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International Centre for Science and High Technology

PHOTOENERGY CENTRE AIN SHAMS UNIVERSITY

Photoenergy Centre

INTERNATIONAL WORKSHOP ON

"PV Applications"

27-29 May 2002
Cairo, Egypt

A I N S H A M S U N I V E R S I T Y

International Workshop on
"PV Applications"
Cairo, Egypt 26 – 30 May 2002

CONTRACT NO. 2002/133

Annex: Proceedings [part 1]

Cairo, Egypt

International Centre for Science and High Technology

PHOTOENERGY CENTRE AIN SHAMS UNIVERSITY

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"PV Applications"

27-29 May 2002, Cairo, Egypt

Organized by:

The Photoenergy Center, Ain Shams University, Cairo, Egypt

In collaboration with

The International Center of Science and High Technology, Trieste, Italy

Sponsored by:

Ain Shams University
Ministry of Higher Education and Scientific Research
Ministry of Agriculture and Lands Reclamation
Bank MISR

ICS – UNIDO

CONTENTS

FORWARD

"PV Applications"

Good morning,
First of all, I would like to thank you all for being with us this morning in the *Opening Ceremony of the international workshop on PV applications.*

Let me emphasize the following main points:

***The history* of this series of important events could be discussed by answering the following question; why the Photoenergy Center?**

This is the third time the Photoenergy Center of Ain Shams University has been selected by the ICS-UNIDO authorities to collaborate in organizing and hosting the Workshops on photovoltaics. This time we are organizing the international Training Workshop on "PV Applications". It should be mentioned that:

- The whole PV activities being currently undertaken were initiated by the Photoenergy Center five years ago, based on a project proposals submitted by Prof. Sabry Abdel-Mottaleb on 1998 to Prof. G. Denardo, the ex. Head of the external relation office of the ICTP, Trieste, Italy.

- The Expert Group Meeting has been held in Cairo on April 2000 and it has been organized in collaboration with the ICS and hosted by the Photoenergy Center. This activity was a result of our initiative. It was very successful with important outcomes that encourage continuation of this fruitful activity. The role of the Photoenergy Center has been proven to be important.

- Furthermore, we have already collaborated with ICS on different occasions. The authorities of ICS and UNIDO described our role as "very professional and active in all aspects. Moreover, the Center is the most suitable focal point as a regional center due to its excellent activities and facilities for the training of PV systems and applications and to its geographic position."

The Problem?

In the developing countries of our region vital demand exists for offering better energy services, in particular in rural areas to overcome the problems of population growth and aspects of environmental hazards arising from the exploitation of the natural resources. The high solar irradiance as an efficient energy source to produce electricity, by using PV, offers a viable means to cope with the problem.

The Solution is: PV Factory in Egypt!

The PV market is split regionally: In the industrialized countries, which found various ways to subsidize solar appliances, the market is developing at a fast rate. In the contrary, markets in the developing countries seem to be stationary. This situation is not acceptable. We have to do our best to raise our voices: The transformation of energy services to solar and renewable resources is a responsibility of mankind, which should be worked out as a joint task.

It is well known that the largest part of the global PV production is oriented to customers in the industrialized countries. Only a small fraction is left to cover the small needs of the people in the developing countries. This disproportion with regard to the utilization of renewable energy resources is based on the acquired idea by the PV producers that the utilization of solar resources is widely discarded, despite of the fact that in most of the developing countries solar conditions are quite favorable. The situation will become much more difficult because of the increasing demands for PV by the industrialized countries. In the nearest future there will be no more PV cells available in the global market for our nations. It seems that our market is of minor importance to the PV producers. Thus, to meet with our regional relatively small needs - compared with the global production- at present and in the nearest future we have to produce our own solar cells. This should be based on the process of technology transfer from the developed countries and the involvement of the private sector and Banks (National and International). Encouragement from the Governments is essential. It should be emphasized that the transformation of energy services to solar and renewable resources is the responsibility of the mankind, which should be accepted as a joint task.

The suggested main objectives of the workshop are:

1- To show the necessary prerequisites in order to establish a sustainable PV application according to the needs of local users.
2- To show the most useful PV applications in the country and in the relevant region.
3- To enable the participants to develop critical skills in PV applications and to provide to the industry a development forecast for the new technology.
4- Update engineers, scientist/technicians in the basic field of planning and design of efficient PV application systems. Tell successful stories.
5- Help developing countries to improve their awareness of tools relating to efficient PV application systems.
6- Initiate contacts and promote co-operation on PV application between industries, important research institutions and governments.
7- Who should care and finance PVP systems?

The expected outputs are:

- Lecture notes, case studies and basic information on photovoltaic cells.
- Approximately 10 delegates from Europe, Africa and Middle East will meet to share experience and discuss PV cell technologies, manufacturing procedure; statistics on working conditions of existing PV applications in each country, actual running problems and how to cope with.
- Gain experience - State of the art in the field of PV applications.

Who we are?

The participants of our workshop are a good mix of academicians, expert engineers, laboratory researchers, technicians and high rank (directors) government employees and industry owners all of whom are involved, in a way or another, in the research and development of PV cells and in the management or responsibility of installation, running a PV System. High-level engineers, scientists and experienced economists and researchers in PV cell development are gathered from different Egyptian institutions. Most of who are specialists in the field of photovoltaic cell research and production and management of PV Water Pumping Systems.

The following topics will be covered and discussed:

- PV market characteristics, and growth scenarios concerning cells availability.
- Cells production specifications, performance testing, and results.
- PV cell technology, history, future directions.
- PV cell manufacturing procedures.
- How to better use cells in a module: case study.
- PV Water purification.
- PV Grid connected systems.
- How can we improve these Systems?
- Identification of the region needs and develop projects.

Acknowledgments

I would like to thank Mr. Kenichi Ushiki the former Material Science area director and Mr. Umberto Moschella, consultant at the ICS, AREA Science Park, Padriciano, Trieste, Italy for very collaborative efforts in realizing holding this workshop and making it a very successful one. Sincere thanks go to the President and the authorities of Ain Shams University and to the colleauges from the Faculty of Science for solid and continuous support. I also express my sincere thanks to the Ministry of Agriculture and Land Reclaimations and to Bank Misr, Dr. B. Helmy, the President of the steering committee and the union of the Egyptian banks for their support. Moreover, I express my special thanks to the staff members of the photoenergy centre and my research group and to the Public relations Department for the sincere assistance offered during the organization of this fruitful scientific event of applied nature. Last but not least, I thank all lecturers and participants for their scientific and technical contributions that enrich the content of this international event.

I wish you all very sucessful meeting and a nice stay in Egypt and safe return back to your home countries.

M. S. A. Abdel-Mottaleb
Professor of Chemistry,
Director, Photoenergy Center

May 27, 2002

International Centre for Science and High Technology

PHOTOENERGY CENTRE AIN SHAMS UNIVERSITY

Photoenergy Centre

WORKSHOP

on

"PV Applications"

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Cairo, Egypt

Aide-Memoire

BACKGROUND

All renewable forms of energy including sun, wind and biomass will be an increasingly important source of future energy. Photovoltaic technology provides a reliable and in many cases a cost effective way of harvesting this solar energy. While a number of developing countries are reaping industrial and social benefits from the deployment of PV technology, many countries are still not gaining significant benefits from the extensive solar energy resources that are available. In order to exploit this resource, it is essential to increase research, development, commercialization and market awareness, and undertake prudent capital investments to increase the viability of PV applications.

The cost of PV systems has been a long-standing issue for PV applications, however, in recent times, the cost has decreased due to improvements in the efficiency of cells, improved manufacturing techniques and the larger market size. The trend is for photovoltaic systems to become quite competitive with the conventional power supplies and to have an increasingly important role in electricity generation in the future, especially in isolated zones. PV based systems are currently commercially competitive for a number of niche applications, but not for the daily essential needs of millions of people. Increasing the market size, producing cheaper cells and new technological developments will furthermore increase the competitiveness of PV technologies in these areas of North Africa and Middle East.

The viability of PV applications is also dependent on the skills available, and the planning tools that are accessible to the system designer. Cost effective solutions need to be capable of providing a balance between resource availability, generation systems, storage and other balance of system items according to the specific application. Reliable sources of PV modules and system components, that are of good quality and competitively priced is a fundamental prerequisite to increasing the utilization of PV in every application. Financial packaging will also become an important focal point for widespread replication.

JUSTIFICATION

The successful and sustainable application of photovoltaics requires the experience of specific knowledge and expertise during the project life cycle i.e. during the planning, design, product selection, PV components rating versus appliances fit verifications, control of all working limit conditions existing in the site etc. The creation of awareness and the dissemination of PV applications to improve basic knowledge and technology transfer, are all essential to ensure the sustainable development of photovoltaic solar technology and its numerous applications in developing countries.

The application of photovoltaic systems must take into account regional conditions, i.e. the resources available, the efficient energy use and demand management, and system optimization to ensure that cost-effective systems are developed. System knowledge, special skills in project development and the achievement of the various needs that may arise locally, are clearly critical in the sustainable and effective application of PV based systems.

The knowledge of the components market is also a critical parameter in establishing sustainable industrial applications on different activity sectors.

The world currently has approximately 2 billion people who do not have access to electricity by way of lighting during the night or who do not have the minimum quantity of water during a day for their survival; many of them do not have medical assistance or elementary education. It is known that many of these needs can be alleviated by numerous possible PV applications.

The forecast of the PV module demand by 2003 will be double of what the product is today (i.e. 442 MW_p in 2003). Developing countries that want to move towards this new technology have to face the problem of the correct awareness of the capability of PV application to give a solution to every human need.

In reality, photovoltaics is one technology that allows the production of electricity with only two components: one component being technological - which is a PV module and the other component being environmental – which is the sun. When a sunny location is chosen to install a PV application we have from our side the main important prerequisite of the useful exploitation of the PV energy.

The advantages of photovoltaics is that you can install a system anywhere that has sunlight beams, even if it is very far from an electric grid of distribution. In any case, the economical comparison between the cost of power from the grid and that from PV systems, is the cost of the electric grid installation and, above all, the cost of the electric losses due to power transportation along the grid; without taking in account the cost of the effect of combustion products as pollutants of the air.

As mentioned previously, in regions where petroleum or other fossil fuels are not available, and where the remote areas are not connected to the electrical grid, there is a strong and increasing demand for the technologies related to photovoltaic application systems and specially to water extracting and pumping systems, telecommunication systems, lighting systems, irrigation systems, electrical driven cars and trucks.

ICS, with its access to laboratories, and its international network clearly provides an ideal mechanism for developing relevant skills and diffusing among international industrial communities, interesting research issues and building industrial capacity.

OBJECTIVES OF CURRENT ACTIVITY

- To show the necessary prerequisites in order to establish a sustainable PV application according to the needs of local users.
- To show the most useful PV applications in the country and in the relevant region.
- To enable the participants to develop critical skills in PV applications and to provide to the industry a development forecast for the new technology.

- Update engineers, scientist/technicians in the basic field of planning and design of efficient PV application systems.
- Help developing countries to improve their awareness of tools relating to efficient PV application systems.
- Initiate contacts and promote co-operation on PV application between industries, important research institutions and governments.

OUTPUTS

- Lecture notes, case studies and basic information on photovoltaic applications in North African and Middle East countries.
- Establish tight connections within the North Africa and Middle East region, who are interested in developing PV systems and who can discuss current PV systems in their relative countries.
- To discuss the state of the art in the field of PV applications.

PROFILE OF PARTICIPANTS

The participants will be a mix of engineers, laboratory researchers, technicians and government employees all of whom are involved in the research and development of PV applications and in the manage or responsibility of running a PV system.

TENTATIVE PROGRAM

The following topics will be covered:
- How to get cheaper and more reliable PV Systems; **Identification and Hands-On Approach**.
- PV market characteristics and growth scenarios concerning PV applications.
- How are the existing PV applications in North Africa and Middle East working?
- How can we improve these systems?

PROFILE OF RESOURCE PEOPLE

High level engineers, scientists and experienced economists and researchers, specialized in the field of PV applications, production and management of PV Systems will be invited to give lecturers at this event.

DOCUMENTATION

The documents available for the workshop will be:
1. Aide-Mémoire.
2. Programme.
3. List of participants and lecturers.
4. Lecture notes.

LANGUAGE

The workshop will only be conducted in English and therefore the participants are expected to have a good command of the language.

VENUE

The workshop will take place from 27-29 May 2002 at the Photoenergy Center, Faculty of Science, Ain Shams University, Abbassia, Cairo, Egypt.

NOTE

ICS and the Photoenergy Center will not assume responsibility for any of the following costs, which may be incurred by the participant while attending the workshop:
- compensation for salary or related allowances during the period of the event;
- any costs incurred with respect to insurance, medical bills and hospitalization fees;
- compensation in the event of death, disability or illness;
- loss or damage to personal property of participants while attending the event.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

International Center for Science and High Technology

International Workshop on

"PV Applications"

Organized by

Photoenergy Center, Faculty of Science, Ain Shams University, Cairo, Egypt 26 – 30 May 2002

SUMMARY TIMETABLE

0th Day: SUNDAY 26 May 2002

Arrival (meet and assist at the airport)
Transportation to Sonesta hotel
6.30 PM REGISTRATION
7.30 PM WELCOME RECEPTION

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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Cairo, Egypt 27 - 29 May 2002

1st Day: MONDAY 27 May 2002

08.30 - 09.30 REGISTRATION <Ambassador Hall>

GENERAL OPENING SESSION <Prince Hall>

09.30 - 10.30	O P E N I N G [Abdel-Mottaleb, Moschella] Welcome Address [OFFICIALS, ASU]
10.30 - 11.15	Opening Address [*Sean Cavendish (United Kingdom)* Let's Make this a Solar World - The Implications and The Applications]
11.15 - 11.45	Exhibition Opening and Coffee BREAK
	Chairman: U. Moschella (Italy)
11.45 - 12.30	Opening Address [*Dr. Wolfhart Bucher (Germany)* "PV Systems - An environmentally benign Resource for Energy Services"]
12.30 - 13.15	Opening Address [*Dr. Eng. Ingo Stadler (Germany)* "Water desinfection by autonomous PV systems (UV and /or anodic oxidation)"]
13.15 - 14.00	Opening Address [*Dr. Ahmed O. Al-Amoudi (Saudi Arabia)* "Progress of PV Applications in the Kingdom of Saudi Arabia; Economic Aspects"]

End of the General Opening Session

Closed sessions follow for only registered participants

14.00 - 15.30 Lunch Break [Green House]

EXPERT REPRESENTATIONS <Prince Hall>

Chairmen: Abdel-Mottaleb, Bucher, Moschella

15.30 - 16.00 **Amor OUNALLI (Tunis)**
"The Photovoltaic Applications in Tunisia, Experience and Prospects"

16.00 - 16.30 **Eng. Ibrahim Odeh**
"From Research to Investment in Photovoltaic Water Pumping Systems"

16.30 - 17.15 **Posters and Coffee BREAK**

17.15 - 18.00 **General Discussion and Conclusion**

2nd Day: TUESDAY 28 May 2002

Prince Hall

Chairmen: Bucher, Cavendish, Moschella, *Ingo Stadler*

08.45 - 09.30	Malek Kabariti (Jordan) "Solar Applications in Jordan"
09.30 - 10.15	*Eng. Stratis Tapanlis (Germany)* "Innovative hybrid system design for modular PV systems"
10.15 - 11.00	*Dr. Wolfhart Bucher (Germany)* "Grid-connected Systems - the main application on the German PV market"
11.00 - 11.30	Coffee Break
11.30 - 12.00	*Eng. H. Rakha (Egypt)* NREA Activities in Egypt
12.00 - 13.30	*Sabry Abdel-Mottaleb , Samah El-Bashier* (Egypt) Hands-on Demonstration, Case Studies and Discussions
13.40 - 15.00	BREAK Lunch
15.00 – 15.45	*Dr. H. H. Afify (Egypt)* "Electrical Aspects of Solar Energy"
15.45 - 16.15	*Dr. K. Habib (Kuwait)* "Activities of Photovoltaic Applications in Kuwait"
16.15 - 16.30	Coffee Break
16.30 - 17.30	Prof. Alhousseini Issa MAIGA "Solar Photovoltaic Application In Mali"
17.30 - 18.00	*General Prof. Dr. Salama Mohamed, Aswan* "Utilization of Solar Energy in Water Pumping in the New Vally and Toshka" Round Table Discussion

3rd Day: WEDNESDAY 29 May 2002

Prince Hall

Chairman: Abdel-Mottaleb, Bucher, Ingo Stadler and Cavendish

09.00 – 13.30 [PV CELLS/MODULES FACTORY] FEASABILITY STUDY

09.00 - 09.45	Eng. Umberto Moschella "Prerequisites for PV Applications in Egypt"
09.45 - 10.30	*Dr. N. Raslan (Egypt)* PV Solar Energy Systems: Country Status, Economics and Technical Aspects
10.30 - 11.30	Prof. F. Abulfotuh (Egypt) "Photovoltaic Technology Advances, Market evelopment, and Local Manufacturing"
11.30 - 12.00	Coffee Break
12.00 - 12.45	Eng. Y. Bahnas (BIC, Egypt) "PV Industry in Egypt"
12.45- 13.30	*General M. Abdel-Hai (*ASET, Egypt) "Providing PV Solutions in Egypt"
13.30 - 14.30	Outcomes and Conclusions (Abdel-Mottaleb, Moschella and the Group)

4th Day: THURSDAY 30 May 2002

DPARTURE

We wish you a safe and nice return flight to your home country

Titles of the Presentations
And List of Participants

Eng. Sean Cavendish (United Kingdom)
Solar World, South Sea, Hampshire, UK
Let's Make this a Solar World - The Implications and The Applications

Dr. Wolfhart Bucher (Germany)
DLR (German aerospace Research Centre), Cologne
1- "PV Systems - An environmentally benign Resource for Energy Services"
2- "Grid-connected Systems - the main application on the German PV market"

Dr. Ingo Stadler (Germany)
University of Kassel/Department for Efficient Energy Conversion
"Water desinfection by autonomous PV systems (UV and /or anodic oxidation)"

Eng. Stratis Tapanlis (Germany)
Universitaet-Gh-Kassel/Rationelle Energiewandlung
"Innovative hybrid system design for modular PV systems"

Dr. Ahmed O. Al-Amoudi (Saudi Arabia)
Director of Solar Village and Head of PV Group, KACST, Saudi Arabia
"Progress of PV Applications in the Kingdom of Saudi Arabia; Economic Aspects"

Dr. K. Habib (Kauwait)
Materials Science Lab., Department of Advanced Systems
KISR, P.O. Box 24885 SAFAT, 13109 Kuwait
"Activities of Photovoltaic Applications in Kuwait"

Eng. Ibrahim Odeh (Jordan)
National Energy Research Center (NERC)
From Research to Investment in Photovoltaic Water Pumping Systems

Dr. Amor Ounalli (Tunis)
Agence Nationale des Energies Renouvelables (ANER) Tunis, Tunisia,
"The Photovoltaic Applications in Tunisia, Experience and Prospects"

Dr. Hassan H. Afify (Dokki, Egypt)
National Research Center, Dokki, Egypt
"Electrical Aspects of Solar Energy"

Eng. S. Bahnas (Cairo, Egypt)
BIC, Egypt
"PV Industry in Egypt"

General M. Abdel-Hai (Sinai, Egypt)
ASET, Egypt
"Providing PV Solutions in Egypt"

Eng. Umberto Moschella (ICS-UNIDO, Italy)
"Prerequisites for PV Applications in Egypt"

General Prof. Dr. Salama Mohamed, (Aswan, Egypt)
"Utilization of Solar Energy in Water Pumping in the New Valley and Toshka"

HANAFI Menouar (Algeria)
Faculty Of Science, University Of Science And Technology Of Oran-Algeria
"The Experience with PV Electrification of some Localities in the South of Algeria"

HADJEL Mohamed (Algeria)
Faculty Of Science, University Of Science And Technology Of Oran-Algeria
"The Experience of the Desert Tracks Beaconed with the Solar Energy in Algeria"

Prof. Alhousséiny Issa MAIGA (Mali)
"Solar Photovoltaic Application In Mali"

Dr. N. Raslan (Egypt)
National Organization of Military Production *NOMP*
PV Solar Energy Systems: Country Status, Economics and Technical Aspects

Prof.Dr. F. Abulfotuh (Egypt)
Middle East Center for Energy and Environment Technologies (MCEET), Arab Academy for Science and Technology and Maritime Transport, Alexandria
"Photovoltaic Technology Advances, Market Development, and Local Manufacturing"

Prof. Dr. Sabry Abdel-Mottaleb (Egypt)
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"PV Training Facilities and Study Cases; Environmental Impacts"

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Dr. Nadia Hilal Yehia Hilal
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Prof. Of Solid State phys., National Research Center.
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Dr. Mervat Hassan Khalil
Solar Energy Applications
Building Resource Center, Ministry of Housing
hbrc@idscl.net.eg

Solar World

Sean Cavendish

<sean@sunpowered.co.uk>

I'M currently a serving member of and active within: -
UK-ISES (International Solar Energy Society)
PRASEG (Parliamentary Renewable and Sustainable Energy Group)
SEEMG (Solar Energy and Environmental Management Group)
AQSG (Air Quality Steering group, Hampshire and the IOW)
Solar World (The solar club of Great Britain)

My task or mission is to give you a brief outline or overview of solar energy and it's long-term implications.

If you care to ask, you will find children are very aware of air pollution and the problems it brings. **Even now** one in five of our (YOUR) children and grandchildren have a serious breathing related disorder. I can confirm the situation is getting worse.

The finger can easily be pointed at industrial production processes and the elevated use of petrol and other fossil fuels. However, it is not widely known that the average home in the UK discharges around 7.5 tons of pollutants into the atmosphere each year, as a direct result of heating our homes and hot water for washing or bathing. Some 30% of all fuel used in this country is in the private home.

Contrary to popular belief, in the UK household water heating represents some 40 to 60% of fuel consumption. You will save a considerable amount of monies by utilizing solar thermal energy into the home. It is an immediate tax-free and long-term savings investment. In terms of an investment it is better than having the equivalent money in the bank. You cannot financially lose.

I studied, educated myself and became involved with solar energy following the earth summit in Rio 1992. The conclusion is being Agenda 21 Or SUSTAINABLE DEVELOPMENT.

How many people in this room know about or really understand Agenda 21?

For those of you who are unaware or unsure of Sustainable Development, it means simply: -

Development that meets the needs of the present, without compromising the ability of future generations to meet their own needs.

BIG WORDS. BUT THEY ARE MUCH MORE THAN WORDS. **THEY ARE A WAY OF LIFE.**

Agenda 21 is a mammoth task. And it is facing us now. According to Agenda 21 we must cut energy consumption be some 50% by the year 2050. We have made a start. Since Rio much has been achieved by dedicated individuals, some are here in this room tonight. Yet it has still taken some 9 years for this meeting to take place. Currently I'm seeing UK government reports and climate change documents, etc, that indicate realistic fuel reduction figures of some 60% plus.

We at Solar World believe that all new developments should have solar energy incorporated.

The UK government currently spends 2 hundred and 82 million pounds per year on asthma through our national health service. If a proportion of this were spent on solar energy, then the savings to our health and our health service would be considerable.

Now some good news.

The Government has reduced VAT to 5% and has now introduced capital grants on professionally installed solar PV systems. This is too stimulating the market and builds a professional solar industry in the UK. This is not good news for the DIY person. It has been designed this way for Health and safety reasons and to dissuade the DIY and the accidents that can happen while going on roofs. Roofs are dangerous places. One of oür entertainers Rod Hull and his EMU fell off a roof and was killed. HE WAS ONLY ADJUSTING HIS ARIAL.

It will also not help the thousands of caravan and boating people who are at this time turning off petrol generators and turning on to solar photovoltaic. If our space ships can be powered by solar why not our new home? Makes sense to me. We have the technology; it's in my office.

Climate Change, Global warming, it is not a joke. Solar Architecture is not about fashion. It is about SURVIVAL. We have no choice but to commit our-self's to solar energy whole heatedly. We need to come together, by doing this we will stimulate local employment, training and growth while securing a diverse but sustainable competitive future for Egypt. This is in accordance with the present worldwide climate change program.

I'm not speaking politically. Sustainable Development is not just a political issue. Air pollution has no vote and it knows no boundaries.

After all, if leaders of society are not using solar energy why should the layman in the street?

IT STANDS TO REASON.

Of all life on this planet MAN **is** and has been the most destructive. We may not want to believe it. Yet we all know something is seriously wrong. FLOODS, DROUGHTS, NATURAL DISASTERS, I believe in future years this period will be known as FOSSIL FUEL MADNESS.

I believe our children and we are possibly the last generation with maybe the last chance to **get this right.** When we build either new build or refurbishment. Presently, money dictates what will be done. We need not to just tot up the pennies that we are saving. We need to accredit all the values and add them up.

Some things, like fresh air, and healthy children, you cannot buy.

In America the government has declared that all municipal buildings must have solar energy. In Israel, India and across Europe solar must incorporated. In Germany grants were introduced years ago.

Solar energy must be seen to work. You really need legislation on this point. People will support solar energy but it does not follow they will install it. People will say solar, great. But they need to have a carrot or a stick. Not everybody can afford solar energy, just like organic foods.

The UK social and economic strategy shows that 80% of domestic fossil fuel is used by the 20% of people in the higher income bracket. These people can afford to burn fuel. These people can also afford solar energy. However, people in the UK social housing sector who have lower energy consumption pay a higher percentage of income to the utilities. They cannot afford solar.

Most good quality solar systems cost no more than a new kitchen, carpets or a driveway. Yet those products have no financial payback.

People do not use solar because of the low profile of the product. Nobody wakes up and thinks I'LL buy a solar system today. DO THEY. They purchase once they have been introduced to solar. Once they know and understand what they are buying. **I THINK IT'S TIME TO START EDUCATING.**

The UK Government has become more pro-active. Regional and local government along with environmental bodies across the country are working very hard to incorporate renewable energies into future projects. Some do fair better than others. This is due to lottery grant system we have created in the UK. Most demonstration projects only get done when they are funded or part funded. With solar energy seeing believes. We believe we should take solar to the people, and that is what the UK solar clubs do. It's time to wake up and start making some noise. Over the years UK-ISES and I have debated and lobbied with most political leaders. We still lobby and we still debate. However now is the time for action, because action speaks louder than words?

WE MUST UNITE

We did not inherit this earth from our fathers. We are simply borrowing it from our children. These are wise words spoken by GERONAMO an Indian chief over one hundred years ago. Have we learned from those words? NO. But then it brings it all back to education in the first place.

I formed the Solar Club of Great Britain now called Solar World back in 1994. Following 2 years of research and in direct response to Agenda 21. I found that by direct action and going round the country using proven technology we were slowly able to change the attitude of the public and leaders of society. And for me today is a great result.

Worldwide, there is still A TOTAL LACK OF EDUCATION AND AVAILABLE INFORMATION ON SOLAR ENERGY, from the layman in the street to the UK prime minister, and after all, if you don't know about something. How can you ever use it? We are pleased to say we have members all over the country, in fact all over the world.

Do you not have solar on your home? You know it makes both financial and environmental sense. When people ask me about solar energy. I say don't ask me; ask him or one our members who has a system.

The first 2 Questions ever asked are.

1. How much is a system.
2. How quickly will it pay for it's self

People actually phone me to ask me QUESTION.

The answer is.

1. Price depends on what kind of system you chose.

2. How much will electric cost 3 years from now?

I DON'T REALLY KNOW. BUT I DO KNOW SOLAR IS FREE ONCE YOU HAVE IT.

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Sunpowered Energy Systems Ltd.

Lets' Make This a

Solar World

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SUNPOWERED

SEAN CAVENDISH

Sunpowered Energy Systems Ltd.
Southsea, UK

Our mission :- By direct action and using proven technology inform and change the attitude of the governments, general public, and leaders of society in relation to sustainable development and environmental protection issues.

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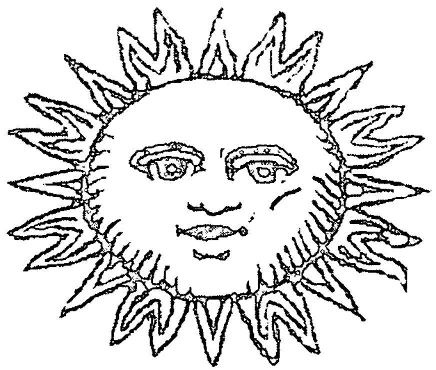

SUNPOWERED

- We are a trailblazing innovative environmental protection organization
- Formed in 1994 as a direct result of AGENDA 21 - Earth Summit (Rio 1992)
- We began by researching the availability of alternate forms of energy while developing an effective educational marketing strategy
- We now evaluate proposed or existing projects and recommend suitable economic systems, addressing both sustainable and environmental issues
- We run a follow up educational program world-wide in the form of Solar World
- We are Active members of the International Solar Energy Society (ISES), established 25 years
- We have experience in all forms of renewable energy, - Solar, Wind, Hydro, Hybrid, Wave
- We have recently opened the first in a series of Solar Educational, DIY Training and Design centres in Southsea
- We promote our belief that every new property built should incorporate alternate energy systems

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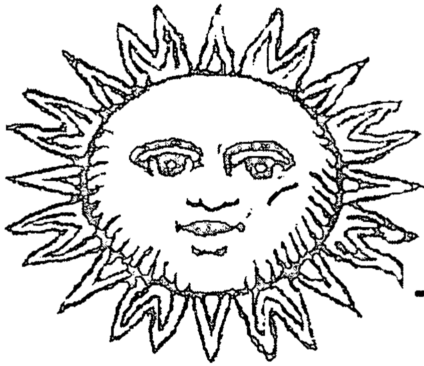

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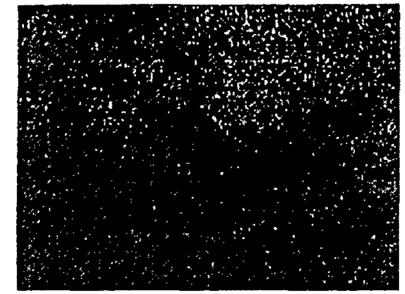

The Environmental Issues that need addressing

- Fossil Fuels – Limited supply
- Pollution
- Global Warming
- Disturbed Weather Patterns
- Rising Sea Levels

Its up to YOU to change it !

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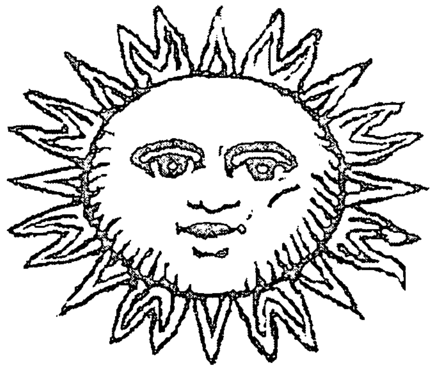

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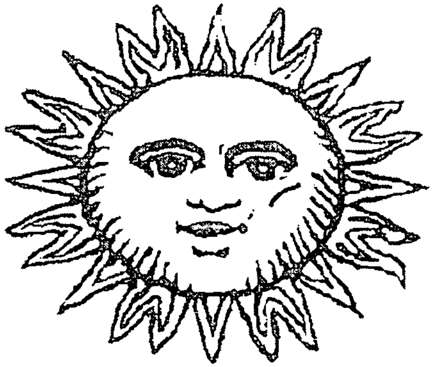
Facts of Life

- If we could capture just one ten- thousandth of the energy provided through sunlight, we could have more energy than we currently get from burning coal, oil and gas put together
- After initial Investment energy bill wills reduce - pollution will reduce
- Most of the energy we use in our homes, cars, and at work comes from fossil fuels like oil, gas and coal, either in its natural form, or in its converted form as electricity
- All of these fuels were originally formed by the energy of daylight, but they need to be extracted, processed and distributed for us to use them. So they cost us money and damage the environment

Now there is an alternative to rising fuel bills and the pollution we have come to accept as a fact of life when we use energy.

Wasting Energy Costs the Earth - Save it

www.sunpowered.co.uk



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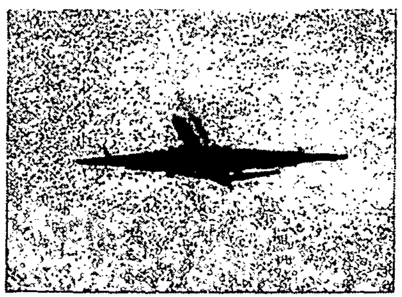
Renewable Energy, Clean Energy

SOLAR ENERGY

Wasting Energy Costs the Earth – We have a duty



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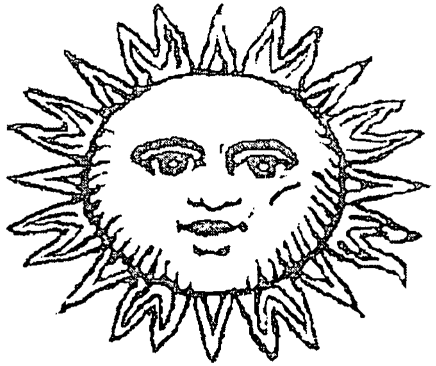

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Solar Energy and Its Proven Uses

- Industrial Plants – Laser Smelting, Water Desalination, Power Stations
- Manufacturing – Driving Steam Turbines
- Social – Hospital Hot Water Systems , Emergency Electricity Generation
- Water Pumping, Lighting Systems, Mobile Refrigeration, Solar Cookers, Traffic Control
- Domestic - Independent Energy Source for home and mobile recreational purposes

If sunbeams were weapons of war they would have been utilised eons ago

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SUNPOWERED

Solar Energy Collection via Photovoltaic Cells

Uses gentle technology to generate electricity

- Electricity is generated from sunlight using solar modules
- The energy produced can be stored in batteries for later use
- Can be transformed to 110V and 230V
- Electricity is available whenever needed, even if the sun is not shining
- Energy is produced silently with no pollution and no depletion of resources
- Easily integrated into commercial and residential building architecture
- Can be used in a remote location (off-grid), as an upgrade to existing utility power, or as an environmentally superior alternative to conventional grid-supplied electricity

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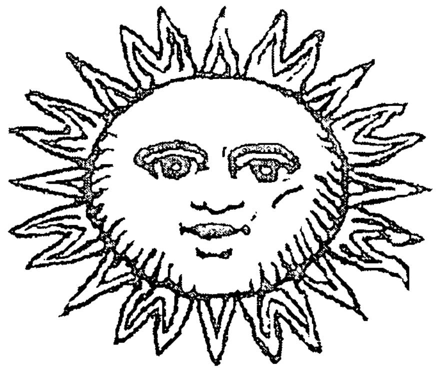

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Solar Energy Collection via Photovoltaic Cells

The Advantages

- Noiseless Operation
- No exhaust fumes to harm the environment
- All components are robust and durable to give long low maintenance life
- Easily installed and can extended to almost any size at a later date

Total Independence with Solar Energy

- Wherever mains electricity is not available or expensive to supply
- Electricity for isolated locations, pumping stations and hospitals

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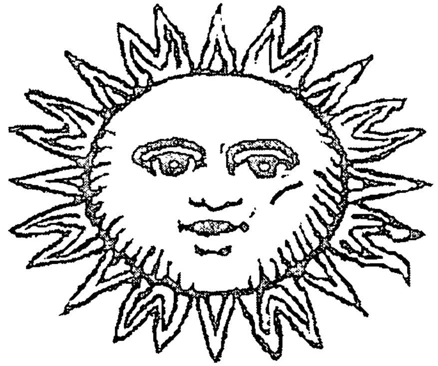

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We shall continue our journey of discovery in Session 2

We shall further explore **SOLAR ENERGY** and its practical applications

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And Finally

The airs full of pollution
- and you send me outside to play

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Session 2

SOLAR ENERGY

and its practical applications

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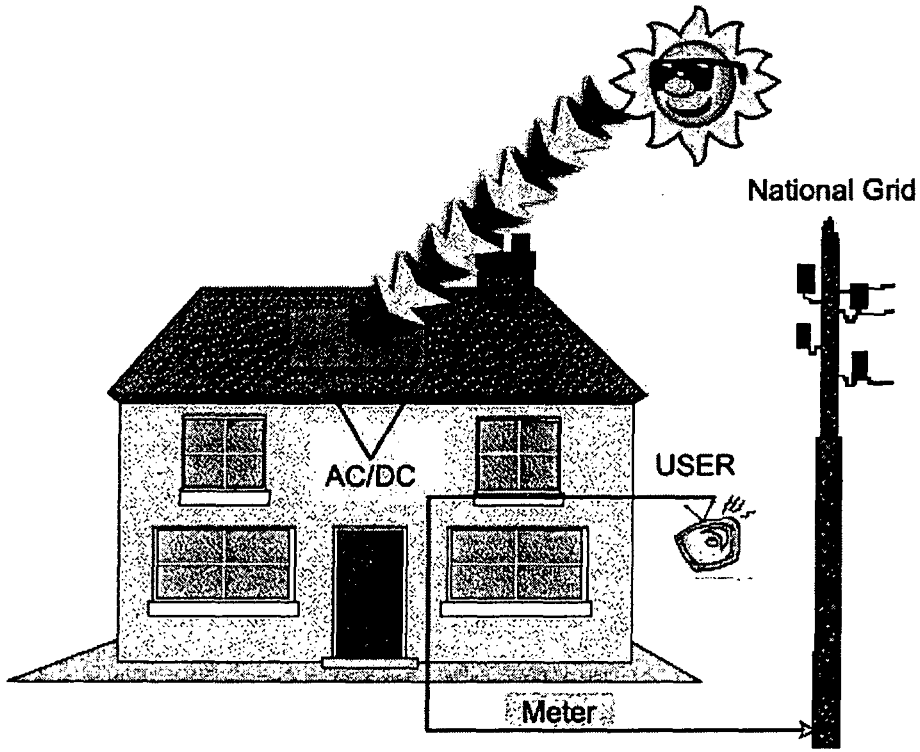
PV Domestic Applications – Grid Connected



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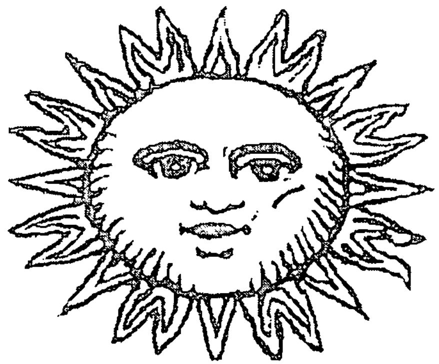

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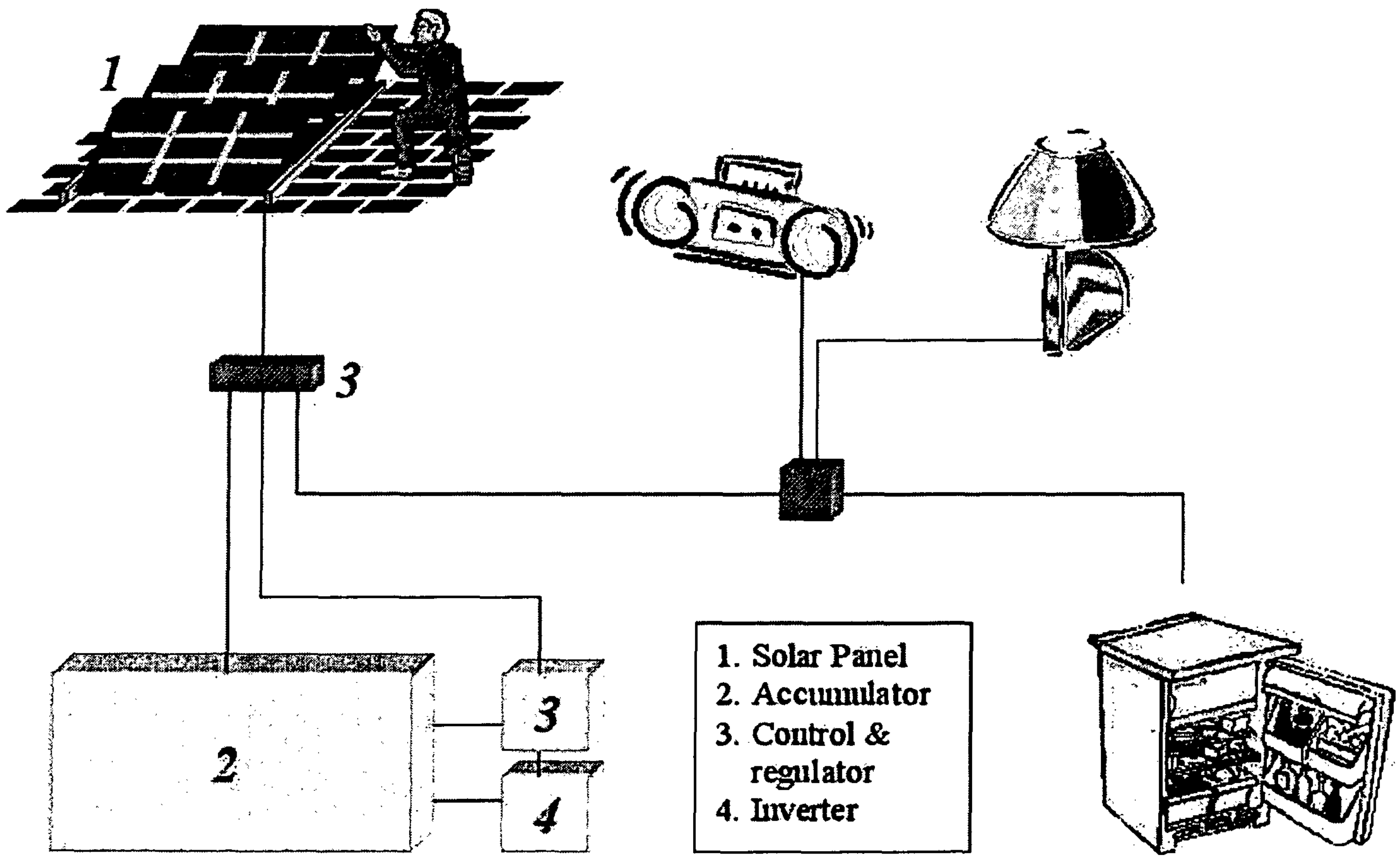
PV Domestic Applications Off- Grid

Components of a Solar Power Pack



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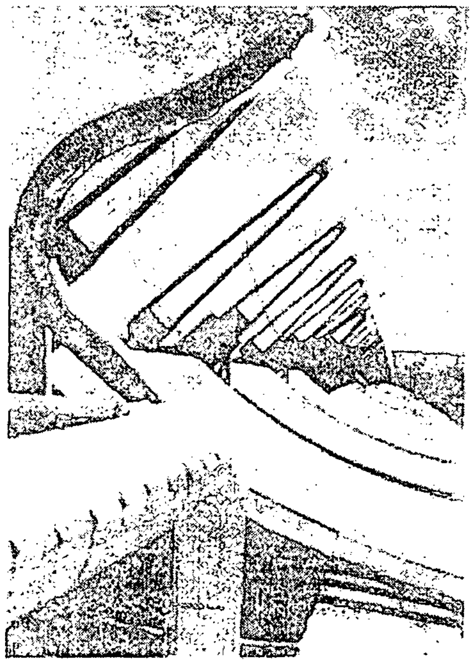
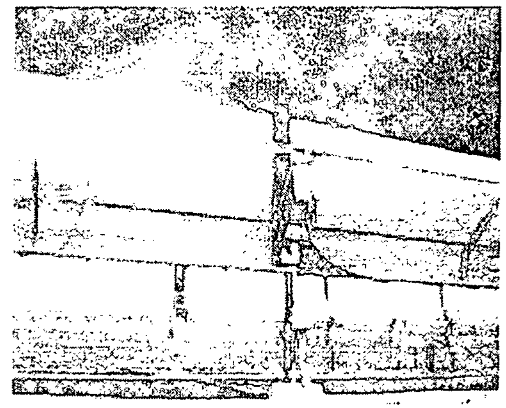
PV Commercial Power Applications



Parabolic Trough
Concentrated Solar Collector



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PV Social Applications

- Hospitals
- Water Desalination
- Refrigeration
- Water Pumping
- Remote Locations
- Street Lighting
- Traffic Lights and Signs

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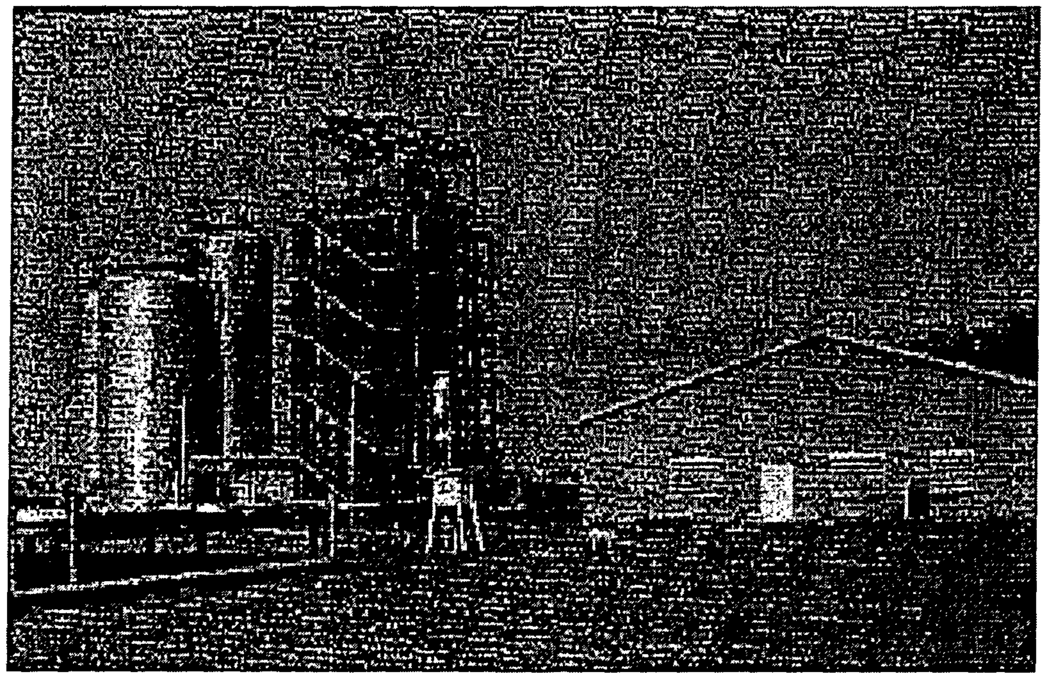
Water Desalination



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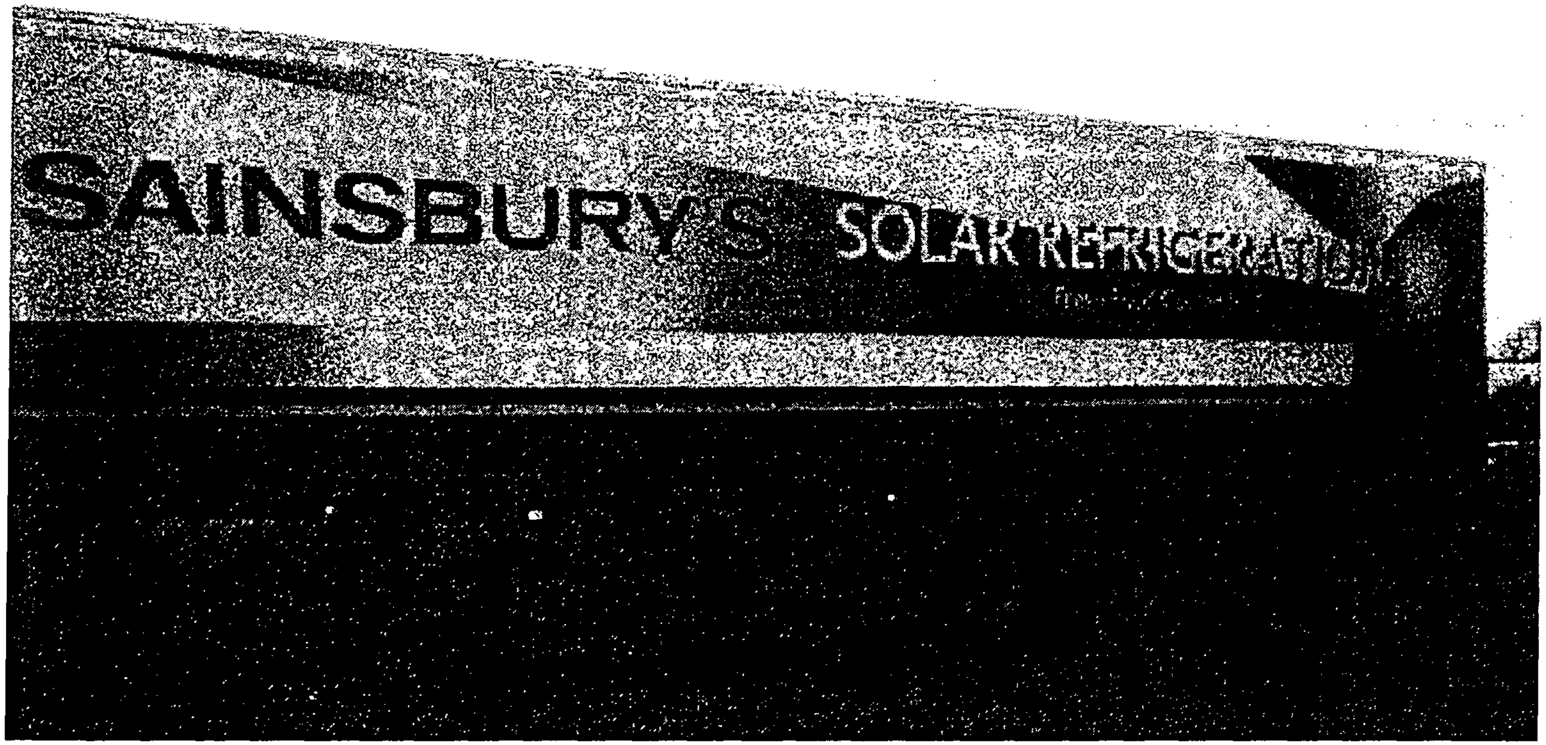
Mobile Refrigeration



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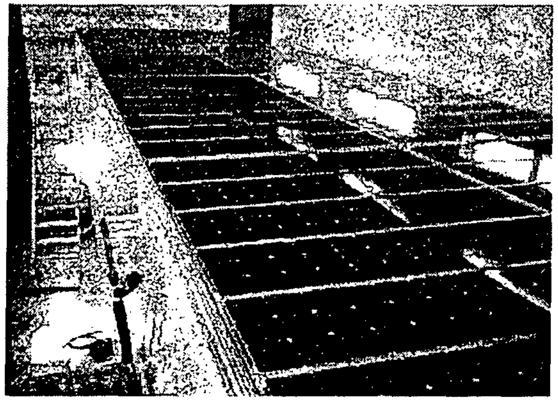
Mobile Refrigeration
Solar Panels and Compressor Unit



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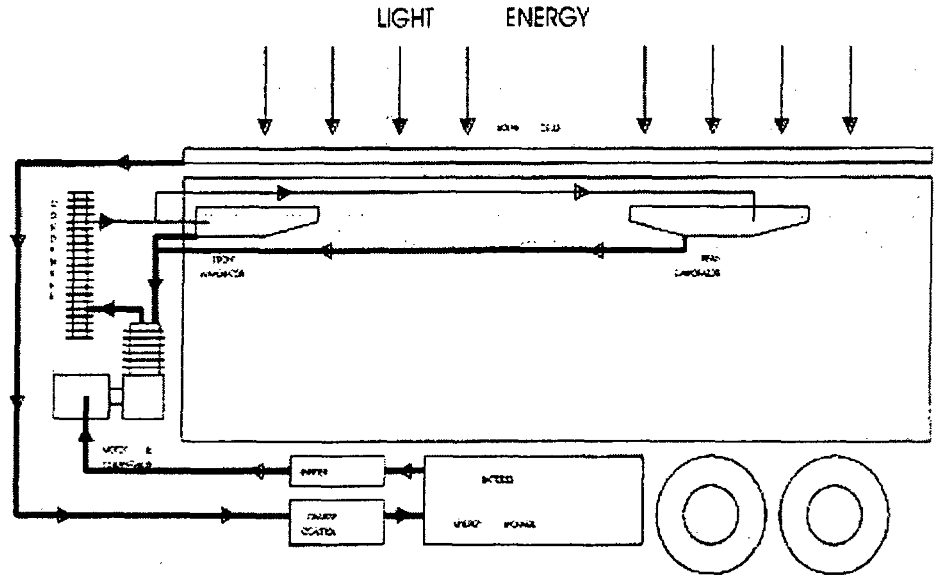
Mobile Refrigeration – Technical Details



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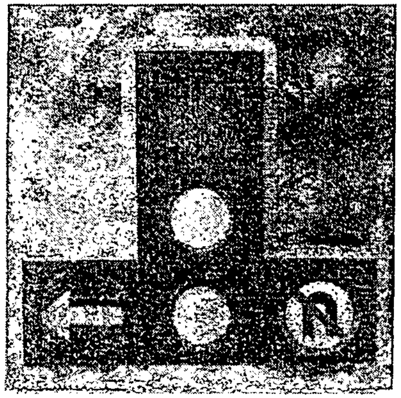
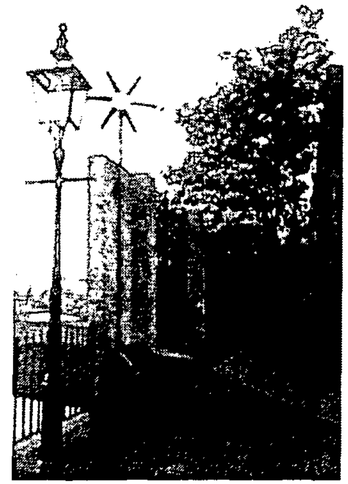
Solar Traffic Lights, Signals and Street Lighting





Savings –

- Utilizes long life – low energy L.E.D Technology
- Less maintenance
- Cheaper replacement parts
- Significant reduction in fossil fuel required to make electricity
- Pollution free

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Limitation of Photovoltaics

- You cannot use more than you can produce
- Matched system sizing required

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Associated Technologies

- Hot Water
- Wind Turbines
- Solar Powered Pumps
- Hydro Applications

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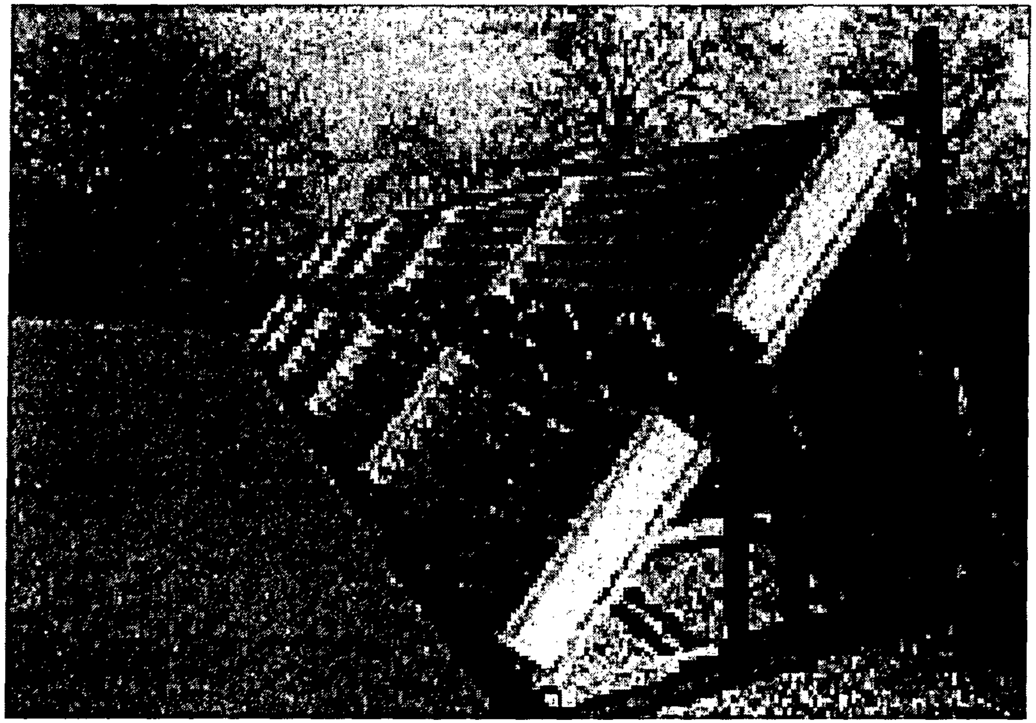
Solar Hot Water



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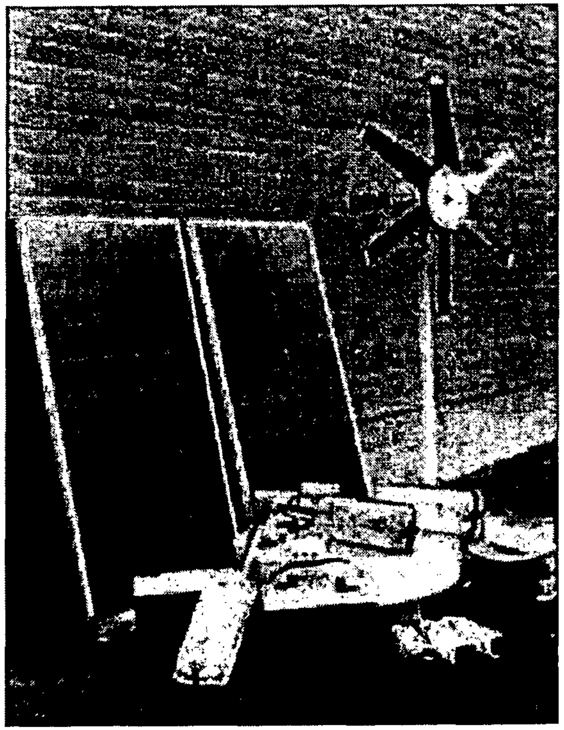
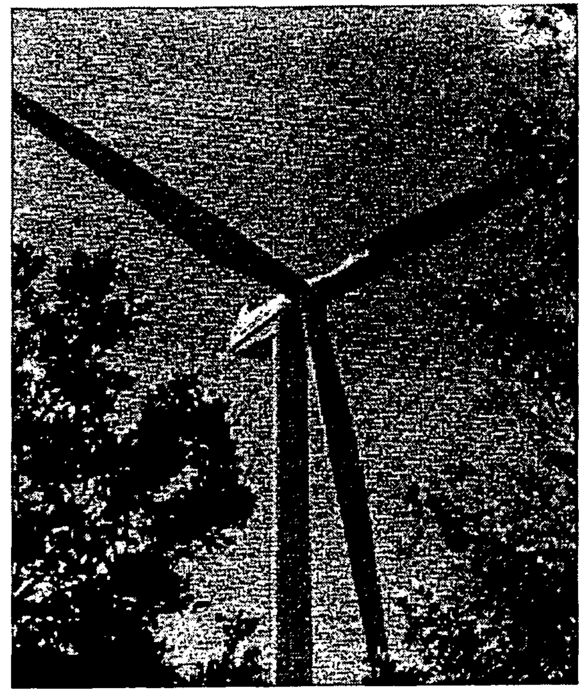
Energy from the Wind





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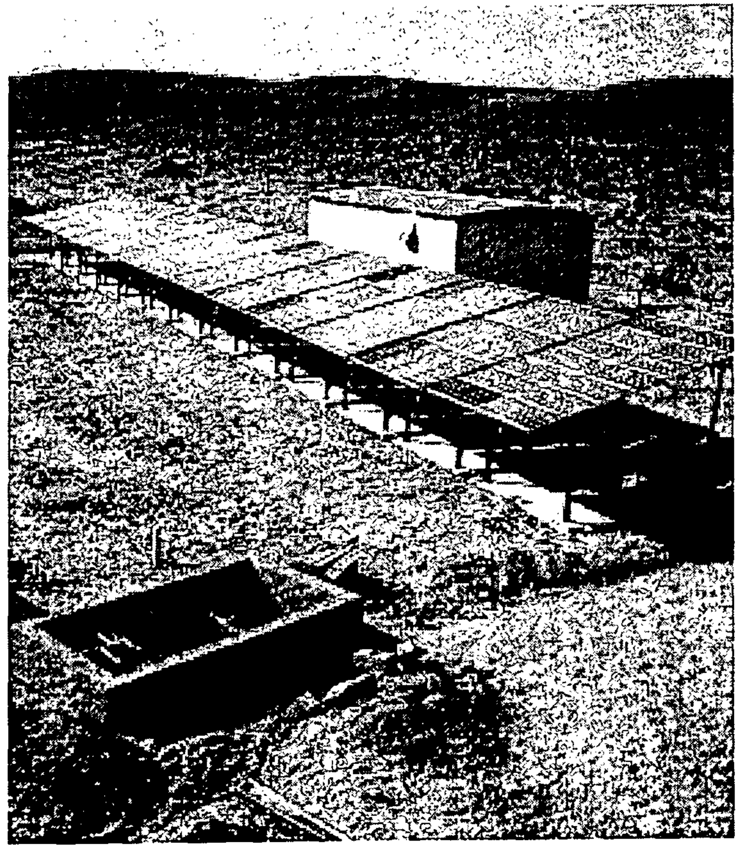
Solar Water Pumping Station in Saudi Arabia



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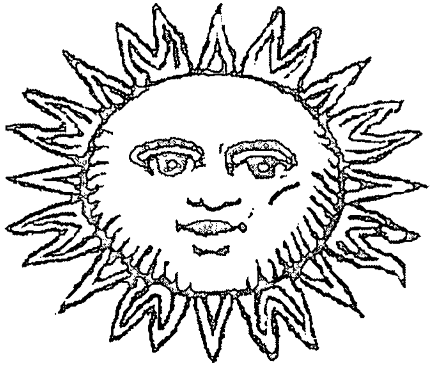

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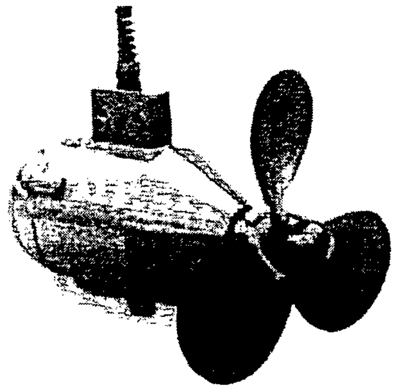
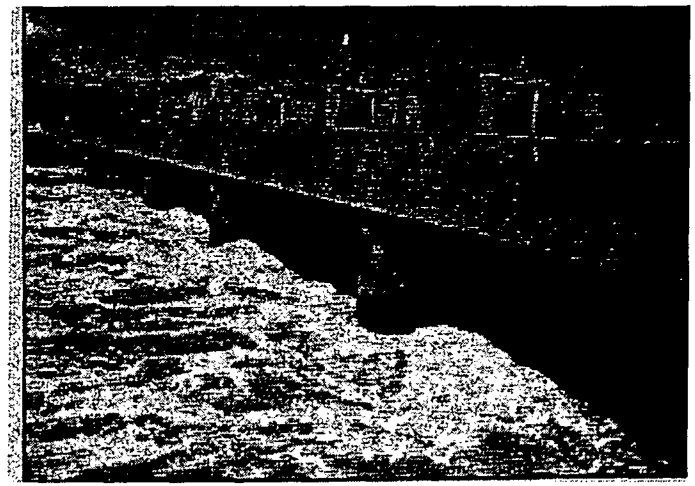
Power from Water



Individual Hydro
Generator



Hydro Power Station

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Benefits of using Solar Energy

- Pollution Free
- Sustainable
- Reducing Unit Costs as scale of use increases

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YOU can make this a

Solar World

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PV Systems – An environmentally benign Resource for Energy Services

Dr. W. Bucher
DLR – German aerospace Center, Cologne, Germany

Abstract

In the developing countries vital demand exists for better energy services: Population growth, necessary improvement of living conditions – in particular in rural settlements – and aspects of environmental hazards arising from an intensified exploitation of the natural resources endorse good reasons for the search for sustainable solutions. Solar irradiance as an energy source offers a viable means to cope with the problem.

The global PV market does not reflect the fact that the most urgent need for modern energy services is in the Third World: The by far largest part of the PV production is shipped to customers in the industrialised countries. Only a small fraction is attributed to the needs of the people in the developing nations. Consequently, this paper deals with the issues of further disseminating solar technologies – and tries to explain, why there is so much disproportion with regard to the utilisation of renewable energy resources.

1. Introduction

A comparison of the distribution of global PV shipments and of population figures of the respective regions makes a large disagreement apparent (Figure 1) [1 ; 2]. In the regions with rapid population growth only a very slow progress is observed with regard to investments to install contemporary electricity generating equipment. The utilisation of solar resources is widely discarded, despite of the fact that in most of the developing countries solar conditions are quite favourable.

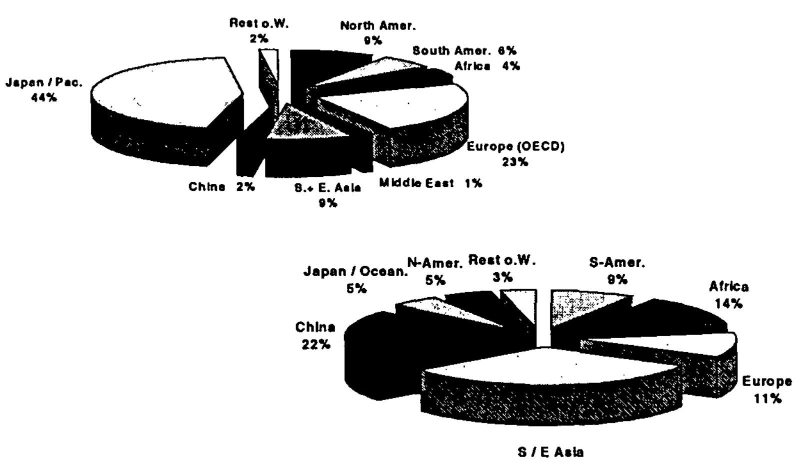

Figure 1: Global distribution of PV installations (above)
vs. Regional Population (below)

(Statistical Data are not fully identical)

The situation becomes still more unsettling, if the actual data for the energy consumption and for investments favouring the installation of novel electricity generating facilities are assessed. In Table 1 the specific figures of per capita energy consumption and the equivalent

of the yearly installed PV infrastructure are compiled [1 ; 3]: customers in the industrialised countries are much more involved in market development of PV devices than are the inhabitants of developing regions. The behaviour of the users is also different: An essential driving force for the investment in the "Western" regions is private involvement (even if triggered by governmental programmes), a factor for market evolution which seems to be only of second order in the developing world.
The overview presented here is a very rough approach, but it reflects the overall pattern quite good and makes the essential trends apparent. From data in the table an estimate could be undertaken, how long it might take to reach a significant contribution from solar powered plants to the energy demand. Without compiling the figures in detail it is obvious that there is still a long way ahead, until solar concepts will play a significant role.
A more detailed assessment on a regional basis was not undertaken, since it could be misleading due to apparent differences between single countries. The data in Table 1 illustrate the existing disparities and give also some hints about the large "internal" differences within the regions. The last column in Table 1 shows some examples of said divergences between states located in the same region.

Table 1: Energy Consumption and energetic Equivalent of PV installed

Region	**Energy consumption**	**Energy Equlv. (ann. install. PV)**	**Examples of p.cap. energy consumption (specific states)**
	kg CE p.cap.(annual)	**kg CE** p.cap.	
North America	11500	0,9	
Europe	5400	1,5	Germany (5690) - Poland (3680)
Japan / Ocean.	2600	4,2	Japan (5200) - Philippines (550)
S / E Asia	1050	0,9	Thailand (1450) - India (420)
South America	890	0,5	Brazil (1010)
China	990	0,1	
Africa	400	0,4	Egypt (820) - Tanzania (37)
Rest of the World	350	0,2	

The visible disparity in the global review also indicates that - if no corrective action is taken - the gap between the "two worlds" will be widening (there is some doubt that a distinction into "two" worlds will be adequate, since population growth acts as another factor in the forecast, which may increase the energy problem in some areas).
From the facts described in Table 1 and Figure 1 it may also be doubted, whether market forces will be able to compensate for the disparities in a short term. A joint endeavour of economical and political decision-makers will be necessary to change the situation.

The rather high expenditures for equipment are certainly the main reason for the rather slow progress to build up or to modernise the energy infrastructure in the developing countries - and to make the first steps toward an exploitation of renewable resources (where electricity generation plays a pivotal role).
Scarcity of funds is but one possible hindrance: In the industrialised countries nearly everybody has access to the grid, the mains are reliable, replacement and up-date of the power generating and distribution infrastructure is routine. Therefore, consumers are not inclined to spend money to invest into energy infrastructure: Governmental subsidies [4] make the difference, offering incentives, which support the market for PV equipment.
The situation in the developing countries is still more complex: Not only is it much more difficult for investors to acquire reliable and not too expensive systems. In most of these countries it is also difficult to find experienced partners for technical and sales services. Moreover, since the available income in these regions is lower, necessary funds to purchase a PV system often exceed the capabilities of the customers. And finally – as a very stringent impediment – the energy costs in most of the countries in question are rather low. For most customers devices to exploit renewable energy sources must seem to be quite expensive in comparison to the cheap electricity rates.

Given the reasons mentioned it is understandable that the solar option is not very attractive in most countries; at least as long as there are no other arguments taken into consideration and as long as no incentives – like subsidies, cheap loans or tax refunds - are introduced.

Anyway, if long-term consequences are regarded, renewable energy technologies have promising aspects and the scientific community should reflect their contributions to assess the various factors impeding the exploitation of sustainable resources and to look for proper steps to overcome the constraints. It is obvious that efforts towards a more widespread use of renewables will only be successful, if supporting activities were performed.

2. Factors inhibiting the use of solar systems and means to overcome the hindrances

2.1 Financing of solar devices

The citizens of industrialised countries live under very favourable economic conditions – at least in comparison to the population of Third World countries. Statistical data confirm that also the market development for PV systems [1] is much stronger in the industry nations.
Figure 2 shows the details, putting the purchasing power [2] in relation to the investment for PV systems. There would be a close correlation, were it not for one exception: From the US the highest income figures are reported, but investment into solar devices is comparatively low. One reason is the prevalent opinion that the energy infrastructure in the states must not be dependable from solar contributions. This is at least correct for the time being.
A few years ago tax incentives have had much effect on the US market. The opportunity of tax reductions was apparently an important factor boosting the development of solar thermal power plants in California. Also many other solar appliances were very popular at that time. Lately the US government published an ambitious plan to install 1 Million PV systems on buildings until 2010. This would lead to a large growth of the American PV market [5].
The coincidence of purchasing power and installation of PV systems leads to the suspicion that PV must first of all be envisaged as a technology for wealthy people only. There is certainly no simple answer, but widespread opinion is that such a preposition is not true and that solar devices may be adequate as a means to "energize" a world, which otherwise be left more and more behind the global development.
Concepts towards an accelerated introduction of PV to the Third World must take into account that it depends on the availability of significant budgets. Even with an intensified marketing initiative similar procedures as in the Western countries will hardly work, since it is not expected in the short term that single persons or small companies in the Third World would be in the situation to purchase the hardware for solar electricity conversion from their own assets. Therefore a search for other concepts is suggested.

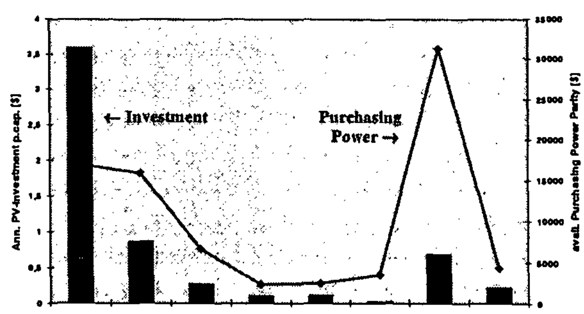

Figure 2: Annual Investment (PV) and Purchasing Power Parity [$]

Contributing to the financial problem is the fact that the most urgent demand for a better infrastructure is apparently not in the cities or in the quarters of the better-off people with a certain purchasing power. In the rural areas, where even small PV systems could contribute significantly to increase the living conditions of the population, regular income is very low. So, personal financing is a concept, which will hardly work in the third world.

There is certainly not a single solution for the budgetary problems dominating the renewable energy markets. Therefore, any approach to evaluate the various concepts must take into account also the many constraints and the qualification for the proposals (Table 2) .
An – already proven - alternative to a market strategy aiming at private entities is to entrust the banks and institutions on the finance market to step into the solar business. Credits and loans could be proven to be a viable approach. When the PV system and its components are accepted as securities for the credits, the handling of such crediting procedures is rather straightforward, and as soon as a certain experience is gathered and the banking conditions adopted, the further market development is evolving steadily and almost without interference from governmental authorities.
The experience made in the countries following such concepts suggests to include into the banking services insurance jobs (which reduces the risk for the creditors and is very convenient for the customers in case of any troubles with the system). Governments having initiated [6] such activities can expect some repercussion of this task not only with respect to the energy situation: the consecutive demand for maintenance and service jobs exerts positive effects, too, which are related to the PV marketing. Often customers get some additional profit from their newly acquired equipment, making use of secondary effects, which need not be restricted to financial issues but may also include technical services.

Table 2: Financing Schemes for Solar Appliances

Strategic Concept	**Preconditions**	**Remarks**	**Future Aspects**
Private Investors	Significant Purchasing Power with private entities; This condition is hardly applicable in 3rd World	Not promising in the short-term (sufficient liquidity ?), but this concept is rather successful in Europe!	Possibly important, if comforting devices become available
Banking instruments	Revolving funds depend on a sufficiently strong banking system and aim at a long-term effect	Successful approach in S.Amer. and East Asia	Banks must accept the PV as assurances. Lifetime of the PV-system can be critical.
Government. programmes	Large funds may yoke the gov. budgets	Chances of a "fast" progress, but problems with political decision making	Limited budgets may curb the achievements. Politically risky!
International Subsidies	Often confined to cases of urgency or to agreements between governments	Limited budgets, not oriented on demand but on available budgets	No feed-back to the local market, limited involvement of local labour

In comparison to the concept of dedicated credits for consumers governmental programmes are much less efficient. Since the budgetary constraints apply to most of such tasks, the impact on the market is usually not high. Moreover, political influence on the decision, which systems should be realised (technical details), and which community or person(s) should profit from the installation (socio-economic arguments), is a difficult process.
Nevertheless, governmental activity can play an important role in the field of joint projects, preferably with international partners [6 ; 7]. Such projects do not always seem to be very effective in terms of marketing and of dissemination strategies, but may serve in the technical progress, if exemplary concepts are realised.
An important factor in this assessment must be mentioned: The reported costs of most of the international projects were high, in part due to the early stage of marketing efforts (equipment was much more expensive then), in part, since most of the applications were sort of "firsts of its kind" with rather high expenditures.
To the category of "international co-operation tasks" belong projects carried out by non-governmental, often supra-national organisations. Many of these entities were involved in

test and demonstrations projects all over the world, frequently in the intention to show the viability of novel concepts. The outcome contributed decisively to the public awareness of the advantages of solar systems, the repercussions on the PV-market were – in comparison – rather weak, since also for such endeavours the statement applies that they were not considered to demonstrate low cost applications.

Which ever financing or supporting concept is applied: The costs of the equipment and the expenditures for installation, assembly, etc. play an important role. Therefore, as a precondition for a successful market introduction any additional cost factors should be reduced to a minimum. Regrettably many governments still impede – in most cases not intentionally - marketing efforts by charging high customs and taxes. Thanks to the international community reconsidering such political obstacles seems to take place: In many countries special tariffs apply to PV modules and B.o.S. equipment. International entities even required tax exemptions prior to starting assistance programs. One example is the European program on solar pumps for the Sahel region [8] and some other bilateral tasks between European and African countries.

2.2 Technology Issues

Electric energy fits easily nearly any application; with the exception that direct storage of electric energy is not feasible. Especially in a larger scale (and if the system voltages are high) this may lead to problems in off-grid applications. As disadvantages related to "electricity" storage different factors may exert some influence: increasing costs, reduced reliability of the system (in many cases), and additional losses incurred by the processes of storage. The latter is often an indirect cost factor also for the PV components, since the solar arrays have to be larger to compensate for the loss mechanisms.

The lack of proper methods to store electricity triggered some discussion about a "reversible" conversion of electricity into storable chemicals as an alternative to fossil fuels, which represent the backbone of the existing energy infrastructures world-wide. The actual research directed to evaluate the prospects of Hydrogen as a valuable medium to support a post-fossil energy system is just an indicator of the trend to follow novel strategies.
The difficulties related with buffer storage of electric energy were for many years the reason for a very slow progress. In the meantime most of the problems related to storage and energy management could be solved, state-of-the-art solar devices include adequate storage capacities, when ever this is necessary.
But it should be kept in mind that the preference to grid-connected systems being the prevalent approach in the industrialised countries is not the least motivated by the intention to avoid storage-related problems.

With reference to the reported technological status the following Table 3 presents an overview of the technical solutions common for small electric power generation and gives also some hints about the practicability of the concepts.
In Table 3 some sketches are included about possible "technical" alternatives. An additional remark must be attached: It is almost a rule that in competition to different alternatives PV is superior in the low power range. World-wide tests confirmed the experience: In many applications PV energy is competitive below certain thresholds, and in a wide range specific conditions may make it superior to the conventional methods of energy services.

Table 3: Solar appliances – Purpose and Utilisation Aspects

Purpose	Techn. features	Status	Econ. Viability	Convent. Solution
Basic electric. concepts:				
Home Lighting	Low-voltage systems with batteries, 25 ... 150 W_{Pk}; fluorescent lamps	commerc. produced, many manufacturers offer various types; local manufacturing is feasible	advantageous, if compared to world-market fuel costs; not viable "against" fuel subsidies	Kerosene / gas lamps, (isolated) grid (where accessible: Diesel; solar; wind power is viable)
Battery Charging	similar to Lighting	" - "	economic, can support small enterprises (limits: see above)	small combustion engines
Home appliances (TV, audio, VCR)	similar to Lighting (combination with lighting system)	mature systems are available, "home-made" solution often more cost-effective	economic	no alternatives for low-power demand (grid connection (?))
Small community applications:				
Street Lights	similar to Lighting, but also dedicated solutions	commercial, see "Lighting"	economic	no fossil alternative in off-grid locations (even in industr. regions)
Publ. Addr. / Educ. Systems	various concepts, 200 ... 2500 W_{Pk}; battery buffer >3^{Day}	Commercial; power system part of the overall concept	Economic	
IT-Stations - power systems	broad power range; 150 W.. >5 kW_{Pk}; battery buffer >5^{Day}	State-of-the-art also in industr. countries	Fully commercial	No competition in off-grid applications (mountain. regions)
Isolated Grids - El.generation	Standard AC output; typ. 5....15 kW_{Pk}; with battery or hybrid back up	From the shelf solutions available, but still except. Application	Under favour. Conditions economic	Diesel or WEC is usually cheaper, limit about 15 kW
Agricultural Applications				
Water Pumping	150 W... 5 kW_{Pk}; various Pumps available, standard systems use AC conversion	Commercial, many manufacturers and types; local types can be used (standard motors / pump sets)	Advantageous in the low power range for remote settlements	Diesel pumps, wind power. Environmental concerns for Diesel
Water Treatment	Low power range, many different concepts	Test and prototype status; promising	Some devices in "routine" field service (military applic.)	No alternative for low-power applications
Irrigation - pumping - water treatment - control	Similar to Pumping	Tests under way! Local B.o.S.-components essential	No reliable data	Convent. Irrigation with Diesel, Wind or grid driven pumps
Other Applications:				
Refrigeration	150 ....500 W_{Pk}; with / without batt.	Commercial types for small (vaccines!) to med. sized devices	Very favourable for remote applic.	Practically no alternative
Air Conditioning	up to some kW, different methods applied	Prototypes and small series production	Favourable, if adapted	Grid-connected systems

Since in the table only short notes are given, some more detailed explanation seems to be essential, at least with regard to the most renowned appliances:

- Solar Home Systems (SHS) are common in the power range up to 200 W. For such applications there is nearly no alternative viable. This is true even in grid distances of a few 100 meters – and it is the most reliable solution, if the design is done correctly and if the users be trained to avoid deep discharge of the batteries. For lighting purposes in many countries fossil fired lamps (Kerosene, Gas) are

common. For such devices the comparative cost assessment leads to the question, whether high start-up costs (PV installation) can be compensated by higher regular costs for fuel and replacement of parts. The essential factor in this comparison is the price for fuel. Where subsidies make cheap fuels available, the chances for PV diminish.
Gasoline- or Diesel operated small combustion motor / generator sets present an alternative only in a higher power range (beyond 1,5 kW). Even if such gen-sets are not expensive, fuel costs, maintenance and service expenditures put them into second position against PV. The breakeven limit, where PV and gen-sets systems reach equivalence lies at about 3,5 to 5 kW.

- PV as the energy converter for power systems in tele-communication services has also reached a status as the "one and only" solution for off-grid locations even in the industrialised countries. For such applications often "un-interrupted power supply (UPS)" must be warranted. PV systems with an adequate battery storage can easily fulfil this requirement.
  Within a power range of below 1 kW to 7 or even 10 kW (depending on local conditions) PV is the preferred technique to power transmitters etc. Similar systems are also familiar in nearly all countries with heavy automobile traffic for emergency phones along the auto routes. PV-systems with 35 to 65 Watts common, replacing practically all battery-only operated systems. Even for grid-connected appliances PV-powered UPS becomes attractive, since this solution offers a reliable power in cases of grid failure. The decisive factor here are quite high stand-by losses of standard transformers and grid-connected battery monitoring devices.
- Electricity generation feeding into isolated grids is a viable concept, which has to compete with many other alternatives, anyway. Besides the conventional powering using fossil energy sources also hydraulic turbines, wind energy conversion and combinations from various sources are common.
  Such isolated grid concepts may also include battery buffers, which warrant a reliable energy service. The feasibility of the combination of the different energy resources must be investigated in any single case.
- Water pumping is a very favourable application. From an economic point of view the solar alternative is reportedly superior for small concepts. Depending on the local conditions (first of all of the water well and water consumption schemes) the threshold for PV lies at 1,5 to 2,5 kW – as compared to conventional Diesel pumps. Since the access to save (not contaminated) water becomes increasingly difficult, the issue of contemporary water pumping concepts seems rather important.
  With regard to polluted water it must be mentioned that Diesel pumping stations often bear some environmental risks (lubricants and fuel are hazardous liquids), but the same is true for the transport of water in open barrels by means of small trucks (this is a very common practise with Bedouins). It can be shown that in any such cases PV pumps present a viable - and from an energetic point of view preferable – alternative.

All the applications mentioned so far are state-of-the-art. For such installations the technology is well established and mature components are available. Even in cases, where the economic viability may be in question, environmental aspects imply to stick with the solar system. A lot of data is available for various techniques, which can be used to evaluation in any single case the advantages and constraints in detail.
This does not apply to the applications listed in the following, since here the performance statistics are partial – at the best. Even if by means of tests or demonstrations projects a proper function could be proven, many engineering details and the economic parameters are open issues. Also the market situation is not really clear: Only a few manufacturers can offer full services. For satisfactory operation the customer is requested to take care of proper layout, often even service and monitoring the system is left to special arrangements. This leads to the question of warranty and responsibilities in case of malfunctions.

Since the power generating part (the PV system) can be regarded as "safe" investment, the engineering endeavour has to concentrate on the other components. Sometimes standard equipment from grid-connected applications can be adapted to the solar operation mode, in any other case it is suggestible to take any efforts to find adequate solutions.
Nevertheless, many of the applications discussed here seem to be very promising.

- Filtering, cleaning, and decontaminating water from dubious sources to make it save for human consumption becomes an increasingly important issue. Many different procedures – or even combinations of them – have been proposed. Some equipment utilising PV powering is already marketed successfully. Anyway, the components from the shelf are not for "regular" use, but were designed for military or leisure purposes (that means for rather small output). An adaptation for rural settlements and a development towards simple and reliable operation including provisions for local maintenance and service seem adequate.
- Water for irrigation purposes can be conveyed by PV pumps. The problem (and an urgent issue for engineering and optimisation) lies in the high pressure requirements of most of the irrigation systems – and in the choice of proper water distribution systems. Conventional irrigation devices operate a rather high internal pressures (typically more than 1 bar) and the tolerances for the water flow are pretty large: This leads to a very unpredictable water distribution in the fields.
  Thus, improvement of the irrigation systems seems highly desirable in terms of: lowering internal pressure requirements (which helps save energy), reducing the tolerances of the drip or sprinkler elements (which can reduce the overall water consumption and warrant an equal water distribution), and providing facilities to control the water flow under part load conditions. Any of the topics cited would help to reduce the overall energy demand. An this – in consequence – will influence the costs of the PV system positively.
- Refrigeration of agricultural products for storage and to keep them fresh during the transport is a standard procedure, still not in any customary forms applicable with PV powering. Small PV driven units are commercial for vaccine cooling and for domestic use. For an application in a larger scale component development seems adequate. First trials for cold stores and processing of cooled products were successful and indicate that a technical development in that direction would be valuable with regard to the needs of the people in the Third World.
- Air conditioning by means of active cooling is – even if a standard procedure in grid connected operation – no option for solar power conversion in a large scale. Since most devices are driven by electric motors PV powering would be easy, but with regard to the costs of such an installation it would not be financially viable – at least for the time being. Moreover, there is an alternative concept in discussion using adsorption processes for cooling (utilising solar heat), which seems to be more promising in terms of energetic requirements. That even such systems need electric energy for monitoring, driving pumps, and to power control elements opens a less powerful but nevertheless important opportunity for PV systems.
  Better adapted to PV powering seem the so-called "Desert Coolers", devices, which make use of the effect of evaporation cooling. Such equipment needs only low amounts of energy in order to regulate the water flow and to drive a fan. Such power can be provided by a PV array not much larger than common for SHS. Since Desert Coolers are not marketed in the industrialised countries (the physical conditions for the cooling effect prevail in very arid climates only), cooperation between neighbouring countries within the Southern belt is suggested to give the technology the necessary push.

Solar energy is capable to power many other appliances. Inter alia tests with PV driven Reverse Osmosis plants were successfully performed to gain drinking water out of saline sources. At present costs of PV components such endeavour is primarily of scientific interest, anyway. On the other hand it is worthwhile to keep those issues in mind, since in the long term also such technologies may become attractive.

2.2 Cost factors and benefits

The prices for PV equipment [9] are not only controlled by market forces. Some influence by other factors is obvious: Governmental programmes supporting PV installations in Europe and Japan led to a strong "pull" on the market, which for a certain time exceeded the manufacturing capacities. The result is a nearly constant price for a Peak-Watt. Consequently the trend aiming steadily at lower costs for many years stopped or even inverted.
On the world market the costs per Watt on a module basis lie between 3,50 and 6,5 $ (shipment ex manufacturers` premises), for a system installed the costs may reach between about 8,50 $ and slightly more than 13,50 $ (depending on installed power, complexity of the system, local situations, and type of equipment). A rather reliable approach to the actual PV system costs is the German rule to grant about 6,-- $ per Watt at the maximum for grid-connected systems. For such plants German law warrants refunds per kWh conveyed to the grid of about 0,45 $ [10].
These data can be used for a compilation of the "realistic" costs for a solar system. The figures are listed in the Table 4.

Table 4: PV system costs and energy costs per kWh

Location	PV module costs	El. energy refunds	Remark
USA	6,15 $ / W	0,08 ... 0,17 $ / kWh	Refunds depending on tariffs (base load/peak load conditions)
Europe	> 6,30 $ / W	0,10 ... 0,45 $ / kWh (highest value: Germany)	kWh-refunds in Europe are subsidised, inspired by an assessment taking into account low insolation conditions
Mediterranean	>6,-- $ / W	0,1 ... 0,3 $ / kWh	favourable solar conditions lead to higher annual output, refunds from utilities may be subsidised
Mediterran.; concepts for remote areas	> 6,50 $ / W	t.b.d.	Complex systems may incur higher costs, but any other energy services are more expensive in remote regions

The data in the table refer to the kWh-refunds available from the utilities (resp. the customers). The "politically influenced" refunds for electricity reflect the fact that the solar conditions in Central or Northern Europe are not as favourable as in the Mediterranean. The governmental programme in Germany can be judged as very effective to stimulate the market and the competition. System costs in Germany and the refunds reflect this situation.
Systems adequate for countries in the Mediterranean might necessitate a somewhat higher complexity (in the meantime German customers can buy systems "from the shelf" with almost no engineering costs. This makes the acquisition very cost effective), which will cause higher costs. Since the system costs are envisaged as one of the critical factors, it seems worthwhile to reflect about possible means to reduce these costs.

In view of the data collected in German an assessment is possible concerning the allocation of costs: For the time being the PV components (array) represent only about 50 % of the overall costs. With progress in terms of economy of scale effects, new products, and other technical improvements it can be expected that these costs will still decrease.
So, with more than 50 % of the overall costs the "Balance-of-system" components become more and more cost effective. For many of these devices local manufacturing seems viable (to avoid any misunderstanding: this would require that "customer countries" join their efforts founding local enterprises manufacturing dedicated types of e.g.: charge controllers, switching arrays, etc.). Given the differences in wages between the industrialised countries and the Mediterranean region a substantial cost reduction should be possible for the components manufactured locally. Not to talk about the effects on labour.
The other effect of such concepts is if equivalent importance: The German experience shows that only after local partners for technical and engineering services had amassed a certain know-how competent design and counselling was practical. Such a dialogue between planners and users is felt to be a precondition not only for the satisfying operation of a system, but much more a prerequisite for a decision to invest in novel technologies. The individual

knowledge seems to be a decisive factor in the introduction a new products to the market. So far not many signs of an adequate infrastructure can be found in the developing nations. It would be worthwhile to encourage such attempts. Contemporary media could be used to facilitate training and educational tasks [11].

A cost factor, which cannot be evaluated as far as applications in the developing countries are concerned, is the reliability of the energy services. Since PV is perceived as a very reliable resource, the argument of "avoided costs" by an persistent service may support any decision. In Table 5 some figures for the costs of power interrupts are compiled [12]:

Table 5: Values of reliability of energy services (commercial applications)

Service	**Average costs of down time**	Example:
Small business	7500,-- $ / day	
Cellular communication	40.000 $ / hour	
Telephone sales services	>65.000 $ / hour	Airlines, Brokers

It is not by chance that many of the data refer to the telecommunication services, which became of increasing importance in the Western world. It might be interesting to assess, what`s the value of life saving services (like water pumping in arid areas, vaccine cooling, etc.). Regrettably, those figures are not available.

3. Conclusion

The PV market is split regionally: In the industrialised countries, which found various ways to subsidise solar appliances (even if this endeavour is still far from contributing essentially to the promised reduction of products from the combustion of fossil fuels), the market is developing at a rather fast rate. In contrary, markets in the developing countries seem to stagnate. Whether this situation is acceptable, shall not be commented, but an encouragement seems adequate to the people in the Southern belt to raise their voices: The transformation of energy services to solar and renewable resources is a responsibility of mankind, which should be accepted as a joint task.

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Grid-connected Systems – the main application on the German PV market

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Summary

Grid-connected PV is the dominant option on the German PV market. Even if – in terms of contributions to the energy demand – the output of such solar appliances is still small, there is a high public acceptance for the related concepts.

Progress in approaching a mature technology eliminating many of the early annoyances with the equipment was a precondition for marketing. Large advancement was made especially with regard to the balance of system components and in training tasks for local technicians. Also the public awareness of the necessity to refrain from an excessive fossil fuel consumption was helpful to further the PV market.

Of similar importance are subsidies from public entities and the involvement of the utilities. German laws warrant an adequate price for electricity derived from renewable energy sources, which gave the technology a significant push.

Based on these very favourable conditions the German PV-industry has taken the lead in Europe in the last years, which is one decisive factor for the Europeans having reached second place in the world-wide production capacity, which illustrates the rapid development achieved.

Introduction

Public opinion prompted the political establishment in Germany to incite a legal situation supporting solar and wind applications. According to the well developed energy infrastructure in Germany a connection to the grid, which acts as buffer and stabilises the operation of the attached systems, is the usual procedure. Moreover, integration of solar modules in buildings has become a challenge to architects. Outstanding examples of such endeavour were realised in the course of the transfer of the German capital from Bonn to Berlin. At new buildings for Ministries and governmental offices many examples of contemporary methods of solar energy utilisation can be found: PV arrays with an area of nearly 10000 m² were installed on roofs and at facades of public buildings[i]. Those efforts and the still proficient program to subsidise the setting up of 100 000 PV systems[ii] on privately owned roofs is the basis for a rather swift market development.

This has also had a significant (and highly welcomed) effect on the work force: Estimates assign more than 20 000 jobs to the renewable energies industry (not talking about various jobs in maintenance and servicing), the annual turnover of the branch amounted to $1,2 \cdot 10^9$ Euros[iii] (equal to $1,1 \cdot 10^9$ \$). An annual PV-market growth of about 60 per cent in Germany is very impressive even in view of an also quite strong market escalation of 30% world-wide.

A few years ago privately owned PV plants averaged below 2,5 kW_{PEAK}. Many systems built were in the range of 1 to 3,5 kW. This was true as long as the access to public subsidies was limited to plants of a maximum size of 5 kW. In the meantime the average system size is increasing according to the rules for public subsidies, which have been modified: Regular subsidies allow a peak power of 10 kW for private investors and 50 kW under certain circumstances. Separate financing schemes on a voluntary basis have been brought forward by some utilities for customers being willing to pay an extra charge for "green" electricity.

The subsidies for PV installations in Germany and Japan explain, why in the last years the grid-connected appliances show the by far largest expansion (Figure 1)[iv].

On the other hand this development has disadvantages, too: The trend towards cost reductions, which could be observed for two decades, did not extend in a similar rate in the last years. PV costs seem to stabilise on a constant level due to the high demand in comparison to the production capacity. It is expected, anyway, that further cost reductions

can be achieved as soon as new technologies and a higher productivity of the new plants come into effect.
Another shortcoming of a rather strict "national" PV-policy in many of the industrialised countries is not so obvious: The technological drive towards more reliable components for grid connected systems was so dominant that many manufacturers now pay less attention to other PV applications. There is good reason to predict a considerable potential for improvement also for other appliances (e.g. batteries, inverters for off-grid use, sensors and control equipment). Regrettably minor priority is allocated to such tasks for the time being. The involvement of the industry in PV-installation at the home market provoked a neglect of the export markets, which is especially true as far as Third World countries are concerned.

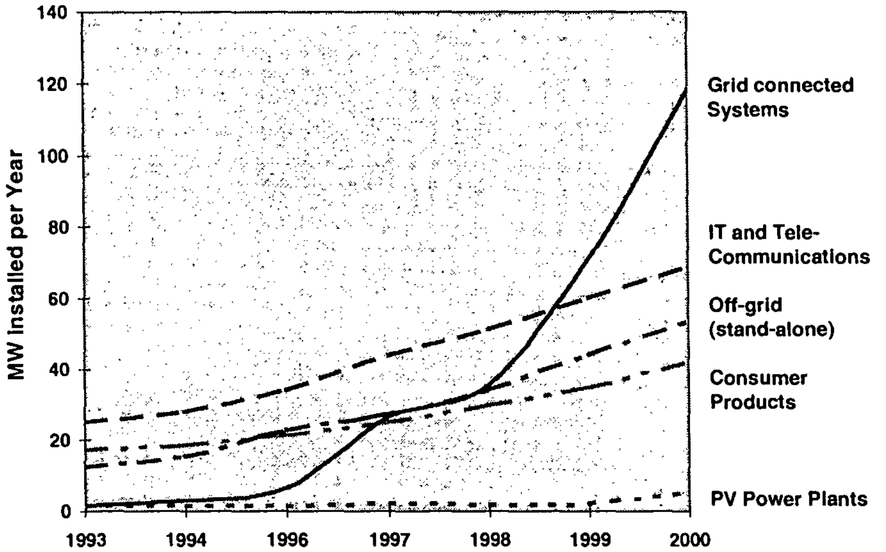


Figure 1: PV Market - development of applications Sectors

Technology Highlights

Cell Materials

Crystalline Silicon still is the standard material for PV modules. Only for consumer products (preferably low power appliances) amorphous Silicon is still the first choice. Other thin film cells (for instance: CIGS) make some progress and may become of rising importance, if the production capacities commissioned will reach their nominal output. Figure 2[v] shows the efficiencies of some selected types of PV cells. The data represent "best of its kind". For mass production cells the module-efficiency is usually about two thirds of the values in the figure[vi].
The figure also shows data representing PV-module costs and the production output. The curves suggest that the trends – as well with regards to costs as to market development - are stable, even if the slope of the efficiency curves may lead to the conclusion that the technical progress becomes slower – at least as long as "established" materials are concerned.
With regard to other alternative materials for cells the situation is rather complex. CIS and CIGS cells mentioned above seem to be most promising for the time being, if the planned capacities to become operable in the near future are taken as indicators. Presently also CdTe is of importance, other concepts are still in the experimental status.
This is especially true for some not-so-conventional approaches, e.g. organic liquid cells, dye sensitised cells, etc. Modules based on such concepts are being tested as facade elements in small scale applications. The attraction of such solutions lies not the least in the opportunity to give architects a wider choice in the colouring of "solar" facades. Estimates concerning long-term stability and costs of such products are very difficult, anyway.

The predominant purpose of grid connected PV systems in Germany aims at an assembly at roofs or Southerly oriented walls. Accordingly flat plate modules are the rule. In order to keep the installation costs low and to simplify the design of supporting structures the manufacturers tend to increase the size of modules: more than 1 m^2 is common, up to >2 m^2 is viable.

In comparison to this well defined practice solar concentrators in combination with PV conversion are an issue for research and for very specific purposes only, without any major significance on the market so far.

System Components

Similar important as the stability and performance of the PV modules is the reliability of the other hardware components needed to make the system operable. Since German manufacturers warrant the lifetime and performance of their modules for 20 years and more, it was very important to achieve similar longevity also for any other elements of PV systems. Accordingly, much endeavour was allocated to improve those products.

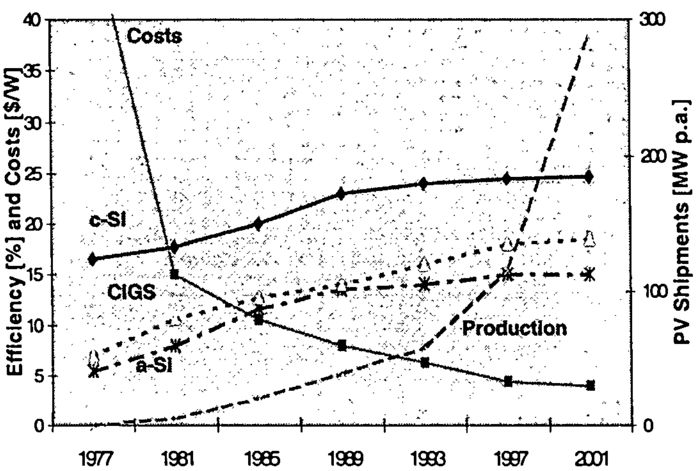
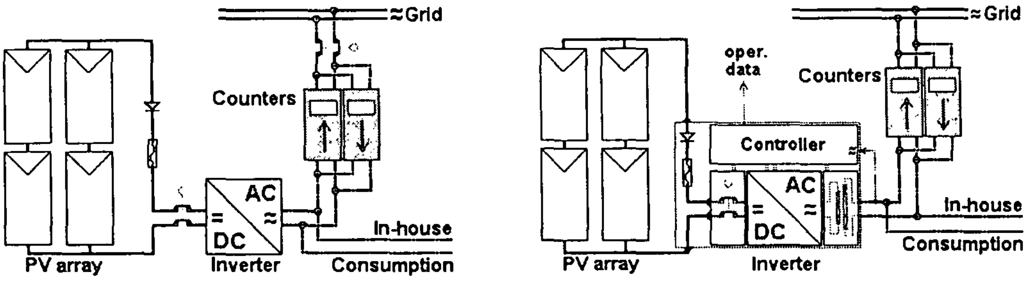


Figure 2: PV-cell efficiencies, Market and Cost figures

The results of the move towards more reliable systems are remarkable, not only with reference to costs but also in terms of safety and of compliance with utility regulations. German laws are rather strict as far as risks for users and for maintenance personnel are concerned. Therefore, one very helpful strategy was to reduce the risk of any failures during the process of assembly, cabling and interconnecting. Starting from an assembly of dedicated single elements (module, inverter, switching gear, fuses, grid interface; including in most cases two counters (bi-directional)) an improved concept was developed. Modern inverters assure switching and safe operation under any circumstances, some models also offer the opportunity of remote surveillance and data transfer for distant monitoring. This development was done in a very close co-operation between manufacturers, utilities (setting the terms for the grid interfaces), and standardising entities. Finally, many of the products marketed are certified, reducing widely any risks for the investors and customers.

Figure 3 presents two different concepts, epitomising different steps of the development: As the schematic shows the state-of-the-art has many smart functions introduced into the inverter. Safety related issues – as a first priority - comprise an automatic interrupt of the regular operation, if the grid fails. This makes dedicated circuit breakers obsolete, which were formerly esteemed necessary to avoid "erratic" voltages in case of grid shut-down.
The inverter connections to the DC-inputs were also modified to simplify the cabling efforts.

To comply with harmonics and demanded grid characteristics in most cases filters are installed (capacitors and/or inductances are common, if no transformers are provided, which may also serve as filtering devices). Automatic control is almost the rule for the inverters on the market, in most cases the control uses internal sensoring to monitor the in- and output parameters and to make corrections in case of deviations. The latest trend is the exchange of the monitoring information between different devices not only to facilitate a remote supervision but also to allow a master / slave operation, if different arrays are operated in parallel. Such interconnection often is realised even without dedicated data cables (via grid lines).



1.) 2.)

Figure 3: Functional Schematic of grid-connected PV Systems

Trend to more Smart Devices (Inverter Concepts)
illustrated by Comparison of different Stages in System Development

Parallel to the technical development also cost cuttings were necessary. From Figure 4 the reasons for the endeavour to trim down the costs of the B.o.S.-devices become understandable. The illustration presents a dissection of grid connected PV system expenditures. As can be seen the PV modules represent still about half the costs. But it is obvious that with a decreasing PV cost level the other components become more and more important.

This can also be deduced from a historical view: in the past the PV system investments were rather high due to predominant module costs. In the meantime the electronic power conversion electronics, the load management system, and the auxiliary equipment become more and more cost effective. When the economic viability of PV installation is examined, the integration of functions, standardisation of elements, and the exploitation of the economy of scale effects (mass production) were essential to give way to the present cost situation.

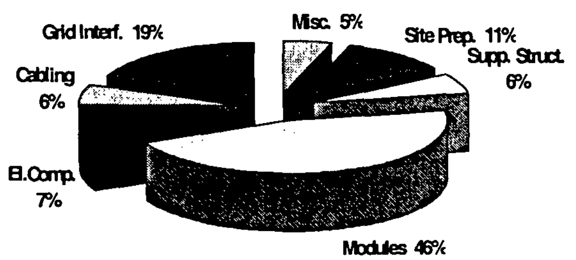


Figure 4: Cost breakdown of a grid-connected PV System

The data refer to a medium sized plant. For less powerful systems the relative expenditures for the PV array will be of still smaller influence

The trend aiming at still larger modules and more powerful systems and the request to simplify the cabling efforts on site and to reduce the material costs led to the development of module-integrated inverters. The solution anticipated for such a concept would facilitate the interconnection of panels and the grid, since the module output would be in compliance with grid voltage and frequency.
Modules with integrated inverters are produced in a small scale, preferably with module sizes in the largest dimensions manufacturers can deliver from the shelves: outputs between 150 and 300 Watts were envisaged as the adequate rating to be "grid compatible". With technical progress in integrated circuitry functional design will become easier, possibly extending the limit for the application of module-integrated inverters to smaller devices.

Table 1 presents some features requested for grid-coupled devices in Germany. With regard to the number of plants installed so far small "domestic" PV systems (in the Kilowatt-range) prevailed. For those applications a very well documented state-of-the-art is established. Compared to this no adequate standardisation exists for larger plants. Even if the system arrangement is practically not different, the balance-of-system components for PV plants with peak powers up to the MW range have to be tailored for the very specific needs of the customers. A few German enterprises offer such services on the market dominated by the utilities. In most cases the power conversion and switching hardware has to fulfil quite complex functions, since utilities tend to order additional features, which may comprise the capability of load matching in weak grids, filtering, grid stabilising, and load management – including remote control of plant output and of parameters of the electric power fed to the grid.
The Table lists the typical functions for small "standardised" system components as well as for the devices used in larger PV plants. That module-integration is a task which includes the handling of some additional problems may also be assessed from the information given in the table.

Table 1: Functional description of grid coupled system components

	Inverter	Switching Cabinet	Remarks
Small Systems	**MPP-tracking**		
	Conversion DC → AC; single phase	**Galvanic separation (mechan. switches)**	Safety-related issues have first priority
	Filtering to keep harmonics within accepted limits	**Fuses**	
	Auto-synchronisation	**Current (power) metering**	usually bi-directional counters are requested
	Auto switch-off (in case of grid failure)		this is a safety requirement
	logging data / interrupts		for remote monitoring (optional)
Large Systems	as for small systems with the following modifications:		
	3-phase AC conversion		Voltage stepping up transformation is standard
	cos φ - control, V_{max} / V_{min} monitoring (optional) and (frequently) Peak Load compensation	**Interface to hybrid power sources (batteries; wind or hydraulic turbines)**	remote control (fully bi-directional) as a viable option for grid-stabilising efforts
Module-integrated Inverters	as for small systems with the following modifications:		
	single phase inverter with stepping up transformer		
	electronic overload protection (instead of fuses)		
	simplified switching gear		
	Separate (remote) Power meters / counters		

Stand-alone applications

Even if in Germany the public grid branches to nearly any place in the country, there are some Alpine areas and remote locations, where no access to the mains is viable. Therefore

the German industry sells also stand-alone applications in a wide power range. The technical features of such concepts are quite distinct from those ones applicable for grid-connected operation, especially if the solar powering is intended to warrant a reliable operation. In this case the combination with any back-up resource is essential. For such purposes a large variety of alternatives is on the market. Most of them have been tested thoroughly and have reached a high degree of maturity.
The market for such systems can roughly be split into "commercial" applications (the most important example presenting the power supply for transmitters in the tele-communications network), which have demonstrated technical and economic viability, and electricity generating systems for dwellings in off-grid areas (Alpine refuges, farms), for which the technology is established, but costs can still present a major hurdle. Since for such systems adequate subsidies are scarce (differentiating this application from domestic electrification schemes), a rather slow market expansion is observed.
The overall capacity of the autonomous systems is small in comparison to the grid-connected PV systems (installations of the latter one surpassed last year the margin of 60 MW). Thus, the role of off-the-grid generation is only secondary, not the least due to the fact that the rated power of the particular systems is mostly restricted to some 100 Watts.
An also rather small but not the least attractive application of PV power refers to the recreational sector, be it for lodgings used only seasonally, be it for boating and mobile homes. The hardware components of such applications can be envisaged to be exemplary also for systems in other regions, which makes this an important issue for the German industry, since it represents a key to the world-wide demand for small domestic and rural applications.

Costs vs. Benefits of PV generated electricity

To assess the economic parameters of solar systems some information about the subsidies influencing the electricity generation costs and the revenues per kWh produced is important.

Subsidies for PV systems in Germany

The rules for financial support for solar energy systems in Germany are quite complex. This is true not only because some of the conventions are subject to modifications, but also because various entities grant funds for PV applications. Besides the national government the governments of some states and banks and communities are involved in the subsidising network. The following paragraph is therefor a slightly simplified compilation of the funding schemes in Germany:

For private persons, small enterprises, and schools or similar institutions governmental subsidies are granted for renewable energy and especially for PV system installations. Basically the support is given by means of loans (the credits being handled by banks), which are contracted for 10 to 20 years at a reduced rate of 1,9%. This figure is not fixed, since it is adaptable to the overall banking conditions. Effective credit costs may still be slightly more favourable, since for the first two years no back-payments are demanded.
There is an upper cost limit for the amount of money credited: only plants with specific costs below 6557,- € / kW (i.e. about 5,95 $ / W) are fully subsidised, in case of higher expenditures the credit is limited to the maximum allowable figures.
PV systems installed under this rule must be rated between 1 kW and 5 kW (for private owners); 10 kW for enterprises. For systems larger than 5 kW a more complex calculation applies: funds for such plants amount to 3279,- € for any kW exceeding 5 kW.
The overall pattern of the funding is still more intricate, if funds from states are included (in Germany different states make up the Federation). Since not all of these states have subsidising programs of their own, additional subsidies are not generally available. Among those countries, which grant funds of their own, are Northrhine-Westfalia, Hessia, Thuringia[vii].
The regional funding method in these countries is based on direct (investment) subsidies. Between 750,- and 2500,- € / kW can be allocated. Whether the user gets funding and which amount is available (usually granted supplementary to the credits, sometimes reducing the credited amount) depends on aspects of personal (familiar and financial) circumstances, on

technological issues (whether the system can be envisaged as exemplary or not), and on a judgement of local "public" interests.

In comparison to many other countries tax incentives are not common in Germany. Such means were found not to be very effective.

In addition to the subsidising efforts from government and local authorities a dedicated German law enforcing "Renewable Energies[viii]" was put in force two years ago. According to the stipulations of this law attractive compensation for electricity generated by renewable sources is warranted (with refunds depending on the technology applied):

Presently the rate for PV is 0,48 € / kWh (roughly 43 $cents_{US}$), to be paid for 20 years. For plants put into operation in the years to come the revenues will be reduced slightly, but still the 20 years` duration of the contract between the investor and the utility will apply. The trend for the refunds per kWh (which were originally 0,99 DM / kWh, i.e. 0,51 € / kWh) can be deduced from the data in Table 2. Despite of the fact that the reimbursement is reduced with the years the German law provides a very stable basis for calculating the overall pay-back time for the investment.

The impact of the law supporting PV generated electricity is remarkable, as the second line in Table 2 – listing the PV capacity installed in Germany annually - illustrates. The data for 2002 are preliminary, but there is good reason that (as already in 2001) the limit will be reached, since it is defined by the amount of funds being allocated by the government.

Table 2: Revenues for Electricity from PV according to the German law (EEG)

	1996	1998	2000*	2002	2004	2006	2008	2010	
Revenues per kWh	<10	<10	50,6	48,1	43,4	39,2	35,5	31,9	Cents $_{€URO}$
Installed PV	6	16	43	>65	?	-	-	-	MW_{PEAK} p.a.

*) in 2000 the new rate for electricity delivered from PV plants was put in force

The subsidies mentioned may not cover the total investment for PV systems. The overall investment for PV and balance of system components (inverters, cables, switching devices, fuses, measurement sensors), the labor costs (assembly), and the costs for the grid interface may sum up to total betwwen 7000,- (for very cheap and simple concepts) to 9500,- € / kW. Furthermore, assessing realistic plant costs one has to keep in mind that the figures depend on design features, too: In the process of planning a new building provisions can be made to facilitate the future installation of a PV array. Under such circumstances (e.g., if the PV modules were used as integral part of the outer shell of the building) the amount of 6557,- € may be sufficient to provide a functional PV system. Otherwise the investor has to find additional funds to cover the expenditures.

Benefits and Revenues

In a dedicated measurement campaign performed in the course of the first German program to install PV on "1000 Roofs"[ix] (how the program was named) the energy output from grid-connected PV systems was monitored. With some variation caused by differences in the geographic location of the sites, orientation, inclination of the roofing area or supporting structure, and – finally – the efficiency of the power conversion system and the reliability (defining the operation hours per year) an average of 700 kWh / kW_a was established for the electricity production of PV systems. With this figure and the data for investment costs based on the limits for subsidies from public funds a rough cost-benefit analysis is viable. The data are compiled in Table 3. The results show that there is only a small profit margin left.

Table 3: Costs and Revenue Assessment for PV electricity generation per kW_{PEAK} (simplified)

		Cost factors and *Revenues*	
1	**Total Investment per kW_{PEAK}**	**6557,- € / kW**	Credited Costs per kW

2	**Annual Revenues (due to EEG)**	*700 x 1 x 0,481= **336,70 €*** / kW_a	Electricity produced
3	**Repayment rate for the credit** *)	**320,78** € / kW;a	20 years payback time at 1,9% (including depreciation)
	Yearly profit (Values from Line 2 minus Line 3)	**8,70 € / a**	

*) Calculated using standard banking procedures, no payments for the first 2 years taken into account.

As the table shows the funding is such that investors and manufacturers have to design and build the plant carefully (first of all: keep it at a reasonable price): Profits can only be achieved, when the expenditures do not exceed the available credit sum very much. Higher costs reduce the profitability significantly. Further preconditions for an economic success are that the lifetime of the PV system is sufficiently high (20 years as the minimum to reach a "balanced account"), and that maintenance and repair costs come close to zero (such expenditures have been omitted in the table).
This makes the incentives of the German government become obvious: On the one hand a promotion of solar energy exploitation is reached, on the other hand the limits set for the purchasing costs and of reimbursement are such that there is some pressure imposed on industry and investors to try hard to reduce overall costs.

Outlook

Even after several years of subsidies the installed PV generation capacity in Germany is still very small in comparison to the total electricity generation capacity (below 1 ‰). Nevertheless, studies have been undertaken, whether the vision of covering the national electricity demand by renewable resources is realistic.
With respect to the quite different electricity generation costs an assessment of the contributions from solar energy conversion must first take into account the possible alternatives (wind power, biomass, hydro-electricity, geothermal energy)[x] and consider their contribution to the energy services. Only then an estimate can be undertaken as to the role of solar conversion.
Summarising this process leads to the conclusion that an at least one-thousand-fold increase of the presently existing PV capacity would be necessary for a solar infrastructure sufficient to cope with the demand. This consequence is independent from the technology used to exploit the solar resources: the yearly irradiance level in Germany is such that the plants could be operated for a limited time (700 hours p.a.) only, whereas conventional power plants operate between 2800 and 4700 hours per year (nuclear power plants: 6700 h p.a.).

The thousand-fold increase of the PV installations seems quite large. But, even if it seems to be a very ambitious task, a careful review of the opportunities to fix PV arrays on roofs, to cover un-used areas in cities (e.g. parking lots), and to use the South-oriented facades of buildings leads to the conclusion, that – even in a country like Germany with rather weak insolation conditions - a future energy concept based on renewables would be feasible[xi]. Certainly, many technical and financial difficulties must be expected prior to an even partial realisation of such an endeavour. But it is a challenge engineers, scientists, and politicians should envisage as an opportunity for the not too far future.

Whatever the outcome: Another side-effect of the German programmes for market introduction and dissemination of PV is also noteworthy: The experience derived will help to optimise any new plants in other parts of the world. Thus, the German national activities have brought PV energy conversion a decisive step forward towards a reliable and mature technology.

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[i] Renewable Energy Journal Nr. 10, June 2000
[ii] 100.000 Dächer Programm der Bundesregierung, 01.01.1999
[iii] IDEE, Informationsdienst Erneuerbare Energien, 2002 [ISSN 1431-8245]

[iv] P.D. Maycock: The PV Boom, Renewable Energy World July/Aug. 01, pp. 177-189

[v] B. Rever: Grid tied markets for PV, Renewable Energy World July/Aug. 01, pp. 145-161

[vi] P.D. Maycock: PT Technology; performance, manufact. cost & markets, Renewable Energy World July 99, pp. 62-67

[vii] REN-Programm: Photovoltaikanlagen, (regional programmes in the German states)

[viii] Erneuerbare-Energien-Gesetz, Dt. Bundestag - 01.04.2000

[ix] FhG-ISE: Jahresjournal 1995, 1000 Dächer Meß- und Auswerteprogramm

[x] According to (vi) electric kWh from wind energy conversion is rated 0,062 ... 0,091 €

[xi] Personal communication: M. Gutschner, Fribourg

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Workshop on PV Applications, 27-29 May 2002 - **Cairo**, Egypt

Grid-connected Systems – the main application on the German PV market

Dr. Wolfhart Bucher
DLR (German Aerospace Research Centre), Cologne

02.06.2002

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Functional description of grid coupled system components

	Inverter	Switching Cabinet	Remarks
Small Systems	**MPP-tracking**		
	Conversion DC → AC; single phase	**Galvanic separation (mechan. switches)**	Safety-related issues have first priority
	Filtering to keep harmonics within accepted limits	**Fuses**	
	Auto-synchronisation	**Current (power) metering**	usually bi-directional counters are requested
	Auto switch-off (in case of grid failure)		this is a safety requirement
	logging data / interrupts		for remote monitoring (optional)
Large Systems	as for small systems with the following modifications:		
	3-phase AC conversion		Voltage stepping up transformation is standard
	cos φ - control, V_{max} / V_{min} monitoring (optional) and (frequently) Peak Load compensation	**Interface to hybrid power sources (batteries; wind or hydraulic turbines)**	remote control (fully bi-directional) as a viable option for grid-stabilising efforts
Module-integrated Inverters	as for small systems with the following modifications:		
	single phase Inverter with stepping up transformer		
	electronic overload protection (instead of fuses)		
	simplified switching gear		
	Separate (remote) Power meters / counters		

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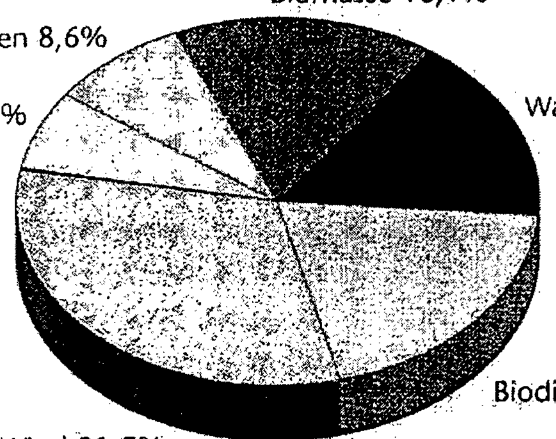

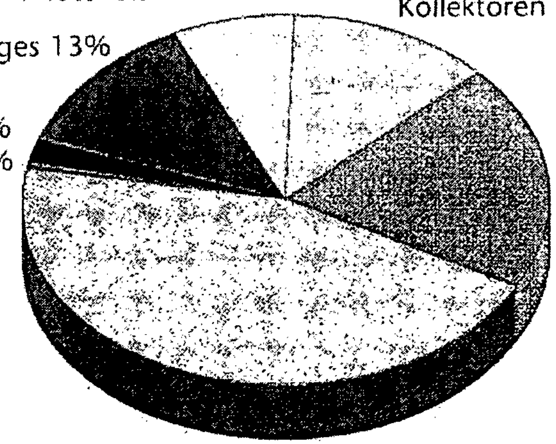

Expenditures for RE-related Research and Energy Services Investment (Germany 2000)

J. Nitsch, FVS-Themen 2001

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Costs and Revenue Assessment for PV electricity generation per kW_{PEAK} (simplified)

	Cost factors and ***Revenues***	
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<u>Yearly profit</u> (Values from Line 2 minus Line 3)	**<u>8,70 € / a</u>**	

*) **Calculated using standard banking procedures, no payments for the first 2 years taken into account.**

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Subsidies for PV – Systems (grid-connected) according to the German Rules (EEG)

Loan on Investment (federal Program)	**5960,- $ / kW** **2980,- $ / kW** (per kW exceeding 5 kW)	Minimum 1 kW installed, max. 5 kW (under spec. conditions 50 kW)
Interest Rate	**1,9 % p.a.**	Depending on banking rate, variable
Duration of Contract	**20 years**	2 years free of back-payments
Direct Subsidies (regional programmes)	**~ 750,- .... 2500,- $ / kW**	Not available in all states, sometimes also causing reductions in federal program applic.

Revenues for Electricity from PV according to the German law (EEG)

	1996	1998	2000*	2002	2004	2006	2008	2010	
Revenues per kWh	<10	<10	50,6	48,1	43,4	39,2	35,5	31,9	Cents $_{€URO}$
Revenues per kWh	~9	9	46	44	39,5	35,6	32,3	29	cents $_{US}$
Installed PV	6	16	43	>65	?	-	-	-	MW_{PEAK} p.a.

*) in 2000 the new rate for electricity delivered from PV plants was put in force

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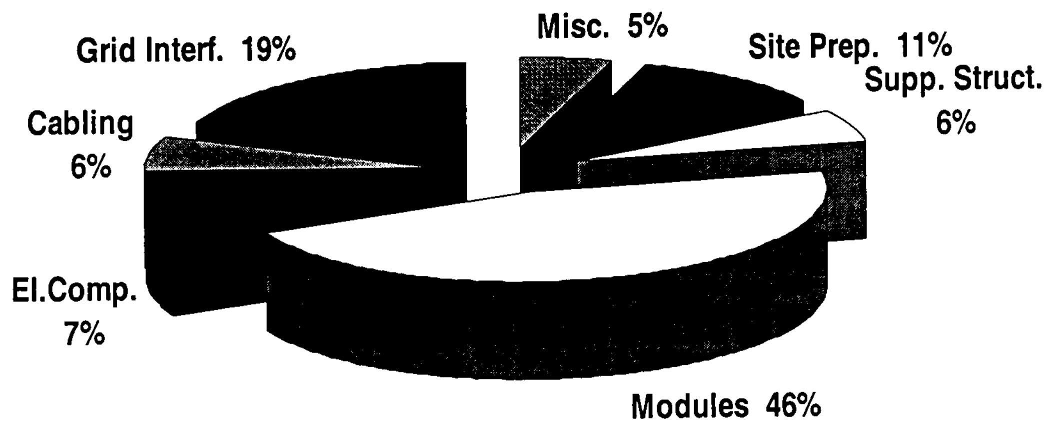

Cost breakdown of a grid-connected PV System

The data refer to a medium sized plant. For less powerful systems the relative expenditures for the PV array will be of still smaller influence

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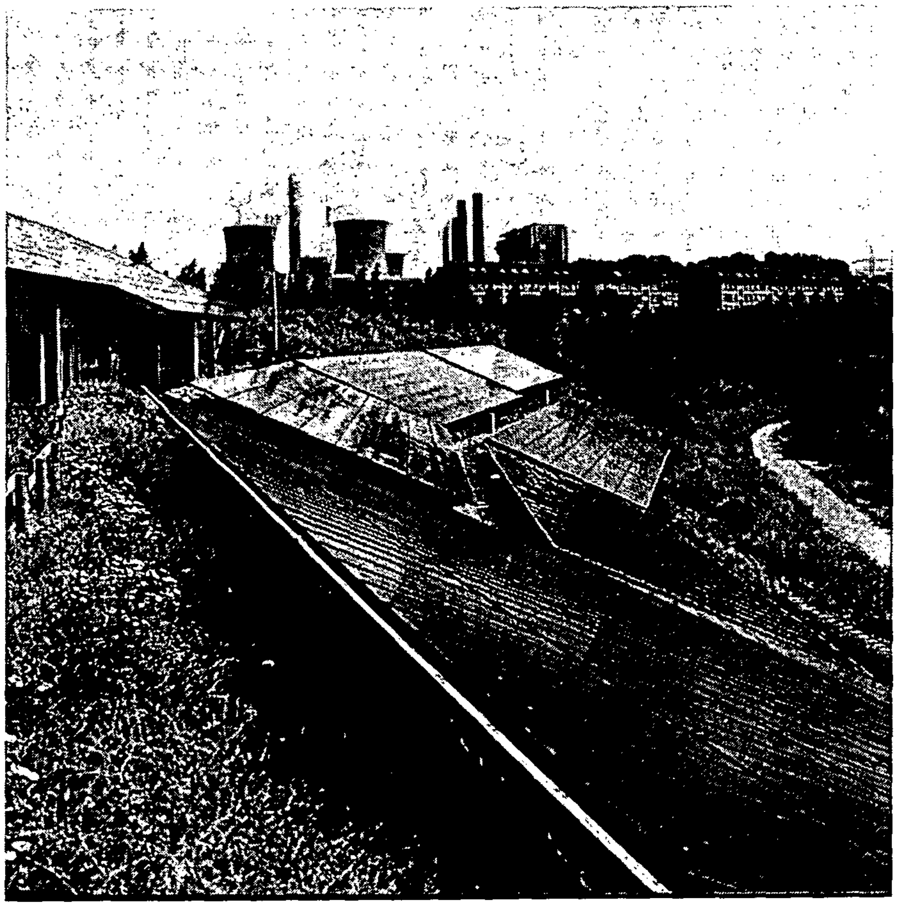

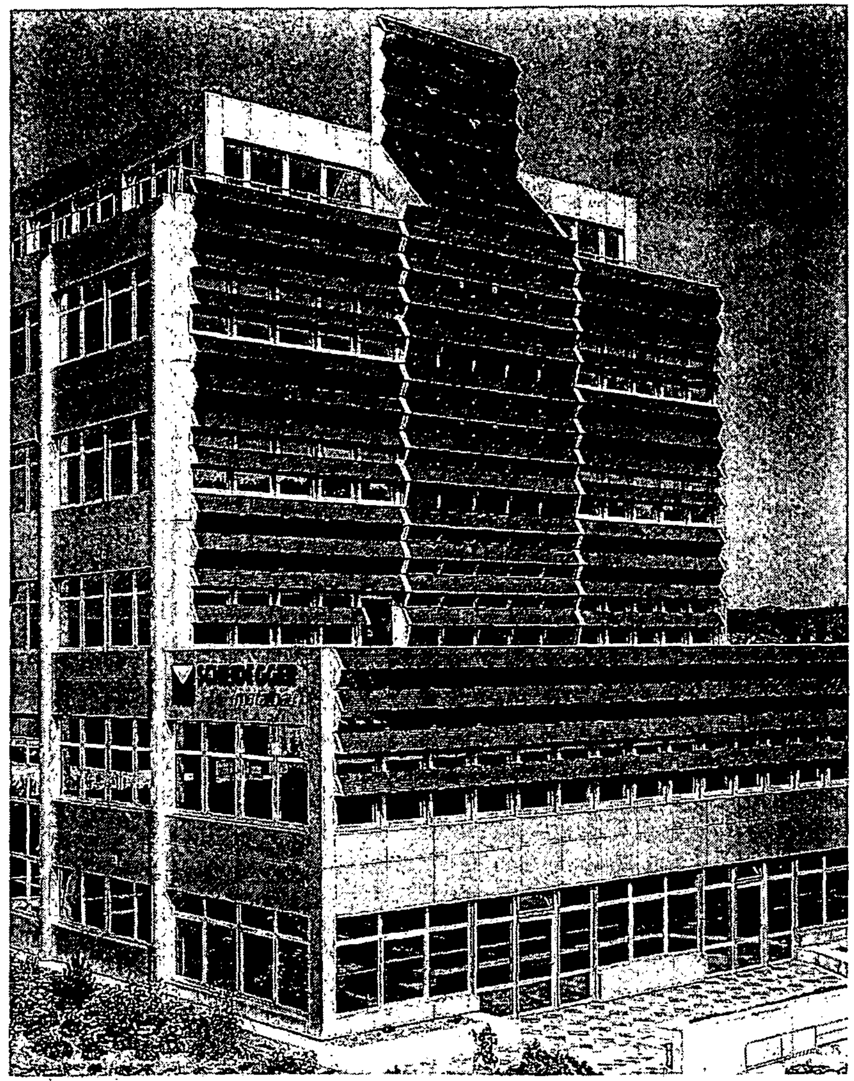

German Power Plant (Demo and Test) and PV on an Office Building

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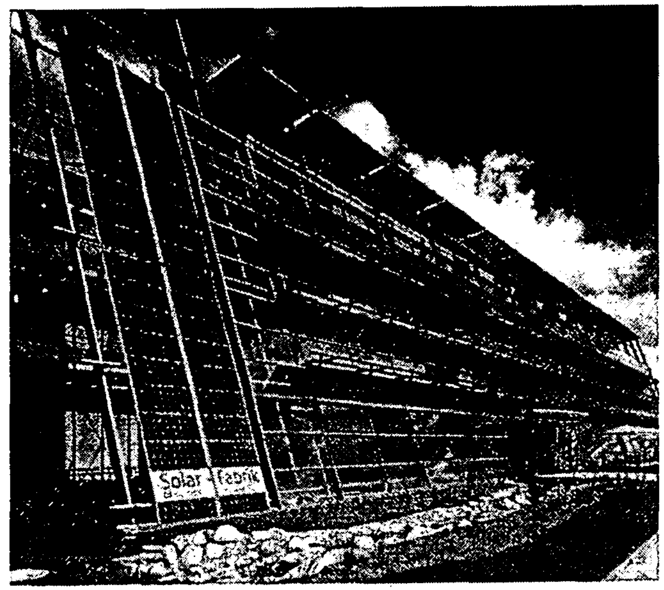

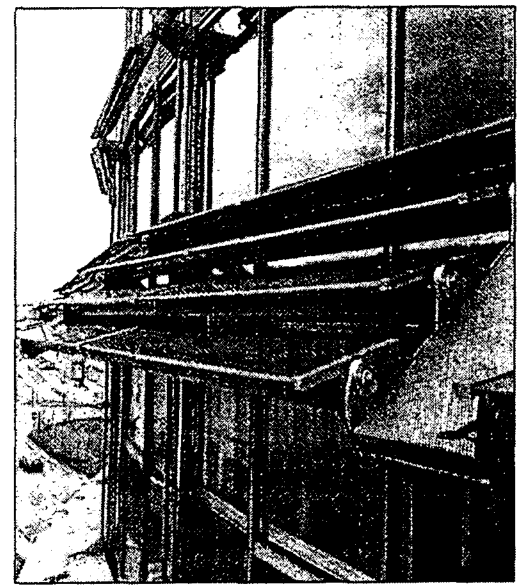

PV – Building Integration

From Roof-Top Modules to „active“ Facade-Elements

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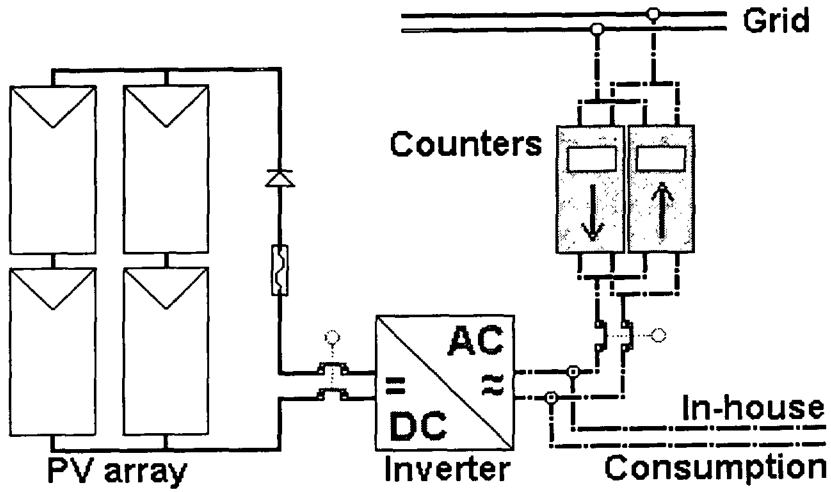
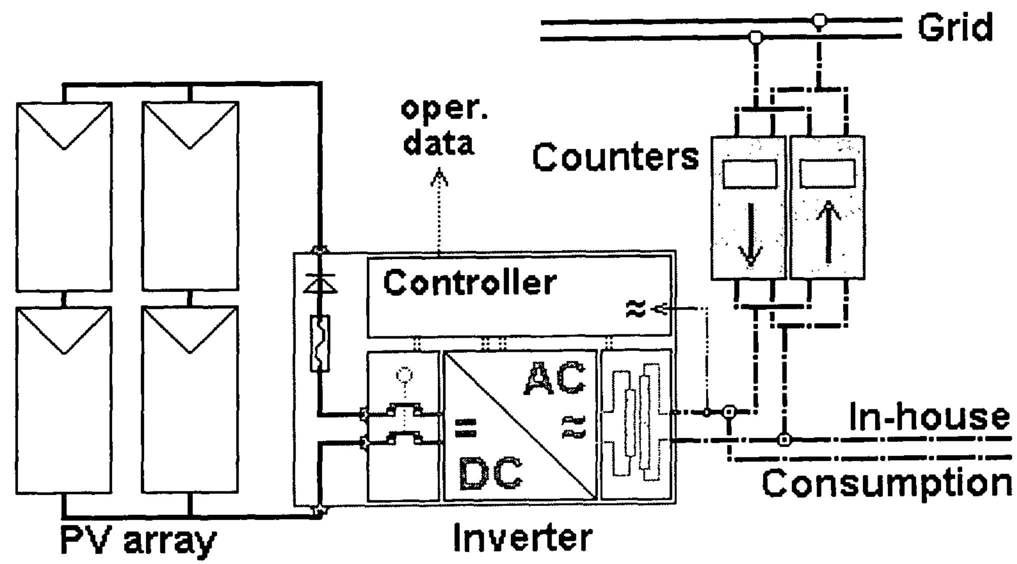


Grid-connected PV-System

Functional Diagrams of Inverter Architecture and Grid Interface - Development Stages



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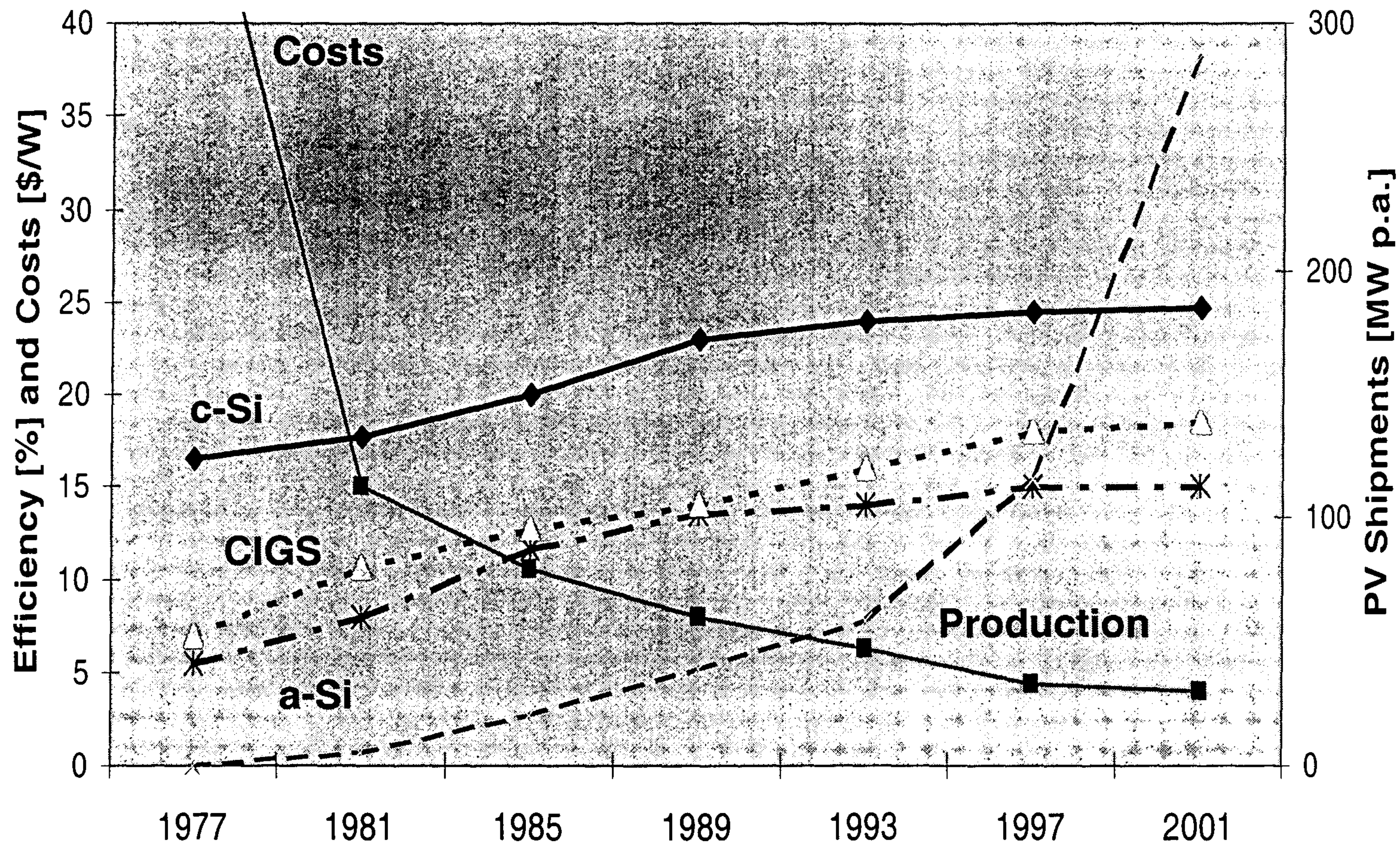
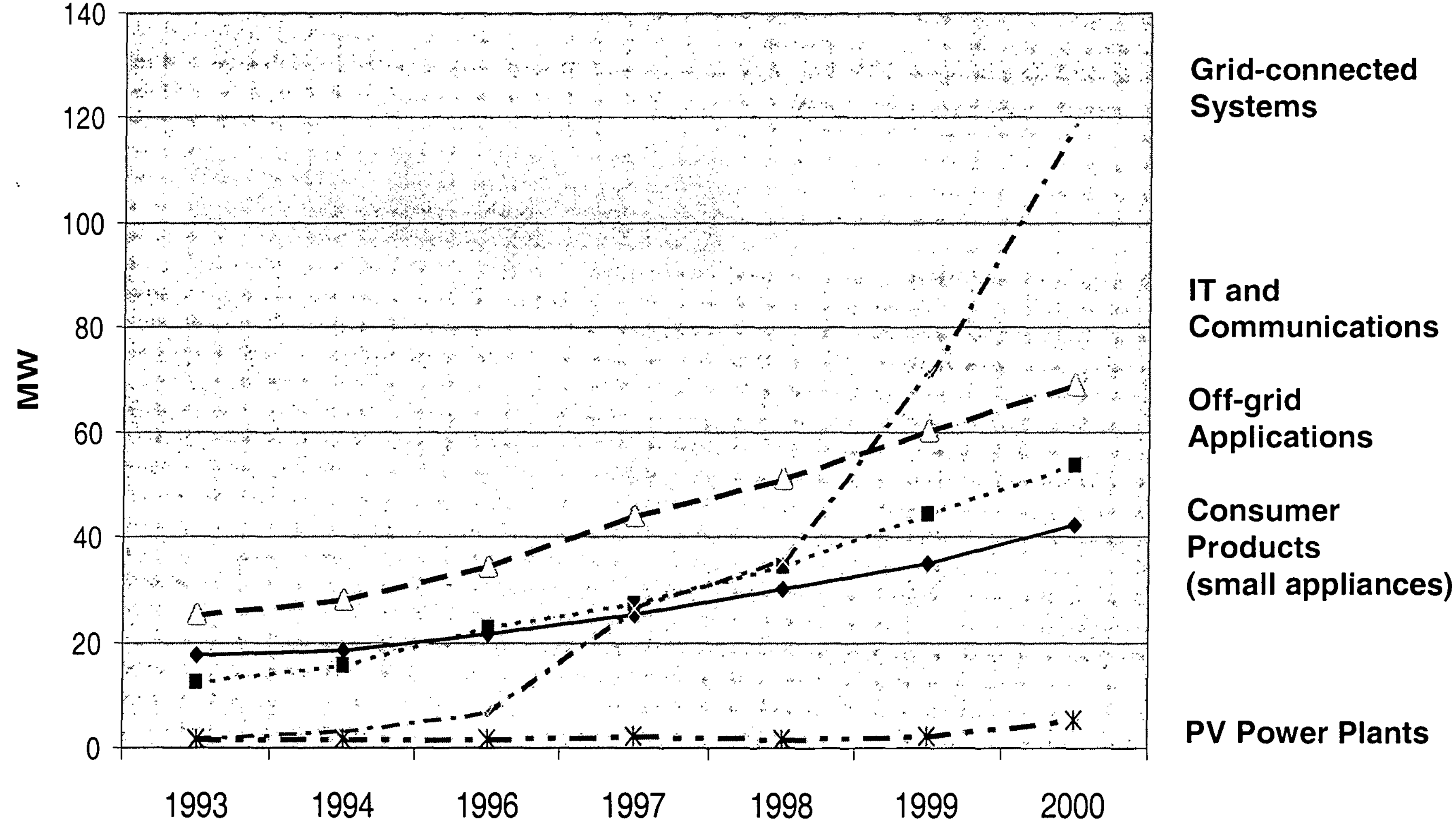


PV-cell efficiencies, Market and Cost figures



PV-Applications and rapid Development of the grid-connected Sector

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Availability of Electric Energy - illustrated by illumination levels

Source: NASA, 2001

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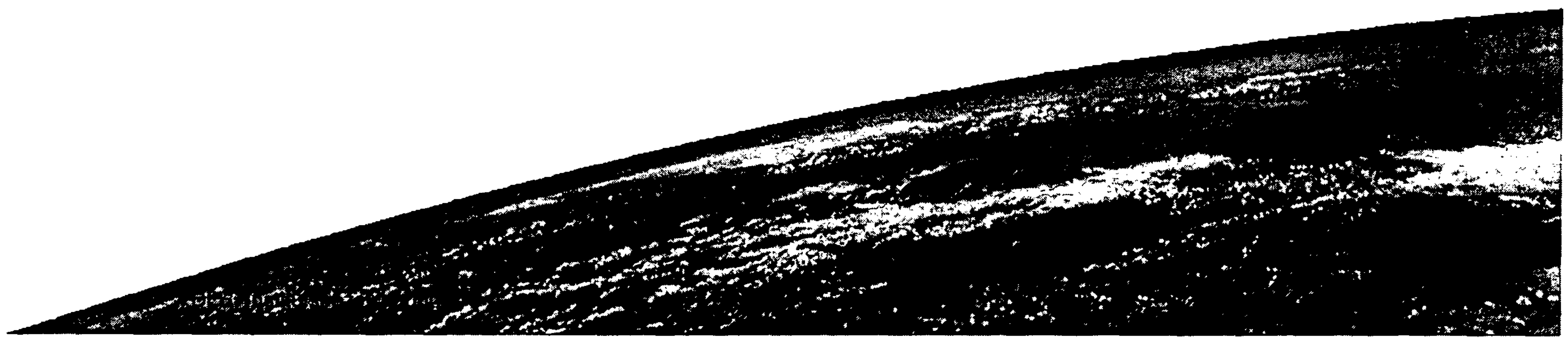
Energy Consumption and energetic Equivalent of PV installed

Region	Energy consumption kg CE p.cap. (annual)	Energy Equivalent (ann. install. PV) kg CE p.cap.	Examples of p.cap. energy consumption (specific states)
North America	11500	0,9	
Europe	5400	1,5	Germany (5690) - Poland (3680)
Japan / Ocean.	2600	4,2	Japan (5200) - Philippines (550)
S / E Asia	1050	0,9	Thailand (1450) - India (420)
South America	890	0,5	Brazil (1010)
China	990	0,1	
Africa	400	0,4	Egypt (820) - Tanzania (37)
Rest of the World	350	0,2	



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Financing Schemes for Solar Appliances

Strategic Concept	Preconditions	Remarks	Future Aspects
Private Investors	Significant Purchasing Power with private entities; This condition is hardly applic-able in 3rd World	Not promising in the short-term (sufficient liquidity ?), but this concept is rather successful in Europe!	Possibly important, if comfort devices become available
Banking instruments	Revolving funds depend on a sufficiently strong banking system and aim at a long-term effect	Successful approach in S.Amer. and East Asia	Banks must accept the PV as reassurance. Lifetime of the PV-system can be critical.
Government. programmes	Large funds may yoke the gov. budgets	Chances of a "fast" progress, but problems with political decision making	Limited budgets may curb the achievements. Politically risky!
International Subsidies	Often confined to cases of urgency or to agreements between governments	Limited budgets, not oriented on demand but on available budgets	No feed-back to the local market, limited involvement of local labour

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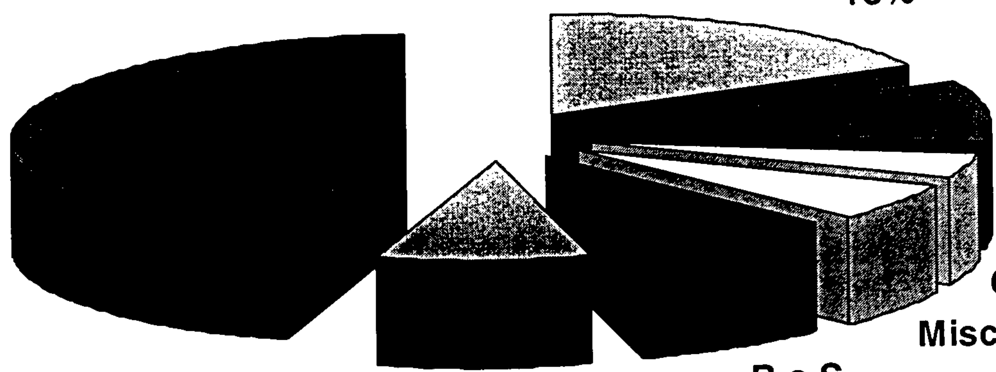

Cost Breakdown of a PV-System for User Appliances

(The Cost Distribution depends on the System Size and the Location)

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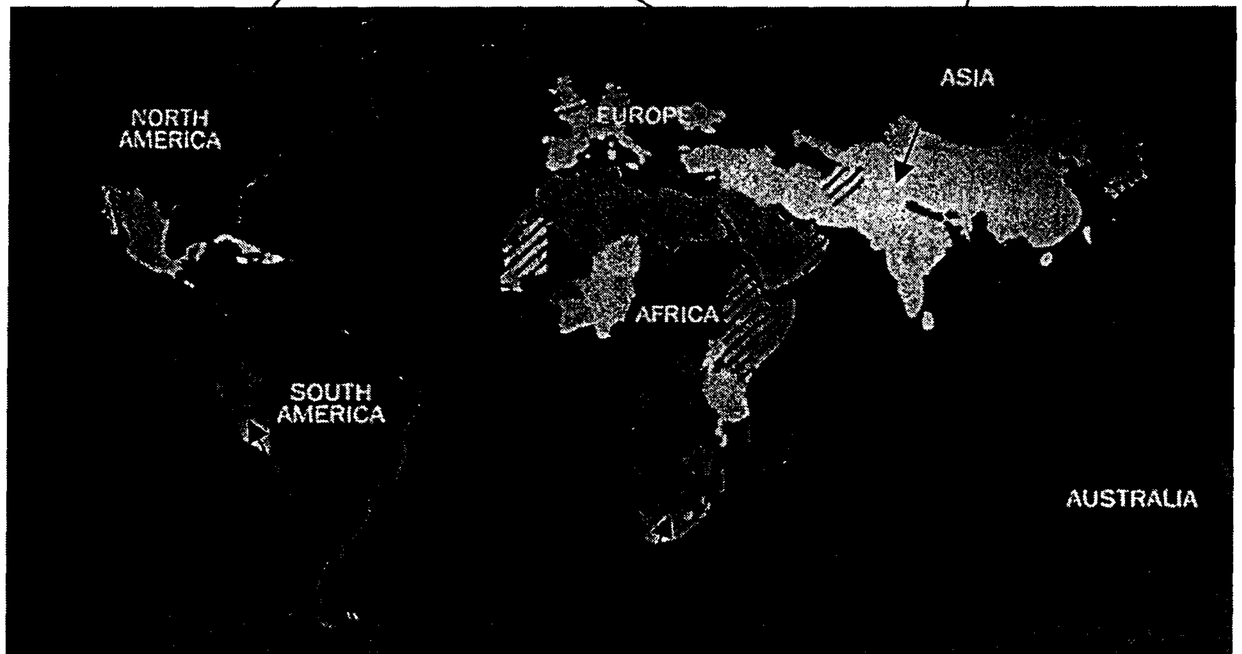
Water Resources, m^3 per capita and year



/// Shaded areas: Access to safe water for less than 50% of population

Source: National Geographic, 2001

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Values of Reliability of Energy Services (commercial applications)

Service	**Average costs of down time** Industrialised Countries	Example:
Small business	Up to 7500,-- $ / day	
Cellular communication	40.000 $ / hour	
Telephone sales services	>65.000 $ / hour	Airlines, Brokers

C.J. Weinberg: Keeping the Lights on – Renew. Energy World, Jul/Aug. 2001

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PV - System Costs and Energy Costs per kWh

Location	PV module costs	El. energy refunds	Remarks
USA	6,15 $ / W	0,08 ... 0,17 $ / kWh	Refunds depending on tariffs (base load / peak load conditions)
Europe	> 6,30 $ / W	0,10 ... 0,45 $ / kWh (highest value: Germany)	kWh-refunds in Europe are subsidised, inspired by an assessment taking into account low insolation conditions
Mediterranean	>6,-- $ / W	0,1 ... 0,3 $ / kWh	favourable solar conditions lead to higher annual output, refunds from utilities may be subsidised
Mediterranean – (remote areas)	> 6,50 $ / W	No generalised data available	Complex systems may incur higher costs, but any other energy services are more expensive in remote regions

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Solar appliances – Purpose and Utilisation Aspects (Part 2)

Small community applications:

Street Lights	similar to Lighting, but also dedicated solutions	commercial, see "Lighting"	economic	no fossil alternative in off-grid locations (even in industr. regions)
Publ. Addr. / Educ. Systems	various concepts, 200 … 2500 W_{Pk}; battery buffer $>3^{Day}$	Commercial; power system part of the overall concept	Economic	
IT-Stations - power systems	broad power range; 150 W.. >5 kW_{Pk}; battery buffer $>5^{Day}$	State-of-the-art also in industr. countries	Fully commercial	No competition in off-grid applications (mountain. regions)
Isolated Grids - El.generation	Standard AC output; typ. 5….15 kW_{Pk}; with battery or hybrid back up	From the shelf solutions available, but still except. Application	Under favour. Conditions economic	Diesel or WEC is usually cheaper, limit about 15 kW

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International Subsidies	Often confined to cases of urgency or to agreements between governments	Limited budgets, not oriented on demand but on available budgets	No feed-back to the local market, limited involvement of local labour

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Solar appliances – Purpose and Utilisation Aspects (Part 3)

Agricultural Applications

Water Pumping	150 W…5 kW_{Pk}; various Pumps available, standard systems use AC conversion	Commercial, many manufacturers and types; local types can be used (standard motors / pump sets)	Advantageous in the low power range for remote settlements	Diesel pumps, wind power. Environmental concerns for Diesel
Water Treatment	Low power range, many different concepts	Test and prototype status; promising	Some devices in "routine" field service (military applic.)	No alternative for low-power applications
Irrigation - pumping - water treatment - control	Similar to Pumping	Tests under way! Local B.o.S.-components essential	No reliable data	Convent. Irrigation with Diesel, Wind or grid driven pumps

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Solar appliances – Purpose and Utilisation Aspects (Part 4)

Other Applications:

Refrigeration	150 ... 500 W_{Pk}; with / without batt.	Commercial types for small (vaccines!) to med. sized devices	Very favourable for remote applications	Practically no alternative
Air Conditioning	up to some kW, different methods applied	Prototypes and small series production	Favourable, if adapted	Grid-connected systems

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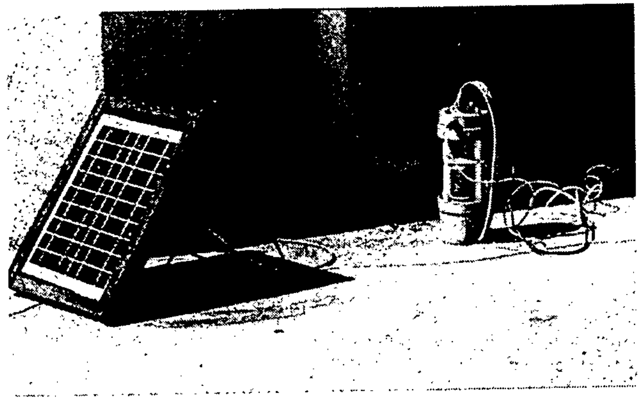

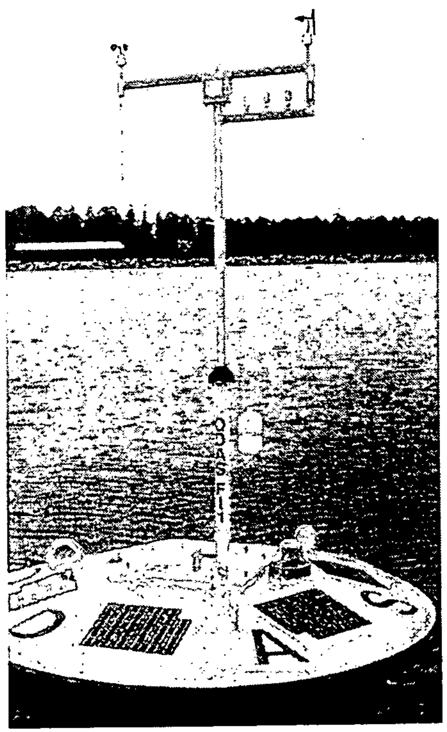

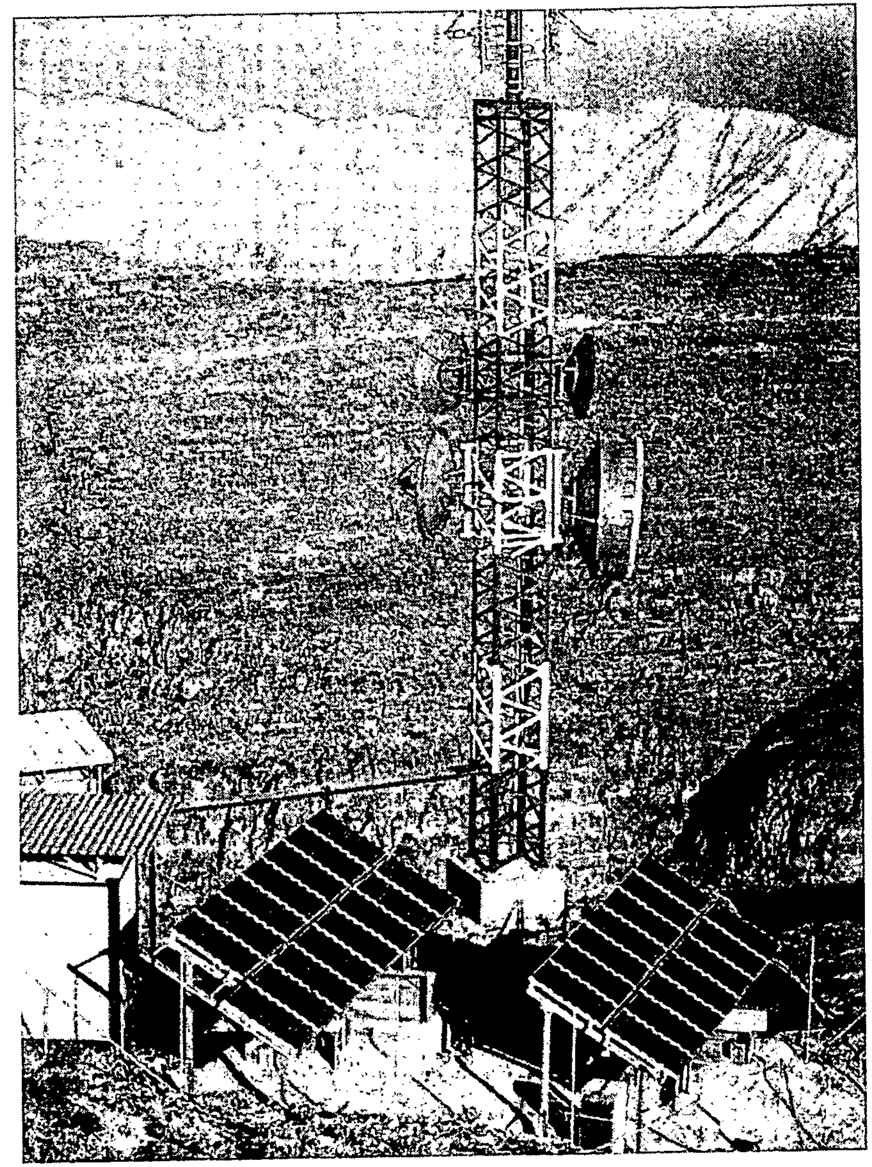

PV-Systems for remote Applications

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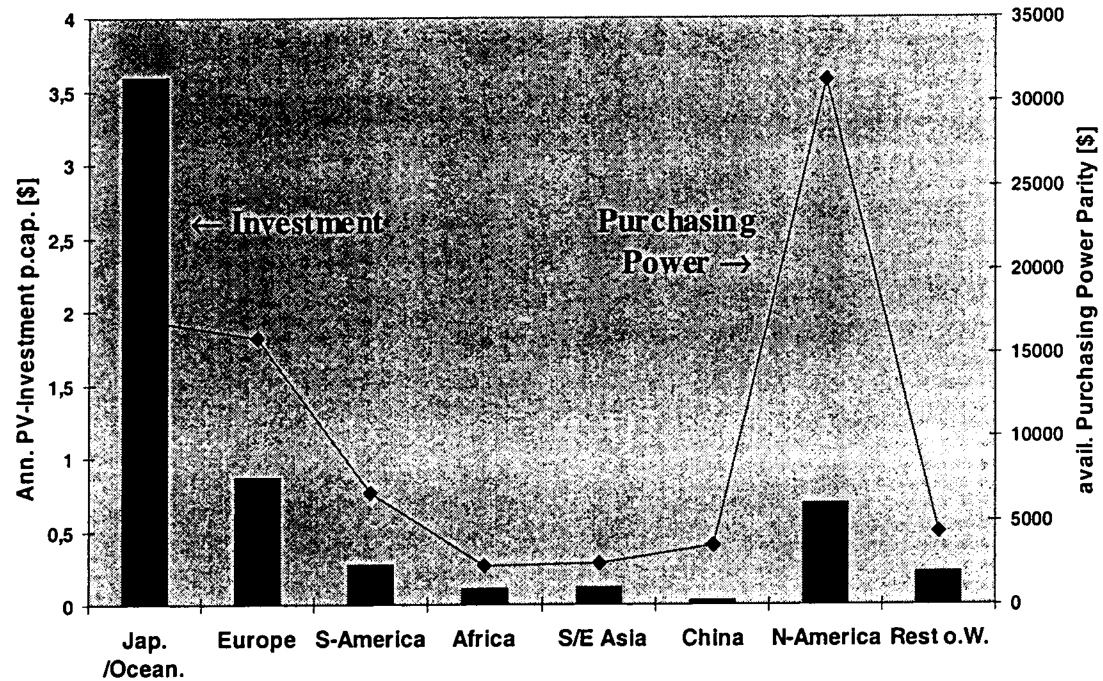

Annual Investment (PV) and Purchasing Power Parity [$]

Photovoltaic powered water purification for rural areas

by
I. Stadler, F. Kininger
University of Kassel, Germany

1. INTRODUCTION

In the last two decades photovoltaic pumping (PVP) systems were introduced very successfully. Thousands of systems were implemented in rural area of developing countries. Some of them with more than 10 years of continuous operation without any failure and maintenance. A great part of this systems were mainly constructed for public drinking water supply and build the base supply for hundreds of villagers. This drinking water frequently contains pathogen micro organisms, however the well water is still clean and potable. Latest at the stay of several days in the storage tank or at the transportation in open buckets it becomes contaminated.
For this reason several disinfection methods as

- Chlorination (Cl),
- Ultraviolet radiation (UV),
- Reverse osmosis (RO) and
- Anodic oxidation (AO),

were regarded and compared in terms of

- bactericidal long-term effect
- low energy consumption
- variable operation capability
- provability
- maintenance and
- operation costs.

In respect to the special conditions of public water supply systems in semi arid regions the AO was selected as a possible and suitable method.

2. ANODIC OXIDATION

The anodic oxidation is an electro-chemical disinfection method where no substances must be added, they are produced from naturally occurring substances in the water, i.e. salt. This oxidizing substances are short-lived free radical species such as oxygen and more stable substances such as hypochlorous acid and hypochlorite [1][2]. The production of this substances will be achieved through the electrolysis of water, principally at the anode of a electrolysis cell which is integrated in a suitable flow through reactor. Due to the special alloy of Titan/Titanoxide and the design of the electrolysis cell (Fig. 1) a so called "In Situ" operation is possible. Thus the whole well water flows through the reactor system without the need of a secondary circulation systems.

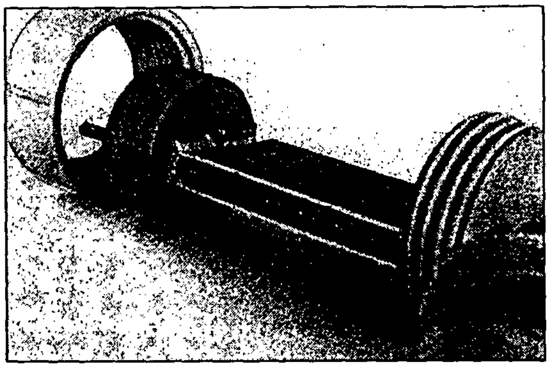

Fig. 1 : Laboratory prototype of a Titan/Titanoxide electrolysis cell

The production of chlorine products as hypochlorous acid and hypochlorite is depending on the reactor and cell design (Fig. 1), the current and voltage at the cell, as well as on the content of chlorite in the well water. Figure 2 compares the dependence of the total chlorine production rate by different chlorite contents on electrolysis voltage. The measurement was made with a current of 4 A at a water flow of about 400 l/h.

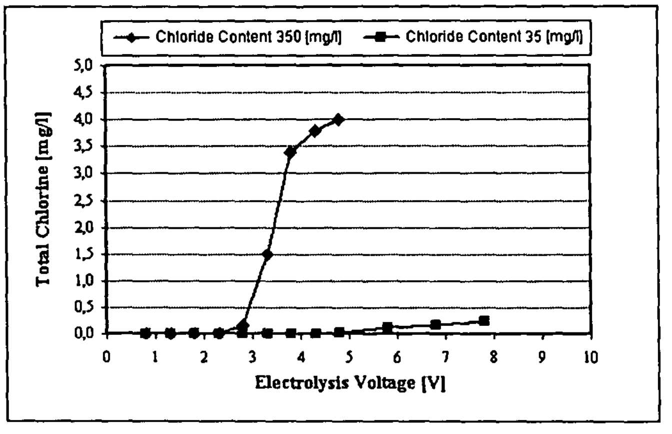

Fig. 2 : Chlorine production by chlorite content on electrolysis voltage

In the Brazilian directive for drinking water [3], the concentration of chlorine for tap water is recommended in the range of 0.2 and 0.8 mg/l. Based on a self consumption of chlorine of about 10 % per hour a higher mean chlorine production of 1.0 mg/l is sufficient to guarantee the disinfection effect.

3. CONTROL

To control the AO-system, this means to adapt the disinfection effect if the chlorite content or the water flow is changing during the year, a "RedOx Potential" sensor was implemented in the water storage tank. The "RedOx Potential" is a measure for the potential of a liquid to oxidize pathogen micro organisms [4]. This RedOx potential corresponds to a specific value of chlorine as it shown in figure 3. This means for the control unit, if a RedOx potential of 650 mV up to 750 mV is measured a concentration of about 0.3 up to 1.1 is given, so the water could be used as drinking water.

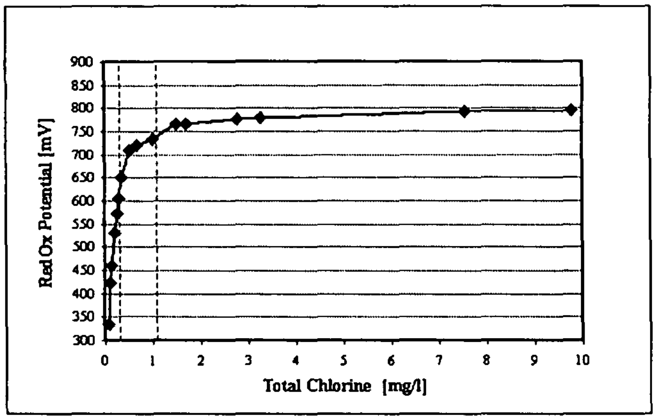

Fig. 3 : Relation between total chlorine and RedOx potential

This information of the disinfection effect is turned over in a control unit. In combination with the information of the water flow of the pumping system the current output of the electrolysis cell will be influenced in a manner that the disinfection effect could be guaranteed. In case that this aim couldn't reached the system will be switched of.

4. PROTOTYPE

Based on the mentioned knowledge a prototype of a "Photovoltaic Pumping Anodic Oxidation System" was realised in a semi arid region, with saline groundwater in the north-east of Brazil. The system was installed in a small village called Coité de Pedreiras that consist of about 20 households of which most have a traditional well.

Fig. 4 : AO-system with PV-generator, water storage and technical building

The system were installed in the centre of the village beside the elementary school (Fig. 4). A membrane DC-pump was installed in a 36 m deep well which ground water level is varying from about 16 m during rainy season down to 25 m in the dry season. Even the chlorite content is varying from about 300 mg/l up to 700 mg/l.

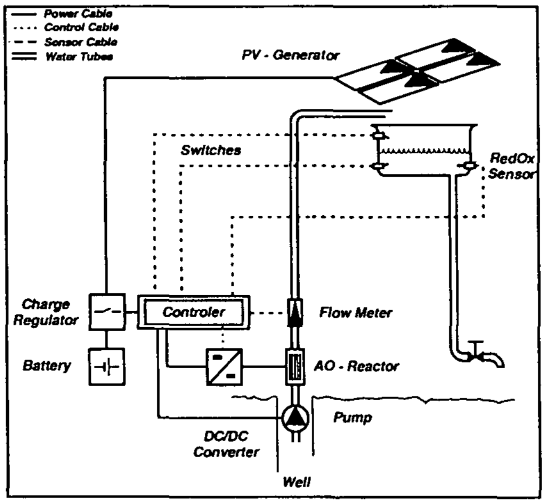

Fig. 5 : Block diagram of the AO-system

The power supply of the AO-system is integrated in a standard battery based PV-system which is powered by a 220 W_{peak} PV-generator connected at a standard charge regulator with a 24 V car battery with 45 Ah. The standard car battery was selected with the back ground that the pumping system is only in operation during day time. So no deep cycling of the battery occurs and the battery live time is acceptable. The controller has a defined operation window depend of day time and battery voltage.

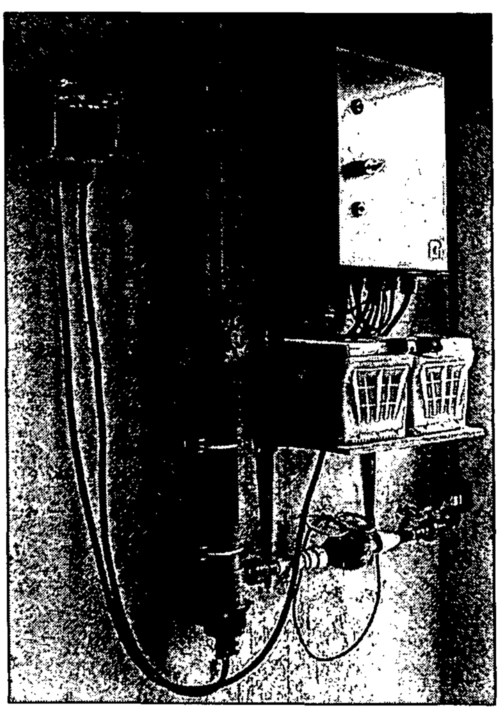

Fig. 6 : AO-system with DC/DC converter, control cabinet, AO-reactor, battery storage and flow meter

The AO-system is designed for a disinfection rate of about 400 l/h and installed between the pump and the storage tank (Fig. 5). Related to the lowest chlorite content of 319 mg Cl^{-}/l the maximum power of the AO-system is about 12,4 W at a electrolyse voltage of 3,1 V. Thus the highest specific energy consumption is 37,5 Wh/m³.

5. CONCLUSIONS

The prototype was tested comprehensively over several months. The disinfection effect was proved by measuring the chlorine concentration at the water tap. A biological water analysis was additionally made, with the result that the water is corresponding the Brazilian directive of drinking water. The energy consumption is between 30 Wh/m³ and 40 Wh/m³. Compared with the energy consumption of the water pump between 170 Wh/m³ and 210 Wh/m³ this is in an acceptable value. The power supply system was slightly oversized, however this is related to the relatively low average water consumption of 1,6 m²/day and the relatively low average pumping height of about 20 m.

A major problem is the formation of calciferous deposits on the cathode surface. These deposits should be removed manually, depending of the content of the calcium of the well and the water treated, monthly or yearly. For this a toothbrush and some ml of citric acid are necessary in order to clean the cathode in about five minutes.

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Improvement of the Quality of Life by Rural Electrification with PV:

Water Disinfection with UV and AO

Franz Kininger, Ingo Stadler

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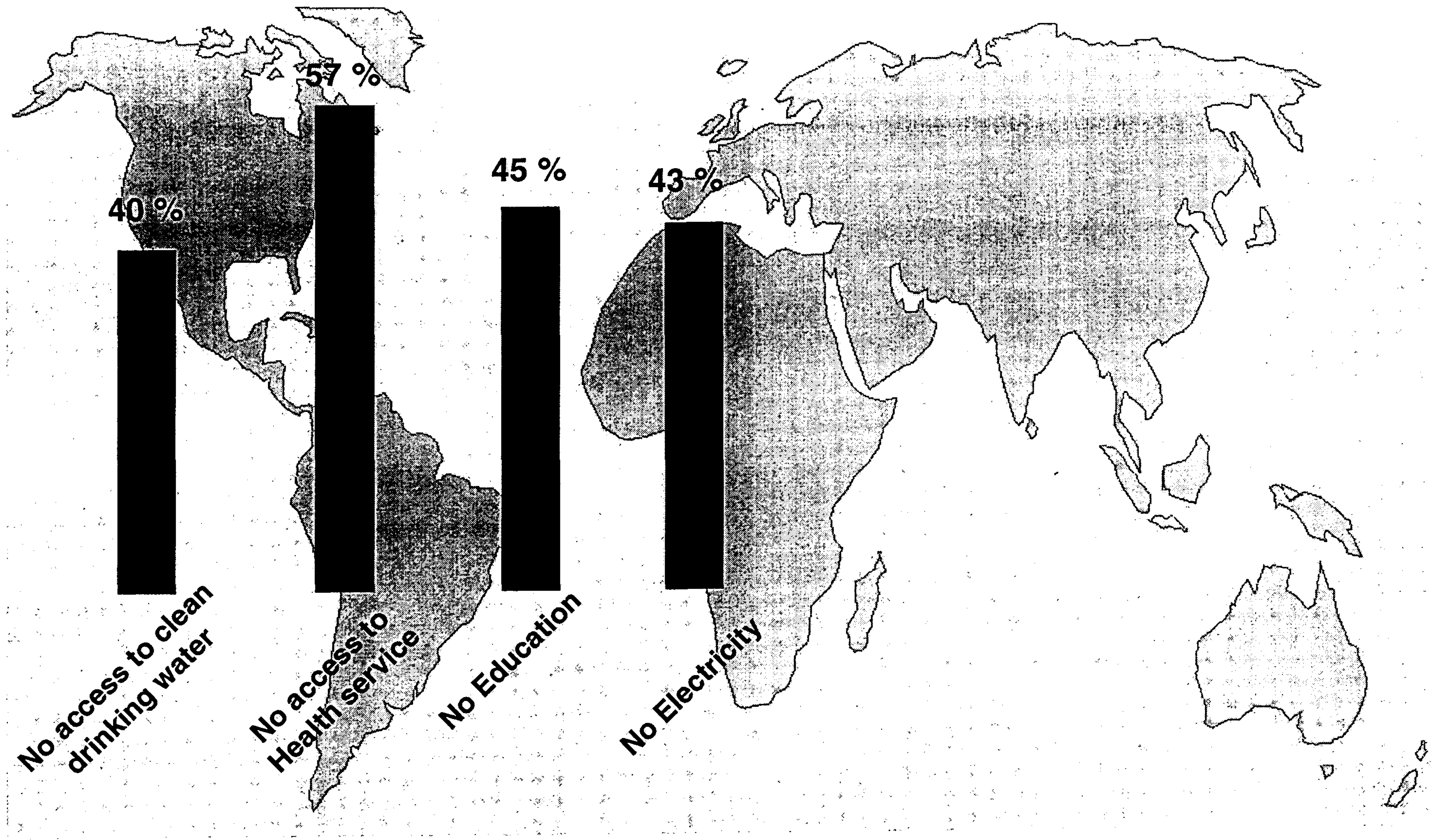

Rational Energiewandlung IEE

Rural Population without basic supply

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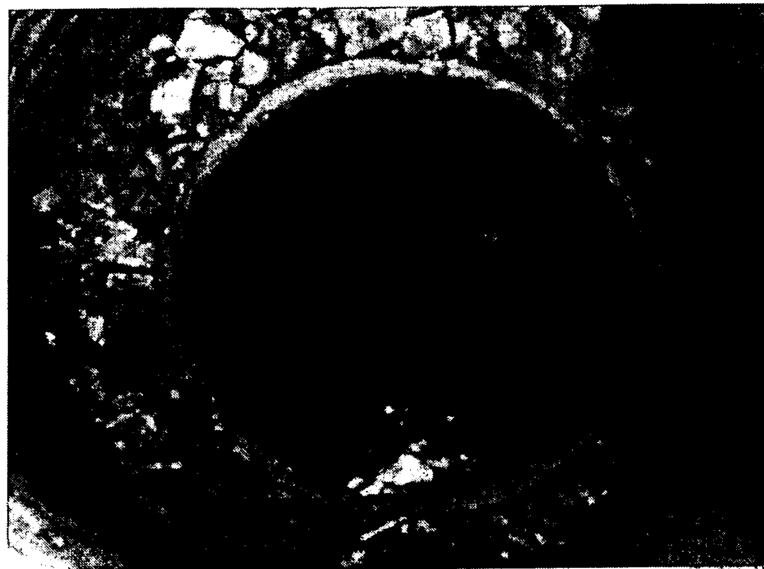
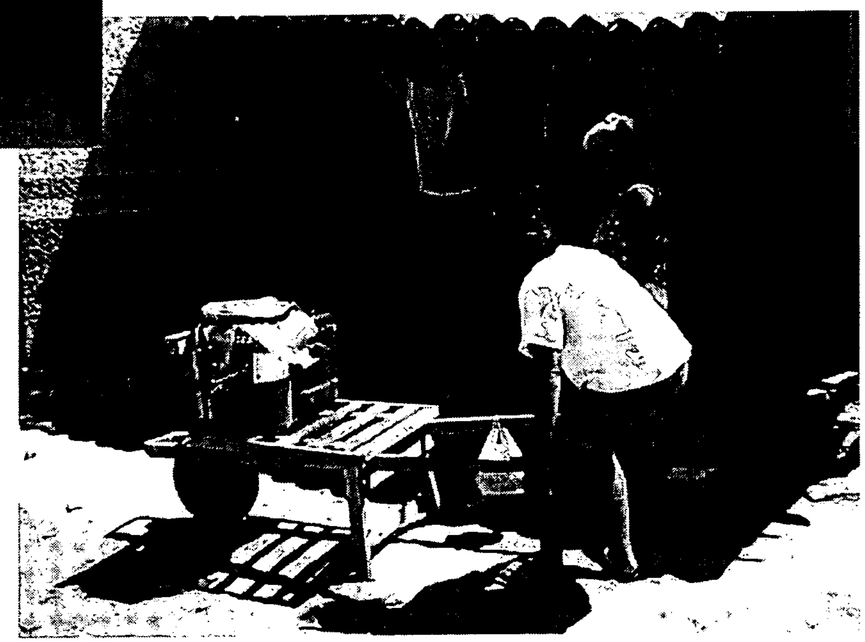
Quelle: EPIA

Humans:		
Necessary to survive	5	Ltr.
Minimum	10	Ltr.
Normal circumstances	30	Ltr.
WHO	40	Ltr.
Animals:		
Cattle	40	Ltr.
Horse	40	Ltr.
Pig	20	Ltr.
Sheep, goat	5	Ltr.
Plants:		
Rice	100	m^3/ day and hectare
Vegetables	60	m^3/ day and hectare
Cotton	55	m^3/ day and hectare
Wheat	45	m^3/ day and hectare





- 80% of illnesses in rural regions are caused by polluted water
- 2 billion diarrhoea sicknesses every year

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Current situation

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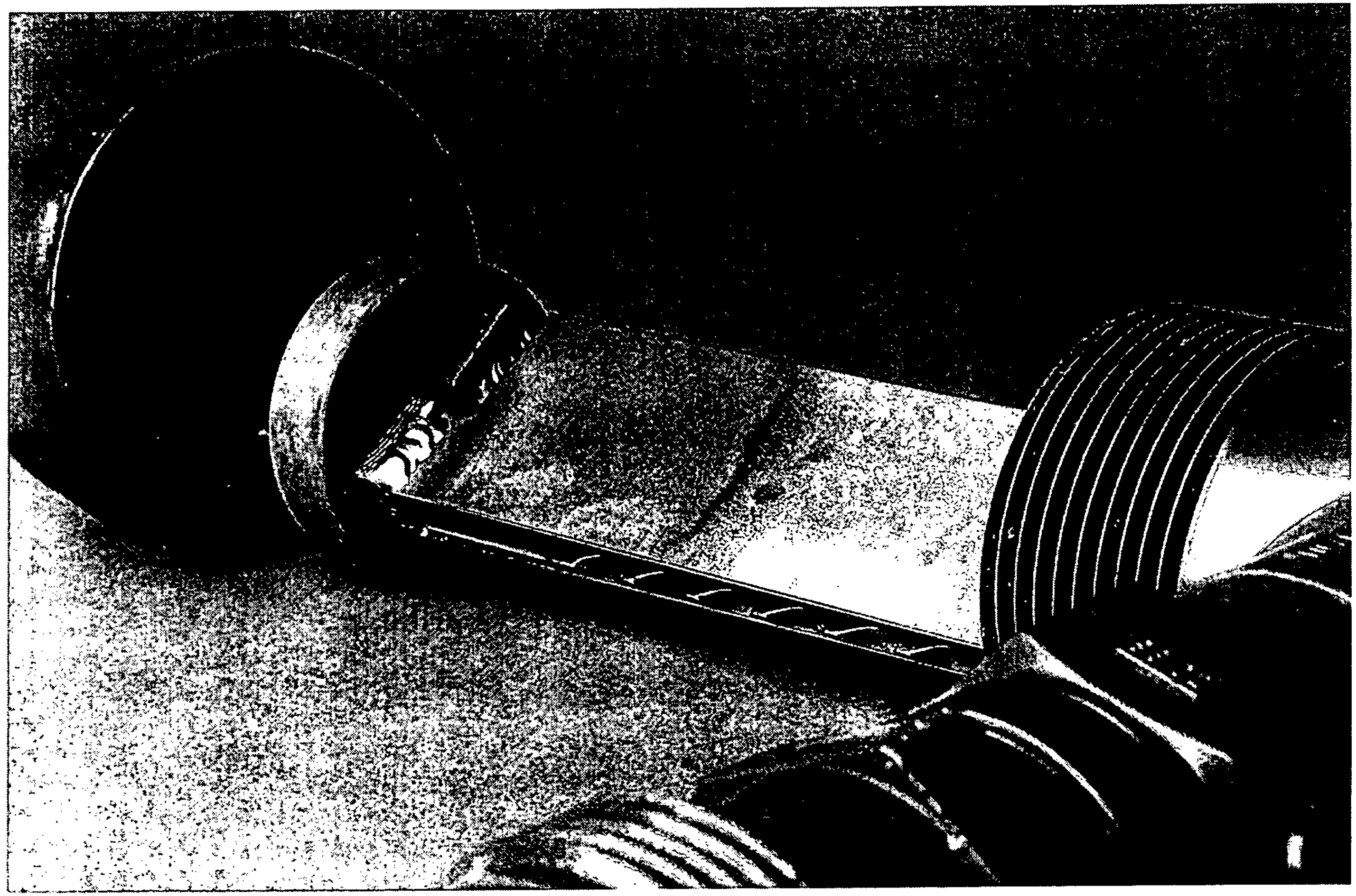

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Anodic Oxidation

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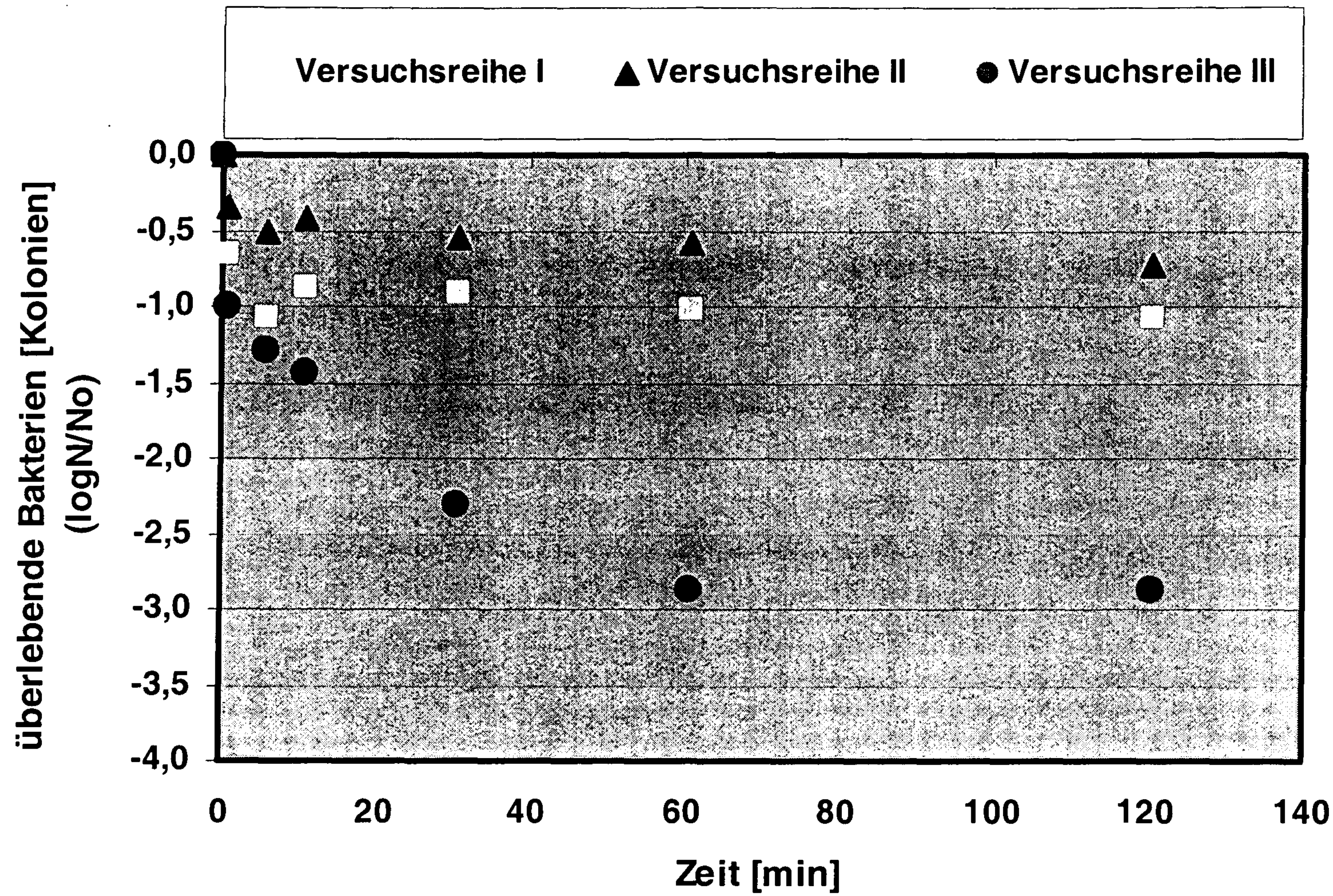

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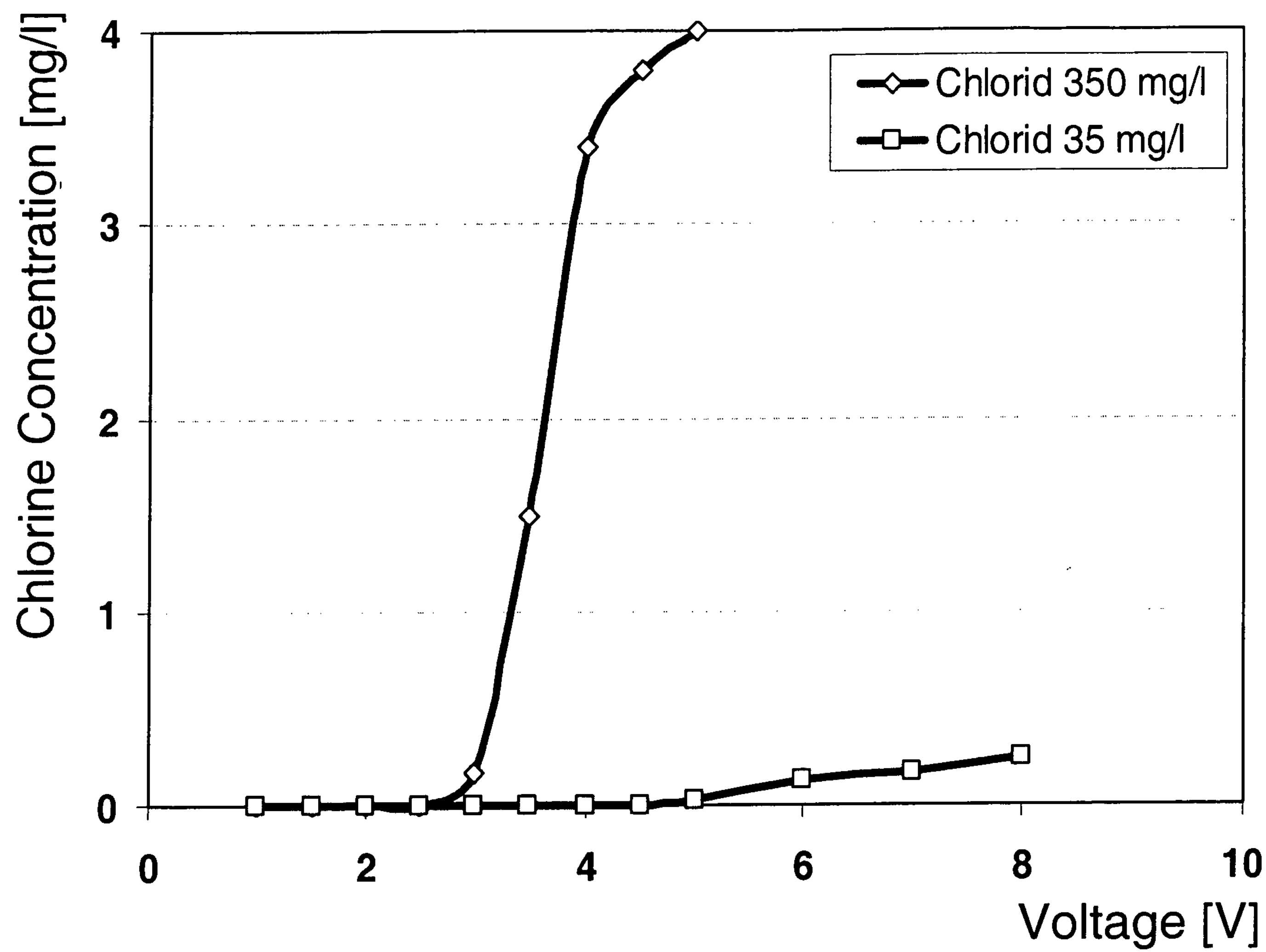

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Chlorine Concentration in Dependence of Voltage and Chloride Concentration

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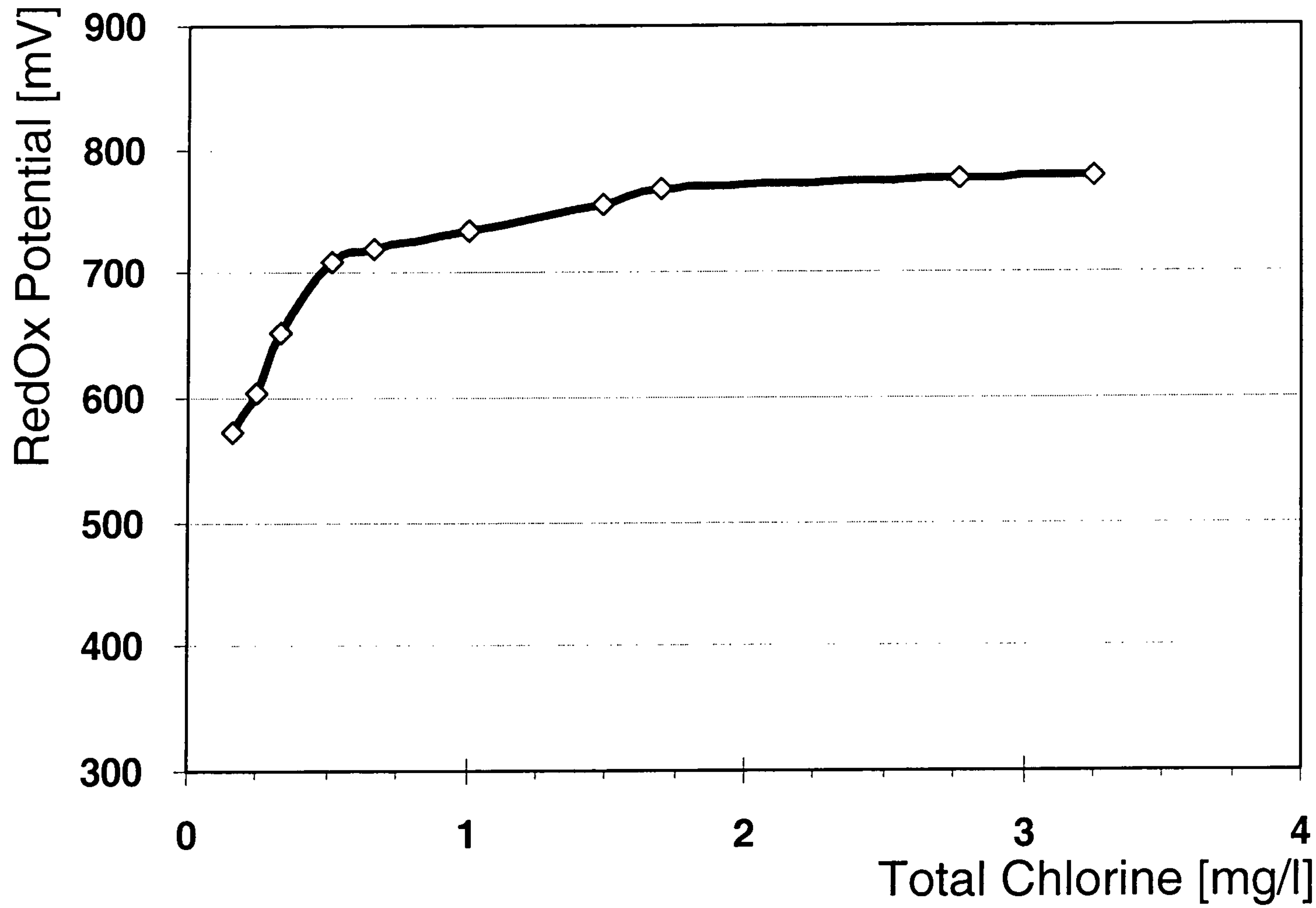
•Solubility limit in Water:	217,9 g/l
•Dead Sea:	200,0 g/l
•Red Sea:	23,2 g/l
•Oceans:	19,0 g/l
•Pedreiras drinking water:	0,35 g/l
•Limit for drinking water TVO:	0,25 g/l
•Limit for drinking water GDW:	0,5 g/l
•Kassel drinking water:	0,04 g/l



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RedOx Potential in dependence of total Chlorine concentration

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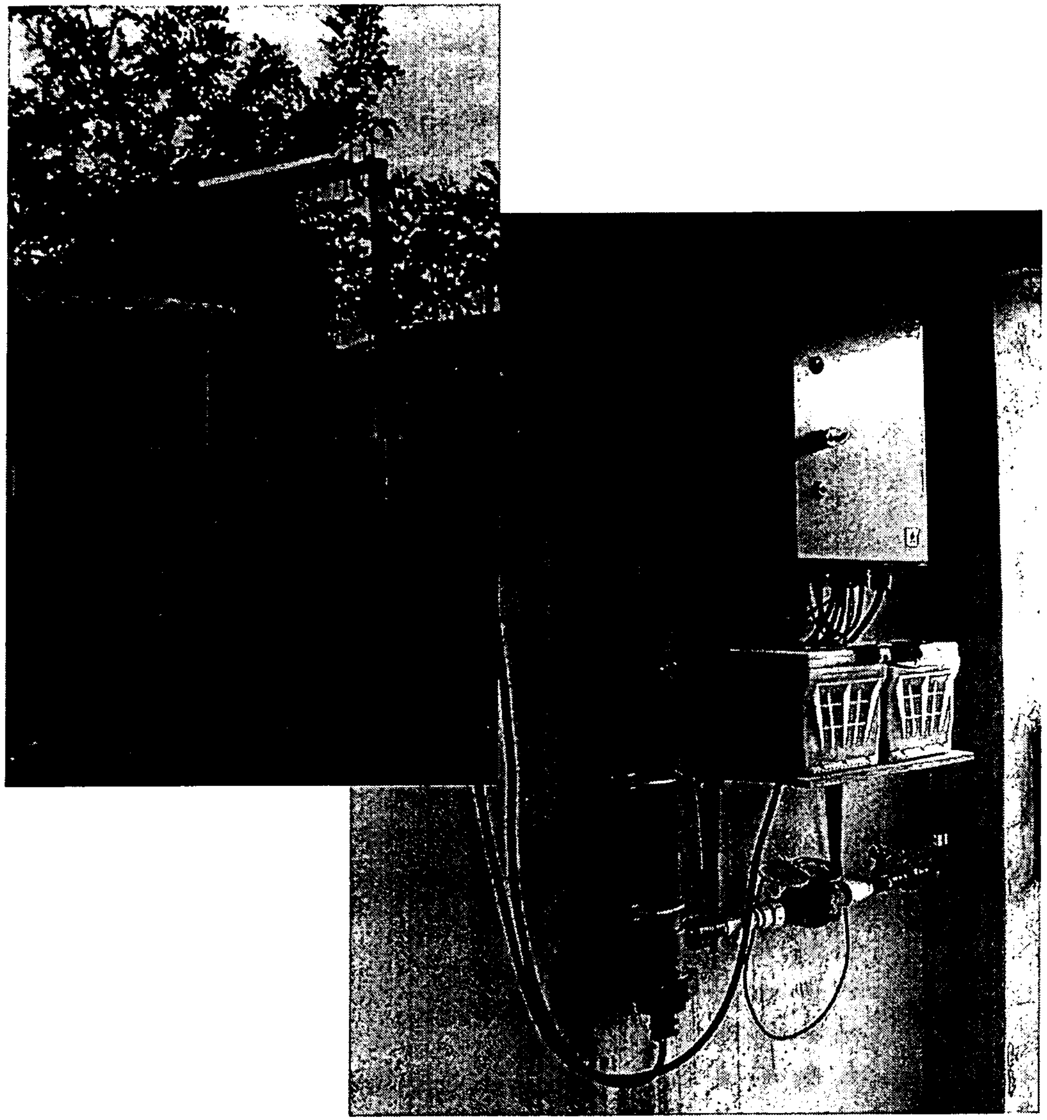

Technical data:

Disinfection capacity	400 l/h
Voltage	12 V
PV-Generator	220 W_p
Charge Controller	20 A
Battery	100 Ah
Pump	78 W
Control Unit	1 W
Head	18 m
Water Reservoir	1.000 l

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Chlorine electrolyses plant in Pedreiras CE - Brazil

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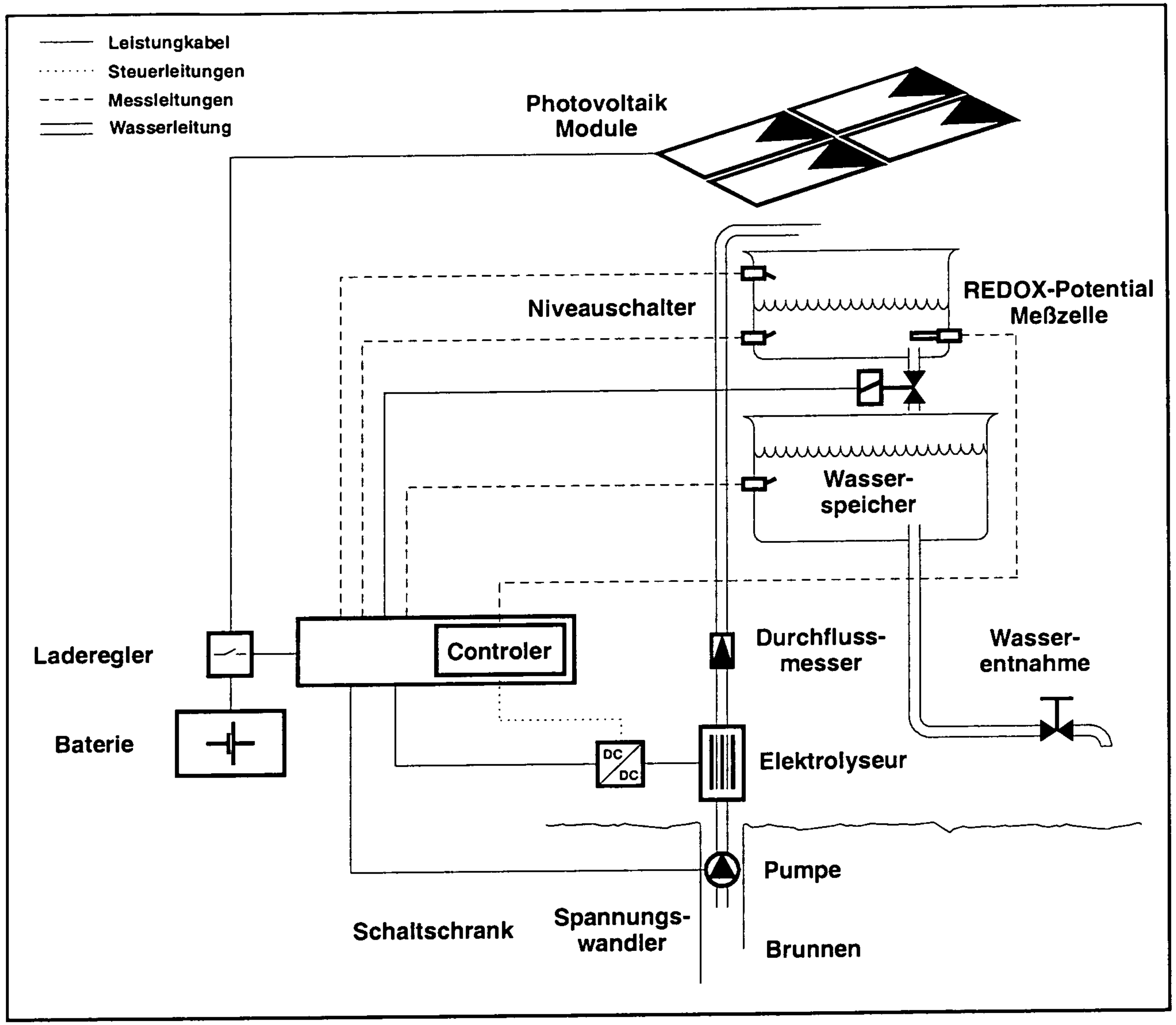

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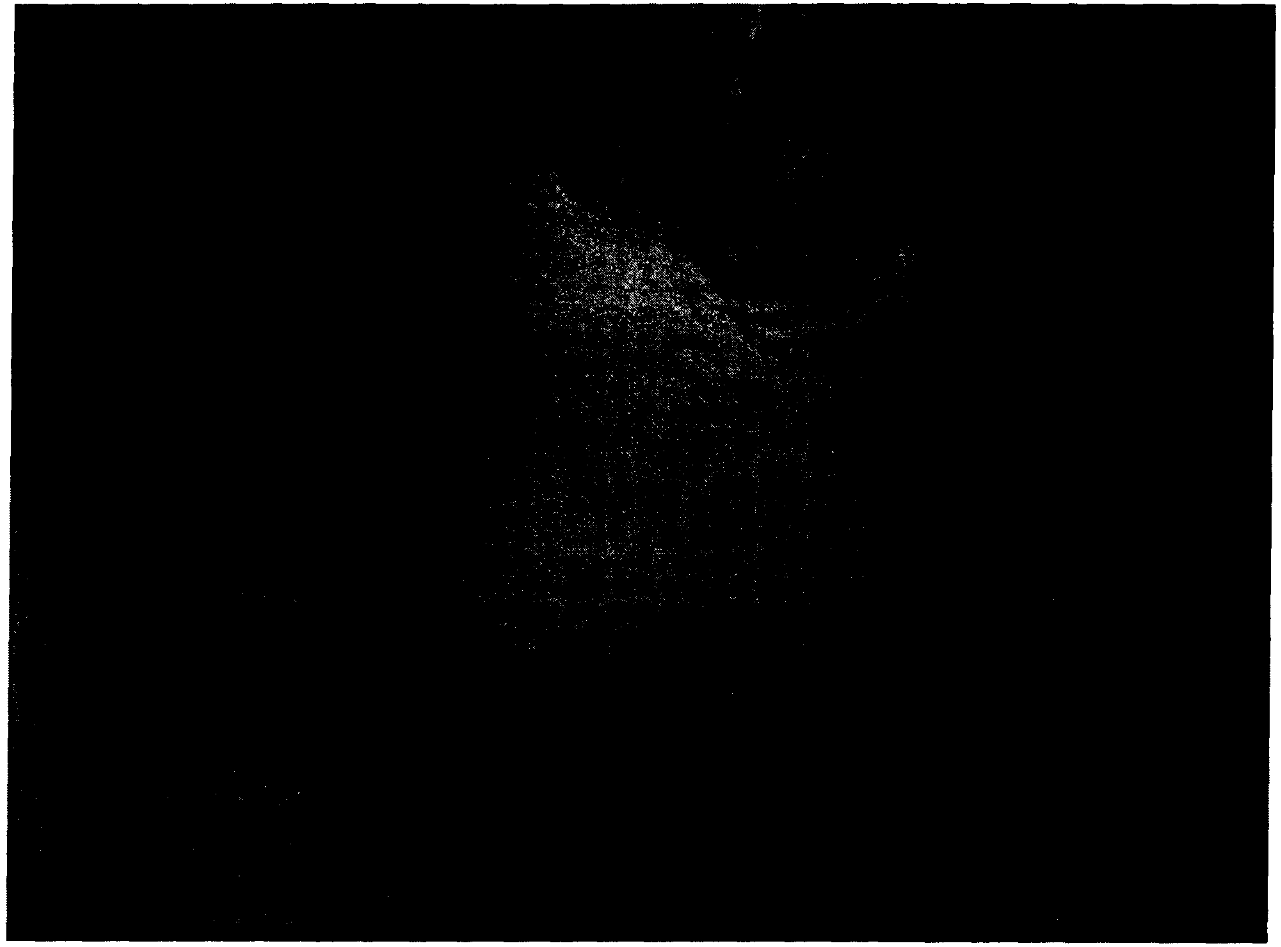
Concept of Chlorine electrolyses plant

U N I K A S S E L
V E R S I T Ä T

My skin after one hour walk around the pyramids in Cairo!



Conclusion:

- PV is better suited for Egypt than for Germany
- UV radiation is dangerous for life

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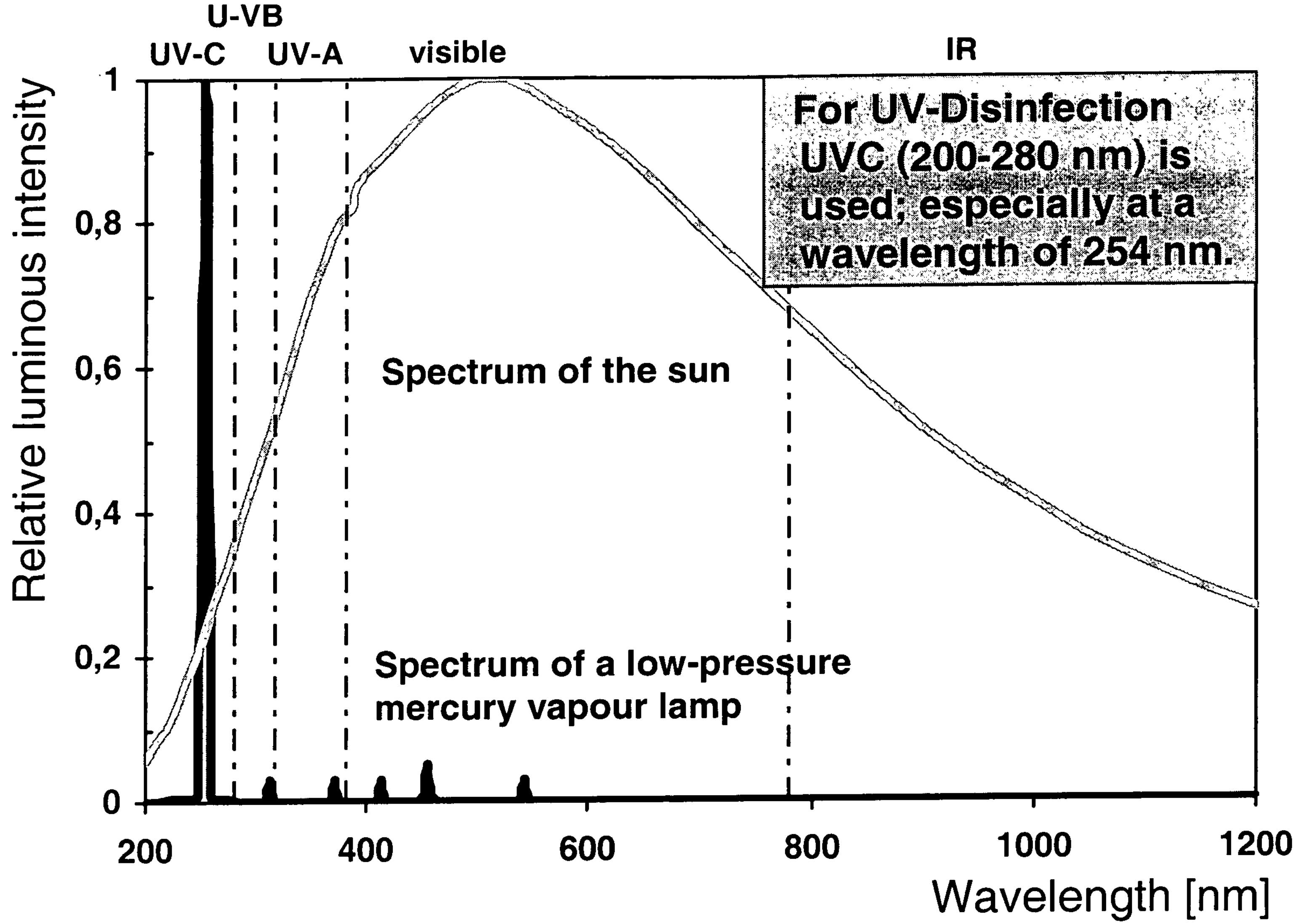

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UV Radiation

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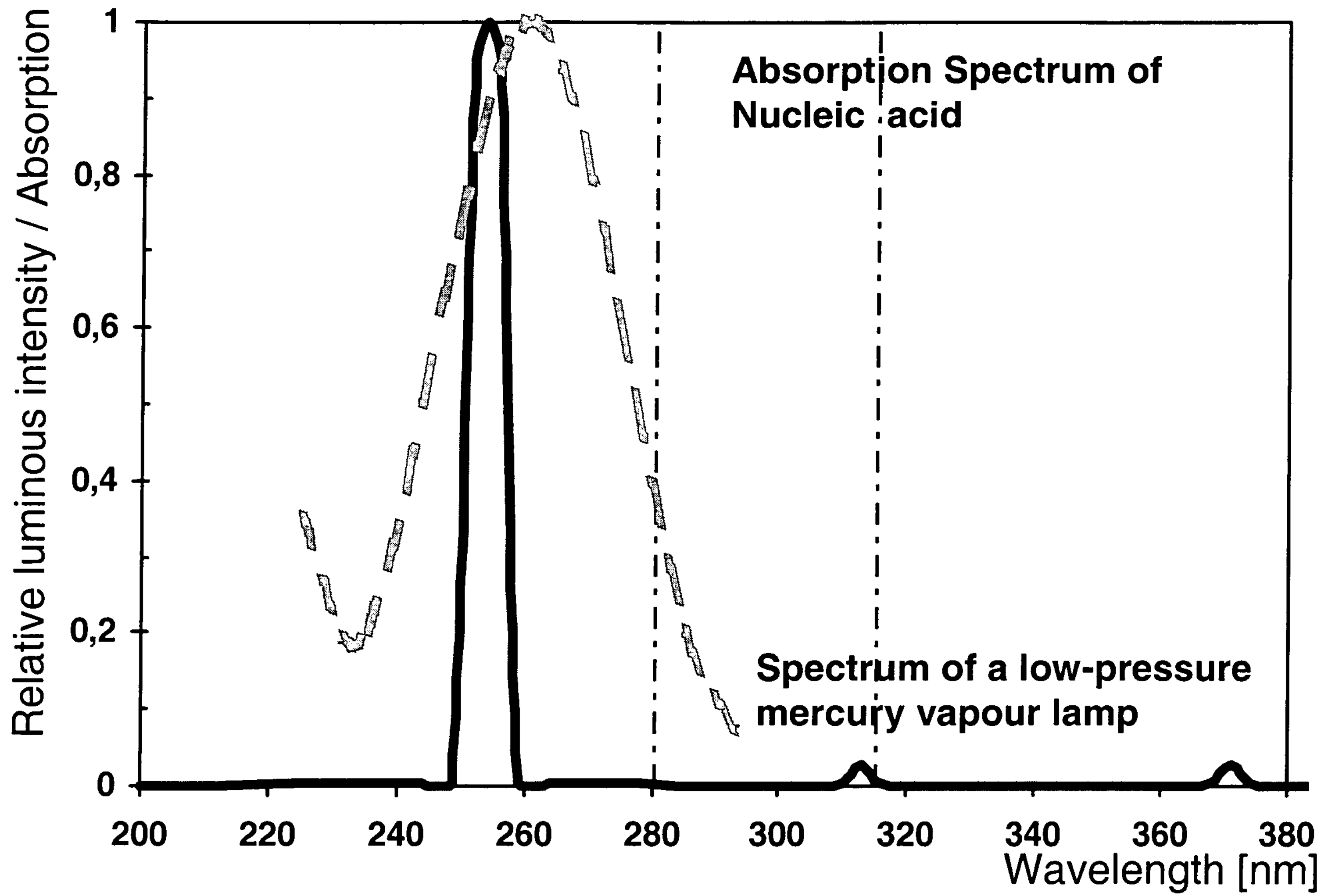

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Absorption spectrum of Nucleic Acids

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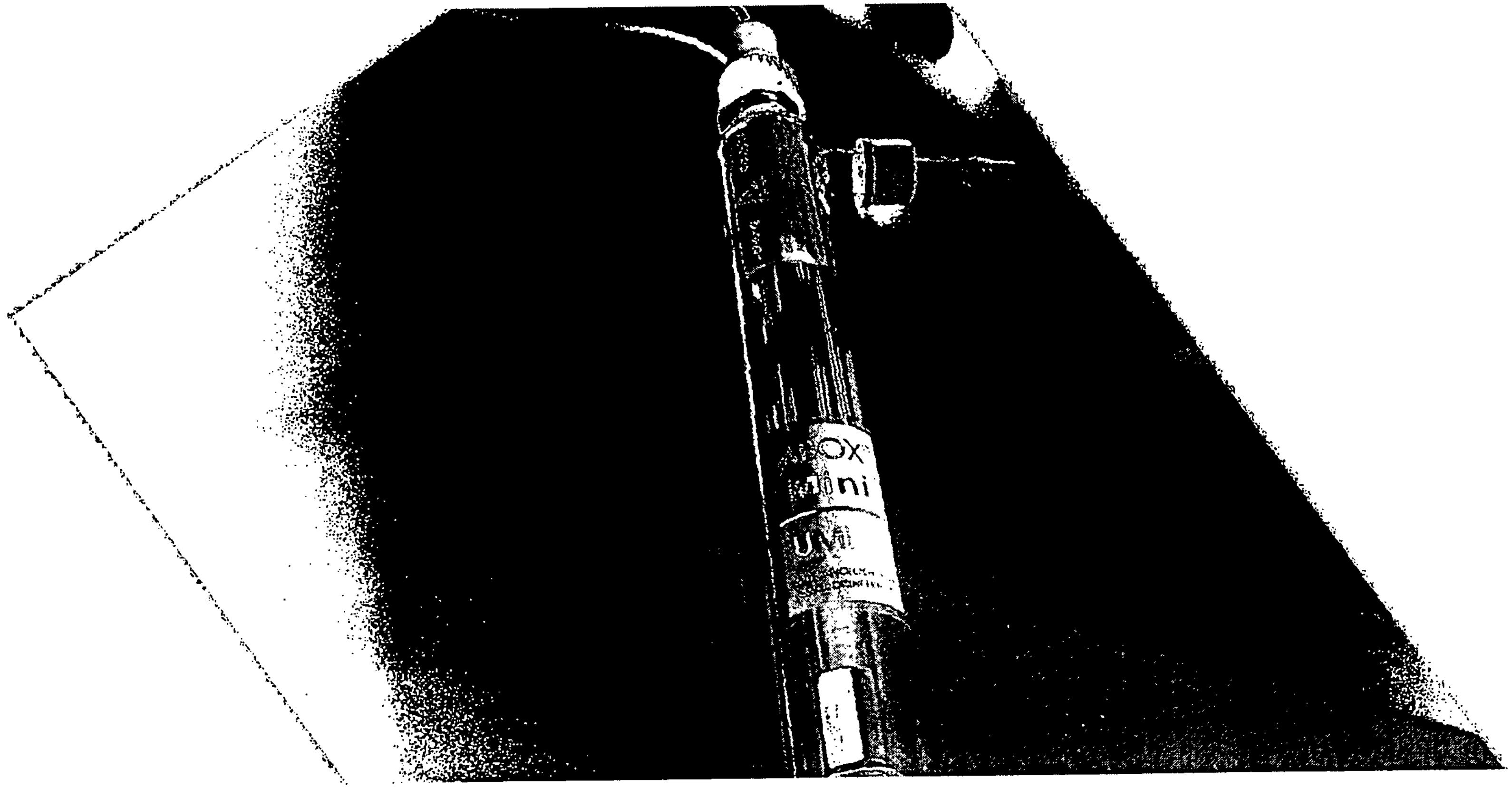

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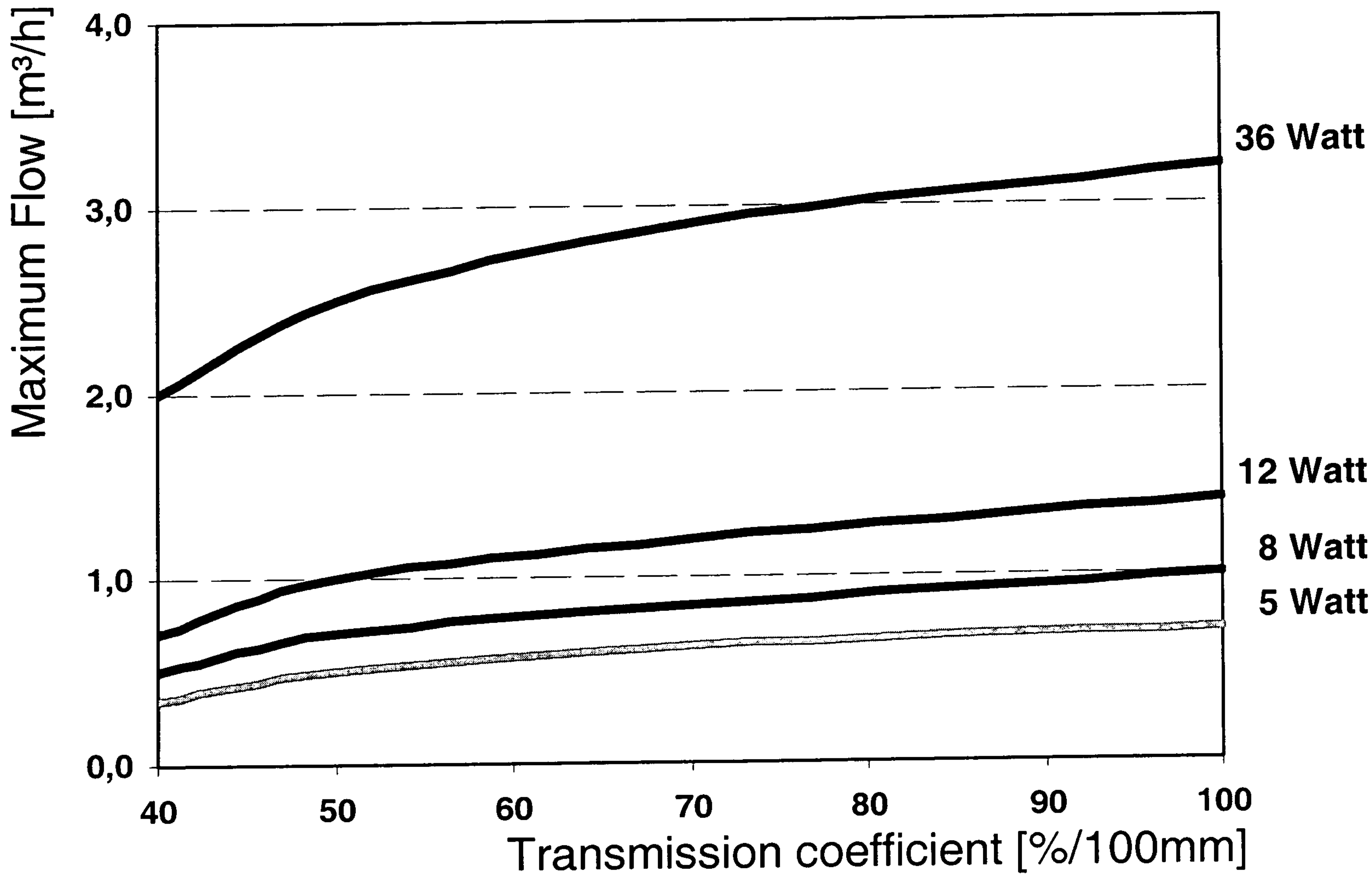

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Influence of UV-transmission coefficient

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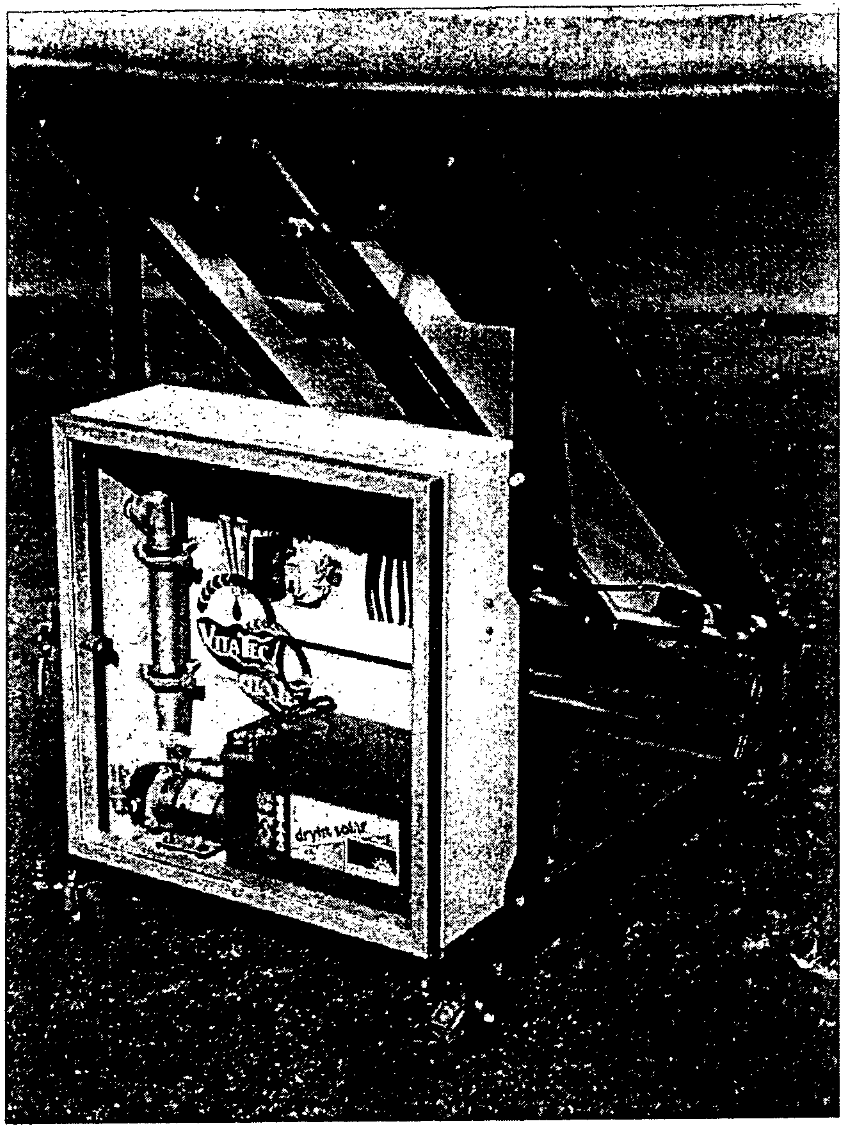

Technical Data:

UV-Reactor:

Disinfection capacity	250 l/h
Power	11 W
Durability	8.000 h

Energy Supply:

Voltage	12 V
PV-Generator	110 W_p
Charge Controller	12 A
Battery	80 Ah

System components:

Control System	1 W
Pump	11-66 W
Valve	4 W
Twilight Switch	0,25 W
Float Switch	

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Portable UV-Disinfection PV plant

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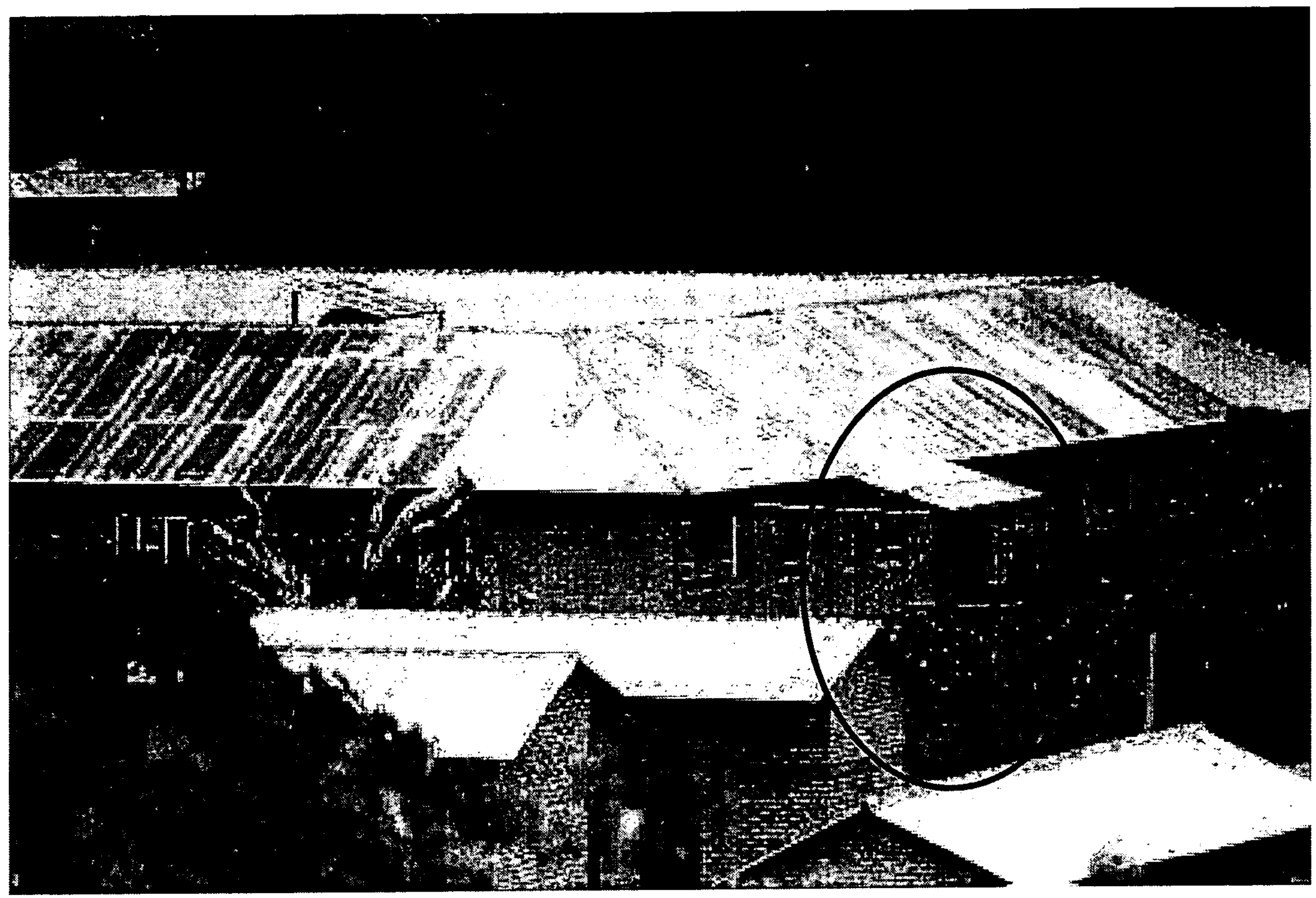

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UV Disinfection in Uganda

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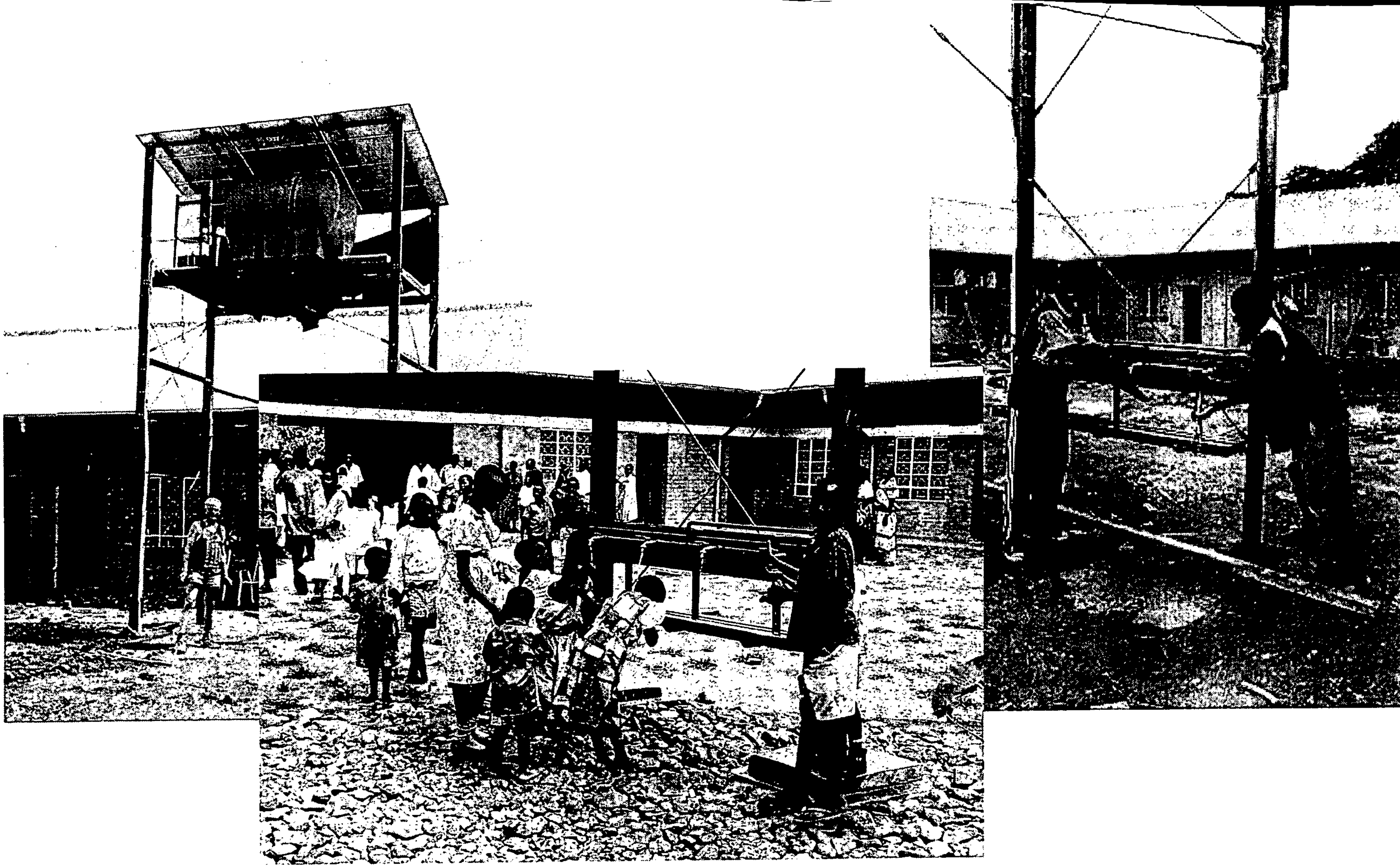

UV Disinfection in Uganda

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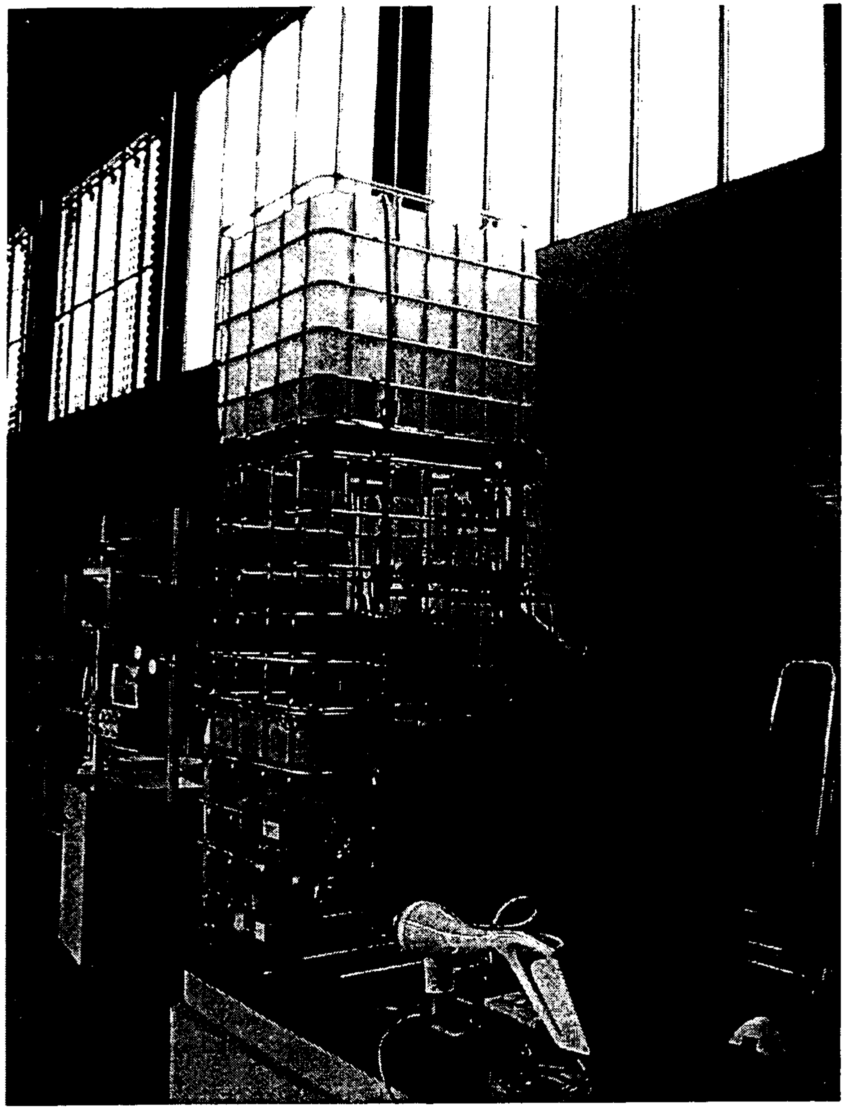

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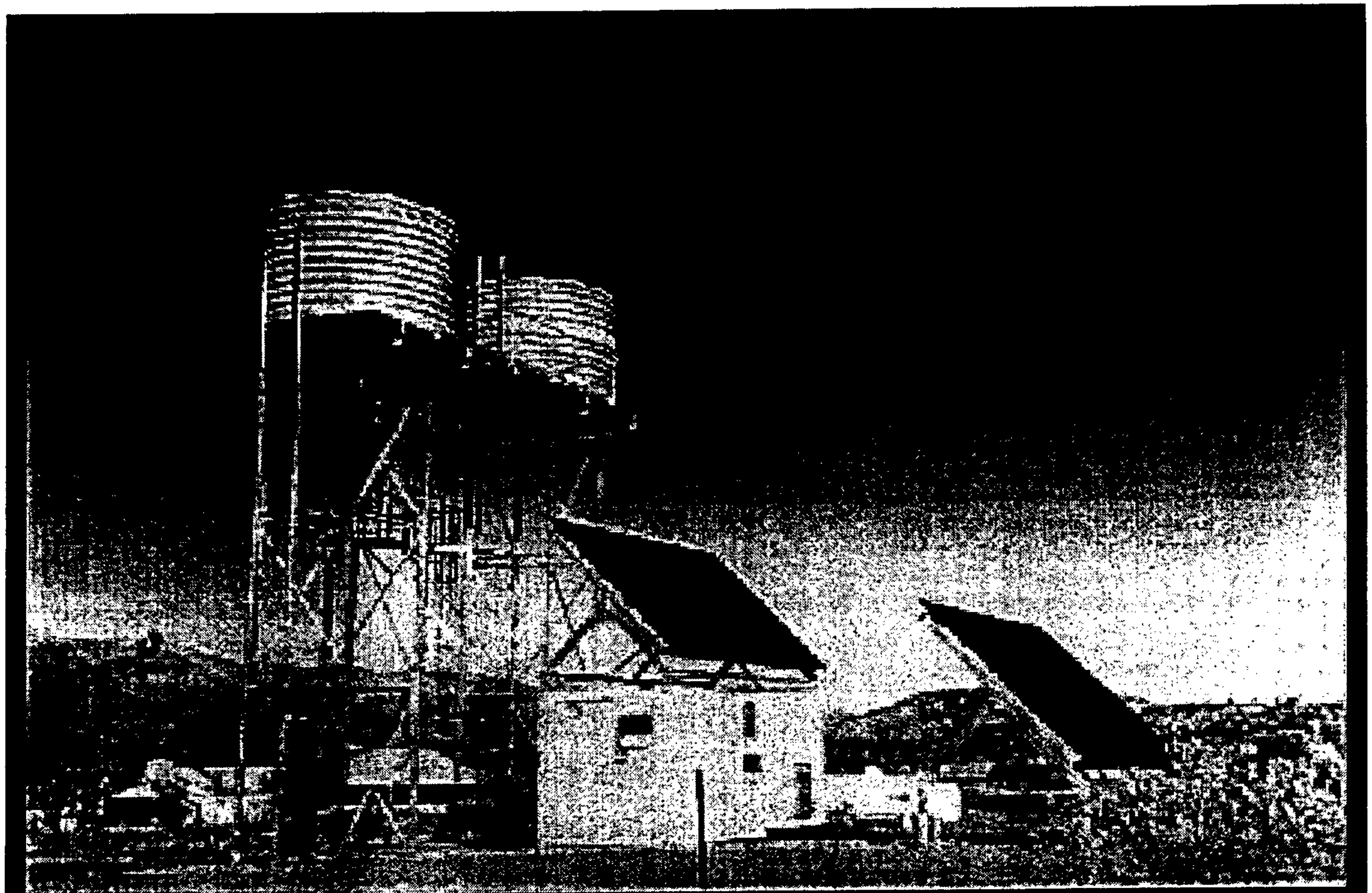

Solar powered reverse osmosis water treatment plant at Hamilton Downs youth camp near Alice Springs in Central Australia. 4 kWp of panels in front of the tanks are part of the hybrid power station. 480 Wp of panels on the tank stand power the reverse osmosis system.

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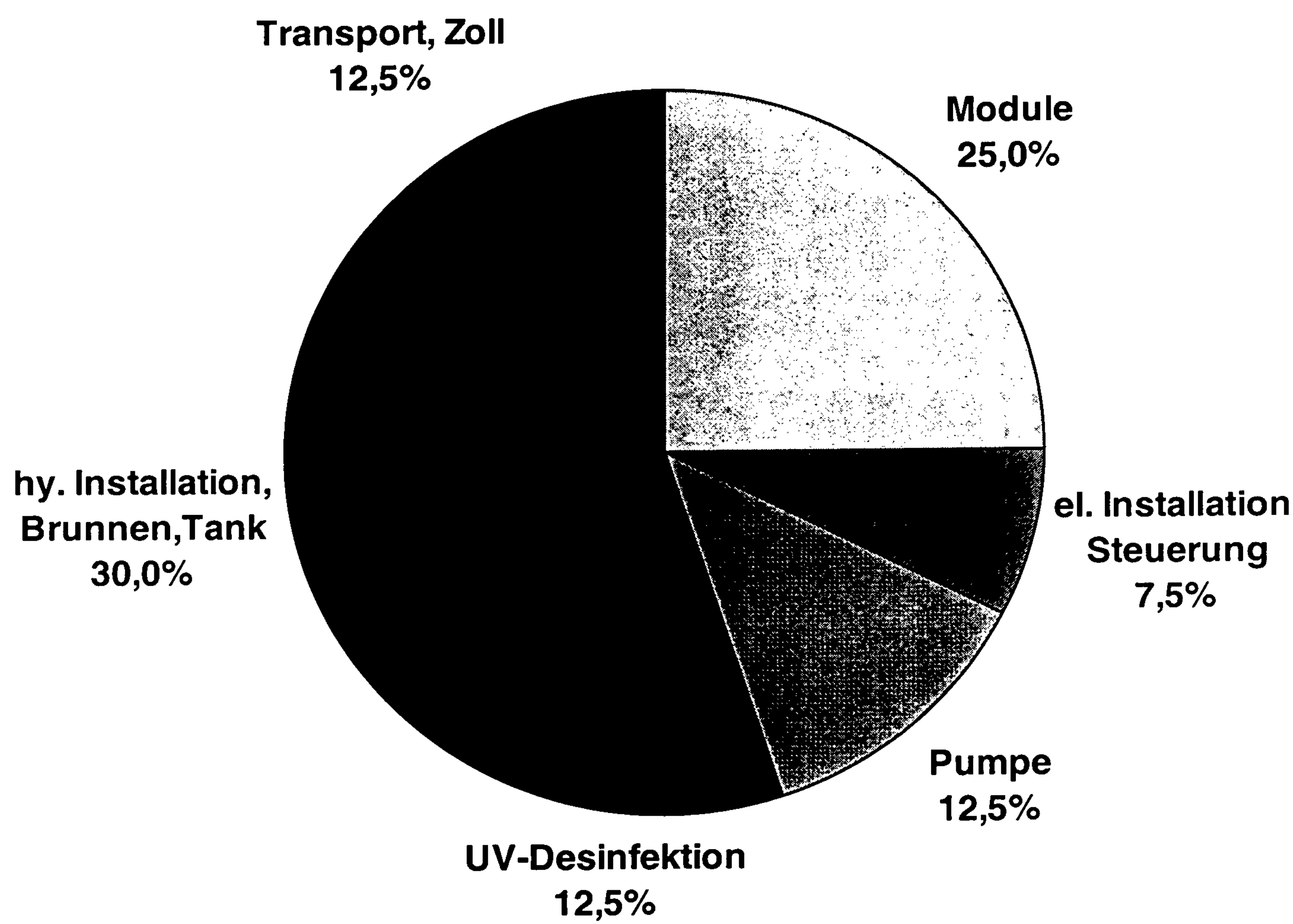
Advantages

- Inactivation of micro organisms occurs within seconds
- No chemical products are added
- No derogation to taste and smell
- No production of by-products that are dangerous for health
- Low maintenance
- Low energy consumption
- Well known technique
- No corrosion problems

Disadvantages

- No storage
- Long heating phase
- High energy consumption



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Cost distribution

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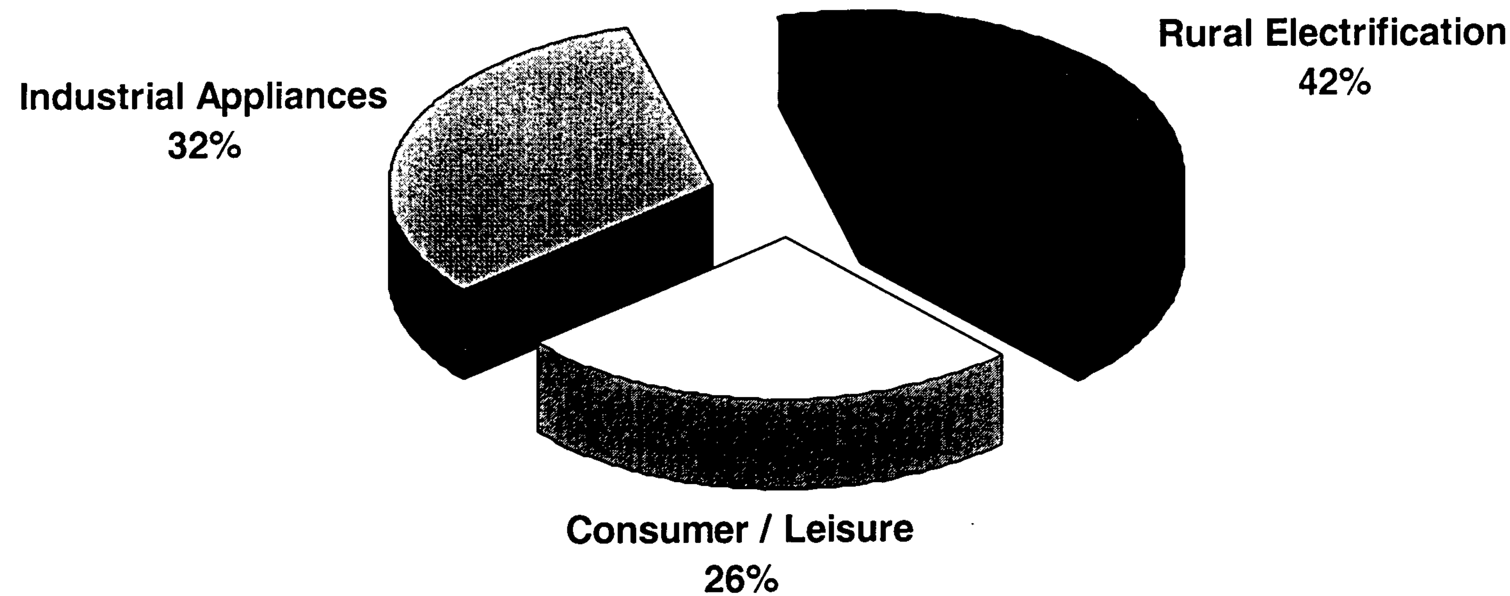
- Stand-Alone PV systems have proven in many cases to be a reliable technique

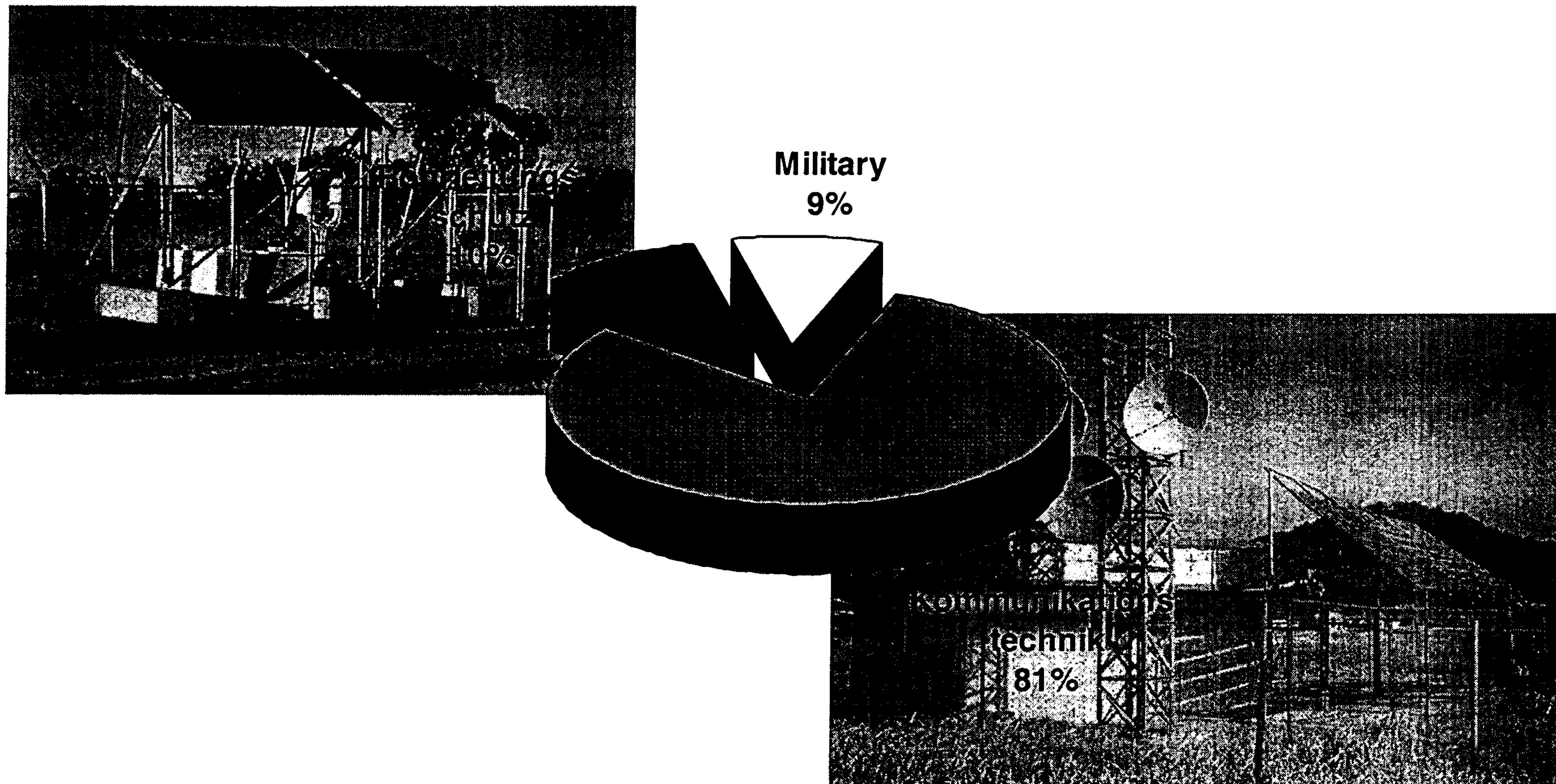
- Nevertheless, PV has still the reputation not to be "professional"

391 MWp between 1982 und 1994



Quelle: EPIA

Industrial Appliances: 124,6 MWp



Stand-Alone PV-Systems

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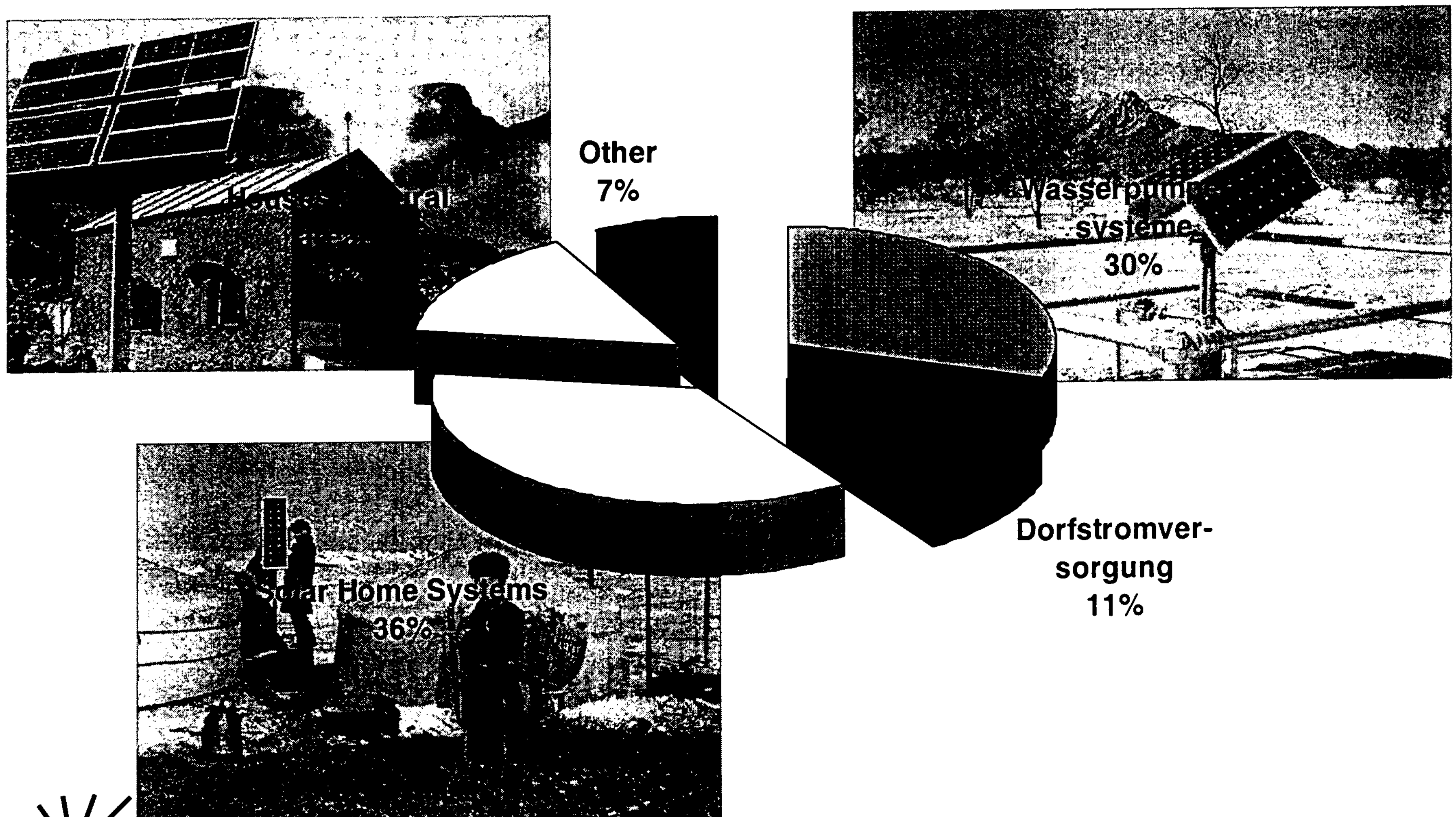
Quelle: EPIA

Ländliche Elektrifizierung: 165,5 MW_p



Stand-Alone PV-Systems

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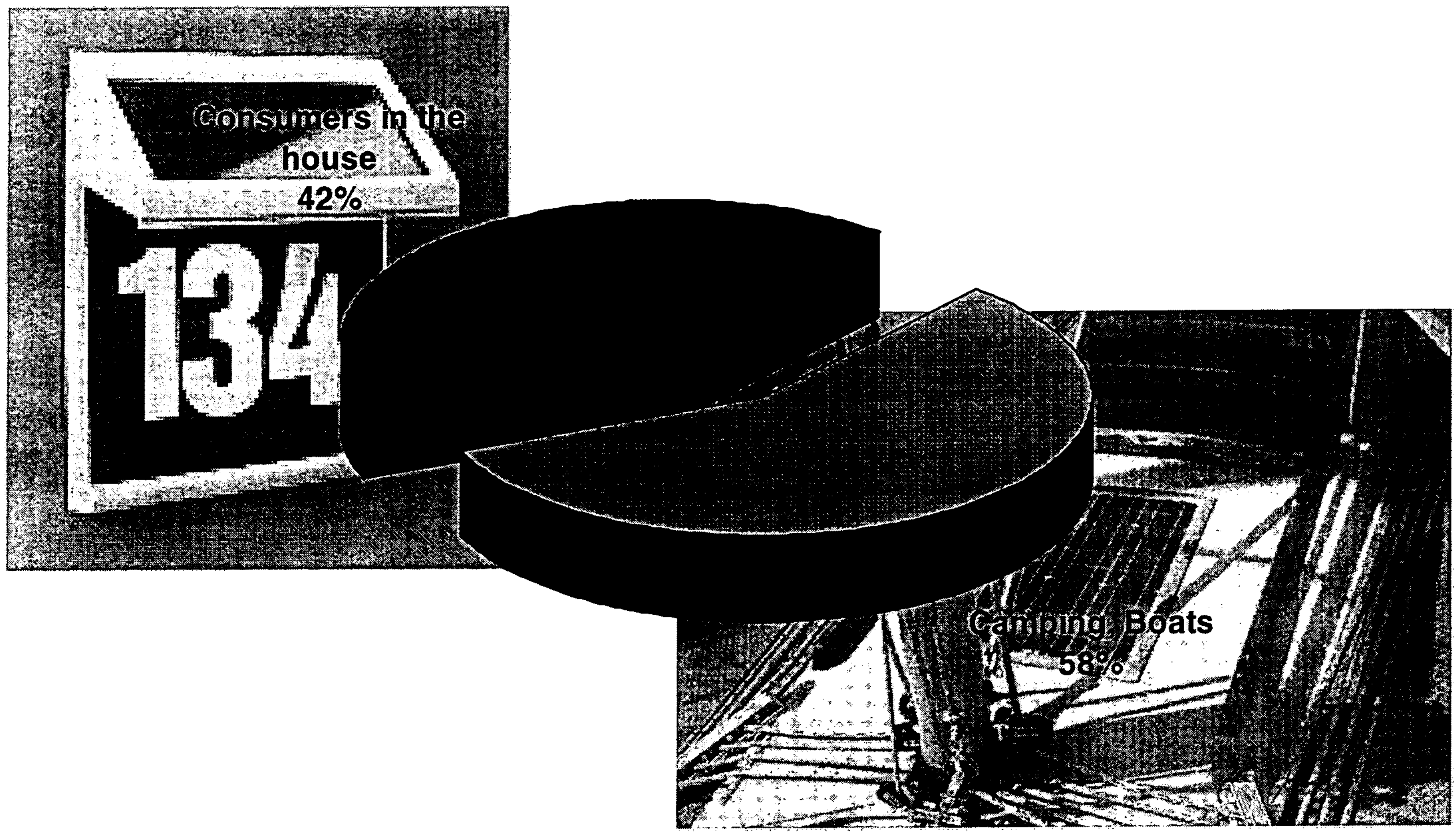
Quelle: EPIA

Consumer / Leisure market: 101,2 MW_p



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Stand-Alone PV-Systems

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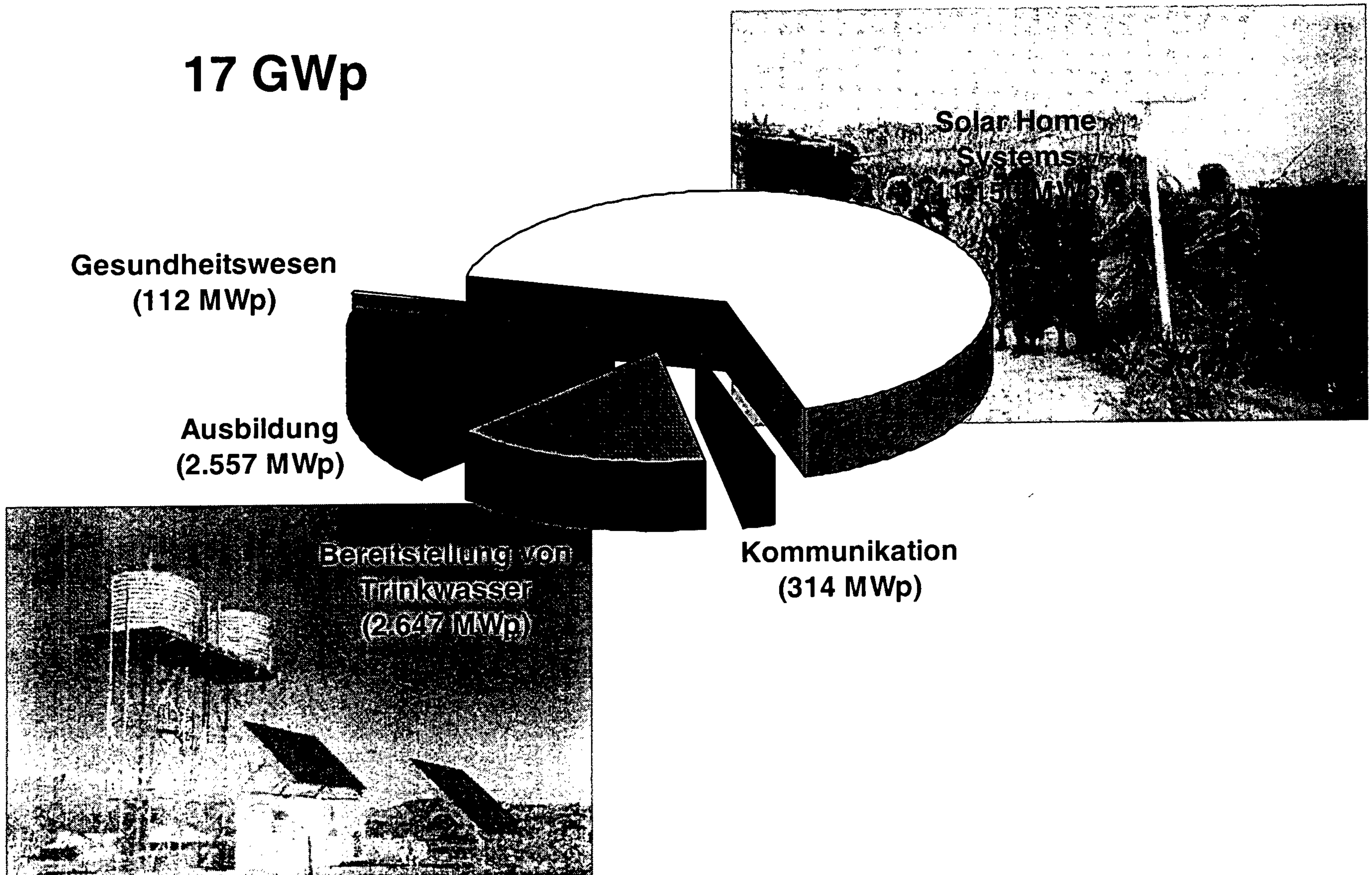
Quelle: EPIA



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Potential of stand-alone PV systems in rural regions (until 2010)

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Quelle: EPIA

Task 3: PV Applications for Stand-Alone and Island Applications

Subtask: Quality Assurance, Experience from the member countries has been gathered:

There are a lot of reasons why PV projects fail and very seldom those reasons have a primarily technical cause!

10 Reasons for failure:

1. Whatever the problem is, it's someone else's problem: responsibilities have clearly to be defined
2. Missing of adequate training to the installers lead to bad system performance
3. The users are an integral part of the PV system:
   - Sometimes their needs have not been taken into consideration – but this should be paramount throughout the project
   - Sometimes the users are in charge of maintenance – but but they have not been trained to do it
   - Who in a user community is responsible for maintenance
4. Still sometimes batteries are not shipped dry; when stored for longer time system failure is not far away

10 Reasons for failure:

5. In many projects with public funding only investment costs are covered by the donor:
   - No money for maintenance and replacement of broken parts
   - The first failure of a part of the system is equivalent with the end of operation of the system
6. How will the users pay for the energy, can they afford it?
7. To have sustainable projects income generating activities have to be taken into account (e.g. to replace components)
8. Are spare parts present at the remote location?
9. Population growth, migration and increase in user expectations and needs have to be taken into account for the system design
10. In all countries theft and damage is a problem

Thank you for your attention

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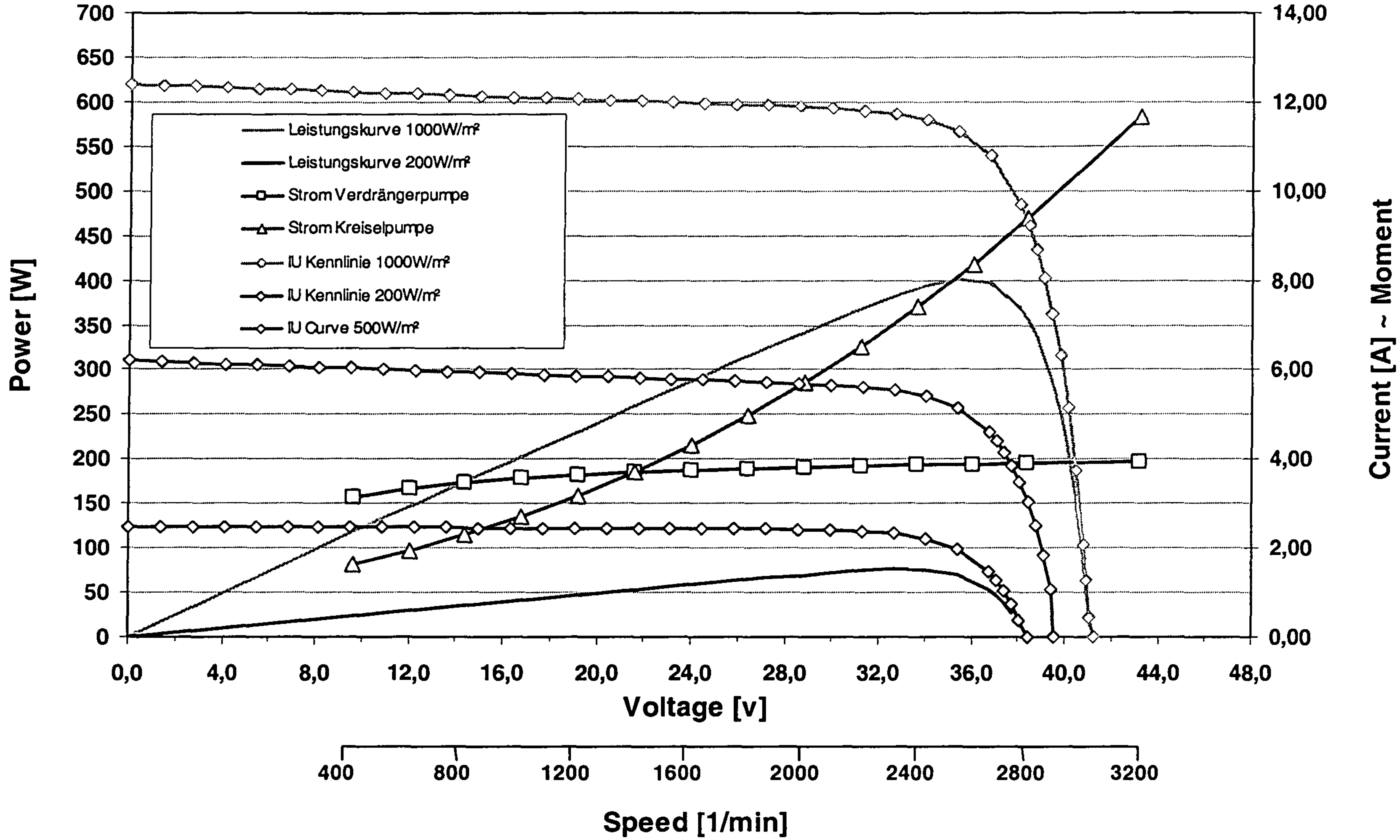

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Characteristic curve of PV-Pumping systems

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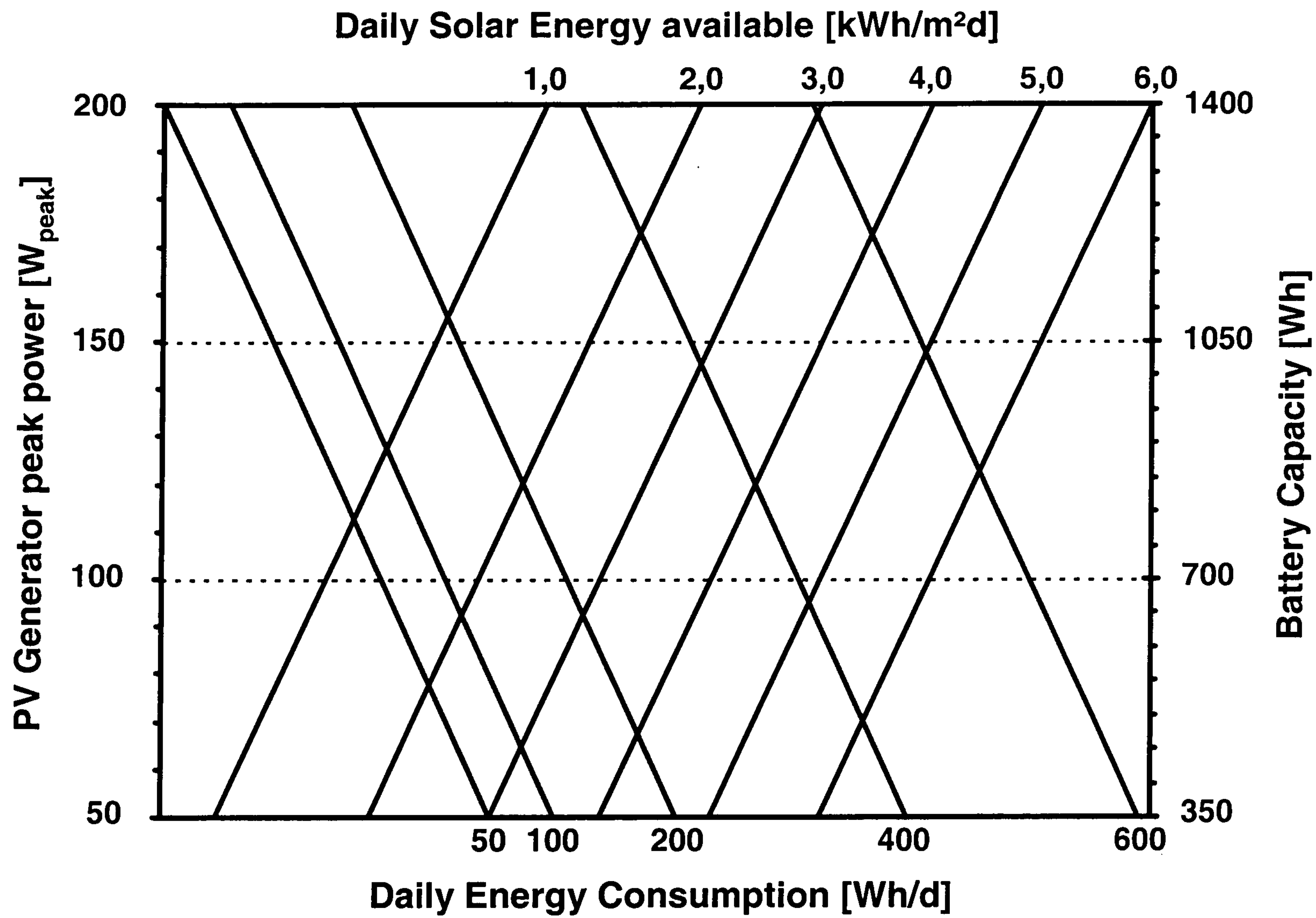

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Nomogram for Plant Design

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Innovative concepts and computer aided sizing of Photovoltaic and Hybrid autonomous systems

by
Stratis Tapanlis, Jürgen Schmid
University of Kassel, Germany

INTRODUCTION

The high reliability and flexibility of photovoltaic modules can be seen as a result of previous efforts in standardisation and certification. Most of the other components in a photovoltaic system are far away from a similar level. In general it can be stated that still today photovoltaic systems are being individually designed for grid-connected as well as for stand-alone applications. For a wider use of photovoltaics there is a need for standardised components and systems which will allow for simpler and cheaper systems. Modular and standardised systems make it possible to exchange individual components of different manufacturers. In the following paper some developments in this direction will be highlighted.

MODULAR COMPONENTS IN GRID-CONNECTED SYSTEMS

Historically inverters had to grow with the system size. In this way the specific inverter costs can be reduced by enlarging its size. Compared to a normal industrial production bigger inverters for grid-connected photovoltaic systems can still be regarded as prototypes resulting in production costs which are typical for this approach.

In this situation the use of mass-produced standardised and modular components can lead to cost reductions for the whole plant. The smallest possible size of such a standardised inverter results in the DC-connection of one PV-string. Since the DC-input current for the inverter determines strongly the overall inverter cost, the input voltage should be chosen in such a way that its absolute level still remains manageable which is in the range between 100 and 300 volts. The resulting input power range can be seen in figure 1 which shows that the practical power range of a string inverter is approximately 1 to 3 kilowatt peak.

Since the module input cables can be connected directly to the inverter the need for junction boxes are being eliminated this way. If the inverter is weather-protected, the unit can be installed directly at the end of a PV-string.

Compared to the string inverter concept, which has been described above, module integrated inverters have to deal with the same input current but at a very much lower voltage. In this situation it becomes difficult to reduce the specific inverter cost even at high production rates.

This situation will be drastically changed if modules become available with high output voltage. In principle thin film technologies which allow economic series connection of many cells inside the module will have this potential. From the system's technology side the availability of high voltage modules is therefore highly desirable.

STANDARDISED STAND-ALONE SYSTEMS WITH AC-POWER-SUPPLY

The typical layout of a conventional stand-alone PV-hybrid system is shown in figure 1. These systems have been applied for remote houses to a wide extent. In the conventional approach all power generators, such as the PV-generator, wind or diesel generator feed DC-power into the battery. Each component has therefore to be equipped with an individual charge controller and in case of an AC-output even with a rectifier. Existing systems of this kind have battery voltages between 24 and 240 volts. It is obvious that in such a situation the use of standardised components becomes impossible.

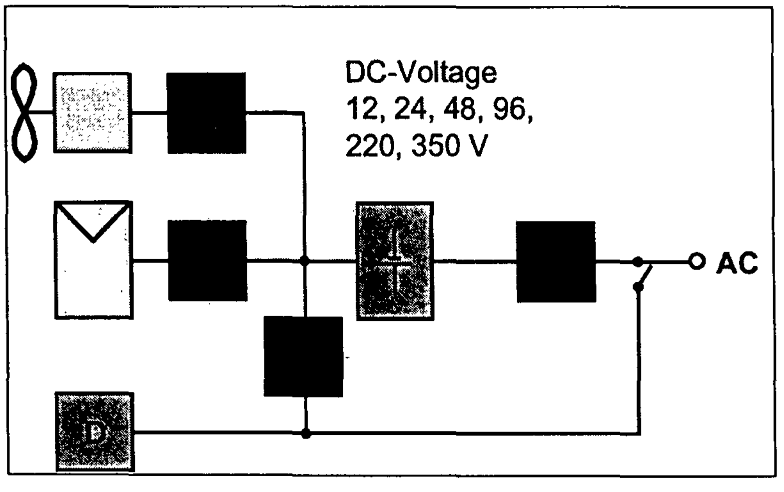

Fig. 1 Typical layout of a conventional PV-hybrid system

This situation can be changed completely when coupling all components, the generators as well as the consumers to the AC-side. In this case the standardised voltages of the public grids can be applied to all components. The typical layout for such a standardised modular concept is shown in figure 2.

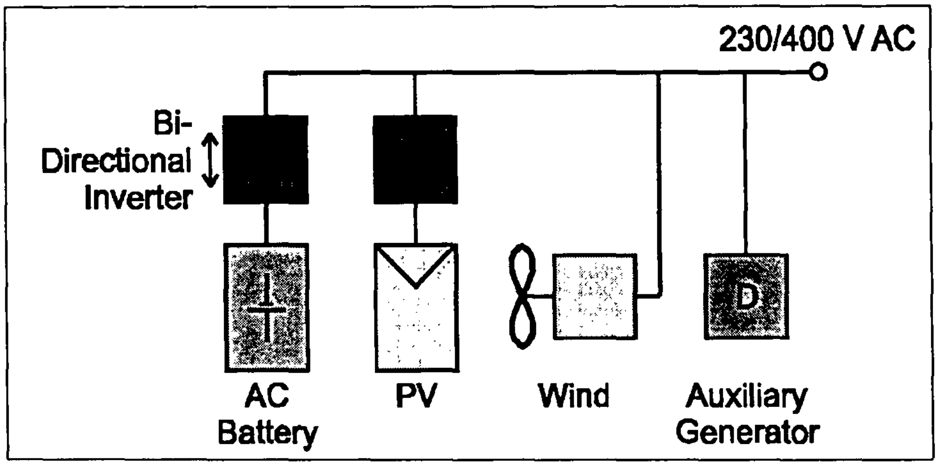

Fig. 2 Advanced modular PV-hybrid system withAC-coupled components

This concept allows for an extremely flexible reaction to all needs concerning· changes of the consumption structure. The heart of this concept is an inverter with special features; beside the standard function of the inverter of keeping the output frequency and voltage stable, this inverter has also to compensate for the reactive power needs and in addition to allow the surplus energy to flow backwards into the battery. In this sense the combination of the battery and inverter forms an AC-battery. Based on this component all other power sources or loads can be connected without further interfaces to the AC-terminal of the inverter.

In many parts of the world diesel generators are being used to supply power in remote areas. This system can now be easily expanded in a first step by the AC-battery, which allows to stop operation of the diesel generator, for instance during night time. The connection of photovoltaic generators as a next step can then be done by using string-inverter coupled units. If in a later stage grid connection becomes possible through the extension of the existing electrical grid, the system keeps its full value. In case the diesel generator or the AC-battery is no longer necessary those units can be transferred to another plant and integrated without further modifications because of their modularity.

STAND-ALONE DC-SYSTEMS

Very small photovoltaic DC-systems consist of a module, a battery, and a charge controller. Despite the fact that this system looks extremely simple, experience shows that electric installation can become difficult and failures in cabling have been observed. This is not a surprise because a standard charge controller has six terminals to be connected. Any changes in size of such a system are normally only possible by adding further modules in parallel. If the user wants to change his battery voltage, for instance, from 12 to 24 volts he has to redesign the system completely. After adding a second module in series connection with the first one and changing the charge controller and the battery, the system is ready for use. If the user wants to add another module this becomes practically impossible without making major changes.

By using a new charge controller with special features, a modular standardised approach becomes possible even in this low power range: the basis of this charge controller is a combination between a step up and step down conversion principle. By multiplying or dividing the module output voltage by a factor of 3, a nominal battery voltage between 6 and 50 volts can be covered this way. The second feature of this charge controller is its ability to automatically identify the battery's nominal voltage. This becomes possible even if there is a certain variation in the battery's voltage between charging and discharging. Even with fully discharged batteries the range of the nominal voltage can be detected through the charging process. At the DC-input side MPP-tracking can be performed at the same time. The result of such a universal charge controller is a very high flexibility in the system configuration as can be seen in figure 3.

In the situation described above, the addition of a certain module can be either performed in series connection of all three modules or by using two modules in series connection and the third one in parallel. By integrating this type of charge controller into the module, a universal purpose module becomes available. In addition the DC-system consists now of only two components, namely the module with the integrated charge controller and the battery. The terminals of the module (only two wires) can be directly connected to the battery's terminals, the resistance of the wiring will be detected automatically and the resulting voltage drop will be taken into account. The universal charge controller can also be integrated into small wind turbines as well as micro-hydro power systems and small motor generators. This allows to connect all power sources without any further modification to the battery as can be seen in figure. 3. This way a fully modular and standardised PV-DC-system can be obtained.

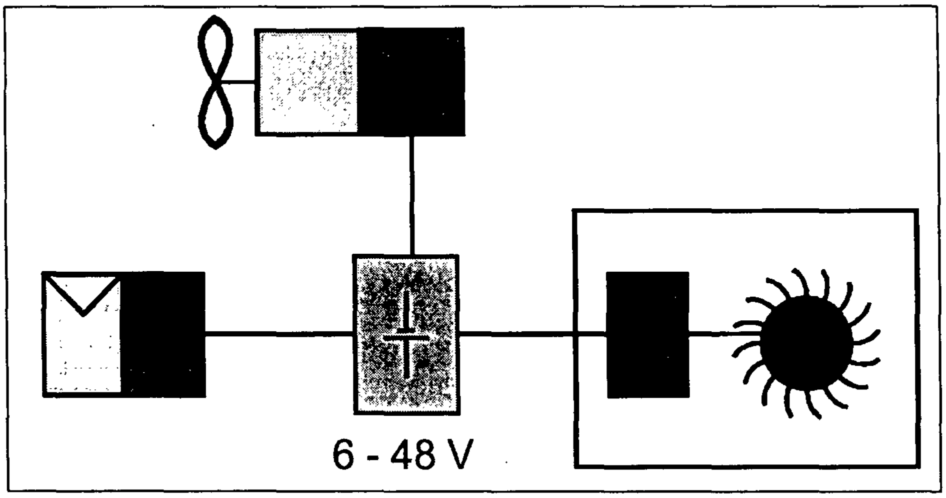

Fig. 3 Universal charge controllers for simple configurations in low power DC-systems

SIZING OF PV-HYBRID SYSTEMS

Many practical hybrid system designs and implementations are often based on progressive experience, including trial and error. Monitoring studies frequently report unanticipated problems, such as premature battery degradation, requiring design corrections after installation. This can be costly, especially for remote applications in a developing country. Two problem areas repeatedly mentioned have been the sizing of system components and control, particularly in more complex systems but also in simpler PV/diesel hybrid systems and even after prior simulation studies.

There are many methods for designing and sizing of PV or PV-Hybrid systems. The way of system sizing can be categorized in "Rules of Thumb methods" (e.g. Performance ratio method), "Paper methods" (e.g. Ampere-hours-method), "Diagram methods" (e.g. Grundfos method) and "Computer aided methods".

Many different software packages exist with a varying degree in user friendliness, validation of simulation models, accuracy of system models, and possible configurations to simulate. Most of these software tools simulate a given and predefined hybrid system based on a mathematical description of the component characteristic operation and system energy flow, and often incorporate financial costing of the system configuration. These packages are valuable to assess a certain hybrid system design and enable to view the effects of changing component sizes and settings manually. However, the majority of these packages require the user to come up with a pre-designed system, for example through using rule of thumb methods. Therefore, a better system performance with lower costs could be achieved in many of these designs if the system configurations could be optimised. "PVS 2000" from Econzept / Germany and "PVSYST" from University of Geneva / Switzerland are two of the most known computer sizing tools in Europe.

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Stratis Tapanlis
Department for Efficient Energy Conversion (RE)
University of Kassel, Germany

ISET, Institute for Solar Energy Technology

ZUB, Centre for Ecological Architekture

CESR, Centre for Environmental System Research

University of Kassel
RE, Professor Schmid
EVS, Professor Kleinkauf

SMA GmbH

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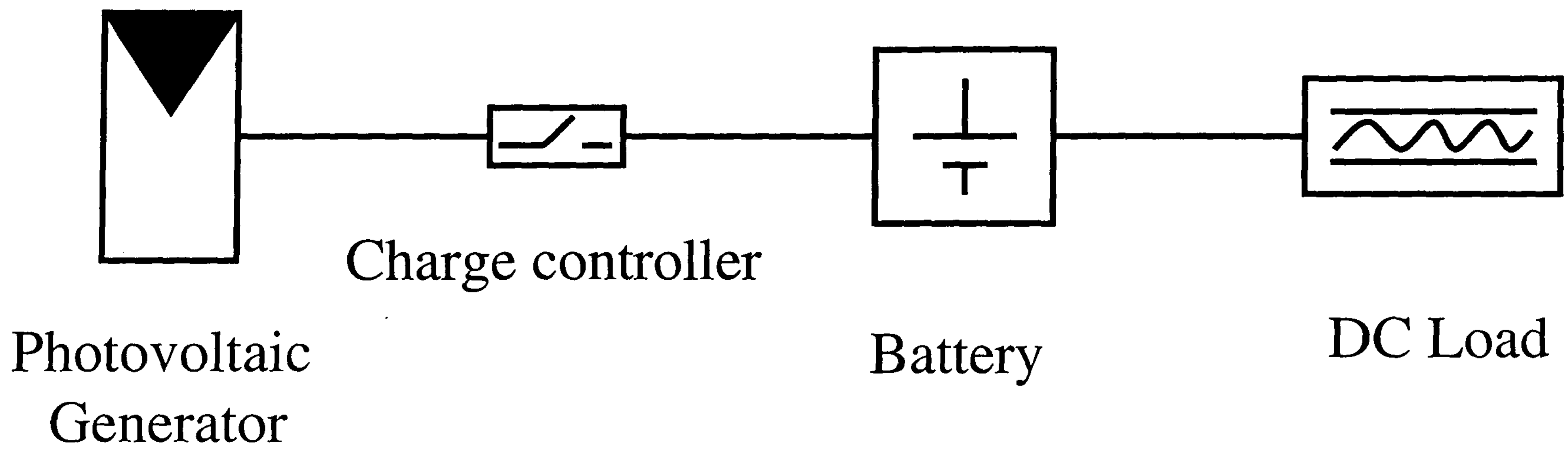
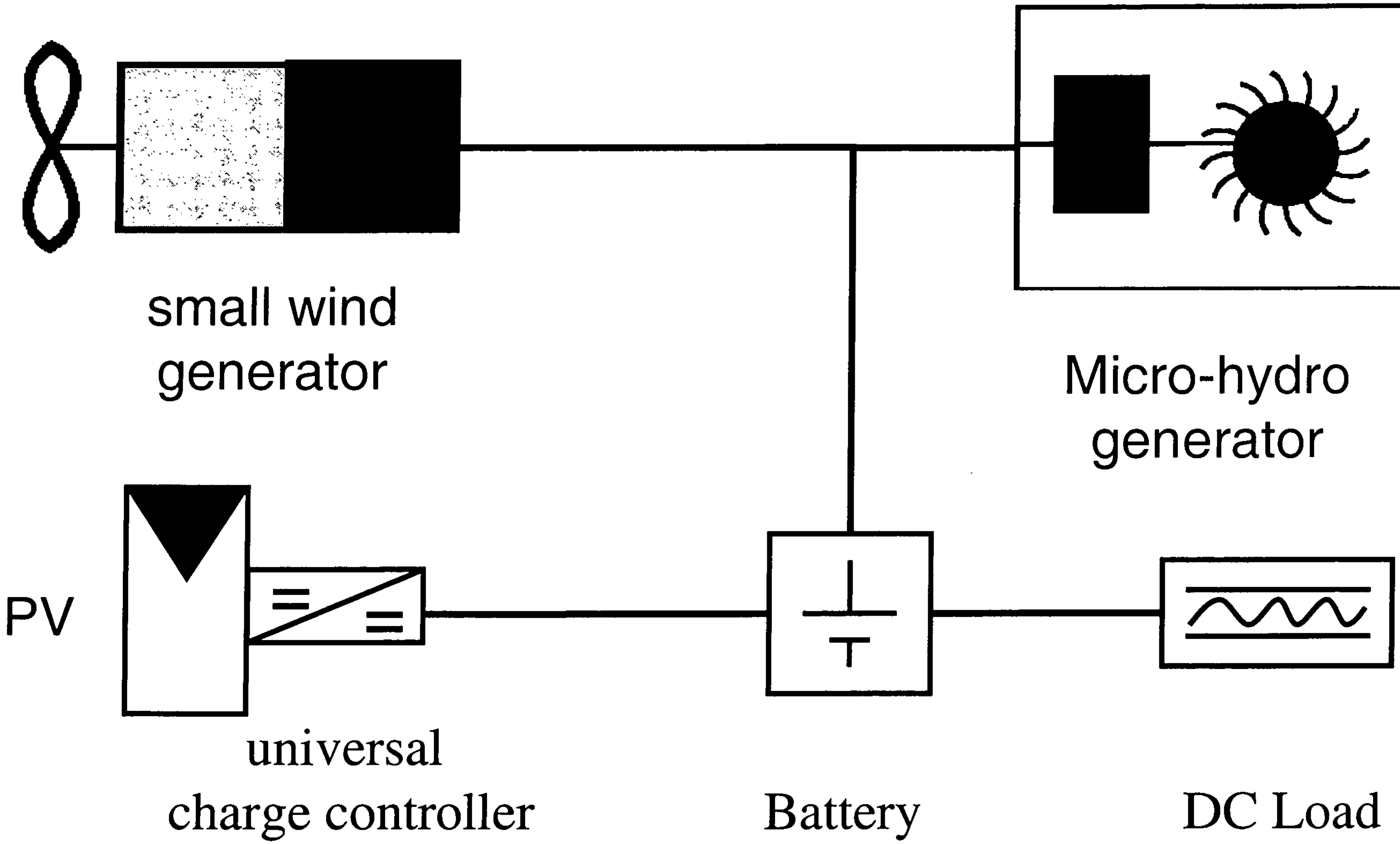
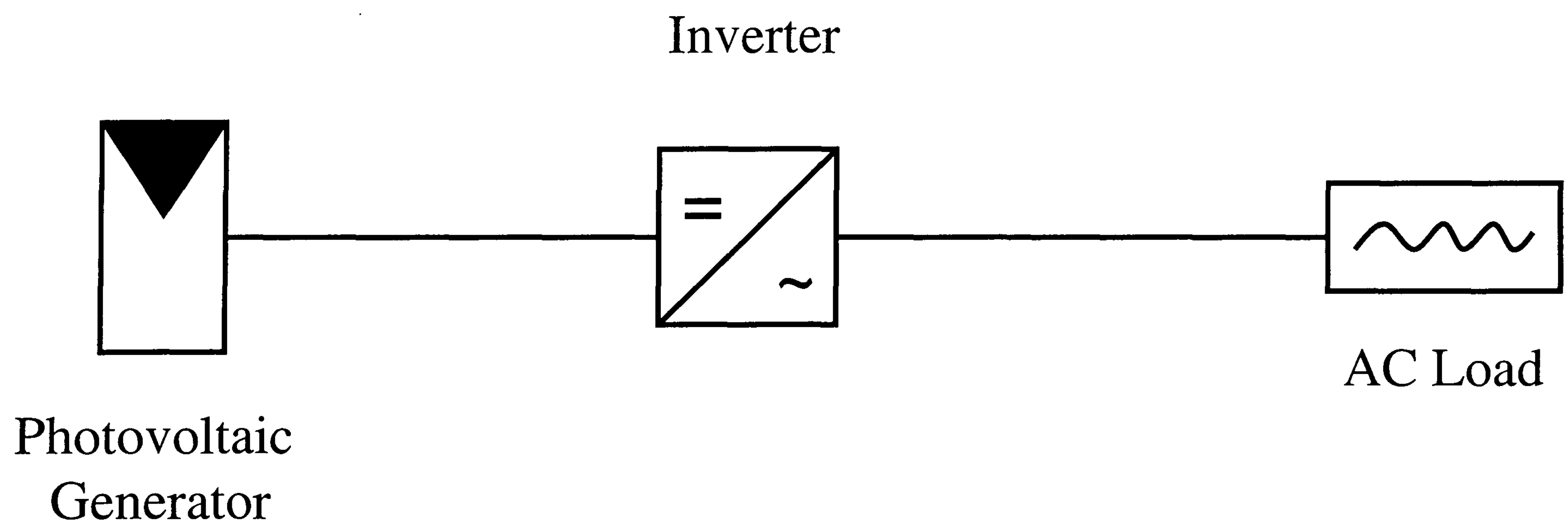
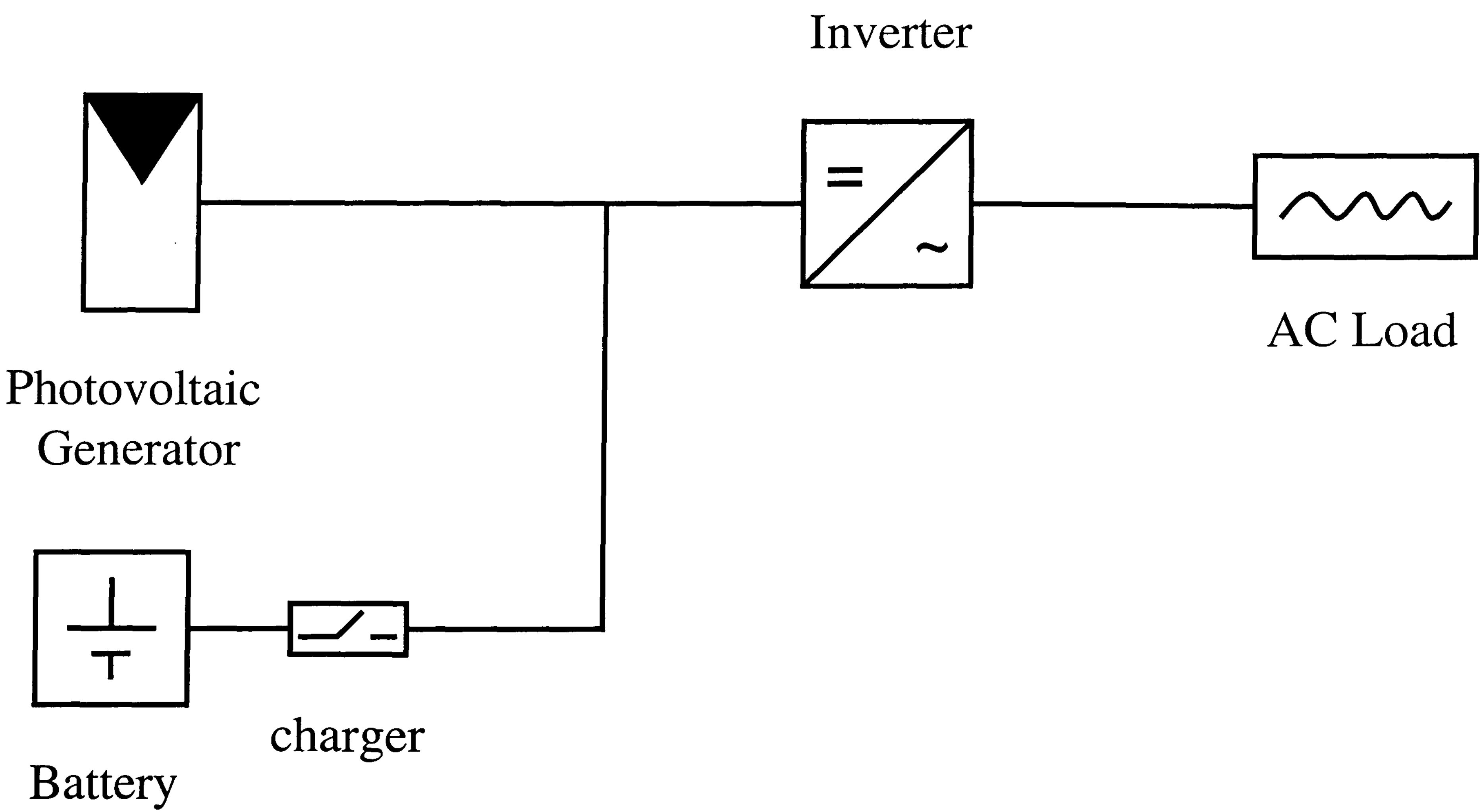

Photovoltaic Generator
Charge controller
Battery
DC Load


small wind
generator
Micro-hydro
generator
PV
universal
charge controller
Battery
DC Load


Inverter
=
~
AC Load
Photovoltaic
Generator



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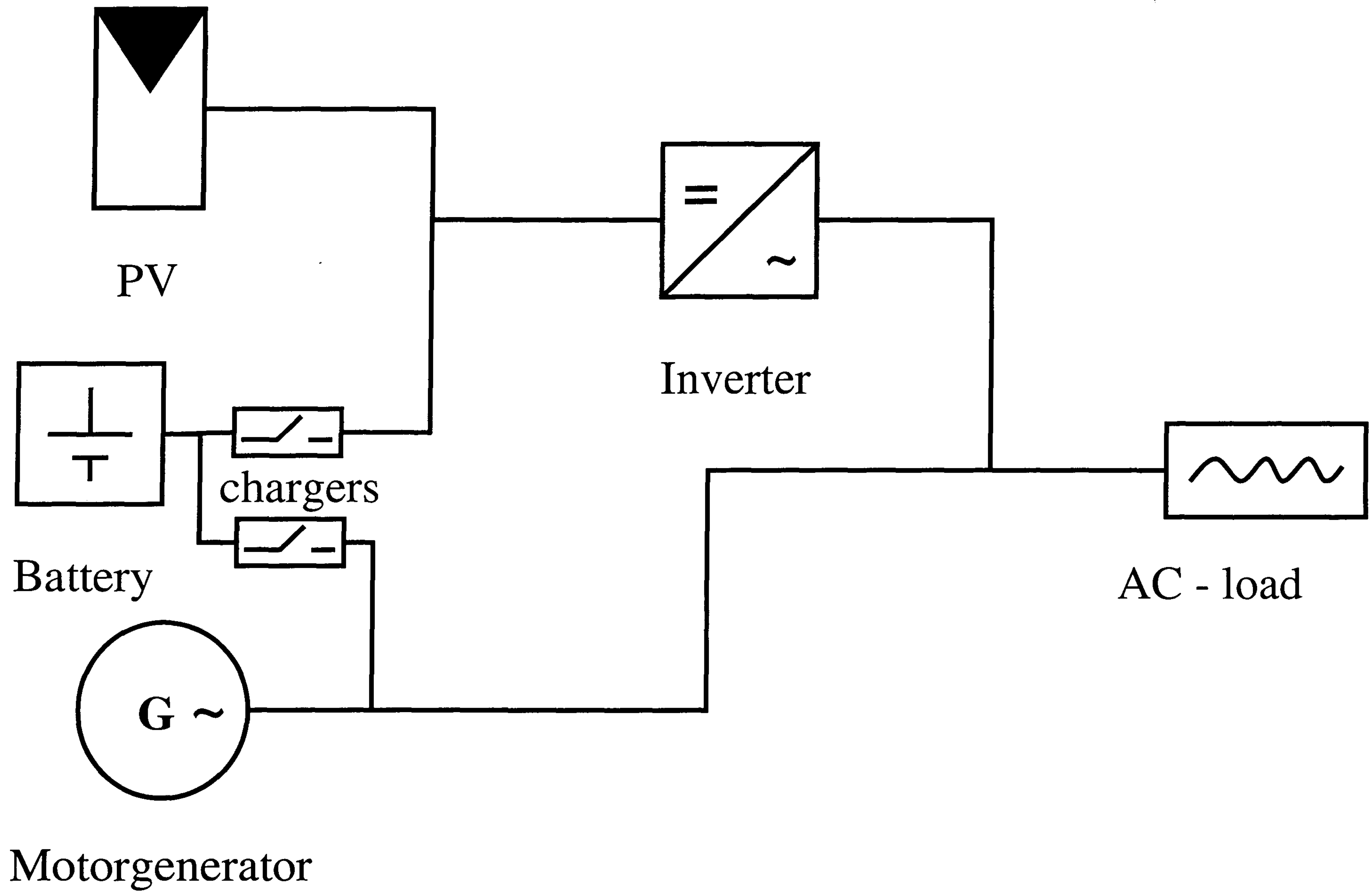
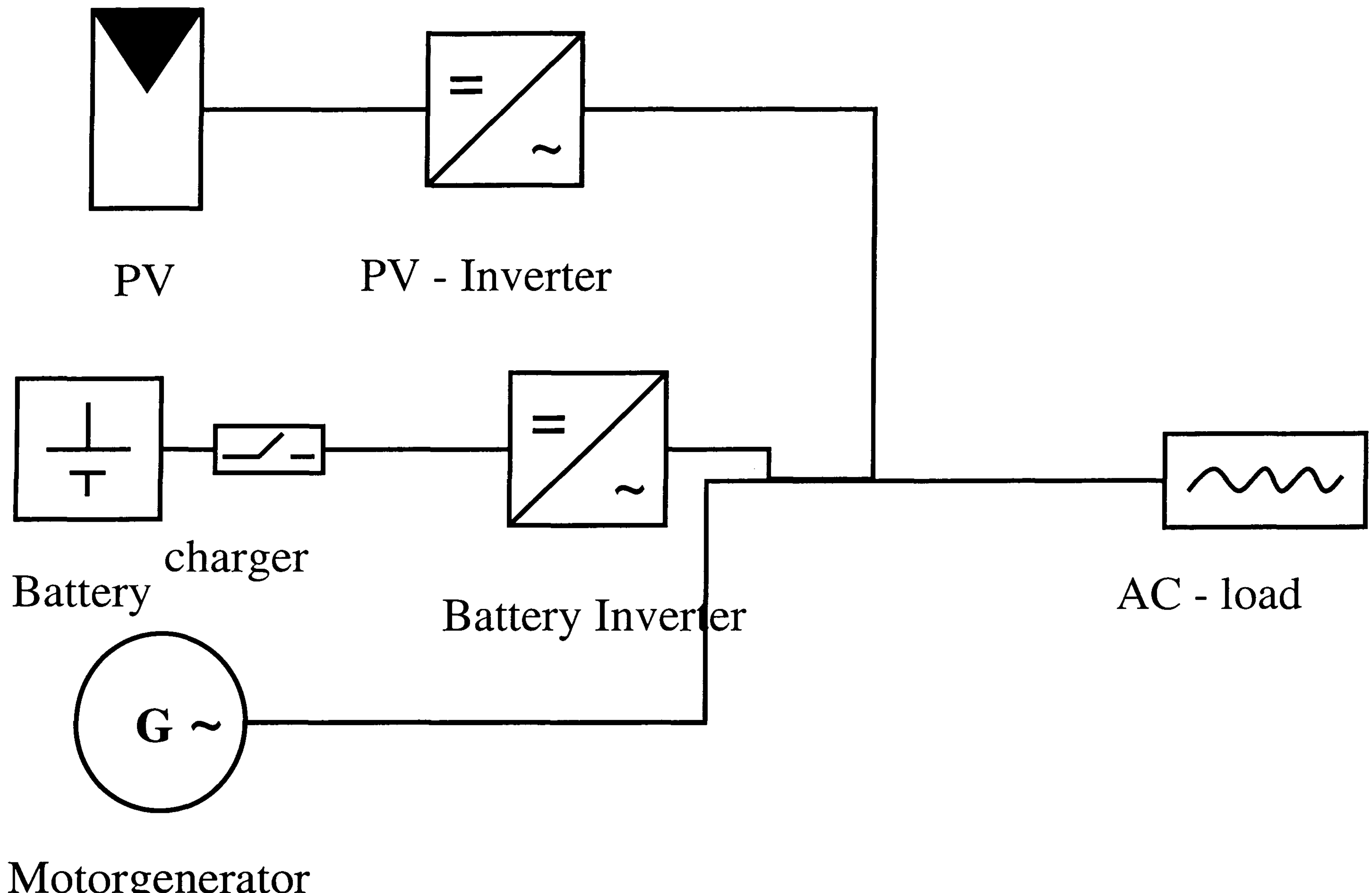
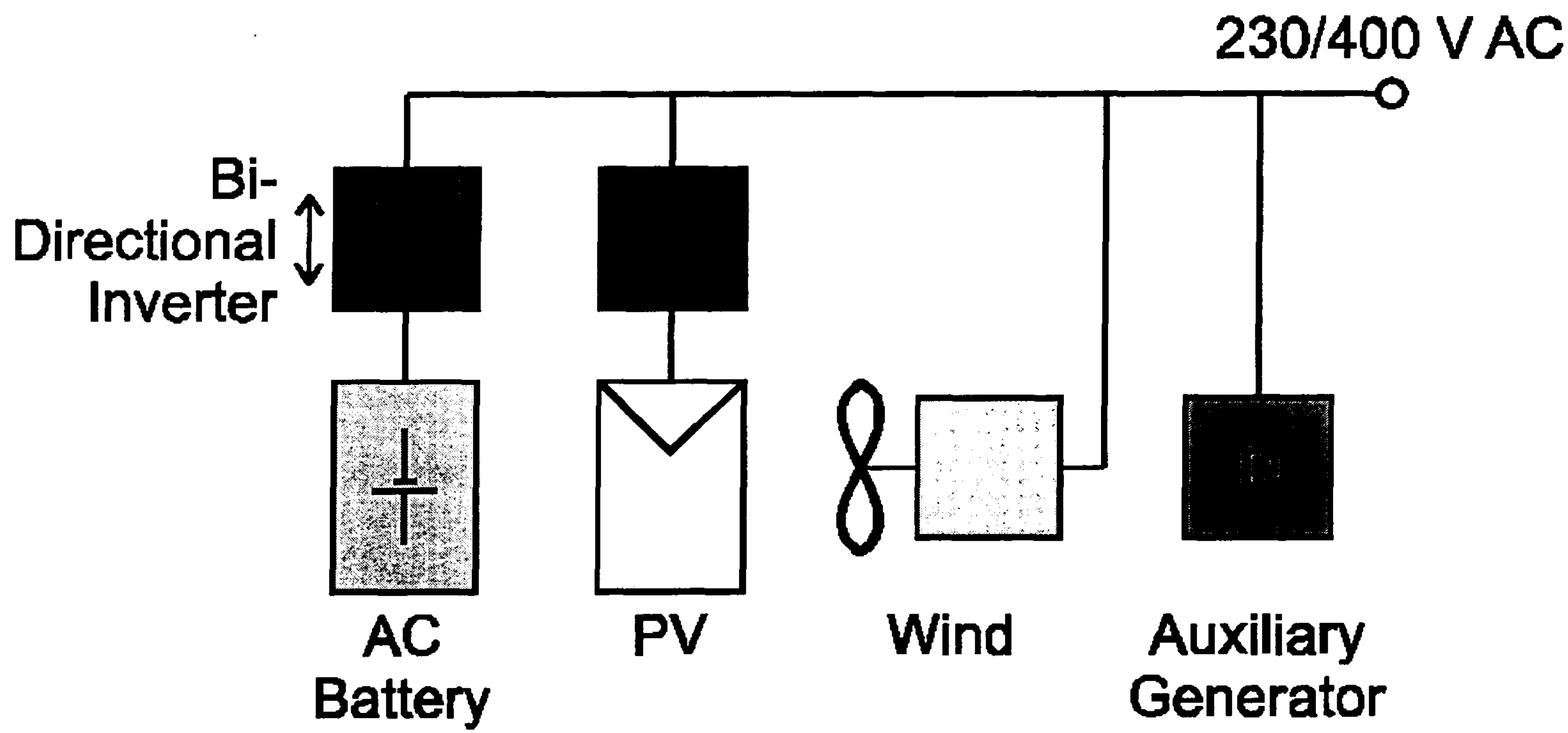
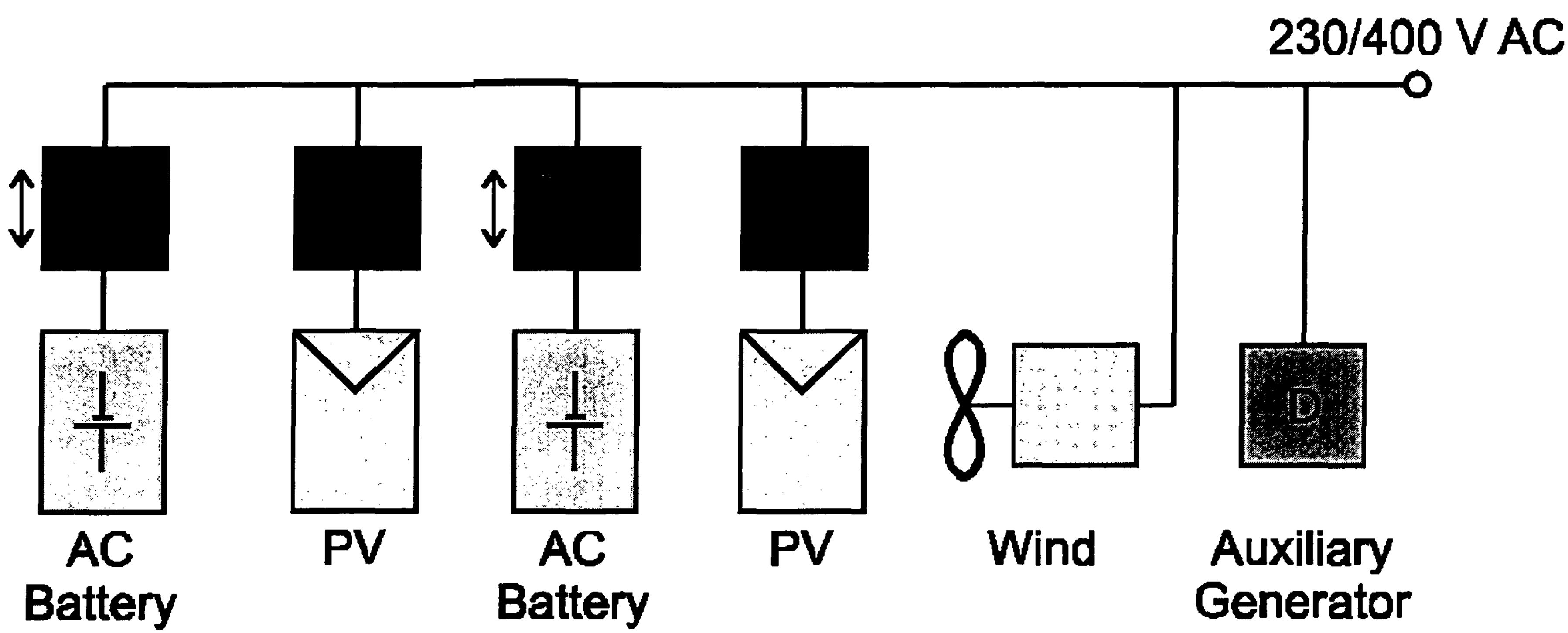
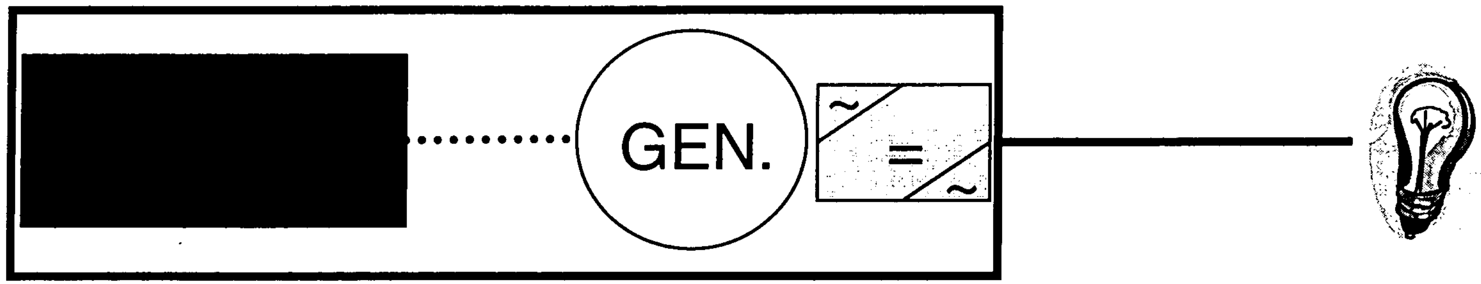

PV
Inverter
Battery
chargers
AC - load
G ~
Motorgenerator

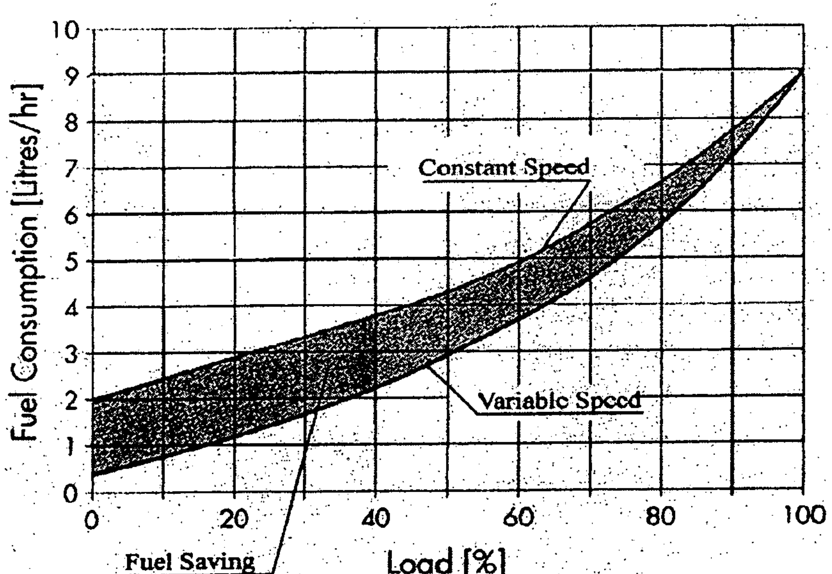


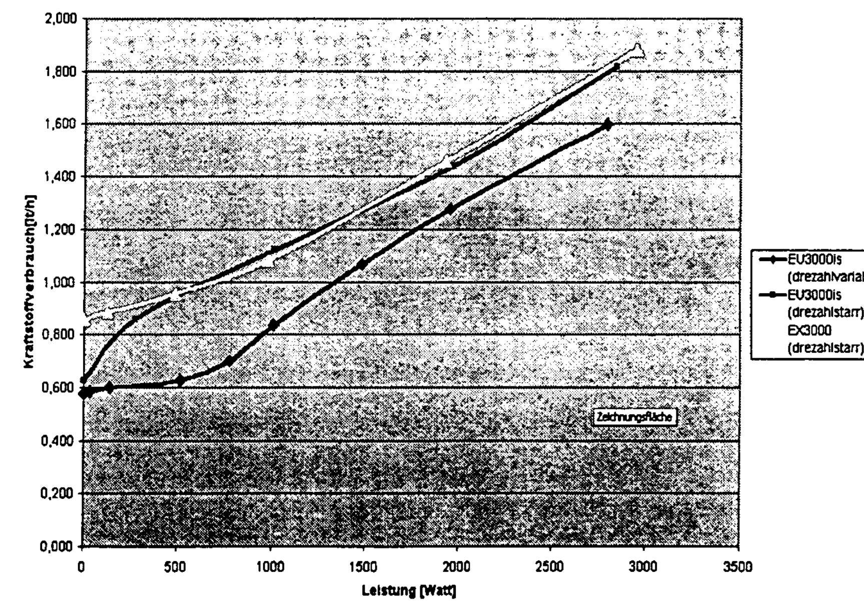
PV
PV - Inverter
=
~
Battery
charger
Battery Inverter
AC - load
G ~
Motorgenerator


230/400 V AC
Bi-
Directional
Inverter
AC
Battery
PV
Wind
Auxiliary
Generator


230/400 V AC
AC Battery
PV
AC Battery
PV
Wind
Auxiliary Generator


GEN.
~
=
~


Fuel Consumption [Litres/hr]
Load [%]
Constant Speed
Variable Speed
Fuel Saving
0
1
2
3
4
5
6
7
8
9
10
0
20
40
60
80
100


Kraftstoffverbrauch[lt/h]
Leistung [Watt]
EU3000is (drezahlvariabel
EU3000is (drezahlstarr)
EX3000 (drezahlstarr)
Zeichnungsfläche
0,000
0,200
0,400
0,600
0,800
1,000
1,200
1,400
1,600
1,800
2,000
0
500
1000
1500
2000
2500
3000
3500

Sizing of PV and Hybrid Systems
Thumb rules

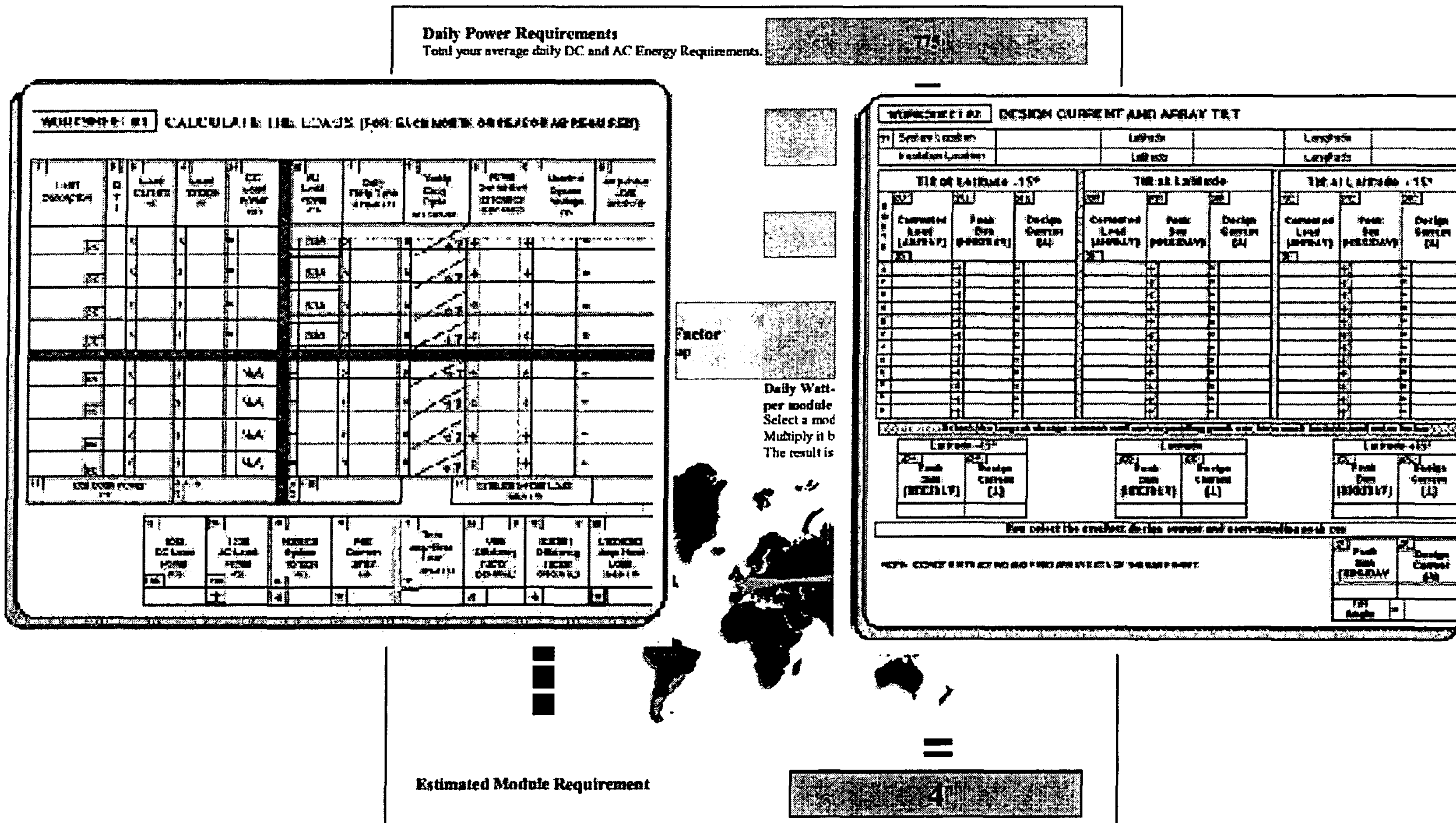
$$E_{el/täglich} = P_{Nenn} \cdot \frac{E_{Glob/täglich}}{S_{STC}}$$

$$E_{el/täglich(real)} = E_{Glob/täglich(geneigt)} \cdot A \cdot \eta \cdot Q$$

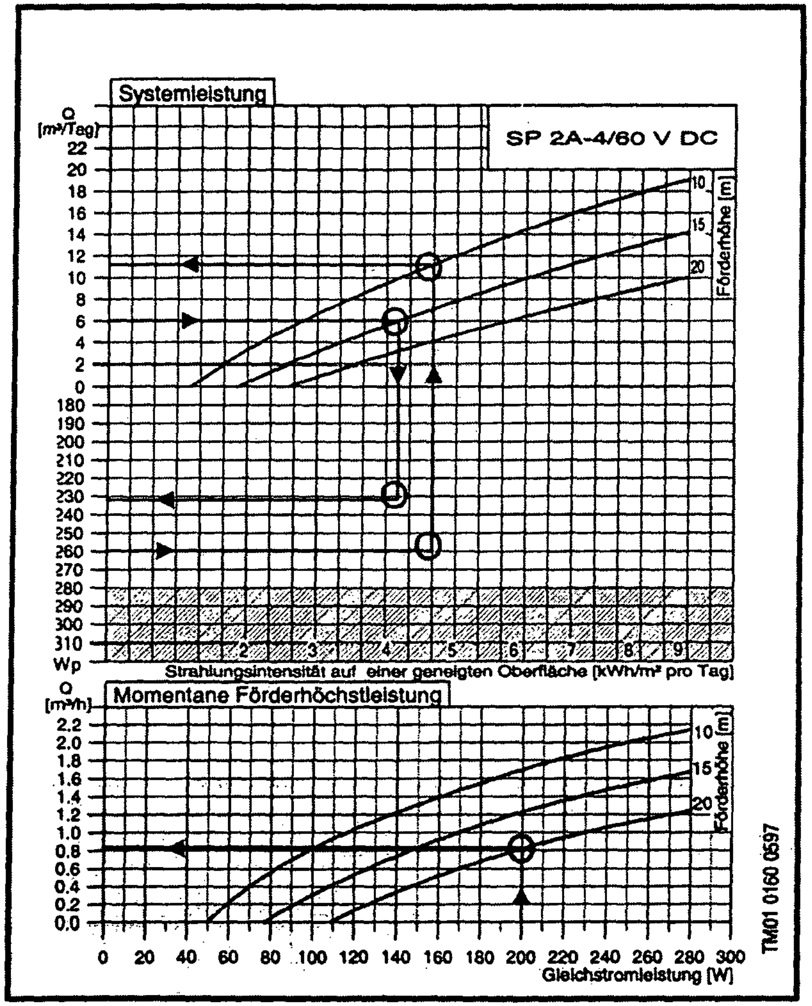
$$n_{Anzahl} = \frac{E_{Gesamtverbrauch}}{E_{el.eines\,Moduls}}$$

$$C_{Batterie} = \frac{E_{Verbrauch/Tag} \cdot n_{Tage/Systemautonomie}}{f}$$

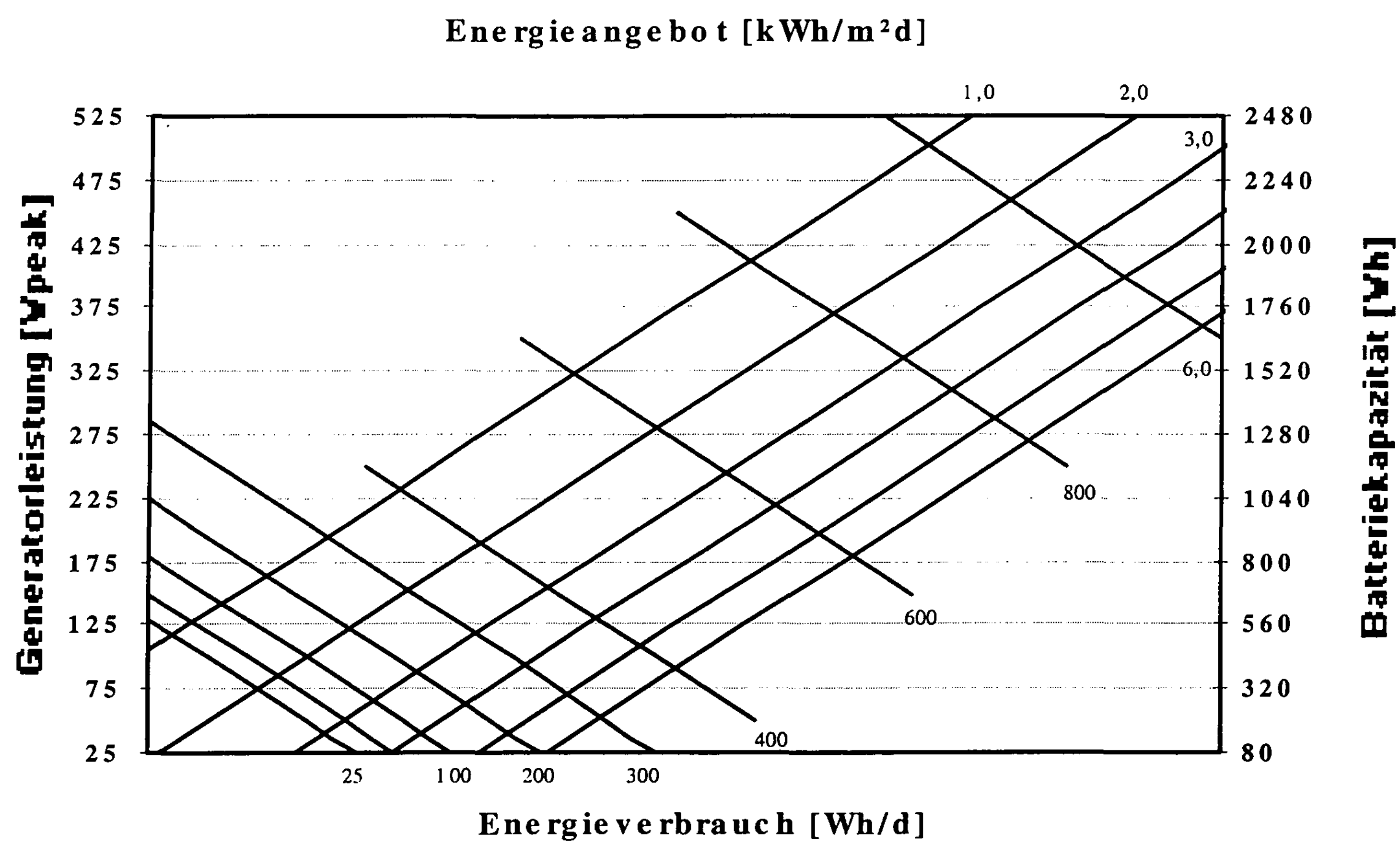
Calculation Sheets

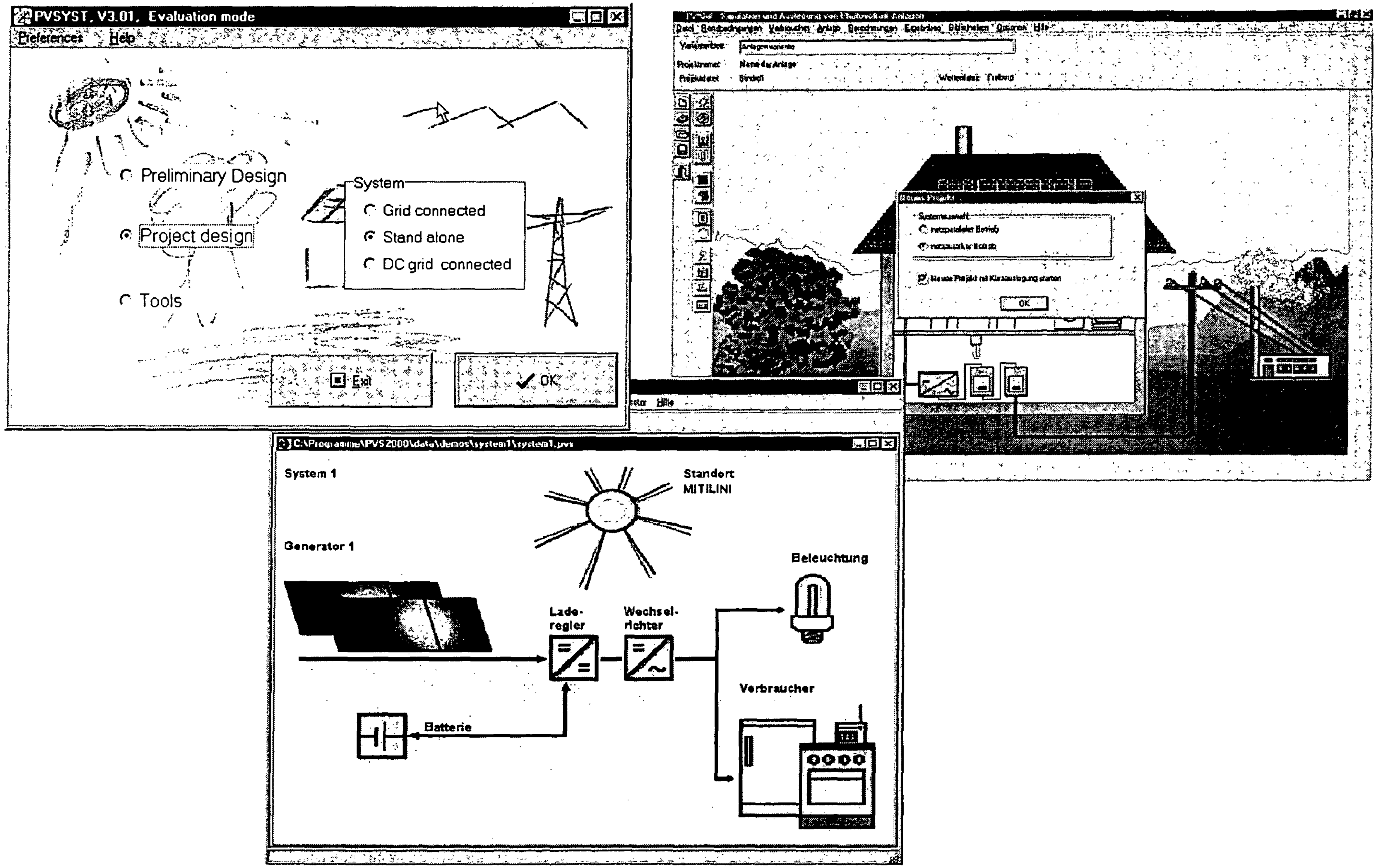


Diagrammes


Systemleistung
SP 2A-4/60 V DC
Q [m³/Tag]
22 20 18 16 14 12 10 8 6 4 2 0
180 190 200 210 220 230 240 250 260 270 280 290 300 310 Wp
Förderhöhe [m]
10 15 20
2 3 4 5 6 7 8 9
Strahlungsintensität auf einer geneigten Oberfläche [kWh/m² pro Tag]
Momentane Förderhöchstleistung
Q [m³/h]
2.2 2.0 1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2 0.0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
Gleichstromleistung [W]
TM01 0160 0597

Franz Nomogramme





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Prerequisites of PV applications in Egypt

INTRODUCTION - The demand of energy is always increasing in an insatiable way all over the world.

The PV energy is one of the prominent energies among the Renewable Energies. According a recent evaluation at present these constitute almost 1% of the world's 3,300 GW electricity generating capacity. The 2001 PV production tops 390 MW_p , with 36% increasing over 2000.

The European Union plans that one fifth of its energy will come, next decade, from "renewable". Shell Renewables estimates that next few decades 40% more people across the world will be relying on renewable energy and that will hint at where renewables are hoped to fulfil a vital function: in some of the world's poorest communities that are not served by power grids.

The rush of PV and others renewables is a recent phenomenon, and understanding that will help developing countries to get renewable strategies they are deploying in perspective.

The perspective of the change of energy future and the connection with the long term reality created the involvement of big companies such as BP, Enron, Shell, Total, etc, who already see PV and others renewable energies as an integral part of their future portfolio.

Among the renewables, Photovoltaic Energy has this advantages:

- It is the most easy to use,
- it is the most reliable to exploit,
- it is the most versatile to apply:
  - for the size of generating units
  - for the power of generating units and, for North Africa countries like Egypt,
  - for the location because PV primary energy exist everywhere including desert,
  - for its exploitation also during travels (including planetary mission)

We can identify five key drivers of the move towards PV energy:

1- environmental concerns in developing countries and industrial countries too

2- growing energy demand in developing countries

3- the green consumer

4- declining cost of PV and others renewable energies

5- the characteristic of being irreplaceable in some locations (desert, sea, mountains, space).

For PV applications we will not give a list of possible applications, for the simple reason that all the existing and thinkable applications of electric power can be easily realize with PV. As a matter of fact PV technology finally nothing is but a versatile generator of electric power without any limitation in voltage or current required by the specific application. From the point of view of what can be possible with PV, the original concept of humble zip is meaningful: it was first intended for securing industrial packaging and later, due to its easiness, was applied to clothes.

The PV technology is simple and it is well known how to exploit it; but in the deserts we do not see enough PV running systems: the thrust for PV is more powerful, but implementing PV systems is less straightforward . There must be something different than technical aspects; but I do not know Egypt and its energy strategy. A very useful aid is given to me by Prof. Arafa.

Salah Arafa, professor in the Physics Department of American University in Cairo, is heavily involved in PV and others renewable energy technologies and their application in the community- particularly the impoverished community (in Egypt: New Basaisa- Sinai). Prof Arafa found in his travels around the world that his learning, and that of other Egyptian academics, is on a par with that found in developed countries. This lead him to wonder:

"what is going wrong in Egypt",

people at all levels are smart, but what is missing to create the advanced level of other countries has resulted in the answer that:

"The system and education are wrong" .

If these can be changed and attuned in this case to renewables, energy needs can be met across the society.

In Egypt, where there is a very high annual insulation in very stretched (95%) deserted area, while we can support PV **solar farms** for intensive production of electric power, useful for instance in isolated lands for water desalination, there is an equally valid and important social role of PV applications within communities (lighting, cooking, communication [radio, TV, cellular, internet, e-mail, informatics], school, medical centre, health care, heating and air conditioning, goods or vaccine or human transportations, water pumping and irrigation for nursery or crop, sheep farming, poultry farming, fish farming, livestock or stable drinking, human drinking , household appliances, local business, mini-grid, etc.).

PREREQUISITES - PV electric power works on many levels: at national level with huge infrastructure and at the community level with many small systems. For it to be realized it is not enough to import technology:

"Local capabilities need to be nurtured".

It is essential that community plumbers and electricians need to be **educated** on Photovoltaic technology so it can be correctly maintained and replaced when necessary.

It is very important that the local people are **able to keep the technology going**.

If Egypt, at the moment, is not able to produce advanced technologies such as solar cells, it is not a problem; but on the contrary, it is a problem if there are not in Egypt people **able to deeply control** the characteristics of a PV module imported. This is a problem, because perhaps that module does not fit with required characteristics and that can be a reason because the plant will not work correctly; that is not fault of PV plant ! By the way Prof Arafa in this case say:

"realizing the benefits of Photovoltaics needs the right cadre of people"

but for any "society-wide success, **the key catalyst** for adoption in Egypt, and indeed in many North African countries,

must be brought in the play- namely the government.

He argues that "if the government in its many guises adopt PV (and others renewables) technology itself, it will create the impetus for a community-wide embrace".

"The government needs to adopt PV technologies in its own operations...

People look to the government for the lead". So the Egyptian Government need to provide real incentive for people to adopt PV technology,

including tax breaks or reduction in import duties.

Financial assistance is also needed to make PV attractive "This includes tax breaks on the importation of Photovoltaic cells for example".

Financing from government is vital,

given that the initial outlay on renewable technology such PV cell is quite expensive. PV in the long run is cheap, but financing is necessary early on if it is to be widely adopted. Happily the cost of the PV watt has fallen as low as $3,5; today this technology is really affordable. But Egyptian Government should

establish a strategy taking care of PV and other renewables.

Today Egypt is placing great emphasis on the development of natural gas exports in pipeline: the government should adopt a balance approach where renewables (especially PV) have a role, along with gas and oil, according availability, affordability, and convenience.

<u>FUTURE OPPORTUNITY</u> - The use of PV (with others renewables) can be useful because it could allow the Government of Egypt to solve the energy problem of its programme concerning 20 million persons mass migration out of the Nile Delta to the desert area; power energy can come from hundreds of thousands of PV (with others renewables) initiatives within communities. The community aspect of these energies in developing nations require local market knowledge: the opportunity is there for lead nations in Africa to prove themselves as capable partners to take PV to the entire continent. It is potentially a huge export opportunity.

<u>GREETINGS</u>- Egypt could export expertise in Photovoltaics in the future:

But that presume that the Government adopt PV and others renewables.

<u>LAST PREREQUISITE: TO FIRE AT FALSE MYTHS</u> - In the last December Workshop on PV in Cairo I heard, with too much persistence, that the cost of PV systems is too high. Some persons adopt the axiom "*PV = high cost*" as an incontrovertible myth.
But in a country as Egypt, which is stretched for about one million of km^2 and have lands distant one from the other more than 1,200,000 km, and where the grid is not so extended in every direction, it is very easy to find lands which are so far that the cost of potential extension of the grid, or the transportation of gasoline for diesel-motors is so costly to overcome the cost of an equivalent-in-power PV system installed there.

Remind the second myth to be killed: *grid power is very cheap*! Do not forget, in economical comparison between fossil-derived power and PV power, to take correctly in account the cost of environmental effects (noxious gas pollution, CO_2 effect, social diseases, oil-tankers disasters) and donation on the one hand, taxes and import duties on the other hand. In such a way you can really catch how PV is competitive, clean and cost effective.

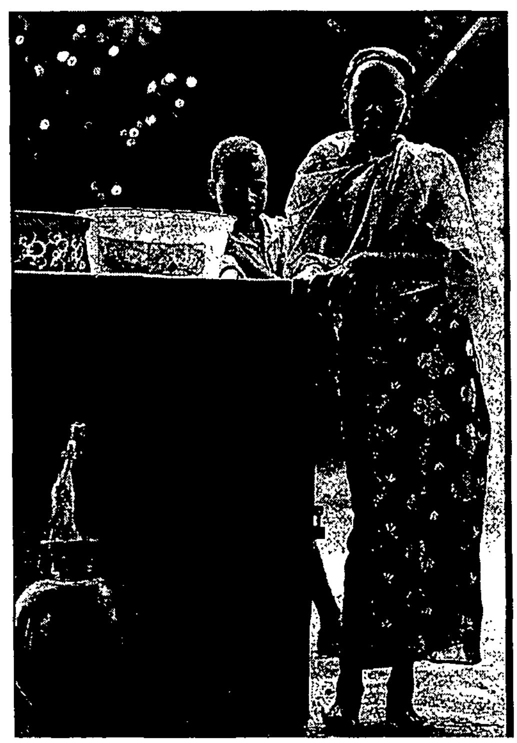
The end.

UNIDO-ICS TC on "PV APPLICATIONS"
Cairo 27th -29th May 2002

"PREREQUISITES ON PV APPLICATIONS IN EGYPT" Pictures

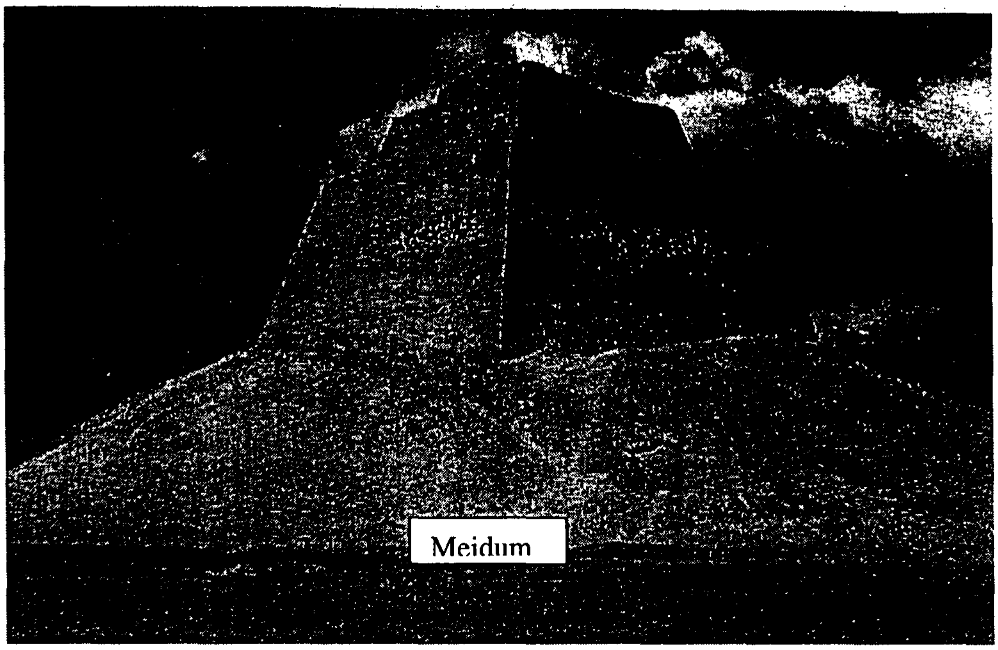
By Umberto Moschella

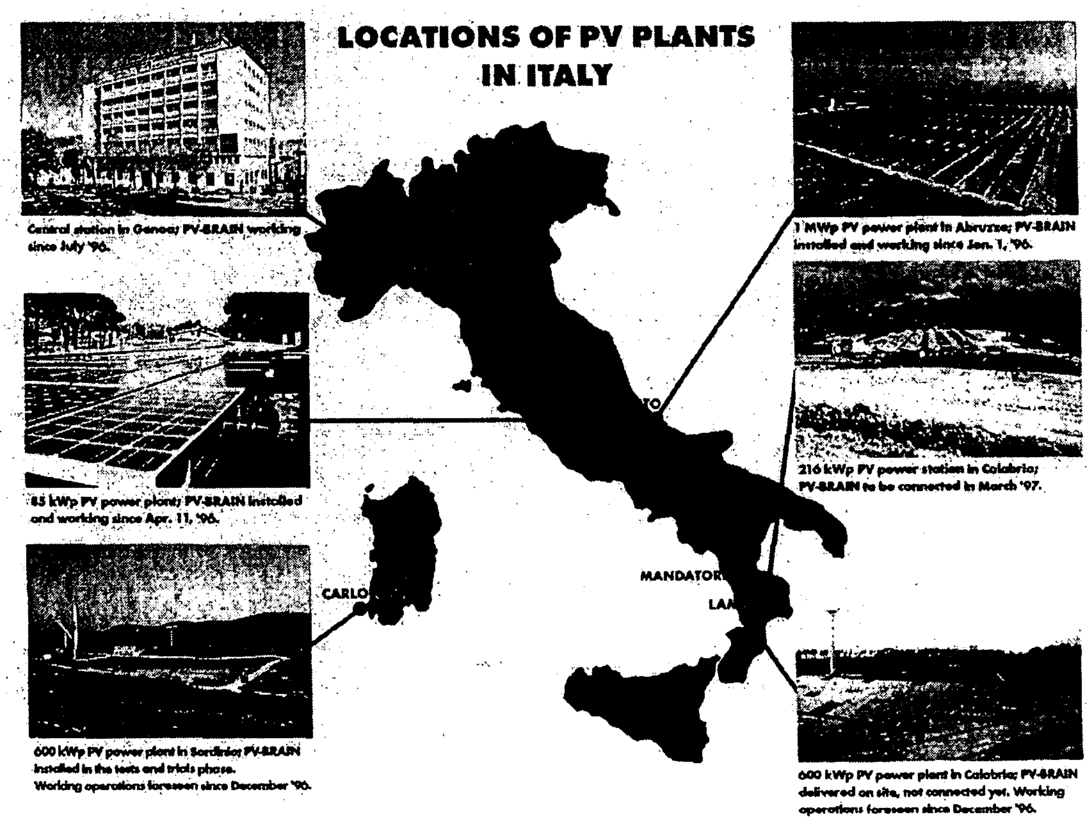
When will I have a Water Pumping PV System in my village?



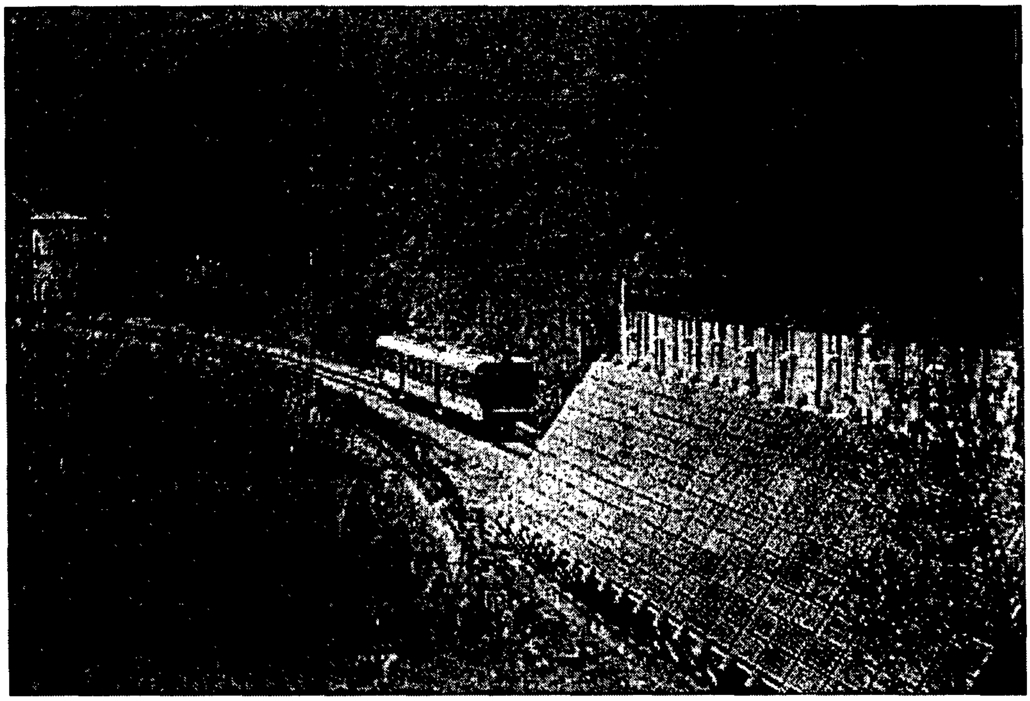
Do I have to wait that before Prof Gaballah Ali Gaballah enveil the mummy of Snefru he will sooner disclose in.....

the pyramid of Meidum

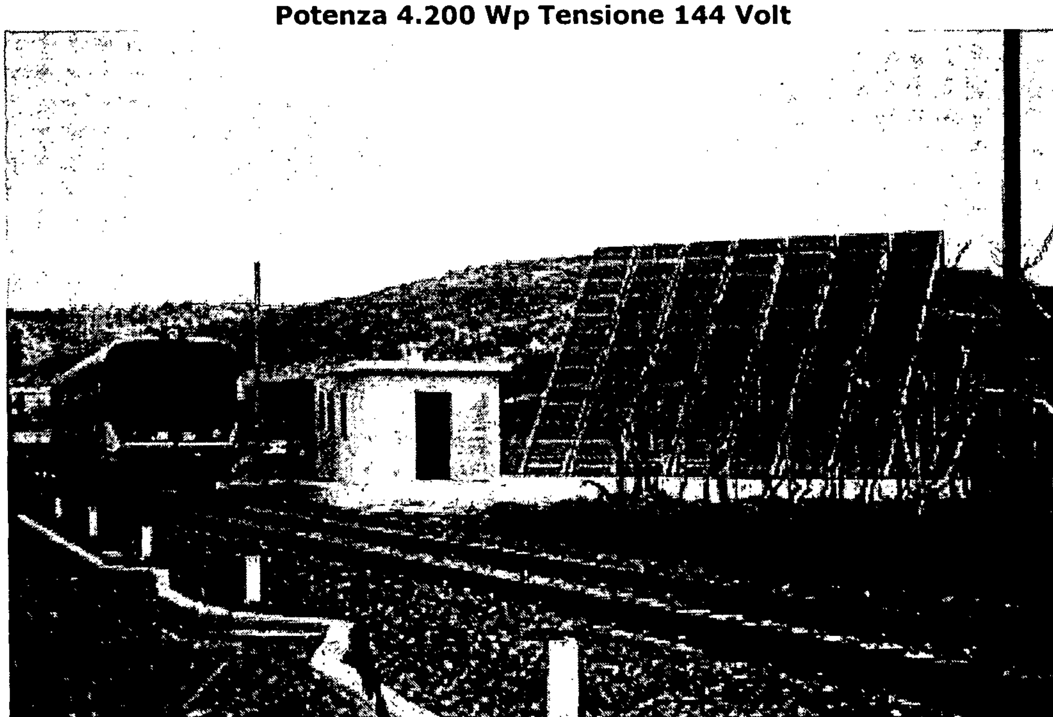

Meidum


LOCATIONS OF PV PLANTS IN ITALY
Central station in Genoa; PV-BRAIN working since July '96.
1 MWp PV power plant in Abruzzo; PV-BRAIN installed and working since Jan. 1, '96.
85 kWp PV power plant; PV-BRAIN installed and working since Apr. 11, '96.
216 kWp PV power station in Calabria; PV-BRAIN to be connected in March '97.
CARLO
MANDATOR
LA
600 kWp PV power plant in Sardinia; PV-BRAIN installed in the tests and trials phase.
Working operations foreseen since December '96.
600 kWp PV power plant in Calabria; PV-BRAIN delivered on site, not connected yet. Working operations foreseen since December '96.

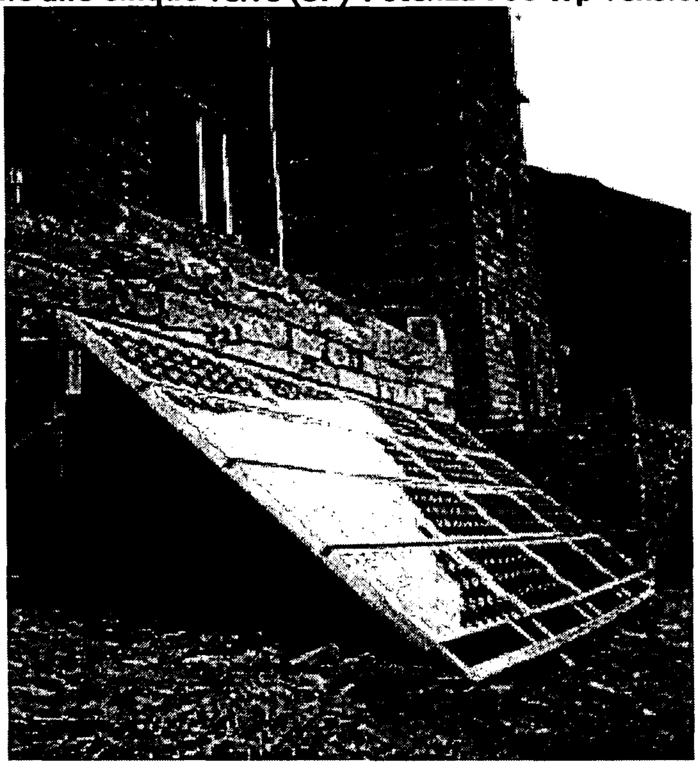
1-Impianto Fotovoltaico per l'illuminazione della galleria di 4,5 Km sulla linea Ferroviaria Firenze-Faenza.
Dispositivo automatico di accensione e spegnimento luci con fotorivelatori.
Potenza 10.000 Wp Tensione 120 Volt



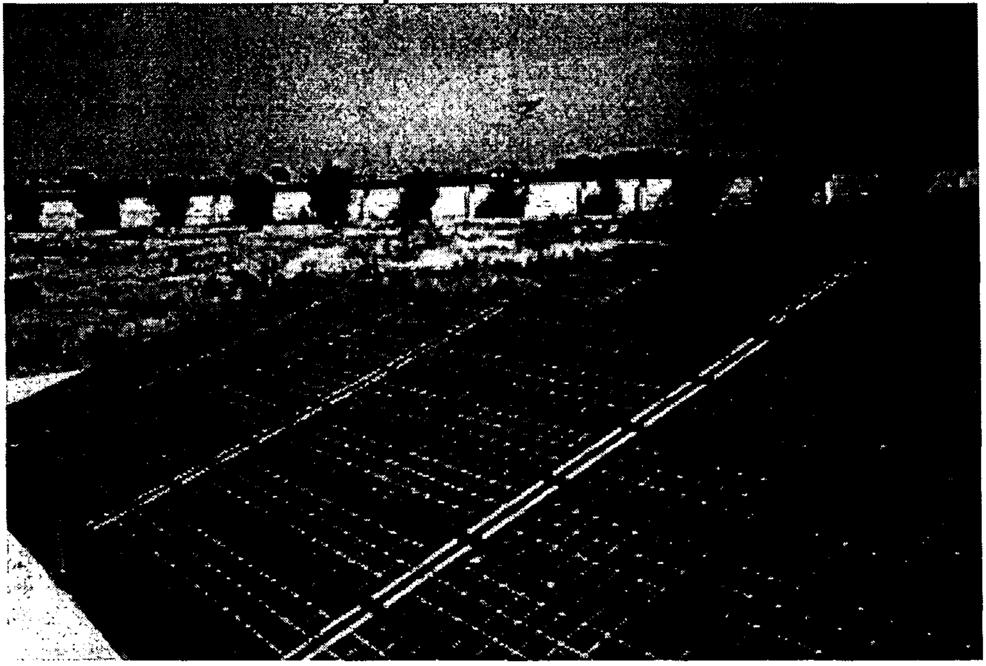
2-Impianto Fotovoltaico per l'alimentazione di passaggio a livello PL V301
Potenza 4.200 Wp Tensione 144 Volt



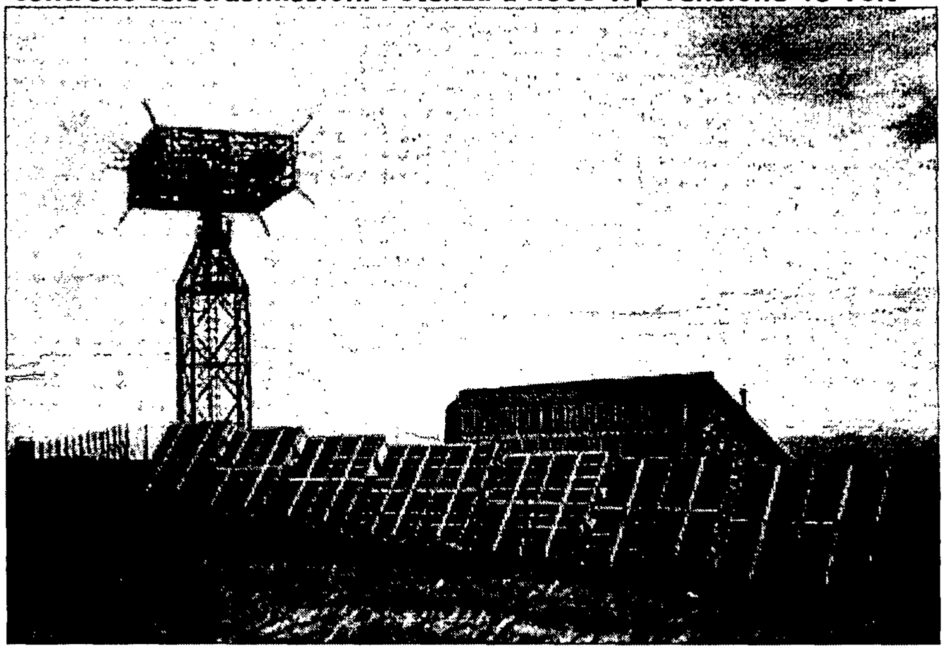
3-Impianto Fotovoltaico per l'alimentazione di utenze residenziali isolate Installazione alle Cinque Terre (SP)-Potenza 700 Wp Tensione 24 Volt



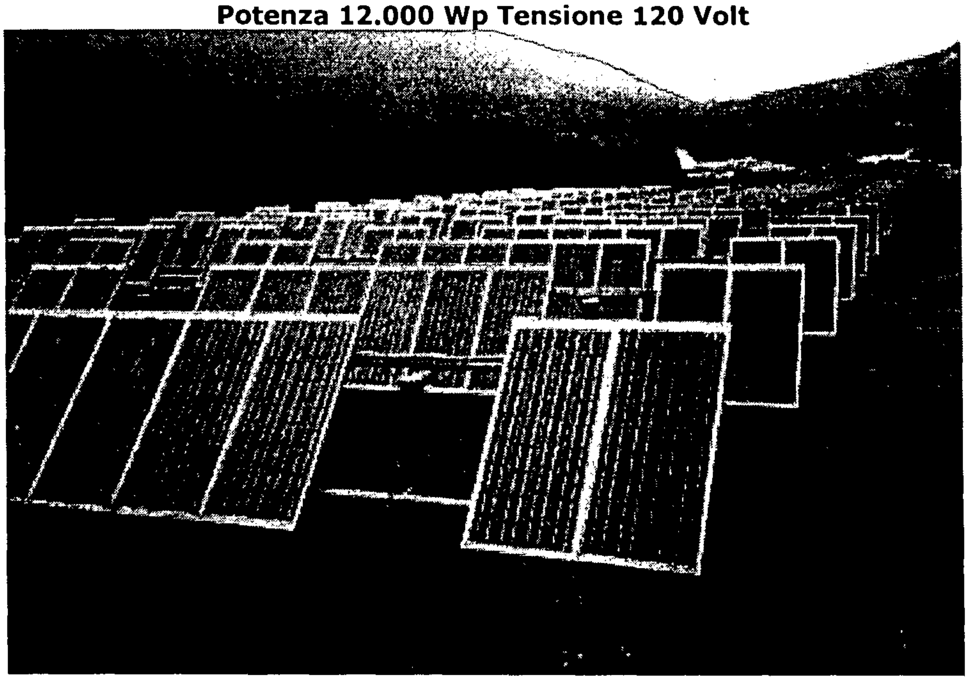
4-Tetto fotovoltaico autoportante installato a Catania Direttamente collegato alla rete elettrica-Potenza 6.000 Wp Tensione 120 Volt



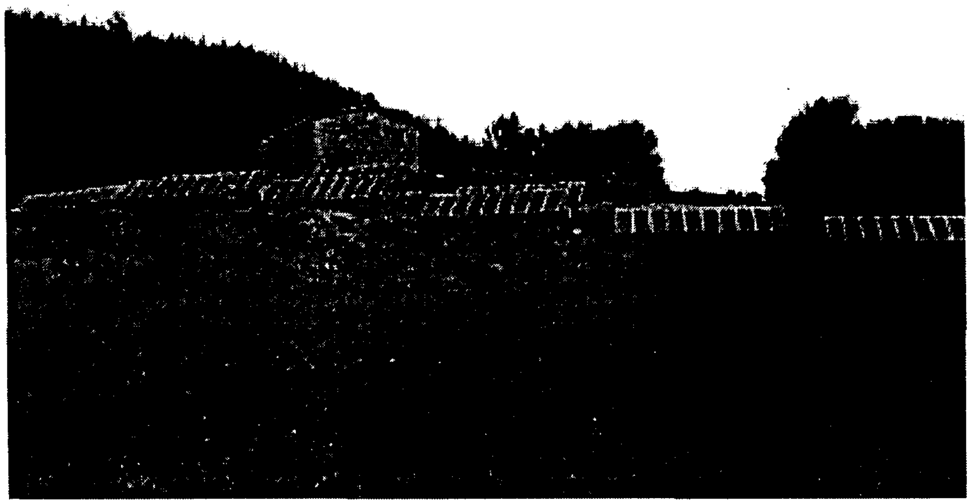
5-Impianto Fotovoltaico sul Monte Pratomagno, per fornire energia a torre di controllo teletrasmissioni Potenza 14.000 Wp Tensione 48 Volt



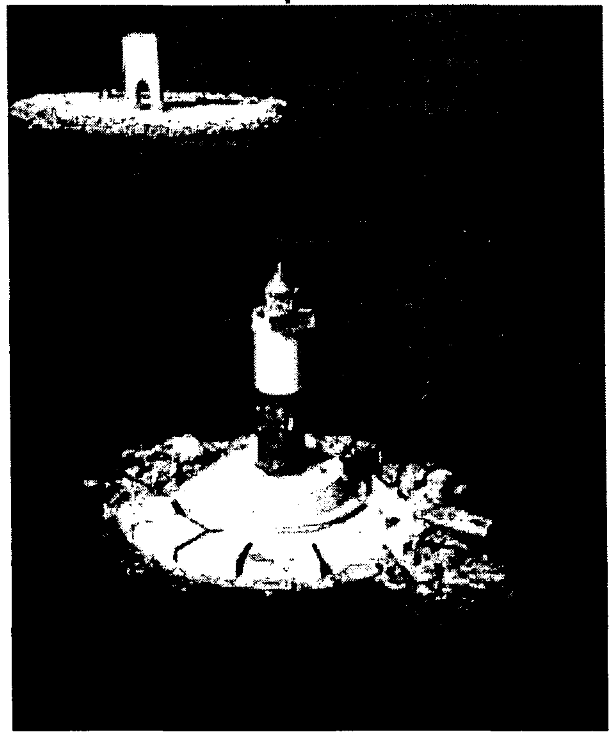
6- Impianto Fotovoltaico per l'alimentazione di luci per illuminazione aeroporto Potenza 12.000 Wp Tensione 120 Volt



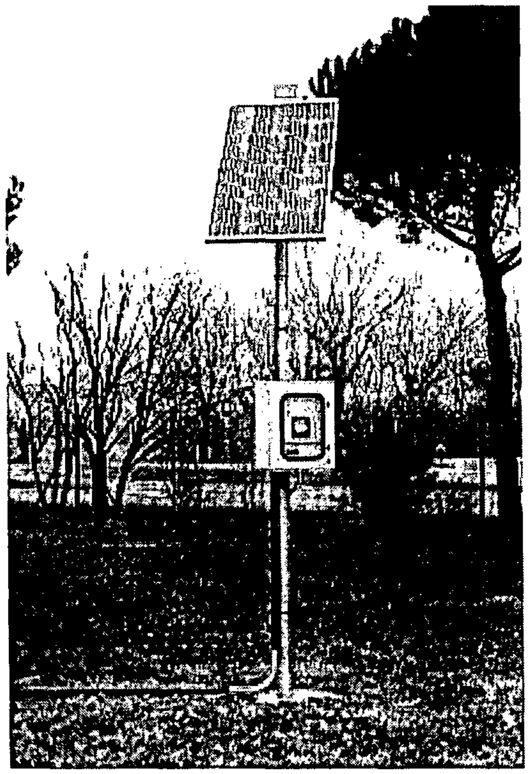
7-Impianto Fotovoltaico realizzato a Monterufoli Potenza 12.000 Wp Tensione 120 Volt



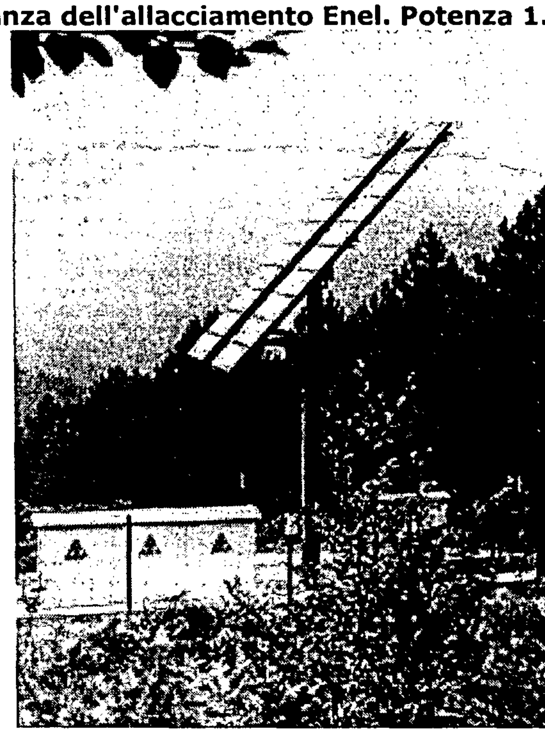
**8-Impianto Fotovoltaico realizzato sul faro dell'Isola Meloria
Potenza 600 Wp Tensione 12 Volt**



9-Impianto dimostrativo per produzione di energia elettrica connesso in rete, "Green Connected" per uso didattico. Potenza 110 Wp Tensione 24 Volt.

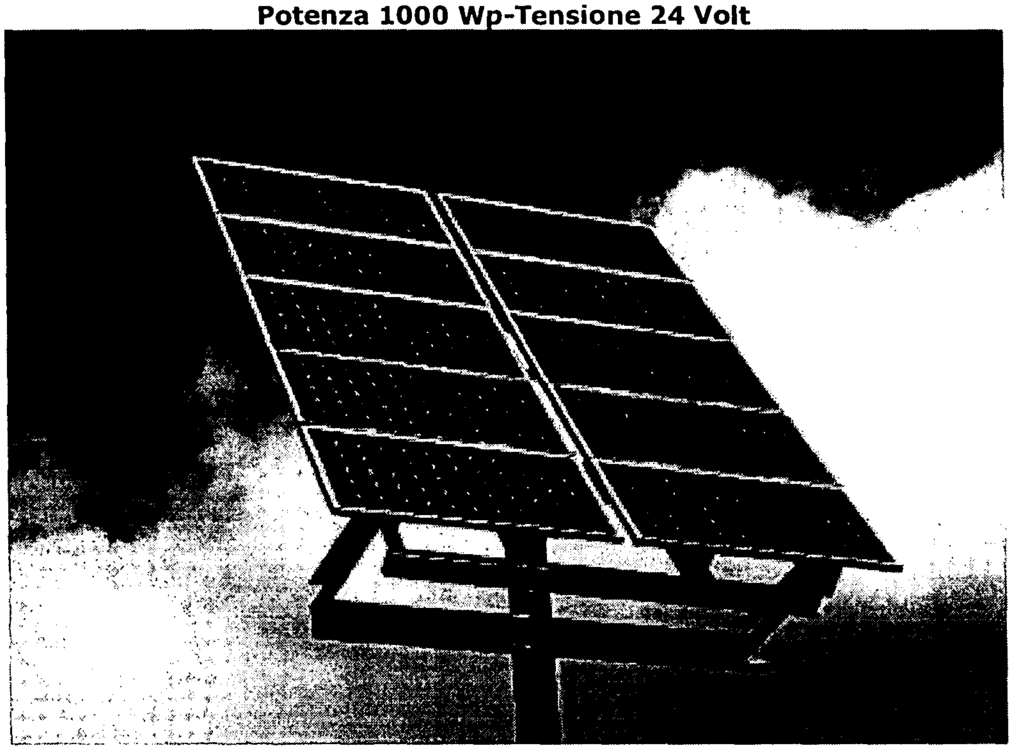


10-Impianto Fotovoltaico realizzato presso il Rifugio Pacini per fornire alimentazione elettrica in mancanza dell'allacciamento Enel. Potenza 1.000 Wp Tensione 24 Volt.

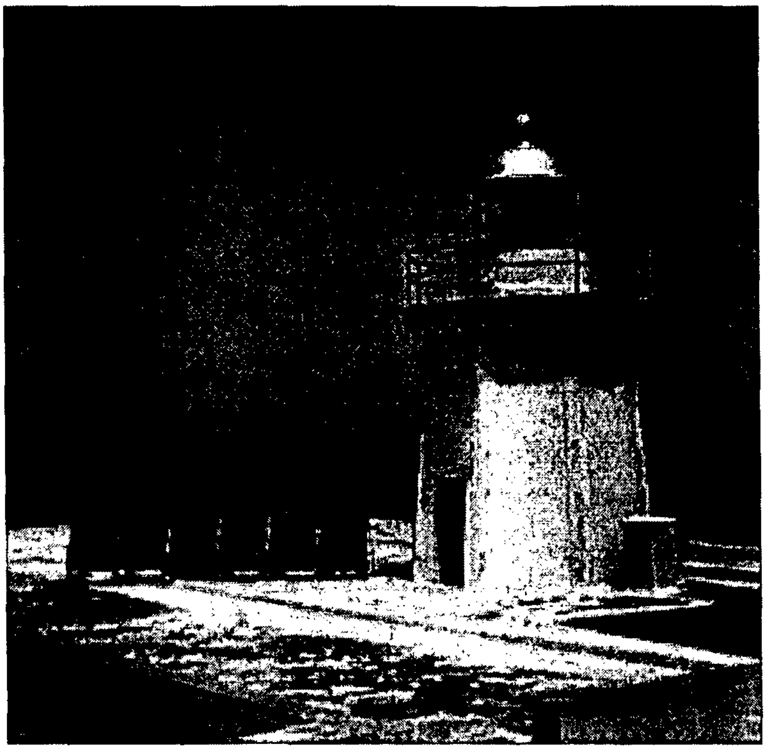


11-Impianto Fotovoltaico per l'alimentazione del Faro sull'Isola della Palmaiola. Potenza 8000 W_p-Tensione 110 Volt

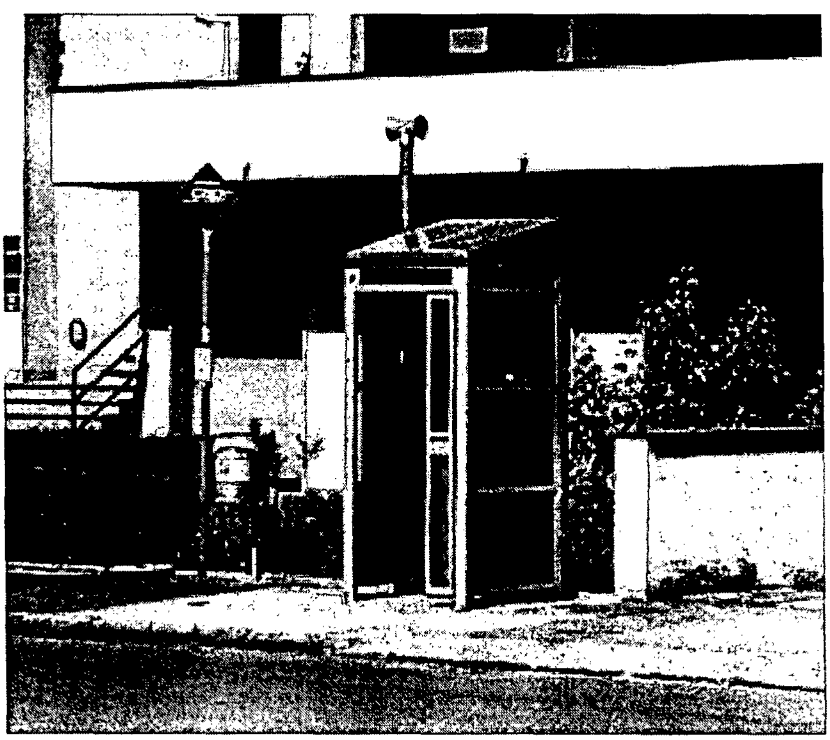
**12-Impianto installato a Licata per alimentazione di Passaggio a Livello.
Potenza 1000 Wp-Tensione 24 Volt**



**13-Impianto Fotovoltaico per l'alimentazione del Faro sull'Isola di Zannone
Potenza 1500 Wp-Tensione 24 Volt**

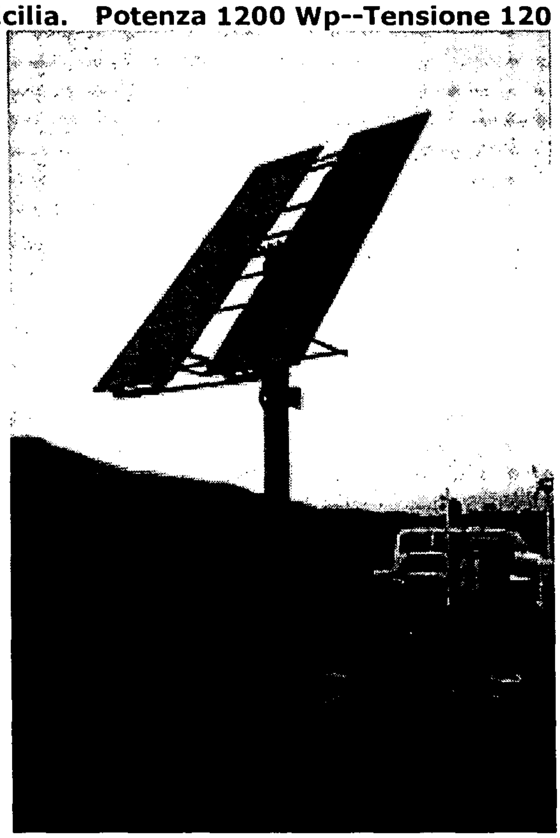


14-Cabina alimentata da modulo fotovoltaico. Potenza 100 Wp-Tensione 12 Volt.

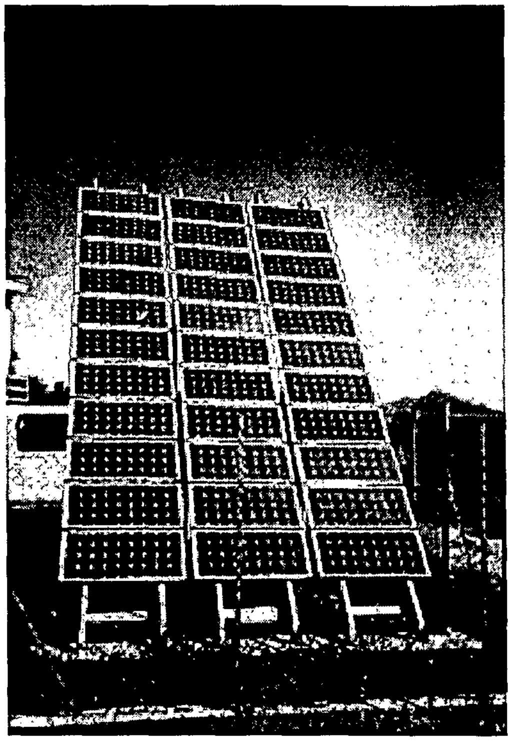


15-**Impianto Fotovoltaico installato a Cetona**
Potenza 25.000 Wp--Tensione 300 Volt

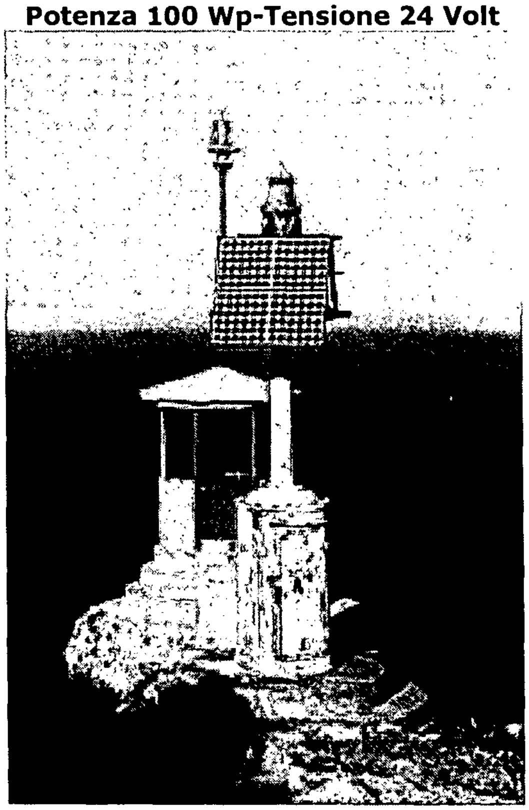
16-Impianto PL V308. Per alimentazione di Passaggio a Livello, installazione in Sicilia. Potenza 1200 Wp--Tensione 120 Volt



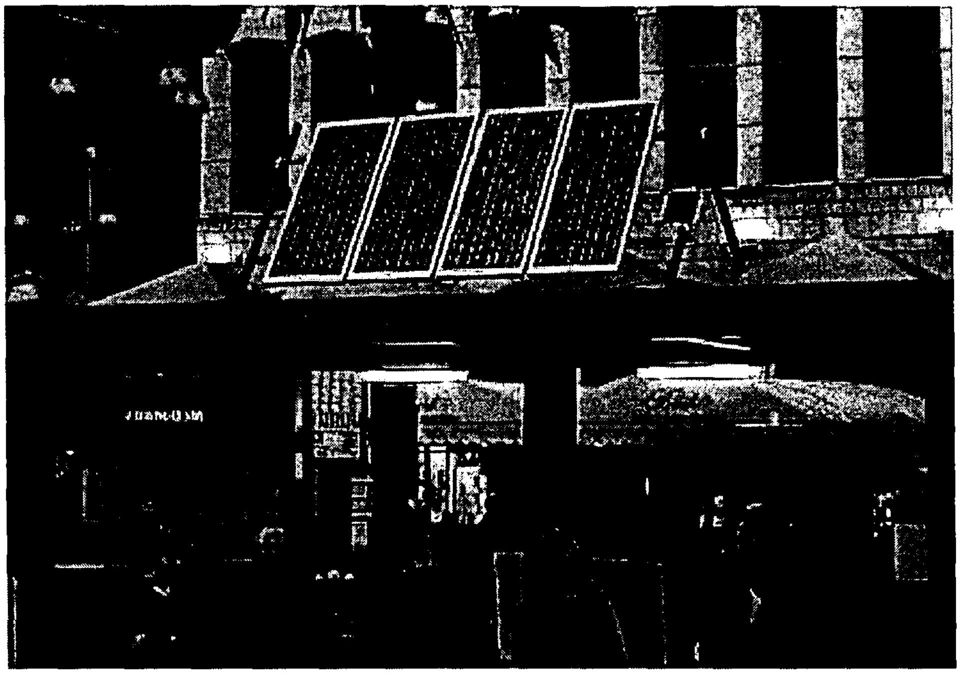
17-Impianto Fotovoltaico per l'alimentazione di un Passaggio a Livello a S. Gavino (CA)
Potenza 1800 Wp - Tensione 144 Volt



18-Impianto Fotovoltaico del Faro dell'Isola di Gorgona.
Potenza 100 Wp-Tensione 24 Volt

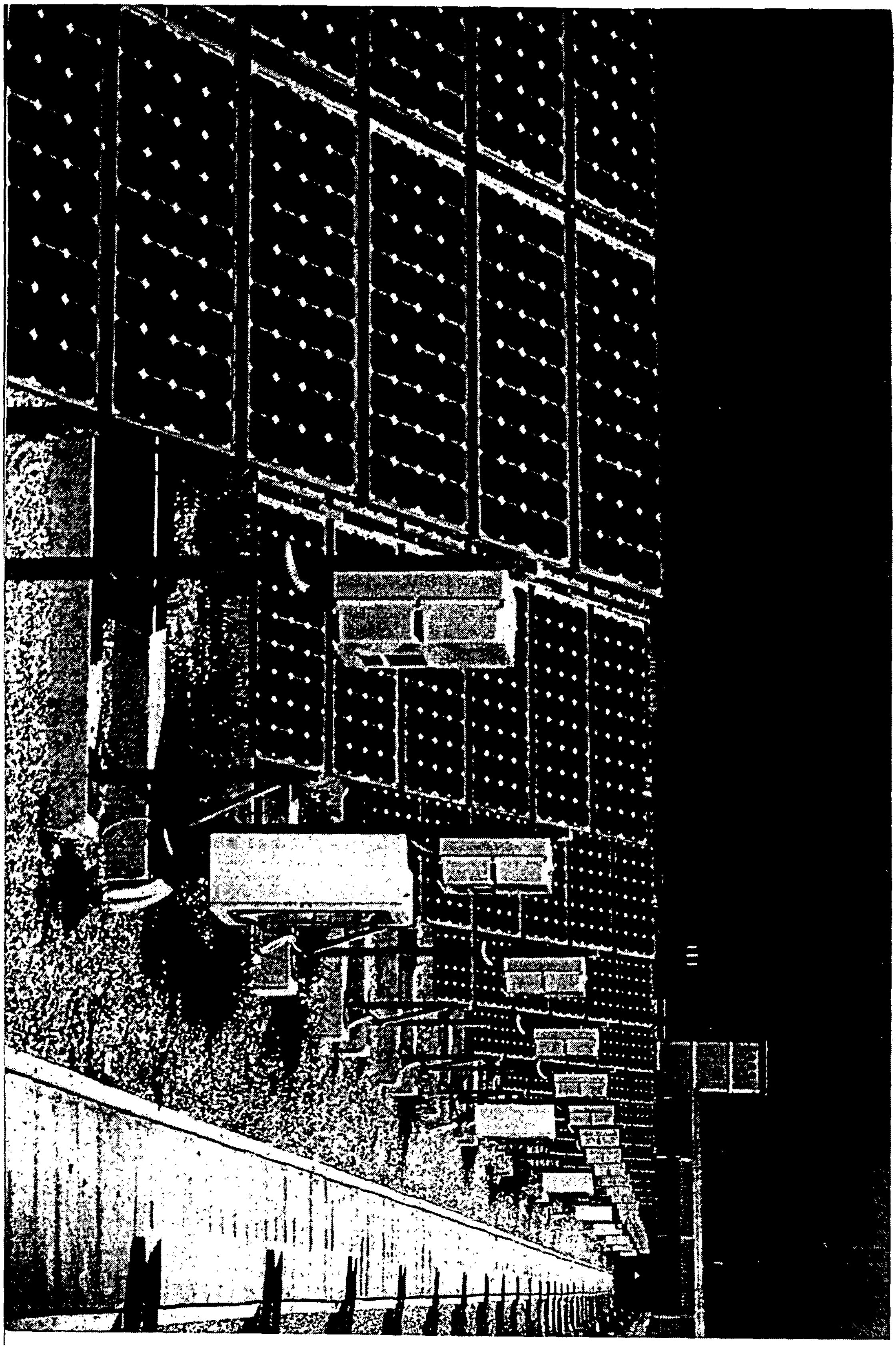


19-Impianto Fotovoltaico per illuminazione pensilina fermata autobus a Livorno.
Potenza 200 Wp--Tensione 24 Volt

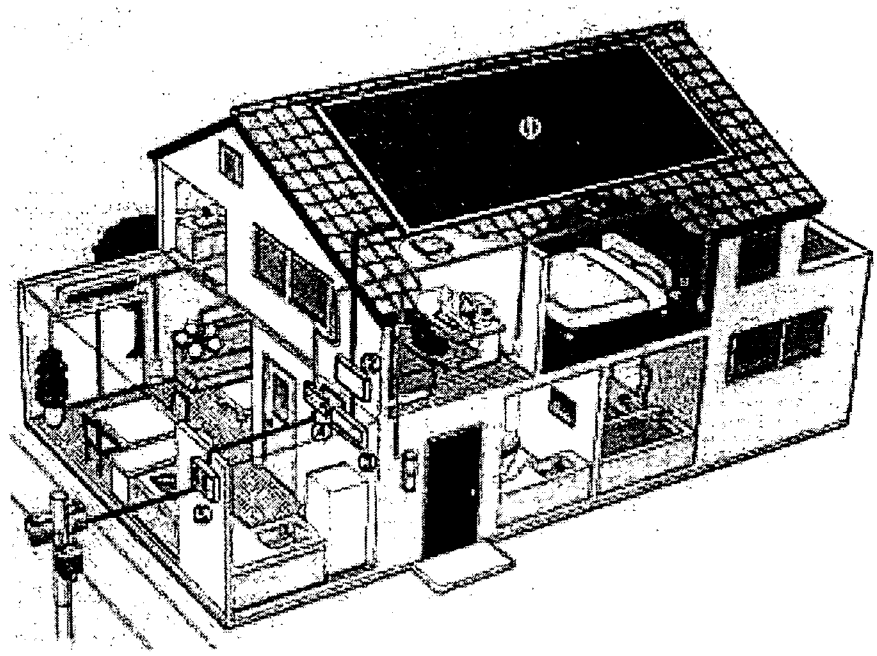


20-PV power source for radio and cellular telephone batteries

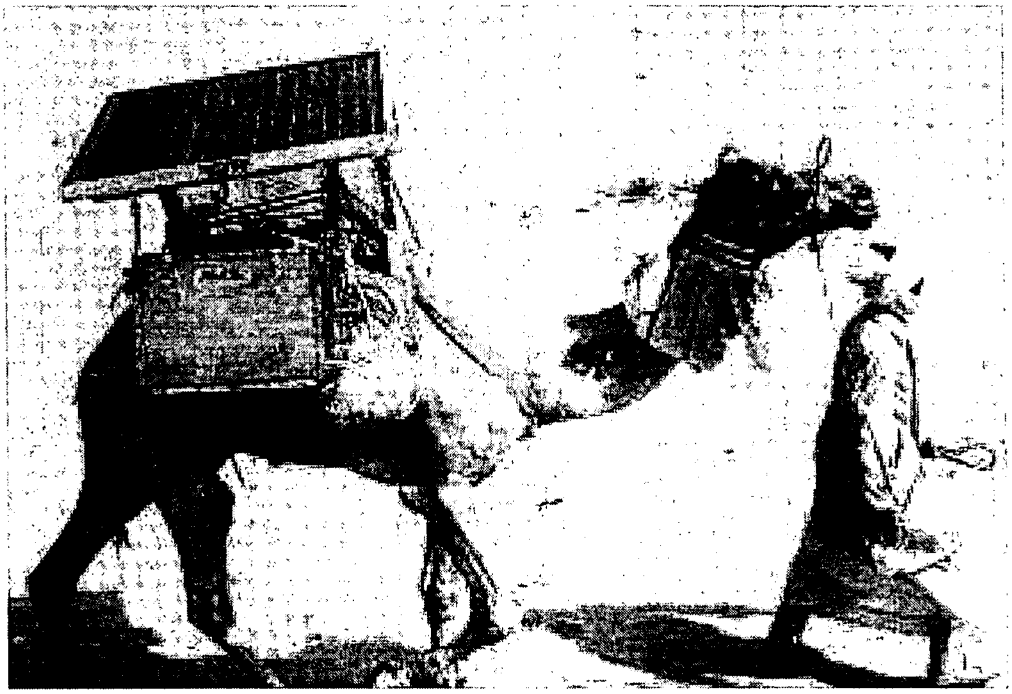
22- Veduta parziale dell'Impianto fotovoltaico di VASTO (CH) Italy 1 MW_p 600 V_{dc}



23-Esempio schematico di impianto PV per alimentare una abitazione

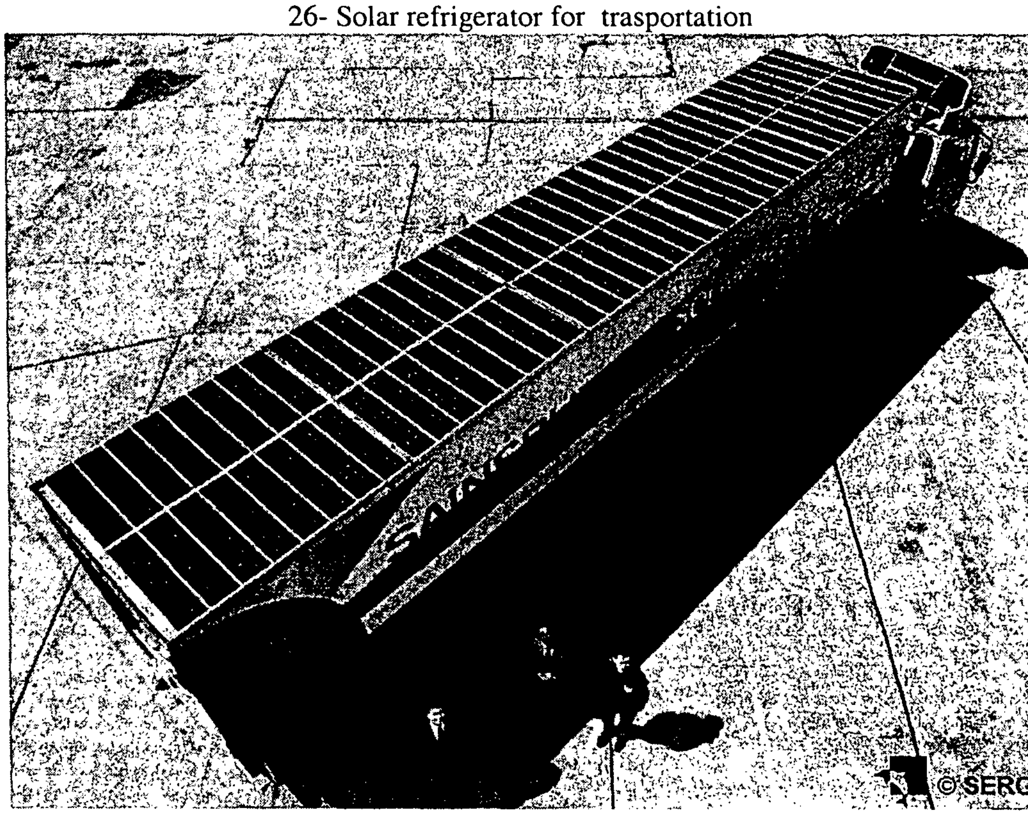


24- Frigorifero per vaccini alimentato da Impianto Fotovoltaico

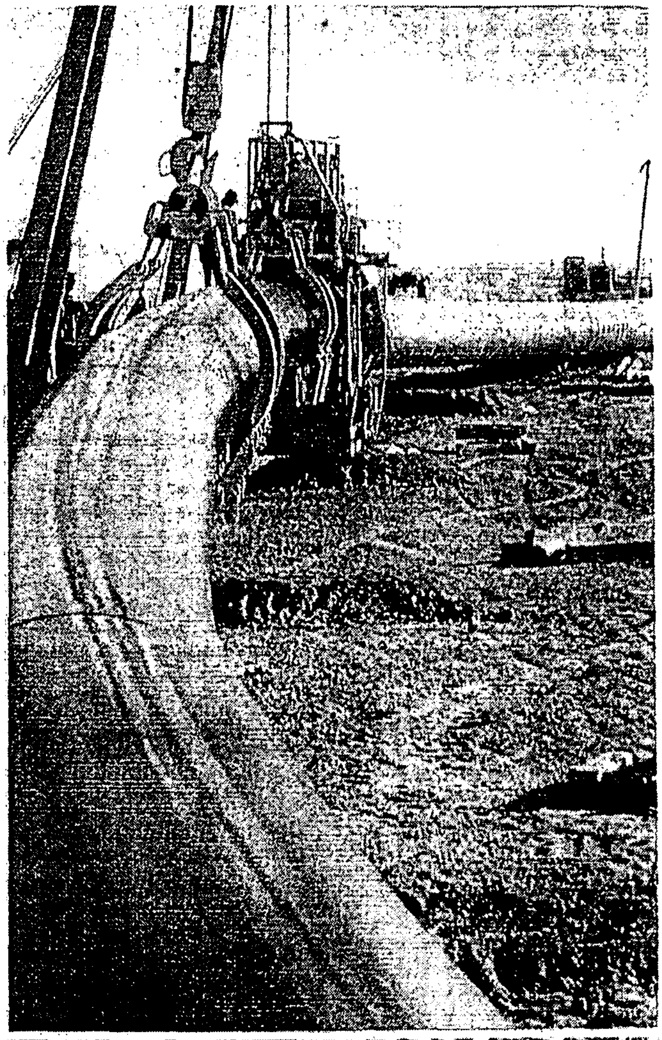


25- Airport Signalling Lucca Italy

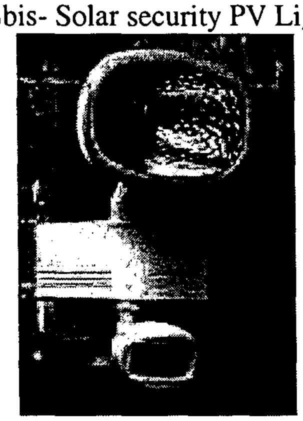
26- Solar refrigerator for trasportation



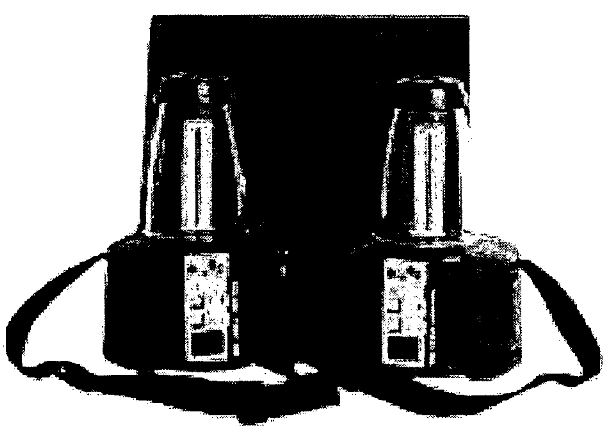
27- Catodic Protection



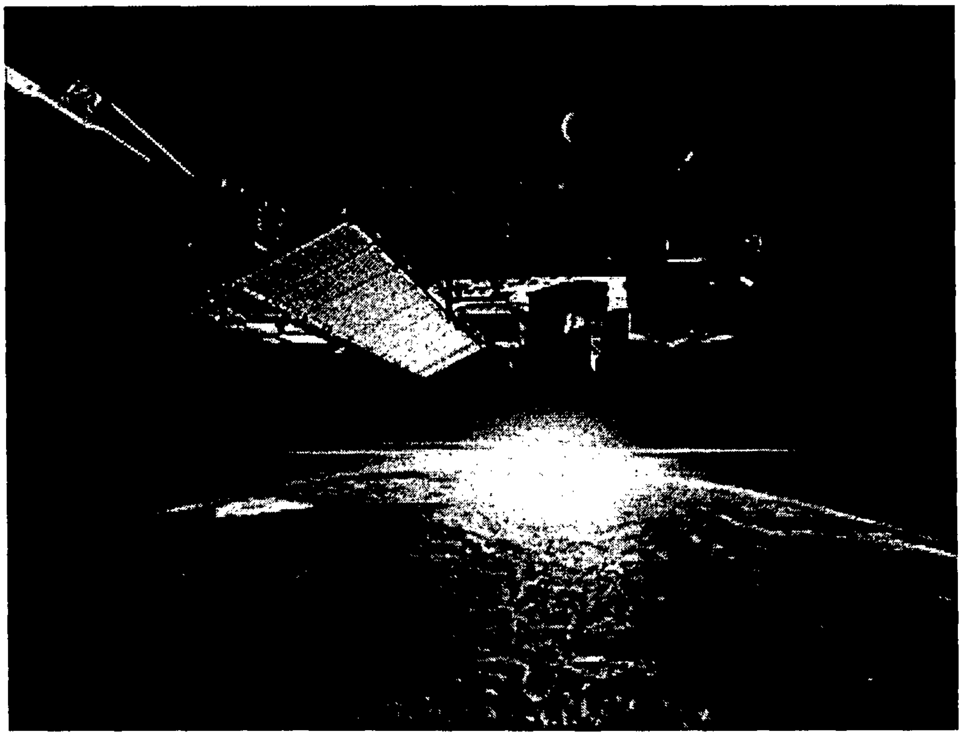
28bis- Solar security PV Light



28- Portable Lantern

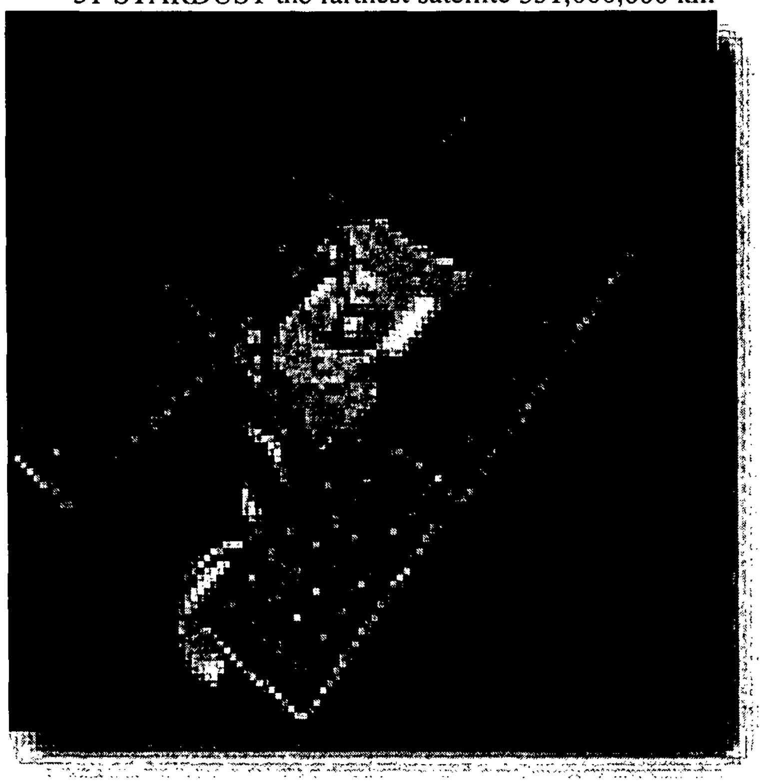


29-ENVISAT satellite di ricerca

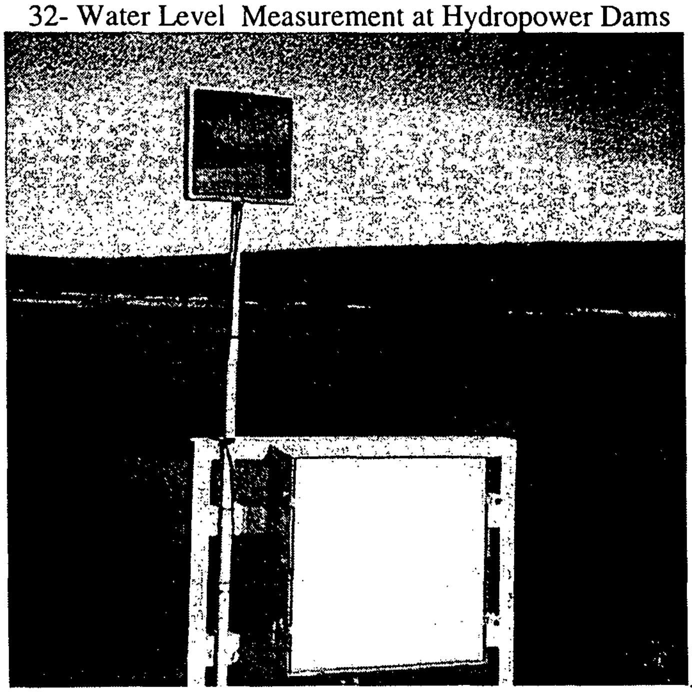


30- ISS International Space Station

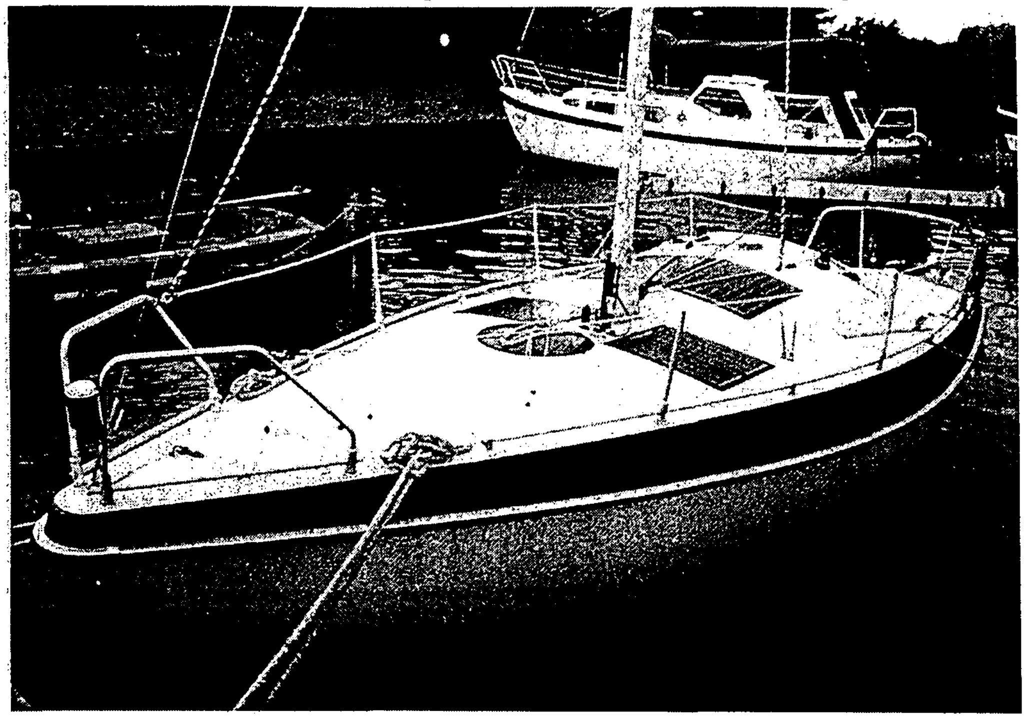
31-STARDUST the farthest satellite 351,000,000 km



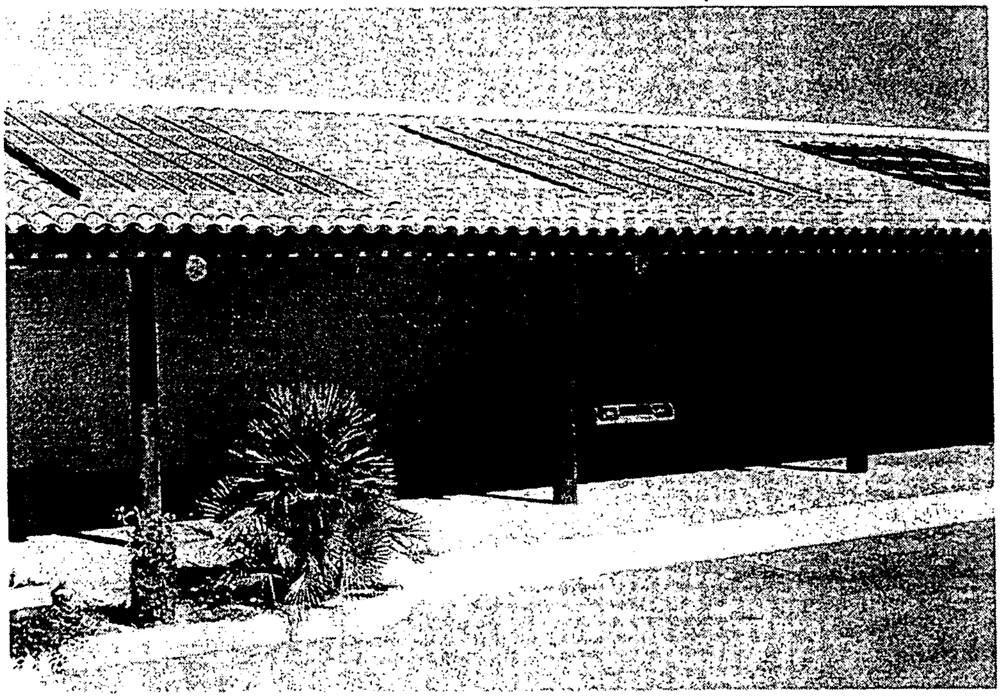
32- Water Level Measurement at Hydropower Dams



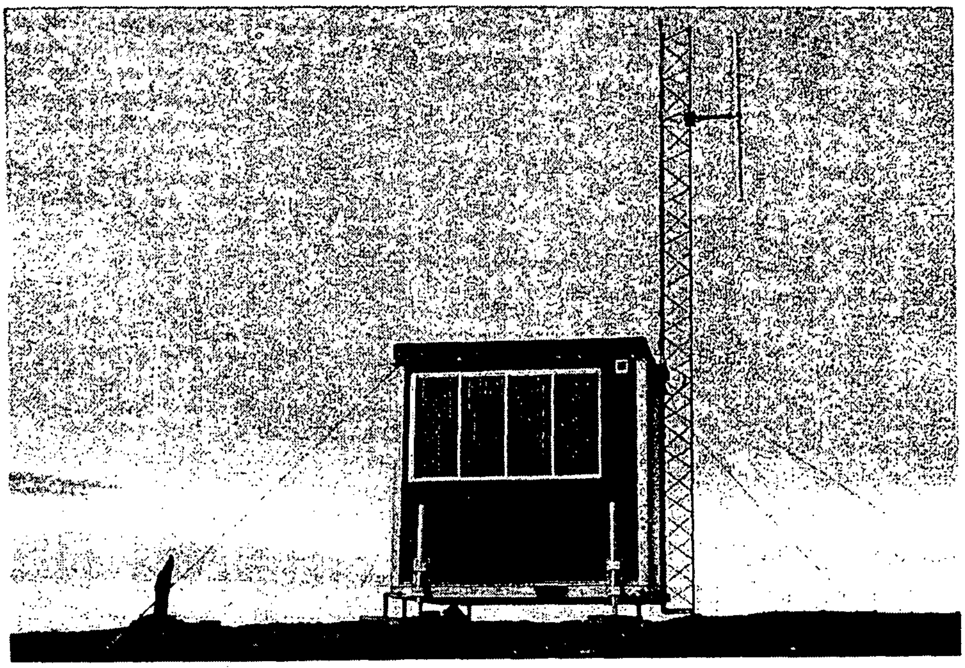
33- PV electrical Propulsion of Recreation Boats 120Wp



34-Electric Car Charger Shed 1kW$_p$

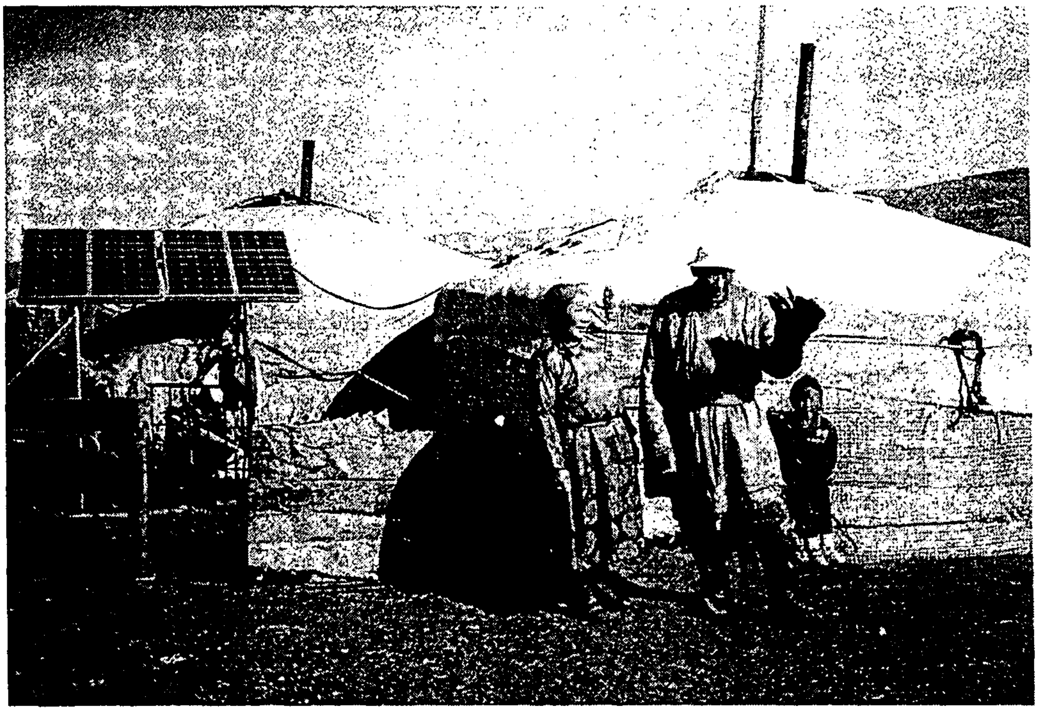


34-Repeater Stsation for Mobile Emergency Phones in Mountains at 68°N lat



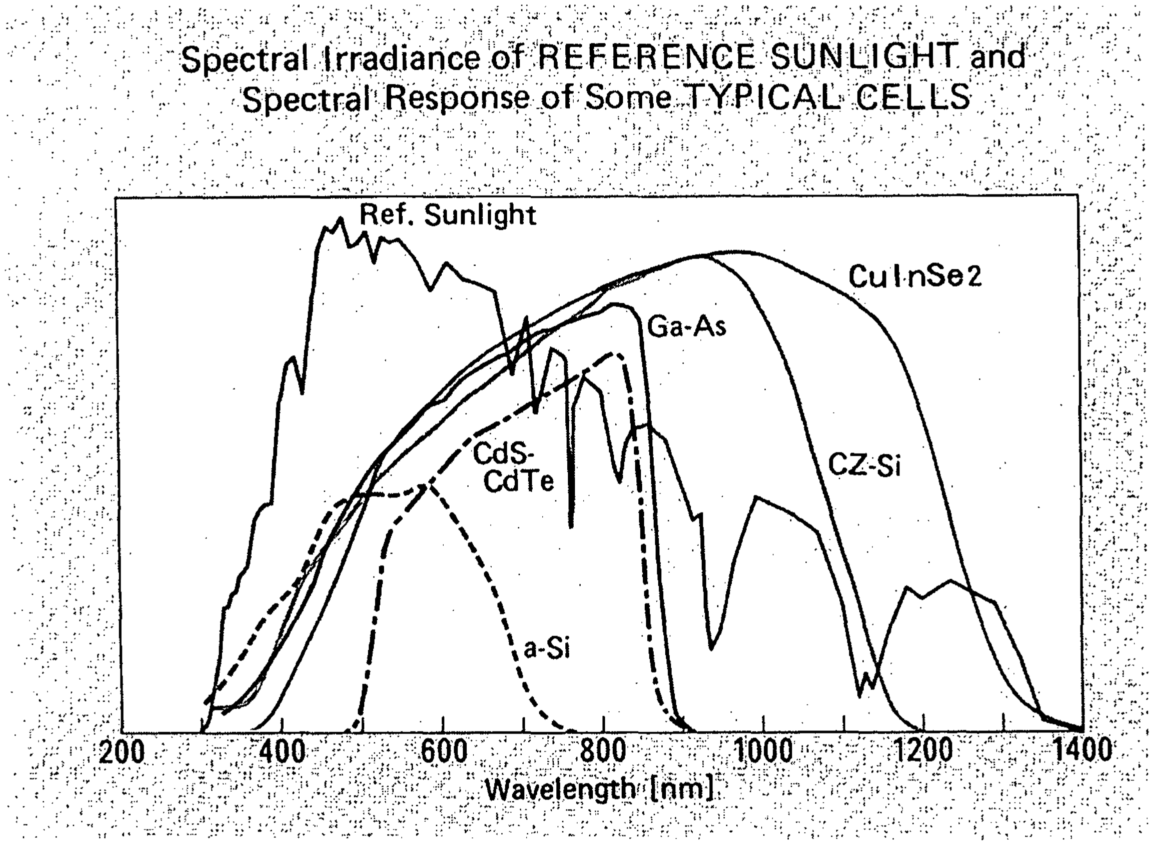
35- Houseboat and Barges NL 1kW24V450Ah

36-Mobile House energized by PV System 204Wp24V70Ah Mongolia

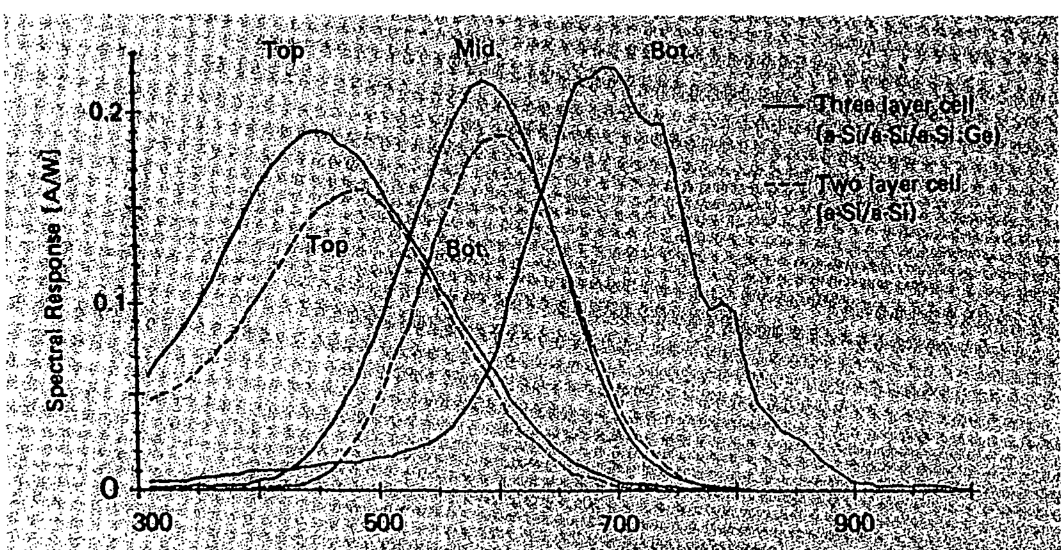


37- LET THE DESERT GENERATE LIFE

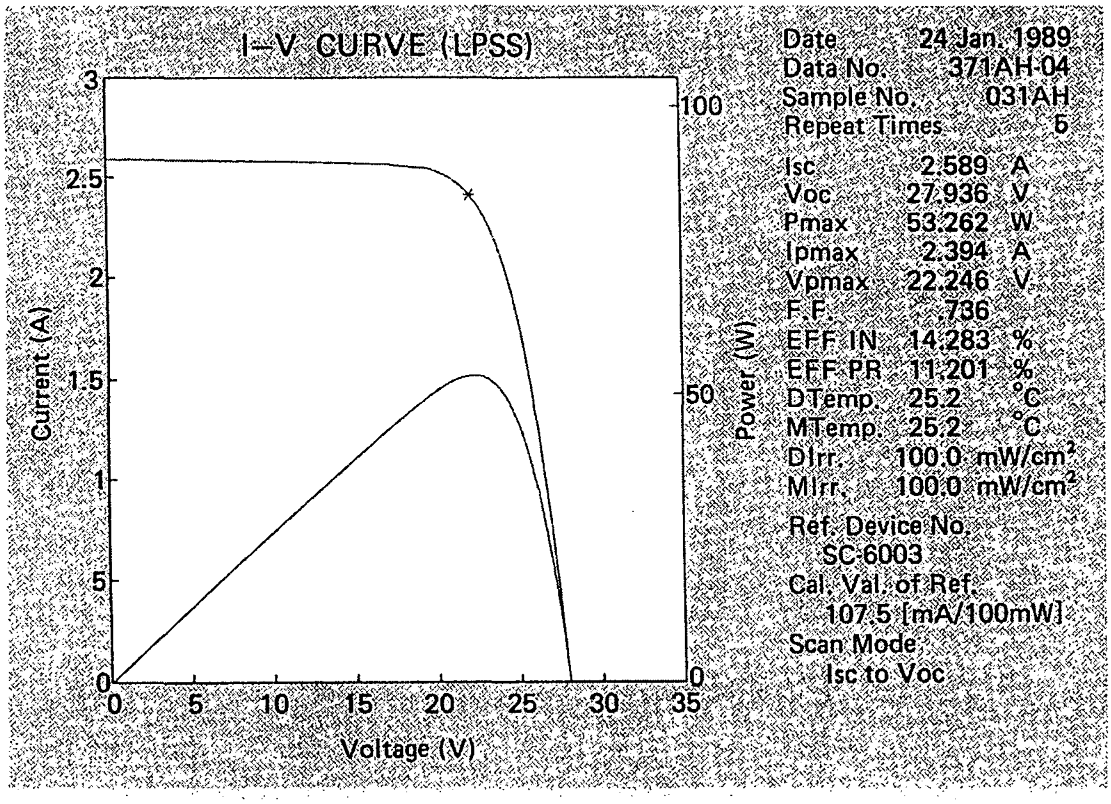
cccc



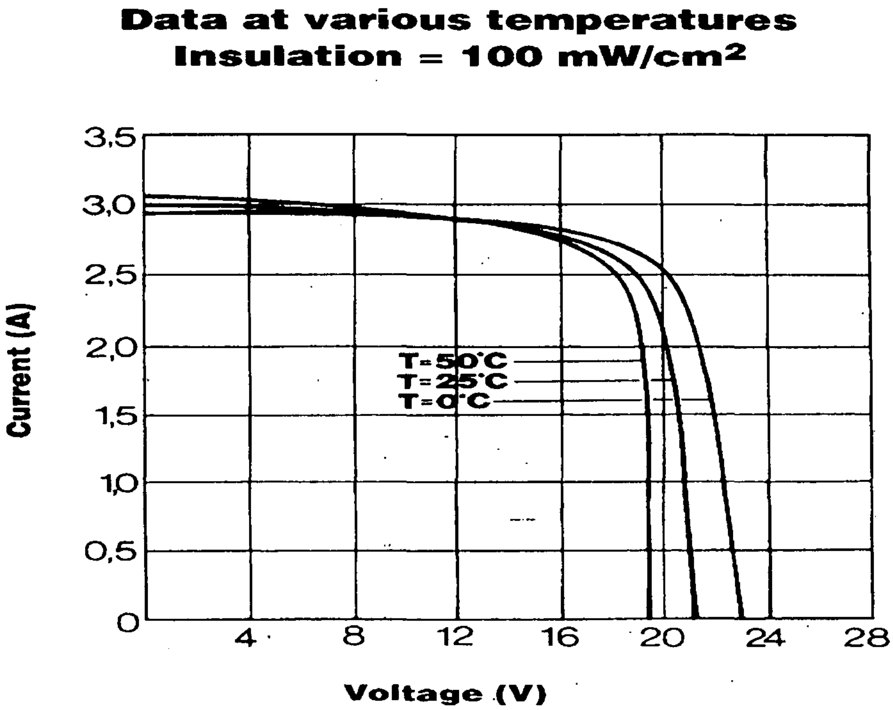
bbbbbb



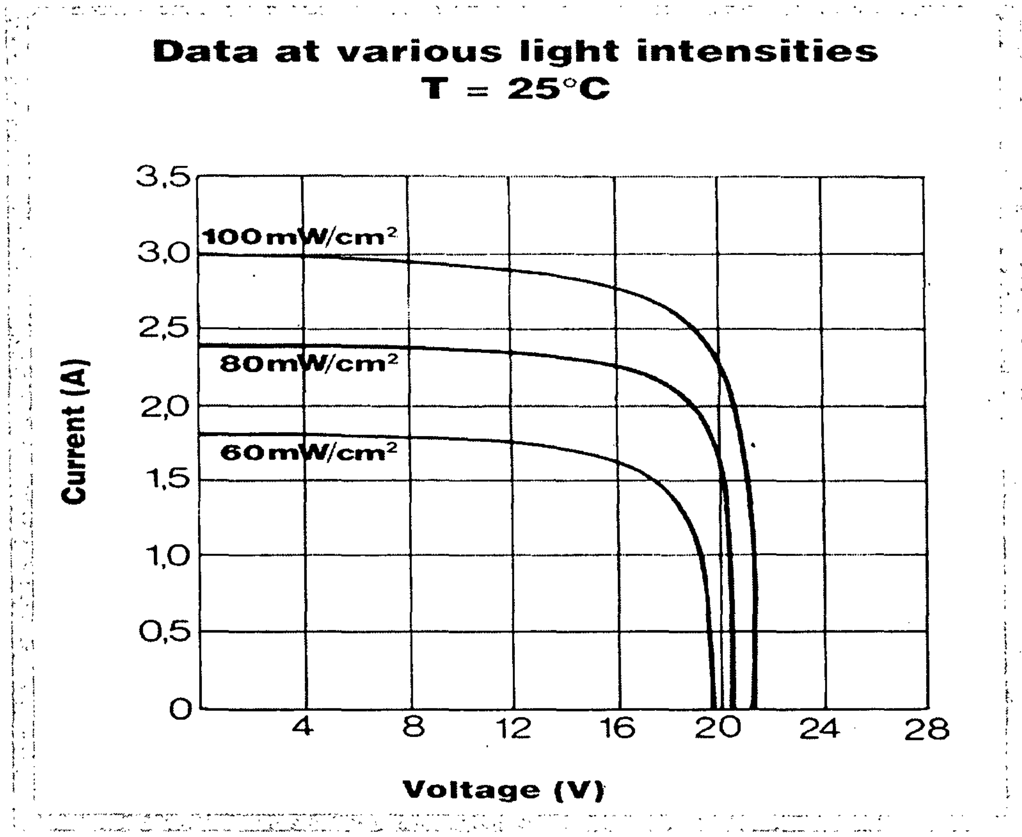
Spectral responses of two layer and three layer Tandem solar cells eeee


I–V CURVE (LPSS)
Current (A)
Power (W)
Voltage (V)
Date 24 Jan. 1989
Data No. 371AH-04
Sample No. 031AH
Repeat Times 5
Isc 2.589 A
Voc 27.936 V
Pmax 53.262 W
Ipmax 2.394 A
Vpmax 22.246 V
F.F. .736
EFF IN 14.283 %
EFF PR 11.201 %
DTemp. 25.2 °C
MTemp. 25.2 °C
DIrr. 100.0 mW/cm²
MIrr. 100.0 mW/cm²
Ref. Device No.
SC-6003
Cal. Val. of Ref.
107.5 [mA/100mW]
Scan Mode
Isc to Voc

ddd

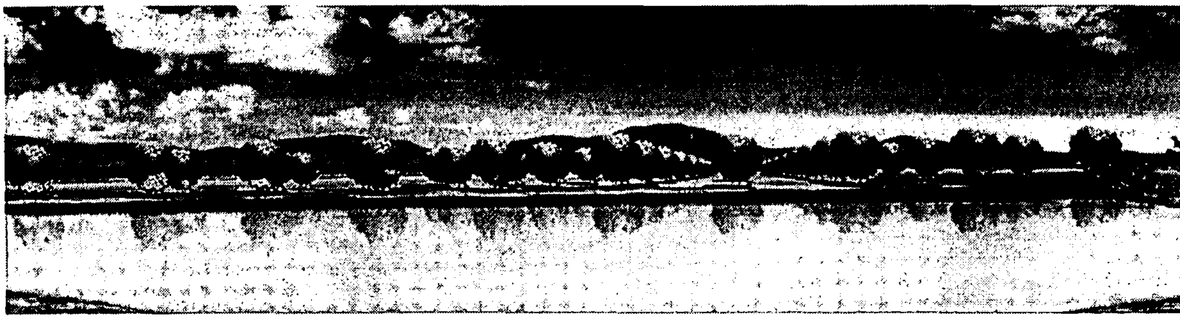

Data at various temperatures
Insulation = 100 mW/cm2
Current (A)
Voltage (V)
T=50°C
T=25°C
T=0°C

fff



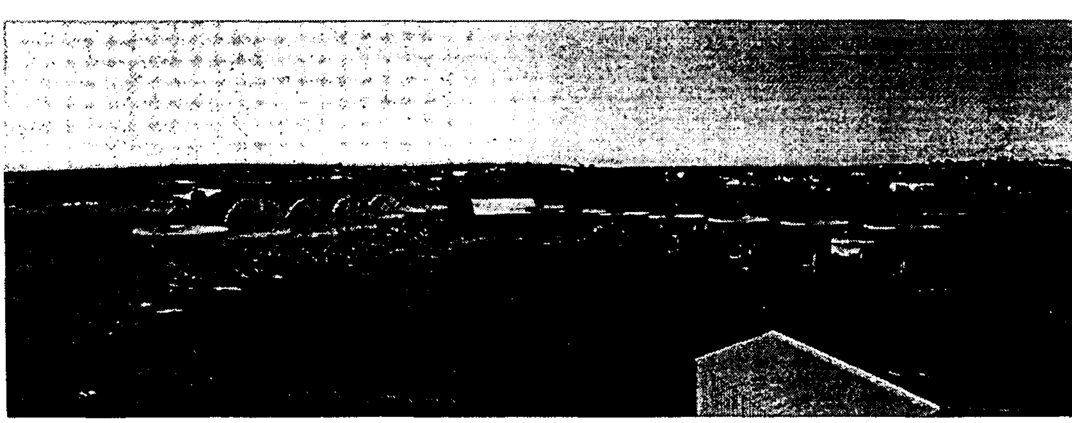
ff

Caravanning PV

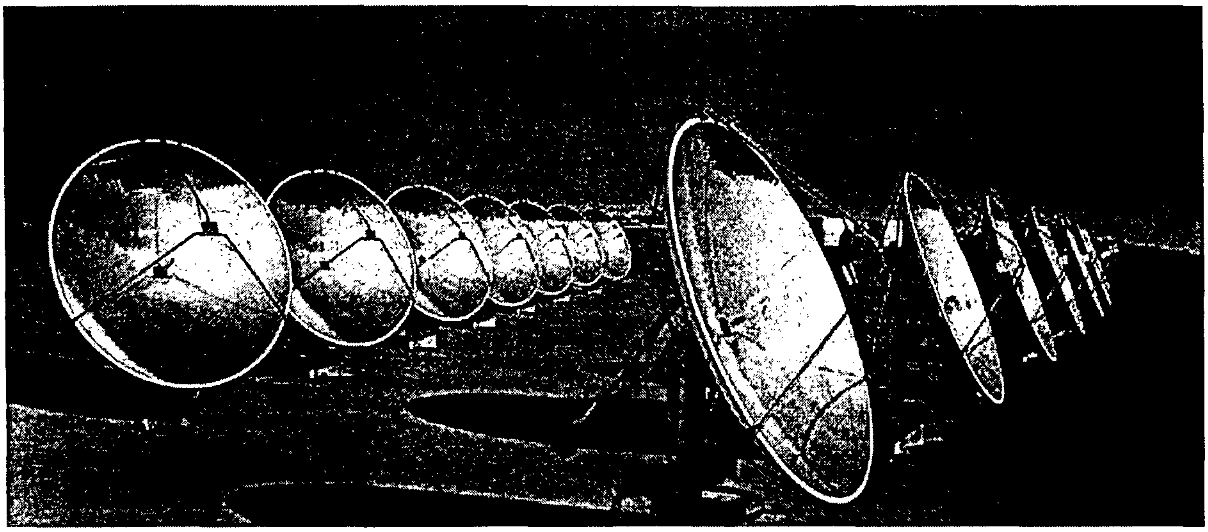


Fosterville Northern Victoria 2MW PV system

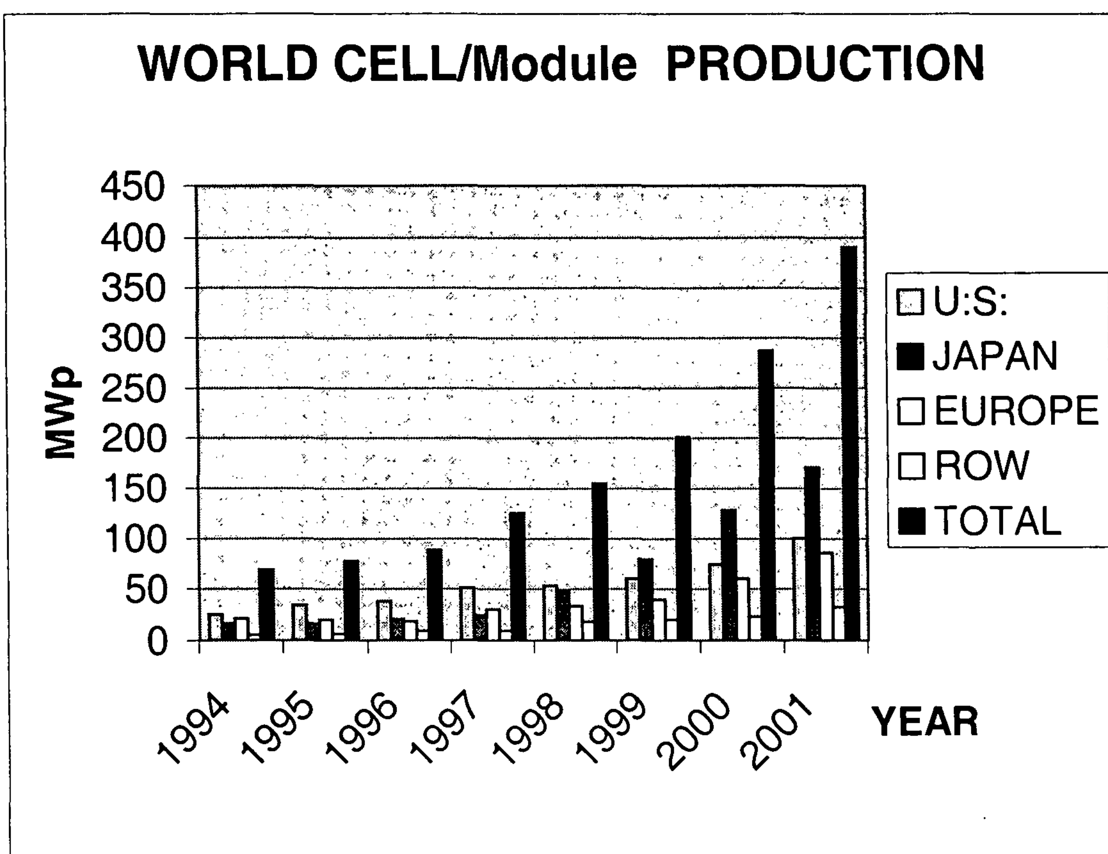
Fosterville SS20 20kW

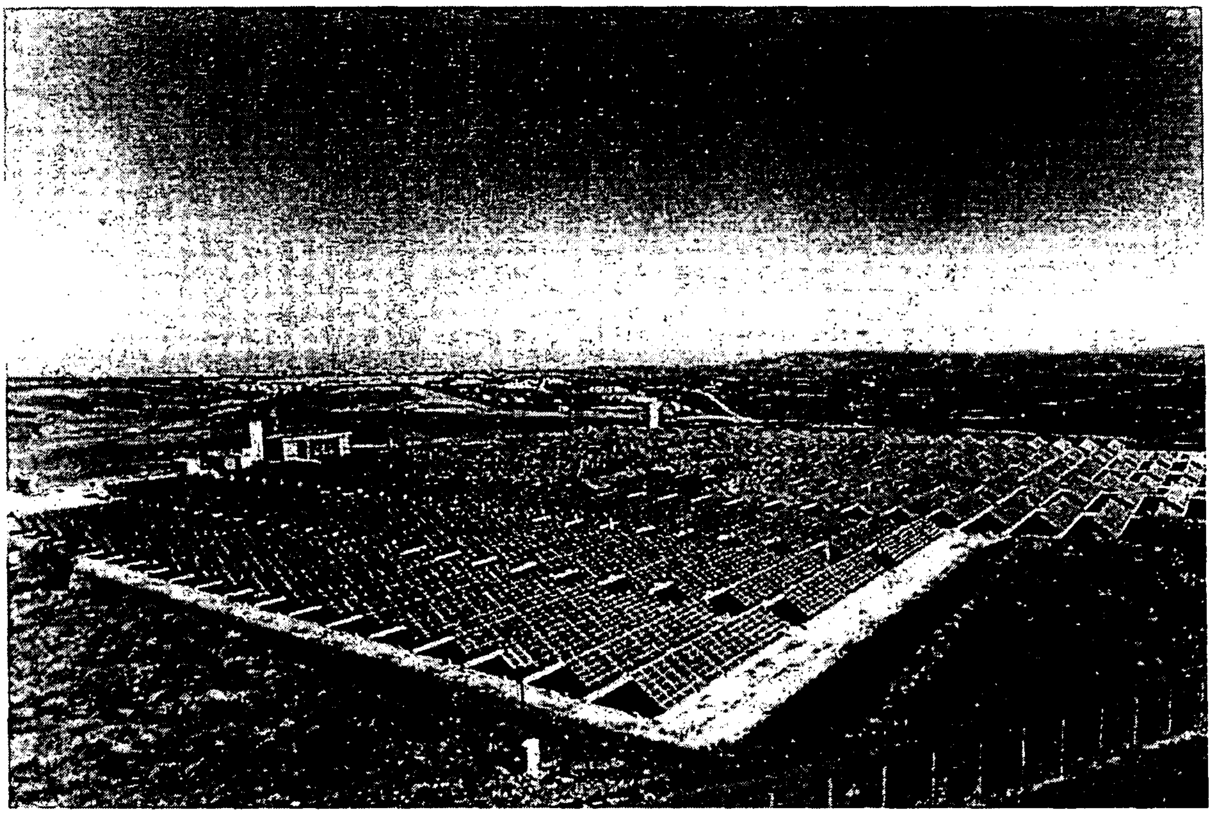


Whitecliffs 280 kW



Whitecliffs 1400 kW





1MW vasto –Italy

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development project for the world's poor.
Application proposee - Nouveaux Horizons de Kadei (en francais)
Application proposee - Nouveaux Horizons de Tchaourou (en francais)
Solar Spring Solar submersible horizontal axis piston pump technology.
Village Life Spring rebound inertia (or water oscillation) handpump technology.
Beosite (R) Products technology.
The role of micro-credit in self-financing integrated development projects
Water supply aspects.
PV and biomass aspects and their financing Paper prepared for the Conference on Renewable Energy for Rural Development, Dhaka, Bangladesh, 19-21January 2002
PV, a coernerstone of self-financing development projects for poverty alleviation in dveloping countries Paper presented for the 17th European Photovoltaic Solar Energy Conference, Munich, 22-26 October 2001.
New horizons for RE technologies in poverty alleviation projects Article published in "Refocus" October, 2001 edition pp.22-25

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Products - all key words
Key words : Applications
Key words : Types of pumps
Key words : Types of impellers
Valves flanges and accessories
Suction cups

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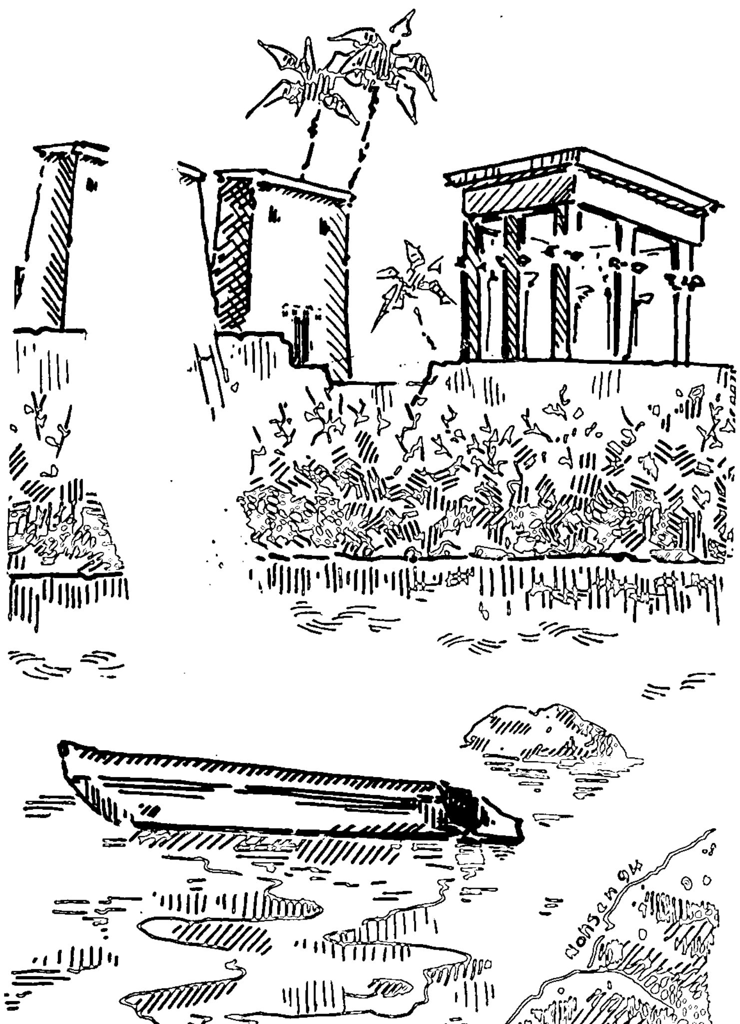
by e-mail on : pumps@flowman.nl or
telephone or fax him at 0031-227-604128.



Cairo, Egypt