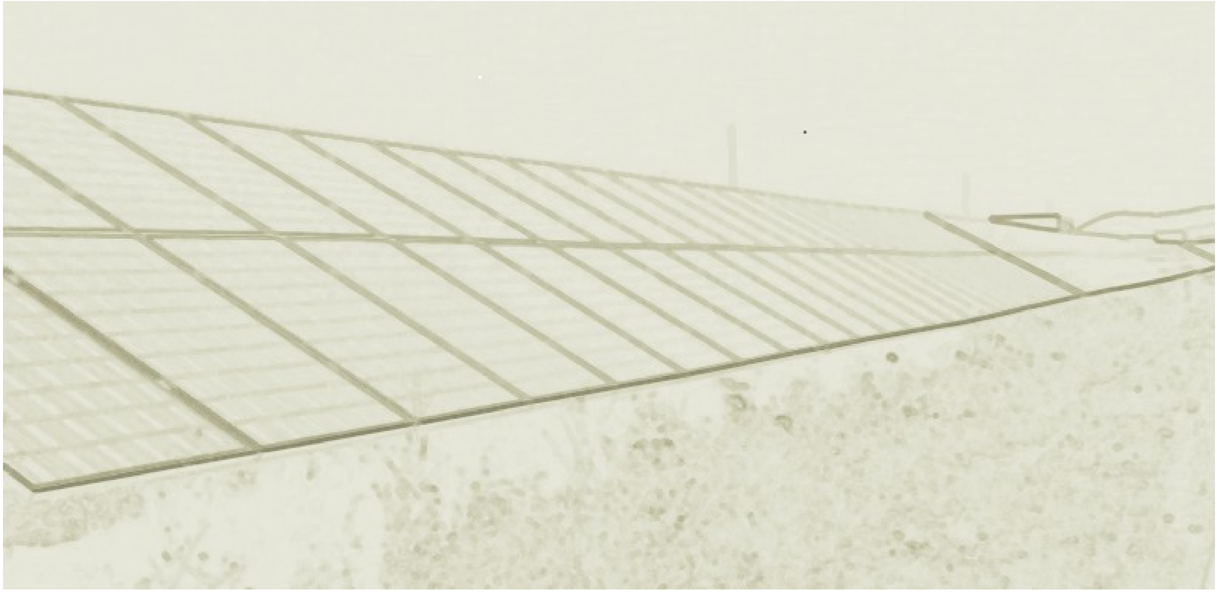

Business Case

for

Implementation of Net Metering Regulations 2015

20th April, 2016

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

AEDB

Imprint

As a federal enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by the
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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Place and date of publication
Lahore, Pakistan, May 2016

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Abbreviations

a	Year
AC	Alternating Current
AEDB	Alternative Energy Development Board
CAPEX	Capital Expenditures
CPI	Consumer Price Index
DC	Direct Current
DISCO	Distribution Company
etc.	et cetera
FESCO	Faisalabad Electric Supply Company
FiT	Feed-in Tariff
GHI	Global Horizontal Irradiance
i.e.	id est
IRR	Internal Rate of Return
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt-peak (Nominal Power)
LCOE	Levelized Costs of Electricity
NEPRA	National Electric Regulatory Authority
NPV	Net Present Value
O&M	Operations and Maintenance
OPEX	Operational Expenditures
PKR	Pakistani Rupee
PV	Photovoltaic
PR	Performance Ratio
RE	Renewable Energy
UPS	Uninterruptible Power Supply
USD	United States Dollar

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A. Context

In today's world, reliable and cost-efficient energy supply is considered the key determinant of economic development and prosperity of any country. Pakistan has been facing an unprecedented energy crisis for the past few years as the demand and supply gap has widened. The country's current energy demand far exceeds its indigenous generation resources, fostering dependency on imported oil that puts substantial burdens on the economy. The dire implications include a burgeoning oil import bill and increasing costs of power production, leading to a severe domestic shortage of electricity and gas. Recently, much hope has been put onto Liquefied Natural Gas (LNG) imports[1].

Growing at an average of 3.8% a year from 2006 to 2013, Pakistan's economy has the potential to achieve higher growth to accommodate a rapidly growing working-age population. The country has considerable natural resources which can be harnessed to address its energy problems and improve economic productivity. Furthermore, given the government's target of accelerating the growth rate to 7% by 2017, a lot needs to be done on the energy access and supply side to support the country's development. Access to clean, reliable, and modern sources of energy is a crucial ingredient in achieving economic growth and development.

The country faces a significant challenge in revamping the transmission network for stable supply of electricity. Load-shedding and power blackouts have become severe issues for the country in recent years.

Pakistan's energy constraints have become more pronounced over the past seven years, as energy supplies have failed to meet the demand. The demand-supply mismatch has affected millions of domestic consumers, industries, and the overall economy. According to the Annual Plan 2014-15 of Ministry of Planning, Development and Reform, Pakistan, the average supply of electricity remained at 14,400 MW against the demand of 18,400 MW, implying a power shortfall of 4,000 MW. The electricity load pattern in the country varies from season to season with highest demand during summer season, mostly due to air conditioning of buildings. As per the National Power Policy 2013, such demand-supply gaps lead to load-shedding of 12 to 16 hours per day especially in the countryside which is what is observed to be the case in many villages across Pakistan. These acute power shortages are forcing the industrial sector to work at underutilization levels which is severely threatening the trade balance of the country.

[1] See e.g. Pakistan Observer, Feb 2016: http://pakobserver.net/2016/02/23/energy-crisis-auspicious-developments/

Approximately 21.8 million industrial, commercial and domestic consumers across Pakistan are connected to the national grid through various Distribution Companies (DISCOs). The electrification ratio in Pakistan is approximately 71%, with 90% connections in urban areas, and 60% in rural areas.

B. Net-Metering in Pakistan

The Government of Pakistan promotes investment in the generation of small scale distributed renewable energy, through the Alternative Energy Development Board (AEDB), on the basis of net-metering concept. The National Electric Regulatory Authority (NEPRA) announced the official Distributed Generation and Net Metering Regulations on September 1st, 2015[2]. As per these regulations, any customer of the electric grid (three-phase connections) can avail the possibility of Net Metering for small-scale renewable energies installations.

NEPRA has indicated that the Net Metering Regulations may be revised based upon international best practices and inputs and comments by relevant stakeholders. In this regard, AEDB has requested the GIZ REEE project to provide professional input and recommendations regarding the Net Metering regulations. With a view to promote Net Metering in different sectors, AEDB also suggested to develop detailed business cases for investment.

GIZ REEE has subsequently hired the services of 8.2 Obst & Ziehmann International GmbH to review NEPRA's Net Metering regulations and present clear and concise recommendations in accordance with the best practices exercised around the world along with the lessons learned as well as to elaborate the business case for investment in small scale RE projects.

C. Background on Net Metering

Net Metering is an incentive scheme for consumers of an electric grid related to Distributed Generation, typically through renewable energy sources. Net Metering aims at maximizing the utilization of a renewable system installed at the consumer's premises through off-taking power through the electric grid at hours when the production of the system exceeds the consumer's own consumption. A consumer who installs an on-site renewable energy generator, primarily for reducing his own grid consumption, is now allowed to supply any surplus energy units from his installation to the electricity grid. These units are recorded and

[2] SRO 892 -2015

are later on “netted-off” (i.e., subtracted) against the units consumed from the grid. In this way, a Net Metering scheme provides an incentive to consumers to install decentralized renewable energy systems as it gives them the certainty that they will benefit from any electricity produced through the system, either through own consumption or through feeding it into the grid.

In this scenario, a bi-directional electric meter is placed between the consumer’s connection point and the grid and records any units drawn from the grid or fed into the grid.

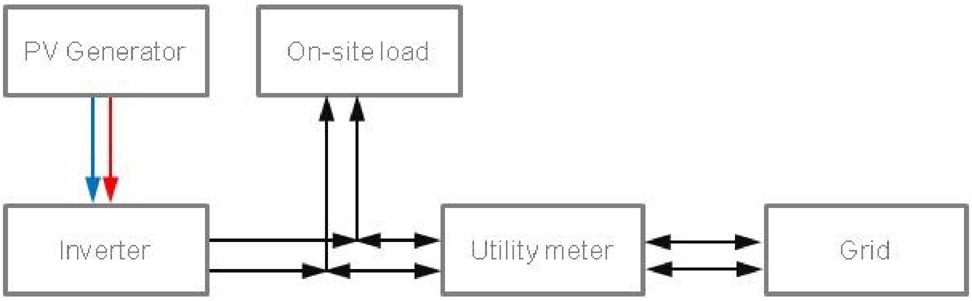

Figure 1: Typical Net-Metering: Consumption - Generation = Billed amount

Another scheme widely deployed uses the Feed-in Tariff. In such a system, an additional meter is placed directly after the renewable energy generation unit and is monitored by the utility company. This allows the utility company to monitor the electricity produced and provided to the grid with the flexibility to set a different tariff for these units. In the consumer case, this essentially results in the consumer having two separate connections with the utility company: One for monitoring of renewable energy production and another one for recording of energy consumed.

Feed-in Tariff schemes usually offer additional incentives such as long term purchase agreements with guaranteed grid access. The goal of such a scheme is to promote investment in the renewable energy systems on a small to medium scale via guaranteed returns.

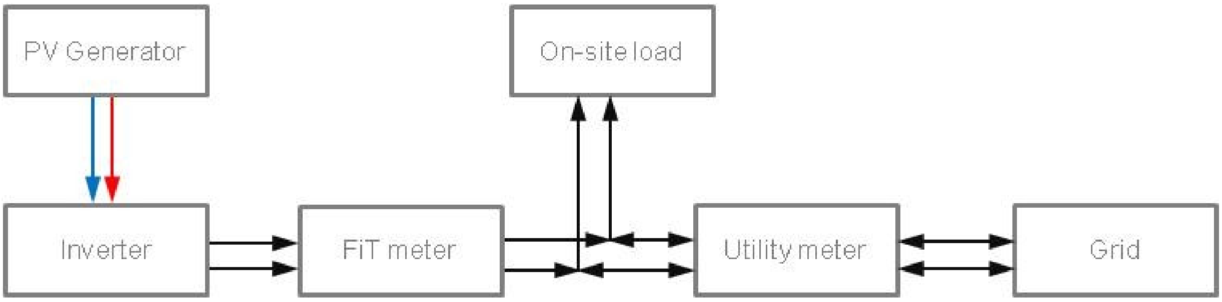

Figure 2: Typical Feed-in Tariff Connection:

Consumption = Billed amount
Generation = Billed amount

The Net Metering regulations enforced as of September 1st, 2015 also allow the consumer to get paid on quarterly basis for any excess electricity supplied which has not been consumed during this period, similarly to a Feed-in Tariff. The rate for the excess electricity units supplied to the grid is the off-peak rate of the connection.

D. Overview of Photovoltaic Technology

D.1. Basic Principles of Photovoltaic Technologies

Photovoltaic technology is based on the photoelectric effect, in which the light coming from the sun is converted directly into electric energy through a semiconductor in the solar cell. Photovoltaic modules differ primarily in the raw materials used for the solar cells and in the type of manufacturing process. This leads to different manufacturing costs and therefore price ranges on one side and different performances for the different technologies on the other. Further differences in technology concern the physical setup of a photovoltaic plant, i.e. the arrangement of the modules on the available space, whether or not the modules follow the sun through a mechanical tracking mechanism and how the electric connections (DC part, AC part, conversion between the two) are accomplished.

In economic terms, all of these different technical options are summed up in the specific cost (USD or PKR per kWp installed) and the module (or system) efficiency.

D.2. Performance Ratio and Losses

The Performance Ratio (PR) is the actual amount of electric energy produced by a solar power plant divided by the amount of energy that would ideally be expected based on the per solar irradiation, plant size and module efficiency. The actual electricity production amount of any solar power plant is always lower than the ideal amount due to losses in the system and due to defaults of material which is not immediately replaced (e.g. broken inverters etc.). Typical PRs of state-of-the-art solar power plants may range between 75% and 85%, depending on the location and plant configuration.

There exist different kinds of inherent systematic losses in a PV plant. These include shading losses, soiling losses, temperature losses, cable losses, module quality losses, conversion losses and further loss categories.

D.3. Solar Irradiance

The amount of annual solar irradiance is the most important local variable which influences the solar power plant yield (electricity generated throughout the year, given as kWh per m²). Sunshine in Pakistan is very favorable compared to other locations like Europe. However, even within Pakistan, solar resources vary considerably with higher irradiance numbers in the south of the country.

The estimated sunshine hours, available from measurements from different sources throughout the last decades, only indicate an average of many years while volatility from one year to another of up to 15% always needs to be expected[3].

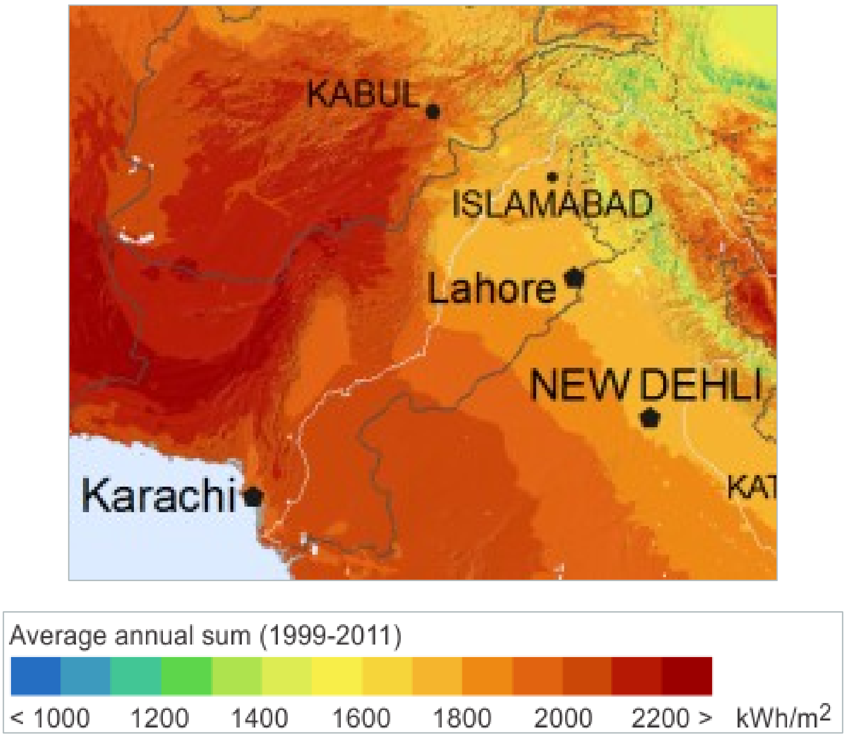

Figure 3: Global Horizontal Irradiance (GHI) for Pakistan, Dource: SolarGIS 2012

[3] Volker Quaschning „Unstete Planungsgröße“; Maximum deviation of measuring periods of different duration from the long-term average in the years 1937-1999 at the Potsdam/Germany site

E. Assumptions

This report provides a financial cost-benefit analysis of solar power plants of three different size categories for three different consumer types.

In Pakistan, hours of load-shedding and non-availability of the electric grid are common in most areas. Therefore, in most cases, a grid-connected solar power plant would typically not only be connected to the grid, but would also be used independently during times when the grid is not available (load-shedding) through a backup battery bank or by supporting a diesel generator. In this case, the overall system is a called a hybrid solar power plant.

The cost of such a hybrid solar power plant depends on comparative costs and the quality of service provided. In order to do this, the further analysis is based on three different system categories:

1. 5 kWp system for a Residential application,
2. 50 kWp system for a Commercial application,
3. 500 kWp system for an Industrial application.

For the development of business cases, the following assumptions and data sources i.e. irradiation, load profiles, tariff, grid availability etc. have been incorporated.

E.1. Irradiance and System Losses

The electricity generated from a solar power plant is mostly dependent on the actual (local) irradiance, on the characteristics of the solar modules and the system losses. For simulation, an average solar power plant with the ambient temperatures and irradiance in central Punjab has been used as a standard case[4]. The simulation of the performance of the solar power plant is based on a typical state-of-the-art technical concept. The result of the simulation provides an estimation of the potential electricity production of the solar power plant. The energy yield numbers in the model include the overall shading situation, a simulation of the yearly energy production, the determination of the Performance Ratio (PR) considering typical system losses, the calculation of the availability of the plant (planned and forced outages) and the long-term performance taking into account the module degradation.

Metrological data for Pakistan is readily available from three different sources, namely Meteonorm 7, SolarGIS, and NASA.

[4] The solar irradiation and other parameters can be varied in the model.

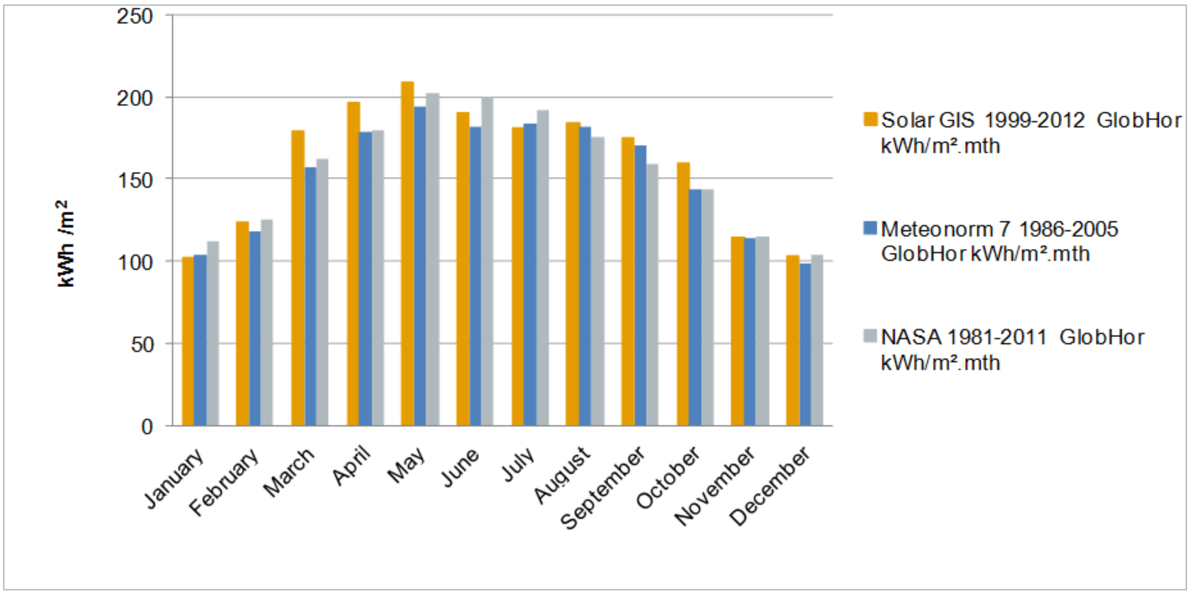

Figure 4: Results from different Sources for Irradiance Data at one location (Bahawalpur, average monthly sums; sources: Solar GIS, Meteonorm 7 and NASA)

The model used for the analysis is based on the estimated annual specific yield for a typical system at a specific location (kWh per year for every kWp installed) with Faisalabad, Punjab region, assumed as location for the base case.

E.2. Load Profiles

The load of the specific consumer, where the solar power plant is installed, influences the profitability of the solar power plant: In the case of diesel backup availability (which is assumed as the standard case), electricity produced by the solar power plant can be used to reduce diesel costs, as diesel generation is more expensive than electricity from the grid. In the case without diesel, in many instances there will be a battery backup system for covering local consumption during hours of load-shedding, so again the load has an influence on the solar power plant's profitability. Only in a scenario with zero load-shedding, the actual load of the consumer has no influence on the business case of distributed solar power plant – but such a scenario is not realistic in Pakistan at the moment[5].

For the economic analysis, a total load value is assumed as well as the correlation of load and direct solar production.

[5] See for example http://www.lesco.gov.pk/ShutdownSchedule

E.3. Grid Availability

In order to allow an export of electricity to the grid, the grid must be available. Any electricity produced during times when the grid is not available is lost – unless it is directly consumed by the local load or it is stored in a battery. Both of these options are only possible in a hybrid system. Grid non-availability is common in Pakistan and is mostly due to intended load-shedding by the DISCOs during such hours when the demand exceeds the supply. In the model used for this analysis, a specific estimated number of load-shedding hours per day has been assumed.

E.4. Battery and Diesel Backup

Due to the load-shedding situation, it is assumed that availability of a diesel generator backup is the standard case for commercial and industrial consumers participating in Net Metering in Pakistan. During the hours of load-shedding, the value of electricity from solar production then equals the cost of the same amount of diesel-generated electricity, as diesel is actually saved in the backup system. It is further assumed that the diesel backup is in operation all the time throughout times of load-shedding.

For the residential case, a battery backup system is assumed to be in place. In the case of a battery system, two kinds of benefits are considered: (1) Solar power generated during load-shedding can be either consumed or stored for later usage and is therefore not lost. (2) The available battery capacity can also function as an uninterruptible power supply (UPS) which means that grid electricity can be stored and consumed later during load-shedding hours, whether the sun is shining or not. In this case, the value attributed to every kWh consumed during load-shedding is the price for electricity generated via a diesel generator set.[6]

In the case of no backup system, solar electricity during the load-shedding hours is lost.

[6] As many consumers are ready to purchase a diesel backup system and pay the diesel cost with the only benefit of availing a continuous power supply, this shows that the fact of having this continuous power supply has a high value to these customers. For analysis purpose, it can therefore be assumed that also for the owners of a solar system including battery, every kWh consumed during the time of load-shedding has approximately the value of the corresponding cost of diesel.

E.5. Electricity Unit Cost Consideration

As per NEPRA regulations, the electricity units provided by the distributed generator will be purchased by the utility company at the off-peak rate of the respective consumer connection type. "Off-peak rate" is a term used in the Net Metering regulations which refers to the normal billing rate of electricity for a consumer. This is opposed to the "peak rate" which is a higher rate applicable to specific consumers mostly during four evening hours of the day as these are the hours of peak consumption. The rate of electricity per unit (kWh) applicable to the consumer determines the sales price of any units fed into the grid and is therefore needed to give a clear overview on the project feasibility and profitability.

The cost assumptions used for the solar power plant are based on the life cycle cost of each system category. Assumptions are taken for the following cost items: initial investment, regular operation & maintenance, replacement costs in the case of battery storage[7].

E.6. Economic Assumptions

For this study, off peak electricity costs of 12.5 PKR/kWh and peak electricity costs of 18 PKR/kWh including surcharges (FESCO tariff) have been considered.

The diesel generation cost is assumed to be 27 PKR/kWh (80 PKR/liter at an efficiency of 30% of the generator)[8].

Costs for solar power plants are commonly given as benchmark rates as the market for photovoltaic plants and components is quite standardized on the international level. Rates assumed here are 130 PKR/Wp (1.24 USD/Wp at current exchange rate[9]) for the plant sizes of 5 kWp and 50 kWp, and 120 PKR/Wp (1.14 USD/Wp) for a plant size of 500 kWp[10]. Recurring operation and maintenance costs (O&M) for the solar power plant are assumed to range between 3,000 PKR/kWp and 1,500 PKR/kWp per year, according to the plant size. These cost rates are typical standard rates achieved in developed solar PV markets[11].

An average annual energy price increase of 5% is assumed which affects both electricity and diesel prices. The average annual increase of the CPI in Pakistan during the last few years

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[7] For batteries, full replacement after 4 years is assumed as the number of assumed cycles is very high (2-6 per day, according to the number of load-shedding hours).

[8] Average diesel price (HS Diesel) in Pakistan during the last year was PKR/liter 79.785 according to PakBiz (http://pakbiz.com/finance/petroleumprices.html). Currently, the price is about PKR/liter 72.

[9] See for example http://www.xe.com/currencycharts/?from=USD&to=PKR&view=5Y

[10] The technical setup which is assumed here and which corresponds to the mentioned costs is the most common of the last years for decentralized PV systems: Polycrystalline Silicone modules installed on a fixed structure.

[11] Costs for some technical equipment might be slightly higher in Pakistan as the solar market is not yet fully developed, but costs for man power are lower which compensates these effects.

has been 8%[12], but as the model looks at the lifetime of the solar power plant of 25 years, a continuous increase of 8% is assumed as too high. A more conservative CPI value of 5% is chosen instead. This is an important value as the initial costs of the solar power plant represent a fixed value while the revenues generated every year depend strongly on the price development of electricity and diesel throughout the lifetime of the plant.

For the financing scenarios, a debt ratio of 75% with 10 years debt tenor is assumed as well as an interest rate of 10%[13]. Apart from the financing scenarios, result numbers are also given on equity only basis, without external finance.

As all financial numbers in this report are denominated in PKR, the conversion rate between United States Dollars (USD) and Pakistani Rupees (PKR) is not needed as an assumption. The effect of the exchange rate on the development of the CPI is assumed to be included in the above assumption and is not considered separately.

[12] http://www.tradingeconomics.com/pakistan/consumer-price-index-cpi: Annual CPI increase of 8.0% between 2010 and 2016. Between 2006 and 2016, annual increase is even 9.6%.
[13] Assumption: Current KIBOR rate + 3% margin. KIBOR is 6.95 according to latest available information, so KIBOR + 3% is 10%. See e.g. http://www.pakistaneconomist.com/c-database/kibor.php - “3 years, Offer”

F. Simulation Model

8.2 Obst & Ziehmann International has developed a simple but realistic simulation model specifically for this project[14]. The results are presented in the following chapter.

The model uses the following input parameters:

- Load and solar power plant data:
  - Electric load data of one year
  - Solar power plant capacity
  - Battery storage capacity
- Site-specific data:
  - Hours of load-shedding per day
  - Specific solar yield at the given site (in annual kWh/kWp[15])
  - Cost of electricity (off-peak and peak)
  - Existence of a diesel backup system (yes or no)
- Finance details:
  - Specific solar costs (PKR/Wp installed)
  - Fixed costs
  - Battery costs
  - O&M costs

The main results of the model are as follows:

- Payback period in years
- Net present value (NPV) of the solar power plant
- Internal rate of return (IRR) (with and without debt finance)

Besides the main results, several intermediary results are also calculated such as annual savings on solar power, percentage of load which is covered by solar power, percentage of solar power which is exported to the grid and which is used for diesel savings.

[14] The simple model is supported by a more complex simulation tool using hourly data for load, load-shedding and solar production for a whole year which is used by the consultant for detailed case specific evaluations for feasibility studies.
[15] The kWh/kWp value is a similar number as the site-specific irradiance value kWh/m² from chapter D.3, but includes other factors such as site temperature and technical losses of the system.

G. Business Cases

For demonstration, the scenarios for the three analyzed cases are defined as follows:

1. A residential solar power plant with an installed capacity of 5 kWp at a home with an annual electricity consumption of 15,000 kWh (solar coverage[16]: about 50%)
2. A commercial solar power plant with an installed capacity of 50 kWp at a shop with an annual electricity consumption of 100,000 kWh (solar coverage: about 75%)
3. An industrial solar power plant with an installed capacity of 500 kWp at a factory site with an annual electricity consumption of with 1 million kWh (solar coverage: about 75%)

[16] Solar coverage here means: Total annual amount of electricity produced through solar divided by total annual load. As load and solar often do not coincide (e.g. evening hours), even for a 100% coverage case, there are still many situations throughout the year where grid electricity is consumed.

G.2. Residential System

For the residential system, an electricity consumer (three-phase) with the following parameters is chosen:

- Annual electric consumption: 15,000 kWh (average consumption: 1.7 kW)
- Hours of load-shedding: 6 hours per day[17] - Faisalabad
- Generator backup system: Yes
- Electricity price including surcharges: 12.5 PKR/kWh / 18 PKR/kWh (normal / peak rate) – FESCO price
- Diesel price: 80 PKR/liter

These parameters represent a typical upper middle-class household in Faisalabad city. The installed solar power plant for this consumer is assumed with the following parameters:

- Installed capacity: 5 kWp
- Additional battery backup: 3 kWh (This allows almost 2h until full discharge at average load or about 1h until full charge at maximum solar power output.)

The cost breakdown for this system is given in the table below.

No.	Equipment & Services	Cost (PKR)
1	String Inverter (hybrid, 4 kW)[18]	200,000
2	Polycrystalline PV Modules and DC Wiring	325,000
3	Mounting Structure	81,250
4	Battery system (3 kWh)	120,000
5	Planning, Studies, Quality Assurance	16,250
6	Installation	65,000
7	Contingencies & others (fix amount, includes licensing)	50,000
8	Grid Study (only if installed capacity exceeds 10 kWp)	-
9	**Total System Cost**	**857,500**
10	Annual O&M Cost	15,000
11	Annual Battery Replacement Cost[19]	25,200

Table 1: Cost Break Down - Residential System

The specific costs for the solar power plant are 130 PKR/Wp for the basic solar plant (excluding battery, hybrid functionality of inverter, fixed contingencies) in this case. Including

[17] 6-8 hours, depending on the month of the year, is a typical value for most cities in Pakistan (2015/2016 situation).

[18] Cost of this inverter is 42,500 PKR higher as compared to normal inverters, as it is a hybrid inverter which is able to run an island grid during load-shedding hours and thus allows the operation of electric consumers during this time.

[19] The battery system is assumed to be replaced every 4 years during which it can run up to 3,500 cycles.

everything, the specific investment costs amount 172 PKR/Wp. These are realistic prices for Pakistan in 2016, assuming no complicated installation.

The following figure shows the cash flow development of this project. As for all renewable energy installations, there is high initial equity investment after which annual savings or revenues can be seen. In the case of debt financing, the initial equity investment is much smaller, and the annual returns during the first 10 years are even negative due to battery replacement and O&M costs as well as debt repayment.

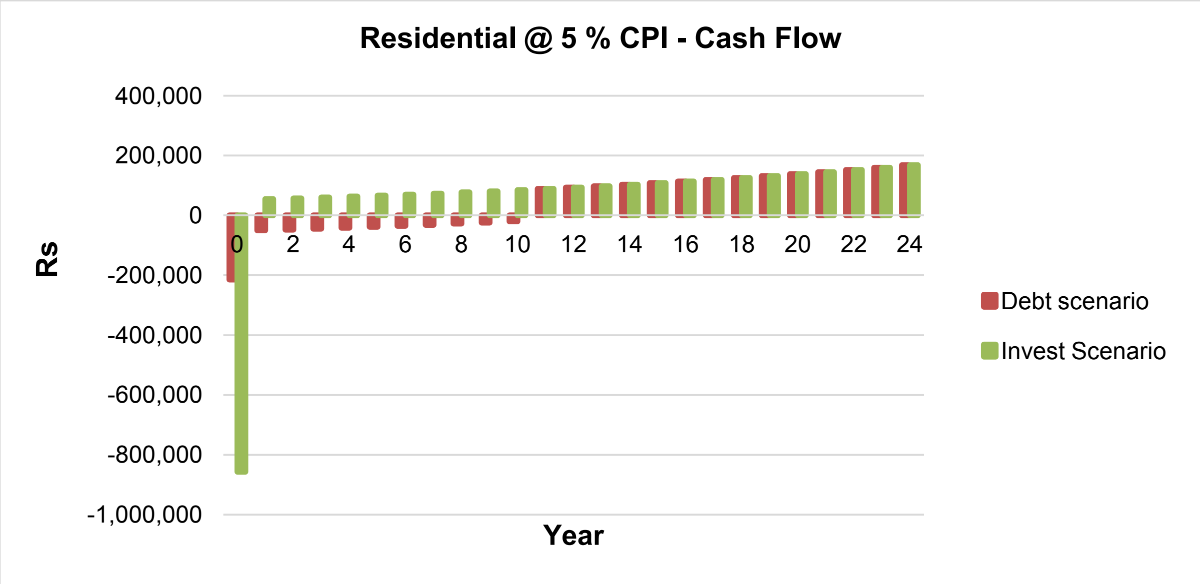

Figure 5: Annual Cash Flow - Residential System
(with battery; considering only solar storage benefit of the battery)

In this case, the payback period on the investment is 15.7 years when considering only the solar storage effect of the battery (see E.3, benefit (1)). When considering additionally the added value of storage for continuous electricity supply, the payback period is 10.4 years. Without any battery system, the payback period is 12.5 years.

The main reason for the relatively long payback period is the load-shedding (6 hours in this case): Without battery, all solar power generated during these hours is lost as there is no backup system. By integrating a battery, the solar power during load-shedding hours can be utilized, but the additional cost of the battery significantly increases both the capital and the operational expenses. For comparison, in a scenario without any load-shedding, the payback period would drop below 9 years.

The following table shows the financial assumptions for the residential case.

Specific cost solar only (PKR/Wp)	130
Inflation / CPI increase (% p.a.)	5 %
Debt case:	
Debt (% of total)	75 %
Interest rate (%)	10 %
Tenor (years)	10

Table 2: Financial Assumptions of Residential Case

The following table shows the financial results of the residential case.

	With battery, assuming both solar storage and continuous supply value[20]	**With battery, assuming only solar storage value**	**Without battery**
Investment	857,500 PKR	857,500 PKR	700,000 PKR
Payback (years)	10.4	15.7	12.5
NPV	229,309 PKR	-110,950 PKR	50,345 PKR
IRR (unleveraged)	11%	8%	11%
IRR (leveraged)	11%	8%	11%

Table 3: Financial Results of Residential Case

[20] see E.3

G.3. Commercial System

For the commercial solar power plant, an electricity consumer with the following parameters is chosen:

- Annual electric consumption: 100,000 kWh (average consumption: 11 kW)
- Hours of load-shedding: 4 hours per day[21]
- Generator backup system: Yes
- Electricity price including surcharges: 12.5 PKR/kWh / 18 PKR/kWh (normal / peak rate) – FESCO price
- Diesel price: 80 PKR/liter

These parameters represent a typical multi-storey shop with several air-conditioning units in Faisalabad city.

The installed solar power plant for this consumer is chosen with the following parameters:

- Installed capacity: 50 kWp
- Additional battery backup: 0 kWh

As there is a generator system in place, no battery system is assumed.

The cost breakdown for this system is given in the table below.

No.	Equipment & Services	Cost (PKR)
1	String Inverter (40 kW)	1,625,000
2	Polycrystalline PV Modules and DC Wiring	3,250,000
3	Mounting Structure	812,500
4	Battery system	-
5	Planning, Studies, Quality Assurance	162,500
6	Installation	650,000
7	Contingencies & others (fix amount, includes licensing)	100,000
8	Grid Study (only if installed capacity exceeds 10kWp)	100,000
9	**Total System Cost**	**6,700,000**
10	Annual O&M Cost (Battery Replacement, Repair etc.)	100,000
11	Annual Battery Replacement Cost	-

Table 4: Cost Break Down- Commercial System

[21] For the commercial system, a slightly lower number of hours (4 instead of 6) of load-shedding is assumed as a conservative case under the assumption that commercial buildings are slightly privileged in the load-shedding schedules compared to residential buildings.

The specific costs for the solar power plant amount 130 PKR/Wp (134 including fix contingencies and grid study), which is a realistic assumption for Pakistan in 2016, assuming no complicated installation.

The following figure shows the cash flow development of this project. The characteristics are similar to that of any renewable energy project: High initial equity investment and stable annual revenues later on. In the case of debt financing, the initial equity investment is much smaller, and the annual revenues are decreased by debt installments during the first 10 years.

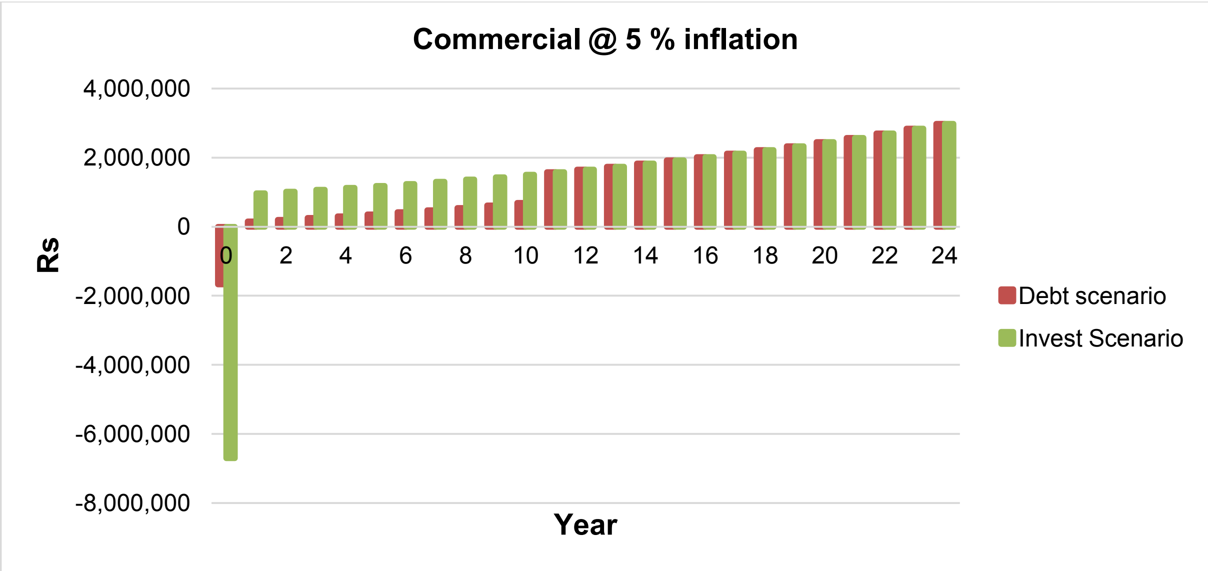

Figure 6: Annual Cash Flow – Commercial System

The payback period of the investment in this case amounts to 6.9 years. The reason for the shorter payback period as compared to the residential case is mainly that solar electricity during load-shedding hours replaces expensive diesel as fuel which is highly profitable. Economies-of-scale effects in the O&M costs of 33% (2,000 PKR/kWp instead of 3,000 PKR/kWp) also contribute to the lower payback term.

The assumed amount of hours of load-shedding positively effects the payback period as more solar energy can be used for the lucrative diesel replacement; e.g. 6 hours of load-shedding instead of 4 lead to a payback period of 6.5 years.

Because of the expensive cost of electricity produced via the diesel backup system which can be avoided through solar power generation, a change in diesel price affects the profitability of the solar power plant: Assuming a diesel price of 72 PKR/liter (current rate in Pakistan at the moment of publishing of this document), the payback period becomes 7.1 years, whereas for a diesel price of 100 PKR/liter, the payback becomes 6.4 years.

The following table shows the financial assumptions for the commercial case.

Specific cost solar (PKR/Wp)	130
Inflation / CPI increase (% p.a.)	5%
Debt case:	
Debt (% of total)	75%
Interest rate (%)	10%
Tenor (years)	10

Table 5: Financial Assumptions of Commercial Case

The following table shows the financial results of the commercial case.

Investment	**6,700,000 PKR**
Payback (years)	6.9
NPV	5,778,419 PKR
IRR (unleveraged)	19%
IRR (leveraged)	26%

Table 6: Financial Results of Commercial Case

G.4. Industrial System

For the industrial system, an electricity consumer with the following parameters is chosen:

- Annual electric consumption: 1,000,000 kWh (average consumption: 114 kW)
- Hours of load-shedding: 4 hours per day[22]
- Generator backup system: Yes
- Electricity price including surcharges: 12.5 PKR/kWh / 18 PKR/kWh (normal / peak rate) – FESCO price
- Diesel price: 80 PKR/liter

These parameters represent a medium-scale industrial site including an office building and a factory with electric driven machinery in Faisalabad city.

The installed solar power plant for this consumer is chosen with the following parameters:

- Installed capacity: 500 kWp
- Additional battery backup: 0 kWh

As there is a generator system in place, no battery system is assumed.

The cost breakdown for this system is given below in table below.

No.	Equipment & Services	Cost (PKR)
1	String Inverter (400 kW)	15,000,000
2	Polycrystalline PV Modules and DC Wiring	30,000,000
3	Mounting Structure	7,500,000
4	Battery System	-
5	Planning, Studies, Quality Assurance	1,500,000
6	Installation	6,000,000
7	Fix Costs (Licensing, Initial Planning, etc.)	100,000
8	Grid Study (only if installed Power exceeds 10kWp)	100,000
9	**Total System Cost**	**60,200,000**
10	Annual O&M Cost (Battery Replacement, Repair etc.)	750,000
11	Annual Battery Replacement Cost	-

Table 7: Cost Break Down- Industrial System

[22] Same assumption as for the commercial case.

The specific costs for the solar power plant are 120 PKR/Wp in this case. This is less than the cost for residential and commercial case as better equipment prices can be achieved for this size.

The following figure shows the cash flow development of this project. The characteristics are similar to the commercial case: High initial equity investment and annual savings later on.

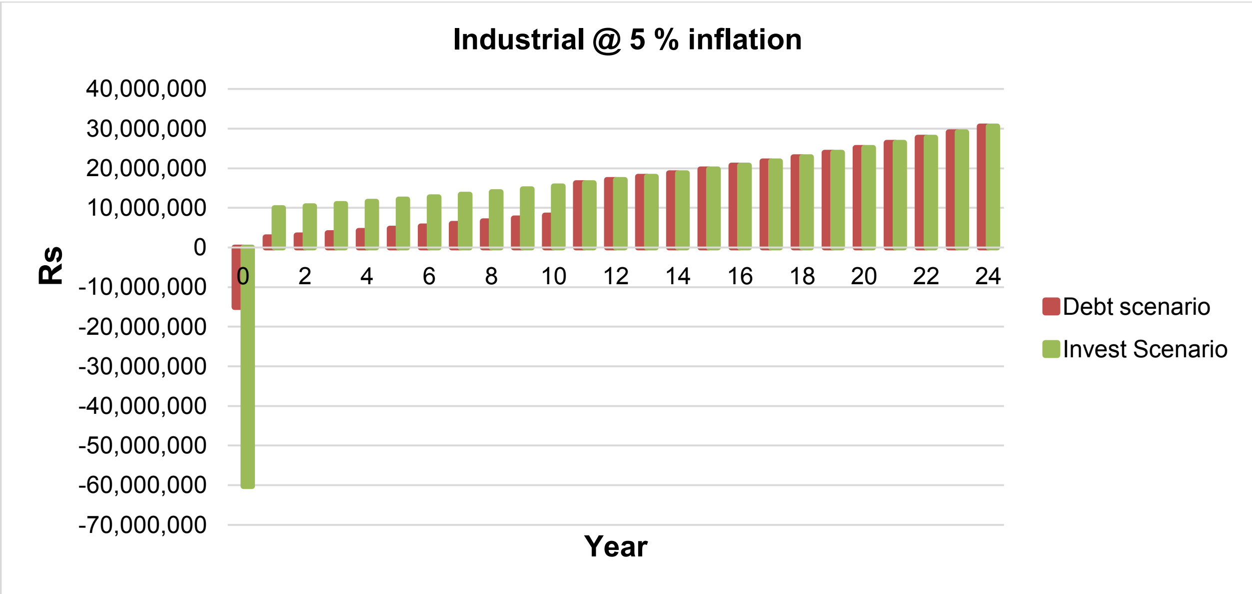

Figure 7: Annual Cash Flow – Industrial System

In this case, the payback period on the investment amounts to 6.0 years. The reasons for better payback period compared to the residential and commercial cases are the lower investment cost and further economy-of-scales effects in the O&M costs. Assuming a diesel price of 72 PKR/liter, the payback period becomes 6.2 years whereas for a diesel price of 100 PKR/liter, the payback becomes 5.6 years.

The following table shows the financial assumptions for the industrial case.

Specific cost solar (PKR/Wp)	120
Inflation / CPI increase (% p.a.)	5 %
Debt case:	
Debt (% of total)	75 %
Interest rate (%)	10 %
Tenor (years)	10

Table 8: Financial Assumptions of Industrial Case

The following table shows the financial results of the industrial case.

Investment	**60,200,000 PKR**
Payback (years)	6.0
NPV	67,023,147 PKR
IRR (unleveraged)	21%
IRR (leveraged)	32%

Table 9: Financial Results of Industrial Case

H. Sensitivity Analysis

For the sensitivity analysis, the commercial case is assumed as the base case. Based on this base scenario, deviations in the different assumptions have been applied and their effect on the financial results has been observed. The result is shown in the following table.

	Payback (years)	IRR (unleveraged)	IRR (leveraged)[23]
Base case (50 kWp, load 100,000 kWh/year, hours of load-shedding 4 per day, annual output of solar 1,518 kWh/kWp = Faisalabad area, inflation rate for energy prices 5%, cost for PV 130 PKR/Wp)	6.9	19%	26%
Load 50,000 kWh/year	8.1	16%	21%
Load 200,000/year	6.5	20%	29%
Hours of load-shedding 2 per day	7.4	18%	24%
Hours of load-shedding 6 per day	6.5	20%	29%
Annual solar output 1,400 kWh/kWp	7.5	18%	24%
Annual solar output 1,600 kWh/kWp	6.6	19%	28%
Inflation rate for energy prices 3%	6.9	17%	23%
Inflation rate for energy prices 7%	6.9	21%	30%
PV costs 120 PKR/Wp	6.4	20%	30%
PV costs 140 PKR/Wp	7.4	18%	24%

Table 10: Financial Results of the commercial case for different assumptions (sensitivity analysis)

It can be seen that all the applied factors have a certain impact on the payback period and the IRR. The payback periods range from 6.4 years up to 8.1 years while the IRR rates range from 16% up to 21% (equity case/project IRR) and from 21% to 30% (finance case).

[23] Assumed finance conditions are the same as for the above chapters; see e.g. Table 5: Financial Assumptions of Commercial Case.

I. LCOE Calculation

The following table shows the levelized costs of electricity (LCOE) for the three discussed cases under different assumptions:

- LCOE at 5% discount rate (=assumed inflation rate)
- LCOE at 10% discount rate (=assumed cost of capital / debt interest rate)
- LCOE at 5% discount rate without a diesel backup, so all energy produced during load-shedding hours is lost

It can be clearly seen that the LCOE vary according to the conditions (plant size, discount rate, existence of a diesel backup). Note that the difference between cases “residential” and “commercial” is significant for the “no diesel backup” scenario as the assumed hours of load-shedding differs between these cases (6h per day for residential case, 4h for commercial and industrial case). For comparison, the cost of diesel based generation assumed in the simulation is 26.7 PKR/kWh (considering only the fuel costs of 80 PKR per liter).

All in: PKR/kWh	Residential PV (5 kWp)	Commercial PV (50 kWp)	Industrial PV (500 kWp)
LCOE @ 5% discount rate	12.4	7.1	6.2
LCOE @ 10% discount rate	16.0	9.9	8.8
LCOE @ 5% d.r., w/o diesel backup (energy lost during load-shedding)	16.6	8.5	7.4

Table 11: Levelized Costs of Electricity (LCOE) for different Options (PKR/kWh)

J. Conclusion

The future deployment of Net Metering in Pakistan strongly depends on the profitability of its application. In this document and the associated model, three different cases of distributed solar generation in combination with Net Metering have been presented: a residential case (5 kWp capacity), a commercial case (50 kWp) and an industrial case (500 kWp). The following conclusions can be drawn from this analysis:

- The profitability of Net Metering strongly depends on the load-shedding situation: If no backup system is used, every hour of grid disconnection per day decreases the profitability of solar power plants as available solar power is lost. If a diesel system backup is assumed as the base case, the profitability of a solar power plant becomes better for longer periods of grid disconnection as high expenses due to diesel costs are saved through solar power. Where no diesel backup is present, the economic advantage of adding a battery system together with the solar installation compared to not using a backup system depends on the assumptions taken (i.e. the battery control system, inverter type and economic assumptions). However, the profitability of the total plant including battery is always lower than for the situation without any load-shedding at all due to the high battery costs.

- The installed capacity of the solar power plant also affects the profitability: if the system is too small, the specific costs for the equipment and some fixed costs for installation will increase. On the other hand, if the solar power plant is of comparatively large size so that its annual production exceeds the consumption of the consumer, then its production will be mostly be fed into the grid via net metering and not consumed locally which, in the case of a diesel backup, reduces the percentage of diesel replacement and therefore the overall benefits.

- The site of the solar power plant also influences strongly its profitability, not only through the grid availability situation, but also through the amount of sunshine available throughout the year. Generally speaking, locations placed further in south of Pakistan have more sunshine and therefore a better profitability potential.

- Other obvious influencing factors are the diesel price (higher price = higher savings through solar), the electricity price development (higher annual price increase = higher revenues of solar), loan conditions for the debt financing case and last but not the least, the general price which is achieved for the capital expenditure of the solar power plant installation itself.

- The payback periods for the modeled cases vary from 6 to about 15 years (Faisalabad case). The payback periods in reality will always vary, e.g. the payback period will be better in Karachi than in Faisalabad, worse if diesel replacement is not considered and it will vary according to the achievable equipment prices and actual system performance as well as - last but not least – the actual inflation in energy costs during the next years.

The introduction of the Distributed Generation and Net Metering Regulations is an important step into a decentralized energy policy for Pakistan, based on locally available resources. The first Net Metering “pioneers” are expected to be consumers who already have solar power plants installed to cope with grid unavailability.. Secondly, early adaptors are expected to be industrial companies seeking investment in renewable energy sources.

Compared to other countries which have introduced Net Metering Regulations, the profitability of decentralized solar power plants in Pakistan is currently modest due to the relatively low electricity prices and loss of solar power due to load-shedding (where no backup system is in place). Therefore the market share of distributed generation systems is expected to rise steadily, but at a modest rate unless additional benefits are provided to distributed generators.

K. Appendix – Suggested tools for individual cases

Yield Estimation – Simplified Model PVGIS

To allow location specific Solar Energy Simulation, the free accessible tool PVGIS http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?map=africa can be used. The specific site needs to be selected on the map or the latitude and longitude need to be introduced and parameters should be adjusted as given in figure below.

Figure 8: Site Selection – PVGIS

This tool also provides the user with options of different parameters which are needed for a simple simulation.

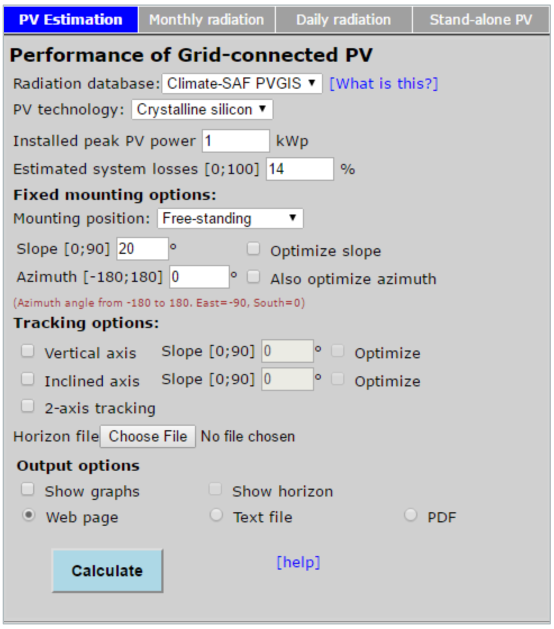

Figure 9: Parameters – PVGIS

- Options: PV technology used (Crystalline silicon, CIS, CdTe)
- Mounting position
- Tracking options

After selecting the different parameters and calculations, the output is presented as follows

Location Samundri: 31°2'36" North, 72°53'39" East, Elevation: 171 m a.s.l.,

Solar radiation database used: PVGIS-CMSAF
Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature and low irradiance: 15.1% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 2.9%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 29.1%

E_d: Average daily electricity production from the given system (kWh)
E_m: Average monthly electricity production from the given system (kWh)
H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Fixed system: inclination=20°, orientation=0°				
Month	***E_d***	***E_m***	***H_d***	***H_m***
Jan	3.18	98.6	4.16	129
Feb	3.78	106	5.08	142
Mar	4.71	146	6.59	204
Apr	4.74	142	6.88	206
May	4.82	149	7.17	222
Jun	4.45	133	6.61	198
Jul	4.21	130	6.14	190
Aug	4.28	133	6.20	192
Sep	4.38	131	6.31	189
Oct	4.21	130	5.98	185
Nov	3.62	109	4.94	148
Dec	3.48	108	4.59	142
Yearly average	**4.15**	**126**	**5.89**	**179**
Total for year	**1520**		**2150**	

Figure 10: Solar Irradiance – PVGIS

The 8.2 Economic Model used for this Report

Business Case Solar Net Metering - 3 Cases

Author: 8.2 Obst & Ziehmann International GmbH
Version: 10-06-2016

		Select	Residential	Commercial	Industrial
Load & Solar Power Plant					
Annual Consumption	kWh/a		15,000	100,000	1,000,000
Average Consumption	kW		1.7	11	114
Noon Peak	kW		7	34	285
Solar System Size	kW		5	50	500
Batteries - Usable Size	kWh		3.0	0	0
Site (Load Shedding, Grid Prices & Irradiance)					
Hours of Load-Shedding	h / day		6	4	4
Grid Availability	%		75%	83%	83%
Specific Output of Solar Panels at given Location		kWh/kWp	1518	1518	1518
Cost of Off-Peak Electricity	PKR/kWh		12.5	12.5	12.5
Cost Peak Electricity	PKR/kWh		18.0	18.0	18.0
Weighted Average Electricity Price			13.4	13.4	13.4
Cost of Diesel	PKR/liter	80	26.7	26.7	26.7
Diesel backup (true/false)			FALSE	TRUE	TRUE
Finance Details					
Debt	%		75%	75%	75%
Interest Rate	%		10%	10%	10%
Tenor	years		10	10	10
Inflation	%p.a.	5%	5%	5%	5%
Cost (CAPEX)					
Fix Costs (Licensing, Initial Planning, etc.)			50,000	100,000	100,000
Grid Study			0	100,000	100,000
Specific Cost Solar	PKR/Wp		130	130	120
	PKR/kWp		130,000	130,000	120,000
Costs of Battery			120,000	0	0
Total Cost	**PKR total**		**857,500**	**6,700,000**	**60,200,000**
PV Modules	PKR total	50%	325,000	3,250,000	30,000,000
Inverter	PKR total	25%	200,000	1,625,000	15,000,000
Mounting Structures	PKR total	13%	81,250	812,500	7,500,000
Planning, Studies, Quality Assurance	PKR total	3%	16,250	162,500	1,500,000
Installation	PKR total	10%	65,000	650,000	6,000,000

Cost (OPEX)

Battery Costs, specific	PKR/kWh	40,000	40,000	40,000
Battery Costs for this Project	PKR	120,000	0	0
O&M Costs	PKR/a	15,000	100,000	750,000
Battery replacement costs (100% every 2 years)	PKR/a	25,200	0	0
O&M Cost including Battery	PKR/a	40,200	100,000	750,000

Results

Invest	PKR	857,500 PKR	6,700,000 PKR	60,200,000 PKR
Payback (years)	**Years**	**15.7**	**6.9**	**6.0**
NPV		- 110,950 PKR	5,778,419 PKR	67,023,147 PKR
IRR		8%	19%	21%
IRR with Finance		**8%**	**26%**	**32%**
Actual Solar Coverage Net Metering	%	51%	74%	74%
LCOEs	PKR/kWh	16.6 PKR	7.1 PKR	6.2 PKR

Solar Production & Savings Calculations

Solar Production

System Noon Coverage (approx.)		44%	88%	105%
Direct Solar Coverage	%	71%	80%	80%
Potential Solar Production	kWh	7,590	75,900	759,000
Solar Gross Coverage	%	51%	76%	76%

Savings (Electricity)

Direct Savings	kWh	7,590	63,000	630,000
Net Metering Revenues	kWh	0	10,750	107,500
Potential Storage	kWh	0	2,150	21,500
Storage Revenues	kWh	0	0	0
Total Solar Revenues	kWh	7,590	73750	737500
Averge Direct Saving Value	PKR/kWh	12.50	14.86	14.86
Net kWh Savings	kWh/kWp	1,518	1,475	1,475
Net Saving Value	PKR/kWh	12.50	14.52	14.52

Savings (PKR)

Direct Savings	PKR/a	94,875	936,250	9,362,500
Net Metering Revenues	PKR/a	0	134,375	1,343,750
Storage Revenues	PKR/a	0	0	0
O&M Cost and battery replacement	PKR/a	40,200	100,000	750,000
Annual Savings	PKR/a	54,675	970,625	9,956,250

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