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ISLAMIC REPUBLIC OF IRAN

Technical report: Research and development activities oriented to the utilization of renewable sources of energy*

Prepared for the Government of the Islamic Republic of Iran
by the United Nations Industrial Development Organization

Based on the work of W. Bucher, expert in
renewable energy technology

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* This document has not been edited.

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ABSTRACT:

The potential for the application of renewable energies in the Islamic Republic of Iran is excellent: Hydropower is exploited routinely, solar and wind energy conditions are favourable, and also geothermal resources have been found to be easily accessible in certain areas.

Of similar importance is that the scientific, engineering and industrial capacity to explore and utilise any sort of renewable energy apparently is available. Many of the industrial enterprises seem to be quite capable to not only install and make use of imported equipment, but also to manufacture those items - at least to a significant part - in the country.

On the other hand (with respect to high costs of renewable energy exploitation) the existence of fossil resources was - and still is - an essential draw-back for a widespread use of techniques to apply non-fossil energy. But at least some contributions from inexhaustible sources of energy to subsist the Iranian energy demand could be expected, if adequate endeavour is made. And - once series fabrication of equipment would be reached - also an export of components or of whole systems should be feasible.

This report describes the situation of the country, possible ways to be used to exploit renewable energy resources, and the facilities and capabilities to implement said techniques in a larger scale. It also gives some advise, where measures or action should be taken to promote this progress.

From May, 3rd to May, 25th 1994 the author was member of an expert team to visit the Islamic Republic of Iran. The aim of this study group was ***an assessment of the work done and the capabilities available at the Iranian Research Institutes***; and to give ***advise to the Ministry of Industry***, how R&D-results could be optimally transferred to industrial enterprises to contribute to the country's welfare in various disciplines.

In the course of preparing this study many institutions were visited and contacts with persons and institutes arranged. Certainly, after a few weeks the information cannot be sufficient for an in-depth judgement, also because of the fact that especially in the field of renewable energies the situation in those areas should be studied in detail, where conventional energy is not as easily available as in the large urban centres. But it could be found that there is a remarkable potential of unexploitable resources, a stable substructure of scientific capabilities, and a large amount of practical knowledge, ability and motivation. Thus, it should not be difficult to keep in pace with the advancement of science and technology towards adequate applications.

The research institutes thus could be important with respects to many issues, e.g by

- ***supporting the Iranian government*** by means of making preparatory studies and providing a scientific basis for the process of decision making;
- ***collecting data and compiling*** them into ***a comprehensive documentation*** about the advantages and constraints of renewable energy exploitation;
- ***preparation or adaptation of techniques*** to the local conditions; and
- ***assisting local enterprises*** in the process of further development of the technology and in market introduction;

Certainly, some organisational and structural modifications might be necessary to tighten the connections between the governmental entities and the research institutes as well as to intensify the co-operation between them and the Iranian industry. Concerning these issues some statements have been included in this report.

Tehran, May 1994

1.1 INTRODUCTION

A world-wide move towards Renewable Energy (R.E.) utilisation could be observed in the recent years. Accordingly, the government of the Islamic republic of Iran decided to study the application of such alternative ways of energy conversion also in their country and asked UNIDO for support in that endeavour. This paper presents part of the results derived from an expert mission, started on behalf of UNIDO, which included a visit to Tehran and many discussions with institutions and people involved.

There is no doubt that in Iran very good preconditions exist for the use of R.E. This is not only true with respect to the natural resources, but also, because the Iranian society can rely on the skill and ability of their people and on the work of scientific institutes. If problems exist, the reason can be allocated to some difficulties in the past, when it was not easy to keep in pace with the development abroad. This became apparent during some of the discussions held, when Iranian engineers mentioned that due to administrative and budgetary constraints international periodica and congress proceedings were not available.

In the very special field of R.E. exploitation this disadvantage was strongly felt, since solar and renewable energy research has become a multinational activity, where contributions and ideas were forwarded from many sides. Given the economic situation of renewables today (competitiveness to conventional - i.e. fossil - energy sources in a few fields of applications only) it seems to be due time to engage in the task to catch up with the state-of-the-art.

As far as the national resources are concerned, a very good and comprehensive information is available in Iran. These data indicate that there is some potential for various conversion paths. Which of the methods be applied best - and what source should be exploited with first priority - depends on decisions, which have to take into account not only the resources, but also the needs of the population. Possible techniques and the involvement of Iranian entities in the development can be deduced from an overview presented in Annex "A".

The prospects for widespread application of R.E. in Iran are good not only with respect to electricity generation in a grid connected mode. Especially in rural areas the energetic service for the local population is a quite challenging task. From about 36000 villages with more than 20 families (households) only 25000 are connected to the grid or another reliable source. The number of 11000 villages lacking any distribution network shows just part of the problem, since the data count only for settlements of a certain size. But also these figures indicate the importance of the issue.

In urban areas environmental conditions can be observed to be influenced negatively by the traditional ways to use energy. Traffic is by far the largest source of pollutants, but also heating contributes to them - especially in the huge cities. At least for the domestic needs solar energy utilisation could facilitate some environmentally benign alternatives.

But so far in Iran a market for R.E. products does not exist and only a few activities correlated to that issue have been reported. Lack of information on side of the consumers may contribute to the problem. This could only be overcome by a joint endeavour of all entities concerned, which must include some activities to help the market develop, has to provide means and measures to encourage the industrial enterprises to increase their efforts, and should also stimulate the demand side by a transfer of information and by demonstrating the applicability.

Many of the issues linked to this process of market enhancement can be handled by the research institutes in Iran, provided that adequate support from public and governmental institutions is granted.

1.2 RESULTS, FINDINGS AND SUGGESTIONS

The proclamation of a more widespread utilisation of R.E. is a very ambitious plan. First of all it will require some preparatory meditation by the Iranian government. But it also necessitates an encouragement of the market including some research and development steps, and it demands an enforcement of industrial activities in that field. Finally, it will depend on the success of a campaign to be conducted to summon up the co-operation of the consumers.

In view of the capacity and qualification of the national research institutions they seem to be well equipped to not only give scientific advise but also to actively take part in the endeavour to apply R.E. sources.

The following remarks refer to different topics, which - subject to further interpretation or definition in detail - mainly concentrate on the issues of

- the involvement of the research institutes in the process of decision making on the political level,
- efforts towards an adequate development of the market, and
- scientific work to be performed.

Some conclusive remarks concerning the financial situation, structural and organisational measures will be made ultimately.

PREPARATION OF PAPERS FOR POLITICAL DECISIONS

Energy influences the aspects of modern societies in many ways, not only business and living standards depend on the availability of energy. Exploiting new sources of energy is an important task, which will need time, co-operation between many institutions involved, and considerable funds. Prior to this, preparatory studies, a priority program, cost and benefit assessments, and a contingency plan should be prepared in advance. The homogenous institutes could take a lead in many of the activities.

Suggestion:

A working group should be established to assess in detail the potential of R.E. resources in Iran. It can be built up of experts from scientific and research institutes with relevant experience. Based on mostly already existing data for the respective sources

- Solar Energy - to be exploited by solar Thermal Power Plants; or by Photovoltaic Systems (the latter ones mainly for remote applications);
- Wind Energy; and
- Geothermal Potential

a compilation should be performed, estimating the yield figures for the different technologies under Iranian weather and environmental conditions.

Combinations of various sources should also be taken into account and put against the predictions of future demand to define possible contributions to cover energy needs.

In a similar endeavour the potential of the water resources should be addressed. The assessment of

- Hydro-Power (large and small scale plants)

has to handle some specific questions, since besides the estimate of possible energetic yield from streams and rivers also the utilisation of water for other purposes has to be counted for. Priorities defined in a Water Management Plan could lead to the consequence that a combination of various sources need be taken into account, too (according to the state-of-the-art additional energy contributed from solar plants could help to use limited water resources more efficiently).

Estimating the potential of R.E. conversion not only electricity generation but also the applicability of solar water heating (for domestic or industrial purposes) should be included. It is recommended that the issues of electricity production and water heaters be treated separately (using demand-oriented utilisation strategies), and it also should be distinguished that different priorities (and cost figures) apply for

- rural areas (far from the grid); and
- areas, where grid connected operation is feasible.

The results of these studies should be submitted to an inter ministerial Board, where the Ministries involved in affairs related to energy and reconstruction tasks (energy, industry, rural infrastructure, agriculture, and education) should be represented. The outcome of the discussions and decisions about the related issues will be a prerequisite for consecutive activities and for a definition, which technologies would be of primary interest for the Iranian republic and its population. Making such plans it could also be of importance to agree upon, which of the research institutes should take the lead in further investigations.

Suggestion:
An economic analysis for the utilisation of R.E. should be worked out. According to the state-of-the-art not only the energetic figures should be accounted for, but also the data concerning secondary effects (labour force employment, environmental hazards, reliability, etc.). For this task either a separate working group should be designated, or experts working in the field of economics should be assigned to the group mentioned above.

For the different energy conversion techniques the Cost/Benefit-ratio should be compiled and documented.

Suggestion:
A simultaneous realisation of too many R.E. conversion techniques is not recommended not only for cost reasons, but also because of limited scientific capabilities and industrial capacities. A step by step plan for the implementation of R.E. systems should be issued. The arguments to be taken into account for such a judgement about priorities are:

- availability of technology and proven practicability;
- possible contribution to the energy needed by the Iranian people;
- cost / benefit data for the intended utilisation;
- feasibility of partial (or even significant) manufacturing in Iran;
- environmental aspects and possible other hazards.

Applications, which were found to be not of importance under short- or mid-term aspects, should be subject to academic studies better than allocating substantial funds. Which - anyway - should not affect the subject of research at University institutes.

MARKET DEVELOPMENT FOR RENEWABLE ENERGY EQUIPMENT

So far there is nearly no market for R. E. products in Iran. Even if for a few applications R.E. equipment has proven commercial competitiveness (e.g. for remote telecommunication transmitters), private entities or persons do not seem to participate in the purchasing or utilisation of R.E. equipment significantly. In the private market only very small appliances (calculators, hand lamps) could be found. Consumers of more powerful equipment are in nearly any case organisations belonging to or closely related to the public sector.

As a matter of fact, this was also the case in most industrialised countries (where energy prices are definitely higher, making an economic breakthrough for R.E. sources easier to be reached) as long as no actions towards market development were undertaken. Given the present cost situation industrial enterprises would neither be willing nor able to take a lead towards technical or economical advancement of R.E. applications - not speaking of the difficulties to make significant investments.

To encourage market mechanisms different means could be envisaged:

- Legal measures (restrictions for fossil sources' utilisation, directives to introduce R.E., e.g. at new buildings; rules to include non-pollutant sources in any energy-related investments, etc.);
- Monetary incentives and / or tax exemptions, financial subsidies given to consumers or manufacturers;
- Technical assistance for the producers (by means of funding R&D activities; Subsidies for investments into manufacturing facilities, tools, etc.);
- Financial support (facilitating bank loans etc.).

Some examples, how this was performed in different countries abroad, are given in the Annex "M". But, whatever means should be selected to be applied with priority, the information, to what degree subsidiary measures would be necessary, will be of utmost importance. Since the figures for such an assessment depend on the local market conditions and the technological progress, an updated survey has to be made.

Suggestion:

A market review to be prepared should figure out the issues of

- financial drawbacks for R.E. systems on the local market (in comparison to conventional ones);
- number, status and financial capabilities of likely consumers;
- cost paramters of techniques to be introduced with priority, and
- production potential (related to demand figures) for such equipment.

The data mentioned being prepared, additional activities may be necessary to establish manufacturing capacities. Experiences with tasks to encourage the market abroad show that, if incentives were given (of what type ever), a premature market growth could be a consequence, leading to an unwanted competition and to uncontrolled flow of subsidies. Thus, some administrative measures to direct the development towards intended goals could be compulsory.

As part of the market survey data should be collected about the information available in Iran be it on the industrial level, but also as far as the consumers are concerned. Based on the results of this task, a strategy could be issued, which be the most adequate procedure to establish a certain status of knowledge at any level of personnel concerned.

Suggestion:

Information should be prepared (to the extent necessary) aiming at:

- Transfer of knowledge;
  this should apply in the first order to the information flow from research institutions to companies interested in or involved at the manufacturing of components; but it also should include public or private entities, which could use this information.
- Providing reliable documents about advantages and possibilities of R.E. systems by means of consumer information sheets and published matter to give the citizens (possibly distinguishing between rural and urban people) an advise about viable applications. Anyway, also the constraints to be taken into account should be named to avoid future disappointment.

- Demonstration of feasibility; preferably by means of the installation of practical systems, yielding operational data and giving "hands on" experience.

Suggestion:

Enterprises should be encouraged to take part in the development of the market. This necessitates inter alia the preparation of a list of goods adequate to the utilisation figures and standards in Iran, which could be made locally. Research institutes could be involved to issue such a list. But they also should assist in a screening process, which companies offer the best chances for a successful endeavour with said respect. In the search for Iranian enterprises capable to co-operate in manufacturing tasks the research entities could be involved either by means of undertaking a market survey of companies already active in similar fields, or by issuing a questionnaire to be answered by industrial enterprises willing to participate in this field. Finally they could give directives, how to use the results of such an interrogation.

Recommended topics to be taken into account when making such judgements are:

- existing facilities to manufacture similar products;
- capability to warrant service and maintenance for the units sold (after sales service is a decisive issue introducing new products);
- status of the enterprise (well-known companies preferred); established firms more easily step into new fields than new-comers.

Anyway, there will be the need to ascertain that the technical features of the equipment are in conformity with the required performance. In most cases the customer will not be able to verify this by himself. This could be done by standardisation measures and/or by sort of quality assurance procedures (see below).

Once an economic breakthrough of a technique could be reached, market forces will warrant the further development. On the other hand, when it is foreseeable that in the near future some novel devices will be available on the market to be used successfully, some preparatory provisions should be made to facilitate the introduction of such equipment. E.g. a more widespread use of solar water heaters (having the potential to significantly change the situation as far as urban smog from domestic heaters is concerned) is certainly desirable. But neither standardised types are available on the Iranian market nor was any documentation found, which yields (or energy savings) could be expected. But: even if such data and equipment were available, the introduction in a large scale depends on the rate of new buildings to be erected (since an installation after finalisation of the buildings structure and tubing is not easy). This situation could be changed by preparatory measures.

Suggestion:

As a prerequisite for a customary application of solar water heaters provisions should be introduced (at least, where new buildings are erected) for the tubing, connections to the water distribution system, and for an access to roof areas in favourable orientation to the sun.

This should mainly involve planning institutes and communal authorities. Incremental costs are in most cases minimal, if the design was done accordingly.

SCIENTIFIC AND TECHNOLOGICAL ASPECTS

Scientific entities and research institutes could be involved in the activities mentioned in a propitious way. It would not only be suggestive, to make use of their skill by arranging for a participation in the process of elaborating studies and performing assessment tasks as mentioned already. Moreover, some additional work need be done, which could be undertaken by these organisations.

Suggestion:

The research institutes should be entrusted to proceed in their activities performed, but they should also be obliged to reconsider their tasks in terms of importance for the economy and of practical viability, i.e., whether the results or the equipment developed could be applied or introduced in Iran.

They might be asked to provide engineering support to the industry at any adaptation and modification processes to meet the requirements under local conditions, and to take part in tender actions, at least at the first phase of purchasing from abroad.

In the long term they should be engaged in the transfer of manufacturing know-how to local enterprises and in supporting measures to achieve fabrication practice.

A list of topics suggested for further research is compiled in Chapter "2.4 - Technol. and Research Aspects".

Suggestion:

Prior to a more widespread introduction of R.E. equipment tests under local conditions should be performed, the results documented, and system modifications be initialised when necessary. The experience with many prototypes of solar and wind systems indicates that such a step-by-step procedure is highly recommendable.

At least to a certain part these trials could become obsolete by the collection of data and experiences with prototype testing and the operation of demonstration plants abroad. Such endeavour seems advantageous also in terms of widening the basis of knowledge.

In those cases, where a realisation within Iran would not be adequate, the research institutes should be entrusted to keep in pace with the technical development in the international scene. Anyhow, as soon as novel technical concepts show up, which could influence the pattern of R.E. utilisation in the country, the homogenous institutes will immediately report to the decision making entities.

In view of the wide variety of R.E. components and machinery in utilisation world-wide a certain limitation of types and appliances may be necessary. The scientific institutes could play a decisive role by choosing the equipment acceptable for the home market. This will become of utmost importance, if local manufacturing be intended.

The research institutes could take over as an intermediary partner for foreign companies and local enterprises, as soon as domestically manufactured components shall be introduced.

Suggestion:

Research entities should take a lead in performing standardising tasks for any components of R.E. equipment to be imported to or manufactured in Iran. Moreover, they should assist the consumers and the local manufacturers by means of working out quality assurance procedures for R.E. systems and their components.

This applies especially to the sizes of units (e.g. wind energy conversion equipment or types and sizes for domestic water heaters). In the long term a high proportion of domestically made components should be looked for. By standardising the components not only sort of mass production can be warranted, also the quality and availability of spare parts will be increased.

The capabilities of local manufacturers should be taken care of (e.g. by means of using design principles in accordance with local manufacturing practice), when standardising is applied.

INFRASTRUCTURAL AND LOGISTIC MEASURES

Many activities performed to encourage or support R.E. utilisation will necessitate joint endeavour of more than one entity or enterprise. And at least in the beginning public funds will also have to be allocated to such endeavour. This - in general - cannot be done sucessfully without some supervisory business. Research institutes seem to be adopted to be involved in this:

Whenever public funds were allotted to subsidise and promote R.E. utilisation, the homogenous institutes could assist, controlling the flow and the proper use of the money; and reporting to the governmental entities about the outcome of the tasks.

For such a co-ordinated action also some measures should be taken to optimally use available budgets. Thus, cooperations between research institutes and universities should be strengthened. According to a well established practice in other countries an agreement might be favourable, which organisation(s) should be the main contractor(s) in charge for the advancement of technology or applications.

Suggestion:

Entrust one (or a certain number, according to their involvement in the technology) of the research institutes to supervise the ongoing process to perform the technical, managerial, and financial control tasks. This should include the definition of goals and milestones, negotiating the arrangements concerning performance verification, but also assignments of technical assistance.

Suggestion:

The entity should also take the lead in international relationships as far as foreign participation (joint research projects, co-operation with foreign companies or institutes) may be concerned. These activities should also comprise the search for funds (be it from local or foreign governments, the European Community, Development Banks, or from other organisations) and the related correspondence.

As a preparatory step it is recommended to update the information about the conditions valid for such funds, opportunities connected to them, and the applicable rules to be observed. The success of such activities may probably depend on some official political backing, which should not be inaccessible, anyway.

Suggestion:

A strategic plan should be issued, based on

- the work done so far by the institutes,
- the instrumentation and labour-force available, and
- the organisational structures already existing for respective tasks (to arrange for a "concerted action" between the research- and university institutes involved).

Even if only part of the cooperations and relationships mentioned above become true, the homogenous research institutes will have to extend their activities. Additional and closely specified projects with industrial enterprises possibly will necessitate some modifications in the organisational structure of the institutes. Since part of these jobs will be "business-oriented", the possibility should be provided that commercial enterprises make use of the facilities of institutes on their interests, reimbursing the costs allocated.

This might - in consequence - have positive side-effects, especially when tasks being executed will become commercially successful. The institutes may be entrusted to use such funds on behalf of their own. Doing so, it should not be excluded that the persons involved could benefit in part. As a model for an organisational structure which allows for such secondary financing a short description of similar institutes in Germany is given in Annex "C".

FINAL REMARKS

Any strategy suggested with respect to furthering the R.E. applications will only be successful, if some accompanying measures be taken:

Adequate funds and personnel should be provided to collect any relevant information about the state-of-the-art reached internationally, and about experiences with any type of R.E. equipment. This is especially valid as far as the access to foreign literature and proceedings is concerned.

Co-operation and exchange of results with partners abroad having the respective know-how in the techniques to be applied should be encouraged. This could be done either by mutual agreements with R&D institutions in other countries or by concluding licence contracts between foreign companies and local enterprises in some specific cases.

Necessarily this activity should include an **"internal" exchange of information** between Iranian institutes, universities and partners in politics and the industry on different levels.

1.3 SUMMARY

Research on Renewable Energy resources is an issue at many of the Iranian research institutes and universities. This work was found to be well established, based on sound physical concepts. Aspects of engineering and manufacturing are also dealt with properly, a transfer of the results of the scientific work into practical application will not be difficult.

In some fields further advancement may depend on an intensified consideration of results derived abroad. Progress reached internationally in the recent years could easily be adapted to the Iranian conditions. This applies primarily to small systems for lighting, pumping, refrigerating, etc. in remote settlements. Electric energy derived from the utilisation of solar radiation (photovoltaic) or wind in connection with adapted equipment offers a lot of opportunities, which should be looked after in more detail.

Also for the use of solar heat by rather simple units to heat water, provide for cooking, crop drying etc. some progress was reached internationally. Here "contemporary" concepts, based on new materials (mostly plastics) and applying simple fabrication procedures to reduce the structural costs offer some advantages and can be envisaged to suit the living conditions in remote areas in an optimal way.

The potential of an introduction of such techniques in Iran seems to be quite favourable, if a few inadequacies and drawbacks be overcome to profit from the developments mentioned. The scientific community in Iran suffered - at least to a certain degree - from some lack of information, being segregated from what was going on in other countries. There were also nimble chances to purchase equipment and components (e.g. modern semiconductors, integrated circuitry, computer equipment, etc.).

It should be an issue of common interest to circumvent such difficulties. This being done, there is no doubt that renewable resources will increasingly find an application in Iran.

Measures and activities to promote a steady development towards an intensified R.E. exploitation were cited in short in the preceding chapters. The ideas and recommendations compiled were based on informations gathered on site, but also on facts and documents representing the state-of-the-art in R.E. technology.

Some more detailed remarks are subject of the reflections contained in the following chapters: Starting with a survey of energy resources in Iran and correlated topics, the issues of research in the homogenous institutes, the involvement of industrial enterprises in the activities directed towards strengthening the market, but also the important question of costs and benefits from the use of R.E sources are reconsidered.

Some suggestions were also made, which topics should be envisaged to be more intensively investigated by Iranian scientists. These ideas were intended as a guideline for an evaluation about the influence of such concepts on the Iranian situation. But this is not only an issue of scientific valuation, but also has a political dimension.

Some of the comments refer to recent experiences in the international marketplace. In connex with the work done in Iran they allow an assessment about the status and the level of national research efforts.

Still more information was collected and sorted. Reference was made to these papers, where it seemed to be helpful, and excerpts are compiled in the Annexes and Documents.

2. FACTS and DATA

2.1 Renewable Energies in Iran

Nearly in any aspect of R.E. utilisation the potential in the Islamic Republic of Iran is good (see ANNEX "R"). Hydraulic energy is an established source of energy for the country. In 1990 the installed capacity amounted to about 2 GW. The utilisation being essentially limited to the mountainous areas with adequate precipitation power generation statistics show that the contribution of hydro-energy to the electricity produced annually is essential. In addition to the energetic value for power generation the water resources are of importance for drinking water supply and agricultural use. Thus, aspects of energetics present just one of the arguments for still more endeavour to harness and exploit this resource.

Hydraulic power plants require comparatively large investment funds, but their competitiveness is undoubted, since they can be used for service times of many years, once the civil engineering is done.

The application of hydropower as an interesting alternative for small settlements is also a rather traditional discipline. In this case the combined utilisation of the water for human demand, agricultural and energy production makes the planning and evaluating process still more challenging. But the figures of another 300 MW of hydropower, which already have been allocated to available resources by the Ministry of Jahad-e Sazandegi, seem very impressive and will for sure not be the last decisive step in that direction.

An excellent potential was also found for the conversion of sunlight. Yearly incident solar radiation on the surface of Iran equals about 300 Bill tons of oil equivalent (t OE), to be compared to the annual consumption of 82 Mill t OE (1990), to show the importance. Due to its geographical position the yearly average insolation (measured in a horizontal plane) exceeds in many parts of Iran 4,5 kWh/m² daily, in some parts even 5 kWh/m². This (details see on the insolation graph in the ANNEX "R") leads to the conclusion that with few exceptions in the northern part of the country (mountainous areas) vital amounts of energy could be derived from sunlight. Various paths to exploit this resource have been demonstrated to be feasible: Large solar power plants could be one alternative, but with a unit size of more than 30, preferably more than 80 MW, they are mainly intended for grid connected operation modes.

For small scale applications - which is mainly the case in the remote villages in Iran - direct conversion from sunlight into electricity is more feasible (photovoltaic effect = pv) and can be used to provide lighting and auxiliary energy. In rural areas, where the infrastructure for fuel transports is expensive and frequently not reliable, also solar water heaters can represent a valuable source under sanitary and comfort aspects. And "solar heat" could contribute to fuel saving especially when during the summer season the hot water preparation be performed using solar collectors.

Anyway, this technique is by no means restricted to rural areas. It can also be of importance for large urban agglomerations, where polluted air is becoming an issue of major concern. Under environmental aspects solar water heaters seem to be a good alternative to those using fossil heating, since they offer a great potential to reduce gaseous emissions.

Any of the applications mentioned was found to be feasible in Iran, and to each of them some advantages can be allocated.

Wind energy is not as equally distributed over the country as solar irradiance. But it could be found that in many parts of the country the "critical" wind speed for an economically viable utilisation (depending on the demand values rated "useful" lie somewhat beyond 5,6 to 5,8 m/sec in the yearly average) is exceeded by far.

Finally, also geothermal conditions are favourable at many locations in Iran and the conversion into any sort of end-energy seems promising. In contrary to the other renewable resources a detailed economic database is not available, since the costs for such an endeavour depend largely on the geological situation in detail.

As a prerequisite for an assessment field explorations - which are in the planning stage - can firmly be suggested. Taking other countries with already existing geothermal power generation and district heating plants as a basis, further investments and investigations in that type of energy will pay off certainly.

2.2 The Situation of Ren. Energy Research in Iran

In the Iranian Research Institutes excellent conditions to deal with R.E. utilisation and to elaborate solutions for practical applications exist. Number and qualification of personnel is adequate, and proof was found that people are highly motivated and engaged.

But looking to the results of their work, the impression is somewhat ambiguous. Besides some very advanced studies, representing state-of-the-art, also some details could be found, where an update to the standards reached internationally seems necessary. There is no doubt that this could easily be done, since the basic knowledge for the understanding of the effects implicated with the utilisation of R.E. equipment is excellent. This is not only true for the physical, mathematical, and meteorological sciences important for an accurate assessment and yield predictions of the resources, but it also applies for the related topics of mechanical, electrical and electronical engineering. Other disciplines, like chemical engineering and material sciences, which are not directly connected to most of solar (or wind) applications, could be found to be well represented, too.

A certain drawback lies in the fact that too little contacts to the "outside world" seem to exist. This could be understood basically in terms of connections to researchers in other countries (which is for sure one issue, which could be solved easily). But it can also be perceived - at least in some cases - as a lack of orientation towards practical applicability. To tighten the links between the scientific entities and the industry or commercial enterprises is a topic, which should be kept in mind. The best way to reach this, would be the realisation of marketable products, be it newly invented, just developed, or even only adapted from foreign products to the Iranian situation.

Some recommendations and directives towards such activities are given in Chapter 2.4. Additional remarks and topics are cited in the ANNEX "T", which could potentially serve as sort of starter for such a process.

Most of the research institutes are closely associated with either Ministries or other public entities. This gives them for their main field of activities a sound economic basis, but there is also risk that a certain bias in the orientation is caused by these links. It could be helpful, if a broader scope be adopted. Moreover, in many cases of R.E. application an interdisciplinary approach is advantageous.

Having visited some research institutes it is felt that some profit could be gained from a more close co-operation. Whether this also applies to contacts with universities, cannot be ruled out finally. But an examination of the situation aiming towards possible improvement is suggested.

2.3 Ren. Energies and the Iranian Industry

Neither established manufacturing processes for R.E. equipment nor serious marketing initiatives could be found in Iran. This is disappointing, since the renewable resources in this country are good and also nearly equally distributed. But a similar observation can be made in many other countries, where aggregates and components to exploit the inexhaustible energy sources are marketed with very moderate success.

Once the necessary state of market introduction would be reached, the Iranian industry will certainly be able to cope with nearly all of the manufacturing problems arising from the fabrication of R.E. components. Possibly, some hints might be needed to facilitate a start-up to manufacture equipment in a limited series production. Looking after technical details it can be deduced that the following industrial branches could be involved (or should be encouraged to step into) a first phase of market development.

Industries with capabilities to make R.E. parts, components or even systems:

Workshops experienced in Metal Handling

Cutting, shaping, welding, etc., applicable at the following technologies:
Water heaters: frames and structures;
Solar electricity conversion (PV and Thermal): structures, tubes, components;
Wind power conversion: structures, casings.

Electric Industry

All electric parts for any type of R.E. equipment: switches, cables, motors, alternators, connector boxes;
Control equipment: boards, switching gear, electronic components, sensors (for many applications in connex with any R.E. engineering).
Regulators, Converters, Interface connectors for electricity generating units.

Chemical and Glass Industry

Raw materials and goods for collectors, mirrors, structures (glass or plastic), foamed or hot formed parts (e.g. insulating parts), covers, etc. (for many applications, with large potential in any technique used).
Batteries and rechargeable cells for small appliances using pv/electricity.

Also other - more sophisticated - parts could in the long term be produced in Iran:

Mechanical Industry

Wind Energy Converters: Rotor blades, shafts, gearboxes, couplings, brake elements, electro-hydraulic elements (pumps, pistons, levers), etc.;
Hydraulic Machinery: Shafts, bearings, guide vanes, impellers, casings, structures, sluice parts, locks, flood gates;
Solar Power Plants: Mechanical parts (axles, shafts, gearboxes), tracking elements, collector tubes, turbo-machines, pumps, etc.

Especially in the beginning licence contracts with partners abroad would facilitate such activities. It is a prevalent trend in many of the industrialised countries to cooperate with local manufacturing enterprises (including know-how transfer) to be cost-competitive with products from countries in regions with lower wages. The Iranian industry could profit from the geographical situation and the potential of skilled people.

A rough assessment about the situation in the neighbouring countries leads to the conclusion that many of the products developed for the domestic market could be also useful for the population in adjacent regions. This seems to be an additional argument for intensified endeavour to adapt fabrication processes and to step into the new technologies.

2.4 Technology and Research Aspects

More R.E. utilisation in Iran can certainly be reached - nota bene within a relatively short time - by encouraging market introduction of proven foreign products (eventually with some modifications), which are already available from the shelf. Nevertheless, this strategy is not fully satisfying: Imported goods will always be relatively expensive and would therefore not easily penetrate the market in a larger scale; and the specific requirements of the Iranian people and the adaptation to local conditions can best be fulfilled by local research entities involved in the development - and local enterprises producing such systems.

Having this in mind the following points have been elaborated, subject to further detailed definition and an assessment, which priorities should be allocated to them. The remarks follow a schematic of R.E. applications as discussed before (see Annex A) and are arranged in a scheme, which inter alia takes into account the capabilities and activities of existing R&D institutions.

Hydro-Energy

Hydraulic equipment (in a wider sense not only the mechanical parts of turbine and alternator, but also locks, shutters, etc.) could be made locally at least as far as elementary types and small hydro-systems are concerned. To gain an overview of the machinery and components needed mainly, some preparatory studies might be necessary to collect experience data on proper sizes, water heads, and flow figures applied in the country. These data being available a first decision where to centre the activities of local manufacturing will be feasible.

After some considerations to assess the capabilities of local enterprises and to evaluate the influence of design modifications (if an adaptation to available fabrication practices is necessary) the research institutes should take part in purchasing activities, in an involvement of the Iranian industry in the (component-) manufacturing, and in the quality assurance procedures. This seems inevitably necessary not to take any risks as far as the traditionally high reliability of such systems is concerned.

It is suggestible that this task be performed step by step, starting with low power equipment of conventional design, but subsequently proceeding to more complex systems. The know-how and the managerial qualification for this job are certainly available at the EPRC.

Wind Energy

In addition to the activities in wind energy conversion techniques observed at ME-ARC (Material and Energy Application and Research Centre; Ministry of Education) and at IROST (Iran Research Organisation for Science and Technology) it seems of vital importance to start a phase of collecting operational experience. Wind Energy Converters (WEC) of different sizes are readily available on the international market. So it is suggested to purchase some units to be installed as part of a demonstration and data recording endeavour.

To establish a basis for optimal siting these wind turbines monitoring the wind speeds in the country should be intensified.

Since the development done in Iran refers mainly to equipment of rather small sizes, whereas global trends head towards systems of increasing sizes, it is recommendable that the WEC's bought from abroad should preferably be of sizes >10 to >100 kW, or even more. As a rule, larger units are designed for grid connected operation. In view of the fact that in remote areas certainly also wind energy converters in stand alone configuration will be needed, smaller ones operable in such modes should also be tested. For comparison as well also models made locally should be included in the trials.

For a first phase of field testing investment funds as well as an allocation of man-power will be needed. This could favourably been done by inviting experts from the entities cited above to form an integrated team.

This group of engineers should be selected to elaborate the measurement program and to act as a task force for the data evaluation and for any unexpected events to be recorded and assessed. In parallel, the development in this field should be reviewed, concentrating on the topics of

- new technical trends and their applicability in Iran (e.g.: the installation of an AC/AC- interface between WEC and grid to allow a more flexible operation of the unit);
- novel types on the market (e.g.: vertical-axis rotor "H"-Type);
- stand-alone WEC and/or wind and Diesel hybrid mode experiences for remote settlements.

Depending on the outcome of these tasks an assessment should be made, which types and sizes of WEC would fit best the demand in Iran. As a basis for decision making, a market survey should be elaborated (including the equipment available and its characteristics). Also possible conditions of co-operations with companies selling such sort of equipment should be compiled, including a résumé on governmental funds obtainable. It would be of great importance, to grant also financial support for licence agreements (see ANNEX "M").

These data being prepared, a decision could be made, which equipment suits best the demand and should be chosen for the next phase of installations in a larger scale in Iran. Provided that a sufficient number of systems is needed, the fabrication of parts and components should be "engineered" by

- involving industrial enterprises into the process of system evaluation;
- selecting techniques not too complex - with emphasis on simple production methods, materials easily accessible, etc.
- preparations made for assembly and installation by local staff (which - first of all - necessitates a complete, reliable, and adequately detailed documentation);
- investigations about possible cost reductions by local fabrication; and
- redesigning components according to production schemes in Iran.

The activities performed to evaluate wind energy utilisation for remote areas should also include the topic of "hybrid" operation, i.e. the combination of a WEC and a Diesel-gen-set. Favourable solutions have been found using such concepts for islands, which also should be applicable under the conditions common in Iran, be it in the very remote areas or at some of the islands.

Photovoltaics

Only a few activities related to photovoltaic (pv) energy conversion were observed in Iran. Basic investigations - dealing with the physical effects, material properties and cell manufacturing techniques - are conducted at ME-ARC (Material and Energy Application and Research Centre). And a near commercial (pilot plant scale) production line for pv-modules was installed at the Fibre Optics and Solar Energy Company (affiliated to the Iran Telecommunication Company). Both activities were for sure hindered by the fact that the necessary raw material (high grade silicon) is not available in Iran. Nevertheless, the fact that there is hands-on experience in the field of pv basics should be appreciated.

Many activities are undertaken world-wide to find cost-effective ways for this type of energy conversion, utilising a multitude of semiconducting materials. In Silicon technology advantages are expected from thin film deposition, crystals growth in very narrow layers, etc. In addition, sophisticated processes for surface treatment were developed, aiming at better light trapping capabilities and better utilisation of incident light.

Scientific research in this field is expensive, indeterminate in terms of possible progress, and subject to a strong competition. Whether it should have priority in view of limited financial resources, and whether manufacturing of cells or modules in Iran were opportune in a larger scale, cannot be answered in this study. Anyhow - it should not be understood that basic investigations were not valuable. In contrary, such studies facilitate an assessment of novel techniques, as soon as they woud be available (e.g. amorphous semiconductors, thin film technology, or new processes with cost-cutting potential), and to check their applicability. But as far as the production of pv is concerned, the plant capacities to reach a break-even point presently are quite large, possibly too large to step into a market, which is still limited, with new products.

In many countries a move towards application of pv-technology can be observed, which follows a very pragmatic concept: To use the technique effectively with any of the module types common to convert solar radiation into electricity. A significant portion of engineering is needed to adapt the components to the demand and to reach satisfactory reliability and function - at reasonable costs. Thus, system aspects of pv form a discipline of it's own, which becomes increasingly important as more and more different ways to make use of pv conversion were viable. In this field more efforts towards research and development can be suggested.

Also here some differentiation is necessary: Concepts aiming at an advancement of grid connected pv are undertaken in many industrialised countries. With electricity generation costs of about 1 $/kWh pv-generation is even in those countries not cost-competitive to common electricity tariffs (in Western Europe 0.15 to 0.2 $/kWh). Field tests for such applications are intended to promote the technical progress with respect to system components (where some success was reported already).

Cost reductions were expected from new cell technologies, but also from pv in concentrator configurations, and (with some potential in the years to come) from very large plants in "lean" design. For the scientific community in Iran it is recommended that trends in bulk electricity generation using pv be observed only, and that activities on a national level be postboned until the costs come down to comparative figures.

The situation is very distinct for pv in remote applications. In comparison to many other appliances advantages can be attained from pv especially in the low power range.

For many purposes dedicated equipment had to be developed (fluorescent lamps, load and charge controllers, connectors with smart functions to fulfil the interface conditions), but not in any case the status reached is satisfactory. And it is felt that here some potential for improvement and for the participation of research institutions exists.

A very cursory review of some shops in Tehran showed that in Iran similar products are fabricated for conventional applications. Therefore, also the production of components for PV-subsystems could be envisaged. Nota bene there is no high-tec involved, but adequate engineering skill. Parts, which potentially could be provided from the local market for PV products, comprise:

- Batteries (lead-acid, 12 V; 50 - 150 Ah in sealed version);
- Batteries (Ni-Cd; or -Hydrid, < 12 V; 5 - 25 Ah, quick-rechargeable);
- Battery chargers / controllers (low loss, micro-processor control);
- Fluorescent lamp load conditioners;
- Converters (DC-AC) for small and medium sized equipment (Battery-operated, 50 Hz, rectangular/trapezoid/sinewave inverters);
- Converters (DC-AC) with MPP-Tracking for direct operation of: pumps, tools etc. with 3-phase AC motors;
- Adequate types of control units for DC motors (DC/DC conv.);
- Measurement sensors, control and data recording equipment.

For the manufacturing of any of the devices cited it is assumed that the basic knowledge is available in Iran, similar parts being common in the local market (batteries, chargers, converters). So only few adaptation and innovation would be necessary to develop marketable products also for pv.

According to a world-wide experience (and as suggested for a wind program) it is recommended that feasibility and demonstration projects be performed especially in the field of rural electrification and correlated tasks (drinking water supply, village electrification, etc.). To provide reliable energy to remote settlements is a far-sighted approach, and technically challenging, since various disciplines are involved.

In the long term also some other technologies may become an attractive research field: Once the fossil era will expire, other concepts, e.g. Hydrogen as an universal fuel could become one of the alternatives. But there are also other ideas to think about (long distance electricity transport by super-conducting media, High Voltage DC Transfer etc.). The research activities found in the homogenous institutes dealing with such issues are appreciated in view of the aspects of future alternatives.

Still more effort is certainly justified to cope with the problems of electrochemical storage by means of fuel cells and rechargeable batteries. Many systems are under investigation, actually a certain state-of-the-art was reached, but the technical applicability is still not ascertained. This issue is for sure a long-term task, but it's importance will be increasing. At the EPRC research is under way in this direction, it is certainly correct to proceed in that endeavour.

Some challenge for the Iranian market lies in the adaptation of "standard" equipment to perform on the basis of R.E. utilisation. Many consumer appliances common in connection with conventional sources could be adopted to electricity from R.E. resources. This applies e.g. to

- evaporative (air) coolers powered by solar.
  Such devices are found all over the country, and since the demand is closely correlated to times of maximum outside temperatures, a combination of this type of equipment with pv (which also depends on the insolation) could not only contribute to a reduction of peak load.

Such equipment, moreover, seems nearly perfectly adopted to local manufacturing and the solar alternative can possibly comfort people even in settlements far from the grid. Finally it could become an export product, since it is most useful under climatic conditions which prevail also in neighbouring countries.

- the modification of ventilators and fans.
  With similar arguments also such devices for domestic appliances can be pv-powered. This also seems an attractive issue for remote homes.
- conversion of refrigerator aggregates to pv powering.
  For such products 'precursors' exist in the industrialised countries. Since there is no urgent need for such sort of equipment (it is mainly built for the camping and boating sector), production figures numbers were low and did not reach cost competitiveness.

The institutions best suited to deal with the suggestions made above are in a first order the EPRC (many of their activities could be envisaged as closely related to most of the tasks), but also university institutes could be involved and the solar experts at ME-ARC and IROST.

Some tasks were performed in Iran with high concentrating parabolic dish concepts. In this case it is suggested to just observe the development of Stirling motor design and the experiences gained with such equipment, which is under way in some industrialised countries.

Different conversion principles of solar energy into electricity or heat utilize in part global, in part direct radiation only. To assess the methods suited best for application, detailed solar irradiance measurements will be necessary, complementing the data already available. This task could preferably be performed as a joint activity of the research institutes.

Solar Thermal Power Plants

The Ministry for Power and the EPRC is evaluating a proposal to erect a 100 MW solar power plant in Iran. A consortium of European companies prepared a draft paper in this sense, more detailed studies are under way. The main issue seems to be the funding of the project, since an essential portion of the investment is expected from foreign (public) funds abroad.

To gain experience with the technology in question a pilot plant with about 725 kW (thermal) and about 200 kW electric power output is planned to be built in advance. With respect to the importance of collecting data about the operational behaviour and the characteristics of such a plant this proposition seems to be challenging for Iranian engineers to gain the experience needed for detailed planning and lay-out of a solar power plant.

The engineering capability to operate and monitor the plant is certainly available at EPRC. Additional activities could be helpful, namely concerning a survey of the international status of the relevant techniques. The results should carefully be assessed, since the funds allocated require a cautious evaluation, anyway.

Moreover, some endeavour should be allotted to study the issue of contributions from R.E. sources and grid stability: The stochastic nature of solar power can influence the grid, if these effects were not taken care of already in the design phase. Certainly this is the case with any of the R.E. application schemes, but in the context with a large solar power plant the ratio between the power contributed from a variable source and the base load can be rather high. This necessitates investigations in advance. Methods to compensate for such effects have been proposed, inter alia by means of hybrid power plant concepts, energy storage, fast step-in control devices, etc. But the optimal solution has to be found in any specific case.

Also peak load compensation is feasible on the basis of solar power systems. It might be an issue for further studies, whether this could be applied in Iran. Some concepts have been investigated, the most recent ones applying a pv generator with battery back-up to stabilise the grid, where large distances or high load fluctuations influence AC quality.

Even in conventionally powered networks such smoothening capacities have been used successfully, where sufficient hydro-power for peaking and stabilising duties was not available. In this case fuel cell based compensation systems were installed. For grids with large extensions and with no or only low surplus capacity the "solar" alternative was introduced. Hardware to handle the problems is available, even if yet in a prototype stage. The electronic devices built for such purposes react instantaneously, dynamic grid response can be avoided or limited.

Solar Heat Collection

At the ME-ARC (Material and Energy Application and Research Centre) and at IROST (Iran Research Organisation for Science and Technol.) such activities were performed. Part of them was directed towards utilisation of solar heat by means of solar collectors to heat water for domestic use, but also solar dryers were investigated. Anyway, it is felt that especially in this field some development was reached abroad, which could be transferred to Iran, tested, and - in proper time and type - offered to the market. Commercial or industrial enterprises should be involved in such a task.

Scientific and engineering action to be taken in advance should aim at

- judgements about the techniques of novel designs to be applied;
- transfer of laboratory scale equipment into economically competitive and marketable types;
- customising the systems (i.e. system engineering)
  Tasks to incorporate the necessary accessories (sensors and controls, hot water storage, meters) into a prefabricated kit, which can be delivered to distributors and customers.

Subject to a more detailed market analysis the types of heat collectors to be developed should comprise:

- Flat plate collectors (with storage) for "one family" households (private homes), preferably with natural convection, pre-assembled kits for do-it-yourself installation;
- Flat plate or evacuated tube collectors for larger buildings, with separate storage, forced recirculation and fossil back-up;
- Storage collectors (highly insulated collector with integrated storage) for domestic use or for small enterprises;
- Low-cost collectors (air cushion insulated) for large buildings and industrial applications (preheating of hot water).

The topics of freezing protection, temperature control, natural or forced convection, etc. need be handled with respect to the situation in Iran. Possibly not any equipment in use abroad can be directly applied in Iran due to the more differentiated ambient temperatures between summer and winter. But none of these problems seems to be insurmountable. The homogenous institutes can rely on some experience already gained. They should be encouraged to proceed in such activities.

New trends, which were to be observed in the field of solar heat collectors are outlined in short in Annex T

Concerning the efforts to build up solar dryers some fundamental considerations are apt: Food conservation is a very important issue, and solar drying has a long history. Certainly, modern engineering principles can solve a lot of problems in this field, but in any case the investment costs of the dryer need be affordable for the users. Thus, not any solution which seems physically advantageous and practically feasible, will also be economically viable for the customers. Accordingly, future research should be directed mainly towards

- cost reduction by means of using low-cost materials; design principles should keep in mind self-making of the dryers;
- development of (simple and cheap) types for small scale applications.

Some designs were made recently in Europe, which could be advantageous also for Iran. Studies in this sense are recommended.

Biomass

An "engineered" utilisation of biomass in a large scale is not suggestible. Neither Iranian climate nor it's infrastructure can be used as arguments for tasks to go beyond the traditional customs to use firewood and similar applications. But one research issue met at the IROST might be of importance, regarding the utilisation of biogas in small units: The modification of internal combustion engines (nota bene from Iranian origin) to operate on fuel gas leads to a concept, which may be applicable for combustion of biogas, too. If yes, the export to international markets seems to have good chances, since such engines in small sizes and in reliable types are missing so far, and there are areas in the world (especially in developing countries), where biomass is digested for other reasons. and biogas is available as a by-product.

Cooking (combusting wood and dung) is an issue, which is directly related to the exploitation of biomass. Many local traditions, but also the scarcity of raw material for such purposes have to be taken into account, when alternatives are being discussed. In view of some quite positive experiences in other countries an evaluation can be suggested, whether solar cookers would be applicable in Iran. This is certainly not a technical problem (a prototype of a solar cooker was demonstrated at the Sharif University at Tehran) but one of acceptance and convenience. Research - at least to collect the informations, what's going on in that field, and a verification, whether this could be transferred to Iran - seems to be attractive.

Geothermal Energy

In view of the favourable aspects of a utilisation of geothermal resources an update of tasks performed in the past would be worthwhile. From theoretical and empirical data collected at the EPRC a positive potential for geothermal exploitation can be assessed. As a prerequisite for studying the matter in technical terms and to calculate the obtainable energetic contributions the drilling of a test well and the exploration into the most interesting geological formations is suggested.

Based on the results of that endeavour a more precise estimate could be issued (also using recent experimental data from abroad). Certainly, exploiting the geothermal resource is not a short-termed activity, but it could become a very attractive basis to cover part of future energy demand.

Related Topics

Rational use of energy is an issue directly connected to R.E. utilisation. Whatever component be powered by R.E. sources, the most efficient way to use energy has to be introduced. Thus, energy saving methods are familiar to all those involved in R.E. development. In many publications the rational use of energy is handled, there is nearly no discipline, where such ideas could not be applied successfully. Some examples, where side-effects of a development to exploit R.E. sources could profitably looked after are:

- The application of speed control (by means of AC/AC-converters) instead of other methods to adapt the output of fans, pumps, compressors, etc. to the demand. In some cases, where this means was introduced, the return on investment by energy savings was within less than four years.
- Energy storage as a means to cut peaks (and infrastructural costs) in mechanical machinery so far is still a rather difficult issue (performed e.g. by fly-wheels, pump-turbine-gen-sets, etc.). But this is an important task in heat recovery and storage systems. A multitude of activities is under way world-wide, concentrating at present in the storage of latent heat in adequate media. Even if water storage, stones, gravel beds and other principles are studied, excellent aspects were found using phase-change media.

In the housing sector this is e.g. performed by means of solutions or mixtures from salts with liquefaction temperatures in the range from 25 to about 85° C. Using different media (with adequate chemical and physical properties) the desired storage temperature can be reached. For Iranian climate with strong differences between day and night temperatures such storage concepts could significantly contribute to energy savir 3. Homogenous Institutes were so far not involved in investigations in this field, but could possibly catch up with the development in relatively short time.

The international progress in the field of high temperature storage media (ceramics) should be observed. But as long as no large scale industrial application of such technologies is perceivable, larger funds should not be allocated.

Additional recommendable activities refer to more complex exercises applying R.E., as e.g.

- solar equipment in agriculture (solar heat and PV), e.g. utilisation of PV for pumping (irrigation), lighting and/or for tools;
- combined / hybrid systems using solar heat and electricity;
- water desalination.

Many of the tasks mentioned may became of increasing importance. This is especially true for the latter one, since water resources were depleted in the past by high consumption and negligence. From the various concepts for desalination Reverse Osmosis seems for the time being the method best suited to solar energy utilisation, but other principles are feasible, as some investigations under way have proven. This issue should be studied more intensively with respect to the Iranian situation.

Also in the combination of R.E. equipment and conventional (fossil) systems further tasks are compulsory. There are nearly no technical problems involved, the knowledge about the equipment to be used is well established. But the interconnection of different aggregates and components requires smart control measures and need be designed properly. Homogenous institutes could certainly contribute to the technological development in this area.

Finally it has to be mentioned that in many countries "modelling" of systems became an issue of detailed investigations. Such methods, mainly based on the application of computer software, should be transferred to the situation in Iran. Such tools might be of importance for any decision making processes. To catch up with the state-of-the-art in modelling contacts to scientific organisations abroad would be helpful. Since part of the tasks in that direction were performed at universities, the relationships could be arranged on that level, anyway.

Research Budgets

To a very high degree the suggestions made could be followed at the homogenous institutes without additional staff by some re-orientation of manpower. Therefore additional personal costs (exceeding the present budgets of the entities) were not anticipated. But significant hardware investments will be required to perform further tasks in a few outstanding disciplines:

Costs for test and demonstration activities in Wind Energy Conversion were expected to amount to 550.000 - 700.000 $. The equipment is not too expensive, thus in the budget guessed measurement equipment and infrastructure costs already have been included. And with unit costs of less than 200.000 $ the investment could be distributed over some years.

The investment for the Solar Thermal Power Plant is significantly higher. Even if the Iranian contribution will be equivalent to the costs for a conventional power plant of adequate size only (according to the proposal agreed upon), funds to be allocated will amount to 100 Mill $.

From the costs proposed for the 100 MW power plant the figures for a pilot project ("prototype" solar power plant) of 220 kW can be assessed to be about 1,5 Mill $. Additional manpower and maintenance costs will be needed, but no more accurate guess is feasible for the time. With respect to the high costs it is recommended to find out, whether not only technical but also financial support for the prototype plant could be found abroad.

A first estimate for drilling an exploration well for the Geothermal Resources leads to slightly more than 1 Mill $, which does not seem to be too much in view of the importance of this issue.

Any other activities can be assumed to be comparatively low-cost, since the unit prices for parts, components etc. do not exceed some thousand $ at the maximum. The real costs then will depend on the number of activities undertaken in parallel.

Some amount of funds should anyway be allocated to the purchase of documentations and international publications. Urgent need for such papers could be observed to catch up with the state-of-the-art. And in this context it is recommended to issue a list of books and publications concerning R.E., which were available at the homogenous institutes or at the university libraries to facilitate the exchange of information.

2.5 Costs and Energy Yield Assessment

The stochastic nature of renewable resources of energy makes it difficult to assess reliable cost and yield figures. But, on the other hand, a large number of systems is in operation now, and their results have been recorded. A transfer to new installations gives a guidline, anyway.

On the basis of present electricity generation data in Iran the prediction for the future demand is feasible (Annex "C"). If R.E. sources should be exploited and yield a significant contribution to this figures an adequate power generation capacity need to be installed. A first guess can be made, assuming a reasonable limit for the utilisation of such resources: In view of the fact that this will have to be realised within the next decade about 5% of the - then - installed overall rating of the power plants in Iran seems to be an ambitious goal and defines the upper limit for an engineering guess. This would lead to an estimated capacity of about 1.5 GW plants operating on non-exhaustible resources.

Taking present plant costs for such equipment as a basis (even if inflation is accounted for, cost reductions could also be suspected on the other hand), the investment capital for different technologies would amount to:

Technology	*Plant costs (GWxsp.Costs)*	*Installation costs Bill $ (1993)*	*Costs with estim. trend extrapol.*
Wind En. Conv.	*1,5 x 2000 $/kW*	*3,0*	*2,3 Bill $*
Sol.Th.Pow.P.	*1,5 x 3000 $/kW*	*4,5*	*3,5 Bill $*
Photovoltaics	*1,5 x 12000 $/kW*	*18,0*	*10,5 Bill $*

Investment Costs for a 5% Contribution from R.E. sources in 2000+

These data show clearly that for bulk electricity generation wind presently offers the by far most economic alternative. And this is even true, when trend extrapolations be made. It has to be mentioned that the plant size is an important issue for some of the techniques. And the availability of the resource is another one. Thus, the figures can change significantly, if low power applications are looked after.

For remote settlements technical solutions based on pv conversion were found to be competitive for lighting and small appliances in the houses. The installed power requirements for such purposes (so called Solar Home Systems) lie between 50 and 130 Watts. Utilising the figures of villages not connected to the grid and the average number of buildings the total capacity of such (small) pv systems for the rural popolation in Iran can be assessed: For *>10.000 settlements* with about *20 households* each, with a specific power demand of *100 W* for pv *Solar Home Systems* an overall *Power Demand of 20 MW* can be compiled. Given "standard" system costs of >15 $ per Watt, the Investment equals *>300 Mill $*. This figure has to be compared to the total grid extension length to provide the electricity (or with the costs for Diesel equipment).

For only *5 km* transmission line to reach each of the 10000 settlements, the figures cited above would equal a grid expansion in the order of magnitude of *50.000 km*. Certainly, the power transferred is low, thus a rather cheap solution could be realised. But counting simply for cabling and hardware costs, the grid extension would need funds of more than *450 Mill $*. There is no "financial" figure to count for comfort, reliability of the grid, possible use for any other purposes, etc. Therefore more detailed data (e.g. also for Diesel systems) cannot be given here. But even this small example illustrates the situation.

For the R.E. conversion technologies mentioned the yearly yield is well documented. Field test data exist for the climatic conditions in Europe and tne USA, respectively. In specific values (corresponding to one Kilowatt installed) the following table gives average yield data, and also presents assessment data for the conditions in Iran:

Technology	Yield p.a. (location)	Yield p.a. (Iran)
Wind En. Conv.	2500 - 2300 kWh/kW (Germ.)	> 3000 kWh/kW
Sol.Th.Pow.P.	1250 - 1650 kWh/kW (Calif.)	1300 - 1600 kWh/kW
Photovoltaic	700 - 900 kWh/kW (Germ.)	1050 - 1200 kWh/kW

Yearly Yield Assessment of Electricity Generated by different R.E. Plants

A remark has to be made: As well for wind energy conversion as for solar power plants the combination with a fossil source (Diesel gen-set or additional gas-fired boiler) is common. This so called hybrid operation is favourable in terms of reliability of energy generation. And it increases plant economics, since the annual operation hours of the system can be influenced.

Looking to the other alternative, namely water heating by solar energy, the data derived from existing units differ largely. The reasons can be first of all allocated to different types of collectors, but also other parts of the system play a decisive role (storage, connecting tubes, control, etc.). In general, it can be said that low-cost systems have also decisively lower efficiencies, which can be a disadvantage, when the collector costs represent only a fraction of the overall system costs.

In the following table some data were compiled, allocating the technique to cost and yield figures on a reasonable basis of about 4,5 kWh/m² daily solar irradiance. The temperature increase is correlated to the type of collector (some collectors operate economically only in a very narrow temperature range).

Type of Collector	Costs \$/m²	Eff.	Yield p.d.	Lit/d at Δ Temp.	
flat plate/lo-costs	150 \$/m²	30%	1,5 kWh/m²,d	25 - 35	<30°C
flat plate/standard	>200 \$/m²	>40%	<2 kWh/m²,d	30 - 45	<40°C
vacuum tube coll.	>350 \$/m²	>50%	2,5 kWh/m²,d	> 50	>40°C
hi-insul./storage	>450 \$/m²	>50%	>2,2 kWh/m²,d	> 50	>>40°C

Costs and Yield Figures of Solar Water Heaters

The cost figures cited above refer to small units, including the "balance of system" costs for connecting, structures, etc. But simple collectors contained in the table do not include a storage device, which is needed in most cases and can increase the system costs significantly. Solar collector prices depend largely on labour costs and could be reduced by local manufacturing (or even by do-it-yourself kits, available in some countries). Still cheaper collectors (all plastic design) are available in the USA and in Europe, but they are not suggested for domestic use (main application: swimming pool heating). Other collectors with some cost-cutting potential are in development (see Chapter 2.4 and Annex "T").

The data cited in the tables can be used to assess the possible effects on national fuel consumption figures. For this compilation the reference for electricity generation was taken from Diesel gen-sets, for hot water preparation from standard fossil heaters with an adequate output. These data vary widely, average values have been used here.

For electricity production from pv two separate lines were compiled in the table, since a correction is appropriate for very small systems. Under such conditions also the energy utilisation factors of fossil equipment become very low, fuel consumption figures of standard (Diesel) equipment high (be it because of economy of scale effects, frequent part load operation, neglected maintenance, and others more).

Technology	*Yield p.a.*	*Oil Equivalent p.a.*
Wind En.Conv.	*> 3000 kWh/kW*	*600 kg OE / kW*
Sol.Th.Pow.P.	*> 1500 kWh/kW*	*300 kg OE / kW*
Photovolt.(grid)	*> 1000 kWh/kW*	*220 kg OE / kW*
Photovolt.(S.PV)	*> 1000 kWh/kW*	*330 kg OE / kW*
lo-cost Water Heater	*> 500 kWh/m²*	*70 - 95 kg OE / m²*
hi-eff. Water Heater	*> 800 kWh/m²*	*100 - 120 kg OE / m²*

Fossil Energy Savings by means of R.E. Utilisation (Iran, annually)

For remote areas the fuel consumption data have to be corrected by a factor of 1,5 to 2 to account for transportation expenditures, losses, infrastructural demand, storage requirements, etc. Published data indicate that for an electricity demand below 1,5 to 5 kW (where no other reliable technique is applicable) photovoltaic presents the most economic alternative, if solar conditions are favourable.

For all results some cost reduction potential is presumed, exploitable by further R&D and by larger fabrication numbers. An estimate, how far - and when - such trends become reality, was not undertaken here.

2.6 Environmental Issues and Hazards

Renewable energy conversion is characterised by the fact that no - or nearly no - emissions are produced during routine operation. This need not be true, if all the life cycle of the system is taken into account (from production of the components until is decommissioning), and if - in addition - also not anticipated effects, transients, accidents, and other events may be included.

Starting with the production of the various types of plants, it can be stated that - in general - the environmental hazards connected to their making are low. At least this is the case, when compared to other established technologies: e.g. to the processes of steel making, glass production, plastics and resins fabrication, but also semiconductor manufacturing. The material consumed to manufacture R.E. equipment is in any case just a small fraction of the bulk consumption of matter for other purposes.

Raw products needed (even if sometimes poisonous gases, aerosols, dust particles, etc. are emitted during the manufacturing process) are the same as used in many other processes with much higher throughputs. Thus, the R.E. technologies can be envisaged as part of an established production scheme. A few exceptions need be made:

First of all for photovoltaics. Small amounts of heavy metals are used (silicon is not dangerous, gaseous complexes could be poisonous and have to be manipulated in protected rooms only), also GaAs, InTe, CuInSe2 etc. should be handled with care. Some restrictions also exist, if modules after use should be disposed of. Many scientists think of a recycling infrastructure, once these processes should become used in a larger scale.

Also the issue of batteries (especially Ni-Cd) is to be mentioned. Here recycling is feasible (even if still not established for many applications). And it should be compared to the common practice, to use non-rechargeable cells (primary cells), which after use were simply regarded as waste and thrown away. It can be assumed that for Ni-Cd's a similar infrastructure for recycling could be established as for Lead-Acid batteries (automotive and solar batteries), which presently are collected and re-used to more than 90%.

Heat transfer media used in solar thermal applications need be taken care of, too. This could be anti-freeze additives in water heaters or thermo-oils in power plants. These products are dangerous with respect to water contamination (if spoiled), and their reaction products in case of fire are toxic. Careful handling is suggestible in any case. But it should be mentioned that similar arguments also apply for fuels and lubricants (from Diesel engines), when they are spoiled.

Summarising the points discussed above, it can be put in short that with any technology used a certain amount of environmental hazard is connected, but that these risks are not exceptional ones - at least when the manufacturing processes, routine operation, and decommissioning are handled according to the state-of-the-art.

In the following the inadequacies, emissions and risks, which are typical for any of the various techniques in use, shall be addressed:

Hydropower-Plants

In routine operation no environmental hazards occur. Losses of lubricants into the water usually are minimal, far below the limits of detection. Even extraordinary operation conditions can not change this pattern.

As a fact, there is a risk of dam fractures at the occasion of earthquakes or other strange events. But statistics of high dam operations show that this issue can be handled by engineering skill and proper design. And it has to be balanced against the protection of people living on the river banks from flooding caused by heavy rains.

Wind Energy Conversion Systems

The most frequently effect exerted by WEC's is noise. This can be handled by engineering means to a certain degree only. Therefore, suggested distances from houses should be observed. There is also in some cases a certain loss of lubricants or oil, especially if the converter uses hydraulic components (e.g. for the braking system and for control purposes). The amounts of contaminating materials are small, anyway.

Larger hazards have to be taken into account, if a WEC is operated in an environment with very strong winds or gusts. If wind forces exceed the maximum allowed value (usually : 150 km/h) mechanical fractures (rotor blades, tower) might occur. Loose parts from rotors bear some risks, but statistics within the last years certify that this is not a very probable danger (some exceptions were published, e.g. when a lightning stroke the WEC and this was not taken note of by the operators).

Some environmentalists suspect that WEC's pose a risk to flying birds. This cannot be ruled out definitely, but experimental proof of a significant number of casualties could never be made.

The issue of earthquakes for sure also relates to the towers of WEC's. But with respect to this the experience with towers of high voltage transmission lines is directly applicable.

Photovoltaic Systems

PV systems have no moving parts (with exception of concentrating ones with tracking capabilities, which move very slowly), therefore their risk potential is low. Of specific concern (see below) is the fact that pv produces DC-current of voltage levels, which might be - depending on the application - quite elevated. This need be handled carefully, when nominal voltages exceed 60 V.

PV mounted on roofs can influence the probability of lightning strokes. Caution when designing and assembling according to established protection techniques should be applied.

Solar Thermal Power Plants

High concentrated sunlight may be hazardous, but with plants according to the Farm concept this risk is very low (range of danger is within the focal distance). But in the fields of such plants the danger of hot media cannot be ruled out, if any fracture exists. In case of direct steam generation consequences of such leaks will be limited to very small areas. Systems using thermal oil pose hazards to the soil (contamination of ground water) and of fire.

The remarks concerning earthquakes, lightnings, .etc. apply accordingly.

Generally precaution is suggested with any electrical equipment, power lines, cables, connector boxes, etc. To avoid any risks, the handling of those parts should be left to people familiar with high voltage protection measures.

Solar Heat Collectors

Since these components are usually passive ones (and mounted on roofs, i.e. out of reach), their risk potential is low. And mostly the temperatures are in a range, which does not impose specific risks.

Accidents have been reported, if the necessary precaution was not taken, when assembling the collectors on the roof, or when cleaning them. Also the importance of storm resistant design and of lightning protection should be stressed. Anyway, most of the related events refer to a very early stadium of the application.

Vacuum collectors (tube or flat plate) can implode. The probability of such an accident is not high, but it is - on the other hand - explicitely different from zero for flat plate types, especially at the impact of any object. For larger areas of such collectors a protective mesh is suggested.

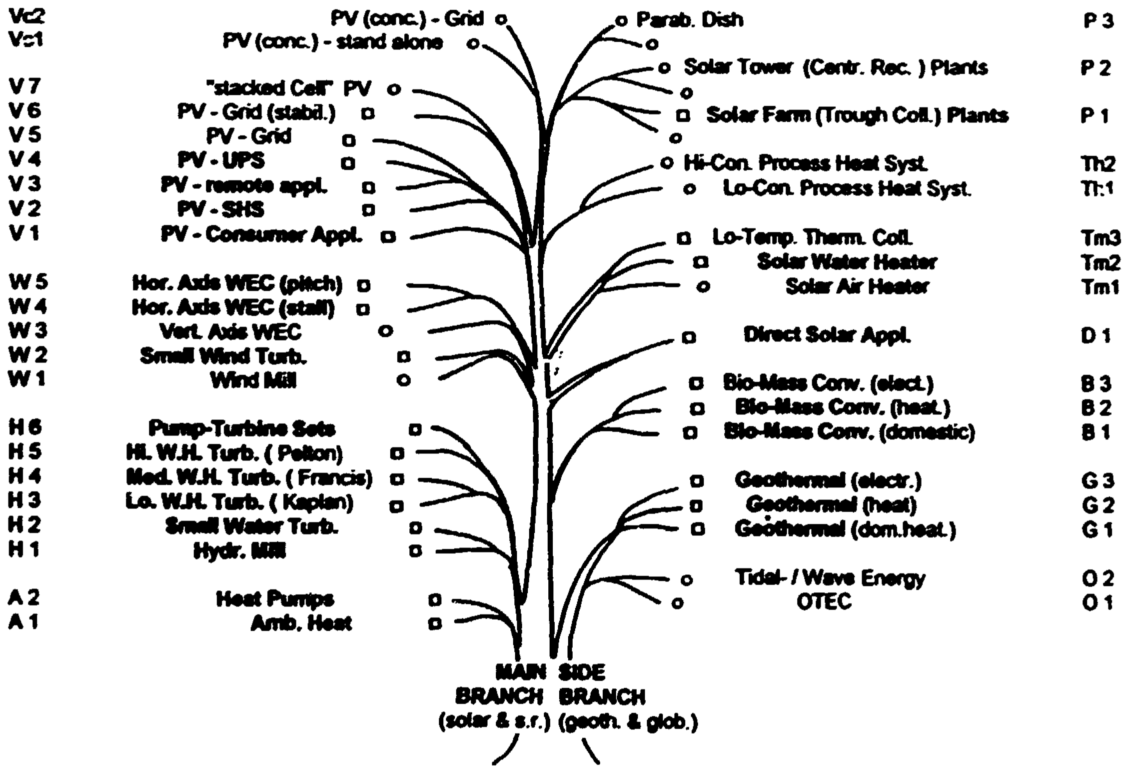
RENEWABLE ENERGY CONVERSION SYSTEMS: STATE-OF-THE-ART

By definition "Renewable Energies" are derived from an inexhaustible source of energy, which may either be the solar irradiance or one of the effects, which are correlated to specific properties of global (geothermal) or planetary system.

In terms of physics also wind energy – as a consequence of (seasonal) thermal gradients on the surface of the globe – and hydro-energy (the sun provides the energy source to transport water to the elevated areas of the landscape) depend on sunshine. Also the production of biomass is influenced mainly by sunlight (besides soil characteristics and water).

Accordingly, two main sources of renewables have to be taken into account, each of them branching into various conversion paths. The first figure gives some classification of the technologies and visualises the sorts of end-energy gained. As can be seen, nearly any type of energy can be derived converting renewable resources.

Not included are some "secondary" conversion facilities, which could become of future importance. E.g. this is true for methods of water desalination (be it using electricity or heat sources), water pumping for drinking demand or irrigation, cooling equipment driven by electricity or absorption principles (using solar heat), and – finally – potential options like Solar Hydrogen production. Also not shown are applications (part of which is fairly common) combining fossil and renewable sources ("Hybrid" systems, like Wind-Diesel, Solar Farm Power Plants with auxiliary gas boiler, PV plus Hydro-Power, etc.).



The Renewable Energy Tree

Legend: o Circles: Technologies in Test
□ Squares: Commercial (or near commercial) Applications
Bold Characters: Economically viable (compared to conventional Techn. - at least under certain conditions)

In the overview the development status and the technical importance of the different conversion techniques are highlighted by dedicated symbols.

The certainly most common application is the utilisation of solar energy by means of exploiting ambient heat ("Group A"), be it by direct (architectural design, orientation of buildings) or by indirect methods (e.g. using heat pumps). The main field of such techniques lies in the domestic and housing sector. In many cases this implicates some means of short-term or seasonal storage, which is frequently also true for an application of heat pumps. For such equipment the climate plays an essential role. Even if practical viability has been demonstrated, cost competitiveness is so far still limited to climates, where bivalent operation is feasible. But the potential for using ambient heat for district or domestic heating must not be underestimated, anyway.

A 1. Utilisation of ambient Heat: direct Use
A 2. Indirect Use of ambient Heat (e.g.: Heat Pumps, Storage Concepts)

The "Group H" with the numbers 1 to 6 refers to Hydro-Electric energy conversion, which is also routinely used world-wide. Hydro-Turbine (Water-Turbine) technology is well established and has a long tradition also in Iran. Any of the alternatives mentioned in the figure is readily available on the market. In most cases the design has to be made according to the parameters of the hydraulic resource (water flow, water head, power demand, control strategies, and infrastructure). This requires specific skill and experience from the manufacturers.

H 1. Traditional Water Mills, yielding mechan. energy
H 2. Small Water Turbines: Electricity Generation
H 3. Low Water Head Turbines (Kaplan Type, vertical or horiz. types)
H 4. Medium Water Head Turbines (Francis Type or mixed flow)
H 5. High Water Head Turbines (Pelton Type), mainly for peak power
H 6. Pump-Turbines (load levelling and/or grid stabilising)

Wind Energy Conversion (WEC) devices are depicted in "Group W", comprising the numbers 1 to 5. The techniques are reliable and mature (with some R&D still done, mainly to achieve cost reduction); some systems are under test as prototypes with promising results (e.g. V.A. WEC). Different operational characteristics have to be taken into account, when WEC-systems are installed, and also different cost figures apply, depending on complexity and size of the units, development status and type of the machinery.

W 1. Traditional Wind Mill (mechanical energy; various types avail.)
W 2. Small Wind Turbine (designed to yield electricity, low voltage DC)
W 3. Vertical axis Wind Energy Converter (H-Type Rotor, Darrieus)
W 4. Horiz. axis Wind Energy Converter, stall control (fixed blades)
W 5. Horiz. axis Wind Energy Converter; pitch control (var. bl. angle)

Most WEC units installed belong to the horizontal axis, stall controlled type, mainly equipped with asynchronous alternators - operating preferably in a grid connected mode. Sizes between 7 kW and >750 kW are available.

Photovoltaic (PV) modules directly convert solar radiation into (DC-) electricity. Various concepts are compiled in the "Group V". Many appliances are feasible, the numbers V 1 to V 6 represent just some examples. Even if the market is dominated by silicon cells (mono- or polycrystalline), many other cell types are available.

Methods to increase pv efficiency and to cut costs are investigated in a world-wide effort; "stacked" cells present an interesting research issue (V7) with potential to higher outputs.

The PV module types using concentrated sunlight ("Group Vc", numbers Vc1 and Vc2) are presented separately. With this kind of energy converters it is expected to profit by some cost saving potential due to a better utilisation of the expensive cell area and by better gathering incident light (the device is tracking the sun).

V 1. PV in consumer appliances
V 2. Small PV systems (e.g. Solar Home Systems), Telecomm.Tr. etc.
V 3. PV in remote applications, e.g. for water pumping
V 4. PV in Uninterruptible Power Supplies (PV battery recharging)
V 5. PV (grid connected) - with battery: grid stabilising operation
V 6. PV (grid connected) - direct electricity generation
V 7. PV (prototypes): stacked cells

Vc1. PV (concentr.) in stand alone applications
Vc2. PV (concentr.) for bulk electr. generation (grid connected)

Especially for very small consumption or for use in remote areas cost/revenue studies reveal that PV conversion can already be viable in terms of economic competitiveness. But for bulk electricity generation PV is still far more expensive as conventional sources. And this will be true as long as there is no break-through in cell technology, which would allow to catch up with relatively cheap fossil energy.

Bulk electricity generation is the aim of Solar Power Plants (SPP, "Group P") utilising the Solar-Thermal principle. Different types have been tested, which can be differentiated by the way the light concentration is performed. The examples corresponding to the numbers P 1 to P 3 represent techniques, which are - or have the potential - of technical importance:

P 1. Parabolic Trough Collectors - Solar Farm Concept
(Plants using Thermo-Oil are commercial, others in test)
P 2. Solar Tower Power Plants, Heliostat-Receiver-Systems
(Differentiated concepts with steam / air / salt in test)
P 3. Parabolic Dish - electricity generators (Stirling)
(Different types and various motor concepts are in test)

As indicated, of any of the three power plant concepts different versions have been built. Many modifications are viable: e.g. heat transfer media being used (air, steam, fluids - like thermal oil, liquefied metals or molten salts); the type of the primary mover can be a distinctive element (Stirling engine, gas turbine, steam motor or -turbine). And many design parameters also influence the characteristics of the plants.

Farm type Solar Power Plants are available from the shelf. In California about 350 MW electricity generation capacity was installed according to this principle. These plants use thermal oil as a heat transfer medium (limiting the upper temperature level to about 400 °C). The systems operate in a hybrid mode (i.e.: having an additional gas boiler). A technical alternative to the oil cooled collectors is under test, intended to achieve better efficiencies and cost reduction by directly evaporating water to steam. All other techniques in this group are in a laboratory scale or prototype testing status. So far the proof of the competitiveness of the Solar Tower Plant concept is still open, it's disadvantage being the fact that large units (definitely >100 MW) had to be built to be manufactured at reasonable costs. So far all efforts to find the funds for a demonstration project of such size were not successful.

Parabolic Dishes were tested in various configurations. Due to a very limited number of motors (be it Stirling type or other converters from heat into mechanical or electrical energy) large scale application could still not be reached. The experience with the cost reduction potential as derived from the WEC-technology could lead to the conclusion that the rather small units "on the marketplace" will possibly not have the chance to overcome the cost barrier.

The "Group T", characterised in part by similar thermal energy conversion techniques as applied at the solar power plants mentioned before (but directly yielding heat instead of transforming it into electricity), is represented by various types, which also stand for different qualities of thermal energy. High temperature systems (Th1 to Th2) are in test for process heat applications; high concentration principles correspond to the elevated temperature levels. Systems yielding heat at moderate temperatures (numbers Tm1 to Tm3) already found some practical applications, based on some variety of types.

Tm1. Solar Air Heaters (applied e.g. in solar dryers)
Tm2. Solar Water Heaters (in domestic use and for small appliances)
Tm3. Low Temp. Collectors (Vacuum-tube or high effic. flat plate coll.)
Th1. Low or moderate Concentration Ratio Collectors (Troughs)
Th2. High Concentr. Collectors (Parabolic Dishes or Heliostat/Receiver Systems)

Solar dryers and solar water heaters could be shown to work properly under Mediterranean climates. This should also apply for their utilisation in Iran. Some new designs have been presented (using novel materials, in some cases incorporating also storage capabilities), which offer some additional advantages. In this field numerous examples demonstrate that economic solutions are within reach, especially in the low temperature range.

The direct use of solar radiation "Group D" (by means of indirect lighting, heat gain by means of dedicated techniques like translucent insulation etc.) could be differentiated in various techniques. Even if of potentially large importance, direct solar input is summarised here in one number only, since it is so far not correlated to "industrial technologies", more depending on planning and engineering concepts in the realisation of buildings than in commercially available hardware.

Another direct application is by means of solar cookers. Such units have been introduced in arid areas successfully, where people lack of firewood or other organic matter to prepare their meals. Then solar cookers, frequently home-made and cheap, can provide a favourable solution.

D 1. Direct Solar Radiation Utilisation

The "Group B" with the numbers B 1 to B 3 indicates the - in many versions well established - utilisation of biomass for energy conversion. The traditional techniques of combusting fossil fuels need only be slightly modified to incinerate biomass in any of its common forms (urban waste, wood chips, biofuels, biogas). Thus, electricity generation and the utilisation of thermal energy (eg. drying of timber in the wood industry) are well established. Also the use of firewood or other types of biomass for domestic needs is common.

B 1. Direct Biomass Firing for domestic and cooking purposes
B 2. Biomass Boilers to produce process heat
B 3. Biomass Conversion to generate electricity

The "Group G" summarises the exploitation of geothermal energy, which is one of the types of energy, which is not a solar one. The numbers G 1 to G 3 specify methods in use. Any of the topics presents established practice at places, where geothermal occurrences can be used favourably.

G 1. Geothermal Energy for District Heating (low temp.)
G 2. Process Heat from geothermal sources (med. to high temp.)
G 3. Geothermal Electricity Generation Plants

The principles in the "Group O", indicate the utilisation of ocean, tidal and wave energy, correlated in part to solar (ocean temp. gradients), in part to global (tidal) sources, or may represent a mix (wave energy).

The methods are characterised by the fact that they are limited to very specific places. With some exceptions they are so far not of technical importance. Test plants also reveal that commercial viability is not easily reached.

O 1. Ocean Thermal Energy Conversion (low temp. ORC process)
O 2. Conversion of tidal / wave energies into electricity

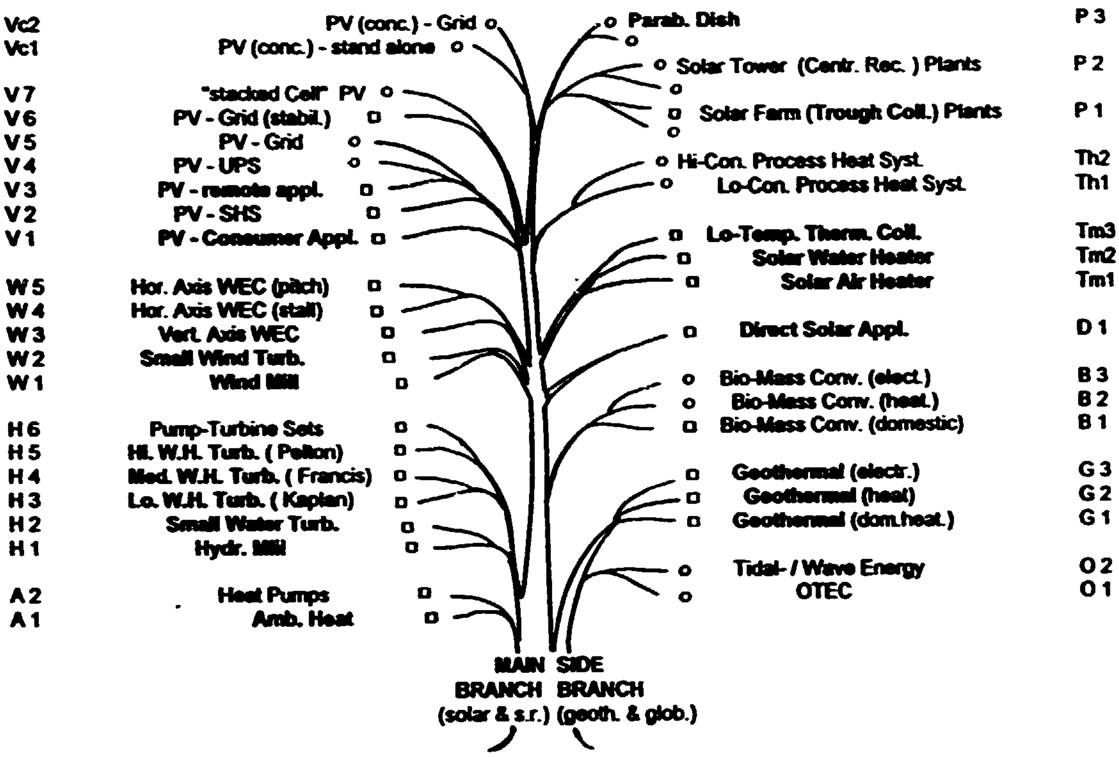
Renewable Energy Conversion Technology in Iran

The situation of R.E. research in Iran can be summarised by means of a slightly modified figure: The activities observed at the Iranian research centres (respectively the technologies used routinely) are highlighted by bold characters in the denomination of the technology. And an assessment, whether any technique had some potential or seems likely to a more widespread utilisation is indicated by symbols.

Assessing the situation it can be stated that for many of the disciplines seemingly important activities in research institutes exist. But there are also some "blanks", which possibly can be explained by shortcomings of a limited mission, but which - if definitely missing - should be dealt with in a proper way.

This is e.g. true for hydraulic engineering (which is certainly a very important technology, since not only the issues of energetics but also the ones of water management and multiple use of the water resources are entangled), but it also applies for the methods to cope with the energy demand in remote regions. In this field the aspects are promising.

ANNEX A



Renewable Energies in IRAN

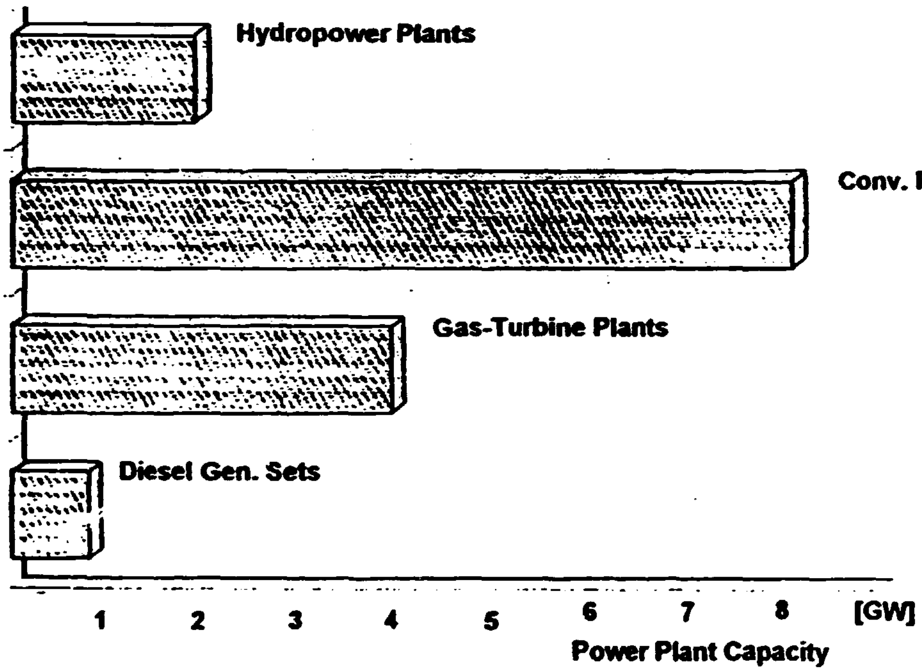
LEGEND: o Circles: Technologies in Test
□ Squares: Techniques of possible importance for Iran
Bold Characters: Research Activities in Iran

RENEWABLE ENERGY RESOURCES IN IRAN

In Iran nearly any kind of Renewable Energy could be found. Important contributions can be expected from the exploitation of

Hydro-Energy
Solar Radiation (by many methods)
Wind Energy
Geothermal Energy

Electricity generation from hydraulic resources is already well established. A significant portion of the installed capacity for electric energy production (14.8 GW in 1990) is from this source (see the figure below). Still more potential exists, planning and exploration is under way.

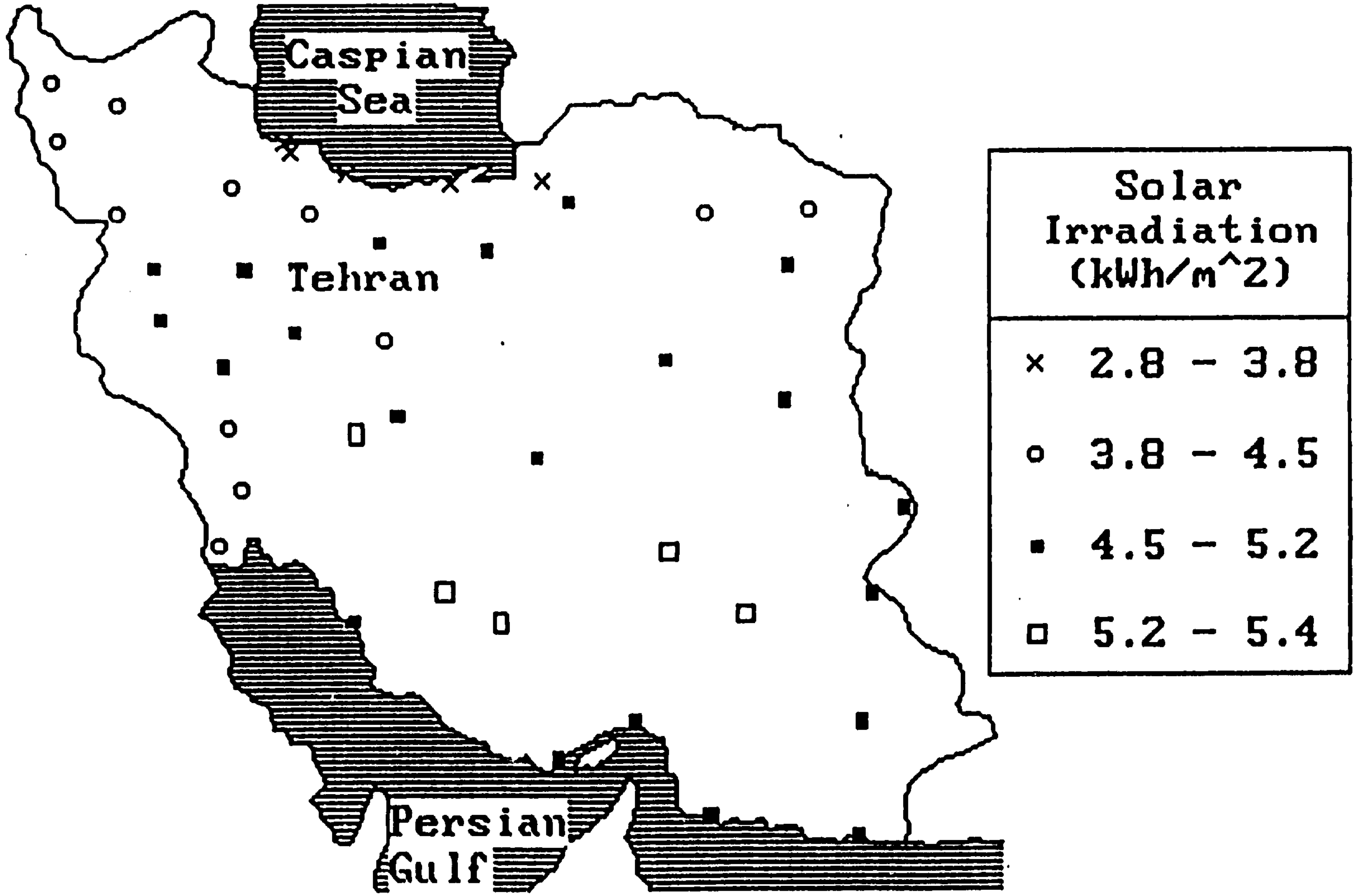


Electricity Generation Capacity in Iran (1990)

Also for the solar and wind resources a reliable database was established by the national institutions. The second figure illustrates the solar potential, and in the table the wind velocities for some exemplary locations in Iran were compiled.

An assessment using international experiences shows that in large parts of the country solar conditions are excellent (a yearly average of >4.5 kWh/m² is excellent for utilisation in nearly any application of solar energy). And this is also true for many places as far as wind energy is concerned. Average wind speeds exceeding 5.8 m/s can be considered as "good", more than 6.8 m/s as "excellent".

Whether seasonal variation could influence this assessment need be clarified by detailed measurements.



Annual-mean daily global solar irradiation map
of Iran with cloudiness.

NO	City	Mean average wind speed m/s	Mean Power density w/m^2
1	KENARAK CHAHBAHAR	4.42	52
2	ARAK	5.39	106
3	BIRJAND	5.91	126
4	YEZD	5.43	98
5	ZABOL	10.5	745
6	ABADAN	5.94	127
7	KERMAN	7.1	220
8	ZAHEDAN	6.6	177
9	KISHISLAND	6.1	138
10	BANDARLENGEH	6.95	205
11	SIRI ISLAND	6.07	136
12	ABOMOOS AISLAND	5.6	107
13	JASK	6.8	194
14	MAKOO	8	312
15	ARDEBIL	7.3	237
16	MAHABAD	5.6	107
17	GORGAAN	5.9	125
18	SANANDAG	6.3	148
20	Tehran	5.5	110

Chart.1. Mean Annual Wind Spead and related Mean Power Density in some cities of Iran.

MARKET ENFORCEMENT STRATEGIES FOR RENEWABLE ENERGY EQUIPMENT

In many countries public funds were allocated to promote the utilisation of renewable energies or to facilitate the purchasing or installation of dedicated equipment for such purposes.

Initially the main idea was, to encourage citizens and the industry to invest into R.E. systems as a means to make "national" resources more popular and to increase their contribution to the energy produced. Anyway, an economic break-even for the non-fossil energy conversion techniques was by far not reached. Thus, despite of various attempts R.E. does not play a significant role. But the public interest in that field triggered a lot of scientific and engineering activities. This consequently led to some technical advancement, which - together with rising fossil energy prices - now makes the introduction of R.E. also economically viable - at least for certain applications.

Meanwhile also the motives for R.E. utilisation have changed. The primary arguments now are the circumvention of global consequences of a too high energy consumption and the need for pollution control. The cost issue became less important, as scientists tried to estimate the "non-pecuniary" costs of traditional energy conversion utilising fossil fuels (i.e.: the influence of emissions on the environment, health and risk aspects, etc.).

The following examples are certainly not consummate, but they illustrate the endeavour undertaken by many governments to facilitate the exploitation of R.E. resources.

<u>USA:</u> The first decisive promotion of R.E. was done by federal and local governments during the Carter-administration, when tax exemptions were granted. Moreover, in some areas the erection of new fossil power plants was prohibited. The main paragraphs of the "PURPA" law (Public Utility Regulatory Policy Act) stated that

- investments into R.E. systems (solar, wind, geothermal, but also co-generation) could warrant a tax exemption (up to nearly 30% were allowed in California);
- utilities had to buy any electricity generated from those plants at their "highest avoided costs" - i.e. the electricity generation costs allowed for the least economic (peak power) plant the utilities operated (at that time about 0,16 to 0,18 $/kWh);
- hybrid operation was accepted (i.e. a mix of fossil and R.E. conversion) up to a maximum ratio of 25% fossil and 75% R.E. contribution.

As a consequence solar power plants (mainly of the "Solar Farm" type), wind parks, and some cogeneration plants were installed.

In the following years some of the paragraphs of the PURPA-act were amended and tax exemptions reduced. Also the utilities reduced their "avoided costs". Thus, financing R.E. systems became more difficult, and the trend changed.

Actually, the utilities are reshaping their policy: Instead of increasing the plant capacity measures to save energy are encouraged. Customers can get a bonus, if they replace old equipment by new, more economic types. This strategy seems to work.

Besides the tasks to enforce the introduction of R.E. systems various R&D activities were financed or subsidised. This applies not only for research institutes but also for industrial endeavours. Initially the policy aimed at the advancement of the technology (PV-cell development, solar power plant engineering), now a more practical approach can be observed. Programs to demonstrate the feasibility and large scale field tests are conducted.

Japan: In Japan essentially the Ministry of International Trade and Industry (MITI) is responsible for technological progress. The structures of financial aid are quite different from those in USA or Europe, but - in effect - in Japan nearly any R.E. technology was investigated. Solar power plants (from the "Tower" and the "Farm" type) were tested, pv plants installed, and the industry encouraged to compete on the international marketplace also in wind energy converter technology. Latest news tell that Japan also announced a large program of pv on rooftops of private homes and small enterprises. 700 systems will be installed in 1994, the total number of units planned amounts to 70000.

Israel: Solar energy utilisation methods are of particular interest for Israel. Nearly any fossil fuels have to be imported, therefore the exploitation of available resource is of great concern. Solar engineering has high priority; the government issued a rule, that any new building has to be equipped with solar water heaters. This technique now is fully established. Furthermore, the government subsidises solar research in various respects. Private companies (LUZ-Internat'l) and scientific institutes (Weitzmann-Stiftung) made remarkable contributions to the progress of solar techniques. With financial and political backing institutions from Israel are also very active in bi- and multinational endeavours, aiming at the advancement of solar power plant tests, technical progress in the farm (trough) technology and in many small appliances.

Jordan: Similarly lacking natural resources also in Jordan the installation of solar water heaters is propagated. Communal information centres have been inaugurated, where illustrative installations and equipment are exhibited. Technical advise and financial consultations can be obtained.

Moreover, the Royal Scientific Society keeps close relationship to European scientific and development supporting entities, which is of some advantage, since in Jordan a large number of pilot projects and trials with solar and wind energy conversion equipment were performed.

Germany: The German Ministry of Research and Technology funds many activities related to R.E. For years the public research entities got substantial subsidies for their work, which was a decisive factor for development. The funds were partially also allocated to bi- or multi-national tasks, intended to spread the technology.

For years substantial funds were spent for basic research and even the development of manufacturing procedures (pv production plant costs were in part subsidised at AEG, also investigations into new processes at NUKEM). Now decisive impulses are given to the market by a supporting strategy for "establishment of the technology". Inter alia dedicated funds were allocated to wind energy utilisation (250 MW program) and to the introduction of pv systems into the private home sector (1000 roofs program). These activities aim at an enforcement of the market until it reaches self-sufficiency. For the wind energy conversion equipment this has been derived, the option, whether also solar energy techniques will be successful in bulk electricity generation is still open.

It has to be mentioned that also utilities spend some money to install and operate wind and pv demonstration plants. Inter alia two pv plants of >300 kW have been erected by RWE, another utility is involved in a Solar Hydrogen project. In co-operation with another utility in Spain a 1 MW pv-plant in Spain is built, operating in a hybrid mode together with a hydro-powerplant.

INTERNATIONAL ACTIVITIES:
Besides their national research tasks many countries are engaged in bi- and multilateral projects. Many of the partnerships in this context belong to "North-South" relationships. In part these activities are augmented by governmental programmes. Sponsors in Europe are inter alia the European Community, Germany (ELDORADO-Program), Italy, Denmark, France, Spain. A short review of some of such supra-national tasks are cited in the following (just as examples, much more projects, partly of limited duration or scope have been conducted):

PSA (Plataforma Solar de Almeria): Installed 1979 - 1981, joint activity under the umbrella of IEA (Internt'l Energy Agency); participating: Austria, Belgium, Germany, Italy, Spain, Sweden, Switzerland, USA. Since 1986 it was modified into a bilateral task (Germany, Spain).

Denmark-Egypt: Joint venture to transfer the know-how (licence) to produce Danish Wind Energy Converters (100 kW class) in Egypt. Intended fabrication number: 100.

Italy-Egypt: Co-operation in the field of "rural energy concepts" (using a combination of wind, pv, biomass, rated power >400 kW) and in solar heat collectors (building a test facility for "Solar Process Heat").

Spain-Germany-Maroc: Conceptual studies (involving also commercial enterprises) for a solar power plant (Farm type) in Maroc.

Germany-China: Technical assistance by German experts and institutes to manufacture and test R.E. equipment in the Northern Autonomous Provinces, centering in wind power and pv for small remote settlements.

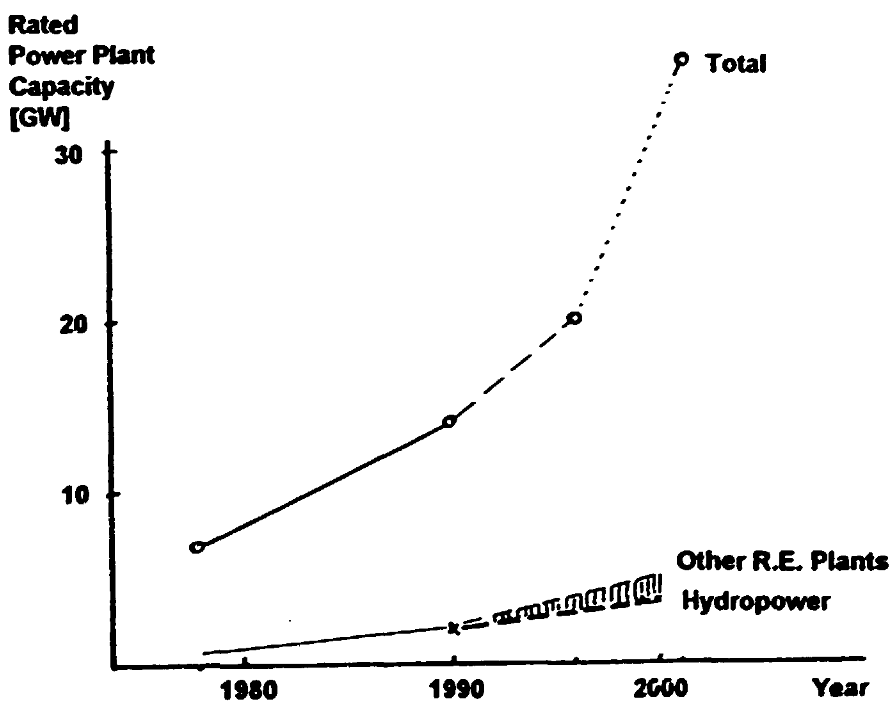
Germany-N.N.: ELDORADO-Program: Subsidies for German contractors (up to 70% of the equipment costs "ex works" can be refunded), if R.E. equipment be exported to some selected countries (Argentina, Brazil, Tunisia, Egypt, Jordan, Indonesia, China, some republics of the former Sowjet Union).

DEMAND PREDICTION AND COSTS OF POWER GENERATION

The electricity demand in Iran shows a steady increase in the past. And it is easy to forecast that this trend will go on, even if there might be some tolerances due to various demoscopic and economic parameters (see the following figure). Taking the planned power generation capacities as a basis, an assessment, how much plant rating would be needed, if R.E. were to play a not negligeable part, leads to estimated figures between 1 and 2 GW of electricity generation capacity for the renewable sources (Hydro-power not counted for in this estimate).

The necessary investment funds required to install such a capacity were discussed in Chapter 2.5. The specific values used for the calculations and the other significant data for the economy of R.E. power systems were compiled in the following table. The data represent average values for contemporary techniques and prices, the yield was assessed assuming favourable weather conditions. The table contains only data of mature techniques. Those ones which are in development status, were not considered. Nevertheless, examples of such systems will be discussed later.

Some cost parameters cannot be estimated exactly in a generalised review; maintenance costs depend on the plant size, the yearly operation hours, the design of the components, and - in part - even on the characteristics of the demand side. Certainly for all of the plant types some potential of cost reduction exists, but only for WEC a significant price decrease was observed. Equipment costs in wind converter techniques were cut to half in about 10 years.



Power Plant Capacity (Iran)
Trend Extrapolation and Ren. Energy Contributions

Source	Technology	LifeTime years	Investm. Costs	Annual Op.Hours	Electr. Gen. Costs
Solar	Photovoltaic	>25	12000 $/kW	>1050	0,9 .. 1,3 $/kWh
Solar	Thermal P.Pl.	>15	>3000 $/kW	>1600	0,2 .. 0,3 $/kWh
Wind	WEC	>15	<1500 $/kW	>2500	0,07.. 0,1 $/kWh
Hydro	Hy-Power-St.	>40	>6000 $/kW	>6000	0,06.. 0,12$/kWh
fossil	Diesel P.St.	<15	800 $/kW	<3500	0,04* $/kWh
fossil	Power Stat.	>20	>1000 $/kW	>4500	<0,03* $/kWh

Cost Figures of different Technologies

Values used in the table: *Linear devaluation (life time)*
6% annuity
Maintenance costs not included, also not the costs for the fossil fuels (*)

For the Solar Thermal Power Plants cost reduction can be achieved by hybrid operation modes. This was demonstrated at the plants from the Parabolic Trough type installed in California, using fossil fired boilers in times of weak insolation. This mainly influences the operation hours per year, and allows a more flexible plant control.

Solar Thermal Tower Plants did not come near to commercialisation. Thus, also no plant costs on a confirmed basis are documented. First proposals state similar costs as mentioned for the Farm type plants.

Recent publications indicate that for Geothermal Power Plants specific investment costs of <2500 $/kW were adequate. Taking into account the fact that such plants could operate nearly continuously, power generation costs of less than 0,12 $/kW seem feasible, slightly cheaper than the values derived for wind energy conversion. In any case, the costs for exploration and drilling present an uncertainty factor.

Still more expensive in terms of original investment is an exploitation of the Ocean Thermal Energy. Pilot plant costs for a plant in the Indian ocean were proposed to be >5000 $/kW. This could be economically viable, if the life time is sufficiently long, since nearly no "secundary" costs are expected (the sea surface is free, also no drilling or site preparation is necessary). But the experience with such types of plants is not sufficient to predict the costs with acceptable accuracy.

Organisational Structures for Research Institutions

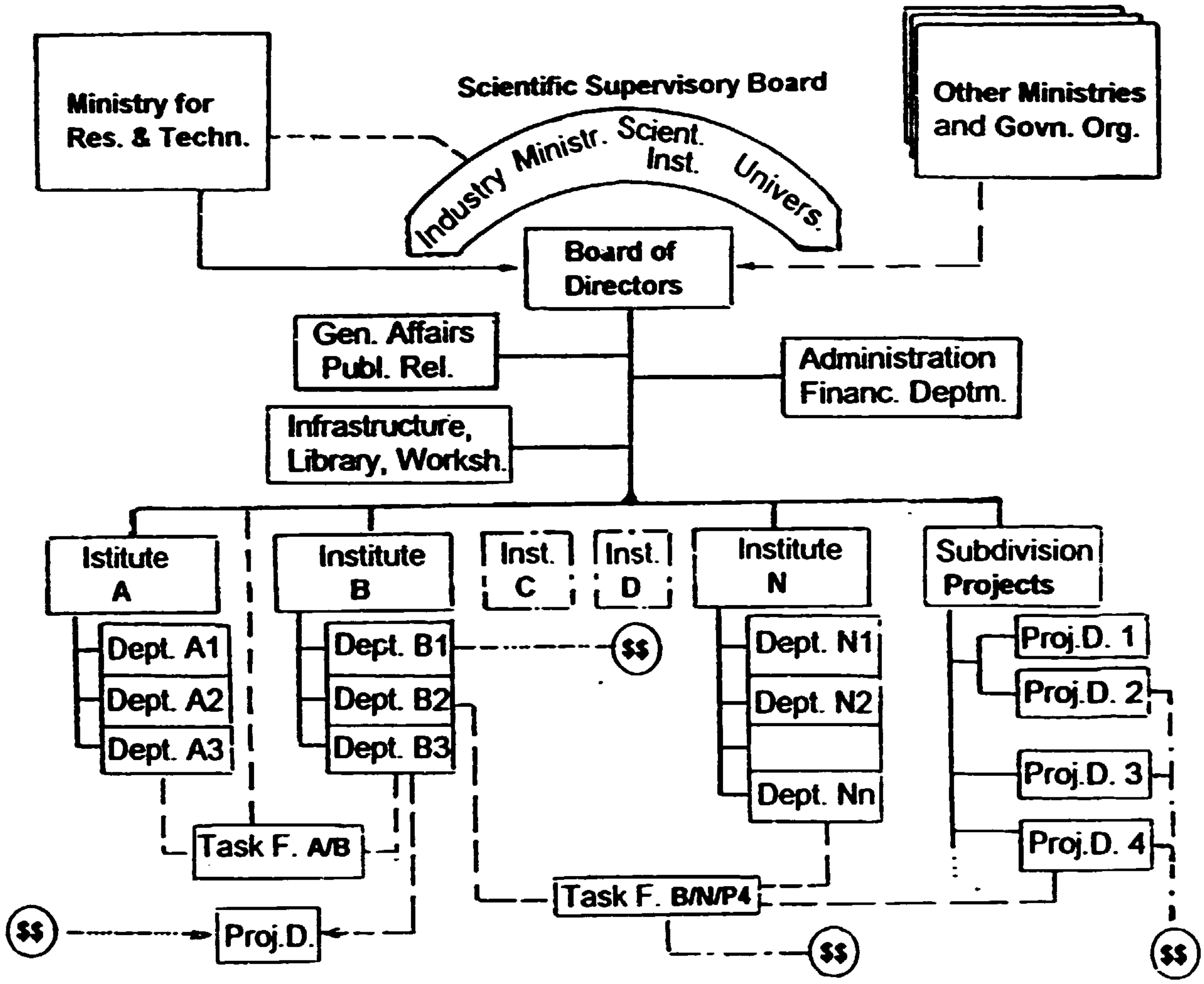
In nearly any of the industrialised countries research institutes exist. financed by public funds. and with close links to governmental institutions. The motivations for the inauguration of such research facilities were manifold. Even if the intentions may have changed in part with the technical and scientific progress and with the political situation. the reasons to spend public budgets in research and development related areas are still essentially valid:

- Long lasting research in fields of common interest.
  This applies e.g. for health problems (Cancer institutes. bio- and gen-technology). for environmental investigations. and for fundamental questions of life sciences.
- Investigations. which need extremly expensive infrastructure.
  Here the historical examples are the nuclear research centres and facilities to investigate particle physics (e.g. by means of large Accelerators. Synchrotrons) and material properties.
- Large-scale projects and (or) supra-national tasks.
  Space exploration. marine research (including the polar regions). and some international activities in environmental control belong to this group.
- Strategic and military research.

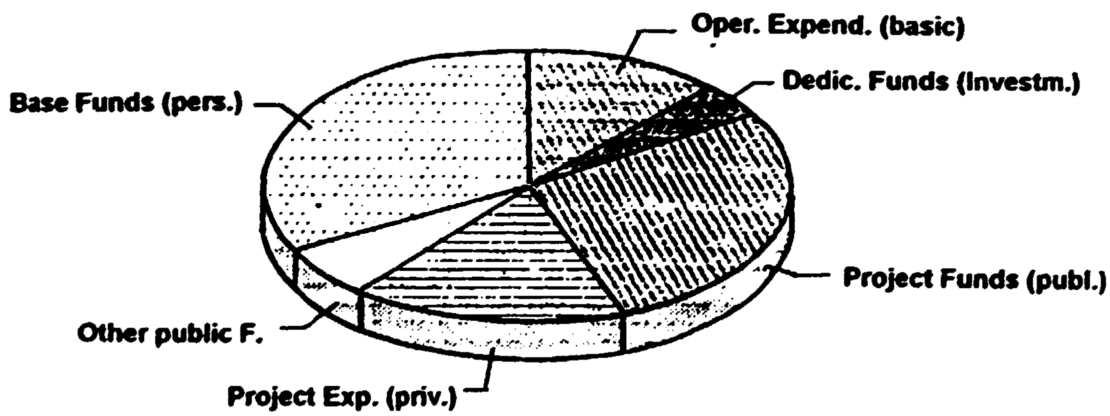
In times of economic growth the role of these institutions is accepted widely. But during recessive periods questions arise. whether the funds allocated to keep such organisations afloat. are used wisely. To cope with this dispute and to gain public acceptance many of the research institutes in the Western countries were restructured trying to re-orient their scope of work. offering engineering assistance and know-how to commercial enterprises. and - last but not least - increasing their efforts in public relations.

The first figure presents a simplified example of the organigramm of a German research entity. which already followed such strategies. The figure makes clear. that - and how - tendencies from outside can influence the scientific approach. Significant changes in the structures can be summarised to be based on:

- Less dependency from the Ministry:
  Other Ministries can (and do) participate in the capabilities and results of the research institutes. And they will also refund that part of the budget. which is directly correlated to the intensity of cooperation.
- Scientific orientation and results are supervised by other scientists:
  Regular discussions take place between the Board of Directors and a Scientific Advisory Board (being independant in it's findings).
  Comments were taken into consideration in the long term planning and priority setting. and also can influence decisions about the nomination of scientists. their promotion. etc.
- Change the "linear" structure of the traditional organisation:
  Task forces and project groups are allowed. which directly can acquire financial and personal resources also from private entities. These task groups also can arrange for access to different institutes to broaden their competence.
- Advantage from co-operation with external companies:
  Income derived from third parties is in part left to the institute and thus increases the cash flow. This gives the departments and working groups a certain autonomy. But it also requires some structural flexibility. since as a rule projects performed together with industrial partners have to present results in a required period of time.
- Better flow of information.



Organisation of a Research Entity with mixed (project related) Funding



Breakdown of Funding Structures

As a consequence of the intensified contacts with partners outside of the governmental sector, organisational structures were modified, opportunities created to react quickly to influences and trends on the market, and to link the institutes closer to industrial partners.

After some years of efforts towards a reshaping of the institution and of trials to find contemporary solutions, some firm status could be reached - at least in terms of a widely accepted standing of the research institutions in the public. And also the financial basis could be broadened. In the second figure the different financial contributions have been compiled in a qualitative way. The fractions allocated to different sources vary from year to year, but there are also differences, if personal costs only or global costs (comprising also investment, facility operation costs, etc.) are compared. Nevertheless, about 50% of "foreign" resources seem to be quite a large portion. And indicate that the orientation towards the market was performed effectively.

Comparing this organisational scheme with the structure of Iranian research institutes it can be concluded that as well as the influences of "third parties" are concerned (be it other Ministries or private enterprises), differences exist, as in view of the financial basis of the institutes. It is certainly no disadvantage, if research institutes can operate on a sound financial basis. But if a cost effective work and efficiency also in terms of the communal welfare is intended, means and ways should be looked for to institutionalise an exchange of ideas with people of other organisations. One suggestion could be to install a scientific advisory board, another one to link part of the financing to a procedure of evaluation of the success of their trials.

The Iranian scientist are mainly active in quite practical oriented fields. In Ren. Energy research they are far ahead of the state-of-the-art in the application of such resources. It should not be too difficult to establish a close relationship with the industry and commercial enterprises, to promote such techniques in a larger scale.

Technological Trends in Solar Equipment

In the international market some trends could be observed in the recent years: Main efforts were directed towards cost reduction of components and of whole systems. And since mass production is an option which is still not fully realised, the investigations centered on simpler manufacturing procedures and on cheap materials. Especially in the field of solar heat collectors this concept proved to be quite successful. In the following some examples of contemporary designs are presented. Nearly in any case the introduction of such equipment to the Iranian market seems feasible.

For electric equipment to be powered by renewable sources (in the small appliances pv conversion is the rule) the key to solve the economic problems lies in more energy efficient aggregates on the demand side (cost reduction potential in manufacturing pv modules is promising, but depends on still more technical progress). Ways to reach the intended goal were either an energetic optimisation of components (e.g. more efficient motors), or in smart control devices. A few examples of contemporary devices for pv powered aggregates for households or small enterprises are given in the second part.

PART I:
Solar Heat Collectors and Dryers

For low temperature heat (e.g. swimming pools) very elementary collectors were developed.

For the - at present -- cheapest systems tubes and body are mass produced as an endless tape, extruded from plastic material or rubber. On site the mats are adjusted to the proper size and finished by joining them to an upper and lower header.

The main advantage of this type of collector lies in the low price. And at low medium temperatures it works properly. But it is not suitable for hot water (>45°C), since then the performance is influenced by heat losses. Also is this specific type not adequate for highly pressurised water, which could deform the headers and causing leakages.

Simple and rather cheap collectors can also be made with an air cushion as insulating device at the front and foamed parts at back and sides. The material for this collector is mainly plastics and foil. Since years collectors in similar design have been tested, but acceptable performance could not be reached until recently, when plastics with high durability also under ultraviolet radiation were available. This now being the case, the technique can be introduced into large scale application.

As well water heaters as solar dryers according to this principle have been tested successfully. If the collector should be mounted on an inclined support, an additional frame will be necessary. In horizontal position no rigid structure is needed.

The figures show examples of collectors and dryers according to this concept, details are explained in the legend.

Since hot water is needed mainly in the evening hours, in nearly any case the water heated by solar irradiance has to be stores in a dedicated storage vessel. Since this influences the costs, many trials to store the hot water within the collector were undertaken.

The precondition to do this successfully is now fulfilled: Insulating materials with extremely low heat conductivity are available on the market. This so called "translucent insulating cover" consists of two plastic liners with a capillary structure in between. The lower part of this collector is shaped as a trough, forming a volume of some hundred liters. It consists of an inner liner made from sheet metal (galvanised or stainless steel) and a foamed body, which also warrants very low heat losses.

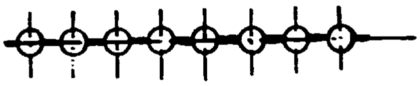
Furthermore, some examples of solar cookers and greenhouse designs were included in the illustration.

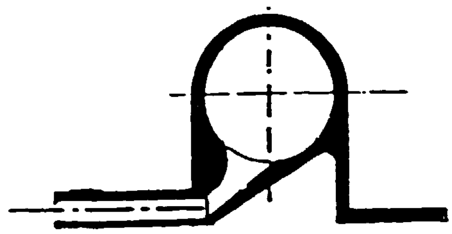
PART II:

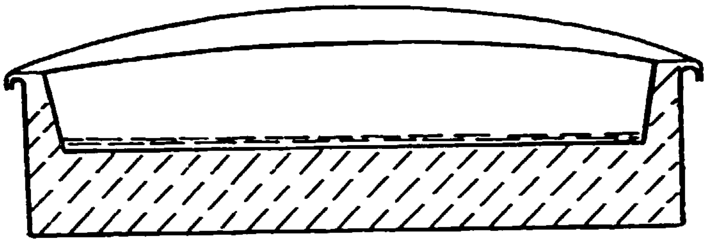
The issue of converting solar radiation into electricity was not handled in detail, since this principle is felt to be well understood.

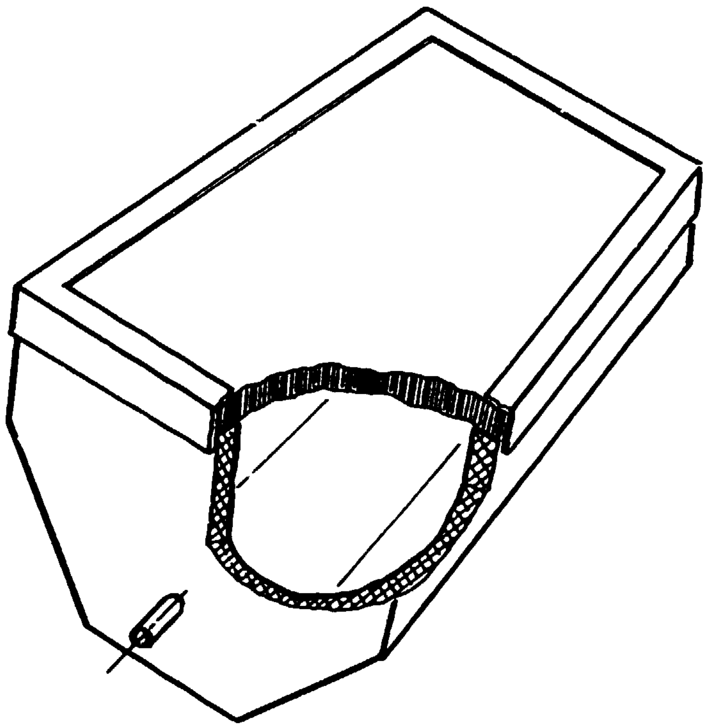
Some equipment, which was developed for pv powering, is presented also. The examples were taken from commercial advertisements, illustrating that such types in the meantime represent the state-of-the-art.

At least part of the equipment shown in the schematic overview could be envisaged to be produced locally in Iran.







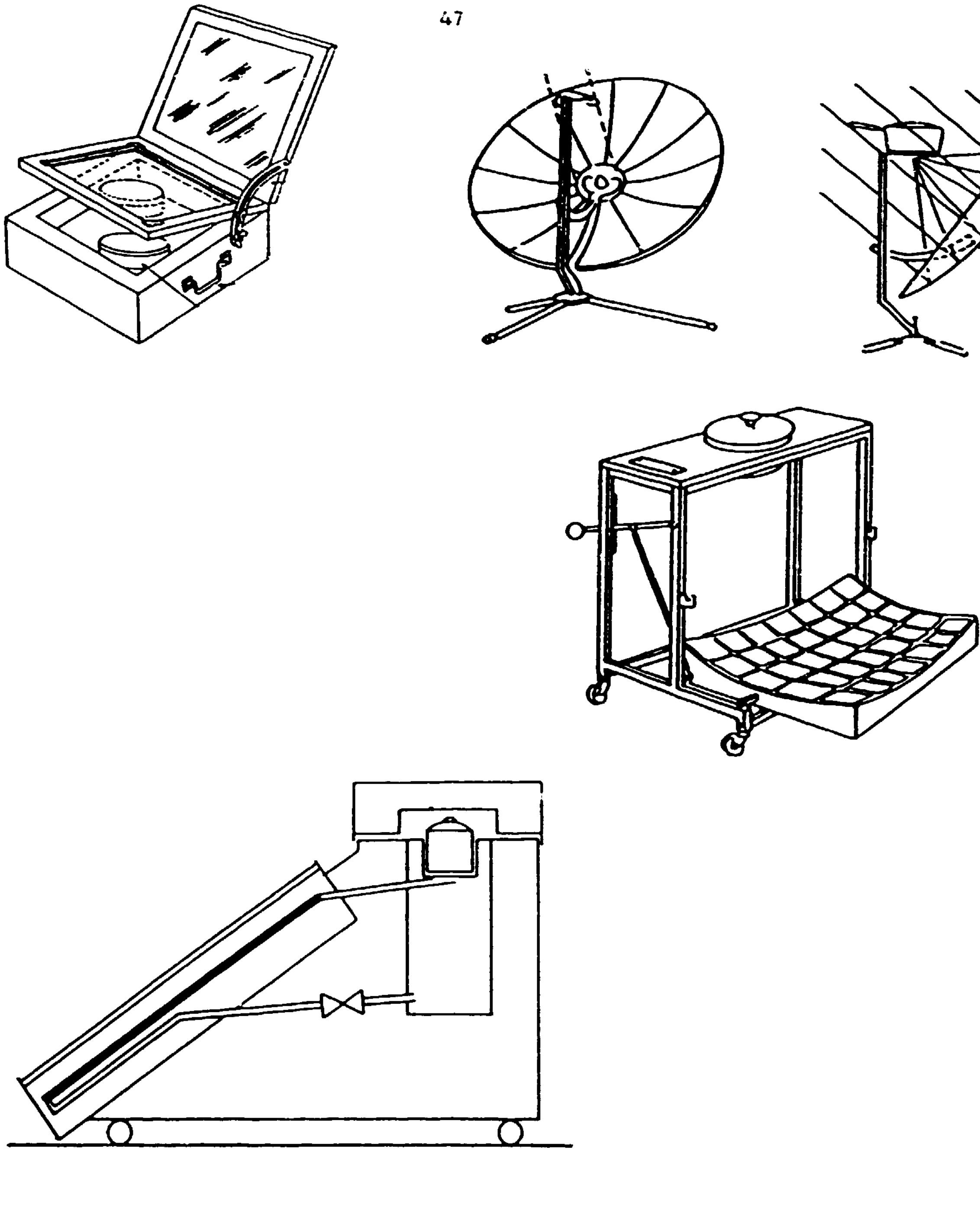


Solar Thermal Applications (1): Solar Water Heaters

Extruded Heater Rug (cross section and header)

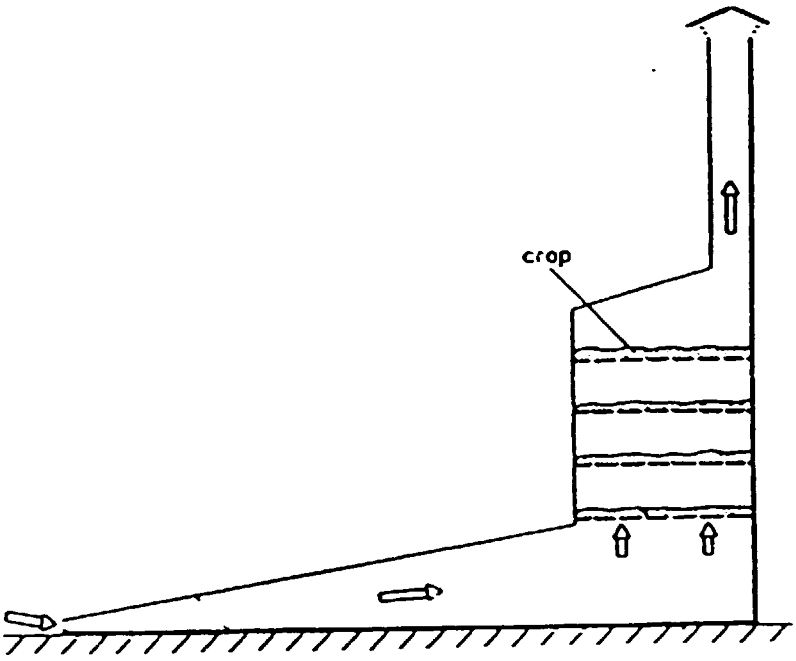
Air Cushion insulated Foil Collector (also for dryers applicable)

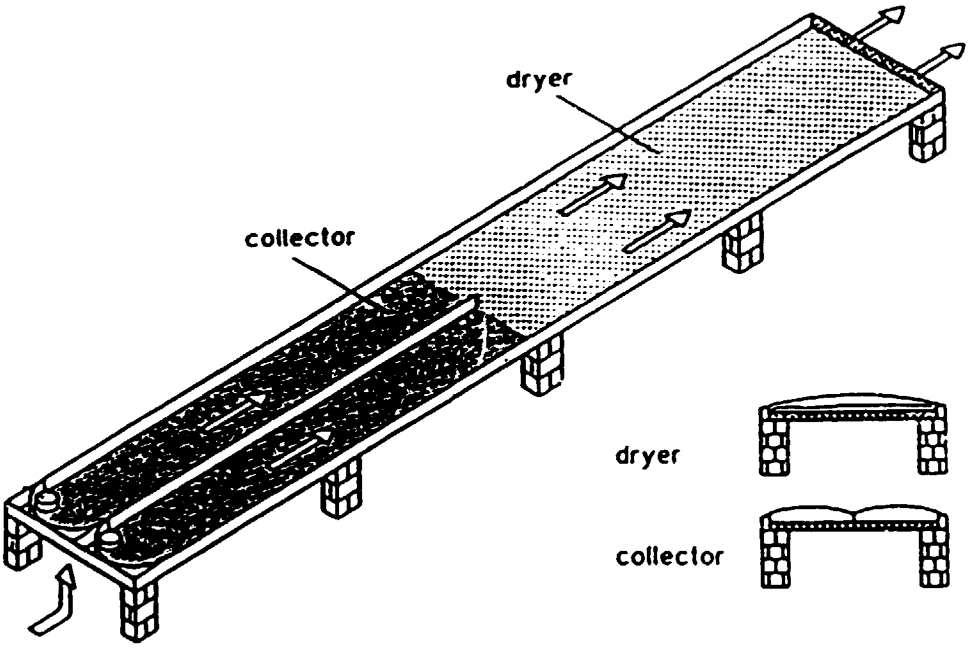
Storage Collector with Transparent Heat Insulating Surface



Solar Thermal Applications (2): Solar Cookers

Box Type / Concentrating Devices / Collector and Storage Types



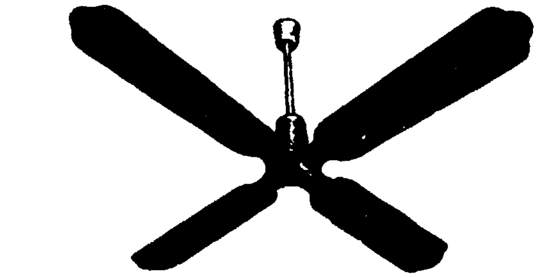


Solar Thermal Applications (3): Solar Dryers

with Natural Convection

and

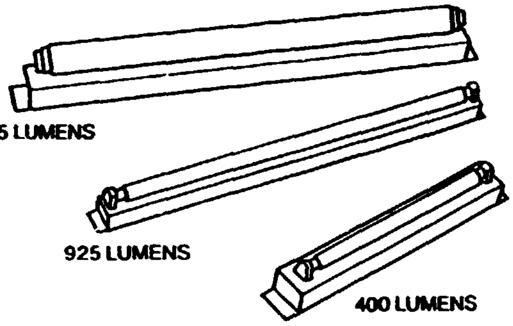
Forced Convection (by means of Fans)



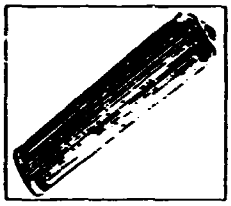
Technical data

Rated voltage	12 V
Amperage	1 A
Blade circle diameter	1222 mm Ø
Blade length	520 mm
Fan height	560 mm
Speed	280 rpm

24 V unit available on request

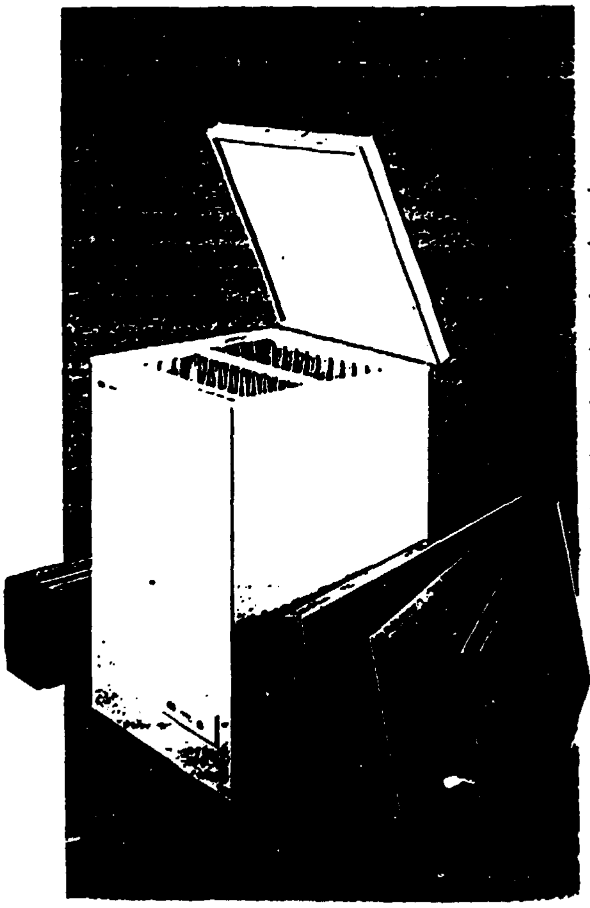


Dip-water-proof ceiling lamp



18 W
10.5 V - 14.5 V
21.0 V - 29.0 V
e.g. Phillips TL-D 18 W
- protected against reverse polarity-
open-circuit protected

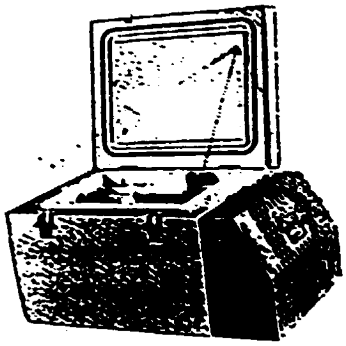
Catalogue Number	Watts	Length	Height	Width	Current Consumption (Amps)	Weight
BL8	8W	364mm	60mm	45mm	0.8A (12V), 0.5A (24V)	0.3kg
BL13	13W	570mm	50mm	32mm	1.1A (12V), 0.75A (24V)	0.35kg
BL20	20W	660mm	77mm	45mm	2.2A (12V), 1.1A (24V)	0.65kg



Description	Capacity	Array	Battery	Dims (cms)
DR100 Refrigerator	105L	150Wp	360Ah	55×55×85
DDF100 Freezer	105L	410Wp	641Ah	55×55×85
DR140 Refrigerator	140L	140Wp	360Ah	78×63×85
DDF140 Freezer	140L	410Wp	641Ah	78×63×85
DR200 Refrigerator	200L	210Wp	360Ah	93×63×85
DDF200 Freezer	200L	410Wp	641Ah	93×63×85
DR300 Refrigerator	300L	280Wp	480Ah	125×63×85
DRF200 Refrigerator/freezer	184L Refr. 16L Freez.	210Wp	360Ah	93×63×85

Fan, Lamps, Cooling Devices

Electric Devices (Photovoltaic Applications - 1)



Type	RCW 32
Rated voltage	12 (24) V
Volume	36 l, thereof 2.4 l icecomp.
Outer dimensions	97 x 56 x 50 cm
Weight	40 kg
Material of housing	PE Polyethylene
Vaporizor	Aluminum
Mounting	Steel, galvanized
Max. power consumption	60 W
Temperature regulation	Thermostat, automatic

Vaccine Refrigerator

Type	LR 107	LR 114	LR 30	LR 45
Nominal Voltage	12/24 V	12/24 V	12/24 V	12/24 V
Max. carge current	8 A	16 A	30 A	45 A
Max. solar power	130/260 Wp	260/520 Wp	475/960 Wp	700/1400 Wp
Max. discharge current	16 A	16 A	20 A	20 A
Connection clamps	4 mm²	4 mm²	10 mm²	10 mm²
Battery securing	external	external	internal	internal
Housing	Plastics	Al-cast	Al-cast	Al-cast
Protection class	IP 65	IP 65	IP 65	IP 65
Dimensions (mm)	160x110x60	175x110x60	260x160x90	260x160x90

Battery Charge Controllers

DC-/AC-Converters

Input voltage	10-15 V DC / 20-30 V DC	10-15 V DC / 20-30 V DC
Output voltage	220 V ± 5 %	220 V ± 5 %
Output frequency	50 Hz ± 1 %	50 Hz ± 1 %
Power peak	200 W	400 W
Permanent power	100 W	200 W
Efficiency	90 %	90 %
Weight	appr.0.5 kg	1.1 kg
Dimensions (WxHxD)	125x35x96 mm	182x105x60 mm

Electric Devices (Photovoltaic Applications - 2):

Visisting List from Electric Power Industry and Renewable Energy Research Centers.

0) Saturday 7 May — Ministry of Energy, Dept. Ministry for Power

1) Sunday 8 May

Electric Power Research Center Introduction Meeting and Program Finalization of visit schedule.

2) Monday 9 May

Electric Power Research Center
morning: Technical committee with solar energy group.
afternoon: Technical committee with fuel cell energy group.

3) Thuseday 10 May

Electric power research center.
Technical committee wiht geothermal energy group.
To visit Geological Organization of Iran.

4) Wendesday 11 May

To visit Electric Power Research center (Main Campus).

5) Thurseday 12 May

Electric Power Research Center Technical Committee with wind Energy group.

6) Friday 13 May

Sightseeing tour of Tehran.

7) Saturday 14 May

To visit Materials and Energy Research Center - Affiliated to the Ministry of Culture and Higher Education and have a meeting with Center's Director (Dr.F.Moztarzadeh), his assistand and incharge of department.

8) Sunday 15 May

To visit scientific and Industrial Research Organization of Iran - Affiliated to the Ministry of Culture and Higher Education and have a meeting with Organization's director, assistant director in Research and Technology and incharge of energy group

9) Monday 16 May

Cancelled

To visit center for Research and Application of Research Energies - Affiliated to Atomic Energy Organization of Iran and have a meeting with Organization's head (Mr. Amrollahi) incharge of new energies branch and solar energy department superviser.

10) Tuseday 17 May

To visti Water & Energy Co.-Affiliated to Sharif University of Technology (Dr.M.Bahadornejad). To visit Electronics Research Center-Affiliated to Sharif University of Technology (Dr.F.Farzaneh).

11) Wednesday 18 May

To visit Fiber Optics & solar Energy Co.-Affiliated to Iran Telecommunication Company.

12) Wednesday 18 May

To visit Department of Power & Energy - Minstry of Construction Jahad.

13) Friday 20 May

Sightseeing tour of Tehran.

List of senior counterparts

name	title	affiliation	adress
Dr.Ali.A.Tofigh	Deputy minister	m.o. Industry	No,10,Kabkanian Lane, Keshavarz- Blvd valey- e- asre sq. TEHRAN- IRAN
Dr.Mohammad Ali Mirmohammadi	Head of the Department of Mining Eng.	M.o.Higher Education	TEHRAN University
Dr.Manoochehr Oliazadeh	Professor, of Mineral processing	M.o.H.Education	TEHRAN UniversitY
Nader . Niktabe	Organizing manager	M.O.I	R&D Department

LIST OF PERSONS AND INSTITUTIONS VISITED

Saturday, May 7, 1994 / Ministry of Energy
Tavanir Central Buiding, Vanak Sqr. Brezil Street,
TEHRAN, P.O.Box 19835-359

Mr. M. Hojjat, Acting Deputy Min. for Power, Min. for Energy,
Tel.: (021) 684086, Fax: 6419311

Sunday, May 8, 1994 / Electric Power Research Center (EPRC)
End of Pounake Bakhtari Shahrak Ghods,
TEHRAN, P.O.Box 15745/448
Tel.: (021) 8093950, 8093130 Fax: 8094774

Mr. Iraj Kaveh, Assist. Managing Director, EPRC

Mr. N. Aghajani, Deputy of Manag. Director - Technology, EPRC

Mr. Parviz Ghiasseddin, Deputy of Manag. Director for Planning, EPRC

Mr. Daryoosh Azarm (M.Sc.), EPRC, Mechan. Department

Mr. Ramin H. Khoshkhoo, EPRC, Mechan. Department

Monday, May 9, 1994 / EPRC / Solar Power Working Group

Dr. M. T. Mohammadi Tochaie, EPRC, Mechan. Department

Mr. Daryoosh Azarm (M.Sc.), EPRC, Mechan. Department

Mr. S. A. Ahmadi, EPRC, Chem. Eng. Department

EPRC / Fuel Cell Working Group

Mr. Hassan Pishbin, Ass. Prof., EPRC, Chemical Department
(Univ. of Tehran, Material Techn. Department)
Tel.: 8006076, 8020403

Mrs. Ezzat Seyyedi, EPRC, Chemical Department

Tuesday, May 10, 1994 / EPRC / Geothermal Energyy Working Group

Mr. Manuchehr Fotouhi, EPRC, Mechan. Department

Dr. Abbas Afshar Harb, EPRC, Mechan. Department

Wednesday, May 11, 1994 / EPRC - Campus

Mr. Mohammed Ali Kassai, Quality Control Manager, EPRC

Mr. Mohammed Tayefeh (M.Sc), Electron. Department Manager, EPRC

Dr. Soheil Ghorashi, Ass. Prof., EPRC
Univ. of Tehran, School of Management
Tel.: 8000245, 8003575 Fax: 8006477

Mr. A.K. Sedigh, EPRC, Electrical and Electron. Eng. Commun. Department

Thursday, May 12, 1994 / EPRC

Dr. Majid Jamil, MERC - Materials and Energy Research Center,
TEHRAN, P.O.Box: 14155 - 4777

Mr. Bahman Habibzadeh Sheikh (B.Sc.) EPRC, Mechan. Department

Saturday, May 14, 1994. Materials and Energy Research Center,
(Ministry of Culture and Higher Education)
KARAJ, Meshkin-Abad, Near Morgh-Ajdad
Tel.: 0261 - 664361

Dr. Rakhim Khasan Nani, Director

Sunday, May 15, 1994 / Iran Research Org. for Science and Technology
IROST, Old Karaj Road - Alishah-Avas Rd., TEHRAN-SHAHRIAR
Tel.: 021 - 8828051/8

Dr. Hossein Bolanadi, Vice-President - Research and Technology,

Dr. Mohammad Badr, Internat. Relations Manager

Dr. Samad Moemen B. Faro, Inst. of Electricity and Computing Engin.

Tuesday, May 17, 1994, Institute of Water and Energy,
Shari Univ. of Technology
TEHRAN, P.O.Box: 11365

Mr. S.J. Hashemian, Ass.Prof., Dir.
Tel.: 021 - 6005118 / 918406 Fax: 021 - 6012983

Wednesday, May 18, 1993 / Ministry of Jahad-e Sazandegi
TEHRAN, P.O.Box: 15875/1864

Mr. A. Saremi, B.S.A.E. Min. of Jahad-e Sazandegi
Tel.: 6136425 Fax: 6469614

Mr. M. Shiravandi, Min. of Jahad-e Sazandegi
Civil Engineer
Tel.: 654702 - 651668

Mr. H. Akramian, Min. of Jahad-e Sazandegi
El. Engineer
Tel.: 651681 - 651688

MINUTES OF MEETINGS

Ministry of Energy (Mr. M. Hojjat. Acting Deputy Min. for Power)
Tehran. Saturday. May 7. 1994.

After an introductory briefing about the aim of the UNIDO mission the global situation of power generation in Iran and the issue of Renewable Energy (R.E.) utilisation were discussed in detail:

Statistics in Iran show a rapid increase in demand. Therefore. the Ministry for Power is preparing for an extension of it's capacities. Hydro-energy will play an important role in the future energy concepts. not only for energetic reasons many dam and water management projects are studied. Also proposals for new fossii fired power stations are worked out. since until 2005 predictions estimate about twice the present power plant capacity to be needed. Besides such conventional planning a scheme for a solar power plant was submitted to the Iranian government. which is considering the issue (site exploration is under way. facts and data collected).

Financing concepts. questions of yield predictions for solar plants. environmentol benefits from an infrastructure oriented towards larger contributions from R.E. (hydro already established. solar in planning stage. wind energy conversion being studied. geothermal also in the phase of exploration) were other topics of the meeting. Especially for the urban areas in Iran measures devoted to alleviate the situation of pollutants
seem recommendable. Without going into details in this context also some experience with rational use of energy in other countries were mentioned. and the feasibility of R.E. systems for rural and remote areas.

Electric Power Research Center (EPRC) (Mr. J. Kaveh. Assist. Managing Director; Mr. N. Aghajani. Deputy of Manag. Director - Technology;Mr. Parviz Ghiasseddin. Deputy of Manag. Director for Planning)
Tehran. Sunday. May 8. 1994.

The EPRC. mainly involved in tasks in the field of power generation. high voltage grid distribution. control of plants. monitoring and operational strategies. is affiliated to the Ministry of Power. EPRC manages research activities not only towards bulk electricity generation. but also handles the engineering endavour related to R.E. utilization. So far the engagement in R.E. techniques was centering to the basic questions. A set of data was collected concerning the potential of wind and solar resources in Iran. Additional investigations are under way or in preparation.

Part of the meeting this day was used to plan and arrange other visits. and to discuss the activities of Iranian institutions in various fields of R.E. applications.

At the EPRC study groups or teams exist for the agenda of wind power. solar power plants. fuel cell technology. and geothermal resources. Detailed discussions about many of the topics were arranged for the following days.

Electric Power Research Center (EPRC); Solar Power Working Group: Dr. M. T. Mohammadi Tochaie and Mr. Daryoosh Azarm (M.Sc.). EPRC. Mechan. Department; Mr. S. A. Ahmadi. Chem. Eng. Department
Tehran. Monday. May 9. 1994.

The issue dominating the activities for the time being is the plan to install a 100 MW solar power plant according to the "Farm-Type" (using parabolic trough collectors).

Comparative studies (assessing the advantages of different design concepts) and investigations in the plant siting, lay-out, operational strategies, and yield predictions are undertaken. Great interest could be found as to the experiences gained abroad with such types of plants.

Not any of the questions could be answered in brief. E.g. there is not much ducumentation available about the maintenance requirements of solar plants. But a number of publications deals with comparisons of system concepts with thermal oil or direct water/steam loops, with alternative condenser concepts (heat rejection by means of dry cooling will have priority due to scarcity of water resources in the desert environment). Some advise was feasible from papers published. For a final evaluation the site-specific conditions have to be taken into account, anyway (e.g. on dust deposition and thus cleaning intervals). Also the issues of hazards, fossil back-up heating, storage concepts, possible advantages of solutions with or without storage and/or fossil heaters were considered thoroughly.

To gain hands-on experience with the technique in question, EPRC is planning to build a prototype of about 750 kW thermal energy input, yielding 220 kW electricity (rated data).

Certainly, whatever the decision regarding technical details may be, an important point will be the raising of funds. International organisations will be asked for assistance, since the financing of the solar plant solely from national resources seems not probable.

In a second meeting the activities of EPRC in the field of **Fuel Cell Technology** were presented and details and aspects of this approach for power generation purposes discussed (Prof. Hassan Pishbin, EPRC Chemical Department and Univ. of Tehran, Material Techn. Department; Mrs. Ezzat Seyyedi, EPRC, Chemical Department).

Main interest is the direct conversion of natural gas into electricity by means of Phosphoric Acid fuel cells, which is somewhat ahead of the state-of-the-art, where "pure" reactands are preferred. Accordingly, the scientific challenge lies in the problems of electrode stability and process parameter optimisation. Co-operation with other research institutes abroad were envisaged as an important approach to exchange ideas and to collect experience data. Grid stabilising aggregates could benefit from this work immediately, but also electric propulsion could be of significance in view of the large amount of atmospheric pollutants emitted from cars and buses powered by internal combustion engines.

EPRC / Geothermal Energy Working Group (Mr. M. Fotouhi, Dr. A. Harb), Tehran, Tuesday, May 10, 1994.

Due to it's geographic position and the geological structures (fracture zones are abundant in the country) the conditions for geothermal energy exploitation are very favourable. Accordingly, since more than 20 years explorations were undertaken to evaluate the potential and to localise areas of possible utilisation. From physical and geo-chemical tests the temperature range (240°C) and the temperature gradients (0.1°C/m) were known for sites in the Damawand area and in many other places.

The data and results of the studies were compiled at EPRC, which also keeps the documents of many joint projects with foreign scientists and institutions in this field, which were performed some years ago. From that time also estimates exist that in Iran more than 100 MW could be installed on already known sites, which gives - seen in an international comparison (USA: 3 GW; Iceland: 500 MW; New Sealand: 700 MW) the country quite good opportunities.

Some inadequacies were felt in terms of updated information about the development in terms of economic figures and technology. And, to make the estimates more accurate, field experiements (drilling of a test well) would be needed. This will be a matter of political decisions, which should be applied for.

Campus of EPRC, Research Laboratories and Civil Eng. Group (Mr. M. A. Kassai, Quality Control Manager; Mr. M. Tayefeh, Electron. Department Manager; Prof. Dr. S. Ghorashi, EPRC and Univ. of Tehran, School of Management, Mr. A.K. Sedigh, El. and Electron. Eng. Commun. Department),
Tehran, Wednesday, May 11, 1994.

For the various activities of the EPRC a dedicated campus is in construction. Some institutes are already working here. The visit and discussions were devoted to the areas of electric and electronic components of power electricity networks, measurement and monitoring equipment, data processing and operational surveillance, quality control, civil engineering and auxiliary equipment qualification (including standards), and educational and managerial duties.

It could be confirmed that the Iranian institutes are well equipped to cope with the problems the large distance electricity transport, but also the harsh environmental conditions pose to power grids.

One of the means investigated to reduce transfer losses over long distances is high voltage transmission. Remarkable work has been done. This principle is also of increasing importance in Europe, where the connections between grids of different states were in part realised by such concepts. Since the synthesis of the AC of the secundary side is done using semiconductors, the avoidance of harmonic distortions became a matter of interest. Also for this problem interesting solutions have been found.

Certainly, if investment were made in new equipment and in the re-conditioning of older plants, quality assurance becomes an issue of utmost importance. Therefore, EPRC also is active in this field. Par instance problems, which arise from the climatic conditions in the country (hot, humid climates in the gulf region with consequences on the durability of materials, conductivity of insulating parts, e.g. due to layers of moistage and salts) are handled properly, but also the high probability of earthquakes, necessitating specific care at the design of towers and foundations.

EPRC, Wind Energy Group (Dr. M. Jamil, ME-ARC; Mr. B. H. Sheikh, EPRC), Tehran, Thursday, May 12, 1994.

Inspite of the fact that wind turbines were in use in Iran during centuries, contemporary wind energy converters are not in operation for the time being. Some designs of small turbines were done in the country, but only scarce information is available about the status of wind energy conversion world-wide. Accordingly, part of the discussion handled the experiences with wind machinery, selection of types, behaviour of wind parks in the grid connected mode and of wind energy converters (WEC's) in stand-alone applications.

Some data on wind energy potential exist in Iran, feasibility studies for a number of locations have been made. What is planned next is to gain more experience (2 WEC's of 550 kW have been delivered to Iran, their installation will start soon) and to compile a broader data base on the wind conditions.

The issue of yield prediction and numeric tools to assess the energy output of the plants can certainly be handled best in international co-operation. First contacts have been made to institutions in Germany and Denmark (where the largest experience in Europe is available).

As a suggestion updated information should be looked for about the methods to warrant stable grid supply by means of a combination of a WEC and Diesel generation and/or a battery set. Here some advanced designs were proposed abroad especially for systems to serve in isolated grids, which applies certainly also for many places in the Islamic Republic of Iran.

Materials and Energy Appl. and Research Center (ME-ARC) (Dr. R. K. Nani, Director; Dr. M. Jamil)
Karaj, Saturday, May 14, 1994.

This institute is affiliated to the Ministry of Culture and Higher Education, and it is active in some advanced fields, which are directly correlated to R.E. research. The laboratory for crystal growth and semiconductor application has facilities for melting, purifying, shaping, cutting, and surface preparation of silicon wafers for pv cells, for quartz crystals (e.g. for electronic devices) and related components. Thus, the essential knowledge in the processing of such elements is available. Practical experience in thermo-electricity and related effects also is abundant, which possibly could be of future importance in connection with R.E. utilisation.

A materials research laboratory with many facilities to study material properties (physical, non-destructive methods) was provided, which could be interesting for characterising specific samples of semiconducting materials, ceramics, metallic and non-metallic alloys. Even if for the time being this lab does not directly work in R.E. related fields, it could be of help, if thin film techniques will gain more importance (e.g. to identify the properties of amorphous layers on various substrates, qualifying the methods to produce such layers, etc.).

Related to R.E. applications are the tests performed with solar equipment, which could be visited. There a wide range of applications is investigated: Low temperature solar heat for water heaters and solar dryers, water desalination by solar still concepts, heat pipes as a means to transfer the thermal energy heat from dedicated solar collectors to other appliances, a solar dish (parab. concentrator) to operate a heat engine, and a small wind turbine to power a DC generator.

Iran Research Org. for Science and Technology (IROST) (Dr. H. Bolanadi, Vice-President; Dr. M. Badr; Dr. S. M. B. Faro)
Tehran-Shahriar, Sunday, May 15, 1994.

IROST, affiliated to the Ministry of Culture and Higher Education, too, has ten institutes spread all over Iran, dealing - besides educational and qualification activities - with various scientific disciplines. In many of the disciplines M.S. courses are held, and close relationships exists with the universities in the areas. At Tehran the main issues are telecom and computer techniques, electronics and measurement devices, agricultural and biotechnological (health related and environmental) research, and energetics. In this field exemplary work was done on internal combustion engines, aiming towards a significant advance in fuel economy of petrol engines, and towards the modification of Diesel engines to operate on natural gas.

This development will not only be of importance for the emissions from urban traffic (e.g. if buses will be powered by "clean" gas engines, or if the more efficient carburators for private cars are marketed in a larger scale), but could also find some applications in bio-gas systems. Gas motors - even if of larger size - are installed in Europa as aggregates to utilise land fill gases and by-products of chemical reactions. Similar service could be envisaged in Iran or in the neighbouring countries, where excess gases of some caloric value are available.

Solar energy systems of many types were developed at the institute, mainly converting solar radiation into useful energy (parabolic dish/stirling motor aggregate) or heat (solar water heaters and a solar dryer). Also a wind driven pump (farm wheel) for rural areas was developed successfully. Regrettably a practical realisation for routine operation was only reached for low temperatur water heating. On the other hand, architectural design principles were advantageously realised in some of the buildings of the institute, which can be suggested to be made to an issue of further dissemination.

Institute of Water and Energy and Electr. Research Centre, Shari Univ. of Technology (Dir. S. J. Hashemian, Ass.Prof.)
Tehran, Tuesday, May 17, 1994.

This Institute of Water and Energy has a long tradition in R.E. investigations and also in international co-operation. Inter alia the institute was involved in tests and the installation of seawater desalination units in the 70-ties. Actual research deals with wastewater treatment (anaerobic digestation). Pilot plants of different size have been designed successfully. Also "natural" treatment systems (applying a series of lagoons, one by one increasing the water quality) were found to be feasible under the specific climatic conditions of Iran.

Trials with differently shaped tubal heat exchangers, parameters of water jet pumps, but also design problems of a vapour compressor for desalination purposes are further fields of activities, all of which are more or less closely related to solar engineering. More dedicated tasks were attributed to solar heat collectors, a solar cooker, and heat exchanger designs for such types of equipment.

In the Electronic Research Centre interesting work is performed in the fields of signal processing and identification, with practical applications in system control, medical appliances (audiometry), and in artificial intellegence. This is in coincidence with worldwide investigations in the related disciplines.

Ministry of Jahad-e Sazandegi (Mr. A. Saremi, Mr. M. Shiravandi, Mr. H. Akramian)
Tehran, Wednesday, May 18, 1994

The development of the infrastuctures in rural areas, especially for remote villages, is a matter of great concern in Iran. R.E. present some - also in terms of economy - viable solutions. This is true, as far as wind powered stand alone systems are concerned, but also for solar home systems using pv modules and batteries, pv pumping units, telecommunication equipment etc. In the mountainous regions hydropower is a very favourable alternative: In the Min. of Jahad plans and evaluations to further exploit hydraulic resources already fixed the potential of 300 to 400 MW. The issue of local contributions to the technological progress and of an involvement of the Iranian industry in the manufacturing of components was discussed in detail, also the cost/benefit figures for small pv systems.

In this case not much experience is available in the country. Further activities can be recommended - an aspect, which is of utmost importance in view of the large number of villages, which cannot be connected to the public grid.

The ongoing tasks in the field of wind energy conversion should be observed and foreign eperiences be compiled. In the long term some demonstration plants for rural electrification using wind and solar sources were recommendable. This could be facilitated, if local fabrication at least of components of wind turbines and of pv equipment could be initialized. Even if this would not be easy for some essential parts, the balance-of-system components can certainly being made in Iran, and also the main-tenance should not pose unsurmountable problems.

UNIDO

M. Sanchez/epg
2 March 1993

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

JOB DESCRIPTION

DP/IRA/87/013/11-51

Post title	Expert in research and development activities oriented to the utilization of renewable sources of energy
Duration	1 month
Date required	as soon as possible
Duty station	Teheran, Iran
Purpose of mission	To provide advice and assistance to the government of the Islamic Republic of Iran in assessing the present situation of the national research activities oriented to the development of renewable sources of energy and evaluation of the capabilities of the research and development institutions for its practical application.

Duties

The expert is expected to perform the following activities:

1. To evaluate the on-going research and development activities for the utilization of new sources of energy and determine the most efficient way to utilize the traditional sources of energy.

2. Recommendations on new research and development activities oriented to the above.

3. Identification of indigenous sources of energy which could be utilized both in rural and urban areas.

4. Possibilities of utilization of solar and windpower for the production of energy mainly for small towns and rural areas.

..../..

5. To indicate the estimated costs for the performance of the research works and the estimated duration of the suggested research programmes.

6. Estimated outputs of the recommended research works and possibilities of industrial and massive application.

7. Availability of infrastructure and qualified personnel for the foreseen activities.

8. To indicate the possible influence of the suggested activities to the environment and measures for protection.

9. The expert must present the typed mission report including findings, conclusions and recommendations.

Qualifications Electro-mechanic or industrial engineer with experience in production and consevationof energy

Language English

Background information:

The MOI intends to implement a national plan within the overall gamut of the first five-year Plan to establish a linkage between the programmes of the research institutions and the existing industries to upgrade ageing technology and ensure improved production and commercialization of the research findings. This, it is envisaged, will also increase export and encourage the private sector entrepreneurs to invest in industries.

Through the project, the Ministry of Industry of Iran will receive concrete advise on the utilization of existing research and development institutions in the field of chemical research in order to orient these institutions to the planning, organization and execution of their plan of activities addressing them to the development of the chemical industrial sector and improvement of its efficiency. Fulfillment of the project objective will entail an investigation of the means and ways for stronger direct working contacts as well as active promotion of closer working association among different institutions and industry.

The project will allow to define the surplus capacities of the research institutions, high level educational centres, engineering designs and development organization which could be made available for the development of the industrial potential in the country.