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SOLAR ENERGY AND HEALTH

ENERGIE SOLAIRE ET SANTE

High-level Expert Meeting
Réunion d'experts de haut niveau

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Solar Energy and Health
Energie solaire et santé

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SOLAR ENERGY AND HEATLH

A STRATEGY FOR RURAL HEALTH AND DEVELOPMENT

SUMMARY

Health and energy are interdependent, critical factors which determine the progress of rural development. Health interventions have already shown great improvements in child survival and reach out to most communities in the world.

Energy needs are however an area of concern. The quality, availability and cost of conventional energies, plus the associated environmental effects are a growing problem -- not only for the health infrastructure but also for agriculture and domestic life. This is true not only in developing countries where the fast growing industries and urban populations demand a soaring proportion of available energy ***at the expense of the rural communities,*** but also in the poorest countries with weak energy infrastructures and, coincidentally, the lowest child survival rates.

Renewable energies, much studied in the last 20 years, can meet the needs of rural health services and communities by providing high quality, low cost, non-polluting energy. Solar energy, in particular, has the flexibility to produce electricity, heat and cooling. Solar technologies, furthermore, are backed by an established and experienced industry.

This report proposes to meet the energy needs of rural communities by a coordinated international effort with three major thrusts:

- In countries with insufficient rural cash economies to expect the development of a commercial and domestic solar market, **provide financial and technical support for the implementation of solar energy** to district level health and community services
- In countries with large rural populations and stronger rural economies, **provide solar energy to meet health needs** through local production and production-sharing, thereby stimulating a commercial and domestic market.
- **Coordinate international research** to optimize the introduction, local production and market development of solar technologies and to further improve their performance and reliability.

Considering that the spearhead of this initiative is health improvement, WHO proposes to collaborate with other international organizations and donors to determine how best this strategy can be implemented.

ENERGIE SOLAIRE ET SANTE

RESUME

Santé et énergie sont deux éléments indissociables et déterminants du développement rural. La santé publique a réalisé de remarquables avancées dans le domaine de la survie de l'enfant et de nombreux services sont maintenant accessibles à une grande majorité des populations dans le monde.

Toutefois, les besoins en énergie sont encore, dans leur majeure partie, insatisfaits. La qualité, la disponibilité et le coût des énergies fossiles ainsi que leur effet sur l'environnement sont causes de difficultés croissantes--non seulement pour l'infrastructure de la santé mais également dans l'agriculture et dans la vie quotidienne des populations. Cette situation ne s'avère pas seulement dans ceux des pays en développement où le fort taux d'industrialisation et d'urbanisation se traduit par une soif inextinguible de l'énergie disponible **aux dépends des communautés rurales**, mais également, dans les pays les plus pauvres ne possédant qu'une infrastructure squelettique et où la mortalité infantile est souvent la plus forte.

Les énergies renouvelables, qui ont fait l'objet d'études approfondies au cours des 20 dernières années, peuvent satisfaire les besoins des services ruraux de la santé et ceux des communautés villageoises, en fournissant une énergie de bonne qualité, non polluante, à un coût modéré. L'énergie solaire, en particulier, offre la possibilité de produire de l'électricité, de la chaleur ou du froid. De plus, les technologies solaires sont maintenant commercialisées par un réseau industriel expérimenté et solidement établi.

Ce rapport propose qu'afin de subvenir aux besoins en énergie des communautés rurales, une action internationale coordonnée soit mise en place, avec trois axes prioritaires d'action:

- Dans les pays ne disposant pas d'un niveau économique suffisant dans les zones rurales, **fournir une assistance technique et économique** afin d'équiper en énergie solaire les districts sanitaires et satisfaire un certain nombre de besoins communautaires.

- Dans les pays fortement ruraux et jouissant d'une économie rurale suffisamment développée, **fournir des technologies solaires pour la santé, en favorisant la production locale** totale ou partielle, stimulant ainsi le développement d'une économie de marché, locale.

- **Coordonner la recherche internationale** afin de promouvoir l'introduction, la production locale et le développement d'un marché des technologies solaires et, par ailleurs d'améliorer leurs performances et leur fiabilité.

La présente initiative étant axée sur l'amélioration de la Santé, l'OMS est déterminée à collaborer avec les agences et les bailleurs de fonds internationaux afin de définir les meilleures conditions de mise en oeuvre de cette stratégie.

1.0 HEALTH, ENERGY AND RURAL DEVELOPMENT

Health and energy are interdependent, critical factors which determine the progress or decline of rural development. Improvements in health are reflected directly in terms of increased agricultural productivity and enhanced performance in education. Health in the family and the health service infrastructure depend heavily on the availability of energy of the highest possible quality at the lowest possible cost. As development progresses, the interdependence between health and energy becomes more and more pronounced.

1.1 Health drives rural development

Rural development can thrive in communities which have good health, an economic family size and high quality of life. Other economic factors also have an effect but it is the health, vigour and peace of mind of the individuals which provide the driving force behind development of a society.

Survival of children is the first essential

In rural areas of industrialised countries almost all children survive to their fifth birthday. This contrasts with much of Sub-Saharan Africa and parts of Latin America where, in 1990 for instance, less than eight children in ten survived to their fifth birthday.

Since 1980, most countries with improvements in child survival have also seen corresponding reductions in average family size -- for example, countries with mortality rates of less than 150 per 1000 for under-fives have recorded significant reductions in family size. China provides another example: with one-quarter of the population of developing countries, the mortality rates in China of children under five have dropped from the 1960 figures of 206 per 1000 to 42 per 1000 for 1990. During the same period, the total fertility rate has declined from 5.7 to 2.3. This phenomenon is repeated in many other developing countries such as the Philippines (where it has dropped from 6.7 to 4) or Egypt (from 7 to 4.2) and follows the experience of industrialised countries where the average family size is under 2. Further fall in fertility rates can now be expected in those countries where the under five mortality has been drastically reduced[1].

Improvements in child survival in the rural areas of developing countries have been largely due to the effectiveness of health interventions. In 1991 the global coverage showed 82% of children under one year were provided with a full series of immunizations against selected childhood diseases. Coverage does, however, tend to be lower in rural areas. An estimated 6 million deaths from these diseases were prevented by immunization and, if coverage in rural areas can be improved, diseases including Neonatal Tetanus, Polio and Measles will be eliminated completely.

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[1] Human Development report, United Nations Development Programme, 1993.

Reduction and elimination of disease is the second essential:

Survival of children is not sufficient to ensure an active and productive rural population. Disease, particularly in childhood, has a devastating effect on productive life and sharply reduces the number of active years of each person. WHO and the World Bank have measured this as "disability-adjusted life years" (DALYs). Developing countries lose more than 500 million DALYS in children under one year, more than 80% of these being lost through diarrhea, respiratory infections, malnutrition and other communicable diseases. This is a disease burden which can be substantially controlled at a cost of less than $US 100 per DALY saved.

Many studies have also confirmed that health affects education which, in turn, affects rural productivity. The World Bank estimates that four years of primary education boosts farmers' annual productivity by 9% on average. Poor health and bad nutrition, however, lessen the gains of education -- they reduce enrollment, compromise the ability to learn and restrict participation by girls. A study in Nepal, cited by the World Bank, found that the probability of attending school was 5% for malnourished children compared to 27% for those at the norm[2].

Improvements in the quality of life are the third essential

In 1977, the World Health Assembly adopted a resolution that the main social target of governments should be "the attainment by all people of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life".

> **"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"[3]**

To achieve "Health for all by the year 2000", WHO adopted a policy of 'Primary Health Care' which prioritises interventions at the family level, the community level and the first levels of the health service infrastructure (Figure 2). WHO now believes that the district level should be sufficiently autonomous to provide all the routine and forward planning support necessary for the network of health centres and health posts which serve the villages. If adequate capacity and accountability can be achieved at district level this decentralisation will improve efficiency.

Moreover, the health infrastructure is no longer seen as providing a static, passive service but a dynamic service reaching out to the community, the family and the individual. For many rural communities today, these health interventions are the only outside help they receive. So, in addition to disease prevention and clinical services, WHO is strongly committed to achieving targets in the environment which include sanitation, nutrition and food and water safety, all of which require close and effective communications between the family and health personnel.

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[2] World Development Report, The World Bank, 1993.

[3] Constitution of the World Health Organization

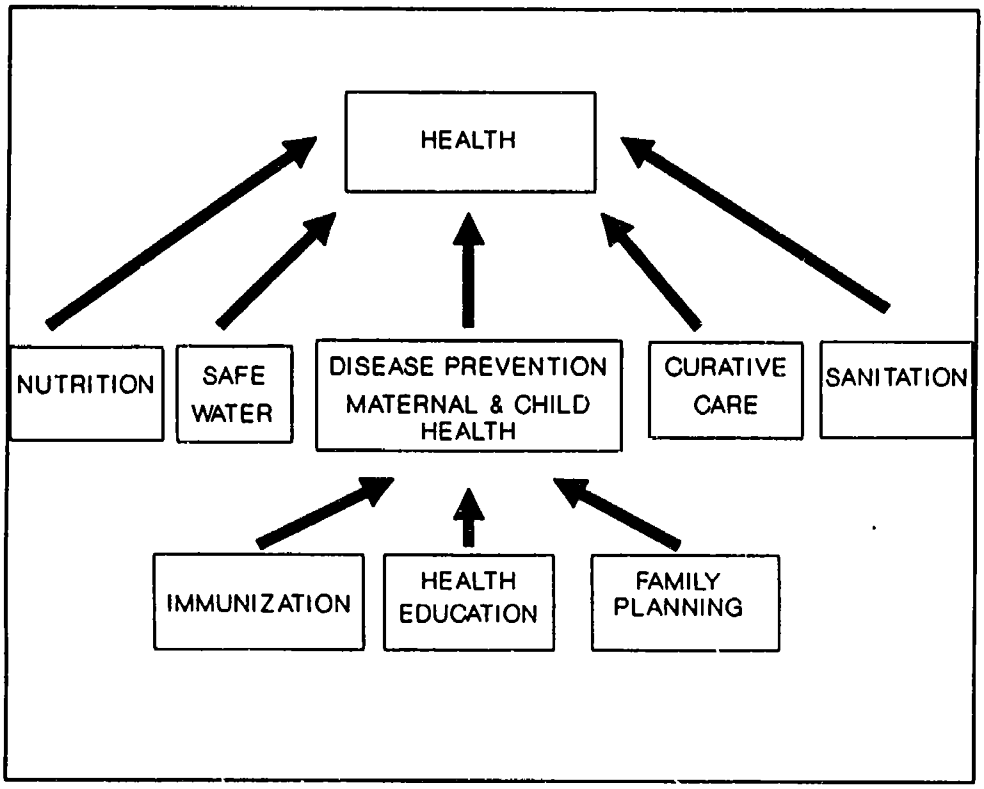

Figure 1:
Essential components contributing to health
Principaux éléments contribuant à la santé

In this context, the contact of rural communities with the outside world through radio and television, the quality and availability of light at night, passive ventilation (or heating) of domestic and health buildings and the environmental safety of technologies used both in the home and the health centre are considered to be strongly health-related issues. Health, including the attainment of a better quality of life, will provide the necessary human potential for rural development and will help to control the drift of the population to urban areas.

A rural population which is healthy, active and educated, a supportive agricultural economy and a controlled rise in urban populations are keys to the future success of all developing countries.

1.2 Rural development competes for energy

Energy is also a critical 'driver' for rural development, including health. Today, as the demands of industry and urban areas rapidly increase, rural areas also compete more for the limited energy supplies from conventional sources. In developing countries where industrial and commercial demands exceed capacity, the quality and also the availability of fuel and electricity in rural areas is threatened. The average income in rural areas is lower than that in urban areas so the cost of conventional energy, particularly in countries with high rates of inflation, hits rural populations hardest.

Industrial and urban energy needs are growing most rapidly in developing countries whose economies are expanding. In some South East Asian countries the projected needs for grid electricity far exceed the current and planned increases in capacity. Although oil prices have remained low, costs to the consumer are steadily rising in developing countries which import oil products. Demand for LP gas in urban and suburban areas has risen and, in poorer countries, supply has become uncertain.

The consumption of commercial energy per head is a staggering 16.6 times higher in industrialised countries than in developing countries.

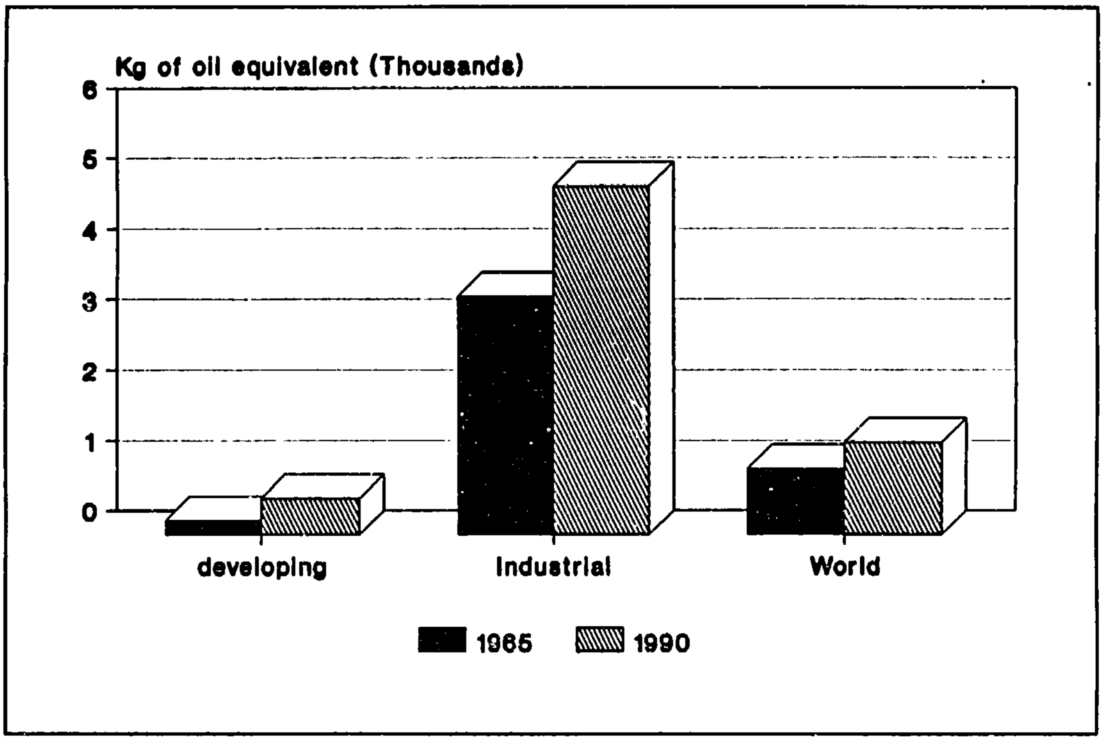

Figure 2:
Per capita commercial energy consumption, 1965 & 1990[4]
Consommation d'énergie commerciale par personne, 1965 et 1990

[4] Human Development report, 1993, UNDP

Energy needs in rural areas are less than those in urban and industrial areas but they remain vital for rural development. The effect of industrial and urban demand on scarce resources has been to reduce the availability and quality of energy in rural areas and to increase its cost. Where the electricity grid has been established widely in rural areas, such as in India, Bangladesh and Pakistan, interruptions and 'load shedding' are increasingly common. Poor maintenance of the system has also been destructive to electrical equipment in several countries monitored by UNICEF and WHO.

Four out of five rural inhabitants of the developing world still do not have access to electricity. Where the electricity net is not yet fully established in rural areas, as in several large African countries, plans to extend it are delayed by ever increasing demands on the existing grid serving more populous areas. The increase in the cost of establishing an electricity grid increases delays plans still further (see table 1). It has been projected that global population growth is sufficient to keep the absolute number of people without electricity static in spite of the planned increases in grid electricity in the future.

Table 1:
Costs of rural village grid electrification[5]
Coût de l'électrification de villages ruraux

Countries	Cost per village (1985 US $)
India	20,000 to 30,000
Bangladesh	70,000
Zambia	73,000
Tunisia	83,000
Bolivia	105,000
Pakistan	80,000 to 110,000
Indonesia	125,000
Benin	300,000
Burkina Faso	320,000

The cost of liquid fuels are always higher in rural areas which are distant from the points of storage. As the cost of fuel rises nationally, the increase in rural prices is more burdensome on communities with a lower average wage than in urban areas. The situation is exacerbated by inflation which also drives up prices in local currencies and, in poor countries, results in breaks in national supplies of fuel.

[5] Recent approaches to Rural electrification, Derek Lovejoy, United Nations Department of Technical Cooperation for Development, January 1993.

1.3 Energy is critical for health development

Energy needs for health in rural areas are small in relation to all other needs but they are arguably the most vital. The availability and quality of energy provided for the health infrastructure must be very high, *while the cost* of energy available for households, many of whom are outside the monetary system, *must be low or zero.*

The following types of need and levels of energy are considered to be the minimum guide for health in the household and for health service buildings:

Household needs:

- Light
- Safe water
- Cooking
- Water heating

Health service needs - the Health centre:

- Water heating
- Electricity for:
  - Light
  - water pumping
  - sterilization
  - radio/communications/tv
  - refrigeration for vaccines
- Passive ventilation (or heating)

Health service needs - the District Hospital:

- Water heating
- Electricity for:
  - Light
  - lab.equipment
  - radiology
  - oxygen concentrator
  - water pumping
  - Water treatment
  - sterilization
  - radio/communications/tv
  - refrigeration for food, vaccines, blood storage
  - maintenance tools
- Passive ventilation (or heating)

The minimum needs required to reach the goal of Health and Development are elaborated in Annex 1.

1.4 Health hazards of conventional energy sources

In addition to being costly and increasingly inaccessible for rural development, conventional energy sources have a number of environmental and health drawbacks in relation to the needs listed in the previous section. Many documents deal with the health effects of damage to the global environment[6]. Here we shall concentrate on the health effects of damage to the household environment caused directly or indirectly by conventional energy sources and the technologies which use them.

Although it is hard to quantify morbidity and mortality caused by an adverse household environment, the effects are evident and are a serious barrier to improving health, particularly of women and children.

Cooking on wood fires exposes the cook and other persons in the surroundings to dangerous quantities of smoke (See Table 2). Most of those endangered are women and children. They are exposed to a variety of pollutants which are similar to those exhaled when smoking.

Table 2
Exposure of women and children to pollutants during cooking[7]
Exposition des femmes et des enfants à des polluants lors de la cuisson

Pollutants	Cooking emission factor (mg/kg)	Concentration during cooking (mg/m3)	Multiple of recom-mended standards	Equivalent dose (number of cigarette packs per day)
CO	40,000	200	5 (WHO)	2
BaP	1	5000	800 (USSR)	29
TSP	2000	15	15 (Japan)	4
HCHO	400	20	16 (Europe)	11

Cooking burning rate:	1.5 kg/hour
Cooking duration: :	3 hours
Respiration rate	1100 litres per hour
Room volume:	40 m3

Recent studies in Mexico, Nepal and South Africa have shown that non-smoking women who cook on biomass stoves or open fires in the home have seven times more chance of contracting obstructive lung diseases than those who use other heat sources. Children from such homes are also at an increased risk of acute and other respiratory infections.

Moreover, wood has to be carried, invariably by women, over increasingly long distances. This

[6]See Report of the Panel on Energy of the WHO Commission on Health and Environment, WHO, Geneva, 1992

[7]"Alternate Energy Utilization in Myanmar", Prof. S.K. Sharma, Unicef, 1992.

compromises their health and the time and energy which they need for other tasks in the family. Kerosene stoves, particularly pressure stoves, used for cooking also pollute the air which the family breathes and are often the cause of household accidents.

Light, provided by kerosene lamps, is not directed downwards nor is it sufficiently powerful for reading or writing safely. Only 3-4 lux is produced at 1 metre from a wick lamp, 2.5% of the standard light recommendation for reading. Inadequate light at night is a serious risk and a hindrance to rural populations attempting to educate themselves and their children. Kerosene lamps are also used during childbirth in health centres and are widely criticized by health staff. These lamps pollute the air in rooms where families are living or where people are working.

Refrigeration for vaccines is powered by kerosene burners in more than half the rural health centres of the developing world. This poses a significant fire risk. The absorption refrigerators which use kerosene burners are not able to control vaccine storage temperatures automatically, nor do they make sufficient ice for outreach immunization operations in high tropical ambient temperatures.

A study in Mali (See Figure 3) has shown that well maintained kerosene refrigerators operated by trained staff exceeded the correct storage temperature more than 35% of the time on average with some of them even exceeding that figure, an experience common in many other countries.

LP Gas powered absorption refrigerators do not share these disadvantages but the distribution of LP gas to rural areas where there are no routine deliveries is hazardous. Even net electricity is frequently too unreliable to run refrigerators in the health centre and, in areas with electrical storms or poor power lines, is actually destructive to vaccine refrigerators.

Dry cell batteries are used very extensively worldwide to power radios and cassette players in communities without electricity. For example, in the Dominican Republic alone, over 200,000 radio-cassette players consume several million dry cell batteries each year. Not only is the disposal of these batteries a risk to the environment, but they are the most costly form of electrical energy available (between US $ 900 and US $ 2,000 per KWh).

Water hand pumps provide water at a very slow rate, to one person at a time. The average output that can be expected is about 3 m3 per day (10 litres per person for a community of 300 people). Hand pumps are not therefore suitable for large communities and they consume much of the productive time, mainly, of women.

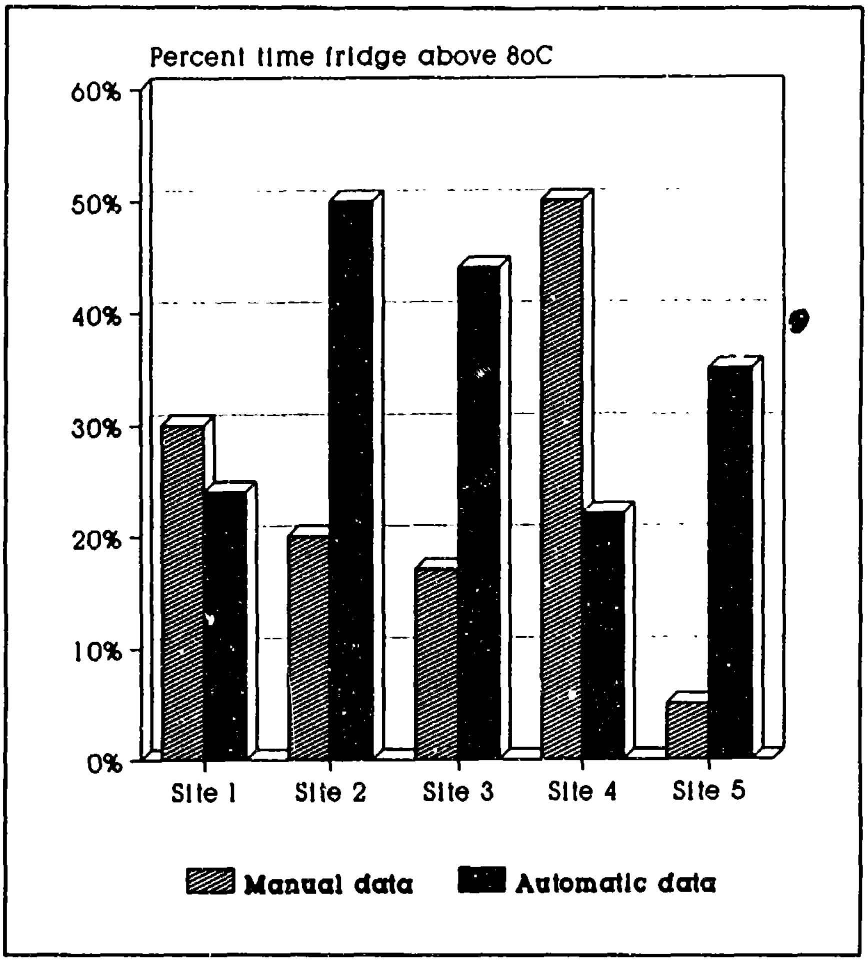

Figure 3:
Temperature monitoring in kerosene refrigerator in Mali[8]
Suivi des températures dans des réfrigérateurs à pétrole au Mali

1.5 Renewable energy, the best choice

Environmentally sound, qualitatively superior, and demonstrably feasible, renewable energy is the best choice for rural development, although it is not always the most economic choice. Of the renewable energy alternatives, solar energy is the most ubiquitous and the most widely researched and implemented. Solar energy can cool and produce heat directly and, through photovoltaics, it generates electricity -- the most flexible form of energy -- for light, cooling and motive power. The total energy needs of a rural community fall well within the economic limits of decentralized applications of renewable energy technologies.

[8]Monitoring of Kerosene refrigerators in Mali, IT Power-WHO/EPI, 1990

The photovoltaic industry has attracted the greatest investment and has enjoyed greater market penetration, in industrialized as well as developing countries, than any other renewable energy. Figure 4 shows the breakdown of the global PV market during 1992. Although the growth of the market is well below the expectations of the eighties when output tripled, it still reached 7% in 1992. Applications of photovoltaics in the health sector are small in comparison to industry but 1360 kWp is nevertheless now installed globally for this health purposes (See Figure 5).

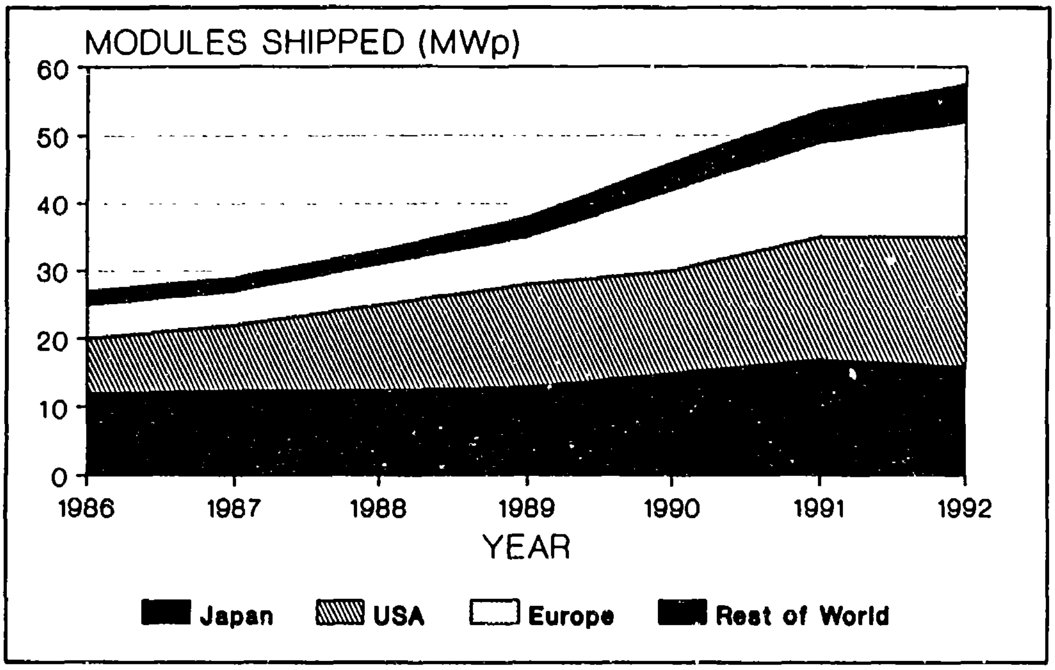

Figure 4:
Growth of global photovoltaic market by region
Croissance du marché photovoltaïque par région

It is clear that a relatively high capital investment is needed to purchase and install photovoltaic applications and the benefits accrue over time to the rural population who use the technology at low cost. These costs and benefits have been weighed by many large development agencies including the World Bank and the European Community, and are considered to be favourable to national scale photovoltaic implementation in rural areas.

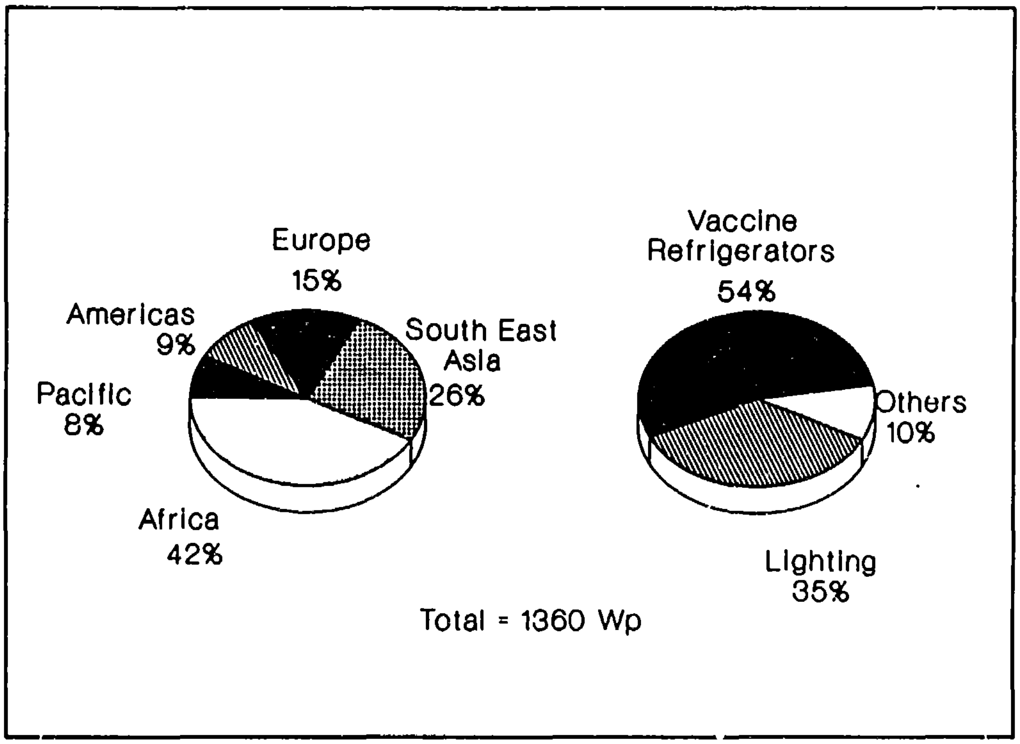

Figure 5:
1992 Photovoltaic health market by region & by application
Le marché photovoltaïque dans la santé par région et par type d'utilisation en 1992

1.5.1 Solar refrigeration:

WHO has been active for fourteen years in the development and evaluation of photovoltaics for vaccine refrigeration. Studies in all regions of the world and independent testing in five laboratories have shown the following:

- In terms of icepack production and temperature control the performance of photovoltaics compression refrigeration is far better than for kerosene refrigerators which, for 75% of rural health centres without electricity, are the sole means of refrigerating vaccines.
- The mean time between breakdowns is good (the average in three African countries using four proprietary systems was 3.5 years). Considering the high cost of repair skills, this can and should be progressively increased to seven years.

The application of photovoltaics is acknowledged to be more economic than extending the electricity grid in rural areas where consumption is below 20 kWh per day.

Economic studies become complicated when they compare the costs and benefits of individual photovoltaic technologies with existing technologies using conventional energy sources. When the results are favourable to photovoltaics, the method of analysis tends to generate skepticism. The balance of costs is heavily affected by the reliability (mean time between failures) of the installations, the lifetime, the cost of repair and the value attached to the consequence of a failure, such as a loss of vaccines.

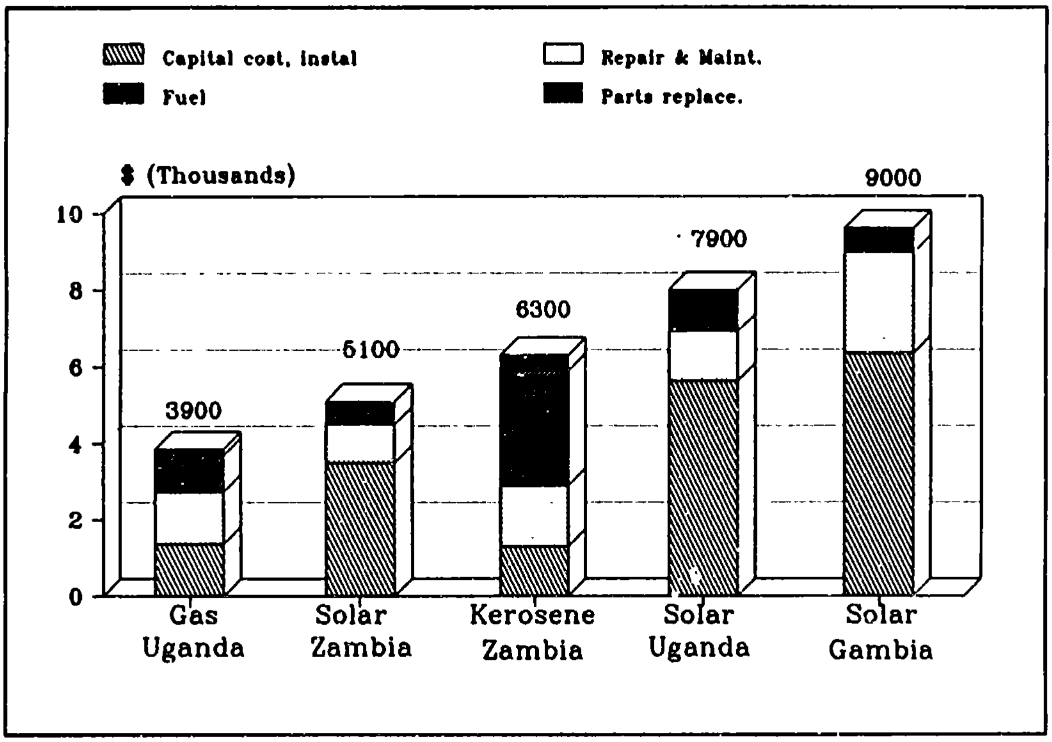

Figure 6:
Lifecycle cost, refrigerators, PV, gas & kerosene
Coût sur 10 ans, réfrigérateurs, PV, gaz et pétrole

- The overall lifetime cost is only close to the lifetime cost of conventional fuel alternatives if factors concerning the value of vaccine losses and other assumptions are included in the cost/benefit equation. If not, the lifetime cost of a PV refrigerator is approximately $US 500 greater than the closest alternative.

- PV refrigerators give good, reliable service provided that installation is carried out to a high standard by trained technicians and instruction is given to health personnel who use them.

WHO believes that solar refrigeration are becoming indispensable with the introduction of new vaccines and the special, large scale immunization activities which are becoming more frequent. The reason for this is that the security provided by solar refrigerators and their storage volume permits longer term storage of vaccines at the periphery (for kerosene refrigerators storage is limited to 1 month). Vaccine can therefore be passed more rapidly down the distribution system thus taking pressure off higher level storage facilities and enabling the vaccine to be stored closer to the point of use.

> **WHO/EPI concludes that these benefits are sufficiently important to outweigh the marginal differences in the cost of purchase and maintenance, if the burden of cost can be shared with other applications sharing the same photovoltaic power source.**

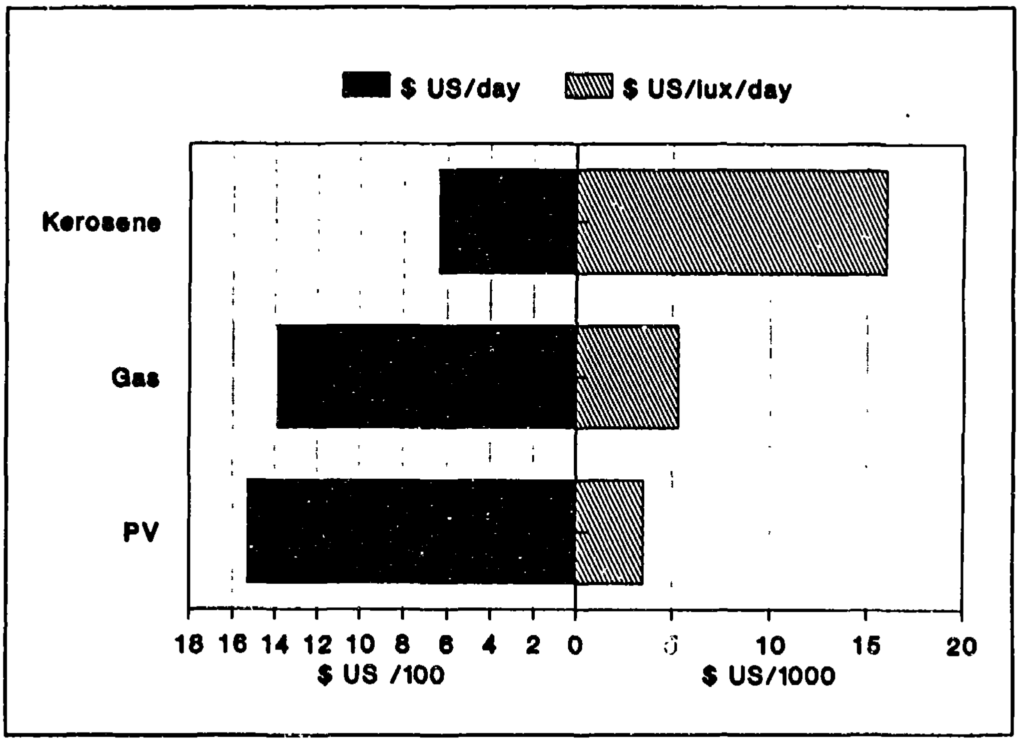

Figure 7:
Costs and quality of light for gas, kerosene and solar lanterns
Coût et qualité d'éclairage des lampes à gaz, au pétrole et solaire

1.5.2 Solar thermal market

This market is well established for water heating in many developing countries and many industrialized countries in temperate climates also. Several types of water heating exist and two are suitable for small systems in health centres.

1.5.3 Solar lighting (portable lanterns or static systems)

Solar lighting provides a high quality light (fluorescent lights). It has a low power consumption and is economic on a life cycle basis. Figure 7 show the comparative costs of solar, gas and kerosene lanterns and highlights the fact that the solar lantern provides the best quality of light at the lowest cost.

1.5.4 Solar water pumping

Solar water pumping systems operate best when the insolation is at least 4 Kwh/m2/day and needs exceed 20 m3 per day.

Approximately 24,000 systems are installed worldwide with a significant proportion for livestock purposes in industrialized countries.

It is now commonly agreed by development agencies that the community must be involved in the maintenance of the systems for water supply and irrigation programmes. Water is therefore sold for a fee in order to generate revenue for the maintenance infrastructure and technician. A recent large scale project even required the participation of the community in the initial investment (approximately 50% of the capital cost)[9].

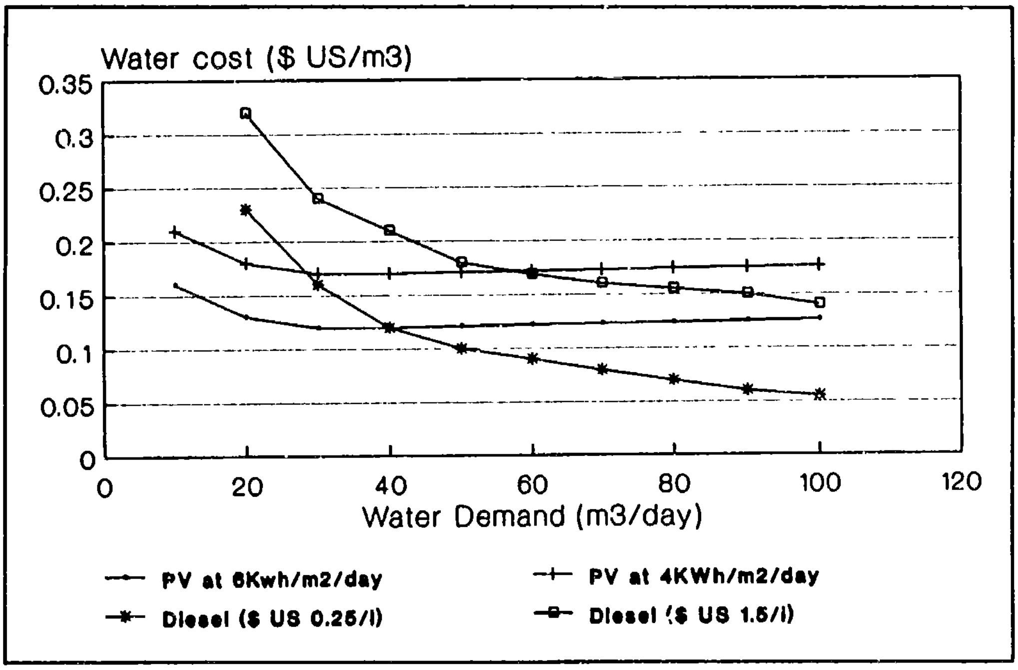

Figure 8:
Comparative costs of solar and diesel pumps
Coûts des pompes solaire et diesel

[9]CILSS/EEC "1000 solar water pumping systems, Regional Solar Programme."

Figure 8 provides an indication of where solar power becomes cost effective in comparison to diesel pumps. Health centres and district hospital needs are obvious cost effective locations for solar water pumping.

1.5.5 Solar battery chargers :

Perhaps the most promising way out of the dilemma posed by the high cost and poor reliability of rural power supplies is by charging batteries to provide essential lighting and broadcast reception for rural populations. In Sri Lanka, for example, 300,000 of the 1,5 million families rely on charging stations in near-by grid-connected villages to charge automotive type batteries. For families in such conditions PV battery charging stations promise a lower cost and a more reliable and convenient solution.

PV battery charging stations offer similar services to current diesel (or central grid) charging stations. Typical 1-2KW systems can be operated and managed by a local entrepreneur or a health committee. In one day they can charge 10-20 100 Ah batteries which have been 30% discharged.

1.5.6 Solar cooking

Many research and development projects have focused on solar cookers, primarily for domestic use. The results of the research programmes are clear: the technology works. However, the dissemination programmes have never been particularly successful, primarily because of difficulties in introducing new equipment at a cost into a domestic market where the collection of wood prevails.

In addition to being safer for the health of women and children, solar cooking has a lot to offer in terms of energy savings and being environmentally friendly. Initial use should focus however on institutions such as health centres, district hospitals and schools where training can be given to a limited number of users.

1.5.6 Climatic housing

Passive cooling (or heating) through the climatic design of buildings has been known for centuries. With the introduction of building materials, such as concrete and corrugated iron, it has gradually been forgotten as these materials facilitate strong construction without the need to pay attention to orientation, natural cooling etc. The resulting loss of comfort is, however, significant and, furthermore, the negative impact (huge variations of temperatures inside the building) both on the health of the inhabitants and the performance of the equipment[10] cannot be ignored. An effort should be made to reinstate a certain observance of climatic rules in health centre/district hospital building or rehabilitation programmes.

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[10] A study showed that the performance of vaccine refrigerators was greatly improved (more stable temperatures) when the health centre was built with a North South orientation and local materials as compared to those operating in buildings made of concrete and corrugated iron roofs. (WHO/EPI/Ministry of Health of Chad, 1990).

2.0 APPLICATION OF SOLAR TECHNOLOGIES IN RURAL HEALTH

Mature, solar photovoltaic and thermal technologies exist to meet almost all the health needs of the growing rural population of the world. The application of these technologies will require rural development resources devoted to energy. To ensure that these resources stimulate local commercial markets, a strategy is required to establish local production or production-sharing where justified. Finally, research and development needs to be focused primarily on field monitoring, auto-financing of maintenance costs and improving the reliability of equipment in use.

2.1 The rural market is vast...and growing

Due to urbanization, rural population growth in Asia is expected to slow down but it will still exceed 180 million by the year 2000. In contrast, the rural populations of Africa, the Middle East and Central America are expected to increase by 50% over the next generation. The combined rural populations of developing countries will exceed 500 million by the end of the decade.

Thirty-eight countries with the highest under-5 mortality rates (over 140) also have the highest proportion of rural populations (73%). The health development of these countries is a priority for WHO, other international agencies and the donor community. An energy strategy for their rural areas will be critical in achieving lasting health improvements.

The district focus of health services which has been mentioned and the accessibility of the health infrastructure to the population suggests that the market might be developed in three phases:

- **First, the district hospital, health centres and schools** of the district should be provided with the minimum needs listed above.
- **Second, financing mechanisms** should be set up to enable the farming cooperatives or other rural agricultural organisations to invest in solar technologies
- **Third, at village level and, finally, at home level** the domestic market should be stimulated through an increasing availability of reliable low cost applications and the local presence of skilled technicians.

A very broad estimate of the total solar energy needs (electricity and thermal) of health services for the first development phase of the market is outlined in Table 3[11] and shows that the potential market is far from being negligible.

APPLICATION	POWER (Wp)	NUMBER	TOTAL (MWp)
Vaccine Refrigeration	150-200	126,000	18-25
Food refrigeration	150-250	21,000	3.1-5.2
Blood refrigeration	150-200	21,000	3.9-5.2
Lighting	40-100	126,000	5-12
Water pumping	600-1400	126,000	75-176
Transceivers	50-100	21,000	1-2.1
Sterilization	150-250	126,000	18.9-31.5
TOTAL SOLAR PHOTOVOLTAICS : 125- 257 MWp			
Water heating	2 m2 thermal	21,000	
Cooking	2 m2 thermal	126,000	
TOTAL SOLAR THERMAL: 294,000 m2			

Table 3:
Global estimates of PV energy needs for health facilities in rural districts of priority developing countries
Estimation globale des besoins énergétiques des services de santé rurale dans les pays en développement pouvant être satisfaits par le solaire

Even if this estimate is scaled down by a factor of 5, to assume a smaller range of equipment for the health facilities, it still adds up to 12 MWp or 20 times more than the current installed capacity of the health sector.

[11] Assumptions based on calculation for 21,000 rural health districts:

- with each health district having a population of 100,000 with 5 health centres and one district hospital;
- the population concerned (rural population in rural areas of developing countries, with no access to grid electricity), in areas with the adequate climate (insolation greater than 1600 kwh/m2.year) being around 2,100 millions (source World potential of renewable energies, CNRS, AFME, MRT, 1992).

2.2 Technologies mature for widespread application

Photovoltaic and thermal solar applications are available which already have a long history of development and optimization. "Maturity" here will be taken to indicate that testing in the laboratory and experience in the field prove that the technology:

- performs satisfactorily
- has a history of reliability
- is environmentally safe
- has an expected lifetime of at least ten years
- is supported by established, competitive suppliers
- has an acceptable training burden
- has a low recurrent cost affordable to the user

The following technologies (stand-alone applications) which have been selected for health applications in rural areas are described separately in Annex II:

A Photovoltaic lighting systems
B Portable photovoltaic lamps
C Photovoltaic water pumping
D Photovoltaic refrigeration/freezing
E Photovoltaic radio & communications
F Photovoltaic battery charging stations
G Solar thermal refrigeration/freezing
H Solar thermal water heating
I Solar thermal sterilisation

Full performance specifications are needed for each technology and those products which are known to meet the specifications need to be identified in a product information system similar to the WHO UNICEF Product Information Sheets[12].

2.3 Prioritising aid for local production

In countries with large rural populations and a rural cash economy, local production or assembly of photovoltaic systems to meet priority rural energy needs for health can be used to build a sustainable local commercial market which will meet domestic and agricultural energy needs. Once a domestic market has established itself, it can be expected that maintenance skills will become more available and affordable.

Certain essential components of solar technologies require an industrialized setting for their manufacture and, to ensure their financial viability, they require a large domestic or export market. However, the assembly of systems and the manufacture of many components can be undertaken by countries with a lower level of industrialization but a sound domestic market.

[12] WHO/UNICEF *Product Information Sheets*, WHO, Geneva, 1993

The larger the domestic market, the more feasible the production or production-sharing in a country will be; while the higher the gross national product (GNP), the less the need for external financial support will be. It is therefore proposed to prioritize international financial and technical support for local production, partial production or assembly, according to these two parameters: the gross national product and the size of the rural population.

Figure 9 plots countries, both industrialised and developing, according to their per-capital gross national product and their rural population in 1992.

Three categories based respectively on size of the rural population and categories of GNP have been defined so that each country falls into one of nine market categories. Annex 4 lists the countries by category.

The black squares on the figure represent countries which have already established photovoltaic panel manufacture and also produce photovoltaic appliances such as refrigerators or lighting. The dotted squares represent the existence of local assembly and/or existing local marketing in the private sector.

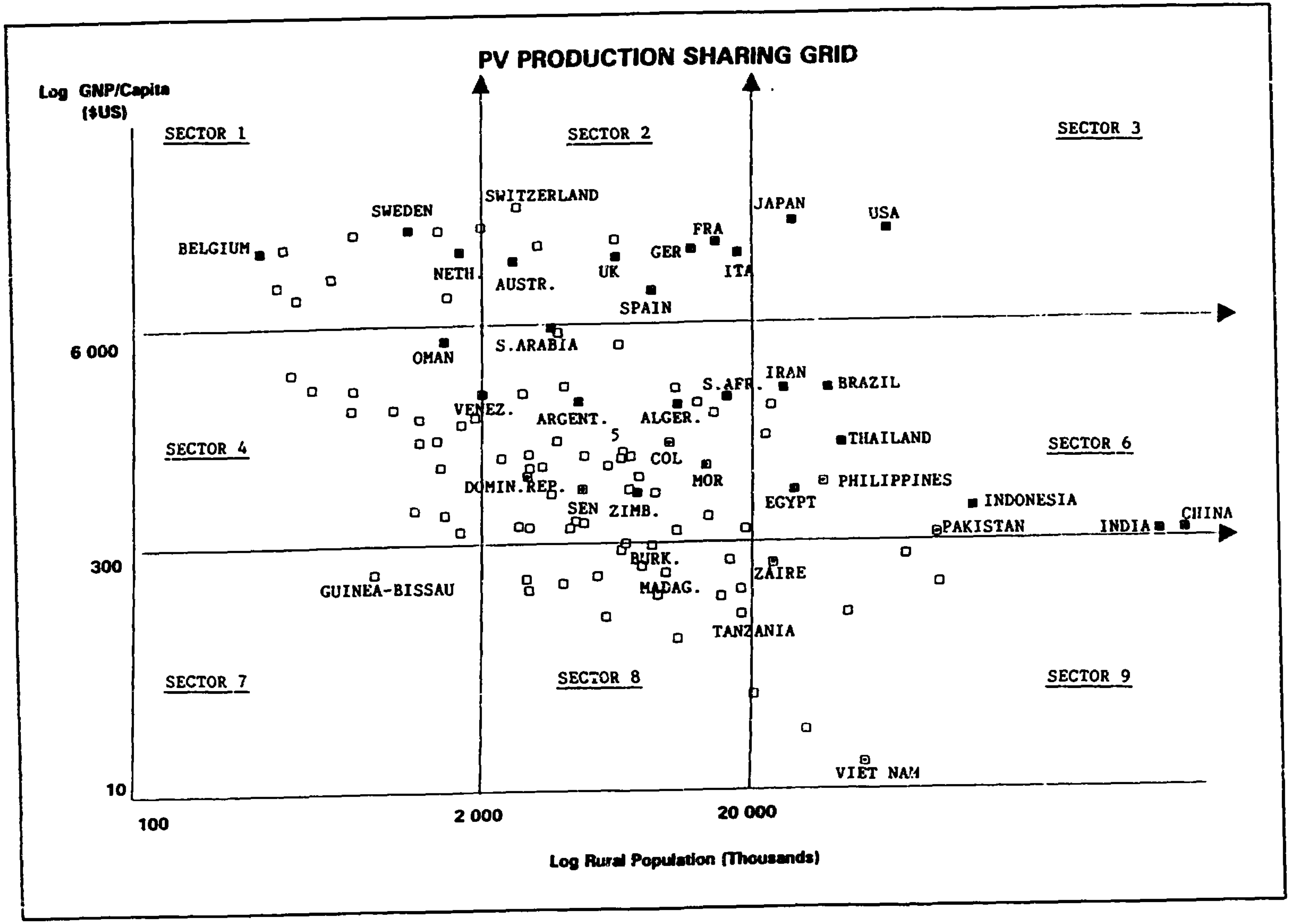
Sectors 1,2 and 3 in this grid represent countries, great and small, which have per-capita GNPs of more than $US 6000 and do not, therefore, require financial aid to build local production. They may require technical assistance but are more likely to become sources of technical assistance. Many of these countries already have a production infrastructure.

Sectors 4,5 and 6 represent middle income countries,often with a sizeable rural population and some industrialization. Sector 4, the smallest of these middle income countries will import a greater proportion of photovoltaic components and will therefore need international pressure to make import tax concessions so that local assembly can be affordable. Marketing will need to receive special attention and this is an area where external support is likely to be needed. Sector 5 countries will require a mixture of production and marketing support, in addition to support needed to implement energy for health projects Sector 6, the largest of these countries, has the best potential to establish primary production of major photovoltaic components. A commercial market in the agricultural sector and, finally, a retail domestic market could be expected to develop once primary production and demand from health or public sector projects has been established.

Sectors 7,8 and 9 represent the poorest countries, under $US/Capita 300, where the necessary income to generate a domestic rural market for solar energy will be most difficult. These countries will remain dependent on financial aid to provide solar energy for the public sector for some time and, only exceptionally would it be feasible to invest in production ventures which survive by a private sector market.

> **A pre-feasibility study of the potential of the market and the feasibility of local production and/or assembly of components will be needed in a short-list of target countries.**

Figure 9:
Prioritization of countries for "solar energy and rural health" strategy[13]
Classification des pays prioritaires pour une stratégie "énergie solaire et santé rurale"



[13]This grid is inspired by the "Batson-Evans grid" applied to vaccine manufacturers, source: Children Vaccine initiative Task Force on Situation analysis.

2.4 Financing a maintenance infrastructure

Local production and widespread implementation are the critical factors for efficient and sustainable repair and maintenance services.

Photovoltaic technology requires specific repair skills which are as costly as private sector electrical services. When private sector services are scarce and remote from the user they become exceptionally costly. Studies of solar refrigeration have shown that limited implementation of photovoltaics for a single purpose results in high repair costs. Integration of a number of applications in one location with widespread implementation acts as an incentive for local entrepreneurs to develop the maintenance skills required and helps to share and reduce costs.

Some auto-financing projects to meet costs at community levels have yielded promising results:

- During 1990-1991, at the initiative of WHO/EPI, the Ministry of Health of Zaire initiated a "sale of solar electricity study" in one health district of Bas Zaire. This study consisted in the supply of battery chargers, a community television and a VCR which were used by the district hospital to generate income to contribute to the recurrent costs of their health programmes. The mid-term evaluation conducted during 1991 showed that, with an investment (battery chargers, TV and VCR) that represented less than 13% of the total funds provided by the EEC to equip the health centres with solar vaccine refrigerators and lighting systems, the district was able to generate more than 50% of the recurrent cost of the primary health care activities of the whole district[14].

- In the Dominican Republic, a local commercial organization providing hardware and maintenance together with a local NGO has initiated, with US $ 20,000 seed money, a programme leading to the sale of 1000 photovoltaic domestic lighting and broadcast reception kits[15]. In this project, the PV modules are imported but the automotive batteries and the other hardware are locally made.

- A rapidly growing programme was initiated in Sri Lanka by three young entrepreneurs who founded a local PV module assembly company. Almost 4,000 domestic lighting and broadcast reception kits have already been installed and another 35,000 systems are being installed.. The local government-owned bank offers consumer loans for solar rural electrification up to 80% of the system cost, with 5 years to pay.

- Similar experiences have been initiated in Colombia, Senegal, French Polynesia, South Africa and many other countries.

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[14] "Vente d'électricité solaire, une contribution au recouvrement des frais récurrents du PEV, Nselo, Bas Zaïre. Evaluation à mi-parcours du projet pilote", WHO/EPI, January 1991

[15] Source: "United Nations Natural Ressources Forum, 1988 and Solatech 1991 conference".

There are, in effect, several modalities for financing the purchase and maintenance of solar systems:

- through community organizations and cooperatives, such as in the Dominican Republic;

- through the provision, within an assistance project, of an income generation component such as in Zaire;

- through local power utilities which may be in a position to offer long term credits or leasing, such as in French Polynesia and in South Africa;

- through purely commercial channels.

2.5 Priorities for Research and Development

Solar technologies exist to meet most rural health energy needs. However, there is still need to improve the performance and reliability of these technologies and to find ways to fund mechanisms and reduce the cost. Other technologies, not yet mature enough for widespread use but with important potential to meet needs, also require further research and development.

> **The approach advocated in this paper is to implement the technologies which exist. In large scale implementation there is much to be learnt in a short time in order to be able to respond to problems which inevitably will arise.**

The first priority is to monitor the use of technologies which are widely applied and to concentrate on operational research in the field in order to optimise applications and their local financing.

The second priority is research designed to reduce the cost or raise the reliability and performance of applied technologies.

The third priority is to develop new technologies to an acceptable level of maturity for widespread use, starting with those already in an advanced stage of development.

A priority list for research areas is presented in Annex 3 and a discussion of these priorities follows.

Discussion:

We need to find the best ways to generate the recurrent funds to repair solar technology when needed. Auto-financing studies are very promising in this regard. Equally, we must reduce the need for repairs by improving and standardizing the design of systems and components. If health service solar energy applications are to be a stimulus for the beginning of a domestic and agricultural energy market, more must be known about today's market.

We need less expensive and more reliable versions of the current technologies. We need to promote an integrated use of the technology in the health sector which will in turn facilitate the emergence of local entrepreneurs and technicians, thus greatly reducing the overall installation and maintenance costs.

2.6 Role of International Agencies

A vicious circle was created in the early 1990s which, for a number of factors including the economic situation and a lack of donor investment, contributed to a decline in the renewable energy industry and has made the solar market less attractive, less competitive and therefore less successful.

The prospects for the industry back in the 1960s which lead to strong political support in the United States, were that renewable energies would contribute significantly to the energy market in industrialized countries. Falling oil prices and high solar technology prices subsequently depressed that market and reduced industrial investment.

However, considerable investment has already been made in production of PV technology in particular and growth, although modest, is continuing. The international community, if united on the priority of adopting solar energy as a key energy strategy for integrated rural development, has the power to break the vicious circle and create a trend which will rapidly gather its own momentum.

Simply by identifying mature technologies which are broadly applicable and by agreeing on minimum levels of provision to meet basic health needs, the process of development can begin. By directing technical and financial assistance to establish local production and production-sharing in countries where domestic markets can be expected to flourish, an infrastructure of maintenance can be generated. By prioritising research towards field application and towards technologies which are closest to maturity, more needs can begin to be met with a wider choice of technologies.

3.0 STRATEGY FOR IMPLEMENTING SOLAR ENERGY FOR RURAL HEALTH

Goal: Every developing country of the world should have short, medium and long term plans for the national implementation of renewable energies to meet health priority needs using existing, recommended technologies by the year 2000.

3.1 Agree and declare an international policy:

- Decide what 'health' needs have priority (see annex 1).
- Decide which technologies are ready for scale application, now (see annex 2).
- Prioritise countries for technology transfer,market building and health sector energy projects (see annex 4).
- Set industry and field research priorities for the future (see annex 3).

3.2 Establish a secretariat within WHO with the following responsibilities:

- Liaise with industry and funding agencies to coordinate the introduction of production, production-sharing and financing schemes into countries according to their industrial base and their market.
- Provide technical support as needed by countries and other agencies in planning and implementing large scale projects.
- Review multi-lateral and bi-lateral rural development projects & propose additions and/or modifications to the energy-health element of each.
- Help to establish internationally agreed performance standards for those solar components which are not already covered by existing standards.
- Produce WHO/IAPSO *Product Information Sheets* for solar technologies which have been tried and tested and which have the necessary performance, cost and environmental safety evidence to interest project planners and purchasing agencies.
- Maintain a global electronic conference and bulletin board through 'INTERNET' to ensure that there is a continuous dialogue between those interested and those active in production or implementation of solar energy.
- Coordinate efforts to direct research towards internationally agreed priorities and organise the necessary meetings to review those priorities annually.

3.3 Mobilize the support of international agencies, the interest of governments of developing countries and the awareness of the general public in the development of renewable energies for the health and well-being of rural populations by:

- disseminating clear policies and practical guidelines;
- regularly providing feedback of global progress to the international community;
- Monitoring the costs and benefits of national projects and making this information public;
- seeking funds required for 'start-up' of large scale production once small scale production has proved the feasibility of an approved technology.

ANNEX I

GUIDE LIST OF MINIMUM NEEDS TO REACH HEALTH & DEVELOPMENT OBJECTIVES

Household needs		
Type	**Needs (per person/per day)**	**Comments**
Light	40 lux, 4 hours	Good quality lighting can only be met with electricity
Water	50 litres per person	Includes 20 litres per person, 20 litres for animals and 10 litres for gardening. Survival level = 5 litres; Standard aid = 20 litres
Cooking	2 kgs of wood	The objective being that more convenient and less polluting energies, such as gas or solar, be used

Health service needs -- the health centre (less than 10 beds)		
Type	**Basic needs**	**Comments**
Light	* 4x8W fluorescent for 10 hours * 2/16w fluorescent for 4 hours	Electricity is the best source. Light (and small quantities of electricity) is also required for the staff personal uses if they are to be motivated to stay in rural areas
Water pumping	200 -400 litres	Amount depends on the size on the health centre
Water Heating	100 -200 litres	Used for babies, washing and cooking
Sterilization	1 hour 120°C	-
Radio	24 hour standby; 0.5 hour transmission	Approximately 15 AH per day
Refrigeration	0oC-8°C 2 kgs ice	-

Health services needs -- The District Hospital (appı oximately 50 beds)		
Type	**Need**	**Comments**
Light	* 12 x 8W fluorescent 10 hours * 2 x 40W fluorescent, 8 hours	See above
Water pumping	1000 litres	-
Water heating	40/65°C, 500 litres	-
Sterilization	120°C, 3 hours	-
Radio	24 hours standby 2 hours transmission	Approximately 32 AH per day
Oxygen concentrator	24 hours operation	approximately 0.2Kwh/day
Laboratory	8 hours micro power instruments	0.6 Kwh/day (centrifuges
Food refrigeration	200 litres	1.2 Kwh
Radiological equipment	30 minutes per day	-
Blood refrigeration	Whole blood 2oC/8°C & Plasma freezer	0.3 Kwh
Vaccine refrigeration	0-8°C 100 litres Freezer	0.7 Kwh
Maintenance tools	-	0.3 Kwh

ANNEX II

SELECTED SOLAR TECHNOLOGIES FOR HEALTH

A. SOLAR PHOTOVOLTAIC LIGHTING 31

B. PORTABLE SOLAR PHOTOVOLTAIC LAMPS 32

C. PHOTOVOLTAIC WATER PUMP 33

D. SOLAR PHOTOVOLTAIC REFRIGERATION 34

E. PHOTOVOLTAIC RADIO / COMMUNICATIONS 35

F. PHOTOVOLTAIC BATTERY CHARGING STATIONS 36

G. SOLAR THERMAL REFRIGERATOR- ICEPACK FREEZER 37

H. SOLAR THERMAL WATER HEATING 38

I. SOLAR THERMAL STEAM STERILISATION 39

A. SOLAR PHOTOVOLTAIC LIGHTING

Description: Fixed, Fluorescent 8-13 W tubes; Moveable, Halogen 20-40 W spot - linked to a storage battery and PV panels via an electronic controller

Performance:

Fluorescent - 900-1000 lux; Halogen - 2000-4000 lux

Economics: Approximate cost for a stand-alone system in a bedded health centre (comprising 3 fluorescent lights, 1 halogen light, a 100 Ah battery and 2 50 Wp PV modules) : $US 2000

Approximate recurrent cost : replacement of lights and battery : $US 150 pa

Applications: District hospital, school, health centre, home. Typically this system can provide 1 small reference light all night and specific light for deliveries for 2 to 4 hours per day.

Experience: Lighting systems are being increasingly implemented by development agencies but also by commercial companies through direct marketing. In 1992: 10,000 home systems in Indonesia 4,000 systems in Sri Lanka 12,000 in Mexico 28,000 in Colombia 10,000 in Kenya Large number of system suppliers including local agents in many developing countries in Sector 3, 4 and 5 (see annex IV).

Environment:

Rechargeable battery disposal each 5 years

Remarks: This technology is probably the one that will show the way for the introduction of solar energy in rural areas. It is relatively cheap, and "visible".

B. PORTABLE SOLAR PHOTOVOLTAIC LAMPS

Description: Portable, robust lantern with built in 6-7 W fluorescent tube(s) and rechargeable battery. It is recharged every day by connecting it to the solar array.

Performance: 35-60 lux at 1 m, 4-7 hours on full charge

Economics: Purchase cost: $US 228 Battery life: 2 years

Recurrent cost: US $ 60 per year

Applications: Domestic and health centre portable light

No.producers: More than 10 major producers

Experience:
- Senegal/GTZ
- 300 by Unicef for Yugoslavia, Somalia and Sudan
- 120 in health centres in Haiti

Environment: Disposal of lantern after ten years. Disposal of battery after 5 years

Remarks: Re-charged on PV system. Can be rented to the community to help pay maintenance costs of the PV system. Can also be supplied to the health centre or hospital staff as an incentive and a way to improve their living conditions (and therefore their motivation)

C. PHOTOVOLTAIC WATER PUMP

Description: Submerged centrifugal pumpset or submerged pump with surface mounted motor, connected to the solar array (less than 1500 Wp)through an inverter

Performance: Up to 100 m3/day

Economics: Submerged borehole motor pump providing 25 to 40 m3 of water per day at 20 meter head with an insolation of 5 Kwh/m2/day: $ US 6,000 to $ US 8,000. Life cycle cost: $ US 0.11 to 0,22 per m3 of water (over 10 years)

Application: Community water supply and irrigation. Best performance and operating cost with heads of 25-40 m or less. Minimum insolation required of 4KWh/m2/day

Experience: More than 24,000 units installed around the world with a substantial part used in industrialized countries for livestock. One on-going 1000 pumps project in 8 countries of the Sahel region (CILSS). More than 10 major manufacturers and systems suppliers.

Environment: Pump to be replaced after 10-15 years. No batteries.

Remarks: Most solar pumps operate directly from the solar panels and therefore without batteries. The water is stored in tanks when the pump operates.

D. SOLAR PHOTOVOLTAIC REFRIGERATION

Description: Low energy 12 or 24 V compression refrigerator freezer linked to storage batteries and solar PV panels via an electronic controller

Performance: 0 to 8oC vaccine storage temperature range at +43 °C ambient. Minimum 2 kgs / 24 hours icepack freezing at +43oC ambient 72 hours 'no-sun' autonomy at 32oC ambient

Economics: Cost: approximately $US 3,500 to $US 6,00 without installation.

Applications: Storage of vaccines and other biologicals Storage of Whole blood and single user plasma Freezing of icepacks for immunization programmes

Experience: 3500 systems installed globally, 14 years experience worldwide. Ten refrigerators meeting WHO/UNICEF Standard Performance specifications and currently listed in the Product Information Sheets. 15 system suppliers qualified by WHO/UNICEF Environment;rechargeable battery disposal, 2-4 batteries (lead acid) every 5-7 years.

E. PHOTOVOLTAIC RADIO / COMMUNICATIONS

Description: VHF or HF radio transceivers typically equipped with a 100 W transmitter, a 30-50 Wp PV array, a 105 Ah 12 V battery and transceiver equipment. The solar array is sometimes pole mounted on the antenna of the transceiver.

Performance: 10 hours standby, 0.5 hour reception, 0.5 hour transmission very day.

Economics: US $ 3,000 to US $ 4,000

Application: Communications from and to remote areas. For example for disease surveillance to connect all health centres to a national public health. Up to 80 km : VHF; up to 300 km: HF

Experience: Very wide experience with the radio equipment operating on 12 V (vehicles, portable, etc). Limited experience with solar powered radios, however, the solar part is really only a battery charger which provides DC current to very well known and reliable radio transmitters. 2-3 major multinational manufacturers of transmitters designed for tropical countries. Many system suppliers. Gambia: PV powered VHF transmitters equip health centres. Zaire, Mali, Central African republic: Missionaries and NGO's commonly use VHF transmitters solar powered or recharged with generators.

Environment: Disposal of the battery after 5-7 years. Disposal of the radio after 10 years.

Remarks: The use of two way radios can meet with difficulties in some countries because of the Monopoly that the military may have on telecommunications within the country.

F. PHOTOVOLTAIC BATTERY CHARGING STATIONS

Description: PV array installed with or without a charge regulator, used to recharge automotive batteries brought by users.

Performance: Small chargers (40-200 Wp) deliver 150 to 800 Wh/day at 5 kwh/m2/day insolation. Larger charging stations (1 to 2 Kwp) will charge ten 100 Ah batteries in 3 days

Economics: Approximate costs:

40 Wp:	US $ 900
200 Wp:	US $ 3,000
1 KWp:	US $ 13,000

Application: Charge of batteries for domestic use (light, 12V television, VCR's, tape recorders, portable computers, two way radios, etc.) Large charging stations can be used to geneıate income by replacing commercial grid connected charging stations.

Experience: 20-30 large village battery charging stations in Thailand. Zaire WHO pilot project ri Lanka, Dominican republic Several manufacturers.

Environment: Disposal of electronic charge regulator after 4 years. Batteries are owned by the users and will typically last 2-3 years (automotive batteries).

Remarks: Very simple system. Most reliable components (PV modules mainly).

G. SOLAR THERMAL REFRIGERATOR- ICEPACK FREEZER

Description: Absorption or a-sorption refrigerators operating on an ammonia-calcium chloride pair on an intermittent day/night cycle. No batteries and no moving parts.

Performance: 0-8 °C at 43 °C ambient and, 2 kgs ice per day or 10 kgs of ice per day for freezers only. 5 days no sun autonomy at 43 °C ambient

Economics: US $ 4,000 to US $ 5,000 without transport and installation.

Application: Vaccine refrigeration and icepack freezing; Food conservation; Production of ice

Experience: Limited to approximately 50-100 appliances including large cold rooms for fish in The gambia, milk chilling plants in India and ice making machines in Mexico.2-3 manufacturers in Europe and USA. No large scale implementation to date

Environment: Ammonia can be released in case of leakage

Remarks: The technology offers great potential mainly because of the total absence of batteries and moving parts. Experience of large scale programmes missing.

H. SOLAR THERMAL WATER HEATING

Description: • Integral collector storage (or batch solar water heaters) consisting of a glazing, a collector-storage tank and an insulating box connected to the cold water distributive or gravity system or static; or

• Thermosiphon made of flat plate absorbers, an insulated water tank placed higher than the collector. Hooked up to the cold and hot water distribution systems.

Performance: 200 litres capacity, low temperature: 340oC/+65°C

Economics: 10 year min life, cost approx $US 2000

Application: Health centre, domestic.

Experience: Widespread use for more than 20 years in the domestic sector and for commercial uses such as in hotels, in mediterranean countries (Cyprus, Israel, Greece) southern USA, etc. Limited experience in Central Africa (Zaire, Congo), Madagascar

Environment: n.a.

Remarks: Particularly appropriate for technology transfer ventures.

I. SOLAR THERMAL STEAM STERILISATION

Description: Flat plate collector, solar box or heat pipes.

Performance: 121 °C during 30 minutes, 3-5 times a day at 4 KWh/m2/day insulation.

Economics: US $ 100 to 500 for low cost prototypes (heat pipes and solar box) US $ 2,000 for flat plate collector types

Application: Rural health centres and district hospitals, sterilisation of syringes and other invasive medical equipment

Experience: Field trials only. No Large scale projects to date except 24 units in Kenya with a device no longer manufactured. High initial costs have hindered wider experimentation. Sterilisation needs to be conducted after noon to allow the appliance to warm up.

Environment: n.a.

Remarks: Two low cost appliances (US $100 to 300) are being developed and will undergo field trials in the near future. Local manufacture needs to be encourage to further reduce the costs.

ANNEX III

LIST OF PRIORITIES FOR RESEARCH & DEVELOPMENT

1ST PRIORITY:

All technologies

- Prepare information dissemination materials/activities (publications, videos, slides) on the potential and the application of solar technologies in health, aimed at :

  - International and bilateral agencies
  - Non Governmental Organizations
  - Foundations
  - Ministries of Health
  - Health staff
  - Schools

- Improve reliability through the development of Standard Performance specifications, design changes, standardization, independent testing and assessment of performance in the field.

- Conduct market research in rural households of Developing Countries for energy needs.

- Develop guidelines on the safe disposal of batteries

- Develop Standard Performance Specifications for sale of electricity/income generating kits (battery charging, community television/video, renting of lighting systems/lanterns) for inclusion in all health/education assistance projects.

Solar Lighting systems:

- Conduct "impact" studies (social and economic) in areas/countries which are benefitting from the introduction lighting systems either in the domestic, education or health sectors.

- Develop Standard Performance Specifications for 2-3lighting kits (including portable lanterns) aiming at meeting the majority of the needs in the health centres, district hospital, schools and household.

Vaccine refrigeration

- Develop and introduce new standards for CFC free PV compression refrigerators .

- Conduct medium scale field trials of existing battery-free photovoltaic refrigerators.

Solar water heaters:

- Conduct country and regional assessments of practices and quantitative and qualitative requirements for hot water in health centres and district hospitals.

2ND PRIORITY:

Safe water:

- Investigate technical feasibility and cost of PV water treatment by UV radiation

Climatic architecture:

- Conduct an inventory of the architectural design of health buildings (from the health centre to the district hospital) in a representative sample of developing countries.
- Prepare practical guidelines on climatic architecture for health building and disseminate them.

Solar water heaters

- Identify countries with existing infrastructure for the local manufacture of batch or thermosiphon solar waters heaters and encourage manufacturing and production for the health sector according to the needs.
- Promote the concept of one or two demonstration large scale "solar water heater for health centres and district hospitals" implementation projects.

Solar thermal steam sterilization

- Develop and field test low cost (US $ 100) solar cooker type steam sterilizer
- Conduct medium scale controlled field trial
- Identify target countries for local manufacture

Photovoltaic data collection and transmission (telephone/radio)

- Conduct reviews of experience to date on the use of solar power radios for transmission of health data.
- Identify countries with interest in implementing a health data transmission system making use of solar power, for rural health centres and district hospitals
- Secure funding and conduct large scale implementation programmes.

3RD PRIORITY:

Climatic architecture:

- Conduct pilot project for the construction or the rehabilitation of health buildings according to the above guidelines.

Solar cookers:

- Develop use of solar cookers in institutions such as schools, refugee camps, district hospitals, military camps.

Communications:

- Conduct demonstration project on the use of satellite communications for improved surveillance and health data transmission.

Small PV powered medical appliances:

- Encourage the development and production of small PV powered medical appliances by

  * collecting and analyzing experience
  * Identifying needs at district and health centre levels,
  * liaising with the relevant medical appliance industrial sector
  * developing standard performance specifications and * conducting independent testing.

ANNEX IV

COUNTRIES STRATIFIED BY PV STRATEGY

Key to table below:

SECTOR 1 GNP/Capita over $US 6000 and rural population under 2 million

SECTOR 2 GNP/Capita over $US 6000 and rural population between 2 and 20 million

SECTOR 3 GNP/Capita over $US 6000 and rural population over 20 million

SECTOR 4 GNP/Capita between $US 300 and $US 6000 and rural population under 2 million

SECTOR 5 GNP/Capita between $US 300 and $US 6000 and rural population between 2 and 20 million

SECTOR 6 GNP/Capita between $US 300 and $US 6000 and rural population over 20 million

SECTOR 7 GNP/Capita under $US 300 and rural population under 20 million

SECTOR 8 GNP/Capita under $US 300 and rural population between 20 and 20 million

SECTOR 9 GNP/Capita under $US 300 and rural population over 200 million

SECTOR 1 Belgium Denmark Honk Kong Ireland Israel Kuwait Netherlands New Zealand Norway Sweden U. Arab Emirate	**SECTOR 2** Australia Austria Canada Finland France Germany Italy Spain Switzerland United Kingdom	**SECTOR 3** Japan United States
SECTOR 4 Botswana Central Africa Chile Congo Costa Rica Gabon Jamaica Jordan Lesotho Mauritania Mauritius Oman Panama Trin. & Tobago Uruguay	**SECTOR 5** Algeria Angola Argentina Benin Bolivia Bulgaria Cameroon Colombia Cote d'Ivoire Dominican. Rep. Ecuador Ghana Greece Guatemala Guinea Haiti Honduras Hungary Zimbabwe Kenya Malaysia Morocco PNG Paraguay Peru Poland Portugal S. Arabia Senegal S. Africa Syria Togo Tunisia Venezuela Yemen Yugoslavia Zambia	**SECTOR 6** Brazil China Egypt India Indonesia Iran Mexico Pakistan Philippines Thailand Turkey
SECTOR 7 Guinea Bissau	**SECTOR 8** Afghanistan Burkina Faso Burundi Chad Laos Madagascar Malawi Mali Mozambique Nepal Niger Rwanda Somalia Tanzania Uganda	**SECTOR 9** Bangladesh Ethiopia Myanmar Nigeria Sudan Viet Nam Zaire