Science Plan on Sustainable Energy

ICSU
International Council for Science
Regional Office for Asia and the Pacific
Strengthening International Science for the Benefit of Society

About ICSU ROAP

ICSU Regional Office for Asia and the Pacific was inaugurated on the 19 September 2006 by the Deputy Prime Minister of Malaysia, Y.A.B. Dato' Seri Najib Tun Abdul Razak. The new office will promote the development of science throughout Asia and the Pacific and help strengthen the voice of developing countries in this region. It will also ensure that its scientists become involved in those aspects of the ICSU 2006-2011 Strategic Plan that are especially relevant for this area.

Mission Statement

ICSU mobilizes the knowledge and resources of the international science community for the benefit of society, to:

- Identify and address major issues of importance to science and society
- Facilitate interaction amongst scientists across all disciplines and from all countries
- Promote the participation of all scientists in the international scientific endeavour, regardless of face, citizenship, language, political stance or gender
- Provide independent, authoritative advice to stimulate constructive dialogue between the scientific community and governments, civil society, and the private sector

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Science Plan on Sustainable Energy

Report of ICSU ROAP Planning Group
on Sustainable Energy

June 2009

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Emeritus Professor Derek J. Gardiner
Chair
ICSU ROAP Science Planning Group on Sustainable Energy

EXECUTIVE SUMMARY

The existing energy supply and demand situation means that conventional sources, such as oil and coal, will be depleted at an alarming rate. Growing concern about the environmental impact of the various energy resources places restrictions on their use. The Kyoto Protocol requires participating countries to reduce carbon emissions drastically over the next decade. To improve the energy situation and make it sustainable, serious efforts need to be made to advance knowledge in the following directions:

- new and energy efficient methods for recovery, power generation and distribution
- energy conservation techniques,
- increased utilization of renewable energy sources, and
- development and utilization of emerging energy sources and techniques.

There exists a huge additional potential for conservation and reduction in energy consumption in both industrial and domestic sectors by using energy-efficient designs and products along with improvements in energy storage and management practices. In parallel with these developments there needs to be an awareness of the resultant social impacts and associated social policy changes. In particular the affect of new energy source utilisation on land use, food production, transport and visual environment will need to be addressed along with technician capacity building and public information.

Sustainable energy is regarded here as energy to meet our needs today without compromising the ability of present and future generations to meet their energy needs and without overloading the ecosystem. It can thus be regarded as energy for sustainable development. Sustainable energy sources and energy management considered here for Asia and the Pacific region include: solar, wind, geothermal, hydro, wave, biomass, energy from waste, ocean energy, and energy efficiency. The science plan reviews the current position for each of these energy sources and recommends priority areas for research and development.

The Asia- Pacific region with its rapidly growing energy demand should utilize its abundant natural resources to move away from heavy dependence on fossil fuels. Governments in Asia-Pacific region have started considering sustainable energy as serious alternative to conventional fuels. It has been estimated that investment in the sustainable energy industry would generate more jobs per megawatt (almost 10 times) than is the case for the conventional energy industry. This will require investment in education and training to provide the technical support and development skills along with increased public awareness of the environmental sustainability issues and efficient energy use strategies.

If the new and emerging energy technologies are to make a serious contribution to sustainable development in the Asia-Pacific region then investment, intellectual effort and capacity building need to be planned for the short and long term. The following are a summary of the proposed areas of endeavour, identified by ICSU regional committee for Asia Pacific to achieve this aim and should be interpreted broadly and positively by researchers, funding agencies and governments.

- Exploration assessment and Mapping of resource potential.
- Improvement of existing technologies, manufacturing processes and mass production.
- Fault prediction and protection.
- Use of new, improved and smart materials and techniques.
- Resource and waste management.
- Waste treatment technologies including biochemical.
- Use of traditional technologies and best practice for low energy buildings.
- Development of guidelines on low energy buildings, culture and new.

01
INTRODUCTION TO SUSTAINABLE ENERGY

Over the last two decades there has been an almost 50% increase in world energy consumption arguably because of (i) an approximate 45% increase in world population and (ii) worldwide improvement in economic activity and the consequent improvement in the standards of living. Human Development Index (HDI) and per capita energy consumption for a globally representative sample of countries, covering industrialized, developing and poorly developed regions for the year 2002 are plotted in Figure 1. The sample includes the most populous countries, which represent nearly 90% of world population and 90% of world energy consumption. The correlation points to large, additional energy requirements in the next two to three decades as the developing economies strive to compete with the developed economies and the least developed nations move ahead towards "developing nations" status. Clearly, substantial effort is needed to contain population increase, limit our energy consumption and to explore sustainable sources of energy if we are to maintain present standards of living in the developed countries and improve those of the developing countries.

Fossil fuels, which cater to more than 80% of our energy needs, have a deleterious effect on the global climate. According to the International Energy Agency (IEA), 50% of the world's electricity must come from sustainable sources in order to significantly reduce global carbon dioxide emissions by 2050. In particular the Asia Pacific region with its growing economies and population as well as diverse geography has a crucial impact on world energy consumption and climate change. These are the countries where energy consumption is expected to grow exponentially due to emerging economies and increasing standards of living. In April 2008, UN Secretary-General called on Asia-Pacific countries to promote the sustainable and efficient use of energy, given the backdrop of surging oil prices and the health problems caused by traditional fuels.

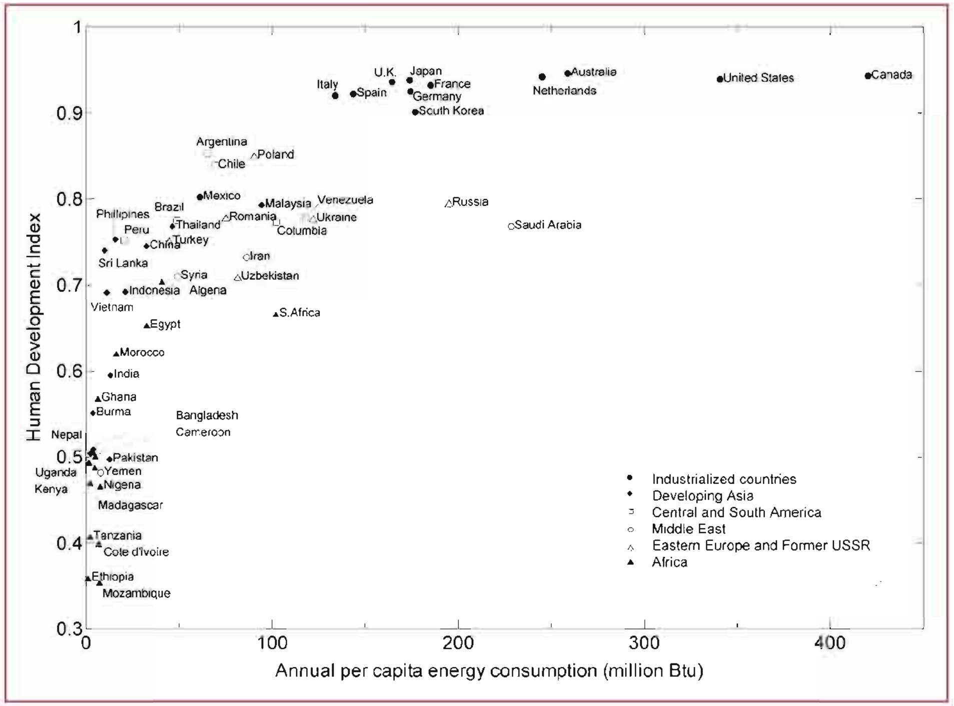


Figure 1 : *The United Nations HDI and annual per capita energy consumption for 60 most populous countries, 2002 (Human Development Report 2004, U.N.D.P.; International Energy Annual 2003, Energy Information Administration)*

Asia Pasific Region

The Asia Pacific region is variously defined but is generally accepted as comprising the following countries:

Australia,
Bangladesh,
China: Beijing,
China: Taipei,
India,
Indonesia,
Iran,
Japan,
Kazakhstan,
Korea DPR,
Korea Rep. of,
Malaysia,
Mongolia,
Nepal,
New Zealand,
Pakistan,
Philippines,
Singapore,
South Pacific,
Sri Lanka,
Thailand,
Tajikistan ,
Uzbekistan,
Vietnam.

The region is immense and embraces many varied and contrasting, countries, economies, religions, geographies, climates and stages of development. There are the large land masses of China, India and Australia with their dense and sparse population areas. This is in contrast with the small and remote island states of the south Pacific. The economies and states of development also vary from advanced and developed wealthy countries with abundant natural resources to less developed countries, some with health, food and conflict problems. The climate ranges from tropical to near Antarctic and the terrain includes everything from desert to tropical rain forest, river deltas to high mountains and small coral atolls to vast open plains. Population density and distribution is also varied with major metropolitan and urban centres contrasting with scattered and isolated communities. The development of squatter settlements at the peripheries of large towns adds to the complexity. Generalizing about such a region is not possible and yet global energy needs and the diminishing fossil fuel reserves make the exploration of alternative and sustainable energy sources an imperative for us all.

The existing energy supply and demand situation means that conventional sources, such as oil and coal, will be depleted at an alarming rate. Growing concern about the environmental impact of the various energy resources places restrictions on their use. The Kyoto Protocol requires participating countries to reduce carbon emissions drastically over the next decade. To improve the energy situation and make it sustainable, serious efforts need to be made to advance knowledge in the following four directions:

1. new and energy efficient methods for recovery, power generation and distribution
2. energy conservation techniques,
3. increased utilization of renewable energy sources, and
4. development and utilization of emerging energy sources and techniques.

As the demand for energy continues to grow, new energy-efficient technologies can play an increasingly important role in meeting future energy demands and reducing environmental impacts and climate change. There exists a huge additional potential for conservation and reduction in energy consumption in both industrial and domestic sectors by using energy-efficient designs and products along with improvements in energy storage and management practices. In parallel with these developments there needs to be an awareness of the resultant social impacts and associated social policy changes. In particular the affect of new energy source utilisation on land use, food production, transport and visual environment will need to be addressed along with technician capacity building and public information.

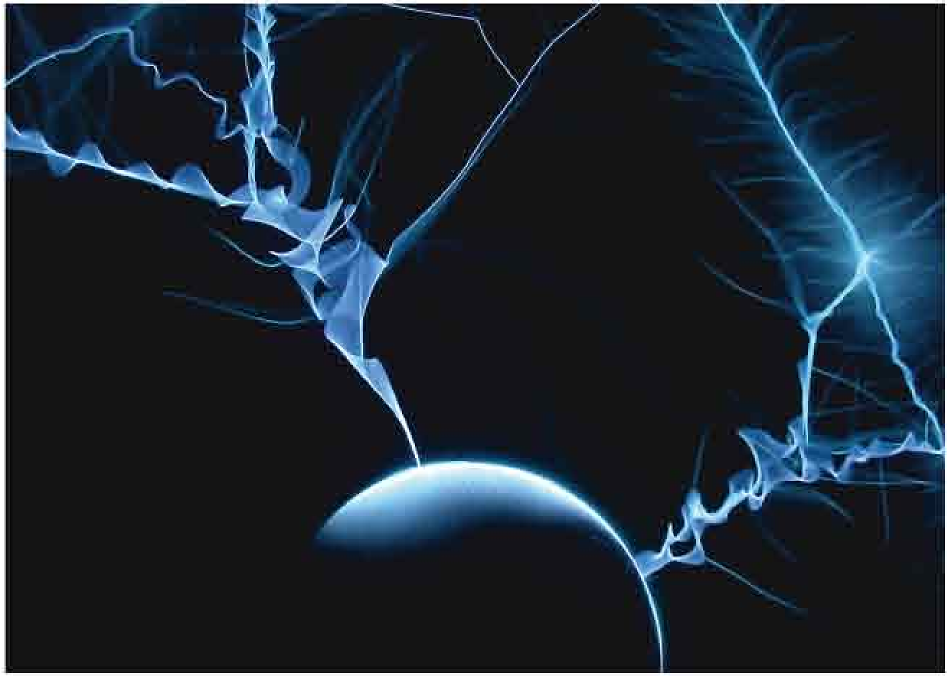
Sustainable Energy Sources

Sustainable energy is regarded here as energy to meet our needs today without compromising the ability of present and future generations to meet their energy needs and without overloading the ecosystem. It can thus be regarded as energy for sustainable development.

Sustainable energy sources and energy management considered here for Asia and the Pacific region include: solar, wind, geothermal, hydro, wave, biomass, energy from waste, ocean energy, and energy efficiency. The science plan reviews the current position for each of these energy sources and recommends priority areas for research and development. Although over the last few decades, nuclear energy has emerged as a significant addition to the traditional energy sources, but is not considered here because of growing concern over long-term storage, disposal of radioactive wastes and the consequences of a serious accident arising from natural disasters or human error. Another new resource of energy, gas-hydrates, is drawing worldwide attention. Both of these resources are excluded from this document.

Capacity Building and Public Awareness

The Asia-Pacific region with its rapidly growing energy demand should utilize its abundant natural resources to move away from heavy dependence on fossil fuels. Governments in Asia-Pacific region have started considering sustainable energy as serious alternative to conventional fuels. It has been estimated that investment in the sustainable energy industry would generate more jobs per megawatt (almost 10 times) than is the case for the conventional energy industry. This will require investment in education and training to provide the technical support and development skills along with increased public awareness of the environmental sustainability issues and efficient energy use strategies.



02

WIND ENERGY

Wind power is today one of the more favoured options for electricity generation. Its use has a great relevance and potential for many Asia and Pacific countries and provides a large development potential. In many areas in the region, such as isolated islands, electricity can be provided economically using the energy available in the wind. In many continental countries large wind farms can contribute a significant amount of energy to the grid. The integration of wind energy into national electricity supply systems is a priority by 2010. Asia Pacific is now emerging as a key global wind power region and many governments have set ambitious goals for wind energy applications.

Regional Availability

The largest component of renewable generation capacity is wind power, which grew by 28 % worldwide in 2007 to reach an estimated 94 GW. The annual growth rate reached 48% in India and 65% in China in 2006. The typical wind turbine size in India and China, is around 300 kW; however some 500/600 kW wind turbines have also been installed. In Australia, Japan and New Zealand, the 500 to 600 kW range is predominant, while there are projects in Japan and Australia where 1.5 MW and larger turbines are used. The possibility to supply isolated areas has been especially utilized in Mongolia and the Pacific region where smaller wind unit installations supported by batteries or diesel are more often found.

Significant wind mill industry has developed in India, China and Australia and some of their manufacturers are leading in the region with a large share in the domestic market; India over 70%, and China over 55%. Some large European manufacturers have established offices in the Asia and Pacific region. There are many joint-venture companies in India, especially for production of 250 KW and bigger units, while in China it is required that each new installation comprises 70% domestic components. Table 1 lists the installed capacity for the region.

Nation	2005	2006	2007
India	4,430	6,270	8,000
China	1,260	2,604	6,050
Japan	1,061	1,394	1,538
Taiwan	104	188	
South Korea	98	173	
Philippines	25	25	
Others	13	13	
Iran	23	48	66
Total of Asia	**7014**	**10715**	**15654**

Nation	2005	2006	2007
Australia	708	817	824
New Zealand	169	171	322
Rest of Oceania	12	12	12
Total Australia, New Zealand and Oceania	**889**	**1000**	**1158**
Total Asia and Pacific	**7903**	**11715**	**16812**
World total (MW)	**59,091**	**74,223**	**93,849**

Table 1 : *Installed wind power capacity (MW) in Asia and Pacific region (http://www.wwindea.org)*

Current Technology

Wind energy is increasingly being viewed as mainstream, providing the following benefits to new and existing markets: very low lifetime emissions of harmful gases, especially CO2, large resource at costs approaching that of current thermal plant, increased diversity and security of electricity supply, removal of cost uncertainties caused by fuel supply price fluctuations, employment, rural income and an opportunity for industry.

Windmills have grown in size rapidly in the past 30 years, from a capacity of only a few kW to individual installations of 5 to 6 MW and power plants currently under construction (farms) of few MW to a few hundreds of MW. Physically, the diameters of wind turbines may now reach to more then 120 meters. They also vary from very simple and robust designs, to those which incorporate very elaborate materials and control systems enabling them to meet grid requirements and heavy working conditions. The two main methods used in windmills to control power are: constant rotor speed with passive load control due to flow separation, and variable rotor speed with active load control by blade pitching. The control of constant speed is cheap and straightforward but results in high loads, so heavy turbines are necessary. This method is not suitable for variable load grid conditions. The variable speed constant frequency (VSCF) turbines are used to match the grid frequency. The majority of commercial turbines in the

MW range and connected to a grid employ the VSCF concept. The generators are either directly connected to the turbine or via a gearbox. A smaller number of MW installations use synchronous generators while the use of doubly fed induction generators (DFIG) is predominant today. DFIG provides good control of frequency and control of the active and the reactive power capable of meeting the variable load conditions at the grid.

Large grid connected wind turbines typically have capacities ranging from 600 kW to 2 MW and are set to increase in size. The largest single capacity at present is 6 MW. They are often placed in wind parks or farms with a total capacity of 10 to 100 MW. There are many suitable sites for wind parks in Asia and the Pacific region which satisfy several geographical and technical conditions such as high annual wind speed, low turbulence and easy access to the distribution network. In small wind turbine systems, used in combination with batteries and/or diesel generation systems (stand alone wind turbines), the turbines of capacity up to few hundred watts are most successful commercially and are used for electric power supply to remote, off-grid loads, such as small islands, homes, sailing boats, or telecommunication systems. The design of small wind turbine systems differs significantly from that of large, grid-connected wind turbines and they often employ DC generators.

Construction of the mechanical structure that supports the generator requires special attention. Large cranes are necessary for building these structures, and the size of a development may present a significant limitation. Although wind power plants were initially located mainly at onshore sites, recent trends indicate that offshore locations are currently predominant. Many studies have found that offshore wind energy resources are significantly higher than those available onshore.

Emerging Technology

Wind energy today is in a state of fast implementation. Research and development has had a key role in achieving the improved performance. Many improvements in windmill technology lead to cost reductions and over the medium term wind energy will be able to compete with conventional energy sources. However, there is still a need for further cost reductions. It has been predicted that a cost reduction of 50% can be achieved by the year 2020 with additional performance improvement.

The emergence of 2 MW turbines and larger requires an improved understanding of machine loads, the response of the supporting structure, uncertainties in the incident wind field, application of new materials and more sophisticated control systems. Special attention has to be paid to the integration of wind generation into future energy supply systems. This may involve wind energy in combination with long and short term energy storage, in combination with hydrogen generation, in

combination with other sustainable sources as well as the integration of large (500 MW +) wind farms into grid systems.

The windmill industry now needs to address – repowering or replacement of old machines by modern turbines, diversification and market entry into other technological sectors, offshore and onshore use of wind energy, and innovations and new applications of wind energy. Condition monitoring wind turbines in order to detect incipient faults in the mechanical drive train or electrical gear is attracting great research interest. There is room for improvement in windmill monitoring and fault prediction. This is mainly in the area of real time turbine data collection as well as in the fault detection algorithms that can potentially be used, such as those based on neural networks, fuzzy logic, or spectrum analysis for predicting faults on blades, gearboxes and generators. It is also important to point out that mechanical damage is a dominant feature in windmills.

Special grid codes exist in some countries for connecting wind farms to the grid, which, depending on the national grid operator, tackle or define reactive power capability, voltage dip ride-through capability, fault current levels, harmonics and flickers, frequency and other important parameters. This is an issue that requires attention in those Asian and Pacific countries that have not already adopted grid codes for windmills. The work on development of new standards on energy yield calculation, grid connection, risk assessment, design criteria, operation and management standardization is also essential. The ultimate goal is to achieve the level of development of components and technologies for grid connection as well as control strategies and requirements for grid compatibility that will support and maintain stable grid operation.

Large scale grid integration modeling and the management of loads within local or high voltage national grid is of great interest. This involves the control of the flow of active and reactive energy, as well as operation of the wind systems incorporated in the local grid under grid fault conditions. Further areas of interest include: the possibility to maintain a stable grid and provide a safe and reliable energy supply with a high percentage of generated power coming from unpredictable wind energy; modelling of the system response to wind energy embedded in low voltage distribution networks (distributed generation), and the development of models describing wind turbine and large wind farms electric behaviour.

Development of robust, low maintenance offshore turbines with increased reliability is essential as it is estimated that there are, especially in the Pacific region, many attractive offshore wind locations. There is also a need to develop design tools for turbines in extreme conditions and laboratories for accelerated testing of large components. Smart technology will need to be fully exploited to achieve further improvement of windmill blades.

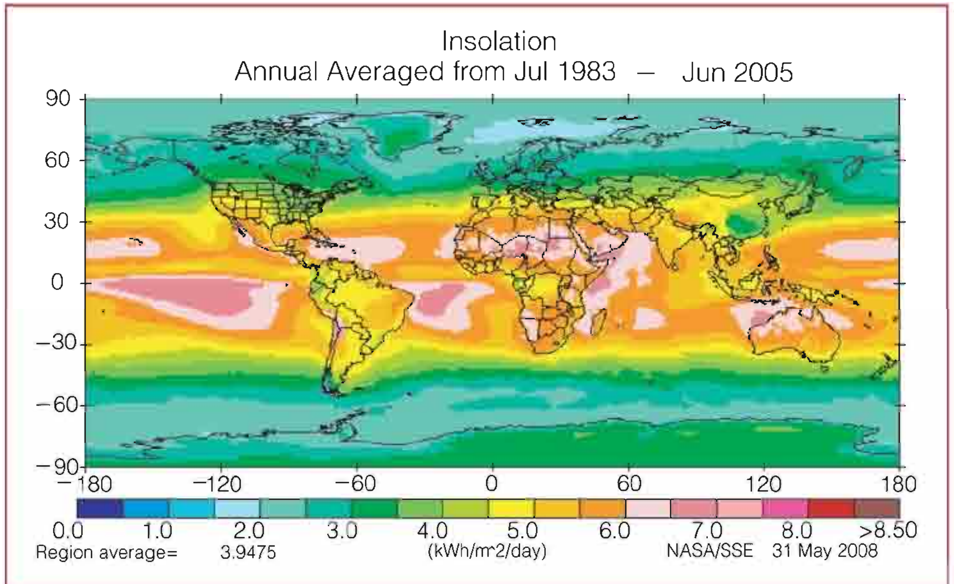
03 SOLAR ENERGY

The solar energy that reaches the Earth in a year is thousands of times the world's annual traded energy. Approximately 35% is directly reflected as short wavelength radiation (albedo), 43% is directly converted to heat, 22% drives the world's hydrologic cycle, 0.2% is converted to kinetic energy (wind) and 0.02% is used for chemical energy (photosynthesis). The average irradiance on a horizontal surface is approximately 170 Wm^{-2}, or, in each year, 5.4 GJm^{-2}. Sunlight intensity distribution on the earth's surface is affected by geometric and local factors so that insolation varies significantly, both geographically and temporally. Global estimates of insolation provided by NASA's Atmospheric Science Data Center (Figure 2) indicate that the annual average daily global radiation varies from below 3 to above 7 $kWh.m^{-2}.day^{-1}$. Seasonal variations are small in the tropics but 40:1 or more at high latitudes.

Regional Availability

Estimates of wind, biomass and solar energy potential for world regions indicate large solar resources in the South Asia, Middle East and especially the Oceania regions and predict an excess of energy supply availability relative to electricity demand in 2050.

Global and national energy statistics are commonly restricted to traded energy and exclude, for example, direct solar warming of buildings, forest and crop production, outdoor clothes drying, etc. Here, we restrict the term "solar energy" to the direct capture and conversion of solar radiation either as heat, with optional subsequent conversion to electricity or other forms, or through direct conversion to electricity. These two categories are termed "solar thermal" and "photovoltaics" respectively.



Current Technology

Photovoltaics

In a photovoltaic device, electricity is generated directly in a semiconductor. It accesses the solar radiation of shorter wavelength than some threshold that is a fundamental quality of the chosen semiconductor. "Screen-printed" silicon wafer solar cells dominate the photovoltaics market at present. There also exist established and developing technologies for thin-film, amorphous silicon, cadmium telluride and copper indium diselenide photovoltaics. At least 63% of 2007 global production was in the Asia-Pacific region. Mainland China, India, Taiwan, Malaysia and Korea are all experiencing very strong growth as manufacturers. Global photovoltaics production has been supply-limited, due to restrictions on the available industrial capacity for production of purified silicon. However, this bottleneck is in the process of resolution within a year or two and Asia is playing a major role. Significant existing and imminent purified silicon production capacity is in Japan, Russian Federation, mainland China, Taiwan, Korea and India.

There are two families of applications for photovoltaics in energy systems: feeding into electricity grids and, usually with battery storage, in stand-alone systems to supply individual remote dwellings, water pumps, telemetry stations, lights, etc. Grid systems dominate in Japan but stand-alone systems are more prevalent in other regional countries. Apart from Japan, the region does not have major active photovoltaic markets. Photovoltaics are expensive per unit of energy generated but have the advantage of aesthetic acceptability that make them particularly suited to urban use, close to loads, where they compete with retail electricity and offer grid augmentation benefits and, possibly, peak shaving savings. Their small scale, modularity and availability makes them attractive for small, remote domestic and industrial systems where competing energy sources are expensive, for example on islands.

Photovoltaics in concentrators have a tiny fraction of the overall photovoltaic market but the sector is growing rapidly. One major developer is based in the Asia-Pacific region, which has installed solar concentrator photovoltaic power stations in some remote settlements in central Australia. High concentration

ratios demand consistently clear skies. Opportunities exist for electricity production from concentrated sunlight in desert communities and near existing power grid infrastructure in high-insolation locations. Special opportunities exist for concentrating photovoltaics if nearby markets are available for low-temperature heat in addition to electricity.

Solar thermal

In solar thermal technology, solar radiation impinges on a collector and heats it. Advanced collector surfaces incorporate glazing and "selective surfaces" that have low emittance in the infrared spectrum, resulting in reduced losses. The heat is usually transferred to a circulating working fluid which may be used directly or drive a chemical or physical process or power a turbine to produce electricity or be stored as heat.

Solar thermal collectors with concentration ratios up to about five take the following forms: stratified solar pond, flat plate absorber, evacuated tube or compound parabolic reflector. Such solar thermal energy collection for domestic hot water or space heating is in widespread use around the world, especially in China. The collector area worldwide is estimated at more than 58x106 m2. Global solar hot water and heating capacity (excluding unglazed swimming pool heating) grew 19% during 2006 to 105 GW (thermal output). Most of the world's installed capacity is in the Asia-Pacific region. Australia is an exporter of flat-plate domestic solar water heaters and China is a major manufacturer, consumer and exporter of evacuated tube water heaters.

Concentrated solar thermal power can be used for electricity production or to drive industrial thermal loads, including the direct facilitation of chemical processes. Parabolic troughs, parabolic dishes and tower-heliostats are alternative concentration methods, all three of which can also be applied to photovoltaics. Solar thermal concentrator demonstration plants are built or planned for Spain, United States of America and north Africa but few in the Asia-Pacific region (in China and Australia).

Installed capacity of solar cooker stills and crop dryers is difficult to define but likely to be extremely small. These technologies can have major social benefits in rural areas of developing countries. Flat plate and evacuated tube water heaters are ready for extensive application throughout the region, in urban and remote areas alike, for domestic, commercial and industrial water heating and pre-heating. Solar heat can be used to drive cooling processes, and high temperatures from concentrated sunlight may be used for driving chemical transformations of fuels with higher energy content. Within the Asia-Pacific region, dish concentrator technology is to be used for separation of ammonia, for storage and transport. Concentrating solar thermal, especially with integrated thermal storage and grid access, might soon compete directly with fossil fuelled electricity grids.

Emerging Technology

Photovoltaics

Significant advances in wafer cells continue to be made in all of the following areas: front and rear contact formation with localised dopants, use of lasers and inkjet printers to define and form features, localized incorporation of dopant impurities, shifting of front contacts to the rear, use of n-type doped wafers and thinner wafers.

Two thin film photovoltaics technologies, cadmium telluride and copper indium diselenide, are emerging. New thin film crystalline silicon devices are under active development by many groups and amorphous silicon is starting to be used in conjunction with crystalline silicon wafers. Expensive but high-efficiency multijunction photovoltaics made from compound semiconductors are being used in terrestrial concentrators.

Multijunction solar cells are already available in the market in two forms: low-cost, low-efficiency amorphous silicon structures and high-cost, high-efficiency compound semiconductor devices. Research is underway in the Asia-Pacific region on silicon-based tandem structures, based on absorption by quantum-confined nano-particles of silicon in new, engineered materials. The hot carrier cell concept also relies on quantum confinement, this time in the special contacts. These "third generation" structures offer hope for future devices of high efficiency and low cost, but those are currently far from mature.

Organic solar cells are under development in the Asia-Pacific region and elsewhere but are not yet commercial. There is a range of different approaches including hetero-junctions between polymer and small molecular weight organic materials and organic/inorganic hybrids. Dye-sensitised electrochemical solar cells are a major area of current research, including in the Asia-Pacific region but the technology remains pre-commercial.

Photovoltaic concentrators are increasingly available. The conversion efficiency increases with light intensity, so long as the temperature is not allowed to increase significantly. On the other hand, concentrators "see" only a restricted sector of the sky, so (a) tracking is required, and (b) their output can be lower than non-concentrating receivers in overcast conditions.

Solar thermal

Design of air heaters is more challenging than water heaters due to lower density, lower heat capacity and lower thermal conductivity of air relative to water. Methods used to enhance heat transfer to the air tend to increase the pressure drop across the collector, thereby requiring additional fan power. One low cost air heater design uses a perforated, unglazed collector plate with a rear duct maintained at negative pressure.

There have been decades of research into devices to combine photovoltaics and thermal energy collection, with twin aims of cooling the photovoltaics and thereby improving their efficiency and obtaining dual outputs of electricity and heat. Both air and liquids have been used as thermal transfer media, with one special case of air transfer being hot air collection from ventilated building façades. These systems are mainly at research and development or demonstration stages and there exists a significant research gap to overcome before widespread adoption is feasible.

Integrated thermal storage is a keenly sought accessory for concentrating solar technologies. Storage offers the opportunity for "baseload" availability, as is provided by fossil fuels. Best developed is molten salt (sodium nitrate with potassium nitrate), used both as heat transfer fluid and as energy storage medium.

04

GEOTHERMAL ENERGY

Geothermal energy is an abundant resource of energy, which has been successfully catering to both industrial as well as domestic energy requirements in many parts of the world over the past few decades. Geothermal energy uses the Earth's internal heat. Being environmentally benign and renewable, it has been a preferred choice for a sustainable energy resource.

Regional Availability

In favourable geological situations, such as plate boundaries and sometimes well within the plates (as for example, in active or geologically young volcanoes associated with mantle hotspots as in the Hawaiian Islands), heat may be transferred to within a few kilometers of the Earth's surface through the process of convection by magma or molten rocks. Under certain suitable geological conditions, the heat becomes trapped, forming heat reservoirs. In such situations, temperatures of the order 200–300°C are found at depths of a few hundred metres. The major producing geothermal fields of the world exploit such situations.

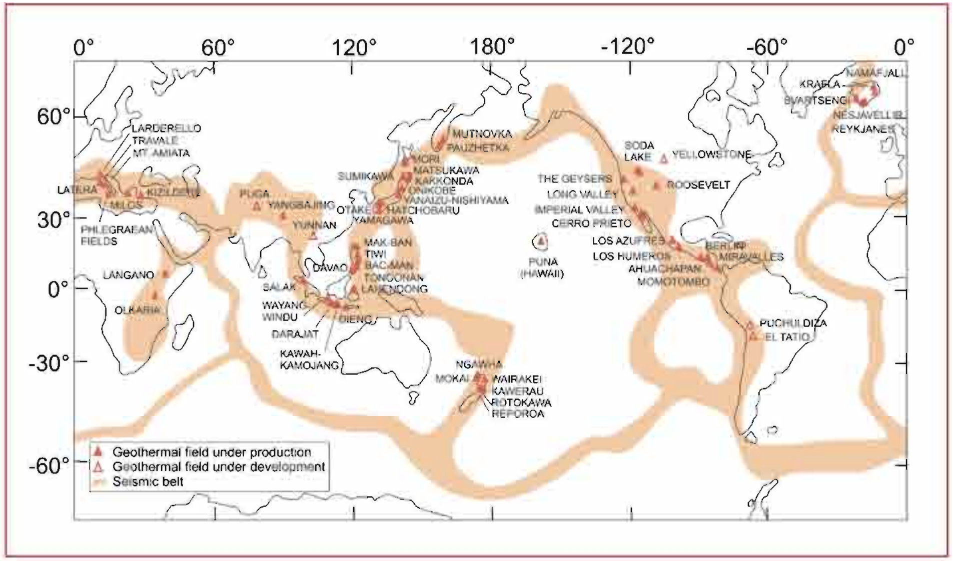


Figure 3 : *Worldwide distribution of major geothermal fields under production (filled triangles) and under development (open triangles). All the geothermal fields are located near to the plate boundaries. (Gupta and Roy, 2006).*

The global distribution of geothermal fields is shown in Figure 3. The "Pacific Ring of Fire", which defines the active volcanic belt surrounding the Pacific Ocean, has the largest conglomeration of geothermal fields, clearly reflecting the presence of magmatic heat sources in the upper few kilometres of the Earth's crust. This active plate boundary zone is replete with surface thermal manifestations such as hot springs, geysers, mud pools, fumaroles, steam vents, and active volcanoes. The four major geothermal power producing countries in the Asia-Pacific region, Japan, the Philippines, Indonesia and New Zealand, are located in this zone. Of the worldwide installed geothermal electric power production of 9732 MW, approximately 42 % is produced in the Asia-Pacific region. The Philippines is the second largest producer of geothermal power in the world, behind the United States of America.

The major geothermal fields under production in the Asia-Pacific region predominantly use hot water / wet steam systems with temperatures in the range 225–350 °C. A few dry steam fields occur in Indonesia, Papua New Guinea and New Zealand. On a much smaller scale, power is produced from hot water resources with temperatures <150 °C in Tibet, Thailand and Australia. Warm to hot springs with temperatures <100 °C occur in a number of other countries in the region such as India, Pakistan, Nepal, Bhutan, Mongolia, China, Taiwan, Malaysia, Burma, Vietnam, South Korea, Fiji, Solomon Islands and Vanuatu.

Utilization of geothermal resources

At present, eight countries in the Asia-Pacific region produce electric power from geothermal energy resources (Table 2). Of these, four countries – the Philippines, Indonesia, Japan and New Zealand figure in the top ten geothermal power producing countries in the world. Geothermal electric power contributes substantially to the national capacity in the Philippines, Indonesia and New Zealand (Table 2). In the Philippines, the installed geothermal electric capacity accounts for almost 13% of the installed national electric capacity and up to 23% of the total energy of the country. Significant capacity additions are expected in all the four countries during the next 5-10 years. The potential for direct (non-electrical) uses of geothermal energy is increasingly being recognized in the region. In Japan, geothermal energy finds use in recreational, agricultural, animal husbandry and space heating activities. Ground source heat pumps have been employed abundantly for space heating and cooling in a large number of localities, thereby reducing the dependence on fossil fuels as well as providing for a cleaner environment, particularly in big cities. In small, developing countries, geothermal power can replace fossil fuel energy substantially, and at the same time improve the quality of life by reducing carbon dioxide emissions.

Country	Total electric installed and planned geothermal (MW)I capacity					% National capacity (2005)
	1995	2000	2005	2007	2010	(MW)
Philippines	1227	1909	1931	1970	1991	12.7
Indonesia	310	590	797	992	1192	2.2
Japan	414	547	535	535	535	0.2
New Zealand	286	437	435	472	590	5.5
China (Tibet)	29	29	28	28	28	30 (Tibet only)
Papua New Guinea	0	0	6	56	56	-
Thailand	0.3	0.3	0.3	0.3	0.3	Negligible
Australia	0.2	0.2	0.2	0.2	0.2	Negligible

Table 2 : *Summary of geothermal power production in the Asia-Pacific region (Bertani, 2007).*

In the Oceania, development of geothermal energy resources in Papua New Guinea serves as a model for the small island nations. A 56 MW plant has been set up on the tiny Lihir Island, located about 700 km northeast of the national capital, Port Moresby. The geothermal exploitation arises from an unusual combination of the geothermal resource, a gold mining environment and the isolated location remote from the power grid. Geothermal power meets up to 75% of the electricity requirements for the mining operations, translating into an estimated saving of USD 40 million in 2007 from replacement of heavy oil for power generation. Direct uses of heat from geothermal waters have been reported from Papua New Guinea, Fiji, Solomon Islands and Vanuatu.

Current Technology

Geothermal resources vary widely from one location to another, depending on the temperature and depth of the resource, the rock chemistry, and the abundance of groundwater. They are predominantly of two types: high–temperature (>200° C) such as found in volcanic regions and island chains, and moderate-to-low temperature (50°-200° C) usually found extensively in most continental areas. High temperature resources (dry steam / hot fluids) can be gainfully utilized to generate electric power, whereas the moderate-to-low temperature resources are best suited for direct use. However, even the moderate temperature resources (~100° C) are now being utilized using the binary cycle method. The geothermal fields in Asia are dominantly hot water fields with steam mix only in a few fields in Indonesia, Papua New Guinea and New Zealand. Therefore, depending on the nature and quality of the resource, electricity is produced using one of the following technologies.

Dry steam plant, though rare, utilizes high temperature (>200 °C) geothermal reservoirs producing mostly steam and very little water. The steam is piped directly into the plant to run the turbines. The spent steam can be used in the plant's cooling system and injected back into the reservoir to replenish water and pressure levels.

Geothermal technology		Steam consumption, kg/kWh	Efficiency	Remarks
Vapour / steam based	Non-condensing cycle (gas content > 15% by weight)	15-25	Up to 12%	Highest efficiency, due to high enthalpy of steam
	Condensing cycle (gas content < 15% by weight)	6-10	Up to 17%	Possible only when dry steam is available; rare
Hot water based	Flashed steam	-	< 10%	Relevant for Asia-Pacific
	Binary cycle	-	2.8 – 5.5%	Small binary units are available commercially. Cascading is possible to get higher production rates. Can be installed in large numbers in Asia-Pacific.

Table 3 : *Typical efficiencies of different geothermal power generating cycles*

Flash steam plant, utilizes hot fluids from geothermal reservoirs with temperatures usually in excess of ~150 °C. These are passed through one or two separators where, released from the pressure of the deep reservoir, part of it flash converts to steam and is used to drive the turbine generator and then recycled to conserve water and maintain reservoir pressure. Most geothermal power plants operating today are "flashed steam" power plants.

Binary cycle plant. Low to medium enthalpy reservoirs with temperatures between about 85°C and 150 °C are not hot enough to flash enough steam but can still be used to produce electricity in a ***"binary" power plant.*** Here heat is transferred to a low boiling point binary (secondary) liquid which flashes into vapour and powers the turbines. The vapour is condensed and recycled. Although binary power plants are generally more expensive to build than steam-driven plants, they operate from reservoirs with lower temperatures, use the reservoir water more efficiently and have virtually no emissions.

In general, geothermal power plants have lower efficiency when compared with fossil-fuelled and hydropower plants depending upon the type of power generating cycle used. Typical efficiencies of the different power generating cycles are listed in Table 3.

Emerging Technologies

Enhanced geothermal systems

Enhanced geothermal systems (EGS) exploit the geothermal heat stored in hot and poorly permeable rocks without any fluid availability to store or transport the heat, by artificially enhancing the permeability in the top few kilometers of the earth's crust. The fractured rock at depth acts a heat exchanger, and heat is "mined" by circulating water from an injection borehole towards a production borehole. Regions characterized by recent volcanism, high heat flow, and localized pockets of highly radioactive rocks with substantial depth persistence are potential targets for this energy resource. All magma chambers have a surrounding hot rock environment of varying size. High heat flow areas underlain by poorly permeable basement rocks are possible hot dry rock resource areas. Geologically young igneous intrusive bodies at shallow levels of the Earth's crust occur in several continental areas. It has been estimated that cooling of 1 km^3 of hot rock by 100 °C will enable operation of a 30 MW geothermal electric power plant for 30 years. However, generation of large heat exchangers at depth, availability of large quantities of water, and controlling the loss of circulation fluids present the biggest technological challenges in exploitation of the hot dry rock / hot fractured rock geothermal energy.

Australia: A Case Study in the Asia-Pacific region

Pioneering research on EGS including deep drilling (up to 5 km) is underway in the Cooper Basin and a number of other localities of South Australia, where works are in progress to demonstrate the feasibility of using hot and fractured rocks at depths of up to 5 km as potential geothermal reservoirs. Parts of South Australia are endowed with very high levels of radioactive heat production in the upper crust (Fig. 2). The Cooper Basin is an area of very high heat flow. The basin is underlain by high heat producing granites (7-10 μW m^{-3}), and temperatures of ~240 °C have been measured at depths up to 3.7 km in several oil and gas wells. The borewell Habanero-1 met with temperatures exceeding 250 °C at 4.4 km. The project holds promise for the first successful demonstration of hot fractured rock technology in the Asia-Pacific region.

Geothermal heat pumps

A geothermal (or ground-source) heat pump makes use of the relatively stable temperature at a depth of few meters in the ground. During winter, the subsurface temperature is warmer than the room temperature inside a house, whereas during summer the subsurface temperature may be cooler. Geothermal heat pumps, therefore, can be extensively used for space heating in winter and cooling in summer, replacing fossil-fuel driven electrical heating and cooling systems. Heat pump systems use groundwater aquifers and soil temperatures in the range 5°C to 30°C.

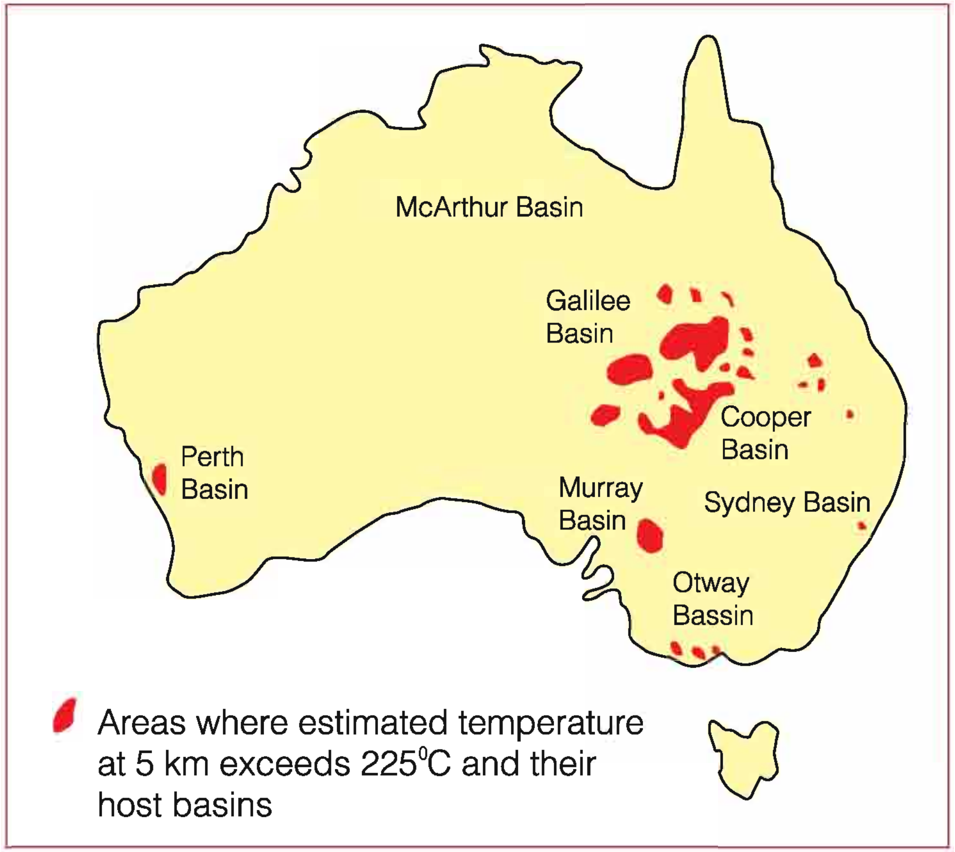


Fig. 4 *Map of Australia showing the areas where estimated temperature at 5 km is above 225oC (Source: GEODYNAMICS, Australia. URL: www.geodynamics.com.au)*

Harnessing the magma reservoirs

Magma is the ultimate source of all high temperature geothermal resources. Plate boundaries are the most common sites of volcanic eruptions. At several volcanic locales, magma is present within the top 5 km of the crust. The heat energy available from such sources, if harvested, would constitute very large additions to the global energy inventory.

Although extraction of thermal energy from magma was tested during the 1980s by drilling into the still-molten core of a lava lake in Hawaii, the necessary technology has not been developed to recover heat energy from magma. Economical mining of heat energy from magma presents several practical difficulties such as prohibitive locating and drilling costs and the hot corrosive environment. A much bigger challenge would be to tap the magmatic heat at the mid-oceanic ridges where magma from great depths is brought naturally to the surface. In view of the existence of potential sites in the Asia-Pacific region, renewed research efforts albeit on a long term scale, could be made to develop the necessary technology.

Geopressured reservoirs

Geopressured resources occur in basin environments where deeply buried fluids contained in permeable sedimentary rocks get heated in a normal or enhanced geothermal gradient by their great burial depth. The fluids are confined at supra-hydrostatic pressures by impermeable cap rock. Thermal waters under high pressures in sandstone aquifers are potential drilling targets for such resources.

To date, potential geopressured geothermal fields have been discovered mainly in the Texas-Louisiana Gulf Coast region. Similar systems may exist in other hydrocarbon bearing deep sedimentary basins elsewhere. Although the huge potential of geothermal-geopressured aquifers has been recognized, the commercial development has been considered marginally economic in only special circumstances. In the future, new technologies including use of binary cycle plants may allow more efficient extraction of thermal energy from geopressured brines. The release of large amounts of methane from geopressured brines needs also to be taken into account.

05
HYDROPOWER

Hydropower is a proven and well advanced technology based on more than a century of experience. The production of peak load energy from hydropower allows for the optimisation of base-load power generation from other less flexible sources such as nuclear and thermal power plants. Small scale hydropower, decentralized development, brings much needed electricity to rural and other isolated communities throughout the world. During last few years, the international community has recognized the important role of hydropower as a leading renewable energy technology "to be substantially increased with a sense of urgency".

Out of world's total primary energy supply of about 11,204 millions of tonnes oil equivalent (toe), only about 2.16% is from hydro sources. Out of a total 18,930 TWh of electricity generation, only 16.0% of electricity is generated through hydro sources. Hydropower provides the majority of electricity supply in 55 countries. For several countries hydropower is the only source of electricity production. Figure 5 shows the global hydropower feasible and actual generation.

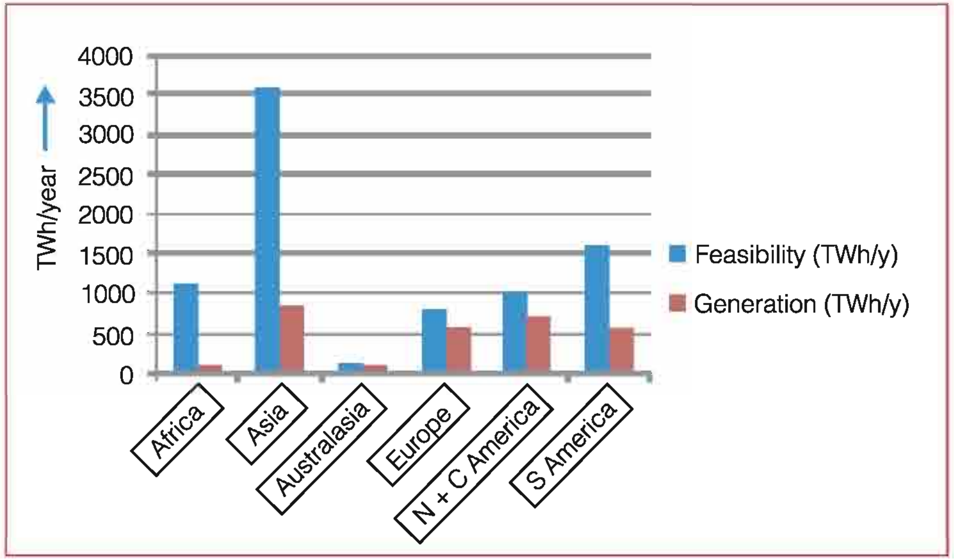


Figure 5 : *Global hydropower potential and generation (Source: World Atlas and Industry Guide, 2008)*

Regional Availability

About 130,500 MW hydropower capacity is under construction in 36 countries of Asia. In Asia, a large number of hydropower plants are under construction in Australia, China, India, Bhutan, Iran, Japan, Laos, Malaysia, Myanmar, Nepal, Pakistan, the Philippines, the Russian Federation, Sri Lanka, Tajikistan, Turkey and Vietnam. Asia and the Pacific region has excellent opportunities for both large and small hydropower development. Figures 6 and 7 show hydropower generation in this region.

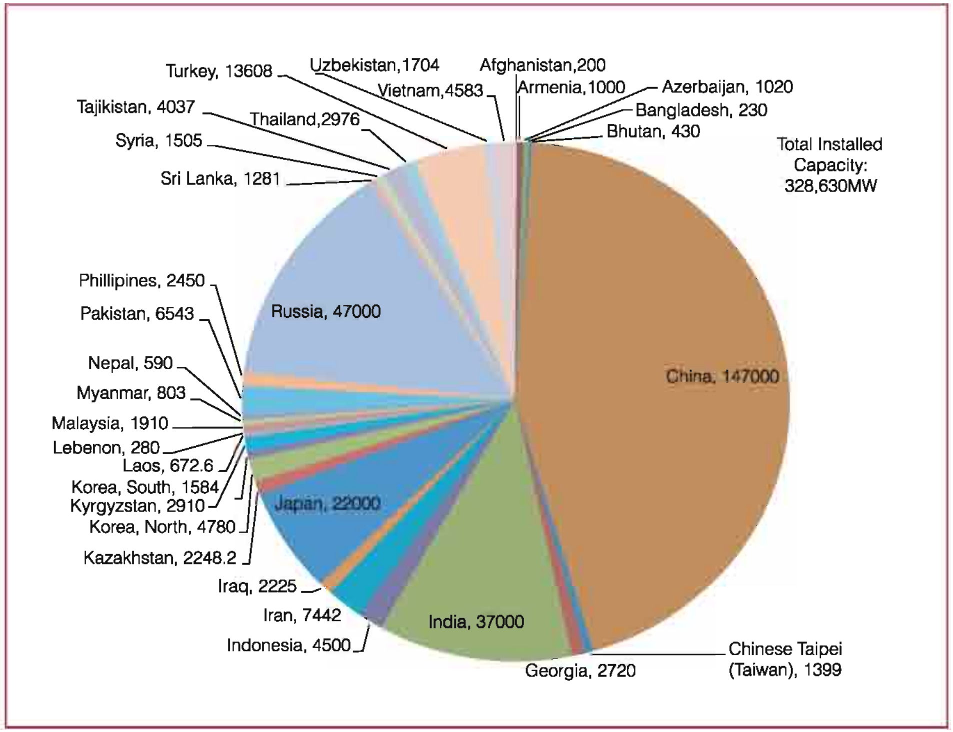


Figure 6 : *Hydro Generation by Countries in Asia (Source: World Atlas and Industry Guide, 2008)*

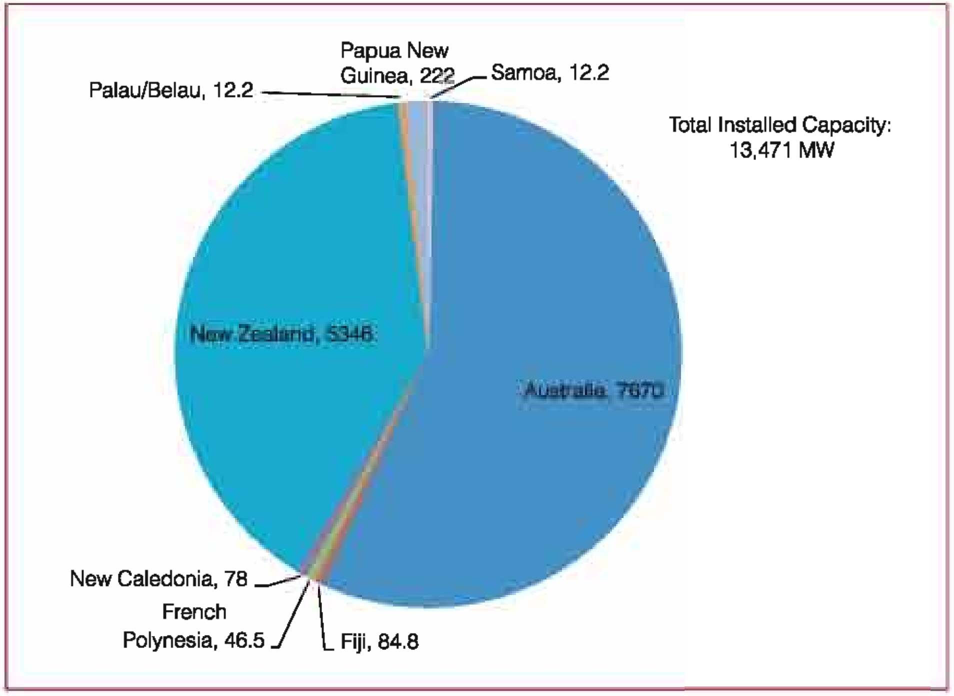


***Figure 7 :** Hydro Generation by Country in Australia and Pacific*
(Source: World Atlas and Industry Guide, 2008)

Current Technology

Hydropower generation uses the energy of flowing water to generate electricity when it passes through hydraulic turbines. The water then joins the river course or is used downstream for other purposes such as irrigation and water supply.

Based on installed capacity of hydropower projects, classification of hydropower varies differently in various countries. A general classification may be taken as: Pico ≤5 kW ; Micro ≤100 kW; Mini ≤2000 kW ; Small ≤25000 kW; Medium ≤100,000 kW; Large ≥100,000 kW.

Emerging Technology

Water withdrawal, silt removal, efficient generating equipment, environmental impacts are some of the areas where new developments are taking place. Efforts are being made to improve component efficiency and lifetime, reduce maintenance and operation costs and to optimise the utilisation of water especially in view of growing conflicting demands and competition with other energy sources. The size and scale of a plant may dictate the adoption of new technology. Large scale projects as major contributors to the grid need to be reliable and stable.

Hydropower, especially small hydro, has considerable scope to evolve, especially in assessment, equipment, and design practices. Investment is needed to support development of the environmentally friendly hydropower technology and to improve hydropower's competitiveness in current and future power markets. Water management is the fundamental challenge at hydroelectric projects for large and small hydro as non-power uses compete with power generation. Hydropower potential for new development is very large and is well distributed in Asia. Hydropower is important for mass-storage for electricity in synergy with other uses of water. Hydropower storage can contribute to large-scale water management needs including water supply, irrigation, flood control, navigation, tourism, recreation and fisheries.

In this environment, the importance of scientifically based solutions to support cost-effective decision making is critical. Further research in water management, civil work, materials design and equipment, centralised and distributed systems will speed development.

06

BIOMASS ENERGY

Biomass includes all plant and animal matter from water and land-based organisms, vegetation, and trees, or virgin biomass, and all dead and waste biomass such as, forestry and agricultural residues and certain types of industrial wastes. Municipal solid wastes (MSW) are here considered separately.

Regional Availability

The global technical potential for biomass was estimated to be more than 200 EJ year[-1] in 2000, while the utilization was 50 EJ year[-1]. Most of this consumption took place in developing economies, where biomass is utilized primarily for cooking and heating.

The Asia-Pacific region is lagging behind in providing efficient access to biomass energy sources. Over 1.7 billion people in the region are using traditional biomass fuels inefficiently leading to health hazards. Both China and India are making substantial investments in biofuels. Malaysia and Indonesia are investing heavily in oil palm plantations for biodiesel production. The Philippines has a mandate of blending gasoline with 5 percent biofuel, while India has passed a legislation for blending 5% ethanol and 1 % biodiesel with all fuels.

Out of the total land area of 3005 million ha in the Asia Pacific region, 17 % is arable and permanent crop land, 34 % is permanent pasture and 26 % is forest and wood land amounting to nearly 80 % under vegetation. This value contrasts with 70 % for the world. About 16.6 % is under agriculture in the region as against 9.5 % in rest of the world.

Table 4 consolidates major crop production in the region from FAO reports. The agro production, excluding sugar cane, amounts to about 2200 million tons which is comparable to rest of the world crop production.

Region	Rice	Wheat	Maize	Millet	Cereals	Pulses	Ground nut	Coconut	Power potential
	(in 1000 tons)								(in MW)
SOUTHEAST ASIA	171152	149	27063	163	198156	3589	16268	34834	30091
SOUTH AND SOUTH WEST ASIA	199943	111563	21904	10666	355866	16782	5086	12013	48921
CENTRAL ASIA	573	23829	1154	6	25250	192	11	0	3401
PACIFIC ISLANDS	22	0	10	0	35	8	4	1924	133
OTHER COUNTRIES	10821	10933	552	35	28954	922	44	0	3484
ALL ASIA-PACIFIC	**573336**	**244329**	**192221**	**12688**	**1049224**	**27345**	**35830**	**49071**	**145602**
REST OF THE WORLD	58080	357598	502725	18346	1108269	33068	11626	5876	139705
WORLD	**631416**	**601927**	**694946**	**31034**	**2157494**	**60413**	**47455**	**54947**	**285308**

Table 4 : *Major crop production (in 1000 tons) and their power potential (in MW) within the region and the world*
(Source of Data: Food and Agricultural Organization, 2007)

Analysis based on agricultural production data and satellite images suggests a power potential of 145000 MW in the region. Residues from forest activity are also available as bioresources. Fuel wood production in the region is about 768 million m^3 against 2313 million m^3 in the rest of world. The region produces 5237 million m^3 of charcoal against 9824 million m^3 in the rest of the world. Industrial round wood production is 2442 million m^3 compared to 13304 million m^3 in the rest of the world. Residues, from processed industrial and fuel wood amount to about 600 million tons with an estimated electric power production potential of 50,000 MW.

Sugar cane is a major crop in the region used for co-generation, sugar and ethanol production. Table 5 provides details for the region, amounting to about 590 million tons; nearly 60 % of the world production. The potential for power generation through cogeneration is in the range of 10000 MW. Bagasse cogeneration has an estimated potential of 5000 MW with 800 MW currently installed in the sugar industry.

Region	1000 tons
Southeast Asia	125107
South and South West Asia	335906
South and South West Asia	0
East Asia	87768
Pacific Islands	3450
Other countries	39419
Asia- Pacific	591650
Rest of the World	747680
World	1339700

Table 5 : *Sugarcane production in the Asia-Pacific region.*

Current Technology

Most of the biogas technology packages are first generation type, using mesophylic conditions and easily digestible substrates. A few packages for other raw materials such as plant material and vegetable wastes, are being tried out at pilot scale demonstrations and large scale activities are yet to be realized. Even though improvements are possible to provide better and more reliable technology packages, high installation costs and unattractive feed-in-tariffs offered by the utilities for industrial plants are hampering large-scale commercialisation of biogas power generation in the region.

China has made significant progress in utilizing biogas plants for domestic applications. About 18 million domestic plants were built by 2006, and over the 3455 plants for livestock farm based plants to generate biogas were in place. About 189 million fire-wood saving stoves are in use along with over 500 centralised gasification systems for cooking. Some of the packages use prefabricated fibre glass structures to popularize biogas use. In India, against a potential of 12 million domestic biogas plants, about 4 million plants have been constructed, mostly under government subsidy schemes.

Thermo-chemical conversion (combustion) of biomass is a primary source for domestic needs in the region. Improved cooking stoves aimed at reducing indoor air pollution with improved efficiencies, continue to be researched, but actual field data rarely support claims on their performance. A significant fraction of the population uses charcoal as a cooking fuel. Charcoal preparation is a highly polluting and an environmentally hazardous process. One notable technology started in India and slowly reaching other Asian countries uses agro residue pellets as fuel with improved efficiency and lower indoor emissions. Cogeneration is gaining importance as the sugar industries use bagasse as the fuel for power generation. There is still a significant challenge in drying bagasse to improve efficiency and also use of sugar cane trash as a fuel. Some attempts in this regard have been carried out in Australia, India and other countries.

Biomass gasification yields producer gas (20% H_2 , 20% CO, 1 - 2%CH_4) by the partial combustion in a controlled air supply. The energy value of producer gas is about 5.0 MJ/m³. It can be used as an internal combustion engine fuel for mechanical and electrical applications. Distributed power generation using biomass gasification is gaining impetus and offers grid quality electricity even at small capacities with high fuel conversion efficiencies. Cofiring with biomass is also being explored by various industries to substitute fossil fuel.

Biodiesel is derived from the transesterification or alcoholysis of edible oils including soya, rapeseed, vegetable, peanut, coconut and palm oil of which Asia is the largest producer and consumer. Ethanol, produced primarily by the fermentation of starch from grains (mostly corn) or sugar from sugar cane is most commonly used as an oxygenate in reformulated gasoline and in a gasoline blend called "gasohol." These fuels can be burned in gasoline engines. Specialized engines, on the other hand, are needed to burn pure ethanol.

Since the 1960s both Malaysia and Indonesia have developed the use of palm oil for biodiesel production. Different types of fuels have been produced: (1) blending petroleum diesel with palm diesel, known as envo diesel; and (2) converting palm oil into methyl ester, known as palm diesel. Malaysia produced about 15 Mt of crude palm oil in 2005, and intends to convert over 500,000 tons into biodiesel. Currently, 10% of palm oil production has been allocated for the biodiesel program. Malaysia has about 92 licensees to produce palm oil based biodiesel. It plans to produce about 50 000 tons of biodiesel and export nearly 70 % to Australia, EU, Hong Kong, Japan, Korea, Germany and USA. It is important to address utilization of the cake, a byproduct in the oil production, for energy purpose.

Use of biomass as a source of energy can be virtually in all the sectors. Prioritizing is an important aspect depending upon the requirement. It is important to recognize that the region has a responsibility of meeting the electricity demand from renewable resources. Biomass energy to a large extent can support this energy demand. In the region, countries like Australia, Japan and New Zealand are generally pursuing various renewable energy mixes to produce green energy.

Emerging Technology

Figure 8 depicts various biomass conversion technologies in use or in development. End devices to utilize the bio-derived fuels are currently being adapted from fossil fuel technologies.

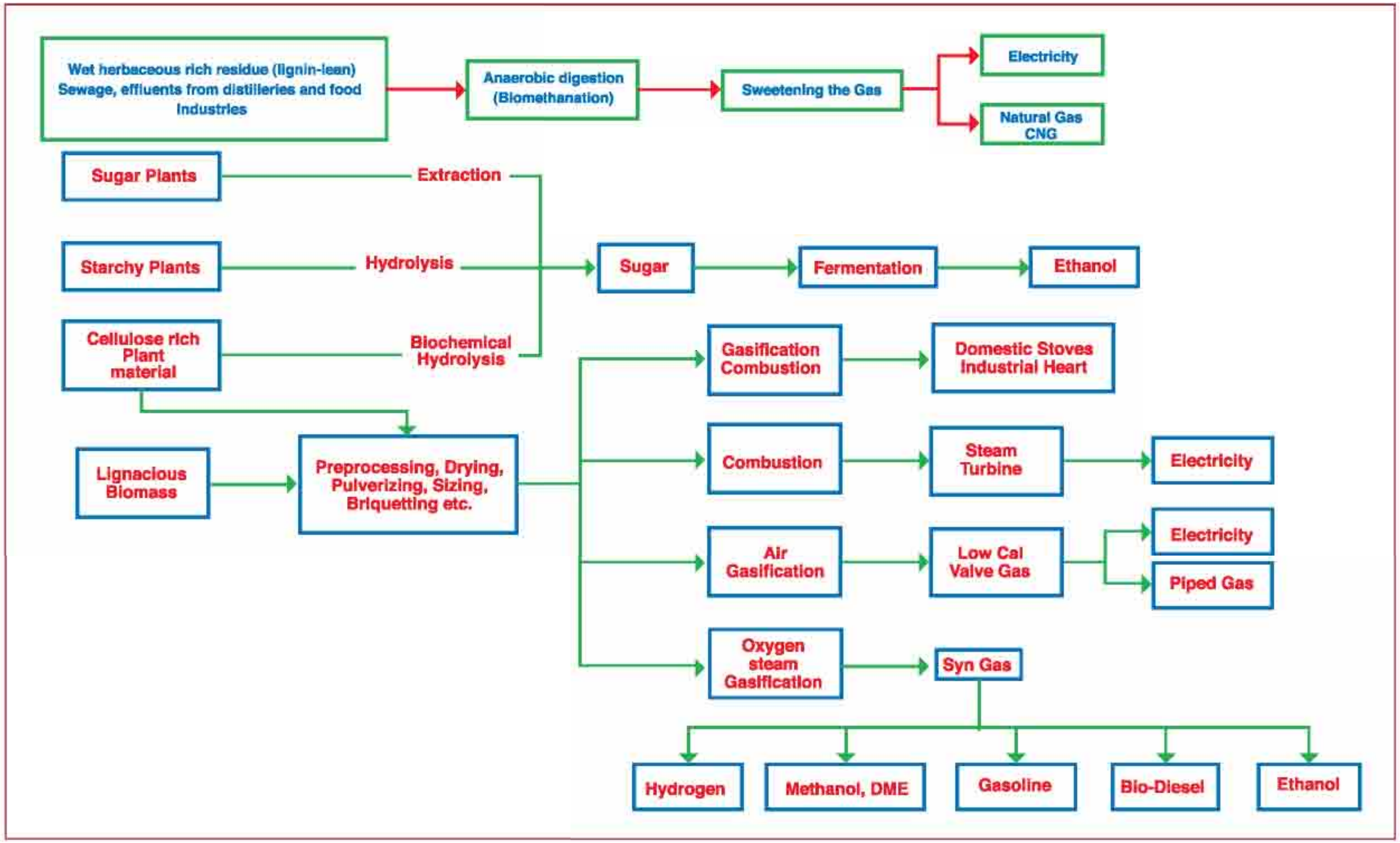


Figure 8 : *Various conversion technologies being practiced and researched.*

Biological conversion using ligno cellulosic material in bi-phase processes and plug flow digesters is being seriously addressed in the region. The bi-phase digesters with thermophylic operations also have advantage of higher conversion efficiencies and compact designs. These technology packages can also be adapted for treatment of waste from process industries. Use of biogas for various other end uses like fuel for engines, hydrogen generation, liquid fuels through catalytic cracking, etc is emerging as an alternate energy source.

Figure 9 provides the information on ***thermo-chemical conversion*** performance. It is clear that at small capacities (few MWs) devices like gasifier based power generation, Stirling engines and Integrated Gasification Fuel Cell (IGFC) would be the ideal technology packages.

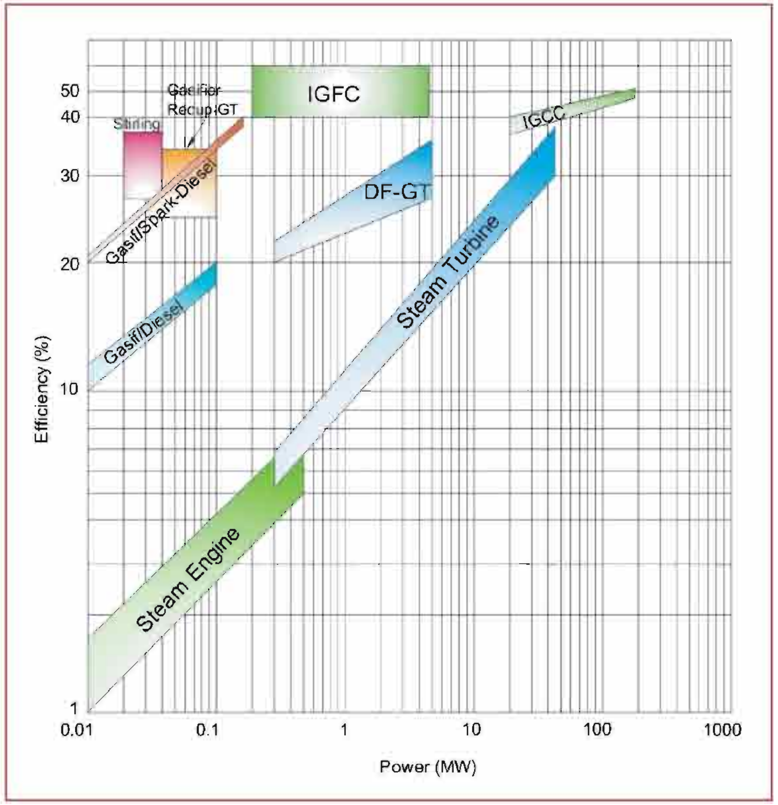


Figure 9 : *Performance of various thermo-chemical conversion technologies (after Overend, 1998). IGFC – Integrated Gasification and Fuel Cell;IGCC – Integrated Gasification and Combined Cycle; DFGT – Dual Fluid Gas Turbine; Recup-GT – Recuperated Gas Turbine.*

Adapting different technology packages (Grate combustion, Fluid Bed Combustion, Circulating Fluid Bed Combustion) to handle various biomasses singly or in co-firing and meet emission requirements and operational issues is a challenge. There are critical issues on ash fusion and inorganic oxide deposition in the power sector. Attempts to generate byproducts like cold storage using vapor absorption cycle are being considered. Co-generation is gaining importance in the sugar sector and is probably easy to replicate in all the sugar growing countries.

Biomass based hydrogen generation is an emerging technology through syngas. It is also a starting point for Biomass to Liquid fuel; a technology which is being contemplated for the transport sector. Japan has been working on the Fischer Tropsch synthesis process to optimize the yield and the fractions of liquid fuel to match the petroleum sector. Low temperature fuel cells using hydrogen have evolved, while the high temperature ones are in the transition towards commercialization. The syngas generated using thermo-chemical conversion is an ideal process for solid oxide fuel cells.

Higher quality biofuels with acceptable shelf life, clean combustion and easy adaptation of existing fossil fuel devices are clear development areas. For example, Australia and Japan are addressing biofuel productivity from land areas using algae as a source of raw material and this is being researched extensively in various other countries.

07
WASTE TO ENERGY

Waste-to-energy refers to any waste treatment that generates energy in the form of electricity or heat from a waste source and may include the use of waste or marginal land. The total amount of solid waste generated each year in the Asia-Pacific region is about 700 million tones and industrial activities generate 1,900 million tones of waste per year. This is set to increase with growing economies and populations. Except in few countries, comprehensive assessments of waste generation are not available.

Regional Availability

The UNESCAP Reports on State of the Environment in Asia and Pacific (UNESCAP, 2000, 2006) highlight environmental health implications arising from improper storage and inadequate waste collection along with poor standards of disposal. In many countries, only around 70% of urban municipal waste is collected, of which only about 5% is treated. Solid waste disposal is a particular problem in the small island states where it has often been used for land reclamation resulting in pollution of coastal areas. Expansion of chemical-based industries in the region has generated significant hazardous waste adding to the waste management problem. Social and environmental accountability is requiring governments across the region to streamline the collection, disposal and treatment of waste. Sewage treatment and more specifically the management of biosolids across Asia-Pacific is in a poor state. Improvements are being implemented and will add on to the sewage sludge streams that are currently available. Poor sanitation systems have compounded the water quality issues in many countries.

Energy recovery from waste has enormous potential in Asia and is being used for various on-site power generation systems in which different types of alternative fuels are used. It helps to meet the demand for reliable electric power in a way that is both economical and environmentally friendly. All waste streams generated from day-to-day activities, agriculture systems and industry have potential for energy recovery. It is estimated that Japan is home to nearly 70 percent of the world's waste incinerators and nearly three-quarters of the nation's waste is burned in these facilities. Taiwan, China and Singapore are significant proponents of this method of WTE. Landfills with complete gas recovery and utilization systems are limited. China generates an estimated 280 million tons of waste annually, most of which is disposed via land-filling. The Ministry of Construction of China has outlined a National Waste Disposal Plan to increase energy-from-waste from less than two percent of waste disposal in 2005 to 30 percent by 2030.The waste availability and expected growth by 2010 for some of the region's countries are presented in Table 6.

Types of Biomass	Sri Lanka		India		China		Philippines		Thailand	
	2005	2010	1997	2010	2005	2010	2005	2010	2005	2010
Agricultural residues	62.9	64.6	4715	6565	5589.2	5307.2	395.4	431	557.9	619.8
Biomass from conservation	50.8	50.2	-	506	104.4	104.4	212.3	232.3	35.7	59.1
Municipal Solid Waste	4.5	4.8	86	219	77.6	91.1	42.8	46.8	20.6	21.3
Waste water	0.3	0.35	4	200	101.9	101.9	-	-	7.8	7.8
Black liquor	-	-	-	-	207.4	287.1	0.01	0.02	4.6	4.6
Palm oil	-	-	-	-	-	-	-	-	1.3	1.3
Biomass from substitution	7.88	15.5	-	900	456.8	913.6	169.1	253.7	60.7	94.3
Total	**132.7**	**141.95**	**5141**	**8764**	**8135.7**	**8899.8**	**823.7**	**968.7**	**701.6**	**821.2**

Table 6 :*Total non-plantation bioenergy potential in selected Asian countries (PJ).*
(Source of data: Bhattacharya S. C., Abdul Salam P., Runquing Hu, Somashekar H. I., Racelis D. A., Rathnasiri P. G. and Yingyuad R. (2005), An Assessment of the potential for non-plantation biomass resources in selected Asian countries for 2010, Biomass and Bioenergy, 29, 153-166)

The nature of waste for WTE is critical; with biological techniques being the preferred choice for waste with high organic and moisture content. Waste analysis and city versus rural differences will influence processing options; little of this detail is available. The thermal process based WTE systems in Asia-Pacific amounts to about 300 facilities handling 50 million tones per year. These are mainly in Japan, Taiwan, China and Singapore. The WTE industry needs to take on a broader definition using a wider technology base.

Current Technology

Most WTE processes produce electricity directly through combustion, or produce a combustible fuel commodity, such as methane, methanol, ethanol or synthetic fuels. Incineration is the most common WTE method. Modern incinerators reduce the volume of the original waste by 95-96 %, depending upon composition and degree of recovery of materials such as metals from the ash for recycling. Implementation of a modern incineration scheme is expensive and there are no appropriate incinerators to suit developing economies due to the nature of the operation, environmental demands and legislation. Incinerators have electric efficiencies on the order of 14-28%; the rest of the energy can be utilized for district heating where appropriate. The WTE sector (thermal processing segment) is the most regulated waste related industry in the developed economies. Problems regarding the operation of incinerators include fine particulates, heavy metals, trace dioxin and acid gas emissions; however, few countries have facilities to study these concerns.

There are a number of WTE technologies that are able to produce energy without direct combustion. These can be catalogued as thermal and non-thermal technologies. The choice between thermal and non-thermal technologies is based on the degree of moisture.

Thermal technologies include: gasification (produces combustible gas, hydrogen, syn fuels which can be burned to produce electricity), thermal depolymerisation

(produces synthetic crude oil, which can be further refined), pyrolysis (produces combustible tar/[[bio-oil] and chars]), and plasma arc gasification or plasma gasification process (produces rich syngas including hydrogen and carbon monoxide usable for fuel cells or generating electricity, vitrified silicate and metal ingots, salt and sulphur).

Non-thermal technologies include: landfill systems and landfill bioreactors, anaerobic digestion (biogas), liquid biofuel production (saccharification and fermentation), liquid biofuel production (trans-esterification), and mechanical biological treatment (+ anaerobic digestion).

Other biological pathways may involve fermentation schemes to produce liquid biofuels such as bioethanol and biobutanol. Chemical reactions can also be used to produce energy products such as biodiesel from specific wastes like cooking oils.

Emerging Technology

The WTE technologies are complex, capital intensive and require strong technical support. Specific human resource needs will have to be considered when implementing these technologies. There is a tendency to move from low-end inappropriate technologies to more effective WTE options. The present WTE diversity calls for specific case analysis in order to develop technology management guidelines and new developments will require significant research commitment.

The following are seen as potential thermochemical areas for research and development: plasma gasification, pyrolysis and gasification, waste oil gasification and RDF operations. Biochemical development areas include: biocell systems, landfill gas systems, high rate plug flow biogas systems and different biogas reactor configurations. Fermentation, second generation biofuels (cellulosic ethanol) and microbial fuel cells also need research effort.

08
OCEAN ENERGY

Ocean energy is an indirect form of solar energy. Other than geothermal energy, it is the only renewable energy resource which can generate a few hundred megawatts of power from a single plant and can be used for supply of base load power. The three forms of ocean energy conversion systems which have reached a 'Technology Demonstration' or 'Pre-commercial' phase are: Ocean Thermal Energy Conversion (OTEC), Wave Energy Conversion (WEC) and Tidal Energy Conversion (TEC). The technology to tap energy from "salinity-gradient" at river estuaries is in a preliminary stage only and requires long term research.

Regional Availability

Ocean Thermal Energy Conversion (OTEC) technology utilizes the temperature-difference between warm surface sea water of around 27 – 29° C in tropical waters and the cold deep sea water of around 5 to 7°C, which is available at a depth of 800 to 1000 m, to run a heat engine using a Rankine cycle. Typical temperature depth profiles in the sea are shown in Figure 10.

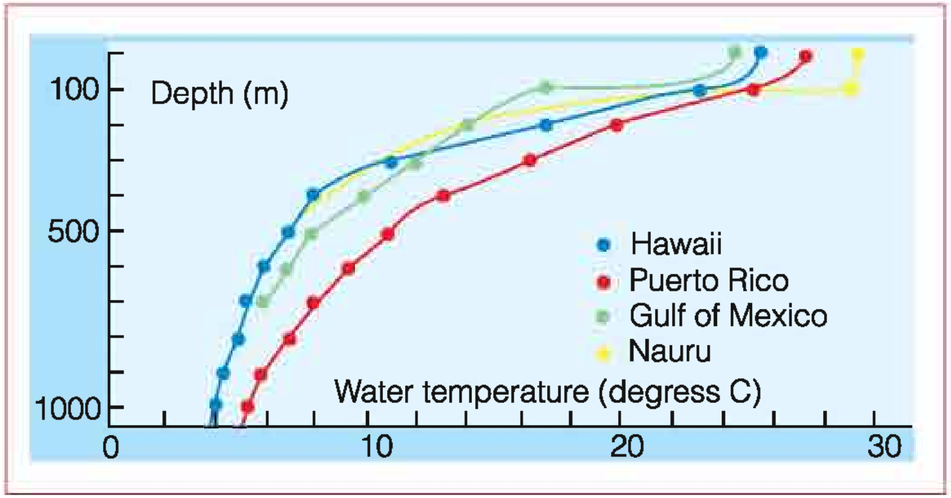


Figure 10 : *Temperature profiles in sea-water up to a depth of 1000 m obtained from measurements at four different tropical locations. (Source: Institute of Ocean Energy, Saga University, Japan; http://www.ioes.saga-u.ac.jp/english/index_e.html)*

A map showing the distribution of the estimated temperature differential in the top 1000 m, in the latitude band 40° N to 40 °S, is given in Figure 11. The Asia-Pacific region, with a temperature differential of more than 20° C, has a vast potential for OTEC. It is roughly estimated that for every 2000 square kilometre of sea area with these temperatures, one 400 MW OTEC plant could be established. The potential around India alone is estimated to be 55, 000MW.

Figure 11 : *Map showing the distribution of estimated temperature differential within the top 1000 m in regions where OTEC is feasible. Note that OTEC is particularly suitable for tropical oceans extending from 20° N to 20°S, where the temperature differential is greater than 20°C. (Source: Institute of Ocean Energy, Saga University, Japan; http://www.ioes.saga-u.ac.jp/english/index_e.html)*

Globally, two variants of the OTEC technique have been developed and tested. In closed-cycle OTEC, the warm surface sea water exchanges energy with low temperature boiling fluids like ammonia and the vapour generated is passed through a turbine to produce work and then recycled using deep sea cold water. In an open cycle system, warm surface sea water at 28° C is flash evaporated in a vacuum chamber. The resulting low pressure steam drives a fairly large diameter turbine and then condensed by the cold deep sea water. The condensate is potable water which is a valuable byproduct. The closed cycle OTEC plant is more compact and can be easily scaled up to the megawatts range, but it does not produce desalinated water.

In the Asia and Pacific Region, Japan and India are countries actively involved in OTEC research and demonstration projects. India started their research on ocean energy in 1982 soon after Japan demonstrated the operation of a 100 kW closed cycle plant in the Republic of Nauru in 1981. India has a number of islands in the Lakshadweep and Andaman Nicobar region where such shore based plants are feasible. However, for mainland India, floating power plant technology is needed, because the deep water from 1000 m is available only at a distance of 25 to 35 km from shore. However, most of the small island nations in Pacific have the required temperature differential for OTEC within 1 to 10 km from their coast, which are suitable for shore-based OTEC plants. Additionally,

for the small island nations, OTEC plants could bring water and food security by producing fresh water along with electricity and facilitating aquaculture using the nutrient-rich, pathogen-free cold water effluents.

Current Technology

Starting in the late 1970's, a number of OTEC technology demonstration plants have been tested across the world (e.g., Republic of Nauru; Keahole Point, Hawaii; on-board U.S. Navy tankers). They varied form floating- to land- based plants with closed cycle or open cycle system. In the mid 1990's, the National Institute of Ocean Technology in India started the design and construction of a 1 MW floating plant with a closed cycle ammonia system. Even though the barge and on-board systems were tested, the plant could not be commissioned due to the failure of the flexible joint between the barge and the 1000 m - long cold water pipe. The Republic of Palau is planning for an OTEC plant of 3 MW capacity.

The potential of ***Wave Energy Conversion*** generally varies between 10 and 15 kWm^{-1} in countries lying between 10° N and 10° S latitudes. For regions in higher latitudes, the potential varies between 20 and 70 kWm^{-1}. Most of the countries including island nations possess this wave energy potential all along their coasts. Even though energy from waves has less variability compared to wind energy, the actual wave power varies from time to time and from season to season. Offshore devices offer higher potential because deep water waves possess higher energy when compared to waves in shallow waters.

Japan was the first nation to use wave power almost 50 years ago, for application in navigational buoys. The United Kingdom started serious research on a variety of devices during the mid 1970's. During the early 1980's, Japan and other countries in Europe such as Norway, Sweden and Portugal started testing a variety of devices which heave or oscillate under the action of waves. India, China, Korea, Australia and the United States of America joined the group during the mid 1980's. Among all these devices, the Oscillating Water Column (OWC) device was the most studied and tested by many countries in Europe, Asia and Southeast Asian countries. The OWC device has a submerged opening through which waves enter a chamber which rises above the mean sea level. The wave oscillates the water level inside the chamber like a piston and causes bidirectional airflow, in and out of the chamber. The power take off system consists of an air turbine and generator. There has been a variety of turbines developed with flow rectifying valves and without valves. The turbine types varied from the Wells type to impulse turbines. Also, different types of generators and controls were developed. The OWC based plants built in Japan, Norway, United Kingdom, Portugal and India have demonstrated the technical feasibility of generating electricity from waves, but with output power in the range of few hundred kilowatts only. The plant erection and operational costs are high. But, if scaled up to multiple megawatts, the cost of energy from waves is estimated to be around 8 cents (USD)kWh^{-1}.

In the Asia Pacific region, the south western Australian coast has the highest wave energy potential of 40-70 kWm^{-1}. It is estimated that the total wave energy potential in Australia is around 200,000 MW and that 10% of "near-shore energy" using submerged heaving buoys could meet 35% of the present power needs of near-shore regions of Western Australia. Japan and other island nations in the region, with wave power potential of 15-40 kWm^{-1}, can choose between shore-line devices or offshore devices depending on the sites. In India, the achievable resource from wave energy is estimated at 20,000 MW. Other mainland countries like China and Korea can also have a choice of wave energy devices with a capacity of about 10-40 kWm^{-1} of the wave crest length.

The most promising wave energy device with large capacities for shore-line applications is the bottom standing OWC device. Field experiments have been conducted on OWC based systems in various capacities, namely, 30 kW unit at Kujukuri, China, a 60 kW unit at Sakata port in Japan, 75 kW unit at the island of Isaly, Scotland, a 150 kW unit at Trivandrum in India, 500 kW unit at Toftesfallen, Norway and at the island of Pico, Azores in the Atlantic Ocean. Australia has also tested OWC devices at few locations. The offshore devices for depths of more than 40m mainly consist of vertically heaving submerged buoys or multiple floating bodies hinged together.

Power from ***Tidal Energy Conversion*** can be generated either by using the level difference between the open sea and the basin by allowing the water to flow through turbines located in the barrage separating the estuary from the sea, or by allowing the tidal current to directly drive the freely located turbines in the creeks or the channels. Locations suitable for tidal power are limited.

Among the three forms of ocean energy, the tidal energy was the first to be exploited on a large scale. The Rance tidal plant, commissioned in 1966, with a barrage across the Rance river estuary in France, has an installed capacity of 240 MW with 24 bulb turbines of capacity 10 MW each. The plant is working efficiently even today, highlighting the reliability of tidal power generation. Smaller tidal power plants have been built at Kislaya Guba in Russia and at Bay of Fundy in Canada. China has built 10 mini-tidal plants with a total capacity of 20 MW. When an ocean barrage is required the cost of construction is very high and in smaller power plants where constructing a barrage renders the economics unviable, free stream turbines are preferred.

India has tidal power potential of around 20,000 MW mainly from two states of Gujarat and West Bengal. The Gulfs of Cambay and Kutch in Gujarat have a peak tidal range of 11 m and the current velocities reach a value of about 5 ms^{-1}. The Sundarbans region in West Bengal has a tidal range of around 5 m and the Indian government has approved the building of a tidal power plant of 3.65 MW capacity in the Durgaduani creek of Sundarbans area.

South Korea is actively involved in the development of tidal power. A 1 MW plant is being built at the Myeongnyang channel and a 252 MW plant is planned at Gari island. South Korea is planning to build the world's biggest tidal power plant with a capacity of 812 MW by constructing barrages to connect four islands in Ganghwa region. It is expected to provide 8.2 % of power needs in Korea.

China is designing a tidal power plant of 300 MW capacity. New Zealand is planning to locate a tidal current power plant at the entrance to its Kaipura Harbour with 200 free stream turbines having a total capacity of 60 MW. A multi-megawatt rating tidal power plant has been planned in the Philippines. North West Australia has high tidal power potential. The resource in Derby region alone is 3000 MW.

Emerging Technology

A superior OTEC thermal cycle has been developed by Japan, which is expected to have an overall efficiency of around 5% compared to the maximum thermal efficiency of the conventional Rankine cycle at 2.5%. Further advancements in technology, such as innovative designs for the floating platform and its mooring, exploring the feasibility of using flexible steel riser pipes instead of cold water pipes made of high density polyethylene, reduction in the cost of plate heat exchangers using improved materials are being researched. Efforts are being made to popularize OTEC plants by demonstrating the valuable by-products such as fresh water and hydrogen.

In many countries, the coastal regions and islands need to augment drinking water supplies and wave energy installations are being used to desalinate sea water, apart from generating power. The Indian oscillating water column (OWC) plant with its installed capacity of 50 kW is used to run a reverse-osmosis plant supplying 10,000 litres of fresh water per day to a nearby village. Further, the single air-turbine, which has been upgraded from Wells type to impulse type, is being modified to a two-turbine system, one for each direction of air flow from the OWC. This is expected to increase substantially the overall performance of the plant. Australia is planning to install an array of submerged heaving buoys to pump sea water to a Pelton wheel for power generation up to 300 MW in addition to a reverse-osmosis based desalination plant.

The main aim of the future tidal power plants is to reduce the installation cost and to maximize the power output from a single turbine. Shrouded turbines or free standing turbines located in a duct are most promising in this direction. A tidal pontoon of size 8 m x 13 m, fitted with vertical axis Savonius type turbines below the pontoon has been developed in United Kingdom. The turbines are connected to vertical axis generators on top. This system promises to have the minimum installation cost because the pre-fabricated pontoon, with turbine – generator systems assembled, can be towed easily to the site and moored in the stream.

The major cost of a closed cycle OTEC plant comes from the cost of heat exchangers (evaporator and condenser), the floating barge and the 1000 m deep cold water pipe system and its moorings. Compact titanium plate heat exchanger plates used in the Indian plant have been coated with stainless steel powder to enhance the heat transfer coefficients which help to reduce the required heat transfer area. Studies are ongoing to evaluate cheaper plate materials like aluminum alloys and the use of flexible steel riser pipes, along with innovative designs for the floating platform and its mooring.

08

EFFICIENT ENERGY USE

Buildings consume a large amount of light and heat energy in order to supply a comfortable and safe living environment. The Asia and Pacific regions experience extreme range of outdoor environments and consequent varying energy requirements for a comfortable living situation. In addition, air pollution from heating and lighting systems and exhaust gas from automobiles is a serious problem in many cities of the region.

Regional Availability

Energy used in the building sector is almost 30% of the world energy consumption and almost half of the world's new buildings are in China, India and other Asian countries. In hot regions, the low performance of building thermal insulation creates a large energy consumption burden from air-conditioning. In such regions, it is necessary to introduce buildings with low space heating and cooling loads. Other effective measures include: utilization of renewable energy and waste energy (e.g. exhaust heat and drainage water from factories, etc.) as well as the introduction of efficient regional energy supply systems. In addition, low energy buildings should be designed to minimise carbon dioxide emission.

In general, traditional buildings were built according to regional climate conditions, local culture, and the availability of building materials. For example, houses with high ceiling and large underfloor void space found in Sumatra, Indonesia, are comfortable due to natural ventilation in the hot-humid season. Many houses are built on water surfaces in Sandakan, Malaysia, and take advantage of the evaporative cooling effect from the water surface. There are many cave dwellings in the Northwest part of China where the indoor climate is stable for the whole year due to the high thermal mass. The potential of these traditional technologies and the technical characteristics of traditional buildings e.g. building materials, design, construction and control methods of the living environment should be assessed for modern architecture application. The relationship between climate conditions and lifestyles of the occupants has also to be taken into account.

Globally, lighting constitutes about 19 % of total electricity consumption. This figure is expected to reach 2550 TWh by year 2550. Asia-Pacific region accounts for approximately 40% of the lighting market and this is growing rapidly. Energy for lighting (including automotive lights) was responsible for 1889 MT of CO_2 emission in 2005 with 1528 MT coming from the grid based systems. In 1997, 28% of the total lighting electricity was used in the residential sector, 48% in the service sector, 16% in the industrial sector and 8% in the street lighting and other applications.

Current Technology

Buildings

The outdoor environment - temperature, humidity, wind, solar radiation, geographic location and the potential for natural disasters, all impact on building design. In addition the external environment due to human social activities is an additional factor in urban areas with high population density. For instance, air pollution, noise, and reduction of greenery, waste heat from air-conditioners cause heat island problems. Bad ventilation and lack of sunshine in densely constructed buildings are further complications. Living environment is largely affected by the performance of the building envelopes in areas such as insulation, air-tightness and heat resistance performance. From a sustainability perspective, recycling of building materials after the demolition is being actively promoted. A comfortable and safe living environment is achieved not only by improving the building performance, but also by utilizing equipment for ventilation and the heating and cooling systems with increasing reliance on sustainable energy sources.

Bad indoor environment significantly increases the risk of occupant health problems. For instance, 'Sick Buildings' result from the pollutants generated by building materials, furniture and household goods and 'Damp Buildings' result from microbial pollution (e.g. mould) which exists in high-humidity environments. Residences and infrastructure for the infirm and elderly demand a safer and more comfortable inner environment.

Worldwide, best practice buildings which provide a more comfortable living environment and consume less energy with the utilisation of new technologies, strategies and materials are being realised. In Japan, a sustainable database website is available online to disseminate Japanese Sustainable Building (SB) in information on architectural projects, including CASBEE score and technical details, building techniques and policy frameworks etc.

Efficient lighting

There are about 1.6 billion people globally without any access to electricity and 64% of them live in the Asia-Pacific region where many rely on candles and kerosene lamps for lighting. The global annual bill for kerosene used for lighting is almost 40 billion USD, with an average family spending about 80 USD per year. This represents more than 15% of the annual family budget in many communities. In India over 78 million households, that is approximately 390 million people, still use kerosene for their daily lighting needs while in Papua New Guinea close to 4.5 million people use kerosene lamps spending 100 million USD each year.

Kerosene lamp is one of the most inefficient light sources. This lamp produces only one lumen/m^2 (1 lux) at a distance of 1 m while the cost of useful energy ($ / lumen-hour of light) is 325 times higher than that for an incandescent bulb (which itself is a very inefficient device) and 1625 times higher than that for a compact fluorescent lamp (CFL). Kerosene lamps are also environmentally polluting (1 litre produces 2.6 kg of CO_2) and health risks to children exposed to kerosene fumes cannot be overemphasized. Most of the kerosene users live away from the national grid network and only option to make electricity accessible to them is through distributed generation using sustainable energy sources.

Emerging Technology

Buildings

A voluntary partnership, namely Asia-Pacific Partnership on Clean Development and Climate, among six major Asia-Pacific nations (Australia, Canada, China, India, Japan, South Korea, and the United States of America) was formed in 2005. This coalition aims to accelerate the development and deployment of cleaner, improved and efficient technologies to meet national pollution reduction, energy security and climate change concerns in ways that promote economic development and reduce poverty. Outcomes from this group will have clear implications for building technologies and practice for the Asia-Pacific countries.

Low energy technologies over recent years have been considered by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007), one part of which is shown in Table 7. For example, structural insulation panels are economically feasible technologies for cold climate countries. However, it is not necessarily cost effective and appropriate for cold climate regions of developing countries. Solar thermal water heating is available, cost effective and an appropriate technology for all countries.

Energy Efficiency or Emission Reduction Technology	Developing Countries – Cold Climate: Technology stage	Cost/ Effectiveness	Appropriateness	Developing Countries – Warm Climate: Technology stage	Cost/ Effectiveness	Appropriateness	Developed Countries – Cold Climate: Technology stage	Cost/ Effectiveness	Appropriateness	Developed Countries – Warm Climate: Technology stage	Cost/ Effectiveness	Appropriateness
Structural insulation panels	blue	blue	blue	green	green	red	blue	green	green	green	green	green
Multiple glazing layers	blue	blue	blue	blue	green	red[1] - green[2]	~	blue	blue	blue	blue	green
Passive solar heating	blue	green	green	blue	green	red	blue	green	blue	blue	green	green
Heat pumps	green[3]	red	red	green - blue[4]	red[5] - green[6]	red[7] - green[8]	blue[9]	green	green	~[10] - blue[11]	green[12] - blue[13]	green[14] - blue[15]
Biomass derived liquid fuel stove	blue	green	blue	green	red	red	~	green	blue	~	green	red
High-reflectivity bldg. materials	red	red	red	green	blue	green	blue	green	green	~	green	blue
Thermal mass to minimize daytime interior temperature peaks	~	blue	green	~	blue	red[17] - blue[18]	~	blue	green	~	blue	red[19] - blue[20]
Direct evaporative cooler	red	red	red	~	blue	red[21] - blue[22]	red	red	red	~	blue	red[23] - blue[24]
Solar thermal water heater	~	blue	blue	blue	blue	blue	~	blue	blue	~	blue	blue
Cogeneration	blue	green	green	green	red	red	~	green	blue	~	green	green
District Heating & Cooling System	blue	green	green	red	red	red	~	green	blue	blue	green	green
PV	blue	green	green	red	red	red	~	green	blue	blue	green	green
Air to air heat exchanger	blue	green	blue	blue	green	blue	blue	blue	blue	blue	blue	blue
High efficiency lightning (FL)	~	green	blue	~	green	blue	μ	green	blue	μ	green	blue
High efficiency lightning (LED)	~	green	blue	~	red	blue	green	green	blue	green	green	blue
Light shelves	blue	green	blue	blue	green	blue	blue	green	blue	blue	green	blue

Energy Efficiency or Emission Reduction Technology	Developing Countries						Developed Countries					
	Cold Climate			Warm Climate			Cold Climate			Warm Climate		
	Technology stage	Cost/ Effectiveness	Appropriateness	Technology stage	Cost/ Effectiveness	Appropriateness	Technology stage	Cost/ Effectiveness	Appropriateness	Technology stage	Cost/ Effectiveness	Appropriateness
HC-based domestic refrigerator	green ●	green ●	blue ●	green ●	green ●	blue ●	~	blue ●	blue ●	blue ●	green ●	red ● [25] - blue ● [26]
HC or CO2 air conditioners	red ●	~	μ	red ●	~	μ	red ●	green ●	green ●	red ●	red ●	μ [27] - green ● [28]
Advance supermarket technologies	red ●	blue ●	blue ●	red ●	blue ●	blue ●	~	blue ●	blue ●	green ●	blue ●	blue ●
Variable speed drives for pumps and fans	~	green ●	green ●	~	green ●	green ●	~	green ●	green ●	~	green ●	green ●
Advanced control system based on BEMS	blue ●	green ●	green ●	blue ●	green ●	green ●	blue ●	green ●	green ●	blue ●	green ●	green ●

Notes 1: *For heat block type, 2.For Low-E, 3.Limited to ground heat source etc, 4.For air-conditioning, 5.For hot water, 6.For cooling, 7.For hot water, 8.For cooling, 9.Limited to ground heat source, etc., 10.For cooling, 11.For hot water, 12.For hot water, 13.For cooling, 14.For hot water, 15.For cooling, 16.Limited to ground heat source, etc, 17.In high humidity region., 18.In arid region, 19.In high humidity region, 20.In arid region, 21.In high humidity region, 22.In arid region, 23.In high humidity region, 24.In arid region, 25.United States, 26.South European Union, 27.United States, 28.South European Union.*

Evaluation ranks:

Visual representation	Stage of technology	Cost/Effectiveness	Appropriateness
red ●	*Research phase (including laboratory and development)*	*Expensive/Not effective*	*Not appropriate*
green ●	*Demonstration phase*	*Expensive/effective*	*Appropriate*
blue ●	*Economically feasible under specific conditions*	*Cheap/Effective*	*Highly appropriate*
~	*Mature Market (widespread commercially available without specific governmental support)*	*"~" Not evaluated*	*"~" Not evaluated*
μ	*No Mature Market (not necessarily available/ not necessarily mature market)*		

Table 7 : *Examples of low energy technologies in recent years (IPCC, 2007) [Original table shows the columns of "Developing Countries", "OECD" and "Economies in transition, Continental". However in this table, "Economies in transition, Continental" is omitted and "OECD" is replaced by "Developed countries"]*

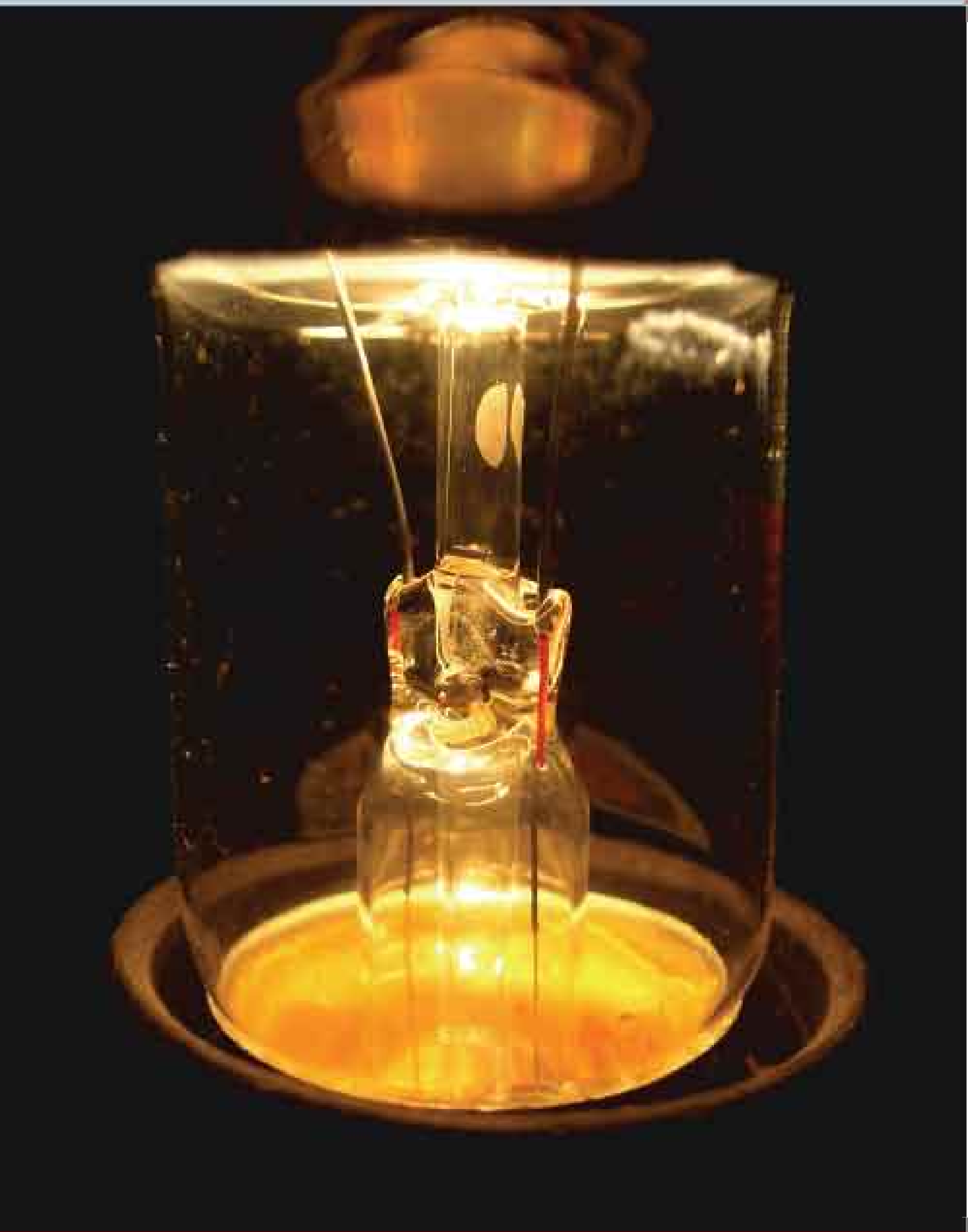
Efficient lighting

In the past few years white LEDs (WLED) have emerged as an attractive alternative to compact fluorescent lights (CFL) as very efficient and robust lighting sources that contains no mercury. A high quality WLED lasts for at least 50,000 hours, has a colour rendering index (CRI) of greater than 70 and a correlated colour temperature (CCT) between 2500 and 6500 K . Table 8 shows the luminous efficacy of several light sources as of October 2007. Research is underway to improve the efficacy, CCT and CRI of WLEDs. US Department of Energy has a goal of achieving an efficacy of 160 lumens/watt by 2025 for commercial LEDs.

Development of large sustainable energy systems requires planning and investment from the governments concerned. What can be done almost immediately however, is to replace highly inefficient lighting devices by clean and efficient lamps based on solar PV. These lamps utilize either CFLs or WLEDs as lighting sources.

Lamp Type	Lumens watt-1
Kerosene lamp	~ 0.1
Incandescent (no ballast)	10-18
Halogen (no ballast)	15-20
Compact fluorescent (CFL) (including ballast)	35-60
Metal halide (including ballast)	50-90
Cool white LED 5000 K (including driver)	47-64
Warm white LED 3300 K (including driver)	25-44

***Table 8:** Luminous efficacy of various light sources*
(source: USDOE , 2008)



A small 5W PV module can provide enough power for LED cluster lamps to light up a rural home. PV lanterns based on WLED are sturdy and combine portability with efficiency.

There are a number of ways to charge the batteries of a WLED system ranging from pedal-power to bio-fuel (e.g., coconut oil) generators. In the case of a project developed by "Light Up the World Foundation" (LUTW) in Nepal, a 200W pico-hydro system provides power to LED lights in 28 households. The key to the sustainable lighting will be to find the right mix of technologies and available resources. The developing countries in the Asia-Pacific region should take advantage of this new technology and strive to replace all inefficient and polluting lighting devices currently being used.

According to a 2008 IEA report, it is possible to reduce global electricity consumption by 28,000 TWh accompanied by a decrease of 16 GT of CO2 emission over the period 2008 – 2030 by switching to efficient lighting.The internal rate of return (IRR) for a switch to CFL for domestic applications is 186%, while shifting to ceramic metal halide lights from mercury vapour lamps has an IRR of 50%. LEDs are increasingly being used for indoor directional, task based lighting and also for general lighting of commercial and residential areas in urban settings. There is also a global movement called the LED City™ programme supported by governments, communities and industry. The main thrust of this programme is to encourage replacement of existing high pressure sodium lamps, incandescent bulbs and even CFLs by LED fixtures.

There is a very high potential in the Asia Pacific region in general and in its mega-cities in particular, to reduce the lighting electricity consumption by switching over to more efficient devices.

09
CAPACITY BUILDING

In 2007, about 71 billion dollars were invested in sustainable energy projects globally and this investment is bound to increase even in the face of current global downturn. While many sustainable energy developments in the region are technically feasible, they all crucially require trained manpower. Skilled people are needed to plan, design, construct, operate and maintain any sustainable energy based system. Many smaller countries lack sustainable energy resource assessment, and development of a regional databank requires trained people. Much work is being done in Asia-Pacific, but more investment is needed if the benefits of the sustainable energy objectives are to be realised.

Education and Training

Educational and training institutes have a key role to play. Universities and polytechnics will need to produce designers, engineers and energy specialists, with technical institutes providing a variety of skilled implementation and support technicians. People trained in energy policy, environmental law and other ancillary areas will also be in high demand. Many traditional engineering courses do not necessarily prepare a student for the sustainable energy field and more specialised courses will need to be developed. For example, recent assessments of photovoltaic installations in Africa indicate that more than many of the systems fail due to lack of professional maintenance. Another survey among remote Australian communities discovered that only two-thirds of the installed hybrid Remote Area Power Supply Systems were in working order. Lack of training of the users and installers was considered to be the root cause. There are a number of un-maintained and hence unusable systems to be found all over the Asia-Pacific region. Most of the systems were bought with donor funds with only a minimal training component attached. It is imperative for the donors and the receiving country alike to set-up training facilities. Short-term certificate courses are needed to produce technicians capable of rectifying most of the common problems encountered by the sustainable energy systems and ensure longevity.

The following areas in sustainable energy education need attention:

- Retraining of professionals who wish to move into the renewable energy industry;
- Retraining of technicians and trades people;
- Initial training of scientists and engineers to design and develop new renewable energy systems;
- Training in renewable energy technology and policy for financiers, investors and policy analysts;
- Short, in-service, professional development courses;
- Lessons and resources for schools on energy issues; and
- Contemporary information about renewable energy technology for the general public.

In order to develop a Capacity Building roadmap for the Asia-Pacific region, it is suggested that work is also initiated in the following areas:

- Determination of potential demand for sustainable energy professionals (all levels) in the region.
- Production of a database of existing sustainable energy education and training institutions in the region.
- Current supply of sustainable energy manpower.

Public Awareness

It is essential to inform public organizations and residents through all the various media, about the seriousness of the global warming threat and the need to use energy efficiently and to move increasingly toward an sustainable energy culture.

The following issues need to be publicly raised, discussed and understood.

- Air pollution, its causes and prevention.
- Safety and efficiency of residential environments
- New employment and new business
- Energy security

10
PRIORITIES FOR ASIA AND THE PACIFIC

If the new and emerging energy technologies are to make a serious contribution to sustainable development in the Asia-Pacific region then investment, intellectual effort and capacity building need to be planned for the short and long term. The following are proposed areas of endeavour, identified by ICSU regional committee for Asia Pacific to achieve this aim and should be interpreted broadly and positively by researchers, funding agencies and governments.

Wind Energy

- Mapping and statistics of wind potential
- Improvement of mechanical properties of wind mills
- Improvement of electrical characteristics
- Integration in centralised and decentralised systems
- Fault prediction and protection

Solar Energy

- Manufacturing processes and mass production
- More effective use by solar cells of blue end of visible spectrum
- Monitoring and environmental protection
- Third generation silicon cells
- New and improved materials and techniques
- Reflectors and concentrators
- Optimisation of the work fluids and thermal storage media (solar thermal)
- Coating of solar thermal installations
- Designs for sun tracking systems

Geothermal Energy

- Exploration and assessment of conventional and enhanced geothermal systems
- Drilling, production and distribution technologies
- Reservoir management
- Assessment of technology for geothermal heat pumps for space heating / cooling and adaptability to different climatic environments; integration with building designs.
- Direct uses targeted towards partial replacement of fossil fuel use, especially in small island nations and remote localities

Hydropower

- Improvement in hydrological assessment
- Planning, design and construction of civil works
- Equipment and design for small hydro
- Hydropower performance for large and small hydro

Biomass Energy

- Direct thermal applications
- Transmission and grid integration
- Applications – heating / cooking
- Bioconversion technologies
- Co-generation
- Combined fuels

Waste to Energy

- Waste management
- Waste treatment technologies including biochemical

Ocean Energy

- Resource mapping for OTEC, wave and tidal energy potential
- Reduction in cost of OTEC installations through design of efficient heat exchangers, mechanical design of the interface between the floating barge and cold water pipe, floating platforms and mooring devices
- Research and analysis on shoreline devices for wave energy through detailed study of breaking wave forces; fatigue analysis, corrosion and wear analysis of mechanical parts exposed to wave action in offshore devices.
- Reduction in cost of the barrage based tidal plants through deployment of prefabricated caissons, and capture of large tidal power by enhancing the operating efficiency of turbines.
- Improving the economics of ocean energy sources through provision of valuable by-products such as fresh water and aquaculture.

Efficient Energy Use

- Use of traditional technologies and best practice for low energy building
- Development of guidelines on low energy buildings, culture and new / smart materials
- Integration of regional climate conditions with designs for low energy buildings
- Effective use of daylight in buildings

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ANNEXURES

Annex I Planning Group on Sustainable Energy

Name	Address
1. Emeritus Professor Derek J. Gardiner	Northumbria University Newcastle Upon Tyne Tyne and Wear, United Kigdom, NEI 8ST Email: djgardiner@hotmail.co.uk
2. Dr. Sukanta Roy	National Geophysical Research Institute P.O. Bag 724, Uppal Road, Hyderabad 500007, India Email: sukantaroy@yahoo.com; sukantaroy@ngri.res.in
3. Prof Momir Djurovic	Rista Stijovica 5 81000 Podgorica, Montenegro Email: canu@cg.ac.yu; momird@cg.ac.yu
4. Dr. Richard Corkish	Australian Academy of Science School of Photovoltaic & Renewable Energy Engineering University of New South Wales Sydney NSW 2051 Australia Email: r.corkish@unsw.edu.au; s9091279@unsw.edu.au
5. Prof Ajith de Alwis	Dept of Chemical and Process Engineering University of Moratuwa Moratuwa, Sri Lanka, Email: Ajith@cheng.mrt.ac.lk
6. Prof Hiroshi Yoshino	Department of Architecture and Building Science Graduate School of Engineering, Tohoku University Sendai 980-8579 Japan Email: yoshino@sabine.pln.archi.tohoku.ac.jp

Name	Address
7. Dr Atul Raturi	School of Engineering and Physics Faculty of Science and Technology University of the South Pacific Suva, Fiji Islands Email: raturi_a@usp.ac.fj
8. Prof M Ravindran	17 C Vignaraja Pondicherry Road, Kottur Chennei 600085 India Email: ravindranvanaja@gmail.com
9. Dr S Dasappa	Center for Sustainable Technology Indian Institute of Science Bangalore 560012 India Email: s.dasappa@gmail.com sdasappa@cgpl.iisc.ernet.in
10. Dr. Arun Kumar	Alternate Hydro Energy Centre Indian Institute of Technology, Roorkee-247667, Uttaranchal, India Email: akumafah@iitr.ernet.in
11. Prof Mohd Nordin Hasan *(Ex Officio)*	Director ICSU Regional Office for asia & Pacific c/o Academy Sciences of Malaysia 902-4, Jalan Tun Ismail, 50480 Kuala Lumpur, Malaysia Tel: 603 - 2694 9898 Fax: 603 - 2694 5858 Email: nordin.hasan@icsu-asia-pacific.org

Annex II Abbreviations and Acronyms

°N	Degree North
°S	Degree South
°C	Degree Celsius
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CCT	Correlated Colour Temperature
CFL	Compact Fluorescent Lamp
CH_4	Methane
CO	Carbon Monoxide
DC	Electrical Generators
DFGT	Dual Fluid Gas Turbine
DFIG	Doubly Fed Induction Generations
EGS	Enhanced Geothermal System
EJ	Exajoule
FAO	Food and Agriculture Organization
GJm^{-2}	Giga Joule per Metre Square
GW	Gigawatt
H_2	Hydrogen
HDI	Human Development Index
ICSU	International Council for Science
IEA	International Energy Agency
IGCC	Integrated Gasification and Combined Cycle
IGFC	Integrated Gasification Fuel Cell
IPCC	Intergovernmental Panel on Climate Change
kg/kWh	Kilogram per Kilo Watt Hour
km	Kilometre
kW	Kilowatt
$kWh.m^{-2}.day^{-1}$	KiloWatt Hour per Metre Square a Day
LED	Light-Emitting Diode
LUTW	Light Up the World Foundation
m^2	Metre Square
m^3	Metre Cube
MJ/m^3	Megajoule per Metre Cube
MT	Metric Ton
MW	MegaWatt
NASA	National Aeronautics and Space Administration
OECD	Organisation for Economic Co-operation and Development
OTEC	Ocean Thermal Energy Conversion
OWC	Oscillating Water Column
RE	Renewable Energy
Recup-GT	Recuperated Gas Turbine
ROAP Pacific	Regional Office for Asia and the
SB	Sustainable Building
SE	Sustainable Energy
TEC	Tidal Energy Conversion
TWh	Terawatt Hour
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
USA	United States of America
USD	United States Dollar
VSCF	Variable Speed Constant Frequency
WEC	Wave Energy Conversion
WLED	White Light-Emitting Diode
WTE	Waste to Energy

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International Council for Science

ICSU Regional Office for Asia and the Pacific

902-4, Jalan Tun Ismail, 50480 Kuala Lumpur, Malaysia

Tel : +603-26984192 Fax : +603- 26917961

Email : secretariat@icsu-asia-pacific.org