Introductory Overviews: Research, Development and Education

- Global Research and Development on Renewables
- UNESCO's Global Renewable Energy Education and Training Programme (GREET Programme)

Global Research and Development on Renewables

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The aim of the following paper is

- to emphasise the urgent necessity of global research and development (R&D) on renewables,
- to discuss the context in which R&D on sustainable energy systems must be viewed,
- to identify the favourable conditions for co-operative R&D and
- to summarise some ideas on the financing of global R&D on renewables.

The paper mostly focuses on public R&D.

Needs for global research and development on renewables

Transformation of the global energy system

The transformation of the global energy system towards a strictly sustainable energy supply scheme is one of the main global challenges. Many studies have shown that it is feasible to install a world wide sustainable energy system that is strongly based on renewables, thus avoiding unacceptable climate change and other non-sustainable situations in the future which are related to energy production and consumption *(fig.1)*.

In all such scenarios the contribution of renewable energy sources to the global energy supply is impressively high. These targets can be reached only if more or less all countries contribute actively to the transformation of our energy systems. Strong world wide activities in the research and development on renewables including efficient use of energy are an inevitable prerequisite for the success of such a global undertaking. These activities must be planned strategically and they must expand continuously while increasing the utilisation of renewable energy sources at the same time.

Main topics in R&D

From today's point of view the main relevant topics of R&D are [2]:

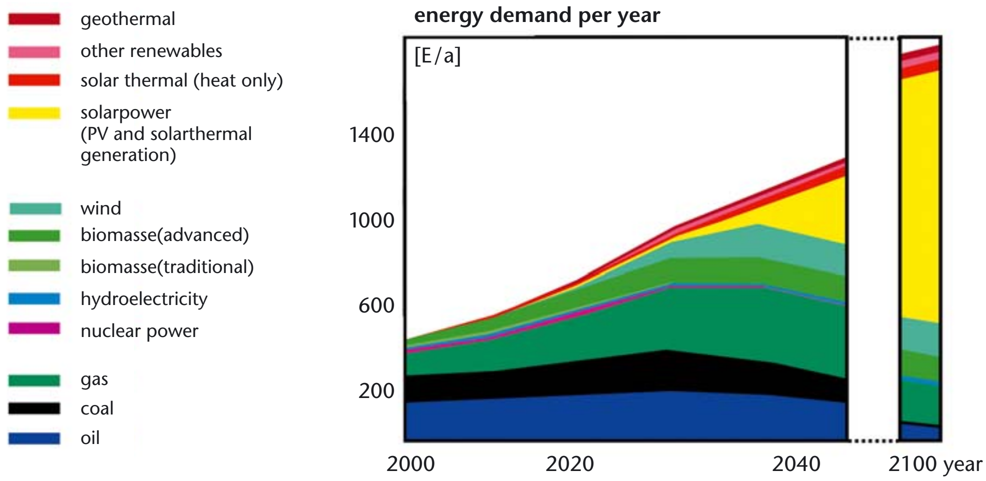


Figure 1
Exemplary path for the transformation of the global energy system [1].

This special scenario stipulates an extremely strong global economic growth. Even under the assumption of a significant increase in energy efficiency this results in a global energy demand that is by 2050 approximately three times larger than today. By the end of the century, the energy supply is mainly based on renewable sources. For a limited period geological CO_2 sequestration is applied. Under such assumptions the CO_2 concentration in the atmosphere will not be higher than 450 ppm. This will lead to a global warming probably not exceeding 2 °C.

- Development of sustainable technologies: energy conversion, transport, storage and systems,
- Management of the global transformation process of the energy system, political, institutional, and economic schemes, including the monitoring of the transformation process,
- Implementation of new energy technologies into societies.

Thus, non-technological issues have to be addressed by the research community to a significant extent.

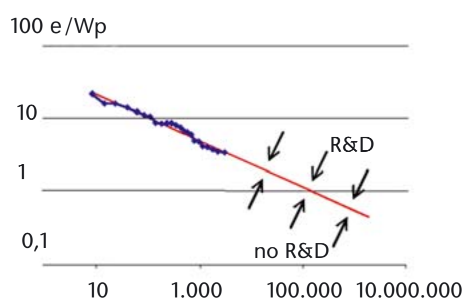
Technology oriented R&D

In the area of technology oriented R&D, the main goals are

- cost reduction (see below) and
- development of new technologies for the energy market.

Some examples of technologies to be (further) developed are: solar and energy optimised (low cost) buildings for various climates; water technologies (clean water based on clean energy); offshore technologies for wind; photovoltaic power plants utilising optical concentration; distributed electricity generation schemes including optimised grid structures and sustainable energy carriers for mobile applications, just to name a few.

Figure 2
Price experience curve for photovoltaic modules.



Prices on the global market are plotted against the cumulated world wide shipment (logarithmic scales). Historically each doubling of the shipment resulted on the average in a price reduction of 20%. The extrapolation of such experience curves is of course speculative. Nevertheless, there are sound technological arguments that a further price reduction by a factor of at least two or even a factor of three is possible and likely. An essential prerequisite for this price reduction is strong R&D. Without this R&D, the curve will tend to show a lower price reduction characteristic.

Cost reduction through R&D

As with most emerging technologies during the early stages of market introduction, cost reduction is the most important issue for renewable energy technologies. Cost reduction in renewables will be achieved in particular through:

- optimised manufacture (economy of scale),
- higher efficiencies of energy conversion,
- less material consumption and
- longer technical life of components.

In order to achieve progress in these fields, targeted R&D is indispensable.

An impressive example is the achieved cost reduction experienced in photovoltaics (solar cells). The four points mentioned above contributed jointly to the steady decrease of the price experience shown in *fig. 2*. Without strong and focused R&D, such a curve tends to display a lower gradient. Benefiting from the profits of R&D, photovoltaic electricity will be cost effective within a reasonable time span, provided that external costs are implemented in the energy price system world wide.

Extensive global R&D on renewables

Although a first supply of reliable renewable energy technologies is available today, it will be necessary to activate further strong R&D resources world wide in order to bring down the costs of renewables, to develop new and regionally optimised technologies and to implement renewables into the different societies. This task can not be mastered by a small number of countries. In order to accomplish the necessary transformation of the global energy system in due time, almost all countries and regions have to be involved in targeted R&D as well as in the manufacture of renewable energy components and systems.

Context of R&D on renewables

R&D on renewables is not an end in itself. The focus of the R&D must be directed according to the demand of (regional) energy supply schemes and the industrial strategies (including export) specific to each country. Furthermore, in order to be effective, R&D on renewables must be incorporated into existing academic structures or be developed in parallel to the evolving academic system.

Energy supply structures and R&D

Sustainable energy supply structures based completely on the import of knowledge and technology do not seem to be favourable for countries and regions. Local or regional R&D constitutes a good basis to optimise energy systems and to reduce vulnerability. Besides, the yield of renewable energy sources and the types of optimal technologies depend, in part, on local (climatic) conditions. Thus, specific technologies have to be developed – mostly by means of local or regional R&D.

Industry and R&D

A successful transformation of the global energy system will require renewable energy industries in most countries. In order to be competitive in the world market, it will be essential for such industry to focus on certain technologies. Since industry and R&D on energy technologies depend mutually on each other and since local R&D offers a considerable advantage for industry, it will be essential to tune local or regional R&D activities carefully with the strategies of industry. Private actors' R&D in industry and public R&D should complement each other.

R&D on renewables and the academic system

In order to be efficient, R&D on renewables has to be embedded amongst others into national or regional academic systems. An excellent training in science or engineering constitutes a R&D on renewables. This does not mean that a standard (canonical) academic training is an indispensable prerequisite for efficient R&D on renewables: an innovative structuring function of renewable energy R&D is well conceivable within the academic education. Semiconductor physics, as part of solid state physics, can be taught well using photovoltaics as a leading example. The same concept can be used regarding mechanical engineering and wind power or electrochemistry and fuel cells. Furthermore, a focus on solving real and pressing problems (here: the future energy supply) fosters an interdisciplinary approach to science which is a general prerequisite for future oriented academic activities and a great advantage to industry.

Co-operative global R&D on renewables

Without any doubt, co-operative global R&D is desirable when extensive capacity building and large-scale R&D activities have to be initiated in a short time span. In order to find the optimal form of coordinated capacity building and R&D activities and global co-operative action, potential sources of conflicts have to be analysed and identified. From such an analysis, optimal conditions for global co-operations may be derived.

Areas of tension

The principal advantages of joining forces may in part be compensated by conflicts that can arise in national and international R&D co-operations. Examples of advantages versus conflict areas are:

- synergies in R&D versus competition for intellectual property rights,
- open information transfer versus unbalanced opportunities of the partners to transform ideas into innovations,
- enhancement of coherence in R&D through binding co-ordination versus the reduction of diversity of scientific ideas and
- control of R&D via targeted management versus freedom of science.

The structured informality of innovation networks promises to combine the conflicting advantages best without compromising individual interests.

Favourable conditions for global co-operation in R&D

From this short compilation of possible areas of tension, favourable conditions may be derived under which global co-operation will prosper:

- if complementary skills and/or interests of co-operating partners are given,
- if the scientific and technological problems to be solved exceed the capacities of the individual partner countries or institutions and
- if sufficient budgets are available for international R&D clusters on renewables

In any case "complementary skills and/or interests" and "sufficient budgets" that will generate a stable and fruitful international R&D co-operation are the key points here.

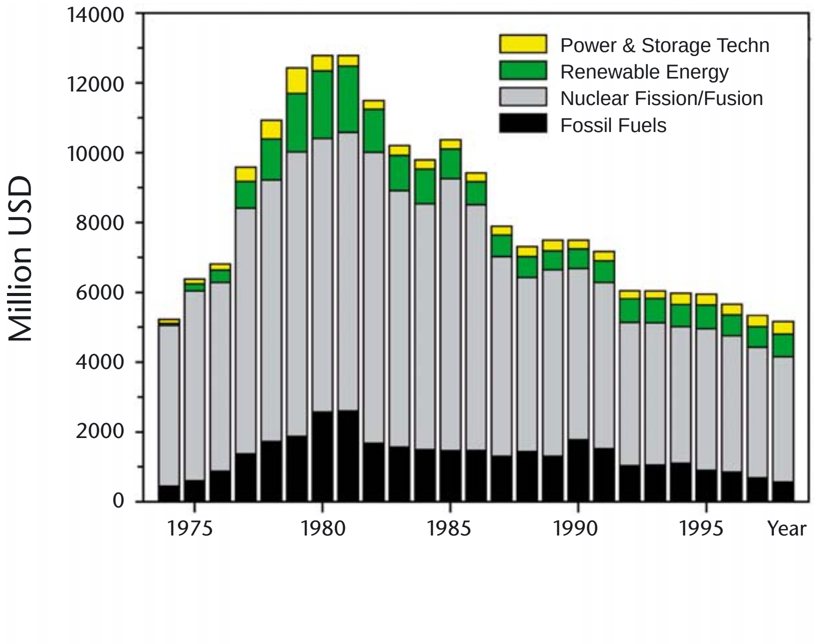


Figure 3
Public RD&D budget of 23 IEA member countries [3]

Financing global R&D on renewables

In contrast to the unquestionable needs for national, regional and global R&D on renewables, the public budgets in this area have been reduced considerably during the last decades. As an example, *Fig. 3* shows the research, development and demonstration (RD&D) budget of 23 International Energy Agency (IEA) member countries. Most of the money is still directed towards non-sustainable [1] energy technologies. This is definitely not in accord with the urgent necessity of a transformation of our energy systems towards sustainability within the next decades.

The need for strongly increased global R&D activities on renewables calls for new and strong budget sources. A large number of proposals exists how to raise needed funds [1]. The most important seem to be the following:

- The R&D budget for renewables of all industrialised countries should on the average be increased by a factor of ten until 2020. A large part of these funds should be used for global R&D.
- Financing of national and regional R&D in other countries should be realised through partnership activities from industry, private investments and as far as possible by governments.
- Financing of global R&D should be realised through charges on “emission trading”, “clean development mechanism” and “joint implementation”.

Benefits of global R&D on renewables

The main benefits of strongly fostering R&D on renewables on a national, regional and global scale may be summarised as follows:

- enabling a strictly sustainable energy system,
- reducing global conflicts,
- abatement of energy poverty and
- setting up new high technology industries with new products for the markets, strong growth rates and stable employment.

Without dedicated measures to set up a real co-operative, sufficiently funded global R&D system on renewables, these important benefits will not materialise in time.

Literature

[1] World in Transition – Towards Sustainable Energy Systems, Earthscan, London, ISBN 1-85383-882-9, http://www.wbgu.de/wbgu_jg2003_engl.pdf

[2] Research and Development – The Basis for Wide-spread Employment of Renewable Energies, Thematic Background Paper, renewables 2004 conference, Bonn 2004, http://www.renewables2004.de/pdf/tbp/TBP07-research_development.pdf

[3] IEA Energy Technology R&D Statistics Service, http://library.iea.org/rdd/eng/ReportFolders/Rfview/Explorerp.asp

UNESCO's Global Renewable Energy Education and Training Programme (GREET Programme)

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Capacity Building for Human Resources and Renewable Energy

In every development process, there is a pressing need to increase the availability of qualified human resources. Developing countries tend to experience a crucial lack in precisely this area. They are confronted with many difficulties in developing scientific education. It is costly to teach in these countries and there is a lack of equipment and laboratory materials. Moreover, they often lack capacity for local production. Science and technology help forming a world view, including values, which stimulates creative capabilities, open mindedness, and a perception of nature and the environment that provide people with indispensable tools to cope with a globalizing world. The rational use of scientific and technological progress can contribute powerfully to solving development problems, particularly those of hunger and disease. Increasingly, science is becoming a direct productive force that underpins economic growth and social progress.

The role of training in the scientific field is apparent at three levels: for upper echelon staff and researchers, for mid-level technicians and for qualified workers. In recent years, important achievements have been accomplished in this regard, particularly in developing countries. Much work has been done in order to ensure a higher priority for the scientific teaching process, both to improve its quality and to direct it more towards solving problems related to everyday life.

A diversified training programme is needed to meet increasing demands for qualified personnel in the developing countries. This training should consider the latest developments in science and technology. It must strengthen competence and technical polyvalence, in such a way as to produce a technical staff of high quality in judgement and decision making. Both of these qualities are necessary for project planning and management, and for being able to identify the most appropriate application and utilisation for local conditions.

There is a particular need for training and education in energy technologies due to the key role energy plays in sustainable development for many other issues. In light of energy costs and energy's important role in the economy, recent growth in energy consumption has led all countries to formulate and execute various strategies in three interrelated areas to:

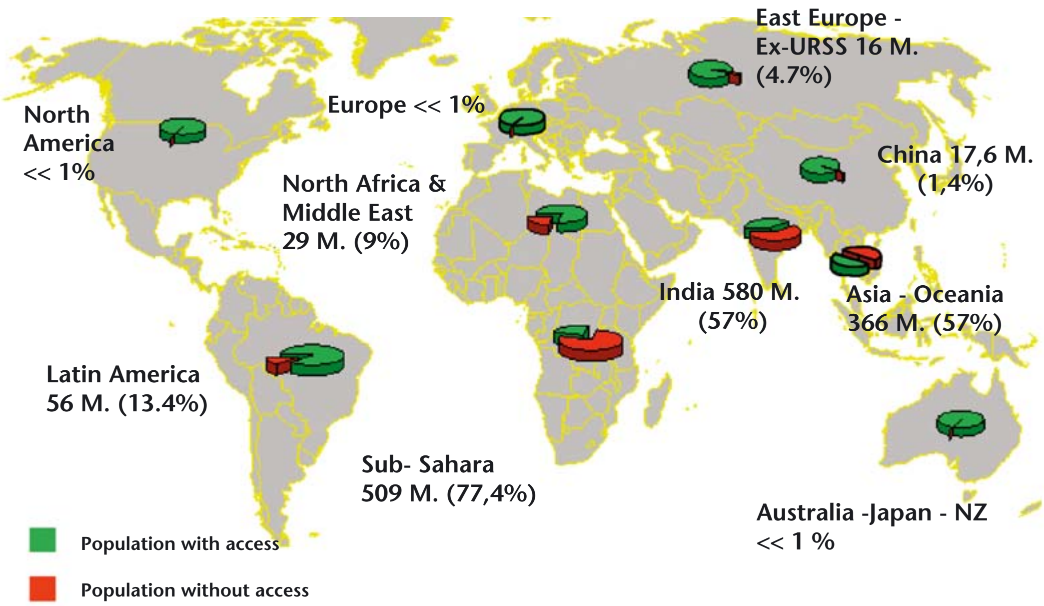
a) improve the efficiency of energy use;
b) increase energy conservation;
c) explore and develop new and renewable sources of energy.

At the same time, growing awareness of the role that renewable energies can play in the global energy system, especially for the supply of energy in rural areas, most countries are showing increased interest in creating appropriate training programmes related to these energy sources.

The training needs, important in the short term as well as in the mid term, can be understood in the context, that the desire of using renewable energies combined with the decrease in equipment costs stimulates the countries to conduct research on new equipment and on the utilisation of renewable energies.

It is evident that all programmes using renewable energy equipment depend upon the availability of specialists of various levels, who are able to use and properly maintain the supplied and installed equipment. Again, this underlines the crucial need for the training of specialised personnel. Several countries have strongly confirmed their interest in training staff and specialists who will be able to rationally utilise renewable energies.

Figure 1
Needs in term of electricity Access



Calculations based on data from World Energy Outlook 2002 -IRA

In order to be effective, training in the field of renewable energy must be ensured along four distinct axes: researchers, decision makers (engineers, economists, administrators, etc.), local maintenance technicians and users. It should concentrate on the following elements:

- progressive reinforcement of research centres and the development of qualified personnel,
- establishing better coordination between energy needs and the choice of appropriate equipment,
- creating maintenance teams capable of interacting with the rural population in order to solve technical problems, they might encounter, and to provide them with necessary information on operating installed equipment,
- raising the users' awareness on how to use this equipment effectively.

Following the identification of training candidates, every effort should be made to minimise the duration of training, especially for decision makers and those engaged in field activities.

The Way Forward for Renewable Energies

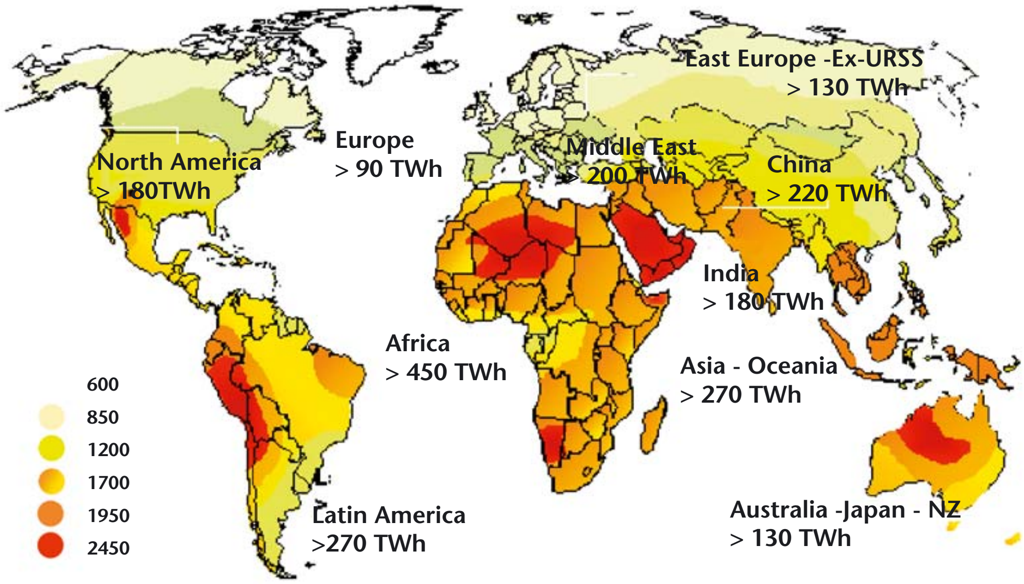
The necessity for renewable energy

The goal of education and training is to prepare a population for its future. In order to meet actual training and education needs, one must first examine societal needs for the first part of the 21st century, that is, for the period 2000 to 2030.

Energy is vital and essential for any society, but has two contradictory aspects. Firstly, it reflects the standard of living and the progress status of a nation. It also represents growing awareness concerning the level of risks that a given nation would face in attempting to satisfy its energy needs. The first half of the 21st century will certainly see rapid progress[1] in both the level of energy consumption and in the diversification of energy production methods, which can be linked to several factors:

- Population growth especially in Asia, Latin America and Africa will lead to overall increases in energy consumption.[2]
- Ecological risks associated with some energy sources are becoming increasingly evident

[1] Rapid, means here: "in some decades". It is the required time for a new energy source to become part of the energy system, even when a voluntary policy is continuously practised.
[2] Quantitatively, the future population growth is estimated with a good precision contrary to the development level. The scenarios for the future on this subject must take into consideration mere realistic hypotheses.



Based on data from B. Dessus & UNESCO´s Summer School of rural electrification

Figure 2
Solar Energy Reserves (yearly) > 2130 TWh forecast 2020

and worrisome. Two examples include the Earth surface warming due to the greenhouse effect caused by gas emissions[3] and the uncertainty regarding methods for long-term storage of nuclear residues.

- The need of humankind to follow a strong policies of improving energy efficiency in the North as well as in the South.
- The need to strengthen diversification of energy resources[4] and, more importantly, the growing need to use renewable energies in the future.

The preceding constraints lead to inevitable changes in energy strategies requiring a long-term obligation to move toward an energy flux, rather than continuing to rapidly deplete fossil fuel stocks.

Renewable Energy Credibility

The successful path to a future sustainable energy system will depend on four conditions: technical credibility, economic credibility, ecological credibility and political credibility. Unless all four of these conditions are satisfied, the massive growth in the contribution of renewable energy during the 21st century will not occur.

Regarding technical credibility, the generation of energy splits up in the production of heat, of electricity and of fuels. There are numerous renewable energy technologies and applications having market potentials, as shall be listed briefly[5]:

Heat production: biomass if not causing deforestation and desertification; district heating through geothermal energy; solar architecture;

[3] The conten of CO_2 in the atmosphere has increased by 50 % since the beginning of the industrial era. The human activities (combustion of carbon oil and gas, the change in living habits) are mainly responsible. According to the "Intergovernmental Panel on Climate Change" (1996), "the earth surface temperature in average increased globally by 0.3 o 0.6 °C since the beginning of the 19th century…. Analysis of a group of elements suggests that, there is a perceptible influence of man on the global climate." This climate change evolution will continue with very serious consequences. We mention, as an example the more or less realistic figures: a warming-up of 2 °C and the increase of ocean's level by 50 cm by the year 2100.
[4] This trend will not evolve automatically. In the 19th century coal was dominating while for the 20th century it is oil. Fossil fuels accumulated during hundreds of million of years are being burned today at such a rate that they will be largely depleted in few centuries. For example, oil crisis in 1973 and 1979 have been overcome due to major discoveries (the North Sea, Alaska, Siberia). However, the likely absence of such discoveries in the future will affect the energy situation if the oil share in the energy balance continues as it is.
[5] For further details, refer to the following EU documents: "Renewable Energies in Europe", Int. J. of solar Energy No 1 – 4 (1994); and T. Wrixon, A.M.E. Rooney, W. Plaz "Renewable Energy 2000" (Springer Verlag, 1993).

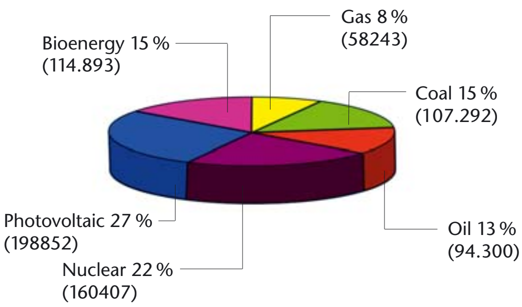


figure 3
Job Creation for Energy Production

solar heating for crop drying, water heaters and space heating.

Electricity production: hydroelectricity if not flooding local environments; wind generators; thermal power plants burning organic residues; solar thermal power plants; stand-alone photovoltaics particularly for rural electrification or grid-connected and integrated in buildings.

Fuel production: alcohol from sugar cane; "green fuels" from biomass so called biofuels. Some of these are still in the research and development phase and show a reasonable, or even significant, level of progress, some are, with respect to economic credibility at the operational level and provided satisfactory results.

Particularly, in specific contexts certain renewable energy technologies are already today competitive or nearly competitive, as for example hydroelectricity and green fuels,or in some localities and under appropriate conditions wind generators, stand-alone photovoltaics, and geothermal and solar heat. With political support this competitiveness can often already launch technologies in the market. So, there is an actual niche of competitiveness, which will increase in the medium term as a function of research results and market growth.

At this point, it is important to introduce the concept of the social cost of energy. This reflects the actual cost paid for the consumption of energy, not only by consumers but also by citizens in general. In reality, the costs of classical energy sources are currently under-estimated, as they do not include important 'external' costs, related to factors such as environment protection, research subventions or the need to transmit a heritage unburdened or negatively influenced by present consumption to future generations. This problem is treated, for example in reference.[6] Increasingly, specialists are recommending the internalization of external costs. This would lead to the formal improvement of the competitiveness of renewable energies, which, in general, have a limited ecological impact.

All the above-mentioned techniques produce more energy than is necessary for their manufacture and installation. For example, photovoltaic systems have an energy return period of two to four years, compared to a lifespan of at least 20 years. In most cases, the ecological balance of renewable sources of energy is better than all other sources of energy. It is important to recall that a pro-active policy in the energy economy is beneficial for the whole planet, from both the economic and ecological points of view. "The best energy is that which we do not produce."

In addition, most of these techniques are ecologically benign (dams that retain water reserves of extended surfaces are an exception). The associated social costs of renewable energy are extremely small. As demonstrated by field inquiries in Great Britain, wind generators are very well accepted by the local population, proving the ecological credibility.

In reality, all of the above will depend on the political will of energy decision makers, both within individual countries and at the global level. Over the past 20 years, many major countries have shown a firm and constant will to develop renewable energies. State and private credits granted to renewable energies in these countries have increased on a regular basis. In addition, the European Union has a dynamic policy of research and development. Some other countries, in which public opinion is strongly against nuclear energy, are now at the forefront of the movement to utilise renewable energies. A smaller number of countries are more reluctant, but still active. Among developing countries, India, Brazil, China,

[6] O. Hohmeyer, R.L. Ottinger, Social Costs of Energy (Springer Verlag, 1994).

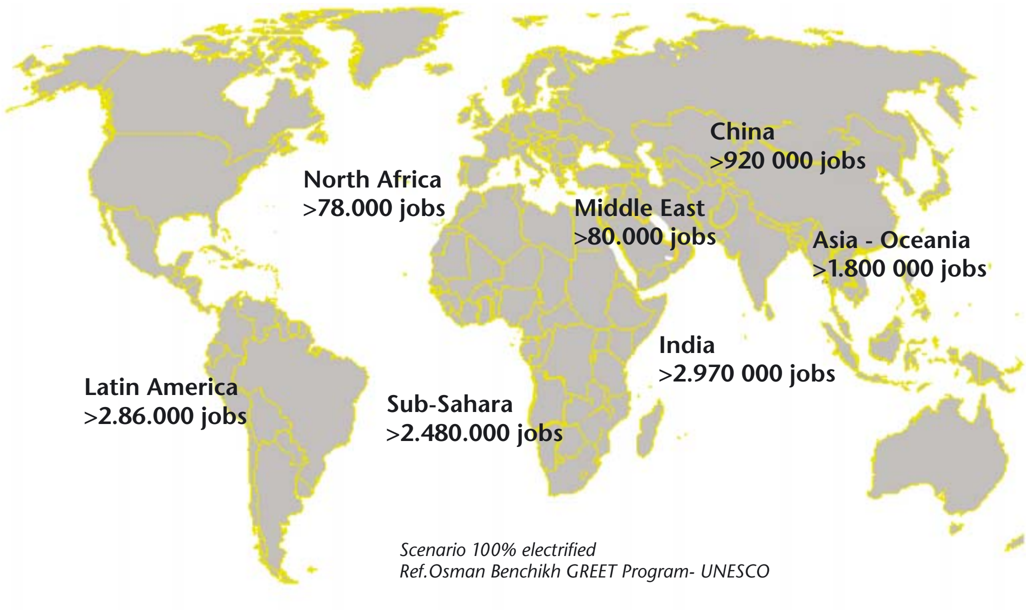


Figure 4
Direct Jobs in Operation & Maintenance Created by RE Electrification

Morocco and others are pro-active in some aspects; in 1993 the World Bank started financing renewable energy in these countries.

Nothing guarantees the permanence of a constant dynamic policy in favour of renewable energy. This depends on the political credibility. However, it is generally safe to presume that renewable energies will become more valued for their two favourable characteristics:

- Flexibility – the possibility of creating local energy sources, hopefully to complement and compete with the supply from large central grids.
- Responsiveness – the possibility of meeting the rising expectations related to sustainable development and environmental protection. The plan of implementation resulting from the World Summit on Sustainable Development (Johannesburg, 2002) and concerns on climate fragility expressed at Earth Summit (Rio de Janeiro, 1992) highlight the major role that renewable energies can play in both issues.

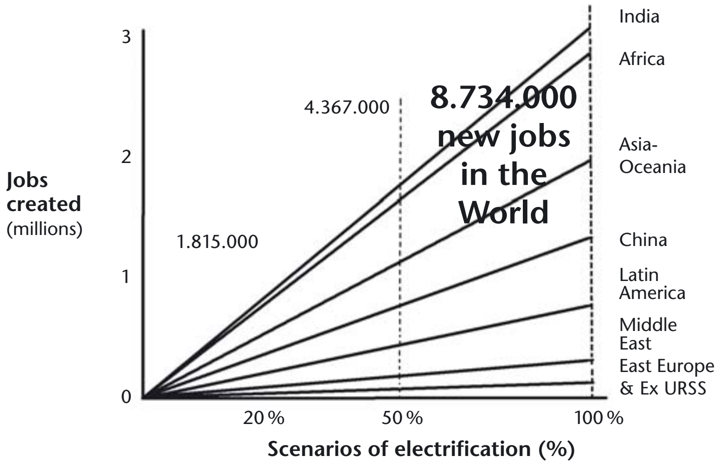
Admittedly, one of the principal obstacles facing the widespread use of these technologies is the lack of information. The GREET Programme aims precisely at improving knowledge on intrinsic merits that renewable energy possesses. Increased awareness of these merits should lead to a growing interest of use and applications of renewable energies at worldwide level.

Job creation

Comparing all sources of energy production renewable energy sources represent one of the most important reservoirs for job creation.[7] For the production of the same amount of energy, the job creation growth of renewable energies is higher than that of other sources such as gas, coal, oil and nuclear *(see Fig. 3)*.

Comparing jobs created by the different forms of energy *(see Fig. 3)*, biomass and photovoltaics generate the highest number of jobs. As these resources are particularly abundant in developing countries struggling with rural electrification,

Figure 5
Direct Jobs in Operation & Maintenance Created by RE Electrification



[7] J. Percebois, Vol. 2, Summer School „Solar Electricity for Rural and Isolated Zones", Ellipse/UNESCO, 1993

the use of renewable energies apart from jobs creation will help to improve the local economy and ensure a better quality of life and decease poverty.
In only a few years, figures have passed from 1.5 to 5.6 jobs per installed megawatt – a sign of a more advanced industry. This brings to mind an indication from the World Watch Research Institute regarding the manpower needed to build a piece of equipment producing 1000 GWh annually:

Sector	No. of persons required
Nuclear	100
Coal	116
Solar thermal	248
Wind generation	542

These numbers will certainly decrease in the future. However, renewable energies will remain an important source for job creation compared to conventional energy sources. In general, renewable energies have high upfront investment costs, but lower operating costs despite of the higher employment rates. For conventional sources of energy have high operating capital costs due to the commodities like gas, coal, oil or uranium needed to operate power plants, not to mention the high costs of grid maintenance of centralised energy systems.

Those quantitative comparisons must be completed by new studies, updated and generalised to other technologies. They should also be performed for different regions, including rural zones of developing countries where renewable energies (basically photovoltaic) play an important role.

We can provisionally conclude that various renewable energy technologies are a significant source for new jobs. In just a few years, tens of thousands of jobs have already been created. The locations and natures of these jobs, as well as their number, are still evolving. Thus, it is clearly a sector for which an appropriate training policy seems absolutely necessary.

Training on renewable energy[8]

Current situation

Education in the area of renewable energy is certainly a field where almost everything still needs to be done. The current lack of ambitious educational programmes can be explained by two principal factors:

- the multi-disciplinary and diverse nature of the subject, and
- general non-recognition of renewable energies as a major component of the energy issue.

Specialisation in this field assumes a general knowledge of diversified technologies and their adaptation to different contexts and different fields of applications. At present, no specific, degree-granting university training and education programmes exist in the field of renewable energy. Another problem is the lack of information on the topic in general. Both of these issues must be adequately addressed.

1. Training

a) There is no specific secondary school course on renewable energy that is capable of capturing the interest of young people and orienting them toward choosing a career in this field.
b) There is a lack of coordination among the diversified activities related to renewable energy within the education field.
c) At the university level, very little information is available concerning prerequisites and the procedures that could lead to a degree or training programme in the renewable energy area.
d) Training needs in the area of renewable energy are poorly defined. Organisations concerned with energy and renewable energy issues, interested in training their own personnel, should be identified.
e) Very little information is available concerning needed training programmes to be initiated: specific technical as well as practical courses, advanced education, summer schools, etc.

Poor distribution of research and training centres is another issue. In many cases, the

[8] Since the GREET Programme has been founded under World Solar Programme the following remarks regarding the training needs for renewable energies will mainly focus on solar energy.

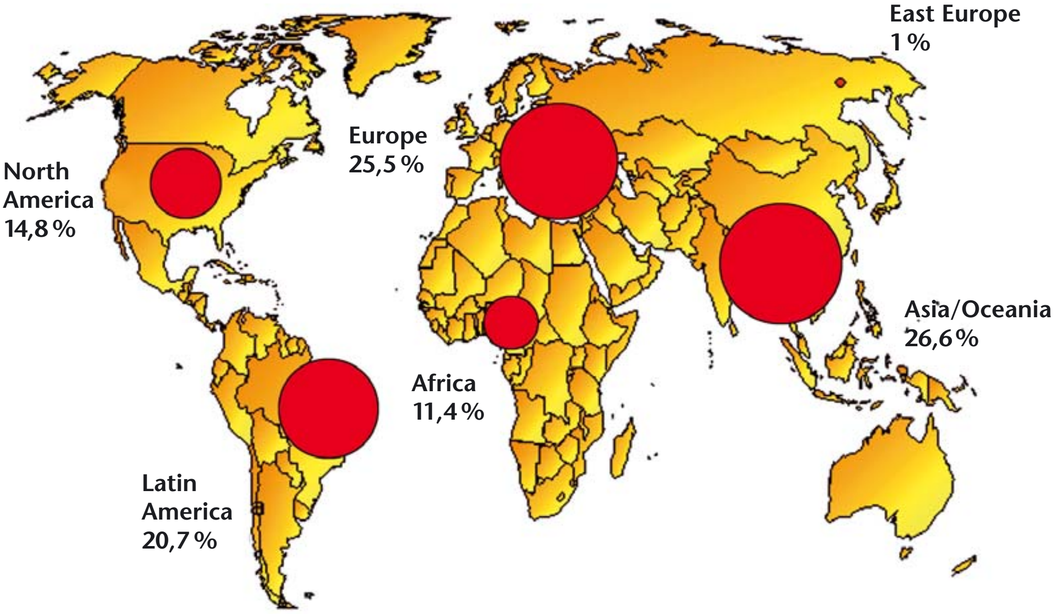


Figure 6
Distribution of training and research centers by region[9]

regions favoured by a high potential of solar energy and confronted by a deficit in electricity – mainly rural areas – are those that have the smallest number of specialised training centres. Similar discrepancies can be seen in the case of photovoltaics, whose potential is enormous on the international scale.

2. Lack of information

a) Both non-experts and the general public have very little information on the current state of the art in renewable energies, or on the true potential of these resources. More-over, the limited information they do have is often distorted by 'fashions' and 'anti-fashions' related to the environment and energy economy, particularly when this concerns renewable energies.
b) Very few practical educational manuals about renewable energies are addressed to the general public, especially for the youth adapted material is missing.
c) Very little information is addressed to secondary school students on the prospects and employment chances that would be gained by specialising in the renewable energy field.

Fig. 1, 2 and 6 combined show that the very regions with greatest energy poverty have the largest potentials but the least training capacities in relation to their solar photovoltaic energy potential.

Training needs

General aspects of the needs for training are analysed from two angles:

- What should be the foci for the educational process?

It is evident that renewable energies must become competitive to provide sustainable energy and thus that market development must be fostered. To this end, current needs are the actual prospects of the market.

- What courses should be taught?

Training and education should be oriented to the demand of the market. Production, use and application of renewable energy systems require diversified components. These components should be improved by intensive research and development and by more efficient industrial production. However, it is not the fundamental research which presents the principal barrier to their development, but it is the lack of trained personnel to design, install, and maintain the systems. Most of the new jobs to be created do not require a radically new competence. The manpower

[9] UNESCO international directory of renewable energy information sources and research centres.

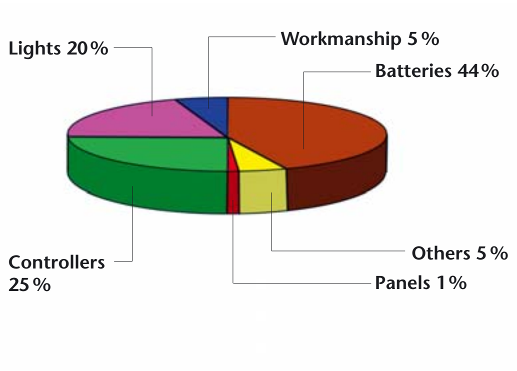


Figure 7 (left)
Contribution of components to systems fault

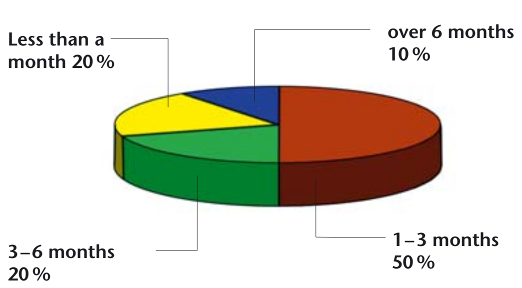


Figure 8 (right)
Time taken to repair a fault (average in Africa)

needs vary according to the different project stages and the systems' components. This can be summarized as follows:

- meteorologists and analysts for the identification of sites and appropriate programs,
- metal workers with good competence in hydraulics for the assembly of wind rotors and towers or assembly of solar collectors, plumbers and tube workers for the installation of solar heaters,
- electricians for photovoltaic and wind energy systems,
- carpenters and building craftsmen for the integration of solar systems in buildings and power plants,
- architects for the urban planning and building design,
- engineers and designers in several sectors: civil engineering, power electronics, electric engineering, process control, quality control, chemistry etc.

The various technicians mentioned above need an appropriate training based upon their original background. For instance, engineers, designers and architects do have sufficient basic knowledge. However a radical change in their usual behavior is necessary. They are used to work with conventional systems in always the same environment, while the renewable energy technologies depend on the site and climate as they also interact with consumers. They do not offer universal solutions (except for some applications, such as calculators and solar lighting kits). This constitutes one of the principal barriers to their wide-spread use. In general, they require more work than conventional systems for their design, adaptation, and use. This implies the creation of more jobs in order to get sustainable and efficient systems.

Specific training aspects[10]

In order to improve training of researchers, engineers, technicians and superior technicians, several specific considerations should be taken into account. This is also true for the information required by decision makers, local elected representatives, consultants and the general public. As an example, the following develops some of these considerations with a focus on the training of technicians. This is the most important and necessary action for the success of a renewable energy programme. Thus, it will be presented first.

Training for technicians

Technicians play a principal role in all aspects of solar energy projects: beginning with the levels of laboratory work, test centres, industrial production of components, commercial distribution, and system assembly, reaching to the optimisation of system design and size, which should be based on the precise needs of individuals or the village community, installation, operation and maintenance, in order to ensure the best quality of energy service. The success of solar projects will not be achieved unless each step is realised successfully by competent technicians. Thus, the most important requirement is the availability of competent technicians to ensure the installation, repair and maintenance of systems. Rural electrification will be achieved through technicians in local networks of service businesses.

[10] O. Benchikh, UNESCO, "Renewable Energy education and Trainig Program".

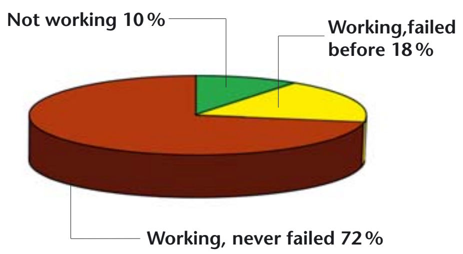


Figure 9
Fault occurences in Solar PV installations

Past experience reveals that, even if photovoltaic modules are of an extraordinary quality, they are subject to failures. These are most often caused by defects in classical components (switches, batteries, power conditioning, connections, etc.).

If one can rectify them in due time, such problems will be without consequences, but it is regrettable to neglect these aspects of after-sales service. So, there are very precise needs for training technicians in specialties.

Technical education institutes are obviously the best places to carry out this training. Therefore, institutes should work in close relations with the solar testing centres, particularly where it is possible to use their technical facilities to support training and education.

Continued education is another important aspect to consider for technician training. It should permit technicians qualified in other disciplines to acquire, in a relatively short time, the knowledge necessary to master one of the above-mentioned specialties. Organising this type of training represents one way of ensuring the formation of solar technicians.

The availability of high quality, specialised literature is a necessary and complementary aspect of technicians' training. Technicians will benefit greatly by acquiring material such as:

- Technicians' guide or handbook that collates, in a condensed manner, the theoretical results, schematic diagrams, basic formulas, rules and practical recommendations that would be useful to solar technicians.
- Documentation on components and solar equipment, which could serve as a kind of 'user's guide', indicating suppliers, cost, performance, best ratio of quality / price, etc.

Training for researchers

One must underline the importance of promoting a research programme in the relatively new sector of solar chemistry, which is dedicated to fuel production. It is convenient also to mention other research topics that are already well established, but should at least continue or even be amplified.

First of all, it is important to consider research on photocells and photovoltaic systems. The performance and cost of these systems still need to be improved substantially. As an outcome to the rural electrification programme and resulting market expansion, progress in this field will be accelerated. This dynamism would lead to an increase in industrial efforts and justify the reinforcement of research facilities in this sector.

Universities and schools of engineering, in the countries of the North and of the South, must committ to take up the mission of forming tomorrow's researchers. In turn, these individuals will ensure progress in the GREET Programme. The following actions can be adopted now to help these institutions achieve their mission:

- Reinforce theoretical and practical education in the basic disciplines, upon which the research depends. Within this frame, several other disciplines should be considered amongst the first rank: solid-state physics, physics of materials, molecular physics, thermo-chemistry, photochemistry, thermal sciences and thermodynamics.
- Define research topics in the field of photovoltaic (photocells, photo-chemistry, and solar fuels) for student thesis or graduate projects.
- Incorporate these research topics into a global vision of the role of renewable energies among the energy resources for the 21st century (analysis of energy supply and demand, economic considerations, and environmental constraints).
- Organise cooperation programmes amongst higher education institutions, in the North and South, on research related to solar energy. This collaboration could be made through

common studies of scientific projects and could lead to student exchanges.

- Create a 'think tank' (under the framework of the World Solar Summit, for example) on the training of researchers in the disciplines that would support the progress of solar energy. The task of this group would be to define the actions to be taken for training researchers, to elaborate a strategy, and to aid university departments in establishing such programmes.

Training of engineers

The realisation of renewable energy programmes, particularly solar rural electrification, constitutes a large industrial project for the coming decades. Industrialised countries can have an appreciable contribution in this area, which will also have a beneficial impact on job creation. This dynamic could help generate a domestic industry with the capacity to significantly contribute to those programmes as the GREET Programme.

The industrial boom foreseen in solar and wind electricity, as well as in passive architecture, requires a new generation of engineers whose work, initiatives and competence will be the best guarantee for success. There is a clear need to ensure the development and training of future engineers who will have the task of creating, organising and establishing the solar industry of the future.

The required fields of competence for engineering curricula are identical to those mentioned above for the researchers: solid-state physics, physics of materials, molecular physics, thermochemistry photochemistry, thermal sciences and thermodynamics. In addition, they would require expertise in power electronics, electrotechnology, and fluid mechanics.

In this educational process, practical aspects should have top priority. In fact, the course contents should leave a large portion for experimental work and for projects related to real equipment and full-scale installations. There is a strong interest in establishing the training institutions for engineers near solar testing centres, of which a certain number already exists.

Specialised education and training in renewable energy leading to a university degree, at the Master's level, represents a programme that could be proposed for both researchers and engineers working in this field. This type of education would allow planners and those who carry out renewable energy programmes to have access to complete information and know-how within a reasonable period of time (18 months).

Continued education represents another important aspect for the training of engineers. In fact, this would allow engineers who specialised in other disciplines to acquire, during a minimum of time, sufficient knowledge to enable them to work efficiently in a new field. Short training courses, such as summer schools, are very responsive to this need. The annual summer school on 'solar electricity for rural and isolated zones' organised by UNESCO presents an example of action in this direction. This initiative should be encouraged, continued, and even extended to other sectors such as biomass and wind energy, as well as other renewable energies.

To summarize, the following recommendations can be made:

- Encourage and support the activities of solar testing centers to promote their contribution in the education and training of engineers.
- Promote the engineering teaching of the above mentioned disciplines and encourage introduction of renewable energy topics on the occasion of practical training in enterprises, graduation projects, practical work, etc.
- Organize the exchange of students of engineering schools from the North and South, in a thoughtful study on topics related to renewable energy projects.
- Respond to the needs related to continued education on renewable energies. The model of summer schools programs should be reinforced and expanded.
- Set up an international advisory committee on education and training of engineers in order to elaborate a strategy in the capacity building and human resources development area.

Information for decision makers, locally elected representatives and service technicians

One of the difficulties to be overcome in promoting these programmes is convincing decision makers of the solid basis of these proposals, in order to get their support. The current context falls short by far of being favourable for such action. The current low cost of oil products and the existence of other technologies – considered, correctly or incorrectly, to be more credible – create a degree of uncertainty, scepticism and even hostility towards solar technologies amongst decision makers and experts. This difficult situation can also be linked to the lack of general knowledge of the results and successes of solar technologies in recent years.

This insufficiency of information on renewable energies is due to the limitations of the facilities offered to solar researchers in the past. A real effort is needed to improve general knowledge outside the solar research community.

Past experience shows that the main obstacle to the development of solar technology is the indifference or opposition of electricity-producing and distributing companies. This is coupled to the indifference of decision makers. For an electricity planner, rural electrification usually means the development and the extension of the existing grid. A locally elected representative, who does not have a good knowledge of the various available technologies, may simply go back to the national electricity utility. The final result is that the safest solution is adopted either by inertia or by tradition.

It is therefore necessary to convince both electricity utility staff and local representatives that the adoption of solar technologies is a bonus card for all stakeholders. Decentralised solar technologies are not necessarily antagonistic to interconnected networks, but rather are complementary to them. Certain electricity utilities hold this viewpoint, especially when the construction of new power stations or the electricity grid extension encounter financial, ecological or regulatory difficulties.

In developing countries, the concept of 'pre-electrification' would result in promoting certain solar technologies as a first step towards the construction of an interconnected network. Solar energy's best ally is the electrical engineer who understands that it is not a competitor of, but rather a tool for the development of electricity supply. A major effort to improve general knowledge and training in this field is still needed.

Actions required for the development of general knowledge programmes oriented towards decision makers should include:

- Organising seminars, workshops or summer schools that target decision makers and experts related to other energy fields. The goal should be to inform them about possible future solar applications, including the anticipated progress and economic aspects.
- Developing presentations on the possibilities of solar technology market penetration in the form of alternative scenarios.
- Reporting on the prospects of renewable energies in scientific and economic journals.
- Organising technical visits to the most outstanding solar energy installations.
- Producing audio-visual materials that illustrate existing solar installations, as well as future prospects for these technologies.

Information to the public

Training and information activities, similar to those elaborated in the previous section, should equally be undertaken for the general public. At present, most people are unaware of most of the achievements, possibilities and prospects of solar technologies. In countries where solar programmes could be implemented, or where the population would have direct contact with solar equipment, this information programme would join that for users.

There is much work to be undertaken in the information and training of the general public, including the following:

- Publishing information, in the form of study articles and comprehensive, well documented reports, on solar energy and its prospects.
- Distribute such information and/or documentation to consumer associations.

- Produce and broadcast programmes and documentary films for television.
- Create fixed exhibitions at technology parks to allow the presentation of a wide array of solar equipment and its applications. Organise general public visits to solar test centres.
- Encourage teaching of renewable energy technologies in primary and secondary schools. Within the context of courses in physics, chemistry and technology, a scientific base on solar energy can effectively be introduced to the thinking of young students. In the very near future, these individuals will be the implementers of the large energy programmes, currently being launched.

Table 1
Guide of technology options

Technology	Hydro-electric	Wind turbines	Photo-voltaics conv.	Solar therdyn.	Solar thermal	Geo-thermal	Biomass
Related disciplines							
Mechanics	••	••		•	•		
Geology	••					••	•
Atmosph. phys	•	••	•	•	•		•
Thermodyn.				••			
Thermal sci.				••	••	••	
Building eng.					••		
Chemistry			•	•	•	•	•
Chem. eng.			•	•			••
Phys.of mat.	•	•	••		•		
Electro. phy.		•	••	•			
Electro. tech.	•	•	•	•			
Agronomy							••
Bio. eng.							••

General contents of teaching programmes

The overall objective of education and training programmes is to address general problems related to energy, as well as the need to conserve energy and use renewable energy sources. At the same time, the particular technology should correspond to the competence of the instructor and the desire of the learner.

In the past, most training programmes focused on a specific type of renewable energy, concentrating on a certain technology without placing it in a more general context. In addition, existing general training programmes on energy conservation were not oriented toward a specific renewable energy form or a particular application. This situation is unsatisfactory in that it does not respond to real needs.

A general training programme on renewable energies and related technology options is proposed as an example. It could be compared to a 'general store' of basic courses and 'menus' from which particular options can be selected for each target audience (researchers, engineers, technicians, decision makers, industrialists, end-users, the general public, etc.).

At present, there is a scarcity of appropriate disciplines in relevant teaching programmes for each technology. If an individual would like to intensify his technical capabilities to solve the problems encountered, he must select one of these particular technologies. This should be supported by the usual basic knowledge, which remains the foundation for building up the trainee's abilities, together with any other complementary knowledge that is necessary for the training.

The complementary knowledge would be acquired partially through the basic general courses mentioned above, which would help clarify the role of renewable energy in today's world. Depending on each technology option, it would also include other particular points to help trainees to deal with problems in the field. Sensitising trainees to the real state of the art of the system's use and manufacturing is a high priority; it will also help clarify the role and importance of the various technology options. Therefore, the proposed training programme should cover at least one or two of the technologies referred to in the following table.

Each scientific education unit will select its technology options according to its field of interests. It is important to note that this does not exclude a simultaneous selection of one renewable energy option and one other form of energy. In addition, sufficient time should be allocated to general knowledge. Units that currently specialise in economics or human sciences but wish to initiate training programmes on renewable energies could call upon external specialists to deliver the necessary information to the target audience. The most important consideration is that the information be realistic and cover the use and application of renewable energies, especially in different contexts. That is, trainees should be made aware of the potential of renewable energies to meet sustainable targets, to contribute to poverty reduction and to support job creation.