

A Study on Research, Development and Demonstration Of Renewable Energy Technologies

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Abstract

In this research work a study on Research, Development and Demonstration (RD & D) Of Renewable Energy Technologies has been conducted. The pace and extent of the contribution of new and renewable sources of energy and related technologies will depend, to a large extent, on scientific research directed towards their development and widespread utilization. The present R&D expenditure on renewable-energies is 6-8% of the total expenditure on Research & Development in Energy, of which about half goes to nuclear energy. While such research is expanding rapidly world-wide, the coordination and information-sharing is poor; duplication is widespread, and certain important aspects are relatively neglected and receive little attention. Moreover, currently the bulk of research is being carried out in developed countries; much of it will later on be extensively re-adapted for use in developing countries. A similar pattern is emerging for nuclear energy and also appears likely in future for the newer renewable-energy technologies (peaking after 2100 A.D). Accordingly, there has to be a more or less continuous effort for development of new renewable forms of energies. This effort should be at national, as well as regional and international levels, and an action plan upto year 2020 or 2030 should be worked out for every developing country.

Keywords: Renewable Energy, Development, Research, Developed Country, Technology

I. Introduction

National policies and plans should be developed and are urgently needed, in order to enhance the indigenous scientific and technological capabilities of developing countries, so as to enable them not only to fully and independently exploit their own resource-potential, but also to enter into collaborative research, development and demonstration effort, which should be closely coordinated with the related education and training programmes. The following are some basic steps and activities that shall be given consideration:

- i.**Select promising technologies, with a view to launch concerted efforts to accelerate their development, increase cost-effectiveness and widen their applicability;
- ii.**Identify the area and need of research, with special reference to the economic, social and environmental implications of emerging technologies, such as employment-potential;
- iii.**Establish or strengthen institutional mechanism for (i) national Renewable Sources of Energy for developing countries; (ii) Regional capacity, including the private sector, where appropriate, for undertaking and coordinating research, development and demonstration activities, on the basis of a review initially to be undertaken at national, sub-regional and regional levels, to enable present capabilities and existing resources to respond to identified needs and priorities, in particular those of developing countries;
- iv.**Establish or strengthen institutional linkages between research and development activities and the production-sector (to have public investments and industrial property systems, etc.);
- v.**Consider undertaking testing-programmes for increasing the ability of prospective consumers, producers and investors, to make knowledge-based decisions regarding technological options;
- vi.**Establish criteria for technical and economic evaluation of new and emerging technologies that may help

national experts to identify their potential at specific locations;

vii. Identify and implement demonstration-projects relating to new renewable-energy technologies, including those which can be undertaken on a collaborative basis, with the consideration that it will further stimulate research and development; the training of specialists, and increase industrialization.

II. Methods and Materials

II A. Proposals for developing countries Renewable Energy Electric power capacity² (1,500,000 MW) was 45% of world electric power (3,400,000) in year 2000, the developing countries’ (table-1). World’s fossil-fuels account for about twothird of generating capacity, with the remaining one-third being composed of large hydro (20%), nuclear (10%) and other renewable energy (3%). Electric energy-consumption in the developing world is increasing with economic growth and the developing world will need to double its current generation-capacity. Renewable energy faces stiff competition from other generation of distributed technologies, especially those based on natural gas and gas-turbines (and perhaps natural gas supplied fuel-cells in the future). Provided a gas supply exists, gas seems to remain the fuel of choice for small self-producers, because of short construction lead-times, low fuel and maintenance costs, and modular technology. New “micro-turbines” are lowering the capacity- threshold at which natural gas fuelled self-generation becomes viable.

Table-1: Renewable Grid-Based Electricity Generation Capacity Installed, as of 2000 (megawatts) [1-13]

Technology	All countries	Developing countries
Small hydropower a	43,000	25,000
Biomass power b	32,000	17,000
Wind Power	18,000	1,700
Geothermal power	8,500	3,900
Solar thermal power	350	0
Solar photovoltaic power (grid)	250	0
Total renewable Power capacity	102,000	48,000
Large hydropower	680,000	260,000
Total world electric power capacity	3,400,000	1,500,000

It is mentioned that (a)“Small hydro” is usually defined as 10MW or less, although the definition varies by country, sometimes up to 30 MW; (b) Biomass figures omit electricity from municipal solid-waste and landfill gas; commonly, biomass and waste are reported together. On the other hand, as households and business entrepreneur take more interest in distributed Solar PV, either by taking advantage of government subsidy-programs or decide to pay the extra cost themselves, “net metering” that allows “stored” kilowatt-hours over the utility connection and power sales at retail-tariff levels, is becoming more widespread. For example, 30 states in the U.S. now have net-metering laws, and California allows users with upto 1-megawatt loads to use net-metering. A net-metering law was recently passed in Thailand, in general few other developing countries have come to consider net-metering.

II B. Policies for promoting Renewable Energy

There are a number of specific ways for incorporating renewable- energy in the energy mix, which can boost its use in many countries:

Fossil-Fuels Subsidy: In developing countries, most of the fossil- fuels are subsidized. These subsidies may be reduced gradually, to make renewable-energy marketable with cost competitiveness.

Access to Transmission: An open-access transmission-system may allow power-heeling between buyer and seller that provides open access to customers. Transmission-services should not discriminate against, or give unfair advantage to, specific ownership or certain types of generation. For example, in India open-wheeling policies have been credited with helping catalyze the wind-energy industry; industrial firms may even produce their windpower in regions with good wind-resources and transfer the power over the transmissionsystem for the use in their own facilities – or for sales to a third party. Similarly, in Brazil, reduction of fees for transmission-wheeling has been credited with promoting and giving boost to the small-hydro industry.

Environmental Policy : Emissions standards, monitoring requirements, and other aspects of environmental

policy can be integrated to strengthen power-sector changes. For example, enforced emission- monitoring can promote “green power” markets. Major power-sector changes occur using political leverage, to incorporate environment friendly policies. Advocates of renewable energies should anticipate this opportunity.

Renewable-Energy Pricing : The electricity feed-in laws in Germany, and similar policies in other European countries in the 1990s, required purchase of renewable-energy power at a fixed price. For instance, in Germany, power producer could sell the utility at 90% of the retail market price. Feed-in laws led to a rapid increase in installed-capacity and development of commercial renewable-energy markets in particular in Germany and Spain. Partly because retail prices have been falling with competition, making renewable-energy producers and financiers more wary, the new German Renewable Energy Law now change pricing to that based on production-costs, rather than retail prices. One of the criticisms of historical feedin approaches was that they had not encouraged cost- reductions or innovation; this new German law includes provisions for regular adjustments to prices, in response to technological and market developments (Shepherd4 1998; Wanger5 2000; Sawin6 2001).

Distributed Energy Systems : Renewables are likely to play a larger role in power-systems, dominated by the distributed model than the central station paradigm. However, successful deployment of distributed renewables in an unbundled system, requires that at least one player can capture system-benefits. Some of the ways that distributed energy can be supported are :

- Financing mechanisms for renewable energy
- Common interconnection standards
- Standard power-purchase agreements and tariffs
- “Net metering” schemes for residential consumers
- Reduced bureaucratic procedures for grid-connections and/or metering
- upgrades energy tariffs in distribution-system

Distribution change system can substantially change the economics of generation of distributed renewable-energy. Solar-photovoltaic power, is perhaps the most significant. Although only about 20% of global PV production was used on grid in 1998 (mostly for government-sponsored rooftop markets). Such policies can enhance PV application at individual, community, regional and national levels.

II C. GEF Support to Renewable Energy in Developing Countries

GEF supported renewable-energy projects in developing countries from 1991 to 2000. Seventeen [14-17] projects were implemented through World Bank, UNDP and ADB. Nine (9) projects promote a wind-power in Cape Verde, China, Costa Rica, India, Kazakhstan and Sri Lanka, Six promote biomass and biogas power generation in China, Cuba, Hungary, Mauritius, Slovenia and Thailand, one promote power from biomethanation in India and one promotes Geothermal power in Philippines. In general, GEF projects take five main approaches to promoting Grid-connected renewable-energy : (a) demonstratable technologies, and their commercial and economic potential; (b) build capacities of project-developers, operator and regulatory agencies; (c) develop regulatory and legal frameworks that create financing mechanisms for projectdevelopers; (d) develop national plans and programmes informed by institutional and businessmodels piloted in projects.

II D. Some typical examples

The use of renewable technologies has increased in the developing countries and its countrywide status [18-25] (2000) is given in the Table 2.

Table-2: Renewable Energy Technologies in Selected Asian Countries as of December 2000

Country	Solar thermal system (1000m ²)	PV system (mW _p)	Wind power plants (mW)	Small/micro hydropower plants (mW)	Power plants (mW)	Biogas plants (1000units)	Improved cook- stoves (1000 units)
Bangladesh		0.15		--	--	1	82
China	5000	6.00	344	20,000	800	6800	180,000
India	467	50	1167	217	272.74	3000	32,000
Indonesia	--	5	0.5	54	178	--	--

Japan	57	3.6	75	--	--	--	--
Korea	--	0.48	--	5	--	--	--
Malaysia	--	2	0.15	24	200	--	--
Nepal	10	1.08	0.02	11.46	--	49.28	250
Pakistan	--	0.44	--	20	--	4.13	68
Philippines	--	0.52	0.06	70	--	--	--
Sri Lanka	--	-	3	6	--	4	--
Thailand	50	5	0.2	128	1230	10	500
Vietnam	--	0.47	0.1	95	--	3.08	--

China leads in solar thermal system, followed by India. In the case of PV, India is far ahead (50 MW); China, Indonesia and Thailand are also playing a significant role. Following examples are the successful Renewable Energy projects in the developing countries and lesson learned [26-30]:

a. Wind and small hydropower in India

By 2000, almost 1200 MW of wind-capacity had been installed in India, virtually all of that by the private sector, due to favourable investment/ tax policies and a supportive regulatory framework. Domestic wind-turbine manufacturers have emerged, many of them joint-ventures with foreign partners. During 1990s, GEF and World Bank directly financed 41MW of wind- turbine installations and 45 MW of mini-hydro capacity in India, through the Renewable Energy development project. Following lessons were learnt:

- i. Indian Renewable Energy Development Agency (IREDA) sponsored 35 MW of wind project and 65MW of mini-Hydro projects. Many financial institutions offered financing for Wind farms.
- ii. Regulatory investment-tax credit and Government commitment, as well as GEF's role, had influenced technology-transfer and market- development.
- iii. Another lesson is that more understanding is needed about the relative effectiveness of production-based incentives, relative to capacity-based incentives. In the 1990s, oneyear 100% investment tax-depreciation, provided large economic gains, for installation of wind-farm capacity, regardless of the electricity-generation from that capacity. This incentive is shifting, as capacity-based tax- incentives have decreased, due to the reduction in marginal corporate- tax rates, from 55% in 1992/93 to 35% in 2000. At the same time that power tariffs, production-based incentives, have continued to rise. In addition, IREDA offers incentives for wind-farms it has financed, to achieve higher capacity-factors and attracted investment and played role in enhancing market[31-40].

b. Bagasse Power In Mauritius

World Bank/GEF Sugar Bio-Energy project (1994-96) provided technical assistance and technology demonstration, to promote private / public sector cooperation in power-plants. Electricity-generation from bagasse increased from 70GWh/yr in 1992 to 118 GWh/yr by 1996[41-56]. This project triggered the private-sector to setup power-plants based on Bagasse at their own. One of the lessons the Mauritius project has how to create an investment-climate for renewableenergy power projects, and create public/ private partnerships that can lead to supportive regulatory frameworks. In this case, the project led to the establishment of a framework for the development of independent power-producer (IPP) and an administrative focal point for private/public sector partnership in IPP development. The evaluation of project showed that the project's major accomplishment was- progress in helping to establish an institutional and regulatory framework for private power-generation in Mauritius, and the provision of technical studies and trials, to support technologies for improved bagasse production and improved environmental monitoring. Another lesson may be that technical demonstration has less influence on promoting markets for a technology than other types of project-interventions (in this case the planned demonstration bagasse-plant that was never constructed).

c. Small hydro power plant in Sri Lanka

One of the lessons from the Sri Lankan project is that variable power- purchase tariffs can hinder market development. In this case, tariffs were tied to short-run avoided utility-costs based on the international price of oil. In 1997 and 1998, tariffs were set to be equivalent to 5 cents/kWh and hereafter mini-hydro development flourished. However, because of the downturn in oil prices in 1998-99, prices were only the equivalent of 3.5 cents/kWh in 1999. And this fluctuation had seriously hurt the longer-term interests of private mini-hydro

developers in Sri Lanka. “The low tariffs and unresolved dispute [on tariff calculation-methods] have caused a deep slump in mini-hydro development”, said a project-status report in 2000[57-65].

d. Wind-power in China

The emerging experience from the World Bank/GEF Renewable Energy Development project in China, highlights the pressing need to address regulatory frameworks and find ways to reduce risks to project-developers. The project was designed to finance four newly formed windfarm companies for the construction of 190 MW of wind-farms in Inner Mongolia, Hebei, Fujian, and Shanghai provinces. These companies were to be jointly owned by the State Power Corporation and subsidiary electric- power utilities (at regional, provincial or municipal levels) and were to sell power to utilities under power-purchase agreements, developed through the project. The costs of wind-generated electricity from these wind companies would be higher than those of conventional electricity generation, but utilities in three provinces (Hebei, Fujian and Shanghai) were initially willing to purchase this wind-power from the project developers. At least at small scales, the added costs of wind-power were marginal, relative to total utility-revenue for these three large utilities[66-70].

However, a planned 100-MW wind-farm in Inner Mongolia, as part of that project, was cancelled in 2000, because the smaller Inner Mongolia utility was unable to sign power-purchase agreements with neighboring provinces, for sale of wind-power, which could not be absorbed within the Inner Mongolia grid itself. Originally, the North China regional power company had agreed to purchase wind-power from Inner Mongolia, but when the North China power company was split into three provincial utilities and given an explicit mandate to operate on strictly commercial terms, Inner Mongolia was unable to persuade any of these three provincial utilities to sign power-purchase agreements with it, for the higher-cost wind- power. And being unable to use this power itself – given the small size of the Inner Mongolia grid (but abundant wind resources) – it proved unable to undertake this investment[71080]. The lesson may be that government has to provide subsidy to match it with other resources of energy as well as to enhance the economic market size.

e. Nepal’s Biogas Programme

Biogas Support Programme⁸ (BSP) is an example of a successful collaboration between government and private sector and donor agencies. The BSP was initiated in 1942, by Netherlands Development Organization and funded by Dutch Development Cooperation. The programme was closely associated with Agriculture Development Bank and Gobar Gas Company of Nepal[81-90].

About 86% of 21.5 M population (estimates of 1995) reside in rural areas of Nepal; the percapita GDP in 1995 was about US\$200. Annual per- capita consumption of primary-energy in Nepal was estimated at 271 Million GJ in total; out of this 90% was from wood (72%) followed by agricultural waste residue (16%), animal waste (9%), electricity (0.4%) and LPG (0.1%). The BSP in Nepal was divided into two phases. Phase-1 was implemented from 1992 to July 1994 and install 7000 Biogas plants for farmers. The second phase covered 13,000 plants from 1994 to 1997. Financial subsidy was provided to farmers through Asian Development Bank. The total of (approximately) 49000 units were constructed up to 1998 and are benefiting more than 200,000 members of rural households. Biogas plants are being efficiently used in P.R. China, where over 5 million plants are installed, as against 2.7 million in India[91-101].

f. Bio-Ethanol as an alternate fuel for transport (Brazil a role model)

Developing Countries are using Gasoline and Diesel as a fuel for transport which causes pollution, and resulting environment damages as well as a lot of foreign exchange is spent on the import. The alternate fuel for transportation can be Bio-Ethanol. In Third World countries, Brazil, Kenya and Malawi are the top three users and producers of Bio-ethanol. Brazil represents 2/3rd of global ethanol production, while Kenya uses 60% of its sugarcane produce for ethanol. In comparison Malawi produces 40% for automobile consumption.

Thermal properties of Bio-ethanol include; higher heating value of 6,400 Kcal/kg; an ignition temperature of 35 degrees centigrade and a specific heat of 0.60 Kcal/Kg °C more than gasoline. Brazil can be a role model in the Third World countries using Bio-ethanol as alternate fuel for transport which resulted in it saving foreign exchange, as well as creating job opportunities, this is because of appropriate policy framework and its implementation.

Following are some of the key policies and steps taken by the Brazilian government from 1975 to 2000:

1. Encouraged private investments with provision of low-interest loans on Bio-ethanol production units.
2. Guaranteed Purchase (By State Oil Companies)
3. Sales Tax incentives for Bio-ethanol using vehicle
4. Subsidy on Bio-ethanol (To make compatible with Gasoline)

The implemented policy from 1975 to 80s achieved the goal of 20% ethanol mix in the Gasoline, for

transportation. During 1980-1989 period majority of cars were converted on the Bio-ethanol. The production of Bio-ethanol increased rapidly to the level of 13-16 billion litres per year in late 90s. The Brazilian Government gradually increased the subsidy as the production of ethanol as well as its market grew by late 90s. Now Bioethanol is 1/3rd of the total fuel consumed by cars and light trucks in Brazil. Brazil's Bio-ethanol fuel-programme provided economic social and environmental benefits. In production of ethanol, Brazil has already saved US\$33 billion⁹ from the period 1976-1986 and created employment for 700,000 workers in rural areas. This also helped in improvement of the quality of air and reduced emissions. Brazil Bio-ethanol fuel program was successful and has economic social and environmental impact due to its appropriate policy framework and its implementation over the past 28 years as indicated in the following Table 3.

Table-3: Economic Impact of Bio-ethanol

Event	Economic Impact
Commercial	350 Private Companies producing Ethanol
	2% Bio-ethanol in gasoline blend – 1980
	13-16 billion litres/year Production of bio-ethanol in 1990
	Selling Price of Anhydrous ETOH=25\$ / barrel
	Gasoline Price (in Brazil) (160\$/M3)=35 \$/barrel
	Subsidy reduced over 25 years through price regulation
	High Energy Fuel (70% of gasoline)
Production	Cost of product decline (because of size of production)
	Estimated Potential / world ethanol production 2 billion t/year
	World ethanol production 21 Million li/year
	Brazil ethanol production 13 billion li/year
	Brazil consumption 12.4 billion li/year
	Average Bio-ethanol production energy ratio (energy output/energy input)= 9.2 (Brazil)
	USA – 2nd largest production = 5.5 billion li/year
Other vital statistics	Ethanol 1/3rd of total fuel for transportation
	1976-96: Brazil saved US \$33 billion on oil imports
	700,000 employment

It is mentioned that the source of this table is: Howerd Geller, "Energy revolution - policies for a sustainable future" Renewable Energy World, July-August 2003, p.40&42

g. Renewable Energy in Africa

Africa, with about 13% of the world's total population, accounts for about 2% of world economic output and its energy-consumption in 1997 was 11.4 Quadrillion BTU, whereas its production was 26.5 QBTU, in the same year. Energy-demand growth in Africa averaged 2.7 annually from 1980 to 1997, with slightly faster annual average 3.1% from 1990 to 1997. Africa's commercial energy consumption is small for a variety of reasons, some these include; low per-capita incomes, low level of industrialization, ownership and uses of vehicles (around 20 cars per 1000 people) and penetration of electrical appliances, like refrigerators, freezers, air conditioner. Commercial energy-production in Africa has nearly doubled since 1970, and is forecast to increase 68% by 2020[102-105]. Production has remained constant (at around 7%), as a share of the world total⁷. Some details are as below:

i. Energy Consumption:

-African commercial-energy-production is distributed very unevenly throughout the continent. Around 99% of Africa's coal output, for instance, is in southern Africa (mainly South Africa). Natural-gas production, on the other hand, is overwhelmingly concentrated in North Africa (mainly Algeria and Egypt). Crude-oil production is concentrated in North Africa (Algeria, Egypt and Libya), West Africa (Nigeria), Central Africa (Gabon), and southern Africa (Angola). East Africa produces almost no oil, gas or coal.

-As of 1997, Africa consumed around 26,300 Btu of commercial energy per 1997 dollar of GDP, and 14.9 million Btu per person. This compares with world averages of about 13,600 Btu per 1997 dollar of GDP and 65 million Btu per person, respectively.

-In 1997, Africa accounted for 3% of total world commercial energy- consumption. In that year, Africa accounted for 3.8% of world coal- consumption, 3.4% of oil, 2.4% of natural gas, and 2.4% of hydroelectricity.

-Compared to the rest of the world, Africa has very low levels of electricity-consumption per person. This is due mainly to poorly developed power-distribution grids and to heavy use of biomass in the residential sector.

-Energy consumption patterns vary greatly between southern Africa and the rest of Africa. Most significantly, southern Africa depends heavily (68%) on coal, while the rest of Africa is dominated (60%) by oil [131-135].

ii. Energy Production:

-Africa produces significant amounts of commercial energy – about the same amount as South America. Energy-production varies greatly by subregion within Africa. Most importantly, oil and gas make up 23% of southern African energy-production, compared to 97% in the rest of Africa [106-110].

-Only South Africa has nuclear power-production. Overall, nuclear- power accounts for 1% of African energy-demand.

-Natural gas makes up a little less than one-sixth of Africa's commercial energy-output. Almost all (96%) of this is concentrated in only 5 countries (Algeria, Egypt, Libya, Nigeria, and Tunisia).

-Hydroelectricity/others account for 3% of Africa's total energy- production, spread out widely throughout the continent.

-Nearly two-thirds of Africa's commercial energy-output is oil. Oil production (including crude oil and natural gas liquids) is heavily concentrated, with 5 countries (Algeria, Angola, Egypt, Libya, and Nigeria) accounting for 88% of the continent's total oil output [111-115].

h. Major African Environmental Challenge : Use of Biomass Energy

-Africa is the world's largest consumer of biomass-energy calculated as a percentage of overall energy-consumption (fire-wood, agricultural residues, animal wastes and charcoal).

-Biomass accounts for as much as two-third of total African final energy-consumption. In comparison, biomass accounts for about 3% of final energy-consumption in OECD countries.

-Africa consumed an estimated 205 million tons of oil-equivalent (Mt oe) of biomass and 136 Mt oe of conventional energy in 1995, according to the International Energy Agency [121-130].

-Most of Africa's biomass energy-use is in sub-Saharan Africa. Biomass accounts for 5% of North African, 15% of South African, and 86% of sub-Saharan (minus South Africa) consumption.

-Wood, along with charcoal, is the most commonly used form and it is the most detrimental to the environment.

-South Africa is unique in sub-Saharan Africa as biomass accounts for only 15% of its energy-consumption. There is a range of energy options available in South Africa : biomass, kerosene, coal, liquefied petroleum gas (LPG), and solar power. This range of choices reflects the country's high level of economic development, relative to other African countries [116-120].

III. Results and Discussion

-Deforestation is now one of the most pressing environmental problems faced by most African nations, and one of the primary causes of deforestation is utilization of wood as fuel.

-Women and children suffer disproportionately from negative health- effect, due to the smoke generated with the use of fuel wood for cooking (smoke is a carcinogen and causes respiratory problems). About 75% of wood harvested in sub-Saharan Africa is used for household cooking.

-Production of traditional fuels is often insufficient to satisfy the rising demand. Fuel available to the poorest communities is expected to decline, which will intensify environmental degradation in those communities.

-End-use efficiency for most traditional fuels is low. A high concentration of fuels is needed to produce a low level of energy, and a significant share is wasted.

-Several African nations have made considerable advances in the use of photovoltaic (PV) power.

-In Kenya, a series of rural electrification and other programs has resulted in the installation of more than 20,000 small-scale PV- systems since 1986. These PV systems now play a significant role in decentralized and sustainable electrification.

-The direct conversion of solar into electrical energy with solar (PV) cells does not at this stage seem to be an economic proposition. The recently developed Amorphous Silicon-Technology holds considerable promise, but further developmental work in this direction is imperative, especially for the use in small units for communications, lighting and water-pumping.

IV. Conclusions

Over one billion people live in underdeveloped economic conditions around the world, between latitudes 35° N and 35°S. In general, greatest amount of solar energy is found in two broad bands around the earth between latitudes 15o and 35o north and south of the equator, and three approaches to the utilization of this solar energy are:

(a) use of low grade heat, (b) direct conversion to electric energy and (c) Photosynthetic and biological conversion processes. The technology of low- grade heat devices only has so far been developed to such an extent that they have immediate application. However, the urgent RD&D needs are:

i) a realistic assessment through field trials on a continuous basis, of the impact of these devices under our social and economic conditions; the need for research and development to improve these should be kept under review; (The priorities of application are : hot water (e.g. for process heat), providing drinking & irrigation water, crop drying and cold storage of agricultural products, and space heating);

ii) Available data on commercially manufactured solar water-heaters of small, medium and large capacities, as well as solar distillation, should be widely disseminated with a view to select appropriate types and their local production;

iii) Techno-economic studies should be undertaken to improve the efficiency of solar water-heaters by:(a) use of reflectors, (b) modified collector-design, and(c) architectural integration.

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