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Feasibility Assessment of the Implementation of Solar and Wind Energy Technologies in the Current Context of Iran-Case Study: Kerman

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Abstract

One of the most important issues in various energy issues is to decrease fossil fuel energy usage and promote renewable energies in developing countries. Iran as a developing country began exploiting renewable resources from the early 1990s. This paper investigates the financial viability of renewable energy technologies in Kerman, which is located in the hot and dry parts of Iran and has a high potential of solar and wind energy. First the potential for solar and wind energy sources are studied and afterwards through two quantitative methods, the cost of this implementation is compared to the benefits gained. The results prove that without a massive financial support by the government, renewable energies would not be economically feasible to be implemented into private households.

Keywords: Renewable energy; solar energy; wind energy; collaborative design; design management; knowledge management

1.0 INTRODUCTION

Climate change and Peak Oil are two driving forces behind a new trend of adopting renewable energies. Traditional technologies that relied on fossil fuels disseminate Green House Gases (1), which further intensify global warming and climate change (2). Moreover, our understanding of Peak Oil and the fact that in possibly near future, fossil fuels would be too expensive for the general population have tempted us to consider alternative means of energy production.

However, the renewable energy industry is rather young and the current technologies are not so efficient. Furthermore, their large-scale implementation is limited to developed countries. While developing countries have taken some steps to transition to a fossil fuel free economy, most of their efforts have been curbed to pilot projects or academic research endeavors. In order to assess the feasibility of a large-scale implementation of renewable energy technologies, the on-site potentials and the economical feasibilities need to be investigated.

Iran, as a major producer of oil products, relies heavily on fossil fuels and is a rich country in terms of hydrocarbon resources (3).

Every sector of the Iranian economy is involved with natural oil and its products, either directly or indirectly. While the Iranian oil sector invests huge amounts of capital on the maintenance and development of its oil fields, there is always the question, whether it is viable to switch to renewable energy sources or not. Therefore, Iran is a perfect candidate for this study.

Regarding the price of energy carriers and required fuel in Iran, the exploitation of renewable energy became so important (3). The potential of renewable energy such as solar and wind energy is high in Iran, 17% of total energy production in Iran came from renewable sources in 2007 (4). Wind has the second level in renewable energy source in Iran, as the average wind speed in Iran is 6m/s (5). On the other hand, being on the world's sun belt, Iran has 2800 sunny hours per year, so this country has appropriate situation for using solar energy (6).

Kerman, a hot and dry medium-sized city with semi-arid climate in southeast Iran was selected as the case study for this research because of high potential of solar and wind energy with high number of sunny days and high speed winds.

2.0 METHODS AND DATA

In this research, two common renewable sources of energy were chosen for further investigation: wind energy and solar energy. The potential of these energy sources was determined in this specific context, through various literatures. The next stage was economic viability assessment. Based on the results of the potential study, it was decided to focus on solar energy, specifically two rather common technologies in this sector, which proved to have a high potential in Kerman; Solar water heating and solar electricity generation.

In both cases, a basic system suitable for a family of four was selected as the subject of cost-benefit investigation. In case of solar water heating, a simple cost-benefit analysis was performed, based on the current data acquired from valid sources. The aim of this part of research was to find out if this technology is financially feasible.

Regarding solar electricity generation and Photovoltaic technology, due to the sophistication of the matter, RETScreen software suite V.4 was used. RETScreen 4 is an Excel-based clean energy project analysis software tool that helps decision makers quickly and inexpensively determine the technical and financial viability of potential renewable energy, energy efficiency and cogeneration projects. This software is capable of considering many variables in its calculations. It is developed by Natural Resources Canada and is free of charge.

Fully integrated into these analytical tools are product, project, hydrology and climate databases (the latter with 6,700 ground-station locations plus NASA satellite data covering the entire surface of the planet), as well as links to worldwide energy resource maps. An extensive database of generic clean energy project templates is also built in to help the user rapidly commence analysis. Table 1 demonstrated the input values and assumptions used in these simulations.

Table 1 Input assumptions

Cell module type:	mono-Si
Cell module manufacturer:	Sunpower
Cell module model:	SPR-320E-WHT
Cell module efficiency:	19.6%
Tracking:	Fixed
Slope:	30°
Azimuth:	0°, Due south
Annual solar radiation horizontal:	1.91 MWh/m^2
Annual solar radiation tilted:	2.03 MWh/m^2
Power capacity:	3.2 kW
Nominal operating cell temperature:	45°C
Temperature coefficient	0.4%/°C
Solar collector area	16 m^2
Inverter:	Single Phase, 3.3 kW, SMA
Inverter efficiency:	97%
Length of construction:	1 month
Interest during construction:	17%
National inflation:	31%
Cell module price:	15,680,000 Rials/Panel
Number of modules:	10
Inverter price:	123,200,000 Rials
Installation and engineering costs:	30,000,000 Rials
Project lifetime:	25 years
Annual electricity exported to the grid:	6 MWh
O&M[1] costs:	1,100,000 Rials/year
Miscellaneous losses	1.0%
Transportation costs	5,000,000 Rials

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In order to make these calculations more realistic, the prices in these calculations were officially quoted from Mehrabad Company, a local supplier of renewable energy production tools and machinery, in September 2013. In designing photovoltaic systems, the slope and azimuth of the modules can be designed in several ways, each maximizing the energy production in a certain period, i.e. during summer. For these simulations, the maximum annual power production was assumed as the reference point for the calculation of slope and azimuth.

The government reported the inflation rate as 31% (7); however, there are several reports that the actual inflation is far more than the reported value. Nevertheless, in this study, the official inflation values were adopted. Based on current and predicted future trends in Iranian energy market, the following scenarios were simulated in RETScreen:

Table 2 Simulated scenarios

Energy Export Escalation Rates	Debt Interest	Feed-in-Tariff
10%, 15%, 20%	4%,12%,24%	Base:316.18Rials/KWh Improved:3225 Rials/KWh

■3.0 RESULTS

3.1 Solar Energy Potential

Solar radiation is an important source of renewable energy. The horizontal solar irradiation varies globally and is at its peak point in the solar belt.

With about 300 clear sunny days a year and an average of 2,200 kilowatt-hour solar irradiation per square meter, Iran has a great potential to tap solar energy (8). In Kerman, the average annual sum of global horizontal irradiation is about 2,100 kwh/m^2. In the Iranian context, the photovoltaic systems' efficiency never drops below 25% during the day, and on average these systems produce 80% of their maximum capacity (9). Due to very low precipitation in Kerman, the building roofs are flat; therefore it is possible to align the solar collectors to the most efficient direction as the buildings architectural form does not dictate a specific direction.

3.2 Wind Energy Potential

In 2009, the Renewable Energy Organization of Iran (SUNA) ordered a feasibility study on the potentials of wind farms across the nation. Lahmeyer International GmbH, a German firm, performed this analysis. They calculated the spatial distribution of the annual mean wind speed within the whole country, based on the numerical flow simulations with the three-dimensional atmospheric model KLIMM, originally developed at the Institute of Atmospheric Physics of the University Of Mainz, Germany. For final calibration, SUNA and LI implemented a short-term measurement campaign, in order to improve the accuracy of the calculation, after which a refined wind map was calculated (10).

However, the annual mean wind speeds cannot be solely taken as input for a precise energy production calculation as required for financial and economic analyses in the course of detailed wind farm planning procedures. This map rather shall serve for decision support in the selection of suitable wind farm areas with comparative good wind conditions within investigated region. According to this study, the whole country has the potential of producing about 18,000 MW electricity in the wind farms, of which only 109.4 Megawatts has been harnessed (5).

In case of Kerman, the annual mean wind speed is less than 5 m/s within the city limits, which is not very ideal for commercial production of electricity. However, this wind speed is enough to operate wind pumps, which were also used in the city during 1930s to 1980s. Some of these wind pumps still remain in the old farmlands within the city (East of Kerman) that have not been converted to residential areas yet. These wind pumps are a part of the local skyline heritage, but since private stakeholders own them, there is no specific plan for their preservation and renovation.

3.3 Solar Electricity Cost-Benefit Analysis

As mentioned before, there is a very large potential for harnessing renewable energy sources in Kerman, especially from the solar radiation. However, currently less than 2% of the total national energy production is from renewable sources, most of which is hydro-electrical. As of 2010, Iran had 8,500MW of hydroelectric capacity and 130MW of wind energy capacity (11). Electricity prices in Kerman, as of 2013, range between 270 – 1900 Rials/kWh (12).

In summer 2003, the Ministry of Power published a guideline on the conditions and prices of electricity purchase by the government. This document, which was slightly updated in 2006, was devised to address the introduction of private power plants (on an industrial scale), and so far is the only official document governing the production of electrical energy by the private sector. According to this document, the government buys the produced energy with a price ranging between 50 – 448 Rials/kWh, depending on the time and date of production and demand (13). Between March 2013 and September 2013, the median purchase price was 316.18 Rials per kWh (14). The gap between the sell and buy prices of the energy is very notable. There are talks to increase the feed-in-tariff to 13 cents/kWh, roughly around 3225 Rials/kWh but it is not finalized yet (15).

Although private investors may be interested in investing on the Iranian electrical energy market on an industrial scale, there is not enough economic incentives for the general public to invest on small-scale energy production units. Moreover, the source of this electrical energy does not play a role on the price of the final product and the production of renewable energies is not encouraged through the pricing regime.

In 1391 (2011-2012), the total electrical energy consumption of Kerman was 417,631,601 kWh. With the population of 534,441 (1), the per capita energy consumption is 781.43 kWh per year.

RET Screen calculates a number of key indicators of financial viability. Three of the best known are the Simple Payback, the Net Present Value (NPV), and the Internal Rate of Return (IRR). The simple payback is the number of years required for the initial cost of the project to be paid for out of annual savings. While it is often used, the simple payback is misleading and ignores financing and long-term cash flows, such that project benefits beyond the payback period are accorded no value (16). If only the simple payback period is considered, very profitable projects may be missed. However, when cash flow is tight, a quick payback may be essential.

The NPV is the golden measure of discounted cash flow mechanics. It is the sum of all costs and benefits, adjusted according to when they occur in the project. If the NPV is positive, then the project is financially attractive at the discount rate specified by the user. If it is negative, then money would be more profitably invested elsewhere. Unfortunately, picking an appropriate value for the discount rate can be tricky.

Table 3 RET screen results

Electricity Export Escalation Rate	Debt Interest	IRR	NPV Rials	Equity Payback Years
10%	4%	Negative	2,298,438,100	13.8
10%	12%	Negative	2,362,676,900	> Project
10%	24%	Negative	2,468,362,700	> Project
15%	4%	Negative	285,349,500	10.0
15%	12%	Negative	221,110,700	11.0
15%	24%	Negative	115,424,900	12.4
20%	4%	24.1%	6,372,756,300	8.5
20%	12%	22.3%	6,308,517,400	9.2
20%	24%	20,00%	6,202,831,700	10.2

The IRR, also known as the return on investment (ROI), is the true interest yield of the project over its lifetime and does not require the user to assume a discount rate. The IRR for a project can be compared to the return associated with investing the same amount of money in competing investments with a similar level of risk. An investor will typically have a "hurdle rate," or target IRR that they require an investment to exceed. The IRR generally yields the same results as the NPV, although it can give confusing values in certain cases, such as when cash flows are always positive.

The results of this feasibility study are quite astonishing. With the current power purchase prices the payback period would be more than the projected lifetime of the system. Therefore, under current circumstances, these projects will not be feasible at all.

With the introduction of a rather attractive FiT, the project's equity payback period is between 8.5 and 13.8 years (Table 3). The Electricity Export Escalation Rate seems to play the most important role in these fluctuations. This rate should be reasonably adjusted, considering the national inflation rates. Furthermore, since the equipment prices are very high, the government has to create attractive financial incentives in order to endorse private investments in renewable energy sector. These incentives can be in form of low interest loans (which have been investigated in the RETScreen analysis), or long-term contract with the producers.

3.4. Solar Water Heating Cost-Benefit Analysis

On average every person consumes 50 liters of hot water each day. The average tap water temperature is 20°C and the desired hot water temperature is around 55°C. The specific heat capacity of water is 4.18 kJ/kgK. Therefore, in order to provide a family of four with hot water:

4.18 kJ/kgK * 35° * 200 kg = 29,260 kJ energy is required. (1)

The efficiency of the common water heaters used in this region is about 70% (heat loss due to storage is also included), thus the total energy required per day would be 41,800 kJ. These water heaters consume natural gas. The gross heat of combustion of one cubic meter of commercial quality natural gas in this city is around 39 MJ. Ergo, a medium sized family consumes around 1.1 m^3 of natural gas for hot water each day.

Natural gas prices (17) vary according to the region and the consumption of the users. As of summer 2013, these prices vary between 300 – 3500 Rials per cubic meter (6). For the purpose of this research, the median value of 1900 Rials/m^3 is assumed as the reference value. Therefore, a price that a family would pay for hot water per year would be:

1.1m^3 * 1900 Rials/m^3 * 365 days = 762,850 Rials per year (2)

As the solar water heater requires maintenance every two years, which costs around 500,000 Rials per year, the family will save 262,850 Rials per year, if they switch to the solar water heating. This means that considering the investments in appliances and costs of installation, the payback period would be more than 87 years, which is far from being financially viable, as it is more than the lifetime of the mentioned solar equipment. However, this calculation does not account for the time value of money, risk, financing, or other important considerations, such as the opportunity cost.

Table 4 Solar water heating calculations

Renewable Energy Production Unit	Thermosyphon solar water heater
Capacity	200 liters
Costs of appliances	21,000,000 Rials
Installation costs	2,000,000 Rials
Maintenance costs, every two years	1,000,000 Rials
Payback Period	More than 87 years

Nonetheless, Pouramiri and his colleagues (2011) demonstrate that by adopting solar water heating in a residential district with 151 units in Jiroft, Iran, 502.53 MWh of energy is conserved each year. This energy is equal to 304.53 metric tons of CO_2 emissions, which requires 105.7 acres of forestland to balance. This pollution is equal to 634.2 barrels of oil or 122763 liters of gasoline (18). Although these installations may not be economically attractive to the private homeowners under the current circumstances, they can play a major role in the mitigation of climate change, as they reduce GHG emissions.

■4.0 ENERGY CONSERVATION AND CONSUMPTION

A change in the energy consumption pattern, not only mitigates the climate change through reducing further strains of greenhouse gases on the atmosphere, but also it can be considered as an act of adaptation to climate change, since it reduces the reliance of the citizens on fossil fuels. Especially in the wake of Peak Oil, this fact is even more significant.

The studies on the current status of renewable energy production in Iran proved that while there is an enormous potential, especially for solar energy, these energies have been neglected. In case of wind energy, within the limits of Kerman city, there is not enough potential for a sound financial investment. As mentioned before, although wind might not be a reasonable source of electricity, still it can be used for pumping water, both in private gardens and public parks and facilities.

Solar energy is much more promising, both as a source of heat for domestic and industrial purposes and electricity. However, considering the current financial situation and the lack of government support in this field, private investment in renewable energy production is out of question. Cheap fossil fuels and the absence of reasonable Feed-in-Tariffs and other motivating official initiatives eliminate the chance of small-scale clean energy production.

While local investment in Iranian renewable energy sector is not practical at the moment, international investment seems to be very plausible. Some international projects, i.e. Desertec, seek to invest in renewable energy production of high potential regions, aiming to export the energy to markets with higher values, i.e. Europe (19). In the feasibility studies of the Desertec project, Iran has been identified as a suitable place for Concentrating Solar Power (CSP). However, involvement in international projects like this needs a well-established international network of relations, which does not exist at the moment.

■5.0 CONCLUSION

It seems that financial matters are the most effective means in hands of policy makers. In fact, the government should promote the local production of renewable energies through introduction of attractive FiTs, reduced customs taxes of the related appliances and raising the awareness of the general public to attract more private investment in this sector. In order to promote climate-conscious lifestyle changes, energy conservation can be endorsed by precise alterations in energy prices and official subsidies on energy carriers. However, the general awareness of climate change will increase the public acceptance of these policies.

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References

[1] Keyvanfar, A., Shafaghat, A., Majid, M. Z. H. Lamit, H., Hussin, M. W. Binti Ali, Kh. N., Dhafer Saad, A. 2014, User Satisfaction Adaptive Behavior Criteria For Assessing Energy Efficient Building Indoor Cooling and Lighting Qualities. *Journal of Renewable & Sustainable Energy Reviews*. Elsevier. 39: 277–293.

[2] Keyvanfar, A., Shafaghat, A., Majid, M. Z. H. Lamit, H., Hussin, M. W. Binti Ali, Kh. N. 2014. Correlation Study on User Satisfaction from Adaptive Behavior and Energy Consumption in Office Buildings. *Jurnal Teknologi (Sciences & Engineering)*. 70(7): 89–97.

[3] Fadai. D, Shams Esfandabadi. Z., Abbasi. A. Analyzing the Causes of Non-development of Renewable Energy-related Industries in Iran

[4] Energy Balance Sheet. 2007. Department of Electrical and Energy Department of Energy Ministry.

[5] Renewable Energy Organization of Iran (SUNA) report collections, "What Do You Know About Renewable Energy? Wind Energy". 2009.

[6] Renewable Energy Organization of Iran (SUNA) website; http://www.suna.org/.).

[7] Statistics Center of Iran. Official Inflation Report. Statistics Center of Iran. August 18, 2013. http://www.amar.org.ir/Portals/0/Files/reports/nerkh_tavarom.pdf (accessed November 18, 2013).

[8] Zawya. Solar Power Plants to Replace Fossil Fuels. Zawya. December 10, 2010. http://www.zawya.com/story/ZAWYA20101220044922/ (accessed February 7, 2012).

[9] Iranian Fuel Conservation Company. Solar Energy. Iranian Fuel Conservation Company. December 9, 2012.

http://www.ifco.ir/building/renew/photovol.asp (accessed August 13, 2013).

[10] Renewable Energy Organization of Iran. Wind Map Iran in 80 m above ground. Tehran: SUNA, 2010.

[11] Renewable Energy Organization of Iran. Capacities and statistics of Iranian wind farms. November 13, 2012. http://www.suna.org.ir/fa/wind/capacity (accessed October 7, 2013).

[12] Organization for Protection of Consumers and Producers rights. Electricity Prices. Organization for Protection of Consumers and Producers rights. July 3, 2013. http://124.ir/attachedFiles/4384e245-b6a7-4c5a-88dc-49cb7788e268/4/bargh.pdf (accessed October 14, 2013).

[13] Ministry of Power. Energy Purchace Manual. Ministry of Power. February 13, 2003. http://www.iransana.net/uploads/1_22_sharayet%20va%20tazmine%20kharide%20bargh.pdf (accessed July 5, 2013).

[14] Iran Grid Management Co. Statistics. Iran Grid Management Co. October 14, 2013. http://www.igmc.ir/Default.aspx?tabid=69 (accessed November 19, 2013).

[15] Alic, J. Invest In Iran's Renewable Energy? Not So Crazy. The Christian Science Monitor. September 10, 2012. http://www.csmonitor.com/Environment/Energy-Voices/2012/0910/Invest-in-Iran-s-renewable-energy-Not-so-crazy (accessed November 13, 2013).

[16] RETScreen International. 2011. FINANCIAL & RISK ANALYSIS WITH RETSCREEN-SPEAKER'S NOTES." RETScreen International. December 8.

[17] Natural Gas Prices. June 13, 2013. http://124.ir/attachedFiles/4384e245-b6a7-4c5a-88dc-49cb7788e268/5/gas.pdf (accessed October 21, 2013).

[18] Pouramiri, M. A., M. Samareh, and Q. Heydari. 2013. Investigation of Energy Conservation by Adopting Solar Heating Units In A 151 Unit's Complex In Jiroft, Iran. Mehrabad New Energies. March 13, 2011. http://mehr-abad.ir/Default.aspx?tabid=67 (accessed August 4, 2013).

[19] Shafaghat, A., Keyvanfar, A., Zakaria, W. Z., Majid, M. Z. A., Lamit, H., Ali Kh. N., Ahmad, M. H., Iskandar Ariffin, S. A. 2014, Investigation of Future Building Performance Factors Towards Energy Efficient Travel Plan in Regional Development. *Jurnal Teknologi (Sciences & Engineering).* 70(7): 77–81.