sion of the Seminar (aggravated by the additional year it took the publisher to bring out the book) does seem somewhat excessive. Many of the articles have numerous elementary grammatical errors, occasional incomplete sentences, and the like. Unlike collections of articles in the humanities, the role of editors in collections of scientific articles is (conventionally) much more limited – the blue pencilling is far more restrained, often to the point of being absent altogether. The collection under review is presumably no exception, and one does wish some more care had been taken by some of the authors in preparing written versions of their lectures for publication.

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Renewable Energy: Sources for Fuels and Electricity – Johansson, T. B., Kelly, H., Reddy, A. K. N., Williams, R. H. (eds) and Burnham, L. (Ex. ed). Island Press, Washington DC, USA. 1993. 1160 pp. Indexed. Price: US$ 85/- (HB), US$ 45/- (PB)

This volume, as complement to the Report of UN Solar Energy group for Environment and Development (UNSEGED), provides a state-of-the-art assessment of renewable energy sources for making fuels and electricity on a cost effective basis. The report and this complement were inputs to the 'Rio Earth Summit' held in June 1992 with the aim of defining means and goals for worldwide sustainable development. As a result, Agenda 21 has specifically called for 'increasing the contribution of environmentally safe and sound and cost effective energy systems, particularly new and renewables, through less polluting and more efficient energy production, transmission, distribution and use'. The authors and editors featuring in this volume and the members of UNSEGD comprise most of the reputed specialists from around the world and, therefore, the publication of the book is a historical landmark in the renewable energy Scene. It is rare to come across an edited volume where analytical rigour has been used to enhance and detail a vision in the field of Renewable Energy. It is almost akin to acquiring an adult status on the eve of 21st century.

There are 23 chapters, of which the first one details a 'Renewables-intensive global energy scenario (RIGES)' and the last one deals with utility strategies for incorporating the renewables. Remaining 21 chapters comprising the techno-economic status of renewable technologies have six chapters on solar photovoltaic, eight on biomass, one each on solar thermal power, hydropower, ocean thermal, geothermal and solar hydrogen, and two chapters on wind energy systems. There are no chapters on solar thermal as fuel, solar passive systems for buildings or integrated rural energy systems. These are no omissions but follow from implicit thinking underlying the preparation of this book. However, it is not known whether this was dictated by the Brief commissioning this report or was the strategy chosen by the editors. The review, therefore, is proposed to be done at three levels: (1) As a compendium of selected and upcoming renewable energy technologies. (2) For a utility based RIGES (3) Relevance of this scenario to sustainable development of the rural sector of the developing countries.

Compendium of selected renewable energy technologies (RETs)

As a compendium of RETs, this book is unique and timely in many ways. It is the first time that a single volume has up-to-date data on all these technologies renewable and conventional and that too in a comparative format. Apart from components, full systems are taken into account and their performance and cost figures are given. Wherever the projects are completed, shortfalls in terms of design goals and possible reasons have also been enumerated from the latest reports and publications. Renewables are considered cost-effective when energy costs on life-cycle basis are comparable to costs of conventional power using current or near-future technologies. Realistic operating hours, discount rates (6% and 12%) and common base year (extrapolated where necessary) have been considered. Ongoing advances in renewable technologies or the desired developments and their possible impact on system costs and configurations are also stated. One notable omission except for biomass-based alcohols is the absence of energy output–input ratios over the lifetimes of technology products, wherein the inputs also include the energy contents of manufacturing and the materials used. Energy efficiency and conservation savings are accounted for in terms of reduced demands. Environmental effects of the technologies are mentioned but not explicitly costed as benefits. Two major groups of technologies are discussed in the sections that follow.

Solar photovoltaic PV technology

This is covered in six chapters in an up-to-date and comprehensive fashion. In 1990 the silicon needed for solar cell manufacture was 9% of the total semi conductor grade silicon. Module costs at 50–60% of the total system costs are likely to continue and semiconductor-grade silicon is unlikely to become cheaper in the near future. Reduction in material losses due to better sawing of wafers and thinner wafers (200 μm), ultrathin wafers using light-trapping (20 μm) by techniques like laser grooving and chemical etching, recycling scraps from semiconductor industry at half the price, larger use of polycrystalline material rather than single crystal by offsetting efficiency losses by better cell designs are the ongoing approaches. Avoiding sawing by growing material on substrates or drawing films and ribbons from the melt (50 μm thick) for reducing material requirements by 80% are under active research. Thin-film cells (1 μm) using amorphous silicon, copper–indium diselenide (CIS) or cadmium telluride (CdTe) with acceptable stabilized efficiencies are of great promise. They use far less material and are amenable to mass production. Most approaches use multijunction designs of wavelength-sensitive layers of α-Si or mechanical stacking of α-Si/CIS as layers. A threefold increase in efficiency is expected to be realized over the presently available commercial thin film cells (3–4% efficiency) in the next few years. Active materials, however, constitute only a quarter of the total material cost in a PV module. Also PV module production costs are based on unit area whereas power costs per peak watt depend on the efficiency. So, higher efficiency has a dominating effect. On the systems side, integral manufacturing of PV modules like windows and mass-produced power conditioners for being integrated within the junction boxes permitting 220 V connections of arrays are the desired short term future. One-axis tracking enhances the radiation capture cost-effectively. Laser-grooved PERL-type silicon solar cells are expected to cross 20% efficiency on a commercial production basis while retaining the in-use durability of crystalline cells, by the turn of century. For sunny regions, 10× concentrator cell systems are likely to emerge as competitive for centralized village installations in kW range, with plastic concentrators following the cost and technologies of luminaires. Thin film multijunction cells using crystalline silicon/amorphous silicon combination with CIS and CDTe are in precommercial stage. With advances in efficiency and stabilization over time and because of the higher demands and competition with electronic devices for silicon requirements, these low-material cells are expected to lead the market after 2000 AD. Solar PV power competitive with utility peak rates is expected to be available for sunny regions by the turn of the century.

Biomass-based technologies

Biomass derived from wood, agroindustrial wastes, urban garbage, crop residues and from dedicated energy plantations has the advantages of decentralization, renewability, availability on demand and zero net carbon emission, if grown sustainably, or pollution reduction in case of waste recycling. Technologies for converting these into energy comprise eight chapters outlining the resource potential, cook stoves, small-scale gasifiers and advanced gasification systems, anaerobic biomethanation, liquid fuels production for combustion and transportation and two case studies, one on use of biogas for village electrification in India and the other for alcohol as partial replacement for gasoline for transportation in Brazil. It is recognized that land and water can be constraints for grown biomass, and gathered rural fuels for cooking do not lead to deforestation.

For cooking in urban areas land fills biogas and biomass-based ethanol are recommended thereby reducing emissions of greenhouse gases and pressures on land for fuel to nearly a quarter of the current practices by using biomass residues for electricity generation after production of alcohol. Plantation biomass grown sustainably on excess agricultural land in industrialized countries and on degraded and deforested lands in developing countries has the largest potential for energy production in the long term. Recoverable residues can provide the starting fuels for bioenergy industries in the near term. Pura village electric grid based on 40 m^3/day community biogas plant with 5 kW engine and capacity utilization of 16% brings out the fact that above 7.5% interest rate, biogas power is cheaper in installed cost per kW than the centralized grid power. Similarly, experience with 5 kW and 100 kW open-top gasifiers coupled to dual fuel engine gensets, used respectively, for village electricity and onsite captive power for small-scale timber mill show that payback periods of about 3 years are obtainable with annual capacity utilization factors of nearly 30–35%. Current capacity utilization factors are between 15–20%, depending upon the demands, which are governed (if equipment reliability is assured) by affordability rather than by needs. These important lessons are critical for capital starved developing countries and rural poor and have been ignored in RIGES.

Advanced biomass based fixed-bed gasification technologies can be coupled to latest generation of gas fired steam-injected turbines: heavy-duty power type or lightweight aeroderivative types in combined cycle/cogeneration modes, respectively, to achieve power efficiencies higher than 40% with biomass fuel having less than 15% moisture content. Problems of sulphur removal do not exist with biomass; tar and alkali vapour problems can be handled within gasifier exit temperature range of 500–600°C per day, just by cyclone-based particulates clean-up systems only. Scales of 50–100 MW_e are economically possible as these technologies are not so much sensitive to scale as coal-based steam turbines were.

Products from biomass gasification technology can also be reformed or shifted to produce a syngas with low methane content and right proportions of H_2 and CO. This syngas is later upgraded by removing CO_2. Synthesizing of methanol is done by reacting CO, H_2 and steam in the presence of traces of CO_2 over a catalyst. Most of the unit operations are known from existing methanol synthesis systems used with natural gas as feed stock. This methanol can be used as a blend with gasoline up to 5% or used as neat fuel for an alcohol-based engine cell or for transformation on board to H_2 for hydrogen-powered fuel-cell-based electric vehicles. Choices will be dictated by costs, air quality considerations and technology advances. Electric vehicles with fuel cells using methanol via hydrogen are quickly refuelled, are 2.5 times more energy efficient than gasoline based IC engine vehicles, have excelled air quality emissions but cost more and are slower to start up.

Ethanol can be produced by enzymatic hydrolysis of cellulosic biomass, mainly sugar cane, corn, sweet sorghum stems and other starch crops followed by fermentation. It has been directly used in cook stoves for homes in stoves similar to kerosene oil stoves. In Brazilian alcohol programme, it has been used as an additive to gasoline for ordinary IC engines or as a neat fuel for alcohol engines (hydrated ethanol). Fuel value of ethanol is nearly 80% that of gasoline in terms of conventional IC engine output and in Brazil its price is put at almost the same level. Ethanol is an excellent motor fuel and its full value will be realized when engines specifically designed for ethanol become available. Presently gasoline engines using 22% anhydrous ethanol are performancewise superior to using leaded gasoline in terms of emissions quality and neat ethanol vehicles emissions are still less polluting at the same level of emission control technology. Fuel costs at US$ 0 20 per litre of hydrated ethanol are equal to US$ 8 00 per GJ of energy in Brazilian programme based on sugar cane. Equivalent costs from other feed stocks are still to be achieved. Energy ratios are around 40% for the existing technology and are expected to go up to 55% for advanced technology.

Biogas production from anaerobic biomethanation of biowastes from animal and human sources has been extensively practised in India and China in small-scale onsite made digesters with capacities of 2–85 m^3/day with volumetric ratios of 0 5 and a very little energy input except human labour. In industrialized countries this process has been used to handle industrial wastes from distilleries, dairies, paper mills etc., and urban sewerage in high-rate digesters requiring lot of energy inputs. In either case it provides excellent fuel source, fertilizer and an efficient primary level waste treatment system, thereby reducing water and air pollution. Recent studies have shown that biogas can be produced from Vinasse having a COD of 500 kg m^3 of ethanol produced, which is presently treated aerobically or dumped in surface waters, creating a pollution load equivalent to that of 5000 persons/m^3 of ethanol. Biogas can be used in dual fuel engines to produce electricity or shaft power or can be burnt directly as fuel. It has been used to supply practically all the energy needs of distilleries.

Other technologies

Other technologies such as wind farms have an excellent pay-back period with capacity utilization factors of about 25% and rated wind speed of 25 kph. With availability of grid interphasing, this is a promising intermittent renewable at suitable sites. Both wind power density and energy conversion efficiency are higher than for solar thermal per unit area of converters. With better electronic coupling with grid, variable speed wind turbines of up to 400 kW each are now available commercially and can compete with grid power in regimes with wind power density of 450 W/m^2.

Renewable intensive global energy scenario (RIGES)

This scenario, detailed in Chapter 1 and supported by extensive appendices is based on strategy for investment portfolios discussed in Chapter 23. Energy demand estimates are taken from the projections of Response Strategies Working Group of the Intergovernmental Panel on climate change except that the world is divided into 11 regions instead of nine. The set of projections corresponds to accelerated policies scenario for adoption of energy-efficient technologies, which together with renewables could lead to competitive costs for overall energy services and minimal energy demand growth without impairing economic growth. High economic growth allows for doubling of world population and eightfold increase in world economic product between 1985 and 2050 with allowances for different growth rates between developing and already industrialized countries.

Electricity

A critical choice underpinning RIGES is of electricity as major energy carrier of the future. This is justified by the observation that demand growth for electricity has outpaced the growth on demand for fuels with modernization i.e. industrialization and more comfortable life styles. Electric demand per capita is projected to rise by 70% between 1985 and 2050 overall and by 500% for developing countries leading to a total electricity demand of nearly 2.65 times that of 1985. This in turn implies wide-scale availability/creation of electric transmission grid even though there is marginal recognition of need for stand-alone systems in areas distant from the existing grids or those likely not to be connected with grid, e.g. scattered islands in Indonesia or alpine and Himalayan villages. In RIGES, global electricity production would double by 2025 and triple by 2050 AD (baseline 1985). Renewable share is 20% in 1985 (mostly large hydro) and 60% in 2025 AD with almost equal share between hydro, biomass and intermittent renewables, namely, wind, solar thermal, solar PV electricity (wind and solar contributing equally). In 2050 AD the contribution would be nearly 63%, with hydro at 15%, biomass at 18% and mixed intermittent renewables at 30%. Natural fired-gas turbines will contribute about 25% as they can buffer the variability of inputs from intermittent renewables without need for electrical storage and follow the variability of loads efficiently and more sustainably. These turbines can later be switched over to biogas from biowaste recycling or electrolytically and photochemically generated hydrogen with solar energy. All these are meant to be achieved at comparable energy tariffs with considerable reduction in carbon emissions. A case study for Northern California, where wind, solar and hydro are close to world averages and field experience of integrating renewables into utility grid exists (Fig. 8 p. 25 of the book), indicates that advanced biomass and natural gas power systems with 30% mixed intermittents and 2% hydro can give almost the same tariff as advanced fossil fuel systems with hydro but without intermittents with carbon emissions reduction of 24 times, provided the distributed PV credit is allowed for.

Direct fuel use

Direct fuel use (for nonelectricity uses) accounts for 65% of primary commercial energy used in 1985 and nearly 75% of CO_2 emissions. Because of electric power being designated as the major energy carrier in demand projections adopted by RIGES and because of the radical change in forms of biomass to be used in future, direct fuel use is expected to grow by less than one-third of 1985 (219 EJ/yr) level till 2050 AD Renewables are expected to contribute nearly 25% by 2025 AD and 40% by 2050 AD. Because of demands of increased end-use efficiency, CO_2 emission requirements and need for replacing oil and coal for transportation, solid fuels have been completely eliminated. Only liquid fuels such as methanol, ethanol and gaseous fuels such as biogas and hydrogen derived mainly from biomass with small quantities of hydrogen from intermittent renewables (electrolytically) are being visualized. Direct fuel uses still account for nearly 61% of the total primary commercial energy used.

High technology systems

Apart from intermittent renewable sources using dedicated technologies developed for wind turbines, solar cells and solar thermal collectors, spin-off technologies and apart from developments in aerospace industry and conventional power generation are the main planks of biomass power generation and direct fuel use systems. These are advanced biomass gasification systems deriving from pollution-reducing developments in coal gasification, advanced gas-fired turbines originally developed for aircraft engines, hydrogen (methanol) based fuel cells originally developed for space vehicles, developments in power electronics for interphasing intermittent renewable energy from wind and solar photovoltaic generators into grid, and automated management of electric transmission and distribution systems for variable loads and multiple resource generators with variable/steady inputs.

Gas-fired turbines and biomass-based power units are considered economically viable at 100 MW_e scales and can be dispersed with respect to resource availability as well as load characteristic for the areas served. Solar PV systems can vary from multiple units of kW system to MW range with credits for distributed location provided proper safeguards are taken with respect to grid interphasing and utility buy back is at peak tariff rates. Mini hydro in MW range is treated as intermittent renewable for lack of storage in the same way as wind-generated electricity. Solar-based systems shave off the peak loads where space conditioning loads are a major fraction of building loads, which are nearly 50% of the total electric loads in advanced industrialized countries.

A plausible scenario

RIGES thus provides a technically possible and economically viable energy scenario till 2050 AD by using high-tech systems requiring state-of-the-art management tools and infra-structure comparable to conventional utility route. Greenhouse gases (e.g. CO_2 emissions) are kept below the double of preindustrial levels during the entire 21st century. Inter-regional trade balances, existing structures for marketing/generating fuels and electricity and responsible use of conventional finite resources are consciously preserved with minimal adjustments, if at all. Sustainability requirements in terms of land and water (quantity and quality), biodiversity and yield stability are also taken note of for biomass-derived fuels. An agenda of action for R&D priorities, public policy questions, institutional framework and possible funding from Carbon Tax is also suggested.

Relevance of RIGES to sustainable development of rural areas of developing countries

RIGES is renewables intensive as well as global, and has thus overlooked the special challenge offered by non-grid-connected rural regions of developing countries for use of renewables. Technology-driven options relying on heavy infrastructure such as utility grids are capital-intensive and could be ideal for industrialized countries, where population and load densities are fairly high and much of the infrastructure already exists With renewables taking care of sustainability of physical resources and allowing for medium-scale decentralization to 50–100 MW_e levels, these could also be the options for urban areas of developing countries, wherein grid-based options fit in with expectations and development plans. It is true that urbanization is increasing in all developing countries and population pressures would only accentuate it but no energy options should be allowed to promote it if they have to be sustainable in human as well as physical context by promoting equity, employment and participation.

The experience of rural electrification schemes has so far been dismal because even when physical distance from grid is not large, the economic distance still is because of low loads on account of poor affordability. Statements like loads following solar peak because of air-conditioning loads (p. 21) or solid fuels not being available for cooking (p. 1090), noncommercial biomass being neglected, are far from ground realities and are likely to be so even after 50 years. Employment creation due to industry-type biomass plantations in rural areas will be minimal and industrial-scale production of equipment has hardly ever created rural employment – it has only accentuated migration to urban areas. However, if the obsession with cost effectiveness in terms of 6 cents/kWh is discarded and full benefits of pollution reduction and reduced consumption of fossils via renewables are costed as benefits, it should be possible to design integrated and reliable rural energy packages with local grids for villages/cluster of villages. Upgradation of human skills and attitudes required is no greater than that required for use of equipment with better end-use efficiency implied in RIGES. This option in lieu of grid extension is still available for large number of rural areas and does meet ground realities of capital starvation and need for increasing affordability, and cannot be just given away by default because of global thinking Rural energization has to be integrated with other priority concerns, such as shelter, potable water, sanitation and agricultural sustainability on an affordable basis on an increasing scale of empowerment for being relevant to a large number of people (almost 30% of human race). It is true that there are problems of equipment efficiency, reliability and management but they are not more serious than the fact that all capital-intensive centralized development has only aggravated economic stratification so far and left the poor still poorer in relative terms and heavy indebtedness of developing countries.

RIGES can and should meet this challenge without affecting its stated options for urban and industrialized world. If not, the already created potential for application of renewables based on indigenous R&D in countries like India and China will have to be shelved in favour of international agreements and import of renewable equipments and experts, with the poor gaping on and once again by-passed

In spite of multiple authorship, the book has been edited into a unified volume with detailed cross-referencing and indexing. There are very few printing errors but some are there – p. 325, Table 13; p. 327, Figure 4; p. 668, Table 4, p. 709, Figure 6 – and also a few mistakes in cross-referencing the skipped matter (p. 899) and substituted figures on p. 820, p. 822 and p. 829. But these are minor as compared to the herculean task of editing involved. The book is produced on acid-free recycled paper and bound according to international standards. It is a veritable mine of reliable and up-to-date information on renewable energy technologies. It deserves a place in all the libraries and with all policy makers and researchers in the field of energy – not only renewable energy.

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