The Cold Chain, Bangladesh

- September 2002 -

Introduction

Each year, around 91 million children are born in developing countries. Almost one-third of these children have no access to immunisation against diseases such as HIV, cholera, polio, measles and tetanus. Vaccines are the most cost- effective healthcare intervention, yet while these are given routinely in affluent societies, they are still largely unavailable in poorer nations.

Remote areas pose the greatest challenges to providing preventive healthcare. The population is sparsely scattered over valleys and hill tops, and often the only communication is by word of mouth. Medicines and vaccines cannot be transported easily because they lose their effectiveness if not kept cold. Vaccines and blood products, in particular, only remain safe to use for a few hours without reliable cooling. This constraint severely limits the ability of health clinics to cover a large area, and so the demand for reliable and cost-effective electricity generation for remote medical and healthcare applications throughout the world is increasing.

Using their knowledge and experience of harnessing solar energy, Dulas Engineering, a UK Renewable Energy Consultancy, designed and built a stand- alone solar powered refrigeration system that has been exported widely to developing countries. Dulas has equipped hundreds of remote hospitals and clinics in Africa, Asia and Latin America.

Photovoltaic Power

The sun offers an abundant, silent and non-polluting source of energy. Photovoltaic panels convert this directly into electricity which can be used to power a wide range of medical equipment with the added benefits of low operating costs, little danger of running out of fuel and only minor maintenance requirements.

The use of modern solar photovoltaic technology can help extend power and appliances to communities otherwise seen as beyond the range of modern healthcare. Other technologies, such as kerosene or gas refrigerators, may be cheaper initially, but they need constant maintenance and a secure fuel supply.

A wide range of solar powered equipment is available for medical applications, including:

- refrigerators for vaccine and blood storage;
- ice pack freezers for vaccine transportation;
- water pumps and purifiers; and
- electricity for hospital lighting, laboratory equipment and computers.

Photovoltaic Medical Refrigeration

The use of solar energy (technically termed photovoltaics or PV) to power refrigerators can offer an ideal solution. Despite higher initial costs, solar powered systems are cost-effective over the lifetime of the system. Operation and maintenance costs are kept low, as the PV panels do not require parts replacement, skilled labour, or costly fuel.

The ideal temperature for vaccine storage, between 0 and 8°C, can only be achieved using refrigeration. Vaccines for immunisation require refrigeration throughout transportation and storage in order to be effective. Solar powered refrigerators are considered better than traditional kerosene or bottled gas fuelled refrigerators because of:

- low operating costs;
- abundant supply of free fuel;
- low maintenance needs;
- reduced vaccine losses;
- reliability;
- improved performance and temperature control; and
- benign environmental impact.

The provision of refrigeration for medical use is known as Vaccines Cold Chain. The cold chain is a network of fridges, freezers and cold boxes which ensures the vaccine is kept at the right temperature to retain its potency, from the moment it leaves the vaccine manufacturer, through shipping and storage, until the moment it is administered. The recommended equipment for storage (cold rooms, refrigerators, freezers) and transport (cold boxes, vaccine carriers) has to comply with a set of performance standards defined by the World Health Organisation (WHO) and the United Nations Children's Fund (UNICEF).

In Bangladesh, approximately 3.9 million children under one year old are targeted each year for vaccination against diphtheria, whooping cough, tetanus, tuberculosis, measles and polio. Parts of Bangladesh are still without electricity, and the supply where it exists is often interrupted.

Photovoltaic refrigeration is recognised as a viable way of supplying the missing links in the cold chain and providing back-up where electricity is unreliable. The Dulas Solar Medical Refrigerator, which is low cost and CFC free, complies with WHO specifications for solar systems and rural vaccine storage, and is being installed in remote rural areas with technical assistance from Unicef and financial support from the Bangladesh government.

How Does it Work?

Photovoltaic refrigerators operate on the same principle as normal compression refrigerators but incorporate low voltage (12 or 24V) dc compressors and motors, rather than mains voltage ac types. A photovoltaic refrigerator has higher levels of insulation around the storage compartments to maximise energy efficiency, a battery bank for

storage compartments to maximise energy efficiency, a battery bank for electricity storage, a battery charge regulator and a controller that converts the power from the battery to a form required by the compressor motor.

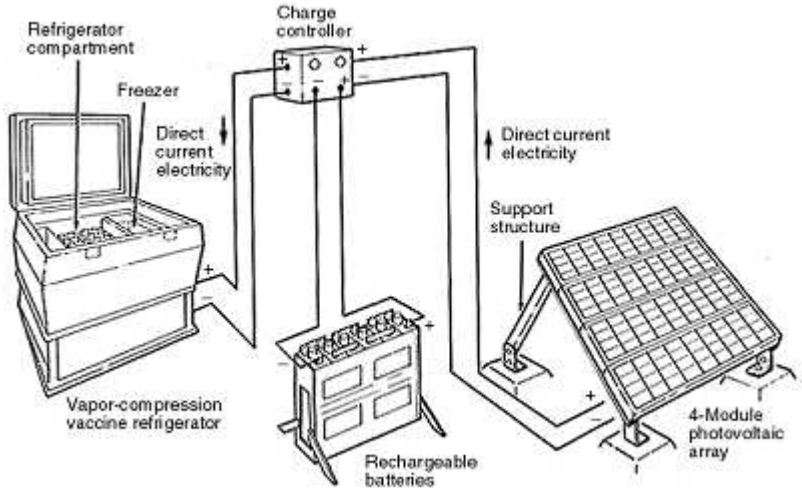

Figure 1. A typical vaccine refrigerator powered by a PV system © Polar Power Inc.

Most refrigerators include a freezer compartment for ice pack freezing. Other systems have separate units to provide solely for refrigeration or freezing.

Array and support structure

The photovoltaic array, or solar panel, can be for roof or ground mounting. Its size depends on the power requirements of the system. The typical requirement of photovoltaic modules is 150–200 Wp (peak watts - the approximate amount of power a PV device will produce at noon on a clear day when the cell is facing directly towards the sun).

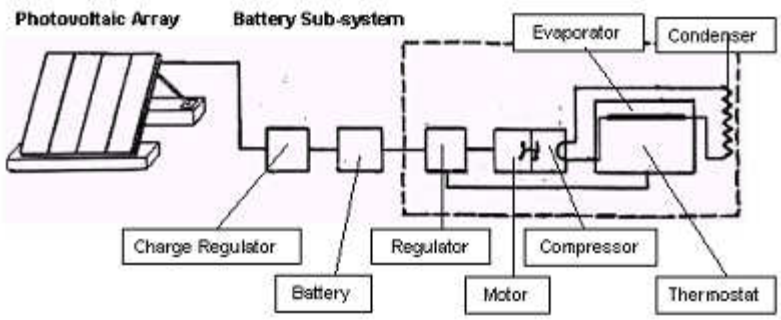

Figure 2. Basic refrigerator sub-system

Batteries

The most commonly used battery is the lead acid, long life, deep cycle battery. A battery with a capacity to run a refrigerator for five days without sun is recommended.

Charge regulator

The array charges a battery via a voltage or charge regulator, which stops the battery from being overcharged. Some models include an

stops the battery from being overcharged. Some models include an alarm or warning light to signal when battery voltage becomes low.

Motor/compressor

The battery powers a direct current motor, which is coupled directly to the compressor. The motor/compressor is usually manufactured as an airtight sealed unit. A second regulator is used to ensure that the motor/compressor is run only within its power range and to prevent over-discharge of the battery.

Temperature

The cooling effect is achieved by the heat absorbed by the refrigerant as it evaporates in the evaporator. A thermostat is used to switch the compressor in and out as required. The insulation of the refrigerator is normally very thick to reduce heat gain, decrease energy consumption and increase the time the refrigerator can keep the temperature down when there is no power.

Performance

The energy consumption of a PV vaccine refrigerator is typically 400–800 Watt- hours per 24 hours for a 100 litre refrigerator without ice pack freezing and at +32°C ambient temperature. An ambient temperature of +43°C and freezing 2 kg of ice packs per 24 hours, would mean an energy consumption for the same refrigerator of 900–1900 Watt-hours per 24 hours. Overloading a PV refrigerator increases energy consumption considerably.

Cost

The output of a PV array varies according to where it is installed and the energy consumption depends on the local climate. This means the size of the solar array, battery storage capacity and the overall system cost vary depending on location. Typical costs are between US$3,500 and $7,500 excluding transport and installation.

Important Considerations

There are three main considerations when using a PV refrigeration system.

1. The failure of one of the main refrigerator components, such as the compressor, requires repair or replacement by skilled technicians.
2. Each system is site specific and more time is needed for planning and implementation.
3. Training users is crucial, as overloading a PV refrigerator can cause it to become too warm.

Assessing Requirements

Consideration needs to be given to the following when estimating refrigerator capacity, including vaccine storage capacity and ice pack

freezing needs:

- type of vaccine to be used and storage temperature needed;
- size of population targeted for immunization, allowing approximately 4 litres storage to fully immunize 150 infants and their mothers;
- how often vaccines are to be administered;
- requirements for ice pack freezing for use in cold boxes;
- storage space needed for other medical supplies such as blood bags; and
- future requirements for approximately 10 years.

Installation

When installing a PV refrigerator, the following points must be ensured:

- The solar array (PV panel/s) is not likely to be shaded and can be cleaned easily and safely.
- Cable lengths are kept to a minimum.
- The refrigerator is located in the coolest room of the clinic.
- There is good air circulation around the refrigerator.
- The sun does not shine on the refrigerator.
- The batteries are mounted in a well-ventilated protective case, away from children's reach.

One important thing to remember - never install a PV refrigerator unless it has the WHO standard of approval.

Maintenance

In order to maintain a PV refrigerator, the following activities are recommended:

Daily

- Record the temperature in a log book each morning and afternoon. Download a free temperature log in Fahrenheit or Celsius.
- Check indicator lights for correct operation.

- Check ventilation grill is not obstructed.

Weekly

- Check freezer evaporator for build-up of ice and defrost if more than 5 mm thick.
- Clean solar array.

Monthly

- Clean condenser and compressor with a soft brush.
- Check to ensure array is not shaded early in the morning and afternoon.

Every six months

- Check level of acid electrolyte mixture in batteries and top up with distilled water if necessary.
- Check all mountings, fixtures and cables for loose connections.
- Check lid seal is tight.

Fault Finding and Repair

General fault-finding can be useful in establishing some basic problems with a PV refrigerator.

If the refrigerator will not work:

- Check the fuse in the compressor controller.
- Check the array cables.

If the refrigerator is too warm but does work:

- Adjust the thermostat setting.
- Check battery state of charge with a voltmeter or hydrometer.
- Check refrigerator is not overloaded.
- Check the array is not being shaded.

If the refrigerator is too cold:

- Adjust the thermostat.
- Check the freezer/refrigerator thermal barrier is not damaged or missing.

For further information, please contact:

Dulas Ltd
Unit 1, Dyfi Eco Parc
Machynlleth
Powys SY20 8AX
Wales
United Kingdom

Tel: **+44 (0) 1654 705000**

Fax: +44 (0) 1654 703000
E-mail: dulas@dulas.org.uk
Website: www.renewable-resources.com

World Health Organisation (WHO)
Avenue Appia 20
1211 Geneva 27
Switzerland

Tel: + 41 22 791 21 11
Fax: + 41 22 791 3111
E-mail: info@who.int
Website: www.who.int

Suppliers

There are many suppliers of PV medical refrigeration systems, some of which are listed here. This is a selective list of suppliers and does not imply ITDG/TVE endorsement or promotion. For a more comprehensive list of solar companies around the world, please see the website link for Solarbuzz.

Norcoast Refrigeration Company
50 Grigor Street
Caloundra, QLD 4551
Australia

Phone: +61 (07) 5491 1849
Fax: +61 (07) 5491 7627
Website: www.norcoast.com.au

Sun Frost
PO Box 1101 Arcata
California 95518
USA

Tel: +1 707-822-9095
Fax: +1 707-822-6213
E-mail: info@sunfrost.com
Website: www.sunfrost.com

BP Solar Headquarters
989 Corporate Boulevard
Linthicum, Maryland 21090
USA

Tel: +1-410-981-0240
Fax: +1-410-981-0278
E-mail: info@bpsolar.com
Website: www.bpsolar.com

Neste Advanced Power Systems
P.O. Box 310

Fin-06101 Porvoo
Finland

Fax: +358 204 7113

NCL Solar Ltd
12 Dock Offices
Surrey Quays Road
Off Lower Road
London , SE16 2SU
United Kingdom

Tel: +44(0)207 394 8667
Fax +44(0)207 394 8273
E-mail: info@nclsolar.com
Website: www.nclsolar.com

Solamatics
31 Edison Crescent
Graniteside
P.O. Box 2851, Harare
Zimbabwe

Tel: 263 4 74 99 30
Fax: 263 4 77 12 12
E-mail: mikem@mcdiarmid.co.zw

Siemens and BPSolar PV products dealer

Websites

www.solarbuzz.com
The Solarbuzz website allows you to connect to solar energy companies worldwide, search solar energy links by topic and utilise a very informative guide to solar energy. All countries are listed.

Further reading

Books with underlined titles can be downloaded for free by clicking on them. Others can be ordered from the relevant address.

WHO Publications

Safe vaccine handling, cold chain and immunizations – a manual for the Newly Independent States
WHO/EPI/LHIS/98.02 Available in English and Russian
This manual was jointly prepared by health officials and staff from Newly Independent States (NIS) countries with the technical assistance of Basics, UNICEF and WHO. It is written for personnel who are directly responsible for the storage and handling of vaccines at all levels of the health system. It is also useful to supervisors and managers. Although originally developed for NIS countries with information and references that apply specifically to those areas, the manual is also of interest to health workers handling vaccines in any part of the world.

health workers handling vaccines in any part of the world.

Product Information Sheets 2000
WHO/V&B/00.13 Available in English
Updated every two years, this is an essential reference guide on the selection and purchase of equipment for use in the Expanded Programme on Immunization (EPI) and other primary healthcare initiatives. It includes information on equipment for use in EPI, the former WHO Programme for Acute Respiratory Infections (ARI) and the former Global Blood Safety Initiative (GBSI). Performance data and purchasing information is given for more than 180 items of equipment that meet established performance criteria, including refrigerators, cold boxes, thermometers, sterilizers, injection equipment etc.. This is the first edition where cold chain refrigeration and freezer equipment will be classified by temperature zone. This edition revises and replaces all previous issues.

Document Centre
Department of Vaccines and Biologicals
World Health Organisation
1211 Geneva 27
Switzerland

E-mail: vaccines@who.int
Website: www.who.int

References

Solar Photovoltaic Refrigeration of Vaccines, ITDG Technical Brief

Solar Photovoltaic Products: A Guide for Development Workers, Derrick, Francis and Bokalders, IT Publishing, 1991

This document is an output from a project funded by the UK Department for International Development (DFID) and the European Commission (EC) for the benefit of developing countries. The views expressed are not necessarily those of DFID or the EC.

Acknowledgements

ITDG would like to thank Jo Gwillim at Dulas for feedback on this paper.

TVE/ITDG gratefully acknowledge support for the HANDS ON programmes from the UK's Department for International Development (DFID), the European Commission (EC), the UN Foundation and UNDP/The Equator Initiative in collaboration with the Government of Canada, IDRC, IUCN, BrasilConnects and the Nature Conservancy.