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Scope for Solar Energy Devices in Kamataka State, India

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Introduction

The primary renewable energy source on earth is solar radiation. The total flow of solar energy through the earth's natural system is some 10,000 times greater than the present flow of energy through man's machines. Even the 1% of the solar influx that generates the great atmospheric pressure systems which drive the winds, and which in turn generates the waves, is some 180 times as large as man's rate of energy use. And though, on average, the photosynthetic process accounts for less than 0.2% of the total flow, even photosynthetic production creates 10 times as much energy as man uses. The flow of solar and solar-derived energy forms is not independent from the activities of man. Radiation fluxes are modified by changing the reflectivity of the earth's surface through, for example, urbanisation, agricultural practices, and deforestation. Man's activities also change wind patterns and modify cloud coverage. Injection of pollution into the environment, removal of forest cover, and man-made structural changes influence radiation, heat, and water flows (Ramachandra 1993).

Solar energy is received entirely as radiation and is subsequently converted so that, at any time and place, an original quantum may appear in any one of several diverse forms. Thus, with respect to the energy encompassed in day-to-day climate at a given place and time, solar energy may appear as the latent heat of vapour, the advected heat of air masses, radiant energy from sky and terrestrial objects, and unconverted solar radiation arriving as direct beams. Unconverted solar radiation in the form of direct beams is a very important form of energy that is dominant in the hydrologic processes of evaporation, transpiration, snow ablation, as well as in the growth and succession of vegetation. The total flux of energy to a site at any given time is difficult to

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measure and current techniques allow us only readily to measure the flux of radiant energy at a point. However, this flux varies so widely over most land surfaces as to render point measurements of limited value. The spatial heterogeneity in the radiant flux is due to the variation in solar-beam irradiation caused by variations in the inclination of the earth's surface with respect to beam direction. Within a geographic region, and subject to uniform atmospheric conditions, irradiation from the sky is fairly uniform regardless of surface inclination. However, the total of sun and sky irradiation would vary widely with surface orientation and slope. The variation of direct-beam radiation varies in time with atmospheric condition and path length, the combined effect of which can be estimated. All in all, these factors are of practical importance since solar energy can meet a large variety of the small-scale decentralised energy needs of a region.

A detailed study (Ramachandra and Subramanian, forthcoming) of five locations of the coastal belt of Uttara Kannada District (Karnataka State, India) in the Western Ghats region demonstrates that good solar energy potential is available in this region during most of the months in the year. The amount of solar energy that could be harnessed by utilising 5% of the present wasteland in coastal Taluks as a solar-collector area, is found to be in the order of 95.7 million kilowatt-hours (kWh) annually from the coastal belt of Uttara Kannada District alone. This means that solar energy could meet at least 32.5% of the District's

present electricity needs. This study suggests that solar-conversion technologies have considerable potential for application, provided that questions of storage can be resolved and that electricity requirements during the monsoon season can be met through other means. The abundance of the solar resource can be illustrated by comparing the land requirements of solar (thermal or photovoltaic) with those of hydro or energy plantation projects. Except for run-of-river projects and for high head sites in deep gorges, the land requirements for such hydel projects average around 25 to 45 times those for solar energy, at today's conversion efficiencies. This means

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that solar energy is capable to supply 5 to 10 times the electricity requirements of Karnataka State, while occupying smaller land areas than those currently used by hydel projects.

Rural communities depend on firewood

and agricultural residues to meet the fuel requirement of domestic needs, such as cooking and water heating. Energy surveys in Karnataka State show that people are receptive to technologies which do not involve major attitudinal change and cultural barriers. In this regard, solar water heaters seem to be the most acceptable device in the domestic sector. Solar energy for water-heating purposes would reduce firewood consumption in the domestic sector.

Karnataka's Energy Scene

Karnataka State depends both on commercial and non-commercial forms of energy. Recent data (Subramanian and Ramachandra, forthcoming) suggest that 53.2% of total energy use is met by non-commercial sources such as firewood (43.6%), cow dung cake (1.4%), and agricultural wastes (8.2%). While commercial energy like coal (5.8%), oil (11.6%), kerosene (2.6%), liquid petroleum gases (0.7%), and electricity (26.1%) account for 46.8% of overall energy use. A significant part of these non-conventional energy sources cater to the heating (domestic) needs of the rural population (about 70-80% of the total) and, to a lesser degree, to that of village industries.

As far as electricity is concerned, the share of the industrial sector in total consumption is around 44.9%, followed by irrigation pump sets with a share of 28.6%, and domestic users which account for approximately 15.5%.

The Rural Energy Scene

A comparative analysis of village-level energy consumption patterns in the domestic sector of Uttara Kannada District has been carried out to assess the dependence of rural people on various energy sources. Our survey results (Ramachandra *et al.* 1995) are based on 18 months of field research in four Taluks of Uttara Kannada, covering 90 (of 119) villages and

all town divisions in Kumta Taluk. While in the Taluks of Sirsi, Mundgod, Siddapur, and Ankola our conclusions are based on randomly selected households of the order of 190 to 220 households in each Taluk.

Our sample of 1304 households from 90 villages in Kumta Taluk shows that most households still use traditional stoves for cooking (97.9%) and water heating (98.3%). Average consumption for cooking purposes ranges from 2.01 to 1.49 kilograms per person per day (kg/person/day) in the coastal region, to 2.322 to 0.9 kg/person/day in the hilly region. A seasonal pattern is also evident in both regions. Specifically, firewood requirements for coastal areas, in kg/person/day, vary from 1.98 during the summer, to 2.11 during the monsoon season. Similarly, for the hilly region the range is 2.22 to 2.51 kg/person/day during the summer and monsoon seasons, respectively.

Firewood requirements for water-heating purposes range from 1.170 to 0.02 (coast) to 1.630 to 0.05 (hilly) kg/person/day. Seasonal variation is also evident from the range for the coastal zone: from 1.12 to 1.22 kg/person/day for the summer and monsoon seasons, respectively. For the hilly region, the range is from 1.53 (summer) to 1.73 (monsoon) kg/person/day.

Analysis of other sources of energy used for domestic purposes shows that in the coastal zone kerosene is used for cooking and also for lighting. Kerosene consumption for cooking, in kg/person/day, ranges from 0.05 (hilly) to 0.34 (coast). The availability of bio-resources in the hilly region is the main reason for the lower consumption of kerosene. Kerosene for lighting purposes ranges from 0.74 litres per person per month (lit/person/month) in the coastal areas, to 0.98 lit/person/month in the hilly region. The latter region is more dependent on kerosene for lighting because of the non-availability of electricity for lighting purposes. In the hilly region, households are distributed over a large area and the electrification of all households has thus far not been carried out.

Based on the fuel consumption averages (by region, season, and end use) obtained from

our detailed survey of households, we estimate that:

a) the firewood required in the domestic sector (for cooking, water heating, space heating, jaggery making, parboiling) of Uttara Kannada District works out to be 1.67 million tonnes per year;

b) the annual electricity consumption in the domestic sector (excluding irrigation) of the District is about 32.65 million kWh; and

c) kerosene demand of the District for cooking and water heating is about 15.9 megalitres per year.

The climate in coastal areas is favourable to setting up solar water-heating devices to meet the requirement of hot water for

bathing purposes. If 30% of the population were to switch over to solar water-heating devices, the estimated quantity of firewood saved would be approximately 66.8 kilotonnes per year from the five coastal Taluks of Ottara Kannada District. The lack of information about the technology and the non-availability of proper service and maintenance backup in this region are the main reasons for energy-efficient devices and alternative technologies not finding a significant place in this rural energy scene.

Rural industries like cashew processing and others are major consumers of firewood in the rural coastal areas of Ottara Kannada District. Primary surveys conducted in some of the cashew-processing industries have revealed that some industries use 4 to 8 kilograms of firewood to process a kilogram of cashews. These industries are seasonal and operate at peak load during the pre-monsoon period (that is, in the months from February to June), so that it would be possible for them to switch over to solar energy for conditioning, mild roasting, and drying operations since that form of energy is plentifully available during this period. In addition, drying is one of the most important processes in the post-harvest handling of agricultural products such as cardamom, peppers, chillies, copra, and arecanuts. And the drying of agricultural products is an energy-intensive process: it is estimated that 2.5 megajoules of heat energy (mainly from firewood and other residues) are needed to remove a kilogram of water.

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These analyses show that solar energy could be a viable alternative in meeting the energy needs associated with the drying of agricultural products, cooking (through solar cookers), hot water requirements for bathing and washing (solar water heaters), and lighting (through solar photovoltaic systems). In light of the above, we now turn to an examination of various aspects of solar water-heating devices, such as the underlying technology and their future prospects.

Solar Energy Conversion Modes

Solar energy is captured by being converted to other forms of energy by: (a) chemical reaction; (b) thermal excitation; and (c) photovoltaic effect. Solar energy is also chemically converted into energy through photosynthesis, which directly produces food and wood. Simple thermal-conversion devices, such as flat-plate collectors, are suitable mainly for providing low-energy, high-entropy heat to systems of the same nature. The flat-plate collector can deliver temperatures of up to approximately 100°C. The direct conversion of sunlight to electricity by means of solar cells is the photovoltaic effect. The solar cell uses energetic photons of the incident solar radiation, converting solar energy into electricity (Wilbur 1985; Mortimer 1991).

Some advantages of photovoltaic devices are that they: 'a) have no inherent lifetime limit; b) have efficiencies that are independent of size; c) are modular; d) are compatible to all environments; e) provide fairly constant voltage, independent of sunlight intensity; f) are relatively low-maintenance; g) have low operating and maintenance costs; h) are simple; and i) do not require water cooling.

Potential areas of commercialisation of solar photovoltaics are: a) domestic lighting; b) community lighting (street lighting); c) health care; d) telecommunications; e) water pumping; and f) entertainment gadgets, like televisions and radios. Solar photovoltaics alone cannot successfully cater to energy requirements without a very high-efficiency balance of system design. Another major requirement is the storage of energy, wherein

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batteries of low-maintenance and high-recycling capacities are to be used. However, some disadvantages are: (a) the combination of theoretical efficiencies of about 25% combined with the low-energy intensity of sunlight means that relatively large collectors are needed; (b) the fact that these sources are not economically competitive with other, more traditional sources; and (c) the need for DC to AC inversion equipment to supply AC loads.

Solar Water Heating

Solar energy for daily use in households is already a popular concept. The current trend is such that these uses are virtually confined to water heating: more than 600 homes in Bangalore City are already using this system. Solar water-heating systems are simple devices, which work on the principle of black-body radiation and the greenhouse effect. These generally involve the use of flat-plate collectors, storage tanks, circulation systems, and appropriate controls and accessories. Solar water heaters can be broadly classified as either thermosyphon (natural circulation) or forced-circulation systems. Usually thermosyphon units are used for domestic applications (given a standard capacity of 300 litres), while forced

circulation is used in the case of industrial and commercial applications.

Industrial and Commercial Systems

As noted above, forced-circulation systems are normally used for these purposes. A pump is used to circulate water through the collector system and a thermostat is used to control the temperature (Kishore and Bansal 1988). The fixed-temperature controller and differential-temperature controller are the two types of mechanisms used to control the flow of water in the system. In the case of the fixed controller, the system will deliver hot water at a constant temperature, but the quantity of hot water delivered depends upon the level of solar insolation and ambient conditions. As far as the differential-temperature controller is concerned, a fixed quantity of hot water is delivered at varying temperatures, depending

upon the solar installations.

Domestic Water Heating

Thermosyphon systems are generally used because of their ease of operation and maintenance. For proper functioning, it is necessary to have as little resistance as possible in the thermosyphon path as well as an adequate supply of cold water. In some cases, an automatic electric backup system is incorporated to ensure hot water availability throughout the year, and storage tanks are usually double-walled, insulated constructions.

The collector is the heart of the system and consists of components such as absorbers, glazing, boxes, and insulation. A wide range of materials and design choices are available now. The basic absorber can be made of galvanized steel, aluminum or copper, and both flat black paint or selective coatings are available options. The glazing can be plain window glass, toughened glass, or acrylic. Sawdust and cork are occasionally used for insulation. However, the majority of commercially-available collectors use mineral wool, glass wool, or even polyurethane foam for bottom insulation. While wooden boxes are once again employed in some instances to contain the other components of the system, metals like steel and aluminum as well as reinforced plastic are more frequently employed.

Present Status in Karnataka

The total number of industrial and commercial systems installed in the State is approximately 150, with 35 systems of 1000 litres per day (LPD), 72 systems of 1000 to 5000 LPD, and 10 systems of 10,000 LPD. Assuming that the system is used effectively for 225 days a year, the amount of equivalent electrical energy saved annually is 6 million kWh. In Bangalore City alone, the amount of electrical energy that could be saved by installing solar water heaters in All Electric Houses (AEHs) is 1.8 million kWh per year. The generation capacity required to meet their demand is 250 MW, the cost of which is higher, by as much as 50%, than that of installing solar water heaters in

AEHs.

The cost of a domestic water heater is between 8000 and 10,000 rupees (Rs.). The Government of India provides a subsidy of Rs.3000 to each person who decides to proceed with the installation of such a system. Solar heaters save about 50 to 75 kWh of energy per month per household. By educating people about solar energy, through mass media, substantial savings in electrical energy and firewood could be achieved. It would appear that the main reasons for the low market penetration rate currently observed are: (a) the high capital cost of the system; (b) the inadequate availability of funds for the disbursement of subsidies; (c) the absence of attractive financial packages for buyers; and (d) a lack of awareness of the technology.

Technical Issues

The main technical snags encountered in solar heaters are:

- (a) Corrosion of various forms has been a nagging problem. While the use of galvanization has produced reasonably satisfactory results in the case of steel absorbers, problems in certain localized areas still persist. The use of copper overcomes this problem, but increases the cost dramatically.
- (b) Formation of scales in absorbers, due to the direct use of raw water, inhibits the flow and increases the resistance to heat transfer. This problem is more severe where thin and narrow passages are employed. A scale thickness of 1.22 millimetres (mm) in a 15 mm pipe would decrease the collector efficiency by about 1 to 2%.
- (c) Failure and very poor reliability of the control hardware in the case of forced-flow systems, namely the fact that simple thermostats change calibration over time (capillary thermostats would provide better performance and reliable operation, but are quite expensive), and problems with solenoid valves and, at times, level controllers.

In addition, inadequate attention paid to controls and their maintenance, and compromises made with the selection and processing

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of materials (to bring down initial costs) would severely hamper the commercialisation of solar water heaters.

Economic Issues

Without accounting for any available financial incentives, the normal payback period in commercially-installed solar water-heating systems works out to be about four to five years for domestic users (when compared with electrical systems). A number of factors such as climate, site location, type of application, conventional alternatives being substituted for also play a role in the economic evaluation of a solar system. As it turns out, the economics works out to be most favourable for applications that require very little storage or when the alternative conventional energy source is electricity. Revised economic analyses, which include various incentives (such as tax savings due to higher depreciation rates) and higher energy costs of conventional sources, show that the payback period for solar devices in commercial applications is about 1.5 to 2 years. However, when solar systems are compared to firewood-based systems, where the price of firewood is highly subsidised, solar-system economics are rather poor. When the subsidy component is removed for firewood, the payback period for solar devices is five years. (In Kumta Taluk, for example, the cost of firewood supplied by government agencies is about Rs.25.6 per 100 kilograms (or quintal) of firewood, while the cost of firewood supplied by private agencies in certain areas can vary between as much as Rs.75 to Rs.100 per quintal.) These analyses show that with attractive payback periods, solar-heating technologies would automatically find acceptance among industries and domestic users, provided potential users are aware of the existence of these technologies. Appropriate policy measures and incentives are required for the accelerated commercialisation of solar devices.

Policy Issues

The energy crunch situation that prevails in Karnataka State is due to its large-scale de-

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pendence on conventional sources and a sectoral approach to energy planning. The conflict between energy demand and environmental-quality goals can be resolved by an integrated approach to the problem of energy planning, with an aim of maximising the efficiency of use, minimising the consumption of non-renewable sources, optimising energy source and end-use matching, and encouraging the use of renewable resources with proper policy and incentive measures. Incentive measures which would help both domestic and industrial sectors include exemptions from excise and sales taxes and the provision of enhanced depreciation. Apart from these, there is also a need to make people aware of the alternative technologies available.

All in all, we would argue that appropriate policy initiatives in this area should ensure: a) the availability of capital for solar installations; b) provisions for the installation and capital-cost recovery of devices along with monthly electricity charges or in monthly instalments; and c) making the installation of solar devices in AEHs mandatory (at least in new installations) in places where the climate is favourable.

Conclusions

It is clear that to encourage sustainable development it is necessary to increase energy supplies from renewable sources like solar. Compared to the enormous theoretical and technical potential of solar energy conversion, little use has thus far been made of developed and demonstrated technologies, such as solar water-heaters, and dryers. A more intensive use of such technologies would reduce the pressure on supplies of electrical energy in urban areas and of firewood in rural areas.

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