MSc Program
Renewable Energy in Central and Eastern Europe

After the sanctions: Iran's renewable energy outlook. A technical, economic and policy analysis.

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
Dipl.-Ing. Dr. Gustav Resch

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November 2016, Vienna

Affidavit

I, **Bernhard Florian Zlanabitnig**, hereby declare

1. that I am the sole author of the present Master Thesis, "After the sanctions: Iran's renewable energy outlook. A technical, economic and policy analysis.",
   148 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, 22.11.2016

Date

Signature

ACKNOWLEDGEMENT

"As you start to walk on the way, the way appears". Rumi (Persian poet)

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I want to dedicate this work to my unborn nephew. You are the future. And so is green energy.

Abstract

Iran is endowed with excellent climatic and tectonic conditions for harvesting green energy. The main objectives of this thesis were to identify the technical potential and the economic feasibility of three specific renewable energy sources, namely solar/photovoltaic, wind and geothermal energy. In addition, this study looked at current energy-policies and how they support or hinder the development of sustainable energy. The strengths, weaknesses, opportunities and threats were aggregated, giving an overview of the country's to-do list for a successful green energy future in particular under the perspective of UN-sanctions relief in January of 2016.

While the technical potential was estimated with mathematical equations based on available data, statistics (e.g. Weibull distribution) and assumptions, the economic potential (NPV, LRGC, project/equity IRR) was calculated for one specific site or plant per energy source under real-time conditions (feed-in-tariffs, escalation rate, inflation exchange, etc.), including a stress test (sensitivity analyses) for O&M costs, feed-in-tariffs and full-load-hours. The research was rounded up with a two month cooperation stay on-site with the Research Institute of Energy Management and Planning (RIEMP). The examination of current energy-policies was conducted with a SWOT analysis, followed by recommendations and strategies for policy-makers and investors.

The technical potential for solar energy was estimated to be 37,145 GW and 56,597 TWh, respectively; 186 TWh for wind, and 35,7 GW (297 TWh) for geothermal. Under current energy policies, solar power plants are considerable while wind and geothermal power plants are highly economically viable. SWOT analysis of Iran's 2021 target of 5,000 MW renewables installed capacity concluded that the country will need to make a comprehensive long-term renewable energy package, tackle environmentally harmful subsidies, maintain highly competitive long-run guaranteed purchase prices and additional incentives on renewable energy sources, empower banks and civil society, invest in education and strive for international technology and know-how transfer.

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Chapter 1: Overview of the electricity supply system in Iran

1.1. Motivation

The last two years were exciting ones- for both, renewable energies and me.

Never before in history more capacities of alternative energies have been added worldwide, at the same time the fossil fuel price fell to an all-time low and the global community signed a historic climate agreement in Paris.
For me, visiting Milan's expo, stumbling into the Iranian pavilion and taking the decision to explore the renewables potential of a country that, getting rid of captivating sanctions, is emerging. Persia- country of desire and full of stories of 'thousand and one nights'. But can those nights be illuminated with renewable energies?
Green energies today are established all over the world and a mainstreamed source of energy. The reasons are diverse: cheaper, competitive technology costs, supportive policies and incentives, energy mix and energy security as well as environmental issues and a huge demand for energy in emerging countries. One of this 'new, emerging markets' obviously is Iran.

The core objective of this thesis is to explore the electricity potential of 3 different renewable energy sources and to assess the economic feasibility or renewable energy projects of those. Eventually, the strengths, weaknesses, threats and opportunities are discussed, giving some recommendations for policy makers and investors.

This thesis encompasses 6 chapters. Starting with an overview of the objectives and methodology, the energy market in Iran, chapter 1 gives an introduction to objective and methodology of this research, an overview of (renewable) energy market in Iran, the latest development of RES policies with a special focus on the post-sanction era. Other sections of this chapter cover governmental incentives and support schemes as well as project development and financing schemes. Chapters 2, 3, and 4 examine the technical electricity potential of PV, wind and geothermal sources as well as their economic viability of specific energy projects (power plants) in these fields. Chapter 5 explains and executes a SWOT analysis on the feasibility of Iran's 2021 target on its 5,000 MW renewable energy target, followed by a strategy; eventually this chapter ends with recommendations for policy-maker and investors for a successful transformation of their green energy targets. The last chapter (6) summarizes and concludes with the findings.

1.2. Objectives, questions and methodology of research

Iran is one of the world's richest countries in terms of oil and gas reserves, but what about its renewable energy sources? How big is its technical and economic potential for green energies? What are the biggest barriers that have to be overcome and where are the country's advantages towards competitors?

This thesis will analyze the developments of Iran in the renewable energy sector, mainly after lifting the sanctions in 2015. 3 renewable energy sources, namely solar, wind and geothermal, will be in the focus of this research. How can the sustainable energies in Iran develop when the highly subsidized fossil fuel industry seems to be a invincible superiority, in particular after Iran returned to international markets after the trade restrictions. This thesis looks at the technical, economical, legal, ecological sides of renewable energy development as well as policy initiatives. Also, the strengths, weaknesses, opportunities and threats are going to be analyzed, leading to recommendations for policy-makers and potential investors.

The main questions to be answered are:

- How big is the technical potential of PV, wind and geothermal energy for electricity generation in Iran?
- Is the exploitation of those 3 renewable energy sources economically?
- What are the strength, weaknesses, opportunities and threats at current political, legal, economical and technical circumstances?
- What are possible strategies to tackle weaknesses and threats and push strengths and opportunities ahead?
- What should policy-makers do to accelerate the expansion and what will potential investors make increase their activities in the renewable energy sector?

For this research a considerable amount of literature review was conducted, as well as site visits, attendances of conferences and fairs in Iran, in-depth conversations with experts from renewable energy organizations, academia-related institutes doing research on green technologies as well as institutions related to the fossil fuel industry were conducted.

More specifically, for the technical estimation of the wind potential the Weibull approach was applied.

For the economic indicators, measures like the project internal rate of return (IRR), the equity internal rate of return, the LRGC (Long Run Generation Cost), and the NPV (net present value) were calculated. The CO2 savings and the EPBT (Energy Payback Time) were calculated.

The technical potential is a net operational number that refers to the amount of energy that can be exploited from renewable energy sources, independent from economic or legal matters, policy frameworks, access to consumers/markets or technological conditions.

The economic potential has to take into account the available technology and energy policies.

A SWOT analysis tries to summarize all legal, economical, ecological, technical, socio-economical and policy initiatives to give a sound overview of Iran's biggest barriers and opportunities, followed by possible strategies for policy-makers and recommendations for both governmental bodies and investors.

1.3. Introducing Iran

The Islamic Republic of Iran with an area of 1,648,195 km^2 is located in Western Asia. With an estimated Gross Domestic Product (GDP) of approx. $1 billion, Iran is the world's 18th largest by purchasing power parity (PPP)[1]. The country is a member of Next Eleven N-11[2] because of its high development potentials. Iran is the 2nd largest economy in the Middle East and North Africa (MENA) region after Saudi Arabia. The country had an estimated population of 78.5 million in 2014 with 60% of people estimated to be under the age of 30[3]. Figure 1.1. shows the development of population in rural and urban areas, with an actual population growth rate of on average 1.54% per year (2000-2010), a decreasing rural population and a strongly increasing urban one. The economy, public banks and financial sector as well as public and parastatal companies are centrally planned and controlled. 60% of the manufacturing sector belongs to the government and transition economy with a large public sector and a

[1] Wikipedia, 2016: Economy of Iran
[2] Wikipedia, 2016: Next Eleven
[3] Wikipedia, 2016: Economy of Iran

small-scale agriculture[4]. With 10% of the world's proven oil reserves (rank 4 worldwide[5]) and 15% of its gas reserves (rank 2 worldwide[6]), Iran is considered an “energy superpower” (Coskun, 2009: 2), strongly depending on oil and gas revenues. Oil production might reach up to 4 million barrels per day by end of 2016[7]. Additionally, Iran has huge zinc and copper reserves.

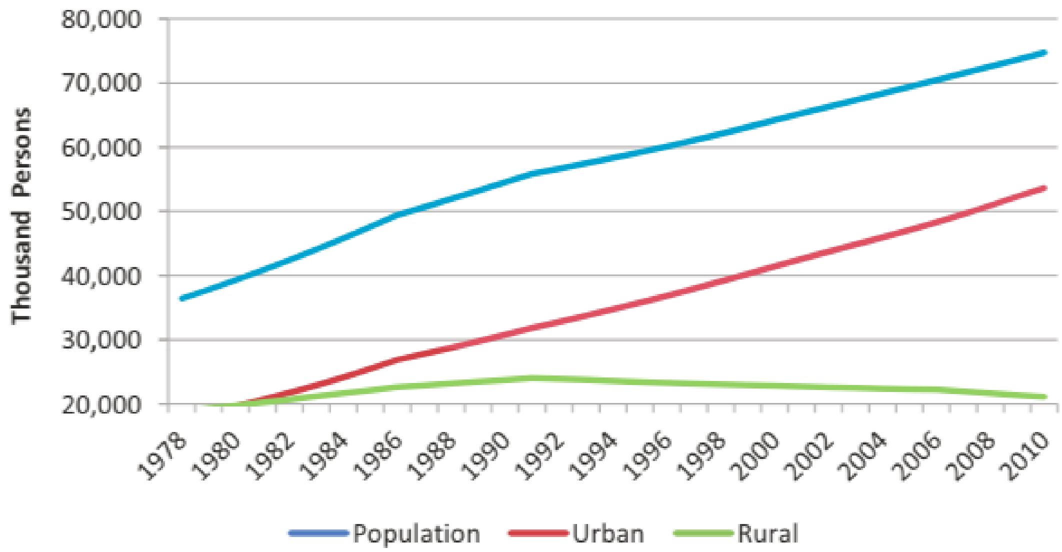

Figure 1.1. Population Trends in Urban and Rural Areas, Iran; Source: Central Bank of Iran, Economic Data (2014)

In 2009 the energy price reform law, also known as the ‘Targeted Subsidies Plan’ or the ‘Subsidy Removal Plan’, was passed by the Iranian parliament Majlis. The main two objectives of the plan were to decrease government spending on energy subsidies, particularly direct subsidies for gasoline, and to reduce energy consumption mainly by gradually increasing energy prices within 5 years (2010–2015) (Farzad, 2014, cited by Aguilar et al., 2016). These indirect subsidies, which are estimated to be approx. $ 77 billion, have been replaced by a direct cash transfer program to Iranian households. One of the implementations resulting from this reform plan will be the development of renewable energy plants for electricity generation (Guillaume et al., 2011).

The energy price reform led to a dramatic income effect due to the cash handout. Overall, the energy price reform was a breakthrough in the Iranian energy sector, which

4 The Economist Newspaper Limited, 2003: Stunted and distorted
5 EIA, U.S. Energy Information Administration: 2015: Iran - International energy data and analysis
6 See footnote 5
7 Oilprice, 2016: Oil Won’t Crash Before The OPEC Meeting

has a long history of heavily subsidizing its energy (Farzad, 2014, cited by Aguilar et al., 2016). It could strengthen the economy and productivity even if critics say it pays too little attention to energy efficiency. It also gives the chance to raise awareness and educate people about energy, efficiency and environmental matters that are weakly developed in a country that has abundant natural resources of all kinds (Moshiri & Lechtenböhmer, 2015: 87)

Apart from the above-mentioned zinc and copper reserves, Iran holds rich silicon mines, which is the raw material for production of photovoltaic cells[8] (see chapter 2.3.). It also gives an opportunity to develop a long-term investment plan for alternative renewable energy resources in Iran. The author got awareness that the IIES institute has developed such a plan[9], however, for unknown reasons does not publish it yet.

The country faces a fast growing demand for electricity and the average rate of electricity generation growth was 5% per year during the last 10 years (Aguilar et al., 2016: 15). Due to its actual Five-Year Development Plan (see Info Box 3: Five-Year Development Plans) country should generate an extra 5 GW each year to supply the demand for the upcoming years.

Although Iran has great potential for renewable energy generation – as this thesis will show in the following chapters - there has been little development in this field so far. The main reasons are enormous oil and gas reserves that, despite the above-mentioned energy price reform, still lead to low prices for electricity (generation). Nevertheless, the government will have to adjust existing regulations and laws and develop new ones to attract national and international investors. This will be further elaborated in chapter 5.

1.4. Relation between Iran & Austria

Austria and Iran have long-lasting relations, starting in the 15th century. In 1857 the 'Freundschafts-, Handels- und Schifffahrtsvertrag', the first international treaty between Persia and Austria was signed, leading into diplomatic relations in 1872. From the end of the 19th century when many Austrian experts, mainly for street construction, coinage and postal system, were in service for Persia until the mid of the 20th century when Austrian

[8] SUNA, 2016: Photovoltaic Energy
[9] IIES, 2016: Iran National Energy Master Plan

came to work for the rail system, Persia and Austria had very close (economic) ties and amicable bonds. Since 1958 Austria holds, apart from the embassy, a chamber of commerce[10] and a cultural institute[11]. Recently, former Austrian President Mr. Fischer visited Iran as the first European representative after lifting the UN-sanctions (see Info Box 2*:* Sanctions on Iran aka Restrictive Measures).

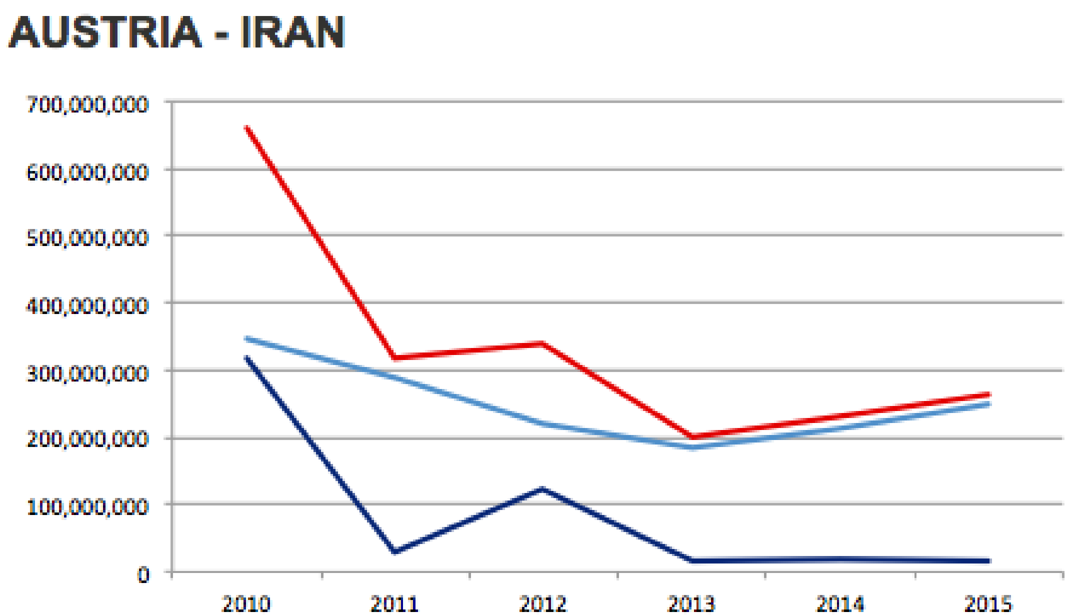

Figure 1.2. Market Development 2010-2015 Austria – Iran (x-axis: years; y-axis: Iranian Real); Source: Advantage Austria/WKÖ Außenwirtschaft

However, the incline of trade between the countries is obvious and presented in figure 1.2. Trade used to be before 2012 with over € 600 million. Today we stand at € 250 million- not even the half (see Info Box 1 Austria – Iran foreign trade in a nutshell).

The Joint Economic Mission of Austria in Iran (JEC) was reinstated after the presidential visit of President Fischer in September 2015. It was agreed to draft a common roadmap for future cooperation (2016-2021). Both sides agreed to establish Working Groups in e.g. the energy field.

[10] Advantage Austria, 2016
[11] Österreichisches Kulturforum Teheran, 2016

Info Box 1 Austria – Iran foreign trade in a nutshell[12]

Export to Iran: € 248.15 Mio.
Main products exported to Iran: Pharmaceuticals, engines, mechanical devices
Import from Iran: € 16.09 Mio.
Main products imported from Iran: Carpets, dried fruits

Info Box 2 Sanctions on Iran aka Restrictive Measures

1979 – First sanctions imposed after storm on embassy

1995 – USA ban on business with Iran

2006 – UN/EU sanctions (enrichment program)

2007/2010 – UN/EU sanctions tightened

2012 – EU oil embargo

2012/2014 – Downfall of Iran's foreign trade

2015 – Join Plan of Action

2016 – Joint Comprehensive Plan of Action (JCPOA[13])* „Vienna Agreement" (16.01.)

Implementation Day (first set out phase)

2024 – Transition Day (UN ballistic missiles)

2026 – Termination Day (UN sanctions dismissed)

2041 – End of IAEA monitoring

- *Only nuclear-related sanctions partially set out
- Human rights-related sanctions untouched
- „Snap back"-mechanism: treaty can be cancelled anytime from any side
- Still listed: persons and entities (<200), dual use goods, military goods; certain metals, software and goods referring to internal repression

1.5. Overview of Iran's energy & electricity market

1.5.1 Introduction

As mentioned above, Iran holds the 4th-largest oil reserves in the world as well as the 2nd-largest gas reserves. The strongly subsidized oil and natural gas are the main

[12] WKÖ, 2015: Außenwirtschaft Iran
[13] WKÖ, 2015b

cause why renewable energies (except hydro power plants) do not play a significant role in Iran’s electricity generation so far.

Iran consumed almost 244 million tons oil equivalent (ToE) of primary energy in 2013 (EIA, 2015). Natural gas and oil accounted for almost 98% of its total primary energy consumption, with little contributions from renewables (including hydropower). Iran's primary energy consumption has grown by almost 50% since 2004 (EIA, 2015) while households, industry and transport are consuming approx. ¼ of this amount each (Moshiri & Lechtenböhmer, 2015: 14).
The total installed capacity was about 59 GW using different technologies: 26% steam, 34% natural gas, 26% combined cycle, 15% hydropower and 0.1% renewable energies. (Moshiri & Lechtenböhmer, 2015: 39ff.)

One year later, in 2014, Iran consumed already 267 million ToE, which equals an increase of more than 9% compared with 2013.[14]. Natural gas and oil accounted for almost all (98%) of Iran's total primary energy consumption, with marginal contributions from hydropower, coal, nuclear, and non-hydro renewables (see Figure 1.3.). Iran's primary energy consumption has grown by almost 50% since 2004!

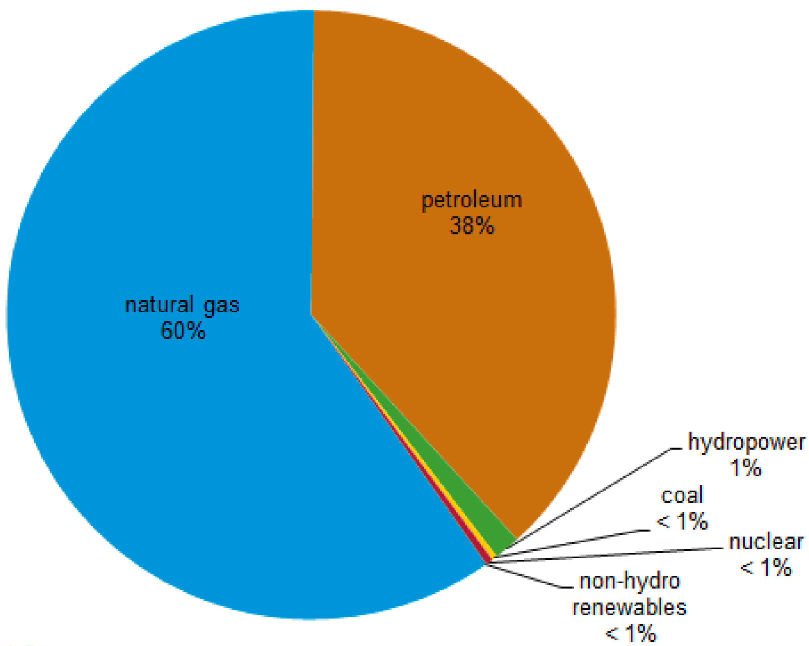

Figure 1.3. Iran’s total primary energy consumption, share by fuel (without biomass and waste, 2013); Source: The Energy Consulting Group (2013)

[14] BP, 2016: Statistical Review of World Energy

The energy intensity in Iran is extremely high as it its reliance on energy-intensive industries like petrochemical and metal industries.
Iran's energy factor, defined as the ratio of the growth rate of energy use to the GDP growth rate, has also been higher by 35 percentage points compared to the world for the period 2001-2011. (Moshiri & Lechtenböhmer, 2015: 15)

The energy consumption as well as the energy intensity is the result of low energy prices and poor energy efficiency. It would be necessary to intensify energy-saving technologies, improve the use of energy resources and encourage activities that do not use energy intensively. All of these measures are in its infancy or have not yet started (Tofigh & Abedian, 2016).

The capacity of installed conventional power plants reached 70 GW in 2013, which is an increase of approx. 70% (see Table 1.1.). Gas, combined cycle and steam turbines contributed about 83% of the installed capacity. Renewable energy technologies only sum up to 0.2%. In other words- the renewable energy industry in Iran is at its beginning only.

Table 1.1. Nominal installed capacity and electricity generation (2005 and 2013)

Power Plant	2005		2013	
	Capacity (MW)	Generation (GWh)	Capacity (MW)	Generation (GWh)
Steam	15,578	93,383	15,829	89,664
Gas	12,049	32,129	24,715	66,039
Combined cycle	6,832	36,194	17,849	87,135
Diesel	493	212	439	71
Hydro	6,044	16,100	10,266	14,582
Wind	48	71	110	376
PV	0.144	0	0.069	0.068
Nuclear	0	0	1,020	4,546
Biogas	0	0	7	21
Total	**41,044**	**178,089**	**70,236**	**262,433**

Source: MoE (2013): Iran Energy Balance 2013

1.5.2. Electricity demand

Today Iran is one of the largest consumers of electricity in the world. Electric power demand grows by 8% per year A research by the Ministry of Energy says that up to 20,000 MW of capacity should be added within the next 20 years and that energy demand will be 200,000 MW in 2030 (Ghorashi et al., 2011). Obviously, fossil fuels will not cover this numbers in 2030. This rising energy demand will have to be met by becoming an importer of energy. Iran will have to re-think its energy mix and strategies. Plans like oil efficient power plants exist as well as an emphasis on natural gas production. The Iranian Power Generation, Transmission, Distribution and Management Company (TAVANIR, see section 1.5.10.) estimated that RES would generate around 10% of Iran's electricity production until the end of the 5th Five-year development plan in 2015, what did not materialize (see Info Box 3: Five-Year Development Plans).
Iran's 6th Five-year development plan (2016-2021) will again include a renewable generation target of 5,000 MW[15].

Info Box 3 Five-Year Development Plans

The Iranian state continues to play a key role in the economy with large public and quasi-public enterprises dominating to some extent the manufacturing and commercial sectors. The financial sector is also dominated by public banks.
One outcome is that the Iranian government has implemented a major reform of its subsidy program (see chapter 1.5.4.), another one the Five-Year Development Plans: Major elements of the government's annual budget and the central bank's credit policy are incorporated into the five-year economic development plan.
These Five-Year Development Plans are a five-year government growth policy.
The first plan started in 1989 and dealt with the consequence of the Iran-Iraq war as a priority.
The fifth version (2010–15) was designed to delegate power to the people and develop a knowledge economy and is part of "Vision 2025", a strategy for long-term sustainable growth. The 5th version should have determined but was extended until the end of the next Iranian year, which dates March 20, 2017.[16]

[15] PV Magazine, 2016: Iran reveals 5 GW plans for solar and wind
[16] AEI, 2016: Iran News Round Up – March 16, 2016

The 6th Five-Year Development Plan (2016-2021) is in discussion at present time in Majlis. It will comprise three pillars: the development of a resilient economy, progress in science and technology, and the promotion of cultural excellence. On the economic front, the development plan envisages an annual economic growth rate of 8% and considers the implementation of reforms of state-owned enterprises, the financial and banking sector, and the allocation and management of oil revenues.
It will include a renewable generation target of 5,000 MW.

1.5.3. Electricity generation and consumption

The total electricity generation capacity in the country was 65 GW. The electricity generation in Iran is mainly based on fossil fuels, namely 69% natural gas, 25% oil and 1% coal; the rest by hydro (4%) and less than 1% by wind, geothermal or solar power.[17]

Calculations of Aguilar et al. (2016: 35) show that on average each Iranian household demanded about 2.6 MWh of electricity in 2013. In public sector, an average consumer used approx. 14 MWh, 4 MWh in the commercial sector, 365 MWh in the industrial sector, and about 100 MWh in the agricultural sector. The distribution given in percentage is shown in figure 1.4. Some provinces with very hot climate have a much higher consumption than others (Bushehr, Khuzestan or Hormozgan) because of the air conditions needed. It shows very well the impact of climate on electricity consumption. There would be high potential for self-consumption roof-top or private-owned small-scale PV systems (Aguilar et al., 2016: 49f., 61f., 69ff.).

[17] EIA, U.S. Energy Information Administration, 2015: Iran's key energy statistics

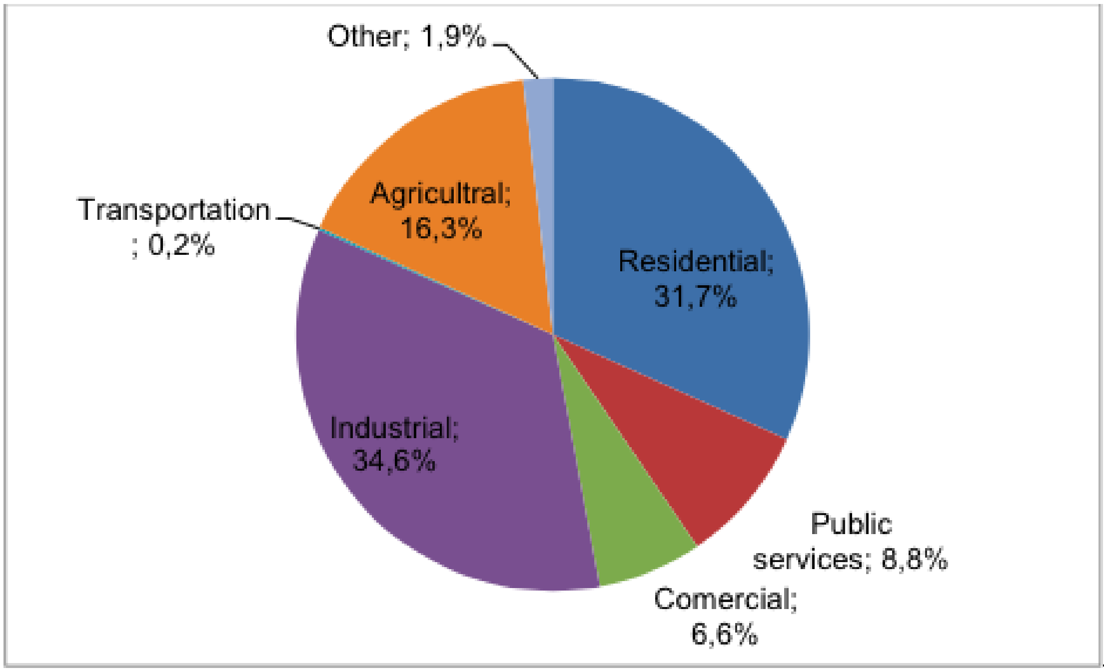

Figure 1.4. Share of electricity consumption per sector (2013); Source: SUNA (2016), History of SUNA

1.5.4. Energy Subsidies and Electricity Tariffs

Until 2011 the energy market in Iran was a monopoly; the government, as the only supplier, set the prices of energy carriers and more or less froze them. For instance, by then, 1 liter of gasoline was sold for less than $9 cent (Sabetghadam, 2005/2006). Tariffs were not a determinant factor for consumers and their behaviors. Also Iran's (energy) subsidies were the highest of the world at $82 billion or 16% of Iran's GDP (Tofigh & Abedian, 2016).

In 2010 the Majlis approved the Subsidy Reform Act aka Targeted Subsidies Reform Act. Within the first year, the average electricity tariff doubled, in the agricultural sector around 268%! It has to be mentioned though that the agricultural sector has benefited most from all the subsidies all the years before. The residential tariff was set below the average price (weighted average). The monthly price also depends on the consumption level set by TAVANIR. In summary it can be said that his reform let to a certain market liberalization but tariffs increased by 96.2% and the consumption collapsed, however, returned meanwhile to its long-term growth rate of about 5% Aguilar et al., 2016: 23). For details on electricity tariffs and their rising see table 1.2.

The reform was implemented according to its Vision 2025 strategy (see Info Box 3 Five-Year Development Plans). The program focuses on essential products and services such as petroleum products, water and electricity. One of the implementations resulting from this reform plan should be the construction of renewable energy plants for electricity generation (Aguilar et al., 2016: 14).

Table 1.2. Electricity tariff in each consuming sector and weighted average tariff-IRR/kWh (2005-2013)

Year	**Residential**	**Agriculture**	**Industrial**	**Weighted Average***
2005	102.7	21.6	201.4	152.0
2008	119.4	22.0	204.7	174.5
2011	334.8	125.7	441.9	409.5
2013	346.7	133.4	442.6	418.5

* Including public services and others not shown in table. Source: Aguilar et al. (2016)

1.5.5. Supporting Policies for renewable energy (systems)

According to the 5th five-year development plan (2010-2015) (see Info Box 3 Five-Year Development Plans), 5,000 MW of installed capacity of REN should have been achieved by the private sector through guaranteed purchase of the electricity[18]. However, this target has not been met. The new target for the next five-year development plan (6th five-year development plan 2016-2021) was set by the MoE, but has not yet passed the parliament. The share of REN should be at least 5% of the nominal installed capacity of the country in 2021 (at the end of the five year period[19]), which would renew its old target of around 5,000 MW out of 100,000 MW installed capacity.

The following policies and support mechanisms have been set in recent years to push the development of renewable energy in Iran[20]:

a. **Revised Feed in Tariffs:** According to the 5th Five-Year Development Plan, TAVANIR, SUNA or distribution companies are permitted to sign long term Power Purchase Agreements (see section 1.5.7.) with the owners of renewable energy power plants. **For a detailed description of Iran’s Feed in tariff system see just below lit. d.**

[18] SUNA, 2016: Opportunities to Construction Renewable Energy power plants In Iran
[19] See footnote 17.

[20] Section 1.5.5 a-d based on: Aguilar et al., 2016: 42ff.

b. **National Development Fund (NDF):** The National Development Fund was established to transform oil and gas revenues to productive investment for future generation. The Fund is based on the annual petrochemical sales. It also can grant soft loans for investors. The economic calculations of this thesis will take into account that the NDF will provide a soft loan for our investment though there are no known examples that those have been granted before so far. For our calculations in chapters 2, 3 and 4 a NDF loan of 6% is estimated.

c. **Budget for purchasing Renewable Energy Electricity:** The MoE is obliged to include an amount of 30 IRR/kWh as electricity duties in the electricity bills. Only rural households are excluded. The money received is used by TAVANIR for rural electrification as well as for the generation of REN electricity. It is like an extra tax on electricity as we know it from some European countries (e.g. Germany for its 'Energiewende'). The parliament set a cap of 4,000 billion IRR per year. However, this amount is not enough to meet the target set by the government. If the government wants to meet this target, the amount of 30 IRR/kWh will have to be increased.
Other financial resources to stimulate REN electricity generation are the equivalent of the saved fossil fuel, or the cost of environmental damage made by generating electricity in fossil fuel power plants, but these have not been implemented yet[21].

d. **Feed-in tariffs** (**FIT)**: The MoE is obliged to purchase electricity from REN power plants established by the private sector with specific tariffs & conditions. These tariffs are announced once a year, the last time on May 8 2016.
It is interesting and important to look at the development of FIT over the last years to forecast future developments and give recommendations to potential investors.

-
- 2012: max. 1,863 IRR/kWh, for 20 years (equals 0.055 Euro)[22]
- 2013: max. 4,442 IRR/kWh, for 5 years (equals 0.132 Euro)
- 2014: max. 4,628 IRR/kWh, for 5 years (equals 0.137 Euro)
-

While the old approach to set FIT was based on avoided costs of fuel, pollution, etc., the new Feed in Tariff system (from 2015) comprises following characteristics:

[21] Renewable Energy Trade Mission Iran, 2016
[22] The exchange rate corresponds to 33,772 IRR/1 Euro.

- It’s technology-specific, based on the LCOE of each technology.
- The size of the power plants is another determining factor.
- The FIT is paid for 20 years (instead of the previous 5-year periods).
- The rates are valid for the first 10 years of guaranteed purchase contract; the second 10-year-period it is decreased to 70% of the original amount (wind power plants excluded).
- An adjustment formula was developed to adjust FIT with the inflation and exchange rate changes (calculation of adjustment formula see chapter 1.5.6.)
- There is up to 15% extra bonus added to the FIT, if the investors use domestic products, i.e. components manufactured in Iran.
- FITs are only guaranteed if the plant is operational within 15 (solar), 24 (wind) or 30 (geothermal) months.

The latest FIT (see figure 1.5.), announced on May 8 2016, decreased 20% compared with previous rates and it looks like they will continue gradually decreasing due to low fossil fuel prices.

1	Biomass	landfill	2700
		the anaerobic digestion of manure, agricultural wastes and wastewater	3500
		Incineration and wastes gasification	3700
2	Wind Farm	above 50 MW capacity*	3400
		with the capacity of 50 MW and less	4200
3	Solar Farm	above 30 MW capacity*	3200
		with the capacity of 30 MW and less	4000
		with the capacity of 10 MW and less	4900
4	Geothermal (including potential assessment and excavation)		4900
5	Waste Heat Recovery (WHR) from Industrial Processes		2900
6	Small Hydropower (with the capacity of 10 MW and less)	installation on the rivers and side facilities of dams	2100
		installation on the water pipelines	1500

Figure 1.5. Feed in Tariffs announced for 2016 per power plant technology type (IRR/kWh); Source: SUNA (2016) (see Appendix I)

For further information on feed-in-tariffs and their conditions, statistics and project implementation stages see Appendix I.

1.5.6. Adjustment Formula

Additionally to the fixed amounts, as described in section 1.5.5, the FiTs are adjusted to the inflation and the exchange rate changes. In figure 1.6. the adjustment formula is presented. For our calculations in chapters 2, 3 and 4 this formula will be taken into account.

Adjustment Formula

Every month the base tariff is multiplied by the adjustment coefficient:

$$k = \left(\frac{CPI_{x1}}{CPI_{o1}}\right)^{\alpha} \times \left(\frac{€rate_{x2}}{€rate_{o2}}\right)^{1-\alpha}$$

K: Index coefficient

CPI: Retail Price Index announced monthly by the central bank of Iran (CBI)

€ Rate: Annual average of the exchange rate of Euro with Rails, as announced by the CBI

α: Power coefficient between 0.15~0.3 set by investors

X_1: Refers to the first month of payment year

X_2: Refers to the year before payment date

O_1: Refers to the first month of contract year

O_2: Refers to the year before contract date

Figure 1.6. Adjustment Formula for the feed in tariffs; Source: SUNA (2016), Opportunities to Construction Renewable Energy power plants In Iran

For instance, looking at a 5 MW PV project with FIT of 4,900 IRR/kWh (0.1450 Euro), if the inflation rate (first part of the formula) is 12% and the annual change of exchange rate Euro-IRR is 8%, the adjustment coefficient for the first year is 1.09 (9.18%). Therefore, the FIT for the first year equals 4,900 x 9.18% = 5,350 IRR/kWh (0.1584 Euro). A more detailed calculation for each REN technology can be found within the chapters 2 (PV), 3 (wind) and 4 (geothermal).

1.5.7.Power Purchase Agreement (PPA)[23]

For medium and large renewable energy plants, a PPA contract between SUNA and the owner of the power plant is concluded. Both sides agree on the purchase of electricity based on the Feed in Tariff.

The most relevant elements of this PPA[24] are:

a. The **duration of the contract and deadlines**:

The duration of the contract is set for 20 years. Further, the applicant needs to commission the power plant within 18 months after signing the PPA, otherwise the generated electricity will be bought with the price of the energy market.

b. **Feed in Tariff:**

The FiT is determined each year by the ministry of energy (MoE). Each Iranian year begins on 21st March. The MoE should announce it at the beginning of each year but it usually takes a few months until it is announced which is one of the barriers for the development of REN identified. For details on FIT see section 1.5.5.d and within chapters 2, 3 and 4. Every year the FIT is adjusted by the 'adjustment formula' (see section 1.5.6.).

c. **Payment:**

Letter of Credit (LC): SUNA has negotiated with some Iranian banks to open LCs for 6 months to ensure the owner of the power plant receives its payment. The LC is revolving every six months. However, the cost risk is on the side of the developer.

Delay Compensation: SUNA compensates the delay in payment based on the minimum interest rate of the country determined by the government each year and on a daily basis. However, this is only valid for changes in law, not for political force majeure events like war, terror, archeological findings or sanctions.

Grid Connection: All the costs of grid the connection are paid by the owner of the power plant including buildings, the required substation and the grid line, if needed.

1.5.8. Process of Project Development

The development process for REN power plants in Iran is quite new, due to the fact that the previous FIT were not granted long enough to attract investors. Although the

[23] Aguilar et al., 2016: 54ff.

[24] The PPA contract is available on SUNA, 2016: Power Purchase Agreement of Renewable and Clean Electricity

development process is standardized by SUNA, there is not enough experience what makes developers hesitate.

The development process for PV power plants with more than 100 kWp is as presented in figure 1.7.

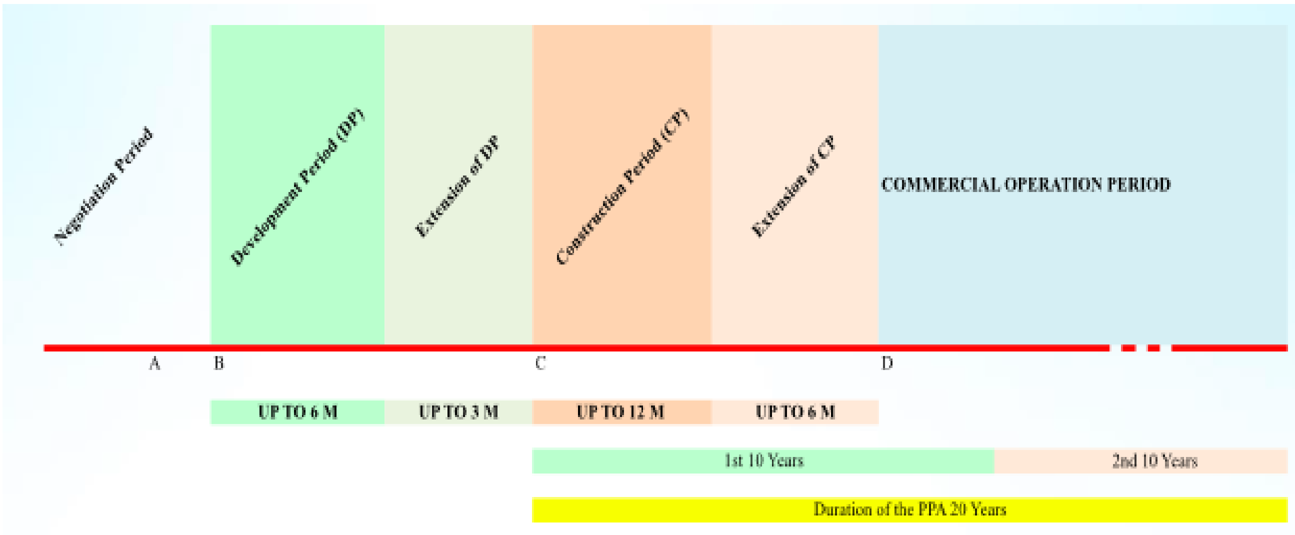

Figure 1.7. PPA Timeline: Simplified Timeline for the conclusion and execution of an Iranian REN PPA between the generator (seller) and SUNA (buyer) for systems > 100 kWp A[25]: end of negotiations between generator and SUNA, and signature of PPA; B: Issuance of license; C: (i) Notification of the PPA by buyer to seller; (ii) effective date of PPA; (iii) commencement of the construction period (CP); (iv) commencement of contract period; D: end of construction period and commencement of the commercial operation period (COP) Source: Renewable Energy Trade Mission Iran (2016).

Based on own research, meetings and conferences' visits with organizations, faculty staff, foreign and local companies and chambers of commerce during the author's stay in Iran in April and May 2016, the average time of the development is around one year. Especially the lead time to lease or buy the necessary land and to register is long. Also the permitting for environmental requirements and grid connection takes its time. Regarding the grid, SUNA stated sufficient grid capacity for 5 GW but developers require greater visibility and transparency on grid availability; further, the grid connection is on the developer's costs. SUNA also started a new approach of licensing: due to number of developers not progressing projects, the grant of new licenses will be limited to one per developer and for smaller projects only before multiple licenses or licenses for larger projects are granted. Existing licenses will be subject to greater scrutiny; projects, which

[25] Necessary permits before signing the PPA: land permit by acquisition or lease (government, private person); environmental permit (department of environment); grid connection permit (regional electricity company)

do not progress satisfactorily, will have their licenses revoked. However, developers' concerns remain around how SUNA will apportion licenses and how grid connection will be prioritized in the event of potential over-capacity (Deign J., 2016).

1.5.9. Process und Financing Schemes

Throughout this research it turned out clearly that one of the main obstacles for the faster and more successful development of REN is the lack of appropriate financing. REN-projects could be financed by Iranian Banks. However, due to the high inflation rate, domestic banks provide loans in Iranian Rial with very high interest rates (around 20-25%!). Also, they do not have sufficient liquidity to finance large-scale projects. This is of course an enormous barrier for investors (if finance is not based on 100% own equity). The National Development Fund (NDF) has been founded to provide soft loans for development projects. The source of the money for this fund is mainly oil export income, which re-started after the sanctions got lifted. However, due to low oil's world market prices there is only little money in this fund. Until end of 2015 there has been no project funded by the NDF and meetings with experts show that it is very difficult to receive these funds. For our calculations, however, we assume a soft load of 6% granted by the NDF. The reason why for our calculations we assume this load is that firstly, there are signs that the NDF will get more funds as SUNA. Secondly, authorities can see the necessity to somehow balance the weakest point of attracting investors, namely the financing of projects. Thirdly, as soon as Iran will be re-connected to the international financing system, cheaper credits with lower interest rates will be on the market. International banks are mindful of the exorbitantly high penalties levied for US sanctions violations in the past and so are still reluctant to finance projects in Iran (Watson, Farley & Williams, 2016). One should keep in mind that only the UN sanctions and not the US ones were lifted (see Info Box 2 Sanctions on Iran aka Restrictive Measures).
During the author's stay in Iran, SWIFT payments were still not permitted for Iranian banks or persons. This leads to difficulties in payment transactions and money transfers into and investment return out of Iran (including conversion of Iranian Rials into Euro). Some European banks with no US exposure, for instance from Germany, Italy and Austria, have started to establish corresponding relationships with Iranian banks (Watson, Farley & Williams, 2016.

1.5.10. Key Actors

In figure 1.8. the main actors of the regulatory framework in Iran are shown.

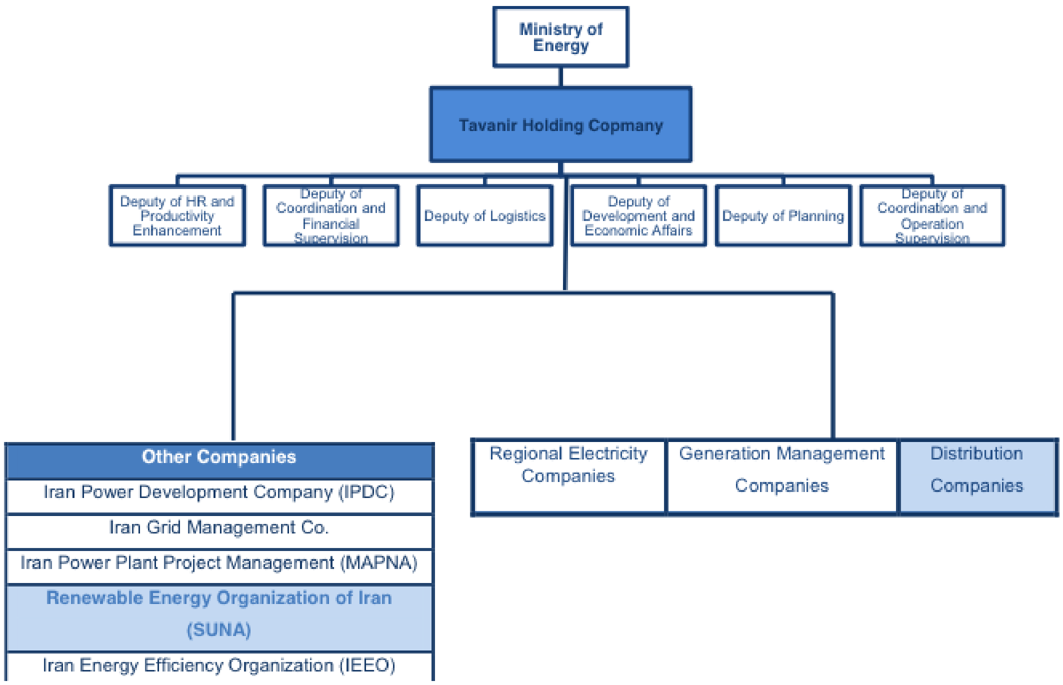

Figure 1.8. Organizational Chart of the Ministry of Energy, incl. TAVANIR and SUNA; Source: TAVANIR, 2015, cited by Aguilar et al., 2016: 38

The **Ministry of Energy (MoE**) of Iran was established in 1975, being in charge of managing and coordinating water and energy activities except oil and gas. The MoE is the main organ of the Government, responsible for the regulation and implementation of policies applicable to four main industries including electricity, renewable energies, water and wastewater services. It also seeks to increase private sector participation and investments (Aguilar et al., 2016: 36).

TAVANIR and Distribution Companies (**DSO**): TAVANIR was established to organize the supervisory activities of the government in the fields of operation and development of the electric power industry. Currently the company is responsible for the management of e.g. 16 regional electric companies and 39 DSOs but also the Renewable Energy Organization of Iran (SUNA) and the Iran Energy Efficiency Organization (SABA). The 39 DSOs are in charge of a province, a city, and they play a main role in the permission procedure (Aguilar et al., 2016: 36).

SUNA[26]: In 1996 the Renewable Energy Organization of Iran (SUNA) was established to evaluate the renewable energy potential, to implement solar, wind, geothermal, hydro and biomass projects and to purchase the electricity generated in the different RES.

SUNA tries to attract investors by different incentives and does research and trainings. In 2000 SUNA became a state organization for the development of renewable energies (Aguilar et al., 2016: 36).

[26] SUNA, 2016: History of SUNA

Chapter 2: Photovoltaic electricity in Iran

2.1. Introduction

Iran on its way to a solar future?

One year ago, in August 2015, Iran amended its laws to increase incentives for investing in renewable energy sources: new guaranteed purchase of electricity rates from renewable and clean power plants were announced (feed-in tariffs differentiating by type of technology instead of a uniform tariff), the guaranteed period of power purchase was extended to 20 years (instead of only 5 years before) as well as the target of 5,000 MW installed capacity of renewable power plants within 5 years was set. Together with the relief of sanctions in January 2015 (see Info Box 2 Sanctions aka Restrictive Measures), expectations were high that foreign investments would rise and renewable energy plant construction boost. However, there have been no noteworthy investments until today. What went wrong?
At first sight, the Iranian government did the right steps into the right direction: Feed-in-tariffs (FIT) have been extended from 5 to 20 years, supplemented by a 'FIT escalation' which makes the market– compared to the European standard – very attractive for investors who find a country with one of the highest solar radiation worldwide: +/-300 sunny days a year and a DNI (direct normal irradiation) for solar energy between 4.5 to 5.5 kW/m^2/day. The government even offers tax incentives like an 'exchange rate escalation' due to inflation up to 20%.

One reason for the above-mentioned rewards and compensations is the weak developed national financing of solar PV projects with interest rates often higher than 25%. Foreign investors still hesitate to enter the market due to the sanctions that are (partly) still in place (until 2024), insecure rule-of-law, bankability and availability of financing. Also, the experience of international investors is missing and makes them hesitate to invest.

However, the upcoming 'Sixth Five-Year Development Plan (2016-2020; see Info Box 3: Five-Year Development Plans) will renew the 5%-renewable energy target: at least 5% or 5,000 MW (out of 100,000 MW) of the nominal installed capacity of the country should origin from renewable energy sources by 2021 (Watson, Farley & Williams, 2016). Additionally, the energy demand all over the country will rise in the next years and decades. Climate change and international obligations as well as falling oil and gas prices might accelerate the development of the RES market.

There are signs that the PV market in Iran will soon emerge due to the combination of excellent topographic conditions and governmental incentives. Iran can reduce its dependency on finite oil and gas reserves while at the same time increase its exports of refined oil and gas products, attract investors, gain from technology transfer from experienced renewable energy countries like Germany or Italy, and last but not least accomplish international commitments to reduce greenhouse gas emissions (GHG).

In section 2.2 the solar market in Iran is described, followed by section 2.3 with a brief statement on PV technology, 2.4. on environmental impacts of PV and 2.5. on the technical market potential of solar PV, with a focus on the system performance ratio (2.5.3.), global solar irradiation (2.5.4.) , solar areas (2.5.5.) and eventually the PV electricity potential by province and in total (2.5.6.). Section 2.6. estimates the economic feasibility, including the business model description (2.6.1), the Power Purchase Agreement (2.6.2.) and the profitability analysis (2.6.3.). Finally section 2.7. covers two kinds of sensitivity analyses.

2.2. Iran's Solar Market

According to SUNA - as shown in table 2.1. -, the total installed capacity of photovoltaic systems in Iran is around 39,777 kW[27]. Another 1,615 MW PV projects are under development and the estimated demand for PV projects is around 1,077 MW (Aguilar et al., 2016: 34)

Table 2.1. Installed capacity of investment projects in PV (2015)

Installed capacity (kW)	**Description**
32,105	Street lights and parks energy supply; traffic light, bus stations electrification; universities, regional power companies; SUNA; telecommunication systems; electrification of rural areas (967

[27] SUNA, 2016: Photovoltaic Energy

	households)
7,158	Installed capacity of PV systems from the electricity levies 2013-2015
514	Capacity installed by private sector company, Atrin Parsian
39,777	**Total installed capacity (kW)**

Source: SUNA (2016): Photovoltaic Energy

Table 2.1. also shows that there are several installed PV systems over the country working as distributed source of electricity. Most of these systems are installed in parks and 967 households, as streetlights or parks energy supply (32,105 KW). There is one private system with 514 kW. Thus, the total installed capacity of PV systems sums up to more than 39 MW. Additionally, there can be found two big solar thermal power plants in Shiraz (parabolic thermal power plant) and Yazd (integrated solar combined cycle/ISCC) with a solar thermal electricity capacity of 250 KW and 17 MW, respectively. (Sharbafian, 2009: 49)

That the private sector can engage with investments into renewable energies is based on ratification of Article 133 (section B) of the 5th five-year development plan (see Info Box 3: Five-Year Development Plans) in 2011 (Aguilar et al., 2016: 30).

Eventually, Iran's renewable energy organisation, SUNA (see chapter 1 for more information on SUNA) developed a new model of FITs that are technology-specified and offers a 20-year power purchase agreement (PPA) contract. See chapters 1.5.5. and 1.5.7. for more information on FITs and PPA. Currently, there are 3 private solar plants that required there PPAs but are not yet on-grid (see table 2.2.).

Table 2.2. PV projects with PPA (2015)

Capacity (MW)	**Province**	**Type of supply agreement**
10	Semnan	PPA with SUNA
0.3	Fars	PPA with SUNA
5	Alborz	Buy-Back contract

Source: Aguilar et al. (2016: 32)

Companies' representatives confirmed that Germany might invest $2.9 billion in Hamedan[28] over a 10-year period. Also, Iran and Siemens reached an agreement to build a new power plant in northern Tehran (Damavand city, 1,250 MW solar power plant) as well as 500 MW solar power plant project in Karaj, Kahrizak and Varamin (Tehran Province), starting next year[29].

Considering the current renewable energy projects under development and potential market in the Sixth Five-Year Development Plan (see Info Box 3: Five-Year Development Plans), about 21.5% is devoted to PV. Therefore, SUNA estimates that the market for PV systems as power plant investments within the next 5 years is equal to 1,077 MW (see Table 2.3.).

Table 2.3. Renewable energy projects under development and potential market in the Sixth Five-Year Development Plan (2016-2020)

RES	**Wind**	**PV**	**Biomass**	**Small Hydro**	**Total**
Under Development (MW)	5663	1615	194	24	7496
Share in total planned investment	75.5%	21.5%	2.6%	0.3%	100%
Estimated demand for RES (MW)	3777	1077	130	16	5000

Source: Aguilar et al. (2016: 34)

2.3. Photovoltaic and state of technology

As a consequence of the 'photovoltaic effect', PV solar cells can convert solar energy directly into electricity. PV electricity was discovered in the 19th century, but the first modern PV cells for electricity generation based on silicon (Si) semi-conductors were developed only in the 1950s. The PV effect describes, that two different semi-conducting materials (e.g. silicon, germanium), in close contact to each other, generate an electrical

[28] Iran Daily, 2016: Germany to build solar power plant in Iran
[29] Renewable Energy World, 2015: German Company to Build Solar Power Plants in Iran

current when exposed to sunlight. IEA-ETSAP and IRENA (2013) stat that "sunlight provides electrons with the energy to move cross the junction between the two materials more easily in one direction than in the other. This gives one side of the junction a negative charge with respect to the other side (p-n junction) and generates a voltage and a direct current (DC). PV cells work with direct and diffused light and generate electricity even during cloudy days, though with reduced production and conversion efficiency."

Basic principles of a solar cell can be found in figure 2.1. just below.

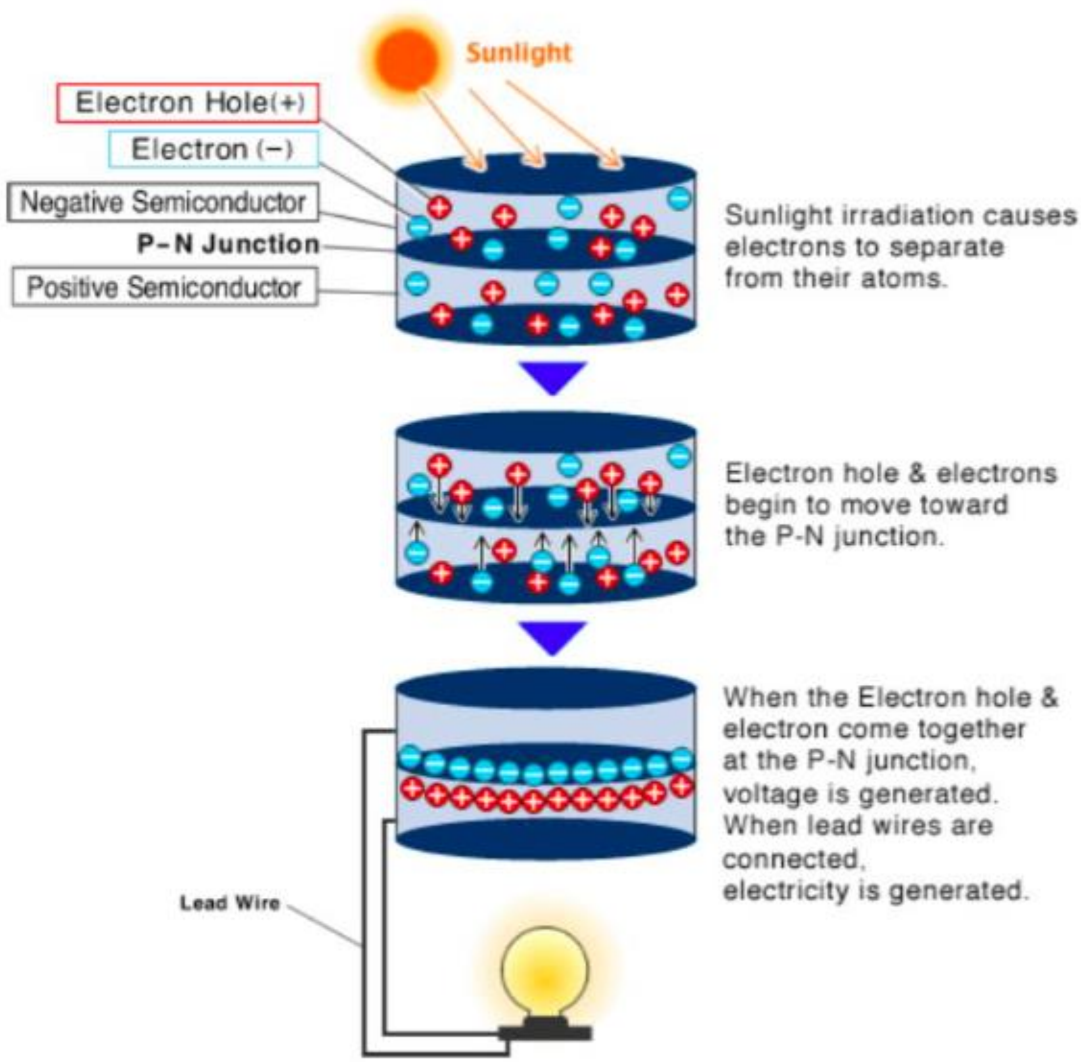

Figure 2.1 Basic principle of a solar cell. Source: Fechner (2015)

The basic element of a PV system is the solar cell, converting solar energy into DC electricity. Systems can be integrated into buildings, installed on roofs or ground-based (IEA-ETSAP and IRENA, 2013).

PV technologies can be grouped into three categories, namely wafer-based crystalline silicon (c-Si); thin-films (TF); and emerging and new PV technologies, including concentrating PV, organic PV, advanced thin films and other innovative concepts.

This thesis will mainly focus on crystalline silicon due to the fact that it shows the highest level of commercialization and economic feasibility at the moment. The manufacturing process of c-Si modules starts with purification of metallurgical silicon to solar grade polysilicon, followed by the melting of polysilicon to form ingots and slicing these ingots into wafers. After the wafer stage the next step is the transformation into cells by creating p-n junctions, metal (silver) contacts and back-coating. The final step, the cell assembly, connects and encapsulates the cells into modules with protective materials (e.g. transparent glass, thin polymers) and frames in order to increase module strength. Silicon is used in the three forms of single-crystal (sc-Si), block crystals (multi-crystalline silicon, mc-Si) and ribbon-sheet grown (c-Si). Sc-Si cells offer higher efficiency in comparison to mc-Si cells owing to their random atomic structure, which affects the flow of electrons. However, they are less expensive than sc-Si cells. A standard c-Si module is typically made up of 60-72 cells, has a nominal power of 120-300 Wp and a surface of 1.4-1.7 m^2 (up to 2.5 m^2 maximum). Crystalline silicon (c-Si) cells have reached a record efficiency of around 25%. The efficiency of the best current commercial modules is around 19-20% (with a target of 23% by 2020). The majority of commercial c-Si modules, however, have efficiencies in the range of 13-19% with guaranteed lifetimes of 20-25 years. Commercial TF modules offer lower efficiency between 6- 12% (with a target of 12-16% by 2020). In addition to the commercial options, a number of new PV technologies is under development (e.g. concentrating PV, organic PV cells, advanced thin films and novel concepts and materials) and hold out the promise of high performance and low costs in the medium-term. (IEA-ETSAP and IRENA, 2013; Kaltschmitt et al., 2013: 373). On average, 14% efficiency (solar panel yield) can be assumed. One reason for a conservative approach in efficiency is that PV modules in Iran have to withstand extreme climate conditions such as dust and heat. Therefore high quality products, proven by accredited testing institutes, should be chosen to guarantee a long life-time. This has also to be assured for related equipment, also called balance-of-system components (BOS) such as wiring, mounting structure, etc. When it comes to mounting of the modules a reliable sub- construction (PV rack) shall be established and static considerations have to be observed. For increasing the power output by up to 30-40% a PV tracker, which adjusts the modules towards the sun (single axis tracker to follow daily changes and two axis tracking system to follow daily and seasonal variations) could be installed. This is especially useful in locations with high portion of direct solar radiation. The single axis tracker has the highest impacts therewith. However, a higher complexity and cost of the system has to be considered (Fechner, 2015).

In 2014, worldwide installed PV capacity increased to at least 177 GW, sufficient to supply 1% of global electricity demands. The European Union remains the main focus of solar PV installation in the world (in 2012), but it accounted for only a little over one half of the global market (about 58% out of a total of 28.9 GWp).

Currently, there are 5 active factories in Iran, which assemble modules and/or produce multi-crystalline silicon solar cells locally. They have each a capacity between 10 MW up to 30 MW. Most of the solar modules however, are imported from China or Europe. Due to the fact that Iran has rich silica resources, there are plans to enter into the PV upstream supply chain in the near future[30].

2.4. Environmental impacts

The potential environmental impacts associated with solar power depend on the size of the system (small, distributed rooftop PV to large utility-scale PV) and are listed as follows[31]:

- Land use: depending on their location, larger utility-scale solar facilities can raise concerns about land degradation and habitat loss. However, as Iran has huge areas for harvesting sun, land use is not an issue of importance - Water use: water is used to manufacture PV components and if a cooling system is required (depending on e.g. location).

- Hazardous Materials: the PV cell manufacturing process includes a number of hazardous materials, most of which are used to clean and purify the semiconductor surface. These chemicals include hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride and acetone.

-Life-cycle global warming emissions: while there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation,

[30] SUNA, 2016: Photovoltaic Energy
[31] Union of Concerned Scientists, 2013: Environmental Impacts of Solar Power

installation, maintenance, and decommissioning and dismantlement (IPCC, 2011: 371) (see figure 2.2.). Compared with other RES, the impact of solar PV is relatively high (48 gCO2eq/kWh for an utility scale); wind onshore technology has a median value of only 11 and geothermal of 38 (Wikipedia, 2016, Life-cycle GHG emissions of energy sources).

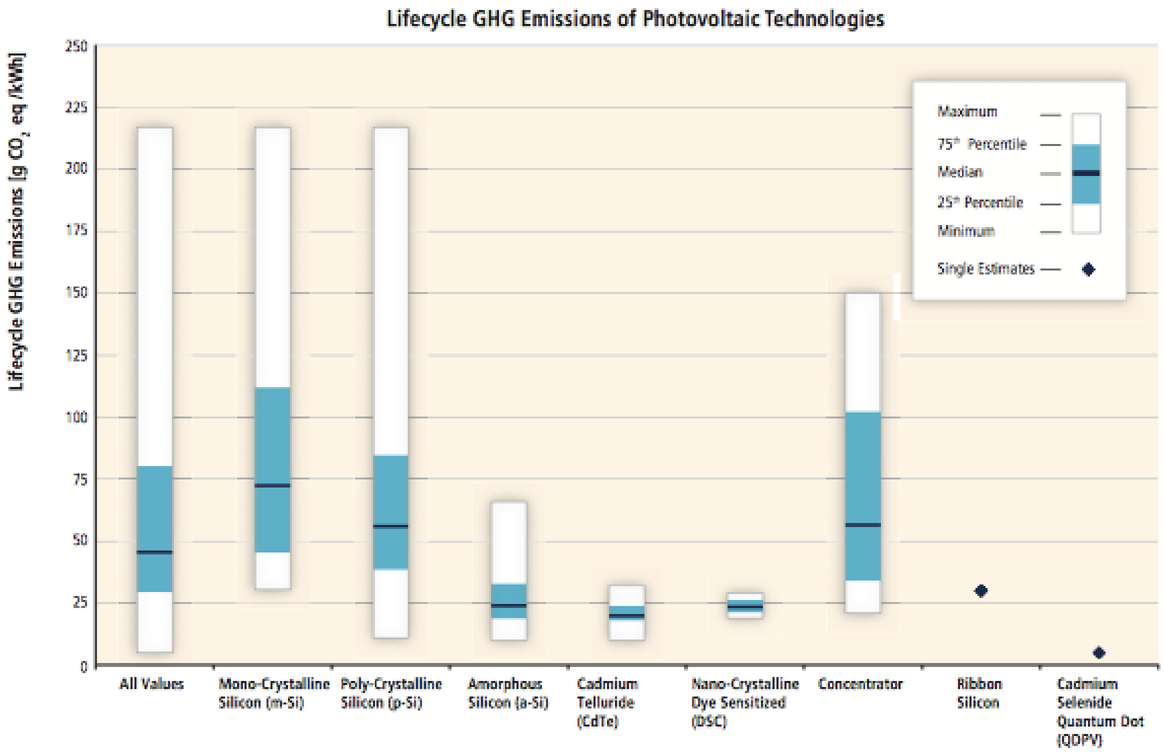

Figure 2.2. Life-cycle GHG emissions of PV technologies; Source: IPCC (2011)

The production of **silicium ingots** is the most energy intensive part of producing a PV system. When looking at the life-cycle of the production of PV cells, the entire so-called energy mix has to be taken into account. As the energy mix contains also fossil fuels, we must not forget CO2-emissions for the calculation of the ecological assessment. Today, less silicon is needed for the production however there are still challenges regarding silicon quality, silicon recycling, sawing, cell and wafer handling, cutting wire strength and kerf loss.

An important parameter to assess these impacts is the so-called **energy payback time (EPBT)**. Fechner (2015: 12ff.) concludes that the EPBT ranges from 0.8 to 3.6 years; latter for systems installed in Central Europe.
For instance, looking at a multicrystalline silicon and fluidized bed reactor technology for silicon feedstock material, 150 µm wafer thickness, 17% module efficiency and no F-gas

(fluorinated greenhouse gas) emissions, the resulting energy pay-back time for a roof-top PV system in southern Europe can be reduced by 50%. Therefore EPBT of less than one year should be achievable in the near future. Alsema et al. (2007) concludes that GHG-emissions out of PV electricity could be as low as 15 g/kWh[32].
Assuming life-cycle CO2-emissions of PV-electricity with 21 g/CO2/kWh and CO2-emissions for electricity out of coal with 1.000 g/CO2/kWh (Fechner, 2015: 13) every kWh of solar energy saves 979 g/CO2 if electricity produced out of coal is replaced.

2.5. Technical Market Potential of Solar PV in Iran

2.5.1. Natural conditions for PV

Iran is potentially one of the best regions worldwide for solar energy utilization. The **average solar radiation** in Iran is between 2.8 and 5.4 kWh/m^2/day, with 2,800 hours per year being sunny enough to be used for PV production (Atabi, 2004). The highest irradiation rates are in central-south areas of Iran; for instance 5.2 to 5.4 kWh/m^2/day in Kerman, Yazd, Fars, Kohkiluyeh va Buyer Ahmad, Hormozgan and Chaharmahal va Bakhtiari provinces. These regions are very dry and dusty what in general is good for harvesting solar radiation, however, also means higher O&M cost of PV systems due to lack of self-cleaning mechanism (Aguilar et al., 2016: 33ff.).

From central area to the coastal area of Persian Gulf the radiation is still excellent (4.5-5.2 kWh/m^2/day). Center and North of Iran (Isfahan, Khorasan, Semnan, and Tehran) receive solar radiation ranging from 4.5 to 5.2 kWh/m^2/day. The coastal area of Caspian Sea receives the least amount of radiation (2.8-3.8kWh/m^2/day). **The solar radiation map (see below figure 2.3.) is used for estimation of solar electricity potential in the next section.**

[32] Renewable Energy World, 2007: Keeping it clean - Reducing environmental impacts from solar PV

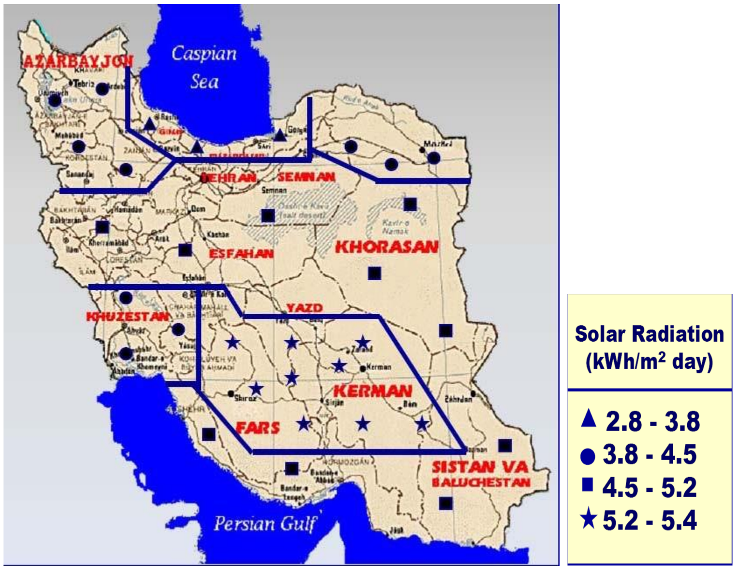

Figure 2.3. Average solar radiation in Iran; Source: SUNA (2016), Opportunities to Construction Renewable Energy power plants In Iran

These extremely high solar radiation rates (1640-1970 kWh/m^2/year) can be found on nearly 80% of Iran's territory, says Moshiri & Lechtenböhmer (2015).

Figure 2.4. just below shows the global horizontal irradiation for Iran.

[redacted]

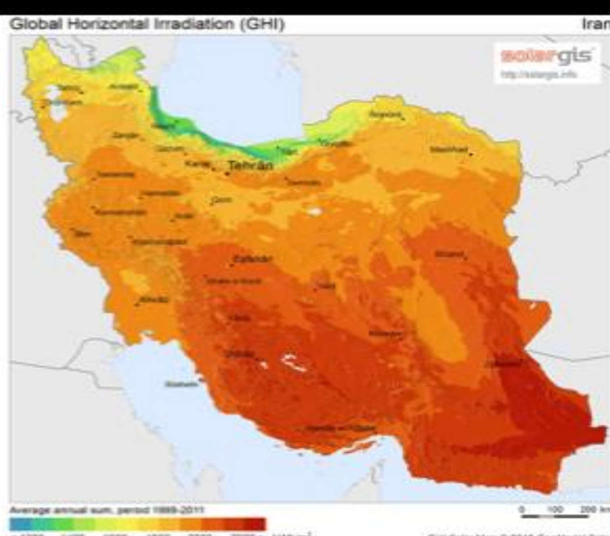

Figure 2.4. Iran Solar Irradiation; Source: Solar GIS (2015)[33]

[33] SolarGIS, 2015: GeoModel Solar

2.5.2. Methodology

Calculation of PV electricity potential needs technical, geographical, technological and environmental details. A detailed research based on GIS system is, however, costly and out of this thesis' scope. Therefore calculations are based on available data, research papers, interviews, estimations and assumptions.

The PV electricity potential in Iran is calculated by the following equations:

$$\boldsymbol{EP_p = 5 * NP_p * \mathrm{H} * PR}$$

Where **5** stands for "5 MW electric power; **EP** stands for solar electricity potential and **p** for different provinces of Iran. **NP** stands for the number of power plants with 5 MWe nominal capacity in each province. Fechner (2015) stats that for 1 MWp, 2.5 hectare (0.025 km^2) area is needed. Thus, for 5 MWp, 12.5 hectare area is needed, which is equal to 0.125 km^2.

H is the global horizontal irradiation (per province). The calculations were based on data from Statistical Center of Iran (2013/2014a), SUNA (2016) and Sharbafin (2009), as well as the Solar Electricity Handbook[34].

The performance factor aka system performance ratio (**PR**) is set with **85%**.

Further elaboration on the system performance ratio, solar irradiation and solar areas per province can be found just below.

2.5.3. System performance ratio

The performance ratio (PR) is an important figure to evaluate the quality of a PV installation. It calculates the proportion of the actual plant output versus the nominal plant output. The difference between actual and nominal output results of losses such as inverter losses, temperature losses, cabling losses, shadings and dust or snow. The closer the PR value approaches 100% the more efficient the PV installation is operating. Due to the favorable conditions in Iran a PR of 85% is applied for the calculation (Fechner, 2015).

[34] Solarelectricity Handbook, 2016

2.5.4. Global Solar Irradiation

Solar irradiance is a measure of how much solar power can be harvested at a specific location. The irradiance varies throughout the year, depending on the month and season. It even varies throughout the day, depending on the time of day, position of the sun and weather. The here used solar electricity handbook takes data collected over a 22 year period into account. Based on this data, the average power generation of a PV system in any given month is calculated. Data of provinces not listed in the solar electricity handbook were assumed based on average bright sunshine hours' data from the Statistical Center of Iran (2016a).-Details can be found in table 2.5.

2.5.5. Solar areas in Iran

Solar areas are the total net territory that is allocable und usable for PV power plants. Areas such as forest, grassland, agriculture, seas, living areas (rural and urban), and water bodies were excluded from the calculation. Table 2.4. summarizes areas by different categories across the country.

Table 2.4. Different areas by type in Iran in 2013/2014

	Area (km^2)	Percentage of territory (%)
Iran	**1,628,750**	**100.0**
Agricultural land	170,864	10.5
Forests	143,190	8.6
Grass land*	848,149	52.1
Deserts	325,764	20.0
Others	128,783	7.9
Sea	12,000	-

* Land area; good, fair and poor quality; Source: Statistical Center of Iran (2016b)

Approximately 52% of Iran is covered by grassland, 20% by desert, 10.5% by agricultural areas and 8.6% by forests. Grassland is categorized in good, fair and poor quality. Only the latter is assumed to be suitable for solar power plants. Agricultural land, sea and forests were excluded as well. Also a certain amount of area (rural and urban) was excluded for living, industrial & commercial sectors as well as national parks & green land. For the calculation, additional 5% of Iran's territory was excluded for current and future living areas. Therefore living areas, agricultural lands, forests, grassland (good and semi condensed) and seas were subtracted from the total area to get a realistic territory that might be used for the construction of solar power plants in each province.

As shown by Sharbafian (2009), there is no potential for any solar power plant in 2 provinces due to existence of huge agricultural areas, forest and grassland. On the other side, Sistan and Baluchestan, Semnan, Qom, and Yazd provinces have huge spatial potential. The total area that can be considered as solar area is about 928,629km^2 or 57% of Iran's territory.

2.5.6. Results of technical electricity potential by province and in total

Table 2.5. shows the solar areas, the percentage of each province of the total area, the average irradiation and eventually the technical PV electricity potential of Iran, by province and in total.

The total technical PV electricity potential is estimated with **37,145 GW** and **56,597 TWh,** respectively.

In all provinces but two there is significant potential for PV electricity production. Especially the provinces Kerman, Sistan & Baluchestan and Yazd should be highlighted due their enormous potential of PV electricity. The main factors are a high solar irradiation, a high percentage of area that can be 'used' for PV plants (leading to a higher number possible plants installed) and the solar irradiation. Regarding the economical potential the value for Yazd (solar irradiation of approx. 2,000) is taken for further calculations.

Table 2.5. Solar area, global solar irradiation and PV electricity potential of Iran

Province (Name)	Solar area (km^2)	% of total area	Global Solar Irradiation (average) (kWh/m^2)	PV capacity potential (GW)	**PV electricity potential (TWh)**
Alborz and Tehran*	6,039	22	1,715	242	352
Ardabil	226	1	1,409	9	11

Azerbaijan, East	8,101	18	1,590	324	438
Azerbaijan, West	9,488	25	1,590	380	513
Bshehr	11,897	52	1,666	476	674
Chahar, Mahaal and Bakhtiari	4,479	27	1,409	179	215
Fars	62,587	51	2,026	2,503	4,311
Gilan	1,431	10	1,715	57	83
Golestan	0	0	2,026	0	0
Hamadan	3,865	20	1,755	155	231
Hormozgan	53,217	75	1,666	2,129	3,014
Ilam	4,479	22	1,590	179	242
Isfahan	83,269	78	2,026	3,331	5,736
Kerman	136,141	75	1,830	5,446	**8,471**
Kermanshah	4,548	18	1,908	182	295
Khorasan, North	15,649	55	1,715	626	912
Khorasan, Razavi	62,952	53	1,409	2,518	3,016
Khorasan, South	66,889	70	1,715	2,676	3,900
Khuzestan	15,894	25	2,026	636	1,095
Kohgiluyeh and Boyer-Ahmad	3,115	20	1,409	125	149
Kurdistan	5,230	18	1,620	209	288
Lorestan	0	0	1,620	0	0
Markazi	4,885	17	2,026	195	336
Mazandaran	1,704	7	1,590	68	92

Qazvin	3,554	23	1,620	142	196
Qom	9,728	84	1,914	389	633
Semnan	79,718	82	1,817	3,189	4,925
Sistan and Baluchestan	155,257	85	1,620	6,210	**8,552**
Yazd	108,253	84	2,058	4,330	**7,575**
Zanjan	6,036	28	1,666	241	341
Total	928,631	-	-	**37,145**	**56,597**

* Alborz Province was split from Teheran province in 2010, data taken from Alborz' capital Karaz; Source: Sharbafian (2009), Statistical center of Iran (2016a and b), own calculation.

2.6. Economic feasibility

In the previous section the technical potential of PV electricity was estimated and calculated, respectively showing that there is an enormous technical potential for PV solar energy in Iran. In this section we look at the economic viability of a 5 MWp PV project. For smaller projects have a look at Info Box 4: Roof-Top Systems.

2.6.1. Business Model Description

For our business model we choose a

- 5 MWp ground-mounted PV project[35]
- With feed in tariffs (2016)
- Based on a Power Purchasing Agreement (PPA)

The PPA is a contract between an electricity producer and SUNA, the Renewable Energy Organization of Iran (see chapter 1.5.10. for more information on SUNA). It fixes a price for the electricity provided by the investor to the off-taker SUNA over 20 years. The investor sells all the generated electricity to SUNA to receive the Feed in Tariff. For more details on the PPA see chapters 1.5.7. and 2.6.2.

As mentioned in the introduction of this chapter, the process depends on the size of the PV system. In the case of our chosen business model of 5 MWp, the process should be

[35] A specific PV power plant system/model was not chosen.

executed with SUNA that is also the off-taker of the electricity produced[36]. According to the size of the system, the Feed in Tariff corresponds to **4,900 IRR/kWh** which is equal to **14.51 €-cent/kWh**[37]**.**

After 10 years the FiT is reduced by 30% of its original amount ("…will be multiplied by 0.7 after adjustment of article 3 of Economic Council Directive starting from the first day of the second 10 years till the end of the contract".) [38]

2.6.2. Power Purchase Agreement (PPA)

As described in chapter 1.5.7., medium and large PV plants (in this case 5 MWp), a PPA contract between SUNA and the owner of the power plant is concluded. The most relevant elements of the 5 MWp PV PPA are:

a. The duration of the contract and deadlines: 20 years and 18 months deadline: the applicant needs to commission the power plant within 18 months after signing the PPA, otherwise the generated electricity will be bought with the price of the energy market.

b. Feed in Tariff: FiT for solar with less than 10 MW is 4,900 IRR in 2016[39]. Every year the FIT is adjusted by the 'adjustment formula' (see chapters 1.5.5.d and 1.5.6.). Details can be found at the calculation sheets, the tariff escalation in our 5 MW PV project yields 1.0918 as $(112/100)^{0.3}$ x $(36,474/33,772)^{(1-0.3)}$.

Table 2.6. Tariff escalation for 5 MW PV project (first 5 years)

Year	0	1	2	3	4	5
Consumer Price Index (Inflation rate 12% assumed)	100	112	125.44	140.49	157.35	176.23
Exchange rate (8% assumed)	33,772	36,473	39,391	42,542	45,946	49,662
Escalation rate (0.3 assumed)	1.0	1.0918	1.1921	1.3016	1.4212	1.5517

[36] The process procedure is described in chapter 1.5.8.
[37] The exchange rate corresponds to 33,772 IRR/1 Euro.
[38] SUNA, 2016: Guaranteed Renewable Electricity Purchase Tariffs
[39] See footnote 13.

Tariff 100% (year 1-10)	4,900	5,350	5,841	6,377	6,963	7,603

Source: Aguilar et al. (2016) and own calculation

Info Box 4: Roof-Top Systems; Source: (Aguilar et al., 2016: 49f.)

The process for developing PV plants less than 100 kWp is a recently developed possibility by SUNA as they can see the demand of roof-top systems being installed and the enormous potential. So far, there is no private installed PV plant <100 kWp system in Iran.

The conditions for developing a <100 kWp system are:

- 20 years contract (same as 5 MWp)

- Feed in Tariff: 7,000 Iranian Real (compared to 4,900 for 5 MWp)

- Procedure simpler than for a bigger system, with less permissions needed

FIT for the construction for PV rooftop systems are much more attractive than they were the years before and also compared to bigger systems (approx. 20.87 €-cent/kWh). Furthermore, SUNA eventually developed regulations and requirements. The conditions are set and standardized, but there is still no experience with it.

This thesis will only focus on a medium scale system with 5 MWp for its profitability analysis (see chapter 2.6.3.).

2.6.3. Results and profitability analysis

As a next step we will do the calculations for the above-mentioned 5 MWp ground-mounted system. The assumptions will be verified and varied in the sensitivity analyses in section 2.7.

The assumptions are:

We calculate a turn-key system with a price of 60 Million Iranian Rial/kWp what equates ca. 1,777 EUR/kWp)[40]. Operational and Maintenance (O&M) costs are set with 3% of the total investment costs per year due to the dry and dusty climate of Iran. These O&M

[40] The exchange rate corresponds to 33,772 IRR/1 Euro (as per 04/08/2016).

costs were escalated by an average escalation rate of 10.5% per year because 50% of O&M costs are accounted in EUR, 50% in Iranian Rial.

In section 2.5.1. the solar irradiation was discussed which ranges between 1,800 and 2,200 kWh/m^2. For this calculation the data for Yazd where the PV plant is constructed is taken into account: 2,000 kWh/m^2.

The performance ratio that takes into account all pre-conversion losses, inverter losses, thermal losses and conduction losses is set with 80%[41]. The decreasing performance due to the dry and dusty climate as well as the lower self-cleaning effect of modules in this region was taken into account by 0.7% per year.

The run-time and project duration is 20 years and based on a feed in tariff of 4,900 IRR/kWh. It is escalated over these 20 years and calculated as weighted average with 9.18%[42]. After 10 years the feed in tariff is reduced to 70%.

The national development fund (NDF) is granting money with an interest rate of 6% p.a. for 80% debt and a loan tenor of 5 years. The discount rate was set at 15% to represent a low risk investment alternative (3% higher than assumed inflation rate).

Table 2.7. Assumptions on feasibility study of a 5 MWp PV power plant in Yazd

Variables	**Value/Unit**	**Result**
PV System Size	kWp	5,000
Specific System Cost	EUR/kWp	1,776.62
Total System Cost	EUR	8,883,098
Fixed O&M Costs	EUR	272,415
O&M Escalation Rate	% p.a.	10.50%
Solar Irradiation	kWh/m^2/a	2,000
Performance Ratio	%	80%
Full Load Hours	kWh/kWp/a	1,600
Degradation	% p.a.	0.70%
Feed-in Tariff	EUR/kWh	0.15
Tarif Coeffizient (Year 1-10)	%	100%

[41] 80% (instead of 85%) performance ratio to make it more comparable with other RES.
[42] Based on the inflation rate (weight 0.3) and the escalation rate of the EUR/IRR-exchange rate (weight 0.7).

Tarif Coeffizient (Year 11-20)	%	70%
Exchange Rate (04/08/2016)	EUR/IRR	33,772
Exchange Rate Escalation	% p.a.	8.0%
Inflation Rate	% p.a.	12.0%
Feed-in Tariff Escalation	% p.a.	9.18%
Project Duration	Years	20
Debt	80%	IRR 240,000,000,000 = € 7,106,479
Loan Tenor	Years	5
Interest Rate	%	6.0%
Discount Rate	%	15.0%
Net Present Value (NPV)	**EUR**	**1,032,72**
Project IRR (Internal Rate of Return)	**%**	**3%**
Equity IRR (Internal Rate of Return)	**%**	**18%**
Long Run Generation Cost of Electricity (LRGC)	**EUR/MWh**	**182.84**
Annuity	**EUR**	**164,988**

Sources: PV System Size, Specific System Cost, Total System cost, Fixed O&M Costs, O&M Escalation Rate, Specific Yield, Performance Ratio, Specific System Performance, Degradation from Aguilar et al. (2016); FiT, FiT Coeffizients and Escalation, Exchange Rate, Exchange Rate Escalation from SUNA, 2016 and own calculation; Inflation Rate from Central Bank of Iran (2015); Debt, Loan Tenor, Interest Rate and Discount Rate assumed; tax exempted for calculations. Detailed overview see **Appendix IVa**.

Despite the debt service (paying back of a loan taken by the investors within the first 5 years), the project is profitable. The main reason is the low interest rate (6%). With a ‘normal’ bank credit (interest rates higher than 20%) the project would not be profitable. The FiT revenues are very high and even rising over the years. The reason is the FiT escalation, inflation rate escalation and exchange rate escalation (based on the adjustment formula, see chapter 1.5.6 and calculations), which make the project highly profitable although the FiT is cut after 10 years (minus 30%).

The LRGC take into account the installation of additional generation capacity and are relatively high. The equity IRR, illustrating the correlation between equity and debt funding, is relatively high. The more important project IRR, measuring the profitability of the investment, is very low but positive. However, the NPV is very high, indicating the profitability of the project (Net Present Value Rule).

2.7. Sensitivity Analyses

Eventually the project was run some sensitivity analyses for selected key input parameters. This method assesses the impact a certain input parameter has on the profitability of a system by increasing or decreasing it. In our case we de-/increased the FIT/FLH/O&M costs by +/- 40% each.

The LRGC sensitivity, shown in figure 2.5. reflects the strongest impact on the FLH (between 131 and 305 Euro) and the project is quite sensitive to changes of those. An in-/decrease of O&M costs does not have such an strong impact as expected and might not be as important on investors' decisions to plan or invest into a project. The FIT level cannot have any impact on the LRGC since it is not considered when calculating them.

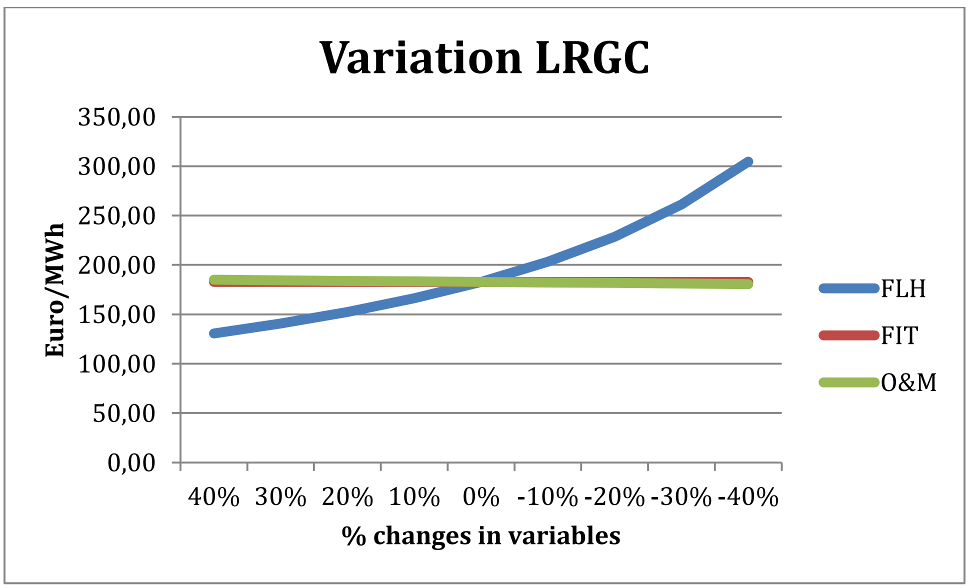

Figure 2.5. Sensitivity analysis, Variation LRGC for O&M, FIT and FLH; Source: Table 2.7 and own calculation

The sensitivity analysis on the NPV in figure 2.6. shows the strong impact on the project when in- or decreasing FLH or FIT while changes of O&M have a much less strong impact on the NPV. Interestingly, the changes of the FLH have the same outcome as changes in FiT.

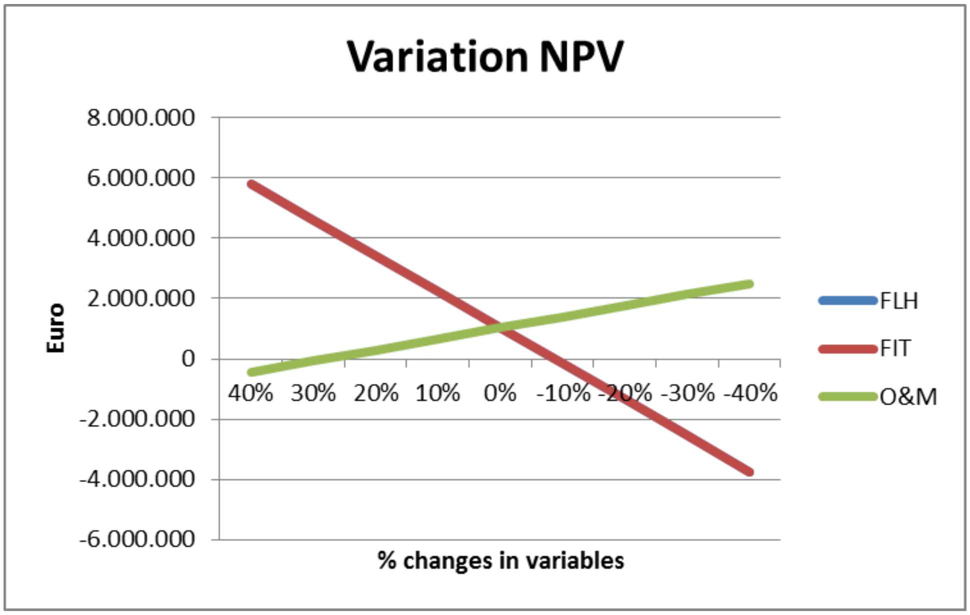

Figure 2.6. Sensitivity analysis, Variation NPV for O&M, FIT and FLH; Source: Table 2.7 and own calculation

Chapter 3: Wind energy in Iran

3.1. Introduction

Iran on its way to a ‘windy’ future?

“Iran can supply over two-thirds of its energy through wind power. The long-term policy within the next decade is to supply over 50% of required energy through renewable energy sources”, says SUNA’s Mostafa Rabie. However, both SUNA and the MoE are aware of “that investments in this sector are absolutely necessary before any of these goals can be achieved.”[43]

Similar as shown in chapter 2 for PV, Iran has, in terms of natural conditions, an excellent situation in order to use wind power. However, also for wind power is valid what was found out for solar energy: it is still cheaper to use fossil resources in order to generate wind. Due to different policies in place - the elimination of subsidy of fuel, fuel price growth rate, decreasing price of wind power plant equipment, and governmental bills to support the development of renewable power generation – a boost in wind energy can be expected if the right, sustainable and long-term measures are set or remain. Measures such as guaranteed FiT or efforts within the recent five-year development plan, where 5 GW RES target (including wind) should be reached. Similar to solar energy, wind power plants can be used to lower the dependency of distribution networks (decentralized usage) and can be used for electrification to remote regions without additional cost (of transmission networks). Apart from positive social effects through wind energy, also positive environmental ones must be considered (Hosseini et al., 2012).

Similar to PV, wind energy industry is a key solution to issues such as climatic changes, air pollution, energy security, price stability and creating new jobs and industries.[44]

In order to evaluate the technical potential of wind exploitation in Iran, wind maps and wind profiles are discussed. Using the real wind data and the capacity factor, the electricity capacity is calculated. For one specific power plant with a 2.5 MW platform in Khaf (province of Razavi Khorasan) a detailed calculation using the Weibull density function, capacity factor, power density and power coefficient is demonstrated. In order

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[43] Globalik Business Group, 2016: Favorable winds in Iran for Basque Renewable energy companies

[44] SUNA, 2016: Wind and Wave Office

to show the economic feasibility under current energy policies the NPV of this 2,500 kW wind turbine is calculated taking into account the actual electricity price policies. The impact of wind exploitation on environment and oil saving is also touched. (Sharbafian, 2009: 20)

Sections 3.2. and 3.3. include some techno-economical data related to wind power, including statements on installed capacities around the world, (3.2.) and an overview of the wind power exploitation in Iran (3.3.); followed by a description of the state of wind technology, mainly a Vensys 2.5 MW platform (3.4.), and a brief statement on environmental impacts (3.5.). Section 3.6. estimates the technical market potential of wind electricity, including the total numbers for Iran and one specific wind power plant in Khaf. Section 3.7. examines the economic feasibility and profitability analysis under current energy policies. The last section (3.8.) concludes with the results, including sensitivity analyses.

3.2. World installed wind capacity

The latest Global Energy Outlook provided by GWEC (2016) shows the future path for wind energy development until 2050. Wind energy could cover 1/3 of the global electricity demand. The Paris climate agreement 2015 should become a strong driving force for investments into renewable energies, including wind. In 2015, the worldwide wind energy production was 433 GW, which covered 4% of the electricity consumption, saving 521 million tons of CO_2, giving employment to 1.1 million people.

Yearly wind energy production is growing rapidly and has reached around 4% of worldwide electricity usage, 11.4% in the EU. In global scale, 63,000 MW of new capacity was installed last year (REN21, 2016: 24).

Wind generated more than 20% of electricity in countries, including Denmark, Nicaragua, Portugal and Spain. Denmark generated even 40% of its electricity from wind, and at least 83 other countries around the world are using wind power to supply their electricity grids, with Iran ranked 30th (GWEC, 2016).

Figure 3.1. shows the worldwide new installed capacity of wind power in 2014, showing that China by far leads this ranking, ahead of Germany and the USA.

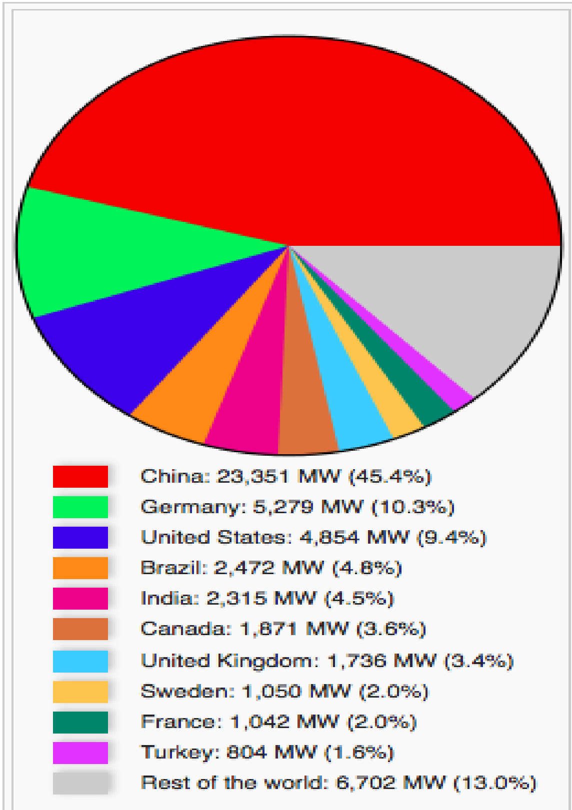

Figure 3.1. Worldwide new installed capacity of wind power 2014; Source: GWEC (2014)

Figure 3.2. shows the trend of cumulative wind installed capacity showing that between 1996 and 2015 cumulated wind power capacity rose by more than 7,000%!

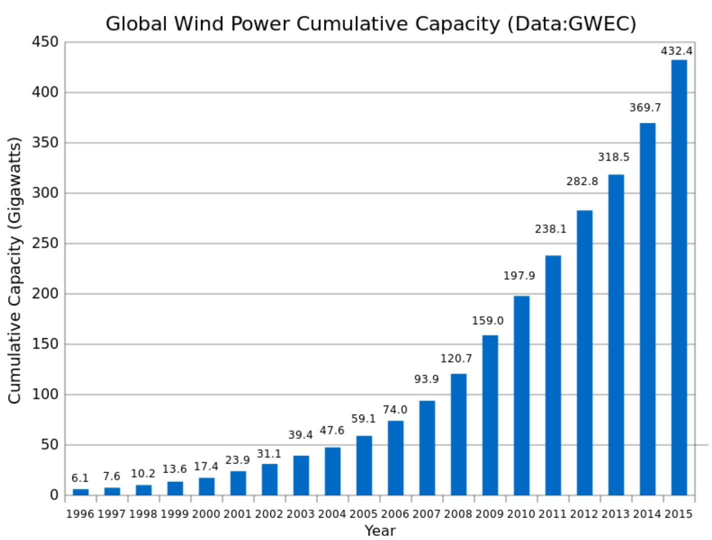

Figure 3.2. Global Wind Power Cumulative Capacity; Source: GWEC (2014)

Wind power creates the most jobs in RES compared with other relevant energy industries. Installing 1 MW of wind electricity in Europe creates 15-19 jobs, and this figure is greater in developing countries, according to SUNA[45]. IRENA estimates that 630,000 jobs are directly related to the wind industry (IRENA, 2011: 4). Further, UNEP, ILO, IOE & ITUC (2008: 108) estimates job creation in the wind sector up to 2.8 million by 2030.

3. 3. Iran's wind electricity market

3.3.1. Installed wind capacity

Studies and evaluations regarding the wind potential estimation in Iran illustrate that in 26 'sections' of the country (including more than 45 suitable sites) the nominal capacity (with a general efficiency of 33%) could be around 6,500 MW[46].

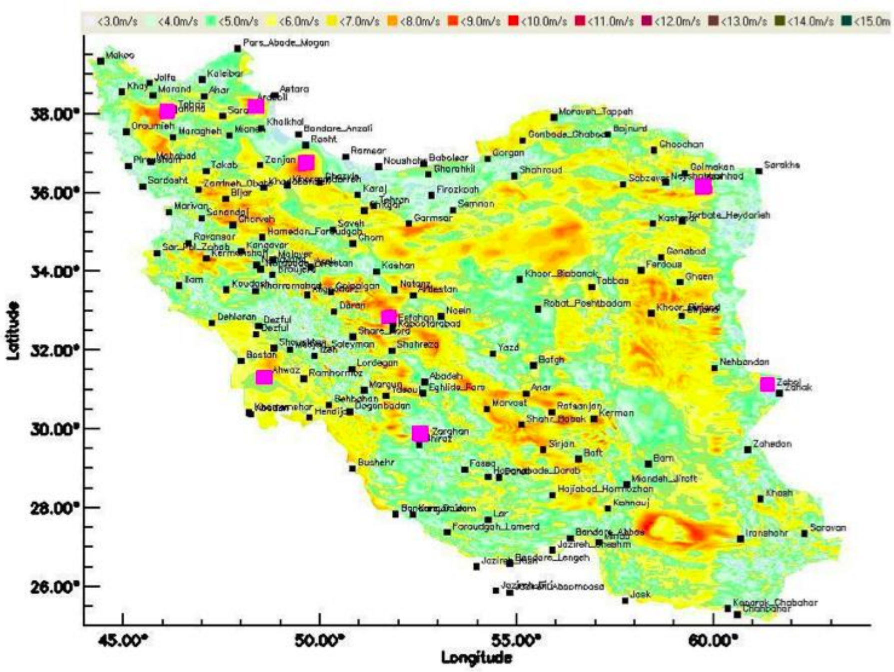

Figure 3.3. Wind map of Iran in 80m above ground, Source: SUNA (2016), Opportunities to Construction Renewable Energy power plants In Iran

The 'Wind and Wave' office of SUNA executes studies, researches and developments in the field of wind and waves energy. One task is to present wind atlases. Figure 3.3. shows the wind potential for many regions of Iran, measured by 100 anemometer stations that recorded the wind data in the country for 1 year.

[45] SUNA, 2016: Wind and Wave Office
[46] See footnote 3.

A more descriptive illustration is seen in figure 3.4. with a map of approx. wind currents at a height of 25m.

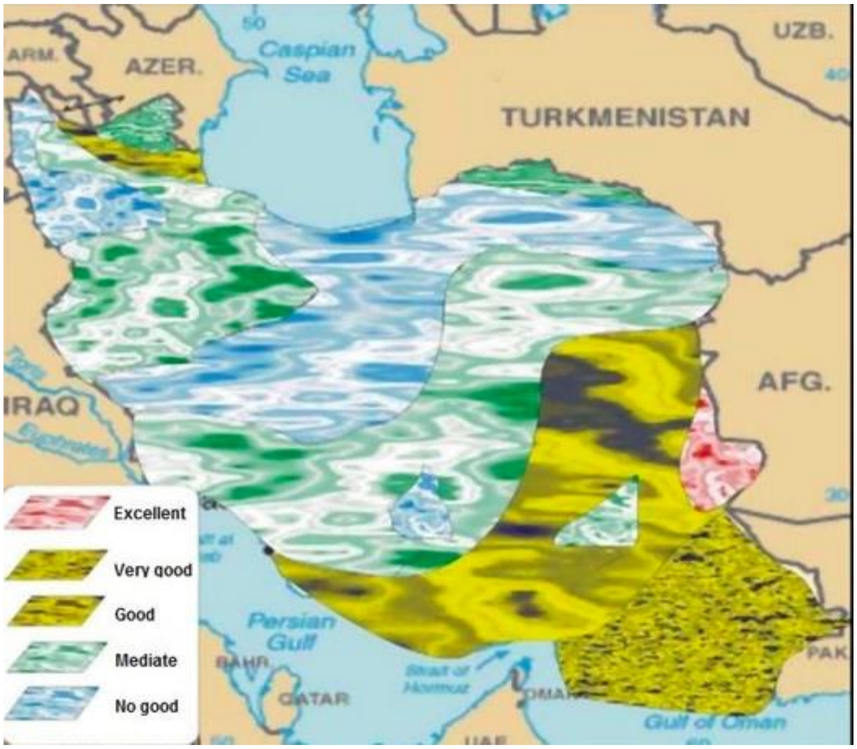

Figure 3.4. Map of wind currents in Iran at the height of 25m; Source: Mostafaeipour et al. (2013)

By 2015, 186+ MW of accumulated wind capacity have been installed. Table 3.1. shows an overview of the installed capacity of the wind parks until 2015. The range is from 0.66 to 2.5 MW turbines.

Table 3.1. Installed wind turbines capacity in Iran, 2015

Site	Province	Capacity (kW)
Manjil	Gilan	90,220 (171 units of 330-660 kWh turbines)
Binalood	Khorasan, Razavi	61,200 (93 units of 660 kWh turbines)
Zabol	Sistan and Baluchestan	660
Babakoohi/Shiraz	Fars	660
Oun ebn-e-Ali/Tabriz	Azerbaijan, East	1,980
Sar Ein	Ardabil	660

Seffeh	Isfahan	660
Mahshahr	Khuzestan	660
Nir	Ardabil	660
Sarab	Azerbaijan, East	660
Khaf	**Khorasan, Razavi**	4,660
Kahak	Qazvin o Khorsan, Razavi	20,000 (8x2.5 MW)
Nishabour - Binalood	Khorasan, Razavi	4,300
Total		**186,980**

Source: SUNA (2016), Wind and Waves; Appendix II

In 2014 one of the first private-sector initiatives under construction is a 20 MW wind farm was built by Iranian company Mapna at Kahak using 2.5 MW Furhlander turbines. In spring 2017 an additional 80 MW might follow. While it already manufactures blades and generators locally, Mapna aims to produce its own turbines, including a 3.2 MW machine in the near future.[47]

Another private-sector project expected on grid this year is a 75 MW wind energy park near Khaf owned by Asia Sazan. It will be equipped with 30 GE 2.5 MW turbines.[48]

For our economical calculations we will take **wind data for Khaf,** and the technical equipment of a **Vensys 112 (2.5 MW) wind turbine (Vensys, 2016).**

Prior to these initiatives most of the turbines installed in Iran were based on Vestas 660 kW machines, elements of which were originally made locally under license by the Sadid Industrial Group.[49]

3.3.2. Wind energy generation

The advantages of using wind energy are the self-contained turbines, which do not need any fuel; the green supply of a part of demanded electrical energy, the high manure possibility of exploitation; no water needed; and little contamination of the environment.[50]

Again, Iran is considered to be an excellent place for developing wind power as it is a mainly low-pressure region surrounded by high-pressure areas in the north and northwest. This shapes a corridor of winter winds from Atlantic Ocean, Mediterranean

[47] Wind Power Monthly, 2015: Analysis: Iran plans for wind powered future
[48] See footnote 5.
[49] Wind Power Monthly, 2013: Iran to build at least 600 MW wind projects
[50] SUNA, 2016: Wind and Wave Office

and Central Asia region and of summer winds from India Ocean and northwest (Liaghati, 2015).

A study in 1999 showed that there are huge capacities for wind power in the country in the northwest, north, northeast and east which could be utilized to generate 19,900 GWh electricity (Liaghati, 2015).

SUNA itself estimates that Iran has a technical potential of wind power generation of 140 GW, of which 20 GW are estimated to be economic.[51]

Figure 3.5. shows the installed wind power capacity in Iran (1997-2014)

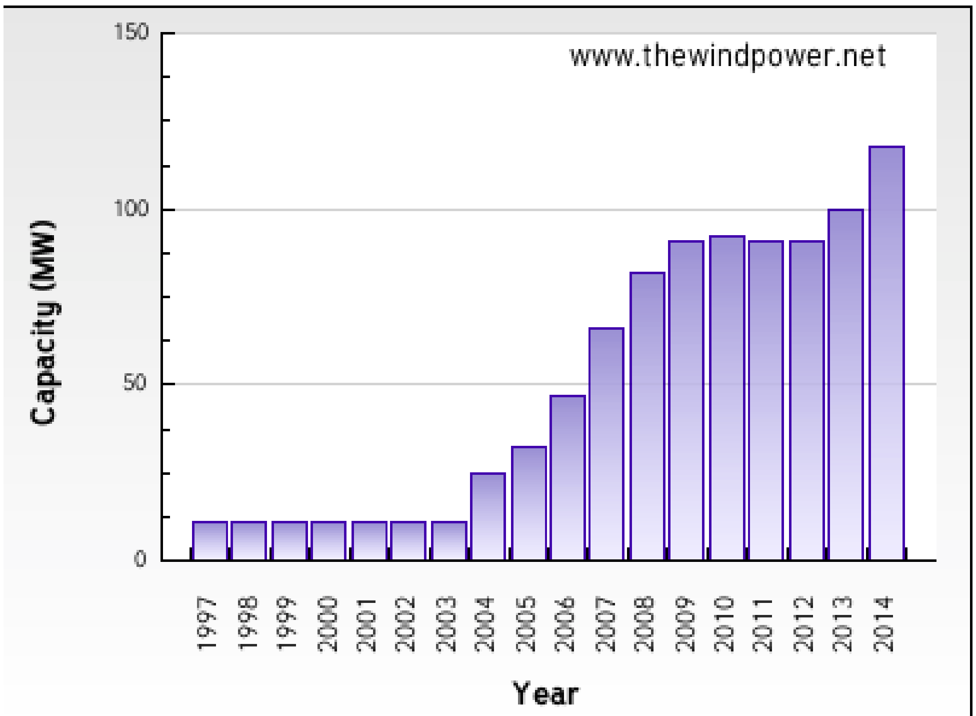

Figure 3.5. Installed wind power capacity in Iran (1997-2014); Source: The Wind Power (2016), Production Capacities

3.3.3. Wind energy policies

As it was mentioned in chapters 1 and 2, the Ministry of Energy (MoE) supports wind project through electricity purchase at guaranteed prices. The guaranteed prices are evaluated time by time to make sure to catch up with the current inflation. The SUNA is providing technical, regulatory and other data requirement needed for wind electricity projects (for details on SUNA see chapter 1.5.10).

In a nutshell a short overview (Boutin, 2016):

[51]SUNA, 2016: Wind and Wave Office

- MoE signs guaranteed power purchase agreements (PPAs) for the duration of 20 years (after the operation of each wind turbine) with wind farm developers.
- The risk of a payment default is covered by:
- Renewable fees: every electricity consumer in Iran must pay 30 IRR/kWh as renewable energy fee that creates a fund support renewable power plants, especially wind farms.
- Letter of Credit (LC) for PPA: it is a deposit at a bank that opens a LC for buying electricity from renewable power plants. When the owner of the plant issues the approved bill, the bank pays the money.
- Payment Guarantee: addition to supports in ‘Foreign Investment Promotion and Protection Act (FIPPA)’ a Payment Guarantee is issued by the signature of the Ministry of Finance only for foreign investors that participate in projects that have a PPA with the MoE (which SUNA is part of). If SUNA defaults in payment, the Ministry of Finance will block all the accounts of MoE and will pay the foreign investor.
- To encourage private investors to develop wind energy, SUNA has provided a wind map of Iran, many guidelines and technical instructions to help the private sector in wind industry participation. For information on ongoing projects see also section 3.3.1.

3.4. State of wind technology

Iranian wind technology is mainly based on technology from Denmark (Vestas) and Germany (Fuhrländer[52], GE Wind Energy and Vensys). In order to customize the wind technology, a wind turbine manufacturer company was established in 2000; the Saba Niroo Company in cooperation with Vestas was established. This company produces 300 kW, 550 kW and 660 kW wind turbines.[53] About 50% of the constructed parts are produced locally; the rest is imported and finally assembled domestically. There are also plans to produce locally sensitive parts such as generator, gearbox, hydraulic system and their electronic boards. It must be noted that transportation, installation and the usage of these turbines require special equipment (e.g. 160-ton cranes that are only available in small quantities) (Sharbafian 2009).
Wind power is one of the oldest large-scale sources of power that has been used by mankind. However, the invention of the steam engine at the beginning of the industrial revolution resulted in decreasing importance of wind energy. The beginning of the

[52] Fuhrländer AG got bankrupt in 2012; FWT Production GmbH took over its core-business and personnel
[53] Sabaniroo company, 2016

modern era of wind power has been market of the production of wind turbines mainly by Danish manufacturers. These turbines had small capacities (10-30 kW) by nowadays standards but laid the basis for today's wind power industry.
Wind power technologies can be categorized into different sizes and styles and can generally be characterized by whether they are horizontal axis or vertical axis wind turbines and by their location, on-shore and off-shore. The power generation of wind turbines is determined by the capacity of the turbine, the wind speed, the height of the turbine and the diameter of the rotors. An arrangement of various wind turbines is referred to as a wind farm. Wind farms encompass the turbines themselves, plus roads for site access, buildings (if applicable) and the grid connection point (IRENA, 2012).

3.4.1 Wind turbine technology

Today, most of the large-scale turbines have three blades that rotate around the horizontal axis. The turbine generally sweeps a diameter of about 80 to 100 meters, has a capacity from 0.5 MW to 3 MW, with higher capacities of up to 6 MW entering the market. (IRENA, 2012).

The example of a Vensys 112 (2.5 MW platform), which later also will be taken for the specific technical and economic calculations, is taken to show the most important parts (see figures 3.6. and 3.7.).

Figure 3.6. Vensys 2.5 MW-Platform (Nacelle, Blades/Rotors, Tower); Source: Vensys (2016)

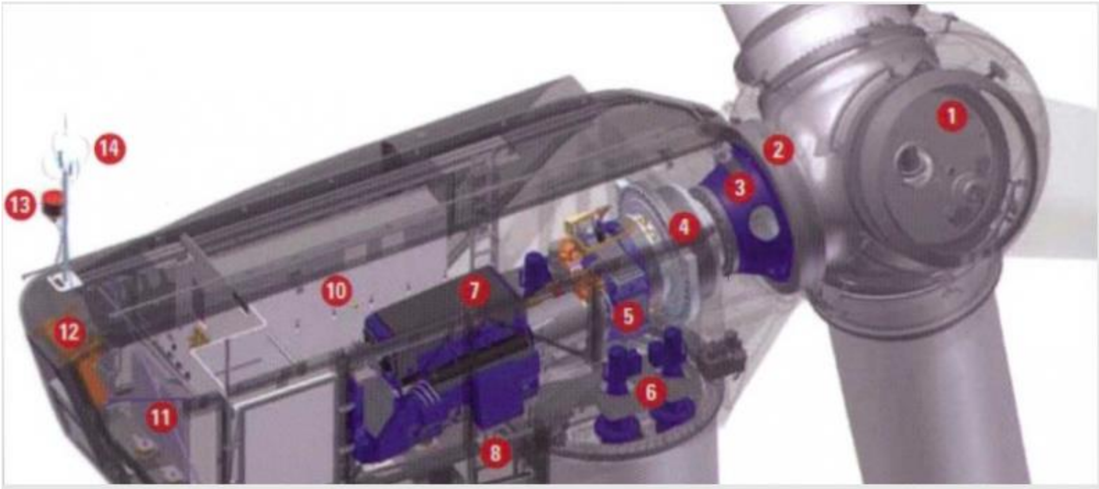

Figure 3.7. FWT 2500 model, nacelle and its components[54]; Source: FWT 2500 (2014)

- Blades (figure 3.6.): Are typically manufactured from fibreglass reinforced polyester or epoxy resin. However, new materials, such as carbon fibre, are being introduced to provide the high strength-to-weight ratio needed for the ever-larger wind turbine blades being developed. It is also possible to manufacture the blades from laminated wood, although this will restrict the size. Our chosen rotor blades are 112m (56m diameter), which yield a swept area (surface) of 9,940sqm ($56^2 \times \pi$)
- Nacelle (figure 3.7.): Is the main structure of the turbine and the main turbine components are housed in this fibreglass structure. It has a weight of 96t.
- Rotor Hub (figure 3.7., Nr. 1): The turbine rotor and hub assembly spins at a rate of 10.4 to 18.1 revolutions per minute (rpm). A so-called pitch system is able to adjust the angle of the blades and main brake. This allows rotor rpm to be controlled and spend more time in the optimal design range. It also allows the blades to be feathered in high wind conditions to avoid damage. The rotors switch-on wind speed is 3 m/s, the rated wind speed: 13m/s, the switch-off wind speed: 25m/s, including a 3 x pitch-control system. The rotor has a weight of 50t. The hub height is at 93,5m.
- Gearbox (Nr.4): The gearbox is placed in the nacelle and converts the low-speed, high-torque rotation of the rotor to high-speed rotation with low-torque for input to the generator. It is a 3-stages gear box with a transmission ratio of 1:72.3.

[54] For a better explanation, the FWT 2500 model is chosen due to the numbering of components.

- Generator (Nr. 7): The generator is housed in the nacelle and converts the mechanical energy from the rotor to electrical energy. The generator operates at 690 volt (V) and provides three-phase alternating current (AC). Doubly-fed induction generators are standard, although permanent magnet and asynchronous generators are also used for direct-drive designs. The maximum rotation speed is 1,310 rpm.
- Controller: The turbine's electronic controller monitors and controls the turbine and collects operational data. Effective implementation of control systems can have a significant impact on energy output and loading on a turbine therefore becoming increasingly important and advanced. The controllers monitor, control and record a vast number of parameters. This enables the wind farm operator to have full information and control of the turbines from a remote location.
- Tower (Nr. 9): There exist two forms of towers. Very often tapered, tubular steel towers and concrete towers with concrete bases with steel upper sections and lattice towers. Tower heights tend to be very site-specific and depend on rotor diameter and the wind speed conditions of the site. Ladders, and frequently elevators in today's larger turbines, inside the towers allow access for service personnel to the nacelle. As tower height increases, diameter at the base also increases. In our case it is a steel tubular tower with a weight of +170t.
- Transformer (Nr. 11): The transformer is often housed inside the tower of the turbine. The medium-voltage output from the generator is stepped up by the transformer to between 10 kV to 35 kV; depending on the requirements of the local grid (IRENA, 2012).

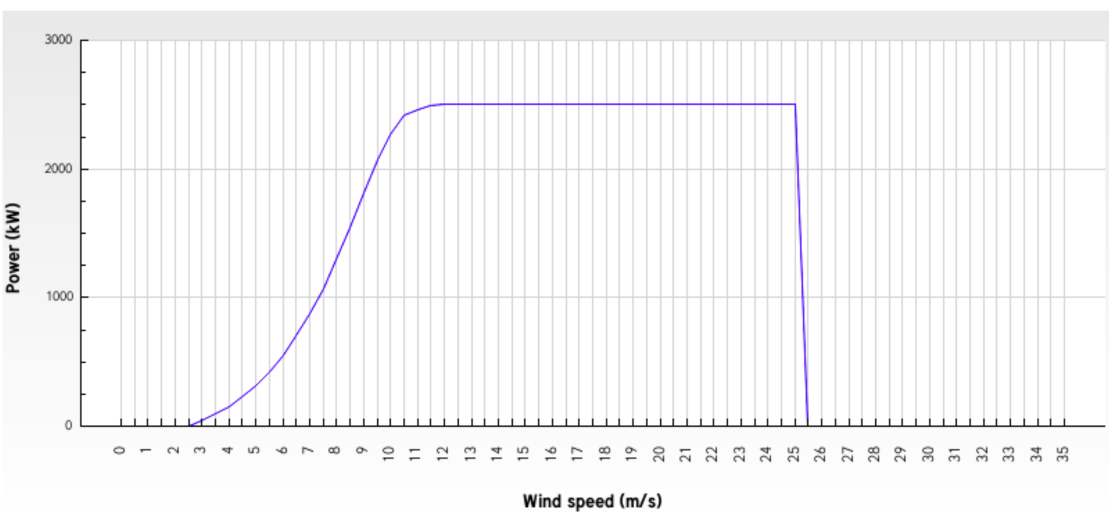

Figure 3.8. Power curve FWT 2500 wind turbine (x-axis: m/s; y-axis: kW); Source: The Windpower (2016), Manufacturers and turbines – Vensys 112

Figure 3.8. illustrates the power curve of the Vensys 112 wind turbine where it can be seen that the wind speed in the range of 13 to 25 m/s gives the best result for electricity generation, but the turbine is operational in the range of wind with 3 to 25 m/s (pitch control shuts down at 25 m/s). The drawn power curve will be used in the economic evaluation of wind projects and estimation of wind potential in Iran.

3.4.2. Average investment cost

The average investment cost of wind electricity projects has been declining. In addition, the share of other costs as a percentage of total costs has generally decreased. Figure 3.9. shows the factors influencing the costs for wind energy. There are the wind turbines and installation, the O&M and the capital costs as main factors.

Other factors are access to the site and the cost of energy/kWh, which is influenced by the FiT and other governmental policies.

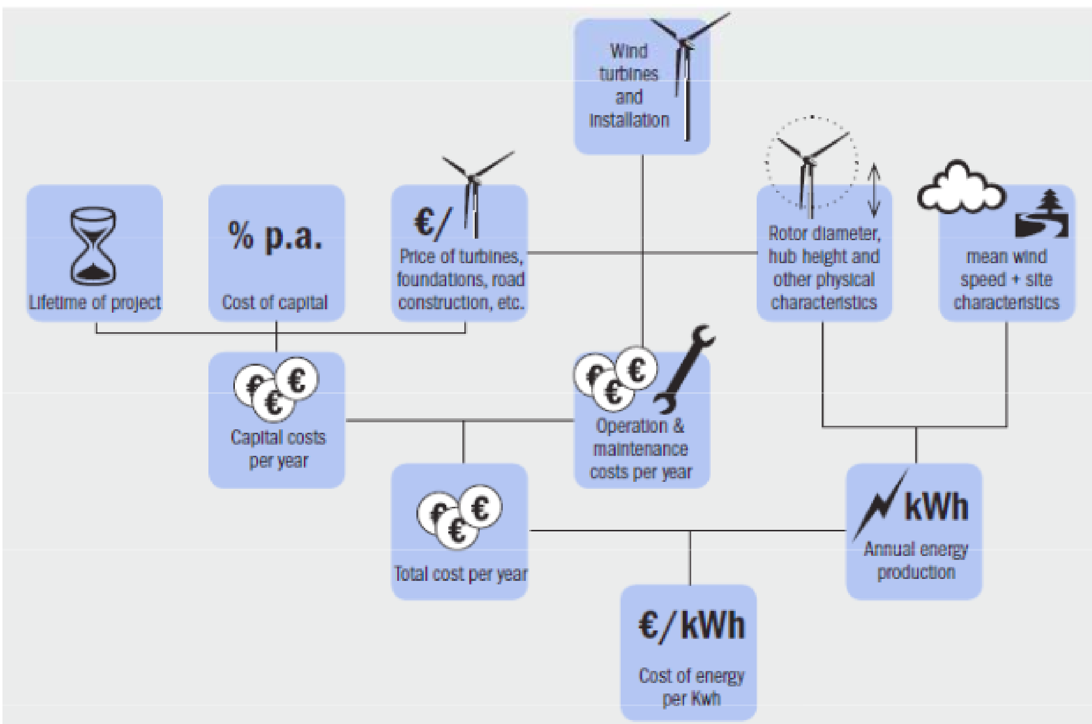

Figure 3.9. Wind Energy Costs; Source: Kalmikov & Dykes (2010)

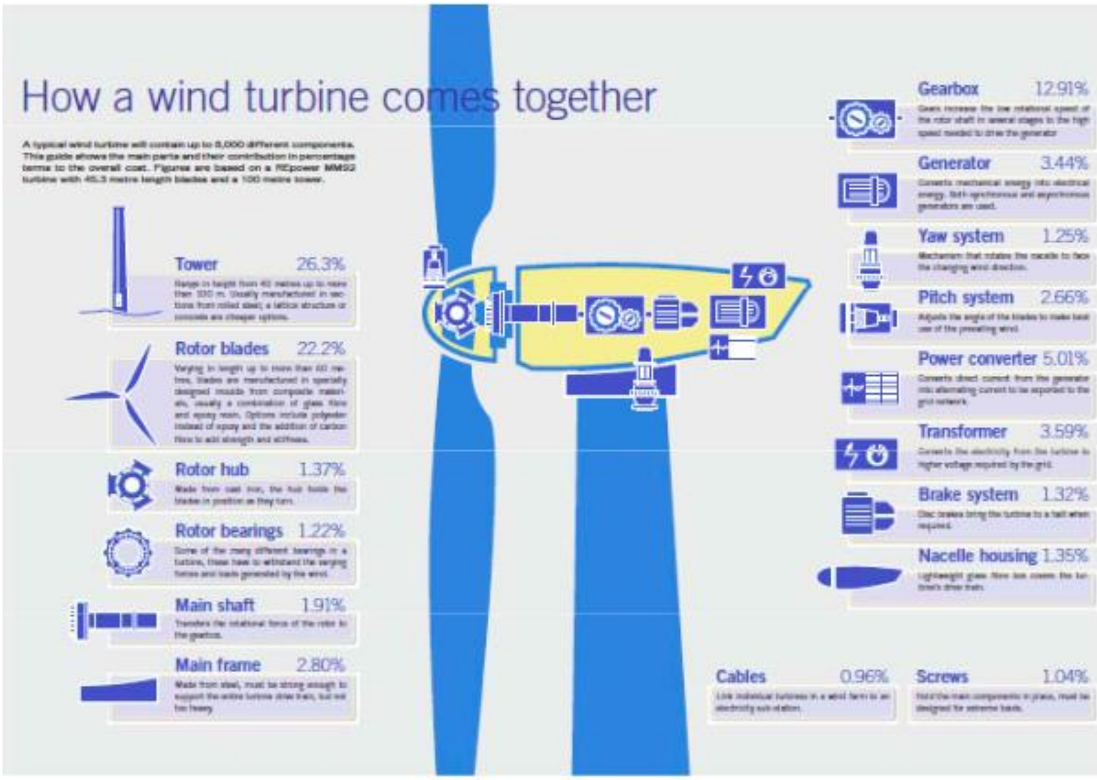

Figure 3.10. Cost share of 5MW Turbine Components (%); Source: Kalmikov & Dykes (2010)

In 1989, almost 29% of total investment costs were related to costs other than the turbine itself. By 2009, as seen in figure 3.10., this share had declined to approximately 11%. Increasing demand for wind turbines along with technological progress will rapidly decline investment cost in the future.

The wind investment costs vary from country to country. Table 3.2. shows the typical cost structure for an on-shore wind power plant in Europe. The average cost of installed wind projects is 1.15 Mio €/MW (et, 2016).

Table 3.2. Cost structure for typical wind turbine

Factors	**Share (%)**
Turbine (excl. work)	70%
Foundation	11%
Electric installation	8%
Grid connection	6%
Management	1%
Installation & Logistics	1%

Insurance	1%
Development, Planning	1%
Other costs	1%
Total	100%

Source: et, Energiewirtschaftliche Tagesfragen (2016)

Due to a less developed market with little experience and too little qualified personnel; worse accessibility and limited numbers of e.g. cranes; higher import-share and import-costs of components and the aftermath of the lifted sanctions the construction of a wind power plant in Iran is higher than in Europe's developed areas. Therefore experts from Vensys recommended to set costs of 1.5 €/MW. Economy of scale will help decrease the cost per kW-installed capacity soon.
For our economical calculations we therefore consider **1.5 Mio €/MW.**

3.5. Positive and negative environmental impacts

Wind energy has many positive effects, as it is
- Independent: it is an unlimited form of energy, breaking the dependence of energy from external suppliers.
- Clean: there is no CO2, no other GHG, no hazardous waste; it does not consume huge amounts of water.
- Fast: there are not long lead times (less than 12 months for construction of a wind power plant).
- Free: Using wind as input 'energy' is free of charge and non-exhaustible.

Further positive effects are elaborated just below.

3.5.1 Life Cycle Assessment and Energy Payback Time

In order to assess the ecological performance of photovoltaic technology a so-called Life Cycle Assessment (LCA) is a proper instrument to do so. An LCA takes into account the complete life cycle, from cradle to grave, by assessing environmental and resource sustainability.
An important indicator for the LCA is the Energy Payback Time (EPBT). The EPBT is defined as the period required for a renewable energy system to generate the same amount of energy (primary energy equivalent) that was used to produce the system itself. Calculating the primary energy equivalent requires knowledge of the country-specific,

energy conversion parameters for fuels and technologies used to generate energy and feedstock.
The LCA approach provides a detailed and comparative evaluation of environmental impacts for wind energy. Wind energy LCAs are generally divided into five phases:
- Construction: include the raw material production in order to manufacture the different components of a wind turbine
- On-site erection and assembling: works to be done to install the wind turbine on site
- Transport: takes into account the transportation of the raw materials for the production as well as the transport of turbine components to the wind farm site
- Operation: is mainly related to the maintenance of the turbines
- Dismantling: includes the dismantling of the turbines and the transport to the final disposal site, taking into account potential recycling of some components (EWEA, 2015).

According to Neubauer (2015: 136) a wind turbine has an energy payback time between approx. two and seven month, mainly depending on the location of the wind farm (on-shore or off-shore). The main factor is the prevailing wind condition of the wind farm location. Each kWh produced after that period leads to a 100% CO2 reduction comparing with fossil fuel. Neubauer (2015: 135) elaborates that with an installed capacity of 16 MW around 24t of CO2 can be reduced per year.
Referring to Iran's total installed wind turbines capacity (see table 3.1.), the CO2 emission is reduced by 280t per year.

3.5.2 Emission savings

Based on information by SUNA, each kWh electricity generated by wind energy would prevent emissions of 1 kg CO2, compared to a fossil fuel power plant. In general, 3% GHG are prevented by replacing 1% fossil fuel power plants by wind energy. Apart from CO2 emissions, fossil fuels power plants also emit NOX, SO2, SO3, CO, CH4 and SPM, which are not emitted through wind power plants[55].

3.5.3. Negative impacts of wind power

There are some negative environmental impacts like impacts on the landscape, land use, wildlife and habitat (birds and bats in particularly), noise pollution and impacts on the electricity network that could be monetized and considered in social cost-benefit analysis

[55] SUNA, 2016: Wind and Wave Office

of wind projects. Social cost of noise pollution by wind turbine varies by wind profile in different region of Iran (Ehyaei & Bhadori, 2006). This study shows that the cost of noise reduction is 0.15 $/kWh in Tehran and 0.25 $/kWh in Manjil region, respectively. Main issues can be addressed directly with the surrounding neighbors by following best practices and starting public dialogs. Another recent study in Manjil wind farm shows the possible negative impact of wind turbine noise on annoyance, sleep and health of wind farm workers (Abbasi et al., 2015).

3.6. Technical Market Potential of wind energy in Iran

"Iran's wind power potential could rival that of big wind power players such as Great Britain or France. Every kilowatt-hour of extra wind power allows them to export more oil, meaning more foreign currency," says Michael Tockuss, managing director of the German-Iranian Chamber of Commerce[56]. The now following analyses of the technical potential of wind power in Iran looks at the country as a whole (section 3.6.1.) with average wind speeds of Iran's provinces together with physical and general assumptions of air density, swept area and efficiency factor as well the theoretical number of turbines per province and the capacity factor. Followed by a more detailed calculation for a specific site in Khaf (region of Razavi Khorasan, see section 3.6.2.). For the calculation of the specific wind power plant in Khaf the real data of wind speed, the Weibull method to estimate the capacity factor, the power coefficient and the power density were taken. The analysis indicates that the plant(s) of land-based 2.5 MW Vensys' turbines are restricted to non-forested, ice-free, non-urban areas.

3.6.1. Estimation of technical potential of wind electricity

$$EP_{real} = NWT_{p} * 2.5 * \mathrm{FLH} \qquad \textbf{(1)}$$

Where

EP_{real} = electricity potential

NWTp = number of wind turbines per province

2.5 for the 2.5 MW wind power plant installations

FLH = full load hours

[56] Bloomberg, 2015: Iran's Thirst for Energy Draws in Wind Developers

The area that is feasible to erect wind power plants in km^2 per province is shown in table 3.3. Wind turbine cannot be erected in the same number as PV systems due to scenery damage and environmental issues among other technical matters. It is assumed that 1.5% of the total provinces' area can be allocated to wind farms[57], which yields **24,431 km^2** ($\propto$ = total free land available, see calculation (2).

Optimal spacing of turbines in an individual wind farm involves a trade-off among a number of factors, including the costs of individual turbines, costs for site development, and costs for laying power cables, in addition to operations and maintenance costs (O&M). Turbines must be spaced to minimize interference in airflow caused by interactions among individual turbines. This process requires a compromise between the objective to maximize the power generated per turbine and the competing incentive to maximize the number of turbines sited per unit area.

Our wind turbine with 2.5[58]) MW for installation has a hub height of 93.5m and a rotor diameter of 112m. The required distance in the main wind direction is 8 times the rotor diameter and 5 times the rotor diameter in the other direction. (Kaltschmitt et al., 2013: 512ff), which equals approx. 0.5km² (896x560). Therefore the maximum number of wind turbines that can be erected per province can be calculated (see table 3.3.).

$$NWT_{p} = \frac{\propto}{0.5} \qquad (2)$$

Where

NWTp = number of 2,500 kW-wind turbines per province

$\propto$ = total free land available (in km^2)

Table 3.3. Wind arable areas of Iran's provinces and its NWT

Province (Name)	1.5% of total area per province (km²)	Number of wind turbines max. possible
Alborz and Tehran*	282	564

[57] For comparison, the Austrian province of Lower Austria identified 1.5% of its territory as suitable for wind-power: ENU, 2016
[58] We assume that the assumption of Kaltschmitt et al. (2013) are the same for a 2.5 MW installation.

Ardabil	267	534
Azerbaijan, East	685	1,370
Azerbaijan, West	561	1,122
Bshehr	341	682
Chahar, Mahaal and Bakhtiari	245	490
Fars	1,839	3,678
Gilan	211	421
Golestan	306	611
Hamadan	291	581
Hormozgan	1,060	2,121
Ilam	302	604
Isfahan	1,605	3,211
Kerman	2,711	5,422
Kermanshah	375	750
Khorasan, North	427	853
Khorasan, Razavi	1,783	3,566
Khorasan, South	2,262	4,524
Khuzestan	961	1,922
Kohgiluyeh and Boyer-Ahmad	233	465
Kurdistan	437	874
Lorestan	424	849
Markazi	437	874
Mazandaran	358	715
Qazvin	234	467
Qom	173	346
Semnan	1,462	2,925
Sistan and Baluchestan	2,727	5,454
Yazd	1,108	2,216
Zanjan	327	653
Total	**24,431**	**48,863**

Source: own calculation

The calculation of the Full Load Hours (FLH) depends on the specific wind speeds. There are many synoptic stations gathering meteorological data of Iran. Figure 3.11. shows the average wind speed in Iran's provinces in 2012, which are taken for the calculations below. This thesis does not take into account the roughness length of different hub heights. It should be mentioned that the results would even increase.

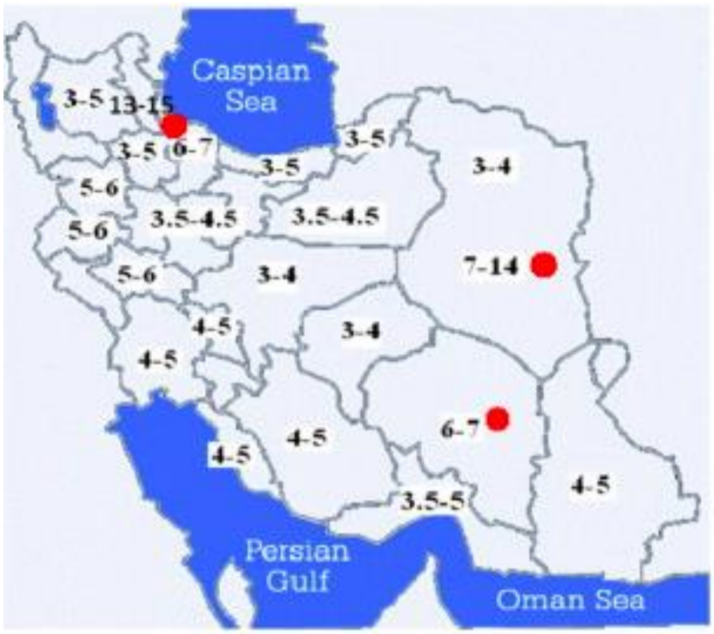

Figure 3.11. Variation of wind speed potential in different sites in Iran (m/s); Source: Bahrami & Abbaszadeh (2012)

Based on the mean wind speed the full load hours (h/a) can be estimated. For the calculation of the theoretical wind electricity output, the data of the average FLH in Kaltschmitt et al. (2009) was taken as the basis.

The result of the equations (1) and (2) is the very rough estimation of electricity wind potential in Iran, yielding **186 TWh** (see details in table 3.3.). A more reasonable potential value is calculated by the Center of Renewable Energy Research and Application with 6,500 MW (Kazemi et al., 2005 cited by Sharbafian, 2009). The estimated potential is affected by many variables including wind technology, the wind profile in sites, and the area allocated for the wind farms in each provinces. A more detailed calculation for a specific wind power plant is shown in the following section.

Table 3.4. Wind electricity potential in Iran's provinces

Province (Name)	Potential of max. possible 2.5 MW wind turbines (MW)	**Wind electricity potential (TWh)**
Alborz and Tehran*	1,411	1.129
Ardabil	1,335	6.274
Azerbaijan, East	342	2.739
Azerbaijan, West	2,806	2.245
Bshehr	171	1.940
Chahar, Mahaal and Bakhtiari	1,225	1.393
Fars	9,195	10.460
Gilan	1,053	2.593
Golestan	1,528	1.222
Hamadan	1,453	1.162
Hormozgan	5,302	5.137
Ilam	1,510	2.737
Isfahan	8,026	4.916
Kerman	13,554	**33.378**
Kermanshah	1,876	3.400
Khorasan, North	2,133	1.306
Khorasan, Razavi	8,914	5.460
Khorasan, South	11,310	**53.156**
Khuzestan	4,804	5.465
Kohgiluyeh and Boyer-Ahmad	1,163	1.323
Kurdistan	2,185	3.961
Lorestan	2,122	3.846
Markazi	2,185	1.748
Mazandaran	1,788	1.431
Qazvin	1,168	0.934
Qom	864	0.692
Semnan	7,312	5.849

Sistan and Baluchestan	13,634	15.509
Yazd	5,540	3.394
Zanjan	1,633	1.306
Total	122,157	**186.102**

Source: table 3.3., own calculations

3.6.2. Vensys 112 (2.5 MW Platform) in Khaf (South Khorasan)

The calculations in section 3.6.1. were mainly based on assumptions. Especially to take the average wind power of an entire country leads to inaccuracies. In this chapter we look at the wind power plant at a specific site in North-Eastern Iran where good wind conditions can be found. The results, of course, will not be representative for the entire country. However, the calculations are more specific and detailed and will give a good overview on how wind power plant capacities and potentials can be priced and evaluated.

3.6.2.1. Wind speed, wind power and power production

The wind speeds at Khaf power plant were measured with synoptic stations gathering meteorological data. The average wind speed over this period of time is 8.90 m/s. (SUNA, Summary Wind Analysis-Khaf, see Appendix III). The monthly mean wind speeds can be seen in figure 3.12. For our calculation the hub height of 80m was chosen (dark blue line).

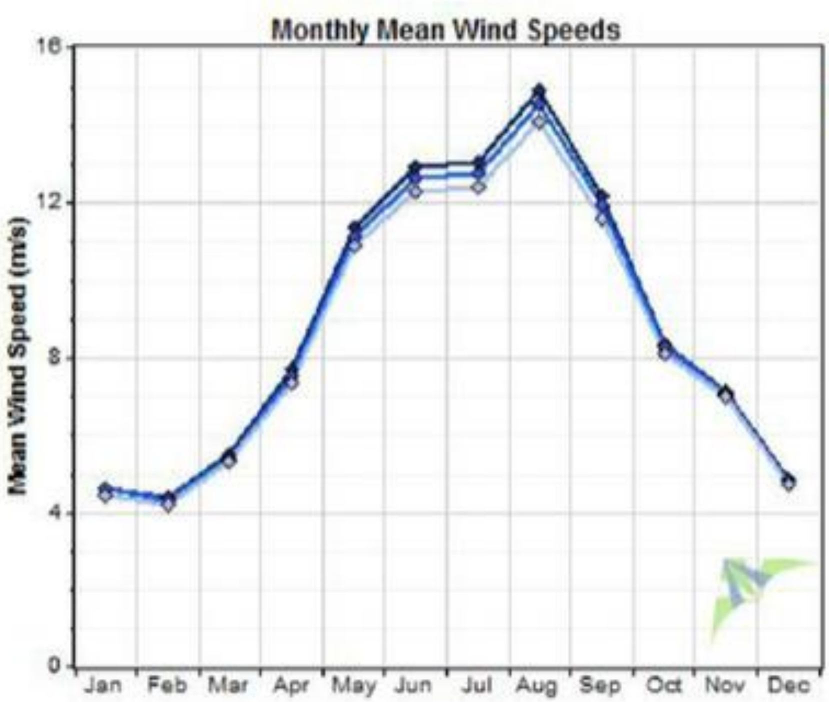

Figure 3.12. Monthly Mean Wind speeds at Khaf (2011-2015) at 40m/60/m/80m hub heights; Source: SUNA, Appendix III

The mean air density at this site is 1.222 kg/m^3[59].

It is very important for the wind industry to be able to describe the variation of wind speeds. Turbine designer need the information for their design as well as investors to choose the right site. The wind variation is usually described using the so-called Weibull distribution. It is a statistical description of wind speeds, taking into account the different wind speeds, the mean value and the shape parameter (skewness). The wind at the Khaf site was measured with an anemometer and the mean wind speed was recorded. The energy contained in the wind at this site can be expressed by the Weibull distribution.

$$f(x;\lambda;k) = \begin{cases} \frac{k}{\lambda} * \left(\frac{x}{\lambda}\right)^{k-1} * e^{-(x/\lambda)^k} \\ 0 \end{cases} \qquad (3)$$

Where

λ = Weibull scale parameter in m/s. It is proportional to the mean wind speed. It is for our site 9.7 (with a mean wind speed of 8.9).

[59] SUNA, Summary Wind Analysis-Khaf, see Appendix III

k = Weibull form or shape parameter (between 1 and 3). In our case we took the coefficient of 1.3 as the wind blows very variably.
x = the wind speed (between 3 and 25m/s)

The Weibull distribution function (blue line) can be expressed graphically as shown in figure 3.13. below.
As shown in our general example in section 3.6.1. the specific power P of the wind can then be calculated by the formula (1) and is shown by the red line (power curve).
The capacity factor as a ratio between the annual production and the maximum technically possible production of a wind turbine is between 30-50%. In our case it is 46.8%, leading to the FLH of approx. 4,700 h/year (as the FLH represent the capacity factor). The FLH are also consistent with the calculations of the theoretical wind power potential from section 3.5. The FLH are the theoretical number of hours that the wind turbine has to run at full load in order to produce the annual yield. FLH are calculated as capacity factor by the number of hours per year (8,760).
With the power calculator of the Swiss wind power data website we then calculated the power production for our chosen site in Khaf[60].

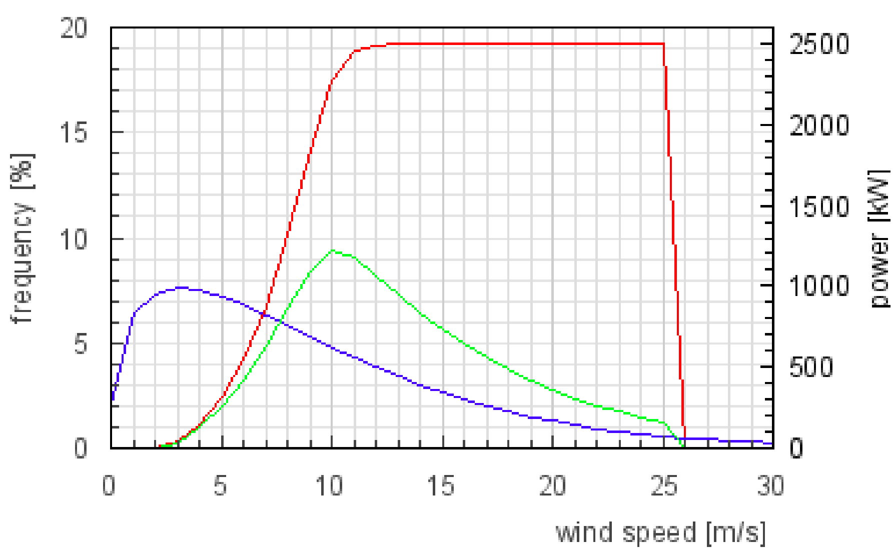

Figure 3.13. Wind speed distribution (blue), Power production distribution (green) and Power curve (red) for Khaf wind plant; Source: The Swiss Wind Power Data Website (2016)

[60] The Swiss Wind Power Data Website, http://wind-data.ch/tools/index.php?lng=en (based on Vensys 112).

The power production is **8,206,368 kWh/year**, with operating hours of 7,193 h/year. These numbers will now be taken for the calculation of the economic feasibility, section 3.7.

3.7. Economic feasibility

In the previous sections the theoretical technical potential of wind energy in Iran and at a specific site was estimated and calculated, respectively. In this section we look at the economic viability of the 2,500 kW wind power plant of section 3.6.3. For smaller projects have a look at Info Box 5: Small Wind Electric Systems and Micro Wind Turbines.

Info Box 5 Small Wind Electric Systems and Micro Wind Turbines (SWT)[61]

- Used for small-scale heat and electric power (not hooked up to the local electric grid) by individuals, small businesses and communities to meet their own needs.
- Advantageous to more remote areas that do not have electrical grid access.
- Canadian Wind Energy Association defines "small wind" as ranging from less than 1 kW up to 300 kW turbines.
- For reference, 100 kW is enough to power a large school.
- Two primary small wind turbines:
- Horizontal axis wind turbine
- Vertical axis wind turbine.
- - Costs between $12,000 - 50,000.
- -2014, a cumulative total of at least 945.000 small wind turbines were installed all over the world.
- -SWT's installed capacity worldwide has reached more than 830 MW as of 2014.

3.7.1. Business Model Description

For our business model we choose a

- 2,500 kW project[62]
- With feed in tariffs (2016)
- Based on a Power Purchasing Agreement (PPA)

[61] Based on CANWEA, 2016; Wikipedia, 2016: Small wind turbine; Wwindea, 2016
[62] Vensys 112 (2.5 MW Platform).

The PPA is a contract between an electricity producer and the Renewable Energy Organization of Iran (SUNA, see chapter 1.5.10. for more information on SUNA). It fixes a price for the electricity provided by the investor to the off-taker SUNA over 20 years. The investor sells all the generated electricity to SUNA to receive the Feed in Tariff. For more details on the PPA see chapters 1.5.7. and 2.6.2.

As mentioned in the introduction of this chapter, the process depends on the size of the system. In the case of our chosen business model of 2,500 kW, the process should be executed with SUNA that is also the off-taker of the electricity produced[63]. According to the size of the system (less than 50 MW), the Feed in Tariff corresponds to 4,200 IRR/kWh which is equal to 12.44 €-cent/kWh.[64]

The difference to PV or geothermal plants is that the FiT is not reduced after 10 years. However, the "tariffs for the wind farms with the capacity factor of 40% and above in the first 10 years, will be multiplied by 0.4 after adjustment of article 3 of Economic Council Directive starting from the first day of the second 10 years till the end of the contract". [65]

3.7.2. Power Purchase Agreement (PPA)

As described in chapter 1.5.7, a PPA contract between SUNA and the owner of the power plant is concluded. The most relevant elements of the PPA are:

a. The duration of the contract and deadlines: 20 years and 24 months deadline: the applicant needs to commission the power plant within 24 months after signing the PPA, otherwise the generated electricity will be bought with the price of the energy market.

b. Feed in Tariff: The feed in tariff is 4,200 IRR in 2016[66]. Every year the FIT is adjusted by the 'adjustment formula' (see chapters 1.5.5.d and 1.5.6.). Details can be found at the calculation sheets, the tariff escalation in our project yields 1.0918 as $(112/100)^{0.3} \times (36{,}474/33{,}772)^{(1-0.3)}$. Tariff escalation is the same as for PV (table 2.6.)

[63] The process procedure is described in chapter 1.5.8.
[64] The exchange rate corresponds to 33,772 IRR/1 Euro.
[65] SUNA, 2016: Guaranteed Renewable Electricity Purchase Tariffs
[66] See footnote 24.

3.7.3. Results and profitability analysis

In the previous section the technical potential of wind electricity systems was estimated and calculated. As a next step we look at the economical potential and feasibility. As mentioned above our calculation is based on a 2,500 kWp platform from Vensys.

The assumptions will be verified and varied in the sensitivity analyses in section 3.8.

The assumptions are:

We calculate a turn-key system with a price of 1.5 million Euro/MW (see section 3.4.2.), what yields 3,7500,000 Euros in total. Operational and Maintenance costs are set with 1.5% (Ragheb, 2015) of the total investment costs per year. These O&M costs were escalated by an average escalation rate of 10.5% per year because 50% of O&M costs are accounted in EUR, 50% in Iranian Rials.

In sections 3.6.1. and 3.6.2.1., respectively the capacity factor (47%) and the FLH (4,700) were discussed and calculated. The performance ratio that takes into account all pre-conversion losses, inverter losses and conduction losses is set with 80%. The decreasing performance due to the dry and dusty climate was taken into account by 0.7% per year.

The run-time and project duration is 20 years and based on a feed in tariff of 4,200 IRR/kWh which equals 0.1244 Eurocent. It is escalated over these 20 years and calculated as weighted average with 9.18%[67]. After 10 years the feed in tariff is reduced to 40% due to SUNA regulations (see section 3.7.1.).

For the financing of the project, the NDF (national development fund) grants support with an interest rate of 6% p.a. for 80% debt and a loan tenor of 5 years. The discount rate was set at 15% to represent a low risk investment alternative (3% higher than assumed inflation rate).

Table 3.5. Assumptions on feasibility study of a 2.5 MW wind power plant in Khaf

Variables	**Value**	**Unit**
PV System Size	kWp	2,500
Specific System Cost	EUR/kWp	1,500
Total System cost	EUR	3,750,000
O&M Costs	1.5% of invest. cost/p.a.	56,250
O&M Escalation Rate	% p.a.	10.50%

[67] Based on the inflation rate (weight 0,3) and the escalation rate of the EUR/IRR-exchange rate (weight 0,7).

FLH	h/p.a	4,700
Performance Ratio	%	80%
Specific Yield (FLH minus performance ratio, 80%)	h/p.a	3,282.55
Degradation	% p.a.	0.70%
Feed-in Tariff	EUR/kWh	0.1244
Tariff Coefficient (Year 1-10)	%	100%
Tariff Coefficient (Year 10-20)	%	40%
Exchange Rate (04/08/2016)	EUR/IRR	33,772
Exchange Rate Escalation	% p.a.	8.0%
Inflation Rate	% p.a.	12.0%
Feed-in Tariff Escalation	% p.a.	9.18%
Project Duration	Years	20
Debt	80%	3,000,000
Loan Tenor	Years	5
Interest Rate	%	6.0%
Discount Rate	%	15.0%
Net Present Value	**EUR**	**5,425,36**
Project Internal Rate of Return (IRR)	**%**	**63%**
Equity Internal Rate of Return (IRR)	**%**	**87%**
Long Run Generation Cost of Electricity (LRGC)	**EUR/MWh**	**74.10**
Annuity	**EUR**	**866,764**

Sources: System Size, Specific System Cost, Total System cost from Vensys; Fixed O&M Costs, O&M Escalation Rate from Economics of Wind Energy; Specific Yield, Performance Ratio from The Swiss Wind Power Data Website; Specific System Performance and Degradation assumed; FiT, FiT Coeffizients, FiT Escalation, Exchange Rate, Exchange Rate Escalation from SUNA (2016) and own calculation; Inflation Rate from Central Bank of Iran (2015); Debt, Loan Tenor, Interest Rate and Discount Rate assumed; tax exempted from calculations. Detailed overview see **Appendix IVb**.

Under current policies, this wind project is not only economically viable but also highly profitable. The project IRR is 63%, the equity IRR even higher (87%). Again, the FiT is a big incentive, even after a cut after 10 years of 60% it pays off to invest in wind energy. When looking at the specific results, the NPV with over € 5,400 underlines the profitability of the investment. The LRGC take into account the installation of additional generation capacity and are also quite low compared to PV, which is another indication for the profitability. The project IRR, measuring the profitability of the investment, is excellent. This project is definitely profitable and recommendable.

3.8. Sensitivity Analyses

In the following the results of a sensitivity analysis performed for selected key input parameters are presented. Again, the O&M, the FiT and the FLH were taken and changed +/-40%. The LRGC sensitivity, shown in figure 3.14. reflects the strongest impact on the FLH (between € 53 and € 123) and the project is quite sensitive to changes of those. Especially a decrease causes a disproportional higher rise of costs. An in-/decrease (even if it is +/- 40%) of O&M costs does not have such a strong impact as expected. The FiT level cannot influence the cost but only the economic viability.

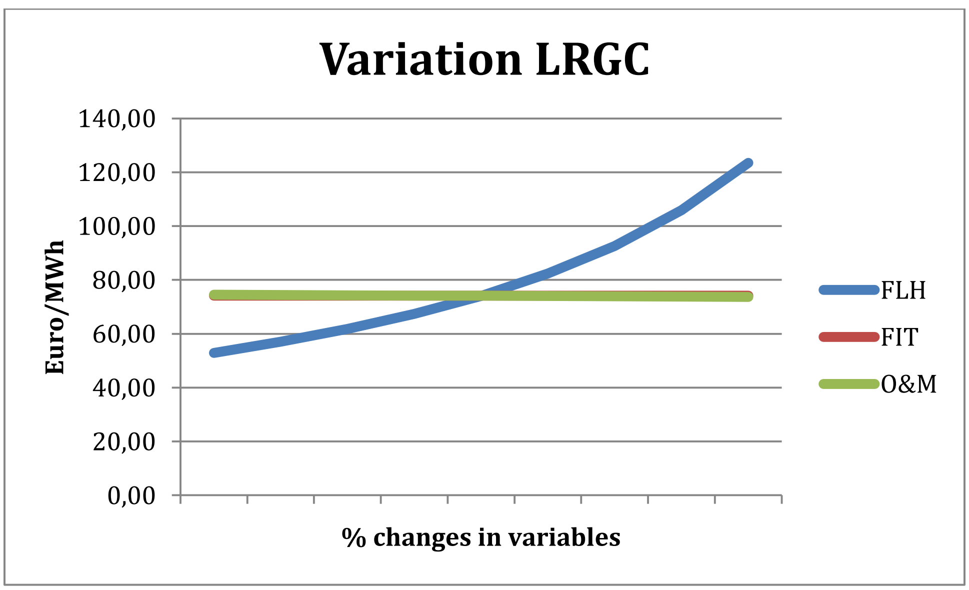

Figure 3.14. Sensitivity analysis, Variation LRGC for O&M, FIT and FLH; Source: Table 3.5. and own calculation

The sensitivity analysis on the NPV in figure 3.15. shows the strong impact on the project when in- or decreasing FLH or FiT, while changes of O&M have much less strong impact on the NPV. Similar to PV, changes of the FLH have nearly the same result as changes in FiT, therefore the FLH-line (blue) is invisible as covered by the red line (FiT).

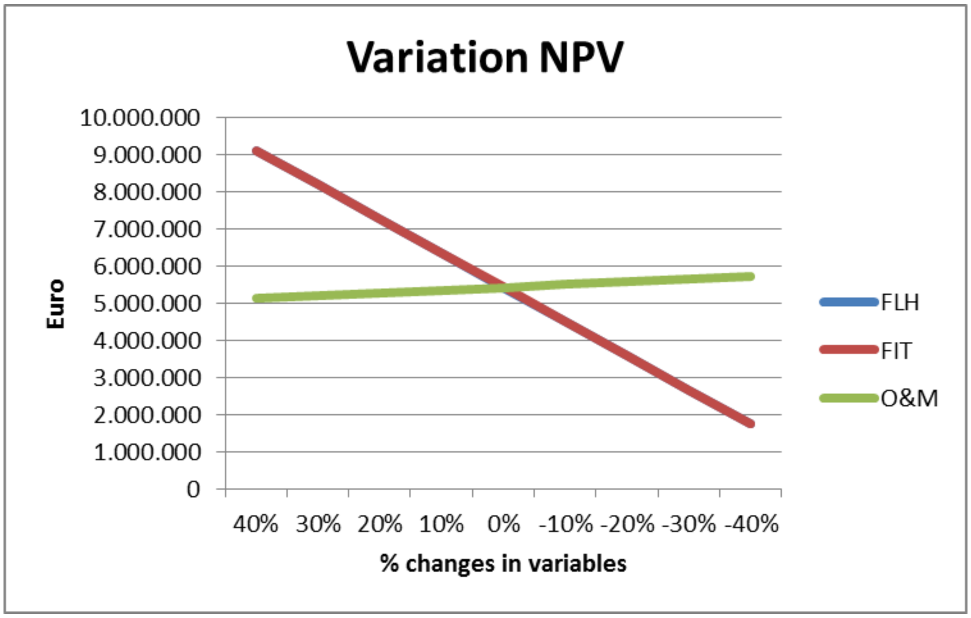

Figure 3.15. Sensitivity analysis, Variation NPV for O&M, FIT and FLH; Source: Table 3.5. and own calculation

Chapter 4: Geothermal Electricity

4.1. Introduction

Iran on its way to a geothermal future?

Geothermal energy is the only form of renewable energy independent from the sun. (Milics, 2014: 12)

Geothermal energy uses the natural heat flow of the earth. This heat flow is larger than the human energy consumption. However, it is not as intense everywhere- along the tectonic plate boundaries the outcome will be higher and the access easier. By now, water is needed as a heat transfer fluid, while future developments (see Info Box 6: Hot Dry Rock) will put a not yet economical drilling method economically viable, geothermal energy will make a big loop forward and be accessible in many world regions where it is not yet feasible (Valdimarsson, 2014: 24).

Info Box 6: Hot Dry Rock (HDR)

HDR is by far the most abundant source for geothermal energy available. Most of this thermal energy is stored in the hot (but dry) crystalline basements rocks of the earth. Nearly everywhere around the world these rocks can be found, however, the drilling technology is not yet advanced enough for commercially successful operation. The main reason is that these rocks can only be found between 3,000-6,000 m. Critics say that this technique could cause similar damages (e.g. earthquakes) as hydraulic fracturing (‘fracking’) in which rock is fractured by a pressurized liquid to gain fossil fuels (mainly gas)[68].

Similar to the sun also the inner of the earth provides energy derived from nature. It yields warmth and power that can be used. However, the access to this kind of energy is incomparably harder compared to energy provide by the sun as geothermal energy is stored below the solid surface of the earth. The deeper one drills the interior, the warmer it becomes, starting from 400m up to some kilometers depth with up to 5,000°C at the earth’s core.

[68] Wikipedia, 2016: Hot dry rock

The global market of GPP (see figure 4.1.) is at about 13.3 GW of operating capacity with potential up to 18 GW in 2021 (including the potential capacity additions of plants with announced completion dates (dark green) and 14.8 GW potential capacity additions of plants under construction (GEA, 2016).

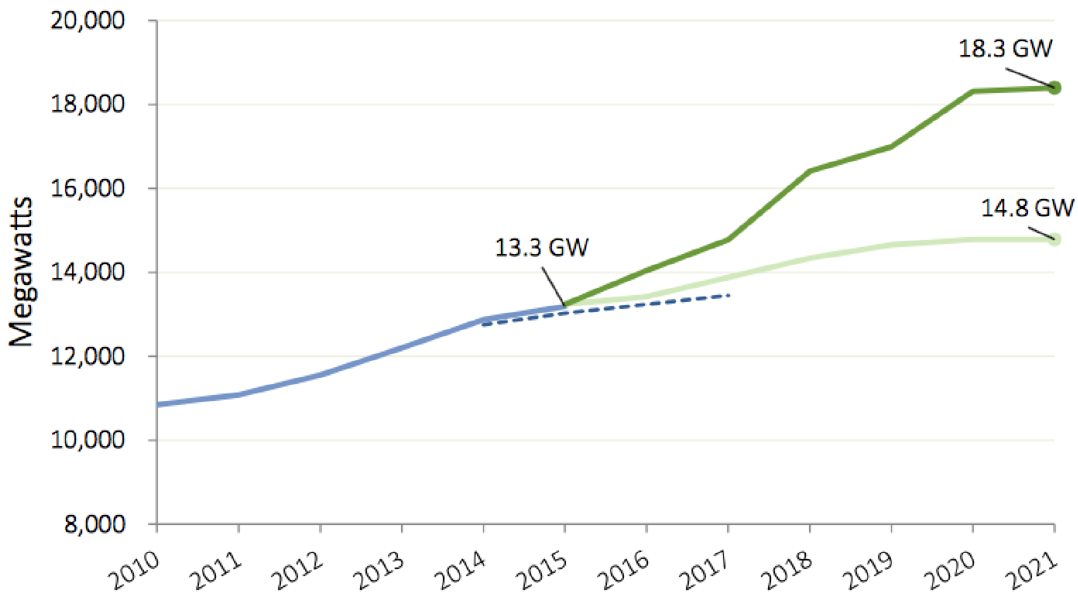

Figure 4.1. International Geothermal Power Capacity (MW) 2016; Source: GEA (2016)

Looking at the theoretical numbers of the heat stored in the earth's crust, it can be stated that geothermal energy has a great potential: the total amount is of 5.4 billion EJ, while the annual use of energy in the world is 400 EJ, i.e. if we could only use 0.1% of the total heat stored in the earth's crust it would satisfy the world energy consumption for 13.500 years (Milics, 2014: 32)!

In order to evaluate the geothermal potential in Iran this thesis' starting point is the geothermal power plant in Meshkinshahr in the province of Ardabil in North-West of Iran. Most literatures this thesis is based on, have done scientific research in this area. It provides a summary of the recent developments and technical analyses, namely the Geographic Information System (GIS) study (Porkhial & Yousefi, 2015; Yousefi & Ehara, 2007; Yousefi et al., 2007; Noorollahi et al., 2009), the Monte Carlo analysis (Porkhial & Yousefi, 2015) and the engineering equation solver (EES) software for the thermodynamic cycles' optimization (Porkhial & Yousefi, 2015; Taghaddosi & Porkhial, 2015).

Sections 4.2. looks at Iran's (not yet existing) geothermal market and its capacity. 4.3. includes some techno-economical data related to geothermal energy, including costs and risks (4.3.1.), job creation (4.3.2.), environmental impact (4.3.3.) and efficiency (4.3.4.). Section 4.4. estimates the technical potential of geothermal electricity in general (methodology, 4.4.1.) and in Meshkinshahr (4.4.2.) in specific. Section 4.5. examines the economic feasibility and profitability analysis under current energy policies. The last section (4.7.) concludes with the results and sensitivity analyses.

4.2. Iran's geothermal market and capacity

Iran is located on the Alpine-Himalayan orogenic belt with five major geological units[69] based on remarkable tectonic history, magmatic events or sedimentary features with the Alborz unit as the most important geothermal potential due to the most active volcanism. The country's geothermal gradient values range from 2°C/100m to 13°C/100m (Noorollahi et al., 2008). As shown in Figure 4.2. the high level of seismicity is a result of the convergence of the Arabian plate and Iran in a continental collision, resulting in the Zagros mountain range as well as good conditions for the formation of geothermal fields. An 'obvious' outcome are the hot water springs in parts of the country (SUNA, 2016: Geothermal Energy).

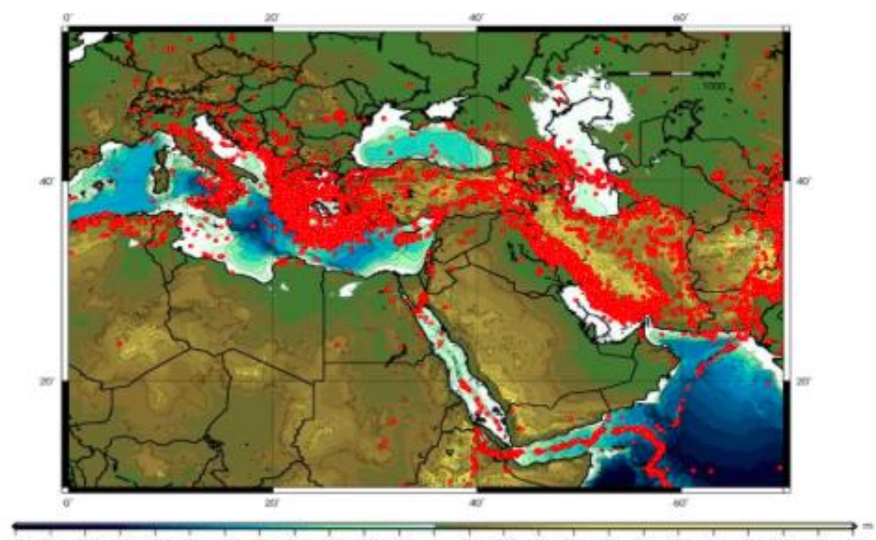

Figure 4.2. Seismicity of the Alpine-Himalayan belt, Source: Saloor & Salaree (2004)

[69] Zagros, Sanandaj-Sirjan, Central Iran, East and South East zones and Alborz.

In 1975 the MoE started to identify existing potentials of geothermal energy. 15 areas with geothermal-reliable zones for energy generation up to 800 MW of electricity production were identified (SUNA, 2016: Geothermal Energy; Richter, 2015). Investigations and research projects at a later date show even 18 potential areas in Iran. (see figure 4.3. and section 4.4.1.)

However, there is no experience in geothermal energy production in Iran until today as at this moment, the first GPP is not even on-grid. Despite this fact, Iran has plans to become a bigger player in the geothermal world. If it wants to become the 9th largest geothermal energy producer, it will have to add 500 MW of geothermal energy (Richter, 2016a).

According to Moshanir[70], the plant in Meshkinshahr, which is developed together with SUNA and the Italian manufacturer and distributor of electricity and gas, ENEL, will go on-grid in spring 2017[71].

Planned as a 20-25 MW plant, and estimated a potential of 250 MW electrical and 1,250 MW thermal energy, it will only start with a 5 MW single flash steam pilot plant (see footnotes 2 and 4). In figure 4.3. the Meshkinshahr GPP is shown as Sabalan area (North-West of Iran)[72].

A newly updated and more detailed digital geothermal potential map of Iran using Geographic Information System (GIS) was developed in Kyushu University in the year 2007 (Yousefi et al., 2007). Findings say that 8.8% of Iran’s area and 18 fields have promising geothermal potential. First priority for the construction of a GPP was given to the Meshkinshahr GPP in the Sabalan area (Noorollahi et al., 2009).

Two more sites (Damavand, East of Tehran and Ramsar at the Caspian Sea) have been considered for aquaculture, greenhouse and space heating. For exploratory surveys in the Damavand region an agreement was made between SUNA and Niroo Research Center (MATN, an affiliate of MoE) in 2003 in order to the efficient recovery of the surrounding thermal springs (Noorollahi et al., 2009).

[70] Moshanir company, 2016

[71] In the 1980s investigation were conducted by ENEL, later approved by Valgardur Stephenson (Porkhial & Yousefi, 2015); Richter A. (2016b).

[72] Moshanir company

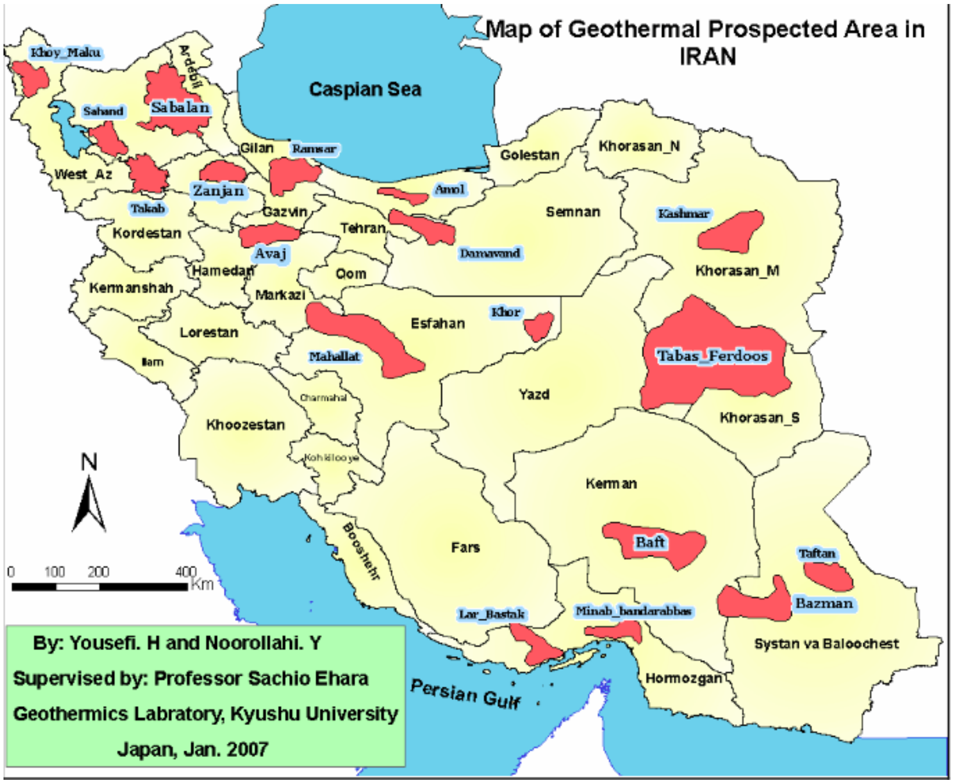

Figure 4.3. Geothermal potential areas in Iran; Source: Yousefi et al. (2007)

Further information on the technical potential and economic estimations of the Meshkinshahr GPP can be found in chapter 4.4.1. and 4.4.2.

4.3. Geothermal power plant technology

Geothermal systems can be either hydrothermal (energy) systems (indirect use); heat pumps (direct use like district heating; see Info Box 7: Geothermal Direct Utilization / Heat Pumps) or earth contact homes (see figure 4.4.) (Milics, 2014: 16).


Figure 4.4. Earth contact homes; Source: Home in the Earth[73]

[73] Home in the Earth, 2016

In general, GPP use steam, heat or hot water from the so-called geothermal reservoirs to spin the turbine (generator) to produce electricity. After usage, the water is then returned through an injection well into the reservoir where it then re-heats, to keep the pressure at the same level and to sustain it (Geothermal Education, 2016).

Info Box 7: Geothermal Direct Utilization / Heat Pumps

Direct use of geothermal energy can be found for

- Snow melting
- Spas
- Greenhouses
- Fish farming
- Heat pumps: Between a quite low temperature of 25-85°C heat pumps might be used for the direct use of geothermal energy. Geothermal Heat Pumps' (GHPs) advantages are low energy consumption during operation, considered to be a stable energy source, low maintenance costs

A project of geothermal direct heat pump's utilization was initiated in 2003: five units of heat pumps (750 kW each) were installed countrywide (Noorollahi et al., 2009).

Further information on heat pump applications and installed capacity and locations can be found in: Porkhial & Yousefi's (2015) paper.

Depending on the temperature, Valdimarsson (2014: 89) distinguishes between different geothermal fields/resources:

- Hot dry rock: see Info Box 6: Hot dry rock
- Vapor dominated fields: deliver steam ready for the turbine
- Water dominated fields: water flows into the wells, and boils partly
- Liquid water: temperature below 100°C

Nowadays, there are three kinds of GPPs. The one constructed depends on the temperatures and/or pressures of the reservoirs (Geothermal Education, 2016):

1. Dry steam reservoir: produces steam and no or little water. The steam is piped directly into the power plant to spin the turbine (generator).

2. Flash power plants: using mainly hot water (150-370°C) reservoirs. At the surface's production well some water goes into the so-called 'separator' where it becomes steam,

which then spins the turbines (generator). We distinguish between single and double flash steam cycles.

3. If the temperature at the reservoir is less hot (120-180°C) to flash enough steam, there is the possibility to produce electricity in a binary power plant. The water goes through a heat exchanger. The heat is transferred into a 2nd (binary) liquid. One example is isopentante that boils at a lower temperature than water. The emerging vapor (with the same effect as steam) spins the turbine (blades/generator) and stays within a closed loop cycle, i.e. is re-used and does not emission.

Figure 4.5. shows the worldwide distribution of the geothermal power plants by type, showing that single flash by far is the most common GPP type worldwide.

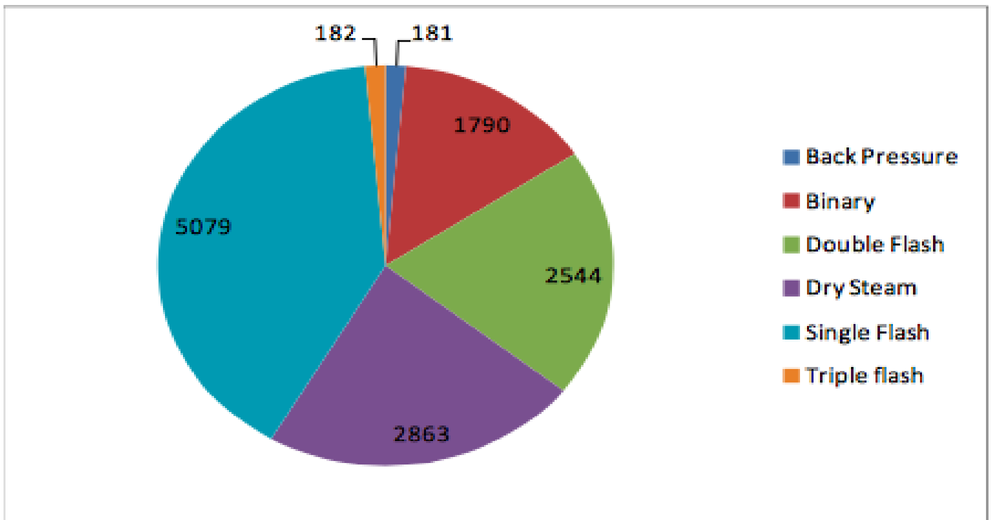

Figure 4.5. Geothermal power plants by type (MW); Source: Bertani (2015)

As shown in figure 4.6., the main components of a single flash geothermal power plant are: Wellhead valves (not pictured in figure 4.6.), controls and silencers (not pictured in figure 4.6.); steam piping; separators; turbine; generator; condenser; pumps (not pictured in figure 4.6.): condensate & cooling water; NCG ejectors or vacuum pumps (not pictured in figure 4.6.); cooling tower. Single flash steam technology is used when the hydrothermal resources is liquid. The fluid goes into a separator (under lower pressure than the fluid), getting vaporized rapidly into steam. The steam then passes through a turbine coupled with a generator. Cooling water is pumped to the condenser to generate more electricity and the brine of the geothermal fluid from the separator is pumped to direct use applications or to the r-injection wells (Noorollahi et al., 2009).

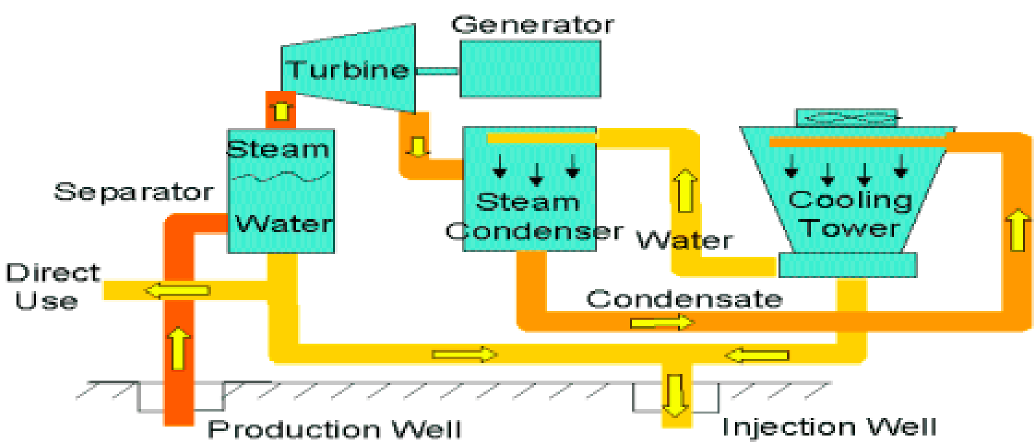

Figure 4.6. Main components of single flash GPP, Source: Indian Institute of Technology Bombay (2009)[74]

A single flash GPP is under construction in Meshkinshahr. Technical and economical potential estimations' of the Meshkinshahr GPP later in this chapter are based on this single flash GPP.

4.3.1. Costs and Risk

The average cost of energy production from power plants using flash technology ranges from 5 t-13 $-cent/kWh and from 7-14 $-cent/kWh for those using binary technology[75]. According to Taghaddosi & Porkhial (2015) the GPP with an outcome of 5.5-6 MWe will cause costs of 14-15 million $ (for a turn-key power plant).
The main costs are caused by drilling; and the equipment and construction of the plant, respectively (which is more than 80%) (Sharbafian, 2009).

GPP investments are a risky business in terms of project risks, especially looking at the period between the pre-survey and the end of the test drilling, whereas the bankability risks rise later in the project (from drilling till the start-up of the plant) (ESMAP, 2012 cited by Milics, 2014: 15).

[74] Indian Institute of Technology Bombay, 2009
[75] SUNA (2016): Geothermal Energy

Taghaddosi & Porkhial (2015) calculates a turn-key system with a price of ca. 2.55 million Euro/MW, which will be the basis for this thesis' economical calculations (see section 4.6.).

4.3.2. Jobs creation

The geothermal energy sector of Iran is totally run by the government. Therefore most of the personnel are government staff. Other corporate (ENEL, Moshanir) and governmental organizations (SUNA) provide major contributions to the handling of various civil and drilling works. The overall investment allocated to geothermal research and development plans for the duration of 2000–2007 was around $ 12.3 million, mainly used for financing the power generation project in Meshkinshahr (Noorollahi et al., 2008).

4.3.3. Environmental impacts

In general, geothermal energy is perceived as being environmental-friendly. Environmental concerns are:

- Surface disturbances and land use: natural geothermal manifestations may change as well as a comprehensive infrastructure (roads, pipelines, etc.) is needed (Valdimarsson, 2014: 40).
- Physical effects, like fluid withdrawal: the hot water pumped from the reservoirs often contains high levels of sulfur. In closed systems the danger of a contamination is low, however there are reported cases of water contaminations. GPP can require between 6,000-15,000 liters of water per MWh. At least most GPP re-inject the water into the reservoir to prevent e.g. land subsidence.[76]
- Noise: well blow into the silencers, the velocity flow in the turbine is high, condenser fans cause noise as well (Valdimarsson, 2014: 40)

- Air emissions: CO_2 and H_2S gasses are emitted. For every kWh electricity produced, 0.13 kg of CO_2 is emitted (compared to e.g. 1.2 kg for coal production) (Shahrokhi, 2008 cited by Sharbafian, 2009)

On the other side, there are positive social and economic effects. It's a sustainable form of energy (re-injection loops can be maintained for decades); costs are predictable and stable (Geothermal Education, 2016).

[76] Union of concerned scientists (no date): Environmental Impacts of Geothermal Energy

4.3.4. Efficiency of GPP

Geothermal energy is possible to be obtained and used round the clock and 365 days/year and unlike other sources it is independent from climatic conditions and enjoys a very high capacity factor (averagely 60% to 95%)[77].

Considering efficiency (capacity factor) of 95%, the weighted capital cost based on utilized capacity can be calculated. As shown by Kagel (2006, cited by Sharbafian, 2009: 78), the weighted capital cost of geothermal energy has the fourth-highest result (after wind, solar thermal and PV) (Lund et al., 2005).

For the technical/economical calculations later in this chapter a capacity factor of 95% (Taghaddosi & Porkhial, 2015**).**

4.4. Estimation of technical potential of geothermal energy

4.4.1. Methodology

When calculating/estimating the theoretical potential of geothermal energy, two main factors have to be taken into account: the geological conditions and the economic viability.

As shown in figure 4.7. there is a correlation between the economic feasibility and the geologic assurance (Dickson & Fanelli, 2004, cited by Sharbafian, 2009).

[77] SUNA, 2016: Geothermal Energy

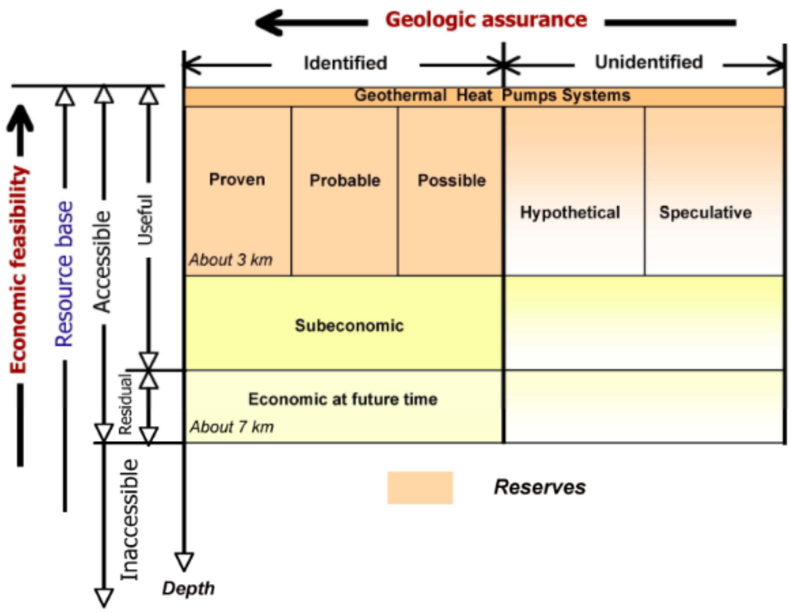

Figure 4.7. Modified McKelvey diagram for the classification of geothermal reserves and resources; Source: Fytikas & Ungemach (2010)

The resource base is limited by the economic feasibility, which itself is related to depth, the state of technology and other possible substitute energy sources on site. There is only a very small fraction that is classified as identified and proven reserve, i.e. accessible (about 3 km depth) and economic.

However, only a fraction of the gross area is the real (net) area available for GPP constructions. These restrictions are (Yousefi & Ehara, 2007; Yousefi et al., 2007):

- (Geo)Physical: slope, rivers, (faults), intrusive bodies, micro/macro seismic
- Socioeconomic: Population centers, access road
- Technical/Geochemical: anomaly, wells, hot springs, alteration zone
- Geological: Faults; volcanic rocks, craters and mud

For estimating the geothermal potential area in Iran Yousefi (et al., 2007) firstly summarized this available and collected information in different datasets.[78] Secondly, an integration model in GIS (based on the Boolean integration method[79]) was run, leading to Iran's geothermal potential sites.

[78] Geological, geochemical and geophysical suitable areas.
[79] The intersect tool ArcInfo calculates the geometric intersection of any number of feature classes and data layers that are indicative of the suitable areas. Before, these areas were identified by using available digital datasets (geological, geochemical, geophysical).

The 18 potential geothermal areas were shown above in figure 4.3. and just below in table 4.1., containing the name of the geothermal area, the location (province) and the gross geothermal area (km^2).

Table 4.1. Geothermal areas in Iran (by name/province/size)

Geothermal area	Province	Area (km^2)
Damavand	Alborz and Tehran	4,648
Sabalan (with Meshkinshahr)	**Ardabil**	**13,037 (Meshkinshahr: 282km²)**
Sahand	Azerbaijan, East	3,174
Khoy-Maku	Azerbaijan, West	3,257
Takab-Hashtrood	Azerbaijan, West	4,639
Ramsar	Gilan	5,532
Avaj	Hamadan	4,283
Lar-Bastak	Hormozgan	4,191
Minab-Bandarabbas	Hormozgan	3,191
Khor	Isfahan	2,334
Mahallat	Isfahan	13,648
Baft	Kerman	11,525
Kashmar	Khorasan, Razavi	7,107
Tabas-Ferdoos	Khorasan, South	46,628
Amol	Mazandaran	1,697
Bazman	Sistan and Baluchestan	8,356
Taftan	Sistan and Baluchestan	4,310
Zanjan	Zanjan	3,285
Total	**-**	**134,842**

Source: Yousefi et al., (2007)

One of these areas is the Sabalan area in the province of Ardabil where the first Iranian GPP is under construction, named Meshkinshahr. A technical potential analysis' is conducted in the next section.

4.4.2. Technical potential of GPP in Meshkinshahr and projection for Iran

Between 2002 and 2004, 3 exploration wells were drilled for the evaluation of the geological conditions and geothermal reservoir assessment in the Sahand mountain region, located between the cities of Tabriz and Marage. Two geothermal reservoirs were identified by Noorollahi et al. (2009) of possibly successful at a maximum temperature of 240°C (at 3,197m depth).

In the southern areas of Meshkinshahr, ten exploration wells and one injection well have been drilled to determine the parameters of the reservoir and develop the field, whereas seven exploration wells have been tested so far, giving this area first priority after the successful tests (Taghaddosi & Porkhial, 2015).

Based on the available and collected information different datasets[80], using the GIS and Boolean integration approach, the locations for three exploratory wells were determined; each with a target depth of 3,000m. Table 4.2. shows the characteristics of three exploration wells which range between 2,266m (NWS4) and 3,197m (NWS1) and a maximum temperature between 148°C (NWS3) and 240°C (NWS1) (Noorollahi et al., 2009).

Table 4.2. Specifications of three exploration wells in Meshkinshahr

Well Name	NWS1	NWS3	NWS4
Well Depth (m)	3,197	3,177	2,266
Max. temperature (°C)	240	148	229

Source: Noorollahi et al. (2009)

This thesis takes the calculations conducted for Meshkinshahr as basis for a projection on the other potential areas (see table 4.1.)

Yousefi & Ehara (2008) conclude that ca. 1% of the gross area is suitable for the installation of GPPs.

Yousefi & Ehara (2008) also conclude that for the 55 MWe GPP a (net) area of 2.23km^2 is needed. Table 4.3. shows suitable sites for constructing GPPs in the research area.

Table 4.3. Location and area of suitable sites of Meshkinshahr

Site	**Area (km^2)**
1	0.141
2	0.053
3	0.312
4	0.323

[80] Based on physical, socioeconomic and technical suitable areas.

5	0.548
6	0.347
7	0.501
Total	**2.225**

Source: Yousefi & Ehara (2007)

Eventually, a projected estimation for the other 17 areas in Iran (based on the assumption that 55 MWe need a net area of 2.225km^2) is given in table 4.4. The total potential for geothermal electricity in Iran yields 35,72 GW. Based on a capacity factor of 95%, this equals 297 TWh. While Tabas-Ferdoos in South Khorasan has the highest potential, another 11 areas' results are higher than 1,000 MWe.

Table 4.4. Estimation of geothermal electricity potential in Iran

Geothermal area	**Province**	**GW**
Damavand	Alborz and Tehran	1.15
Sabalan	Ardabil	3.22
Sahand	Azerbaijan, East	0.78
Khoy-Maku	Azerbaijan, West	0.80
Takab-Hashtrood	Azerbaijan, West	1.14
Ramsar	Gilan	1.36
Avaj	Hamadan	1.06
Lar-Bastak	Hormozgan	1.03
Minab-Bandarabbas	Hormozgan	0.79
Khor	Isfahan	0.58
Mahallat	Isfahan	3.37
Baft	Kerman	2.84
Kashmar	Khorasan, Razavi	1.75
Tabas-Ferdoos	**Khorasan, South**	**11.50**
Amol	Mazandaran	0.42
Bazman	Sistan and Baluchestan	2.06
Taftan	Sistan and Baluchestan	1.06
Zanjan	Zanjan	0.81
Total	**-**	**35.72**

Source: Tables 4.2.; Yousefi & Ehara (2008); author's calculation

4.5. Economic feasibility and Business Model Description

For our business model we chose a

- 5,500 kW project[81]
- With feed in tariffs (2016)
- Based on a Power Purchasing Agreement (PPA)

The PPA is a contract between an electricity producer and the Renewable Energy Organization of Iran (SUNA, see chapter 1.5.10. for more information on SUNA). It fixes a price for the electricity provided by the investor to the off-taker SUNA over 20 years. The investor sells all the generated electricity to SUNA to receive the Feed in Tariff. For more details on the PPA see 1.5.7. and 2.6.2.

Again the process should be executed with SUNA that is also the off-taker of the electricity produced[82]. According to the size of the system, the Feed in Tariff corresponds to 4,900 IRR/kWh which is equal to 14.51 €-cent/kWh.[83]

After 10 years the FiT is reduced by 30% of its original amount ("…will be multiplied by 0.7 after adjustment of article 3 of Economic Council Directive starting from the first day of the second 10 years till the end of the contract".)[84]

4.5.1. Power Purchase Agreement (PPA)

As described in chapter 1.5.7, a PPA contract between SUNA and the owner of the power plant is concluded. The most relevant elements of the PPA are:

a. The duration of the contract and deadlines: 20 years and 30 months deadline: the applicant needs to commission the power plant within 30 months after signing the PPA, otherwise the generated electricity will be bought with the price of the energy market.

b. Feed in Tariff: The feed in tariff is 4,900 IRR in 2016[85]. Every year the FIT is adjusted by the 'adjustment formula' (see chapters 1.5.5.d and 1.5.6.). Details can be found at the calculation sheets, the tariff escalation in our project yields 1.0918 as $(112/100)^{0.3}$ x $(36,474/33,772)^{(1-0.3)}$. Tariff escalation is the same as for PV (table 2.6.)

[81] Based on: Taghaddosi & Porkhial (2015)
[82] The process procedure is described in chapter 1.5.8.
[83] The exchange rate corresponds to 33,772 IRR/1 Euro.
[84] SUNA, 2016: Guaranteed Renewable Electricity Purchase Tariffs
[85] SUNA, 2016: Guaranteed Renewable Electricity Purchase Tariffs

4.5.2. Results and profitability analysis

In the previous section the technical potential of geothermal electricity systems was estimated and calculated. As a next step we look at the economical potential. As mentioned above our calculation is based on a 5,500 kW single flash condensing GPP. The assumptions will be verified and varied in the sensitivity analyses in section 4.7. The assumptions are:

We calculate a turn-key system with a price of 2.55 million Euro/MW (see Taghaddosi & Porkhial, 2015 and section 4.3.1.), which yields 14,000,000 Euros in total. O&M costs are very limited and set with 1.0% of the total investment costs per year (Geolec, 2013). These O&M costs were escalated by an average escalation rate of 10.5% per year because 50% of O&M costs are accounted in EUR, 50% in Iranian Rial.
In section 4.3.4. the capacity factor (95%) and the FLH (6,657.60) were discussed. To get a level playing field with PV or wind energy production we again took into account the performance ratio (replacement of pump every 4-6 years in dusty areas) with 80% and the decreasing performance with 0.7% per year.
The run-time and project duration is 20 years and based on a feed in tariff of 4,900 IRR/kWh which equals € 0.1451. It is escalated over these 20 years and calculated as weighted average with 9.18%[86]. After 10 years the feed in tariff is reduced to 70% due to SUNA regulations (see chapter 3.7.1.).
For the financing of the project, the NDF (national development fund) grants support with an interest rate of 6% p.a. for 80% debt and a loan tenor of 5 years. The discount rate was set at 15% to represent a low risk investment alternative (3% higher than assumed inflation rate).

Table 4.5. Assumptions on feasibility study of a 5.5 MW GPP in Meshkinshahr

Variables	**Value**	**Unit**
PV System Size	kWp	5,500
Specific System Cost	EUR/kWp	2,500
Total System cost	EUR	14,025,000

[86] Based on the inflation rate (weight 0,3) and the escalation rate of the EUR/IRR-exchange rate (weight 0,7).

O&M Costs	1.0% of invest. cost/p.a.	140,250
O&M Escalation Rate	% p.a.	10.50%
Specific Yield / FLH	h/p.a	6,657,60
Performance Ratio	%	80%
Specific System Performance / Electricity Production	kWh/yr	36,616.800
Degradation	% p.a.	0.70%
Feed-in Tariff	EUR/kWh	0.1451
Tariff Coefficient (Year 1-10)	%	100%
Tariff Coefficient (Year 10-20)	%	70%
Exchange Rate (04/08/2016)	EUR/IRR	33,772
Exchange Rate Escalation	% p.a.	8.0%
Inflation Rate	% p.a.	12.0%
Feed-in Tariff Escalation	% p.a.	9.18%
Project Duration	Years	20
Debt	80%	11,200,000
Loan Tenor	Years	5
Interest Rate	%	6.0%
Discount Rate	%	15.0%
Net Present Value	**NPV**	**41,318,81**
Project Internal Rate of Return (IRR)	**%**	**122%**
Equity Internal Rate of Return (IRR)	**%**	**155%**
Long Run Generation Cost of Electricity (LRGC)	**EUR/MWh**	**61.80**
Annuity	**EUR**	**6,601,154**

Sources: System Size, Specific System Cost, Total System cost from Taghaddosi & Porkhial (2015); Fixed O&M Costs, O&M Escalation Rate from Geolec (2013); Specific Yield; Specific System Performance from Taghaddosi & Porkhial (2015); Degradation assumed; FiT, FiT Coeffizients, FiT Escalation, Exchange Rate, Exchange Rate Escalation from SUNA, 2015 and author calculation; Inflation Rate from CBI, 2015;

Equity, Debt, Loan Tenor, Interest Rate and Discount Rate; Performance Ratio assumed; tax exempted from calculations. Detailed overview see **Appendix IVc.**

Investments in geothermal energies seem to be extremely profitable. For having a level playing field, one choose the same parameters like system performance of 80%, debt service 80%, degradations, exchange rates and low O&M costs and a low interest rate (6%, which might not be possible with financing the project with an Iranian bank credit). The feed-in tariff revenues are extraordinary high (compared with European standards) and although the investor has to accept a cut after 10 years (-30%), they will even rise. The reason is the FiT escalation, inflation rate escalation and exchange rate escalation (based on the adjustment formula, see chapter 1.5.6 and calculations), which make the project highly profitable.

The equity IRR is 155% and by far the highest result compared with PV or wind. The more important project IRR also is higher than compared with PV or wind. Additional with the NPV higher than 41,000€ this underlines the profitability of the investment. Although the investment costs are very high, an investment into geothermal energy is a great opportunity for investors in Iran.

4.6. Sensitivity Analyses

In the following the results of a sensitivity analysis performed for selected key input parameters are presented. The O&M, the FiT and the FLH were taken and changed +/- 40%. The LRGC sensitivity, shown in figure 4.8. reflects the strongest impact on the FLH (between 44 and 103 Euro) and the project is quite sensitive to changes of those. Especially a decrease of FLH causes a disproportional higher rise of costs. An in-/decrease of the FiT cannot per definition influence the cost, very little shift can be seen for O&M costs.

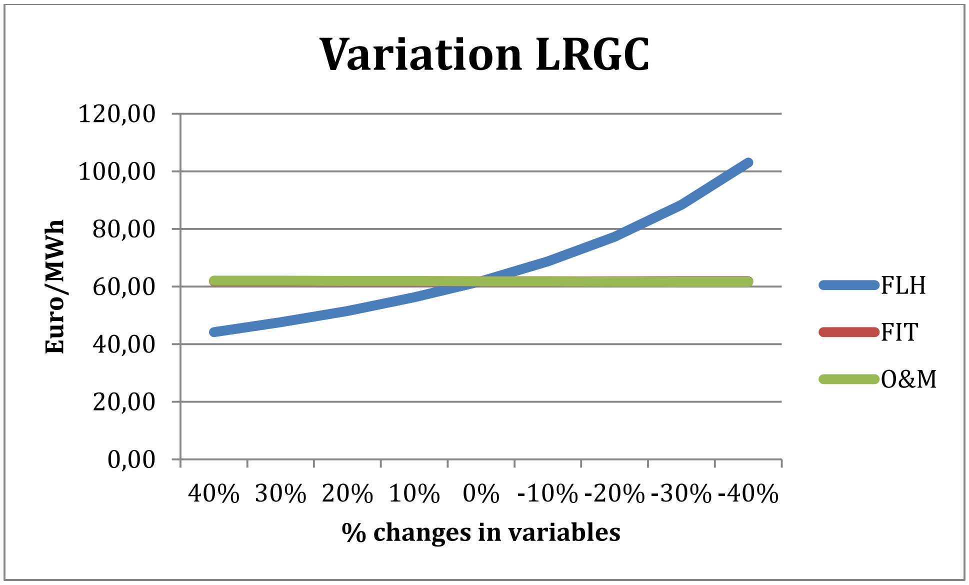

Figure 4.8. Sensitivity analysis, Variation LRGC for O&M, FIT and FLH; Source: Table 4.5. and own calculation

The sensitivity analysis on the NPV in figure 4.9. shows that the impacts on FiT and FLH are nearly the same but high (63,000-19,000 Euro). The impact O&M costs are little.

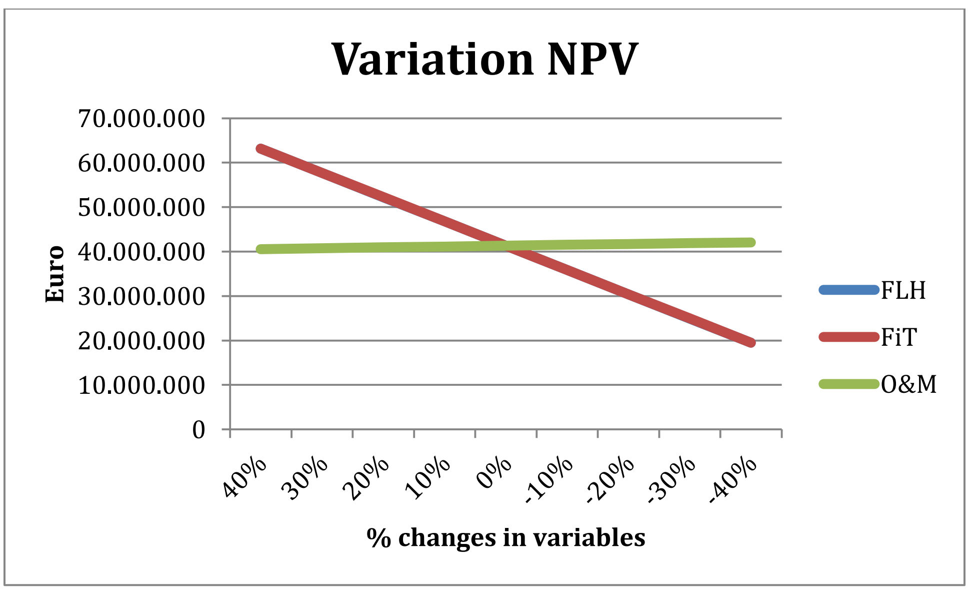

Figure 4.9. Sensitivity analysis, Variation NPV for O&M, FIT and FLH; Source: Table 4.5. and own calculation

Chapter 5: SWOT Analysis, Strategies & Recommendations

5.1. Introduction

In chapters 2, 3 and 4 we have estimated and calculated the (theoretical) technical and economic potential for 3 different types of renewable energies in Iran, namely PV, wind and geothermal.

While there is no doubt that Iran has enormous potential in both, technical and economical regard, during conducting research for this thesis, including a 2 months stay in Iran, it turned out that there are many smaller and bigger hinders and impediments for the development of renewable energies. These obstacles are 'home-made' (e.g. high interest rates) as well as they come from outside (e.g. ongoing sanctions). On the other side there are many existing and developing opportunities for RES: these prospects are based on e.g. incentives like high feed-in-tariffs based on Iran's government policies or are given and influenced from 'outside', e.g. good climatic conditions and a favorable geographical position or new taxes on fossil fuels that must be used for the development of renewable energy.

This chapter will summarize inner and outer impediments and prospects for renewable energy sources based on recent developments on political, (socio-) economical, technical and policy level. All these information is consolidated in a so-called SWOT analysis. Based on it, 4 strategies that combine impediments and prospects are developed. Eventually, some recommendations for policy-maker (government) and investors are proposed.

While 5.2. explains the theoretical approach for a SWOT analysis with its matrix, in 5.3. one model based on the government's 5,000 MW renewable energy target (strategy) until 2021 is created. 5.4. issues 4 strategies combining the strengths, weaknesses, opportunities and threats. Finally, 5.5 gives some recommendations on how Iran might have a successful renewables' future.

5.2. SWOT Analysis Matrix

A SWOT[87] analysis is a useful method to better understand its own weaknesses and strengths but also to recognize existing/new chances as well as risks. It's a structured instrument of planning and of evaluating the strengths (S), the weaknesses (W), the opportunities (O) and threats (T) that exist or might occur in a (future) situation or process.

The strength of a SWOT analysis is to determine one's position and to develop new strategies and possibilities for corporates, organizations (including NGOs), individuals or governments that compare their own strengths/weaknesses with those of competitors. These 'inner' analyses are complemented by 'outer' threats and opportunities that finally should lead to the right action.

A SWOT analysis tries to find out the key external and internal factors that are important to achieve an objective, goal or target.

Looking at the matrix figure 5.1. one can see that there are two categories:

1. Factors with external origin: opportunities and threats related to the environment outside (of an organization, a government, a department, etc.). These may include macroeconomic, technological matters as well as legislation and policies.
2. Factors with internal origin: strengths and weaknesses related to its own organization, government, department, etc.

[87] 'SWOT' is an acronym that stands for: strengths, weaknesses, opportunities, threats.

Figure 5.1. SWOT analysis with its four elements in a matrix; Source: Wikipedia (2016)[88]

SWOT analysis can be used in any decision-making situation. However, it is important to **define a target or objective** beforehand (how a situation should be). Other mistakes that are often made are to mix up **opportunities and strengths** (opportunities = favorable conditions; threats = unfavorable conditions) and not to do a **prioritization**. SWOT analyses, originally depriving from military strategy and martial arts (see Info Box 8: Origin of SWOT) and have been applied to a wide range of issues such as environmental, sustainable development, regional energy planning and renewable energy schemes (Talaei A. et al., 2014).

After having accomplished the SWOT matrix (shown in figure 5.1.), the next step is to maximize strengths and opportunities (and of course to minimize weaknesses and threats). Therefore following combinations have to be searched for. These combinations will then lead to initiatives, actions and eventually a strategy to achieve the before-set goal/target/objective.

1. SO/Strengths-Opportunities combination: which strengths match with which opportunities? How can strengths be used, so to utilize opportunities and realize chances?
2. ST/Strengths-Threats combination: Which threats can we counteract with which strengths? How can we use existing strengths to prevent the realizations of particular threats?

[88] Wikipedia, 2016: SWOT analysis

3. WO/Weaknesses-Opportunities combination: How can weaknesses become opportunities? How can we develop opportunities from weaknesses?
4. WT/Weakness-Threats combination: where are our weaknesses and how can be prevent us from damages?

Based on these combinations, fitting strategies have to be developed. The enhanced matrix is shown in table 5.1.

Table 5.1. SWOT analysis with its combinations in a 2x2 matrix

SWOT		INTERNAL ANALYSIS	
		Strengths	Weaknesses
EXTERNAL ANALYSIS	Opportunities		
	Threats		

Source: Homburg & Krohmer (2009) cited by Wikipedia (2016: SWOT analysis)

Info Box 8 Origin of SWOT[89]

Originally from military and martial art a early SWOT analysis is formulated in 'The Art of War' by Sun Tzu:

"So it is said that if you know your enemies and know yourself, you can win a hundred battles without a single loss. If you only know yourself, but not your opponent, you may win or may lose. If you know neither yourself nor your enemy, you will always endanger yourself."

[89] See footnote 2.

5.3. SWOT Analysis Applied – Iran Government's 5,000 MW renewable energy target by 2021

The market for renewable energy development is rising when looking at different parameters like governmental policies, announcements of interest of international investor's, feed-in-tariffs that are highly competitive compared with European ones. Especially after (part-)lifting of the sanctions the interest for the Iranian renewable energy market rose significantly, linked with hopes of national organizations for 'a change'.

Although the state (in numbers, planned projects, installed capacities) of renewable energies in general is in its infancy, and in need of development and expansion, the presence of international renewables' developers and investors shows the enormous interest and trust in the future Iranian REN energy market. Trust build on the economical prospects and technical potential as well as the government's policies that start yielding fruits. The Iranian government (including SUNA) has facilitated investment rules but also created incentives to attract local and international investors (e.g. guaranteed purchase period 20 years instead of 5; guaranteed purchase prices rises by 30% when using domestic components and technology; tightened and one-stop permit process through at SUNA). The government has set more realistic REN targets including a systematic policy plan that comprises long-term PPAs with its remarkable feed-in-tariffs.

As shown in chapters 1, 2, 3 and 4 Iran has abundant amounts of sun, wind and geothermal resources (this thesis did not look at other RES like hydropower or bioenergy). However, the development has been on halt for many years due to the sanctions that stopped both, international investors from developing projects and international companies and banks from importing power plants or components or investing in and financing business, for the simple but wide-ranging reason that UN, EU and US sanctions stopped any imports and financial transactions. After lifting of the sanctions, Iran is on the slow way back to international markets and global economy. It will facilitate to reach its 5%-target of domestic power generated from RES by 2021 which equals around 5,000 MW of energy. The 6th Five-Year Development Plan (2016-2021) backs this plan with a focus on clean energy (with the target of constructing new green power plants with a total capacity of 26,000 MW).

While in many parts of Europe the ‘hype’ about renewable energy projects is slowing down or stuck, all market opportunities in Iran have not even been explored. It is a fact that in Iran energy demand is rising over the next decades. If Iran will be able to exploit its REN potential (and meet international agreements like Paris 2015 and domestic targets like the 5,000 MW by 2021) depends on economic and political reforms and the degree and speed of market liberalization as well as technology transfer and trade. The government has also implemented plans to ‘cut red tape’ and facilitate investment procedures, as the bureaucracy is still one of the main obstacles for projects to fail.

In terms of national energy strategies, there are signs that the Iranian government considers ‘renewables’ in a broader context, namely to improve the country’s energy security and its commitment to diversify its energy mix. Therefore, investments into renewable energy projects give the government the control over possible price fluctuations in fossil fuels, rise the amount of fossil fuels that can be exported (while the domestic demand is partly satisfied by REN), will facilitate Iran’s ambitions to become a regional electricity exporter when its production could exceed local demand. Investments in renewable energy projects will also help to overcome the aged and underdeveloped infrastructure as well as to attract international experts due to the lack of domestic expertise in the highly specializes REN technologies. By modernizing its infrastructure with international investors the existing academic potential in the country could be fully exploited and the recently established links between academia and industry (e.g. capacity building) strengthened.

On the macroeconomic level, the Iranian government was improving substantially the economic conditions in 2016, real GDP growing at least by 4.5% and reducing the inflation rate (from 43% in 2013 to 12% in 2016, IMF estimates to average 9.2%). To stabilize inflation the government has proposed an overhaul of the monetary policy framework. Also it aims to recapitalize banks and settle safeguards in the financial system to secure access to the global financial system. However, a recently published statement of an IMF staff visit[90] recommends further-going reform efforts on reducing high interest rates (20% and higher) and the deficit; creating space for public investment needs; and a fundamental overhaul of the entire banking system.

[90] IMF, 2016: Iran: Concluding Statement of an IMF Staff Visit

Aim of the following SWOT analysis is to explore the probability that Iran reaches its target to generate 5,000 MW from renewables (installed capacity) until the end of 6th Five-Year Development Plan (envisaged: 2021). More information on Five-year development plans and the Iranian government's targets can be found in chapter 1 and Chaharsooghi et al. (2015).

In the next step we assess the effectiveness of current capabilities, i.e. what is working well (S) and what deficiencies are there (W). We also identify the opportunities (O) and threats (T) in the external environment relative to the 5,000 MW target, i.e. Iran's strategic approach. The matrix just below (table 5.1.) that summarizes all strengths, weaknesses, opportunities and threats will help us draw conclusions about Iran's ability to fulfill this 2021-target.

Table 5.2. SWOT analysis: Will Iran reach its 5,000 MW REN target by 2021?

Strengths	**Opportunities**
1 Diversified industrial-base economy 2 Governmental fiscal policies (energy mix, energy security) 3 Fully-developed national grid; high electrification rate 4 Climatic advantages: solar irradiation, wind density, geological location 5 Skilled labor: young, educated and qualified professionals 6 High Quality Research Data 7 Regulatory and policy frameworks (Five-Year Development Plans, PPAs, FiT and FiT-Uplift for domestic components, exchange/index rates, peak supply) 8 Equipment, facilities, maintenance capabilities 9 Engineering capacity in installation, construction and operation 10 Institutions/Organizations: Iran's	1 New policies: higher tax on fossil fuels earmarked for REN development, less subsidies to fulfill REN targets* 2 Private sector's involvement 3 Supplier of REN products/services to neighboring countries & potential transformation into region's energy hub 4 Educational programs to disseminate knowledge about REN (trainings, know-how transfer) 5 Exploit existing academic potential and the recently established links between academia and industry (capacity building) 6 International cooperation (investments; REN associations) 7 RES will replace oil/gas (leading to higher export rate; *Norwegian model*) 8 Rural areas benefit from decentralized structure of RES (less poverty, electrification of

Industrial Scientific Organisation, Energy Research Institute, Energy Technology Development Centre, Environmental Energy Research Centre, SUNA, SABA 11 Clear project development process (SUNA/PPA)	5,000 households) 9 Realization of climate protection targets (Paris21, Kyoto) 10 Creating green jobs 11 Empowerment of the banking sector 12 Empowerment of civil society and investors 13 Involvement of national and international development banks (Export Credit Agency, China Bank Debt) 14 Reflation of economy after lifting of sanctions
Weaknesses 1 Inefficient energy infrastructures (energy loss) 2 Insignificant renewable installed capacity 3 Lack of state-of-the-art tech 4 Not sufficient financial resources (no access to international finance system) 5 Sanctions: - insufficient investment capital primary - difficult money transfer 6 Lack of R&D, innovation 7 Non-payment by some state industries and competition with quasi-government companies 8 Weak process planning, project execution, human capital management 9 Read Tape, Bureaucracy, top-down decision making process 10 High import taxes 11 Limited budget of SUNA/NDF* 12 High interest rates 13 Lack of a national willingness to use REN (abundance of fossil energy	**Threats** 1 Uncertainty of subsidies/FiT-financing 2 Trade restrictions/sanctions and possible snapback - technology transfer problems - money transfer problems 3 Fiscal instability (policies to support REN weakened by new government 2017) 4 Economic instability (inflation, currency devaluation, budget deficits) 5 Political instability 6 Oil lobby regaining strength 7 Rising electricity demand could lead to fossil fuel imports (quick fix instead of sustainable approach)

resources, issues related to technology lock-in) 14 Low price of energy but high costs for REN (subsidies for oil/gas) 15 Cultural barriers 16 Weak rule of law (intellectual property rights), despite FIPPA 17 Acquisition of land* 18 No experience with REN development process (SUNA/PPA) and reluctance for e.g. roof-top PV	

Source: author; Almonitor (2016); IMF (2016); Energypioneersltd & DNV GL – Energy Middle East & Africa (2016); Talaei A. et al. (2014);
Aguilar et al. (2016: pp. 75-92); Moshiri & Lechtenböhmer (2015: pp.120ff.)

***Targeted subsidies plan**: scrap it cause of inflationary pressures and replace it with energy management and set higher fuel prices/Wiki-Iranian subsidy reform plan)
*Acquiring the required **land**: The acquisition of the land is a time consuming task in the development of PV plants in Iran, securing the land as soon as possible is one of the success factors.
*Project financing is currently difficult in Iran due to the limited budget of **NDF**, not having any specific financial scheme defined by SUNA and limited bank relations between Iranian banks and foreign banks, means that a financial plan for the project factor for a developer.

5.4. Strategies

In a next step we now combine the above-mentioned internal and external factors in various combinations:

1. SO/Strengths-Opportunities combination: Which strengths match with which opportunities? How can strengths be used, so to utilize opportunities and realize chances?
2. ST/Strengths-Threats combination: Which threats can we counteract with which strengths? How can we use existing strengths to prevent the realizations of particular threats?

3. WT/Weakness-Threats combination: Where are our weaknesses and how can be prevent us from damages?
4. WO/Weaknesses-Opportunities combination: How can weaknesses become opportunities? How can we develop opportunities from weaknesses?

Using the SWOT matrix, four strategies for reaching the 5,000 MW renewable energy target until 2021 including strengths-opportunities (SO), strengths-threats (ST), weaknesses-opportunities (WO), and weaknesses-threats (WT) are obtained. The list of strategies is as follows, the most important strategy of each combination can be found in table 5.3.

SO Strategies:

SO1: Establishing sub-companies in Middle East countries SO2: Education and training programs in REN energy organizations, universities (monitoring project development) SO3: Coordination, merger or cooperation among REN energy organizations SO4: Establish international quality control programs (e.g. EFQM[91]) in REN organization SO5: Application for international banks' grants for REN project development, funding, financing SO6: Management of existing human capital SO7: Adapted Vision 2025/Targeted subsidies plans to reach Paris Climate Agreement and develop rural areas SO8: Establish economic package to attract investors (e.g. keep FiT high, one-stop-shop in administration)

For a better and successful development of REN energy projects in Iran the **cooperation and organizational development** of existing REN organizations is key. There is enough existing infrastructure (organizations and project development processes) but the lack of experience of developing projects as well of cooperation in general hinder a more successful REN development. Long-term goal could be a **one-stop-shop** for handing-in REN projects as it is know from Western European countries. To join internationally recognized **quality control programs** are an important step to gain/strengthen trust between developers and authorities.

As important is the access to the global banking and financial system (**SWIFT**); this will empower the banking sector and allow direct bank credits what will reduce exorbitant high interest rates.

[91] European Foundation for Quality Management is a framework for organizational management systems (not-profit membership foundation).

Thirdly, Iran will have to adopt a **renewable energy package** with long-term strategies and incentives (e.g. Feed-in-tariffs for 20 years, index rates, FiT-uplift for domestic components which is a win-win situation for both investors and the local market).

ST Strategies:
ST1: Boost local technology with cooperation (technology transfer) ST2: Comprehensive planning and management ST3: Activities to change fiscal and economic policies (Sustainable Energy Strategy > IMF) ST4: Conferences/Lobbying of inter/national organisation/business to promote REN (promoting the 'Norwegian model')

A fundamental overhaul of the banking system (**recapitalize and empower banks**) to unleash higher growth in the private sector, a proposed Banking Bill for strengthening supervisory capacities and international organizations, like IMF (2016) or private businesses, organizing workshops, conferences and providing information for the just awakened banking sector are of paramount importance for the development of REN energies. Additionally, a **technology transfer** is an important step for the REN development. This transfer takes places with conferences, cooperation and common projects with multinationals (like Vestas/Denmark and Mapna/Iran). Fossil fuel hardliners might change their mind by promoting the 'Norwegian model' ("Develop REN in your country, so there is more fossil fuels left for exports").

WT Strategies:
WT1: Fiscal and economic planning/management of REN programs WT2: Fiscal and monetary policies for REN energy development WT3: Investment in human capital for REN energy development WT4: Preparation of a sustainable REN energy development plan WT5: Privatization or unbundling of quasi-state companies for more national/international competition and break-up exuberant bureaucracy WT6: International technology transfer to improve process planning and execution WT7: Gov' campaigns to promote REN and push back oil industry influence ('Higher REN rate leaves more fossil fuels for export')

Looking at possible threats, Iran's government should, facing their own weaknesses, intensively invest in **human capital** (Technical Universities and Universities of Applied Sciences that offer renewable energy studies, mineral resources engineering, applied geosciences or industrial environmental protection). It is as important to design a national **renewable energy development plan** and implement it within the Five-Year development plans as well as long-term strategies. Countries like Iran, with a strong government and little influence by civil society or interest groups should do easy developing such strategies (compared with e.g. the European Union). However, as the fossil fuel industry is strongly influenced by government-close stakeholders it is a lot at their stake and will create resistance. The same is applicable for possible **privatizations of quasi-state organization**s. For international investors' trust it is of paramount importance to unbundle government-close businesses (that are seen as highly corrupt) and trade. If the government succeeds in gaining trust from international investors, it will be easy to transfer technology, which might then result in a domestic high-tech renewable industry. Iranian government also should start **campaigns promoting renewable energies** (energy access for everyone; independent, save, secure energy; good for environment; saved fossil fuels can be exported).

WO Strategies:

WO1: Developing private-public participation projects WO2: Investment in R&D WO3: Management and investment in human resources of banking sector WO4: Joint research projects with domestic and international organizations WO5: Promote RES investments for the sake of higher fossil fuels export rates ('Norwegian model') WO6: Engagement of international banks providing cheap loans for REN energy investments WO7: Climate programs and international cooperation to reach climate protection goals WO8: Develop a scientific and systematic decision-making process for REN organizations WO9: Establish 'bridging courses' to overcome cultural barriers WO10: Sign international trade agreements (more ex-/imports, less tax) WO11: Public education and awareness of REN energies (by electrification of rural households, campaigns) WO12: Human capital management

Weaknesses could become opportunities by developing **joint research projects** between local and international organizations and supporting the creation of so-called **bridging courses**. They will help graduates, industry and authorities to gain international experience, skills and overcome existing cultural behaviors. As important is the implementation of **international climate protection commitments,** which will facilitate the decision to invest into renewable energies. Last but not least, the government should **raise awareness** of the importance of renewable energies for environmental and climate protection. The author thinks that the public sensitization is the key for a successful renewable energy future.

Table 5.3. SWOT matrix: Will Iran reach its 5,000 MW REN target by 2021?

5,000 MW renewable energy in Iran until 2021- strategy		INTERNAL ANALYSIS	
		Strengths	Weaknesses
EXTERNAL ANALYSIS	Opportunities	**Cooperation and development of existing REN organizations (national/international).**	**Awareness raising of the importance of renewable energies for environmental and climate protection.**
	Threats	**Overhaul and empowerment of the banking system and (recapitalize banks, lower interest rates).**	**Investments in human capital (universities, joint research projects, bridging courses).**

Source: Homburg & Krohmer (2009), cited in Wikipedia (2016: SWOT Analyse)

Based on the SWOT matrix and strategies, section 5.5. summarizes the developed recommendations for the government, authorities, academia and civil society to boost and promote REN shares in Iran.

5.5. Recommendations

In this section we will now list a set of recommendations for both the Iranian government to reach their renewable energy targets and visions (Five-year development plan and vision 2025) and investors to successfully start or develop their businesses in renewables in Iran. This list is based on the SWOT analysis from the sections above, literature review, and own perceptions on the ground. Developments of the renewable energy industry are influenced by factors in- and outside the renewable energy policy.

To give a better overview the recommendations are split up in different policy areas. This list of recommendations is not exclusively nor covering all policy areas. A short description and explanation follows each recommendation.

5.5.1. Energy goals

The International Energy Agency (IEA) has forecasted that natural gas and crude oil will run out within the next 60 and 42 years, respectively. Additionally, the primary energy demand as well as the electricity demand in Iran will dramatically rise in these decades. Obviously, fossil fuel resources will not be able to cover this demand in the future and Iran might become a net importer of energy (Hosseini et al., 2013).
Its **5,000 MW nominal installed capacity target until 2021** is a starting point but will not be enough. New strategies regarding its **energy mix** and **energy security** are needed. A transition to renewable and sustainable energy resources is key. Iran should invest in alternative energy sources (particularly wind and solar energy) and allocate oil and natural gas resources for export and by doing so catch up with new renewable energy technology (**technology-transfer**) and know-how. (Moshiri & Lechtenböhmer, 2015: 87ff.).
The development of RES would also enable Iran to produce and distribute electricity in **rural and remote areas**, which would play an important role in continuing to develop the infrastructure in these areas as well as increasing consumption while protecting the environment. This is particularly important since the level of poverty in areas with rich wind potential and solar radiation is rather high (Moshiri & Lechtenböhmer, 2015: 87ff.).

5.5.2. Renewable Energy Package

There are different reasons why government support and incentives are needed to boost renewable energy sources. First, investment in renewable energy projects requires high financial costs up front, and returns on investment will take time. Second, the new technologies are often associated with uncertainties and, therefore, investors and users may rationally decide to delay their investments until the technology matures. Finally, there are several positive external effects (reduction of GHG emissions) of increased renewable energy use that are not included in current energy prices (Moshiri & Lechtenböhmer, 2015: 87ff.).

Following factors should be included within a renewable energy package as they are either existing and highly important (they should stay) or weak points:

The acquisition of **land** is one of the most time-consuming parts of the project planning. SUNA gives support but could be further developed.

The **Feed-in-tariffs** shall stimulate private investments. However, there are some uncertainties about the future FiT-financing, the government should tackle. The main financial source to pay the renewable electricity generated in Iran comes from the electricity bills of end-users in the country (30 Rials/kWh/household), which yields max. 4,000 billion IRR/year (approx. € 122 million). This amount should be spent for both buying electricity from renewables, and for rural electrification. The share of each one is not clear and annual changes are a source of confusion. Moreover, even if all of this money was spent for buying electricity from renewables, is only sufficient for some hundred MWs of energy produced by renewable (Aguilar et al., 2016). To maintain a reliable FiT-policy for investors, SUNA should announce the new FiT at least at the beginning of a new year. Some more time in advance would be very much appreciated by the investor community. As a better alternative, SUNA could create a committee to determine the appropriate feed in tariffs a few months before each year. This committee would have the responsibility to monitor the market, the system prices, calculate the profitability analysis and recommends the feed in tariffs to SUNA (Aguilar et al., 2016).

The **local content bonus** (which uplifts the FiT) recommends acquiring the products needed for power plants in Iran. The benefits include the bonus for using local products and the avoidance of duties and transport costs. This applies also for hiring staff for construction and maintenance and should remain as part of the FiT-system (Aguilar et al., 2016).

Standards for the **PPA authorization process** are only partly defined yet, The PPA process for large installations (>100 kWp) is well defined, but some procedures such as the grid connection process are still missing. For small installations, the process is still under construction. This creates some planning insecurities and higher information costs. There are not enough experts what leads to personalized decisions and deviation from the standard procedures. Therefore a standard-driven framework should describe clearly, which forms and criteria have to be applied in each step of the process, especially for smaller systems in detail. Local staff should be trained and a catalogue of uniform grid connection requirements should be developed. It is important, that all those standards are applied throughout the entire Iran in a uniform way. This process should be

transparent and presented online to facilitate and simplify the access to project development and permit procedures at national and provincial level (Aguilar et al., 2016).

5.5.3. Environmental and Health recommendations

Environmental protection is one of the main reasons for an increased use of renewable energy sources. Burning fossil fuels will exacerbate the poor environmental conditions as well as CO2 emissions in large cities such as Tehran. According to the WHO, four out of the top ten polluted cities worldwide are in Iran. Furthermore, Iran is one of the largest emitters of CO2 in terms of total fossil-fuel CO2 emissions. The increased use of renewable energy sources will decrease air pollution in cities, thus improving the environment, public health and productivity (Moshiri & Lechtenböhmer, 2015: 87ff.). With investments into renewable energy sources Iran also will fulfill its obligations of international treaties like COP21 (UN climate change conference 2015), the Kyoto protocol, and save thousands of lives per year (premature deaths).[92]

5.5.4. Industry, Economic, Technical, R&D recommendations

Iran should strengthen the (**joint research) cooperation** between the Iranian and international REN associations through best practice exchange as well as to increase the **quality standards** for imported and locally produced components throughout the whole value chain (Hosseini et al., 2013). Additionally, there would be high potential for **self-consumption roof-top** and private owned small scale PV systems (Aguilar et al., 2016: 34).

5.5.5. Legal recommendations (post-sanctions)

Following the JCPOA[93] (see also Info Box 2 Sanctions on Iran aka Restrictive Measures) most of the economic restrictions should be lifted or relaxed in 2016. However, as with this agreement only the UN-sanctions were lifted and the process is also delayed, companies need to have a good understanding of the Iranian legal context in order to mitigate their investment risk. One way to mitigate investment risks is to structure the business in a way that it falls under a Bilateral Investment Treaty (BIT) and/or another investment agreement. There are 52 BITs in force between Iran and other countries, such as Germany, Austria and Switzerland. Amongst other things, BITs with Iran provide

[92] UNICEF, 2016: Clear the Air for Children!
[93] WKÖ, 2015b: JCPOA

protection against expropriation without compensation, free transfer of capital, guaranteed equal treatment with nationals and, in principle, the possibility of arbitration proceedings (UNCITRAL), even though the free choice of the governing law is limited. In addition to the BITs, protection and incentives are also provided under Iranian national law. The Foreign Investment Promotion and Protection Act 2002 (FIPPA) guarantees important privileges to foreign investments such as an equal treatment standard, transfer of funds and dividends, compensation against expropriation and access to foreign courts. However, in order to be privileged, the foreign investor has to obtain a permit from the so-called OIETAI Organization. Iran has concluded numerous double taxation conventions (DTC) essentially based on the OECD Model Tax Convention with Germany, Austria or Switzerland. It is highly advisable to engage a law firm with expertise in international business that has on-the-ground experience in Iran and can demonstrate up-to-date and reliable knowledge (Aguilar et al., 2016: 83).
Iranian policy makers should also keep in mind that renewable energy sources are totally **independent from sanctions** on fossil fuels. Even if, for any reason, the sanctions are installed again, Iran could be independent from energy in- or exports by heavily investing in RES.

5.5.6. Financing and banking recommendations

The financing of PV projects via debt financing from banks is still too expensive. Private banks ask for **interest rates** of approx. 25%, which lowers the IRR and increases payback periods significantly. Therefore, alternative funding is needed. Iran has already established a national funding scheme that can be used for clean energy projects, too. However, this “National Development Fund” (NDF) is not sufficiently financially equipped (the funding also depend on fossil fuels’ revenues that are at a very low level worldwide). Therefore, lower and more competitive interest rates for providing sufficient project financing loans at lower interest rates than available in the free market are needed. The NDF should increase the share for renewable energy projects, including small PV installations. Also more national credit lines for renewable energy investments should be developed, as it is impossible now and difficult in the mid-term perspective to obtain international funding. Moreover, the authorities should streamline and make funding regulations for national credits and other subsidized credits more transparent to avoid additional information cost for investors (Aguilar et al., 2016: 87f.).

Banks must be able to trust that the investments will generate the expected and agreed return. If that is the case they are willing to accept lower interest rates or set up specific credit lines for solar projects. If Iranian banks get familiar (**empowerment of banks)** with RES projects, they would provide developers more simply with loans. SUNA has the authority to start informational talks or even negotiations with domestic banks in order to convey a better understanding of RES technologies, of the recent policy framework, of the project development process and of the plants in operation. This understanding can be achieved by specific financing workshops / trainings supported by international experts, by developing standardized bankability criteria and by an intense information exchange between Iranian bank representatives / associations with SUNA and stakeholders (Aguilar et al., 2016: 88f.).
A greater involvement of **international (development) banks** is also needed. There are some European banks granting lower interest rates but they still hesitate to fully operate within Iran as the US sanctions are still in place.

5.5.7. Educational recommendations

The energy transition will only be successful, if the general public, the industry and policy makers and regulators accept and share the joint objectives. It is crucial, that the introduction of solar and wind energy will be accompanied by **public relation** which conveys positive messages and the various benefits of renewable energy such as economic value creation, jobs, emission reduction, environment protection, satisfaction of growing energy demand or civic participation. SUNA should initiate and plan communication activities that frame and explain the new regulation, the benefits and the maturity of the technology for the general public. Such activities can be campaigns, presswork, workshops, conferences for specific multiplier target groups, online media or printed information material. (Aguilar et al., 2016: 91). The **empowerment of civil society** is THE key for RES development as a new, egalitarian way of the energy sector, where the ‘power’ lies in the hands of civil society and communities. This could take place with ‘civic power plants’ (‘Bürgerkraftwerke’) where people can crowd-fund a plant, which then creates a new way of empowerment of the civil society.
Iran can capitalize on its young population structure and high demand for **education** to become one of the leading countries in the region in the area of renewable energy technologies. This can help the economy significantly by creating new **(green) jobs** and maintaining the standard of living, especially in a case in which oil and gas could no

longer compete with the new energy resources or were no longer available. (Moshiri & Lechtenböhmer, 2015: 87ff.).

5.5.8. Soft skills and further recommendations

One of the most important aspects to consider is to have an **Iranian partner**. This eases the understanding of the complex governmental procedures, get the necessary permissions and to overcome the language barriers. A **good understanding of the country's** history, culture and business landscape is a minimum condition. Given the centralized nature of companies and governments bodies, it will take considerable time to get anything off the ground if companies start at the lower end. It is key to have a middleman ('10-%-guy') who ideally is at a high position in an organization, institution or government. It is always best to go directly to the senior management when possible. Such locals can possess essential know-how on how to navigate within their culture and have the right contacts, but using these individuals requires careful consideration of compliance regulations and it comes with certain risks. Selecting a reliable middleman could be one of the most strategic moves that a company entering Iran makes (Moshiri & Lechtenböhmer, 2015: 82).

Chapter 6: Conclusions

Iran's potential for the chosen renewable energy sources are high. The solar radiation, wind speeds and thermal energy flows at the Earth's surface combined with high energy demand of an emerging state that awakes after the removal of international sanctions give excellent conditions for harvesting those energies.

While the technical potential of PV potential was estimated to be 37,145 GW and 56,597 TWh, respectively, the potential for wind (186 TWh) and geothermal (35,723 MWe and 297 TWh, respectively) are far beyond imagination, with excellent climatic conditions for PV and wind as well as tectonic conditions for geothermal.

The results for the economic calculations are as promising with the same ranking: while the NPV yields € 1,033 for PV, € 5,425 for wind and € 41,319 for geothermal the equity IRR mirrors these results (18%; 87%; 155%). In terms of LRGC however, investments into PV are the most promising (183 €/MWh; 74 €/MWh; 62 €/MWh).

Yet, there are still many challenges to overcome; Iran is an infant renewable energy market. While on the technical side the barriers are low (well established grids) or could be overcome easily (e.g. knowledge transfer, access to power plant components/equipment, well-educated personnel) as long as they are not linked to trade restrictions or fossil fuels' subsidies. The economical hinders are much harder to tackle (e.g. no access to international financial markets, high inflation rate, high interest rates, etc.).

Main challenges are:

- The **empowerment of banks** and access to the market for international finance, which means access to lower interest rates.

- A **transparent, market-oriented, predictable, comprehensive and long-term renewable energy package** for project planning (procedures, contracts, assessments), ambitious renewable targets (beyond the 5,000 MW), and high purchase prices (including possible uplifts) while reducing fossil fuel subsidies.

- The **empowerment of civil society** that includes communication and awareness raising campaigns promoting green energies (creating jobs, reduces climate pollution and helps reaching international commitments, energy self-sufficient regions including self-consumption roof-top systems, independency from restriction measures), adapted educational systems (Master programs, international joint-research projects).

The sanctions' days are numbered, the missing link between the past and the future though is still not strong enough: trust. Trust in its own strengths, trust in international investors, trust into a green future. However, trust is a question of time.

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List of Abbreviations

aka	also known as
Bits	Bilateral Investment Treaties
BOS	balance-of-system components
cbm	cubic meter
CH4	Methane
CO	Cobalt
CO2	Carbon Dioxide
COP21	Conference of the Parties, 2015 Paris Climate Conference
c-Si	ribbon-sheet grown
DNI	Direct Normal Irradiation
DSO	Distribution Company Iran (in Farsi)
EPBT	Energy Payback Time
EU	European Union
F-Gas	Fluorinated gases
FiT	Feed-in-Tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GPP	Geothermal Power Plant
h	hour/s
HDR	Hot Dry Rock
IAEA	International Atomic Energy Agency
IIES	Institute for International Energy Studies
IRR	Internal Rate of Return
IRR	Iranian Rial (currency)
ISCC	Integrated Solar Combined Cycle
JCPOA	Joint Comprehensive Plan of Action
kW(h)	kW(hour)
LC	Letter of Credit
LCA	Life Cycle Assessment
LCOE	Levalized Cost Of Energy
LGRC	Long Run Generation Cost
mc-Si	block crystals (multi-crystalline silicon)
μm	Micrometer
MoE	Ministry of Energy (Iran)
MoO	Ministry of Oil (Iran)
MW(h)	Megawatt(hour)
NDF	National Development Fund
NOX	Nitric/nitrogen oxide
NPV	Net Present Value
O&M	Operations & Maintenance costs
p.a.	per annum
p-n junctions	positive/negative side between two types of semiconductor materials
PPA	Power Purchase Agreement
PPP	Power Purchasing Parity
PR	Performance ratio
PV	Photovoltaic
REN	Renewable Energy/-ies
RES	Renewable Energy Sources

ROR	Rate Of Return
Rpm	Revolution per minute
SABA	Iran Energy Efficiency Organisation
sc-Si	single-crystal
Si	Silicon
SO3	Sulfur trioxide
SO4	Sulfate
SPM	suspended particulate matter
SUNA	Renewable Energy Organization of Iran (in Farsi)
SWIFT	Society for Worldwide Interbank Financial Telecommunication
SWT	Small Wind Electric Systems and Micro Wind Turbines
TAVANIR	Distribution Company Iran (in Farsi)
TF	Thin-film solar cell
TW(h)	Terawatt (hours)
UNCITRAL	United Nations Commission on International Trade Law
V	Volt
Wp	Watt peak

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CHAPTER 5

Appendix I – SUNA: Investment in Clean and Renewable Energy – A General View (FiT per Power Plant Technology Type, including important notes)

Ministry of Energy

Renewable Energy Organization of Iran

Renewable Energy Organization of Iran (SUNA)

Investment in Clean and Renewable Energy A General View

To materialize the Article 44 of the constitutional law regarding enhancement of private sector participation in economic activities of the country and in order to preserve fossil energy resources, safeguarding the environment, diversification of energy resources and passive defense, Renewable Energy Organization of Iran (SUNA) has adopted feed-in tariffs (FiTs) of renewable and clean electricity generated from non-governmental power plants as one of its top programs. In accordance with the decree from the Cabinet Ministers with No. H 52375 T/153440 dated 10.2.2016 and the Directive from H.E Minister of Energy with No. 95/14273/30/100 dated 8.5.2016, the electricity generated by clean and renewable power plants will be purchased as follows:

Power Plant Technology Type			FiTs (IRRs per kWh)
1	Biomass	landfill	2700
		the anaerobic digestion of manure, agricultural wastes and wastewater	3500
		incineration and wastes gasification	3700
2	Wind Farm	above 50 MW capacity*	3400
		with the capacity of 50 MW and less	4200
3	Solar Farm	above 30 MW capacity*	3200
		with the capacity of 30 MW and less	4000
		with the capacity of 10 MW and less	4900
4	Geothermal (including potential assessment and excavation)		4900
5	Waste Heat Recovery (WHR) from Industrial Processes		2900
6	Small Hydropower (with the capacity of 10 MW and less)	installation on the rivers and side facilities of dams	2100
		installation on the water pipelines	1500

* SUNA determines the maximum capacity for the large wind and solar farms according to the total 2000 MW annual capacity development policy.

Allocated to the Subscribers and Limited to their Connection Capacity			FiTs (IRRs per kWh)
1	Wind with a total capacity of 1 MW and less		5700
2	Solar	with a total capacity of 100 KW and less	7000
		with a total capacity of 20 KW and less	8000

Important Notes:

- Power Purchase Agreements (PPA) of power plants subject to this announcement are extended for a 20-year period with the specified tariffs.
- To compensate for devaluation of money, the tariffs will be annually adjusted during the contracts based on Euro exchange rate fluctuations and internal inflation according to article 3 of Cabinet Minister's Directive.
- All tariffs except wind farms, will be multiplied by 0.7 starting from the first day of the second 10 years till the end of the contract.
- Tariffs for the wind farms with the capacity factor of 40% and above in the first 10 years, will be multiplied by 0.4 starting from the first day of the second 10 years till the end of the contract. However those with the capacity factor of less than 20% will be multiplied by 1 and the rest with the capacity factor between 20% to 40% will be multiplied by an appropriate coefficient.

- Tariffs subject to this announcement, multiplied based on the hourly coefficient which is announced and updated by Iran Grid Management Co.(www.suna.org.ir/en/guidelineinformation-Guideline-Information)
- Tariffs can be increased up to a maximum of 30% for power plants constructed, using local know-how, design and manufacturing, according to the instruction of article 6 of Cabinet Ministers Directive.
- For the power plants connected to the distribution grid, a transmission service rate will be added to the FiTs. The transmission service rate wil be announced by Iran Grid Management Co.
- The 20-year PPA starts from the signing date of the contract which includes the progress and the construction period of power plant.
- The rates of this announcement are valid for the PPAs which the power plants will be constructed and commercially operated within a maximum of 30 months for biomass, geothermal and small hydro power plants, also a maximum of 24 months for wind, waste heat recovery (WHR) power plants in industrial processes and a maximum of 15 months for different types of solar power plants since the signing date of the PPA. In case of delay, the tariff which is in current for new contracts or the tariff mentioned in the contract, which ever is lower, will be applied on the start date of commercial operation.
- A maximum delay of 9 months since the commercial operation date allows the Renewable Energy Organization of Iran (SUNA) to terminate the PPA, cancel the construction permit and inform the authorities to return back the state lands which are intended for the construction of the power plant.
- The investors that their contracts are terminated due to delay, their new request will be taken into consideration after 2 years.
- During the period of PPA and after that, the investor is allowed to sell electricity across the country in the form of bilateral contract, power exchange, electricity day-ahead market, or any other form approved by the Ministry of Energy.
- The export of electricity from clean and renewable power plants depends upon separate permits.
- The article 5 of the Minister Directive prohibits dividing the high capacity power plants into several smaller power plants in order to benefit from a higher FiT.
- Tariff for biomass power plants will be multiplied in a coefficient that will be announced by a workgroup subject to Article 5 of Economic Council Directive.
- The application for PPA is not allowed for applicants who benefited from the state grant funds and subsidies for their power plants. The investor shall commit that the state grants funds and subsidies are not used for construction of the power plant.
- The Ministry of Energy will follow up the policy of gradual reduction of tariffs due to the increase of the capacity of clean and renewable power plants in the country by considering the limitations in financial sources. The reduced rates will be applied only in new contracts.
- Construction permit applicants should fill two worksheets and submit to Non-governmental Partnerships Office of SUNA. The documents include a written application which specifies the type, capacity and coordinates of the candidated location along with the company's documentation such as registration ad in official gazette, statute and its latest amendments.
- Upon obtaining environmental permit, grid connection permit and land use permit (for state owned lands), PPA will be signed with applicants.
- For the biomass power plants which are based on waste, the permission for the use of waste, and for the small hydro power plants, the permission for the use of water transmission lines is requierd.
- Both drafts of PPA and construction permit and the commitment letters are available in SUNA website for detailed consideration.
- Power Distribution Companies will sign purchase agreement with limited connection capacity subscribers.
- Foreign investors in clean and renewable energy generation are welcomed. They may apply for a construction permit and concluding the PPA by either registering a company in Iran or joining the Iranian companies.

Appendix II - E-Mail Forouz Baghbani, 14/09/2016 on Installed wind turbines capacity in Iran, 2015

Re: Request - Research Wind

Von: Forouz Baghbani

Vollansicht schließen

14.09.2016 um 13:03 Uhr

Dear Mr. Zlanabitnig

I hope that the following information will be useful for you:

1. Total installed capacity in Iran: 128.92 MW

Kahak (8 x 2.5 MW)
Khaf (1 x 1.5 MW) (1 x 0.66 MW) (1 x 2.5 MW)
Lutak (1 x 0.66 MW)
Einali (3 x 0.66 MW)
Manjil (71.74 MW)
Binalood (43 x 0.66 MW) (2 x 2 MW)

2. As you know, Ministry of Energy signs guaranteed power purchase agreement for the duration of 20 years (after operation of each wind turbine) with wind farm developers in Iran.

Risk of that payment default is covered by below methods:

1. Renewable fees: every electricity consumer in Iran must pay 30 IRR/KWh as renewable energies fee that creates a fund to support renewable power plants, especially wind farms.
2. Letter of Credit for PPA: above found is a deposit in Bank Saderat Iran and this bank opens a LC for buying electricity from renewable power plants. When the owner of power plant issues the approved bill, the bank should pay the money.
3. Payment Guarantee: addition to supports in "Foreign Investment Promotion and Protection Act (FIPPA)" a Payment Guarantee is issued by signature of Minister of Finance only for foreign investors that participate in projects that have PPA with Ministry of Energy (SUNA is a part of MoE). If SUNA defaults in payment, Ministry of Finance will block all the accounts of MoE and will pay the foreign investor.

Forouz Baghbani (Ms.)
Business Development Department
Beheen Group

Email: f.baghbani@beheen.com

Appendix III - Summary Wind Analysis-Khaf, (SUNA, Business Development Department)

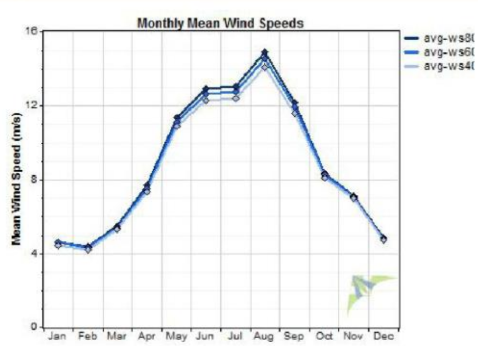
Summary Report: SPC 80m mast, 2011-15.xlsx Page 1 of 5

Data Set Properties

Report Created: 2016-08-05 15:41 using Windographer 4.0.15
Filter Settings: <Unflagged data>

Variable	Value
Latitude	N 34.522962
Longitude	E 60.283823
Site	Khaf
Start date	2011-04-07 16:40
End date	2012-04-08 00:00
Duration	12 months
Length of time step	10 minutes
Calm threshold	0 m/s
Mean temperature	15.0 癈
Mean pressure	101.3 kPa
Mean air density	1.222 kg/m3
Power density at 50m	1,031 W/m?
Wind power class	7 (Superb)
Power law exponent	0.0632
Surface roughness	0.0000075 m
Roughness class	0.00

Wind Speed and Direction



Data Column Properties

#	Label	Units	Height	Possible Data Points	Valid Data Points	Recovery Rate (%)	Mean	Min	Max	Std. Dev
1	avg-ws80	m/s	80 m	52,748	52,722	99.95	8.936	0.000	27.700	6.285
2	max-ws80	m/s	80 m	52,748	52,722	99.95	10.910	0.000	33.200	7.301
3	min-ws80	m/s	80 m	52,748	52,722	99.95	6.908	0.000	23.200	5.188
4	sdev-ws80	m/s	80 m	52,748	52,722	99.95	0.832	0.000	4.400	0.557
5	avg-ws60	m/s	60 m	52,748	52,722	99.95	8.766	-3.200	27.300	6.133
6	max-ws60	m/s	60 m	52,748	52,722	99.95	10.816	0.000	33.300	7.223
7	min-ws60	m/s	60 m	52,748	52,722	99.95	6.649	0.000	22.900	4.952
8	sdev-ws60	m/s	60 m	52,748	52,722	99.95	0.870	0.000	4.300	0.582
9	avg-ws40	m/s	40 m	52,748	52,722	99.95	8.553	0.000	26.700	5.906
10	max-ws40	m/s	40 m	52,748	52,722	99.95	10.681	0.000	33.600	7.093
11	min-ws40	m/s	40 m	52,748	52,722	99.95	6.361	0.000	21.600	4.626
12	sdev-ws40	m/s	40 m	52,748	52,722	99.95	0.904	0.000	4.200	0.614
13	wd-80	°	10 m	52,748	52,722	99.95	66.0	29.0	360.0	77.9
14	sdev-wd80	°	10 m	52,748	0	0.00				
15	wd-60	°		52,748	0	0.00				
16	sdev-wd60	%		52,748	0	0.00				
17	rel-humidity	%		52,748	52,722	99.95	39.3	4.0	100.0	20.2
18	Air Density	kg/m3		52,748	52,748	100.00	1.222	1.217	1.225	0.002
19	avg-ws80 TI			52,748	52,722	99.95	0.12	0.00	2.00	0.10
20	avg-ws60 TI			52,748	52,722	99.95	0.13	0.00	3.00	0.13
21	avg-ws40 TI			52,748	52,722	99.95	0.13	0.00	1.46	0.09
22	avg-ws80 WPD	W/m?		52,748	52,722	99.95	1,143	0	12,998	1,646
23	avg-ws60 WPD	W/m?		52,748	52,722	99.95	1,070	-20	12,443	1,535
24	avg-ws40 WPD	W/m?		52,748	52,722	99.95	979	0	11,641	1,405

Appendix IVa – Calculations PV

PV: Calculation NPV and LRGC							
						0.05	5%
						0.015	1.50%
						0.105	10.50%
						0.15	15%
LRGC			182.8372862	EUR/MWh			
						Exchange Rate	33,772
Costs						Discount rate = x*(1-x/100)	
Investment Horizon				20.00	years		
Discount rate				15.00	%/yr		
Rated Capacity				5,000.00	KWp		
FLH electricity	(Specific Yield: 2000)	1,600.00		2,000.00	kWh/qm/a		
Specific System cost				1,776.62	EUR/kWp	600,000,000.00	IRR
Electricity Production			8,000,000.00		KWhp		
Investment Costs				8,883,098.42	EUR	300,000,000,000.00	IRR
Repair Works				0.00	% of investment cotss		
O&M				272,415.02	EUR	9,200,000,000.00	IRR
Interest Rate				0.06			
Revenues							
FIT (year 1-10)	100%			0.1451	EUR/kWh	4,900.00	IRR
FIT (year 11-20)	70%			0.1016	EUR/kWh	3,430.00	IRR
Electricity Market price					€/Mwh		
Degradation				0.7	% p.a.		
OpEx Escalation Rate				10.5	%		
Discount factor				0.869565217			
CRF				**0.15976147**			

Year		Discounted CF	Nominal CF	O&M	Investment System Cost	Electricity sale	Debt Service	Discounted Costs
	0	-1.776.620	-1.776.620		8.883.098		7.106.479	8.883.098
	1	471.834	542.609	301.019		1.270.016	426.389	261.755
	2	-755.222	-998.781	332.626		1.376.957	2.043.113	251.513
	3	-603.442	-917.760	367.551		1.492.904	2.043.113	241.671
	4	-474.923	-830.644	406.144		1.618.613	2.043.113	232.214
	5	-366.416	-736.994	448.789		1.754.908	2.043.113	223.128
	6	608.184	1.406.767	495.912		1.902.679	0	214.396
	7	569.511	1.514.911	547.983		2.062.894	0	206.007
	8	533.202	1.631.078	605.521		2.236.599	0	197.946
	9	499.117	1.755.831	669.101		2.424.932	0	190.200
	10	467.121	1.889.766	739.356		2.629.122	0	182.758
	11	253.282	1.178.366	816.989		1.995.355	0	175.606
	12	235.615	1.260.600	902.773		2.163.373	0	168.735
	13	219.084	1.347.975	997.564		2.345.539	0	162.132
	14	203.617	1.440.736	1.102.308		2.543.044	0	155.788
	15	189.151	1.539.130	1.218.050		2.757.181	0	149.692
	16	175.622	1.643.403	1.345.946		2.989.348	0	143.834
	17	162.973	1.753.796	1.487.270		3.241.065	0	138.206
	18	151.150	1.870.545	1.643.433		3.513.978	0	132.798
	19	140.100	1.993.878	1.815.994		3.809.872	0	127.601
	20	129.777	2.124.008	2.006.673		4.130.681	0	122.608
NPV		1.032.717	**19.632.601**	**18.251.001**				12.561.686
Annuity		164.988						2.006.873
		3%	18%					
		Project IRR	Equity IRR					

Adjustment Formula (see chapter 1.5.6.); Tariff escalation for 5 MW PV plant (first 10 years, chapter 2.6.2)

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Consumer Price Index (Inflation rate 12% assumed	100,00	112,00	125,44	140,49	157,35	176,23	197,38	221,07	247,60	277,31	310,58
Exchange rage (8% assumed) IRR 33,772 = € 1	33.772	36.474	39.392	42.543	45.946	49.622	53.592	57.879	62.510	67.510	72.911
Escalation rate (^ is power coefficient, assumed 0.3)	1,0000	**1,0918**	1,1921	1,3016	1,4212	1,5517	1,6942	1,8498	2,0197	2,2053	2,4078
Tariff (IRR/kWh) 100% (year 1-10)	0,1451	0,1584	0,1730	0,1889	0,2062	0,2251	0,2458	0,2684	0,2930	0,3200	0,3493
Tariff (IRR/kWh) 70% (year 11-20)	0,1016										
Degradation of Specific System Performance (0.70%)	1.600,0000	1.588,8000	1.577,6784	1.566,6347	1.555,6682	1.544,7785	1.533,9651	1.523,2273	1.512,5647	1.501,9768	1.491,4629

Appendix IVb – Calculations Wind

Wind: Calculation NPV and LRGC							
						0.05	5%
						0.015	1.50%
						0.105	10.50%
						0.15	15%
LRGC			74.10002777	EUR/MWh			
						Exchange Rate	33,772
Costs						Discount rate = x*(1-x/100)	
Investment Horizon				20.00	years		
Discount rate				15.00	%/yr		
Rated Capacity				2,500.00	KWp		
FLH				0.47	46.80%		
80% of FLH		3,282.55			h/year		
Specific System cost				1,500.00	EUR/kWp	600,000,000.00	IRR
Electricity Production			8,206,368.00		KWh/year		
Investment Costs				3,750,000.00	EUR	300,000,000,000.00	IRR
Repair Works				0.00	% of investment cotss		
O&M				56,250.00	EUR/year	9,200,000,000.00	IRR
Interest Rate				0.06			
Revenues							
FIT (year 1-10)	100%			0.1244	EUR/kWh	4,900.00	IRR
FIT (year 11-20)	40%			0.0497	EUR/kWh	3,430.00	IRR
Electricity Market price					€/Mwh		
Degradation				0.7	% p.a.		
OpEx Escalation Rate				10.5	%		
Discount factor:				0.869565217			
CRF				**0.15976147**			

Year	Discounted CF	Nominal CF	O&M	Investment System	Electricity sale	Debt Service	Discounted Costs
0	-750.000	-750.000		3.750.000		3.000.000	3.750.000
1	760.444	874.510	62.156		1.116.666	180.000	54.049
2	211.351	279.512	68.683		1.210.695	862.500	51.934
3	246.073	374.247	75.894		1.312.641	862.500	49.902
4	272.617	476.808	83.863		1.423.172	862.500	47.949
5	292.261	587.840	92.669		1.543.009	862.500	46.073
6	678.987	1.570.539	102.399		1.672.938	0	44.270
7	639.340	1.700.656	113.151		1.813.807	0	42.538
8	601.992	1.841.506	125.032		1.966.538	0	40.873
9	566.811	1.993.970	138.160		2.132.130	0	39.274
10	533.671	2.158.998	152.667		2.311.665	0	37.737
11	179.226	833.830	168.697		1.002.527	0	36.260
12	168.316	900.535	186.410		1.086.945	0	34.841
13	158.056	972.487	205.983		1.178.471	0	33.478
14	148.408	1.050.092	227.612		1.277.704	0	32.168
15	139.335	1.133.781	251.511		1.385.292	0	30.909
16	130.805	1.224.021	277.919		1.501.940	0	29.700
17	122.784	1.321.310	307.101		1.628.411	0	28.538
18	115.243	1.426.184	339.347		1.765.531	0	27.421
19	108.154	1.539.219	374.978		1.914.197	0	26.348
20	101.489	1.661.030	414.351		2.075.381	0	25.317
NPV	**5.425.363**	**23.171.076**	**3.768.584**				**4.509.578**
Annuity	**866.764**						**720.457**

63%	87%
Project IRR	Equity IRR

Adjustment Formula (see chapter 1.5.6.); Tariff escalation for 2.5 MW wind power plant (first 10 years, chapter 3.7.2)

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Consumer Price Index (Inflation rate 12% assumed	100,00	112,00	125,44	140,49	157,35	176,23	197,38	221,07	247,60	277,31	310,58
Exchange rage (8% assumed) IRR 33,772 = € 1	33.772	36.474	39.392	42.543	45.946	49.622	53.592	57.879	62.510	67.510	72.911
Escalation rate (^ is power coefficient, assumed 0.3)	1,0000	**1,0918**	1,1921	1,3016	1,4212	1,5517	1,6942	1,8498	2,0197	2,2053	2,4078
Tariff (IRR/kWh) 100% (year 1-10)	0,1244	0,1358	0,1483	0,1619	0,1767	0,1930	0,2107	0,2301	0,2512	0,2743	0,2994
Tariff (IRR/kWh) 70% (year 11-20)	0,0497										
Degradation of Specific System Performance (0.70%)	3.282,5472	3.259,5694	3.236,7524	3.214,0951	3.191,5965	3.169,2553	3.147,0705	3.125,0410	3.103,1657	3.081,4435	3.059,8734

Provines	1.5% of total area		nr. wind turbines	wind potential (kW)	total area	Wind speed m/s	FLH	Potential of max. possible 2.5MW wind turbines (MW)	Wind electricity potential (MWh)
Alborz and Tehran*	282	1,50%	564	423292,5	18813	2	50	1410,975	1.128.780
Ardabil	267		534	400477,5	17799	3	425	1334,925	6.274.148
Azerbaijan, East	685		1.370	1027125	45650	3,5	612,5	3423,75	2.739.000
Azerbaijan, West	561		1.122	841747,5	37411	4	800	2805,825	2.244.660
Bshehr	341		682	511695	22742	4,25	968,75	1705,65	1.940.177
Chahar, Mahaal and Bakhtiari	245		490	367357,5	16327	4,5	1137,5	1224,525	1.392.897
Fars	1.839		3.678	2758680	122608	5	1475	9195,6	**10.459.995**
Gilan	211		421	315945	14042	5,5	1812,5	1053,15	2.593.382
Golestan	306		611	458257,5	20367	6	2150	1527,525	1.222.020
Hamadan	291		581	435780	19368	6,5	2462,5	1452,6	1.162.080
Hormozgan	1.060		2.121	1590682,5	70697	7	2775	5302,275	5.136.579
Ilam	302		604	452970	20132	8	3400	1509,9	2.736.694
Isfahan	1.605		3.211	2407927,5	107019	9	4050	8026,425	4.916.185
Kerman	2.711		5.422	4066335	180726	10	4700	13554,45	**33.377.833**
Kermanshah	375		750	562680	25008	10,5	4700	1875,6	3.399.525
Khorasan, North	427		853	639765	28434	11	4700	2132,55	1.306.187
Khorasan, Razavi	1.783		3.566	2674147,5	118851	12	4700	8913,825	5.459.718
Khorasan, South	2.262		4.524	3392932,5	150797	13	4700	11309,775	**53.155.943**
Khuzestan	961		1.922	1441215	64054	14	4700	4804,05	5.464.607
Kohgiluyeh and Boyer-Ahmad	233		465	348840	15504			1162,8	1.322.685
Kurdistan	437		874	655582,5	29137			2185,275	3.960.811
Lorestan	424		849	636615	28294			2122,05	3.846.216
Markazi	437		874	655357,5	29127			2184,525	1.747.620
Mazandaran	358		715	536445	23842			1788,15	1.430.520
Qazvin	234		467	350257,5	15567			1167,525	934.020
Qom	173		346	259335	11526			864,45	691.560
Semnan	1.462		2.925	2193525	97490			7311,75	5.849.400
Sistan and Baluchestan	2.727		5.454	4090162,5	181785			13633,875	15.508.533
Yazd	1.108		2.216	1662142,5	73873			5540,475	3.393.541
Zanjan	327		653	489892,5	21773			1632,975	1.306.380
TOTAL	**24.431**			**36647167,5**	**1628763**			**122.157**	**186.101.694**

Appendix IVc – Calculations Geothermal

Geothermal: Calculation NPV and LRGC							
						0.05	5%
						0.015	1.50%
						0.105	10.50%
						0.15	15%
LRGC			61.80390336	EUR/MWh		Exchange Rate	33,772
Costs						Discount rate = x*(1-x/100)	
Investment Horizon				20	years		
Discount rate				15	%/yr		
Rated Capacity				5,500.00	kWp		
Capacity Factor				0.95	95.00%		
FLH electricity		6,657.60			h/year		
Specific System cost				2,550.00	EUR/kWp	600,000,000.00	IRR
Electricity Production			36,616,800.00		KWh/year		
Investment Costs				14,025,000.00	EUR	300,000,000,000.00	IRR
Repair Works				0.00	% of investment cots		
O&M				140,250.00	EUR/year	9,200,000,000.00	IRR
Interest Rate				0.06			
Revenues							
FIT (year 1-10)	100%			0.1451	EUR/kWh	4,900.00	IRR
FIT (year 11-20)	70%			0.1016	EUR/kWh	3,430.00	IRR
Electricity Market price					€/Mwh		
Degradation				0.7	% p.a.		
OpEx Escalation Rate				10.5	%		
Discount factor				0.869565217			
CRF				**0.15976147**			

Year	Discounted CF	Nominal CF	O&M	Investment System Cost	Electricity sale	Debt Service	Discounted Costs
0	-2.795.001	-2.795.001		14.025.000		11.229.999	14.025.000
1	4.334.099	4.984.214	154.976		5.812.990	673.800	134.762
2	2.194.781	2.902.598	171.249		6.302.472	3.228.625	129.489
3	2.245.625	3.415.315	189.230		6.833.169	3.228.625	124.422
4	2.270.335	3.970.830	209.099		7.408.554	3.228.625	119.553
5	2.273.445	4.572.710	231.054		8.032.389	3.228.625	114.875
6	3.654.655	8.453.439	255.315		8.708.754	0	110.380
7	3.443.564	9.159.949	282.123		9.442.072	0	106.061
8	3.244.628	9.925.393	311.746		10.237.139	0	101.910
9	3.057.150	10.754.675	344.479		11.099.154	0	97.923
10	2.880.469	11.653.105	380.650		12.033.755	0	94.091
11	1.872.654	8.712.319	420.618		9.132.938	0	90.409
12	1.763.878	9.437.191	464.783		9.901.974	0	86.871
13	1.661.390	10.222.181	513.585		10.735.766	0	83.472
14	1.564.827	11.072.257	567.512		11.639.768	0	80.206
15	1.473.848	11.992.791	627.100		12.619.892	0	77.067
16	1.388.131	12.989.600	692.946		13.682.546	0	74.052
17	1.307.372	14.068.975	765.705		14.834.680	0	71.154
18	1.231.286	15.237.726	846.104		16.083.830	0	68.370
19	1.159.604	16.503.219	934.945		17.438.164	0	65.694
20	1.092.071	17.873.425	1.033.114		18.906.539	0	63.124
NPV	**41.318.813**	**195.106.911**	**9.396.335**				**15.918.882**
Annuity	**6.601.154**						**2.543.224**

Project IRR	Equity IRR
122%	155%

Adjustment Formula (see chapter 1.5.6.); Tariff escalation for 5.5 MW wind power plant (first 10 years, chapter 4.6.1)

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Consumer Price Index (Inflation rate 12% assumed	100	112	125	140	157	176	197	221	248	277	311
Exchange rage (8% assumed) IRR 33,772 = € 1	33.772	36.474	39.392	42.543	45.946	49.622	53.592	57.879	62.510	67.510	72.911
Escalation rate (^ is power coefficient, assumed 0.3)	1,0000	**1,0918**	1,1921	1,3016	1,4212	1,5517	1,6942	1,8498	2,0197	2,2053	2,4078
Tariff (IRR/kWh) 100% (year 1-10)	0,1451	0,1584	0,1730	0,1889	0,2062	0,2251	0,2458	0,2684	0,2930	0,3200	0,3493
Tariff (IRR/kWh) 70% (year 11-20)	0,1016										
Degradation of Specific System Perf. (0.70%)	6.657,6000	6.610,9968	6.564,7198	6.518,7668	6.473,1354	6.427,8235	6.382,8287	6.338,1489	6.293,7819	6.249,7254	6.205,9773