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Review

Clean energies for sustainable development for built environment

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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: Climate, energy, natural resources, carbon dioxide, technologies.

INTRODUCTION

Over millions of years ago, the plants have covered the earth converting the energy of sunlight into living plants and animals, some of which were buried in the depths of the earth to produce deposits of coal, oil and natural gas (Cantrell and Wepfer, 1984; ASHRAE, 1995; Kavanaugh and Rafferty, 1997). The past few decades, however, have experienced many valuable uses for these complex chemical substances and manufacturing from them plastics, textiles, fertilisers and the various end products of the petrochemical industry. Indeed, each decade seeks 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 (UNFCCC, 2009).

Industrial 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.

Some emphasis has recently been put on the utilisation of the ambient energy from ground source and other renewable energy sources in order to stimulate alternative energy sources for heating and cooling of buildings. Exploitation of renewable energy sources and particularly ground heat in buildings can significantly contribute towards reducing dependency on fossil fuels. This section highlights the potential energy saving that could be achieved through use of ground energy source.
Under the 1997 Montreal Protocol, governments agreed to phase out chemicals used as refrigerants that have the potential to destroy stratospheric ozone (Abdeen, 2011). It was also considered desirable to reduce energy consumption and consequently decrease the rate of

depletion of world energy reserves and pollution of the environment. Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of CO_2, NO_x and CFCs emissions triggered a renewed interest in environmentally friendly cooling, and heating technologies (Rees, 1999).

One way of reducing building energy consumption is to design buildings, which are more efficient in their use of energy for heating, lighting, cooling, ventilation and hot water supply. Passive measures, particularly natural or hybrid ventilation rather than air-conditioning, can dramatically reduce primary energy consumption (Abdeen, 2011). Exploitation of renewable energy in buildings and agricultural greenhouses can, also, significantly contribute towards reducing dependency on fossil fuels. Therefore, promoting innovative renewable applications, particularly the ground source energy will contribute to the preservation of the ecosystem by reducing emissions at local and global levels. This will in turn contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or greenhouse gases. Therefore, an approach is needed to integrate renewable energies in a way to meet high building performance. However, because renewable energy sources are stochastic and geographically diffuse their ability to match demand is determined either by the utilisation of a greater capture area than that occupied by the community to be supplied or the reduction of the community's energy demands to a level commensuratable with the locally available renewable resources (Abdeen, 2010).

ENERGY SOURCES AND THEIR USE

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 displaying 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 (UNFCCC, 2009).

The World Summit on Sustainable Development in Johannesburg in 2002 (UNFCCC, 2009) 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:

1. Trying to ensure economic growth does not cause environmental pollution.
2. Improving resource efficiency.
3. Examining the whole life-cycle of a product.
4. Enabling consumers to receive more information on products and services.
5. 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 has to be changed first. It is now universally accepted that climate change is real. It is happening now, and GHGs produced by human activities are significantly contributing to it. The predicted global temperature increase between 1.5 and 4.5°C could lead to potentially catastrophic environmental impacts (UN, 2003). 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 (UN, 2003). 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 (UN, 2003). 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 renewable to deliver the necessary cuts in GHG emissions is more to do with politics and policy issues than with technical ones (Bos et al., 1994). For example, the single most important step of governments that 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 ones (Bos et al., 1994; Duchin, 1995).

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 (Duchin, 1995). Hence, an approach is needed to integrate renewable energies in a way that meets the rising demand in a cost-effective way.

Alternative energy sources

Utilised renewable resources currently account for about 9 to 10% of the energy consumed in the world; most of this is from hydropower and traditional biomass sources (Abdeen, 2010). Wind, solar, biomass and geothermal technologies are already cost-effective today in an increasing number of markets and are making important steps to broaden commercialisation. The present situation is best characterised as one of very rapid growth for wind and solar technologies and of significant promise for biomass and geothermal technologies. Each of the renewable energy technologies is in a different stage of research, development and commercialisation and all have differences in current and future expected costs, current industrial base, resource availability and potential impact on energy supply chain.

Technology need/justification

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 140×10^{24} joules per day (Abdeen, 2009). Only a fraction of this (5×10^{21} joules) can be regarded as having economic prospects, and only about 10% of this is likely to be exploited by the year 2020 (Abdeen, 2009). Three main techniques are used to exploit the heat available: geothermal aquifers, hot dry rocks and ground source heat pumps. However, only the ground source heat pumps are considered in this study because the other previous two are expensive.

Goals

The purpose of this study is to establish the suitability of ground source heat pumps (GSHPs) for heating and cooling and to develop a design tool and document the necessary design parameters, and the savings in energy use and demand that GSHPs may reasonably be expected to achieve. This design tools will be verified using measured data. The main objective of this study is to stimulate the uptake of the GSHPs. The GSHPs are well suited to space heating and cooling, and can produce significant reduction in carbon emissions. The tools that are currently available to design a GSHP system require the use of key site-specific parameters such as temperature and the thermal and geotechnical properties of the local area. This study deals with the modelling of vertical closed-loop and hybrid, ground source heat pump systems. The challenges associated with the design of these systems are discussed herein.

ROLE OF EFFICIENT ENERGY SYSTEMS

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 organisms taking into 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 focused 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 (Givoni, 1998). 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 efforts need to be made to increase people’s knowledge through training.

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 (ASHRAE, 1993). 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 (Kammerud et al., 1984). 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 (Shaviv, 1989). 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 (Singh, 2000). These include:

1. Making switches conspicuous and switching banks of lights independently.
2. Loading switches appropriately in relation to the lights.
3. 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 (Singh, 2000). The light switching options include:

1. Centralised timed off (or stepped)/manual on.
2. Photoelectric off (or stepped)/manual on.
3. Photoelectric and on (or stepped), photoelectric dimming.
4. 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 often given 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:

1. The application of environmental regulations and policy.
2. The application of environmental science and best practice.
3. Mathematical modelling and simulation.
4. Environmental design and engineering.
5. Construction and commissioning.
6. 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 (CAEEDAC, 2000; Yaldiz et al., 1993; Dutt, 1982; Baruah, 1995; Thakur and Mistra, 1993; Wu and Boggess, 1999) in order to quantify the influence of these factors (Abdeen, 2010, 2011).

RENEWABLE ENERGY TECHNOLOGIES

Sustainable energy is the 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. It is an accepted fact that renewable energy is a sustainable form of energy, which has attracted more attention during recent years. Increasing environmental interest, as well as economic consideration of fossil fuel consumption and high emphasis of sustainable development for the future helped to bring the great potential of renewable energy into focus. Nearly a fifth of all global power is generated by renewable energy sources, according to a new book published by the OECD/IEA, (2004). This book entitled ‘‘Renewables for power generation: status and prospects’’ claims that, at approximately 20%, renewables are the second largest power source after coal (39%) and ahead of nuclear (17%), natural gas (17%) and oil (8%) respectively. From 1973 to 2000 renewables grew at 9.3% a year, and it was predicted that this would increase by 10.4% a year to 2015. Therefore, promoting innovative renewable applications and reinforcing the renewable energy technologies market will contribute to preservation of the ecosystem by reducing emissions at local and global levels. Wind power grew fastest at 52% and should be multiply seven times by 2015, overtaking biopower and hence helping reducing green house gases, GHGs, emissions to the environment. This will also contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or greenhouse gases (during their use).

Table 2 shows some applications of different renewable energy sources. The challenge is to match leadership in GHG reduction and production of renewable energy with developing a major research and manufacturing capacity in environmental technologies (wind, solar, fuel cells, etc.). 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. It has to be integrated in the regional development plans.

Solar energy

The availability of data on solar radiation is a critical problem. Even in developed countries, very few weather stations have recorded 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. Second, the radiation nature of solar radiation makes the computation of the size of such systems difficult. 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

Table 1. Energy equivalent of inputs and outputs (Hall, and Scrase, 1998)

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		
Cereal and pulses	kg	14.7
Sugar beet	kg	5.04
Tobacco	kg	0.8
Cotton	kg	11.8
Oil seed	kg	25
Fruits	kg	1.9
Vegetables	kg	0.8
Water melon	kg	1.9
Onion	kg	1.6
Potatoes	kg	3.6
Olive	kg	11.8
Tea	kg	0.8
8. By products		
Husk	kg	13.8
Straw	kg	12.5
Cob	kg	18.0
Seed cotton	kg	25.0
Total output	kg	149.04 MJ/kg

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

Table 2. Sources of renewable energy (Abdeen, 2007).

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
CHP (Combined heat and power)	High efficiency lighting	Wide
	High efficiency electric	Wide
	Householders appliances	Wide
	High efficiency boilers	Small-medium
	Plants coupled with refrigerating absorption machines	Medium-large

CHP (Combined heat and power).

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 (Duffie and Beckman, 1980; Sivkov, 1964a, b; Barabaro et al., 1978; Abdeen, 2010, 2011).

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 photovoltaic PV systems as 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 belong also to solar energy technologies. 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, though possible, 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 (Sivkov, 1964a, 1964b).

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

$$E_w = \rho_w \, g \, V \, H \qquad (1)$$

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 power required is given by:

$$P_{sa} = E_w / E_{sr} \, \eta \, F \qquad (2)$$

Where: P_{sa} is the solar array peak 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 (1) in Equation (2), the following

Table 3. Classifications of bio-energy resources data requirements (Omer, 2008).

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 4. Effective biomass resource utilisation (Abdeen, 2007).

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

equation is obtained for the amount of water that can be pumped:

$$V = P_{sa} E_{sr} \eta F / \rho_w g H \qquad (3)$$

The approximative values, $P_{sa} = 1.6$ kW$_p$, $F = 0.85$, $\eta = 40\%$, may be taken into consideration.

Further increases of PV (photovoltaic systems) depend on the ability to improve the durability, performance and the local manufacturing capabilities of PV.

Biomass

The data required to perform the trade-off analysis simulation of bio-energy resources can be classified according to the divisions given in Table 3, namely the overall system or individual plants, and the existing situation or future development. The effective economical utilisations of these resources are shown in Table 4, 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 5. However, biomass usage and application can generally be divided into the following three categories.

1. Biomass energy for petroleum substitution driven by the following factors:

a. Oil price increase,
b. Balance of payment problems, and economic crisis, c. Fuel-wood plantations, and residue utilisation,
d. Wood based heat and electricity,
e. Liquid fuels from biomass,

Table 5. Agricultural residues routes for development (Abdeen, 2008a).

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	Urban fuel
		Carbonised	Energy services
	Fermentation	Biogas	Household, and 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

f. Producer gas technology.

2. Biomass energy for domestic needs driven by:

a. Population increase,
b. Urbanisation,
c. Agricultural expansion,
d. Fuel-wood crisis,
e. Ecological crisis,
f. Fuel-wood plantations, agro-forestry,
g. Community forestry, and residue utilisation,
h. Improved stoves, and improved charcoal production.

3. Biomass energy for development driven by

a. Electrification,
b. Irrigation and water supply,
c. Economic and social development,
d. Fuel-wood plantations,
e. Community forestry,
f. Agro-forestry,
g. Briquettes,
h. Producer gas technology.

The use of biomass through direct combustion has long been, and still is, the most common mode of biomass utilisation (Table 5). 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:

1. Carbonisation and briquetting.
2. Improved stoves.
3. Biogas.
4. Improved charcoal.
5. Gasification.

Briquetting and carbonisation

Briquetting is the formation of a charcoal (an energy-dense solid fuel source) from otherwise wasted agricultural and forestry residues. 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.

Charcoal is produced by slow heating wood (carbonisation) in airtight ovens or retorts, in chambers with various gases, or in kilns supplied with limited and controlled amounts of air. The charcoal yield decreased gradually from 42.6 to 30.7% for the hazelnut shell and

Table 6. Energy carrier and energy services in rural areas (Abdeen, 2009).

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 7. Biomass residues and current use (Abdeen, 2010).

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

from 35.6 to 22.7% for the beech wood with an increase of temperature from 550 to 1,150 K while the charcoal yield from the lignin content decreases sharply from 42.5 to 21.7% until it was at 850 K during the carbonisation procedures (Barabaro et al., 1978; Abdeen, 2009, 2010 and 2011). The charcoal yield decreases as the temperature increases, while the ignition temperature of charcoal increases as the carbonisation temperature increases. The charcoal briquettes that are sold on the commercial market are typically made from a binder and filler (D'Apote, 1998).

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 6). However, dry cell batteries can constitute an environmental hazard unless they are recycled in a proper fashion. Tables (6, 7) 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, e.g., (Hall and Scrase, 1998) have investigated the viability of converting the resource to a more useful form of improved charcoal, 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 7). Whichever form of biomass resource used, its sustainability would primarily depend on improved forest and tree management.

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 (Abdeen, 2009, 2010 and 2011).

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 (Hall and Scrase, 1998; Abdeen, 2009, 2010 and 2011).

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, sugar cane bagasse, and other similar fuels to generate capacities from 3 to 100 kW. Many 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, and heating value) (Hall and Scrase, 1998; Abdeen, 2009, 2010 and 2011).

Biomass and sustainability

A sustainable energy system includes energy efficiency, energy reliability, energy flexibility, fuel poverty, and environmental impacts. A sustainable biofuel has two favourable properties, which are availability from renewable raw material, and its lower negative environmental impact than that of fossil fuels. Global warming, caused by CO_2 and other substances, has become an international concern in recent years. To protect forestry resources, which act as major absorbers of CO_2, by controlling the ever-increasing deforestation and the increase in the consumption of wood fuels, such as firewood and charcoal, it's therefore an urgent issue. Given this, the development of a substitute fuel for charcoal is necessary. Briquette production technology, a type of clean coal technology, can help prevent flooding and serve as a global warming countermeasure by conserving forestry resources through the provision of a stable supply of briquettes as a substitute for charcoal and firewood.

There are many emerging biomass technologies with large and immediate potential applications, for example, 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. Table 8 gives a view of the use of biomass and its projection worldwide.

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 pro-duction, harvesting and conservation processes. 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 (Hall, and Scrase, 1998; Pernille, 2004). However, 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 R&D base.

An 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 (Abdeen, 2011). However, it is acknowledged that certain barriers need to be overcome if the objectives are to be fully achieved. These include the followings.

1. Low level of public awareness of the economic/ environmental benefits of forestry.

Table 8. Final energy projections including biomass (metric ton of equivalent 'Mtoe') (Abdeen, 2011).

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

2. The generally low levels of individuals' income.
3. Pressures from population growth.
4. The land tenural system, which makes it difficult (if at all possible) for individuals to own or establish forest plantations.
5. Poor pricing of forest products especially in the local market.
1. Inadequate financial support on the part of governments.
2. Weak institutional capabilities of the various Forestry Departments as regards technical manpower to effectively manage tree plantations.

However, social policy conditions are also critical. This is still very much lacking particularly under developing countries 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. Table 8 gives a view of the use of biomass in 2011 compared to 2020 projection.

Therefore, future research efforts should concentrate on the following areas.

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

GROUND SOURCE HEAT PUMPS

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 configuretions are classified in Figure 1. The GSHP systems consist of three loops or cycles as shown in Figure 2. 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. 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.

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. 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.

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 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 and 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 (Figure 3).

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 installa-tion of the ground loop. The GSHP delivers 3 to 4 times 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. The GSHPs can reduce the energy required for space heating, cooling and service water heating in commercial/institutional buildings by as much as 50%.

Efficiencies of the GSHP systems are much greater than conventional air-source heat pump systems. A higher COP (coefficient of performance) can be achieved by a GSHP because the source/sink earth temperature is relatively constant compared to air temperatures. Additionally, heat is absorbed and rejected through water, which is a more desirable heat transfer medium because of its relatively high heat capacity. GSHP systems rely on the fact that, under normal geothermal gradients of about 0.5°F/100 ft (30°C per km), the earth temperature is roughly constant in a zone extending from about 20 ft (6.1 m) deep to about 150 ft (45.7 m) deep. This constant temperature interval within the earth is the result of a complex interaction of heat fluxes from above (the sun and the atmosphere) and from below (the earth interior).

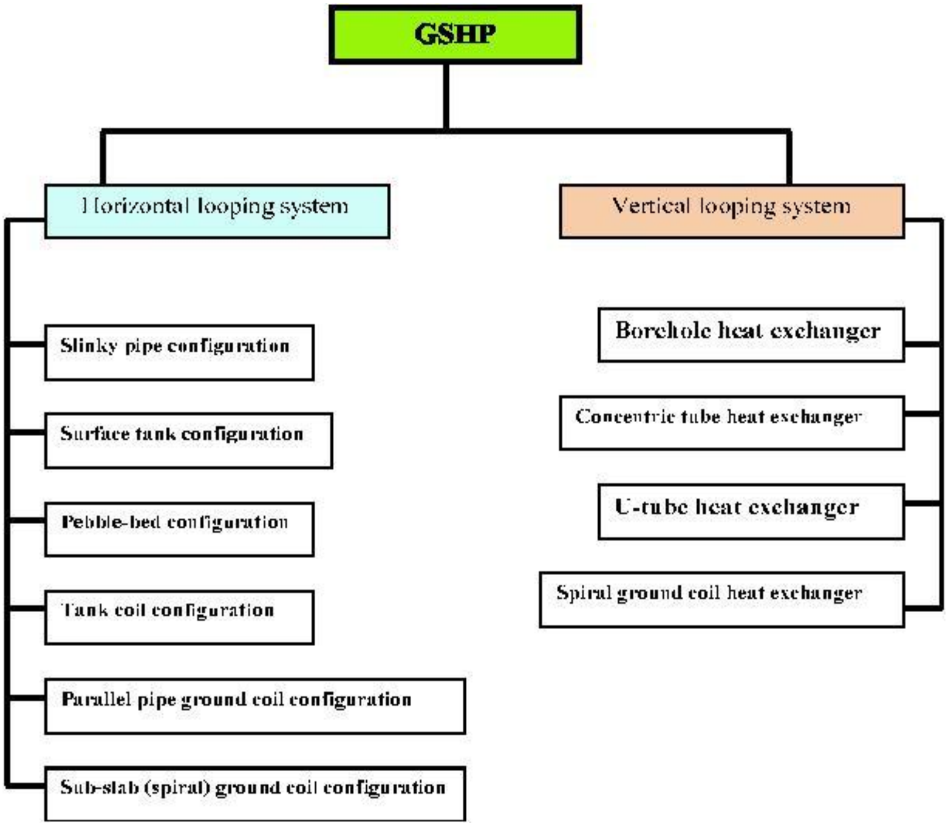

Figure 1. Common types of ground-loop heat exchangers (Abdeen, 2011).

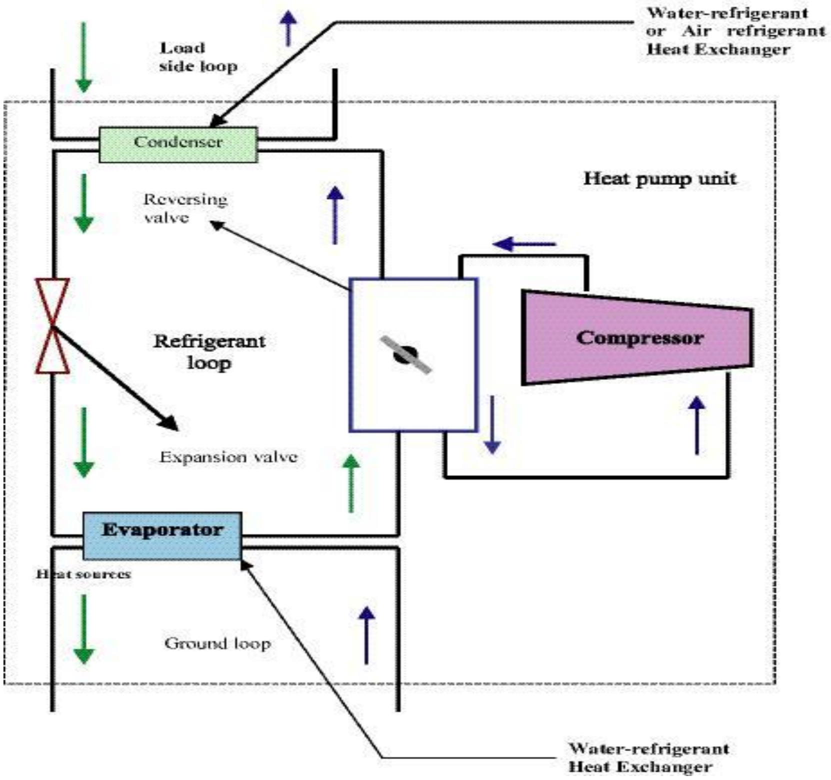

Figure 2. Schematic of GSHP system (heating mode operation) (Abdeen, 2011).

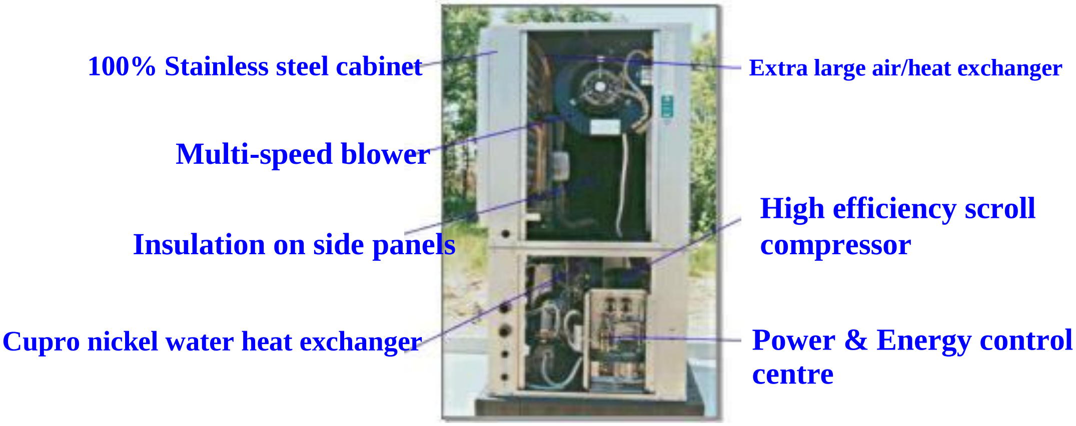

Figure 3. GSHPs extract solar heat stored in the upper layers of the earth (Abdeen, 2011).

As a result, the temperature of this interval within the earth is approximately equal to the average annual air temperature (Abdeen, 2010). Above this zone (less than about 20 feet (6.1 m) deep), the earth temperature is a damped version of the air temperature at the earth's surface. Below this zone (greater than about 150 ft (45.7 m) deep), the earth temperature begins to rise according to the natural geothermal gradient. The storage concept is based on a modular design that will facilitate active control and optimisation of thermal input/output, and it can be adapted for simultaneous heating and cooling often needed in large service and institutional buildings (Abdeen, 2010). Loading of the core is done by diverting warm and cold air from the heat pump through the core during periods with excess capacity compared to the current need of the building (Abdeen, 2011). The cool section of the core can also be loaded directly with air during the night, especially in spring and fall when nights are cold and days may be warm.

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 energy, particularly in the building sector. Energy use reductions can be achieved by minimising the energy demand, rational energy use, recovering heat and the use of more green energy.

This study was a step towards achieving this 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.

However, by adopting coherent strategy for alternative clean sustainable energy sources, the world 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, every nation's resource base would be greatly improved while 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 related to clean energy, 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 present study is one effort in touching all these aspects.

RECOMMENDATIONS

1. Launching of public awareness campaigns among local investors particularly small-scale entrepreneurs and

end users of RET to highlight the importance and benefits of renewable, particularly solar, wind, and biomass energies.

2. Amendment of the encouragement of investment act, to include furthers concessions, facilities, tax holidays, and preferential treatment to attract national and foreign capital investment.

3. Allocation of a specific percentage of soft loans and grants obtained by governments to augment budgets of R and D related to manufacturing and commercialisation of RET.

4. 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 information and literature with technical support from the research and development entities.

5. 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 RET particularly renewable energy.

6. 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.

7. Encouraging the private sector to assemble, install, repair and manufacture renewable energy devices via investment encouragement and more flexible licensing procedures.

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