Iran

Renewable Energy Report

APCTT-UNESCAP

**Asian and Pacific Centre for Transfer of Technology
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Commission for Asia and the Pacific (ESCAP)**

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Executive Summary

Growing energy demands and limited supply of cheap petroleum and natural gas will almost certainly lead to further increases in energy prices, which will have a direct impact on our economies. At the same time our heavy reliance on fossil fuel based energy sources dramatically increases CO_2 emissions, which are a main cause of global warming. We not only need additional energy supplies; the energy also needs to be clean. Ultimately we need to transform our energy system towards renewable energy solutions.

Iran has a high amount of renewable energy sources: there are favourable conditions for the profitable use of wind energy, very good opportunities for the extension of water power use as well as an ideal setting for the use of solar energy. The average global radiation for Iran is about 19.23 MJ/m2/day (= 5.3 kWh/m2/day) and it is even higher in the central region of Iran, with more than 7.7 hours per day (more than 2,800 hours per year).

For renewable energy to make a major donation to economic development, job creation, reduced fossil fuel dependence, and lower greenhouse gas emissions, it will be necessary to improve the efficiency of technologies, reduce their costs, and develop mature, self-sustaining industries to manufacture, install and maintain renewable energy systems.

In this project the government policy, different organization and universities that are involved in renewable energy are discussed.

CHAPTER 1

1. Introduction

Nuclear is the technology of the 20th century, born out of a nuclear arms race; in an era of climate change and nuclear proliferation, solar is the technology of the 21st century. Last year Germany installed new solar cell systems with an electrical capacity equivalent to that of a nuclear reactor, and Japan now has a similar annual manufacturing capacity. Next year one single Japanese solar cell factory will come online that will double this capacity.

Efficient and reliable renewable energy sources would diversify and ensure supply without using up valuable oil and gas reserves. Such sources of energy have a strong potential to tackle the increasingly damaging environmental impacts arising from the use of fossil fuels in cities, as well as their contribution to climate change [1]. Renewable energy also has a rich potential for dispersed job creation in many parts of Iran, in the construction, erection and repair of large scale and micro-generation plant. Given the growing global concerns over energy insecurity and climate change, technologies associated with renewable have a strong export potential.

Iran's varied geography is well suited to a diverse and extensive use of renewable energy sources: hydro and geothermal in the northern and western areas, wind in the eastern and southern plains, and solar energy in the central and southern areas. Until now this potential has remained limited to a modest increase in the exploitation of hydroelectricity; otherwise there are no plans for a significant investment in renewable energy at present [2]. The lack of interest in renewable can be put down to the cheap price of fossil fuels, kept low by subsidies and the historically abundant supply of fossil fuel resources. It is also down to the Iranian government's attraction to nuclear power.

1.1 Hydro

In Iran's modest renewable energy story to date, hydroelectricity is the notable exception. Iran is clearly investing significant resources in its development. The country has an estimated potential for hydroelectric power generation of between 23 and 42GW [3]. In 2003 Iran generated 11,098GWh of hydro electricity [4]. By 2007 the seven hydroelectric power plants being constructed should be generating over 8GW of electricity - more power than all Iran's other power generation projects currently being developed combined. With further expansion planned, the government hopes to be generating 14GW by hydroelectric power by 2021 (representing 20% of Iran's projected electrical capacity).

1.2 Solar

The potential for solar electricity generation in Iran is virtually limitless. Iran is just outside the tropic of Capricorn and much of the country experiences high levels of solar radiation, a daily average of between 5.0 and 5.4 kW h/m2 in the south of the country (in comparison London receives a daily dose of around 1.0 kW h/m^2). This gives an energy generating capacity of approximately 0.5kW /m^2 of solar panels, or 500MW /km2. The deserts of Iran occupy a quarter of the total land area; if only one per cent of the desert area was covered by solar PV collectors, the energy obtained would be five times more than the current annual electricity consumption in Iran [5].

Particularly suitable areas for solar thermal power plants have been selected for future construction at Esfahan, Fars, Kerman and Yazd. The first Iranian Solar Thermal Power Plant is due to be constructed at Yazd [6]. With enough investment and a serious commitment, the potential is vast.

Solar thermal systems on the roofs of buildings have many merits, not least that more primitive designs can be installed with cheap and freely available plumbing components with limited expertise, and provide significant return in energy savings. A study of the economic feasibility for domestic solar water heating systems around Iran was published in 2000 [7], but the technology remains surprisingly under utilized. The total cost of installing a full domestic solar central heating and hot water system in Iran is estimated at 80m Rials (roughly $9,000) [7]. If all the public buildings in Iran were fitted with solar panels, the cost could be as little as 45,000 Rials/m^2 [8].

1.3 Wind

Wind energy for electricity generation and water pumps holds a great deal of promise in the east of Iran. The wind potential has been studied in 45 experimental sites. It was estimated that there was a realistic prospective capacity of 6,500 MW. The currently installed capacity is only 11 MW, compared to Egypt's 69 MW and Morocco's 54MW [9].

1.4 Biogas

Each year Iranian society produces 15m tonnes of municipal waste and 4.6bn m^3 of urban and industrial sewage (with a collection and burial cost of $225m). Biogas technology presents an important energy potential [10]. Indeed, the use of biogas in Iran has steadily grown over the last 30 years but its potential remains largely unexploited. Biogas is a by-product of the domestic waste stream, and does not require complex high-technology for its extraction.

1.5 Geothermal

Iran has substantial geothermal potential [11]. It has been estimated that Meshikin-shahr, Sabalan, Damavand and Azarbaijan could produce 7.5GW of electric power [12]. Geothermal exploration was started in Iran by Ente Nazional per l'Energia Elettrica of Italy (ENEL) and the Ministry of Energy 30 years ago in 1975. After the establishment of the Electric Power Research Center (EPRC) and the Renewable Energy Organization of Iran (SUNA) 1990, a new round of exploration activities began. In 1995, SUNA started to explore other sites for geothermal potential [13].

1.6 Wave and Tidal

There is also some potential for ocean wave and tidal energy in the Persian Gulf. It remains untapped and unstudied.

1.7 Conclusion

Issues of energy security and sustainability are global challenges, though the dynamics may be different in Iran than in developed countries. Industrial development and economic growth, a primary policy objective of every government, mean dramatic increases in the consumption of energy in countries that have not completed their economic takeoff. It is a primary responsibility of governments to ensure that energy supply is adequate to the demand.

The projected level of energy consumption in Iran demands a substantial rethink of energy policy. Iran's fuel subsidies need to be reduced to encourage a more efficient use of energy and the development of energy conservation measures and more efficient means of production. As it is, President electoral boost rested on his call for social justice and more equitable economic opportunities, and is likely to imply even heavier government subsides to energy consumption. The current regime's programme has also discouraged foreign investment in energy infrastructure, and is likely to harm the prospects for the broader economy. The current state of energy infrastructure also causes waste and inefficiencies.

With sufficient political backing and investment renewable energies present an enormous opportunity for Iran.

Renewable energies have been slower to catch on than might have been expected because of fuel subsidies, the easy availability up to now of fossil fuels and a lack of political interest. But while Iran is rich in fossil fuel reserves, it also has a significant potential in solar, wind and hydropower sources. There has recently been a general spark of interest in alternative energy - as an energy source and as an answer to the environmental impact of fossil fuels. Hydropower, already well developed in Iran, is further promoted in its Five-Year Economic Development Plan.

Micro-renewable could play an important role in generating energy at the point of consumption, given the poor state of the country's energy infrastructure and dispersed rural population. Iran has vast rural areas with small towns of one thousand or less in population, which cannot realistically be served by the electricity grid. Renewable energy technology does not require the enormous, lumpy capital investments demanded of, say, an oil refinery or a nuclear power station. It also offers the possibility of supporting healthy local economies, with local job creation both in installation and repair. The abundance of clean renewable energy sources offers a unique opportunity for win-win partnerships with countries leading the global development of renewable energy technology. Renewable energy has the potential not only to defuse the current 'nuclear' crisis, but also to offer an important sustainable self-sufficiency for Iranian electricity generation.

1.8 References

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CHAPTER 2

2. Renewable energy policy

Renewable energy policy is the principal driver of the growth in renewable energy use. Renewable energy policy targets exist in some 73 countries around the world, and public policies to promote renewable energy use have become more common in recent years. At least 64 countries have some type of policy to promote renewable power generation. Mandates for solar hot water in new construction are becoming more common at both national and local levels. Mandates for blending biofuels into vehicle fuels have been enacted in 17 countries**.**

The International Energy Agency estimates that nearly 50% of global electricity supplies will need to come from renewable energy sources in order to halve carbon dioxide emissions by 2050 and minimize significant, irreversible climate change impacts. The principal driver of today's rapid renewable energy growth is policy. Growth of renewable is strongest where and when the policy-makers have established favourable policy frameworks. In many countries, a rich and diverse policy landscape exists at national and local levels.

By early 2009, renewable energy policy targets existed in at least 73 countries, and at least 64 countries had policies to promote renewable power generation, including 45 countries and 18 states/provinces/territories with feed-in tariffs (*A **Feed-in Tariff** is an incentive structure to encourage the adoption of renewable energy through government legislation. The regional or national electricity utilities are obligated to buy renewable electricity (electricity generated from renewable sources, such as solar photovoltaics, wind power, biomass, hydropower and geothermal power) at above-market rates set by the government*). The number of countries/states/provinces with renewable portfolio standards increased to 49. Policy targets for renewable energy were added or modified in a large number of countries in 2008.

The higher price helps overcome the cost disadvantages of renewable energy sources. The rate may differ among various forms of power generation. A FiT is normally phased out once the renewable reaches a significant market penetration, such as 20%, as it is not economically sustainable beyond that point.

The feed-in tariff system has been enacted in some states in Australia, Austria, Brazil, Canada, China, Cyprus, the Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iran, Ireland, Israel, Italy, the Republic of Korea, Lithuania, Luxembourg, the Netherlands, Portugal, Singapore, Spain, Sweden, Switzerland, and in some states the United States.

2.1. Preferential policies encouragement

For renewable energy to make as large as possible a contribution to economic development, job creation, lower oil dependence, and reduced greenhouse gas emissions, it will be essential to improve the efficiency of technologies, reduce their costs and develop mature, self-sustaining industries to manufacture, install and maintain those systems. Today's energy markets include a number of obstacles that frustrate efforts to achieve these goals. Among the obstacles are lack of access to the electric grid at reasonable prices, high initial cost compared to conventional energy sources, and the widespread lack of awareness about the scale of resources available, the pace of development of renewable technologies, or the potential economic advantages of renewable energy.

These barriers have been largely overcome in several countries, allowing a period of sustained double-digit growth in the solar and wind markets over the past decade, and providing policy models for other countries to adapt. These successful models show that a sustained renewable energy market can be developed quickly and efficiently if the right combination of policies is adopted.

Iranian government focuses primarily on grid-connected electricity and vehicle fuels, and briefly on remote uses of photovoltaics (PVs) and heat systems, with the assumption that the policy recommendations can be carried over to other types and uses of renewable technologies. “Success” of policies is defined to cover positive impacts on a range of factors, including: the installed capacity and energy generation from renewable energy technologies; technological advances; reductions in cost and price; domestic manufacturing capacity and related jobs; and public acceptance.

There are five major categories of relevant policy mechanisms [1]:

• Regulations that govern capacity access to the market/electric grid and production or purchase obligations

• Financial incentives

• Industry standards, permitting and building codes

• Education and information broadcasting

• Stakeholder involvement

There is not necessarily a direct link between these policy mechanisms and specific obstacles to greater use of renewable energy, as some of the policy options tackle a combination of barriers. Each of these policy mechanisms is discussed below. An additional critical element is the need or a general change in government perspective and approach to energy policy.

Government investments in research and development (R&D) are important as well. Ultimately, however, it is only by creating a market for renewable energy technologies that the technological development, learning and economies of scale in production can come about to further advance renewable and reduce their costs.

Promotion of renewable energy technology development in Germany began with federal government R&D support for wind turbine development in 1974. The government’s large-scale wind plant project [2] developed the largest wind turbine ever before built, but the technology failed due to limitations in manufacturing and system integration. The GROWIAN plant was dismantled in 1987 and is regarded as an economic failure, despite some technical successes and contributions to the development of wind power in Germany.

Germany has relied on a combination of five primary policy instruments for the promotion of renewable energy:

- Direct investment in R&D;
- Direct subsidies;
- Government-sponsored loans;
- Tax allowances;
- Subsidies for operational costs/feed-in tariffs.

2.2. Renewable Energy Main Policies In Islamic Republic Of Iran Prepared by Renewable Energy Office, Ministry of Energy Summer 2004

• Providing sustainable and accessible energy to the poor and isolated areas in order to bring about improvement in life condition, and social development

• Creating renewable energy research centers to enhance technology performance and therefore reducing the initial cost of renewable systems.

• Laying foundation for renewable energy development by continual mapping of renewable resources which is important for defining priorities and policy making for both public as well as private sectors

• Encouraging private sector to invest in the field of renewable energy by preparing power purchase agreements for all renewable energy resources

Main Achievements

• Ability to design and construct some of renewable energy systems

• Creating manufacturing facilities for wind turbines, solar water heaters, parabolic trough concentrators and solar photovoltaic panels both in public and private sectors

• Building necessary instruments for private sector participation in renewable energy development

• Experiencing geothermal drilling in harsh climate

• Introducing incentives for universities to participate in research and applications of renewable energy

2.3. Iran's Energy Policy: Challenges and Choices

Iran is facing serious challenges in the area of energy policy. To define the problems and possibilities that these challenges represent one must first turn to Iran's energy consumption patterns as well as the energy policy of the Iranian government. . The increase in energy usage in Iran is clearly out of proportion with the rate of the country's economic productivity. Some of the negative structural characteristics of this consumption pattern are an above average energy intensity, an increase in energy consumption in the traffic sector, a high growth rate in the use of electric energy and an inordinate amount of stress on the environment, Fig.(2.1) shows Energy Consumption: U.S.A. Compared to Iran.

Energy Consumption: U.S.A. Compared to Iran

U.S.A. Ratio Iran

Land Area (km^2)

6:1

9,158,960 1,636,000

Population:

(2007 estimate)

4:1

Energy Consumption:

(million metric of

[Type text]

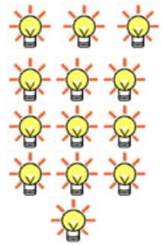
Tonnes oil equivalent)		13:1	
Energy PerCapita: (metric tonnes of oil equivalent per person.	7.66	3:1	2.51

Fig.2.1 Energy Consumption: U.S.A. Compared to Iran

*World Population Balance

Traditionally, Iran's energy policy has focused on satisfying the growing demand for energy by continually expanding its primary energy source of natural gas. However, any further development of the natural gas supply makes sense within the context of a comprehensive energy policy that takes into account the principles of sustainable development. Thus, in the short term, such a policy would take advantage of both the energy-saving techniques, as well as potential renewable sources of energy that can, in the long term, become the exclusive sources for meeting the national demand for energy.

2.4. Related government agencies, related enterprises including the private sector, renewable energy organizations of Iran Preparatory phase.

- Consultation for the National Renewable Energy Development Strategy has been tendered out to an Iranian consultancy firm supported by a foreign consultant.
- A number of RE power plants are under construction, e.g. a 150 MW wind farm.
- Institutional arrangements have been revised. All RE-related activities are now centralized at the Ministry of Energy (MOE), with the exception of solar water heating that remains within the responsibility of the Iranian Oil Ministry.
- Executive Instruction "Article 62," permitting power purchases from non-governmental producers, has been approved by MOE. Based on this decision, talks have been opened with interested private sector companies in view of signing power purchasing agreements.

2.5. Five-Year National Development Plans in Iran

Assuming the fixed cost of fuel and foreign exchange rates in the future, the cost of electricity produced by wind turbines in Iran is estimated to be 4-5 cents/kWh. The cost of electricity for steam and gas power plants is about 2 and 2.5 cents/kWh respectively plus the social costs of the three major air pollutants (CO_2, $SO_2$and NO_2), which ranges from 3 to 4 cents/kWh (2002). Comparing this total east to

the price of electricity generated by wind power plants, could easily demonstrate the cost advantage of wind power plants.

2.5.1 Advantages of investing in wind energy in Iran

1. Great potential for harnessing wind energy in the country and so far very small portion of it has been utilized
2. Power purchase tariffs that easily compete with the rates paid in developed countries,.
3. Signing of long term Power Purchase Agreement for duration of 20 years under Take or Pay scheme while the payment is backed by issuance of Letter of Credit
4. Reliable source of earning
5. Installation and commissioning is carried out in short period of time
6. Attractive return on investment
7. Extremely low operation costs
8. Wind energy is free of charge
9. ability to start from a few KW capacity and going as high as hundreds of MW
10. Investment costs are relatively low in long term
11. No requirement for water
12. Job creation and development of new

The government of Iran in 4th of May has approved to increase the purchase tariff for electricity generated by renewable energies from an average of 620 rial (6.3 USD cents) per KWh to 1241 rial (12.65 USD cents), a hundred percent increase. In addition, during last few years, Iran's Ministry of Power has made considerable strides to develop the necessary legal and financial infrastructures required for growth in wind power sector in Iran. The combination of these two major factors along with many other advantage points found has drastically improved the prospects for investment in this field. Fig. (1.2) shows electricity purchase price (USD cent/KWh) for different countries.

Fig.2.2 Electricity Purchase Price (USD cent/KWh)

[Type text]

2.5.2. Private sector steps into Iran's renewable energy

LONDON, October 26 (Iran Mania) **-** More than 10 domestic private companies have taken the lead to invest in new and renewable energies, acting director of Energy Ministry announced that, according to MNA [3].

The activities in this field in Iran are focused on scientific and research aspects, and research part is aimed at reduction of capital required for exploitation of related resources, he added.

The second step is to work research results into scientific dimension of this field for practical means, i.e. establishing electricity power plants. Due to recent advancements in wind energy, many investors in the country have become interested in investing in this type of energy. At the moment, projects assuming 130 MW of wind power plants are underway, of which, 25 MW is operational, the director stated.

Based on the planning in the 4th Socioeconomic and Cultural Development Plan (2005-2010), private sector is expected to have a share of at least 270 MW in renewable energies. However, it is the government's duty to take the first step for investment in biomass and solar power plants; private sector may then play its part once the infrastructures to this end are laid out, he continued.

At the moment, a 250-KW plant is under construction in Shiraz and two more geothermal units with 5 and 50 MW capacities will follow. Moreover, two biomass and solar energy plants, standing at 10 MW and 17 MW respectively, are of other upcoming projects.

The main activities of renewable energy in Iran are as follows:

➢ **Solar energy**

Iran has an average solar insulation of 2000 kWh/m 2.yr. The sunny hours which sunshine could be utilized are about 2800 hr/yr. Solar energy has not been formally commercialized yet. Regions having high potential for solar energy are: Shiraz, Tehran, Khorasan, Yazd, and Semnan (IAEA, 2000). Some of the completed solar energy projects are:

10 kW Photovoltaic Power Plant at "Dorbeed" village in Yazd Province.

- 2 Photovoltaic Power Plant at "Hosseinian" and "Moalleman" village in Semnan Province with the total capacity of 92 kW.
- 250 kW Solar Power Generator in Shiraz.
- 350 units (1400m^2) Solar Water Heaters.
- P.V. pumping for agricultural use, P.V. electricity generation for a border post and P.V.street lighting
- . Some of the ongoing solar energy projectsare:
- . 1MW Solar Power Thermal Plant under construction in Talegan-Karaj.
- . 45 kW grid connected P.V. under constructed in Talegan
- . 650 units (2600m^2) Solar Water Heaters for domestic use under construction.
- . 2 units (400 m^2) Solar Water Heater for village public baths under construction.

➢ **Wind energy**

According to the research and studies which have been carried out and the present wind turbine technology in the country, it has been estimated that the wind energy potential in Iran is more than 15000 MW for electricity production. Since Iran has many windy regions, utilization of this type of energy would not only be possible but also economically feasible (Ministry of Energy, 1998). Presently, some of the operated wind energy projects in Iran are as follow:

• In the site called Manjil, situated in the NW part of the country, a 10.1 MW Wind Farm with 300 and 500 kW turbines with an aid of the GEF/World Bank has been installed (1995), where average wind speed is more than 11 m/sec at hub height.

- **Geothermal energy**

Iran has high geothermal energy potential and the main regions for geothermal energy generation are Sabalan, Makoo, Khoy (Azerbaijan Province) and Damavand (Tehran Province). The total potential of geothermal energy is approximately 60 billion Giga Jules (Ministry of Energy, 1998). As for geothermal projects, some studies have been conducted to design a prototype Geothermal Power Plant for producing electricity. One of the ongoing related projects is a 100 MW Geothermal Power Plant at
exploring stage in Sabalan.

- **Other renewable energies**

Based on several investigations and researches conducted during recent years, it is not expected any considerable potential for Wave, Ocean Thermal and Tidal Energy in Iran.

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[3] Wednesday, October 26, 2005 IranMania.com

CHAPTER 3

1. Brief overview of the Iran

Location:

- Iran is located in the southwest of Asia, bounded on the north by Armenia, Azerbaijan, Turkmenistan and the Caspian Sea, on the south by Persian Gulf and the Gulf of Oman, On the west by Turkey and Iraq, and on the east by Afghanistan and Pakistan. Fig. (1) shows the map of Iran.

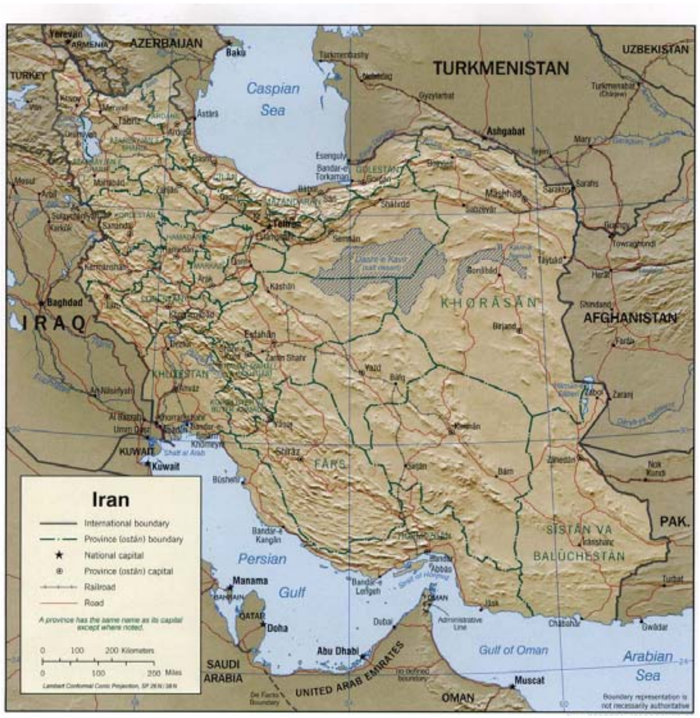


Fig.3.1 the map of Iran

Area:

- *total:* 1.648 million sq km
- *land:* 1.636 million sq km
- *water:* 12,000 sq km

Land boundaries:

- *total:* 5,440 km
- *border countries:* Afghanistan 936 km, Armenia 35 km, Azerbaijan-proper 432 km, Azerbaijan-Naxcivan exclave 179 km, Iraq 1,458 km, Pakistan 909 km, Turkey 499 km, Turkmenistan 992 km

Coastline:

- 2,440 km; note - Iran also borders the Caspian Sea (740 km)

Climate:

- The climate ranges from subtropical to subpolar. During winter temperature is -37° C (-35° F) in the north of country, and in the south 23° C (73° F).

Summers are hot and humid in the south, but fair and pleasant in the north, and the temperatures rang from 25°C (77° F) to 54° C (130° F).

Elevation extremes:

- *lowest point:* Caspian Sea -28 m
- *highest point:* Qolleh-ye Damavand 5,671 m

Natural resources:

- About 40 percent of Iran's territory is considered cultivable if irrigation is available, but because of the lack of water, less than 30 percent of that territory is cultivated. Iran has enormous reserves of oil and natural gas. Oil reserves are estimated at about 130 billion barrels (third in the world behind Saudi Arabia and Iraq), and natural gas reserves are estimated at 20 trillion cubic meters (second in the world to Russia). Mineral resources currently exploited include bauxite, chromium, coal, copper, gold, iron ore, red oxide, salt, strontium, sulphur, turquoise, and uranium

Population:

- 69,018,924 (July 2004 est.)
- *Population growth rate:* 1.07% (2004 est.)
- *Birth rate:* 17.1 births/1,000 population (2004 est.)
- *Death rate:* 5.53 deaths/1,000 population (2004 est.)
- *Infant mortality rate:* 42.86 deaths/1,000 live births (2004 est.)

Age structure:

- *0-14 years:* 28% (male 9,935,527; female 9,411,647)
- *15-64 years:* 67.2% (male 23,608,621; female 22,744,128)
- *65 years and over:* 4.8% (male 1,645,246; female 1,673,755) (2004 est.)

Country name:

- *conventional long form:* Islamic Republic of Iran
- *conventional short form:* Iran
- *local short form:* Iran
- *former:* Persia

4.Renewable energy scenario in Iran

As mentioned above Iran with different climates almost all RET are suitable for application some of these are outlined as following:

- **Solar energy**
- **Wind energy**
- **Geothermal**
- **Biomass**
- **Hydro**

4.1. Government's policy

Sustainable energy is energy that, in its production or consumption, has minimal negative impact on human health and the healthy functioning of vital ecological system, including the global environment. It is an accepted fact that solar energy is a sustainable form of energy, which has attracted more attention during recent years. This paper discusses some of the renewable energy activities in Iran. It covers renewable energy scenario in the country including government's policy, universities, research organization and industries.

In the past several years, renewable energy has been receiving increased attention in Iran especially by Ministry of energy and Iranian Fuel Conservation Organization(IFCO) affiliated to Ministry of oil for use in hot water supply, space heating , solar public bath for remote area and solar power plant namely 250KW_e in Shiraz and 17 MW_e in Yazd(in design stage).

4.2. Important R&D and other support institutions for promoting RET in Iran

The major universities and centres that are involved in renewable energy are listed as follows:

a) Iranian Organization for Renewable Energy (Ministry of Energy)

b) Iranian Fuel Conservation Organization(IFCO)

c) Iranian Research Organization for Science & Technology (Ministry of Science, Research and Technology)

d) Materials & Energy Research Centre

e) University of Shiraz

f) University of Sharif

g) University Tehran

h) University of Meshad

4.2. a. Iranian Organization for Renewable Energy (Ministry of Energy)

Global energy demand has increased by 3.3 percent in the past three decades. The growing need has made countries step up efforts to find new and renewable energy sources. Given Iran's rich renewable energy sources such as the sun and high force wind, Energy Ministry's Energy Department was assigned in 1995 to establish an organization to focus on renewable energy. Iran Renewable Energy Organization (SUNA) was finally set up in February 2000 as per a cabinet ratification. One of the organization's objective is to develop power plants operating on renewable energy sources such as wind or biomass. The organization has signed contracts to purchase electricity generated by private wind farms and biomass sites. This would help encourage private investors in the long run. Organization's managing director said that one-day workshops are arranged free of charge to augment knowledge of teachers and those holding associate degrees in technical majors. Talking to reporters visiting an experimental site for renewable energy sources near Taleqan- 100 Km. from Tehran the official said that such sites will conduct research and add to public awareness. He reiterated that apart from being a hydrocarbon-rich country, Iran has abundant renewable energy sources which should be capitalized on. Researches are underway in the country to identify renewable energy sources and make sites to use them, he elaborated. The official added that these sites are environment-friendly, need no fossil fuel and can be constructed in remote regions. He noted that the government has planned to gradually increase investments made in these sources. A part of the national energy demand should be supplied by these sources, he said. The official cited the Fourth Five-Year Development Plan (2005-2010) based on which one percent, meaning 500 megawatts, of the country's electricity be generated from renewable energy sources. "We have 300 sunny days in 90 percent of the country," He said, adding this gives the country an opportunity to take advantage of solar energy. Referring to a project underway in Meshkinshahr, Ardebil province, to use geothermal energy, the official explained that 21 wells, some of them 3,000 meters deep, have been drilled in the summit of Mount Sabalan for the purpose. He further named biomass as an important energy source. Two projects in the northeastern city of Mashhad and southern Shiraz City are being carried out. Plant material, vegetation and agricultural waste are dumped in these sites to produce 1.6 megawatts of electricity. He noted that Manjil Power Plant was also established to use wind power. The capacity of the plant is planned to reach 100 megawatts. Manjil wind power plant, Iran's first, was launched in 1999. The following is some of the projects financed by SUNA.

4.3 Solar Thermal energy

4.3.1 Shiraz solar power plant

The first parabolic trough solar power plant with capacity of 250 KW_e was designed and built in Shiraz by Shiraz university Fig. (4.1-4.4) [1-4]. To improve solar power plant performance, they study modeling and control of its complete oil cycle. According to various environmental conditions, external disturbances and design constraints among some components, changes of working loops become necessary which cause switching in the continuous systems. For efficient modeling of this multi-loop oil cycle, a new category of hybrid systems called "switched dynamical systems" is used. Because of switching nature of the oil cycle, a conventional continuous controller cannot satisfy all design specifications for these different situations all together. So the model is combined with another type of hybrid systems called "switched controller systems" in which all switching decisions are governed by a supervisory switching controller; it uses PID controller as its basic controller. Combination of continuous and switching controllers is also a hybrid system. Simulation results for Shiraz solar power plant oil cycle show that switching control of this multi-loop plant can efficiently regulate the oil cycle response in different situations especially in the presence of large step disturbances (moving clouds) and white noise.

They are also involved in Sterling engine, solar dryer, solar collectors, storage. This project was supported by Ministry of Energy

Fig. 4.1 Solar parabolic trough

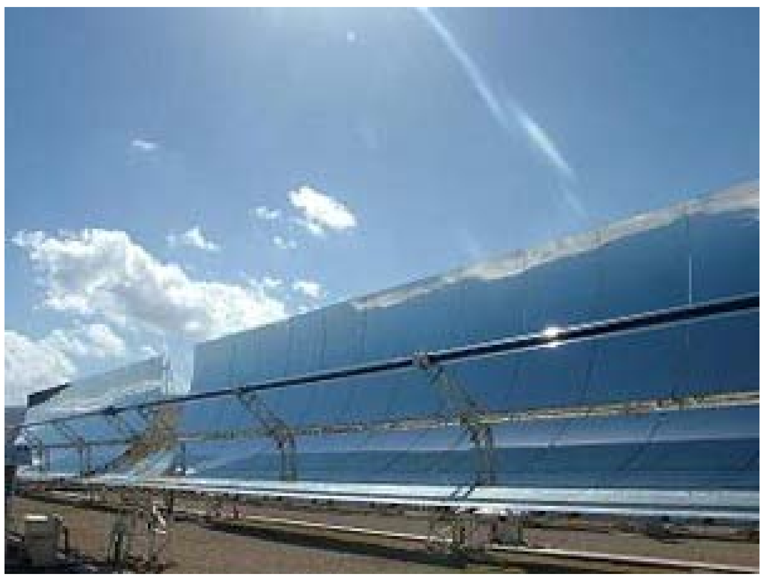


Fig.4.2 One row of parabolic trough

Fig.4.3 Solar parabolic trough under test

Fig.4.4 Piping system

4.3.2Yazd Solar Thermal Power Plant

insistent interest of The Islamic Republic of Iran in CSP is documented through actions already initiated in the early 1990's.In 1992 the German Federal Minister for the Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany and the Vice President of the Islamic Republic of Iran signed a "Memorandum of Understanding Concerning Cooperation in the Field of the Environment" in Tehran. To follow-up, Iranian and German experts organized the "First German-Iranian Seminar on Solar Thermal Power Plants" in September 1993 in Tehran, sponsored by the Energy Ministry and the Electric Power Research Center.

In1994, a Joint German-Iranian Expert Group on Solar Thermal Power, sponsored by the German Federal Ministry of Environment and the Iranian Power Development Company (IPDC), elaborated a concept study for a 100mw Solar Thermal Plant. In 1996, IPDC contacted GEF to investigate the possibility of support for the implementation of such a major solar power plant. At that time, GEF responded that a more through feasibility analysis was needed as a basis for potential commitment and grant support to a project.

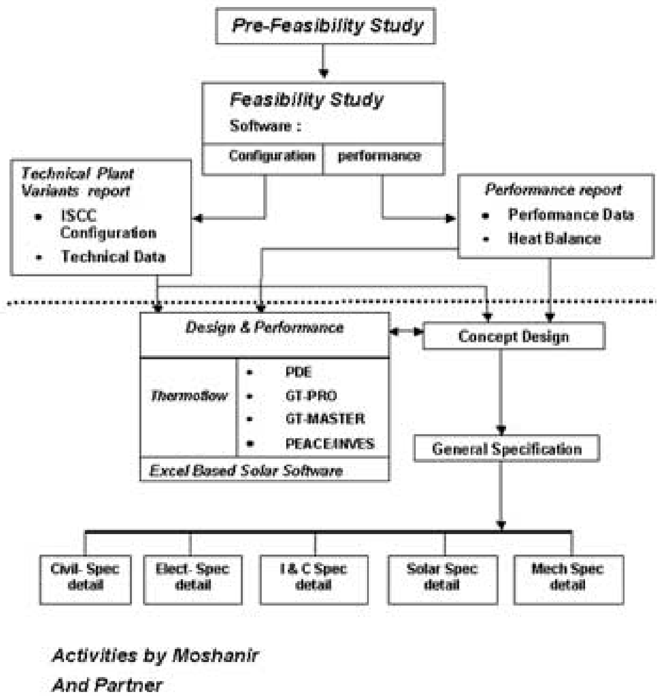
In 1997, IPDC contracted the Electric Power Research Center (now named NIROO Research Institute), Pilkington Solar International (now named FLABEG Solar International)and Fichtner (now Fichtner Solar) to execute a comprehensive feasibility study. NIROO was responsible for the site selection, analysis of implementation strategy in the Iranian electricity sector context, and analysis of local manufacturing capabilities, FLABEG Solar for the solar field lay-out and design, economic and financial analysis and structuring of project financing. Fichtner Solar took responsibility for the optimization of the combined cycle retrofit and optimal integration of the solar field technology into this cycle. The best places for installation of Solar Thermal Power Plant in Iran have been selected as Esfahan, Fars, Kerman and Yazd due to high solar resources. Finally Yazd has been selected for implementation of the first Solar Thermal Power Plant in Iran. is excellent for construction and operation of a solar field, approximately 9 km^2 of land adjacent to the future power complex has already been purchased by the Yazd utility company. It is adequate in size for almost 450mw of solar field capacity and almost level, minimizing grading requirements. The entire high plateau of the Yazd region is characterized by a high annual direct normal radiation of 2,511 kWh/m^2, thus reducing the required solar field size. Annual rainfall is low and wind speeds are moderate, the site water resource, however, is limited. Due to this scarcity of water, a dry cooling system is recommended for the steam turbine condensing cycle. Preliminary activities have been started such as construction of infrastructure, extending gas and water pipeline, water wells, complete weather station and extension of 400kv substation and so on. Meanwhile three older 64mw gas turbines (KWU V93.1) two from Basat Power Station and one from Shiraz have been dismantled and relocated and have been transferred to the Yazd site. About the same time a contract was signed by Alstom GT to supply two gas turbine generator units with the characteristic PG 9171E (123.4 ISO Condition). Alstom Company fulfilled their commitments and two gas turbine units have been installed and the plant was put into operation on the 3rd May 2000. At this stage we had to decide which configuration was the best solution for this power plant. Two plant configurations are considered as a base for study as an appropriate technical solution to meet the requirements of Iran: - one stand-alone Solar Rankine Cycle and another Integrated Solar Combined Cycle System. According to the feasibility study and due to the two gas turbine generator units already installed and technically adopted conventional combined cycle ISCCS short description of Parabolic Trough Integrated Solar Combined Cycle System has been selected for this technology. proven ISCCS has generated much interest because of its innovative way of reducing costs and increasing overall solar electricity efficiency. At this stage Consultancy Services were awarded to Moshanir Power Engineering Consultants on January 2001 for upgrading two gas turbine units to combined cycle power plant and adding an aperture area of 366 240 m² to the solar field.Moshanir scope of services include: - Preparation of General & Technical Specification (Civil-Mechanical-Electrical-I&C-solar field) it is- Preparation of Tender Document- Preparation of Construction Bid Package- Request for quotation- Evaluate the quotation and negotiation EPC-Contract- Award EPC-Contract

- Engineering
- Procurement
- Construction
- Commissioning

Summary of Work Process For Tender Document Production

Activites carried out by consortium

Fichtner - Pilkington - Matn



System Description:

Following Diagram will show the Process Flow Diagram of ISCCS:-

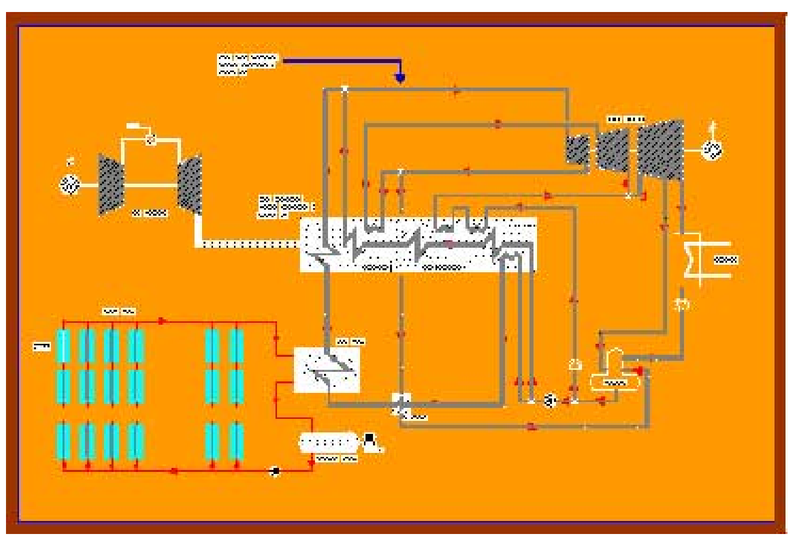


Fig. 4.5. Schematic Flow Diagram ISCCS

The collector field consists of large field of single axis tracking parabolic trough solar collectors Fig(4.5). The Solar Field which is modular in nature and comprising many parallel rows of solar collectors, which is aligned from North-South horizontal axis. Each solar collector has a linear parabolic shape reflector and will focus the direct sun-beam radiation in a linear receiver, which is located at the focus of parabola. The collector will track the sun from East-West all day and will ensure that the sun continuously focuses on the linear receiver. HTF fluid (Monsanto Therminol aromatic hydrocarbon biphenyl-diphenyl oxide) is heated and circulated in the linear receiver and will be transferred to the series of heat exchangers in order to generate steam. This is the general function of a solar field.

On the other hand combined cycle power plants fired by natural gases are a very cost-effective configuration due to excellent performance, cost and emission characteristics. The conventional CC plant consists of a combustion (Gas) Turbine (GT), Heat Recovery Steam Generator (HRSG) and Steam Turbine (ST) bottoming cycle. Hence the energy in the gases or other fossil fuels is used much more efficiently than in a GT alone. Modern cycles can achieve overall thermal-to-electric efficiencies of 55% or higher.

Integrated conventional combined cycle power plant and SEGS Solar Steam System will improve steam parameter and will permit the use of steam reheat turbine. Consequently the steam cycle efficiency increases by 40% and overall cycle easily by 50% fired by clean fuel natural gas combustion turbine. The integration combustion turbine is unchanged, Solar field will be used for steam generation and super heats the steam, which is then passed through high pressure turbine to low pressure turbine. Gas turbine waste heat will be used preferably to feed water preheating and steam generation. Since no superheating is required from solar field, evaporation temprature will be raised for high steam pressure. Elevated waste heat temperature will be used for attainment of high superheat temperature for high pressure steam. ISCCS will generate steam at 500 ^{o}C and 100 bars.

There are four solar field operating modes:-

Operating mode No. 1:

When direct solar radiation is less than 200 W/m² and HTF temperature is less than 391 ^{o}C, HTF, by-passing solar boiler will pump to the solar field. This will continue until HTF heat reaches the desired temperature Fig.(4.6).

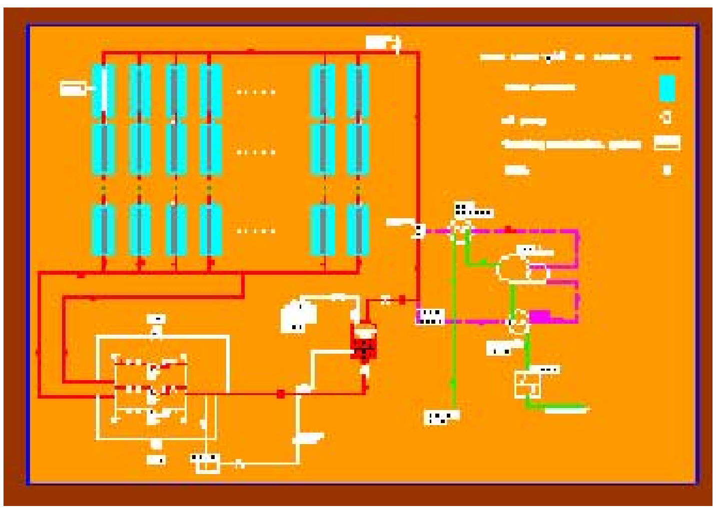


Fig. 4.6. Schematic Flow Diagram ISCCS

Operating Mode No. 2 :

When direct solar radiation is more than 200 W/m² and HTF temperature is about 391 C and HTF, passing solar field will enter solar boiler that consists of preheater, steam generator and superheater Fig.(4.7).

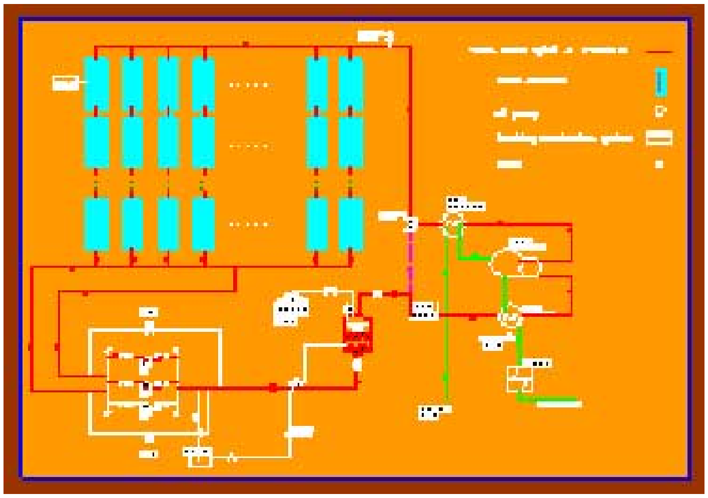


Fig. 4.7. Schematic Flow Diagram ISCCS

Operating Mode No. 3 :

When direct solar radiation is more than 200 W/m² and HTF temperature is less than 391 ^{o}C, with regard to the variable-speed pump it is possible to reduce HTF flow rate until its temperature reaches 391 ^{o}C Fig.(4.8).

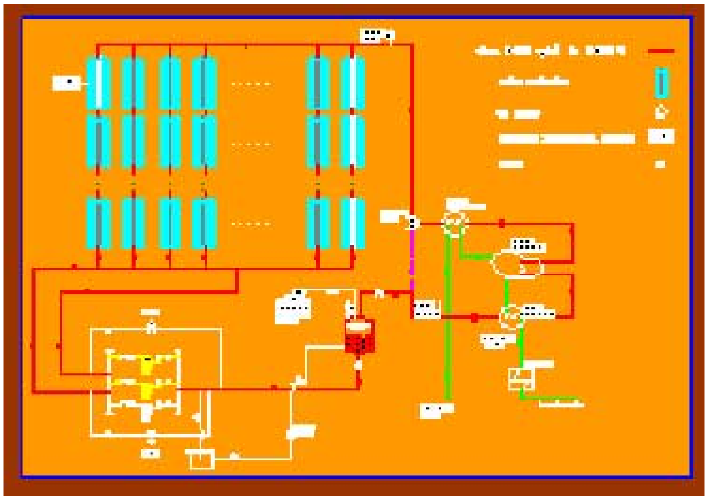


Fig. 4.8. Schematic Flow Diagram ISCCS

Operating Mode No. 4 :

In this case if the temperature of HTF is over 391 ^{o}C, some of the collectors will be dismissed from their focal position and unable to focus the direct insolation towards HCE, this will continue until temperature of HTF reaches 391 ^{o}C Fig.(4.9).

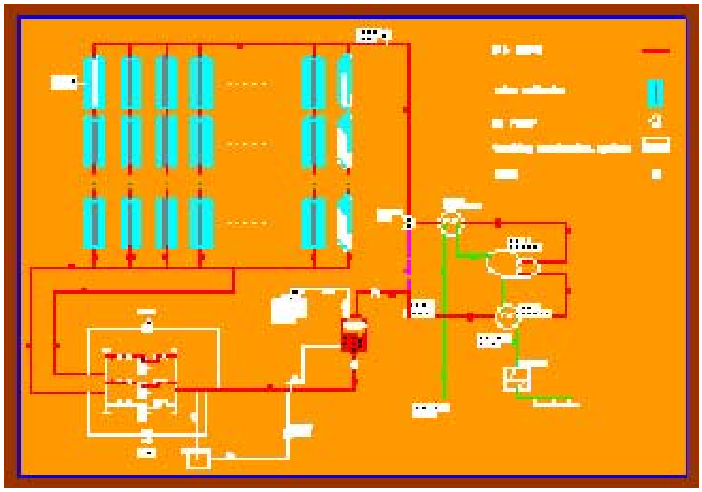


Fig. 4.9. Schematic Flow Diagram ISCCS

The upgrading to combined cycle (CC) adds 118mwe (from 212 to 331) net capacity and 964 GWh/a annual net electricity production. The further upgrading to ISCC will increase the net capacity by another 67mwe (from 331 to 398) and produce additional 156 GWh/a annual net electricity without additional fuel consumption. These conditions result in a solar contribution or solar share of 20% peak at full insolation and 5.5% annual average. The annual average heat rate is reduced from 11177 kJ/kWh for the gas turbines to 7175 kJ/kWh for the combined cycle plant and to 6784 kJ/kWh for the ISCC.Solar energy is used more efficiently in the ISCC configuration than in a stand-alone steam Rankine cycle, such as the SEGS parabolic trough plants operating in California. The incremental solar electricity from the ISCC is 156 GWh/a compared to 131 GWh/a solar electricity from a Rankine cycle plant with the same size solar field.

A further benefit of integrating solar plants into the Iranian grid is the counteraction of the production losses from the gas turbines due to high daytime summer temperatures by the coincidence of high solar power production due to high solar input at those times. For example, from a night temperature of 10°C to a day temperature of 30°C the net electric power from the two gas turbines will decrease by 28mwe, whereas the ISCC will produce solar electricity at high insolation coinciding with the high daytime temperatures. The net result is an increased electricity output of 39mwe for the ISCC.

By upgrading the gas turbines to a combined cycle power plant, an investment of $115m will result in an additional annual net electricity generation of 964 GWhe/a from the high temperature exhaust gases which otherwise will be emitted to the atmosphere. By further upgrading with a solar field, an additional investment of $138m will result in an additional annual net electricity generation of 156 GWhe/a from solar energy.

By comparison, the investment required for a solar stand alone (SEGS) power plant of the same solar field would be $163m and producing 131 GWhe/a of electricity from solar energy.

Additional operation and maintenance requirements for the solar field have been taken into account in the economic analysis. Basically this consists of additional staffing of 14 personnel, and adequate spare parts stores for solar field maintenance.

Project organization and construction planning are discussed, but are not different from conventional power plant development and construction in most aspects. Solar field construction time requirements do not extend the normal construction schedule for a plant of this type.

National and regional employment impacts have been briefly examined. Solar power plant implementation can significantly increase national employment in several key sectors, including manufacturing, construction and plant O&M.

The environmental benefits of the solar addition are significant, notably in the avoidance of CO2 emissions and reducing global warming effects. The amount of CO2 emissions avoided by the ISCC plant over 25 years, compared to gas turbine operation and compared to combined cycle operation respectively, is approximately 17.7 million tons and 1.6 million tons. CO2 avoidance costs range from $3/ton to $31/ton for these two cases.

While a number of conclusions are discussed in this site, the overriding result is that upgrading the Yazd gas turbines to a combined cycle system with solar energy addition is warranted and encouraged.

4.4 Conclusions:

Upgrading of the two new gas turbines at the Yazd site to a Combined Cycle (CC) Power Plant by installing a waste heat recovery steam generator (WHRSG) and a steam turbine system is economically more attractive.

Further upgrading to an Integrated Solar Combined Cycle (ISCC) Power Plant by installing a larger waste heat recovery steam generator and a larger steam turbine system is the next step in economizing. However the upgrading to CC and then to ISCC must be planned and implemented from the beginning, that is, it cannot be carried out in two steps as the WHRSG and the steam turbine systems have to be sized so that both heat from the gas turbine exhaust and the heat from the solar field can be accommodated.

The cost of generating power from the ISCC is lower than the cost of generating power from the gas turbines.

If generation of electricity by means of solar technology in Iran is desired, then the integration with the new gas turbines in Yazd is the most attractive application. This is so because the Yazd site has already the complete infrastructure and superior site characteristics and solar insolation conditions.

Integration of a solar component into a Combined Cycle Power Plant costs less and produces more solar electricity than a stand-alone Solar Power Plant.

The high production losses of gas turbines and consequently of Combined Cycle Power Plants due to high ambient temperatures during the daytime in summer will be compensated from solar electricity production precisely at these times of high temperatures.

It is therefore recommended to upgrade the two new gas turbines at Yazd with a Waste Heat Recovery Steam Generator, a Steam Turbine and a Solar Field.

The advantages and the recommendations to integrate solar components into combined cycle power plants are applicable to all gas turbines in Iran. In particular within three years from now the next sets of gas turbines are scheduled to be installed at Yazd and the same procedure could be applied.

It is further recommended that The Islamic Republic of Iran approach the Global Environmental Fund (GEF) in the future for discussions.

4.5. TECHNOLOGYCAL DESCRIPTION

Parabolic Trough Technology

The Solar field is comprised of parabolic trough mirrors and is connected to a natural gas combined cycle power plant. The option selected was to use two gas turbine units of 123.4 MW (ISO condition), a waste heat recovery steam generator and a steam of 198 MW for a total installed power of 414 MW.

Total net electric power is 2917 GWhe.The Solar field is formed by LS-3 by LS-3 parabolic tough collectors ordered in 84 loops, the solar radiation is about 2515 kwh/m2 and thermal energy from solar field is almost 470 Gwh. The Solar field has been optimized to fulfil the plant requirements and to give solar a contribution of around %5.3 .The total area occupied would be around 366,240 m^2

and the installed power of the solar field would be 67 MW and using the auxiliary firing for a total 1200 hours per year. The type of boiler for this system is HRSG while the condensation cooling will be achieved by indirect natural draft cooling tower with Heller system.

4.5.1.Project financing:

On a feasibility study basis, it is estimated that the local cost of the project will be about US$ 320 million of which about US$ 67 million has been allocated by the Iranian Government for gas turbines and preparation of the site.In the meantime no grant has been provided under GEF operational programs 6 & 7 that deals with the reduction of the long term costs of low greenhouse-gas emitting technology. We are negotiating for financial support as soon as our request for grant has been accepted by GEF we will sign EPC contract.

4.5.2.ProjectImplementation

Several activities have been undertaken in relevance to the preparation of the proposed project. In the period 1996-2001 a consortium of three companies Pilkington, Fichtner and Matn (power research center of Iran) prepared for IPDC a feasibility study (financial and technical feasibility) for possible plant configuration ranging from 215 MW (two gas turbine unit) to 444 MW located in Yazd.

The installation of two gas turbine units (Frame 9E PG9171 E,ISO ratins of 123.4MW) have been completed as the first phase of an integrated solar combined cycle system. At the moment our Consultant as well as our designer Moshanir Power Engineering Consultant is performing the following activities.

- Concept design
- General Specification
- Detail specification - solar field
- Detail specification Civil
- Detail specification Mechanical
- Detail specification Electrical
- Detail specification I & C
- Guarantee & Technical data

4.6. Photovoltaic

Many projects on photo voltaic performed by Iranian Organization for Renewable Energy (SUNA) in different parts of Iran especially in rural area. Figs.(10-11) show two projects one installed in Semnan area with 97 KW_e and the other near the Yazd 5 KW_e. The total capacity within in two years (2002-2004) was 175 KW, Fig. (4.12).

Fig.4.10 Semnan area with 97 KW_e

Fig.4.11 Five KW_e photo voltaic system near the Yazd

Fig.4.12 Design and installation of grid connected and off-grid photovoltaic system
In different area with total capacity 175 KW (2002-2004)

4.7. Wind Energy

4.7.1 The History of Wind

Since ancient times, people have harnessed the winds energy. Over 5,000 years ago, the ancient Egyptians used wind to sail ships on the Nile River. Later, people built windmills to grind wheat and other grains. The earliest known windmills were in Persia (Iran). These early windmills looked like large paddle wheels. Centuries later, the people of Holland improved the basic design of the windmill. They gave it propeller-type blades, still made with sails.

The energy market is a very competitive market. In comparison to fossil fuel power plants, electricity produced by wind power has offered new benefits to those involved in this sector. In addition, the great endeavours made by some world countries in producing electricity from wind energy has become a model for other countries which have a long way ahead of them in that regard. Many of the developing economic resources are situated in Asia.

Economy of Asian countries such as Iran has resulted in these countries feeling the need to produce more electricity more than before and to start to produce electricity by the use of non-fossil energy resources. In addition, the lack of a vast electricity network in the rural areas of Asian countries is another stamp of approval on the fact that there is a need for systems to produce electricity through the use of wind energy. As far as the future economic outlook and the use of wind energy in Iran are concerned, it should be said that the use of this energy will economize the use of oil products as fuel. The primary benefit of this economization will be the preservation of oil products. This will provide the opportunity to export and more importantly transform these by-products into many valuable petrochemical derivatives. Secondly, the production of electricity with the use of this energy will not pollute the environment. This factor will help protect the environment and lay the groundwork for stable socio-economic development. In addition, the use of wind energy in Iran will create new employment opportunities. When the wind energy technology becomes home-grown the country's economy will further flourish. One of the indirect applications of this energy is the charging of batteries, water pumpage, and the production of electricity for remote regions. In addition, this energy can be used for wind turbines and wind farms. In Iran, considerable efforts have been made for using wind energy. According to studies carried out by 45 sites set up for determining the wind potential in 26 regions of the country, the potential of wind energy in the studied sites is 6500 MW. Most of the potential regions in Iran are situated to the east of the country.

Country's Wind Atlas: Initially, 16 stations were set up in Gilan, Western and Eastern Azerbaijan and Ardebil Provinces to record data on wind potentials and to determine the true potential of wind energy in the country. After the data on the wind was collected and the necessary permits were acquired from the Management and Planning Organization, a project was implemented in 2004 to compile the country's first wind atlas. 600 KW Wind Turbines: A 600 K W wind turbine has been set up in Manjil's Babaiyan village in Gilan Province. This region has a wind potential of 100 WM. The average wind speed at the top of the hub (40 metres) is around 10 metres per second. A total of 1250 kwh/m^2.y of energy can be produced in this region. Due to its great potential and efficient wind patterns, this region is one of the most suitable regions for setting up wind turbines.

The technology for setting up 40 metre high gear-boxed horizontal axis wind turbines has been used for this project. A 20 KW electricity transmission line and a 690 volt 20 KW outpost have been set up to transfer the electricity produced by this wind turbine.

Sahand's 10 KW Wind Turbine: This wind turbine has been set up at Sahand Industrial University. This region has great potential. The average wind speed at a height of 20 metres is 8 meters per second. The technology for setting up 20 metre high gearboxed horizontal axis wind turbines has been used for this project. The flaws on the turbine's control wires are being rectified. 130 KW Turbines: These two turbines have been purchased by the Ministry of Agriculture and have been set up on the Dizbad plains. Due to operational problems, work on the turbine was suspended until it was handed over to the Energy Ministry and Iran's New Energies Company. Currently, this turbine is being put into operation by Iranian experts.

Another activity of SUNA is wind energy. So far more than 100 MWe is being produced through wind energy. Each unit can produce 600 KWe and is shown in Fig (4.13-4.14). They are mainly installed in Manjil area.Figs.(4.15-4.16) shows blade and motor part of wind turbine manufactured in Iran.

10 KW unit is installed to produce electricity for a village near Tabriz and is shown in Fig.(4.17).

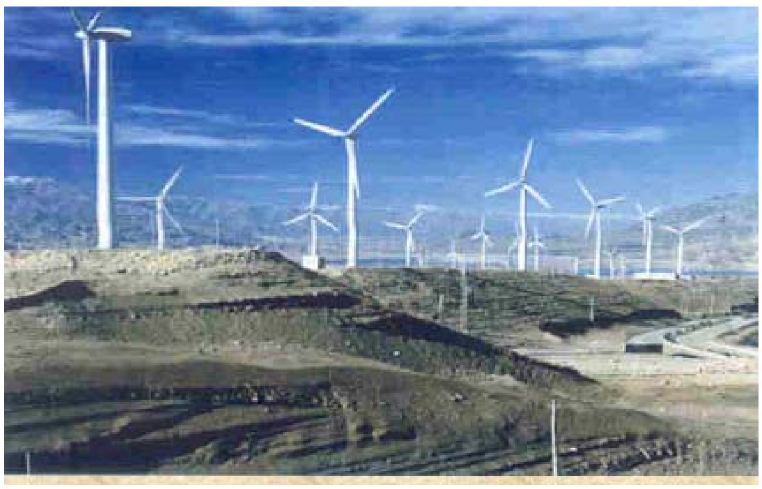


Fig.4.13Wind farm in Manjil with total capacity of 11.2 MW (2002-2004)

Fig.4.14 Wind turbine with 600 KWe capacity in Manjil area

Fig.4.15 Blade of wind turbine made in Iran

Fig.4.16 part of wind turbine made in Iran

Fig.4 17 Ten KW_e unit for a village near Tabriz

[Type text]

According to the research and studies which have been carried out and the present wind turbine technology in the country, it has been estimated that the wind energy potential in Iran is more than 15000 MW for electricity production. Since Iran has many windy regions, utilization of this type of energy would not only be possible but also economically feasible (Ministry of Energy, 1998). Presently, some of the operated wind energy projects in Iran are as follow:

• In the site called Manjil, situated in the NW part of the country, a 10.1 MW Wind Farm with 300 and 500 kW turbines with an aid of the GEF/World Bank has been installed (1995), where average wind speed is more than 11 m/sec at hub height.

• In Manjil, another 90MW Wind Farm equipped with the 660 kW turbines is under construction.

• The eastern parts of Iran have some areas with the average wind speed of about 8-10 m/sec at 40m heights. The local utility is constructing a 23 MW Wind Farm, which will be completed by the end of 2003. In the 3rd Five-Year National Development Plan, it is planned to install a 250 MW Wind Farm.

• A 1000 MW Wind Farm is planned by the end of the 4th Five-Year National Development Plans Assuming the fixed cost of fuel and foreign exchange rates in the future, the cost of electricity produced by wind turbines in Iran, is estimated to be 4-5 cents/kWh. The cost of electricity for steam and gas power plants is about 2 and 2.5 cents/kWh respectively plus the social costs of the three major air pollutants (CO_2, SO_2 and NO_2), which ranges from 3 to 4 cents/kWh (2002). Comparing this total east to the price of electricity generated by wind power plants, could easily demonstrate the cost advantage of wind power plants (CRED, 2002). Iran has been carrying out a set of expert-level studies to set up seven wind power plants in three northwestern provinces. If the results of the studies confirm that the target regions are fine for the purpose, the projects will be immediately started under private sector management. Arastou Sadeqi, the director of the wind and water energies department in the Iran Renewable Energy Organization (SUNA) had earlier said that "the government has removed basic problems on the way of investors and therefore several domestic and foreign companies have applied to subcontract these projects."

He stated that 17 wind measuring stations equipped with 40-meter height masts have been installed in Gilan and Azarbaijan provinces each of which cost the government about $15,000 in investment.

With a youthful population of nearly 70 million and a fast-growing economy, energy consumption is rising by around 7 percent annually. Iran estimates that it may need capacity to generate some 90 GW by 2020, from about 31 GW at present. About three quarters of current electricity needs come from gas-fired power stations, and the rest from hydroelectricity or oil.

4.8 Geothermal

4.8.1. Iran developing geothermal power

Iran has high geothermal energy potential and the main regions for geothermal energy generation are Sabalan, Makoo, Khoy (Azerbaijan Province) and Damavand (Tehran Province). The total potential of geothermal energy is approximately 60 billion Giga Jules (Ministry of Energy, 1998). As for geothermal projects, some studies have been conducted to design a prototype Geothermal Power Plant for producing
electricity. One of the ongoing related projects is a 100 MW Geothermal Power Plant at exploring stage in Sabalan.

In a move potentially telling of the long term state of its oil reserves, Iran is about to drill more geothermal wells.The Renewable Energy Organization of Iran and the National Iranian Drilling Co. (NIDC) have concluded an agreement on the development of an area referred to as the Meshkin-shahr Geothermal Field.

The NIDC has agreed to drill 20 geothermal wells at Meshkin-shahr, located near the northwestern city of Meshkin-shahr, Ardebil Province, according to a report referenced by the Tehran-based news service Mehr News Agency (MNA).

The 600B IRR project ($65M USD) is to become operational by 2009, the managing director of Renewable Energy Organization of Iran said, adding that a 55-megawatt power plant will be also built in the region.

Elsewhere in his comments, he announced that a pilot solar energy generation project is currently underway to provide clean electricity for some 40 households living in the remote rural areas around the cities of Qazvin and Zanjan.In addition to power generation, geothermal heat would assist the development of local communities as a source for multipurpose hot water for use in hot spring facilities, gardening and melting ice on roads.

In Azarbayejan the Iranian Organization for Renewable Energy engaged in geothermal power plant it is plan to finish it by 2011. The Fig.(4.18) shows the site.

Fig.4 18 Geothermal power plant with final capacity of 100 MW in vicinity of mountain Sabalan

CHAPTER 5

5. Iranian Fuel Conservation Organization (IFCO)

Iranian fuel conservation company (IFCO) a subsidiary of National Iranian Oil Company (NIOC) established in 2000 with the mission to regiment the fuel consumption in different sectors through review and survey of the current trend of consumption and executing conservation measures nationwide. IFCO is contemplating to introduce a modern energy management reformation to all Iran economic subsystems and make the way to achieve every goals set for conservation in all energy carriers defined in sustainable energy program of the country. IFOC has defined the CNG projects, substituting the CNG with petrol in the fleet.

-Aims

-Our aims on extending the fuel conservation in Iran are:

- -Enhancing public awareness by publishing books, magazines and advertising campaigns
- -Providing comprehensive programs of energy conservation in transportation systems.(surface, rail, air, sea and pipelines)
- -Enforcing fuel conservation measures in building sector
- -Producing high quality and efficient home appliances and fuel consuming system
- -Implementing energy conservation in industry
- -Providing disciplinary measures to support public conservation culture
- -Assisting research institutes and universities technically and financially to hold energy management training courses for government and private sectors

-

-Energy Conservation Policies

-Wise energy consumption

-Cooperation for reduction of greenhouse gases emission

-

Rule Making Methods

-Regulations, Rules, Standards

-Practical systems

Supporting Methods

-Tax exemption

-Subsidy

-Technology improvement

Informative Methods

-Labeling

-Education & Advertisement

International Cooperation

-Using of Rule Making Methods for Energy Conservation

Step 1: -Establishing standards and set points

Step 2: -Making penalty and encourage industries based on the standards and set points

Step 3: -Inspect the industries based on the standards and set points

With Education, and Advertisement

Commercial sector, houses and household equipment consume more energy than any other economic sectors in Iran.

This consists, 22% of Oil Products, 67% of Natural Gas and 11% of Electricity. The value of energy consumed in year 2005 amounted to 9.898 billion dollars.

The main challenge facing IFCO are dominant non efficient sets of home appliances in the market in one hand and noncompliance's of main stream home builders to the principals of energy conservation on the other.

According to one survey covering whole country consumption per acre meter of buildings is equivalent to 30 m3 of gas per year. This will slime down to 20 m3 in 2020 with implementing IFCO programs, which is still high comparing to European index of 5.5 m3 of gas per year.

The main activities in building department for Fuel conservation:

- The procedure of implementation of the energy regulation in buildings in order to reduce energy consumption in building
- Replacement of proper way of energy with fossil fuels

Increasing the efficiency of home appliances

IFOC support the projects on renewable energy. Their projects are 1000 solar public bath and 120,000 solar hot water supply for residential building in eastern part of Iran. Figs. (5.1-5.2) show 2 systems of residential hot water supply for 4 and 6 persons.

Fig.5.1 Solar hot water for 4 persons

Fig.5.2 Solar hot water for 6 persons

CHAPTER 6

6. Universities activities

6.1 Sharif University:

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Prof. M.N.Bahadori from Sharif University start research on solar energy in 1972. The following article is the review of his activities.

solar energy is five-billion years-old. Living beings have been using solar energy since the start of life on earth. Man began using solar energy since he started roaming the earth. If solar energy can be classed as a new energy, then what are old energies. The only case in which the use of the term "new" for solar energy can be justified is in the production of electricity by this energy.

Solar energy was used for the first time for the generation of electricity for unmanned spacecrafts 50 years ago. In this case solar energy can be classed as a new energy. This is whilst electricity is not the sole energy and mankind used solar energy to generate heat. As a result, the term "renewable energies" can be generalized to include the solar and geothermal energies. Wind and water energies are also classed as solar energies.

The first activities regarding solar energies in Iran date back to some 31 years ago when I was a student at Shiraz University. I became interested in solar energy in the year 1970 and we carried out a number of expert projects at Shiraz University. Some of the projects we carried out that year consisted of the building of solar heaters and water treatment systems and the storage of solar energy in pebble stones.

During my first sabbatical at Arizona State University, all of my time was spent on studying the generation of heat by solar energy. During my second sabbatical in 1975 and the beginning of 1976, I began conducting studies on solar energy at Arizona State University.

When I returned to Iran in the summer of 1976, interest in solar energy had increased in Iran. At that time, Dr. Vozhdani established the Electricals Engineering Centre at Sharif University of Technology. His main area of research was the production of photovoltaic cells for transforming solar energy into electricity. Currently, this centre is located at Karaj's Fardis area under the name of Materials and Energy Research Centre and is affiliated to the Ministry of Science, Research and Technology.

During the 1970s, the Solar Energy Council, in which the then ministers of housing, water and electricity, and head of the Budget and Planning Organization, Dr. Vozhdani and myself were members, was established inside the country. This committee was tasked with outlining the country's solar energy policies.

In the year 1976, the Water and Electricity Ministry invited Shiraz University to take part in projects for the construction of solar power plants.

In the year 1976, the Water and Electricity Ministry invited Shiraz University to take part in projects for the construction of solar power plants with a capacity of one and 10 MW with a capacity of one and 10 MW. We presented a research proposal and it was approved instantly. The projects first credit was secured in 1978. After that, the Islamic Revolution took place and the provisional government's energy minister said that there was no need to use solar energy. As a result, the credit was withdrawn and the project was left defunct. The project was restarted by Shiraz University a few years ago and is now near completion.

Following the Islamic Revolution, the New Energies Development Centre started its activities at the Iranian Atomic Energy Organization. In addition, the New Energies Organization was established by the Energy Ministry some eight years ago. Sharif University has started implementing a few graduate and post-graduate projects from a few years ago. These include:

- The design of a new solar water heater system.
- The design of a new solar heating system.
- The design of a horizontal solar heating system.
- The design and building of green houses which do not use fossil fuels (this project is being implemented under the supervision of the Iranian Fuel Conservation Organization (IFCO))
- A project for the use of solar energy in villages and towns (being carried out under the supervision of the IFCO)
- The project to compare newly designed solar water heaters with those manufactured by the Polar Company (is underway)
- The project for the optimization of solar water treatment systems.

Of course academic research at universities depends on the research interests of lecturers and does not follow a specific general policy. In order for academic research to be in line with the country's needs, related organizations and centres must support such research. To meet this end, lecturers are expected to carry out research in the areas needed inside the country

Prof. M.N. Bahadori from Sharif University his main interest is doing research in natural cooling and has published many papers in this field [5-8]. He tested two new designs of wind towers were tested side by side with a conventional wind tower in the city of Yazd Fig. (6.1). All the towers were of identical dimensions. The two new designs were one with wetted column, consisting of wetted curtains hung in the tower column, and the other one with wetted surfaces, consisting of wetted evaporative cooling pads mounted at its entrance. The air temperature leaving the wind towers with evaporative cooling provisions were much lower than the air temperature leaving the conventional design, and its relative humidity much higher. The air-flow rate was reduced slightly in these new towers. It was found that the wind tower with wetted column performs better with high wind speeds whereas the tower with wetted surfaces performs better with low wind speeds. It is recommended that these new designs of wind towers should be manufactured in different sizes and incorporated in the designs of new buildings. They can replace the evaporative coolers currently employed in Iran, and other hot arid regions, with considerable saving in electrical energy consumption.

Fig.6.1 wind tower in the city of Yazd

6.2Shiraz University:

The University of Shiraz engaged mainly in solar power plant as mentioned earlier beside the academic staff also doing research in solar dryer, solar pond and supervising post graduate student in the field of energy.

6.3University of Tehran

The main activities of Tehran University are doing research on photovoltaic in Dept. of electrical engineering and solar energy in building in Dept. of Fine art.

6.4Meshad University

The academic staffs are involved in solar collector, solar pond, and application of heat pipe in solar and heat recovery system.

CHAPETR 7

7. Materials & Energy Research Centre

The Energy Departments carries out research principally in connection with non-traditional sources of energy, atmospheric and water pollutants presently work on alternatives for fossil fuels is in progress including solar and wind energy.

- The **Solar Energy Group** conducts research on different methods of using solar energy for heating cooling, electrical and chemical applications.
- **The Energy Conversion and Storage Group** is engaged in work on the efficiency and optimization of various methods of storage and conversion of energy and related technological development.
- **The Energy and Environment Group** is involved in the investigation of air and water pollution resulting from traffic, industrial activity and urban wastes. Furthermore, utilization of waster as a source of Energy is also being studied. This group is capable of qualitative and qualitative evaluation of various types of pollutants.

Department of Semiconductors

Activities of this department include growth of various crystals, research on metallic and semi conducting materials, as well characterization of materials and devices mainly by instrumental analytical techniques.

- **The Crystal Growth Group** is engaged in the growth of single crystals, and has so far succeeded in growing single crystals of quartz, silicon, ruby, InSb and cdTe.
- **The Semiconductor Devices Group** carries out research on semi conducting materials and related devices. Notable examples are silicon solar cells, quartz thickness monitors, and Al-doped silicon diodes. Recent work is focused on IR detectors based on materials like PbS, InAs and InSb

CHAPTER 8

8. Iranian Research Organization for Science & Technology (IROST)

In this Organization department of “Advanced materials and renewable energy” are involved in design and construction:

- Solar system design
- Heat pipe
- Solar collectors
- Solar hot water
- Solar public bath
- Storage
- Dryers
- Solar green house
- Solar collectors testing rig
- Heat pipe heat recovery system
- Photo-Voltaic
- Educational kit for school

Some of the projects are shown as follows:

8.1 Solar system design

The direct utilization of solar energy is receiving serious attention due to the increasing public awareness of the worldwide shortage and high price ($120/barrel) of fossil fuels. Various devices for utilizing solar energy have been developed during last decade, among them, flat plate solar collectors, can be used for a number of different applications. The most common applications are residential space and domestic water heating.

The Solar Energy Laboratory (SEL) at Iranian Research Organization for Science and Technology (IROST) is presently operating a solar energy system for heating, service hot water heating, and electricity. It is the first such project to integrate space heating, service hot water heating and electricity for a building in Iran. The solar heating plant was put in full operation in the end of 2006.

A building located in the IROST site with 10 rooms and a hall with kitchen and bathroom. The heating, hot water and electricity were designed to operate with solar energy, Fig. (8.1) shows the plan of the building and solar collectors and solar Photovoltaic for producing electricity (3 KW) are shown in Figs.(8.2-8.3).

Solar system specification

- Collector type — heat pipe
- Collector area — 60 m^2
- Storage tank — 1500 Lit.

- ❖ No. of circulating pumps 2
- ❖ Photo Voltaic 3KW

Fig. (8.1) Plan of the building

Fig.8.2 Solar collectors building

[Type text]

Fig.8.3 Photovoltaic for producing electricity (3 KW)

8.2Heat pipe

Heat pipe is a device to transfer thermal energy with negligible temperature drop, Fig. (8.4) shows a heat pipe. In IROST we applied heat pipes in many field such as solar collectors.

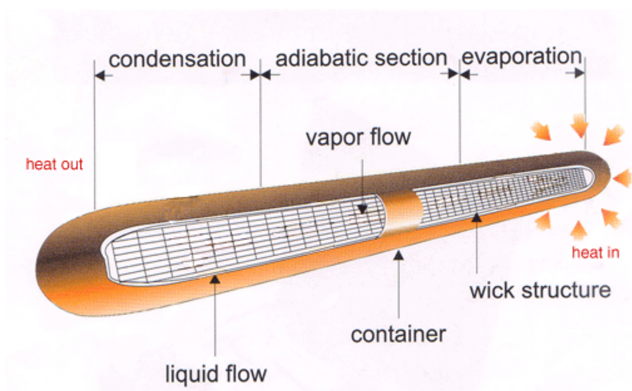

Fig.8.4 Heat pipe

8.3Solar collectors

Different types of solar collectors were designed and constructed, conventional and solar collector is shown in Fig.(8.5) . The collector consists of 6 risers with copper tubes 12.7 mm diameter and 2 headers 25.4 mm diameter. The frame was constructed from aluminium.

Fig.8.5 conventional solar collector

Other types of are heat pipe solar collectors. Heat pipe solar collector was designed and constructed at IROST and its performance was measured on an outdoor test facility. The thermal behaviour of a gravity assisted heat pipe solar collector was investigated theoretically and experimentally. A theoretical model based on effectiveness-NTU method was developed for evaluating the thermal efficiency of the collector, the inlet, outlet water temperatures and heat pipe temperature. Optimum value of evaporator length to condenser length ratio is also determined. The modelling predictions were validated using experimental data and it shows that there is a good concurrence between measured and predicted results. Figures (8.6-8.7) illustrates HPSC [9-10].

Co-axial heat pipe solar collector is shown in Fig.(8.8).The thermal performance of evacuated tube co-axial heat pipe solar collector was analyse theoretically and compared with experimental result. The analysis considers radiative, convective and conductive losses and energy transferred to a fluid flowing through and condenser tube. The theoretical results presented in this paper show good agreement with experimental data. The main advantage of this type of collector is that it is independent of angle of inclination to the horizontal; therefore it can be positioned at any angle from horizontal to vertical [11-12].

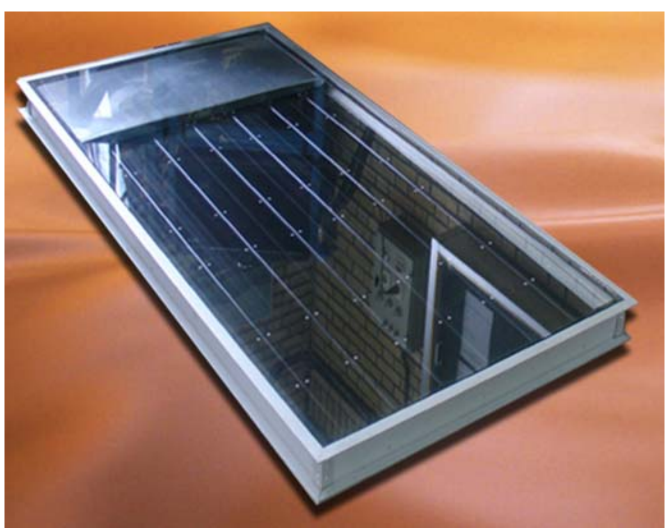

Fig.8.6 Heat pipe solar collector (type 1)

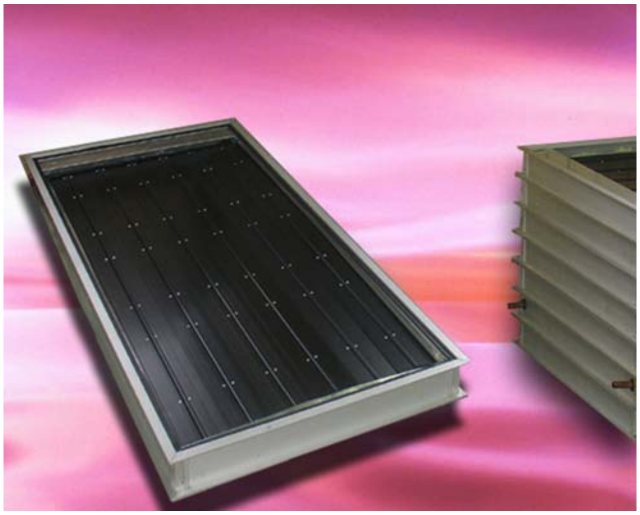

Fig.8.7 Heat pipe solar collector (type 2)

Fig.8.8 Co-axial heat pipe solar collector

8.4 Solar collectors testing rig

IROST is the only centre for testing the solar collectors. Fig. (8.9) shows the testing site of collectors.

Fig.8.9 Collectors under test

8.5 Solar green house

Green house complex consisting of four units 200 sq.m floor area each located in Zabol. This project was sponsored by Sistan development Organization to be heated by solar energy Fig.(8.10). The system was designed and installed and tested. The system consists of 32m2 solar collectors and 2x1000 liters storage tanks as shown in Fig.(8.11).

Fig.8.10 Green house complex

Fig.8.11 Solar Collectors and storage tanks under the structure

8.6 Solar public bath

8.6.1 Bashagard Solar Public Bath

The community of Bashagard is located in an isolated area Fig (8.12), Place where they live (*Kappar*), in the southeastern region of the Islamic Republic of Iran. It enjoys 3,500 hours of sun a year and an average daily irradiation of 22 megajoules per square metre. In 1993, a project to use some of this solar power to heat the water for a new public bath complex was designed and initiated. The solar bath project, which took four months to complete, broke new ground in two ways. It was the first time that public baths were built and opened in the area, and the project uses what is thus far the largest solar power system in the country.

The system consists of two collector fields, each containing four rows of ten collectors. The collectors are connected to a hot-header pipe that feeds a 3,000- litre storage tank by pumps circulating water through a U-tube heat exchanger. The water returns to the collectors via a cold-header pipe. Two 3,000-litre tanks are connected in series and hot water is stored in **a** 6,000-litre main tank that supplies hot water for 12 showers Figs.(8.13). The bath complex can serve up to 400 people a day.

BACKGROUND AND J U S T I F I CATION

Bashagard is a remote community situated some 200 kilometres from the nearest city, Minab, which takes six hours to reach because of precarious road conditions. The area has only five days of rain a year, but the rain that does fall is so heavy that it tends to wash everything away, including the road. Originally, local authorities built a public bath complex that used gasoline to heat water, but this turned out to be far too expensive because of the costs of transporting fuel to the site in Bashagard, gasoline is 15 times more expensive than it is in Minab. It was decided, therefore, that solar energy would be a good replacement for fossil fuel, and the Iranian Research Organization for Science and Technology (IROST) sponsored a project to design and manufacture a suitable solar collector that can supply energy to heat water for the baths.

System description:

Fig.(8.14) illustrates the system that could be used to meet the hot water demand for 400 persons per day. The system designed under the IROST project is divided into three subsystems; the collector subsystem, storage subsystem and demand hot water subsystem.

The collection subsystem: consisted of two collector fields (collector field #1 and collector field #2), each designed with a collector closed loop and the heat exchange;

The storage subsystem: consisting of three storage tanks (storage tank 1 and storage tank 2, 3000 litres capacity each).

The DHW delivery subsystem: This consists of the main storage tank (6000 litres capacity) and the pipeline that delivers hot water to baths.

The collection subsystem:

The 75 solar collectors are arranged in two solar collector fields. These collectors are mounted on a rigid metal frame. The array support structure is tilted 45^o (latitude+20 degrees) toward south. The array row spacing is calculated for no shading of the array on the worst solar day of the year (21 December, when the sun is lowest in the sky in the northern hemisphere). A full assembly solar collector is shown in Figs.(8.15-8.16).

In collector field #1 (33 collectors) there are three rows and each having two banks and each bank contains six and five collectors. The collectors are connected in series through internal manifold built into the collector unit and finally two banks are connected in parallel. Collector fluid in field#1is pumped through U-tube heat exchanger placed at the bottom of storage tank 1. In field #2 (42 collectors) there is three rows and each having three banks and the banks contain 5-5and 4 collectors each that supply heat to the storage tank 2 Fig.(8.17) solar system

The differential temperature controller of the collector loop pump in field#1 is switched on if temperature difference between the collector outlet and tank1 exceeds 5^{o}C and is switched off if the above difference is lower than 5^{o}C. The similar DTC is used in collector loop. In field#1 and field#2 the water is heated indirectly by a heat transfer fluid. The transfer fluid absorbs heat from the collectors. The fluid then passes through a heat exchanger inside the tank that transfers the heat to the water inside the storage tank. A heat exchanger inside the tank provides indirect heating and prevents any cross contamination between the potable water and the collector fluid,

The storage subsystem

Two storage tanks, each 3000 litres capacity are fabricated with galvanized iron to store hot water. The tank diameter is 1.25m and height is 2.5m. Both tanks are well insulated to minimize thermal losses to the environment. The storage tanks are located adjacent to the west wall of the bath in order to reduce the piping cost as well as heat loss due to piping Fig. (8.17) shows the two storage tanks. During a demand hot water consumption phase, cold water from the main enters the bottom of the first tank, thus removing an equal volume of water from the main tank and finally to the user.. This arrangement ensures that the storage tanks are always full. The tanks 1 and 2 are connected in series. The demand hot water is preheated in storage tank1 by solar field#1 before it passes to the storage tank2 take up all energy delivered by solar field#2. In storage tank 2 following the preheat tank insufficient hot water temperature is heated up to required temperature. The water in main storage tank (6000lit.capacity) is heated by circulating hot water between storage tank 2 and main storage tank by a circulating pump. The main storage tank supplies hot water to twelve shower public bath. A 200-litre expansion tank is installed on the roof. This tank provides volume for liquid expansion and permits boiling to occur in the collectors without pressure built up. If the circulating pump fails, boiling result in some loss but expansion tank can refill the.

The DHW delivery subsystem

The main storage tank is 6000 litres capacity is insulated with 0.1m fibreglass insulation and is heated by circulation of hot water from storage tank2 by a circulating pump. The hot water is drawn from this tank.

Fig. 8.12 Place where they live (*Kappar*)

Fig.8.13 Plan of solar public bath

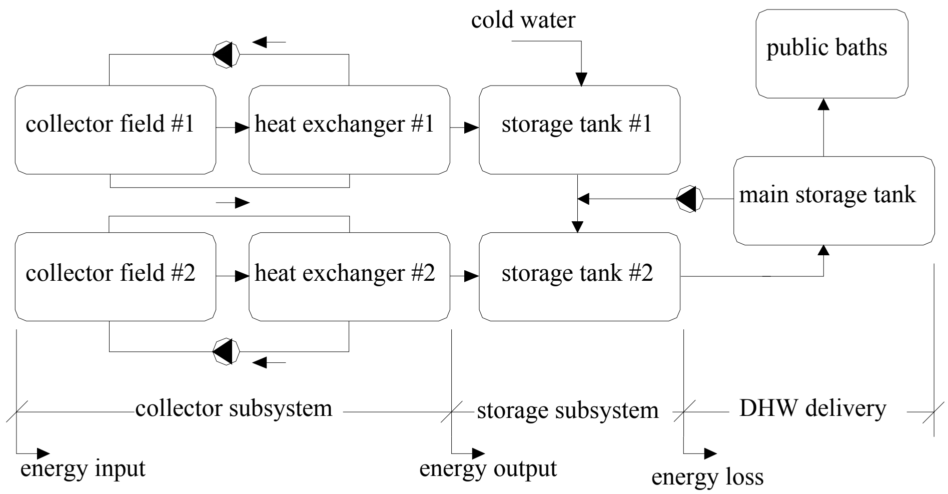

Fig.8.14 solar system layout

Fig.8.15 Front view of solar collectors

Fig.8.16 Side view of solar collectors

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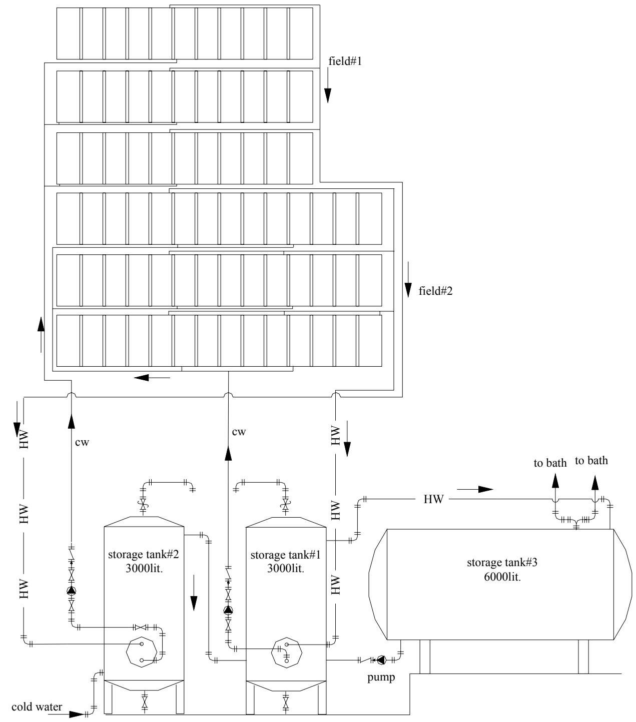

Fig.8.17a solar system

8.7 Hadji-abad Solar public bath

A project that supplies hot water for 12 showers and 4 private baths for a public bath complex was designed and installed to serve 150 people a day. It was built in 2004 in the village of Hadji-abad in the eastern part of Iran. The installation is comprised of two solar collector fields (195 m^2) and two storage tanks of $3m^3$ capacity each Fig.(8.17a). This paper emphasizes the factors associated with subsystems that are required to extract heat from 195 m^2 solar collectors, store this heat in two thermally insulated hot water storage tanks and the heat distribution system with electrically operated pumps for water circulation. Fig. (8.18-8.19) show the installation and completion of the project.

System description

The present public bath consists of 12 stall showers and 4 private baths as is shown in Fig.(8.17b). The solar system is designed for 150 persons per day with 100 liters of hot water at 60 ^oC per person and 100% solar share (part of tender). Fig.(8.18) shows the simplified diagram of the system. The collectors are tilted to the attitude angle plus 12 degrees facing south with 15^o azimuth angle due west, in order to retrofit to existing facilities. The system composed of 100 collectors. Each collector has 1.95 m^2 of absorber area yielding a total collector area 195 m^2. Water from a cold water main enters the preheat tank and is circulated through a heat exchanger. On demand, water from the preheat tank enters heat tank which will boost the water temperature.

Subsystem

The schematic of the solar system. It consists of solar collector fields, storage tank, fluid distribution system and control system. The details of each subsystem are given blow.

Solar collector field

Total collectors are divided into two fields. Although this approach is somewhat more costly, it is improve the ease of construction and allows solar energy to be collected in the event of one system being down due to maintenance or repair. Field 1 (60 collectors) and field 2 (40 collectors) Fig.(8.19-8.20). In field 1the array with sixty collectors divided into two rows with one on the top of the other. Each row is grouped into six banks of five collectors with manifolds built into the collector unit. The collectors are connected in series-parallel arrangement. In field 2 the array with forty collectors has two rows and each row with four banks. The collectors are mounted on a rigid metal frame. In field 1 the solar energy passes through the cover glass is absorbed by the absorber plate. The heat generated is then transferred to the collector fluid, a 20% solution of ethylene glycol (antifreeze) in water. The collector fluid is pumped from heat exchanger into the lower distribution manifold, up through the collectors, and into the upper manifold. From the upper manifold the heated fluid returns to the heat exchanger where heat is transferred to storage tank Fig.(8.21) . In field 2 the hot fluid from collectors heats the water from a cold water main enters the pre-heat tank. The arrays are separated by 5m measured from the front edge of collector to next; this distance is the maximum possible distance that was available. The overall array dimension is 60m by 12m that sits on prepared base of gravel. Fig.(8.22) shows the complete system.

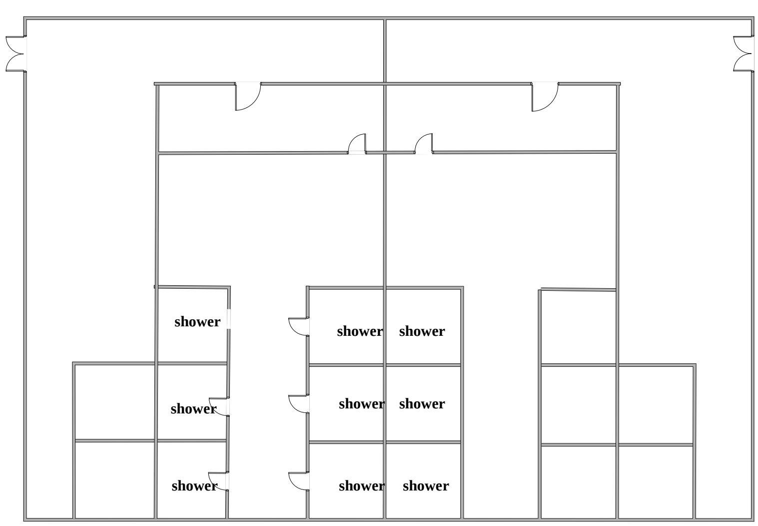

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Fig. 8.17b Plan of public bath

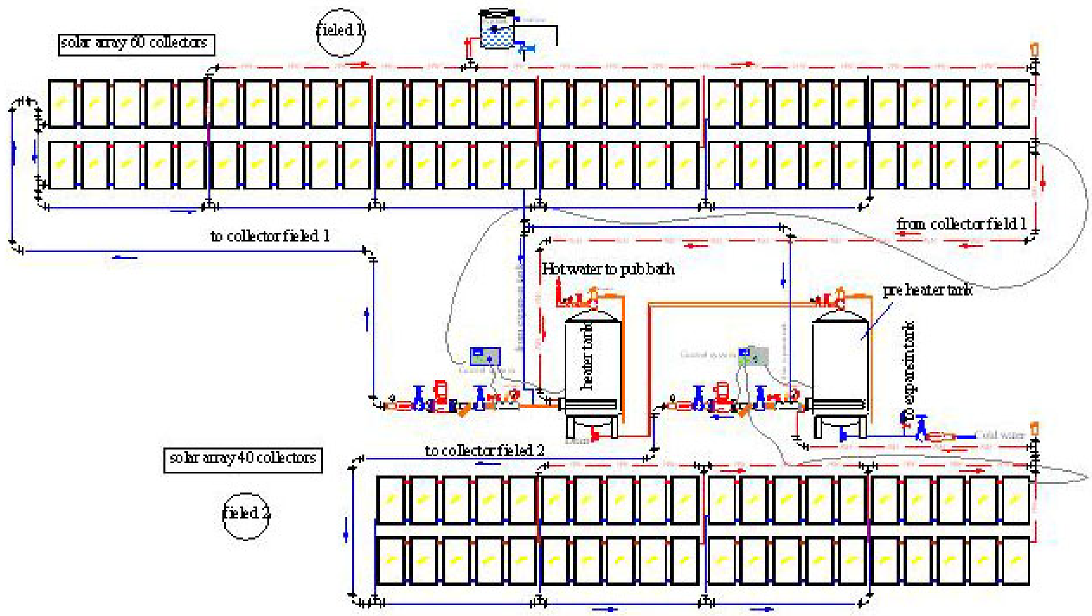

Fig. 8.18 Solar system

Fig. 8.19 Installing solar collectors

Fig. 8.20 One row of solar collectors

Fig. 8.21 Two storage tanks under the structure

Fig. 8.22 System is completed

8.8 solar agricultural dryer for rural area

The solar dryer described in this paper can be used for drying various products in rural area under hygienic conditions. This solar drying system was constructed, consisting of two parts (solar collector and solar drying cabinet). Solar collector with area of 1.2m^2 (1.2mx1mx0.2m) has black painted rocks to absorb solar radiation and a cabinet that is divided into five divisions separated by four removable shelves. Each shelf is 0.3m width and 0.5m length and made of nylon wire net framed in wooden border. Three sides of the drying chamber walls are covered by fibreglass sheet and a door in the back. Grapes were dried during the present work. The moisture content of grapes was reduced from 81.7% to 36.7% within five days of drying. The drying air flows through the product by natural circulation Fig. (8.23).

In this work two modes of operation are discussed. The results were applied to the design of modified large scale solar agricultural dryer Figs. (8.24-8.25). This project deals with a suitable design of a solar agricultural dryer that can be built in rural area with locally available construction materials and skills [14].

Fig. 8.23 Solar dryer

Fig. 8.24 Modified solar dryer

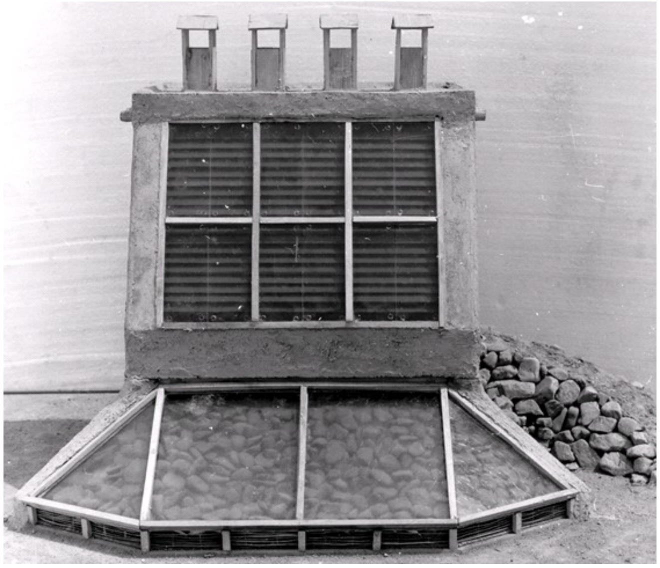

Fig. 8.25 Modified solar dryer

8.9 Forced circulation solar hot water supply

Two projects were designed and installed in Zabol the first one was solar hot water supply for *Mosala* (mosque) of Zabol and 2nd one Mosala of Zahak about 20 Km from Zanol. Figs (8.26-8.27) show the solar collectors in two sites.

Fig.8.26 Solar collectors for *Mosala* of Zabol

Fig.8.27 Solar collectors for *Mosala* of Zahak

8.10 Heat pipe heat recovery system

Different types of Heat pipe heat recovery system (HPHRS) were designed and tested, the types of (HPHRS) are:

- o Air-to-air HPHRS, Fig.(8.28) [15-18]
- o Air-to-water HPHRS [19-20]
- o water-to-water HPHRS
- o water-to-air HPHRS, Fig.(8.29) [21]

New type of HPHRS named split heat pipe heat recovery system Fig.(8.30) was designed [22].This paper describes a theoretical analysis of a split heat pipe heat recovery system. The analysis is based on an Effectiveness-NTU approach to deduce its heat transfer characteristics. In this study the variation of overall effectiveness of heat recovery with the number of transfer units are presented.

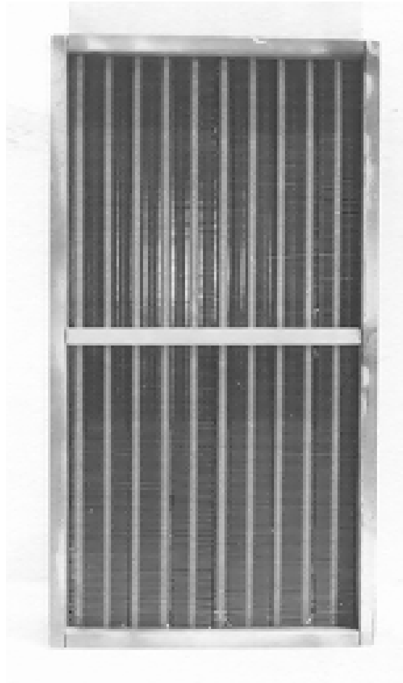

Fig. 8.28 Air-to-air HPHRS

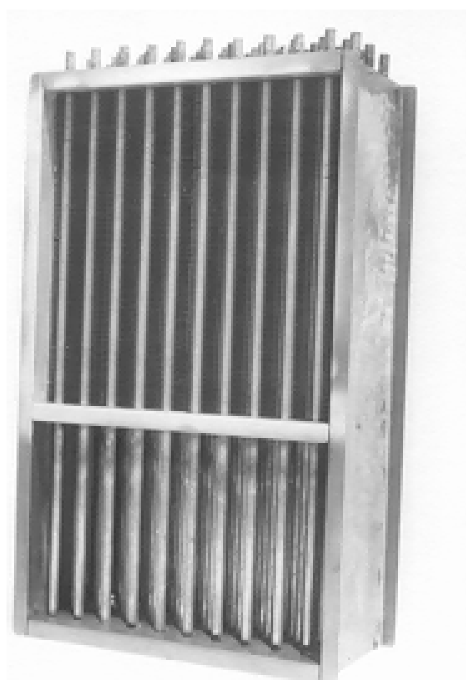

Fig. 8.29 water-to-air HPHRS

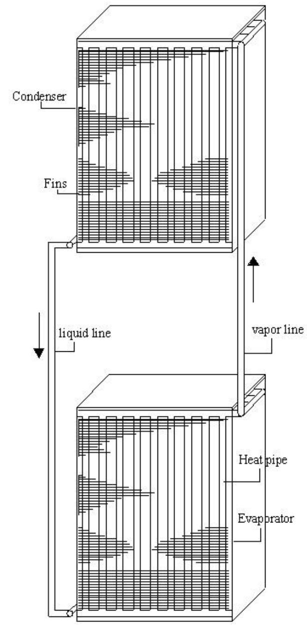

Fig. 8.30 split heat pipe heat recovery system

CHAPTER 9

9. Important R&D and other support institutions for promoting RET for developing contries

١- Renewable energy education from primary school to higher education

- For developing nations would be to reform subsidy programs by focusing them on financial, social and environmental sustainability.
- The largest subsidy is a production subsidy per kWh for electricity generated from renewable energy resources
- To build public awareness of the benefits of renewable energy and energy
- Publishing journal on **renewable energy** by **APCTT**

CHAPTER 10

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CHAPTER 11

Conclusion

Substitution of fossil fuels

Energy technology has to continuously redefine it in order to adapt to the new and emerging situations and circumstances. Renewable technologies are of no exceptions. It is time to think about the likely scenarios in the Five-Year National Development Plan of Iran and how renewable energy can establish

itself in the changing environment. First we need to ask what are the criteria that determine choices of the energy technology. Moreover, as we review this progress during last decades, the renewable sources have not captured even 1% of energy market in Iran. New contexts have emerged recently, as outlinedbelow:

1. How does renewable energy help to replace conventional energy? First, with time, people have more incomes and demand more convenient forms of energy. These energy systems require investment and management. Second it is desirable to switch to better energy forms.

2. How renewable energy can claim higher share of the conventional energy market? Limited availability of fossil fuels and ever increasing environmental concerns would enhance the market share of the renewable energy.

3. What are the environmental concerns both in terms of local and global scale, which would make renewable energy preferable? What opportunities do they offer?

4. Over the years, subsidies have made conventional fuels favorable. Moreover, general population has got used to receiving subsidies in the energy sector.

5. Urban areas need energy on a large scale. Their desire for reliability (24 hours availability) is of extreme importance.

6. The present cost structure is not favourable to renewable energy. If all the external cost is accounted for such as environmental costs, health impacts, etc., some of the renewable energy sources may be advantageous in certaincases.

Now, let us discuss the new contexts in which we have to examine renewable energy, and investigate factors that determine choices for the type of energy system.

Factors that determine choices for energy system

What factors are considered while selecting an energy system? Some criteria are illustrated below. ***Technology***: This, include factors such as Scale of Technology (e.g., wind power or nuclear), Efficiency, Locked-up Infrastructure, Product Designs, and Standards.

Costs: Questions such as Who pays?, Who finances?, What are the Interest Rates, Capital Costs, Economic Conditions, Taxes & Subsidies and Relative Prices of Energy Forms?

Accessibility: Reliability, Infrastructure, Competitiveness, Total Potential, Inadequate Supply, Storage or Hybrid System.

Environment: Pollution, Climate Change, Proximity of Pollution to People, Health and Welfare Concerns, Environmental Impact on humans, property and all living things including plants, animals and agriculture.

Politics: War, Sanctions, Subsidy and Regulation.

Demographic: Life Style, Urban-Rural, Family Size, Age Profile and Personal Values.

Convenience: Time needed Familiarity, Habit and Pleasure.

Safety : Risk Perception, Potential Catastrophe, Sustainability, Renew ability, Future Generation.

Information: Media, Education and Marketing

Challenges in promotion of RETs in Iran

The Islamic Republic of Iran lacks policy frameworks that stipulate provision of energy for sustainable development. This poses a great challenge to promote RETs in the country.Appropriate policies are required to successfully implement RETs. Although policy directives have been issued in Iran, stakeholders have not been advised on how to implement them as strategies and long-term policies, i.e., implementation guidelines are lacking. The contribution of RE to the total energy mix is still small, due to lack of knowledge about their potential and insufficient social and environmental policies and programs to encourage their use / implementation. Iran has found it difficult to implement the existing policies and enforce the laws due to lack of infrastructure. The diffusion of RETs has been hampered by lack of training, maintenance and capacity to purchase the technology. Majority of governments in developing nations rely on bilateral or multilateral funding to support RE activities. The external financial aid is not guaranteed and is sometimes tied to meeting donors' conditions, which vary from country to country. The policies that require more attention are those that restrict dissemination of

RETs. The present policies in Iran have serious shortcomings as they lack provisions on standards to ensure quality in the provision of energy. The techno-economic boundary conditions, lack of infrastructure, capital and the tradition of technical standards, represent severe restrictions to rapid expansion of RETs. There has been a tendency by policy makers to compare RE with conventional sources of energy in terms of amount of energy generated. These collective conditions and restraints have made the Islamic Republic of Iran unable to implement the RETs.

Policy options The philosophy behind any energy related policy change should be to improve the living standards of the rural and urban inhabitants. Policies should make RETs people orientated, i.e. policies that involve or take into consideration socio-economic needs and cultural background of the beneficiaries in its implementation are preferred. Incorporating the local people into new RE projects is part of the solution to the problem. A successful RE program must be based on the wishes and needs of those people who will use it, and must be driven by their demand for services (light, water pumping, etc.) rather than simply focusing on providing energy technologies (Magoha, 2001). With increasing problems of accessing external financial aid, the government of Iran should not rely on donor support to fund RE projects instead, devise or look for other ways to get funds for RE programs. In order to move

forward, formulations of strategies that stimulate development of RE markets are required. The governments of developing countries can encourage the development of RETs by creating legal and fiscal instrument, which promote RE development, contribute financial resources such as direct funding or subsidies, and encourage partnerships between local industry and RE companies in developed countries.

International collaboration

The objective of setting up business partnerships between local industries in Iran and RE companies in developed countries is to rationalize the management of product quality, by reducing the use of sub-standard equipment. In order to sustain the development of RE projects the issues must be approached in a multi-stakeholder approach in decision making and management of the RE projects. The objective of the RE projects should be to build partnerships with stakeholders through a process of mutual learning; familiarizing people in the country with new technologies and practices; and organizing seminars and
workshops to discuss the successes and failures of these technologies and practices. Various partners can either fund the initiative in kind or in cash. The advantage of partnerships will offer comprehensive project capabilities and allow partners to work closely together to bring RE to the potential beneficiaries for sustainable development. The partnership expertise should include assistance
in development of technical, financial and administrative models. The extensive experience that the
international institutions have accumulated can be passed on to upcoming RE businesses in Iran. The funds allocated for implementation of RE systems can be optimized by concentrating on those applications for which economic advantage is plausible and which are socially and ecologically compatible. Technologies related to RE sources are specifically involved with transfer problems,
because they are very specific to local situation and environment. Therefore, there is a need for
clear definition of the roles of different parties involved in partnership.

Role of RE companies/ Organizations in Iran

• Provide bulk of initial capital in the form of loan to fund RE projects. The costs include, provision of hardware and technical knowledge for setting up, implementation and running of the projects.

• Adaptation of the technology to the local conditions. Ensuring that systems are well designed and installed using quality components.

• Supervise RE projects' construction.

• Train local personnel in all aspects of RE technology management to a self-sustaining level. To ensure the success of the RE program, adequate ongoing service and maintenance is very important. This entails organizing training program on manufacture, assembly, financing, installation, maintenance
and use of the RE systems.

Role of the Iran government in international collaboration

• To be responsible and accountable for providing a clear line of communication between the partners involved in a collaborative business venture.

• Ensuring an open and participatory relationship with the partners at all times, together with maintaining a structure and involvement of partners that is unambiguous.

• Ensuring that all administrative issues pertinent to the smooth running of RE projects are in place and maintained.

• Ensuring that there is a cohesive approach to RE project implementation and the required infrastructure in place to support the best practice to flourish and the poor practice to be eliminated.

• Standardization of technology i.e., ensuring that technology transfer is optimized with respect to local production costs (labor, capital, energy and materials), local needs, local regulations and laws.

• Provide security and act as a guarantor for any financial loan advanced to local companies / organizations.

• Provide guidelines for loan recovery scheme. The loan repayment scheme should be agreeable to all parties involved in the partnership.

• Provide legal framework for regulating monopolistic control and restrictive practices that hinder RE systems development.

Role of local business companies / organizations in Iran

• Provide a portion of agreed initial capital (appropriate financial commitment required) for RE project in exchange for the partnership effort.

• Mobilize all communities to support RE projects in kind or cash. With the proper level of involvement and participatory ownership of RE projects by people themselves, it can be a huge success.

• Administer the future management and maintenance of RE projects. The proposed international collaborative business venture model for RE project implementation will work with the following assumptions in place:

• Finance is available to implement RE projects.

• The supporting role of the government in RE projects is corruption free.

• Local communities support RE projects.

Interest groups

The inadequacy of current policies could be addressed by involving various interest groups in RE development plans. Community leaders and NGOs should be instrumental in initiating programs to boost the use of RETs, including convening leaders' meetings to work out plans for promoting RETs. However, these efforts require encouragement by governments and a commitment by communities

themselves. Cultural practices that hinder promotion of RE are issues that can only be addressed through a larger framework. People must define their needs, and the imposition of foreign inappropriate technologies without involving the local people, should be discouraged.

Global environmental concerns: Opportunitiesfor Iran

Climate Change is an expected phenomenon due to the emissions of green house gases mainly from burning of fossil fuels, coal, oil and gas. Renewable energy offers zero-GHG-emissions alternative.

The sixth meeting of the Conference of Parties (COP-6) was held in the Hague. The parties were countries that agreed on the Framework Convention on Climate Change (FCCC) at Rio in 1992. Thus the COP negotiations deal with the future of our domestic energy and its policies. In the climate change debate it is also pointed out that unsustainable consumption patterns of the rich countries account for 70% of fossil fuels. This was recognized in FCCC and a differentiated responsibility for different countries was accepted. Therefore, the convention offered several benefits to the Developing Countries

(DCs) such as access to global environment facility to fund their projects on renewable energy; presents technology transfer and costs of capacity building, reporting and country studies. This is a good opportunity for Iran. Subsequently, the Clean Development

Mechanism (CDM) was proposed in the Kyoto Protocol. This can mobilize private investment in the developing countries (DCs) for more efficient use of fossil fuels and therefore cleaner development by bringing much needed capital and new technology. In return, the investors would claim some emission reductions for their countries. Thus CDM offers developing countries finance and technology. Since the cost of reducing emissions is much lower in developing countries compared to Industrialized Countries

(ICs), the latter would provide incentive to appropriate technology and finance (UNDP,1997). Technology Transfer (TT) promised in the FCCC at Rio could now be linked with CDM so as to ensure wider adaption of the technologies beyond the CDM project. That is, the "CDM project" should have a

programmatic context of a long-term nature. Another way to obtain financial assistance and another opportunity for Iran is through the Global Environment Facility (GEF), which encourages fossil fuel substitution and promotion of renewable energy.

Concluding Remarks

Lack of finances, poor installation and lack of maintenance are the major hindrances to the ongoing adoption of RETs in our country. Any co-operation between international and local institutions is bound to produce productive results because international institutions have developed proven expertise in various RETs. They have also built an enormous level of experience in dealing with RE financing and implementation. The international institutions have ISO 9001 and ISO 14000 registrations that assure the quality and environmental responsibility that the Islamic Republic of Iran requires. The government of Iran could put in place programs that would complement and strengthen RE enterprises by initiating internal reforms that would involve private sector participation. Therefore, RETs offer huge opportunities for social and economic development of Iran. Another critical aspect is the integration of RE courses into a regular training curriculum to tertiary and higher educational institutions at the local, regional and national level within Iran. So Iran needs radical changes in energy sector policies in order to move to harmoniously joint thinking, policymaking and action. The biggest change required is to place environmental objectives at the top of global, national, and personal priorities. This shift definitively does not mean ignoring country's basic needs satisfaction, or its economic and social advancement. But satisfaction of Iran's objectives must be made compatible with environmental goals. This means far greater transfers of financial resources, technology and know-how from industrialized countries to developing ones for environmentally friendly progress.

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CHAPTER 12

List of manufacturers and dealer in Iran

Iran Wind Turbine Co. Ltd
- **Business type:** manufacturer, importer
- **Product types:** wind energy system components (small), wind turbines (small), wind energy towers and structures (small).
- **Service types:** design, engineering
- **Address:** Apt. 31, No. 180, Ghaem- Magham Ave., Tehran , Iran
- **Telephone:** +98-21-872-4222
- **FAX:** +98-21-872-2148

Saba Niroo Co.
- **Business type:** Design, Manufacturering, Installation & Commissioning of large Wind Turbines.
- **Product types:** 1500 kW and 660kW Wind Turbines..
- **Service types:** Design, Manufacturing, Installation & Commisioning ,Technical and after Sales Services of Wind Turbines-Design, Manufacturing and Production of Composite Industrial Structures-Design and Manufacturing of Fiberglass Molds-Test of Composite Materials
- **Address:** P O Box: 33315/187, Shohada-ye-Sadid St., 9th Km of Saveh Road, Tehran 3319973416, Tehran Iran
- **Telephone:** +98 (21) 5525 6136-7
- **FAX:** +98 (21) 5525 5912

C-1 PAYA Engineering Co.
- **Business type:** Consultancy, Design, Engineering, Feasiblity Studies.
- **Service types:** Consultancy on wind energy Systems (for Iran)
- **Address:** (Unit 10) No 4, 9th Mokhberat Ave, Sarve Square, Saadatabaad, , Tehran, Tehran Iran 198119918433
- **Telephone:** 989123108473
- **FAX:** 982122119051

Iran Wind Turbine Co. Ltd
- **Business type:** manufacturer, importer
- **Product types:** wind energy system components (small), wind turbines (small), wind energy towers and structures (small).
- **Service types:** design, engineering
- **Address:** Apt. 31, No. 180, Ghaem- Magham Ave., Tehran , Iran
- **Telephone:** +98-21-872-4222
- **FAX:** +98-21-872-2148

MONA
- **Product types:** biomass energy systems, wind energy assessment equipment, gas turbine electric generators, wind energy assessment equipment, Diferent Parts of electric grids.
- **Service types:** consulting, design, engineering, research services, site survey and assessment services
- **Address:** no 8, Shahed street, Manzarriyyeh, Tabriz, East Azerbaijan Iran
- **Telephone:** 0098-411-4772860
- **FAX:** 0098-411-4791135

SOLARPOLAR

Dear Sir/Madam We're a mass manufacturer & exporter of SOLAR WATER-HEATERS in Iran that can produce HI-FI water heaters in high quantity & capable to transform our technology to you too. We have also cooperation with other countries & a good market among them. We would be so glad to start a new & nice cooperation with you. To know more about us & also our products plz take a look in our websites. For other information, don't hesitate to call me. Solar polar Co. M.Sokoot Manager of Company

Website:www.solarpolar.ir E-mail: .com Add: Solar polar Company, Buali 5, Line 3, Mourche Khort Industrial Zone, Isfahan, Iran Tel: +98-312-5643260 / 5643661-5 Fax: +98-312-5643666

- **Business type:** manufacturer, exporter
- **Product types:** solar water heating systems.
- **Address:** Buali 5 St., Line 3. Moorchekhort industrial, Isfahan, Iran 98
- **Telephone:** +983125643260
- **FAX:** +98-312-564-3666
- **Web Site:** http://www.solarpolar.ir
- **E-mail:** Send Email to solarpolar

Omid Sameh Industrial Engineering Consultants

- **Business type:** manufacturer, retail sales, wholesale supplier, exporter, importer
- **Product types:** solar lighting systems, solar water heating systems, cathodic protection systems, photovoltaic modules, compact fluorescent lighting fixtures and ballasts, LED lighting, packaged power systems, Batteries, Inverters, Controllers and other Alternative Energy Components, solar lighting.
- **Service types:** consulting, design, installation, construction, engineering, project development services, education and training services, research services, site survey and assessment services, architectural design services, contractor services, maintenance and repair services, testing services
- **Address:** 4Th. Floor - No.178 Karimkhan Zand Ave., Tehran, Tehran Iran 15847
- **Telephone:** (98 21) 8882 - 4719
- **FAX:** (98 21) 8882 - 9557

Peyman Energy Nafis Engieering Company

Peyman Energy Nafis is an Iranian system integrator and supplier for Solar and Renewable Energy systems, as EPC contractor of the projects.

- **Business type:** retail sales, wholesale supplier, importer
- **Product types:** batteries lead acid, photovoltaic systems, solar street lighting, solar water pumping systems, telecommunications power systems, water filtering and purification systems.
- **Service types:** consulting, design, installation, construction, engineering, contractor services
- **Address:** Apt. No 3, No. 32, Borna St., Iranshahr st., Karimkhan Ave. , Tehran, Tehran Iran
- **Telephone:** +98-21-88810606
- **FAX:** +98-88844410
- **Web Site:** http://www.mekialenergy.com
- **E-mail:** Send Email to Peyman Energy Nafis Engieering Company

Developing Utilization of Renewable Energies

Developing Utilization of Renewable Energies (D. U. R. E) is a private corporation, mainly dealing with the issue of conservation of energy in the country. Our business targets are to introducing the alternative energies. Also we try to introduce more modern options for the sectors that are active in urban planning and construction as well as to instructing the consumers particularly in the post ear of reduction of subsidize energy. Iran's long term major subsidize policy of energy is a long term problems. Thus the policies of the conservation of energy soon will be reconsidered by the government and that is the field of activities we try to finding solution and offering them to the consumers. We promote solar heat, photovoltaic, Wind and g...

- **Business type:** retail sales, construction, consultation, education, environmental activities.
- **Product types:** Solar heating: solar modules in different types, capacity and sizes. Boilers, different heating transfers. All parts of mechanical or electrical equipments including sensors, thermostats and power controls. Pumps with different capacities and power related to solar heat energy. Photovoltaic: Monochristal and polychristal panels, battery, convertors and control charges and etc□ . .
- **Service types:** consulting, design, installation, architectural design services
- **Address:** Homand, Lavasan, Tehran Iran 334176664971
- **Telephone:** +9821 26551602

- **FAX:** +9821 26550432
- **Web Site:** http://www.dure.ir
- **E-mail:** Send Email to Developing Utilization of Renewable Energies

Renewable Energy Organization of Iran-SUNA

- **Business type:** government organization
- **Product types:** photovoltaic systems, solar water heating components, solar electric power systems, solar tracking systems, solar water pumping system components,solar thermal powerplant,parabolic through,CRS,Mirrors for solar reflectors,control systems,solar dryers, solar water purification, .
- **Address:** Yadeghare Emam Highway Pounake bakhtari Ave.Shahrake Ghods, Mr.Peyman Kanan, Tehran, Tehran Iran
- **Telephone:** +982188362155
- **FAX:** +982188362155
- **Web Site:** http://www.suna.org.ir
- **E-mail:** Send Email to Renewable Energy Organization of Iran-SUNA

Alton Ray Co.

- **Business type:** manufacturer
- **Product types:** solar lighting systems, LED lighting.
- **Service types:** engineering
- **Address:** No 14-Nader St-Tohid Av-Tohid Sq, Tehran, Iran
- **Telephone:** +98-21 66 93 49 00
- **FAX:** +98-21 66 42 21 24

Arianet Network Engineering Co

- **Business type:** retail sales, wholesale supplier, exporter, importer
- **Product types:** photovoltaic module components, solar electric power systems, solar charge controllers.
- **Service types:** consulting, design, installation, engineering, project development services, education and training services, research services, site survey and assessment services, maintenance and repair services
- **Address:** Charbagh Bala Koocheh Sarkoob #124, Esfahan, Iran 81638-54555
- **Telephone:** +98 311 666 2100
- **FAX:** +98 311 666 2007

Diesel Shargh Co.

- **Business type:** exporter, importer
- **Product types:** fuel powered electric generators, marine power systems, solar water heating systems.
- **Address:** 2nd Floor - No.6 - Homa St. - Northern Kargar St - , Tehran, Tehran Islamic Republic Of Iran
- **Telephone:** 0098 21 694 29 87 - 88
- **FAX:** 0098 21 694 45 12 - 0098 21 413 87 54

Electrocontrol

- **Business type:** manufacturer
- **Product types:** solar electric power systems, solar tracking systems, solar collector.
- **Address:** #12 Bldg.135 Molasadra Av., Tehran, Iran 933312
- **Telephone:** +98 21 803 3331

Hamoon Motor Co.

- **Business type:** retail sales, wholesale supplier, importer
- **Product types:** solar water heating systems, photovoltaic systems, solar electric power systems, renewable energy system batteries, dc to ac power inverters, geothermal energy system components, solar powered lights.
- **Service types:** importing the solar system equipments, installation, maintenance
- **Address:** No,11.11Th Floor, Goldis Tower, Sadeghieh 2nd Sq, Tehran, Iran
- **Telephone:** 0098 44288228/44288229/09123727327
- **FAX:** 0098 21 44288228

Infocell Iran Co.

- **Business type:** Manufacturer, wholesale supplier, exporter

- **Product types:** Solar water heating systems, Photovoltaic System integration, Distribution of Photovoltaic Cells and Panels, Air filtering and purification systems, Remote Solar Power systems, Engineering and Supply of Water & Waste Water Treatment Plant Equipment, Chemicals and Instrumentations.
- **Service types:** Engineeing and Project implementation on E. P. C and Turnkey basis
- **Address:** # 84, Manoucheri Ave., P. O. Box 81655-861, Isfahn, Isfahan Iran 81438
- **Telephone:** +98-311-221 1358 (12Lines),
- **FAX:** +98-311-2226176

KARANDISHAN

- **Business type:** Engineering, Wholesale Supplier, Import, Export, Solar Contractor
- **Product types:** Photovoltaic Systems(Grid Connected & Stand-Alone), Solar Water Pumping Systems, Solar Water Heating Systems, Solar Thermal Systems, Solar Water Purification Systems.
- **Service types:** Engineering Services
- **Address:** Apt. 4, No. 96, Ebnesina St., Yousefabad Ave. , Tehran, Iran 14346-53633
- **Telephone:** (+98-21) 8806 4101- 8806 3458
- **FAX:** (+98-21) 8806 4431

NOR AFARIN

- **Business type:** importer
- **Product types:** solar outdoor lighting systems, solar garden lights, solar charge controllers, solar electric power systems, solar garden lights.
- **Address:** AFRIKA AVE.GOLSHAHR ST. NO.15 , TEHRAN, IRAN IRAN 19165
- **Telephone:** 09821-2012939
- **FAX:** 09821 201334

Pasargod Solar Energy Industry

- **Business type:** wholesale supplier, exporter, importer
- **Product types:** solar garden lights, solar electric power systems, solar lighting systems.
- **Service types:** engineering, project development services
- **Address:** Moallem Blvd Serayeh Moallem, Mahestan Building, 5th Floor Suit 9, Rasht, Gilan Iran 41556-45734
- **Telephone:** 09125800337

Solar Sanat Bargh

- **Business type:** retail sales, wholesale supplier, importer
- **Product types:** photovoltaic modules, photovoltaic systems, portable power systems, DC to AC power inverters, DC lighting, solar water pumping systems, Telecommunication power systems, Solar street lighting, ...
- **Service types:** consulting, design, installation, engineering, project development services, education and training services, contractor services, maintenance and repair services
- **Address:** Unit#16 No.3 Golnabi Ave. Shariati Ave., Tehran, Iran
- **Telephone:** 009821-22866282
- **FAX:** 009821-22866281

Trust Trade Co., Ltd.

- **Business type:** importer
- **Product types:** solar electric power systems, solar lighting systems, solar air heating systems, solar roofing systems, solar water heating systems, solar water pumping systems, Generally we are willing to work on Solar systems as importer of the products & Know-how.
- **Address:** No. 38, Shariati St., , Tehran, Tehran Iran 1931654914
- **Telephone:** 0098 912 7240679
- **FAX:** 0098 21 22218259

Yekta Behineh Tavan

- **Product types:** photovoltaic systems, solar thermal energy, wind turbines (small), solar water pumping systems, solar water heating systems, LED lighting, Solar air conditioning.
- **Service types:** consulting, design, installation, construction, engineering
- **Address:** #10 East Taban, South Naft st., Mirdamad Blvd, Tehran, Iran 1549848611
- **Telephone:** +9821 2290 3730
- **FAX:** +9821 2290 3750