Energy from the Sun: The Logical Choice

By: Dr Zubaidah binti Ismail

INTRODUCTION

Global population was about one billion in 1810, about six billion in 2004 and projected to be about nine billion in 2040. The energy and water consumptions also grow in tandem to this population growth pattern. And the environment is showing signs of degradation and an inability to cope [1]. Each time there is an oil price shock or each time OPEC decide to increase the price of crude oil we find consumers designing and operating more energy-efficient machines. Marginal oil fields become economic, and investments are made on new sources of hydrocarbons and on new energy alternatives [2]. Energy audits and projects for energy conservation and more efficient systems are implemented. In 2003 the European Union agreed that by 2010, 21% of electricity consumed in Europe should be from alternative renewable resources. Several countries of the Union which are seen not to be keeping to the schedule have been given stern warnings [3]. The Malaysian leadership has stated that it is now timely to accelerate and make necessary preparations to bring these 'fringe' but unique domestic energy alternative into the mainstream [4]. Out of an estimated 29,000 MW of hydro-power potential available in Malaysia only about 2,000 MW has been exploited. There was a direct reference to solar as having a great potential as well, and that of biomass as another enormous source of renewable energy. Almost ten million tonnes of oil equivalent could be obtained from biomass coming from residues of the wood and agricultural sectors about 50% of which comes from oil palm industry waste. Fiscal incentives for renewable energy projects were given in the form of investment tax allowances and Small Renewable Energy Programme (SREP) which encourages the selling of power to the National Grid. Twenty-eight biomass projects totaling a potential of 194 MW production and four landfill-gas based projects producing a potential of 9 MW of power have been approved. There are eighteen mini-hydro projects producing a total of 70 MW which have also been approved. Resources bring wealth and waste; waste plus renewable energy may bring resources and waste heat. We will see the available so-called renewable energy resources such as solar, biomass, biofuels, wind, currents, waves and tidal, geothermal and nuclear, and assess those that are most practical and have the most potential for Malaysia.

SOURCES OF ENERGY

In one way or another all energy originates from the sun. Generally energy sources can be classified into the following types: those derived from the process of photosynthesis utilising water and carbon dioxide in the presence of sunlight and chlorophyll to form sugars with further conversion to amino acids, starches, oils and other plant constituents which could also be taken up by animals and all these various forms undergo various extents of conversion and chemical and physical reactions and eventually appear in the form of biomass as direct fuel, cellulose which can be pyrolysed to form alcohols, sugars and starches to be fermented also to alcohols which can be used as fuels, esterification of the oils to form bio-diesel, or cooked and fossilised over millions of years to appear as oil and gas. While the biomass, the alcohols and bio-diesels may be viewed as renewable through the propagation of the various energy crops which only take a few years, oil and gas and even coal are considered practically non-renewable. Another type of energy source is where the energy from the sunlight heats the land mass and the water mass of earth at different rates and creating local as well as global winds in the process. The winds blow over water and cause waves. The gravitational forces of the moon and the sun is yet another type of energy source that can be harnessed, and the last type of sources of energy may be looked at as those that mimick what happens in the nuclear reactor in the sky – the sun.

PHOTOSYNTHESIS ROUTE

Biomass

Energy in the form of electromagnetic radiation pours onto the earth heating the earth, creating weather and keeps everybody warm. All living things need energy to live, grow and reproduce. The energy from the sun is transformed into various forms of energy through various routes so that it can conveniently be utilised. Photosynthetic organisms remove about 100 x 1015 grams of carbon per year [5], but the photosynthetically reduced carbon is consumed by living organisms for their survival or by combustion such that there is more carbon dioxide released into the atmosphere than is taken up by photosynthesis. Burning of fossil fuels add on to the amount of carbon dioxide in the atmosphere. The oceans mitigate this increase by acting as a massive CO_2 sink but it is estimated that the global CO_2 concentration is increasing with time. Since CO_2 is a known green-house gas it contributes to global warming which would lead to changes to rainfall patterns and the impact on plants and crops is uncertain. It is essential to appreciate the balance of life on earth with respect to the relationship of living organisms and the atmosphere. Several writers have discussed the subject of photosynthesis [6-8]. Fifty percent of biomass in Malaysia comes from the oil palm industry. The potential of producing renewable energy from the palm oil industry is well established and the industry has been the leading producer and user of solid palm biofuel in the form of palm biomass to produce steam and electricity [9], while the rest comes from wood and other agricultural waste like rice straw and husk. Biomass could also be converted to alcohol and further used as fuel. Looking at the alcohol route, we see that the fermentation of cellulose to alcohol is not

straight-forward and requires more research to make it viable. The general down-side about biomass is that it is costly to transport and store.

Biofuels

Water and carbon dioxide, thermo-dynamically the datum level in terms of energy content, and yet we remember our Form III biology and photosynthesis - water and carbon dioxide reacting to form simple sugars in the presence of chlorophyll and sunlight. Biofuels commonly come either from ethanol or the methyl ester. While Brazil have for a long time pursued the alcohol approach from the fermentation of sugar to support the domestic industry and for socio-economic reasons, the US have concentrated on the fermentation of corn from their cornfields. Malaysia have for the last twenty years or so been looking at the methyl ester route to palm diesel. Experimental studies on the crude form of the oil has also been tested successfully in car engines. These fuels burn cleaner with less emission of green-house gases, and combustion temperature is also lower giving longer lasting engines as compared to petroleum-run engines. Prospects of cocobiodiesel has also been investigated with promising results [10]. For the alcohol route, energy input into the production of high-purity product was said to be high. There has been extensive debates [11,12] on the issue, and several recent studies have focused on showing that there is in fact a definite net energy gain from alcohol production. The principle inefficiency of this route is due to the concurrent production of an appreciable amount of water which has to be removed as much as possible which in itself consumes energy.

Fossil Fuels

Fossil fuels are the bench-marks against which alternatives are sought. Thanks to photosynthetic processes some forty million years or so ago we are now able to burn oil and gas for our energy needs and are producing carbon dioxide some of which is utilised in present-day photosynthetic processes with water and chlorophyll and the help of solar radiation to start another cycle of cooking. The coal cycle may similarly be started but will need a somewhat shorter time to complete.

DIRECT RADIATION

Winds

The different types of land materials and water on the earth's surface result in different amounts of heat being absorbed and consequently cause an uneven heating of the surface by the sun. During the day the air above the land heats up much faster than the air over water in the oceans and the seas. The warm air above the land expands and rises and the heavier cooler air rushes to take its place thus creating what we know as wind. At night the wind direction is reversed since the air cools more quickly over land than over water. The large atmospheric winds that circle the earth are created in a similar manner because the land mass near the equator is heated more by the sun than the land mass near the North and South Poles. People have been harnessing wind energy for thousands of years whenever they use sailing ships to travel, windmills to grind wheat and grains, pump water, cut wood at sawmills and generate electricity. Wind is a clean fuel and wind farms do not pollute the environment. The environmental drawbacks may be the negative effect on wild bird populations and the visual impact on the landscape which again is subjective.

Waves

Waves are created by the wind at it blows across the oceans and the seas. Waves are a powerful source of energy. The wave action can be directed to push air in and out of a chamber which turns turbines in the process [13]. It is renewable and the capital investment is reasonable and it is cheap to operate. There is no waste or pollution, it can generate a large amount of energy and there is no negative visual impact. However, its application to-date is still not widespread. The challenge is to build and secure a structure sturdy enough to withstand the rough sea conditions and at the same time capable of generating enough power from small waves. On top of the need for a sturdy civil structure a suitable site with consistently strong waves has to be found. Furthermore, corrosion and marine growth could add to maintenance costs, and noise is also an environmental nuisance.

Hydro

Solar energy input into surface water evaporates it to form clouds and gain potential energy. The rain hopefully falls into catchment areas and dammed-up collecting into a massive amount of potential energy after losing some through the falling rain. The potential energy is converted into kinetic energy through the water channels before hitting the turbine blades and converting it into mechanical energy. There are losses through the channel and in the conversion process. The energy is further converted to electrical energy through electromagnetism. Again there would be conversion losses. The power is stepped-up for transmission purposes and then stepped-down for suitable consumption. Again there would be step-up and step-down losses as well as heat energy losses through transmission. There would be further losses at the appliances because of heat and other inefficiencies in the conversion process. Hydro is not a major future energy option because the potential of harnessing gravity this way are either already being exploited or are unavailable because of environmental reasons. Although it produces no carbon dioxide and there are no emissions, the down-side, however, is that there need to be vast catchment areas which need to be flooded and this would have some direct negative impact on the environment.

Solar Heaters

Malaysia is blessed with abundant sunshine. Despite the abundance of this energy resource, its utilisation has only been limited to the installation of some 10000 units of solar heaters. The main problem with thermal solar heaters is that they only work well when the sun shines and one needs to have enough storage to cater for night use or during rainy or cloudy days.

GRAVITATIONAL FORCES

Tides

Tides are caused by the gravitational pull of the moon and the sun on the oceans of

the rotating earth. Tidal energy is harnessed by using barrages much like a dam, only that it is very much bigger but have a much lesser height. Either the flow could be used to turn turbines or it could be used to push air which in turn turns the turbine [14,15]. The potential amount of power is enormous, but it is a big challenge to harness. It is renewable and predictable, have low operating cost, and have not muck negative visual impact. The environmental impact could, however, be far-reaching where the mud-flats and the ecosystem of the beach could be changed. The system only works when the tide is coming in or going out so alternative supply needs to be provided in between. Furthermore there are only very limited suitable sites around the world where the system could be installed.

Currents

Ocean currents occur naturally through narrow channels as a result of tidal action or due to temperature gradient. It is still in an early stage of development but areas in UK [16], Ireland, Italy, Philippines, Japan, US, Canada and New Zealand [17] have been identified as suitable sites. The regular and periodic raising and lowering surfaces create the strong tidal currents. The strength of tidal currents depends on location of the site on earth, shape of the coastline, and shape of the sea-bed. The principle is simply the use of kinetic energy of the moving water and converting it to rotational energy and electricity. Currents are predictable both in amount and timing and are not affected by weather conditions. The resource is renewable, have minimal environmental impact, have a high energy density as compared to wind which means more compact equipment, and the velocities are more predictable and less fluctuating giving rise to more accurate sizing of equipment [13]. Further more the land use is minimal, there is no negative visual impact, can be sited near high population areas, able to apply the modular concept and can avoid large civil engineering works. The challenges are in the technical areas of avoiding cavitation, minimising marine growth and ingress of debris into the system. Capital outlay could also be substantial and maintenance could also be high due to possible seawater corrosion of equipment and parts. More research needs to be conducted in this area.

OTHER APPROACHES

Photo-Voltaic

Photo-Voltaic with about 15% conversion gives about one w/m2. There are some photo-voltaic systems for rural electrification in Sabah and Sarawak, and minor applications involving tele-communication, street and garden lighting, and ticket dispensing machines. There have been a few solar-powered cars competitions organised. The advantages of these systems are that the capital and the operating costs are fairly cheap; there are no pollution or the production of green-house gases and it could be modular. With the rapid expansion of the building construction industry the potential development in the application of the building integrated photo-voltaic technology is great. Research and development of such systems are greatly wanting. Commitment of the relevant authorities and organisations is greatly needed. The downside about solar radiation is that it is only readily available during sunny days. And during the winter months the hours of sunshine are very much shorter. The source is also not too efficient on rainy and cloudy days. There could also be some negative visual impact, and the maintenance of such systems could be costly.

Geothermal

In volcanic areas molten rock could be close to the surface. By drilling a hole and pumping water onto the hot rock, steam could be produced, purified and utilised to drive turbines for electricity generation. In countries like Philippines, a high percentage of the energy mix comes from this resource. The technology does not cause pollution, does not produce carbon dioxide, the system is compact, and requires minimal operating cost. However, the sites are limited, the rock structure and properties for drilling through must be suitable, and sometimes the facilities could lose their heating capability for sometime. There could also be some negative visual impact from leaking steam, and poisonous gases could also be emitted.

Nuclear

Stars of which our sun is one, rely on nuclear fusion for their output of heat, light and other radiations. If one believes in the Big Bang Theory, then the Earth may be considered as a fragment of the Sun. Fusion reaction is exactly what is happening on the Sun. Energy from fission reaction is derived from a nuclear reaction involving uranium or plutonium as the fuel which originally comes from the fragment of the Sun. Fission nuclear reactors are either the slow thermal kind using moderators or the fast breeder type using purer fuels and able to generate or 'breed' new fuel form which is useful in the context of renewability. There is more energy potential in nuclear fuels than the combined total potential from oil, gas, coal and hydro put together. There is, however, fears of catastrophic accidents due to human and system errors.

Fuel Cells

Available types of fuel cells are the phosphoric acid, molten carbonate, hydrides and solid oxide types. A fuel cell system running on hydrogen could be compact and light-weight and have no moving parts to maintain. An electrolyser/fuel cell system can store an indefinite quantity of hydrogen which then becomes suitable for long-term energy storage.

CONCLUSIONS

Ultimately all energy comes from the sun. The closer and more direct the technology gets to mimicking the Sun or what happens on the Sun the more efficient would be the process of converting the energy from the Sun. There would be less tendency for losses due to conversion and operational process inefficiencies. The logical choice becomes obvious. ■

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