Clean Energies Development and Sustainable Development

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ABSTRACT

The move towards a low-carbon 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 (GHGs) and provides comfortable coexistence of humans, livestock, and plants. Ground source heat pump systems (GSHPs) are receiving increasing interest because of their potential to reduce primary energy consumption and thus reduce emissions of GHGs. The main objective of the research is to stimulate the uptake of the GSHPs. This paper describes the details of a prototype direct expansion GSHP test rig and details of the construction and installation of the heat pump, heat exchanger, heat injection fan and water supply system. It also presents a discussion of the experimental tests currently being carried out.

Keywords: Direct expansion GSHPs, construction, development and evaluation of the system

1 INTODUCTION

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. An increase in awareness of the environmental impact of CO_2, NO_x and CFCs emissions triggered a renewed interest in environmentally friendly cooling and heating technologies. Under the 1997 Montreal Protocol, governments agreed to phase out chemicals used as refrigerants that have the potential to destroy stratospheric ozone. It was therefore considered desirable to reduce energy consumption in order to decrease the rate of depletion of world energy reserves as well as the pollution to the environment.

One way of reducing building energy consumption is to design buildings, which are more efficient in their use of energy for heating, lighting, cooling and ventilation. Passive measures, particularly natural or hybrid ventilation rather than air-conditioning, can dramatically reduce primary energy consumption [1]. Therefore, promoting innovative renewable energy applications including the ground source energy may contribute to preservation of the ecosystem by reducing emissions at local and global levels. This will also contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or GHGs. An approach is needed to integrate renewable energies in a way to achieve high building performance standards. However, because renewable energy sources are stochastic and geographically diffuse, their ability to match demand is determined by the adoption of one of the following two approaches [2]: the utilisation of a capture area greater than that occupied by the community to be supplied, or the reduction of the community's energy demands to a level commensurate with the locally available renewable resources. 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 [3-5]. 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 [6].

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

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economic growth, employment, investment, trade and the standard of living of individuals everywhere.

2 ENERGY SOURCES AND 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 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 [6].

The World Summit on Sustainable Development in Johannesburg in 2002 [6] 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 GHGs produced by human activities are significantly contributing to it. The predicted global temperature increase of between 1.5 and 4.5^{o}C could lead to potentially catastrophic environmental impacts [7]. 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 [7]. 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 [7]. 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 [7]. 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.

2.1 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 as well efforts made to increase people's knowledge through training.

2.2 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. 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. However, considerable studies have been conducted in different countries on energy use in agriculture [14-19] in order to quantify the influence of these factors.

The performance of the heat pump depends on the performance of the ground loop and vice versa. It is therefore essential to design them together. Closed-loop GSHP systems will not normally require permissions/authorisations from the environment agencies. However, the agency can provide comment on proposed schemes with a view to reducing the risk of groundwater pollution or derogation that might result. The main concerns are:

- Risk of the underground pipes/boreholes creating undesirable hydraulic connections between different water bearing strata.
- Undesirable temperature changes in the aquifer that may result from the operation of a GSHP.
- Pollution of groundwater that might occur from leakage of additive chemicals used in the system.

2.3 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 book published by the OECD/IEA [20]. ‘‘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 1973-2000 renewables grew at 9.3% a year and it is predicted that this will increase by 10.4% a year to 2010. Wind power grew fastest at 52% and will multiply seven times by 2010, overtaking biopower and hence help reducing green house gases, GHGs, emissions to the environment.

2.4 Economics

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 and are not recommended as an energy-efficient heating option. The GSHP system can provide 91.7% of the total heating requirement of the building and 55.3% of the domestic water-heating requirement, although only sized to meet half the design-heating load. The heat pump can operate 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 occupants will be pleased with the comfort levels achieved and find the system quiet and unobtrusive. The heat pump is mounted in a cupboard under the stairs and does not reduce the useful space in the house, and there are no visible signs of the installation externally (no flue, vents, etc.). The GSHP system is responsible for lower CO_2 emissions than alternative heating systems (the emission figures for an all-electric system, and oil- or gas-fired boilers). For example, compared with a gas-condensing boiler, the heat pump system resulted in 15% lower CO_2 emissions (assuming a CO_2 emission factor for electricity of 0.46 kg/kWh) [20]. When compared with new oil fired boiler system or all-electric systems, the emissions of CO2 are cut by over 40% and nearly 60% respectively. Annual fuel costs, based on the fuel prices given in SAP 1998, are about 10% higher than those for a gas condensing boiler and about 20% higher than for a new regular oil boiler, but servicing costs are likely to be lower. Running costs are substantially cheaper than for an all-electric heating system. At present, suitable products are not readily available in the UK, so the heat pump had to be imported. This had some drawbacks, e.g., limited documentation in English and possible difficulty in obtaining spare parts. The controller supplied with the heat pump was not designed for use with an Economy 7 type tariff structure. There is however potential to improve the operation of the system by scheduling more of the space and water heating duty during the reduced tariff period. The performance of the heat pump system could also 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.

3 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.

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