impact on the overall building performance.

It was proposed that the central system objectives were to maintain indoor environmental quality within a predefined control volume, i.e., within parameters, while considering the best course of action with respect to energy and cost efficiencies. Temperature and relative humidity were assigned upper limits, lower limits, and preferred values to be sought when they were achievable without adversely affecting cost or energy efficiencies. Global investment in renewables and energy efficiency now outpaces that for nuclear energy. Renewables also accounted for more than a fifth of new generation capacity built in 2007.

6. Wastes

Waste is defined as an unwanted material that is being discarded. Waste includes items being taken for further use, recycling or reclamation. Waste produced at household, commercial and industrial premises are control waste and come under the waste regulations. Waste Incineration Directive (WID) emissions limit values will favour efficient, inherently cleaner technologies that do not rely heavily on abatement. For existing plant, the requirements are likely to lead to improved control of:

- NO_x emissions, by the adoption of infurnace combustion control and abatement techniques.
- Acid gases, by the adoption of abatement techniques and optimisation of their control.
- Particulate control techniques, and their optimisation, e.g., of bag filters and electrostatic precipitators.

The waste and resources action programme has been working hard to reduce demand for virgin aggregates and market uptake of recycled and secondary alternatives (Appendix 4). The programme targets are:

- To deliver training and information on the role of recycling and secondary aggregates in sustainable construction for influences in the supply chain, and
- To develop a promotional programme to highlight the new information on websites.

7. Chemicals

Humans and wildlife are being contaminated by a host of commonly used chemicals in food packaging and furniture, according to the World Wildlife Federation (WWF) and European Union. The chemical industry has been under no obligation to make the information public. The new rules would change this. Future dangers will only be averted if the effects of chemicals are exposed and then the dangerous ones are never used. Indeed, chemicals used for jacket waterproofing, food packaging and non-stick coatings have been found in dolphins, whales, cormorants, seals, sea eagles and polar bears from the Mediterranean to the Baltic. The European Commission has adopted an ambitious action plan to improve the development and wider use of environmental technologies such as recycling systems for wastewater in industrial processes, energy-saving car engines and soil remediation techniques, using hydrogen and fuel cells. The legislation that has not been implemented in time concerns the incineration of waste, air quality limit, values for benzene and carbon monoxide, national emission ceilings for sulphur dioxide, nitrogen oxides, volatile organic compounds and ammonia and large combustion plants. Measures to maximise the use of high-efficiency generation plants and on-site renewable energy resources are important for raising the overall level of energy efficiency. The world's view of waste has changed dramatically in recent years and it is now seen as a source to feed the ever-growing demand for energy. The road from the initial concept to the production of the first kilowatt of power is long and has many challenges, not least the need for adequate funding.

8. Ground Source Heat Pumps

Ground source heat pumps (GSHPs) can be used to extract heat from the ground and pump it into a building to provide space heating and to pre-heat domestic hot water. In the summer months this process can be reversed to meet the cooling requirements of the building. The GSHPs are becoming an increasingly popular renewable energy technology used within properties in the United Kingdom. Surprisingly, the concept of heating and cooling through the use of heat pump technology is nothing new. Heat pumps are commonplace in most households and offices in the form of refrigerators and air conditioning. They are designed to transfer heat from one place to another, by use of a compressor. The GSHPs are electrically powered systems that tap the stored energy of the greatest solar collector in existence: the earth (Figure 7). These systems use the earth's relatively constant temperature to provide heating, cooling, and hot water for homes and commercial buildings.

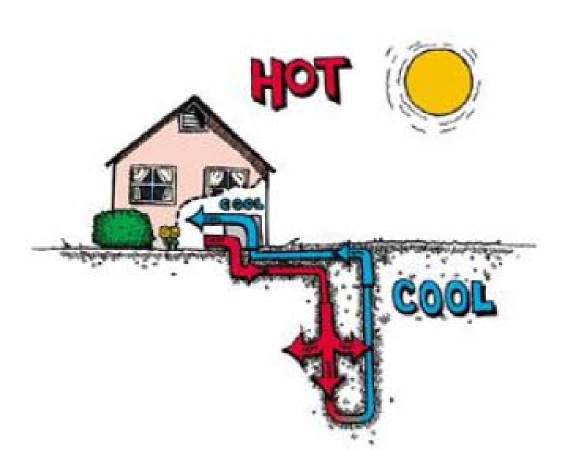


Fig. 7 A sketch showing operation of ground source heat pump

The GSHPs can be categorised as having both closed or open loops and those loops can be installed in three ways: horizontally, vertically, or in a pond/lake. The type chosen depends on the available land areas and the soil and rock type at the installation site. These factors will help determine the most economical choice for installation of the ground loop. For closed loop systems, water or antifreeze solution is circulated through plastic pipes buried beneath the earth's surface. During the winter, the fluid collects heat from the earth and carries it through the system and into the building (Appendix 5).

During the summer, the system reverses itself to cool the building by pulling heat from the building, carrying it through the system and placing it in the ground. This process creates free hot water in the summer and delivers substantial hot water savings in the winter. Open loop systems operate on the same principle as closed loop systems and can be installed where an adequate supply of suitable water is available and open discharge is feasible. Benefits similar to the closed loop system are obtained. The heat is extracted from the cabinet to keep food fresh and the extracted heat is expelled through the radiator grill at the back of the unit.

There are three important elements to a GSHP system: the ground loop, the heat pump and the heat distribution system. These are described below.

8.1 Ground Loops

The ground loops are comprised of lengths of pipe buried in the ground, either in a borehole or a horizontal trench. The pipe is usually a closed circuit and is filled with a mixture of water and antifreeze. This mixture circulates in the pipe, absorbing heat from the ground.

8.2 Heat Pumps

The heat pump works by promoting the evaporation and condensation of a refrigerant to move heat from one place to another. A heat exchanger transfers heat from the water/antifreeze mixture in the ground loop to heat and evaporate refrigerants, changing them to a gaseous state. A compressor is then used to increase the pressure and raise the temperature at which the refrigerant condenses. This temperature is increased to approximately 40°C. A condenser gives up heat to a hot water tank, which then feeds the distribution system. This has three main parts:
The evaporator (e.g., the squiggly thing in the cold part of the fridge) takes the heat from the water in the ground loop.

The compressor (this is what makes the noise in a fridge) moves the refrigerant round the heat pump and compresses the gaseous refrigerant to the temperature needed for the heat distribution circuit.
The condenser (the hot part at the back of the fridge) gives up heat to a hot water tank, which feeds the distribution system.

8.3 Heat Distribution System

Because GSHPs raise the temperature to approximately 40°C they are most suitable for underfloor heating systems, which require temperatures of 30 to 35°C, as opposed to conventional boiler systems, which require higher temperatures of 60 to 80°C.

The GSHPs can also be combined with radiator space heating systems and with domestic hot water systems. However, top-up heating would be required in both cases in order to achieve temperatures high enough for these systems. Some systems can also be used in reverse mode for cooling in the summer.

The heat distribution system consists of the under floor heating or radiators for space heating and in some cases water storage for the hot water supply. The ground loop can be:

1 Borehole: A borehole is drilled to a depth of between 15 to 100 metres and will benefit from higher ground temperatures than a horizontal trench, although installation costs will be greater.
2 Straight horizontal: Horizontal trenches are drilled to a depth of 1 to 2 metres and can cost less than boreholes, but require a greater area of land. Placing coiled piping in horizontal trenches will enhance the performance compared with straight piping.
3 Spiral horizontal (or 'slinky coil')- needs a trench of about 10 m length to provide about 1 kW of heating load.

The efficiency of a GSHP system is measured by the coefficient of performance (COP). This is the ratio of units of heat output for each unit of electricity used to drive the compressor and pump for the ground loop. Typical COPs range from 2.5 to 4. The higher end of this range is for under-floor heating, because it works at a lower temperature (30-35ºC) than radiators.

Based on current fuel prices, assuming a COP of 3-4, a GSHP can be a cheaper form of space heating than oil, LPG and electric storage heaters. It is however more expensive than mains gas. If grid electricity is used for the compressor and pump, then an economy 7 tariff usually gives the lowest running costs [35].

Considerations for using ground source heat pumps:

- The heat distribution systems of the GSHPs can be combined with radiators, however under-floor heating would perform better because of the lower temperature.
- There must be enough space to allow operation of the digging machinery and to accommodate the ground loop borehole.
- Energy from the GSHPs can replace/offset the conventional fuels (electricity, oil, LPG or any other conventional fossil fuel) and reduce CO_2 emissions.
- The auxiliary energy to drive the compressor and the pump can be provided from renewable energy sources.
- The GSHPs are suitable and could be used for providing both heating and cooling loads.
- If the system is for a new building development, combining the installation with other building works can reduce costs.
- Incorporating wall, floor and loft insulation will lower the heat demand and should be included.

The term “ground source heat pump” has become an all-inclusive term to describe a heat pump system that uses the earth, ground water, or surface water as a heat source and/or sink. Some of the most common types of ground source ground-loop heat exchangers configurations are classified in Figure 8.

The GSHP systems consist of three loops or cycles as shown in Figure 9. The first loop is on the load side and is either an air/water loop or a water/water loop, depending on the application. The second loop is the refrigerant loop inside a water source heat pump.

The principle idea was to use the dry-cooler to store cold in the wellfield during early spring, when the required summer peak load cool can be generated very efficiently and cheaply. A geothermal energy system uses the ground as a heat-source or heat sink, depending on whether the systems were used in a heating or cooling mode. The ground is principally suited for low temperature energy exchange. The usual operating temperature bandwidth is between –5°C and 40°C (not taking into account high temperature energy stores). Different systems for exchanging energy with the ground are currently in use, such as direct use of groundwater, closed-loop ground heat exchangers or direct expansion. It is known that during the normal life span of a building the surplus of heat would lead to higher ground temperatures.

Thermodynamically, there is no difference between the well-known vapour-compression refrigeration cycle and the heat pump cycle; both systems absorb heat at a low temperature level and reject it to a higher temperature level. However, the difference between the two systems is that a refrigeration application is only concerned with the low temperature effect produced at the evaporator, while a heat pump may be concerned with both the cooling effect produced at the evaporator and the heating effect produced at the condenser. In these dual-mode GSHP systems, a reversing valve is used to switch between heating and cooling modes by reversing the refrigerant flow direction. The third loop in the system is the ground loop in which water or an antifreeze solution exchanges heat with the refrigerant and the earth [36-40].

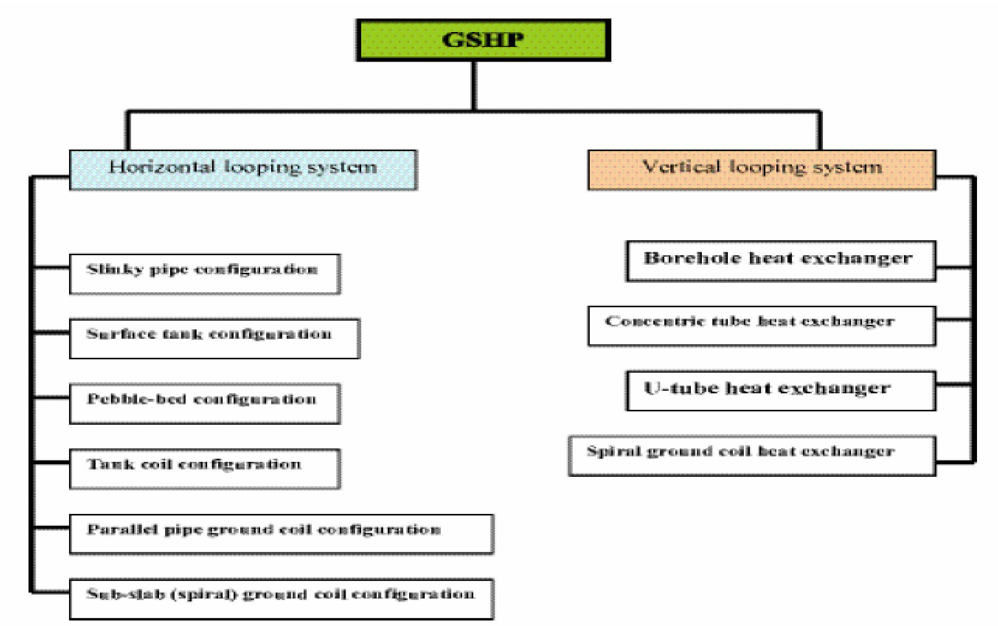


Fig. 8 Common types of ground-loop heat exchangers

The GSHPs utilise the thermal energy stored in the earth through either vertical or horizontal closed loop heat exchange systems buried in the ground. Many geological factors impact directly on site characterisation and subsequently the design and cost of the system. The solid geology of the United Kingdom varies significantly.

Furthermore there is an extensive and variable rock head cover. The geological prognosis for a site and its anticipated rock properties influence the drilling methods and therefore system costs.

Other factors important to system design include predicted subsurface temperatures and the thermal and hydrological properties of strata. An ideal heat source for heat pumps in buildings has a high and stable temperature during the heating season, is abundantly available, is not corrosive or polluted, has favourable thermophysical properties, and its utilisation requires low investment and operational costs.

The GSHP technology is well established in Sweden, Germany and North America, but has had minimal impact in the United Kingdom space heating and cooling market. Perceived barriers to uptake include geological uncertainty, concerns regarding performance and reliability, high capital costs and lack of infrastructure. System performance concerns relate mostly to uncertainty in design input parameters, especially the temperature and thermal properties of the source. These in turn can impact on the capital cost, much of which is associated with the installation of the external loop in horizontal trenches or vertical boreholes. The climate in the United Kingdom makes the potential for heating in winter and cooling in summer from a ground source less certain owing to the temperature ranges being narrower than those encountered in continental climates. This project will develop an impartial GSHP function on the site to make available information and data on site-specific temperatures and key geotechnical characteristics [41-50].

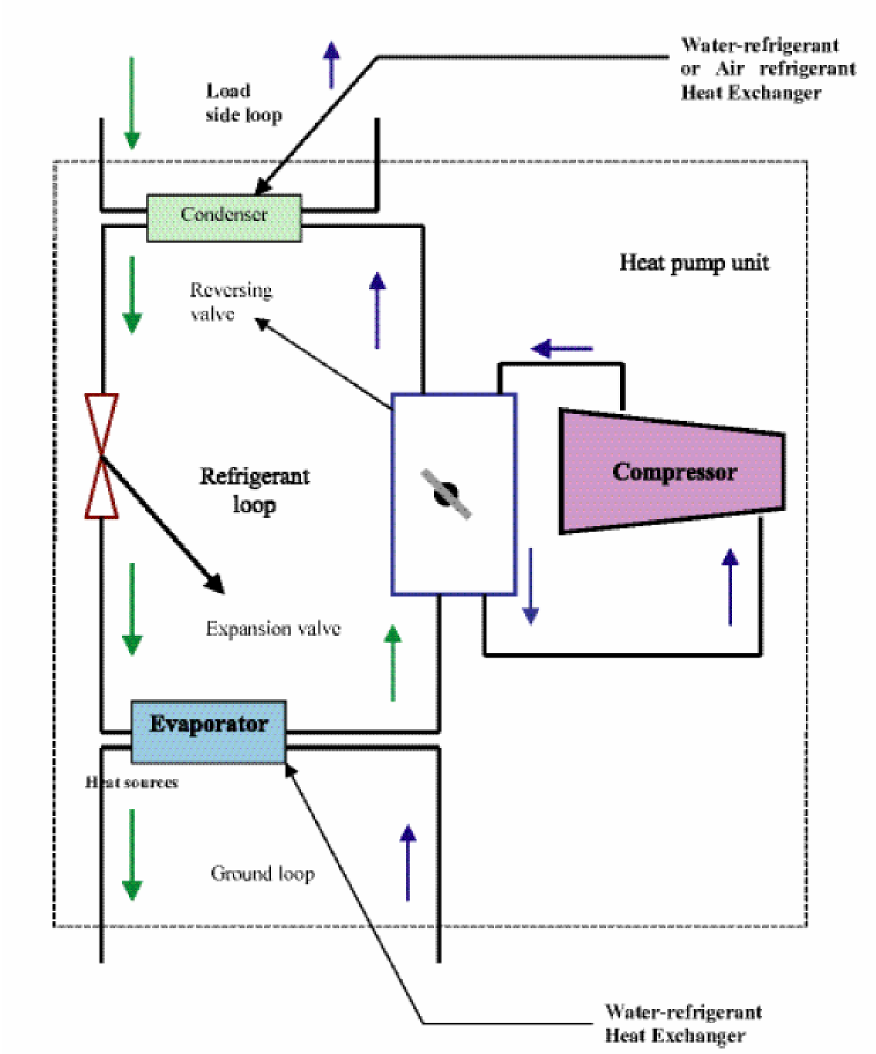


Fig. 9 Schematic of GSHP system (heating mode operation)

The GSHPs are receiving increasing interest because of their potential to reduce primary energy consumption and thus reduce emissions of greenhouse gases. The technology is well established in North Americas and parts of Europe, but is at the demonstration stage in the United Kingdom. The information will be delivered from digital geoscience's themes that have been developed from observed data held in corporate records. This data will be available to the GSHP installers and designers to assist the design process, therefore reducing uncertainties. The research will also be used to help inform the public as to the potential benefits of this technology.

The GSHPs play a key role in geothermal development in Central and Northern Europe. With borehole heat exchangers as heat source, they offer de-central geothermal heating with great flexibility to meet given demands at virtually any location. No space cooling is included in the vast majority of systems, leaving ground-source heat pumps with some economic constraints. Nevertheless, a promising market development first occurred in Switzerland and Sweden, and now also in Austria and Germany. Approximately 20 years of (R & D) focusing on borehole heat exchangers resulted in a well-established concept of sustainability for this technology, as well as in sound design and installation criteria. The market success brought Switzerland to the third rank worldwide in geothermal direct use. The future prospects are good, with an increasing range of applications including large systems with thermal energy storage for heating and cooling, ground-source heat pumps in densely populated development areas, borehole heat exchangers for cooling of telecommunication equipment, etc.

Loops can be installed in three ways: horizontally, vertically or in a pond or lake. The type chosen depends on the available land area, soil and rock type at the installation site. These factors help to determine the most economical choice for installation of the ground loop. The GSHP delivers 3-4 times as much energy as it consumes when heating, and cools and dehumidifies for a lower cost than conventional air conditioning. It can cut homes or business heating and cooling costs by 50% and provide hot water free or with substantial savings [51-55].

The GSHPs can reduce the energy required for space heating, cooling and service water heating in commercial/institutional buildings by as much as 50%. Figure 10 shows the GSHP extract solar heat stored in the upper layers of the earth. It is a good and practical idea to explore ways of minimising space heating and hot water demand by incorporating energy efficiency measures.

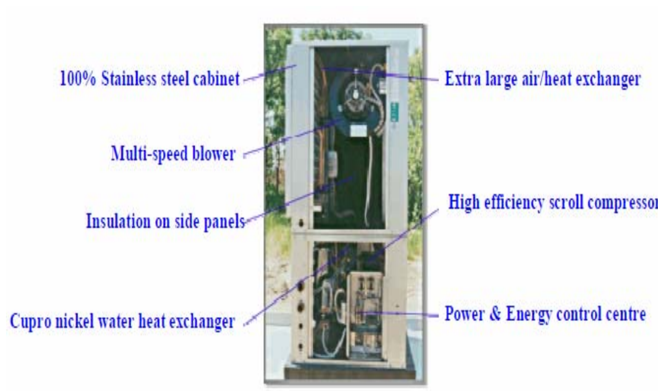


Fig. 10 GSHPs extract solar heat stored in the upper layers of the earth

8.4 Mitigation Measures

Potential mitigation measures to decrease GHG emissions from the oil industry and decelerate the threat of global climate change may include the following:

- Controlling GHGs emissions by improving the efficiency of energy use, changing equipment and operating procedures.
- Controlling GHGs emission detection techniques in oil production, transportation and refining processes.
- More efficient use of energy-intensive materials and changes in consumption patterns.
- A shift to low carbon fuels, especially in designing new refineries.
- The development of alternative energy sources (e.g., biomass, solar, wind, hydro-electrical and cogeneration).
- The development of effective environment standards, policies, laws and regulations particularly in the field of oil industry.

- Activating and supporting environmental and pollution control activities to effectively cope with the evolving oil industry.

9. Recommendations

- Launching of public awareness campaigns among local investors particularly small-scale entrepreneurs and end users of RETs to highlight the importance and benefits of renewable, particularly solar, wind, and biomass energies.
- Amendment of the encouragement of investment act, to include furthers concessions, facilities, tax holidays, and preferential treatment to attract national and foreign capital investment.
- Allocation of a specific percentage of soft loans and grants obtained by governments to augment budgets of (R & D) related to manufacturing and commercialisation of RETs.
- Governments should give incentives to encourage the household sector to use renewable energy instead of conventional energy.
- Execute joint investments between the private sector and the financing entities to disseminate the renewable with technical support from the research and development entities.
- Availing of training opportunities to personnel at different levels in donor countries and other developing countries to make use of their wide experience in application and commercialisation of RETs particularly renewable energy.
- The governments should play a leading role in adopting renewable energy devices in public institutions, e.g., schools, hospitals, government departments, police stations, etc., for lighting, water pumping, water heating, communication and refrigeration.
- Encouraging the private sector to assemble, install, repair and manufacture renewable energy devices via investment encouragement and more flexible licensing procedures.

10. Conclusions

There is strong scientific evidence that the average temperature of the earth's surface is rising. This is a result of the increased concentration of carbon dioxide and other GHGs in the atmosphere as released by burning fossil fuels. This global warming will eventually lead to substantial changes in the world's climate, which will, in turn, have a major impact on human life and the built environment.

Therefore, effort has to be made to reduce fossil energy use and to promote green energies, particularly in the building sector. Energy use reductions can be achieved by minimising the energy demand, by rational energy use, by recovering heat and the use of more green energies.

This study was a step towards achieving that goal. The adoption of green or sustainable approaches to the way in which society is run is seen as an important strategy in finding a solution to the energy problem.

The key factors to reducing and controlling CO_2, which is the major contributor to global warming, are the use of alternative approaches to energy generation and the exploration of how these alternatives are used today and may be used in the future as green energy sources. Even with modest assumptions about the availability of land, comprehensive fuel-wood farming programmes offer significant energy, economic and environmental benefits.

These benefits would be dispersed in rural areas where they are greatly needed and can serve as linkages for further rural economic development. The nations as a whole would benefit from savings in foreign exchange, improved energy security, and socio-economic improvements.

With a nine-fold increase in forest – plantation cover, a nation's resource base would be greatly improved. The international community would benefit from pollution reduction, climate mitigation, and the increased trading opportunities that arise from new income sources.

The non-technical issues, which have recently gained attention, include: (1) Environmental and ecological factors, e.g., carbon sequestration, reforestation and revegetation. (2) Renewables as a CO_2 neutral replacement for fossil fuels. (3) Greater recognition of the importance of renewable energy, particularly modern biomass energy carriers, at the policy and planning levels. (4) Greater recognition of the difficulties of gathering good and reliable renewable energy data, and efforts to improve it. (5) Studies on the detrimental health efforts of biomass energy particularly from traditional energy users.

The GSHPs provide an effective and clean way of heating buildings worldwide. They make use of renewable energy stored in the ground, providing one of the most energy-efficient ways of heating buildings. They are suitable for a wide variety of building types and are particularly appropriate for low environmental impact projects. They do not require hot rocks (geothermal energy) and can be installed in most of the world, using a borehole or shallow trenches or, less commonly, by extracting heat from a pond or lake. Heat collecting pipes in a closed loop, containing water (with a little antifreeze) are used to extract this stored energy, which can then be used to provide space heating and domestic hot water. In some applications, the pump can be reversed in summer to provide an element of cooling.

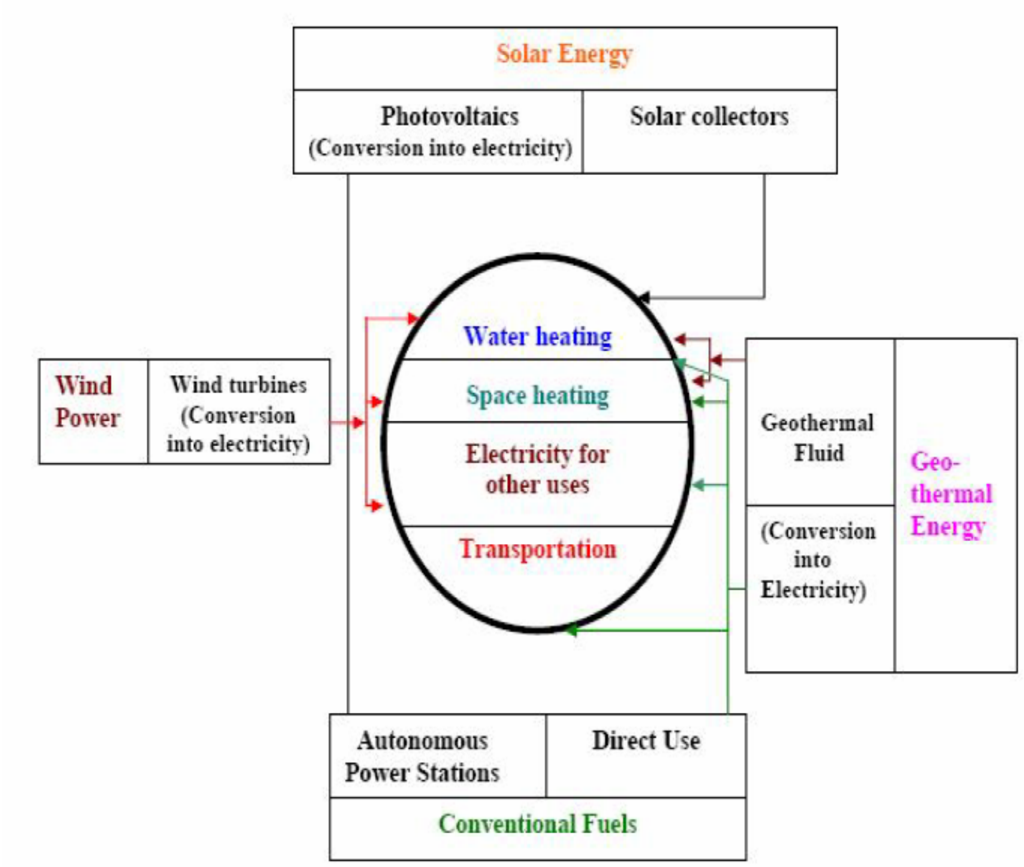
Typically, a GSHP will deliver three or four times as much thermal energy (heat) as is used in electrical energy to drive the system. For a particularly environmental solution, green electricity can be purchased.

Over its first year of operation, the ground source heat pump system has provided 91.7% of the total heating requirement of the room and 55.3% of the domestic water-heating requirement, although only sized to meet half the design-heating load. The heat pump has operated reliably and its performance appears to be at least as good as its specification. The system has a measured annual performance factor of 3.16. The system is quiet and unobtrusive and achieved comfort levels. The heat pump does not reduce the useful space in the laboratory, and there are no visible signs of the installation externally (no flue, vents, etc.). The performance of the heat pump system could be improved by eliminating unnecessary running of the integral distribution pump. It is estimated that reducing the running time of this pump, which currently runs virtually continuously, would increase the overall performance factor to 3.43. This would improve both the economics and the environmental performance of the system. More generally, there is still potential for improvement in the performance of heat pumps, and seasonal efficiencies for ground source heat pumps of 4.0 are already being achieved. It is also likely that unit costs will fall as production volumes increase.

Heat pump technology can be used for heating only, or for cooling only, or be 'reversible' and used for heating and cooling depending on the demand. Reversible heat pumps generally have lower COPs than heating only heat pumps. They will, therefore, result in higher running costs and emissions.

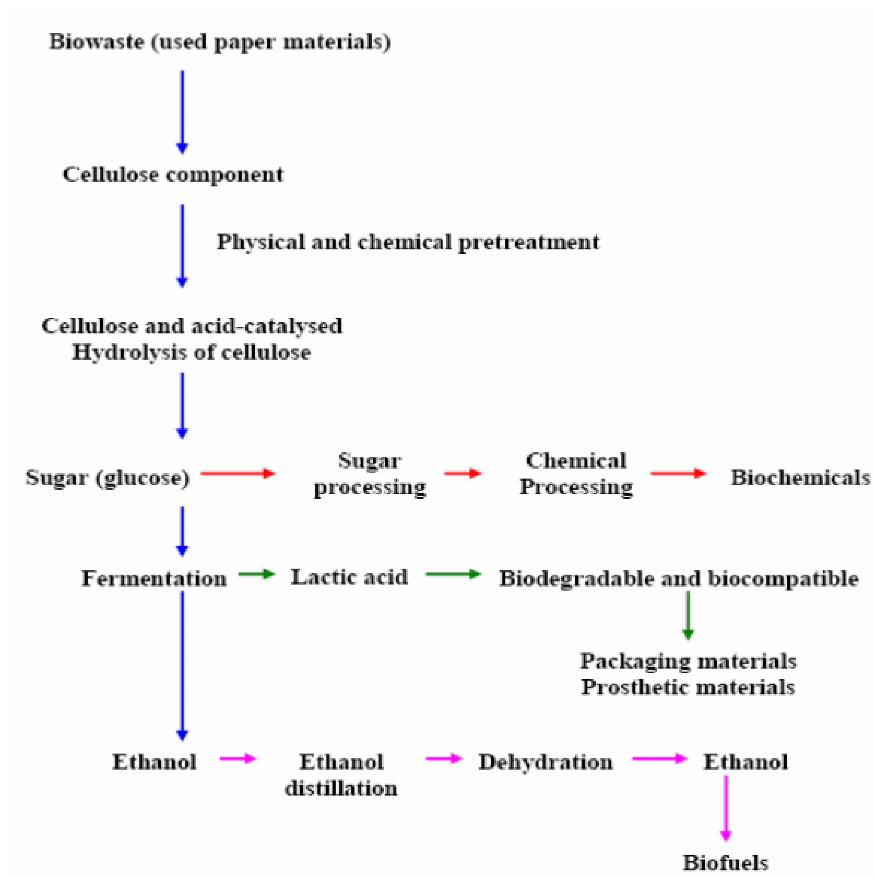
Appendix (1) Energy Sources Their Final Uses

Different sources of energy, which can be used for different final uses. Those sources are: wind power, solar energy, geothermal energy, the existing electricity production system and the conventional fuels with direct use. The main categories of final uses are: transportation, space heating, water heating and electricity for other uses.

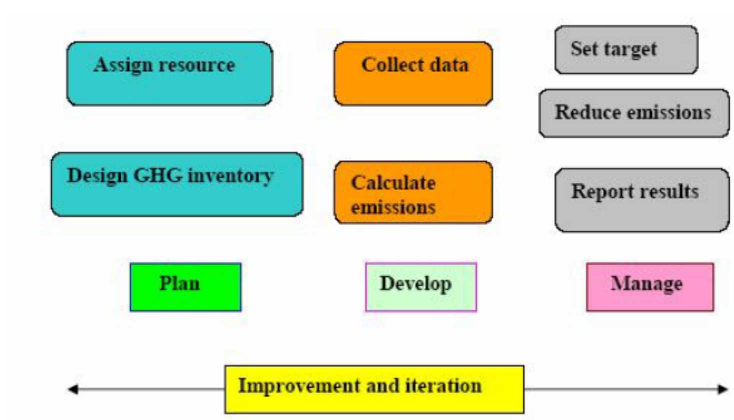


Appendix (2) Solar Photovoltaic Arrays

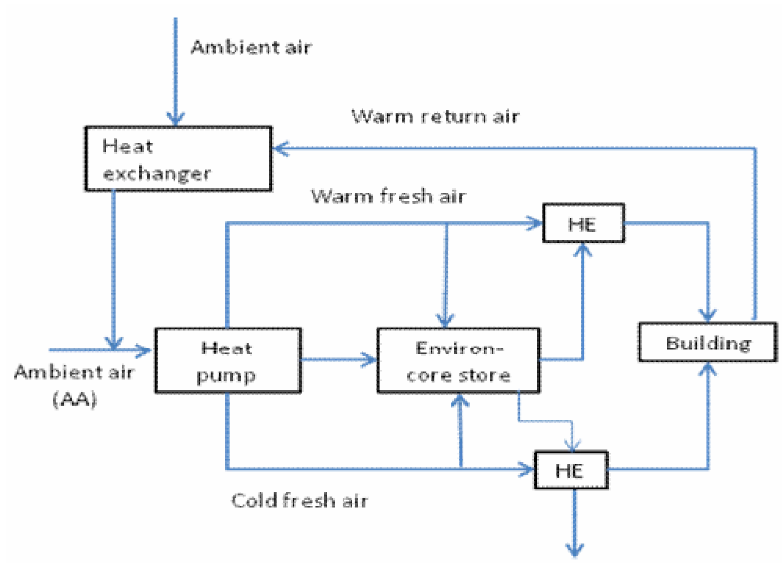
Appendix (3) Utilisation of Biowaste Such as Wastepaper Materials for Bioproduct Development



Appendix (4) Improvement to Tackle Global Warming



Appendix (5) Flow Chart of Combined Heating and Cooling with Air-Source Heat Pump and Energy Recovery from Return Air in Combination with Environ-Core Thermal Storage



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