Department für Agrarökonomie und Rurale Entwicklung
Georg-August Universität Göttingen

2017

Diskussionspapiere

Discussion Papers

Expansion of photovoltaic technology (PV) as a solution for water energy nexus in rural areas of Iran; comparative case study between Germany and Iran

Carl-Anton von Heyking

Tinoush Jamali Jaghdani

Department für Agrarökonomie und
Rurale Entwicklung

Universität Göttingen

D-37073 Göttingen

ISSN 1865-2697

Diskussionsbeitrag 1709

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Abstract

Iran is suffering from groundwater resources depletion through the excessive subsidized electricity for water pumping and the resulting disproportionate water consumption in agriculture. The creation of an alternative income sources for farmers and elimination of heavy subsidies for groundwater pumping simultaneously is a possible option for dealing with this threat. By expanding photovoltaic technology (PV) in rural areas, farmers can have an alternative source of income by supply and sale of renewable energy through feed-in tariff (FiT) mechanism. The latest decision of the Ministry of Energy in Iran in 2016 for purchasing electricity which is generated by low capacity PV owners can be a solution for the above mentioned problem. This study undertakes a comparison between Germany and Iran of the development of decentralized power system and PV expansion by private owners. In direct comparison to Germany, Iran has a far higher solar radiation and significant potential for the generation of electricity through PVs. This study illuminates both countries' costs of conventional/renewable electricity power, their changing FiT´s for renewable power and the renewable energy laws. Comparing the price development shows that a lucrative business arises by selling electricity for the Iranian owners of PV whereas in Germany the trend of self-consumption is clearly preferred. Innovative policies are needed to tackle infrastructural and economic challenges to exploit this potential in Iran.

Keywords

Iran, Germany, photovoltaic technology (PV), groundwater depletion, electricity subsidy, feed-in tariff (FiT), decentralized power system, renewable energy laws

1 Introduction

Due to its rich fossil fuel resources, Iran is one of the countries that strongly subsidize their energy sector. On account of the extremely high subsidies of the energy prices for many years, inefficient consumption of energy is a common phenomenon in Iran which has ended in environmental deterioration (Afsharzade et al., 2016). Cheap energy for the agricultural sector has dramatically increased the overexploitation of groundwater resources. In order to save groundwater resources and rehabilitate aquifers, finding alternative income resource for farmers is an areas of discussion among scholars in Iran (Nuri-Esfandiari, 2016). Decentralized renewable energy production including photovoltaic is an eligible candidate for this goal.

The subsidies are generally introduced to achieve specific political goals that lead to massive price distortions and high social costs as well as fatal impacts on the environment (Lechtenböhmer et al., 2010). In the case of Iran, the first step in a sustainable energy policy would be an energy pricing policy that sends correct signals to the consumers. There must be incentives to use energy more efficiently and make renewable energies more lucrative (Afsharzade et al., 2016).

Through targeted subsidy programs and feed-in tariffs, Germany succeeded in making photovoltaic particularly attractive for companies and private individuals. However, it is noticeable that other countries are subject to much better framework conditions the potentials of which are hardly exploited. Iran is one of these countries. Energy is one of the most important sectors within the Iranian economy and mainly all economic activities are affected by the energy sector and subsidized prices. However, appropriate pricing is necessary to promote energy efficiency and to develop a sustainable energy sector.

This paper aims primarily to provide an overview of the basic conditions of photovoltaic technology and renewable solar energy production in Germany and Iran. This study investigates whether the disastrous environmental situation and water resources deterioration in Iran can be countered by the establishment of small photovoltaic plants in rural areas as an alternative source for improving the income situation of domestic farmers. It is a contribution to the ongoing energy-water-food nexus discourse in Iran.

2 The evolution of solar power generation

In the case of solar power systems, a distinction is made between three types of systems. According to the German Federal Ministry of Economics and Energy (BMWi[1]), these systems are subdivided into thermal solar plants, solar thermal power plants and photovoltaic plants, with different technologies of utilization and conversion of solar energy (BMWi, 2016b). As the focus of this study is photovoltaic, we cover only this technology in the following sections. Moreover, as Germany is the leading country in this field, this country is analyzed in detail below.

2.1 Photovoltaic (PV)

2.1.1 Major historical development and functioning

In Germany, the initial research and development was started and supported by the federal government with state provided subsidies since 1974. In Germany, the electricity feed-in tariff (StrEG[2]) came into force in 1990. At the beginning of the new millennium, photovoltaic industry emerged into one of the largest markets in the world (Gochermann, 2016). The most established system in Germany is the polycrystalline modules. In recent years, however, a new thin-film technology has been developed whose efficiency is lower, but at accordingly lower acquisition costs (Wesselak & Voswinckel, 2016).

2.1.2 From the StrEG to the EEG

Germany has been a pioneer in the promotion of PV technology and decentralized power supply (Gochermann, 2016). Therefore, the Renewable Energy Sources Act (EEG[3]) is highlighted as a guarantor of the *Energiewende* (German term for energy transition) in this section.
Primarily, the forerunner of feed-in tariffs emerged in the USA in 1978 (Pyrgou, Kylili, & Fokaides, 2016). However, in Germany, the Electricity Feeding Act (StrEG), which had already been a milestone in 1990, was replaced by the EEG on 1 April 2000. Later on, this concept has been transferred to many parts of the world. Ensuring the acceptance of electricity from renewable energies (wind power, biomass, PV, hydropower) as well as the provision of fixed minimum remuneration for the producers remained the foundation for the new regulation approach.

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[1] Bundesministerium für Wirtschaft und Energie

[2] Das Stromeinspeisungsgesetz

[3] Erneuerbare Energien Gesetz

PV plants were initially very unprofitable despite this remuneration. This problem was gradually solved by the German Federal Government and the EEG, which has boosted further expansion of renewable energies (RE) (Wesselak & Voswinckel, 2016). Latest statistics show that in 2015, RE provided 33% of gross electricity generation in Germany from which 6.4% was generated by PV (Wirth, 2017).

The first changes to the rapid development of RE were made in 2004 by the first amendment to the EEG, whereby the subsidy rates were increased and plant operators were favored by local network operators. In most cases, a fixed remuneration was provided for more than 20 years that enabled the establishment of a small or medium-sized company (BDEW, 2016).

The next amendment to EEG took place at the beginning of 2009, whereby the share of electricity from RE was set at 35% by 2020 horizon. Rapid expansion of PV plants has derived higher "EEG apportionment"[4]. As a matter of fact, the electricity generated by RE is sold on the electricity markets and receives the market price. The difference between the market price and the feed-in tariff (FiT) which is stipulated by the state is paid by consumers as a portion of their electricity bills. This part is called the EEG apportionment or renewable energy apportionment (Roßegger, 2014). In Germany, the average electricity price consists of several components, such as value added tax (VAT), network charges, procurement costs, etc. The EEG apportionment was 6.35 cents / kWh in August 2016 (BMWi, 2016a, 2017).

Later on, a compensation scheme was introduced to prevent bottlenecks in the electricity feed-in. By introducing the reduction of the rates of compensation (which is named "degression"), adjusted electricity prices are achieved for all electricity customers. As a result, the cost pressure on the producers of new plants has increased. Therefore, these measures have promoted more efficient technologies (Buzer, 2014).

In order to stop any possible competition over land between PV installation and food production, the EEG subsidization for large-scale new installments of PV were eliminated in July 2010. This has encouraged new so-called "Agro-PV" research to combine agricultural areas with photovoltaic use (Wirth, 2017).

2.2 Investment costs and promotion of PV in Germany

There has been dramatic changes on investment costs and benefits of PV installation in Germany during the last years. In spite of falling feed-in tariffs, the falling PV investment costs and

[4] German term: EEG-Umlage

growing electricity prices have made the return rate of 4-7% still feasible after tax deduction. The main factors of these developments can be summarized below:

- Electricity price has approximately increased 4% annually.
- Electricity generation costs by PV remain the same for more than 20 years.
- The investment costs of PV plants have fallen more than 70% since 2006.

The 70% reduction of PV investment costs is mainly due to increased competitive pressure of Asian companies. Therefore, the investments cost has dropped below 1400 Euros per kilowatt peak (kWp[5]) in 2015. These costs depend on the type of solar module, the size / capacity of the PV system, the additional equipment, the installation, the choice of the manufacturer and the state subsidies (Mertens, 2015).

A distinction should be made between three types of solar modules, whereby the monocrystalline module panel being the most efficient. The efficiency is about 14-18% and costs on average are about 675 € per kilowatt peak (kWp) (Wesselak & Voswinckel, 2016). One kWp corresponds to an output of 800-1000 kWh/annum in Germany. For an output of about 4 kWp that comply roughly to the German average size household approximately 32 m^2 are needed (1 kWp = 8 m^2) (Geldermann, 2014). In the case of a normal family house, with a consumption of 4000 kWh/annum (corresponding to about 4 kWp), this results in 2700€ for the solar modules (Pegels & Lütkenhorst, 2014).

The total installation costs can be determined for 4 kWp as follow: the solar modules (already mentioned 2700 €), the inverter (2000 €), the assembly / installation (800 €) and the additional costs for the planning and the grid connection etc. (500 €). Therefore, the total installation cost is around 6000 €. It is also necessary to consider the current operating costs which are relatively low. Approximately 1% (60 € / annum) maintenance costs, about 0.8% (50 € / a) insurance costs and an annual counter fee of about 40 €. Similarly, the return on equity, accrued interest and maturity must be considered. Operating costs may be written off against tax purposes[6].

The high remuneration of 0.58€ per kWh ten years ago enabled the owners to amortize their investment rapidly. Nowadays the average remuneration is approximately 12 cents per kWh which forces suppliers to manufacture their PV technology cheaper still and consumers to use

[5] PV costs are usually indicated in kilowatt peak (kWp). This unit specified how much electricity can be generated at the best possible solar radiation conditions and is therefore the nominal capacity of the system.

[6] These values are calculated from different companies and offers. Definitely, they can change in different installation condition (source: Photovoltaik-Angebotsvergleich.de)

their own electricity themselves. The rate of compensation decreased continuously by a rate of degression of 0.25%.

At the moment, it is possible for private owners of solar power generators to produce electricity between 10-14 cents per kWh (WATTFOX GMBH, 2016). Since the feed-in tariff is only around 12 cents / kWh and the price of external electricity suppliers amounts to 30 cents / kWh, the feed-in business is no longer worthwhile. However, electricity generation for own consumption becomes much more attractive (Weniger et al., 2015).

2.2.1 Effect of irradiation on efficiency

Solar panels that generate electricity are influenced by their operating temperature, which is primarily dependent on the ambient air temperature as well as the distance from the sun. While solar irradiation is important for power generation efficiency, temperature and other environmental factors can significantly reduce the energy generation power (Hill, 2016).

The effect of the temperature on the efficiency of the solar cells is known as temperature coefficients (TC). The TC, which is normally given in the form of a negative percentage, reflects the effect of the temperature on the cell. Solar modules are generally used at 25 ° C so that the percent TC explains how the efficiency changes at an increasing or decreasing degree. For example, if the TC of a particular type of cell is -0.5%, the maximum power of the system is reduced by 0.5% for each degree (Honsberg & Bowden, 2017). Amorphous thin-film plates have a rate of between -0.20% and -0.25% and are particularly preferred for warm areas (Ponce-Alcántara et al., 2014).

2.3 Decentralized power supply

2.3.1 Definition and description

With the *Energiewende* it was decided that the power supply should be ensured by RE and the electricity generation moves away from the central to the decentralized energy generation. The feed-in tariff has become a success story which has already been applied in more than 50 countries (Pegels & Lütkenhorst, 2014). In Germany, solar energy is fed almost exclusively in a decentral way into the grid and a further expansion of the existing transmission grid is not necessary. In areas with high PV plant concentration on high-voltage network, the over-produced power can be transferred to the medium-voltage network by transformers (Wirth, 2017).

Decentralized energy supply is usually categorized as a grid-connected system and an off-grid system which are used for photovoltaic plants. In the case of grid-connected systems, the energy is fed into the public utility network either completely or partially. Off-grid systems are not connected to the public electricity network and therefore they supply only one or more consumers via their own network. The structure of these systems usually includes a separate energy storage which ensures the energy supply also of an unfavorable weather situation. An interconnection of several renewable energy generators is called a hybrid system. This technique allows lower storage capacities, as the power can be used from several power generators (Wesselak & Voswinckel, 2016).

The major advantage of decentralized supply system is their independence from the main providers and the volatile market prices. Thus, price fluctuations and changes in the electricity market can be circumvented. The decentralized energy supply contributes to the energy sector and accounts for far less pollutants than conventional power plants (Müller, 2015).

3 Photovoltaic in rural areas

RE is regarded as essential for new jobs and rural development. In many countries, huge investments were made to promote RE by governmental subsidy programs. PV offers remote rural areas the possibility to produce their own energy (electricity and heat) and the independence from conventional energy (Urmee, Harries, & Holtorf, 2016). This is why the question is being asked whether it is possible for the population in emerging markets to generate reliable and reasonable energy and sell it through remuneration in order to create an alternative source of income.

3.1 Electrification barriers in emerging markets and rural areas

The costs for the network expansion did not always follow a linear pattern, but more the so-called "trunk and branch" pattern. In this approach, the main trunk of the grating is built to supply large industrial and commercial users and later on step-by-step urban areas and smaller users are provided with the expansion of the branches. The further the consumers are away from the grid, the higher the cost of the supply. The purpose of rural electrification is to provide people with modern energy services and to improve the socio-economic situation of the rural people. This leads to enhanced quality of life, reformed education and increased economic activity, as well as improved health and increased agricultural productivity (Urmee et al., 2016).

In most emerging markets, sunlight is an abundant resource and as a result PV technology is a cost-effective option (BMZ, 2016).

The major first obstacle to rural electrification is the economic and financial barriers. These include the high acquisition costs of the PV systems for the end user. The rural population is usually poorer than the urban population. Furthermore, high transaction costs and the subsidies for conventional fossils, as well as non-renewable energies, complicate the electrification. Market development barriers are the next challenge. There is usually a lack of access to the necessary credit and infrastructure, apart from the non-existence of a distribution network. In addition, these countries are usually lacking the capacity and the necessary information to implement such projects. People's awareness of the need to use RE must therefore be encouraged. The last major barrier is the legal and regulatory problems (Urmee et al., 2016).

3.2 Pioneer models from India

How can these barriers be circumvented in order to achieve sustainable energy generation? In Dhundi, a village in the region of Gujarat in India, a cooperative (SPICE) for solar irrigation pumps was established in February 2016. The farmers of this cooperative, the first of their kind, use the solar energy not only for their irrigation systems, but also to feed the surplus energy into the grid of the state feed-in company (MGVCL) for 6 cents / kWh with a 25-year power purchase agreement (Shah et al., 2016)[7].

The solar pumps have a total capacity of 56.4 kWp and generate almost 85,000 kWh in one year. This allows the six members to irrigate their 7 hectares (ha) of land with about 40,000 kWh and to sell the remaining 45,000 kWh to the distribution company. They earn a gross revenue of about 2,684€ (as of Aug. 2016). Through a power purchase agreement (PPA), the six farmers have given their right to purchase the next 25 years' electricity from the grid. They are supported by the International Water Management Institute (IWMI) with 53,650€ (Dave, 2016).

Solar energy is much cheaper for the farmers than diesel while in the past they needed about 3.600 liters of diesel for generating 40,000 kWh. The six farmers were initially unsure about the ecological footprint of the solar facility. However, they already plant high-quality fruits such as spinach, carrots, garlic and turnips which grow under the plates without any restrictions. The SPICE is given a better remuneration (FiT) than the large solar power plants (Verma, Shah, & Durga, 2016).

The government continues to support the solar irrigation systems by subsidizing around 1,210€ / kWp of capital costs. A better alternative would be higher feed-in tariffs by the power purchase

[7] All values are calculated in Euro (source: http://www.finanzen.net/waehrungsrechner)

agreement permits. The capital-cost of solar cells could be reduced and the farmers could instead be offered an average of 11-12 cents / kWh. For the distribution company (DISCOM), it would be a great effort to measure from every small-scale supplier the amount of electricity fed in and to pay out accordingly. In the case of SPICE, even if new vendors were added, MGVCL would only buy the bundled electricity from SPICE on a fixed date. Finally, the task of the cooperative is the right distribution of the individual producers' share (Shah et al., 2016).

This system could also be the solution to the massive exploitation of groundwater, because the farmers are now extracting as much groundwater as they need to sell the excess capacities of electricity. The current government is trying to create incentives to save water and energy (Biswas & Tortajada, 2016).

An 8 kWp solar pump which has a secured PPA of 9 cents / kWh can help a farmer to irrigate one hectare of land and ensure an annual income of around 537€ from which 268€ is saving in diesel. This also makes the irrigation more climate-friendly (Rupera, 2016).

By using electricity and diesel for irrigation with groundwater, over 26 million tons of carbon emissions are generated which are roughly 5% of the total output of the country. If the groundwater is being solarized more and more, the huge carbon load can be reduced while increasing economic growth. Although the SPICE is still a small experiment, it can bring about fundamental changes in the electricity, water and agricultural sectors (Shah et al., 2016).

4 Iran

4.1 An overview

The Islamic Republic of Iran has an area of 1,648,196 sq in South-West Asia. With an estimated gross domestic product (GDP) of 406.3 billion US dollars, Iran is the second largest economy in the Middle East and North Africa after Saudi Arabia. The country is the most populous in the region after Egypt, with about 78.5 million inhabitants in 2014. Characterized by a high proportion of young people, over 60% of the population is under 30 years (The World Bank, 2017).

The Iranian economy is characterized by a high hydrocarbon sector, a small agricultural and service sector and a significant state presence in production and finance. The country is ranked second in the natural gas reserves worldwide and fourth in crude oil reserves. Iran has the highest volume of zinc and the second most copper reserves worldwide with equally inexhaustible deposits of iron (OIETAI, 2016). Despite this, economic activities and state revenues are still largely dependent on oil revenues (The World Bank, 2017).

After two years of recession, the economy expanded again by 3% in 2014. GDP growth is predicted to be 5.8% and 6.7% respectively in 2016 and 2017, as oil production is 3.6 and 4.2 million barrels per day (ICCIMA, 2016). This is because, on 14 July 2015, the five veto-powers and Germany (E3 + 3 states) agreed on long-term negotiations with Iran (Löwenstein, 2015). On 16 January 2016, the Atomic Energy Agency confirmed that the Islamic Republic had fulfilled all the agreements of the convention, wherefore the EU as well as the US had largely reversed their economic activities. The embargo led to a national economic crisis in Iran, which had a major impact on the oil and gas reserves (Gehlen, 2016).

The state still plays a key role in the economy and controls the financial sector with public banks. Large official companies dominate the commercial sector, for instance 60% of the manufacturing sector is owned by the state (ICCIMA, 2016).

In March 2010, the Iranian government launched a subsidy reform plan to gradually increase energy prices within 5 years (2010-2015) (Jafarkazemi, 2014). The reform was based on the 20-year vision plan. In its first period, the direct subsidy payments were estimated at US $ 77.2 billion in 2007/2008 which were transferred to Iranian households through a direct transfer concept. The program focused on essential products and services, such as petroleum products, water and electricity that resulted in a moderate improvement in the efficiency of expenditure and economic activities. The second phase which is still under review includes the gradual oil price adjustment on the one hand and improving the cash transfers to low-income households on the other (The World Bank, 2017). One result of the reform plan should be the development of renewable energy plants for electricity generation (Guillaume, Zytek, & Farzin, 2011).

The country is facing a rapidly growing demand for electricity. The average growth rate of electricity generation was 5% per year in the last decade (TAVANIR, 2014). The country should produce at least 5 GW per year to cover the demand in the coming years. Since the beginning of the subsidy reform, prices for electricity and water have increased and they will continue to rise. The reform is a major change and has opened a new era for both energy conservation and the use of RE generation which has been heavily subsidized for a long time (Jafarkazemi, 2014).

Although Iran has great potential for solar power generation, there has been little development in the solar sector so far. The main reason for this is the abundant oil and gas reserves in the country which are responsible for the low prices of fossil fuels for electricity generation. To stimulate the private sector, some incentives have been created to make solar energy more competitive than non-RE. Nevertheless, the government needs to develop reforms to promote competition, rationalize licensing and authorization requirements, reduce the impact of government-owned enterprises in the economy, and improve the financial and banking sector (The World Bank, 2017). Iran has a huge potential for solar radiation. Over two-thirds of the southern geographic area has an annual average of over 1800kWh / m² (Wang, 2016). Other sources report solar radiation in central and southern desert regions of Iran, which reach more than 3000 kWh / m² per year (Mahmoudi, 2015).

4.2 Reasons for current environmental problems

In Iran, non-sustainable energy supplies have a lasting impact on economic, social and environmental development (Golabi, 2011). According to the Wuppertal Institute, Fossil Energies provide more than 97% of the energy in Iran. Targeted subsidies and rising energy prices had no significant impact on reducing energy consumption in urban or rural areas. The level of energy consumption in Iran is so unrestrained that energy consumption in the country is 68% higher per capita than the global average consumption. This means fourteen times higher than in Japan, five times higher than India and Pakistan (Lechtenböhmer et al., 2010). Energy consumption is growing steadily and undoubtedly this dramatic energy intensity is due to mismanagement (Sabetghadam, 2005).

Iran is faced with growing environmental challenges that are dangerous for the country's long-term environmental stability. One percent of Iran’s area is absorbed into the deserts annually. 90% of the country is very dry, so two thirds of the precipitation evaporates before it reaches the rivers. According to Michel, 12 of the 31 provinces will exhausted their water reserves within the next 50 years (Michel, 2013). The problem is even further reinforced by the government’s energy policies. Due to government subsidies, groundwater is almost free of charge for the consumer. Farmers pay only a fraction of the actual energy costs to pump the groundwater to the surface. The electricity buyers are divided into three categories, so people in Iran pay a different amount for one kW/h depending on the sector. Table 1 shows the extent to which agriculture is subsidized. In general, the paid average price is 0.017 cents (600 rial) / kWh for all electricity customers in 2016 (Sehati, 2016). This shows that the electricity price in agriculture, with 0.0031 cents (110 rial)/kW/h at normal current times, is significantly lower than the average

The water crisis is increasingly becoming a public debate. Some leading individuals /organizations warned firmly in 2015 and anticipated that in 20 years Iran might look like Somalia (Kalantari, 2015; Nouzaripur, 2015). The debate will continue with the question of available renewable water resources. Based on the latest available data of the Ministry of Energy (MoE), which is the responsible organization in connection with water resources management in Iran, the average rainfall will be reduced from 225mm/m^2 to 205mm/ m^2. Consequently, available water resources will shrink from 130 billion cubic meters (BCM) to 100 billion BCM (Hajrasuliha, 2015).

Other figures are also known: Based on the available estimates of Iran Water Resources Management Company (IWRMCO), only about 60 billion CBM of groundwater was recovered in 2014, more than 85% of which was used for irrigation. The MoE states that as much as 92% of the water resources are consumed by agriculture (Chitchian, 2014). Especially in the north-west of the country, dams, irrigation systems and droughts have shrunk the Urmia Lake, one of the largest in the Middle East, by more than 60% since 1995 (Michel, 2013).

Table 1: Electricity prices per sector in Iran

Rial per kWh	Agriculture	Private sector	Industry sector
Low utilization times	55	636	253
normal operation	110	636	506
peak time	220	636	1012

Source: MoE, 2016; own representation via Excel

Additionally, in the north-east part of the country the groundwater resources have declined dramatically during the past decade due to economic activities. In arid areas with small amounts of groundwater, the fresh water is ultimately replaced by salt water. Therefore, the irrigated areas are increasingly threatened by salinization, which in turn leads to desertification. Furthermore, conventional power plants use large quantities of water for cooling, washing and cleaning (BMBF, 2016).

Climate change is another driver of drought in Iran. The drought is one of the most serious challenges for the rural population in Iran, as the MoE categorizes 290 from a total number of 609 plains as "forbidden plains" for further well drilling. Lack of Water and climate change has a negative impact on agricultural production and food security, with severe consequences for rural areas (Garshasbi, 2014).

Table 2 shows that the farmland has declined by 4% in 10 years. According to the Statistical Center of Iran (SCI) in 2011, 29% of the country's population live in rural areas and produce about 11% of the country's GDP. These areas are also responsible for 23% of the country's employment and 80% of the food supply (Alibayghi et al., 2014).

Desertification and as a result eradication of income sources in rural areas is threatening rural life as these areas are heavily dependent on agriculture. In Iran, 81% of the farms are less than 5 ha and cover only 38.7% of the total agricultural area which results in low income and low productivity. Ground erosion, deforestation, social inequality, seasonal migration and the decline in groundwater also have a significant negative impact on the villagers (Amiri, 2015). As it is presented above, the dramatic environmental effects of agricultural activities and energy and water policies, and climate change are some of important factors which threaten rural life in Iran. Expansion of small-scale rural renewable energy generation can be a low water dependent livelihood option for rural areas which is discussed in this paper.

Table 2: Number of gardens and farms in Iran (Source: SCI, own presentation via Excel)

	2003	2014
Number of farms	4200000	4043000
Agricultural land (million ha)	16	14,7

Source: SCI (2015). IRAN Agricultural Census 2014 - Detail Results. Statistical Center of Iran (SCI) http://amar.golestanmporg.ir/ftp/amar/sarshomari/keshavarzi_93/n_tafzili_93.pdf (in Persian)

4.3 The Iranian electricity market and the electricity grid.

Before restructuring the electricity market in Iran in 2004, the government worked as a monopolist in sole responsibility of generation, transmission and distribution of electricity. Due to the high consumption of electricity and the need to improve private investment, TAVANIR, a state-owned power company, has taken some steps in 2001 in order to fundamentally reform the electricity market.

The initial objectives were to encourage competition in the market, increase the share of private investment in power plants and to improve the efficiency of electricity generation (IGMC, 2016). In 1996, the organization of renewable energies of Iran (SUNA) was established to assess the potential for renewable energies, to realize projects (solar, wind, geothermal, hydrogen and biomass) and purchase electricity to guarantee the participation of the private sector in this field. The main tasks of SUMA are the development of PV projects and the solar energy development in the private sector (SUNA, 2017b).

Electricity generation is mainly provided by state power plants which are owned by TAVANIR or regional energy companies. Privatization in electricity generation began with the implementation of the energy conversion agreement and further through the development of some projects with private investors. The main objectives are the monitoring of the national network, the development of a competitive electricity market in production and distribution, as well as private sector involvement in the market (IGMC, 2016)[8].

According to Mahmoudi (2015), the Iranian electrical grid is about 92% interconnected and electricity feed-in is possible at aproximately 70% of the electrical grid throughout the country. The self-sufficient systems are about 8-10% and solar expansion continues to grow. The government in Tehran invested a total of US $ 60 million in solar projects in 2014. More than 99.75% of the villages in Iran are covered by the electricity network (Mahmoudi, 2015).

4.4 Framework conditions for renewable energy development

4.4.1 Overview of political support for RE in Iran

MoE has committed itself for the first time to buy the produced electricity from non-state-owned RE plants since 2001. However, the MoE has been obliged to purchase electricity through long-term contracts with guaranteed tariffs by the new legislation since 2011 (Mahmoudi, 2015).

The MoE is obliged to include an amount of 0,09 Cents per kilowatt-hour as electricity duties in the electricity bills, in addition to the price of electricity sold, and to receive such amount from clients except from rural households. The collected amount is then deposited to TAVANIR and is used for the rural regions as well as for the generation of electricity from renewable energies. The result of the levy is nearly 1.15 million €, which is used for purchase of electricity and rural electrification (IEA, 2017).

Finally, the feed-in tariffs were revised. According to the 5th National Development Plan, TAVANIR and companies associated with the MoE (SUNA and distribution companies) are requested to sign long-term electricity abstraction agreements with the owners of renewable energy plants. The feed-in tariffs are determined each year by MoE, on the basis of a feed-in tariff from the previous year. In 2015, the MoE entered a new system of feed-in tariffs (FiT), according to which each RE receives its own tariff (IEA, 2017).

4.4.2 Power purchase agreement (PPA)

The Iranian State Law aims to improve the involvement of the private sector in the country's economic activities and also to preserve fossil energies, protect the environment, and promote the diversification of energy. This is why SUNA has established the feed-in tariffs for RE from

[8] Iran Grid Management Co. (IGMC)

non-state plants as one of its main programs. Through these new regulations, RE has been remunerated since 2015 with own tariffs over a fixed purchase agreement of 20 years. Subsequently, only the relevant laws and subsidies are going to be considered which have issued in connection with the PV by the MoE. The guidelines for smaller PV systems of 20kW and less are particularly important (SUNA, 2017a).

In order to compensate the inflation, the feed-in tariffs are adjusted annually within the 20-year contracts to the euro exchange rate fluctuations and domestic inflation. This is done by using the adjustment formula (SUNA, 2017d):

$$K = \left(\frac{CPI_{x1}}{CPI_{o1}}\right)^{\propto} \times \left(\frac{\text{€ate}_{x2}}{\text{€ate}_{o2}}\right)^{1-\propto} \quad (1)$$

where *k* is index coefficient, CPI is retail price index announced monthly by the central bank of Iran (CBI), *€rate* is annual average of the exchange rate of Euro with Rails, as announced by the CBI, $\propto$ is power coefficient between 0.15~0.3 set by investors, *x1* refers to the first month of payment year, *x2* refers to the year before payment date, *o1* refers to the first month of contract year and *o2* refers to the year before contract date.

The PV tariffs are multiplied by a factor of 0.7 from the first day of the 11th year of the contract and are thus reduced by 30%. For plants which are connected to the distribution grid, a further rate is added to the feed-in tariff. This is determined by the IGMC. The 20-year PPA starts with the date of signing the contract of both parties and thus includes the development and construction period. By signing the contract, the FiT is defined. If there is a delayed commissioning of more than 15 months of the PV system, and a new remuneration occurs, then the lower amount for the contract is automatically taken. With a period lag of nine months, SUNA is allowed to terminate the contracts, to revoke the building permit, and to inform the authorities to reclaim the state owned lands. Investors whose contracts have been terminated due to delay can submit a new application for a feed-in tariff no sooner than two years (SUNA, 2017c).

Considering the financial resources, MoE will pursue the policy of gradually lowering the FiT´s as the capacity of RE in the country will continue to increase. However, the reduced tariffs are only applied in new contracts (SUNA, 2017a). Applicants for the building permit must complete two forms and submit them to SUNA (SUNA, 2017e).

4.4.3 Development of feed-in tariffs (FiT)

According to Iranian law, the MoE is obliged to buy the electricity of the RE power plants from the private sector at certain tariffs and conditions. The MoE determines these tariffs once a year according to established principles and in consultation with the Economic Committee and the

Board of Ministers. In recent years the feed-in tariffs have been equal for all types of REs for each year. In 2012 the remuneration was between 5.1 - 5.3 cents/kWh (1792-1863 Rials/kWh) for a period of 20 years. A year later these were drastically raised to 12.43 - 12.63 cents/ kWh (4371 - 4442 Rial/ kWh), but the remuneration period was minimized to 5 years. Under the same conditions, the remuneration was raised again to 12.74- 13.16 cents/kWh (4480 - 4628 rial/kWh) in 2014 (SUNA, 2017d). In the previous years, the feed in tariffs were calculated based on the avoided coasts of fuel, pollution, etc.

The approach to determining the feed-in tariffs has been changed since 2015and the technology-specific feed-in tariffs for each technology is applied later on (SUNA, 2017b). The size of the power plant is considered as another factor to define the price of electricity. The average rate is based on the adjustment formula (see equation 1) at the level of 13.86 cents / kWh (SUNA, 2017d).

In May 2016, the Iranian government published the revised feed-in tariffs for 2016, which should be valid until 21 March 2017. Almost all remuneration of the RE technologies has been reduced. The remuneration is increased by a further 30% according to the Iranian feed-in tariff if local and domestic appliances were installed for the plants, or technical know-how, design or local installers were used to erect the plant (SUNA, 2017c). The composition of this 30% is shown in Table 3.

Table 3: 30% Increased FiT's by using domestic production

Item	Component Description		Share of the component	Bonus percentage in 2015
1		Frame	6,67%	2,00%
2		Glass	8,00%	2,40%
3		EVA sheet	7,33%	2,20%
4	PV Panel	Back sheet	7,33%	2,20%
5		Junction Box	5,33%	1,60%
6		Cell	13,33%	4,00%
7		Ribone Tape	3,33%	1,00%
8		PV paste	3,33%	1,00%
9	Cable	DC cables	5,00%	1,50%
10	Invertor	Electronic part	18,67%	5,60%
11		Box and other metal parts	6,67%	2,00%
12	Other Components	Instructure	10,00%	3,00%
13		Solar Tracker	5,00%	1,50%
Total Sum			100%	30,00%

Source: Domestic content extra bonus defined by SUNA(2015) Available at: http://www.suna.org.ir/suna_content/media/image/2015/12/4256_orig.pdf (In Persian - Visited on 14/12/2015)

The falling feed-in tariffs also indirectly lead to an increase of environmental problems. Despite the establishment of the guaranteed feed-in tariff in 2015, the FiTs were drastically shortened in May 2016, so there is less incentive for sustainability. As a result of the updated feed-in tariffs all remunerations have been reduced on average by 22% (Alexandrin & Wachner, 2016). According to Kenning, the feed-in tariffs for solar technology have fallen between 18 and 43% (Kenning, 2016). In the range of PV, a new compensation limit of 30MW and more has been established. The remuneration is 9 cents (3170 rial) per kWh. However, the Iranian remuneration is still very lucrative in direct comparison with most of the world's markets, especially the PV plants, which have a nominal output up to 20 kW. With calculated 23 cents (8000 rial) / kWh, this premium is at a leading level (Alexandrin & Wachner, 2016). Figure 1 shows the differences between different tariffs for different sectors and FiT for small scale PV.

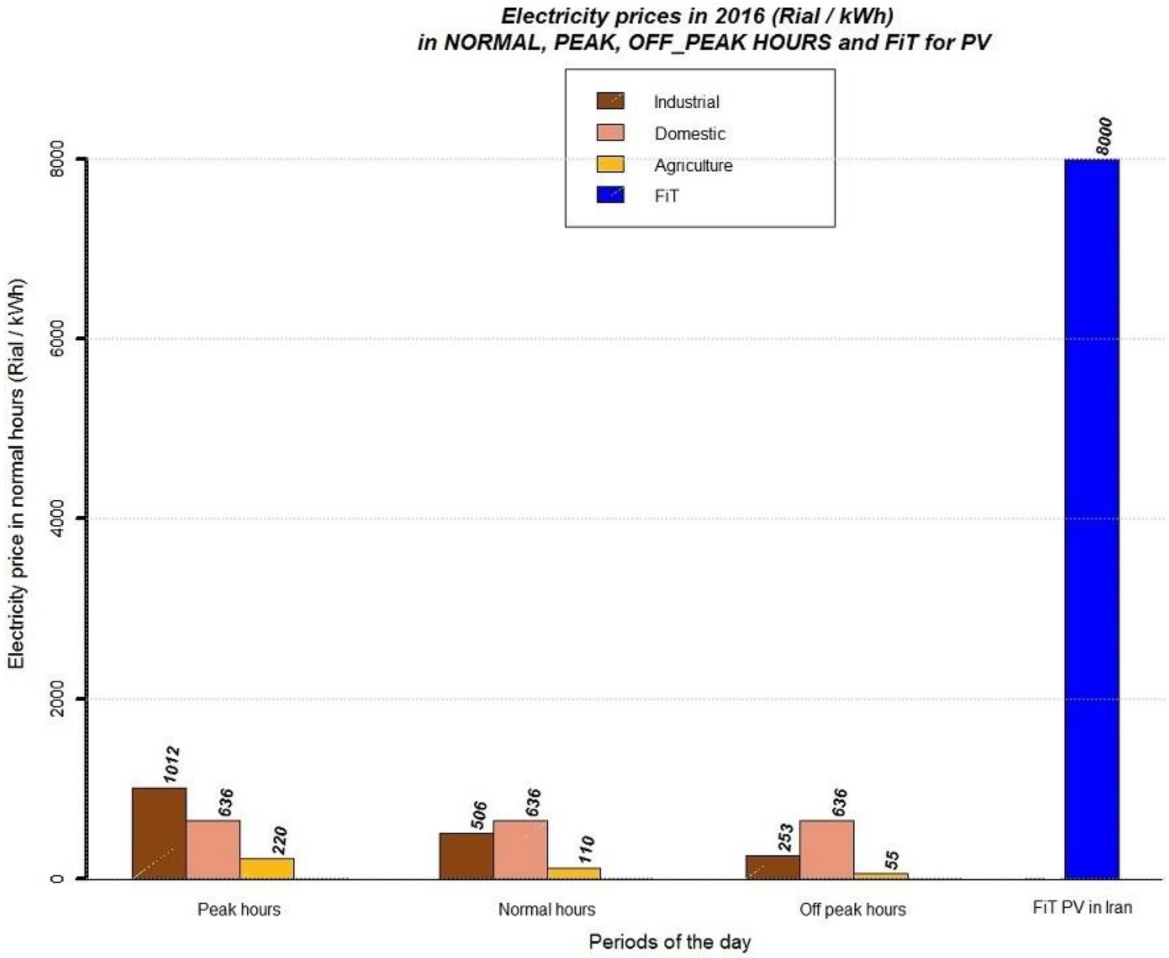

Figure 1: Different tariffs for different sectors and FiT for small scale PV.

5 Profitability of PV in Iran and Germany

This chapter will examine how the investment in a PV plant would affect the farmers in Iran with farms below 5 hectares and whether the investment in a PV plant is worthwhile.

5.1 Investment concept and process

The net present value (NPV) method is applied for assessing the investment of the PV plant. Thus, an analysis is assured over the entire investment period. NPV is the major method in cost-benefit analysis (CBA). The investment plan is the foundation for the investment. The calculated deposits and withdrawals of the project implementation are determined by the investment plan (Mußhoff & Hirschauer, 2016). By compounding or discounting of all future payments over the entire period of use at time zero, comparability can be established (Wöhe & Döring, 2010). There are different formulas for the calculation of the net present value. The following formula is used here (Mußhoff & Hirschauer, 2016, p.251):

$$NPV = -a_0 + \sum_{t=1}^{N} \frac{(e_t - a_t)}{(1+i)^t} \qquad 2$$

where NPV is net present value, a_0 is acquisition value/ initial net investment by t_0, e_t is deposit at the end of the period t, at is payout at the end of the period t, N is number of periods of use, t is periods (t=1,2,3,…,N) and i is discount rate.

The calculation of the net present value (NPV) states the value of the investment in relation to the current date (Wöhe & Döring, 2010). For the present value, the installation date of an investment is selected as the reference time. The discount rate (or discount factor) is the interest rate expected by the investment. In the case of a PV investment, this usually consists of the interest rate, for instance, secure government bonds, illiquidity, a percentage share for guarantees and the risk rate for technical progress and price change (Göden, 2013). In order to determine the profitability of the net present value, the amount of the NPV must be analyzed. If the NPV is greater than zero, an investment is worthwhile considering the profitability aspects (Zantow & Dinauer, 2011). However, this value may be zero or negative. In this case, the investment should be discouraged and an alternative investment should be preferred. The surplus of the deposit, the amount of the interest rate and the temporal structure of accruing payments affect the net present value (Mußhoff & Hirschauer, 2016). Furthermore, the internal rate of return (IRR) is taken into account in the cost-benefit analysis (CBA). There is a close link between the net present value and IRR. The IRR specifies how high the discount rate could be at most that the net present value of zero is reached. The internal rate of interest is therefore the critical discount rate, above which the investment becomes unprofitable (Mußhoff & Hirschauer, 2016).

5.2 Profitability assessment

The following profitability analysis is performed by Excel. The results examine whether the commissioning of a photovoltaic system is profitable both in Germany and in Iran. The final results of this study can be found in the appendix[9]. In the direct comparison between the two countries, the same nominal size of 5kWp and an installation area of about 40 square meters in rural areas in 2016 is assumed. The farmer in Iran should decide for himself whether the PV plant is to be installed partly on its own roof or on the farmland. It is also assumed that both PV systems are mounted at the best possible angle of 30 degrees in a southern orientation without loss of power through shadows, etc. For both countries, the investment costs were determined, which are composed of material, repair, planning and approval costs. Specific operating costs, remuneration rates and technical data were recorded for each country. No tax aspects are considered.

5.2.1 Germany

The literature illustrates that the construction of a PV system in Germany is in most cases only profitable if the self-produced electricity is used for own consumption. Since the introduction of feed-in tariffs, the remuneration has declined continuously (12.31 cents/ kWh, as of September 2016) and the electricity price has risen steadily (29 cents/kWh, as of September 2016). The business of electricity purchase has been no longer lucrative since 2012 (Wirth, 2017). Through this development, so-called electricity storage in Germany is becoming more and more interesting. The device is, more self-consumption led to a higher rate of return. For the analysis, the acquisition costs from the literature were calculated approximately linearly to 5kWh and thus from 6000 € to 7000 €. Due to the persistently low interest rates (1%), 100% debt financing is considered in Germany. A discount factor of 1% is assumed. The current operating costs amount to 2% of the acquisition costs and increase annually by 1% (wear etc.) (Wesselak & Voswinckel, 2016).

The FiTs remain constant over a period of 20 years, whereas the efficiency of the system decreases by 0.1% annually (Wirth, 2017). For a PV plant in southern Germany 1,000 kWh / kWp

[9] The detail cash flow of each scenario can be provided upon request.

are assumed annually. On the basis of the quantified data, three different cost-benefit scenarios are developed for Germany. With 100 % electricity supply of 99055 kWh generated in 20 years, the break-even point would be achieved after 17 years. In an average household, 30% of the energy produced is used for own consumption and the remaining 70% is fed into the grid (Weniger et al., 2015). This variant achieves the break-even point after 11 years after commissioning the plant and achieves an annual turnover of 703 €. If the investor opts a PV plant with suitable storage, the acquisition costs amount to approximately 12500 € (value adjusted to size) (Märtel, 2016). Due to the increased investment costs, amortization is achieved after 13 years, but a higher capital value is also attained. In the long term, this investment appears to be most useful with rising electricity costs. Therefore, the investment of a PV plant is still profitable despite a reduced feed-in tariff in Germany.

5.2.2 Iran

The Iranian currency "Rial" is used for the CBA. Roughly, a current exchange rate of 1 € = 35000 Rials can be considered. The generated electricity should be feed-in into the grids and the investment is 100% self-financed. There are no state subsidy programs for financing PV installations of this size. There are different data on the costs of a 1 kWp turnkey photovoltaic system in Iran. Therefore, four different scenarios (based on different assumptions) are considered two possible capital investment cost; 1) the government estimation as S1 (70.000000 Rial / kWp) (Aguilar et al., 2016) and 2) Iranian Solar association estimation as S2 (100.000000 Rial / kWp) (Shuri, 2015). The composition of the investment costs of the two variants amounts to about 350,000,000 Rial (S1) or 500,000,000 Rial (S2) for 5 kWp which makes a plant twice as expensive as in Germany. The high acquisition costs are due to low technical knowledge and insufficient experience.

The Iranian government has established high import duties for PV technology from abroad in order to promote domestic production. A PV plant, which covers all production units from domestic companies, may receive a 30% increase in the remuneration premium (SUNA, 2017c). The average solar radiation that is calculated in this paper is 2000 kWh /m2 (Aguilar et al., 2016). Other sources estimate up to 3000 kWh/m2 in desert regions (Mahmoudi, 2015). Due to these extreme fluctuations, the results vary dramatically. Therefore, an average value of 2000 kWh / m2 is calculated.

Due to the high solar load of the plant and efficiency reducing components such as dust and sand, the deterioration rate of 0.5% is considered (Aguilar et al., 2016). As already mentioned, the FiT (8000 Rial / kWh = 0.23 cents) are corrected each year by the adjustment formula.

Based on a current exchange rate escalation of 8% and an inflation rate of 10%, the increase rate of 8.6% is considered (Aguilar et al., 2016). These are added annually to the last feed-in tariff. Table 4 shows the main assumptions on the FiTs. The four scenarios on FiTs are investigated, with a 100% feed-in as follow

The first analysis (1.1 and 2.1) examines FiT´s without an 8.6% increase in remuneration over the entire period of use, as this is not clearly defined by the law. However, this increase rate is included in 1.2 and 2.2 scenarios. The third calculation is based on a 30% increase of the FiT´s because the entire plant was purchased from domestic production (1.3 and 2.3). The last calculation is based on applying domestic products with annual increase of 8,6% of the FiTs (1.4 and 2.4).

Based on the current feed-in law in Iran, the FiTs are adjusted to the exchange rates and inflation by a certain percentage of the adjustment formula (8.6%). If, as in Germany, the remuneration remains constant over the entire period of the PPA, a negative net present value will result for both price scenarios S1 and S2 (see appendix table). Another crucial factor is 30% reduction of the remuneration from 11th year. As a result of decreasing efficiency, increasing operating costs and remuneration reduction, these investments are becoming increasingly unprofitable. For all four profitability analyses, the discount factor of 16% (Mehrjoo & Bahadori, 2016) is immensely high compared to Germany (1%) that decrease NPV dramatically.

Table 4: different assumptions on the installation costs and FiTs

Scenarios	Installation cost per kWp (million Rials)	Increase in remuneration over the entire period of use	30% increase of the FiT´s by using domestic products
1.1	100	-	-
1.2	100	8.6%	-
1.3	100	-	30%
1.4	100	8.6%	30%
2.1	70	-	-
2.2	70	8.6%	-
2.3	70	-	30%
2.4	70	8.6%	

If an annual adjustment of the remuneration by 8.6% is achieved, a positive NPV is obtained for both scenarios. However, the internal rate of return differs significantly. With an increase of 30% (8000 * 1.03 = 10400Rial / kWh), due to the use of domestic products, a small negative NPV still exists for S1 at the end of a 20-year useful life, but a positive NPV for S2.

The last scenario proves to be the most lucrative. With an increase of 30% and a simultaneous annual increase of the FiT's, the highest NPV can be achieved. At S1 the break-even point is reached after 9 years. S2 achieves the amortization after 6 years. Based on this analysis, an annual turnover of 19,523,692 rial / a (557 €) could be generated. Finally, a residual value of the plant, which is mostly disregarded in Germany, can also be added in Iran.

6 Summary and Outlook

The results of the literature and economic analysis outline that Iran has a high potential for using PV technology. A sustainable source of income is conceived especially for the deserts, which are not included here, with more than 3000 kWh / kWp / m^2. The first private photovoltaic system was connected to the grid in July 2016 in the northern region of Kerman, under the control of a power distribution company. According to a public report from SUNA, the head of the rural PV office mentions that the 5 kWp plant has been financed entirely by the private sector and a PPA has been signed for 20 years (SUNA, 2016).

This performance potential cannot yet be exhausted for many farmers in rural areas. The current feed-in tariff (8000 rial / kWh), which still has a high level compared to other countries, but the 30% reduction after 10 years, is a major obstacle to exploring the po,tential in Iran.

The newly adopted feed-in tariff law may be a milestone in the Iranian government's renewable energy policy. However, fundamental framework conditions need to be re-optimized and improved so that small PV plants become economically viable and possible investors get promoted.

The high acquisition costs at the moment are disadvantageous. On the basis of the economic viability of the various scenarios S1 and S2, it becomes clear that the business is significantly better with falling production costs. Domestic production has to be promoted in order to ensure a more efficient commissioning. It can be assumed that the costs for the production and assembly of the PV systems in Iran, similar to those in Germany, will decrease due to a learning curve. However, the feed-in tariffs will also modify and fall further. Since the introduction of the FiT for small-scale plants below 20 kWp in 2015, the tariffs fell by 18.12% within a year, from 9770 rial to 8000 rial / kWh.

In Iran, there are currently only a few companies that can build and install PV plants. Most of them are still importing different equipment from abroad. The Iranian government seems to want to attract foreign PV producers to put their assembly line in Iran by high duties and remunerations of 30% of the FiT´s.

Up to now, this business has not been operationalized to be an income alternative in the rural areas. There are no viable financing opportunities for small investors. The state supports the financing of a small PV plant up to 47 million Rial / kWp (Felahatian, 2015), but only if the plant is intended for private consumption but not feeding in the grids. Thus the investment has to be financed with 100% equity, which is usually not possible for the rural population in the case of 100 million Rial/kWp (2850 €). In this case, the government and banks need to create favorable financing opportunities. So far, this promotion has not been clearly defined in law and only a possible arrangement is mentioned (SUNA, 2017c). The high discount rate and inflation are another two major obstacles for this industry to be profitable in small-scale.

As we have seen, the PV at small scale can hardly be an alternative income source for rural areas that are endangered by reducing water resources. A further obstacle is faced by the strongly subsidized electricity prices for agriculture, which makes an investment in a PV system economically pointless. Because of these low costs, water is pumped more and more to manage the agricultural fields. As it is discussed in section 4.2, the immense waste of water and pollution causes more and more land to become desert and can no longer be farmed at all. The number of farms are decreasing and groundwater is declining steadily.

The sample model in India also represents a solution for Iran. The current independent businesses of strongly sub-subsidized power generation on the one hand, as well as the compensated remuneration reduction on the other, must be coordinated. Currently it would be possible for an investor to sell the electricity generated at a certain tariff and to continue to receive the very favorable electricity from the state. The difference between the example in India and the prevailing conditions in Iran is the usage. This approach could help the government to increase revenues, generated by higher electricity prices, to promote higher FiT´s and lower acquisition costs in order to provide a better incentive to the investment. Another option would be to reduce the energy price for pumping water and provision of PV facilities as alternative income source for farmers.

In summary, the structures of Iranian agriculture and the rural sector in photovoltaic could achieve better economic, social and environmental challenges than traditional energy sources. On the one hand, the reduction of CO_2 takes place. On the other hand, some benefits such as job creation, better health, reduced fossil fuel use, greenhouse gas reduction, global warming and sustainable rural development can be accomplished (Afsharzade et al., 2016).

The country is faced with many major challenges for RE development. This demonstrates the need for an innovative policy to create a framework for the development of RE. Key elements must be the withdrawal of subsidization for fossil fuels and the lowering of acquisition costs to promote the necessary incentive mechanisms for this renewable energy. A further reduction in the discount rate and inflation could create a new business segment for rural development and an explicit change of the government's direction towards sustainable energy production in Iran. Due to the increased decentralized use of PV plants, Iran could become the model and pioneer of the MENA countries, despite the enormous fossil resources. The potential is there, but it has to be implemented in a targeted and useful way.

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Appendix1: The CBA scenarios with assumptions and results

State	Scenario	Ecomomic lifetime	Acquisition cost	Cur-rency	Plant size (ha)	FiT per kWh	Currency own use	Feed-in	Own con-sumption	Annual increase of FiT	Increased FiT by domestic products	Discont rate	Net present value	Intern return rate
Iran	1.1.	20	100.000.000	IRR	5	8000	0	100%	0%	0%	0%	16%	-193224323	5,11%
	1.2.	20	100.000.000	IRR	5	8000	0	100%	0%	8,6%	0%	16%	44429721	17,41%
	1.3	20	100.000.000	IRR	5	10400	0	100%	0%	0%	30%	16%	-68476403	12,62%
	1.4.	20	100.000.000	IRR	5	10400	0	100%	0%	8,6%	30%	16%	240473854	23,14%
	2.1.	20	70.000.000	IRR	5	8000	0	100%	0%	0%	0%	16%	-43224323	12,72%
	2.2.	20	70.000.000	IRR	5	8000	0	100%	0%	8,6%	0%	16%	194429721	24,27%
	2.3.	20	70.000.000	IRR	5	10400	0	100%	0%	0%	30%	16%	81523597	21,50%
	2.4.	20	70.000.000	IRR	5	10400	0	100%	0%	8,6%	30%	16%	390473854	31,71
Germany	1	20	7000	EURO	5	0,1231	0,29€/kWh	100%	0%	0%	0%	1%	1233,51	2,70%
	2	20	7000	EURO	5	0,1231	0,29€/kWh	70%	30%	0%	0%	1%	5710,04	7,93%
	3	20	125000	EURO	5	0,1231	0,29€/kWh	25%	75%	0%	0%	1%	6924,82	5,90%

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Die Wurzeln der **Fakultät für Agrarwissenschaften** reichen in das 19. Jahrhundert zurück. Mit Ausgang des Wintersemesters 1951/52 wurde sie als siebente Fakultät an der Georgia-Augusta-Universität durch Ausgliederung bereits existierender landwirtschaftlicher Disziplinen aus der Mathematisch-Naturwissenschaftlichen Fakultät etabliert.

1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

Georg-August-Universität Göttingen
Department für Agrarökonomie und Rurale Entwicklung
Platz der Göttinger Sieben 5
37073 Göttingen
Tel. 0551-39-4819
Fax. 0551-39-12398
Mail: biblio1@gwdg.de
Homepage : http://www.uni-goettingen.de/de/18500.html