No. DOPP/305/Villages /2020
DIRECTORATE OF POWER PROJECTS
ENERGY DEPARTMENT
GOVERNMENT OF THE PUNJAB
206 Shadman-I, Opposite Rehmania Masjid Lahore.
(Ph: 042-99203520-23, Fax: 042-99203519)

15724

Dated: 26 / 10 /2020

To

The Registrar NEPRA,
NEPRA Tower, Atta Turk Avenue,
G5/1,Islmabad.

Subject: - APPLICATION OF LICENSE OF POWER GENERATION FOR MICRO PLANT (300 KWP SOLAR AND 50 KW BIOGAS PLANT) AT VILLAGE 563 / E B, VEHARI FOR THE PROJECT "ENERGY SOLUTION USING INDIGENOUS RESOURCES IN VILLAGES"

Kindly refer to meeting chaired by the Chairman NEPRA held at NEPRA office on 13-02-2020 for the tariff settlement of the project and also refer to CEO, MEPCO Office letter no: 2616/CE/MEPCO/CSD/D (MKT)/PP-61/21403-11 dated: 05-10-2020(Copy attached) for the subject cited project.

2. In this regard, It is informed that the said project has been executed by Punjab Energy Department with engagement of Contractor M/S Dynamic Green (Pvt) Ltd-Fauz Engineering-Bio Tech (JV). The project is 100% owned by Government of Punjab and this license application is being submitted in the name of Director Projects, Directorate of Power Projects (DoPP), Energy Department, Lahore. **(Documents of checklist are attached)**

4. It is further informed that, the license is being applied under mutual agreement / consent of MEPCO and Punjab Energy Department for power purchase. Besides, as the license application being submitted with 100% ownership of Govt. of the Punjab; therefore, the following clauses are not applicable:

3(1)	Authorization from Board Resolution / Power of Attorney
3(5)(a)(i)	Certified Copies of Certificate of incorporation (Certified by SECP)
3(5)(a)(ii)	Certified Copies of Memorandum and articles of association (Certified by SECP)
3(5)(a)(iii)	Certified Copies of Last Filed Annual Return of the company (Certified by SECP)
3(5)(d)(i)	Cash balance held in reserve along with the bank certificates
3(5)(d)(ii)	Expression of interest to provide credit or financing along with sources and details thereof
3(5)(d)(iii)	Latest financial statements of the company

6. In view of the above, the application (Triplicate Copies) is being submitted for further disposal and issuance of license for power generation. An earliest processing of the application will be highly appreciated.

DIRECTOR PROJECTS

C.C.

1. The Chief Engineer (Power), Government of the Punjab, Energy Department, Lahore.
2. M/S 8. 2 Renewable Energy experts Pakistan (Pvt) Ltd – 8.2 Obst & Ziehmann International GmbH (JV) 60 H, Gulberg-III, Near Fardoos Market, Lahore.(Consultant)
3. M/S Dynamic Green (Pvt) Ltd-Fauz Engineering-Bio Tech (JV) 109-1, Block-C, Model Town, Lahore. (Contractor)

ENERGY DEPARTMENT
GOVERNMENT OF THE PUNJAB
206 Shadman-I, Opposite Rehmania Masjid Lahore.
(Ph: 042-99203520-23, Fax: 042-99203519)

Dated: 05 / 11 /2020

To

The Registrar NEPRA,
NEPRA Tower, Atta Turk Avenue,
G5/1,Islmabad.

Subject: - APPLICATION OF LICENSE OF POWER GENERATION FOR MICRO PLANT (300 KWP SOLAR AND 50 KW BIOGAS PLANT) AT VILLAGE 563 / E B, VEHARI FOR THE PROJECT "ENERGY SOLUTION USING INDIGENOUS RESOURCES IN VILLAGES"

Kindly refer to the Power Generation License Application submitted by this office vide letterNo. DoPP/305/DoPP/Villages/2020 dated: 22-10-2020 (Copy attached) for the subject cited project.

2. In this regard, it is requested to kindly grant exemption from the section 24, NEPRA Act-1997 for processing the ssaid Power Generation License Application.

DIRECTOR PROJECTS

C.C.

1. The Chief Engineer (Power), Government of the Punjab, Energy Department, Lahore.
2. M/S 8. 2 Renewable Energy experts Pakistan (Pvt) Ltd – 8.2 Obst & Ziehmann International GmbH (JV) 60 H, Gulberg-III, Near Fardoos Market, Lahore.(Consultant)
3. M/S Dynamic Green (Pvt) Ltd-Fauz Engineering-Bio Tech (JV) 109-1, Block-C, Model Town, Lahore. (Contractor)

MEPCO

Office of the, Chief Executive Officer, MEPCO Multan

No.2616/CE/MEPCO/CSD/D (MKT)/PP-61/21403-11 Dated 05 OCT 2020

The Registrar,
NEPRA Tower, Atta-turk Avenue,
G-5/1, Islamabad

Power Project Directorate Energy Deptt Lahore Diary No 547 Date 7/10/2020

Subject: **DETERMINATION OF TARIFF FOR PURCHASE OF POWER (300KW+50KW) FROM ENERGY DEPARTMENT GOVT OF PUNJAB THROUGH THE PROJECT "ENERGY USING INDIGENIOUS RESOURCES IN VILLAGES" INSTALLED AT CHAK NO.563/EB VEHARI**

Ref: Your office letter No. NEPRA/MCM-02/4799-03 dated 11.02.2020.

It is submitted that a meeting at NEPRA headquarter Islamabad was held on 13.02.2020 at 03:00PM for determination of tariff regarding subject matter. After discussion NEPRA advised representative of MEPCO and Power Producer to mutually decide energy purchase rate and NEPRA will determine tariff of power purchase in the light of mutual decision of both the parties.

It has been mutually decided that the tariff in subject matter may be **"MEPCO Average Purchase Rate of energy as in case of Net Metering"**

It is therefore requested to please determine the tariff as mutually decided for subject matter at the earliest as per procedure, after issuing of Generation Licence in this regard to proceed further into the matter.

(Engr. Ahsan Mohy-ud-Din)
General Manager (CS)
MEPCO Multan

CC: to

1. Chief Executive Officer MEPCO Multan.
2. Chief Engineer (P&E) MEPCO Multan.
3. Chief Engineer Strategic Planner MEPCO Multan.
4. Finance Director MEPCO Multan.
5. Manager (Marketing, Tariff & CM) MEPCO Multan.
6. SE (OP) MEPCO Circle Vehari.
7. Project Director (Construction) MEPCO Multan.
8. Director of Power Projects Energy Department Govt of Punjab 206, Shadman-I Lahore.

PROSPECTUS

Project: 300 KWp solar and 50 KW biogas integrated micro plant at Village 563 / E B Vehari

Scope:

1) Govt of Punjab keeps on taking initiatives for the rural welfare and has totally funded this project itself.

2) The project was envisaged to install two pilot projects for 24/7 electricity availability in rural communities using indigenous sources like sun and dung / silage etc.

3) This 563 / EB Vehari village site is the first pilot project composing of 300 KWp solar capacity and 50 KW generation with Biogas.

4) The solution is also backed up by 200 KWH Li Ion battery backup.

5) The solution will feed the grid when electricity is available through both sources (solar and biogas) in synchronization with grid on 11 KV.

6) In absence of grid, solution will only cater for the load of the village (max load 180 to 200 KW) after isolating the national grid.

7) In absence of grid all three sources can be utilized according to their availability at given point in time.

8) After restoration of grid, all sources will disconnect and grid will be restored for village load (solar / biogas generations will again synchronize with the national grid).

9) The idea of adding this intervention at the tail of the 11 KV feeder is to improve the power factor and to reduce the line losses on national grid.

10) The biogas plant digester capacity is 1400 Cu meter which will be able to produce at full capacity approximate 560 Cu meter biogas.

11) If the entire biogas capacity is used for electricity generation the maximum daily production from biogas plant can reach upto 1100 units (KWH).

12) The installed solar capacity can generate on average 1200 units (KWH) on daily basis.

13) Plan is totally owned by Punjab Energy Department and will be operated by the EPC company for first two years of operations.

14) The rural community will take the operations responsibility after two years when they are trained and SOP's of supply chain and operations are matured.

15) All the energy fed to national grid or fed to local village load during load shedding will be purchased by MEPCO on a mutually agreed tariff.

<u>Social & Environmental Impact:</u>

1) The plant is meant to provision 24/7 electricity for the village as a social service for the village community.

2) The biogas plant will provide a organic fertilizer as well for the village community.

3) Some spare biogas can be provisioned for villagers in barter of fuel (dung for instance) for kitchen purposes as well.

4) The plant will generate utility of dung for the villagers in commercial terms and will also provide a limited employment as well.

5) The success of pilot porojject will lead to install such more project across Punjab based on the alternate energy sources availability in the respective areas locally.

6) At the tail end of 11 KV feeder this plant will also help national grid with line losses reduction and power factor improvement.

7) The 300 KWp solar plant will save 482 tone of $CO2$ emission per year as reduction in global warming potential (GWP).

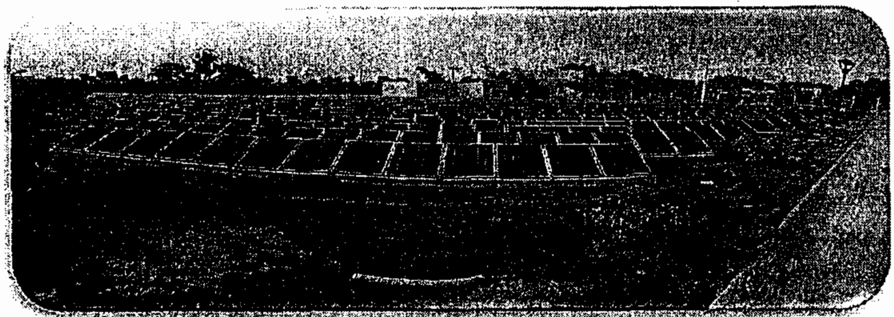
8) The 1400 Cu meter digester production of the biogas plant will help to reduce 327 tons of $CO2$ emission as reduction in GWP when biogas will be used for electricity generation or burning purposes.

9) The biogas will be filtered before feeding the generators from harmful content like hydro sulphide to ensure the anti toxity impact for environment.

10) The heat generated during electricity generation from biogas can also be recycled to maintain the temperature of the digesters for improvement of their operation.

<u>Project Cost</u>:
EPC cost: PKR 100 million with plant life of minimum 25 years
Two Years Operations support: PKR 7.5 million

Dynamic Green
ENERGY SOLUTIONS



Company Profile

CERTIFICATIONS

ISO9001-2008
ISO 14001-2004
OHSAS 18001-2007
SADEX (Ethical Business
Pakistan Engineering Council
category
ZTBL Enlisted Partner for Solar
Pumps, Agricultural Department
ABDB Certified ARE

Major Group of Companies

JUMLISH INTERNATIONAL
JL inK

Major International Suppliers

SUNGROW Green and Effective
OutBack Power Systems
SUNLIGHT
Q CELLS
HT-SAAE
BATER Always full of energy
Trinasolar
JA SOLAR
YINGLI SOLAR
ZIGOR
BAYKEE INTERNATIONAL
SMA

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Fax: +92 42 36272914, Web: www.dgl.com.pk

Company Details

Dynamic group of companies is a leading player in Pakistan for providing industrial & commercial solutions in the domains of complete plant EPC, industrial compressors & pumps, civil works and food industry.

DGL is targeting to serve the market needs using energy efficient and environment friendly means of energy productions with initial focus on photovoltaic & concentrated solar power and later adding wind, bio energy and other alternate energy technologies in its portfolio.

DGL is keenly pursuing the strategic long-term partnerships with the leading manufacturers of solar panels, batteries, mountings / accessories and invertors to serve its customers with the premium quality & affordable solutions as a first milestone of its operations.

DGL believes in managing the business through leading technologies and customer centric solutions with its team of seasoned professionals.

Vision:

To become the leading EPC company in the domain of renewable energy solutions with significant market share in Pakistan and to pursue profitable ventures in other suitable developing countries.

Mission:

To provide customer centric energy solutions for captive industrial needs, IPP's, commercial sector and communities with affordable quality products following a phased, targeted and socially responsible approach.

Our Solution:

- Smart grid hybrid solutions scalable to mega watts
- On grid solutions with internal consumption principle
- In house developed intelligence for energy sources management
- The elimination of generator remains the major focus for hybrid grid solution whereby the return on investment is of the tune of three to four years
- Financing facilitation services
- Solutions are developed as back-up or in synchronization to grid with customizable capacity to cater the diverse needs of the market
- Solutions available for the commercial buildings, industrial needs and communities

Dynamic Green

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- Solutions available for the commercial buildings, industrial needs and communities

Our Services:

- IPP's feasibility studies and support
- EPC for megawatt projects with help of our international partners
- System design, service delivery and O&M services for the diverse locations' projects and megawatt plants
- Technical trainings on solar solutions
- International placement of the solar technicians and engineers

Our Solutions:

- Smart grid hybrid solutions scalable to mega watts
- On grid solutions with internal consumption principle
- In house developed intelligence for energy sources management
- The elimination of generator remains the major focus for hybrid grid solution whereby the return on investment is of the tune of three to four years
- Financing facilitation services
- Solutions are developed as back-up or in synchronization to grid with customizable capacity to cater the diverse needs of the market
- Solutions available for the commercial buildings, industrial needs and communities

Why Us:

We Provide

- Best practices: Requirement generation / presale process
- Efficiency of design
- Service delivery & project management
- Service support (SLA)
- International experience
- Access to supply chain

Core Values:

- Simplicity
- Quality
- Social Responsibility
- Customer satisfaction

Directors' Profile:

Junaid Ishaq Qureshi, Chief Operating Officer of Dynamic Group of Companies

- MBA Marketing
- BSc Electrical Engineering
- 25 years of experience in operations, program management, quality assurance and enterprise services
- Extensive & rich experience from telecom, IT and power industries
- Worked for Schlumbreger, Wateen Telecom, Jumlish International, Wisecom, PTCL , WAPDA & Dawood Hercules in different tenures.

Qamar Ahmad Fazal, Commercial Director of Dynamic Group of Companies

- BSc Electrical Engineering
- 25 years of experience in the Pakistan telecom & power industry.
- Expert in developing emerging market and has a proven record to develop them.
- Strong leadership qualities and a track record of managing medium size technical and business operations.
- Worked for National Engineers as Director Business Development for 10 years and managing NTS & NCI as CEO for last 12 years with business success history.

Past References of Projects

Sr. No	Name of Project	Name of Client	Status	Rating
1	Aitchison Housing Colony (135 Houses)	Aitchison College Lahore	Completed	67.5 KWp
2	Aitchison College Two blocks	Aitchison College Lahore	Completed	340 KWp
3	Aitchison College	Aitchison College Lahore	Completed	27 KWp
3	Nestle 2 Milk Collection Sites (Phase 1)	Nestle Pakistan Ltd	Completed	11 KWp
4	Nestle 8 Milk Collection Sites (Phase 2)	Nestle Pakistan Ltd	Completed	50 KWp
5	Nestle 20 Milk Collection Sites (Phase 3)	Nestle Pakistan Ltd	Completed	105 KWp
6	Nestle 14 Milk Collection Sites (Phase 4)	Nestle Pakistan Ltd	Completed	95 KWp
7	20 Ufone BTS sites	Sagemcom	Completed	105 KWp
8	National Bank Branches (40 sites)	NBP	Completed	120KWp
9	National College of Arts Lahore	NCA Lahore	Completed	50KWp
10	National College of Arts RWP	NCA Rawalpindi	Completed	50KWp
11	SA Farm (Interloop), Faisalabad	SA Farms	Completed	105KWp
12	SA Farm (Interloop), Faisalabad	SA Farms	Completed	205 KWp
13	Integrated Energy and Agriculture Concept (PV-BioGas)	University of Agriculture Faisalabad	In Progress	100KWp (Solar) 125KW (Bio Gas)
14	Energy Solution Using Indigenous Resources (Veharri)	Energy Department Punjab	In Progress	300KWP (Solar) 100KW (BioGas)
15	Energy Solution Using Indigenous Resources (Samundri)	Energy Department Punjab	In Progress	100KWP (Solar) 300KW (BioGas)
16	Installation of Solar System for Operating High Efficiency Irrigation System Agriculture (Water Management) Punjab, Lahore	Agriculture Department Punjab	Completed	17 Systems of 151KWp
17	Office Building	DEC	Completed	5 KWp
18	Office Building	JIPL	Completed	5 KWp
19	Office Building	NTS	Completed	5 KWp
20	Office Building	DGL (Own)	Completed	5 KWp
21	Show room Millat Tractors	Usman Traders	Completed	10 KWp
22	Office Building	Albario	Completed	6 Kwp
23	Campus Solar Lab Solution	UET Taxila	Completed	12KW

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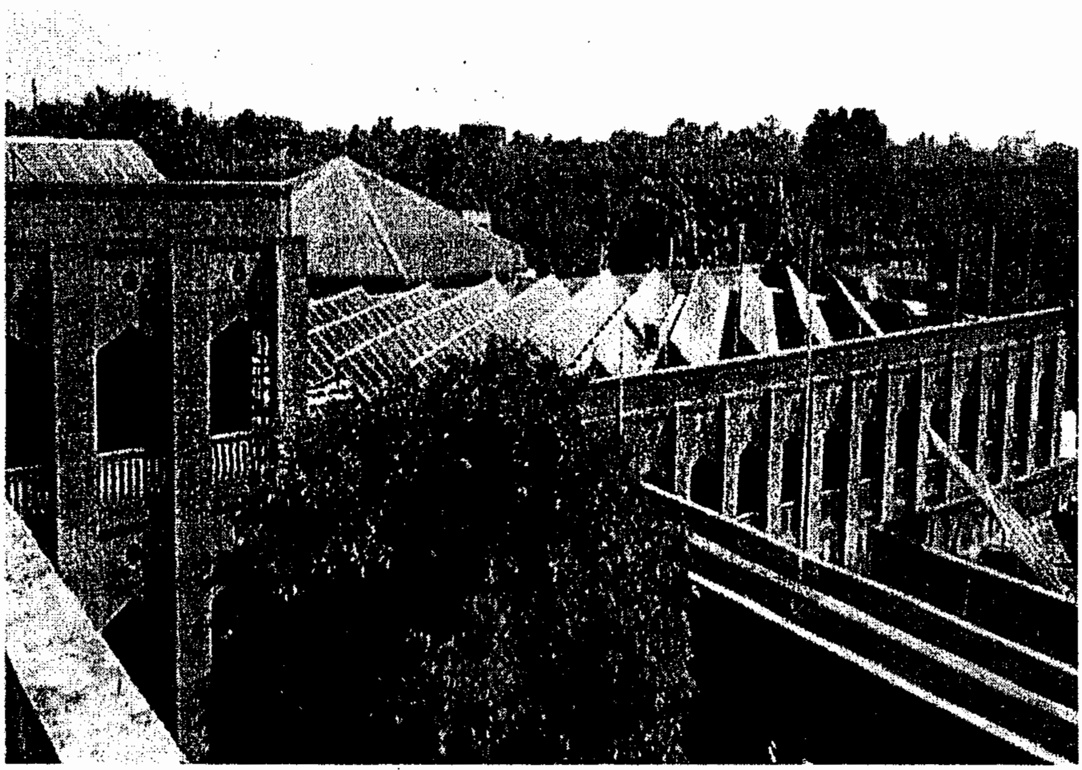
Fax: +92 42 36272914, Web: www.dgl.com.pk

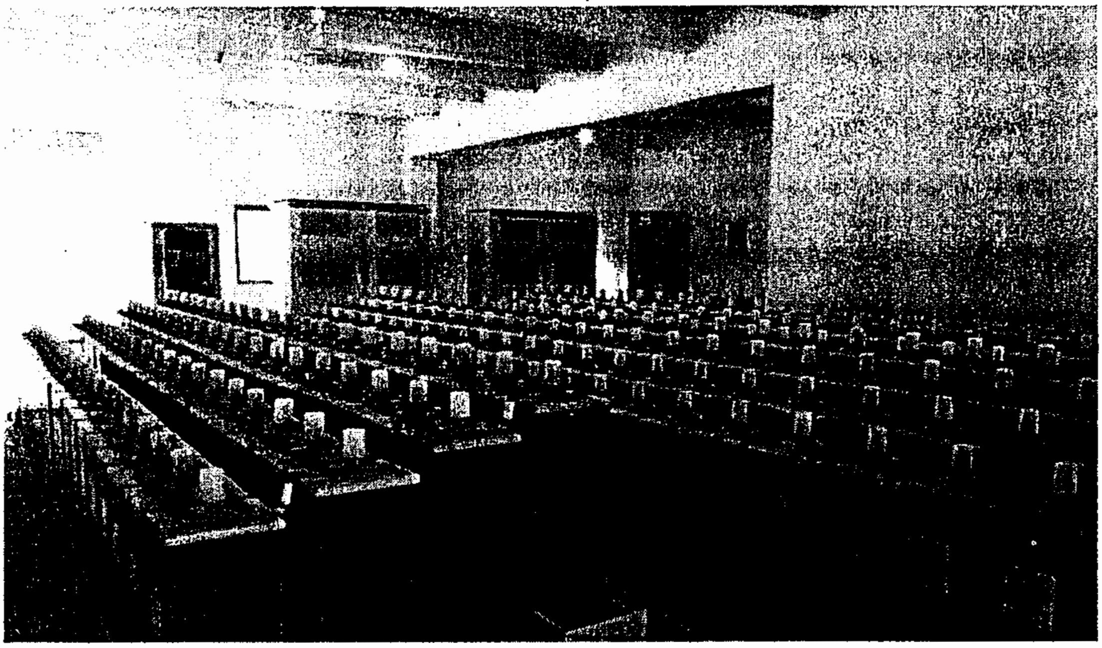
Our Solar Solution Case studies:

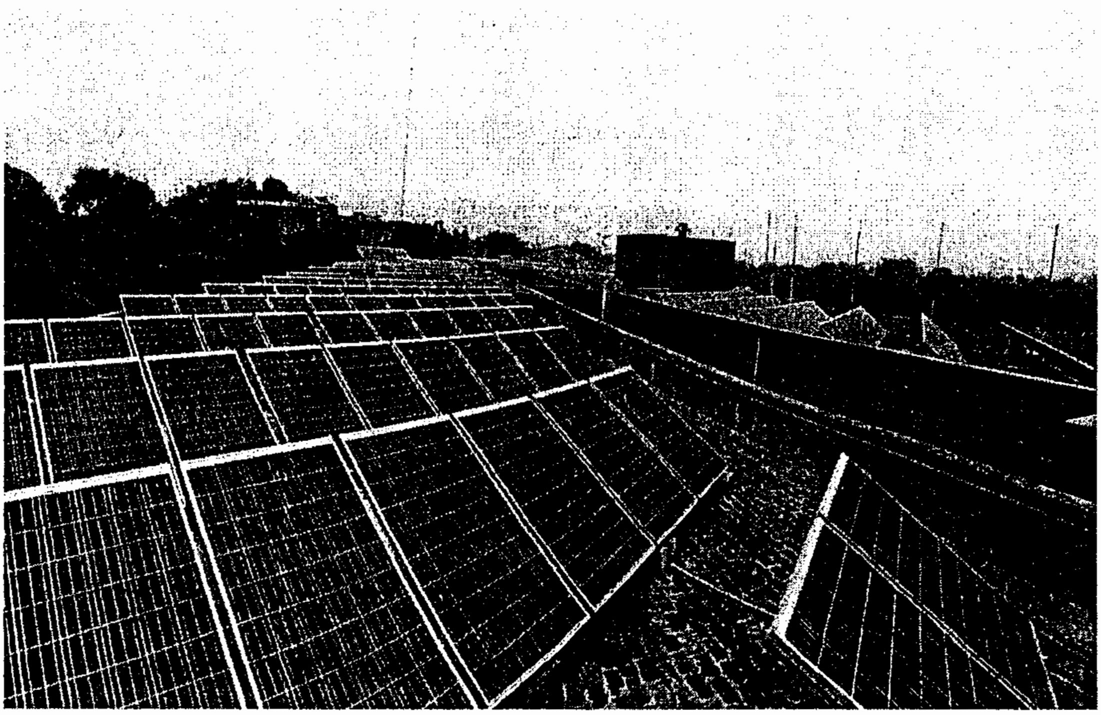
1. Aitchison College Smart Grid Solar System:

PV Modules:	Yingli 340 Wp Polycrystalline
Hybrid Inverter:	2 x 150 KW Smart Grid Inverters - 300 KW 400Vac 500Hz
Battery Bank:	2 X 1525Ah @ 348 V- Opzs Batteries
Grid/Gen Set Input:	400Vac - 50 Hz

As an initiative of transformation to clean energy and to avoid the cost of Generators' fuel, Aitchison College Lahore has invested in innovative Smart Grid/Hybrid Solar System which is able to supply electricity for several blocks of the college. The solution supplies clean solar electricity to a total load of more than 225 KW at day time and also serve evening and night load of hostels & street / security lights. College has been able to avoid cost of fuel of a 250 KVA generator which was serving the prep school area buildings, events hall and of two hostels. In winter when load is low, another 250 KVA generator's fuel is also saved which runs for the workshop and other important school buildings.



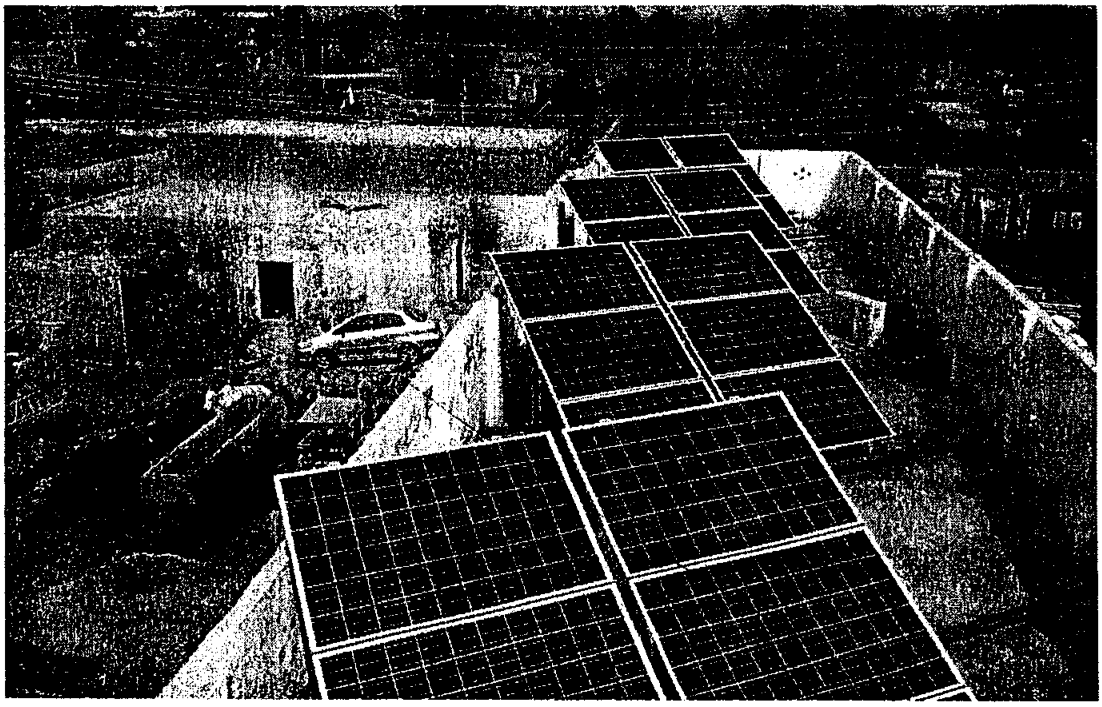


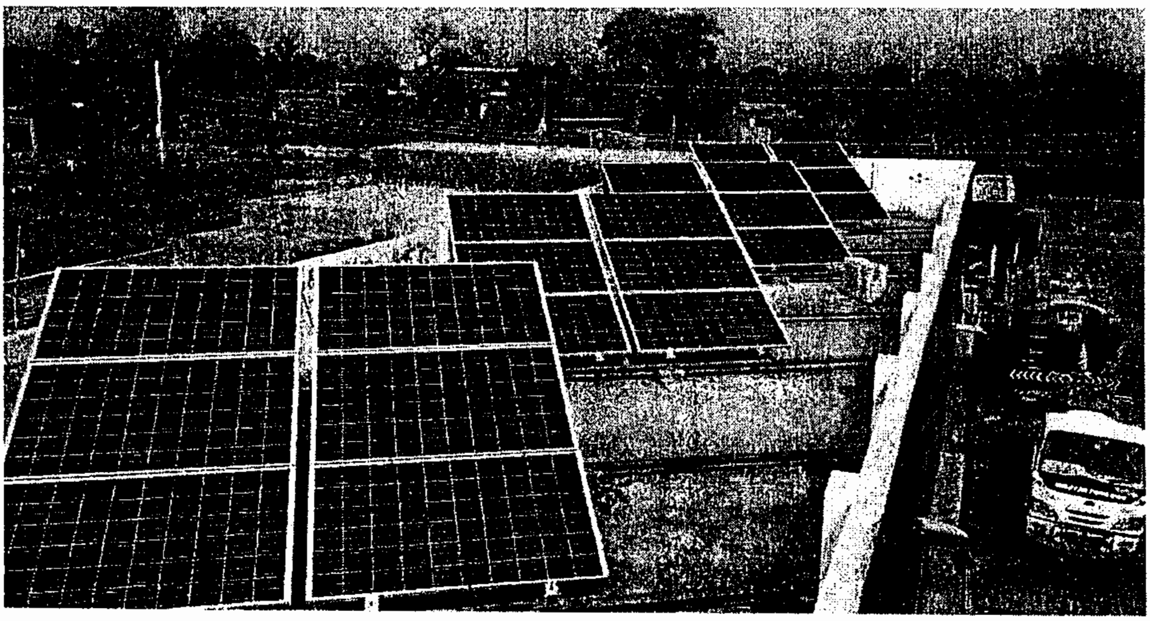


2. Nestle Pakistan

PV Modules: 21 x 250Wp Polycrystalline
Inverter: 3 x 2.3 KW - 6.9 KW 400Vac 50Hz
Battery Bank: 24 x 750 Ah @ 48 V - OpzS / OpzV Batteries
Grid/Gen Set Input: 400Vac - 50 Hz

Dynamic Green has provided a unique, industrial standard solution to Nestle by installing Solar Power Systems at their several Milk Collection Centers. Most of these centers are in rural areas where there is either no grid or poor grid availability. DGL has now installed Solar Power System at 30 milk collection centers in Punjab and Sind reducing Grid usage to bare minimum and eliminating Generator usage to maximum extent. The solutions acts almost off grid in most part of the year and generators are used in very rare cases. The service and business continuity is the landmark of these projects since milk collection is the core operation for the organization. Corporate responsibility and reduction in carbon emission is another drive behind the initiative of Nestle, Pakistan. Payback of the projects is around 5 years.

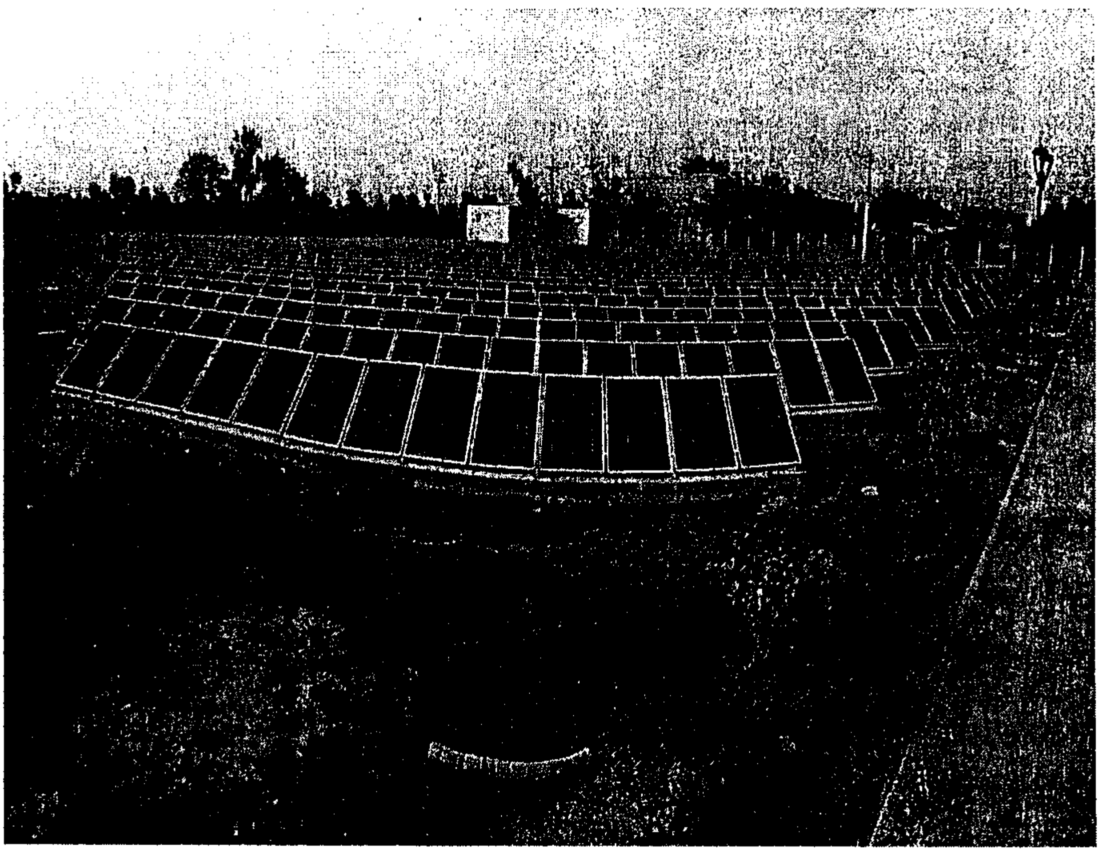


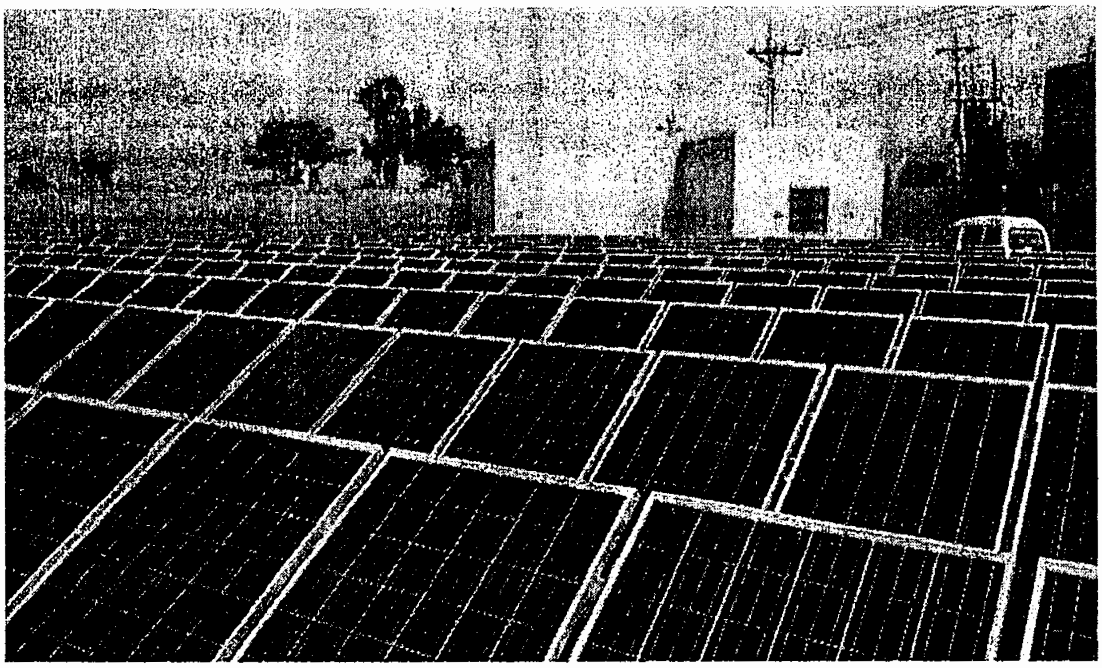


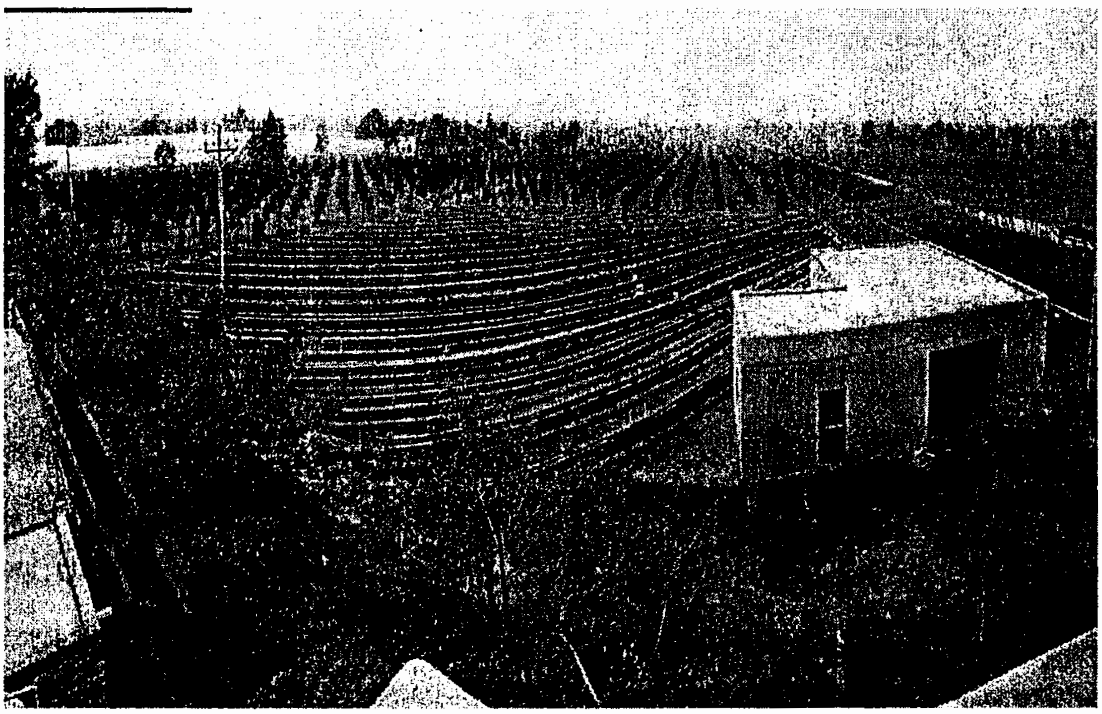
3. SA Farm (A subsidiary of Interloop , Faisalabad)

PV Modules:	250 & 280 Wp Polycrystalline
Inverter	1 x Grid Interactive Inverter - 400 KW 400 Vac 50 Hz
Battery Bank:	174 X 1525Ah @ 348 V- Opzs Batteries
Grid/Gen Set Input:	400Vac - 50 Hz

Reverse Osmosis (RO) plant and general load of SA Farm (spread over 80 Acres) has been shifted to Solar Power by DGL. It will utilize maximum solar energy at day time. Grid will be used only to overcome the deficiency of solar energy in order to run the load. In case of no grid, batteries will be used to run the load; hence, eliminating the use of generator. This solution will run almost on solar energy with 95% plus saving on both generator fuel and grid electricity. Saving on life of 400 KVA generators is another source of saving for the customer. The payback on the solution is envisaged in less than four years. Effective onsite and remote monitoring is possible with appropriate GUI and reporting tool.





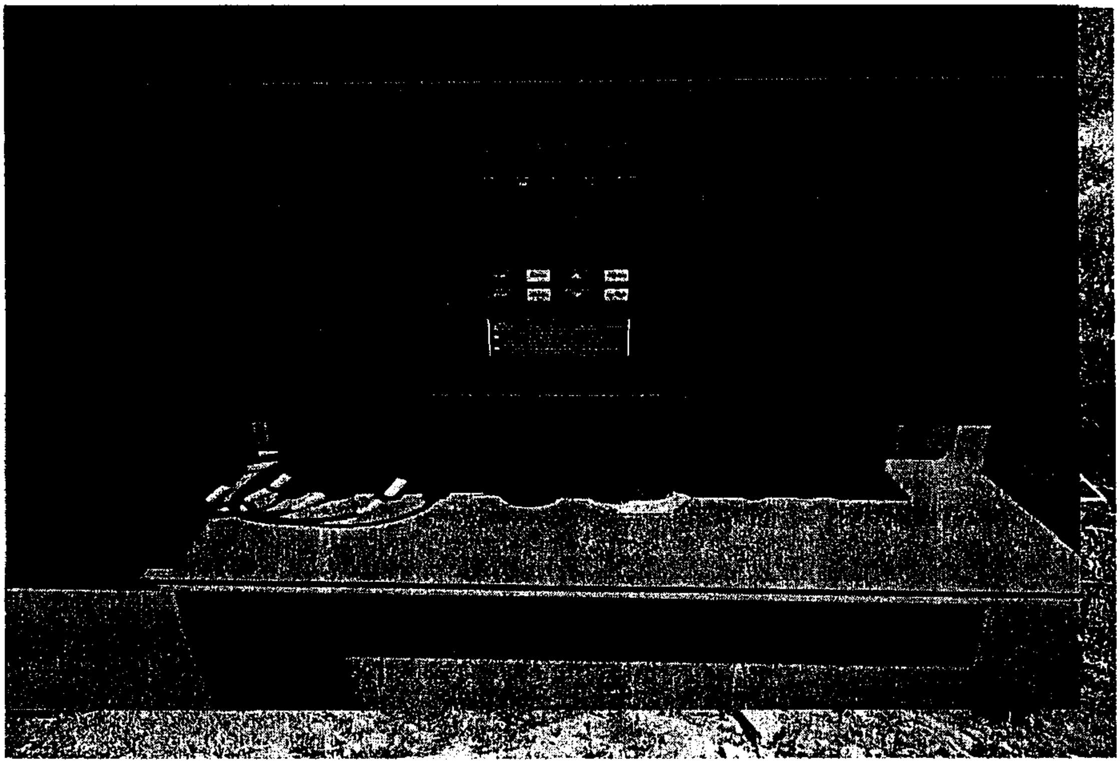


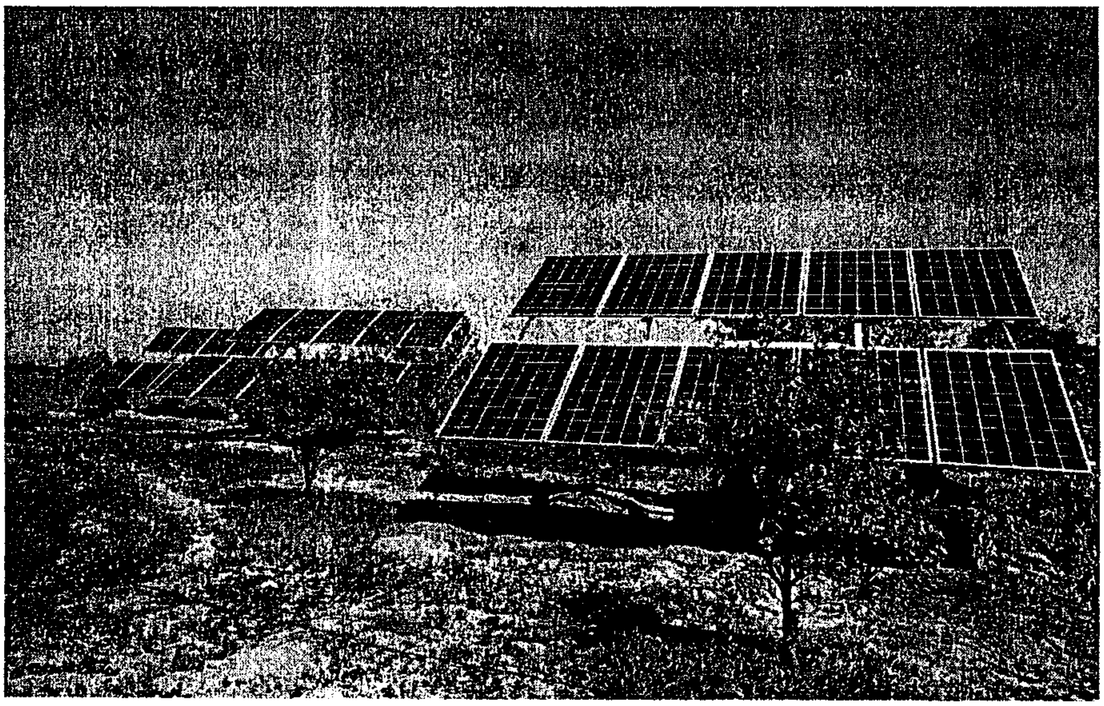
4. Installation of Solar System for Operating High Efficiency Irrigation System Agriculture (Water Management) Punjab, Lahore (30 Sites)

PV Modules: Jinko, Canadian Solar 320 W Polycrystalline
Inverter Off Grid Inverter Baykee 5.5, 7.5 & 11KWp
Grid/Gen Set Input: 220Vac - 50 Hz

In Pakistan, where agriculture is the base of the economy, till date many areas where lands is very fertile, but due to the unavailability of the Electric supply Irrigation is almost impossible or very costly. Not just that even today there are many regions in Pakistan where due to non-availability of electricity pumping drinking water is also not possible.
In Pakistan, where agriculture is the base of the economy, till date many areas where lands is very fertile, but due to the unavailability of the Electric supply Irrigation is almost impossible or very costly. Not just that even today there are many regions in Pakistan where due to non-availability of electricity pumping drinking water is also not possible.

To overcome these problems Dynamic Green Introduced solar water pumping system at a very affordable cost with high reliability. Solar water pumps are specially designed to lift water for irrigation, horticulture farms, gardens, domestic use, drinking and other similar applications. Dynamic Green Installed 30 solar water pumping irrigation sites all over the Punjab province. The Organization installed Off Grid Solar systems of 10 KW and 15 KW solar irrigation systems for 7 HP and 10 HP pumping motors respectively.





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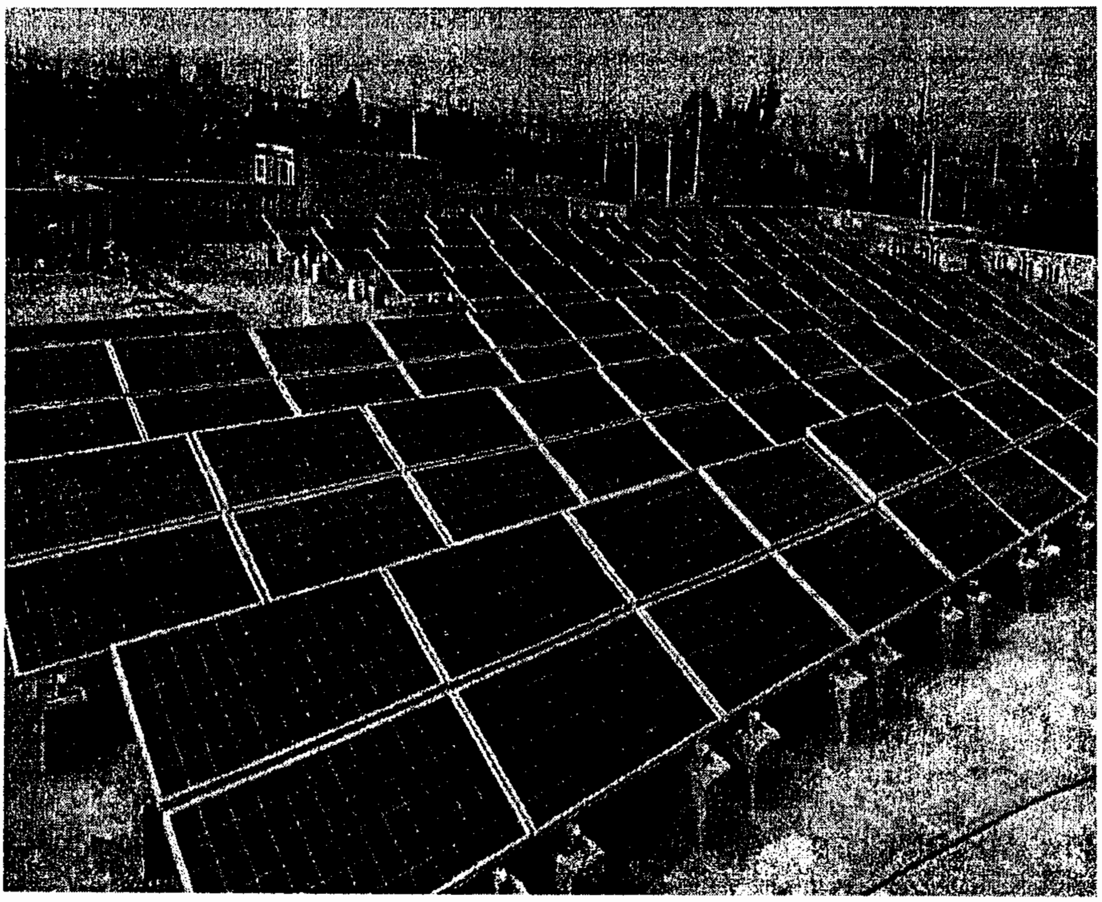
Fax: +92 42 36272914, Web: www.dgl.com.pk

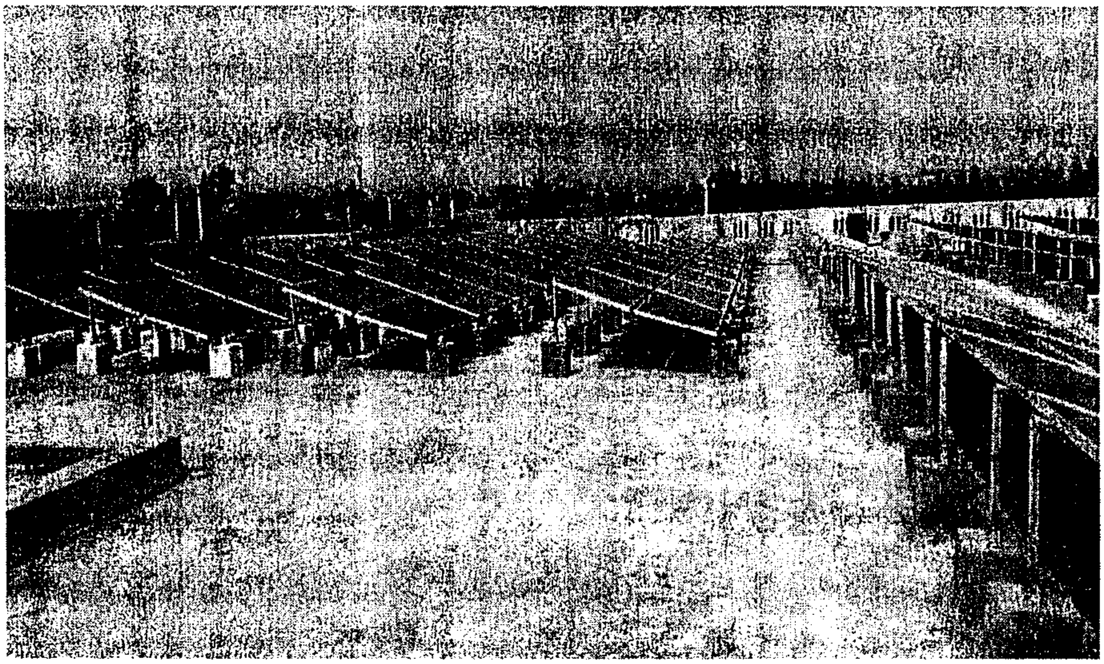
5. **Integrated Energy and Agriculture Concept (PV-Bio Gas) University of Agriculture Faisalabad.**

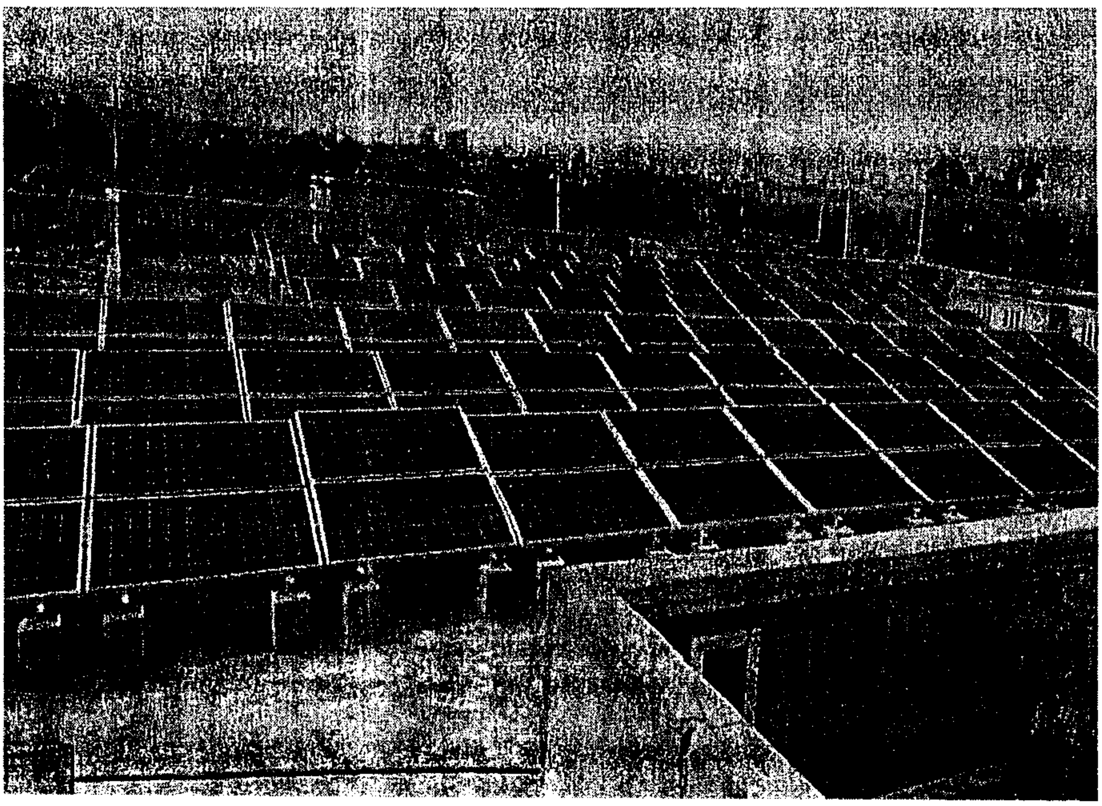
PV Modules:	Jinko 320Wp Polycrystalline
Inverter:	On Grid Inverter of 15, 25 & 50 KWp
BioGas Generation:	150 KWp
Grid/Gen Set Input:	400Vac - 50 Hz

The absence of clean cooking facilities and electricity means billions of rural people are deprived of much needed socioeconomic development. Livestock residues (dung) and solar radiation are two renewable energy resources that are abundantly available in rural areas of developing countries. Although it is not feasible for these two resources separately to meet both thermal (cooking) and electricity demands, hybrid applications have not been given due attention.

Dynamic Green took the initiative of giving the due attention to the integrated energy concept and is one of the pioneer organizations who have worked on the PV-Bio Gas integrated energy projects in Pakistan. A total of 400 KW was installed at University of Agriculture Faisalabad by Dynamic Green where two sources of renewable energy were synched.



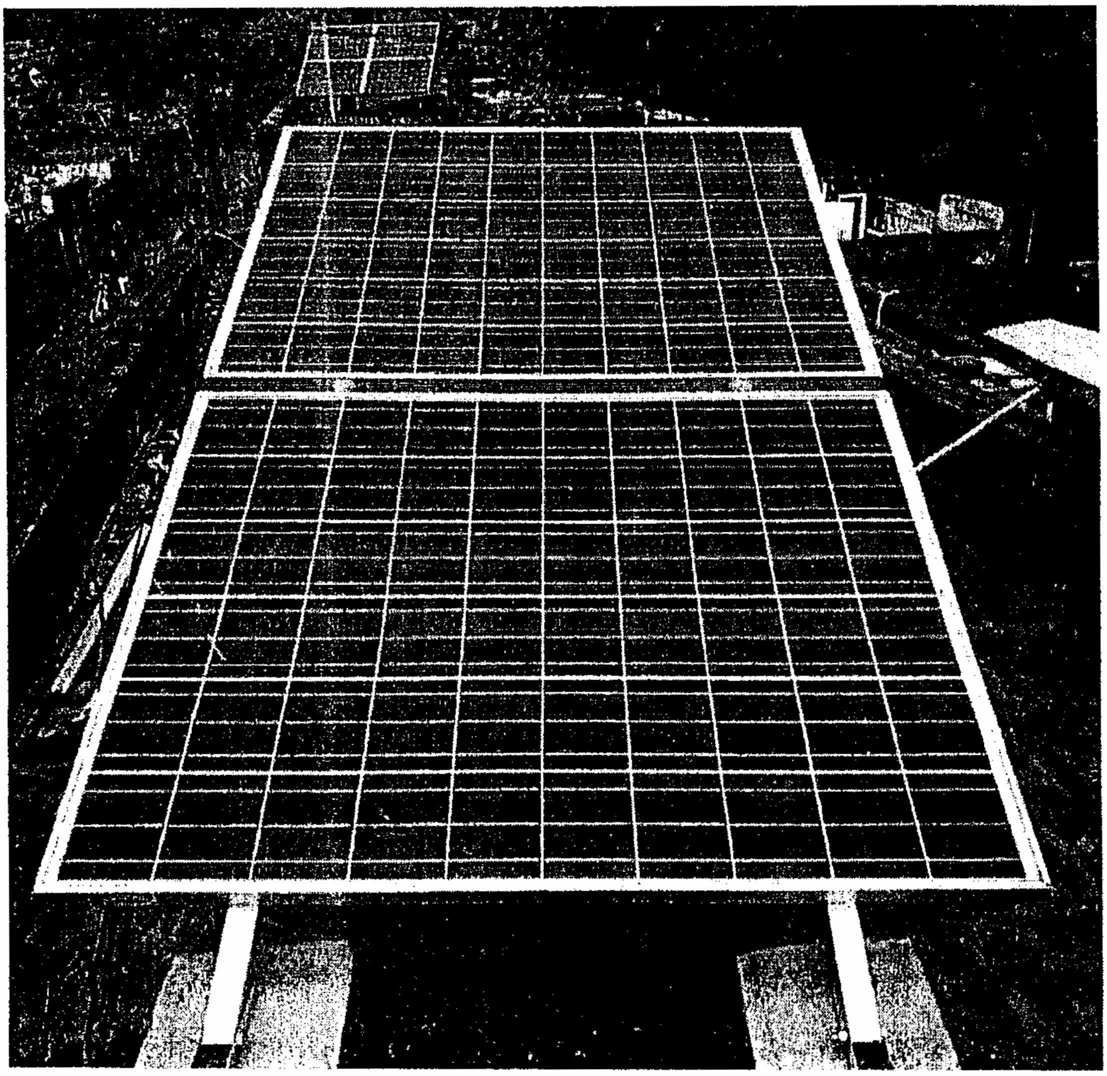




6. Aitchison College Community Service Project

PV Modules:	Yingli 2 x 320 x 135 Wp Polycrystalline
Inverter:	1 x 1KVA x 135 Hybrid Inverters 220 Vac 50 Hz
Battery Bank:	6 X 266Ah x 135 @ 12 V- Opzs Batteries
Grid/Gen Set Input:	220Vac - 50 Hz

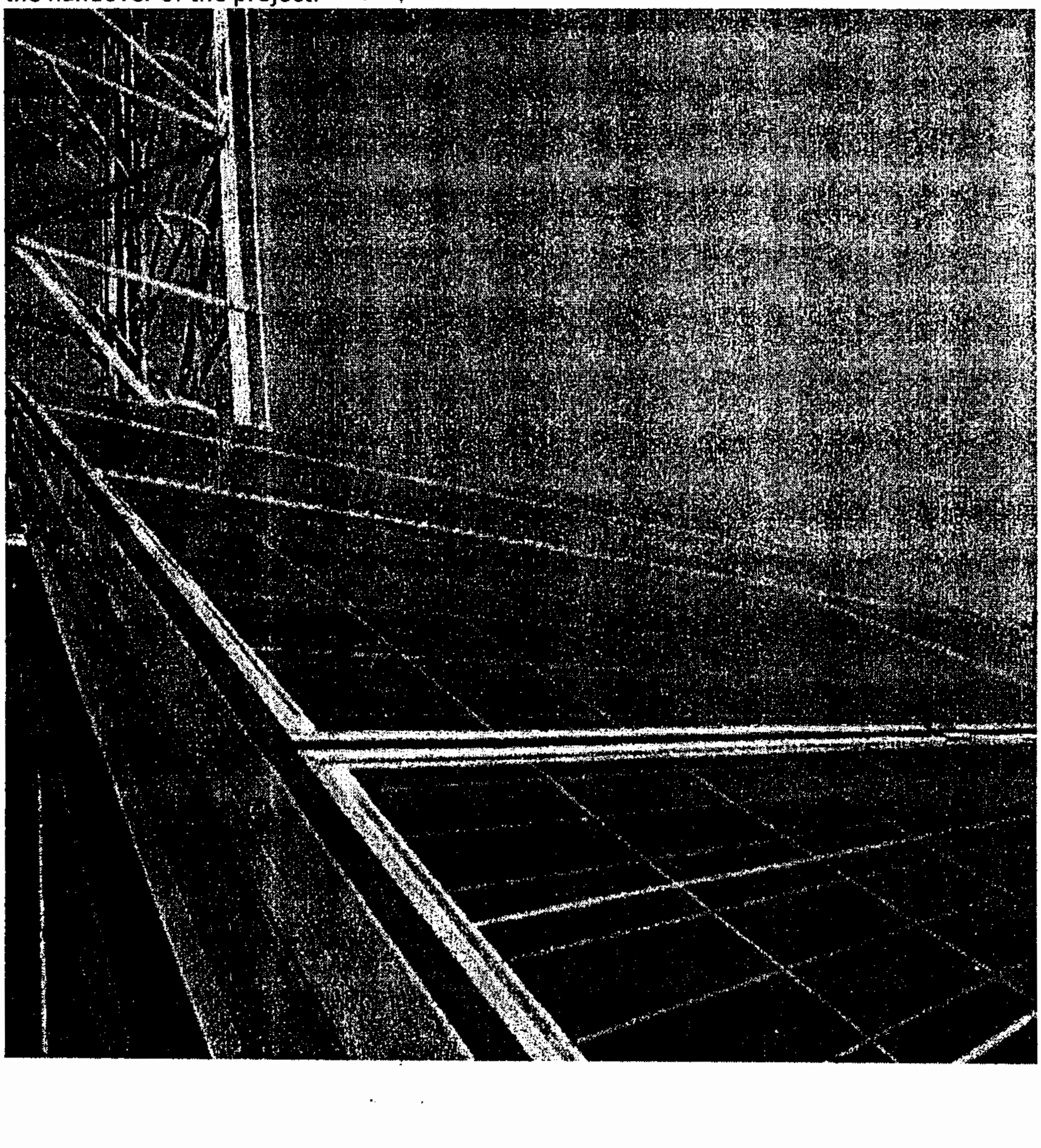
135 (lower staff) residential quarters in Aitchison Housing Colony have been converted to Solar Hybrid Systems by Dynamic Green Limited. The purpose was to provide clean carbon free energy and uninterrupted power supply for the community to overcome the load shedding issue for the college staff houses. The service continuity for essential needs of the lower staff has been met by this project as a CSR initiative. The bill saving is assumed (on the connected load) is more than 30%.



7. National College of Arts

PV Modules: Yingli, GH Solar 250 Wp Polycrystalline
Inverter: Hybrid Inverter Baykee 60 KVA
Battery Bank: 384 V & 400 AH Opzs Batteries
Grid/Gen Set Input: 440 Vac - 50 Hz

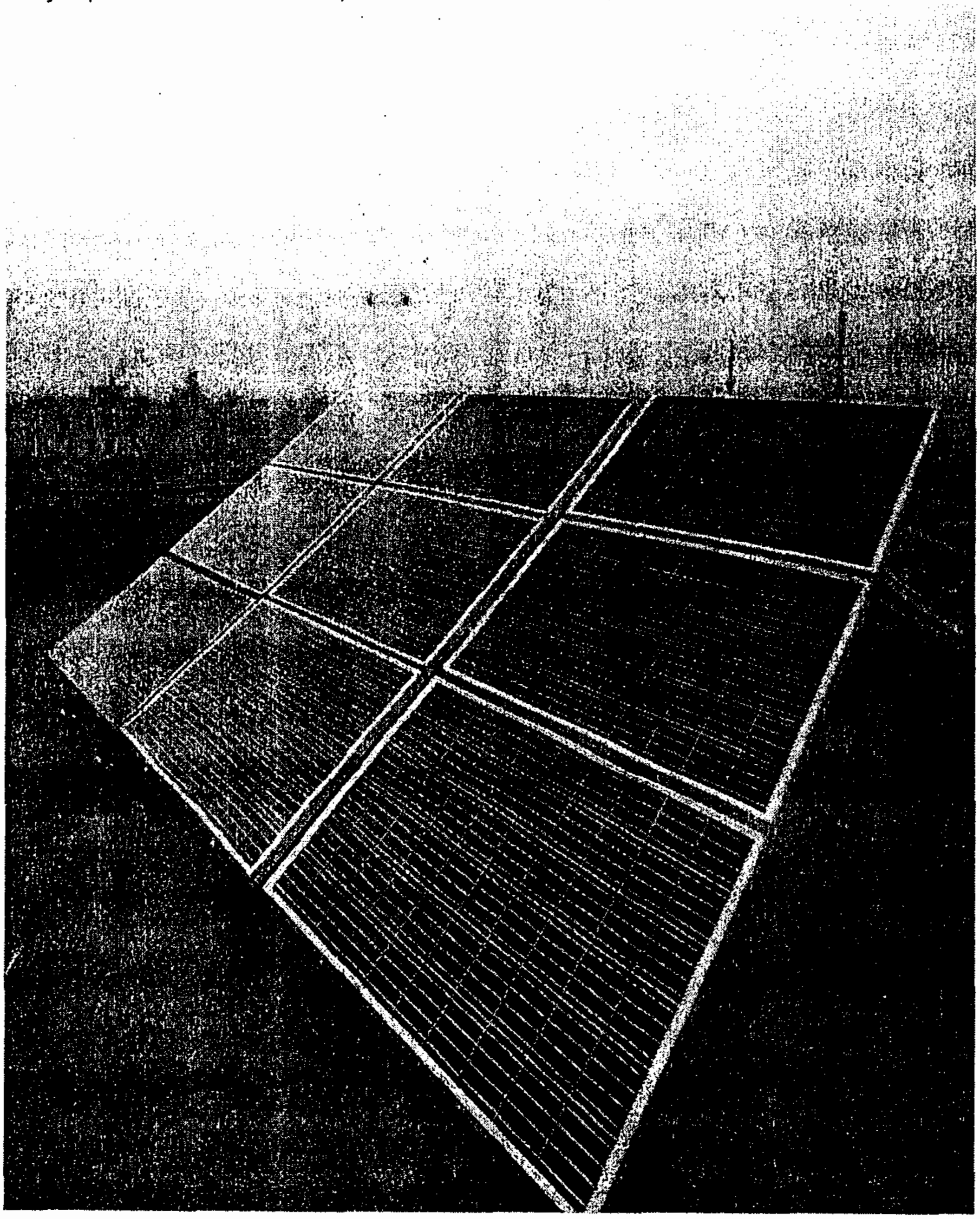
Dynamic Green installed 60 KW solar systems at National College of Arts Rawalpindi & National College of Arts Lahore. The system was Hybrid with Battery Backup of 384 V which lasts for 3 Hours. The contract of Operations & Maintenance was also handed to DGL after the handover of the project.



8. National Bank Sites (40 in total)

PV Modules:	GH Solar 250 Wp Polycrystalline
Inverter:	Hybrid Inverter JFY 3 KVA
Battery Bank:	48 V & 100 AH Opzs Batteries
Grid/Gen Set Input:	220 Vac - 50 Hz

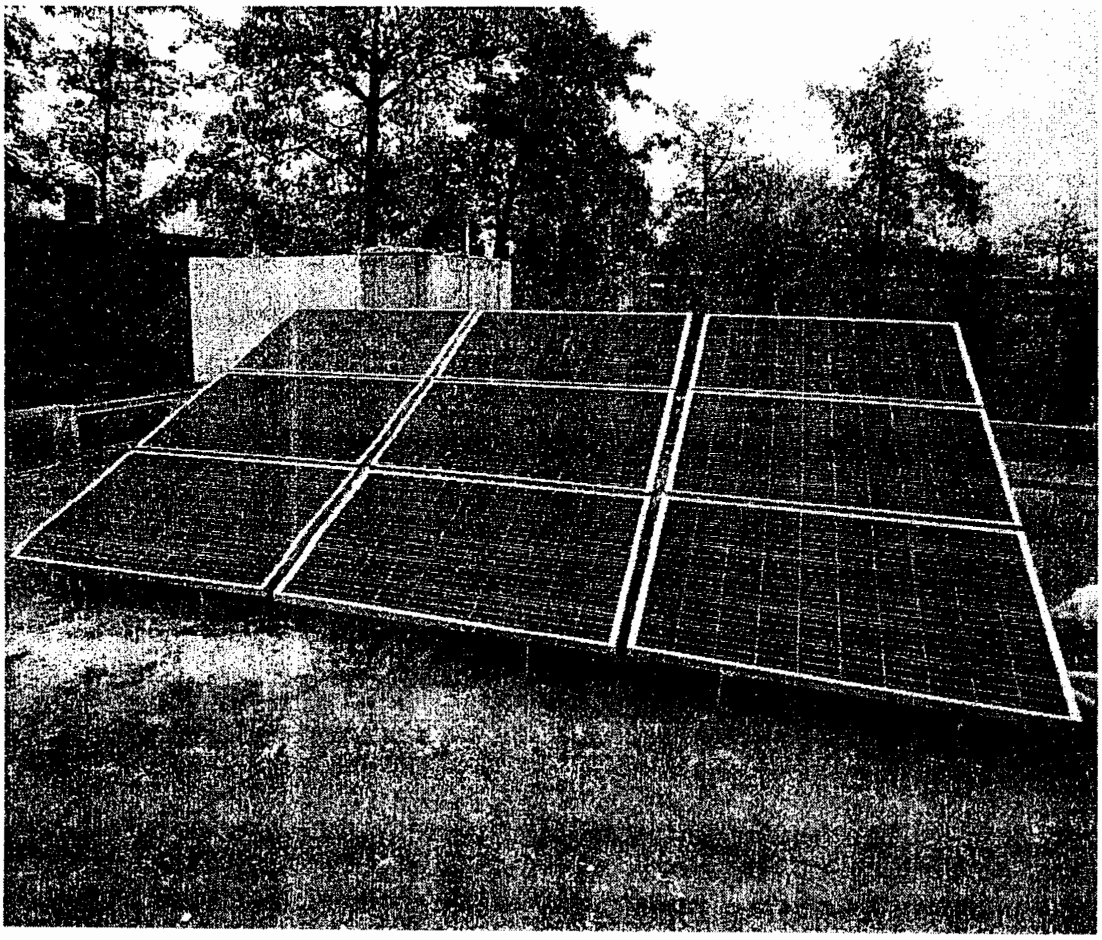
Dynamic Green Installed 3 KVA systems at 40 different National Bank sites all over the Punjab province. All of these systems were with battery backup of 48 V.



9. Telecom Sector

PV Modules: Yingly 250 Wp Polycrystalline
Inverter: Hybrid Inverter Outback 7 KVA
Battery Bank: 48 V & 1000 AH Solar Gel Batteries
Grid/Gen Set Input: 220 Vac - 50 Hz

Most of the telecom towers often face problems with their remote locations as they do not have a reliable energy supply. Additionally, they incur a lot of operating cost on diesel generators. Dynamic Green Limited has provided engineering services (CME) for solar hybrid systems installation and commissioning to address these problems to reduce dependence on Diesel Generator. Solar Powered Electrical system is an efficient solution as it can reduce operating costs of Diesel Generators and provide an uninterrupted power supply. Dynamic Green Limited has provided its engineering services and expertise to Segemcom to install Solar Power system at 20 BTS sites of UFONE saving Diesel expense and generating clean and green energy at economical costs. The solutions can be designed in customized fashion to avoid generator use for 6 hrs, 12 hrs or 24 hours.



10. Energy Solution Using Indigenous Resources in Villages (Samundari, Veharri)

Samundari

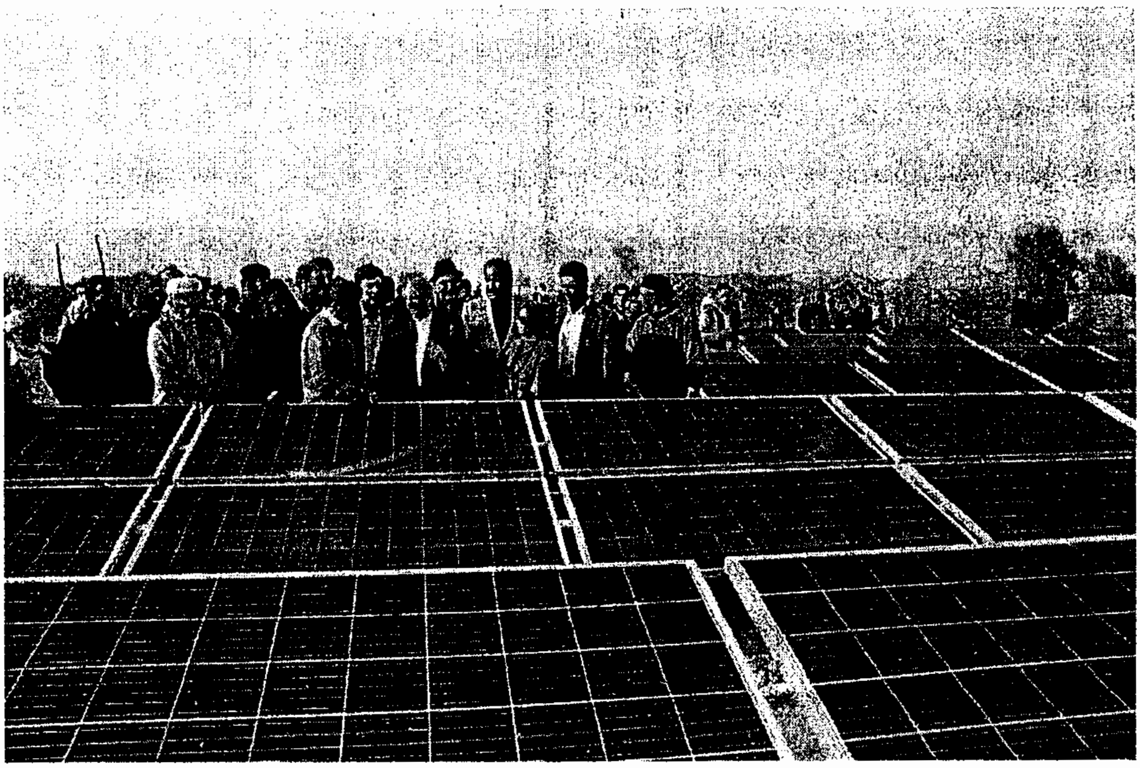
PV Modules: HTSAEE 330 Wp Polycrystalline
Inverter: Grid Interactive Inverter Baykee 150 KW
Bio Gas Generation: 150 KW
Battery Bank: 85KWh
Grid/Gen Set Input: 440 Vac - 50 Hz

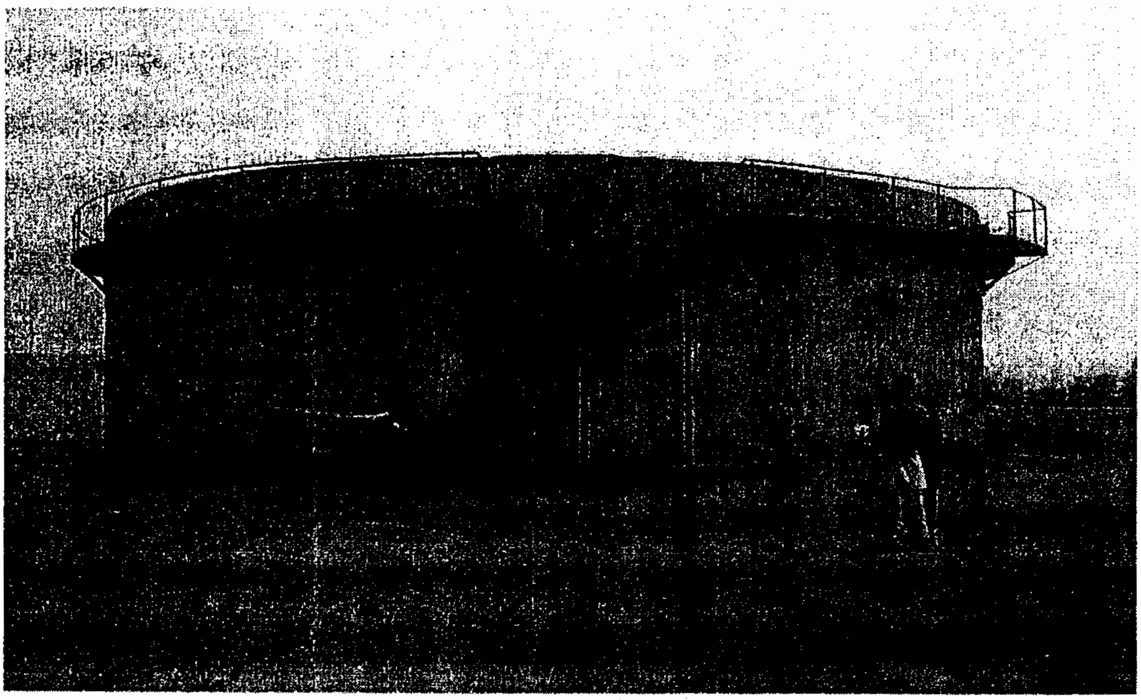
Vehari

PV Modules: HTSAEE 330 Wp Polycrystalline
Inverter: Grid Interactive Inverter Baykee 300 KW
Bio Gas Generation: 100 KW
Battery Bank: 170KWh
Grid/Gen Set Input: 440 Vac - 50 Hz

The Energy Department of the Punjab ("Employer") is developing two model projects for reliable and environmental-friendly electricity supply for rural areas in Punjab. The two PV Biogas Hybrid Systems, located in central and southern Punjab respectively, consist each of a PV part (photovoltaic power plant, "PV System"), a biogas energy part (biogas power plant including all necessary components, "Biogas System"), battery storage ("Battery"), grid connection incl. grid breakers, a control system and all necessary periphery. The PV Biogas Hybrid System shall provide the connected households a reliable electricity and (partially) gas supply around the clock and throughout the year, thus minimizing fuel and combustible expenses requiring foreign exchange and creating economic stimulus. Each PV Biogas Hybrid System shall generate electricity based on the two underlying renewable energies (solar irradiation and biogas). Both systems shall be connected to the electricity grid but shall also operate in off-grid mode when the electricity grid will not be available. Electricity produced shall primarily be used for supplying households in the village where the PV Biogas Hybrid System. At both sites 400 KW integrated energy plants are being installed by Dynamic Green and the organization is proving out to be the pioneers in executing and implementing the integrated renewable energy theory and concept.

Samundri Site





Dynamic

Veharri Site

H. No. 4, 1-Golf Road Lahore, Tel: +92 42 36272914,
Fax: +92 42 36272914, Web: www.dgl.com.pk

COMPANY PROFILE

Brief Introduction about Biogas History of Pakistan

Government of Pakistan started a comprehensive biogas scheme is 1974 and commissioned 4550 biogas units by 1990 throughout the country. The units were designed to provide 3000 and 5000 cubic feet of biogas per day for cooking and lighting purposes. During the first phase 100 demonstration units were installed under grant by the Govt. During the second phase, the cost of the biogas was shared between beneficiaries and the Government. Later on for third phase, government withdrew the financial support. However technical support was continued to be provided free of cost. Unfortunately, after the withdrawal of the government financial support, the project did not progress any further. Pakistan being agriculture based, breeds sufficient live stock to produce enough animal waste for the production of biogas. Currently all such animal waste is burned in dry form as a domestic source of energy. The same can be used for producing biogas on community bases. There is good potential to use biogas as a rural energy source, throughout the country, by a network of community biogas plants.

Potential of Biogas Technology in Pakistan

Livestock sector contributed approximately 51.8 percent of the agriculture value added and 11.3 percent to national GDP during 2008-09 (Economic Survey 2008-09). According to the table given below Pakistan has almost 63 Million cattle and buffaloes (dairy animals). It has been estimated by FAO (2004) that about 50% of the animal waste is collected in the country. Of this recovered quantity, about 50% is used as fuel for domestic cooking, resulting in hardly a quarter of the animal waste being available for use as organic fertilizers.

The rural population in livestock production has been estimated at 30 to 35 million people, with these households deriving 30-40% of their income from livestock (Economic Survey of Pakistan 2004-05). Statistics indicate that national milk production has increased to 43.562 Billion liters from 32 Billion liters in 2005. Pakistan is said to rank 3rd largest milk producing country in the world.

Biogas potential is determined through no. of parameters. These are: availability of sufficient feeding material such as dung and water, warm temperature, availability of construction material, enough land (space) for plant installation, freedom from floods and availability of human resources for plant construction.

As mentioned above the population of dairy animals is about 63 Million cattle/buffaloes in Pakistan. The majority of this livestock population is confined to Punjab, Sind and NWFP provinces. It is estimated that these animals are kept by some 10 Million households in the country. The available buffaloes and cattle are large animals producing 10-15 kg dung every day; water is available in abundance from canals and wells, temperature conditions are favorable especially in Sind and Punjab where summer temperatures can go as high as 40 degree Celsius, Construction material is freely available locally and skilled and unskilled labor is also abundant. .

HISTORY OF BIO TECH

We are working in the field of renewable energy & Bio Fuels since 2010 in the name of Bio Tech Providing Alternate energy solutions like construction of biogas plants on domestic as well as commercial scale. We are also manufacturing and supplying biogas plants related equipments and systems like hydrogen sulphide Gas scrubbers, moisture traps, moisture filters, safety valves, mechanized mixers and feeding systems, pressure gauges, flow meters, thermo couples & Gas Storage facilities according to the need of customer.

VISION

Providing Sources of Alternate & Clean energy for agriculture, Dairy & Poultry sector to make them self sustainable in energy requirement at farm and home from renewable source of energy i.e. biogas from agriculture, dairy & poultry waste
Green solutions for food and energy by utilization nature's own recycling process

MISSION

Our mission is

- *To provide cheaper source of fuel for cooking, heating, water pumping and power generation at all levels*
- *To improve hygienic conditions at both farm & at home*
- *To improve livelihood of the dairy farmers*
- *Provision of bio slurry (rich source of Urea) for fields for maximum output through fertile lands.*
- *Best utilization of natural resources*
- *Clean & Healthy environment*

PROFICIENCY

We can work on any design of biogas plant like floating drum, fixed dome, plug and flow, balloon type etc. Our team is specialized in designing and construction of Bio gas Plants at domestic & commercial levels of any size from domestic usage to power generation. We have the knowledge & capacity to build any sort of bio gas plant according to the need of Customer.
We are also providing storage facilities for gas storage for smooth supply of gas.
We are dealing with both domestic as well as commercial level biogas plants. On commercial scale our clients are generating power and pumping water through biogas.

- **16-A Block 5CII,Ameer chowk ,college road, Lahore 042-35215460**

Sectors who can get Benefit from Bio Gas

- Cattle Farms
- Poultry Farms
- Sugar Mills
- Sanitation Plants
- Green House Farms
- Waste recycling enterprises
- Municipal waste treatment plants
- Food processing units

WORKS COMPLETED

- We have installed about 250 domestic level biogas plants all over the Pakistan of sizes varying from 8 to 20 cubic meters.
- We have also installed Commercial level biogas plant at Punjab Agriculture Farm which is meant for power generation. (30 kW gas generator is running)
- Installation of 150 cubic meters biogas unit at Eastern dairy, Pattoki.
- 50 cubic meters plant installed at SSD (Sacho satram das) temple at Dharki, Sindh providing gas for their Domestic use.
- 75 cubic meters plant installed at khan dairies Okara.
- 100 cubic meters plant installed at Mohsin Toro Farm , Mardan
- 75 cubic meters installed at Hamidpur Dairy, Multan.
- 100 cubic meters plant installed at Pakpattan (running 32 hp Peter Engine)
- We are proud to install 200cubic meter biogas plant at **Nestle Sukheki farm** running 100kw generator, and Providing Gas for Kitchen at site.
- 200 cubic meters Fully Mechanized Plant installed at Kasoori Agri, Farms, Kasur.
- 500 cubic meters Fully Mechanized Commercial Plant installed at Sapphire Unit 5 providing gas for Boilers.
- 200 cubic meters Fully Mechanized Plant installed at SS Dairies Bedian Road Lahore Providing Gas for Power generation of 75 KW & Kitchen on Farm.
- 375 cubic meters Fully Mechanized Plant installed at Bahadur Nagar Farms Okara in collaboration with USAID & Government of Punjab providing gas at the farm for 160 Houses for their domestic requirements.
- 100KW Veharri & 300KW Samundri, Project of DoPP Energy Department, Lahore.

PROFILE

- Company Name: **Bio Tech**
- Address: **16-A Block 5CII,Ameer chowk ,College road, Town ship Lahore**
- Ph. Office: **03334362836, 03454872525**
- Email: **info@biotechpk.com**
- URL: **www.biotechpk.com**
- Director: **Jawwad Ahmed Gill**
- Director Technical:
- Manager Admin: **Hammad Ahmed**
- Chief Financial officer: **Muhammad Adeel Aish**
- Manager Marketing:

DETAIL OF PERMANENT, CONTRACTUAL EMPLOYEES & ASSOCIATES

- Civil Engineer
- Mechanical Engineer
- Civil work Supervisor Muhammad Irshad/ Zahoor Ahmad/
- Skilled Labor 15
- Unskilled Labor 30
- Plumber/Electrician 2

ASSOCIATES

-

Regulation No:

3(5)(d)(vi)

Dynamic Green

Past References of Projects

Sr. No	Name of Project	Name of Client	Status	Rating
1	Aitchison Housing Colony (135 Houses)	Aitchison College Lahore	Completed	67.5 KWp
2	Aitchison College Two blocks	Aitchison College Lahore	Completed	340 KWp
3	Aitchison College	Aitchison College Lahore	Completed	27 KWp
3	Nestle 2 Milk Collection Sites (Phase 1)	Nestle Pakistan Ltd	Completed	11 KWp
4	Nestle 8 Milk Collection Sites (Phase 2)	Nestle Pakistan Ltd	Completed	50 KWp
5	Nestle 20 Milk Collection Sites (Phase 3)	Nestle Pakistan Ltd	Completed	105 KWp
6	Nestle 14 Milk Collection Sites (Phase 4)	Nestle Pakistan Ltd	Completed	95 KWp
7	20 Ufone BTS sites	Sagemcom	Completed	105 KWp
8	National Bank Branches (40 sites)	NBP	Completed	120KWp
9	National College of Arts Lahore	NCA Lahore	Completed	50KWp
10	National College of Arts RWP	NCA Rawalpindi	Completed	50KWp
11	SA Farm (Interloop), Faisalabad	SA Farms	Completed	105KWp
12	SA Farm (Interloop), Faisalabad	SA Farms	Completed	205 KWp
13	Integrated Energy and Agriculture Concept (PV-BioGas)	University of Agriculture Faisalabad	In Progress	100KWp (Solar) 125KW (Bio Gas)
14	Energy Solution Using Indigenous Resources (Veharri)	Energy Department Punjab	In Progress	300KWP (Solar) 100KW (BioGas)
15	Energy Solution Using Indigenous Resources (Samundri)	Energy Department Punjab	In Progress	100KWP (Solar) 300KW (BioGas)
16	Installation of Solar System for Operating High Efficiency Irrigation System Agriculture (Water Management) Punjab, Lahore	Agriculture Department Punjab	Completed	17 Systems of 151KWp
17	Office Building	DEC	Completed	5 KWp
18	Office Building	JIPL	Completed	5 KWp
19	Office Building	NTS	Completed	5 KWp
20	Office Building	DGL (Own)	Completed	5 KWp
21	Show room Millat Tractors	Usman Traders	Completed	10 KWp
22	Office Building	Albario	Completed	6 Kwp
23	Campus Solar Lab Solution	UET Taxila	Completed	12KW

BioTech
FOR GLOBAL HEALTH

PROJECT REFERENCES

WORKS COMPLETED

- We have installed about 250 domestic level biogas plants all over the Pakistan of sizes varying from 8 to 20 cubic meters.
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- 100KW Veharri & 300KW Samundri, Project of DoPP Energy Department, Lahore.

- **16-A Block 5CII,Ameer chowk ,college road, Lahore 042-35215460**

Regulation No:

3(5)(g)(a)

Site Overview

Bio Gas Plant:

- Consists of 14 digesters
- Built on a Nepolizen Design
- 1 Cubic Meter of Gas produced by it generates 1.23 units of electricity
- Has a capacity of producing 630-700 Cubic meters of gas so it generates a total of 861 units of electricity
- Consists of 2 Generators of 100 KVA and 125 KVA respectively. The second generator is there as a backup generator.
- Uses cow and chicken dung as a fuel.
- The biogas plant is designed to provide electricity for a load of 70 KW.
- The biogas stored in the digesters would also be provided to the villagers.

Solar Plant:

- Grid Tied solution with battery backup.
- Polycrystalline solar panels of HTSAEE brand are installed. A total of 912 panels are installed.
- A Baykee hybrid inverter of 300 KW is installed.
- A battery bank designed on 200 KWh is installed to provide a backup for 1 hour.
- The solar plant is designed to provide 1200 units of electricity per day.

Dynamic Green (Pvt.) Limited

Detailed Bill of Quantity

Component	Brand / Make	Model
Solar System		
Modules (300 KWp) inclusive both sites	HT SAAE / China or Qcell / China or Trina / China (or any other equivalent Top Tier brand as per Bloomberg recent reports) as per ready availability at the time of supply	330 Wp above per panel (Polycrystalline)
Inverters (Grid Interactive Hybrid Inverters)	Baaykee 1. 300 KVA	384 Vdc TYN Grid Interactive Series
Structure (solar panels mounting)	Galvanized Steel (equivalent of no of panels)	As per specs (DGL Design)
BOS (Balance of System for both sites)	DC & AC Cables, Data Cable, DC & AC breakers, PVC pipes, 400 VA Transformer Isolation Switches, DB's, String Combiners, Connectors, Bolts and Consumables as per design	Fast cable , rest are miscellaneous as per specs (DGL Design)
Battery System		
Battery cells (total 345 KWH, 48- dc Volt bank inclusive both sites)	Sacred Sun / China or Backey / China	Smart Power 48100/ As per specs
Inverters	NA-Not needed with grid interactive hybrid inverters	
Battery Management System (built in inverters)	NA-part of the inverters to manage the Li Ion batteries	NA
Biogas System		
Civil Works (Each item on both sites)	Digester Tank x1	As per specs (DGL Design)
	Reception Tank x 1	As per specs (DGL Design)
	Feed Tank x1	As per specs (DGL Design)
	Substrate Storage Platforms x1	As per specs (DGL Design)
	Slurry Pound x 1	As per specs (DGL Design)
	Generator Room x 1	As per specs (DGL Design)
	Slurry Channel x 1	As per specs (DGL Design)
	Bore for water motor x 1	As per specs (DGL Design)
	Water Storage Tank x 1	As per specs (DGL Design)
Planning and Engineering		
Equipment and Components		
	Agitator x 1	As per specs (DGL Design)

[redacted] [redacted] [redacted]

	Biogas Generators (125 KVA), 2 No	Kohler
	Grid Synchronizers, 2 No	As per specs (DGL Design)
	CHP (Heat Exchangers) 1 No	As per specs (DGL Design)
	Gas Filters (system), 1 No	As per specs (DGL Design)
	Membrane, 1 No	As per specs (DGL Design)
	Mechanical (piping, valves) for both sites	As per specs (DGL Design)
	Pumps, 2 No	As per specs (DGL Design)
	Gas Storage Balloon, 1 No	As per specs (DGL Design)
	Slurry Separator, 1 No	As per specs (DGL Design)
	Biogas flare Torch, 1 No	As per specs (DGL Design)
	Control Automation & Bio Gas Analyzer (1 No)	As per specs (DGL Design)
	Water motor	As per specs (DGL Design)

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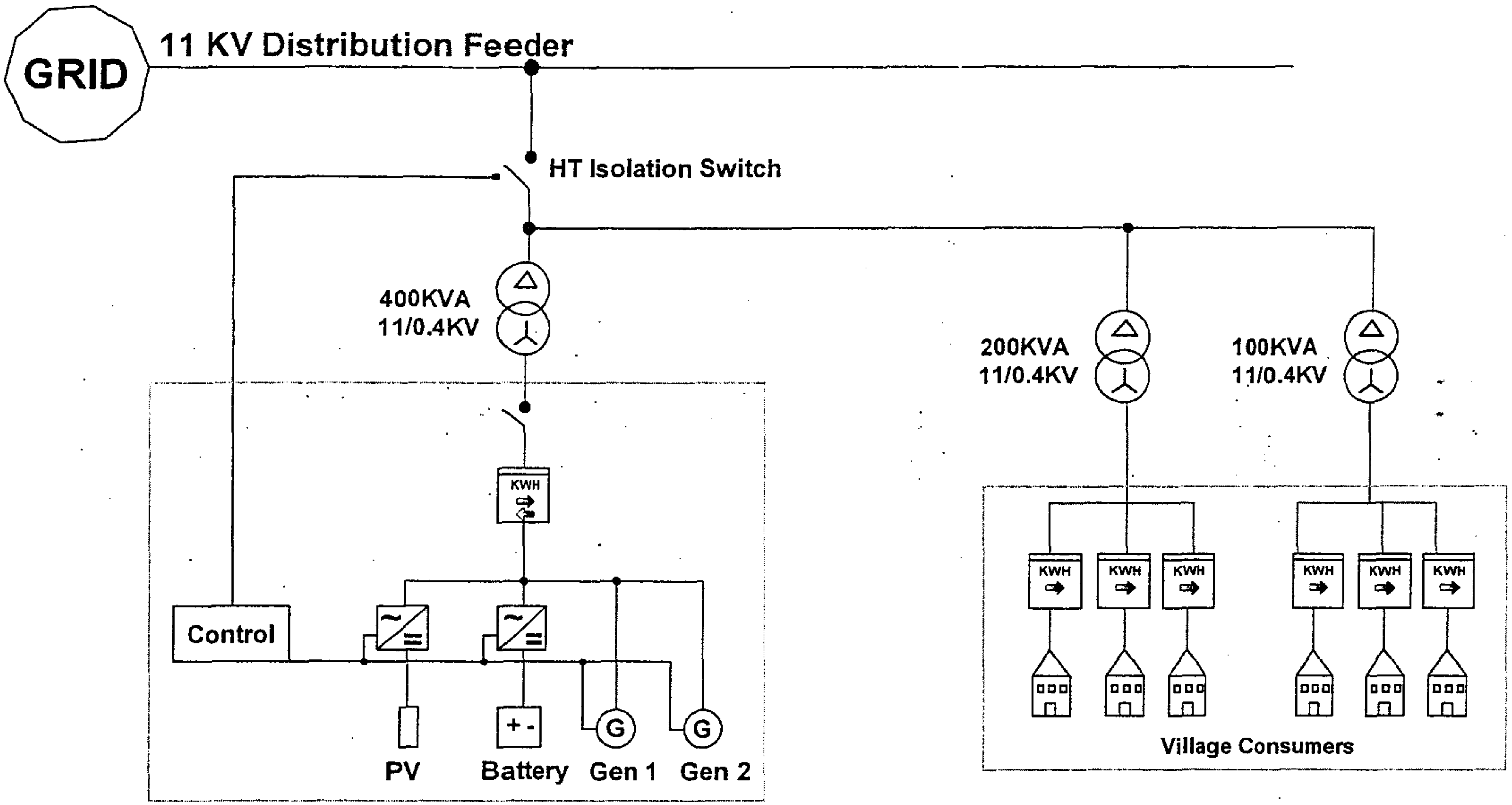
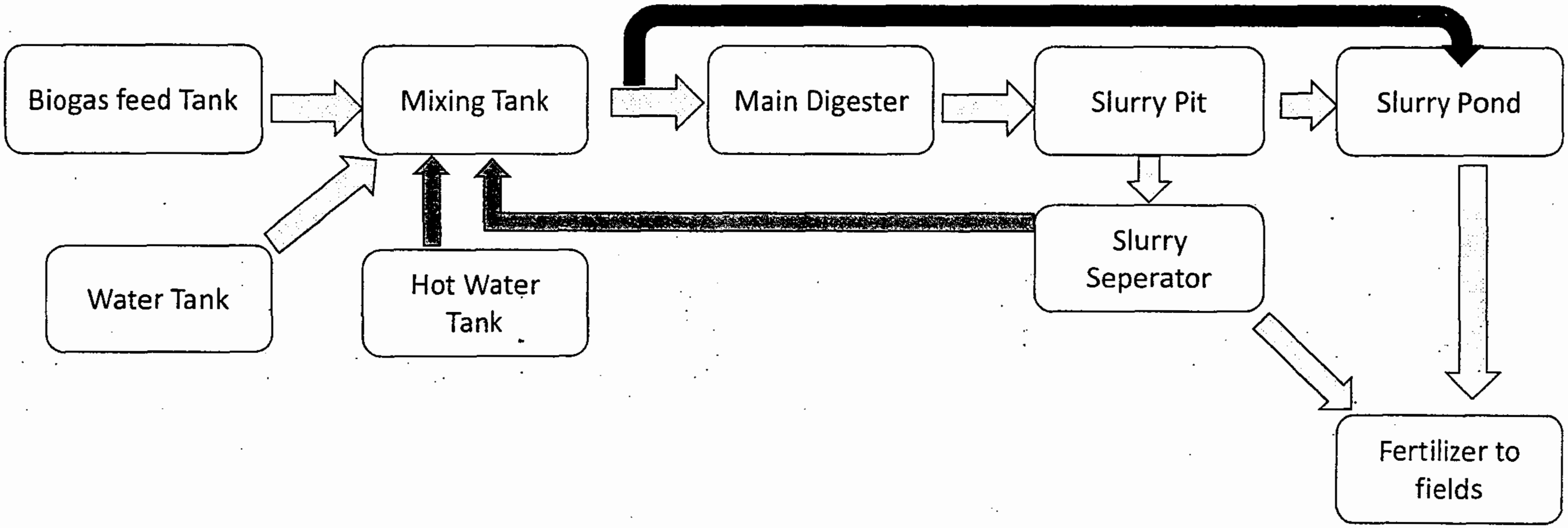


Drawing Name:	Drawing No:	Project Name:	Site Name:	Designed By:	
Single Line Diagram	DGL-D1-V1.1	Vehari Solar & Bio-Gas	Vehari Chak#563EB	Zaheer Ishfaq	DynamicGreen ENERGY SOLUTIONS

Biogas Flow Chart

BIOGAS production

BioGas flow chart -- feed flow



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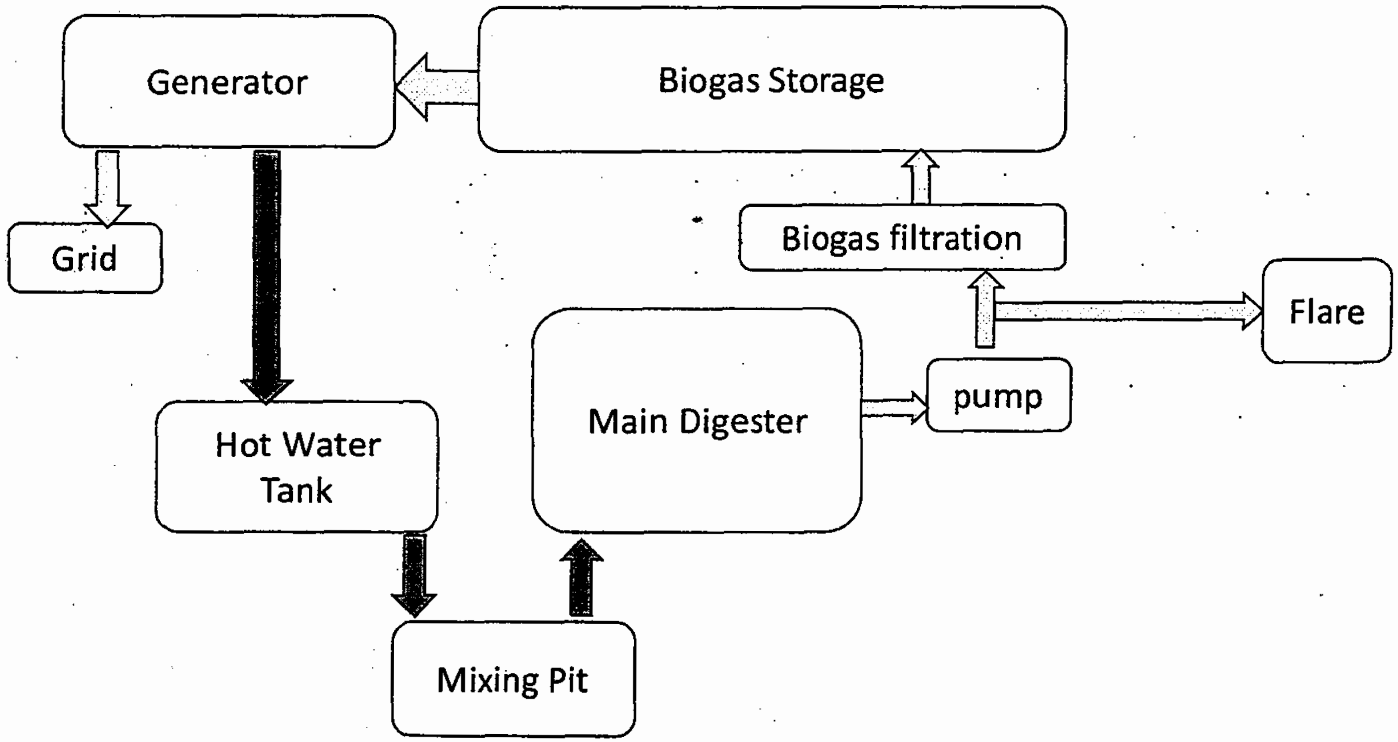
BioGas flow chart -- Gas flow



Basic Work Flow Description

We BioTech are striving for a green alternative energy source which is improving the lifestyle of farmers. BioTech has expertise both in domestic as well as commercial scale biogas plants throughout Pakistan.

Work Flow:

1- Selection and transportation of feed

As discussed and agreed quality and quantity of feed material will be responsibility of consultant and employer. If contractor have to buy the feed its price is written in covering letter.
Feed will be transported through trolleys. Feed will be stored in feed bunkers constructed close to reception tank. From bunkers to reception tank it will be shifted to reception tank according to plant need. Smelly feed part will be preffered to transport on daily basis as stock smell to bad .

2- Reception Tank along with Mechanized mixing through agitators

The manure inlet is meant for daily feeding of plant according to its requirement based on selected retention time. The mixing chamber/reception tank is used for mixing of dung and water in equal ratios with Mixer.
For better gas production mixing is very important.
That's why we suggest mechanical mixing in larger chamber.
Reception tank is divided in two equal parts of 45 cubic meter each first part will receive feed like dung second part will fill with over flow from part one sand free feed material will be mixed in second tank . feed shifting will also be done from second tank after mixing and settling of clay particles.
Feed will be shifted to digester through slug pumps.

2- Digester & Gas Holder:

Main Digester is the place where anaerobic fermentation occurs and produces biogas by methanogen bacteria, this process done in the absence of oxygen.. Gas holders are meant for storing gas. The gas will collect through the gas pipe embedded at the top and the center of the gas holder. Membrane gas holder will be installed on above ground gas is collected there and pumped out in a separate membrane storage.in fix dome design gas is collected in dome and pumped out

3- Outlet Chamber& Slurry Separator

The outlet of the plant in case of fixed dome design receives the fully digested light weight slurry which will be ready to use for agriculture purpose as organic fertilizer having high ratios of nitrogen in it.
In case of above ground design digested slurry is discharged from upper part during feeding of dung or other feed material at lower part of digester.
The discharged slurry will go to the slurry reservoir where slurry separator is installed and we can separate the dry matter from water inside slurry and this water is again shifted to Reception tank and dry Organic fertilizer is available for Agriculture.

4-Slurry Pond:

Excess slurry will be shifted to open Slurry pond fitted with geo membrane for environment protection. And avoid seepage . this open air dried slurry can be used as fertilizer. Employer may use it in field or may give it to dung providers.

5-Hydrogen Sulfide gas Scrubbers & Moisture Filters:

Gas collected in the chamber will be shifted to Storage Tank after removal of Sulfide and Moisture through Filtration system

6- Storage Facility.

After Filtration Gas will be stored in a separate Storage made of Single layered Membrane

7-CHP

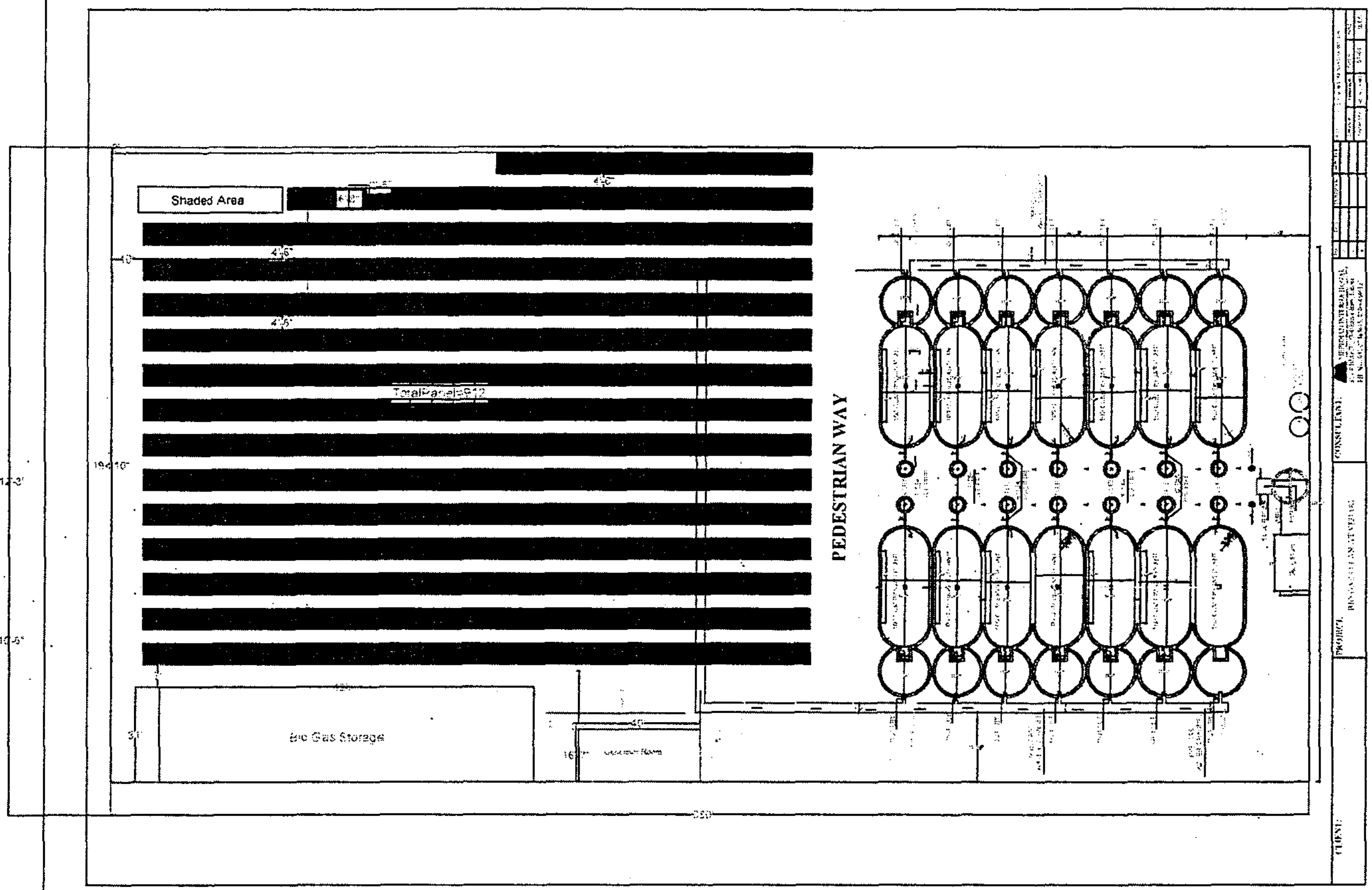
Gas produced will be utilized for power generation along with heat utilization of Generator through CHP Genset from where heat will be transferred to main tain tempreture of plant feed . temp of digester will be maintained with feed temperature control.in case generator is running at time of feeding hot water will be available from a 5M3 steel tank properly insulated.
Heat Exchanger from where temperature controlled water will be supplied to reception Tank to maintain its required temperature for anaerobic reactions.

8- Safety Flare

A safety flare will be installed to fire the excess biogas produced. If system is not using biogas and storage is fill. This flare will ignite as pressure of gas increases in digester. A pressure switch will be there to sense the pressure and dispose of excess gas.

9- Generator

A biogas generator will run on biogas and CHP will be available with prime generator only Secondary generator will be used when more electricity will be required.



Drawing Name:	Drawing No:	Project Name:	Site Name:	Signature:	
Solar and BIO-GAS Layout	DGL-D1-V1.0	DGL-Villages-300 KWp	Vehari	Zaheer Ishfaq	Dynamic Green

Regulation No:

3(5)(h)

Report

Type of Report:	Feasibility Study
Project:	Energy Solution Using Indigenous Resources in Villages
Client:	Energy Department
Purpose:	Site Selection and Feasibility of Installing Solar and Biogas Systems in Villages
Site location, Country:	Punjab, Pakistan
Operator:	Energy Department, Government of Punjab
Report number:	167712-PV-FS-IndigRes-R01
Date of Inspection:	02-04-2017 to 12-04-2017
Date of Submission:	28-07-2017

8.2 Obst & Ziehmann International GmbH
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Revision

Version	Modifications
R00	First Version 28-07-2017
R01	Second Version 24-08-2017

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List of Abbreviations

h	Hour
kV	Kilovolt
kVA / MVA	Kilovolt-ampere / Megavolt-ampere
kW	Kilowatt
kWh	Kilowatt hour
kWp	Kilowatt peak
LV	Low Voltage
PV	Photovoltaic
PV-Module / Module	Single solar module; smallest, essentially planar assembly of solar cells and ancillary parts, such as interconnections and terminals intended to generate direct current power
STC	Standard Test Conditions Irradiance at module level 1,000 W/m² Cell junction temperature 25°C Solar spectral irradiance distribution AM 1.5 (AM = Air Mass)
V	Voltage
Wp	Watt peak, rated power output or peak power at STC is the output data for solar modules or solar plants
DISCO	Distribution Company
MEPCO	Multan Electric Power Company
FESCO	Faisalabad Electric Supply Company
CHP	Combined Heat and Power
NEPRA	National Energy and Power Regulatory Authority
QOFE	Hourly Energy Load and Supply Simulation Tool

A. General Data

A.1. Assignment / Order

Task:	Feasibility Study
Client:	Energy Department, Government of Punjab
Order Date:	26.05.2017
Contractor:	8.2 Obst & Ziehmann International GmbH Brandstwiete 4 20457 Hamburg
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	Paris Zaka Ullah
	Umar Mustafa
Report number:	167712-FS-HYB-IndigRes-R00

A.2. Project Background

Currently, Punjab is facing immense electricity load shedding due to which a large population suffers, especially in rural areas where load shedding can be from 12 to 18 hours. The national grid was unable to supply the demand and this gap was increasing day by day.

Recently, the governments of Punjab and Pakistan have constructed several giga watts of capacity from coal and gas to reduce that burden. However, it can be foreseen that the electricity demand will continue to rise and those locations far out at the end of old 11 kV lines will still suffer from line outages.

On the other side, villages in Punjab have potential indigenous resources which can help to cater their energy needs. These resources are feedstock for biogas and biomass energy plants and solar irradiation for solar power, as well as, to a lower extent, wind energy and water resources for micro-hydro plants. As these resources are distributed and difficult to combine for large-scale projects, it is a promising approach to utilize decentralized power plants for individual villages that have their own power source run by their own community. This would reduce burden on the national grid and reduce the dependency on imported fossil fuels. All operational expenditures during the lifetime of the project will strengthen the local industry and employment, so the net effect for the Pakistani economy is very much beneficial. In addition, the generation of electricity through solar energy and biogas is a truly renewable energy technology addressing the issue of global warming.

The Government of Punjab has decided to develop two model projects, one in southern and one in central Punjab, where power plants based on indigenous energy resources will be built and operated to supply power to two villages. It will also minimize the load on long-distance transmission lines and would allow postponing severe upgrades in the 11 kV networks. Additionally, it can reduce line losses in the magnitude of 10-20% and improve the power quality by keeping up the voltage levels all along the stretched 11 kV lines due to local generation.

Successful operation of such projects would generate a new era of distributed generation in Pakistan. To prove the feasibility for this vision, the Energy Department, Government of Punjab (hereinafter referred to as the Employer) intends to construct one power plant on each of the two pilot sites as prototypes (hereinafter to be referred as the Project).

A.3. Scope of Work

Within the pre-feasibility study, the strengths and weaknesses of six village sites were analyzed in order to select the two most suitable sites. Specifically, the following points have already been assessed in the pre-feasibility study:

- Availability, current usage and prices (if applicable) of biomass in the villages
- Availability of government land in and around the villages and possibility of lease or donation of private land
- Commitment of village communities
- Current electricity and load-shedding situation

Based on these assessments, two sites were selected for the implementation of the Project.

This Feasibility Study analyzes the two project sites, including the project setup and implementation. Where different options are possible regarding project development, these are presented with their benefits and drawbacks.

Specifically, this study is structured in the following order:

1. The background of the Project (C.1)
2. The indigenous resources available at site, i.e. solar irradiation and biomass (0, C.3)
3. The technical concept, including sizing of the two plants, control mechanisms as well as a rough design for the plants (C.4, C.5)
4. The estimated yields of the plants (C.6)
5. Comparison between PC1 and proposed design (C.7)
6. The financial and economic viability of the Project (C.8**Error! Reference source not ound.**)
7. Options for the operational implementation (C.9)
8. Potential risks of the Project (C.10)
9. Social and environmental assessment of the project sites (C.11)
10. An estimated construction schedule (C.12)
11. The technical summary (C.13)

B. Executive Summary / Inspection Result

This Feasibility Study analyses the technical and economic feasibility of the two renewable energy pilot plants for rural areas which are planned to be installed in the Punjab region of Pakistan within the "Energy Solution Using Indigenous Resources in Villages" project. Within the Pre-Feasibility Study from June 2017, two village sites were selected to serve as the locations for the two pilot power plants, based on criteria such as availability of resources (e.g. cow manure), existence of community structures in the village, commitment of the villagers etc.

This study shows that the concept is technically and economically viable, with Levelized Costs of Electricity (LCOE) at 13 to 15 PKR per kWh (at 6.5% inflation, prototype cost assumptions) and down to 11 to 12.5 PKR per kWh (at 6.5% inflation, and roll out cost estimates), compared to decentralized diesel aggregates of 23 PKR and above. It should be kept in mind that the costs for this project in terms of PKR per kWp, especially for the biogas plant, are on the higher side as this project is first of its kind in Pakistan. It will serve as a proof of concept for the region and there will be certainly a potential for cost reduction in future, especially on the control and integration of biogas plants.

The study further defines a suitable sizing for both of the pilot plants and suggests appropriate designs. For the first village, Chak 443/GB in Tandlianwala, Faisalabad region in Central Punjab, a relatively large biogas plant of 200 kWp has been chosen which is built according to international best practices and accompanied by a smaller solar PV plant of 100 kWp and battery storage of 100 kWh. For the second village, Chak 563/EB in Vehari in Southern Punjab, a larger solar PV plant has been chosen with 300 kWp, accompanied by a smaller biogas plant of 100 kWp built based on a simpler design with a higher local share and battery storage of 200 kWh. The goal is to compare these two different designs during operation to assess the pros and cons of both designs and the two different biogas technologies.

Local cow manure and, to a minor part, chicken manure and silage, will be used for feeding of the biogas plant. The manure from goats has not been considered because of their zero collectability.

Each of the plants, in combination with an intermittent grid supply, will be able to ensure around-the-clock electricity supply to all households connected to a 200 kVA transformer of the respective village for most days and hours of the year. Excess energy will be exported to the electric grid.

The benefits of the intervention are as follows:

- Reduction in load-shedding of the electric grid in rural areas to ensure 24/7 supply during most hours of the year, thus improving the quality of life and economic development in rural regions and increased security of energy supply in the selected remote locations
- Contribution to the stability of the remote electric grid areas through distributed generation
- Reduction of losses in the rural electric grid, as generation is close to consumers
- Increased power bearing capacity of the 11 kV line as power supply is situated at the end of the grid. Grid expansion can be delayed.

- A large part of the CAPEX and mostly all OPEX are costs which are on one hand direct income of the local population and also act as a long term economic stimulus. The indigenous power supply has about 75% local cost over its lifetime which stays in country, the central power case has only approx. 5% of local cost. Most of the cost is imported fuel and has no impact on local employment and income generation.
- The foreign exchange requirements of any kilowatt hour generated is much lower than that of any fossil fuel power plant.
- Participation of the rural communities in their electricity generation through the contribution of cow manure and, as a perspective for the future, ownership of the power plant through community mobilization.
- At the same time, no contribution to climate change and its effects (such as global warming) through emission of GHG gases as the electricity is generated through clean technologies, namely solar PV and biogas.

Based on these positive outcomes, Result-Based Lending (RBL) by International Financed Institutions (IFIs) or similar would be a possible option for the financing of further plants of this type and a project roll-out in the longer term.

The study also estimates the total costs and a cost breakdown of the intervention and lays out a rough technical design. Based on these, a Request for Proposal for an EPC contract for the implementation of the power plants can easily be developed.

The study furthermore suggests the most suitable models for connection to the grid (under the active net-metering scheme) and for administrational setup (leasing out of the plant by the Government as owner to a private company as operator, probably through a special-purpose vehicle).

B.1. Project Status

8.2 Obst & Ziehmann International GmbH ("8.2") has been selected to support the Energy Department, Government of Punjab as the primary consulting firm during the development of Request for Proposal documentation for the tender process, the bid evaluation as well as the supervision in execution period.

Six sites were shortlisted by the Department for the Project. The Consultant, 8.2, visited the six shortlisted villages with groups of experts, accompanied by the Employer, during the period of 02-04-2017 to 12-04-2017. Based on the findings, the Department selected the following two villages as prototype sites for the project:

Central Punjab:

- Chak No. 443/GB (Tandlianwala)

Southern Punjab:

- Chak No. 563/EB (Tehsil and District Vehari)

This Feasibility Study analyzes and highlights the remaining details of the project and shows its economic and financial viability. Based on this, tender documents can be developed for a contractor to build the two power plants.

C. Feasibility Study

C.1. Site Assessment

C.1.1. Geographic Parameters

Punjab has 36 districts (please see Figure 1). For the scope of this project, three villages near Faisalabad and three in Muzaffargarh, Vehari and Khanewal regions were chosen by the Employer as candidates for the installation of a PV-biogas hybrid system. The Consultant visited all the sites in order to fully understand the local conditions and requirements. Based on a detailed evaluation table weighing all relevant criteria, two villages were selected in the pre-feasibility study.

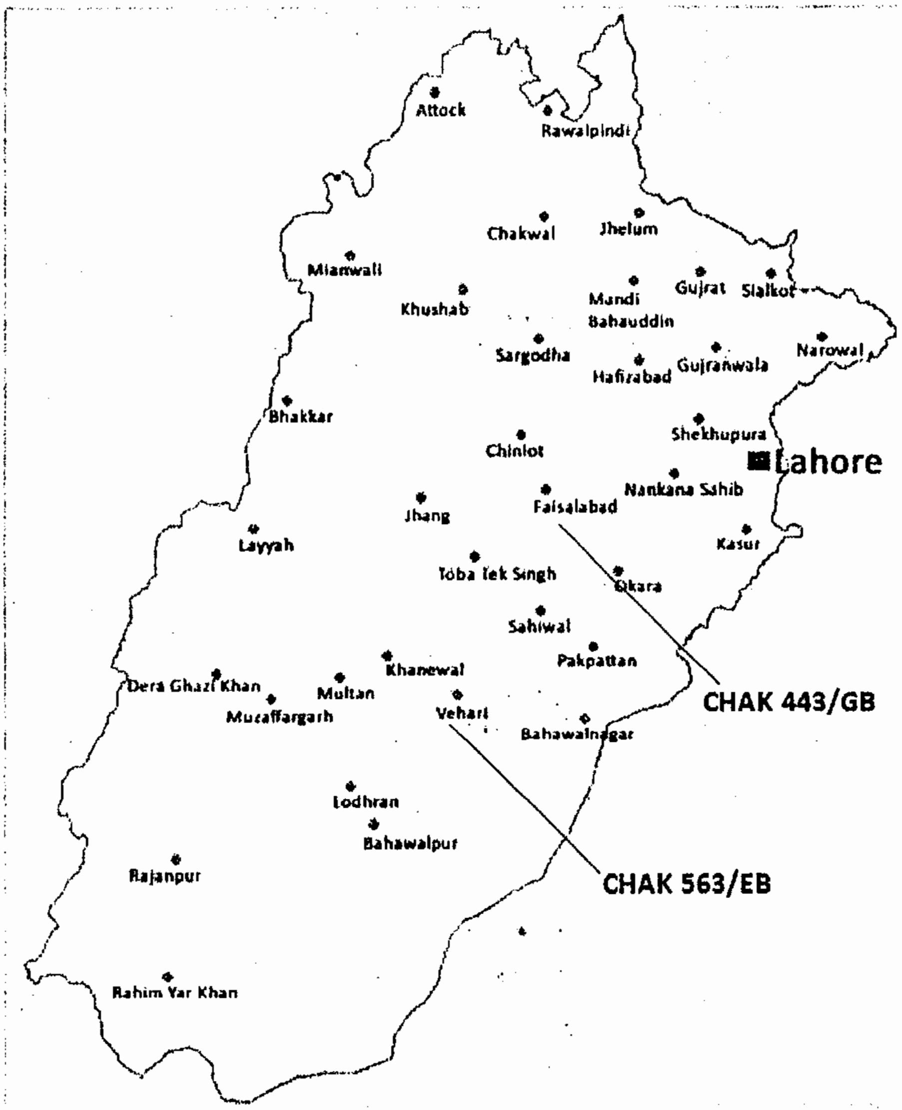


Figure 1: Districts in Punjab with village locations for the two project sites

These villages are accessible by basic or fully developed road infrastructure. Since the power plant will be installed on private or government owned land, there is no associated adverse impact on local settlements, or wildlife.

C.1.2. Climatic Conditions

The climatic conditions of the villages do not vary much and are based on the location of the villages. There are seasonal variations in weather, ranging from cold winters to hot summers, with temperatures of up to 45°C. The monsoon season lasts from May through September with a peak in July and August with an approximate 60 – 70% share of the yearly rainfall sum. There is an average of 8.5 hours of clear sky per day throughout the year and 2900 - 3300 sunshine hours annually.

The region is a generally low wind area with winds of less than 2.5 m/s. During the monsoon season, the wind speeds up especially during the day. Storm events have e.g. been logged by the meteorological station of Bahawalpur with maximum gust wind speeds of 20 - 30 m/s and single events of up to 40 m/s. Expected wind speeds for the specific sites and adequate design of all components need to be assessed during implementation stage.

C.1.3. Grid Access

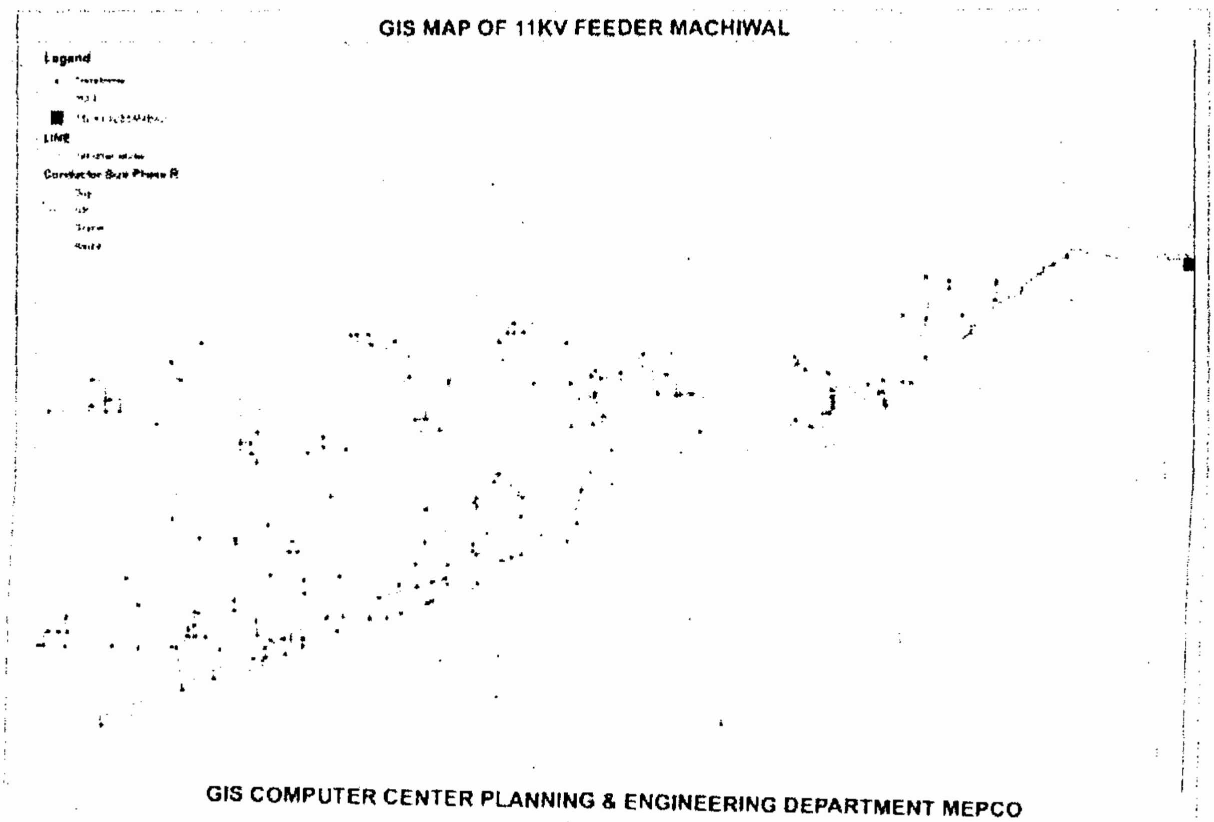


Figure 2: GIS Map of the 11 kV feeder at Machiawal in Vehari district by Multan Electric Power Company (MEPCO)

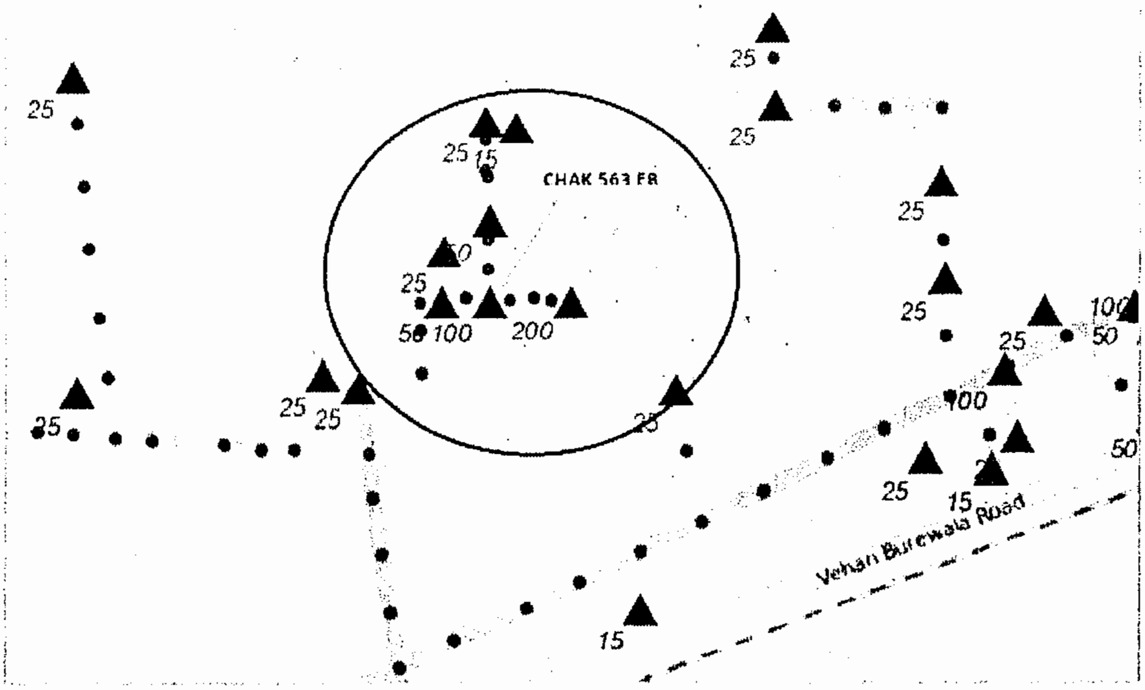
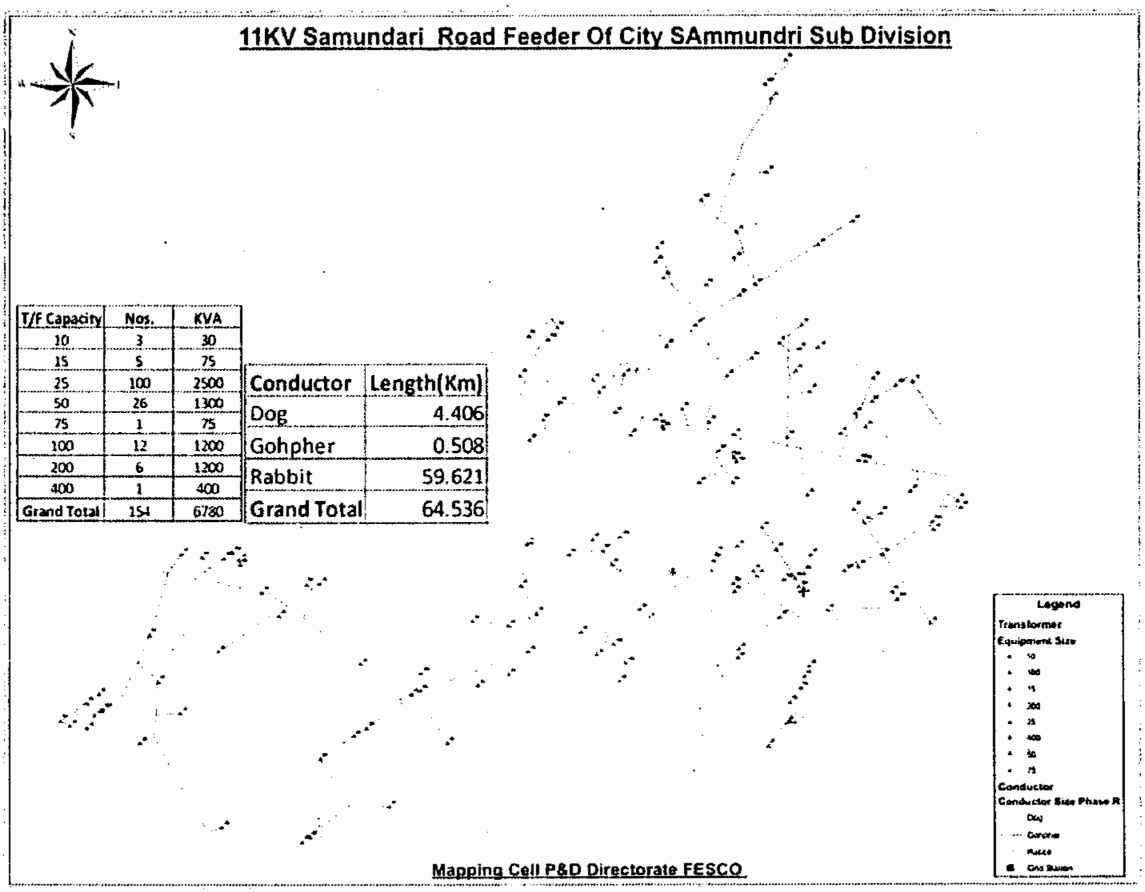


Figure 3: A close-up of the transformer rating for Chak 563 with rabbit conductor as specified in the GIS mapping of the 11 kV feeder.



T/F Capacity	Nos.	KVA
10	3	30
15	5	75
25	100	2500
50	26	1300
75	1	75
100	12	1200
200	6	1200
400	1	400
Grand Total	154	6780

Conductor	Length(Km)
Dog	4.406
Gohpher	0.508
Rabbit	59.621
Grand Total	64.536

Figure 4: Grid situation at Samundri, Faisalabad

From the villages that were surveyed, it was found that all sites had access to the electricity grid. An 11 kV medium voltage (MV) line is available at all sites. The specific feeders are not just dedicated for the individual villages as seen in Figure 3 and Figure 4, but also serve electricity to the local population of surrounding villages. Blackouts and frequent "load-shedding" hours between 8 to 12 hours and more per day were observed on these feeders. Additionally, some of the MV lines suffer from large voltage drop. In an event of low (or high) voltage, the power plant might have to switch to the off-grid mode until the electrical parameters of the grid will be restored to the normal operating range. This will allow a continuous provision of electricity in order to serve the load requirements and also to prevent equipment damage due to low (or high) voltage.

C.1.4. Description of the Two Selected Pilot Sites

C.1.4.1. Central Punjab: Chak No. 443/ GB (Tandlianwala)

Chak No.443/GB, Tandlianwala, is located in Faisalabad district. The village was visited on April 2, 2017. A group of a community mobilizer and the most interested and knowledgeable inhabitants of the village were engaged for the survey. The experts were hosted at a well-established local representative's house which serves as a community canter where information exchange and conversations were held with about 10-12 representatives from the village.

Figure 5: A typical stabled dairy farm

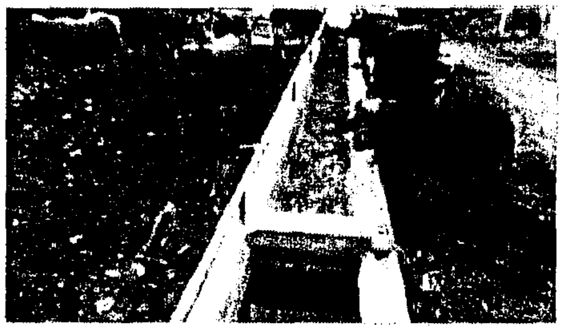


Figure 6: Dung from buffaloes that may be collected for the biogas plant

The village has a population of 528 households and stretches over 1800 acres. The main economic activity is agriculture, and the main agricultural harvests are wheat during winter and cotton during summer.

Figure 7: Community mobilization during survey for a group of women

Figure 8: Government land available for project site

A large space of government-owned land is available on two sides of the village (8 acres on south and 1.5 acres in north), which is more than sufficient to install a solar-biogas power plant of the planned size. This dedicated land can be used for installation of the system and will be available. The 8 acres in the south of the village would imply a longer connection line to the village, but the 1.5 acres in the North have been found very suitable for the project. The distance from the plant to the 200 kVA transformer in the center of the village as shown in Figure 9 is about 400 m and would be covered by an 11 kV line. The biogas plant would be situated adjacent to the road for easy deposit of common your, and the PV plant would be situated behind the biogas plant towards the fields.

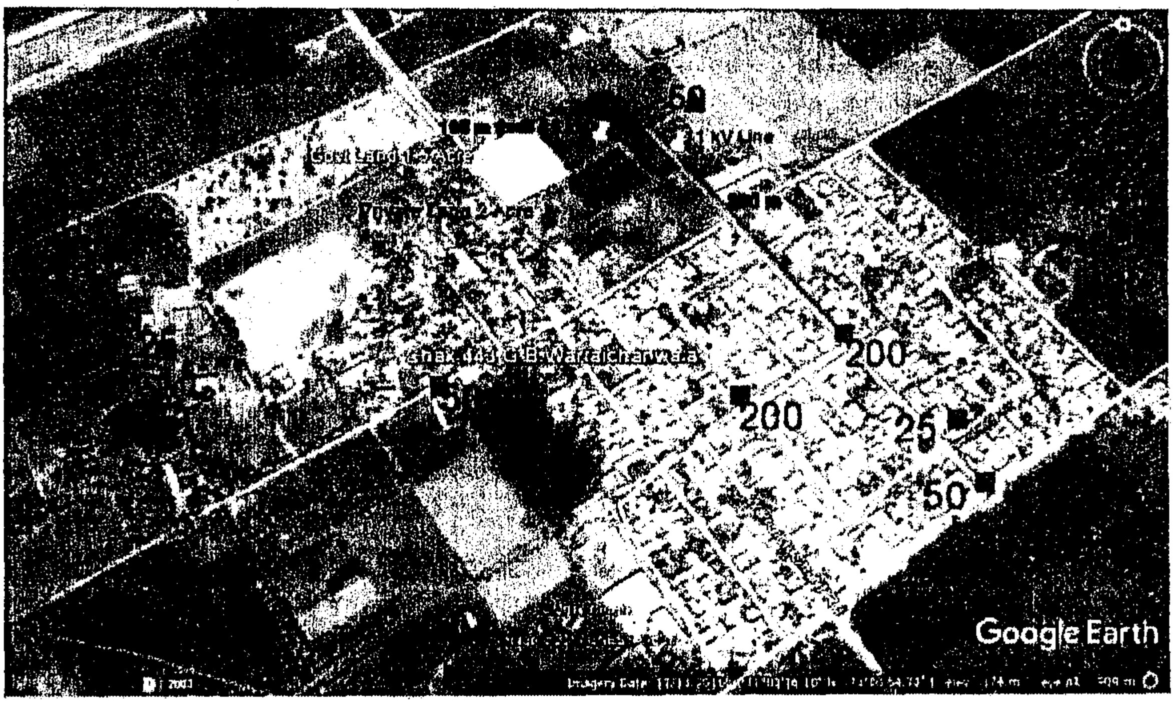


Figure 9: Satellite image of Chak 443/GB, Tandlianwala (Source: Google Earth)

Electricity consumption of the whole village was estimated at 500 kW of peak demand. There are several transformers of 200, 50 and 25 kVA as can be seen in the picture. Village households typically have fans, lights, water pumps, irons, televisions. Sometimes, fodder machines used for cutting straws and stalks are also used in some houses.

A big strength of the site is that cattle size is above 3,000 and cow dung is abundantly available and mostly not used for cooking. Therefore, it is stored beside the streets and around the land near cow farms in order to be taken to the fields for use as fertilizer later on. The villagers are very willing to give the dung to the biogas plant if they can receive the by-product slurry for fertilization of their fields. Apart from that, the presence of a slaughter house, three oil mills, 15 to 20 chicken farms and vegetable markets in near vicinity make it an ideal location for the feedstock resources.

An encouraging and motivating spirit of the villagers was observed and no concerns about the location of the suitable site with security and maintenance risks were mentioned by the villagers. A very positive response was received. The village also has a community committee which takes care of basic needs such as garbage collection and others, where the families contribute financially according to their possibilities. Such community structures will facilitate a possible project implementation on the site.

The village community expressed that it would be possible to dedicate a person for manure collection and they would be willing to provide their tractor-trolleys for this, which shows the general level of motivation and willingness.

C.1.4.2. Southern Punjab: Chak No. 563/EB (Tehsil and District Vehari)

Chak No. 563/EB is located in Vehari. The village was visited on April 6, 2017. A team of experts visited a large group of enthusiastic villagers. The community members of the village were interviewed for the survey. The experts were hosted at a well-established community centre and a local representative's house where most information was exchanged and conversations were held with about 20-25 representatives from the village.

The village has a population of 290 households and stretches over 560 acres. The main economic activity is agriculture, and the main agricultural harvests are wheat, sugarcane and fodder during winter and cotton, rice and maize during summer. Silage and crop residue is available throughout the year and could be bought as additional feedstock for the biogas plant.

A large 6.5 acres of space in form of government-owned land is available surrounding the village which is more than sufficient for the project. However, the land is distributed in two different plots; this needs to be considered for the project design. The land can be used for installation of the system and will be available at an easy lease agreement. The most suitable place for the power plant would be the right corner of the village which had a distance of 200 m to the 200 kVA transformer. One acre would be used for setting up the PV plant (300 kW peak) including battery and inverters, and the other acre would be used for the biogas plant (100 kW peak, underground design).

Electricity consumption of the whole village was estimated at 350 kW of peak demand. Electricity is available for 10-12 hours per day. Village house-holds typically have fans, lights, water pumps, irons, televisions. Sometimes, fodder machines used for cutting straws and stalks are also used in some houses. Air conditioning is not common as with most villages, but air coolers are sometimes used as an alternative.

An advantage of this site is that there are over 2,000 farm animals including buffaloes, cows and goats. Cow dung is abundantly available and mostly not used for cooking and is therefore stored on the roads in order to be taken to the fields for use as fertilizer later on. The villagers are very willing to give the dung to the biogas plant if they can receive the by-product slurry for fertilization of their fields. Apart from that, the presence of an oil mil, chicken farm and vegetable market in near vicinity makes it an ideal location for the feedstock resource.

An encouraging and motivating spirit of the villagers was observed. The village has a committee which is operating a water pump for irrigation since the 1970s. Expenditures for the pump are borne in common by the participants, and the participants take turns in utilizing the pump for their personal agricultural purposes. The existence of such community structures will facilitate a possible project implementation on the site. A very positive response was received.

Figure 10: A suggested government land available for project

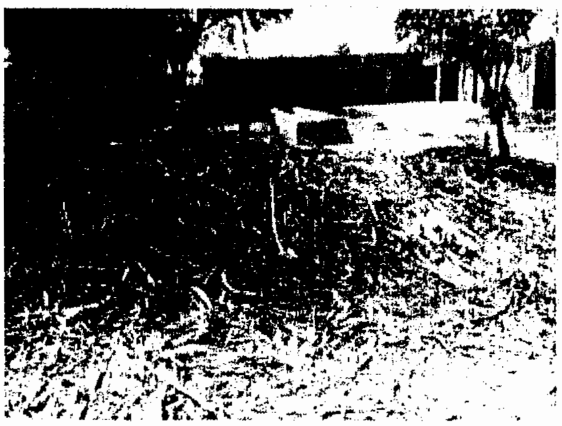


Figure 11: Residual waste outside a farm

Figure 12: Survey questionnaire being discussed in a representative's house

Figure 13: A chicken farm about 5 km from the village

Figure 14: Satellite image of Chak 563/EB, Vehari (Source: Google Earth)

C.1.5. Summary of the two pilot sites

[illegible]	[illegible]	[illegible]
Number of inhabitants	528 households	290 households
Total number of cattle	3000	2000
Other biogas sources of village	Silage and crop residue; chicken excrements from nearby farms	Silage and crop residue
Number and size of transformers	200 kVA x2; 50 kVA x3; 25 kVA x 2	100 kVA; 200 kVA
Government land available and distance to nearest transformer	Total 9.5 acres within 400 m from nearest transformer for each possible site	Total 6.5 acres of land within 200m from nearest transformer for each possible site

Table 1: Summary of the main features of the two sites

C.2. Solar Resource Assessment

For the evaluation of solar resource assessment, there are many professional tools available that allow obtaining of meteorological data from satellite imaging. For the purpose of this study, the Meteonorm software and database was used. The significant parameters for assessment included irradiation data, daily and monthly maximum, minimum and average temperatures, precipitation and sunshine hours.

C.2.1. Chak 443

For Chak 443, the annual total of global horizontal irradiation (GHI) was found to be 1,720 kWh/m^2 and irradiation of diffuse radiation horizontal was 930 kWh/m^2. The average monthly air temperature is 23.7 °C. This data shows that there is sufficient reliable solar energy resource available for harnessing by a PV system. Precipitation is usually high in the summer months, while it is fairly low for the rest of the year except March. Sunshine hours vary from 7 to 13 hours for the whole year.

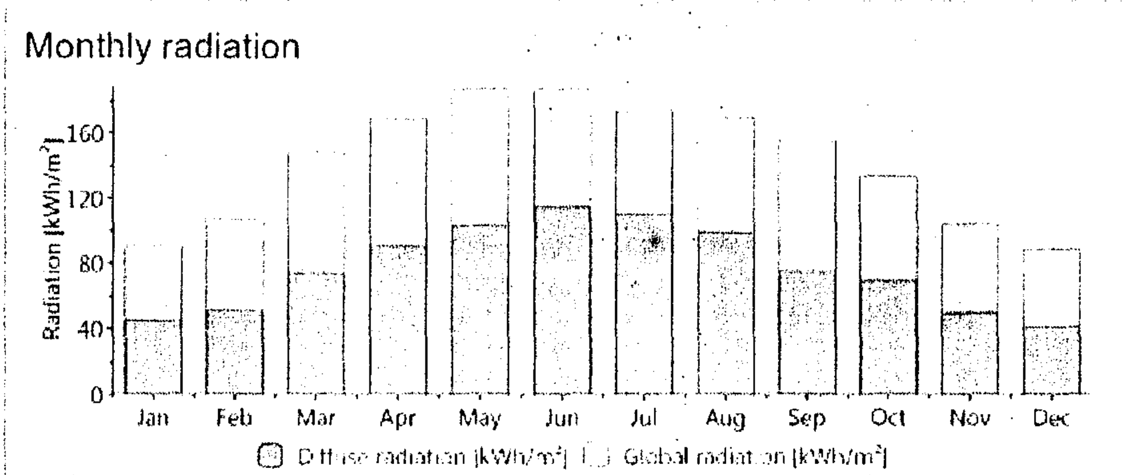


Figure 15: Monthly radiation data for Chak 443 from Meteonorm

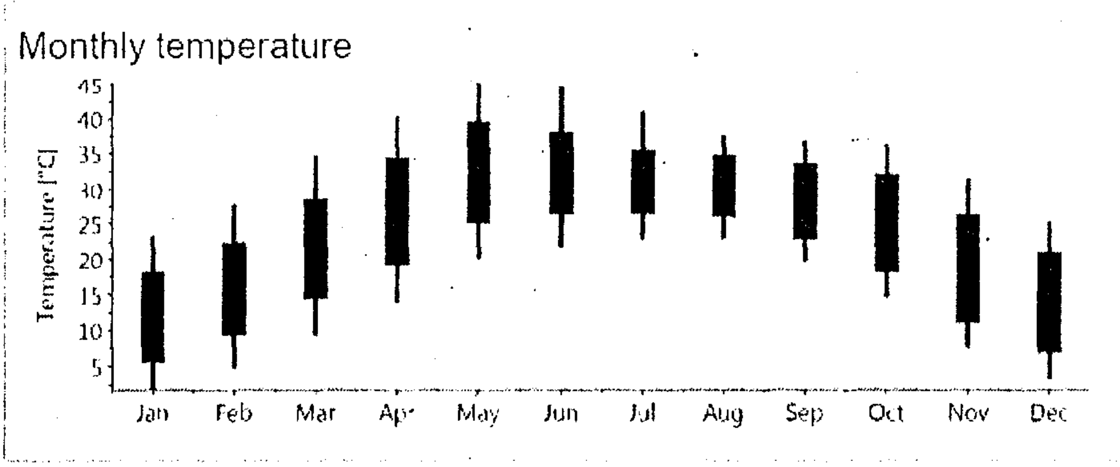


Figure 16: Monthly temperature data for Chak 443 from Meteonorm

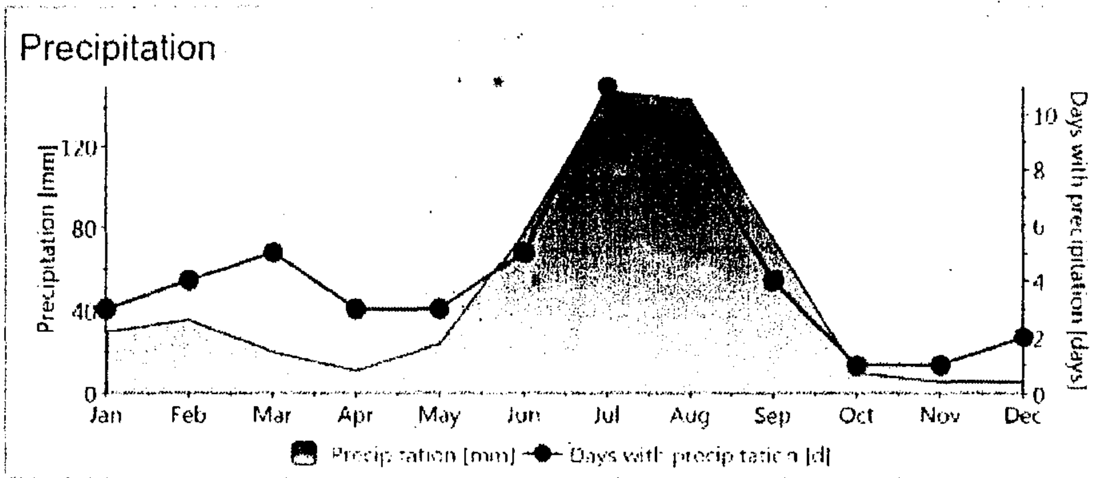


Figure 17: Precipitation data for Chak 443 from Meteonorm

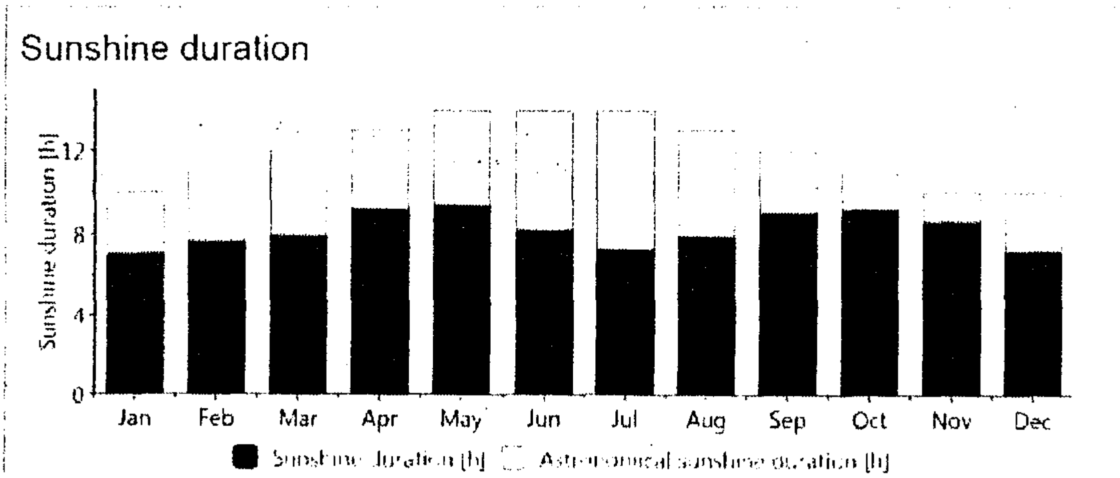


Figure 18: Sunshine hours for Chak 443 from Meteonorm

C.2.2. Chak 563

Chak 563 has an annual total global horizontal irradiation (GHI) of 1,821 kWh/m^2 and irradiation of diffuse radiation horizontal of 923 kWh/m^2. The average monthly air temperature is 24.1 °C. As in the case for Chak 443, this data shows that there is sufficient reliable solar energy resource available for the project; in fact, GHI is slightly higher for this southern location. Precipitation is usually high in July and August, while it is fairly low for the rest of the year. Sunshine hours vary from 7 to 13 hours for the whole year.

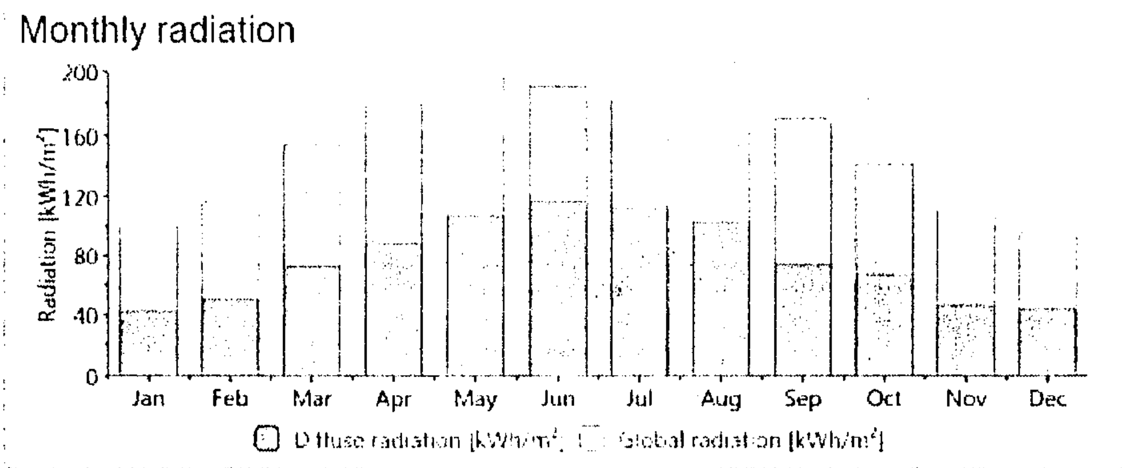


Figure 19: Monthly radiation data for Chak 563 from Meteonorm

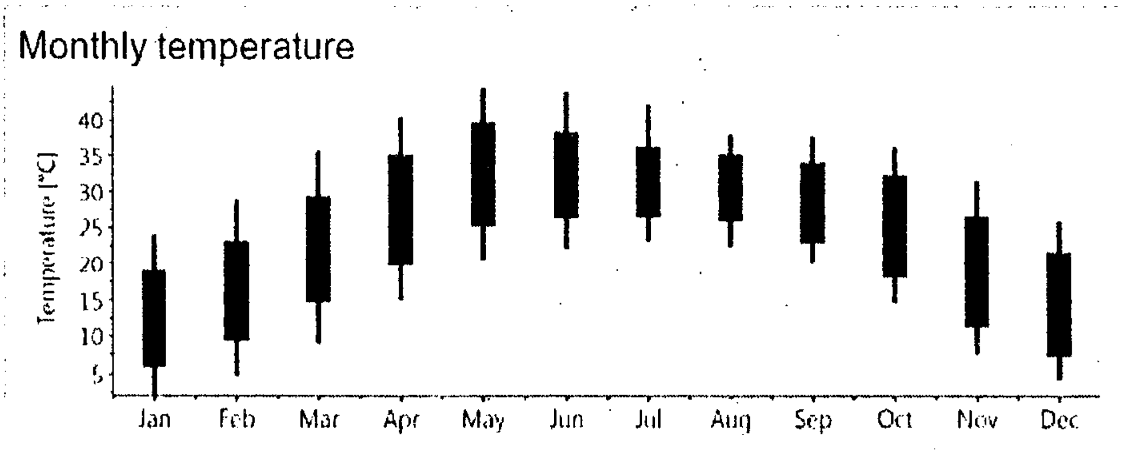


Figure 20: Monthly temperature data for Chak 563 from Meteonorm

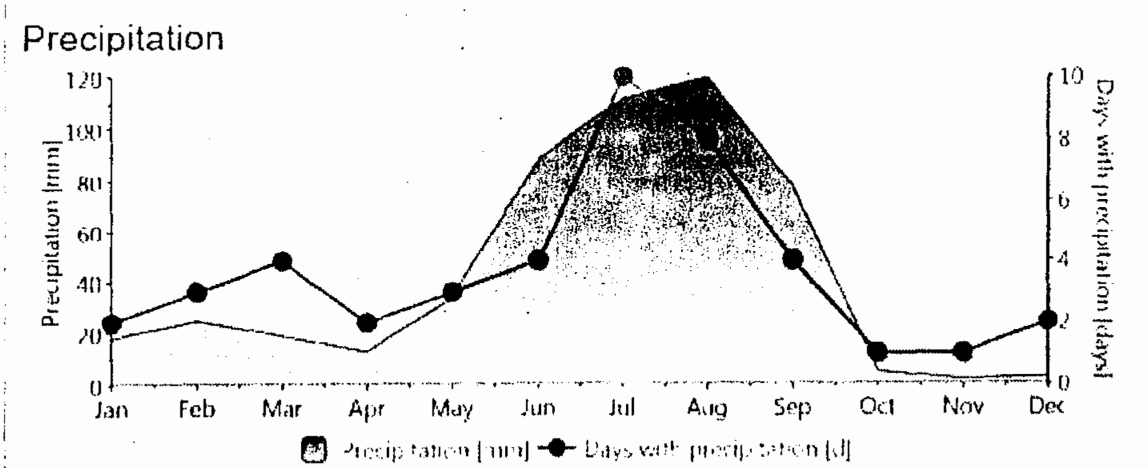


Figure 21: Precipitation data for Chak 563 from Meteonorm

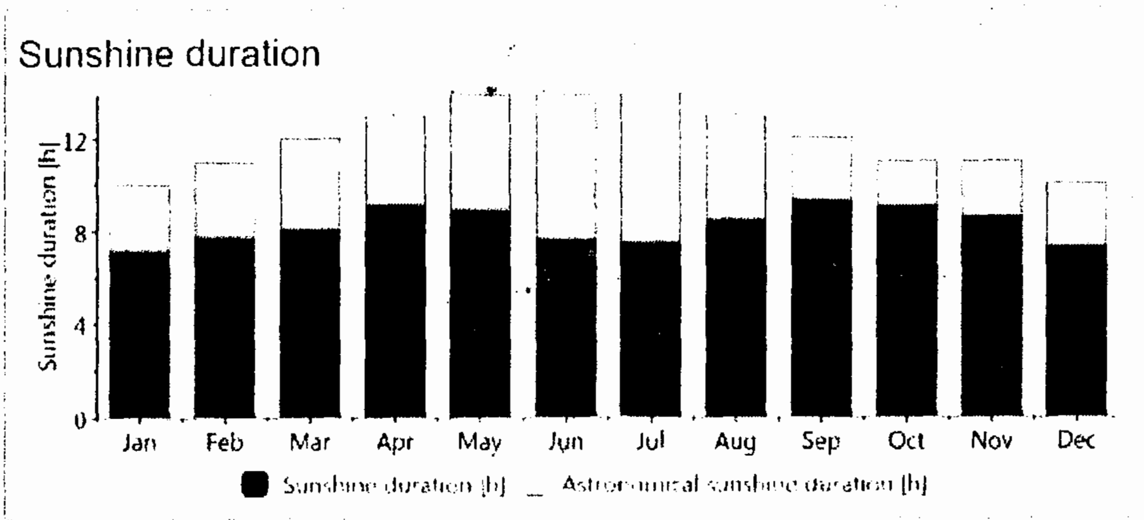


Figure 22: Sunshine hours for Chak 563 from Meteonorm

C.3. Biogas Feedstock Resource Assessment

C.3.1. General consideration

In both village sites, the number of adult cattle is around 2,000 and above, according to the consultant's assessment in the targeted project villages (see attached questionnaires), it is estimated that one adult cow produces 8 kg of cow dung fresh matter (FM) per day on average with a dry matter (DM) content of 40 %[1]. It is further estimated that 50% of this can be successfully recollected and supplied to the biogas unit; the other 50% are assumed as losses due to many roaming animals where excrements cannot be collected, and losses due to biological and physical decomposition and an additional amount of dung that is used for cooking purposes ("Uplay"). Table 2 indicates the given parameters of dung (solid manure) generation per adult animal according to FNR/KTBL, 2013 and the estimations for the available dung in rural areas in Pakistan and for the biogas projects realized by the project team.

No. Animals	t FM per cow and year	total FM per year	total t FM per day	DM	DM per day (t)
1	20	20	0.05	10%	0.005

No. Animals	t FM per cow and year	total FM per year	total t FM per day	DM	DM per day (t)
1	8	8	0.02	2%	0.0004

No. Animals	t FM per cow and year	total FM per year	total t FM per day	DM	DM per day (t)
1	10	10	0.027	25%	0.007

*incl. 4 kg of straw per animal/d

No. Animals	t FM per cow and year	total FM per year	total t FM per day	DM	DM per day (t)
1	3.5	4	0.010	40%	0.0038

No. Animals	t FM per cow and year	total FM per year	total t FM per day	DM	DM per day (t)
1	3	3	0.008	40%	0.003

Collecting Rate	50%	
Collectable	0.004	t FM/day and cow
Number of Cows	2,000	cows per village
Collectable Dung Amount	8.22	t/day per village

Table 2: Dung generation per animal in Germany and Pakistan and estimation of available manure for the project

Based on these calculations. from a village with 2,000 cows where 50% of the dung will be collected will be an amount of 8.22 tons per days of solid manure or dung available brought to the plant with a dry matter content of 40% of which around 75% will be organic dry matter.[2]

According to the assessments, the dung will be collected by the local farmers in trolleys with a loading volume of 100 cubic feet or 1 ton. The price per ton of dung brought to the plant is expected to be maximum USD 5 (PKR 500-600) but will depend on final negotiations with the farmers.

The usage of cow dung within the project has been discussed with the local farmers. Normally, a certain price per ton is applied in the villages. However, it seems that the farmers would be ready to give the dung for free if they receive the slurry which is the byproduct of the biogas plant for fertilizer purposes. The dung also needs to be collected, probably by a local labor person, each day. For the labor and possible substrate costs, PKR 350 per ton is assumed within the USD 5.

In order to provide a buffer for any supply issues with cow dung and in order to reach a diverse, but constant substrate combination which favors a high biogas production yield, additional substrates - chicken manure and corn silage - will be purchased from the market.

Chicken farms are available near both villages. The bird excrements are normally sold as combustible, e.g. to brick factories, and are available on purchase for a price of around PKR 3,000 (30 USD) per ton brought to the plant. In order neither to create strong sedimentation layers in the biogas tanks, cause abrasion on mechanical equipment nor to feed the biogas tank with non-digestive material, the chicken manure must not contain higher shares of sand or saw dusk bedding material, while organic bedding materials such as rice shells and straw can be accepted. Following these rules, the chicken manure provided to the plants is expected to have 65% of DM with 75% of oDM. However, the substrate quality should be analyzed constantly and for each different provider separately. The payment should be according to the estimated DM and oDM concentrations in order to be able to pay for the substrate according to the respective energy value. Concerning the utilization of chicken manure, it is strongly recommended not to feed more than 25-30% of the overall substrate-input in tons per day. The biogas process can operate with a carbon-nitrogen (C:N) ratio of maximum 25:1, and if more than 30% of manure will be fed into the biogas plants, this ratio will be lower, which will inhibit the biogas production.

The third substrate for the biogas plants can be an available energy crop, such as maize silage, grass silage, or miscanthus or it can be a high energetic agro-industrial residue such as potato peels, fat waste or cotton press cake.

In order to reach a pumpable and mixable substrate mix, also water needs to be added to the process. This will be done by fresh water dosification and utilization of the re-circulated liquid phase, which is coming from the separation of the digestate at the end of the process. The input feedstock mix should be below 15% of dry matter, while in the main digester the dry matter content should be maximum 8-9%. Water has no energetic value for biogas production; that is why it should only be added as much a required to maintain the substrate mix sufficiently liquid for pumping in case the recirculation liquid is not enough.

Table 3 compares the final costs of the substrates according to their energy value and the respective electricity output. Although the energetic value of the cattle manure is comparatively low, it offers the lowest cost per kWh_{el}. Chicken manure is still less expensive than e.g. corn silage but has its limitations concerning the usable shares within the overall input.

Cow Dung	164	$	5.00	$	0.03
Chicken manure (dry)	578	$	30.00	$	0.05
Corn silage	343	$	35.00	$	0.10

Table 3: Specific costs concerning the electricity output of each substrate

C.3.2. Tandlianwala

In Tandlianwala, the current cattle number of adult animals is above 3,000. This leads to 12.33 tons usable for the biogas plant per day if 50% will be collected with the stated methodology.

15-20 chicken farms are available near the village with a constant breeding of 100,000 animals in total. These produce variable amount of excrement depending on area. A farm size of 6000 square feet delivers 3-4 trolleys of 2 tons every 2 months. This assumes a total of 0.5 tons of chicken excrements per day as per information from the farms. According to FNR/KTBL 2013, chicken breeding for meat production produces around 7 kg of chicken manure per animal and year of which 0.25 kg is for bedding material that includes sand and rice husk. Poultry farms usually generate around 2 kg of chicken manure per animal and year of which 0.15 kg is for bedding material.

The following table provides an overview about the envisaged substrate mix, the respective biogas production yields and the potential of alternative substrates for the planned biogas plant in Tandlianwala.

Cow Dung	3,000	8.22	40.0%	75%	2.47	55%	148,500	300.0	270,000
Chicken manure (dry)	329	0.9	65.0%	75%	0.44	65%	57,251	550.0	88,079
Corn silage	347	0.95	32.0%	94%	0.29	53%	35,932	650.0	67,797
Recirculate Water	3,650	10	1.0%	50%	0.05	55%	0	0.0	0
Gras silage	0	0	35.0%	90%	0	55%	0	600.0	0
Fresh Water	3,650	10	0.0%	0%	0	0%	0	0.0	0
Potato Peel	0	0	20.0%	90.0%	0	70%	0	500.0	0
Fat Waste	0	0	95.0%	90.5%	0	65%	0	800.0	0
Cotton press cake	0	0.0	90.0%	90.0%	0	65%	0	750.0	0
Total	**10,975**	**30**	**14.2%**		**3.2**		**241,684**		**425,876**

Table 4: Envisaged substrate mix and biogas yields for the biogas plant in Tandlianwala

The substrate concept considers a conservative approach regarding the collection rate of the manure; therefore, it is assumed that just 33% of the available dung from 3,000 adult animals will be collected. The rest of the required substrate mix will be provided by chicken manure and corn silage.

Therefore, the plant will require around 1 ton per day of chicken manure of such quality, but as mentioned above, the purchase of manure should be for 30 operation days in advance in order to be flexible in times of supply problems with the other substrates, especially dung, which will be brought on daily basis to the plants..

In order to reach the required 100 kW average electricity production with the given co-substrates, 1 ton of maize silage (or equivalent) per day is additionally expected to be needed. Therefore, a platform for the annual or seasonal silage storage will be installed in the plant as well. A price of PKR 3,500 (USD 35) per ton maize silage at the silage platform is being envisaged. This allows also enough buffer, to purchase more cost-effective alternative substrates on the market, if available. Since this third substrate is supposed to contribute to 15-20% of the overall biogas production, it will be possible to develop long-term supply concepts for alternative substrates in the future. However, the price for the alternative substrate should not exceed the price for maize silage energy equivalent and also, if the feeding mix will be adapted, feedstock changes should be realized carefully and in small charges per day. Although a mixture of different organic materials is recommended for the stable operation of biogas plants, the biogas producing bacteria also requires a constant feedstock and will adapt slowly to changes within the substrate mix.

C.3.3. Vehari

In Chak 563, Vehari, the current cattle number of adult animals is around 2,000. This leads to 8.22 tons of solid dung usable for the whole village per day, if around 50% of the manure will be collected.

For the provision of an alternative buffer substrate, one chicken farm is available near the village with 60,000 chickens in total. These produce about 1,000 tons per annum of chicken excrements as per estimates. However, it should just be used in case there will not be sufficient cow dung and then also just added in small amounts and well mixed with water and recirculation liquid since the digester design is not prepared for solid organic material.

For the biogas plant, the planned substrate composition is displayed in the following table.

Cow Dung	3,000	8.22	40.0%	75%	2.47	55%	148,515	300.0	270,027
Liquid cattle manure	0	0.0	35.0%	80%	0	55%	0	200.0	0
Solid cattle manure	0	0	18.0%	80%	0	60%	0	400.0	0
Chicken manure (dry)	0	0.0	65.0%	75%	0.00	65%	0	550.0	0
Corn silage	0	0.00	32.0%	94%	0.00	53%	0	650.0	0
Recirculate Water	4,380	12	0.0%	0%	0.00	55%	0	0.0	0
Gras silage	0	0	35.0%	90%	0	55%	0	600.0	0
Fresh Water	4,380	12	0.0%	0%	0	0%	0	0.0	0
Potato Peel	0	0	20.0%	90%	0	70%	0	500.0	0
Fat Waste	0	0	95.0%	90.5%	0	65%	0	800.0	0
Cotton press cake	0	0.0	90.0%	90%	0	65%	0	750.0	0
total	11,760	32	10.2%		2.5		148,515		270,027

Table 5: Envisaged substrate mix and biogas yields for the biogas plant in Vehari

Normally, a price of 1,000-1,500 PKR/trolley is used for cow dung in Vehari village, with 1 trolley equivalent to 3,000 liters by volume or 110 cubic feet (approx.) is applied in the village. Therefore, an approximate cow dung price would be PKR 400/ton.

C.4. Technical Concept Specification

The technical concept entails several topics which are laid out and discussed in the following.

C.4.1. Control System for Electric Generation and Consumption Parts

As for any off-grid system, the generation units (in this case solar and biogas), will be controlled by an overall control system. The task of the control system is to control the different units in a way that allows a stable electricity supply and optimizes the overall technical and economic performance of the system, but it also needs to ensure that the generation units are started, operated and shut down in a proper way. It might also manage the load to a certain extent through switching on and off of certain lines if that is acceptable; if this is the case, it gives more flexibility on how to operate the generation units and the average generation cost per kWh can be driven down.

Operations of the Hybrid Plant

The possible operational states for the mini-grid system will be as follows:

1. On-grid mode: The village is connected to the electric grid while the latter is on. Biogas and PV plants, if connected, feed into the grid.

2. Off-grid/islanding mode: The electric grid is switched off, mostly due to intentional load shedding or brownouts, and the system runs in islanding mode:
   a. Biogas only: The biogas unit is running and, through its generator, gives the grid frequency and power reserve.
   b. Biogas and PV: The biogas unit is running. The PV system feeds additional power into this island grid through its inverters. Grid frequency and power reserve are provided by the biogas generator.
   c. PV only: the PV system runs on its own and provides grid frequency and power reserve. For this mode, a hybrid inverter and at least a small battery bank are needed to actively provide the grid frequency and some power reserve.
   d. Battery only: In this case all the energy demand is met by the battery. This is only possible where the battery is sized for this purpose and does not solely provide for system balance. A hybrid inverter is required.

In order to enable the off-grid mode, the possibility of a separation from the main grid through electric switches needs to be foreseen; however, this is a standard feature for electric power plants.

The first two variations of the off-grid mode are rather simple. However, proper operation and protection against different kinds of faults needs to be implemented properly in the control system.

The third (and fourth) variation of the off-grid mode requires the mentioned hybrid inverter which includes higher investment costs and more sophisticated control compared to a normal inverter, as well as the mentioned battery reserve which also implies a certain cost. On the other side, foreseeing this option brings the flexibility to run the solar part without the biogas which makes the overall system more reliable and robust and also allows the option to run the off-grid mode completely on solar which is the cheaper of both renewable energy sources.

In order to keep the costs low, the battery bank capacity can be kept small; even a total battery bank capacity of five to fifteen minutes at peak PV output may suffice. However, a battery bank of significant energy amount brings benefits of flexibility and also makes sense for the Project.

C.4.2. Dimensioning of the plants

The original technical description in the PC-1 document foresees the following for the two sites:

Solar power plant size	200 kWp	300 kWp
Battery size	200 kWh	300 kWh
Biogas plant size	100 kW / 150 kW peak	20 kW / 50 kW peak

Table 6: System sizes of the power plants

However, these sizes were an initial idea of possible dimensions for the two sites. Now, after assessing the requirements and conditions of the two pilot sites and the corresponding villages, a more individual design can be developed. The new design should:

- Match the load requirements of the chosen transformers of the two villages
- Showcase different setups (high amount of biogas with small amount of solar or vice versa)
- Fit within the given total budget

Based on the findings from the villages, conceptual considerations and simulations, the following design is proposed.

Solar power plant size	100 kWp	300 kWp
Battery size	100 kWh	200 kWh
Biogas plant size	100 kW / 200 kW peak	50 kW / 100 kW peak

Table 7: Proposed system sizing of the power plants

This new sizing maintains roughly the original setup:

- A 200 kW peak biogas plant combined with a smaller solar plant of 100 kW peak on Site 1[3] and a medium-sized battery for balancing

[3] In terms of nominal peak power, both plants are of similar size, but as the capacity factor of the solar plant is only of around 17% compared to around 90% of the biogas plant, the annual produced energy of the biogas plant will be much higher compared to that of the solar power plant.

- A 300 kW peak solar plant combined with the slightly smaller biogas plant of 100 kW peak on Site 2[4] and a relatively large battery size that can completely cover one hour of load shedding.

According to the latest information from the two sites (July 2017), load shedding is seldom longer than one hour in a row, so after one hour, the battery can be recharged by solar or grid.

The peak power size of both biogas plants has been increased in order to fulfill the peak demand requirements of the villages.

C.4.3. Typical daily demand and supply chart for Sites 1 and 2

In order to verify the plant design and sizing, actual demand and grid supply data is needed for the two sites in order so that the performance of the plant system can be simulated. Based on the simulation, basic characteristics can then be derived, such as overall yield of the plant, consumption of the village during load shedding of the grid, exported energy to the grid as well as hours the plant cannot meet the load of the village.

C.4.3.1. Demand data

Demand profile data has been derived from original feeder data received from FESCO. The data set provided gives hourly values of demand and supply for the year of 2014 for the feeder that supplies the village of Chak 443; individual values for the village transformer were not available. In order to derive values for the specific transformer, the data has been scaled down so that the peak demand of a typical summer day in July comes to 180 kW (200 kVA at a power factor of 0.9. The scaling factor between the feeder and the village transformer is 9.7).

C.4.3.2. Supply data

Unfortunately, the situation of grid supply varies strongly all over Pakistan. There are normally several hours per day of scheduled load shedding for all major cities. The number of hours varies between the seasons with the highest number in the summer season. For the villages, the situation is more unpredictable with scheduled load shedding that varies and additional unscheduled load shedding or brownouts. According to Pakistan's development plan for the power sector, the number of hours of load shedding should decrease over the next years, however, it is impossible to know the exact situation. Distribution companies such as FESCO and MEPCO are reluctant to give any forecasts. The supply situation therefore needs to be estimated.

As for the supply, a 1-hour-on, 1-hour-off load-shedding schedule has been assumed for Site 2 (Vehari). This was the information obtained for Site 2 during pre-feasibility stage. For Site 1 (Tandlianwala), the information given during pre-feasibility was 1-hour-on, 2-hours-off; however, according to latest information from the village, the supply was recently 2-hours-on, 1-hour-off, so as an average scenario, the same 1-hour-on, 1-hour-off load-shedding schedule is assumed.

[4] In terms of nominal peak power, the solar plant is much bigger, but in terms of annual produced energy, the annual output of the solar plant will only be slightly higher compared to that of the biogas plant.

C.4.3.3. Simulation results

The following charts show the hourly demand and supply pattern for a typical winter day and a typical summer day for Site 1. The charts show the demand for one transformer of 200 kVA and two transformers (400 kVA total).

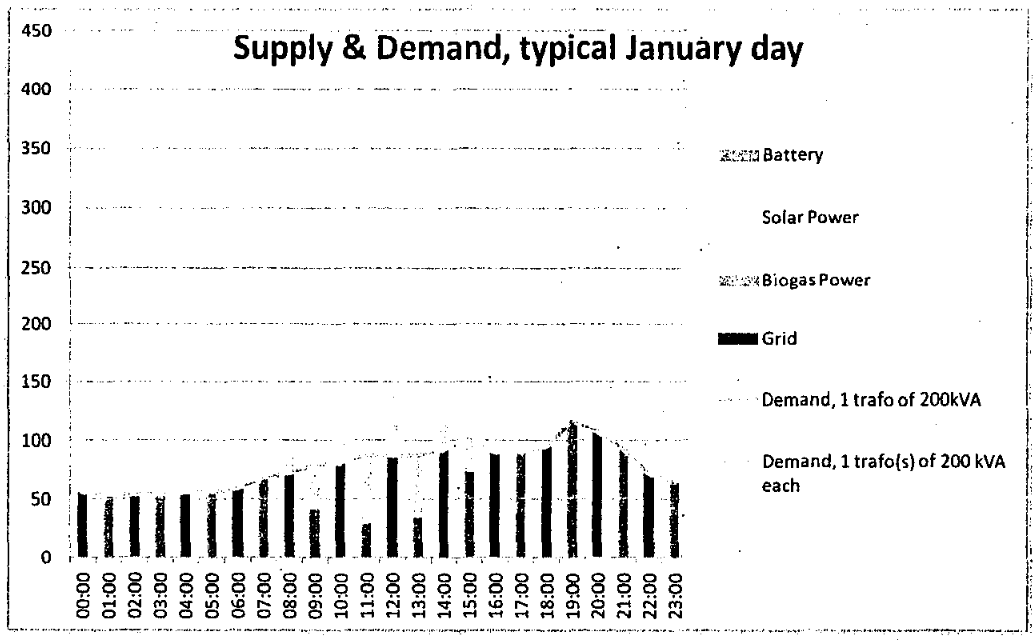


Figure 23: Supply and Demand for a typical January day, one transformer of 200 kVA, Site 1

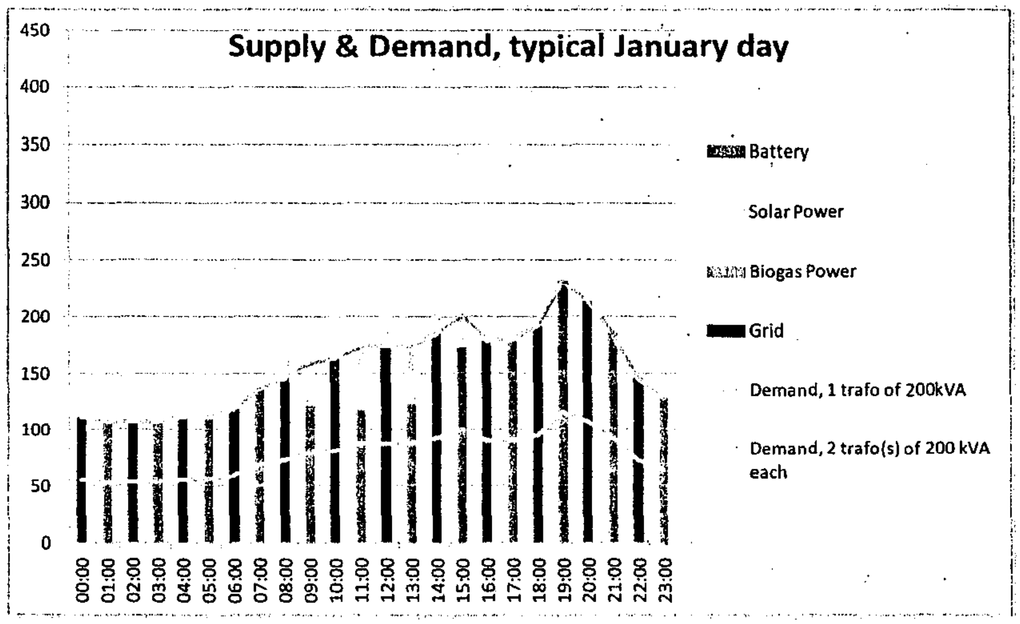


Figure 24: Supply and Demand for a typical January day, two transformers of 200 kVA, Site 1

The dark bars in the chart represent the grid power which is capable of fully covering the demand when it is available. The green bars represent biogas energy; the yellow ones solar. It can easily be seen that the demand of one transformer is easily covered; in fact, the available biogas energy would be sufficient to supply the demand of two transformer of this size at this winter load profile.

Battery is not even used in the scenario for one transformer; however, a battery including islanding inverter is always recommended in order to establish a stable grid when the portion of biogas power is low and solar is high. Also, there will be hours where the biogas plant will not be available due to maintenance or other issues, for these periods, the solar and battery part should be able to operate in a stable way.

There are a few hours where solar electricity is exported to the grid even in the two-transformer scenario; in the scenario for one transformer, a high amount of energy is exported to the grid through the course of the day.

The following charts show a typical summer day for the same site.

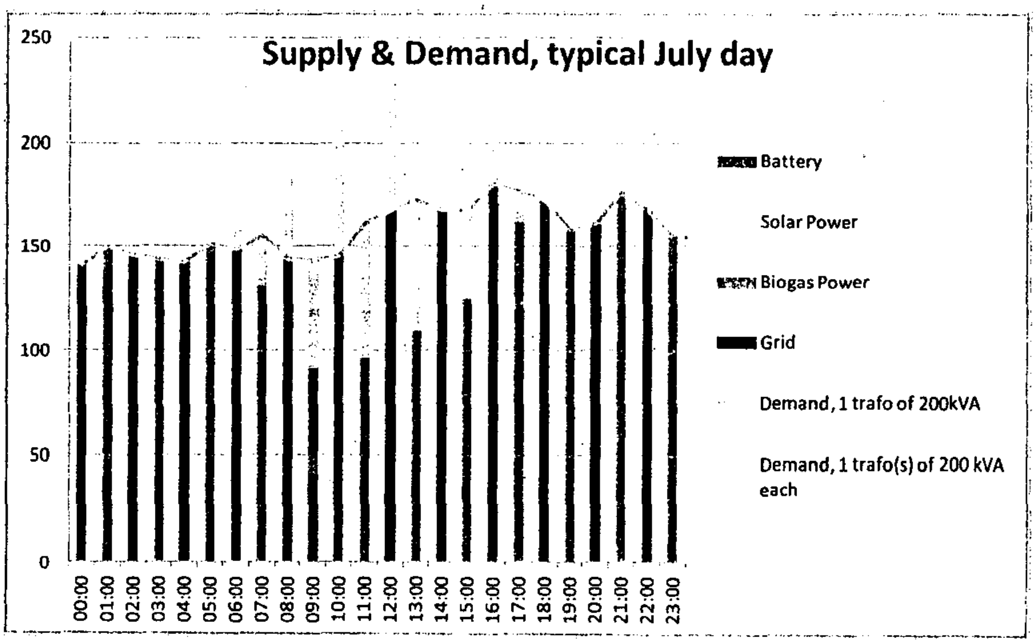


Figure 25: Supply and Demand for a typical July day, one transformer of 200 kVA, Site 1

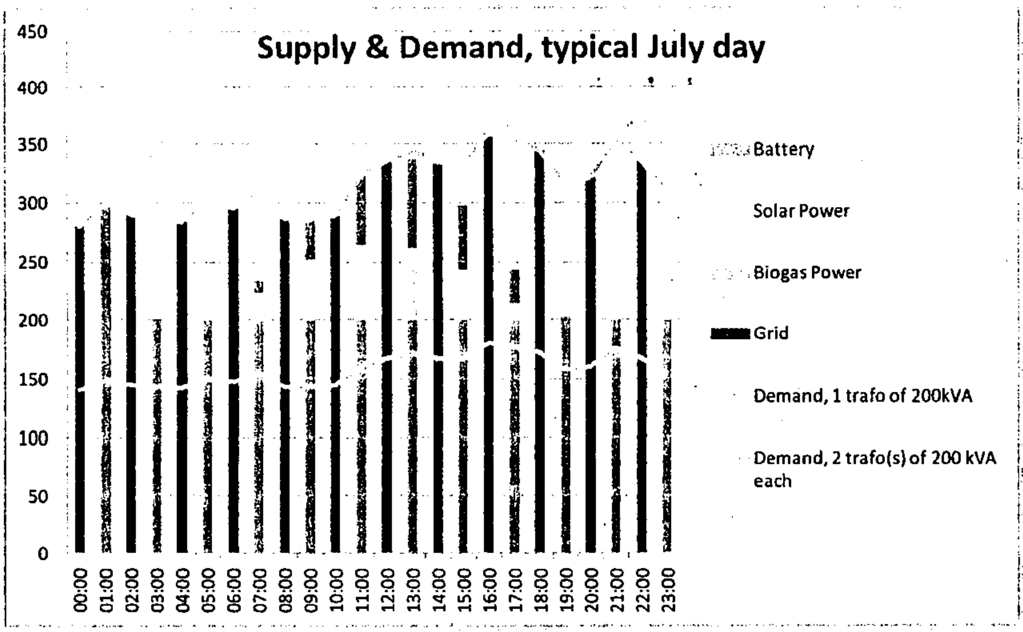


Figure 26: Supply and Demand for a typical January day, two transformers of 200 kVA, Site 1

It is clear that the supply gap to cover two transformers (400 kVA) becomes large. One transformer of 200 kVA size can easily be covered by the biogas plant, while solar power and battery give some additional backup for grid export and flexibility. Solar and battery could also be used to cover a second transformer during the noon hours.

The following table summarizes the figures and numbers under the assumption that only one transformer of 200 kVA would be supplied. Here it also becomes clear, that during the winter day, there is a high margin between the energy available from the power plant and the daily demand of the village which cannot be covered by the grid; however, during a summer day, the margin is only 13% in this scenario. This leads to the same conclusion as above that only one transformer of 200 kVA can be supplied safely throughout the year.

PV	Between 0 and 130 kW output per day (see chart)	324	453
Biogas	Between 0 and 200 kW output per day (8000h per year, controllable; total of 12 hours @ 200kW)	2400	2400
Supply of PV + Biogas per day		**3048**	**2724**
Grid:	Available 12 hours per day	941	1264
Demand:	Between 40 and 100 kW (winter) // between 100 and 180 kW (summer)	1881	3793
Demand after grid		**941**	**2529**
Margin		190%	13%

Table 8: Summary of electricity supply from different sources for Site 1 (Tandlianwala)

The following charts show the hourly demand and supply pattern for a typical winter day and a typical summer day for Site 2. The demand profile used is the same as for Site 1 in the absence of data for Site 2[5]. The charts show the demand for one transformer of 200 kVA, and also the demand for two transformers, totaling 400 kVA.

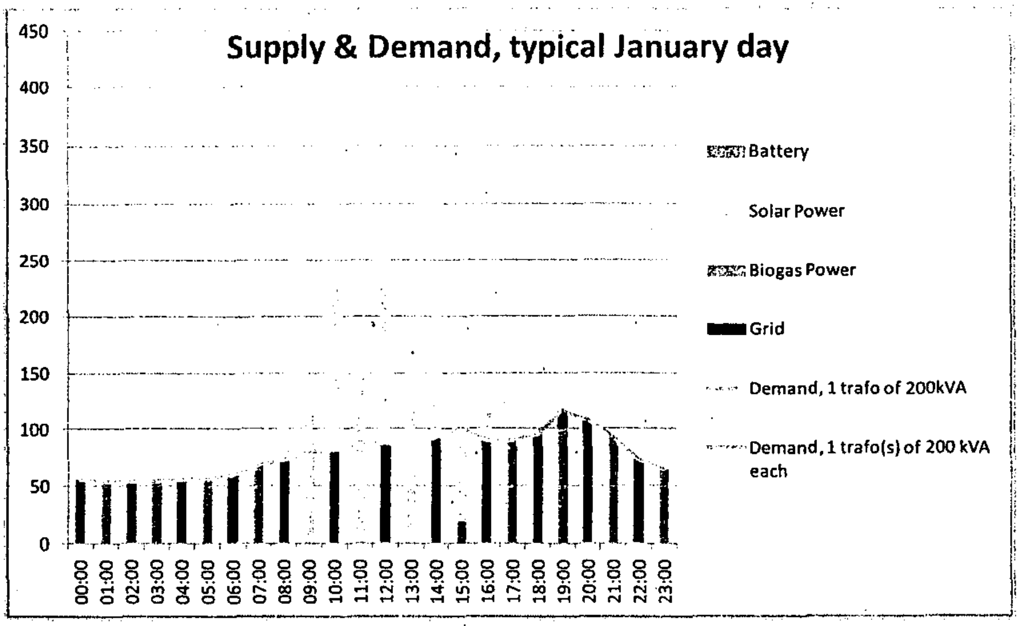


Figure 27: Supply and Demand for a typical January day, one transformer of 200 kVA, Site 2

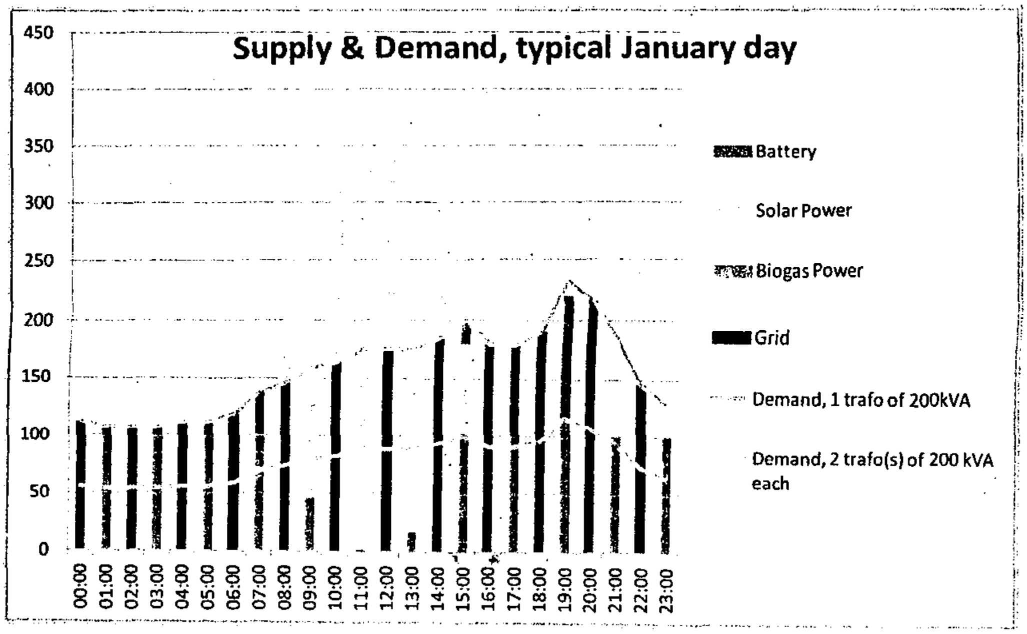


Figure 28: Supply and Demand for a typical January day, two transformers of 200 kVA, Site 2

[5] Load data could not be provided by MEPCO.

The dark bars again represent the grid power which is available to fully cover the demand when it is available. It is clear that in the case of two transformers of 200 kVA, the battery storage has an important role in the evening to cover up the supply gap between demand and biogas output. In this chart, there is a supply gap in the late evening, however, is the battery is also charged via the grid during the evening, then this supply gap can be covered. There are a few hours where electricity is exported to the grid. This means that for this scenario during a typical winter day, the planned power plant can supply two transformers of 200 kVA size each under almost all circumstances.

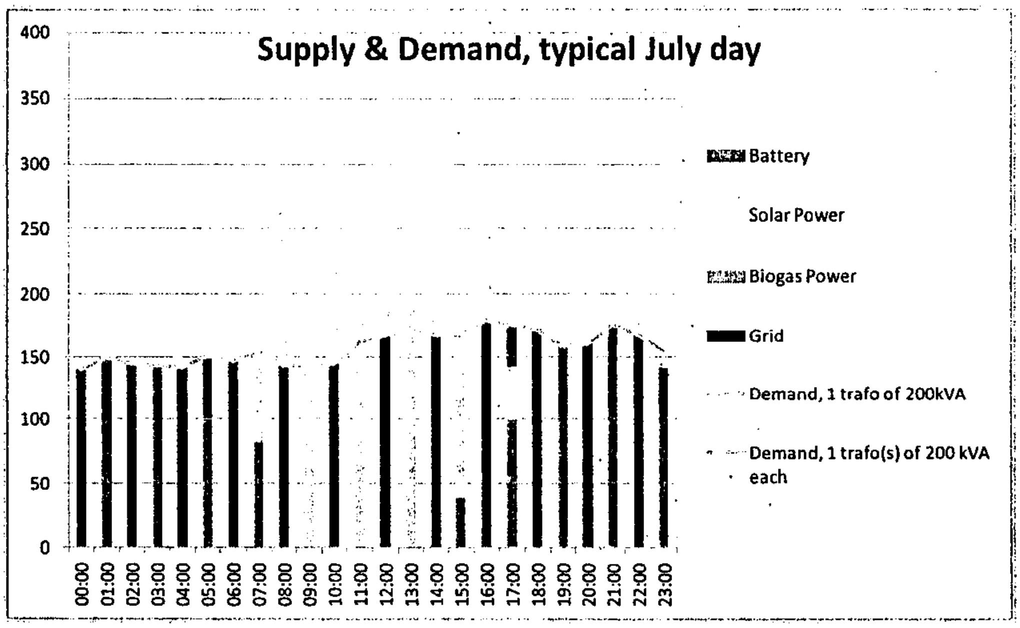


Figure 29: Supply and Demand for a typical July day, one transformer of 200 kVA, Site 2

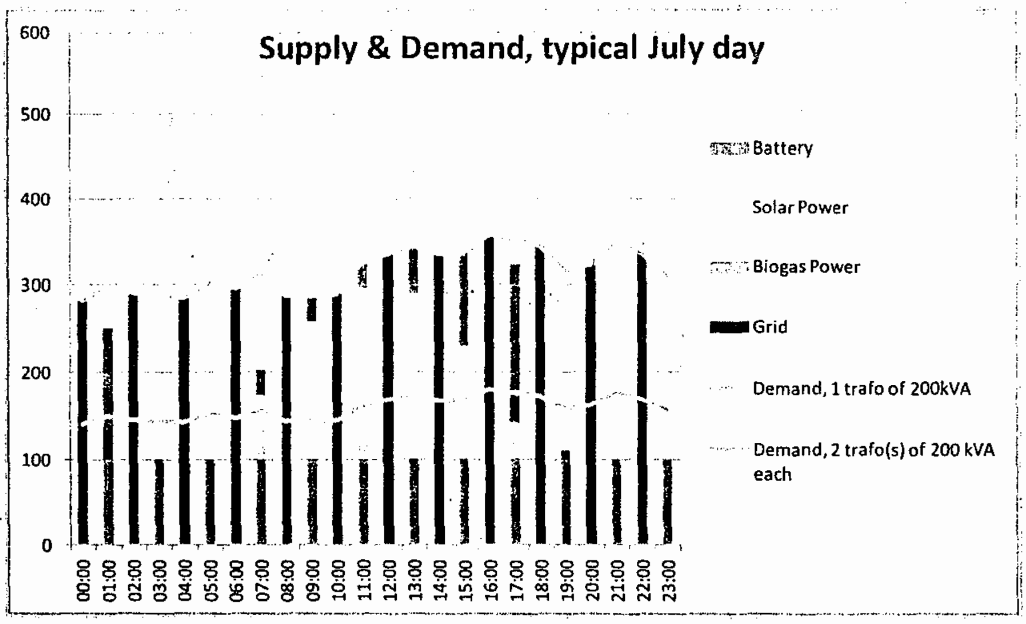


Figure 30: Supply and Demand for a typical July day, two transformers of 200 kVA, Site 2

In the chart for the summer day, it is clear that the supply gap to supply the two transformers becomes quite large during large parts of the day. In this case, it would be only possible to supply one transformer of 200 kVA size and feed into another transformer of the same size during the noon hours. For one transformer, the plant can well supply the demand with a combination of biogas, solar power, battery and grid.

The following table summarizes the figures and numbers under the assumption that only one transformer of 200 kVA will be supplied. Here, it also becomes clear, that during the winter day, there is a high margin between the energy available from the power plant and the daily demand of the village which cannot be covered by the grid; however, during a summer day, the margin becomes very low in this scenario. This leads to the same conclusion as above - that for a safe approach- only one transformer should be supplied by the plant in islanding mode.

PV	0 - 130 kW output per day (see chart)	972	1358
Biogas	0 - 200 kW output per day (8000h per year, controllable; total of 12 hours @ 200kW)	1200	1200
Supply of PV	+ Biogas per day	2172	2558
Grid	Available 12 hours per day	941	1264
Demand	40 - 100 kW (winter); 100 - 180 kW (summer)	1881	3793
Demand after grid		941	2529
Margin		131%	1%

Table 9: Summary of electricity supply from different sources for Site 2 (Vehari)

Obviously, all of these findings depend on the actual power demand and supply curve of the village during the next years. The actual demand of all households connected to a 200 kVA garding the inverter system, two design types can be selected: a centralized or a decentralized or string design.

Total System Cost	Lower nominal power cost (kWp). Fewer component connections. Higher installation cost (e.g., inverter pad work). Higher DC wiring and combiner costs. Larger inverter pad footprint on the ground.	Lower balance of systems costs. Lower ongoing maintenance costs (e.g., no fans or air filters). Simpler design and modularity; ideal for limited inverter pad spaces. Higher nominal power cost (kWp). More inverter connections. Requires more distributed space to mount inverters.
Total Energy Production	Optimal for large systems where production is consistent across arrays. Proven field reliability. Less optimal for systems with different array angles and/or orientations since they default to highest producing strings within a range and block the production of lower producing strings outside of that range.	Modularity of string inverters is better for systems with different array angles and/or orientations. Fewer arrays are impacted with one inverter failure. Newer and less field-tested product.

Table 11: Comparison between Central and String Inverter

C.4.5. Biogas concept

C.4.5.1. Overview of Biogas Technology

The major drawback of photovoltaic power is its dependence on sunshine and therefore its fluctuation and non-availability during night. Biogas technology, although more expensive in investment, maintenance and fuel supply, is a sustainable and renewable complementation for photovoltaic power, especially if organic residues or used as a feedstock. Although the biogas process requires a very constant and homogenous operation in terms of fuel feeding and other process conditions, it is possible to store the produced biogas in on-site storages with a buffer capacity of up to 20-30 hours. Thereby, biogas plants can operate based on demand and can provide the needed back-up power and grid support for the photovoltaic plant.

Biogas, a mixture of mainly methane (40-70%), carbon dioxide (30-60%) and traces of other gases, is created by fermenting biomass materials in a biogas reactor. The biogas technology described here uses this gas for electricity generation through a generator set. Instead of a normal generator set, a combined heat and power unit (CHP) can be used to make further use of the combustion heat. The solid end product of the biogas process is organic slurry which can again be used as an organic fertilizer in the field, especially if it will be mechanically separated into a solid and a liquid phase.

The biomass materials can be animal excrements, crops or crop residues and also household waste, as long as it is mainly organic material which is not that much lignified. For this project, the feedstock would mainly be cattle and chicken manure and maize silage.

		mechanical parts	ences between the manufacturers.
2	Installation Costs	Lower than for tracker solutions, as less complex system. But the difference regarding the total installation cost is minimal compared to the horizontal tracker.	Higher costs than the fixed tilted system, but lower than the vertical tracker.
3	Maintenance costs	Lower than for tracker solutions, as no mechanical parts	Depends on the selected manufacturer (options without mechanical parts available), but cost higher than fixed-tilted
4	Approx. additional yield compared to fixed system	-	20%
6	Site requirements	If a building roof is to be used, it needs to be able to bear the load	Ground may be uneven with slopes up to 35°.
7	Space requirement	Several rows can be installed on top of each other. Space requirement low.	Installation of rows on top of each other is limited, but space requirement not much higher than fixed- tilted.
8	Space factor (Wp/m^2)	About 50 - 75	About 40 – 65

Table 10: Comparison between Fixed Tilt and Single Axis Tracked System

For fixed structures, there are two different options regarding their orientation: fixed structures are usually tilted to face south in the northern hemisphere (north in southern hemisphere) at a specific angle, or may have south as their main angle and a slight inclination to the east and west as secondary angle (for example 10°). An east-west inclination of solar panels offers lower peak capacity and lower total annual yield; however, the space requirement is lower and the generation curve is less spiked and allows the energy generation distribution to be more equal over the day. For this project, as space is not a constraint, the south facing option is deemed the best.

The optimum southbound inclination angle for Pakistan is 25°. However, an angle of 15° offers higher outputs during summer time when power needs are the highest, with an annual output which is only marginally lower. An angle of 15° is therefore chosen for the Project.

Inverter Technology

As photovoltaic panels generate DC electricity, it must be converted to alternating current before it can be fed into the grid. This is achieved by an electronic device called an inverter.

State–of-the-art inverters offer a broad range of operational stages which generally fulfill all the requirements of the international grid codes in terms of fault-ride-through and reactive power provision. Inverter stations provide a protective shell in which PV-strings can be connected to inverters. Centralized inverters typically have a capacity from 500 kWp to 1.5 MWp of DC PV-Power, depending on the size of inverter.

From the inverter stations, the AC power is stepped-up by a MV or HV-Transformer, and then connected to a medium or high voltage grid (for instance 132 kV and 220 kV in Pakistan). Re-

CH_4	50 – 70
CO_2	25 – 30
N_2	0 – 10
H_2O	0 – 5
H_2S	0 – 3
O_2	0 – 3
NH_3	0 – 0.5

Table 12: Approximate Biogas Composition in Anerobic Digestion

Stage 3: In this stage, the digestive material (digestate) is stored in the slurry storage tank. Before this tank, further solid-liquid separation takes place. The outlet material may also be disposed into water or land without liquid separation process.

Stage 4: The 4th stage of this whole procedure deals with the conditioning of biogas. In this stage, the biogas firstly passes through a cooling/drying and de-Sulphurization processes. The Sulphur related contents are removed by these two processes. The treated biogas is then stored into the gas storage tanks. The stored biogas is then utilized to operate a generator for the production of electricity or for cooking purpose. The biogas can be stored for up to 30 to 45 hours on site depending on the available gas storage volume.

The process is shown in the figure below.

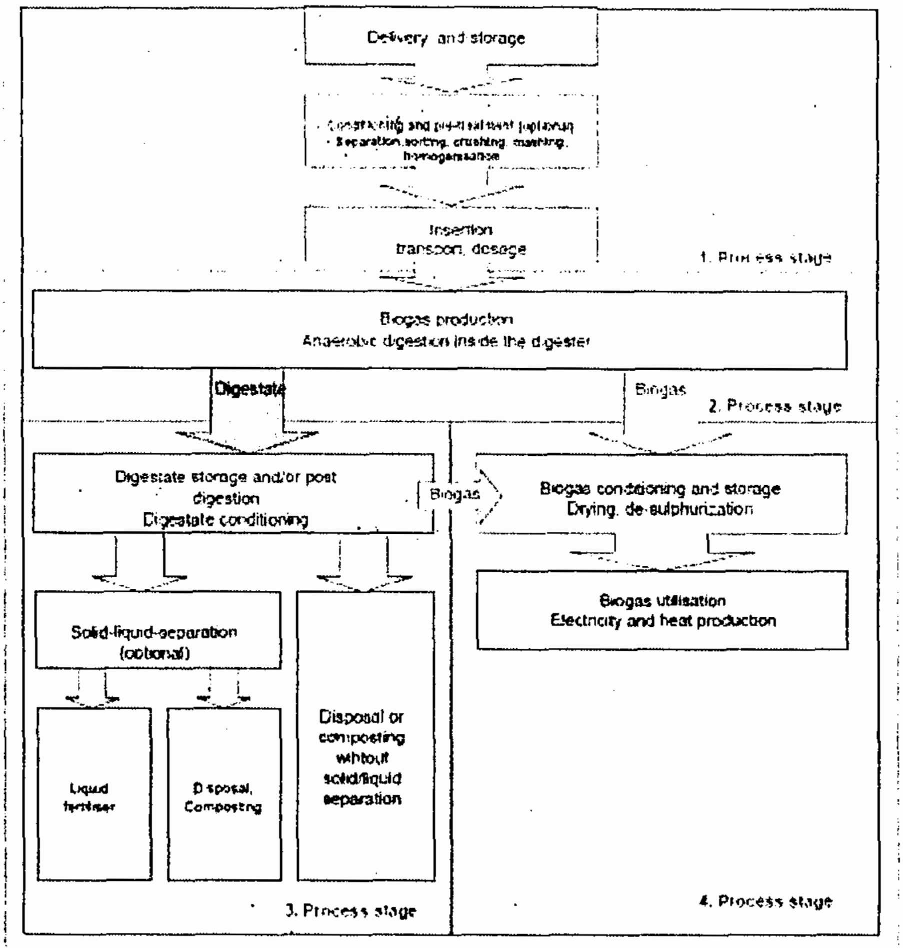


Figure 33: Stages in Biogas Plant

Fermenter/Digester systems

The fermentation systems do not need to withstand any high pressures or temperatures. In fact, the conditions inside need to be sustained at a pressure range of 0 - 0.088 bars and a temperature not higher than 50 °C. The reactor tanks must be airtight for the complete digestion of feeding material under anaerobic conditions. The reactors can be built using concrete or metal, and as they need to cater for variable volumes of gas, they also need to have flexible gas storage which is normally realized through a membrane on the top of the reactors. As the construction of these tanks is mostly civil work, the companies offering these systems are mostly local.

The type of recommended biogas technology mainly depends on the amount and quality of the substrates (size of farm), the climate conditions in the region and the type of biogas utilization.

The biogas production process requires a stable temperature. The anaerobic bacterium, which produces the valuable methane within the biogas process, can whether operate within a psychrophilic, mesophilic or thermophilic temperature area.

Psychrophilic	4-10°C	15-18°C	20-25°C	More than 100 days
Mesophilic	15-20°C	35-40°C	40-50°C	30-60 days
Thermophilic	25-45°C	50-60°C	78-80°C	10-15 days

Table 13: Temperature range and fermentation time[6]

Table 13 shows the different required thermal conditions for each bacterium. Changes of more than 1 K process temperature per hour can additionally cause biogas production stops, especially in the mesophilic and thermophilic operation areas. For biogas projects in regions with colder seasonal periods and cold night temperature, it is necesary to heat the substrate or the digesters constantly in order to maintain a stable process temperature. In Punjab, where the outside temperature seldomly goes below 22°C[7], also simple low-cost biogas technology like the dome digesters may offer a feasible solution modell, especially for high fluid substrates like cattle manure without a high share of sediments or floating solids. This technology can be proposed as a solution for biogas projects that aim to use the biogas for cooking purposes, since a constant supply of biogas is in this case not as important for the investment payback as it is for electricity or industrial heat/steam generation.

There are different types of digesters, such as

- Stirred vessel digesters (standing and laying)
- Plug-flow digesters
- Fixed-dome Digesters
- Floating type Digesters
- Lagoon type digesters

For industrial medium and large-scale biogas plants, stirred vessel digesters or plug-flow digesters, which can be both installed in concrete or steel tanks of different structures and sizes, or membrane covered biogas lagoons are normally used. Fixed-dome, floating dome or small-scale lagoons are rather used for small scale biogas plants in tropical regions.

[6] Lagrange, 1979 and own experience
[7] https://www.worldweatheronline.com/manta-weather-averages/manabi/ec.aspx (03.04.2017)

C.4.5.3. Design of industrial medium and large-scale biogas plants

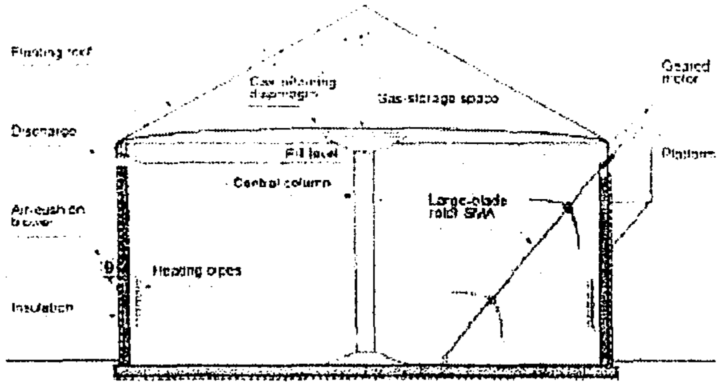


Figure 34: Stirred tank reactor with long-shaft agitator and other internals [Source FNR 2012/ Anlagen- und Apparatebau Lüthe GmbH]

<u>Process with full intermixing (stirred-tank reactors):</u>

Cylindrical, upright stirred-tank reactors are primarily used in agricultural plants for biogas production. In the past years, this type accounts for about 90% of the installed base in non-tropical regions. The digester consists of a tank with a concrete bottom and sides made of steel or reinforced concrete. The tank can be sited either completely or partly sub-grade, or above ground. The cover on top of the tank is gastight, though the design specifics can vary depending on requirements and mode of construction. Concrete covers and plastic sheeting are the most common. The substrate is stirred by agitators sited in or beside the reactor.

<u>Suitability of stirred vessel digesters:</u>

- In principle for all types of substrate, preferably pumpable substrates with low and mid-range dry matter content
- Stirring and conveying equipment must be adapted to the substrate
- Return of digestate if feed is pure energy crop
- Suitable for continuous, quasi-continuous and intermittent feeding

<u>Advantages of stirred vessel digesters:</u>

- Design is cost-effective when reactor volume is in excess of 300 m3
- Variable operation in through-flow or through-flow/buffer-tank configurations
- Depending on design, the equipment can usually be serviced without the digester being emptied

<u>Disadvantages of stirred vessel digesters:</u>

- Flow short-circuits are possible and likely, so dwell time cannot be stated with assurance
- Scum and settlement layers can be formed

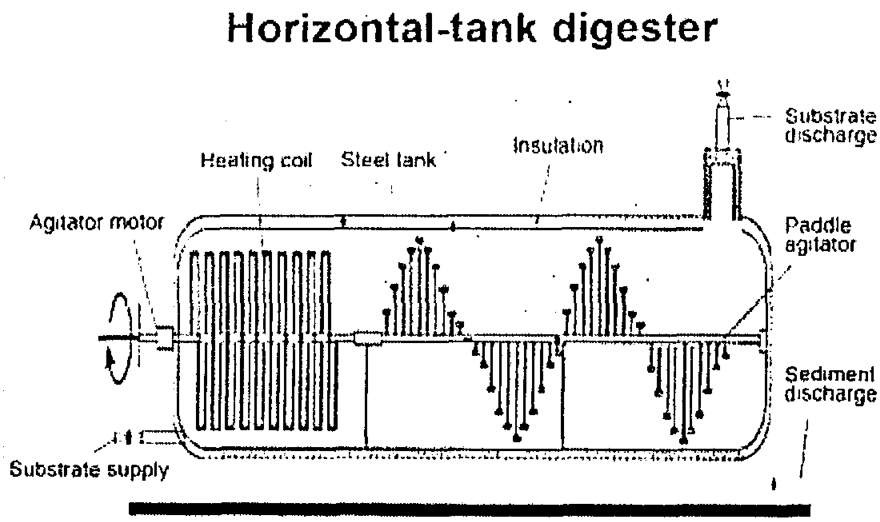


Figure 35: Plug-flow digester (Source: FNR 2012)

Plug-flow digester

Biogas plants with plug flow – the wet-digestion version is also known as a tank through-flow arrangement – use the expeller effect of fresh substrate infeed to create a plug flow through a digester of round or box section. Mixing transverse to the direction of flow is usually achieved by paddle shafts or specially designed baffles.

Suitability

- Wet digestion: suitable for pumpable substrates with high dry matter content
- Dry digestion: stirring and conveying equipment must be adapted to the substrate
- Designed for quasi-continuous or continuous feeding

Advantages

- Compact, cost-effective design for small-scale plants
- Separation of the digestion stages in the plug flow
- Design eliminates the formation of scum and settlement layers
- Dwell times are as predicted because design largely prevents flow short-circuits
- Short dwell times
- Can be heated effectively; the compact design helps minimise heat losses
- Wet digestion: powerful, reliable and energy-saving agitators can be used

Disadvantages

- Space needed for the tanks
- No inoculation of the fresh material or inoculation must be done by return of digestate as seed material
- Economical only when on small scale
- The reactor has to be fully emptied if the agitator requires servicing

C.4.5.4. Possible designs for rural small-scale biogas plants

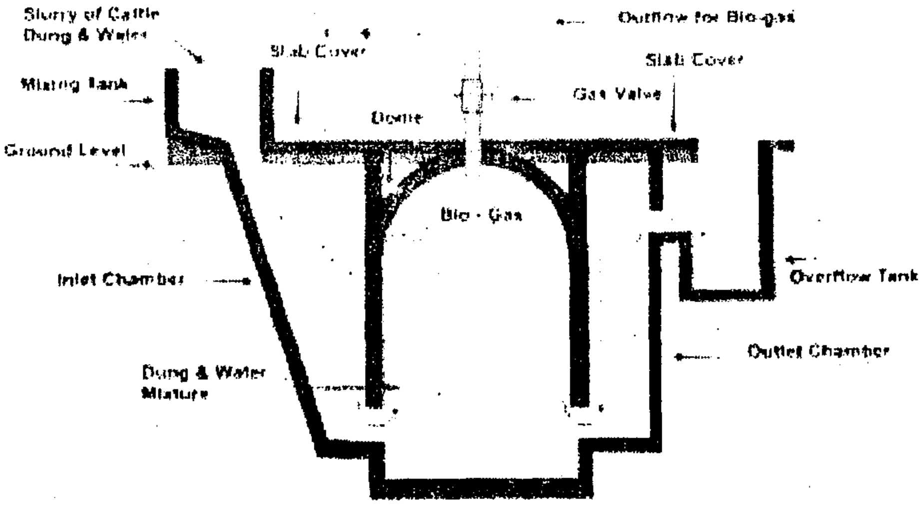


Figure 36: Fixed Dome Type Biogas Plant[8]

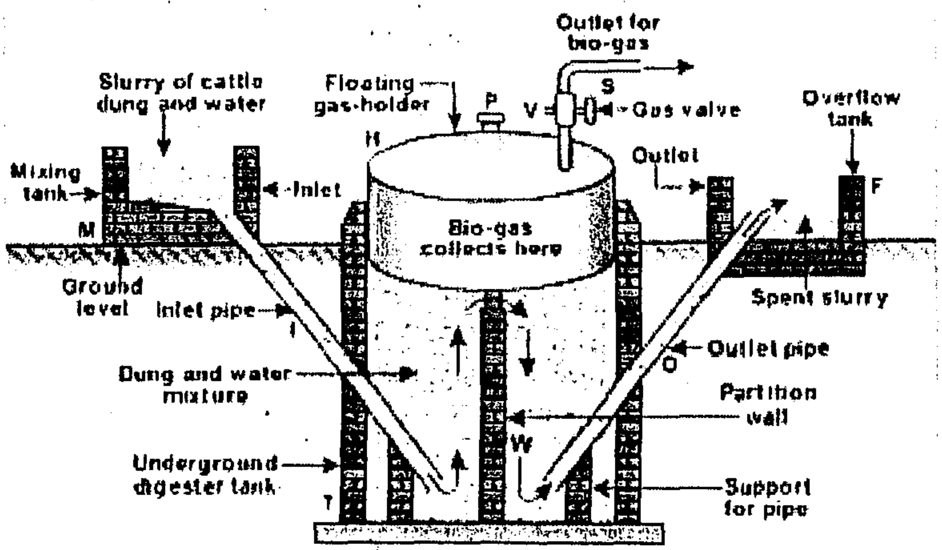


Figure 37: Floating gas holder type Biogas Plant[9]

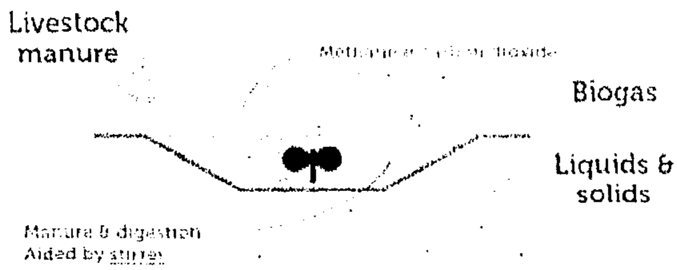


Figure 38: Lagoon Type Biogas Digester[10]

Experimental Setup	The digester is a shallow well-shaped masonry structure. No partition wall is provided.	The digester is a deep well shaped masonry structure. There is a partition in the middle of the digester.	The digester of this plant is lagoon (ship alike) shaped masonry structure which requires more surface area than the other types.
Biogas Holder	Gas holder is the integral part of the plant. Slurry from the gas storage portion is displaced out of the digester with the formation of gas and comes back when it is used.	Gas Holder is generally made of the mild steel. It is set onto the digester and goes up and down with the formation and utilization of gas.	Gas holder is not actually an integral part of the masonry structure; it is rather fixed on the lagoon type digester. The material of gas holder is generally fiber.
Gas Pressure	Varies from 0-90 cm of water (i.e. 0-0.088 bar)	Remains Constant at about 10 cm of water. (i.e. 0.0098 bar)	Varies from 10-20 cm of water. (i.e. 0.0098-0.019 bar)
Cost of Maintenance	Low	Higher because gas holder is to be prevented from corrosion.	Lower than floating gas holder type but higher than fixed-dome type digester.
Life Span	30 years	15 to 20 years.	15 to 20 years
Extra Features	Space above the gas holder can be used.	Identifying the defects in gas holder is easy.	Greater surface area available for the feeding material within the digester.
Required work place	Requires more excavation work.	Requires relatively little excavation.	Requires more excavation due to large ground surface area.
Construction	A trained mason using locally available materials can build entire plant.	Digester can be constructed locally. The gas holder needs sophisticated workshop facilities.	A trained mason can build entire plant but some essential materials are not available locally.
Installation Cost	Relatively cheap.	Much higher for lager digesters because the cost of mild steel gas holder is higher.	Higher than the others for larger digesters (i.e. more than 2400 m^3)

Table 14: Comparison between the three types of digesters

Using the described methods of the biogas plants operation, the fixed-dome type digester is the most feasible and economically favorable small-scale biogas plant for non-industrial purposes in rural Pakistan.

C.4.5.5. Other important components of the biogas plant

Generator or Combined Heat and Power (CHP) Unit

For the generator (or engine), there is a big variety of types that can be used here, ranging from small units to big power systems. Engines vary in their ability to use diesel for co-firing and the minimum share of methane they require in the feeding gas.

The energy losses from power generation and from heat production can be reduced by combining heat and power (CHP) generation. While the fuel utilization efficiency in conventional power plants is typically around 33%, the total efficiency of co-generation for electricity (up to 45%) and heat (up to 47%) generation can be up to 88-92% in total depending on the technology. Cogeneration thus significantly increases the overall energy efficiency and helps reducing fuel consumption - given that the heat can be utilized. At the same time, most power units optimized for biogas power which are available on the market are CHP units anyway.

Further storage tanks

For uniform supply of biogas for power generation at commercial scale, gas storage is highly recommended. Storage enhances the output one can get from biogas by regulating the supply and pressure. Biogas can be compressed up to 7 bars (100 psi) in a biogas storage tank. The tank should be manufactured and tested as per ASTM standard for pressure vessels.

Alternatively, gas can also be stored in a spherical membrane container.

C.4.5.6. Technical Setup of the envisaged biogas plants

For biogas plants, the technology is not as standardized as for solar photovoltaic power. Across different regions and parts of the world, biogas plants range from small household units with storage sizes of a few cubic meters where the gas is only used for cooking purposes, up to two industrial applications with thousands of cubic meters of digester/storage size and electricity generation in the megawatt range. They differ in their degree of automation, durability of the components used, technical setup of the digesters (or stirred tank, plug-flow tank, floating dome, lagoon type, etc.) process supporting components like agitators, heat exchangers, differences in the power generation (simple generation set or combined heat and power, or co-firing together with other combustibles) and others.

In Pakistan, most biogas plants built so far have been of domestic scale for cooking purposes, or medium scale plants with a low amount of automation and mostly built on local resources. For this project, it is suggested to build one plant of an" international standard" with a high lifespan and high output efficiency and a considerable amount of automation according to the stirred-tank reactor design described above which allows optimizing the operation of the plant. For the other site, a second system of the fixed-dome design is suggested which is cost-optimized and maximizes the use of local resources, while compromising on the kWh-per-kg of substrate efficiency.

The "international standard" plant on Site 1 is also able to process more solid substrates like energy crops, chicken manure and others which require a mechanical pre-treatment within the feeding system and a more sophistic agitation system in order to achieve high and constant biogas yields. Furthermore, it will be able to maintain a constant process temperature due to the utilization of generated heat for substrate pre-heating and through an insulated digester design. The two plants can then be compared after a few years of operation, and conclusions can be drawn on their suitability for their application in rural Pakistan.

The two plants suggested for this project are therefore as follows:

Technical setup	Efficiency optimized (international standard, automated, more components)	Cost optimized (higher share of local components, semi-automated, simple design)
Number of digesters	One stirred tank (1,500m³) Alternative Option: Two digesters of 1,000 and 500, increasing efficiency, but also cost and complexity.	Five fixed dome tanks (400 m³ each, parallel, underground; total of 2,000 m³)
Power unit	CHP (combined heat and power unit) with simple generator set for peak power	Simple generator set
Biogas efficiency	90 m³ biogas / t of cow dung	40 biogas m³ / t of cow dung
Size	100 kW average (200 kW peak)	50 kW average (100 kW peak)
Sourcing	Civil local, components international (likely Europe, China)	Mostly local, some regional (likely China)

Table 15: Biogas system sizing for each site

C.4.5.7. Substrate concepts

The determined substrate composition for both plants is, as already presented above.

<u>Site 1 (efficiency-optimized):</u>

Cow Dung	3,000	8.22	40.0%	75%	2.47	55%	148,500	300.0	270,000
Chicken manure (dry)	329	0.9	65.0%	75%	0.44	65%	57,251	550.0	88,079
Corn silage	347	0.95	32.0%	94%	0.29	53%	35,932	650.0	67,797

Recirculate Water	3,650	10	1.0%	50%	0.05	55%	0	0.0	0
Gras silage	0	0	35.0%	90%	0	55%	0	600.0	0
Fresh Water	3,650	10	0.0%	0%	0	0%	0	0.0	0
Potato Peel	0	0	20.0%	90.0%	0	70%	0	500.0	0
Fat Waste	0	0	95.0%	90.5%	0	65%	0	800.0	0
Cotton press cake	0	0.0	90.0%	90%	0	65%	0	750.0	0
total	10,975	30	14.2%		3.2		241,684		425,876

Table 16: Envisaged substrate mix and biogas yields for the biogas plant on Site 1

Site 2 (cost-optimized):

[illegible]									
Cow Dung	3,000	8.22	40.0%	75%	2.47	55%	148,515	300.0	270,027
Liquid cattle manure	0	0.0	35.0%	80%	0	55%	0	200.0	0
Solid cattle manure	0	0	18.0%	80%	0	60%	0	400.0	0
Chicken manure (dry)	0	0.0	65.0%	75%	0.00	65%	0	550.0	0
Corn silage	0	0.00	32.0%	94%	0.00	53%	0	650.0	0
Recirculate Water	4,380	12	0.0%	0%	0.00	55%	0	0.0	0
Gras silage	0	0	35.0%	90%	0	55%	0	600.0	0
Fresh Water	4,380	12	0.0%	0%	0	0%	0	0.0	0
Potato Peel	0	0	20.0%	90%	0	70%	0	500.0	0
Fat Waste	0	0	95.0%	90.5%	0	65%	0	800.0	0
Cotton press cake	0	0.0	90.0%	90%	0	65%	0	750.0	0
total	11,760	32	10.2%		2.5		148,515		270,027

Table 17: Envisaged substrate mix and biogas yields for the biogas plant on Site 2

Site 1, being optimized for efficiency, uses a more optimized and slightly more costly mixture of substrate and can assume changes in the substrate mixture. Due to its optimization concerning feeding, stirring and maintaining a constant process temperature, it can produce an average of 100 kW (electric) from 10 tons of substrate per day by achieving a specific biogas yield of 300-350 l biogas per kg organic matter (oDM). Site 2, being optimized in terms of capital cost, uses 8.22 tons of cow dung for an average production of 50 kW_e.

For both plants, but especially for plant from Site 1 due to the installed pumps and agitators, it is of outmost importance, that the substrates are free of impurities or foreign, non-organic matters like stones, sand, ties for straw, plastics etc. because these can reduce the lifetime of the equipment significantly and even can cause longer process interruptions, e.g. if they block or damage the pumps and other relevant mechanical components. Therefore, a quality control process for the substrate reception needs to be established.

C.4.5.8. Design of the efficiency-optimized biogas plant on Site 1

The climate in the project region is very hot (see C.1.2 and 0). The average annual temperature in Multan is around 25 °C. The winter can be relatively fresh, reaching minimum temperatures of 5°C during the night. Due to the fact that the biogas process requires a stable reactor temperature between 35°C and 40°C (mesophile) in order to result in an adequate biogas production, the input substrate has to be either preheated and/or the reactor has to be heated permanently. Furthermore, in both cases, the heat losses have to be avoided through the application of insulation material on the reactor's outside walls. A constant process temperature of 20 °C can reduce the biogas yield by 70% compared to the theoretic value within the mesophile temperature range (see figure).

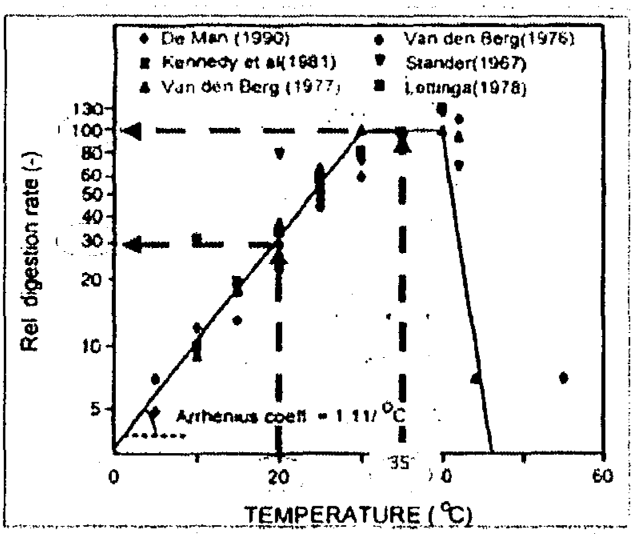


Figure 39: Biogas production yield according to process temperature[11]

Due to these reasons, the efficiency optimized plant on Site 1 will be equipped with a substrate heat-exchanger for pre-heating before entering the biogas process, which will use the generated hot water in the co-generation unit. Also, the digester(s) will be equipped with insulation panels to reduce heat transmission losses of the tanks, especially during the night and the winter season. In summer time, additional heating will be provided through solar radiation, especially onto the gas storage roofs. In that time, substrate heating might not be necessary, and the process

[11] Source: van Haandel et al: Anaerobic Sewage Treatment, A practical guide for regions with hot climate, 1994.

should rather be cooled down by the already cooled digestate or by additional water, if the process temperature increases above 40 °C.

The selected design for plant on Site 1 is a robust, comparatively cost-efficient concept for agricultural biogas plants which are supposed to process solid and liquid feedstock mixes like manure, energy crops etc. This type of biogas plants have been installed in large numbers in Europe and the US and are comparatively easy to handle. They can reach decomposition rates of the organic matter, which defines the final biogas production yield, of up to 70% and more, depending also on the hydraulic retention time of the digester.

A process phase is understood as the biological milieu – hydrolysis phase or methanisation phase (see explanation above) – with its specific process conditions such as pH value and temperature.

When hydrolysis and methanisation take place in a single tank, the term used is single-phase process management. A two-phase process is one in which hydrolysis and methanisation takes place in separate tanks. Stage is the term used for the process tank, irrespective of the biological phase.

Consequently, the plant layout with pre-digester pit, digester and digestate storage tank frequently encountered in agriculture is single-phase, but three-stage. The open pre-digester or reception tank pit as such is not a separate phase in its own right. The sealed holding or receiving vessel, on the other hand, is considered a separate phase (hydrolysis phase). Main and secondary (post) digesters both belong to the methanisation phase.

In the main, agricultural biogas recovery plants are of single-phase or two-phase design, and single-phase plants are the more common. In order to avoid high costs for the plant design a single-phase but three stage system is envisaged.

The proposed biogas system for plant 1 will mainly consist in an open reception tank and a main digester.

In the following, the most relevant equipment and components of the design concept for plant of Site 1 are described. As an additional construction requirement, all components and equipment of the proposed plant should be constructed and installed according to the "*Safety Rules for Biogas Systems* ", prepared by the German Agricultural Occupational Health and Safety Agency (English version available).

1. Substrate reception and pre-treatment:

The solid substrates (cow and chicken dung, corn silage) will be stored for the required intervals at the storage platform. The silage needs to be treated, compacted and covered with silage membranes right after harvesting and the respective amount should endure until the next harvest period. All substrates will be fed manually (optional with a solid feeder with cutting knives for additional mechanical treatment) in constant intervals into the open 50 m³ reception tank. This allows to buffer the substrate input (around 30 m³ per day) for almost 2 days. The automatic solid feeder would additionally support the homogenization of the solid substrates and furthermore, provide additional mechanical grinding and allow an automatized, constantly documented and controllable input of solid biomass.

Figure 40: Reception tank with automatic solid feeder (left) and "manually" fed[12]

In the reception tank, the substrates are homogenized with a propeller stirrer and mixed with the separated liquid phase of the plant's digestate or additional water to maintain the dry matter content of the substrate input into the digester below 15% and thereby still flowable. The liquid level of the reception tank and the temperature of the substrate mix will be constantly measured with the respective sensors. As a redundancy back-up for the main pumping system, there should be installed a submersible slurry pump, which can facilitate the flow of the substrate into the main digester in maintenance times of the pumping distributor.

<u>Equipment and Components</u>

a) Silage platform (asphalted platform with a drainage system surrounded by concrete walls with a protection layer) for up to 500 tons of silage (e.g. area of 25 m x 8 m with 3 m side walls)
b) Asphalted storage platform for up to 50 tons of dung surrounded by concrete walls
c) Solid feeder incl. cutter with a filling volume of 5 m³ connected to reception tank
d) Reception tank of 50 m³ (steel or concrete) with 1 x 7.5 kW propeller stirrer, electronic level meter, temperature meter and connection for water dosification, optional: 1 submersible pump (5 m³/h) to pump into the main digester

<u>2. Substrate distribution</u>

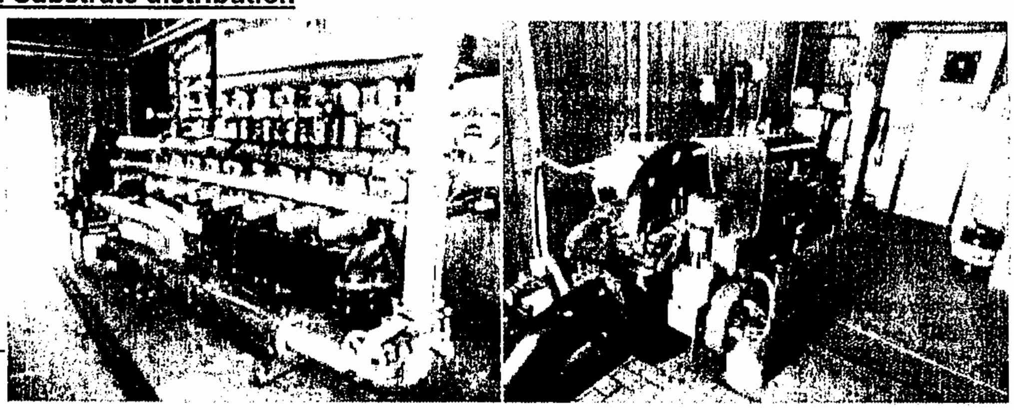


Figure 41: Substrate distributors

The substrate distributor with the two central pumps is one of the core pieces of the biogas plants. It allows to suck from and pump to all relevant substrate vessels within the process (reception tank, substrate heat exchanger, main digester, separation tank and slurry pond) and thereby facilitates a constant substrate flow in the process. Additionally, there will be overflows between the main digester, the post digester, the separation tank and the slurry pond to facilitate the substrate flow by gravitation. The different pumping directions and ways can be facilitated through automatic pneumatic valves or through various electronic three-way valves. Since the substrate to be moved consists in mainly solid biomass with high fiber material, it is strongly recommended to use eccentric screw pumps as central pumps, which are capable to pump viscous substrates with low proportions of interfering substances and long-fibre substances.

After the biogas process, a press screw separator will receive the digestate (around 28 t/d) with a DM of around 7-8% and will separate it by pressing the material into a liquid phase (24 t/d) with a DM below 5% and a solid phase (4 t/d) with a DM of around 25-30%. The liquid phase will be used for recirculation into the reception tank and hydrolyzation of the solid input substrate or will be stored in the slurry pond, while the solid phase will be further dried in an open solar dryer and used as a fertilizer.

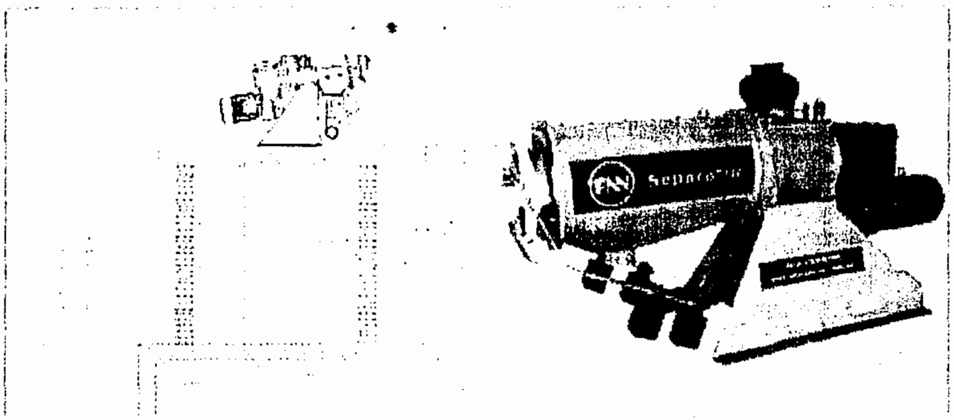


Figure 42: Press crew separation system for manure (Source: Bauer/ FAN)

<u>Equipment and Components</u>

a) Substrate distributer with pneumatics valves (or 3-ways-valves) for substrate distribution connected to reception tank, main digester, post digester and open slurry pond. The system will be installed in a container or a roofed building.
b) 2 central pumps a 5 kW for max 15 m³/h and substrates with high solid contents (operating intermittent)
c) Compressor station for pneumatic valves
d) Around 200 m of substrate pipeline HDPE, PN 10, SDR 17, DN 200 (suction side) – DN 150 (pressure side)
e) 50 kW heat exchanger system for substrate preheating which preheats recirculated substrate from the main fermenter

f) Overflows between main digester, post digester and slurry pond as an additional way to direct the substrate within the process flow
g) Flow meter to measure the substrate flow on the substrate distributor
h) Separation system for digestate consisting in press screw separator 3-5 kW to separate around 3 m³/h digestate with a DM input of around 5-8%, including reception tank, if needed, and integration into existing biogas system by recirculation into main digester

3. Main Digester

Main parameters for the design of the tanks/reactors are the hydraulic retention time and the daily organic loading rate. The hydraulic retention time (HRT) is the average holding time of the substrate in the digester. For pre-digested materials like manure or for substrates with high fats and protein contents a HRT of 20 to 30 days is enough, while for substrates with high contents of celluloses, lignin or fiber material more like e.g. maize silage or straw, HRTs of over 50 days are recommendable. The daily organic loading rate is the amount of substrate fed into a digestion plant per day in relation to the volume of the digester (unit: kg oDM / (m³d)). In order, not to overload the methane producing bacteria with organic material, the organic loading rate should not exceed 5 kg oDM/(m³d). If chicken manure is being used the daily organic load should not exceed 3.5 kg oDM/(m³d). Table 17 shows the relevant design parameters for the selected system for plant Site 1, consisting of a main digester of 1,500 m³, having an internal diameter of 18 m and a total height of 6.5 m. Compared to a two-digester setup, this saves investment costs for substrate distribution (pipes, valves and pumps), automation, stirrers and of course construction costs. The efficiency reduction of the loss of the additional stage is marginal.

Daily Input	30	m³/d
Volume Digester	1,500	m³
Average Retention time	49.9	d
Daily Organic Load	3.19	kg oDMS/m³ d

Table 18: Design parameters plant on Site 1

Equipment and Components

a) Insulated 1,500 m³ digester/concrete tank with following specifications:
- Overall height: 6.5 m
- Max. liquid level height 6 m
- Diameter 18 m for single-tank-solution
- Thickness of concrete wall: 0.25 - 0.3 m depending on final static requirements
- Material: in-situ reinforced concrete, compression strength class is more than or equal to C25/30, exposition class XA 1 (post digester) and XA2 (reception tank, main fermenter), high water entrance resistance, used cement should be highly resident against sulphate
- Epoxy protection layer of upper 2-3 m of the inner tank wall

- Concrete fundament according to local water/leakage protection standard (including geomembranes, leakage visualization, etc.)

b) Working platform on upper level of the digester with stairs and bullseye to the digester
c) Sample take-out
d) Double membrane for roof gas storage including roof blower, fixing system and security valve
e) Electronic pressure sensor in gas hood
f) Electronic level meters/sensor
g) Electronic temperature sensor
h) Slow running agitator for high DM contents, 12-15 kW
i) Fast running propeller stirrer of 7.5 kW

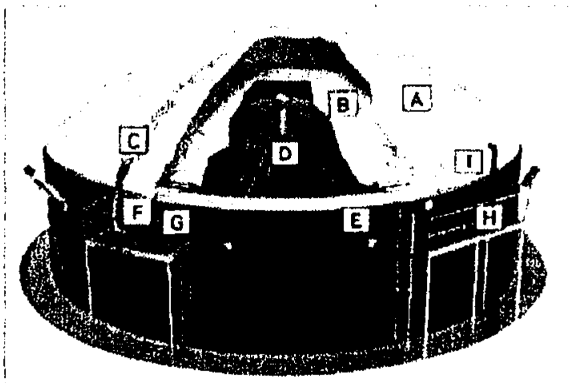


Figure 43: Proposed tank system for main digester[13]

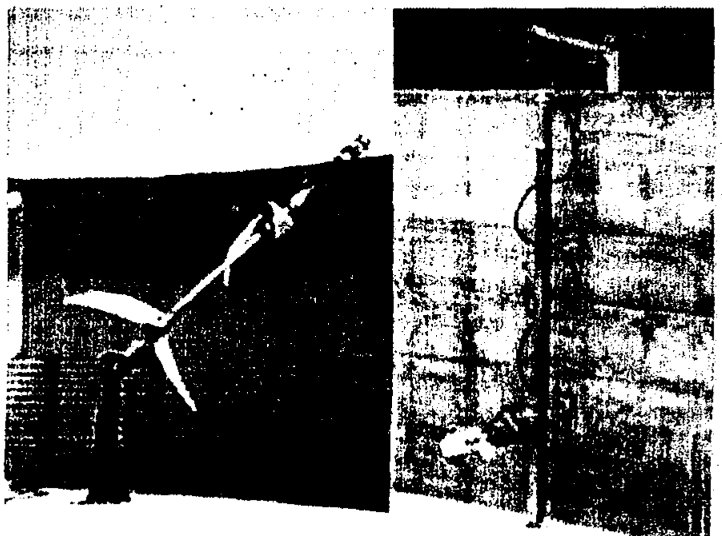


Figure 44: Slow running agitator (left, source: Streisal GmbH BioBULL) and fast running submersible propeller agitator (right, source: SUMA Rührtechnik GmbH)

4. Gas treatment

The biogas captured within the gas hood of the digester requires a treatment process in order to complete the quality criteria for being used in the generators. The main applied processes for the proposed processes design are following:

- Desulfurization through reduction of hydrogen sulphide (H_2S) by air injection into the gas hood and by external adsorption of the biogas flow with an activated-carbon filter to reach a maximum H_2S-content of 100 pm
- Drying of the biogas through cooling and condensation
- Compression of the biogas in order to increase the initial biogas pressure of around 5 mbar on up to the required pressure for the combustion

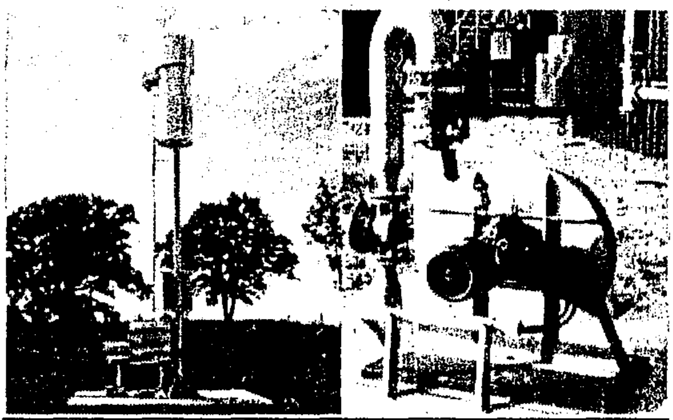


Figure 45: Safety flare and biogas compressor (Source: GT-Himmel GmbH)

For safety reasons, e.g. when the gas storages are accumulating too much gas and the generators are not working, a semiautomatic safety flare should be in place to burn the exceeded biogas. The flare should start to operate after certain pressure in the gas storage is reached (pressure sensors). The flare itself will be operating independently from the rest of the gas pipeline with an own blower and a own flame flap-trap. Although the gas storages have additional overpressure valves, which discharge biogas in case of gauge pressure as well, it should be avoided to use these security valves in order not to mitigate too much biogas and thereby emit the "climate-killer" methane into the atmosphere.

The required overall biogas storage volume including storage roofs on main digester and the optional external storage should be at least 1,500 m³, preferably 2,500 m³. If statics allow installing a double membrane storage roof on the digester with a total volume of 1,500 m³, the external gas storage is not needed.

<u>Equipment and Components</u>

a) UV-resistant biogas pipeline, stainless steel or HDPE, DN 150
b) Gas flow meter
c) Semiautomatic safety flare 100 m³/h
d) Internal biological desulfurization system by air injection into the gas hood of the main digester and post digester
e) External desulfurization system with activated carbon filtration
f) Gas analyser for CH_4, H_2S, O_2
g) Biogas chiller for cooling and condensation

h) Biogas condensation tank with submergible pump and piping
i) Biogas blower up to 150 m^3/h incl. safety valves
j) External gas storage balloon, double membrane, 2,500 m^3 (optional)

5. Slurry Pond

Although most of the digestate will be separated after the biogas process and the liquid phase will be re-circulated and the solid phase used as an organic fertilizer, the system should provide a storage for the liquid digested material, e.g. in case the separation does not work or for any other reasons. This can be realized in an open pond, which fulfils the local standards concerning semi-anaerobic treatment lagoons. However, it should be stated that it is possible that the digestate still will produce a smaller amount of methane. Therefore, in countries like e.g. Germany, nowadays all digestate storages have to be covered in order to capture all remaining methane emissions.

Equipment and Components

a) Open Lagoon for 5,000 m^3 digestate including geomembrane/soil cover which complies with local ground water protection standards

6. Control and Automatization:

The automation concept shall facilitate the complete automatic operation of all mechanical equipment, document the relevant process parameters and provide a safe and adequate alarm chain. This means specifically:

- Controlling the operation time of pumps, agitators and blowers
- Set up the process and alarm hierarchy, e.g. blocking pumps when certain liquid level is reached, starting safety flare when gas pressure is too high, starting gas blowers when gas composition and production can allow the operation of the generators, etc.
- Documenting substrate flows, gas flows, gas composition, temperature and tank levels
- Visualizing the on-going process and the relevant parameters and settings for operators
- Facilitating remote control via internet access

Equipment and Components

a) Control cabinet and automation unit for feeding, pumping, stirring, managing of CHP & flares, alarm settings regarding temperature, liquid levels, pressure, pH, CH_4, H_2S and regarding the handling of other installed equipment (blowers, valves etc.)
b) Container or housing for control cabinet

7. Biogas conversion

The biogas conversion will consist in two generation units. The first one will be a highly-efficient co-generation unit which generates electricity with an efficiency of up to 40% and thermal energy with up to 42%. This unit will be used for the average base load generation of 100 kW_{el} and will also provide the required thermal energy (hot water with 90 °C) for heating up the substrate on the process temperature of 35-40 °C according to the measured process temperature in the main digester. To buffer the time, when no generator is operating, a heat accumulator of 5 m^3/80 kWh will be installed. If the average substrate flow of around 1.25 m^3/h needs to be heated by 20 K, around 30 kW of thermal energy should be provided. The CHP unit is able to provide up to 100 kW_{therm}.

For the peak electricity production, a simple low-cost biogas generator will be utilized. These models from e.g. China have a comparatively low efficiency (around 30%) and are usually not modified to capture the waste heat from the water cooler and the exhaust gas.

The electrical connection to the grid will be explained in the following chapters. However, it should be stated, that it is estimated, that the biogas plant will have an own constant electricity consumption between 5-25 kW (average 8-9 kW). The supply should be provided by both options: By the biogas generators or by the grid, or through the PV plant in case the generators are not working.

Equipment and Components

a) 1 x 100 kW biogas co-generation units including heat exchanger, 5 m^3 heat buffer tank and connection for heating circuit 90/70 °C
b) 1 x 100 kW biogas generator
c) Electric integration
d) Building or container for generator set-up

C.4.5.9. Design of the cost-optimized biogas plant on Site 2

The cost-optimized small-scale biogas plant on site 2 will be built according to the existing standard in Pakistan for biogas manure plants. It will only operate with the manure, which in this case has to be mixed with water as well, since the design only allows to process liquid substrates since there is no internal mixing system in the digester.

The main components of the small-scale biogas plants are:

1. Manure Collection
2. Receiving Chamber
3. Mechanized Mixing & Feeding system with submersible pumps
4. Bio Digesters (a 400 m^3) in parallel with a total volume of 2,000 cubic meters
5. Slurry Reservoir
6. Check Points
7. Pressure Regulating System
8. Applications of Biogas (50 kW power generator and cooking gas preparation)

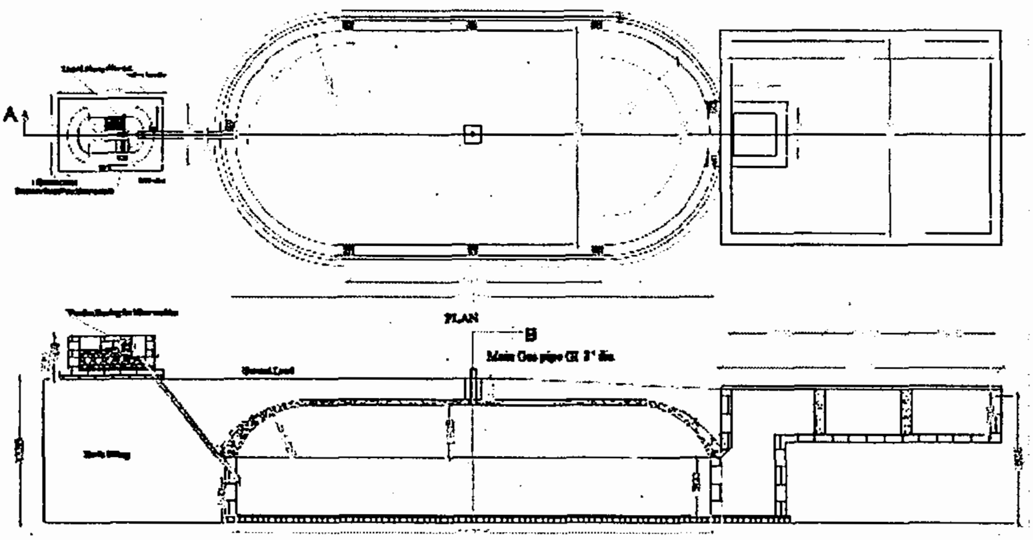


Figure 46: Preliminary design of small-scale biogas plant

The whole design is constructed with local brick material. The substrate flow from the receiving chamber to the digester and out of the digester into the slurry reservoir is facilitated only through gravitation and pressure. The gas storage within the main digester is a fixed dome, constructed with bricks and the whole digester is built subterranean as being visible in the above scheme. Five of the above shown standard biogas systems will be constructed in parallel. Each digester will have a reactor volume of around 400 m³, so the overall retention time for the substrate will be around 60 days. Since the substrate is mainly manure, which requires in standard biogas plants 20-30 days HRT, the additional HRT within the given design leaves enough buffer to reach a similar biogas yield per kg organic matter as in industrial plants. The daily organic loading rate below 1.5 kg oDM/m³ and days leaves also space to up to add additional chicken manure, if cow dung cannot be provided in sufficient amounts or the biogas yield needs to be improved for other reasons.

Substrate flow	32	m³/d
Volume Digester total	2000	m³
Amount of Digester	5	
Volume per Digester	400	m³
Average Retention time	62.1	D
Daily Organic Load	1.23	kg oDMS/m³ d

Table 19: Design parameters plant on Site 2

C.4.5.10. Cooking gas utilization

The purpose of the project is not only to supply electricity, but also improve the infrastructure of the village in general. The standard scenario for cooking in rural Pakistan is based on wood and cow dung cakes, with the according implications of respiratory diseases etc. As the villagers during the surveys conducted at the prefeasibility stage have raised various times the interest to receive biogas for cooking purposes, a pilot distribution system shall be set up which will allow a number of 50 households per village to avail the biogas for the cooking.

The households are supposed to have biogas consumption of around 1-2 m³ per cooking process (1-2 hours). This means in total 50-100 m³ of biogas per day should be provided by the biogas plant. Plant on Site 1 is generating 1,537 m³ of biogas per day, if operating on 100%, while plant on Site 2 would produce around 560 m³ of biogas per day. The additionally needed biogas for household cooking for plant on Site 1 can be provided through the respective additional substrate input or through lowering the CHP generation during that time. For plant on Site 2 there is not enough capacity to increase the substrate input, so the overall electricity generation needs to be slightly reduced for the cooking gas consumption.

The transport of the gas to the households can either be realized through small biogas pipelines, where the cleaned biogas is compressed and transported to the consumers, or it can be filled through a valve in the main biogas pipeline into 5-10 m³ storage bags, which can be transported to the households and refilled every week. However, the management of the biogas pipeline or biogas bag refill station should only be realized under the supervision of trained plant operators. The pipeline solution is the less risky one and to be preferred.

Additionally, the pipeline or the filling station should be separated from the remaining gas system by electric valves and flame flap traps.

Figure 47: Gas storage bags (Source: Baur GmbH 2017)

An alternative to guest storage bags would be the usage of high-pressure tanks. Typical propane gas tanks are rated to 250 psi. Compressing biogas to this pressure range uses about 5 kWh per 1,000 ft^3 (Ross, et al., 1996, p. 5-18). Assuming the biogas is 60% methane and a heat rate of 13,600 Btu/kWh, the energy needed for compression is approximately 10% of the energy content of the stored biogas. This alternative is therefore not deemed a practical solution for this Project.

The gas for cooking purposes in this Project (50 to 100 m³ per site and day) will be produced through additional substrate; therefore, the gas output for electricity generation is not affected. The design of both sites has some volume margin and allows for this small additional feeding.

Purification of biogas

For refinement of biogas e.g. for usage in transport, it can be upgraded to bio-methane (cleaned biogas) by removing H_2S, moisture and CO_2. Biomethane has characteristics similar to those of natural gas, as within both gases, methane is the main component. By purifying biogas to bio-methane, the caloric value is increased from 6 kWh/m³ (biogas) on up to 10 kWh/m³ (bio-methane), since the CO_2, which normally has 30-40% of volume shares within the biogas and is energetically not usable, is removed. However, the specific costs of purifying biogas to bio-methane are around 0.5-2.5 €Ct/kWh$_s$ (0.05-0.25 €/m³ biomethane) according to FNR.[14]

However, for this Project, a purification of biogas is not necessary and too costly in terms of investment costs and additional auxiliary power demand.

Distribution of Biogas

Non-purified Biogas is a low-grade, low-value fuel and therefore it is not always economically feasible to transport it in storage tanks for any distance. Likewise, biogas cannot be economically trucked. However, if the consumption of the biogas is comparatively constant, pure biogas pipelines can be feasible for a distance of up to a few kilometers, at it is realized on several biogas plants in Germany. The costs for the additional pipelines are around € 50-80 per meter distance.

Distribution via Dedicated Biogas Pipelines

If the point of consumption is relatively close to the point of production (e.g., less than 5 km), the biogas is typically be distributed via dedicated biogas pipelines (buried or aboveground). Biogas intended for use as domestic stove fuel can be transported via dedicated pipelines to houses within the village. Therefore, the biogas does not need to be purified to bio-methane. For short distances over privately owned property where easements are not required, this is usually the most cost-effective method.

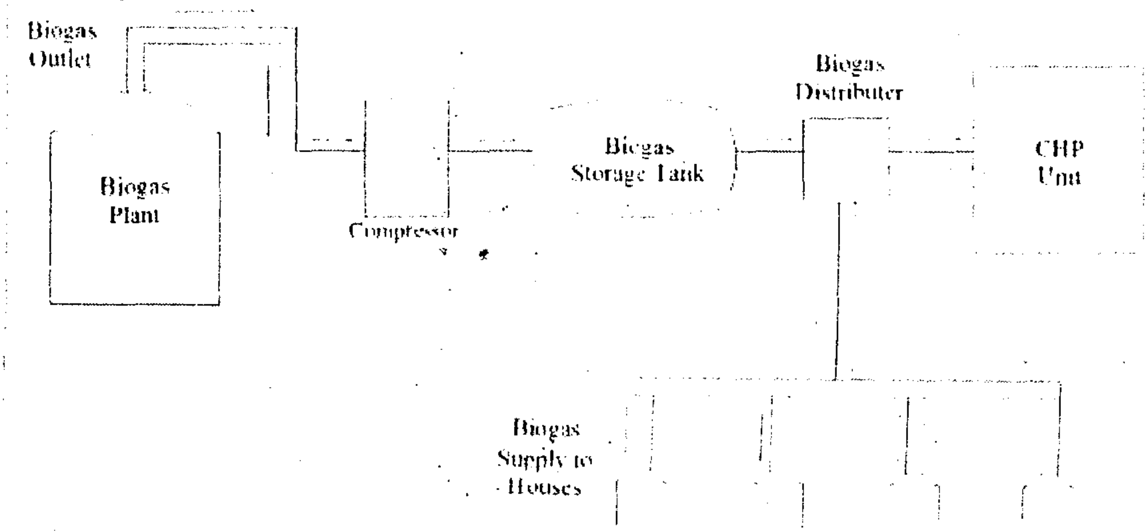


Figure 48: Distribution via Dedicated Cleaned Biogas Pipelines

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Billing of Biogas Use

Billing of biogas could be of two types: The standard case would be to install gas meters at every household for the measurement of the gas consumption, e.g. on monthly basis. If usage of gas does not differ significantly between the households, a standard monthly price per network connection would be another option. The charges of gas utilization would be claimed by the operating company of the power plant.

C.4.5.11. Procurement policy

Cow dung is the cheapest and most readily available substrate. It is in the relevant villages only alternatively used as fertilizer and some minor application for household cooking.

In very approximate terms, 1,000 adult cows or buffaloes of stabled animals or 2,000 adult animals of roaming animals are assumed to be necessary to supply the necessary substrate for a 100 kW (average output) biogas plant. The higher the number of cows in the village, the less supply risk is involved.

The transportation of the cow dung to the biogas plant needs to be arranged. A labor person with a donkey car will be hired to collect the dung on daily basis. The fresher the cow dung is brought to the plant, less decomposition of organic material has been happened and the biogas production potential will be higher. Also, the more animals are stabled, the less the transaction costs will be and the better the freshness of the substrate will be.

It is planned that the farmers contribute to the project by giving the cow dung for free as they in turn receive the slurry which is the byproduct of the biogas plant for fertilizer purposes. Their loss in fertilizing material will be small (only a very small amount of nutrients is lost in the biogas process). However, as a conservative assumption, a total of 180+150 = 330 PKR costs per ton have been assumed for the cost analysis for the labor and a possible substrate price.

Chicken manure is costlier than cow dung, but has an excellent property for the biogas process due to its content in nitrate. A small amount of corn silage is also foreseen to cover up for any shortcoming in the other substrates. As long as cow dung is abundantly available, this share may be omitted and substituted by cow dung.

Other forms of biomass are generally more difficult to utilize, either for economic reasons (e.g. oil press cake is far too expensive for a commercial operation of biogas) or for technical reasons (e.g. cotton stalk has a high amount of lignin and needs elaborated pre-treatment before it can be fed the plant). They have therefore been excluded from the project.

C.4.6. Batteries

The two predominantly used storage technologies used in standalone solar power plants are lead-acid and lithium ion batteries. A comparison of the two technologies can be made by considering the following key factors that determine the feasibility of battery systems for a particular scope and scale for which storage is required:

1. Weight: Generally, lithium-ion batteries are one-third the weight of lead acid batteries. In this project, since weight is not a significant determining factor, lithium ion batteries do not pose a significant advantage over lead-acid batteries on this factor.

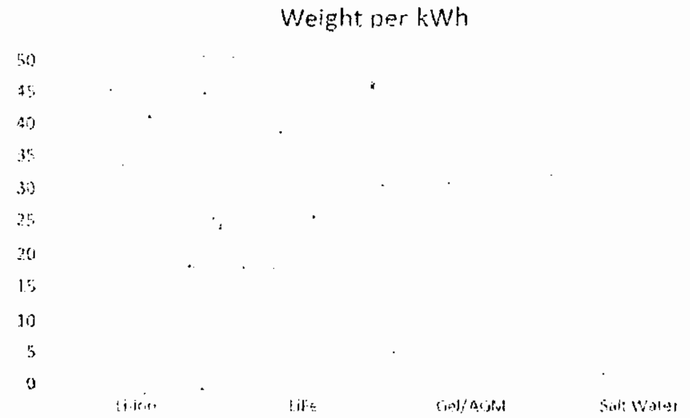

Figure 49: Comparison of weight (in kilograms) for each battery type

2. Efficiency: Lithium-ion batteries have high charge/discharge efficiency in both charge and discharge, allowing their retrieving of almost the same amount of energy which has been fed into the battery. Lead acid batteries' inefficiency leads to a loss of energy, while rapid charging and discharging makes the open circuit voltage drop quickly and reduces the batteries' capacity.

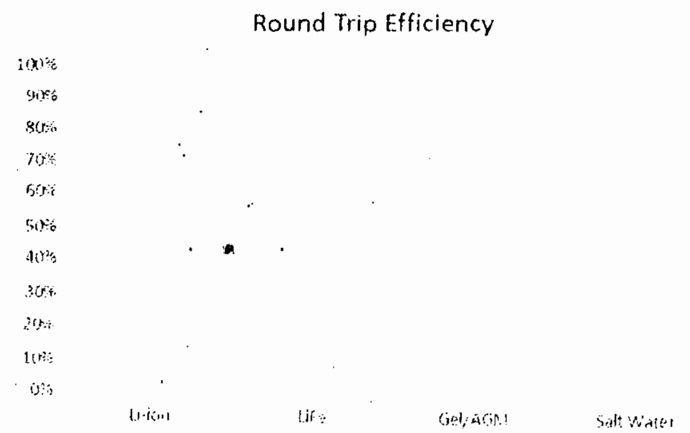

Figure 50: Round trip efficiency for different battery types

3. Discharge: Most Lithium-ion or Lithium Iron Phosphate batteries can be discharged to 90% versus a level of less than 50% of discharge for lead acid while retaining the high cycles. Most lead acid batteries do not recommend more than 50% depth of discharge.

Another critical consideration is the C rating of the batteries; that is, how fast the system can discharge or charge the batteries. The faster the battery can discharge, the greater is the power delivery possible.

4. Life Cycle: Rechargeable lithium-ion batteries can survive 4000-4500 cycles or more compared to just 2500-3000 cycles in lead acid. Cycle life is greatly affected by higher levels of discharge in lead acid, versus only slightly affected in lithium-ion batteries. Lithium-ion has a significantly higher cycle life than lead acid in deep discharge applications. The disparity is further increased as ambient temperatures increase. The cycle life of each chemistry can be increased by limiting the depth of discharge (DoD), discharge rate, and temperature, but lead acid is generally much more sensitive to each of these factors. In the figures below, AGM refers to a lead acid battery.

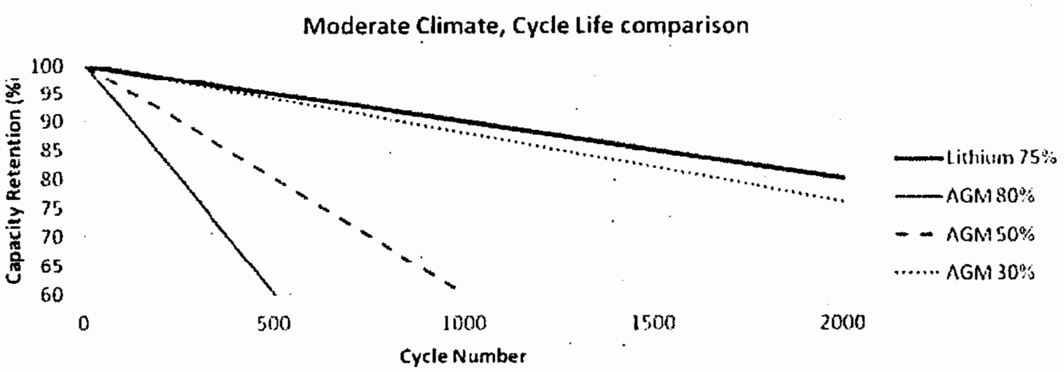

Figure 51: Lifecycle comparison of lithium- ion and lead-acid batteries.

Source: http://www.altenergymag.com/content.php?post_type=1884

5. Lifecycle cost: This total lifecycle cost graph takes into account the depth of discharge and the typical lifecycle. In this case, flooded lead-acid batteries have the lowest lifecycle cost, but that is assuming they are properly maintained and are not abused. This is a best-case scenario. If they get discharged past 50% frequently or if the maintenance gets neglected, then they won't last as long, thereby increasing their lifecycle cost. Lithium-ion batteries require little maintenance and are more resilient to irregular discharging. When taken together, these factors make the lithium-ion battery more appealing for an off-grid solar energy system.

It however should be noted that **the upfront cost of lithium-ion batteries** is considerably higher as the savings against lead-acid occur over time (less maintenance and less replacement).

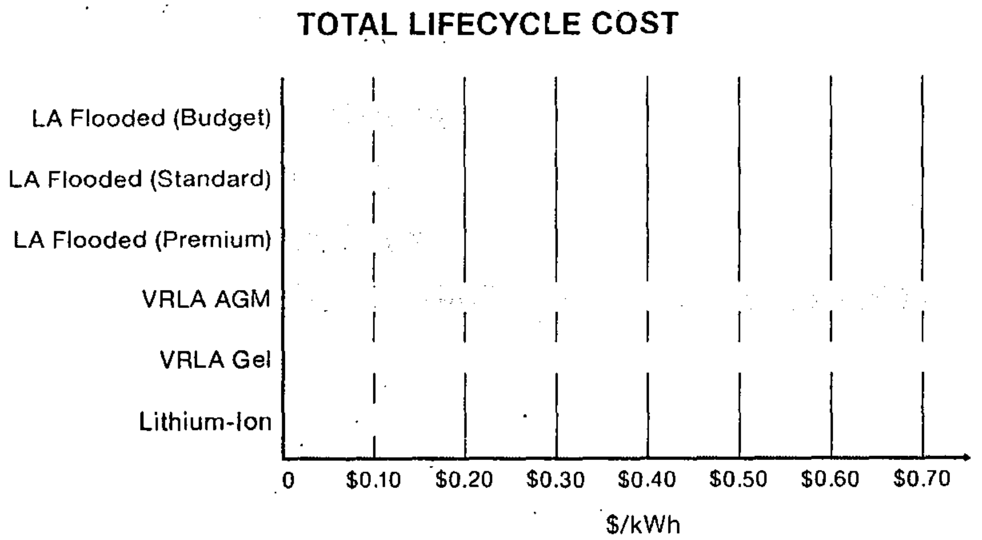

Figure 52: Battery lifecycle comparison. Source: https://medium.com/solar-microgrid/battery-showdown-lead-acid-vs-lithium-ion-1d37a1998287

6. Voltage: Lithium-ion batteries maintain their voltage throughout the entire discharge cycle. This allows for greater and longer-lasting efficiency of electrical components. Lead acid voltage drops consistently throughout the discharge cycle.
7. Environmental Impact: Lithium-ion batteries are a much cleaner technology and are safer for the environment. Lead is a highly toxic and polluting element, while Lithium is not.
8. Control: Li-ion batteries require an additional cell balancing system to balance charge at an individual cell level. This requirement is usually note required for lead acid batteries when looking at a smaller storage capacity. The effort and cost for such a control unit weighs more for small battery quantities; that is why lead acid batteries are still the standard case for small solar home systems etc.

Though they are used to power the same applications, lithium-ion and lead acid batteries have very different characteristics. Lithium batteries deliver high-quality performance in a safer, longer-lasting package. Fast (dis-)charging rate, high energy density, extended cycle life and low maintenance are advantages of Li-ion batteries compared to lead-acid batteries. At present, the main drawback of Li-ion batteries is its high upfront cost. A comparison summary is drawn in the table below.

In conclusion, Li-ion batteries are better suited for the large-scale, frequent-cycle, high power charge and discharge capacities which are required for this project. Their higher investment cost is compensated by less replacement costs due to their higher lifetime and higher discharge capacities.

C.4.7. Control

Control is a critical issue to be solved for the power plant under this project. Whereas for conventional large-size power plants, there is only one source which supplies the power (fossil fuel, Hydro, solar etc.), in this case, there are different sources which have to be combined and integrated:

- The electric grid
- The solar power Plant
- The biogas Plant
- The battery storage

All of these have to be combined in a way that optimizes costs, avoids unnecessary losses and, most of all provides a reliable power supply to the connected village loads with as little outages as possible.

The basic operational states which have to be switched on an off by the control unit have been laid out in C.4.1. But this task of power balance is not the only function that the control system fulfills.

The functions of this control system are:

- Power balance (in islanding mode operation): switch on and off and control the available sources in a way that matches the load in every point in time. This includes synchronization of the different power sources that feed into the same grid
- Energy balance: organize the available energy in such a way that it is available when needed, mostly through the prudent use of storage (biogas storage, battery)
- Ancillary services (in islanding mode operation): provide sufficient spinning reserve for changes in load (and solar power)
- Disconnection from the grid and establishing of an island mini grid for times of load shedding; automatic synchronization and reconnection to the grid afterwards

This case of hybrid-source, mini-grid control is by no means a common standard and surpasses the expertise and resources of a typical solar power or civil structure company, or even a thermal power company. However, due to the spreading out of mini-grids and similar solutions throughout the world during the last years, there are today a number of companies that provide these services. These companies can roughly be divided into different levels:

1. Those providing only control solutions and their implementation (software, PLCs and communication devices, and a human interface)
2. Those that provide a control solution together with the battery storage (storage package solution)
3. Those that provide, apart from the control and battery storage, a small solar power plant and a diesel backup (complete mini-grid solution).

4. Those that provide mini-grids together with high amount of services, such as customer payment technologies etc. (complete mini grid operator solution)

As the idea of this project is to hire a locally present EPC for local value creation and competitive costs, categories three and four of this list which are only available on international level would probably not be the case. Companies of category one and two are interesting; they can function as a partner for the local EPC.

C.4.8. Land requirements and suitable transformer size

As per the design from chapter C.4.1, the two power plants are proposed with the following dimensions:

1. 100 kWp PV, including 100 kWh battery, combined with 100 kW biogas (200 kW peak)
2. 300 kWp PV, including 200 kWh battery, combined with 50 kW biogas (100 kW peak)

The rough land requirements for these two plants are[15] given below.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100 kW Solar PV with 100 kWh battery	100 (200 peak) kW	0.6 acres	0.6 acres	1.2 acres
300 kW Solar PV with 200 kWh battery	50 (100 peak) kW	1.8 acres	0.3 acres	1.8 acres

Table 20: Land requirements for given system sizes

The required amount of land is therefore rather small and both villages have government land available of this size as laid out in C.1.4.2.

[15] Assumptions: 25 m² land requirements for kW of PV, 24 m² land requirements for biogas

C.5. Transmission Line Assessment

C.5.1. Electric connection of the power plant to the distribution system.

In general, the power plant can be connected to the grid in the same way as any standard plant of similar nature. It will be connected to the grid in parallel with all other consumers. The direction of energy into the grid is determined by the voltage and phase angle regulation of the generator.

Protective functions of the generator control or separate protection devices will be used to prevent impermissible operation conditions, like out-of-range voltage, cable overload or other dangerous conditions.

Depending on the specific situation, the connection will be either on the low voltage side of an existing transformer, or through a new, dedicated transformer to the medium voltage grid.

The connection to the low voltage side is usually the cheaper solution, as shown in the Single Line Diagram (SLD) below.

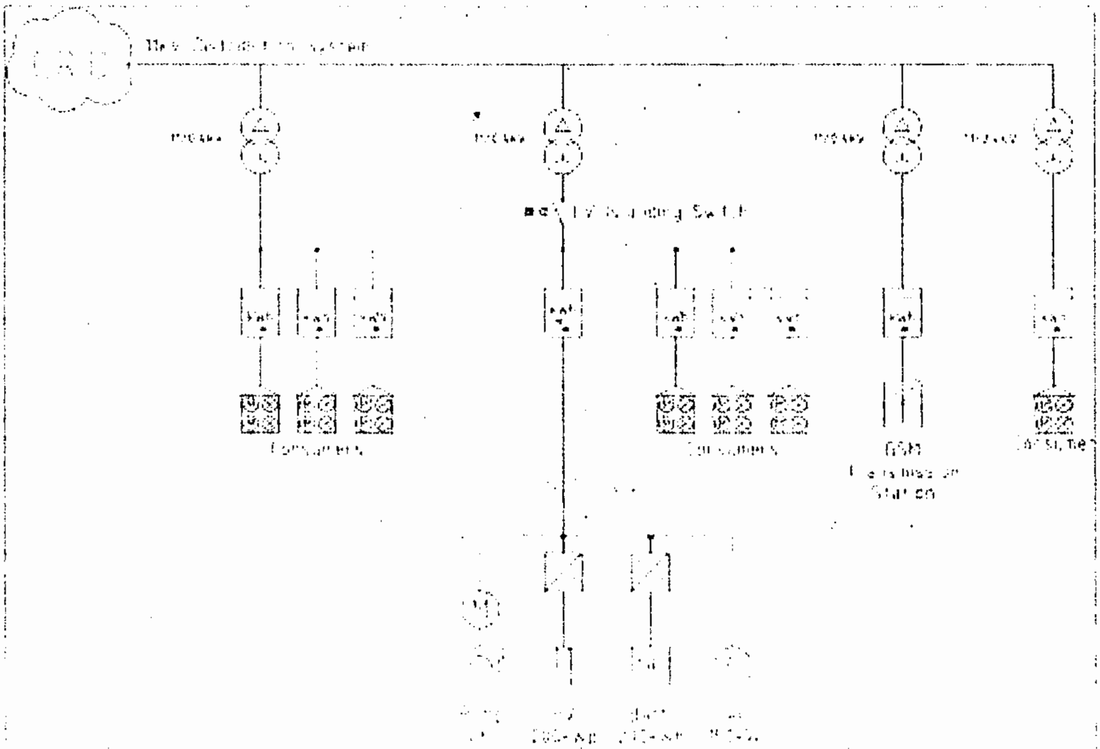

Figure 53: SLD for Connection on LV side

However, it has its limitation by the rating of the existing transformer and the distance from the power plant, as the permissible limits voltage drop require an increased cable cross section in proportion to the cable length. As such, at a certain distance – in our case: a few hundred meters – a low voltage connection becomes uneconomical due to the disproportionate increase in cable costs.

An example for the connection to the medium voltage system is shown below.

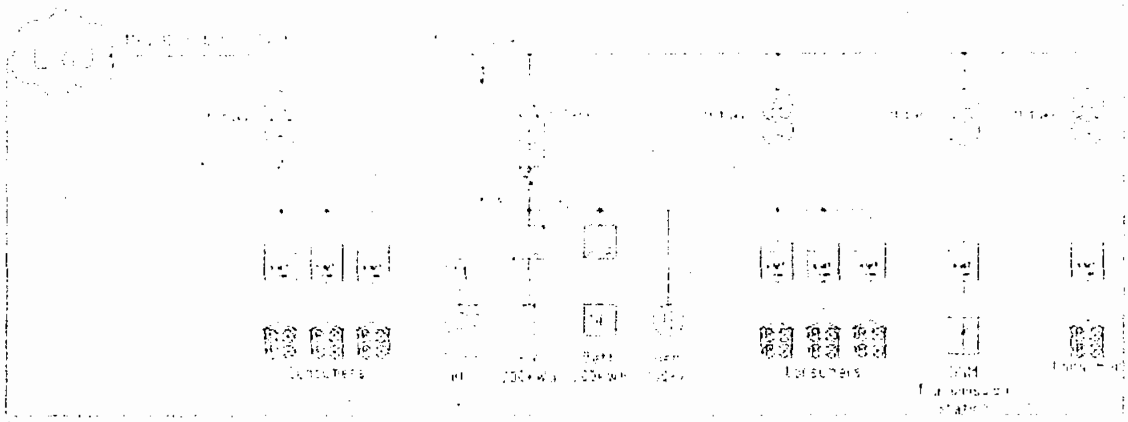

Figure 54: SLD for Connection on MV side

The connection on the 11 kV, i.e., medium voltage (MV) side requires a dedicated transformer for the power plant. In this case, distances do not play a major role.

C.5.2. Switching strategy

The idea of the two pilot plants is to produce renewable power locally and feed it into the grid, thereby supporting the supply of electricity to these remote areas through the distribution companies. The other, even more important part is that the power plants will provide power to the village during times when the grid is under load shedding, thereby facilitating an almost round-the-clock power supply to the village. The power plant therefore needs to operate both in the grid-feeding mode and in island mode.

Based on the findings of chapter C.4.3, both power plants cannot supply more than a 200 kVA transformer reliably throughout the year. The standard scenario therefore should be that in times of load shedding, the power plant would be connected to one 200 kVA transformer, which would otherwise be disconnected from the grid (see Figure 55). Switch S0 would disconnect the consumers and distributed generation from the grid station and allow the system to be operated in island mode. Once isolated, the controller has the flexibility to switch power to the consumer loads connected to Switch S1, S2 and S3 based on the load-generation matching profile or according to an alternation schedule. These breakers therefore should be controlled by the power plant control system. Additional circuits can therefore be controlled by the power plant control system so that it can connect and disconnect the transformers according to the power available.

If the power plant is connected to an existing transformer, the switch will be directly after the transformer terminals. If the connection is through a dedicated transformer to the 11kV system, one or more medium voltage switches (circuit breakers) need to be installed, depending on the local grid geography, so that one or more existing distribution transformers can be supplied, as shown in the figures.

The control of the switches will be automatic and operated by the control unit. Furthermore, a local manual control or blocking of the automatic control must be possible, for the purpose of safety of operational personnel.

During winter, in most cases it would be feasible to supply more than one transformer of 200 kVA along the line. During summer, in most cases only one transformer of 200 kVA would be connected. Whenever the demand of the connected transformers rises above the available generation capacity, the control would disconnect one transformer from the island grid.

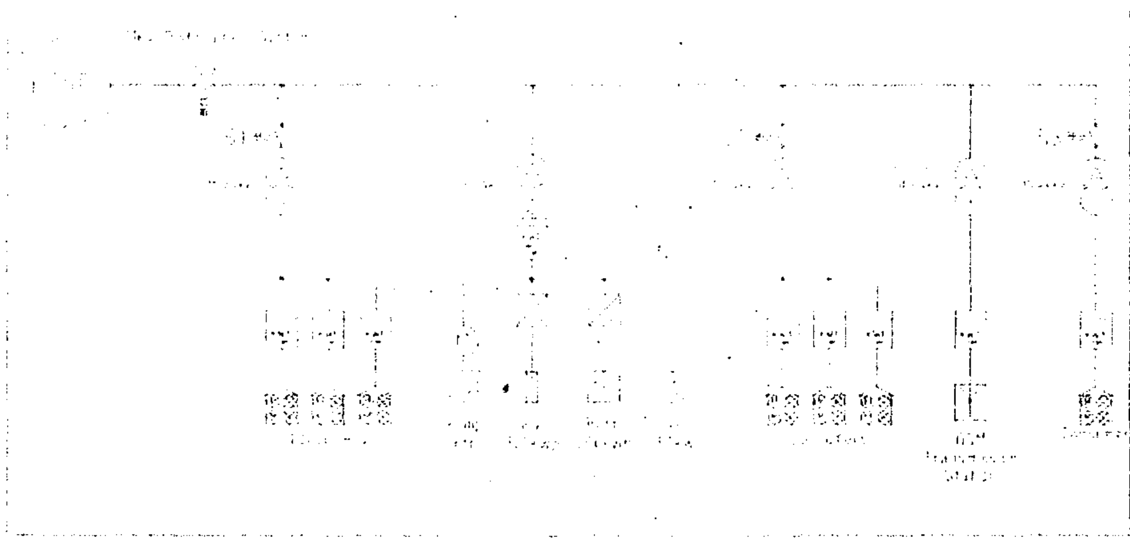

Figure 55: Switching options for island mode

However, the implementation of a system that can switch between these different options requires effort and a higher complexity. Depending on the village situation, the position of breaker (S1, S2, S3 etc.) could be considerably further away from each other; and at differences of a few hundred meters, communication would become an additional issue.

The agreement to these changes by the corresponding distribution company will be needed in any case, but the safety scenarios to be considered as well as the concerns and objections to be expected by the distribution company would increase with the number of breakers and changes involved. The issues to be considered contain, among others:

- Safety concerns on low and medium voltage side for different scenarios.
- Grid maintenance: during grid maintenance, the distribution companies switches off the grid so that the technicians can perform their work; in this case, it also needs to be ensured that the relevant part of the grid is physically disconnected from the distributed power plant and protected with the applicable protection against accidental switching on.
- Control issues: in certain cases, the distribution company might want to switch on or off the breakers due to certain grid situations; the communication between the distribution company and operation company of the power plant therefore needs to be defined and functional.

On the financial side, a certain amount of additional costs is implied by the additional equipment, connections and added operational complexity.

If the distribution company wants to have an overriding access to the breakers, this can be implemented; the power plant control system then needs to shut down the power plant in the case the distribution company opens the breakers.

Conclusion on switching strategy

For this first pilot project, it needs to be mentioned that a connection of two or more transformers, even if desirable from the benefit point of view, implies certain risks in complexity, reliability and costs. If this approach is to be taken anyway, these risks would need to be considered and consciously accepted by the Employer for this pilot project.

For a safe approach, it would be recommended to go with the connection of only one transformer of 200 kVA for the island mode (during load shedding). Once this operation is handled in a stable way and the distribution company is comfortable with the arrangements, it can be explored whether the connection of another transformer for the island mode should be implemented.

Even if the connection of more than one transformers is the final goal of the Project, their connection should be implemented in phases, e.g. two months of operation with only one transformer connected, and then adding of the other transformers one by one.

On the energy side, the feeding into one transformer only does not as such imply a significant amount of loss of renewable energy provided as the excess energy can in most cases be stored in the batteries or fed into the grid.

C.5.3. Benefit analysis.

It is a common assumption, that distributed power generation may create problems in distribution networks. Whilst this is true in certain cases, it is not so common. The typical problems, like voltage increase above acceptable limits or disturbance of grid regulation due to substantial changes in power generation, appear only when distributed generation provides a significant portion of the overall power generation. In point of fact, a single or only few power generators in a feeder, as it is planned here, can actually improve the power quality.

With data about the grid available, the impact of the distributed generation can be simulated with dedicated computer software and possible problems indicated beforehand. Furthermore, modern inverter technologies have protective functions integrated that counteract unwanted situations.

As an example, the simulation of one PV generator, connected to a typical 11 kV distribution feeder at peak load, is shown in the following:

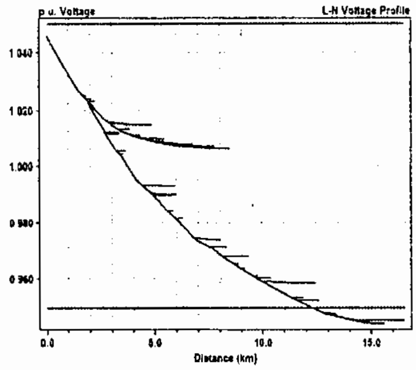

Figure 56: Voltage drop, base case

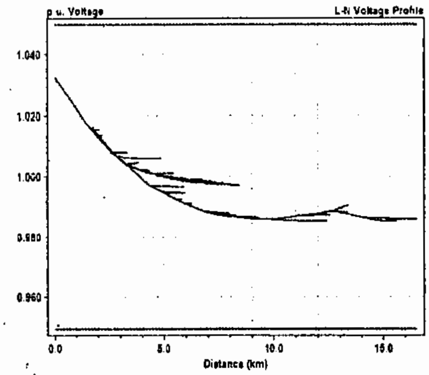

Figure 57: Voltage drop, with PV intervention

As the diagrams show, whilst the voltage level at the remote end currently drops below the permissible margins (+/- 5%, red lines), the distributed generation lifts the voltage level at the remote end and equalizes the level on the whole feeder. By that, connected consumer equipment works more economical. As the power is generated closer to the consumers, there is also a significant reduction in line losses, in the specific case, a distribution loss reduction of up to 50% can be achieved.

C.5.4. Various technical aspects of connection of the power plant to the grid

C.5.4.1. Impact of the planned intervention on the grid

Additional distributed generation facilities in the network have an impact on the fault scenarios. They contribute to the maximum short-circuit current in the network and this effect has to be taken care of in a grid study. However, PV plants typically have a marginal contribution to the short circuit level, as the short circuit current of a PV module is only slightly above the normal operation current. A biogas / diesel generator, like any other reciprocal engine generator can provide a significant contribution to the short circuit current, however this can be safely controlled with common protection technology. On the other hand, the spinning reserve of this generator provides also a stabilizing element. In general, due to the relative small sizes of the plants, it is very likely that the existing network has more than sufficient margin for safely accommodating the additional generation facilities. The details need to be worked out during planning phase (EPC) with the relevant distribution grid during implementation stage.

C.5.4.2. General impact of Renewable Energies on the grid

Photovoltaic (PV) technology has in recent years become a significant form of power generation on many electricity networks. Electricity utilities who manage these networks have raised concerns regarding the impact of high penetration by photovoltaic into these distribution grids. These concerns generally focus on issues of grid management and operation and planning, particularly where there is variability in PV system output due to cloud cover. Variability in PV irradiance is often cited as a major impediment to high levels of PV penetration into existing electrical networks. There is an assumption that large multi-nodal electricity grids are inherently stable (i.e. they do not experience large short term variances in demand) and that the addition of significant PV input and associated intermittency potential could cause disruptions that would increase the risk of operational problems. However, results from studies encounter a significant level of load variance as part of normal operation. In other words, a typical network already accommodates a high degree of variability without compromising on operational outcomes. Results demonstrate empirically that it is possible to install large amounts of PV into existing networks without disrupting the underlying variance that normally exists in grids, as long as there is adequate spatial distribution of the PV input.

C.5.4.3. Grid control strategies

As the installations are of rather small scale, the need for change in grid control strategies will be rather a slow progress than a sudden change. Solar inverters are designed to react to changes in the grid with a stabilizing effect; for example the power injected into the grid can be automatically reduced, depending on grid voltage and frequency. Furthermore, remote commands for power reduction can be processed. As such, the grid operator is able to remotely control the power injected into the grid. Inverters are able to provide reactive balancing power and by that stabilize the grid voltage in the network area of the grid.

C.5.4.4. Faults during island operation mode

The major concern regarding faults during island operation of PV plants is the unusual characteristic of PV generators, meaning the low level of short circuit current. Whilst this can be seen as a safety feature in the sense that high short circuit currents do not occur, it might create problems with conventional protection devices like fuses that rely on the high short-circuit currents that are typical for conventional, rotating generators. This issue can be addressed in several ways: For the protection devices on the consumer end, the generation capability is by far sufficient to operate fuses or a conventional distribution board. As such, no changes at the consumer level are necessary. Concerning faults on the distribution backbone level, all standard inverters have protection devices and functions integrated that detect faults on that level and safely disconnect the power if necessary.

In conclusion of what has been said above, with a proper grid study and protection design it can be assured that all possible electrical faults will be cleared without a problem.

C.6. Energy Yield Assessment

C.6.1. Solar Production

C.6.1.1. Solar Yield assessment

The solar energy yield assessment was performed using a standard tool, PVsyst. The report generated is attached in C.15 for each location with appropriate system sizing and local conditions. Dimension shall be kWh/m² instead of sun hours to calculate energy values. For initial energy yield analysis the annual global horizontal irradiation (GHI) was evaluated as 1720 kWh/m² for Chak 443 and 1821 kWh/m² for Chak 443 (Meteonorm data base) with the uncertainty in GHI at 7% for both villages.

C.6.1.2. Uncertainty Analysis of Irradiation Data

The deviation of single years from the long-term average can amount up to 15% and can show the same trend over several years. To minimize deviations for yield calculations it is necessary to take into account a long term average of irradiation. Regarding the long term of operation these deviations will lead to an average irradiance very close to that number given in the yield analysis.

C.6.1.3. Performance Ratio

A solar cell is the smallest semi-conductor element within a PV module to perform the immediate conversion of sunlight into electrical energy by the photovoltaic effect. Depending on the employed technology, the degree of efficiency amounts up to 18%. The conversion from direct current into alternating current implicates losses depending on the PV system configuration, the choice of components and, to a minor degree, on the local site conditions.

If these losses are identified and evaluated, the system operation quality – the performance ratio (PR) – can be ascertained. The PR is stated as percent and describes the relationship between the actual and theoretical energy outputs of the PV plant considering module efficiency.

PR = energy yield / (un-shaded annual irradiation on array surface * module efficiency according to STC)

$$PR = 100 \times \left[\frac{E_{AC}}{E_{Irradiation} \times A_{Array} \times \eta_{STC}} \right]$$

E_{AC} = energy coming from the inverter or measured at the energy meter in kWh
$E_{Irradiation}$ = un-shaded irradiation at module level in kWh
A_{Array} = total surface of all solar modules in m²
η_{STC} = module efficiency at STC

The module efficiency (contrary to the cell efficiency) considers the gross module surface and can be calculated as following:

$$\eta_{STC} = \left[\frac{P_{Module}}{A_{Module} \times 1.000}\right]$$

C.6.1.4. Shading analysis

From visit to both villages we can safely assume that vegetation and terrain causes no relevant shading at Chak 443 or at Chak 563. No relevant objects can be seen so far. Few trees and small bushes existing at site have been proposed to be cut. This eliminates all chances of external shading.

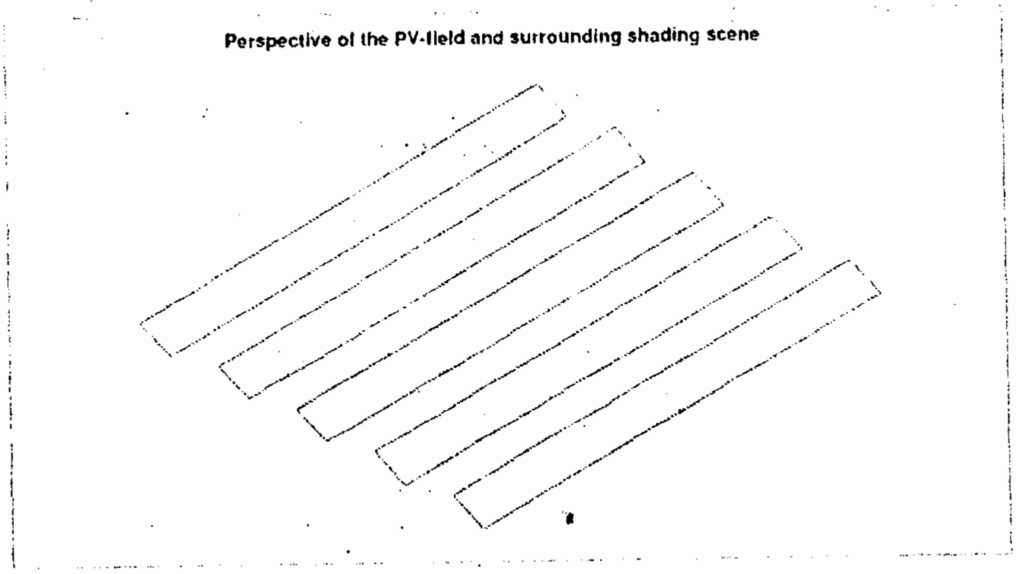

Figure 58: PV field shading situation

C.6.1.5. Expected losses

System Operation Quality / Performance Ratio

A fundamental step in understanding this important quality criterion is the explanation of the typical loss factors affecting the energy yield with different weights. In every simulation step, all described aspects have an hourly impact on the overall result.

Description of technical gains

- *Irradiation gain by inclination of modules*

In non-equatorial zones, the degree of irradiation at module level can be improved by the inclination of modules southwards (northern hemisphere) or northwards (southern hemisphere) against the horizontal. When reaching a normal module inclination angle of 25-30 degrees, the irradiation gain can amount up to 10-15% in temperate zones. The inclination angle causes an additional irradiation because the ground reflects the light to the modules. This reflection on different soil types is expressed by the Albedo Factor. There are empirical values for different soil surfaces.

Description of types of technical losses

Technical losses are calculated in the energy yield analysis depending on system design, chosen components and operation conditions.

- *Technical losses because of shading*

If there are objects in the immediate vicinity of the planned solar plant causing shading of the solar generator, these shadings can be considered and simulated by shading analysis. A distinction is made between "horizon shading" and "nearby shading".

"Horizon shading" causes a shading effect which has a permanent impact on the entire generator field. The simulation considers this effect by adjusting the horizon line. Objects that are in a large distance to the modules, e.g. mountain ranges, are typical horizon shadings. Such shadings always affect a larger module field, i.e. an array.

"Nearby shading", on the contrary, has a temporary and impact only on some parts of the generator field. Other parts of the plant remain absolutely unaffected. Objects at close distance to the modules act as cast shadows, e.g. power poles, trees but also row shading in large rack-mounted solar fields.

Greater distances between the mounting rows will lead to less nearby shading, as the effect of shading at low sun-angle will reduce.

Depending on the site conditions, these aspects are considered in the yield simulation.

Best in class shading losses would be represented by values in the range of up to 1%. Acceptable values would range between 1% up to 5% always depending on the required use of ground and intended energy yield of the PV plant. Shading above 5% would be un-acceptable.

- *Technical losses because of soiling*

Dirt on the modules also causes shading effects which can change over time and season. This shading impact on the energy yield depends, for example, on the surrounding landscape, cultivation and precipitation. The impact can only be estimated and is based on experience. Consequently, the uncertainty is high. It is recommended to clean the modules at least once per month.

Best in class soiling losses would be represented by values in the range of up to 1%. Acceptable values would range between 1% up to 4%. Soiling above 4% would be un-acceptable.

- *Technical losses because of temperature fluctuation*

Ambient temperature and degree of irradiation have an influence on the cell temperature and so affect the energy conversion process. According to the defined STC value of 25° C the electrical power output decreases with higher module cell temperature and increases with lower cell temperature. The module model shows this characteristic by means of temperature co-efficient for current and voltage.

Best in class losses due to temperature fluctuation would be represented by values in the range of up to 10% under the site conditions. Acceptable values would range between 9% up to 13%. Temperature fluctuation losses above 13% would be un-acceptable.

- *Technical losses because of reflection*

In particular inclined irradiation causes reflection of sunlight at the glass and cell surface. For "solar glass" it is considered by an empirically determined factor: IAM (Incidence Angle Modifier) = 0.05.

Best in class losses due to reflection would be represented by values in the range of up to 1%. Acceptable values would range between 1% up to 4%. Reflection losses above 4% would be un-acceptable.

- *Technical losses because of low irradiance level*

Due to production processes, the relative power of the modules might differ under different light levels.

Best in class losses due to this effect would be 0.2%. Acceptable values would range between 0.2% up to 0.8%.

- *Technical losses because of fluctuations in module quality*

Due to measurement errors or contractually allowed tolerances, the module output power under standard test conditions might deviate.

Best in class losses due to module quality are negative if only positive tolerances would be allowed. Acceptable values would range between 0% up to 1.5%.

- *Technical losses because of fluctuations in module arrays*

Due to production reasons, the module performances are subject to fluctuations:

Because of the different manufacturing technologies, the module wiring to module strings causes the so-called mismatch effect.

Best in class losses due to mismatch would be represented by values in the range of up to 0.5%. Acceptable values would range between 0.5% up to 1.5%. Mismatching losses above 1.5% would be un-acceptable.

- *Technical cable losses*

The whole wiring of the solar park is subjected to cable losses due to the natural resistance of conductors - the Ohmic resistance. Due to small-scale plant design and cable dimensioning for maximum performance, losses normally amount to 1-2%.

Best in class ohmic losses would be represented by values in the range of up to 1%. Acceptable values would range between 1% up to 2.5%. Ohmic losses above 2.5% would be non-acceptable.

- *Technical losses because of DC/AC inversion*

The conversion of direct current into grid compatible alternating current entails inevitable losses. The manufacturer's data of the inverters relating to the European standard efficiency regard typical European operating conditions. The temporal distribution of the performance quantity is evaluated here.

Best in class losses due to DC/AC inversion would be represented by values in the range of up to 1.8%. Acceptable values would range between 1.8% up to 3%. DC/AC inversion losses above 3% would be un-acceptable.

- *Technical losses because of transformation (transformer losses)*

Transformer losses depend simultaneously on several parameters. Basic technical parameters like ohmic and magnetic resistance can be taken into calculation. Depending on technology the losses are around 1-2%. For step-up transformers (MV/HV) this value is typically <1%.

Best in class losses due to voltage transformation would be represented by values in the range of up to 0.6%. Acceptable values would range between 0.6% up to 1.2%. Transformation losses above 1.2% would be un-acceptable.

- *Technical losses because of plant-availability*

The technical availability of a PV plant crucially determines the energy yield. Outages due to failure of fuses, disconnected strings or broken inverters are likely to occur and therefore must be considered in the expected energy yield.

Best in class technical availability losses would be represented by values in the range of up to 0.3%. Acceptable values would range between 0.3% up to 0.8%. Availability losses above 0.8% would be un-acceptable.

- *Technical losses because of weathering and degradation*

Changes in the energy yield because of weathering need to be considered in the expected long-term energy yield. As degradation of the modules is a continuous process, depending on time, performance will decrease with the time of operation. Performance guarantees of the manufacturer and different practical results diverge a lot. Former long-term study findings cannot be applied easily to modules produced with today's manufacturing processes and product features. But it is assumed that today's processes and technologies lead to a higher module quality. The consideration of an annual correction value for weathering / degradation is recommended for the overall result.

Best in class degradation losses would be represented by values in the range of up to 0.3%. Acceptable values would range between 0.3% up to 0.8%. Degradation losses above 0.8% would be un-acceptable.

Up to now, the final technical design has not yet been decided for both villages. We have made conservative assumptions by also using state of the art components that are availeble in the market. The loss diagrams for the two villages are given on the next page.

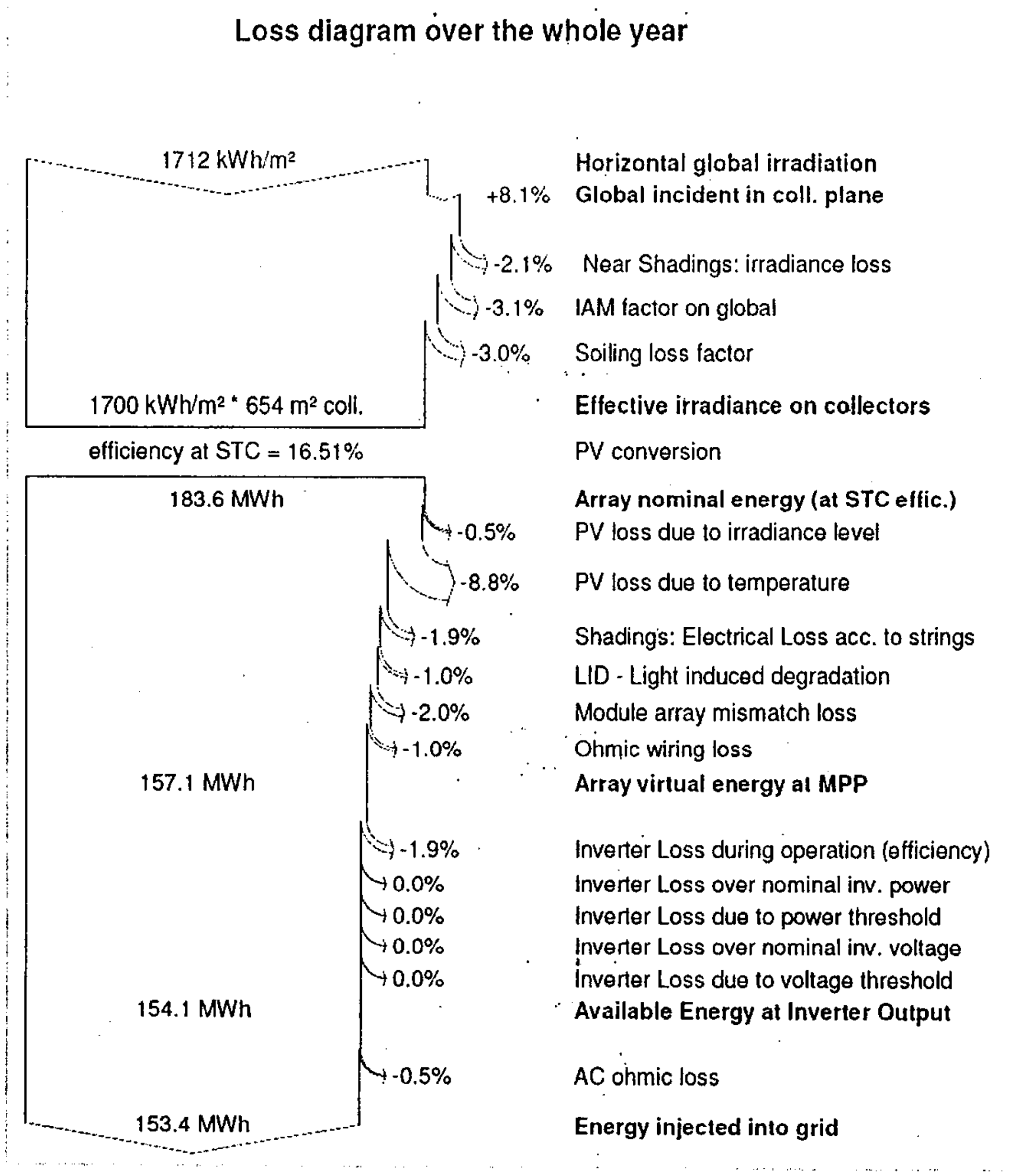

Figure 59: Loss diagram for 100 kW PV System at Chak 443.

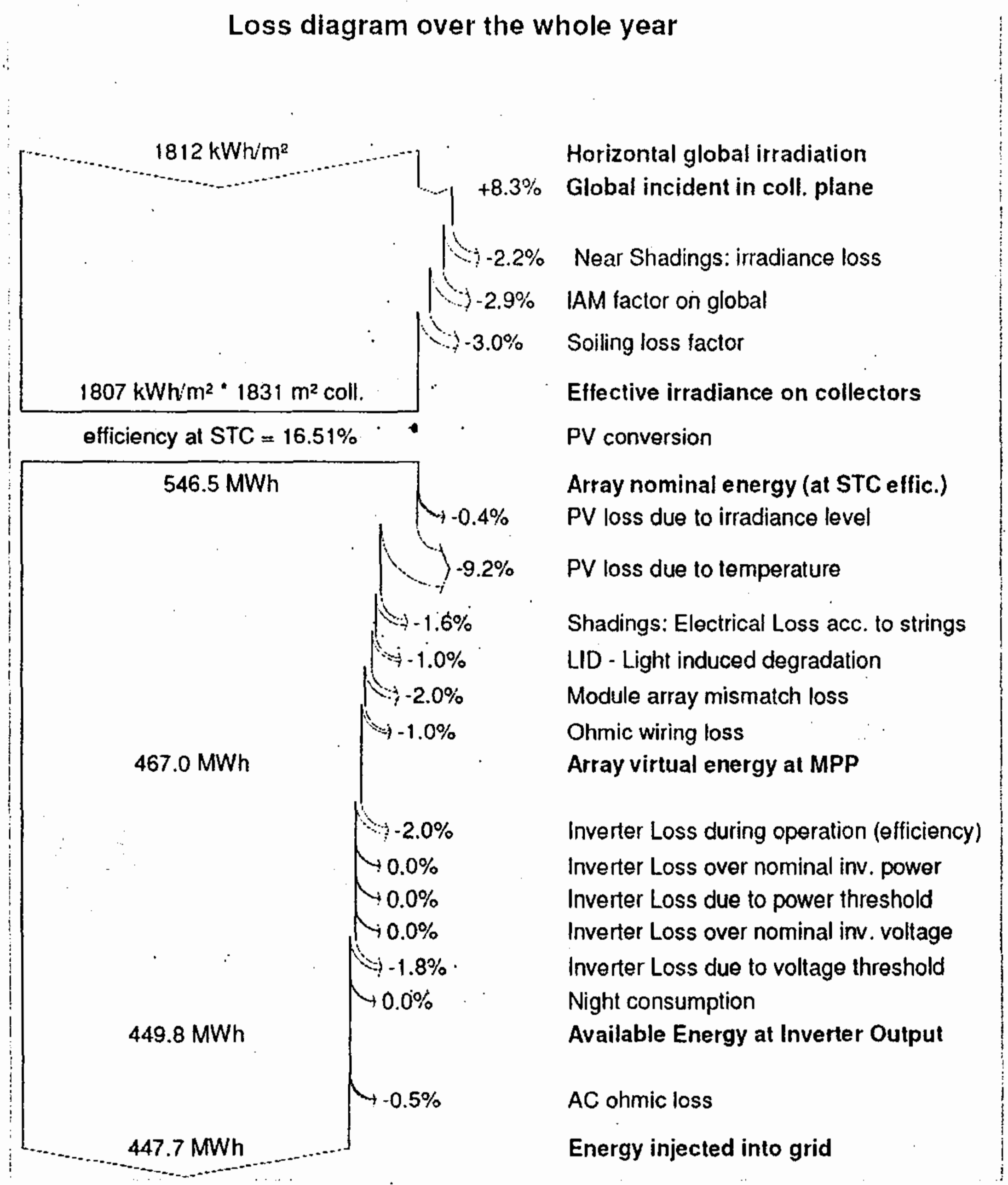

Figure 60: Loss diagram for 300 kW PV System at Chak 563.

C.6.1.6. Solar production and energy yield

Different pre-assessments have been calculated with the simulation software PVSyst.

PVSyst takes as an input the meteorological data as well as a given system design and a component selection. Then it simulates a whole operational year in through a whole year.

The options for technical design are fixed mounted at different tilt-angles. In our case, the fixed tilted was selected at 15°. The yield assessments show following annual outputs to the grid. The results are calculated for the point of interconnection with the MV grid and include transformer losses and cable losses to the point of interconnection to the MV Power line.

[illegible]	[illegible]	[illegible]
Irradiation in Module plane kWh/(m²a)	1700	1807
Performance Ratio (PR)	76.78	75.4
Specific output	1420	1480
Total Solar output (MWh/a)	153.4	447.7

Table 21: Summary of Simulation results

C.6.2. Biogas production and energy conversion

For biogas, the calculation of yield and losses is not as standardized as for solar PV power. Actual values of efficiency, losses of auxiliary consumption depend strongly on the operation of the plant as well as the conditions of substrate and the day-to-day weather. The following yield estimations are therefore of a less accurate nature than for the solar the plant.

Biogas plant on Site 1 will, according to the design, produce around 242,000 m³ of methane (CH_4) per year or 425,000 m³ of biogas. Biogas plant on Site 2 will produce around 113,000 m³ of methane per year for which, due to the lower methane content in the biogas, 205,000 m³ of biogas are produced. The following tables show the energy balance and conversion into electricity and heat in both plants by operating CHP units within an average of 8,000 h per year. Plant on Site 1 is using a German CHP fabricate with a higher efficiency than the simple generator for plant size 2. The tables give the average (not peak) operation. 5% of the generated methane is assumed to be losses due to maintenance and the possible incoherence between biogas production and conversion into electricity. Gas consumption for cooking purposes (see C.4.5.10) does not affect the gas yield, as the necessary gas will be produced through additional substrate.

Production of CH4	**241,684**	**m³/a**
Caloric Value CH4	9.968	kWh/m³
Losses	5.0%	
Energy Potential	2,288,647	kWh/a
Energy Potential Capacity	**286**	**kW**
Generation		
Energy potential	2,288,647	kWh/a
Caloric Capacity	286	kW
Electrical Capacity	100	kW
Electrical Efficiency	35%	
Thermal Efficiency	38%	
Thermal Capacity	109	kW
Overall capacity	286	kW
Full operation time	**8000**	**hours/a**
Electricity Generation	801,026	kWh/a
Heat Generation	869,686	kWh/a
Own Consumption Electricity	8%	
	64,082	kWh/a
Net Electricity Generation	**736,944**	**kWh/a**

Table 22: Biogas production and conversion for plant on Site 1

[illegible]		
Production of CH_4	**148,515**	**m^3/a**
Caloric Value CH4	9.968	kWh/m^3
Losses	5.0%	
Energy Potential	1,406,376	kWh/a
Energy Potential Capacity	**176**	**kW**
[illegible]		
Energy potential	1,406,376	kWh/a
Caloric Capacity	176	kW
Electrical Capacity	53	kW
Electrical Efficiency	**30%**	**-**
Thermal Efficiency	**0%**	**-**
Thermal Capacity	0	kW
Overall capacity	176	kW
Full operation time	**8000**	**hours/a**
Electricity Generation	421,913	kWh/a
Heat Generation	0	kWh/a
Own Consumption Electricity	**5%**	
	21,096	kWh/a
Net Electricity Generation	**400,817**	**kWh/a**

Table 23: Biogas production and conversion for plant on Site 2

C.7. System Sizing - Reasons for Deviations from PC1

According to the estimates and design as approved in the PC-1 document received in October 2016, the approximate technical layout had been chosen for the two pilot plants, based on a rough technical analysis at that time. In 2017, after approval of project and its budget as per PC-1, the first focus during pre-feasibility stage was on site assessments of the six proposed villages in order to select the two most suitable sites for this pilot project.

Now, at the stage of the Feasibility Study, after assessing the requirements and resources of the two pilot sites and the corresponding villages, a dedicated and optimized technical design can be developed for the two sites, according to the specific needs and resources of the villages based on current market prices for the proposed technology. As already mentioned above, the new design should match the requirements of the two villages and showcase different technical setups, while remaining within the approved budget and being cost-effective in terms of levelized cost of electricity.

C.7.1. Technical Description

The original technical description from the PC-1 document has been outlined in C.4.2 including the following system specifications:

Solar power plant size	200 kWp	300 kWp
Battery size	200 kWh	300 kWh
Biogas plant size	100 kW / 150 kW peak	20 kW / 50 kW peak

Table 24: System sizes of the power plants

Based on the findings from the villages, conceptual considerations and simulations, the following design has been proposed:

Solar power plant size	100 kWp	300 kWp
Battery size	100 kWh	200 kWh
Biogas plant size	100 kW / 200 kW peak	50 kW / 100 kW peak

Table 25: Proposed system sizing of the power plants

The new design is better suited to cover hours of load shedding in the two villages due to increased peak output power ratings of the two biogas plants; this change, however, has only slightly increased the costs of the biogas plants.

Higher costs in biogas technology due to the project being the first of its kind in Pakistan, which had not been considered in the PC-1, have been compensated by decreasing battery size and, in case of Site 1, the solar plant; both of these changes do not considerably affect the ability of the system to supply electricity during load shedding hours[16].

C.7.1.1. Comparison PC-1 and Optimized Design for Chak 443

The original proposal was based on the assumptions that due to longer load-shedding hours, more battery storage and solar PV capacity would be necessary. It was also assumed that most of the biogas equipment would be available locally or through import from neighboring countries. However, during detailed feasibility for Chak 443, it has been observed that the load-shedding hours are seldom longer than an hour. Similarly, the equipment available locally might not be suitable to serve as a prototype for subsequent rollout. Therefore, the sizing has been adjusted accordingly.

As this is a prototype design, where proper functionality, efficiency and endurance of the components and the whole system is crucial, the design and costing has been adjusted towards the utilization of more reliable, high-end European equipment in the optimized design proposal developed in this study. Furthermore, an increase in biogas peak output through additional generator capacity was found to be a better option compared to a high battery size as biogas is a cheaper storage medium and can be utilized flexibly by relatively cheap additional generator capacities.

By reducing battery storage and solar PV size at the same time, the overall CAPEX of Site 1 has been reduced in order to match the approved budget from PC-1 without compromising power availability.

Biogas Vol.	m^3/day	1,200	1200	
Battery	Usable kWh	200	100	
Solar power	kWp	200	100	
Biogas-Genset. Peak	kWp	150	200	
Storage Days	Days	2	2	
Payback Period	Years	8	7.7	-4%
kWh wasted	%	0	0.61%	-74%
Load not served	%	0	0.00%	-100%
CAPEX	PKR	120,950,000	104,050,000	-14%
Revenue @ 10 PKR/kWh	PKR/a	8,927,235	7,637,833	-14%
OPEX	PKR/a	7,310,000	7,010,000	-4%
LCOE, discounted	PKR/kWh	14	14.67223834	6%

[16] According to the latest information from the two sites (July 2017), load shedding is seldom longer than one hour in a row, so after one hour, the battery can be recharged by solar PV or grid.

kWh, el from biogas per day	kWh/d	2,100	2100	0%
kW, el from biogas average output	kW	88	87.5	0%
kW, el during 8,000h per year	kW	96	95.8125	0%

Table 26: PC1 and proposed design characteristics for Chak 443

C.7.1.2. Comparison PC-1 and optimized design for Chak 563

Similarly, the conditions prevailing at Chak 563 were simulated during feasibility stage. It has been found that with the PC-1 design for Chak 563, at 50% load-shedding situation (12 hours in 24 hours with a random pattern), the hours where the proposed power plant is not able to supply the energy demand of the connected consumers would still be about 5% of the whole year. That is why the flexible biogas peak output and battery storage were found to be inadequate to cater for the peak demand. Also, cow dung was found to be available in abundance during pre-feasibility site visits, so an increase in the biogas plant size can easily be implemented. An additional benefit of increased biogas capacity is that biogas can be supplied for cooking purposes to compensate for the decrease in availability of dung cake as fuel for cooking. To achieve this additional goal of the project, the biogas production needed to be increased.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Biogas Volume	m^3/day	240	600	
Battery	Usable kWh	300	200	
Solar power	kWp	300	300	
BioGen Peak	kWp	50	100	
Storage days	Days	2	2	
Payback Period	Years	6	7.1	21%
kWh wasted	%	0	4.16%	44%
Load not served	%	0	1.02%	-78%
CAPEX	PKR	80,910,000	94,850,000	17%
Revenue @ 10 PKR/kWh	PKR/a	5,316,259	7,300,313	37%
OPEX	PKR/a	3,060,000	5,700,000	86%
LCOE, discounted	PKR/kWh	13	12.91	0%
kWh, el from biogas per day	kWh/d	420	1050	150%
kW, el from biogas average output	kW	18	43.75	150%

kW, el during 8,000 h per year	kW	19	48	150%

Table 27: PC1 and proposed design characteristics for Chak 563

With the proposed design, the hours without electricity throughout the year can be brought down from 5% to 1% by increasing biogas plant size and peak output. The CAPEX of this plant is higher, but the overall budget of the project is still in line with the approved budget from the PC-1 as the cost for Site 1 was decreased.

C.7.1.3. Summary of technical optimization

As a conclusion, the proposed design for the two sites has been optimized in terms of power availability, utilization of available local resources by applying findings from the villages and energy simulations of the whole year for the two sites. This has necessitated the downsizing of battery and solar components to maintain the budget as per PC-1.

C.7.2. Financial Description

The systems, as originally proposed in PC1, do not meet the load requirements of the two villages. Hence, in order to remain within the budget and meet the local demand, adjustments have been proposed in the system sizes.

As per the new cost estimates of PC1 system sizes, the simulation results show a payback period of 8.08 and 5.88 years for Chak 443 and Chak 563 respectively. In comparison to PC1 system, the new optimized design for Chak 563 comes at a higher cost. Higher CAPEX cost for the system results in a higher payback period of 7.14 years. The revised system has been proposed to provide electricity to more villagers by reducing the "load not served" from 4.70% to 1.02%.

For Chak 443, solar PV system size was reduced to lower the cost so that the overall project cost may be within the limit set in PC1. However, biogas system size has been increased to meet the demand of the village. Overall, the system cost for Chak 443 is lower than the previously proposed cost in PC1. Hence, with the revised system size, the payback period has slightly improved. Also, the overall wastage of electricity has been reduced and 100% of the demand will be fulfilled with the revised system.

As mentioned above, the CAPEX for the biogas component of both the plants has been increased for higher reliability, the solar PV system has been reduced for Chak 443 only and the battery sizes have been reduced for both the systems in order to match the approved budget and to avoid any negative effect on the performance of the plant in supplying reliable electricity to the villages.

The following table gives an overview of the original and the proposed, optimized budget for the two plants and their components. As it can be seen, the CAPEX has increased as described above, while the overall budget can be maintained as the O&M costs will be covered through revenues from electricity sales of the project (for further details please check Annexure V).

Solar System (200 kW)	38,000,000	56,500,000	9,069,471	27,132,241
BioGas Production Facility (1200 m3)	53,900,000	19,907,500	80,486,641	44,989,018
Installation & Logistics	2,500,000	2,500,000	23,518,666	22,607,502
Total Cost	94,400,000	78,907,500	104,005,306	94,728,761
O&M Cost for 10 years		32,000,000	excluded, to be compensated through kWh sales	
Grid Integration Studies		2,000,000	121,804	121,804
EPC Cost without taxes		207,307,500	104,120,900	94,856,776
Total EPC Cost incl. 10 years of O&M	209,380,575		198,977,676	

Table 28: Comparison of Costs of PC1 Oct 2016 and Feasibility

C.7.3. Conclusion

Both the original and proposed designs have been juxtaposed for the Client to consider for the final decision. It has been shown that the newly proposed and optimized design has technical and financial benefits, while the original budget is maintained.

The consultants recommend the Client to agree to the changed system sizes which does not necessitate any budget change or PC1 revision. The proposed change does not affect total cumulative power from solar PV and biogas which stays at 500 kWp and the total budget is the same as initially approved in PC1 that is PKR 198,977,676. Thus, there is no net change in either system sizing or budget. If, however, the Client requires that individual system sizes remain the same and the internal split between solar PV and biogas systems as well as the storage size remain unchanged, then it would necessitate revision in the PC1, especially if the unserved load is to be reduced from 5% to 1% as per new market rates.

C.8. Financial and Economic Analysis

C.8.1. QOFE Simulation Tool

The QOFE simulation tool for Load and Supply optimization was developed within 8.2 since 2010. It is based on an hourly analysis for one year (8,760 hours). For every hour, input parameters are determined such as ambient temperature, solar irradiation, grid availability etc. Based on these parameters, secondary values are calculated such as net generation by PV system etc. An expert system then determines whether solar electricity can be fed into the grid or stored in the battery, and if battery is needed to supply the load. Finally, associated costs of all consumed electricity, i.e. grid electricity, are calculated as well as revenues from sold electricity.

In this way, a financial result for the whole year can be calculated, including other costs such as annual operation & maintenance costs for the Solar or Hybrid system. Variation of the input factors such as solar field size and battery size can be done and the effects on the financial result can be observed.

	Exchange rate	USD-PAK	105
PV System			
	PV kWp installed	kWp	100
	O+M	PKR/a	300,000
	Price / kW	PKR/kW	90,000
	Solar LCOE; 0 for Investment case	PKR/kWh	0
Battery + Control			
	Battery Usable at 90%	kWh	100
	Charge/Discharge	kW	80
	Battery Price, Li Ion	PKR/kWh	100,000
Biogas System			
	Gas production	m^3/day	1,200
	Gas Generator capacity	kW	200
	OPEX	PKR/a	6,710,000
	CAPEX	PKR	79,800,000
Grid Input			
	Grid Max capacity	kW	200
	Grid Price	PKR/kWh	14
	Max Load	kW	250
	Transformer, Disconnect, Control	PKR	5,250,000

Table 29: Simulation tool - technical input window – Village 1 Chak 443/GB

	Exchange rate	USD-PAK	105
PV System			
	PV kWp installed	kWp	300
	O+M	PKR/a	900,000
	Price / kW	PKR/kW	85,000
	Solar LCOE; 0 for Investment case	PKR/kWh	0
Battery			
	Battery Usable at 90%	kWh	200
	Charge/Discharge	kW	160
	Battery Price, Li Ion	PKR/kWh	100,000
Biogas System			
	Gas production	m^3/day	600
	Gas Generator capacity	kW	100
	OPEX	PKR/a	4,800,000
	CAPEX	PKR	44,100,000
Grid Input			
	Grid Max capacity	kW	200
	Grid Price	PKR/kWh	14
	Max Load	kW	250
	Transformer, Disconnect, Control	PKR	5,250,000

Table 30: Simulation tool - technical input window – Village 2 Chak 563/EB

The QOFE simulation tool depends on hourly data of load, solar radiation, and will also use biogas generation and battery. Hourly data provides a higher resolution of simulations to study different load conditions and the different variable associated by renewable energy sources.

Inputs which are necessary for complete simulation are:

- Hourly solar radiation data
- Hourly generated biogas
- Hourly load profile
- PV system and O&M price
- Biogas system and O&M price
- Grid Electricity price
- Diesel Generator Electricity price (as alternative scenario)

These technical inputs beside the price give a complete overview about the system configuration and its alternative using a diesel generator. The technical output which describes how much energy could be produced by each component is the direct input for the financial simulations.

The financial analysis gives a summary about the project feasibility and profitability, depending on the technical simulation as an input. The financial input parameters as shown in Table 29 and Table 30 can be changed, e.g.:

- Inflation rate
- Debt percentage
- Interest rate

The design and sizing for solar PV and biogas plants as well as battery storage has been assumed as described in C.4. Accordingly, it has been assumed that the load shedding will be 50% across the year.

Below graphs show the supply mix of the different energy sources for the two villages for a typical week in April. The two different concepts can clearly be seen in Tandlianwala, where the weight of production is being taken by the biogas, while the plant in Vehari depends more on solar PV and storage. Depending on the availability of cheap feedstock for biogas and the solar irradiation, one or the other solution is more economical. In Vehari, the much higher solar generation will be stored in the battery or exported to the grid.

In Tandlianwala, the system depends more on biogas and hence, the biogas design is of more complex nature. Not only cow dung, but also chicken manure, organic residues and silage can be processed. The gas generation is more efficient and the CAPEX for the system is also higher. Both cases have the option to use biogas for cooking. It is assumed that people will pay for the gas, either in cash or in the form of providing feedstock for the biogas.

The next two pictures give a snapshot of the simulation results for a week in April. It can clearly be seen the focus of Biogas in Tandlianwala, whereas in Vehari the system depends more on Solar and Storage.

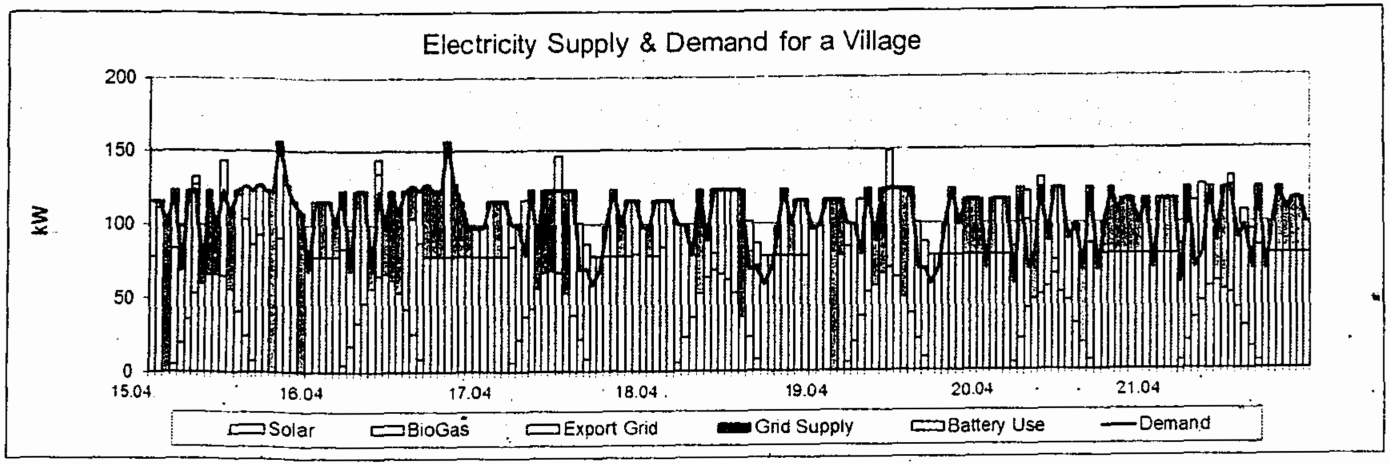

Figure 61: Simulation Results 50% Grid Net Metering April– Village 1 Chak 443/GB

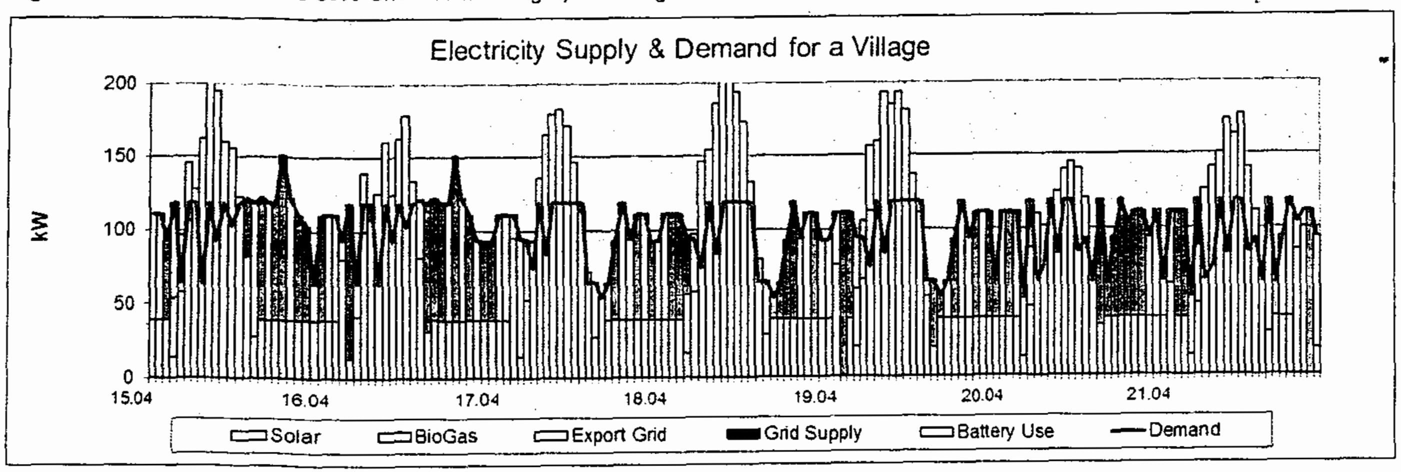

Figure 62: Simulation Results 50% Grid Net Metering April– Village 2 Chak 563/EB

C.8.2. Financial Model

The financial model provides a medium to translate technical aspects of the project into a financial investment case which helps facilitate the decision of execution of the project. The financial model is built on the basis of project assumptions and its validity depends on how realistic these assumptions are.

These assumptions, the input parameters, are uncertain until the time of a financial close or even until the end of project lifetime as far as irradiation and plant performance is concerned. Hence, the decision to build and finance the project has to be taken under some uncertainty. For analysis and contriving strategies to mitigate the uncertainties, sensitivity analysis is of key importance. This analysis has also been conducted as part of this financial model.

C.8.3. Input parameters

Main input parameters for the financial model are:

- Expected estimated annual specific electricity yield of the solar power plant given in MWh per year (based on site-specific solar irradiation),
- Expected estimated annual electricity yield of the biogas plant given in MWh per year (based on site-specific technology and feedstock),
- Investment costs or capital expenditure (CAPEX),
- Annual operational expenditures (OPEX),
- Economic assumptions in general (e.g. Inflation rates, exchange rates etc.) and
- Financing parameters.

C.8.4. Financial Projections

The financial model calculates the yearly revenues of the power plant based on the input parameters. Besides the annual revenue generation, defined decision criteria are calculated to allow for a precise evaluation of the project.

If we assume that the system is running on net metering as the easiest way to let the DISCO pay for the energy provided, the net revenues of this will cover the O&M costs and will also facilitate the purchase of biogas feedstock.

C.8.5. Output parameters

As a result, the financial model derives the following decisions parameters:

- **Net Present Value (NPV)** of the project is a measure for the discounted cash flow. The NPV is a profit based criterion which takes into account the profits of all future years discounted to present with a set discount factor. The discount factor shall be in line with risk of the project. A low risk project shall have a lower discount factor than a high risked project.
- **Return on Equity (ROI or IRR)** is a measure for capital efficiency. The ROI or IRR determines how much interest the invested equity is returning. However, it must be noted note that it is not a measure for the profitability.
- **Payback Period** is a measure of risk for the bound equity. The faster the equity is returned, lesser is the capital risk for the project.

C.8.6. Cost Summary of Model

The following table shows the basic installation of two systems cost including grid connection as provided by the client for fixed mounted systems of 100 and 300 kWp and 200 and 100 kWp Biogas Generator respectively. This cost breakup has been made based on our relevant market experience. The breakdown of the capital costs includes design and all EPC costs, for the project. Duties and taxes do not apply as this is a renewable energy project and components of such projects are exempted from any import duties. Transport costs are included within the different project components.

Further significant costs come from maintenance and repair of the biogas plant equipment; this is a factor that should not be neglected in order to achieve a high lifetime of the infrastructure.

[illegible]	[illegible]	[illegible]
Solar System (100 kWp / 300 kWp)	**9,063,307**	**27,132,241**
BioGas Production Facility (1200 m^3) (200 kW / 100 kW)	**80,431,939**	**44,989,018**
Civil Works	15,247,980	20,482,448
Planning and Engineering	10,049,805	3,712,444
Equipment and Components	49,935,979	15,673,515
Other	5,198,175	5,120,612
Grid Connection	2,887,875	3,200,382
Control + Battery	11,551,500	19,407,119
Total Cost	**103,934,621**	**94,728,761**
O&M Cost for 10 years		*Excluded*
Grid Integration Studies	115,515	128,015
EPC Cost	**104,050,000**	**94,850,000**

Table 31: EPC Cost Assumptions Chak 443/GB and 563/EB

The following table shows the expected annual operation and maintenance costs as well as expected revenues and profits. The operation and maintenance costs are relatively high;

however, this is a conservative estimate and it needs to be considered that this project is the first of its kind; it is reasonable to assume that these costs will decrease in the future. It is clear that a significant amount comes from the substrate (feedstock) for the biogas plant. Here, a total cow dung price of 330 PKR per ton has been assumed; this includes a safety margin for the case that cow dung needs to be bought at 180 PKR per ton. If the agreements with the villagers established during preliminary meetings can be held up, then the cow dung is provided for free and only the transportation cost of 150 PKR per ton applies.

[illegible]	[illegible]	[illegible]
Solar System O&M	300,000	900,000
BioGas System		
Feedstock:		
Cow dung	1,200,000	2,400,000
Silage	1,050,000	-
Chicken excrements	1,500,000	-
O&M Biogas:		
Maintenance & Repair: 2-3% of CAPEX	1,960,000	1,400,000
Control & Others	1,000,000	1,000,000

Table 32: O&M Cost Assumptions for the 2 years included in PC1/contract

C.8.7. Base Case Assumptions

For calculation of the financial decision parameters, the financial assumptions play an important role. Small scale photovoltaic power plants are not new for the entire world. However, this aspect doesn't apply in case of Pakistan, a country that has recently stepped into both small and large scale photovoltaic projects and where the concept of solar project financing is at infancy. The same holds even more for biogas technology. For these reasons, we recommend to take a conservative but realistic approach in respect to the financial assumptions.

The economic analysis compares the indigenous hybrid solution with its alternative for a 24/7 energy supply, a Grid/Generator case. In addition the LCOE of the solution is calculated and will also be compared with a 100% Grid case.

All financial assumptions are drawn from large-scale solar projects in the country. All income calculations or indexations from above document are taken into account in the financial model.

C.8.8. Plant Assumptions

Technology

The Base Case assumes the use of crystalline module PV technology on a fixed mounted structure for 100 and 300 kWp respectively.

For biogas, an energy-efficient and a cost-efficient model are planned, sizing 200 and 100 kWp respectively.

Annual Energy yield

The annual specific energy yield for solar power of the site-specific simulation run according to actual site coordinates is 1484 kWh/kWp/year kWh/kWp/year for 100kWp system and 1882 kWh/kWp/year for 300kWp system. For the base case, we have assumed these figures. The plant capacity factor is the quota of full load production of annual hours, i.e. 1,576 / 8,760.

For biogas plants, total yields of approximately 800 and 400 MWh per year are estimated respectively, at 8,000 operational hours per year (at 50% of peak power).

Annual degradation of module efficiency

The initial production values are conservative.

Start of operations

The start of operations is considered to be the date of grid connection.

System lifetime

An operation period of 25 years is assumed.

C.8.9. Revenue Assumptions

The financial analysis is based on USD currency (United States Dollar and exchange rate is set to 1 USD for PKR 105. This model is assuming a fixed exchange rate of 105 PKR/1 USD and does not assume any increases.

The revenue has been assumed based on a sales rate of 14 PKR per kWh. Currently for net metering in Pakistan, 12.5 PKR per kWh is the sales rate of electricity for most slabs as per NEPRA tariff; according to net metering regulations this would also be the purchase rate that applies. However, due to decreased losses in the remote grid, and due to the economic benefit of a continuous power supply in the villages, the actual value of electricity is estimated to be higher at 14 PKR per kWh and this value is assumed for the revenue calculation.

C.8.10. Financial Assumptions

Income tax

No income tax rate is applied to the electricity sale in case of net metering

Taxable depreciation

A balance sheet analysis has not been performed.

Interest on liquid funds

A balance sheet analysis has not been performed.

Tax on dividends

A tax analysis has not been performed.

Tax Exemptions and Other

Although the EPC contractor is fully liable to assess the relevant taxes applicable for the project, still being an alternate energy project, the EPC bidder is encouraged to seek guidance from the following organizations for exemptions on such projects: AEDB; EDB and FBR. In addition to the above, the following policies may be referred to:

http://energy.punjab.gov.pk/_pages/oppinPunjab.html

http://www.aedb.org/Documents/Policy/REpolicy.pdf

C.8.11. Cost Assumptions

Investment cost

The investment cost includes only the EPC remuneration. The overall estimated CAPEX amounts to PKR 198,00,000 for the Base Case assuming no import duties.

O&M for the first 2 Years

Based on our experience, we assumed PKR 12,555,631 for annual O&M in order to have conservative analysis. However, given that O&M cost will be compensated through sales of the electricity and Gas at the net metering level of 12.5 PKR/kWh. For this reason the model assumes zero value for any additional O&M budget.

Annual inflation rate

The annual inflation rate for Pakistan on 20 years was 8.24% on average. We assume an average between 5 - 8% over the operations period. A 6.5% inflation rate has been used for the financial evaluation.

C.8.12. Project Finance Assumptions

Equity ratio

The Project at hand is fully government-financed and therefore based on 100% equity. However, for scenario analysis, an equity ratio of 20% of the total investment has also been considered; this translates into an equity investment of PKR 39,795,725. With a share of 20% equity and 80% debt, the financing structure of the project can be compared to international project financing standards for similar project.

Total debt

A financing facility is assumed to cover 80% of the total investment for this hypothetical case. This translates into a total debt amount of PKR 159,120,000.

Nominal interest

A nominal interest rate of 3.5% is assumed as the cost of debt using an assumption of a soft loan for this hypothetical case.

Period of loan

Total debt tenure of 12 years from the start of operations of the Hybrid Plant is assumed.

Annuity payment

The debt and interest is assumed to be paid in a fixed annuity over the tenure.

Discount Rate

For the NPV calculation of the equity a discount rate of 10% is used.

Base Case Results

The economic analysis compares the indigenous hybrid solution with its alternative for 24/7 energy supply, a Grid/Generator case. In addition, the LCOE of the solution is calculated and will also be compared with a 100% Grid case. The only source of value generation is the electricity and gas produced by the solar and biogas power plant.

The electricity is evaluated with PKR 14.00 as an average price of electricity in Pakistan. The energy produced locally does not bear any transmission losses either. If we assume some 10% transmission losses at the end of the line, the price is equivalent to 12.50 PKR/kWh for any centrally provided power.

As per model, the project will break even in the seventh year as shown by its payback period for both plants, respectively. This means that the project will be able to recover the equity within the mentioned time span in the form of profits generated from the sale of electricity and from the cost saved on diesel. This is, however, a hypothetical calculation, as profits will not necessarily be accrued to the Employer as the investor, but partly be consumed by the operational company and possibly partly be fed into a local development fund (see C.9 for further details).

In the Base Case, the power plant generates electricity over 25 years. The base case assumes 100% equity, 50% load shedding and net metering. The IRR of 18.4% and 19.7% on the equity portion is generated by the model after taking into consideration project cost assumptions and financing parameters as described above. The base case shows the payback time of 7 years for both the villages, and the NPV of PKR 89,680,431 and PKR 94,798,596 for Chak 443/GB and Chak 563/EB villages respectively after discounting the savings (on diesel) and the revenues generated from net-metering at the rate of 10%.

Equity needed	PKR	104,050,000
Debt needed	PKR	0
IRR	%	18.4%
NPV at 10%	PKR	89,680,431
Payback Period	Years	7
Discount Factor	%	10%

Table 33: Financial Results Base Case for Chak 443/GB

Equity needed	PKR	94,850,000
Debt needed	PKR	0
IRR	%	19.7%
NPV at 10%	PKR	94,798,596
Payback Period	Years	7
Discount Factor	%	10%

Table 34: Financial Results Base Case for Chak 563/EB

C.8.13. Scenario Analysis

In order to understand the alternative possible outcomes, scenario analysis has been conducted whereby 80% debt has also been considered. The results are stated below.

Chak 443/GB	IRR	18.4%	37.6%
Chak 563/EB	IRR	19.7%	42.0%
Chak 443/GB	NPV	61,092,379	85,462,197
Chak 563/EB	NPV	92,969,600	112,574,699

Table 35: Sensitivity analysis for the project sites

Also, if the CAPEX and OPEX cost decrease by 5%, it will significantly affect the IRR and NPV of both systems as shown in the table below. However, an increase in the costs will result in a higher payback period and lower NPV value clearly showing that the costs are inversely correlated with the profits as reflected in the following scenarios. Likewise, an increased cost of biogas will significantly decrease the overall profits. However, the impact of increased biogas cost is more significant on Chak 563/EB village system as this system is more dependent on biogas for revenue generation.

CAPEX Decrease 5%	20.1%	97,105,414	6.94	18.6%	90,782,704	7.63
CAPEX and OPEX Decrease by 5%	20.5%	101,101,183	6.78	19.0%	95,696,799	7.43
CAPEX and OPEX Increase by 5%	18.9%	88,496,009	7.51	17.8%	83,664,064	8.04
Biogas Cost Decrease by 10%	20.5%	98,807,687	6.79	19.7%	96,934,977	7.10

Table 36: Scenario analysis for the project sites

C.8.14. Actual Revenue Case for the Project

The above analysis looks at the Project from a macroeconomic point of view. For the prototype projects the actual income of the operating company will not be 14 PKR per kWh, but the net metering tariff determined by NEPRA which is currently at 12.5 PKR per kWh, which equals the purchase rate of electricity by the DISCOs who will sell on the electricity to the real customers.

Furthermore, no difference is made between energy which is fed into the grid or supplied to the village during hours of load shedding; according to the agreements with the distribution companies to which they have consented in meetihgs with the consultant, that they would remunerate the plant operating company with the same net metering rate for both cases.

Based on the same O&M cost estimate as described above for the financial model, the financial situation as described in the following table, results. It can be seen that the operating company will have sufficient margin to operate the plant and earn some net profits. As the operation and maintenance costs already include assumed costs for administration and operation of the plant, the profit estimate can be assumed as net profit of the operating company. Assuming the case that the operational company will lease the plant from the government, the lease costs would have to be deducted from this annual profit. In any case, it can be assumed that it is financially viable for the operational company to operate the plant under planned conditions.

Total EPC Cost	104,050,000	94,850,000
Total EPC Cost both plants:		198,900,000
Annual O&M costs estimate year 1	7,010,000	5,700,000
Annual revenue estimate @ sales rate 12.5 PKR/kWh after storage losses	8,000,000	7,500,000
Annual O&M profit estimate @ sales rate 12.5 PKR/kWh	900,000	1,800,000

Table 37: Cost and revenue estimates

C.8.15. Lifecycle Cost of Energy (LCOE)

Different sizing and different configuration of the Solar Hybrid System affect the total cost and the levelized cost of energy. The levelized cost of energy is one of the key parameters for the sizing and optimization in order to compare the proposed solution with alternative solutions on the price of electricity.

The Levelized cost of electricity (LCOE) is a long term cost concept which accounts for all the resources and physical assets required to yield a stream of electricity output. The LCOE represents a "break-even" value that a power provider would need to charge in order to justify an investment in a particular energy project. The LCOE can also be regarded as the minimum cost at which electricity must be sold in order to break-even over the lifetime of the project.

For calculation of the LCOE, both expenditures (CAPEX and OPEX) and energy yields of future years are discounted with a specific discount rate (assumed here to be at inflation level of 6.5%). The discount rate influences the LCOE, more so for renewable energy applications where most the largest cost share falls in the first year (investment costs). The life time of the power plant is assumed to be 25 years.

The LCOE discounts Cost and Energy. Due to the discount factor of 6.5% the numbers are higher than present cost, e.g. the LCOE for a straight PKR 14.00 Grid supply for 25 years comes out at 28.69 PKR/kWh. As that number seems uncomfortable we also calculate a discounted LCOE which compare all number to the current year cost.

The following tables show the input data and results of the calculation of the levelized cost of electricity (LCOE) for the two power plants.

These LCOE may seem indifferent to grid supply, but it needs to be considered that the power plant has not been optimized for low electricity costs, but rather to supply the village reliably around the clock. This reliable power supply comes at a certain cost: for example, the battery system and a good part of the control system do not produce energy but only facilitate this independent power supply to the village. They and their corresponding costs could be completely omitted if the plant was only feeding into the grid as it is the case for commercial, large-scale solar power plants.

	Year	0	1	2	3	25
Indigenous System yield	kWh/a		[illegible]	[illegible]	[illegible]	[illegible]
Discounted Yield	kWh/a		[illegible]	[illegible]	[illegible]	[illegible]
Costs	PKR/a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Discounted costs	PKR/a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LCOE	PKR	[illegible]				
LCOE & LCOE disc.	PKR/kWh	[illegible]	[illegible]	Discounted LCOE		
Grid Load	kWh/a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Discounted Load	kWh/a		[illegible]	[illegible]	[illegible]	[illegible]
Energy costs	PKR/a		[illegible]	[illegible]	[illegible]	[illegible]
Discounted energy costs	PKR/a		[illegible]	3,062,097	[illegible]	[illegible]
LCOE	PKR	[illegible]				
LCOE & LCOE disc.	PKR/kWh	[illegible]	14.00	Discounted LCOE		
Hybrid Load	kWh/a		310,288	254,730	[illegible]	[illegible]
Hybrid Cost	PKR/a	[illegible]	10,062,097	10,062,097	10,062,097	10,062,097
Hybrid LCOE	PKR	[illegible]				
LCOE & LCOE disc.	PKR/kWh	30.07	14.67	Discounted LCOE		

Table 38: LCOE Chak 443/GB Indigenous System Yield

	Year	0	1	2	3	25
Indigenous System yield	kWh/a	750,397	750,397	750,397	750,397	750,397
Discounted Yield	kWh/a	0	704,598	661,594	621,215	155,436
Costs	PKR/a	[illegible]	6,070,500	[illegible]	6,885,313	[illegible]
Discounted costs	PKR/a	94,850,000	5,700,000	5,700,000	5,700,000	5,700,000
LCOE	PKR	237,350,000				
LCOE & LCOE disc.	PKR/kWh	23.93	12.65	Discounted LCOE		
Grid Load	kWh/a	177,435	177,435	177,435	177,435	177,435
Discounted Load	kWh/a	0	166,606	156,437	146,889	36,754
Energy costs	PKR/a		2,645,535	2,817,516	3,000,655	12,992,436
Discounted energy costs	PKR/a		2,484,039	2,484,039	2,484,039	2,484,039
LCOE	PKR	62,102,234				
LCOE & LCOE disc.	PKR/kWh	23.69	14.00	Discounted LCOE		
Hybrid Load	kWh/a		871,203	818,031	768,104	192,189
Hybrid Cost	PKR/a	94,850,000	8,184,039	8,184,089	8,184,089	8,184,089
Hybrid LCOE	PKR	[illegible]				
LCOE & LCOE disc.	PKR/kWh	26.46	12.91	Discounted LCOE		

Table 39: LCOE Chak 563/EB Indigenous System Yield

C.8.16. Cost comparison to diesel case

The solar production is cheaper than the biogas electricity production for both plants. For that reason, the combined costs for the plant at Site 2, where solar power has a higher share, are slightly lower. On the other hand, Chak 563 would still face electricity outage 1% of the time which is due to the limited battery storage. A dimensioning of the storage for 100% availability would be too costly.

	Year	0	1	2	3	25
Grid / Generator Case	kWh/a			[illegible]	[illegible]	
Discounted Load	kWh/a		[illegible]	[illegible]	[illegible]	[illegible]
Energy costs: Grid + Generatc	PKR/a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Discounted energy costs	PKR/a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LCOE: Sum of disc. Energy co	PKR	[illegible]				
LCOE & LCOE disc.	PKR/kWh		[illegible]			

Table 40: LCOE Chak 443/GB with Grid-Generator

	Year	0	1	2	3	25
Grid / Generator Case	kWh/a	[illegible]	[illegible]	927,832	927,832	927,832
Discounted Load	kWh/a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Energy costs: Grid + Generator	PKR/a	[illegible]	[illegible]	24,170,050	25,719,284	197,791,9[illegible]
Discounted energy costs	PKR/a	[illegible]	[illegible]	21,292,116	21,292,116	21,292,116
LCOE: Sum of disc. Energy cost	PKR	537,392,903				
LCOE & LCOE disc.	PKR/kWh	47.44	23.16	Disc. LCOE		

Table 41: LCOE Chak 563/EB with Grid-Generator

If the same 24/7 electricity supply was to be achieved with grid and a local generator set for the hours of load-shedding, the discounted LCOE of that solution would be some 23.29 and 23.16 PKR/kWh for the two systems respectively.

The simulation results show that the overall costs of the proposed hybrid system prove to be feasible compared to an alternate case of installing diesel generators to supply the required energy. It also assumes that the cost will increase annually by 6.5% (inflation rate).

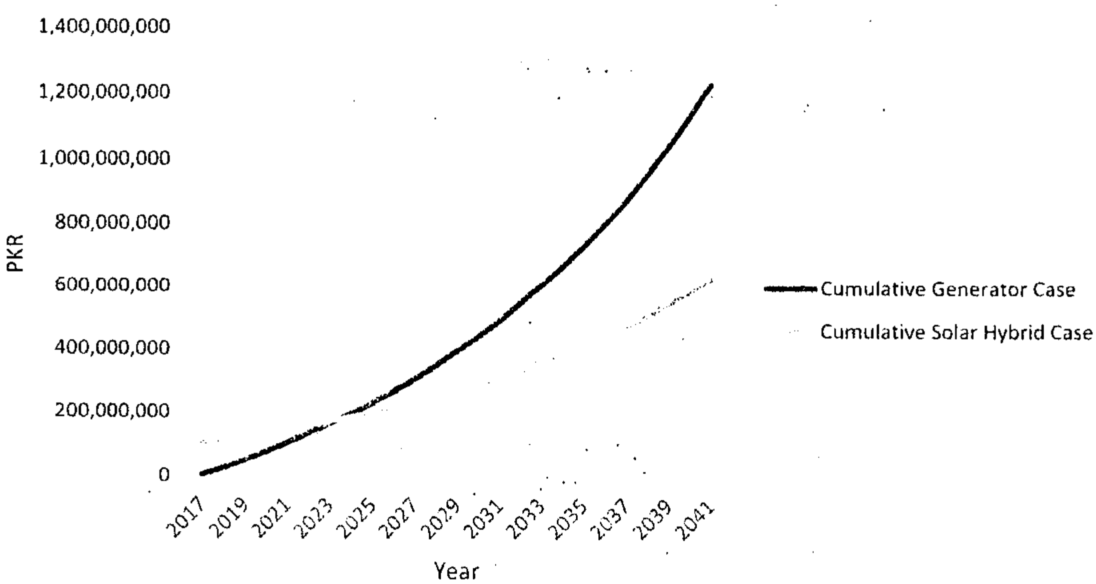

Figure 63: A comparison between the two different cases is summarized in the following table for 25 year for Chak 443/GB

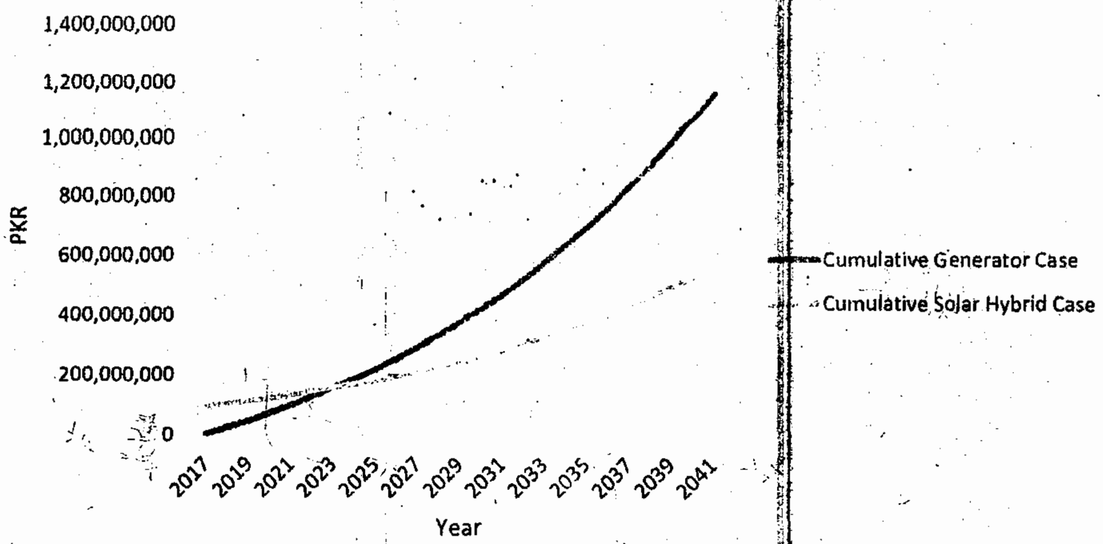

Figure 64: A comparison between the two different cases is summarized in the following table for 25 years for Chak 563/ EB

C.8.17. Uncertainty of Program Cost and implementation time

The expected cost for the two systems amounts to PKR 198,978,626 including taxes. The expected uncertainty (standard deviation) of the cost estimation is below 5%. The consultant proposes a contingency of 4% to cover for the uncertainty mainly on biogas and grid integration part.

Solar modules, also high-quality modules, are a commodity and available in large quantity. The installation time and logistical cost can be estimated quite accurately. Especially with the conformation of the site surveys the contractors can plan without high levels of uncertainty.

The profit expectation of the contractors we assume with 15%.

C.8.18. Cost scenario for future rollout

The following table shows the overview over cost scenario for the future rollout. If the same plants are being built again, considerable savings can be assumed for the costs due to cost optimization by the EPC contractor, design optimization based on learning outcomes from the first plants, as well as a higher share of local sourcing of the components.

[illegible]	[illegible]	[illegible]
Solar System	7,000,000	21,000,000
Biogas Production Facility	49,515,300	23,470,000
Grid Connection	2,500,000	2,500,000
Control + Battery	8,400,000	12,880,000
Total Cost	67,415,300	59,850,000
Grid Integration Studies	100,000	100,000
EPC Cost without taxes	67,515,300	59,950,000
Design etc	3,375,765	2,997,500
EPC Margin	10,802,448	9,592,000
PRA / Sales Tax - 1%	816,935	725,395
Duties & Taxes	0	0
Total EPC Cost	82,510,448	73,264,895
Total EPC Cost both plants:		[illegible]

Table 42: Rollout costs for the project

Overall, saving of about 20% in capital costs is assumed to be very realistic. As savings will also occur in the annual O&M costs, it is realistic to assume that the reduction in costs will be reflected in the LCOE accordingly as shown in the table below:

Village 1	14.67	12.37
Village 2	12.91	10.86

Table 43: Discounted LCOE for rollout stage

Overall decrease in the EPC and O&M cost will result in a lower LCOE whereby the LCOE for indigenous resource energy production in the rollout stage results to be 12.4 and 10.9 for the two plants respectively (20% lower than the original LCOE). Again, it should be stated that these power plants have not been optimized for low electricity costs, but rather to supply the village reliably around the clock; this reliable power supply naturally leads to LCOE higher than those of pure grid feed-in renewable energy plants.

However, the LCOE in rollout case is below the grid price of electricity at the end of line and can therefore be made a feasible investment for IPPs through adequate legislation.

With indigenous power supply, about 60% of the lifecycle energy cost comes with a socio-economic advantage in terms of salaries for local community and usage of local feedstock. On the other hand, in the grid case where fuel mix is predominantly fossil fuels, over 95% of the cost would be needed for imported fuel – assuming peak energy been supplied by imported gas, oil or coal.

C.8.19. Conclusions

The proposed Project is not an investment case by the Government as the Employer; it is rather a showcase project for decentralized electricity generation based on indigenous resources. However, a financial analysis has been carried out for indicated purposes, which shows a payback period of about 7 years for an assumed sales rate of 14 PKR/kWh.

Given that the investment cost is borne by the Government, the operation of this pilot plant can easily be financed through the revenues from electricity sales at the net metering rate of 12.5 PKR/kWh, leaving a profit margin for the operational company and a margin for an annual lease amount for the Government as the owner of the asset.

The LCOEs of the plant are higher than for other renewable power plants, as the goal of providing a 24-7 power supply to the villages requires battery storage and the more cost-intensive biogas technology. Village 1 has LCOE of 14.7PKR/kWh and village 2 has LCOE of 12.4 PKR/kWh. However, they are lower than that for a diesel generator scenario.

For future plants of the same kind, considerable cost savings can be assumed, down to the level where the LCOEs of generated electricity come down to around 11-12.5 PKR per kWh.

In addition, the indigenous power supply has about 75% local cost which stays in country and is income for other people of Pakistan. The Grid case has approximately 5% of local cost, most of which covers imported fuel and has no impact on local employment and income generation.

C.9. Operating company

In terms of the operating company, there are two different options that can be thought of:

1. The Energy Department as the owner and employer of the project can set up a government owned company that owns and operates the plant. Any generated revenue can be used for a local fund for infrastructure improvement in the villages, or be fed back to the government.
2. The Energy Department can own the plant and lease it out to a private company that operates it, takes care of the operation and maintenance and makes revenues through the sales of electricity to the distribution company.

The second option has the big advantage that the government does not need to establish an own company. It can still earn revenues via the lease rate. The lease arrangement should include clauses that ensure the proper operation of the plant by the company.

The operating company could either be a special purpose vehicle (SPV) owned by a private company, e.g. the same EPC contractor that takes care of the O&M for the first two years, or it could be owned by the village community, e.g. through an association with a cooperative housing society as registered with the Social Welfare Department and Registrar Cooperative Societies, Govt. of the Punjab. In the latter case, however, it would need to be ensured that the operation and maintenance is still be done by a professional company which would be hired by the village community association.

C.9.1. Transactional model

In terms of the transactional setup of the generated electricity, there are two directly available options:

1) IPP (Independent Power Producer) Model

Within the IPP model, the plant operator enters into an IPP contract with the respective DISCO. The IPP model means that the power will be sold to the DISCO directly at a fixed rate. In case of the island operation mode, the consumers in the village are supplied by the IPP. However, the power will still be billed by the DISCOs according the individual meter reading, as the same existing distribution system is used, and the IPP is compensated by the DISCO through the agreed arrangement.

The only disadvantage of this approach is that it is necessary to apply to the national power authority NEPRA for a generation license, which comes with certain procedures and constraints and a lengthy timeline.

The net metering scheme is not utilized in this case. In order to apply for the generation license, the standard procedure will probably require that an SPV be established. This company will apply for the generation license.

2) Net Metering Model

In this model, the power plant would export to the grid via the net metering scheme. This normally requires that the part of the distribution grid which the plant feeds into and which has a sanctioned load in the range of the output of the power plant will appear to the local DISCO as one consumer. The DISCO will bill the consumer through a bulk meter set up for the community as a cooperative society or similar entity. However, both FESCO and MEP-CO have indicated in preliminary meetings with the consultant that they would be ready to grant a net metering connection and waive the sanctioned load condition for this specific case.

The benefit of this approach is that the project can simply apply for net metering and does not have to approach NEPRA for the generation license.

In any case, the details of the technical setup also need to be discussed and confirmed with the applicable distribution company or grid operator as described above in chapter C.7.

C.9.2. Conclusion

As for the operation, the easier option is the first one where the Energy Department leases out the plant to an operating company. Whether a community association would be capable and be willing to take over the plant needs to be seen. However, this handing over could also be managed later after a professional company has run the plant for some years.

In terms of electricity connection arrangements, the net metering approach is by far more suitable and easy to handle for this project as long as the DISCOs are ready to cooperate, especially as the timeline of the project is rather ambitious and an IPP approach would bring more delays and uncertainties.

C.10. Preliminary Risk

C.10.1. Land ownership aspects of power plant site

Generally, the land owners from the villagers were found to be either middle-class or low income households, so a donation or a 20-year free lease agreement for the project was found to be unlikely. It was therefore decided to use the available government-owned land nearby the villages which had been found to be sufficient in size.

A letter for reservation of land on behalf of energy department was sent to Deputy Commissioners of each of the six villages during the pre-feasibility stage. The response from Vehari was that two acre of state land in Khasra No. 9/36, measuring 15 km, 08-M (Banjar Qadeem), Chak No. 563 have been reserved for the project. The letter received as a response is attached in C.16.

Similarly, for the other site at Chak 443, revenue papers confirming the availability of state land are attached in C.16. Moreover, the case for allotment of land in favour of the Energy Department for this project has also been initiated by the concerned Assistant Commissioner through Deputy Commissioner Faisalabad. The copy of case file is also attached in the C.16. The Memorandum of Understanding is also available in which the village community has agreed to accept the terms and conditions for their support during the installation of the plant. The Union Council of Chak 443 has issued a No Objection Certificate (NOC) for installing the project on Acre No. 11 and 19, Square No. 30 and allowing this land to be used for the site. The land allotment is under process with the revenue collection officer, assistant commissioner and once the process is complete, the relevant letters will be shared with the Employer.

The land ownership will be discussed in conjunction with transaction model with the Employer for final decision.

C.11. Social and Environmental Assessment

The baseline initial social and environmental assessment for each site is summarized here. The existing information to establish a database for the IEE of the proposed project was collected from different government departments, review of previous studies and through the site visits carried out in the project area. To comprehend the existing environmental conditions, a site survey was conducted and salient observations were noted. The pertinent data were also collected from the Census Report of Vehari and Faisalabad District. The social assessment of the proposed areas was conducted through consultation with the community. Area residents were interviewed to get their opinions and views regarding the construction of the proposed project.

Initial Environmental Examination (IEE) Report, which has been outsourced to a professional qualified company, will be got approved from the Environmental Protection Agency (EPA), Punjab as per TORs and presented as a separate deliverable. The process of IEE approval from EPA shall be got expedited with assistance from the Client.

C.11.1. Chak 563/EB

Vehari District is located between 29°36′ N 71°44′ E and 30°22′ N 72°53′ E and borders with Bahawalnagar and Bahawalpur on the southern side, with Pakpattan on the eastern, with Khanewal and Lodhran on western and with Sahiwal and Khanewal on northern side. The total area of the district is 4,364 square kilometres (1,685 sq mi). It is about 93 kilometres (58 mi) in length and approximately 47 kilometres (29 mi) in breadth and it is sloping gently from North-East to South-West. The coordinates of the proposed project site are 30° 04′ N and 72° 30′ E.

Geologically, the land is made of sedimentary rocks of quaternary types. The soils of the district are quite fertile. This fertility is reflected in the vast agricultural lands that dominate the scenes in the district. The soils lying in the belt that borders River Sutlej are those which are found in the active or young flood plains. The soils in the rest of the district are those that are found in the older flood plains.

Topography of Vehari is flat. In terms of land use, much of the district is composed of arable lands dotted with human settlements. The district is covered with a vast network of canals. Two main canals, Mailsi and Pakpattan with their networks irrigate the district.

Vehari is a plain with a minor slope of its general area towards North South. It lies between Sukh Bias; non-perennial Nala and River Sutlej. The shallow sub soil water of Vehari is brackish and unfit for human consumption. However, the water at deeper depth is of good quality. Present source of water supply system is with deep tube wells installed at depth of 400 ft. Water table is at 60-65 feet.

Majority of the population is associated with agriculture. The main crops which are being cultivated in the area are wheat, cotton and sugarcane. These crops are cultivated and harvested in their respective seasons and after harvesting, products are sold to market to earn profit. Common domestic livestock is found in area, including buffaloes, goats, sheep and cows.

The village population is in favor of the project and are also willing to provide animal dung, crop residues and other waste i.e. poultry excrements for the biogas plant.

C.11.2. Chak 443/GB

Samundari is an administrative subdivision, tehsil, of Faisalabad District in Punjab province of Pakistan. It spreads over an area of 898.42 km2 at an altitude of 168 meters (429 ft). Its geographical coordinates are 31° 4' 0" N, 72° 58' 0" E. The coordinates of the proposed project site are 31° 01' 23" N and 73° 00' 50"E.

The district of Faisalabad is part of the alluvial plains between the Himalayan foothills and the central core of the Indian subcontinent. The soil consists of young stratified silt loam or very fine sandy loam which makes the subsoil weak in structure.

In terms of use of land, much of the district is composed of cultivated lands with human settlements. The district is covered with a vast network of canals. The lands of the Tehsil Samundri are irrigated by Gugera Branch Canal and Burala Branch Canal. Land of Faisalabad District is used for both agricultural and industrial purposes.

Sufficient quantity of ground water is available in district but the shallow ground water quality is not drinkable. The groundwater is badly affected due to haphazard construction of different industries which discharge their untreated polluted effluent into open fields around them. Deeper depth ground water is of good quality and suitable for drinking.

The ecological environment of an area is generally considered sensitive to large-scale developments. Disturbances and imbalances in the ecological environment can adversely affect the biodiversity features of an area.

Majority of the population is associated with agriculture. The main crops which are being cultivated in the area are wheat, rice, maize and sugarcane. Livestock in this area includes buffaloes, goats, sheep and cows.

The population supports the project and is willing to contribute indigenous resources for the biogas plant.

C.12. Construction Schedule

Site Mobilization-Demarcation	1-Oct-17	4-Oct-17	3
Procurement and Import of Equipment	1-Oct-17	30-Nov-17	60
Procurement of Local Supplies	1-Oct-17	15-Oct-17	14
Civil Mobilization for Foundation	16-Oct-17	23-Oct-17	7
Mounting of Structure	24-Oct-17	23-Nov-17	30
Electrical Installation	24-Nov-17	1-Dec-17	7
Electronics Installation	1-Dec-17	8-Dec-17	7
Commissioning Completion	9-Dec-17	19-Dec-17	10
Implementation design (civil works)	1-Oct-17	30-Nov-17	60
Operation concept (automation, plan) etc.	1-Dec-17	1-Mar-18	90
Purchase and Import of equipment and components	1-Oct-17	30-Dec-17	90
Purchase and Import of CHP	1-Oct-17	30-Dec-17	90
Civil works (ground preparation, foundations, tanks, buildings, infrastructure etc.)	1-Oct-17	30-Dec-17	90
Piping (substrate, gas and heat pipelines)	1-Dec-17	30-Jan-18	60
Installation of equipment and technical components: pumps, agitators, filters, gas storage, measuring equipment, flare, etc.	1-Jan-18	1-Apr-18	90
Installation of CHP	1-Mar-18	30-Apr-18	60
Grid connection	31-Mar-18	30-Apr-18	30
Installation and commissioning of automation	30-Dec-17	30-Mar-18	90
Commissioning and test phase	1-Mar-18	30-Apr-18	60
Site supervision	1-Nov-17	30-Apr-18	180

Project Task Information	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18	Week 19	Week 20	Week 21	Week 22	Week 23	Week 24	Week 25	Week 26	Week 27	Week 28	Week 29	Week 30	Week 31	Week 32
SOLAR PV SYSTEM																																
Site Mobilization-Demarcation																																
Procurement and Import of Equipment																																
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Civil Mobilization for Foundation																																
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Electronics Installation																																
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BIOGAS SYSTEM																																
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Operation concept (automation, plan) etc.																																
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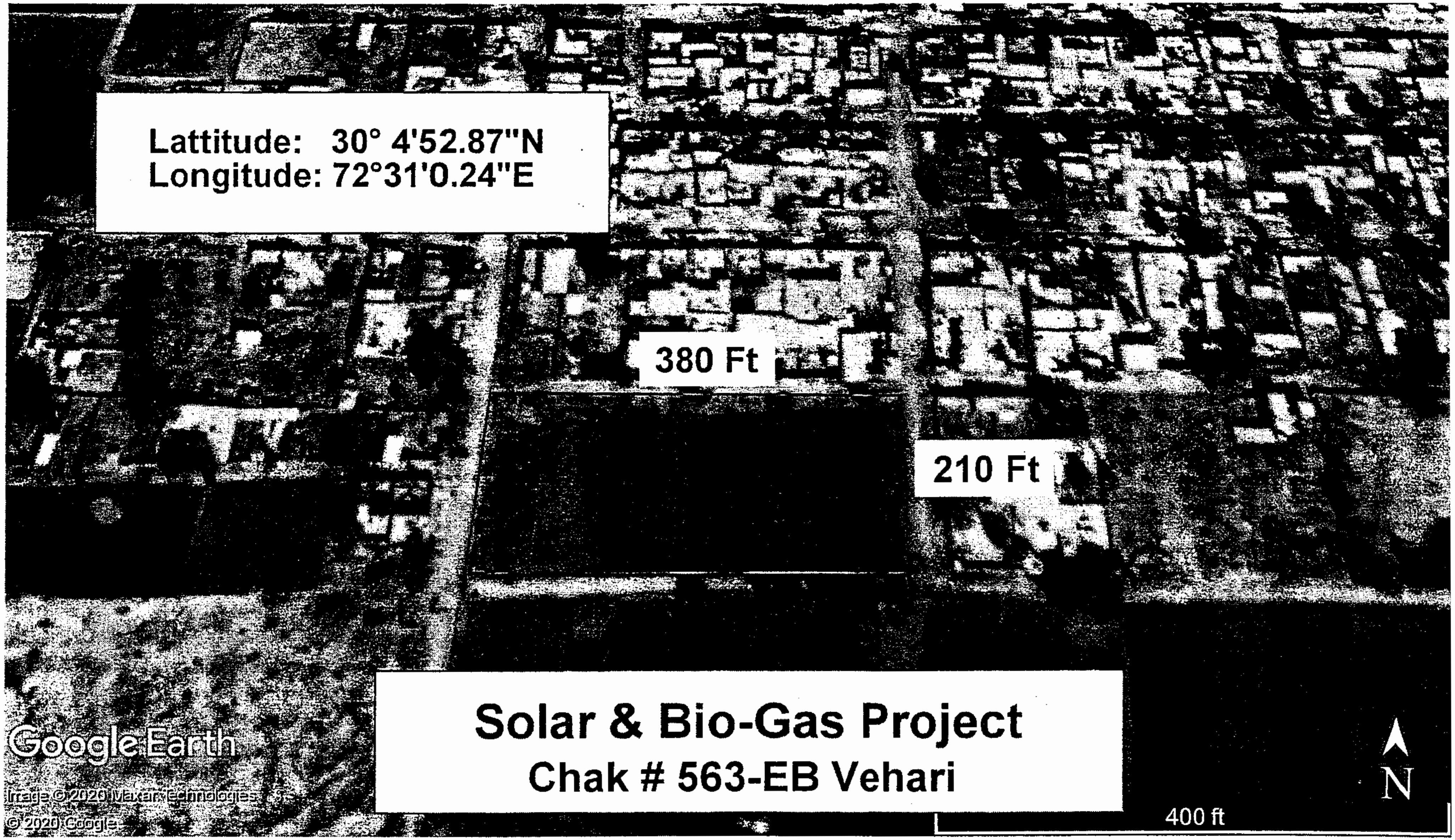
Installation of CHP																																
Grid connection																																
Installation and commissioning of automation																																
Commissioning and test phase																																
Site supervision																																

C.13. Technical Summary

The detailed dimensioning has been made according to the site conditions and budgetary framework. The technical performance for the two sites according to simulations has been shown. The following table summarizes the design as it has been derived within this study.

	Solar	
Power output (peak)	100 kWp	300 kWp
Annual electricity yield (for first year)	153.4 MWh	447.7 MWh
Mounting Structure	Fixed tilt 15°	Fixed tilt 15°
Configuration of Axis	South	South
Inverters	String-type	String-type
Type of Modules	Poly crystalline	Poly crystalline
Performance Ratio	76.78%	75.40%
	Biogas	
Technical setup	Efficiency optimized	Cost optimized
Digesters	One (1,500 m³, round with flexible top)	Five (400 m³ each, underground)
Maximum gas storage capacity	2,500 m³	Within digesters
Power unit	CHP (100 kW); generator set for peak power (100 kW)	Generator set (100 kW)
CHP, electrical efficiency	35%	N/A
Generator set, electrical efficiency	30%	30%
Gas efficiency	90 m³ / t of cow dung	40 m³ / t of cow dung
Electric output	100 kW average (200 kWp)	50 kW average (100 kWp)
Annual net electricity yield (for first year)	737 MWh	401 MWh
Batteries		
Total capacity	100 kWh	200 kWh
Maximum output	100 kW	200 kW
Type	Lithium-ion	Lithium-ion
Lifetime cycle number	>2500	>2500
	Control, data logging & grid connection	
Grid connection / disconnection for islanding mode	Automatic	Automatic
Logging interval of all parameters	15 min	15 min
Control protocol between components	mod-Bus or equivalent	mod-Bus or equivalent
	Total output	
Reliable output capacity	200 kW	200 kW
Annual yield (biogas + solar)	890 MWh	849 MWh
Annual estimated availability	95%	95%

Table 44: Technical summary for the two sites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Longitude: 72°31'0.24"E
380 Ft
210 Ft
Solar & Bio-Gas Project
Chak # 563-EB Vehari
Google Earth
Image © 2020 Maxar Technologies
© 2020 Google
N
400 ft

[redacted] [redacted] [redacted]

Dynamic Green (Pvt.) Limited

Detailed Bill of Quantity

Component	Brand / Make	Model
Solar System		
Modules (300 KWp) inclusive both sites	HT SAAE / China or Qcell / China or Trina / China (or any other equivalent Top Tier brand as per Bloomberg recent reports) as per ready availability at the time of supply	330 Wp above per panel (Polycrystalline)
Inverters (Grid Interactive Hybrid Inverters)	Baaykee 1. 300 KVA	384 Vdc TYN Grid Interactive Series
Structure (solar panels mounting)	Galvanized Steel (equivalent of no of panels)	As per specs (DGL Design)
BOS (Balance of System for both sites)	DC & AC Cables, Data Cable, DC & AC breakers, PVC pipes, 400 VA Transformer Isolation Switches, DB's, String Combiners, Connectors, Bolts and Consumables as per design	Fast cable , rest are miscellaneous as per specs (DGL Design)
Battery System		
Battery cells (total 345 KWH, 48- dc Volt bank inclusive both sites)	Sacred Sun / China or Backey / China	Smart Power 48100/ As per specs
Inverters	NA-Not needed with grid interactive hybrid inverters	
Battery Management System (built in inverters)	NA-part of the inverters to manage the Li Ion batteries	NA
Biogas System		
Civil Works (Each item on both sites)	Digester Tank x1	As per specs (DGL Design)
	Reception Tank x 1	As per specs (DGL Design)
	Feed Tank x1	As per specs (DGL Design)
	Substrate Storage Platforms x1	As per specs (DGL Design)
	Slurry Pound x 1	As per specs (DGL Design)
	Generator Room x 1	As per specs (DGL Design)
	Slurry Channel x 1	As per specs (DGL Design)
	Bore for water motor x 1	As per specs (DGL Design)
	Water Storage Tank x 1	As per specs (DGL Design)
Planning and Engineering		
Equipment and Components		
	Agitator x 1	As per specs (DGL Design)

[redacted] [redacted] [redacted]

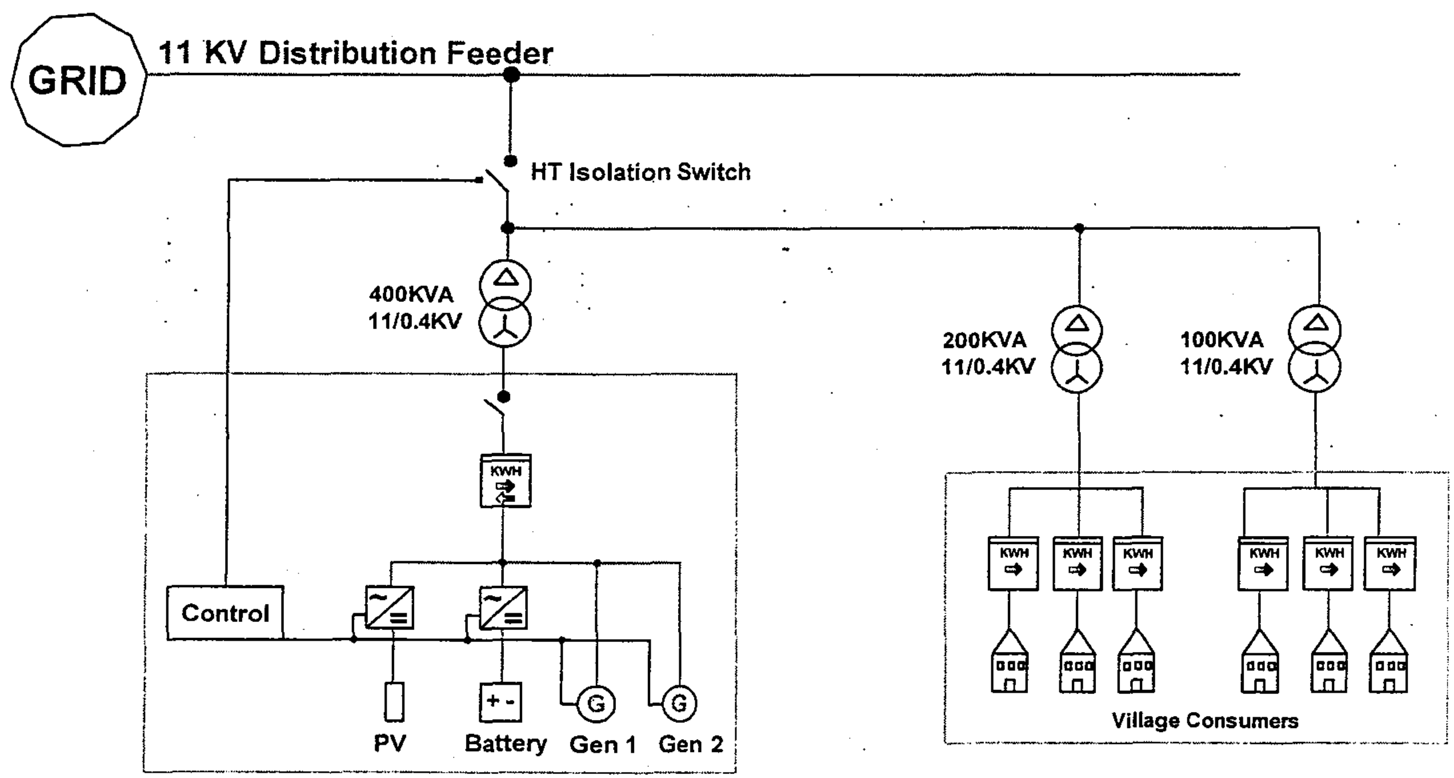
	Biogas Generators (125 KVA), 2 No	Kohler
	Grid Synchronizers, 2 No	As per specs (DGL Design)
	CHP (Heat Exchangers) 1 No	As per specs (DGL Design)
	Gas Filters (system), 1 No	As per specs (DGL Design)
	Membrane, 1 No	As per specs (DGL Design)
	Mechanical (piping, valves) for both sites	As per specs (DGL Design)
	Pumps, 2 No	As per specs (DGL Design)
	Gas Storage Balloon, 1 No	As per specs (DGL Design)
	Slurry Separator, 1 No	As per specs (DGL Design)
	Biogas flare Torch, 1 No	As per specs (DGL Design)
	Control Automation & Bio Gas Analyzer (1 No)	As per specs (DGL Design)
	Water motor	As per specs (DGL Design)

Available Substrates	**Plant Site 2 (Chak No. 563/EB)**
Cattle dung (12-40 % DM)	8-20 t/d FM
Chicken manure (55-65% DM)	0 t/d FM
Corn silage (30-35% DM)	0 t/d FM
Recirculate/Fresh water	l/d, t.b.d. by EPC contractor
Available Organic Matter of Substrates (t/d)	
Cow Dung	2.55 t oDM/d
Chicken manure	0 t/d
Corn silage	0 t/d
Recirculate/Fresh water	l/d, t.b.d. by EPC contractor
Digestion Rate and Biogas Production	
Min. Degree of decomposition of organic matter during digestion process	65%
Min. Biogas yield	768 Nm^3/d
Min. CH_4- content of biogas	55 %
Min. CH_4 yield	422 Nm^3/d
Max. H_2S content after desulfurization	100 ppm
Base Load Generator	
Electr. power output and efficiency	50 kW (30%)
Thermal power output and efficiency	-
Peak Load Generator	
Electr. power output and efficiency	50 kW (30%)
Total installed electr. capacity	100 kW (30%)
Max. self- consumption of electricity	10% of electricity generation
Total Biogas Storage Capacity	1,000 m^3

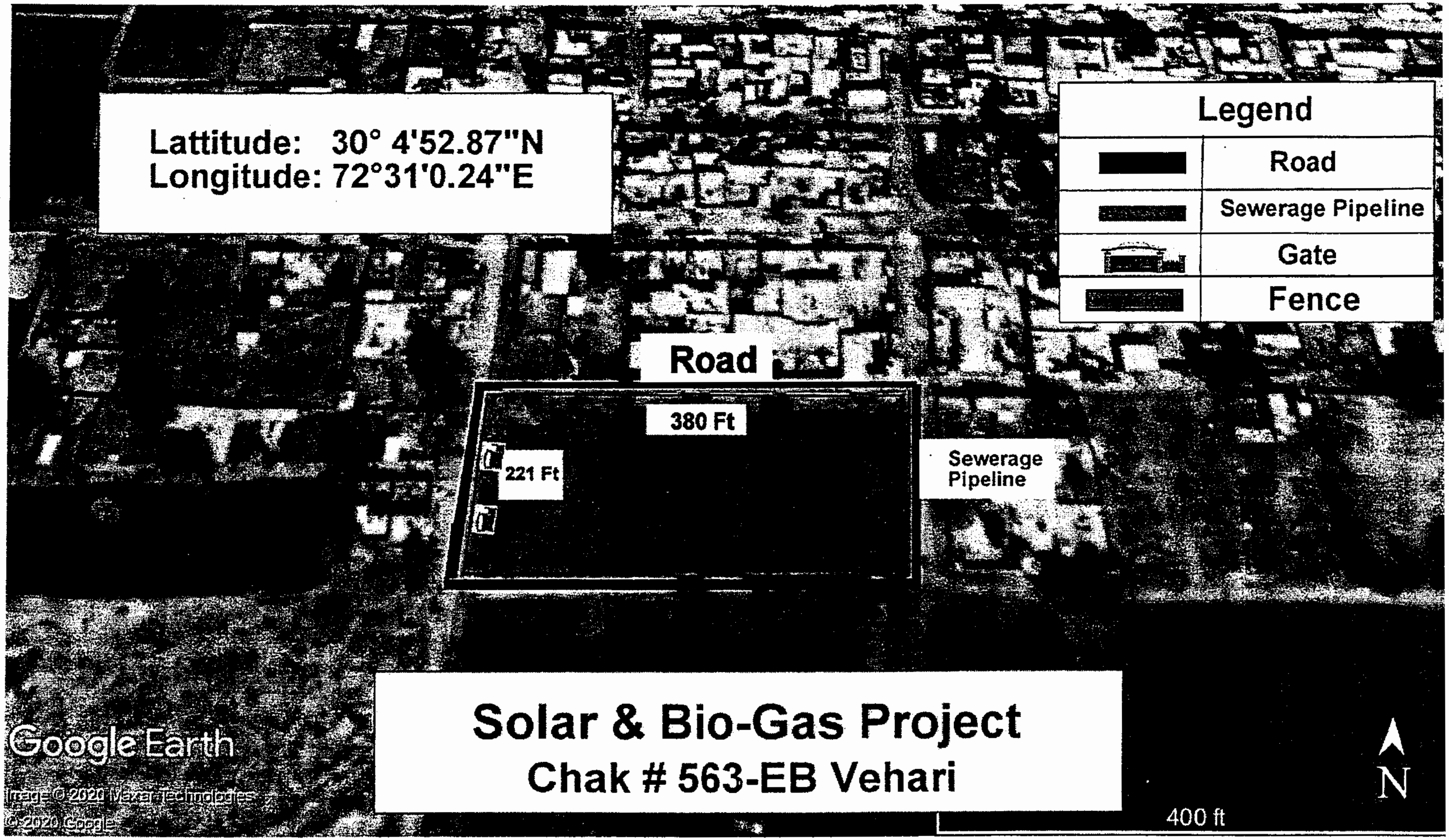
Emissions

Type of Gas	Emission Percentage
Methane	53%
Carbon di Oxide	44%
Nitrogen	1.90%
Oxygen	0.40%
Hydrogen	0.50%

[redacted] [redacted] [redacted]



Drawing Name:	Drawing No:	Project Name:	Site Name:	Designed By:	
Single Line Diagram	DGL-D1-V1.1	Vehari Solar & Bio-Gas	Vehari Chak#563EB	Zaheer Ishfaq	Dynamic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Longitude: 72°31'0.24"E
Legend
Road
Sewerage Pipeline
Gate
Fence
Road
380 Ft
221 Ft
Sewerage Pipeline
Google Earth
Image © 2020 Maxar Technologies
© 2020 Google
Solar & Bio-Gas Project
Chak # 563-EB Vehari
400 ft
N

<u>Project Commencement and completion Schedules with milestone</u>

Task Name	Start	Finish
Contract Signature	3/1/19	3/1/19
Design & BOQ Approval	3/18/19	3/29/19
Procurement	4/1/19	7/14/20
Order Processing for LC's	4/1/19	4/5/19
Battery manufacturing	7/8/19	8/23/19
Battery shipment to sites	8/30/19	7/14/20
Solar Panels Shipment to sites	4/8/19	8/14/19
Inverters Shipment to sites	4/8/19	8/14/19
Biogas Generators shipment to sites	4/8/19	1/1/20
Biogas Equipment shipment to sites	4/8/19	1/29/20
BOS for solar system to sites	4/8/19	1/29/20
Biogas Civil Works completion	6/1/19	1/21/20
Substrate Storage -Dung, Mixing/ Reception Tank, Gen Room & Slurry Pond digging	6/1/19	8/1/19
Digging of Digester base, Steel Fixation & Pouring of Digester Base, Substrate storage-Silage	8/1/19	10/1/19
Digester Walls Steel Fixing, Shuttering & Pouring of Concrete. Slurry Separator Pit-feed tank & Slurry Channel, water bore	10/1/19	1/21/20
Installation of Grid Lines/ Netmetering	1/4/20	5/31/19
Application to regulator, Installation & Commissioning of lines	1/4/20	Thu 11/05/20
Installation of Solar System	**6/1/20**	**3/17/20**
Solar system Installation	6/1/19	3/17/20
Installation of Biogas Equipment	**2/1/20**	**10/15/20**
Biogas equipment installation	2/1/20	10/15/20
Biogas production	7/22/20	11/15/20
Integraed commissioning of systems	**11/5/20**	**11/15/20**
Integrated commissioning	11/5/20	11/15/20

Biogas plant automation details Vehari.

Vehari design is Nepalese design this have certain limitations for automation. Yet the possible automation within budget and process is as under

Reception Tank

- Tank will be fitted with level switches
- If the feed level in tank is low pump will not start. Safety alarm will on.
- Mixers will set to run for 5-10 min before 30 minutes of each feeding.
- Feeding frequency will be adjustable,either all digesters at same time or half of digesters in morning and half in evening. It will depend upon supply of manure.
- Mixers in mixing pit will set to work for a limited time (adjustable) operate with on switch or touch from screen

Main Digester

There are 14 digesters each will be fed seperatly from its own inlet.

- Gas produced in digester will collected in plant dome under membrane.
- A 500 cubic meter storage balloon is directly connected with main gas line to balance the pressure and act as a buffer between digester and biogas storage.
- At set timings blower will start shifting biogas from buffer balloon to storage balloons till the set low pressure attained.
- Low pressure will be set in positive numbers.
- Gas will be transferred from buffer balloon to storage balloons in order to avoid negative pressure in digester.
- If the digester pressure reach at transfer level and storage is full gas will be shifted toward semi-automatic flare, two motorized butterfly valves will be installed after blower to shift gas towards flare.
- Flare ignition time will be set to lower the gas pressure at certain level.

Slurry pit and slurry separator

- From digester slurry will come out by gravity in a 10M3 slurry pit fitted with a level switch.
- When pit filled slurry separator will start and run till low level of level switch.
- Semi solid dry matter may be removed to fields or stored while separated water may be recycled or drained to slurry pond

Safety and alarms

1- If mixing tank is low in feed and you want to start feeding buzzer will on
2- If the gas pressure in main line exceed from set pressure and transfer pump didn't start buzzer will on
3- If the gas pressure in biogas storage exceed from set pressure point and filling continue buzzer will on
4- When buzzer set on problem part will blink on screen

Safety plans for Biogas and Solar System:

1) Safety plan for Biogas:

Safety technology is often confused with explosion protection. However, it includes far more than only explosion protection. Basically safety technology can be regarded as the general protection of staff and the neighborhood from hazards, whether caused by water pollution, collapsing buildings or toxic gases. Safety technology is also often connected to occupational safety. Therefore it covers a very area. The following text can be regarded mainly as safety technology related to explosion protection in view of occupational safety.

For an explosion to take place three things were made necessary:

a.) An inflammable material having a high degree of dispersion was made available. This is usually given with gases.
b.) An ignitable mixture was made be available.
c.) c.) An ignition source of sufficient energy for the existing mixture was made available.

The safety related concept is subject to a hierarchy that in explosion protection specifies and demands that primary explosion protection comes first. This is directed towards all measures that help to avoid the formation of a hazardous, explosive atmosphere. Secondary explosion protection, in which mostly technical measures are taken to ensure that ignition sources do not become effective, is to be listed only in the second position. If these measures too cannot guarantee that hazards cannot be eliminated, tertiary (constructive) explosion protection is to be applied.

Mainly, following points have been taken into account with primary measures:

a) Selection of suitable procedures.

b) Leak proof pipes and armatures, so that no air can enter or escape from the facility.

c) Measuring equipment for monitoring and limiting the concentration.

d) Inserting mixtures by adding non-inflammable gases, so that the mixture is safely below the explosion limit.

e) Supplying air either by natural or technical means, so that inflammable gas is always diluted and not explosive anymore.

According to legal requirements and taking the possible formation of a hazardous, potentially explosive atmosphere in a plant into account, specific actions of the operator were defined. These can be summarized as follows:

a) A hazard assessment is done to determine where in the plant a hazard is to be reckoned with.

b) Specifications are defined for the equipment made available.

c) The explosion hazarded areas are defined. The points are recorded in writing in the explosion protection document.

d) Specifications on the properties of the working materials are defined. Further special protection measures are defined. In addition to this the staff is briefed.

e) Working materials is inspected regularly.

f) All actions of the operator are recorded.

Other safety measures include

a) Briefing the staff
b) Written instructions, work clearance, supervision
c) Identification of explosion hazarded areas
d) Prohibiting specified ignition sources in explosion hazarded areas (e.g. smoking).
e) Prohibiting the entry of unauthorized persons in specified areas.
f) Installation of protection measures, based on the largest possible danger potential.
g) Employment of specifically suitable equipment safety systems.
h) It is guaranteed that only such working materials that will make allowance for the aspects of explosion protection will be applied.
i) The staff should be warned acoustically and visibly prior to reaching the explosion conditions.
j) Ignition sources created by electrostatic charging are avoided.
k) Sufficient escape routes are provided.
l) If necessary, a means of escape are provided.
m) Prior to first use, inspections are carried out. These are conducted by qualified persons. Qualified persons are those that have special knowledge especially in the area of explosion protection.
n) In case of power-cuts, the safe functioning of the equipment is guaranteed.

2. Safety Plan for Solar Plant:

No two worksites are the same. Before a solar installation begins, it's essential for the installer to visit the site, identify the safety risks and develop specific plans for addressing them. Plans include:

a) Equipment to be used for safe lifting and handling of solar panels

b) Type and size of ladders and scaffolding if needed

c) Fall protection for rooftop work

d) Personal protective equipment for each installer

Solar panels are heavy and awkward to lift and carry. Loading and unloading panels from trucks and onto roofs can cause strains, sprains, muscle pulls and back injuries as well as cumulative trauma that stress the spine. The panels can also heat up quickly when exposed to sunlight, causing burns if not handled safely.

Safety measures for solar workers:

a) Lift each solar panel with at least two people while applying safe lifting techniques.
b) Transport solar panels onto and around the work site using mobile carts or forklifts.
c) Never climb ladders while carrying solar panels. To get solar panels onto rooftops, use properly inspected cranes, hoists or ladder-based winch systems.
d) Once unpackaged, cover panels with an opaque sheet to prevent heat buildup.
e) Always wear gloves when handling panels.

Solar construction often involves working on roofs and from ladders. Choosing the right ladder and using it properly are essential.

Safety measures for solar workers:

a) Select the ladder that best suits the need for access – whether a stepladder, straight ladder or extension ladder. Straight or extension ladders should extend a minimum of three feet above the rung that the worker will stand upon.
b) Select the right ladder material. Aluminum and metal ladders are the most commonly used today and may have their place on the job, but they're a serious hazard near power lines or electrical work. Use a fiberglass ladder with non-conductive side rails near power sources.
c) Place the ladder on dry, level ground removed from walkways and doorways, and at least 10 feet from power lines and secure it to the ground or rooftop.

Trips and falls are a common hazard of all construction jobs, including solar. They can happen anywhere on the jobsite, especially off roofs or ladders. Rooftop solar installations are especially hazardous because the work space diminishes as more panels is installed, increasing the risk of falls.

Safety measures for solar workers:

a) Keep all work areas dry and clear of obstructions.

b) For fall distances of six feet or more, take one of three protective measures: install guardrails around ledges, sunroofs or skylights; use safety nets; or provide each employee with a body harness that is anchored to the rooftop to arrest a potential fall.

c) Cover holes on rooftops, including skylights, and on ground-level work surfaces.

its also important to recognize that with PV systems, electricity comes from two sources: the utility company and the solar array that is absorbing the sun's light. Even when a building's main breaker is shut off, the PV system will continue to produce power. This makes isolating the power source more difficult, and requires extra caution on the part of the solar worker.

Safety measures for solar workers:

a) Cover the solar array with an opaque sheet to "turn off" the sun's light.
b) Treat the wiring coming from a solar PV array with the same caution as a utility power line. Use a meter or circuit test device to ensure that all circuits are de-energized before working on them.
c) Lock out the power on systems that can be locked out. Tag all circuits you're working on at points where that equipment or circuit can be energized.
d) Never disconnect PV module connectors or other associated PV wiring when it is under load.

Emergency plans for Solar and Biogas:

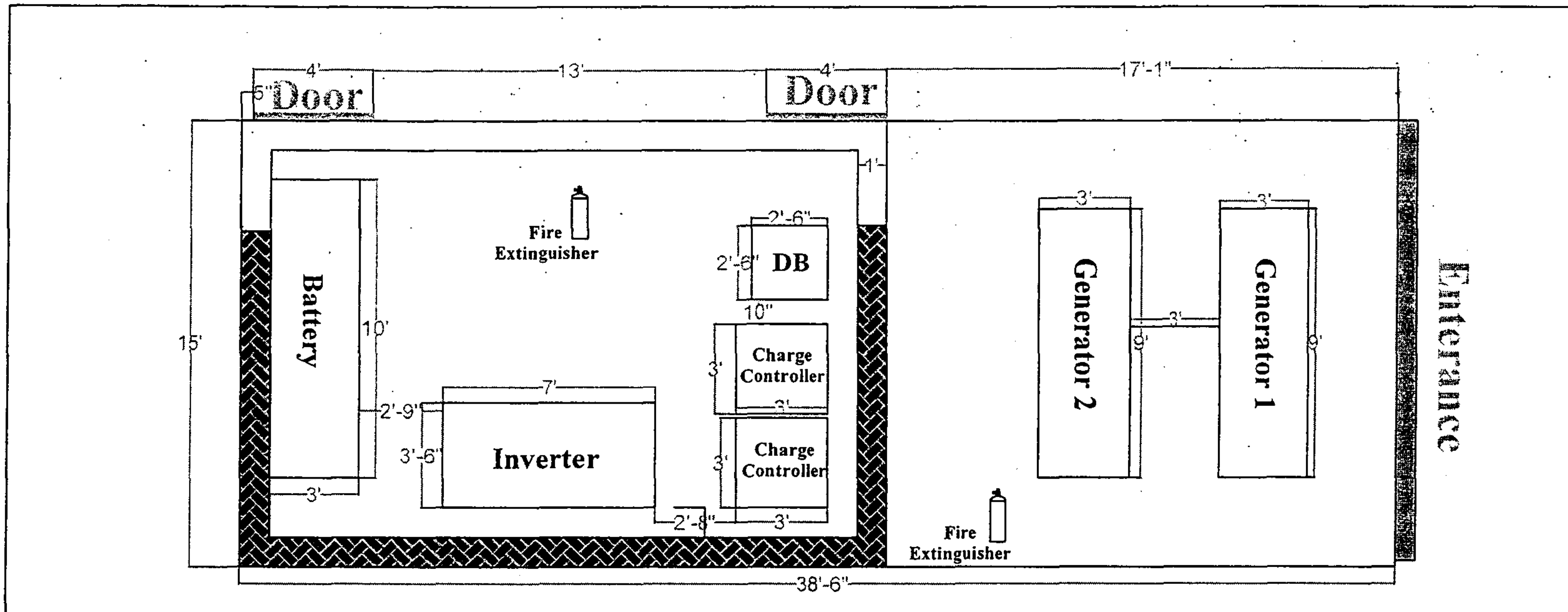
Emergency plan for Biogas plant:

a) In case of increased storage gas pressure the excessive gas is released through flare.
b) The working capability of the Bio gas plant is affected when the gas in the digester reaches a level of 20 psi. To avoid such an occurrence, the safety valves in the digester are opened even when the gas pressure in the digester reach a level of 5 psi.
c) If mixing tank is low in feed, buzzer will turn on
d) If the gas pressure in the main line exceeds from set pressure the buzzer will turn on.
e) If the gas pressure in biogas storage exceeds from set pressure point, buzzer will turn on.
f) When buzzer turns itself on, the problem part will blink on the screen.
g) Emergency response plans first include basic rules on how to behave in the case of a fire (publicly displayed notice). Second, they must establish concrete instructions for all employees on site, addressing measures such as fire prevention and what to do in the case of a fire.

Emergency plan for solar plant:

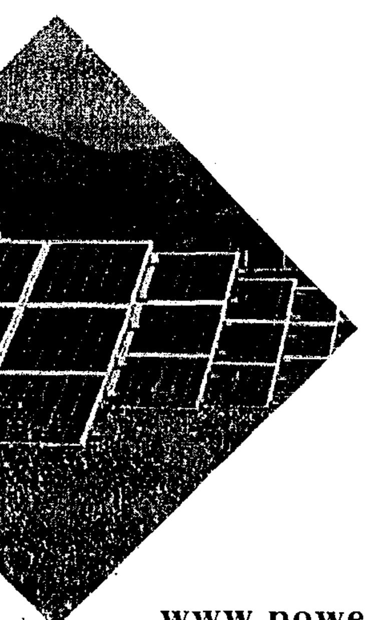
a) To sustain life and safety in emergencies, backup power for critical equipment should be available for a minimum of 3 days.
b) Roof-top PV systems are used to generate electricity for emergency and to provide backup power to augment other energy sources.
c) Portable generators are also available to address emergency power needs.
d) Surge protection devices are installed to overcome short circuiting and other emergencies related to it.

[redacted] [redacted] [redacted]



Drawing Name:	Drawing No:	Project Name:	Site Name:	Signature:	
Fire Plan	DGL-D1-V1.0	DGL-Villages-300KWp	Vehari	Zaheer Ishfaq	Dynamic Green

Power Planners International



Load Flow Study for a Micro Plant (Installed for a village – 563/ EB Vehari)

By

Dynamic Green (Pvt.) Ltd.

Report No. PPI-388.1-Draft/20

www.powerplannersint.com

Load Flow Study for a Micro Plant (Installed For a Village– 563/ EB Vehari) by Dynamic Green (Pvt.) Ltd.

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Executive Summary

- The Load Flow Study report for a Micro Plant (Installed for a village – 563/ EB Vehari) is submitted herewith.
- The study objective, approach and methodology have been described and the plant's data received from the Client is validated.
- Chak 563-EB is currently being supplied MEPCO Network through 11 kV Feeder namely Madina Colony.
- It has been planned to supply the village via a local micro power plant facility to ensure the uninterrupted power supply to the consumers of Chak 563-EB village.
- Micro Power Plant is a Hybrid of Solar PV and Bio Gas based power plant with the backup supply of Batteries. It comprises of 300 kWp solar and 50 kW of Bio Gas generating units. The net AC output of the solar plant is 240 kW, thus maximum output from the plant is 290 kW.
- This village electrification power plant will generate at 0.4 kV voltage level from where it is stepped-up to 11 kV using 11/0.4 kV transformer rated 400 KVA.
- Synergi Electric software has been used to evaluate the voltage profile of the feeder with and without the hybrid generation. The losses incurred on the feeder with and without the hybrid generation have also been examined.
- The analysis has revealed that the losses across the original feeder are 10.61 % with a voltage drop of 28 % across the complete feeder. After the increased length to interconnect the micro power plant the losses are 10.62 % and voltage drop remains the same 28 %.
- It is concluded that because of the increased length to interconnect the micro power plant the increase in the losses across the feeder are only **0.01 %** from original configuration and the voltage drop across the feeder remains same in both cases. Therefore, there is no constraint in adopting this scheme.

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Appendices

Appendix – A: Data provided by client

Appendix – B: ArcGIS Map

Appendix – C: Results of Synergy Analysis

Appendix – D: Required Material

1. Introduction

1.1. Background

Chak 563-EB is currently being supplied MEPCO Network through 11 kV Feeder namely Madina Colony. It has been planned to supply the village via a local micro power plant facility to ensure the uninterrupted power supply to the consumers of Chak 563-EB village.

Micro Power Plant is a Hybrid of Solar PV and Bio Gas based power plant with the backup supply of Batteries. It comprises of 300 kWp solar and 50 kW of Bio Gas generating units. The net AC output of the solar plant is 240 kW, thus maximum output from the plant is 290 kW.

Initially it was planned to supply the power from micro power plant to the village at 0.4 kV level, but because of the high losses at 0.4 kV it has been decided to step up the power of the plant to 11 kV and use this voltage level to supply the consumers. It is for this purpose this study has been carried out to check the impact of 11 kV additional supply line from plant facility to feeding point of the village.

1.2. Objectives

The overall objective of the Study is to investigate any load flow constraint in the supply of hybrid power generated to the consumers of Chak 563-EB village under different possible scenarios. The specific objectives of this report are:

1. To examine the effect of increased length of the 11 kV Madina Colony feeder because of micro power plant.
2. To examine the effect of the hybrid generation on the voltage profile of the feeder and the power losses on the feeder,

2. Assumptions of Data

Based on the data provided by the client following assumptions have been made:

2.1. Power Plant Data

Generating Voltage	= 0.4 kV
Nominal DC power of the solar plant	= 300 KWp
Net AC output of the solar plant	= 240 KW
Net AC output of the Biogas plant	= 50 KW
Total Net Output of the Plant	= 290 KW
Number of GSU transformers	= 1
GSU transformer rated power	= 400 KVA
GSU transformer impedance	= 5% (Assumed)

2.2. Feeder Data

Chak 563-EB is currently being supplied MEPCO Network through 11 kV Feeder namely Madina Colony. This feeder is emanating from Burewala 132 kV Grid Station of MEPCO. The detailed feeder data is provided by MEPCO in terms of input file of Synergi Software.

Total length of the Madina Colony feeder from Burewala 132 kV Grid Station is about 60.35 km. Peak load of the feeder as provided by MEPCO is 280 Amperes. This village is located at the tail end of Madina Colony feeder. Two 11/0.415 kV transformers of 200 kVA and 100 kVA are installed to supply the consumer.

The 11 kV feeding line from the micro plant to the feeding point of transformers is approximately 200 meters. Because of the micro plant the increase in the length of 11 kV Madina Colony feeder is about 600 meters. Arrangement of the feeder is shown in the GIS Map in Appendix – B.

3. Load Flow Studies

Synergi Electric software is engineering simulation and analysis software for power distribution systems. It has been used for this study to examine the voltage profile of the system with and without the hybrid generation. It has also helped in the evaluation of power losses incurred on the feeder.

Based on the above mentioned data and assumptions, three different cases of load flow have been developed.

- Case – 1: Base Case with original Arrangement of Madina Colony Feeder
- Case – 2: Madina Colony Feeder with Additional Length
- Case – 3: Madina Colony Feeder with Additional Length and Micro Plant

3.1. Case – 1: Base Case with original Arrangement of Madina Colony Feeder

The first case simulated is taken as base case, in which the original configuration of the feeder has been kept intact and the losses of the complete feeder and the voltage drop across the feeder has been measured. The load flow results are attached in Exhibit – 0.1 of Appendix – C.

Losses across the feeder are about 10.61 %.

Voltage drop across the feeder is about 28 %.

3.2. Case – 2: Madina Colony Feeder with Additional Length

To connect the micro plant the arrangement of the feeder will be changed. The 11 kV feeder will be disconnected from its main path towards distribution transformers which feeds Chak 563-EB. It will be re-routed towards micro plant site and then from micro plant site to backward towards distribution transformers. The supply from MEPCO and the micro plant has been separated using an HT Isolator Switch which will be controlled at the site of Micro Power Plant.

This arrangement will cause an increase in the length of feeder and thus increase in losses and voltage drop across the feeder. The load flow results are attached in Exhibit – 0.2 of Appendix – C.

Losses across the feeder are about 10.62 %.

Voltage drop across the feeder is about 28 %.

3.3. Case – 3: Madina Colony Feeder with Additional Length and Micro Plant

This case has been performed to check the impact of micro power plant on the losses of feeder and the voltage profile of the village when the load of village is being fed from micro plant locally and thus the load of the feeder is reduced in this case. The load flow results are attached in Exhibit – 0.3 of Appendix – C.

Losses across the feeder are about 9.75 %.

Voltage drop across the feeder is about 25 %.

3.4. Conclusion of Load Flow Analysis

The analysis has revealed that the losses across the original feeder are 10.61 % with a voltage drop of 28 % across the complete feeder. After the increased length to interconnect the micro power plant the losses are 10.62 % and voltage drop remains the same 28 %.

It is concluded that because of the increased length to interconnect the micro power plant the increase in the losses across the feeder are only **0.01 %** from original configuration and the voltage drop across the feeder remains same in both cases. Therefore, there is no constraint in adopting this scheme.

3.5. Required Material

List of required material has been provided in Appendix – D. Please note that this list is just the estimate of the required equipment that will be needed for the interconnection of the micro plant with the village distribution network. The final list of Equipment and may be further validated by MEPCO and any alteration may be proposed in this regard.

4. Conclusion

- The study objective, approach and methodology have been described and the plant's data received from the Client is validated.
- Chak 563-EB is currently being supplied MEPCO Network through 11 kV Feeder namely Madina Colony.
- It has been planned to supply the village via a local micro power plant facility to ensure the uninterrupted power supply to the consumers of Chak 563-EB village.
- Micro Power Plant is a Hybrid of Solar PV and Bio Gas based power plant with the backup supply of Batteries. It comprises of 300 kWp solar and 50 kW of Bio Gas generating units. The net AC output of the solar plant is 240 kW, thus maximum output from the plant is 290 kW.
- This village electrification power plant will generate at 0.4 kV voltage level from where it is stepped-up to 11 kV using 11/0.4 kV transformer rated 400 KVA.
- Synergi Electric software has been used to evaluate the voltage profile of the feeder with and without the hybrid generation. The losses incurred on the feeder with and without the hybrid generation have also been examined.
- The analysis has revealed that the losses across the original feeder are 10.61 % with a voltage drop of 28 % across the complete feeder. After the increased length to interconnect the micro power plant the losses are 10.62 % and voltage drop remains the same 28 %.
- It is concluded that because of the increased length to interconnect the micro power plant the increase in the losses across the feeder are only **0.01 %** from original configuration and the voltage drop across the feeder remains same in both cases. Therefore, there is no constraint in adopting this scheme.

Energy Solutions Using Indigenous Resources in Villages

Chak 563/EB (Village2), Vehari

Initial Environmental Examination (IEE) Report

August 2017

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LIST OF ABBREVIATIONS

ECCS	ECOCARE Consultancy Services
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMMP	Environmental Management and Monitoring Plans
EPA	Environmental Protection Agency
EPD	Environmental Protection Department
FESCO	Faisalabad Electric Supply Company
GHG	Green House Gas
HSE	Health Safety and Environment
IEE	Initial Environmental Examination
Km	Kilo meter
kW	Kilowatt
kVA	kilovolt-ampere
LAC	Land Acquisition Collector
mm	Millimeter
NEQS	National Environmental Quality Standards
NCS	National Conservation Strategy
NOC	No Objection Certificate
PKR	Pakistani Rupees
PA	Project Area
PPE	Personnel Protective Equipment
PEPA	Pakistan Environmental Protection Act
PEPC	Pakistan Environmental Council
PMU	Project Management Unit
PV	Photovoltaic
SA	Study Area
TB	Tuberculosis
TOR	Term of References
LAC	Land Acquisition Collector
CHP	Combined Heat and Power
RCC	Reinforced Cement Concrete

Executive Summary

Name of the Project:	"Energy Solutions using Indigenous Resources in Villages" for Chak No. 563/EB (Village2), Vehari
Location of Project:	Chak No. 563/EB, Tehsil & District Vehari
Proponent:	Energy Department Government of the Punjab
Consultant:	ECOCARE Consultancy Services (ECCS) Private Limited

1. Introduction

Pakistan is suffering from intense shortfall of electricity which is directly effecting the population especially in rural areas. At present, there is a demand-supply gap of about 4000 MW which is increasing at a rate of 6% per annum. Thus it is crucial need to generate power by using renewable resources of energy i.e. solar, biomass, wind, geothermal and hydropower. The government of Punjab has invested in several power generation projects that are using renewable energy resources and have ability to overcome power shortage.

For any development project to be initiated in Punjab, it is mandatory to obtain Environmental Approval from EPA Punjab under Section-12 of the Punjab Environmental Protection Act, 1997 (Amendment 2012) by filing an IEE or EIA, as may be defined in Review of IEE/EIA Regulations, 2000 or recommended by EPA Punjab. This IEE study states various environmental and social impacts of the proposed Solar-Biogas Project and devises mitigation measures for the adverse impacts accordingly.

ECOCARE Consultancy Services (ECCS) Private Limited is the consultant firm which has conducted environmental study and prepared this final IEE report for the Project Proponent in accordance with the EPA-Punjab guidelines.

2. Legal/Regulatory Framework

The national guidelines and legislations related to environment are considered for the proposed Project including National Conservation Strategy (1992), National

Environment Policy (2005), Pakistan Labor Policy (2010), Punjab Environmental Protection Act (PEPA 1997), amended PEPA (2000), National Environmental Quality Standards (NEQS), Punjab Wildlife Act (1974), Punjab Plantation and Maintenance of Trees Act (1974) and Antiquities Act (1975).

Current national environmental policy as well as administrative and legal framework of PEPA 2000, has been reviewed comprehensively which provides an overview of the national policies, laws, guidelines and regulations related to the IEE study. Initial Environmental Examination (IEE) Report is mandatory to obtain Non-Objection Certificate (NOC) according to Pakistan Environmental Protection Act (PEPA-1997). Section 12(1) of PEPA-1997 stipulates that no project involving construction or any change in the physical environment can be undertaken unless an IEE or EIA is conducted and NOC is received from the relevant provincial environmental agency. This IEE Report has been prepared with due consideration of PEPA, 1997, Punjab Environmental Protection (Amendments) Act, 2012 and all other legal requirements of Pakistan and Punjab Government.

3. Project Brief

Project Name	Construction of "Energy Solutions using Indigenous Resources in Villages"
Location of Project	Chak No. 563/EB, Tehsil & District Vehari
Proponent	Energy Department Government of the Punjab 8th Floor, EFU House, 6-D Main Gulberg, Jail Road, Lahore, Pakistan
Total area	2.1 acre
Construction Period	12 Months
Nature of Area	Open Barren Land
Capacity of	300 kW solar PV and 50 kW (100 kW peak) biogas with 200

Project	kWh battery.
Cost of Project	PKR 100 Million
Man Power	Construction: 15 Persons
	Operation: 04 Persons
Raw Material and Technology	Biogas digesters will be constructed using concrete material. Dung and Silage are the raw materials for Biogas Plant. For Solar Power Plant, PV Monocrystalline Panels will be used.

4. The Major Impacts

The major anticipated Socio-Environmental Impacts are summarized below:

Sr. #	Environmental Parameters	Impacts Level by Project at Construction		
		Before	During	After
1	Air Resources	0	-1t	0
2	Land Resources	0	-1t	0
3	Water Resources	0	-1t	0
4	Ecological Resources	0	0	0
5	Social Environment	0	-1t	+3p
6	Economic Environment	0	0	+2p

Legends: 0= Negligible ; 1= Low; 2= Medium; 3= High; 4= Extremely High; NA= Not Applicable; t= Temporary; p= Permanent; app= Applicable;

5. Recommendations for Mitigation Measures

The intensity and severity of impacts, foreseen due to the construction and operation of the Proposed Project vary with change in the nature and magnitude of the impacts as well as depend upon the baseline environmental conditions of the area. The mitigation measures during construction phase will require implementation of environmental management plan in letter and spirit. The adverse environmental impacts significantly be reduced or eliminated by adopting best management and monitoring practices as well as by implementation of EMMP effectively.

7. Proposed Monitoring

To ensure the effective implementation of mitigation measures and environmental management plan during construction and operation phase of the Project, monitoring mechanism is proposed which is given below:

Environmental Component	Parameter	Location	Duration / Frequency	Responsibility
Air Quality	Dust Generation at construction sites	Construction site	Once during construction	EMC of PMU
Noise	Noise Level (dB)	Construction site	Once during construction	EMC of PMU
Surface and Ground Water Quality	Construction waste disposal, Water Quality measurement using standard methods.	Construction site and nearby water bodies	Once during construction	EMC of PMU
Hygiene at Biogas plant and surroundings	Proper training in maintenance to avoid Generation of insects, worms, flies, and mosquitoes	Biogas plant site	Monthly during Operation Stage	Quality control officer
EMC: Environmental Management Committee, PMU: Project Management Unit, dB: decibel				

8. Conclusions and Recommendations

The performed IEE showed all anticipated impacts (both positive and negative), associated with the project. Appropriate mitigation measures as explained in the environmental study that will reduce, if not eliminate, these impacts so that these are within acceptable limits. Moreover, no deterioration, depletion or exploitation of local natural resources is expected to be caused by this project.

Negligible to low adverse impacts can be foreseen during Project implementation Mitigation measures will be implemented to minimize environmental impacts. All the impacts can be managed cost effectively.

It is recommended that the proponent should obtain an environmental approval (No Objection Certificate) from the Punjab-EPA before proceeding further into the construction activities as per regulatory requirements.

1. INTRODUCTION

1.1 Background

Pakistan is suffering from intense shortfall of electricity which is directly effecting the population especially in rural areas. At present, there is a demand-supply gap of about 4000 MW which is increasing at a rate of 6% per annum[1]. Thus it is crucial need to generate power by using renewable resources of energy i.e. solar, biomass, wind, geothermal and hydropower. The government of Punjab has invested in several power generation projects that are using renewable energy resources and have ability to overcome power shortage.

For any development project to be initiated in Punjab, it is mandatory to obtain Environmental Approval from EPA Punjab under Section-12 of the Punjab Environmental Protection Act, 1997 (Amendment 2012) by filing an IEE or EIA, as may be defined in Review of IEE/EIA Regulations, 2000 or recommended by EPA Punjab. This IEE study states various environmental and social impacts of the proposed Solar-Biogas Project and devises mitigation measures for the adverse impacts accordingly.

ECOCARE Consultancy Services (ECCS) Private Limited is the consultant firm which has conducted environmental study and prepared this final IEE report for the Project Proponent in accordance with the EPA-Punjab guidelines.

1.2 Purpose of the Report

The purpose of this IEE report is to examine and assess the environmental impacts of the proposed Project and to devise mitigation measures for the expected impacts that are likely to occur during the construction and operational phases. The proposed Project must comply with the EPA regulations prior to issuing an environmental approval (NOC) for the proposed Project.

The main purpose of this IEE is to work closely with the Project engineers to ensure that the Project design reflects environmental sensitivities and meets the social needs of the beneficiaries especially the people living in the surroundings.

[1] http://www.energy.punjab.gov.pk/_pages/oppinPunjab_Solar.html [Energy Department, Govt. of Punjab]

1.3 Identification of Project

Title of the proposed Project is "Energy Solutions using Indigenous Resources in Villages". The proposed Project will involve the installation of hybrid Photovoltaic-Biogas plant. For this project, the combination of solar and biogas energy is proposed, with a limited amount of batteries that might be added as an additional backup. The combination between the solar and biogas is seems very suitable one; the solar part provides cheap energy during the daytime while the biogas plant provides a reliable supply for the base load. The capacity of Plant is 300 kW solar PV and 50 kW (100 kW peak) biogas with 200 kWh battery.

1.4 Details of Proponent

Energy Department, Government of Punjab is the proponent of proposed Project that is "Energy Solutions using Indigenous Resources in Villages". The details of the proponent are given as under:

Energy Department

Government of the Punjab

8th Floor, EFU House, 6-D Main Gulberg, Jail Road, Lahore, Pakistan

Phone: +92 42 99268017-19

Fax: +92 42 99268016

Email: ed.contact@energy.punjab.gov.pk

1.5 Details of Consultant

ECOCARE Consultancy Services (ECCS) Private Limited is the consultant firm which has conducted environmental study and prepared this final IEE Report on behalf of the Project Proponent in accordance with the Punjab-EPA guidelines. The contact details of the consultant are given as under:

Syed Amir Raza Ali

Managing Director

M/S ECOCARE Consultancy Services (ECCS) Private Limited

F1-328 Jeff Heights, Main Boulevard, Gulberg lll, Lahore

Phone: +92 42 35782191

Email: info@ecocare.pk

1.6 Project Location, Nature and Size

The proposed site for the construction of project is located at Chak No. 563/EB, Tehsil & District Vehari. The coordinates of the proposed Project Site are 30°04′51.25"N and 72°30′57.15"E. Total area of the proposed site is 2.1 acres which is sufficient to install the proposed Solar-Biogas plant. Size of Plant is 300 kW solar PV and 50 kW (100 kW peak) biogas with 200 kWh battery.

The map showing location of Project Area is given below as Figure 1.1. It is also shown as Google map under Annex-C1.

Figure 1.1: Proposed Project Location

2. LEGAL / REGULATORY FRAMEWORK

In this section, the environmental and social regulations are described which are applicable to the proposed Solar-Biogas Energy project. Under Clause 12 of Pakistan Protection Act 1997 (PEPA, 1997) it is mandatory to carry out an Initial Environmental Examination (IEE) or Environment Impact Assessment (EIA) before starting a project. The relevant international laws are being discussed in this section.

2.1 National Policies, Plans, Acts and Legislation

National Policies, Plans, Acts and Legislation are given below in details:

2.1.1 National Policy and Administration Framework

The Pakistan National Conservation Strategy (NCS), approved by the Federal Cabinet in March 1992, is the principal policy document on environmental issues. The NCS outlined the country's primary approach towards encouraging sustainable development, conserving natural resources and improving efficiency in the use and management of resources. The NCS has specific programs in core areas in which policy intervention is considered crucial for the preservation of Pakistan's natural and physical environment. The core areas that are relevant in the context of the proposed project are pollution prevention and abatement, conserving biodiversity, supporting forestry and plantations.

The Government of Pakistan promulgated "Pakistan Environmental Protection Act (PEPA) in 1997. Two organizations, the Pakistan Environmental Protection Council (PEPC) and the Pak-EPA (now developed), are primarily responsible for administering the provisions of the Act at the federal level. The PEPC oversees the functioning of the Pak-EPA. Its members include representative of the government industry, non-governmental organizations and the private sector. The Pak-EPA is required to ensure compliance of the National Environmental Quality Standards (NEQS) and establish monitoring and evaluation systems. The Pak-EPA was authorized to delegate powers to its provincial counterparts, the provincial EPAs or (Environmental Protection Department) EPD-Punjab, but the provinces are now conferred full authority after development. One of the functions delegated by the Pak-EPA to provincial EPAs/EPD is the review and approval of environmental assessment reports of projects undertaken in their respective jurisdictions.

2.1.2 Pakistan Environmental Protection Act, 1997

The Pakistan's Environmental Protection Act, 1997, empowers the Pak-EPA to:

- Delegate powers including those of environmental examination/ assessment to the provincial EPAs/EPD
- Develop environmental emission standards for parameters such as air, water and noise pollutants
- Develop procedures for conducting IEE and procedures for the review and approval of the same
- Identify categories of the projects to which the environmental examination/ impact assessment provisions will apply
- Implement the provisions of the Act through environmental protection orders and environmental tribunals which are headed by magistrates with wide-ranging powers, including the right to fine violators of the Act.
- Under the provisions of the 1997 Act, the Pak-EPA has authorized five provincial EPAs/ EPD (including AJK) for managing the environmental concerns of their respective provinces. The provincial EPAs/EPD can frame environmental regulations tailored to the requirements of their province, provided these regulations meet or exceed the minimum standards set by the Pakistan EPA. They are also essential to review and approve IEEs/EIAs of all the development projects.

2.1.3 National Environmental Quality Standards, (NEQS) 2000

The NEQS 2000 specify the following standards:

- Maximum allowable concentration of pollutants (32 parameters) in municipal and liquid industrial effluents discharged to land waters, sewage treatment facilities and the sea (three separate sets of numbers).
- Allowable noise levels from vehicles

2.2 Provincial Departments

It is the main responsibility of the provincial departments to affirm that the project complies with the laws and regulations controlling the environmental impacts at pre-construction conditions, operation and construction stages of the Project.

2.2.1 Provincial Revenue Departments

Under the National laws, the matters relating to land acquisition and ownership are provincial subjects and the Revenue Department of the concerned province is empowered to carry out the acquisition of private land and built-up property for public purposes, including on behalf of another Provincial or Federal Agencies. For those purposes, the lead department must lodge an application with the concerned provincial government to depute a Land Acquisition Collector (LAC) and revenue staff.

2.2.2 Punjab Environmental Protection Agency

The Proponent will be responsible for providing the complete documentation required by the Punjab Environmental Protection Agency and will remain committed to the approved project design. No deviation is permitted during the project implementation without the prior and explicit permission of the Punjab EPA/EPD.

2.2.3 Agriculture and Horticulture Department

It also requires a liaison with the provincial departments of agriculture, horticulture and forestry in case of issues associated with these departments. The concerns could be relating to the affected vegetation resources, such as trees and crops. In case of some public buildings/ infrastructure is involved, Proponent will approach the building department for relocation/ assessment of compensation.

2.2.4 Coordination with District Government

The Project Proponent will coordinate with all concerned Government Departments to ensure that the project meets the criteria of District Government/Authorities as related to the establishment of construction camps and plants and the safe disposal of waste, solid waste and toxic material. Proponent will also ensure periodic monitoring of the EMP during both construction and operation period through deployment of an Environment Specialist.

2.3 Other Relevant Acts

2.3.1 Local Government Act 2001 and Amended in 2003

These ordinances, issued following the devolution process, establish regulations for land use, the conservation of natural vegetation, air, water, and land pollution, the disposal of solid waste and wastewater effluents, as well as matters related to public health and safety.

2.3.2 Punjab Wildlife Protection Act, 1974

The Punjab Wildlife Protection Act, 1974 was approved by the provincial assembly of Punjab in 1974. This Act is applicable to the whole of the Punjab province for protection, conservation, preservation and management of Wildlife. This Act also addresses designated areas of sanctuaries and protection of rare and endangered species.

2.3.3 Protection of Trees and Brushwood Act, 1979

This Act forbids cutting or lopping of trees and brushwood without permission of the concerned Forest Department and demands a NOC from Forest Department before cutting of trees.

2.3.4 Clean Air Act, 1990

This law sets the release of pollutants into the air. It sets standards for air quality and to enforce regulations to protect the environment from airborne pollutants, which are known to be dangerous to human health.

2.4 Procedure for Environmental Approval

This section describes the procedures required for obtaining NOCs from concerned authorities. The following general stages have to be followed in the application and approval process for obtaining an "Environmental Approval" for the said Project.

a. Classification of the Project

b. Submission of IEE

c. Issuance of NOC

Detailed process for obtaining environmental approval (NOC) according to PEPA-1997 is as follows;

a. Classification of the Project

The proposed project requires an IEE in accordance with Schedule-I of PEPA-1997. According to the TOR and Scope of Work of the Project, Consultants are required to prepare the IEE and to assist in obtaining NOC from EPA-Punjab.

b. Submission of IEE

Under Section 12 of the PEPA 1997, a project falling under any category specified in Schedule-I, requires the proponent to file an IEE with the Federal EPA or provincial agency for obtaining the NOC. After preparation of IEE report, eight hard copies and two electronic copies are needed to be submitted to the concerned agencies along with completed Schedule IV form and a non-refundable review fee. In case of the proposed Project, EPD Punjab based in Lahore will be the main government agency responsible for the issuance of an NOC.

c. Issuance of NOC

Within ten working days of the filling of the IEE; the concerned agencies will confirm that the document submitted is complete for the purpose of review. During this time, should the concerned agency require the proponent to submit any additional information, it will return the IEE to the proponent for revision, clearly listing those aspects that need further discussion. Subsequently, the concerned agency should make every effort to complete an IEE review within 45 days of filing and finally decision on IEE shall be communicated to the proponent in the form prescribed in Schedule V. In case of approval, conditional NOC having validity of three years will be issued. The NOC process for IEE is given below in Table 2.2:

Table 2.1: IEE Approval Process

Category	Description
Project Phase	Detailed Design
Approving Authority	Environment Protection Agency Punjab
Applicable Legislation	Pakistan Environmental Protection Act, 1997 (Amendment 2012)
Application File Prepared by	ECOCARE Consultancy Service Private Limited (ECCS)
Project Title	Energy Solutions using Indigenous Resources in Villages
Timeframe	Approximately 12 Months

Pertinent Regulatory Steps	
Submission of IEE	• Review fee as per rates in Schedule III • Filled Application form (Schedule IV) • IEE Report
Decision on IEE	• Decision communicated to proponent in form prescribed in Schedule V • In case of approval, Issuance of NOC

3. DESCRIPTION OF PROJECT

3.1 General

The proposed Project is Hybrid Photovoltaic-Biogas system designed to generate Electricity. For this project, the combination of solar and biogas energy is proposed, with a limited amount of batteries that might be added as an additional backup. Capacity of the Plant will be 300 kW solar PV and 50 kW (100 kW peak) biogas with 200 kWh battery. The combination between the solar and biogas is seems very suitable one; the solar part provides cheap energy during the daytime while the biogas plant provides a reliable supply for the base load. The electricity that will be generated by the proposed Project will be provided to the grid stations already present in the vicinity of Project Area.

This Chapter provides an overview of the proposed Project, its associated components, design considerations, construction procedures and operation and maintenance activities. The Project alternatives are also discussed in this chapter.

3.2 Type and Category of Project

According to the PAK-EPA (review of IEE and EIA) Regulations 2000, this Project falls under Schedule I and the category B (6) stating "Waste to energy generation projects". Since biogas plant is waste to energy generation project thus it falls in above stated category.

3.3 Objective of the Project

The objective of the project is to add an additional power plant in a remote part of the national electric grid in order to provide continuous and sustainable power supply to a specific branch of the distribution grid. The situation in Punjab is that most villages are connected to the electric grid. The goal is therefore not to substitute the grid, but to provide additional power which is available when the grid is not available due to load shedding. During times when the grid is on, the power plant should be able to feed into the grid in order to utilize the free re-sources (sun, biogas when available). The power plant should therefore be able to connect to the grid and feed any excess solar power into the grid, but at the same time, it should be able to disconnect a part of the distribution network from the national grid in order to supply this area in islanding mode during hours of load shedding.

3.4 Project Alternatives

3.4.1 Site Alternatives

Six sites were considered for the proposed Project out of which two most suitable villages are selected for the Solar-Biogas Project. Two IEEs will be prepared for each village. The sites considered for the proposed Project are:

Central Punjab:

- Chak No. 53/RB (Chak Jhumra)
- Chak No. 443/GB (Tehsil Samundri, District Faisalabad)
- Sath Shahani (Jauharabad)

Southern Punjab:

- Chak No. 563/EB (Tehsil and District Vehari)
- Chak No. 131/10-R (Khanewal)
- Kotla Bakhsh, Khairpur Sadaat (Muzaffargarh)

Villages selected for the project are Chak No. 563/EB (Tehsil and District Vehari) and Chak No. 443/GB (Tehsil Samundri, District Faisalabad).

The selection of villages is done based on different factors which are given as under:

- The sites are not falling under any reserved or protected forests
- No environmental profound types such as water bodies, forests and archaeological sites are found in the close proximity of proposed Project.
- Availability, current usage and prices (if applicable) of biomass in the village
- Availability of government land in and around the village and possibility of lease or donation of private land
- Commitment of village community
    - Existence of any committees operating common goods
    - Economic situation of the village

    - Interest of the village community in the project

- Current electricity and load-shedding situation; hours of load shedding, payment situation, current peak and average demand (kW) etc.
- General knowledge on properties & requirements of biomass
- General knowledge requirements solar power plant
- Site inspections of possible land locations for the power plant (beside the villages)

The sites present in above mentioned selected villages are complying these conditions, thus selected for the proposed Project.

3.5 Location and Site Layout of the Project

The proposed site for the construction of project is located at Chak No. 563/EB, Tehsil & District Vehari. The coordinates of the proposed Project Site are 30°04′51.25"N and 72°30′57.15"E. Total area of the proposed site is 2.1 acres which is sufficient to install the proposed Solar-Biogas plant. The map showing location of Project Area and Site layout is given under Annex-C1.

3.6 Land Use on the Site

Currently the site is open and barren land having no structures. Few shrubs are found at project site.


Figure 3.1: Current Land Use on Site

3.7 Road Access

The road that is connecting the village with Burewala- Vehari Road is metaled. This will be used to transport raw material and machinery to the site. The map showing the road access to the site is given below in Figure 3.2:

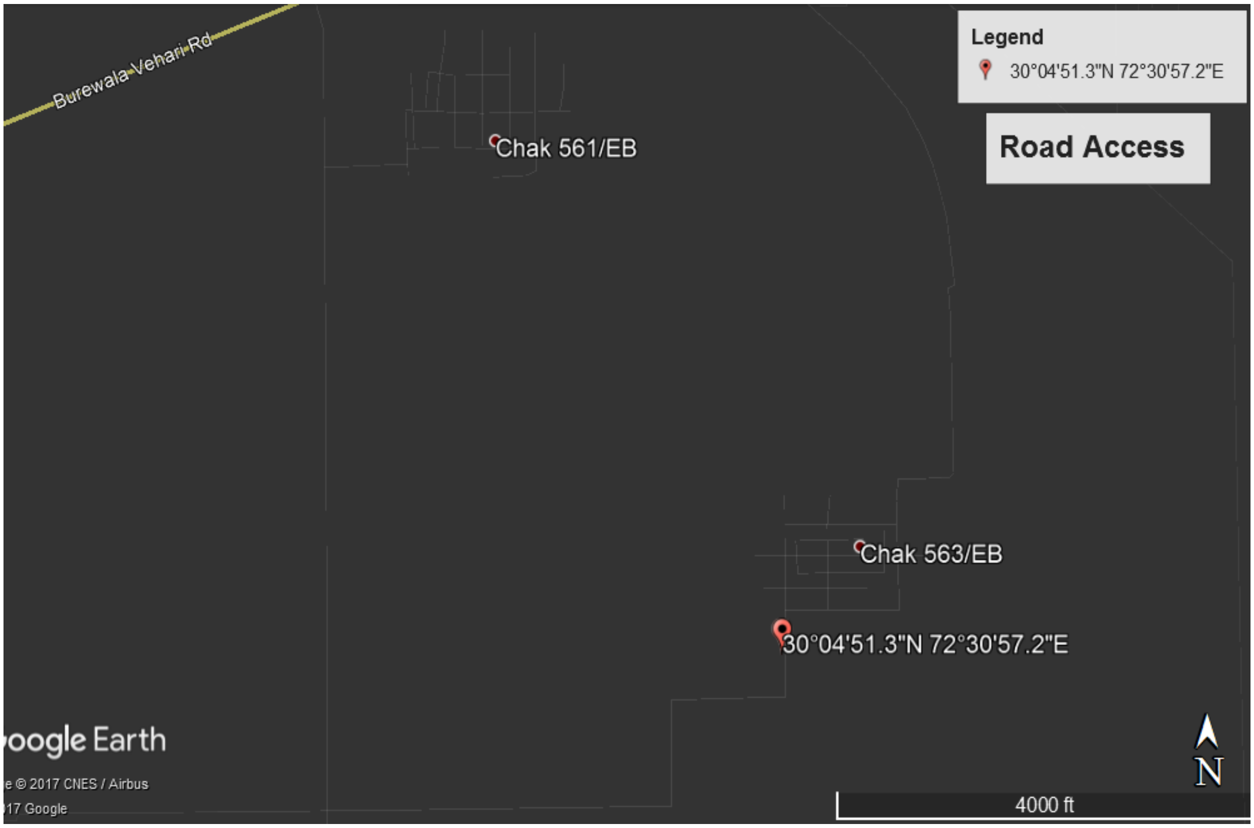


Figure 3.2: Road Access

3.8 Vegetation Features of the Site

Land is clear and there are no significant plants or vegetation present on site, just few species of shrubs are found. So the project will not cause any harm to vegetation of the area.

3.9 Cost and Magnitude of Operation

Total cost of the project is PKR 100 Million. During operation of Project, the solar-biogas plant will have the capacity of 300 kW solar PV and 50 kW (100 kW peak) biogas with 200 kWh battery.

3.10 Capacity of the Project

Capacity of the Plant will be 300 kW solar PV and 50 kW (100 kW peak) biogas with 200 kWh battery. The electricity that will be generated by the proposed Project will be provided to the grid stations already present in the vicinity of Project Area.

3.11 Schedule of Implementation

The period required for the implementation of Project is 12 Months. The timeline for the construction of Project is given below in Table 3.1:

Sr. #	Activities	3 Months			3 Months			3 Months			3 Months		
		4W	4W	4W	2W	4W	6W	4W	4W	4W	4W	4W	4W
1	Detailed Designing												
2	Mobilization of Contractors												
3	Lean Construction Period												
4	Peak Construction Period												
5	Restoration of Site												
6	Commissioning												*

3.12 Description of Project

The project will involve the number of activities during its construction and operation phase. Each activity must comply with the standard practices to carry out that specific work. The project will involve following activities during implementation:

3.12.1 Pre-Construction Phase

The following activities will form part of the pre-construction stage:

- Conducting necessary feasibility studies including the cost benefit analysis and the expected internal rate of return.
- Preparation of the project documents, layout/master plan, architectural & engineering designs and the cost estimates.
- Conducting various investigative studies such as geo-technical studies, environmental impact assessment, and economic feasibility studies.

- Obtaining consents, approvals, and NOCs from different agencies and departments of the Government, wherever applicable.
- Selecting the appropriate and the best suited machinery and equipment for fast track implementation of the project and completion of construction within the scheduled timeframe.
- Signing the contracts for various jobs relating to construction, procurements, installations, and implementation of the project facilities.

3.12.2 Construction Phase

a. Raw Materials and Machinery

Photovoltaic panels will be using the sunlight to generate electricity. Photovoltaic technologies differ primarily by the type of manufacturing process, which leads to different manufacturing costs, price ranges and performances for the different technologies three main solar cell technologies are commercially available:

- Monocrystalline
- Polycrystalline
- Thin Film

Monocrystalline is currently the most common technology and is also supposed to be used for this project.

For biogas plant, raw material will be the biomass that can be animal dung and silage. Biogas, a mixture of methane and other gases, is created by fermenting biomass materials in a biogas reactor. The biogas technology uses this gas for electricity generation through a generator set or a combined heat and power unit (CHP) which makes further use of the combustion heat of the process. The solid end product of the biogas process is organic slurry which can be used as organic fertilizer in the field. Main components of a biogas plant are:

1. Fermenter and digester tanks, often constructed as domes
2. Engine or combined heat and power unit

3. Further storage tanks for solid and liquid feedstock or end products as well as for biogas
4. Additional equipment such as a crusher unit for crushing solid feedstock and others.

Similarly, other construction material will also be used to build allied structures such as office, store room, parking area, switchyard, etc. using framed construction technology. The framed structure will consist of Reinforced Cement Concrete (RCC) using mainly steel, cement and sand aggregate for construction purposes.

b. Manure Availability

Manure availability is the key factor for the success of biogas plant. Number of Cows and Buffalos in village is above 3000 and their dung is abundantly available to be used as raw material for the biogas production. Villagers are also willing to provide dung for the biogas plant.

c. Contractor's Facilities

Contractor will have to construct facilities for labor, machinery and vehicles, etc. There is a lot of space available for this purpose without disturbing any resident, ecology or the infrastructure.

d. Workforce Required

During construction phase of the Project 15 persons are required that will includes masons and labors. During operation phase of Project 3-4 persons are required for the maintenance and operation of the Plant.

e. Electricity Supply

Primary source of power will be WAPDA. A generator of 250 kVA will be there on standby mode.

3.12.3 Operation Phase

The operation phase of the proposed Project will involve the operation and maintenance of Plant. The activities involved in operation of the Project are preparation of slurry that will be used as raw material for biogas generation, maintenance of biogas plant, washing of solar panels that may be tainted by dust, birds excrement etc.

a. Operation and Maintenance of Solar Panels

i. Performance Monitoring

The operation of solar power plant is relatively simple and restricted to daylight hours. With automated functions of inverter and switchyard controllers, the maintenance will mostly be oriented towards better upkeep and monitoring of overall performance of the system. The solar PV system requires the least maintenance among all power generation facilities due to the absence of fuel, intense heat, rotating machinery, waste disposal etc. However, keeping the PV panels in good condition, monitoring and correcting faults in the equipment and cabling are still required to get maximum energy from the plant.

ii. Washing of Panels

The solar facilities operation hardly gets appropriate attention to reduce the losses in a long time. They are vulnerable to on-site omnipresent practicalities such as deposition of dust, bird droppings, sand, tree leaves and salted water stains can significantly degrade the efficiency of solar thermal installations. In recent research works and investigations revealed realize how significant performance loss caused by soiling of PV modules. Soiling accounts for dirt, snow, and other foreign matter on the surface of the PV module that prevents solar radiation from reaching the solar cells. Dirt accumulation is location and weather dependent. The solar modules are increasingly soiling during their operating life causing losses in their electric power production. Thus periodic washing of solar panels will be required during operation phase. Since, water is used only for the cleaning purpose of solar PV modules to remove dust from it. The discharge water does not include any chemical or hazardous material.

b. Operation and Maintenance of Biogas Plant

i. Raw Materials Handling

Raw material handling covers the preparation of many different types of raw materials for gas production. For example: liquid manure, silage, sewage sludge, organic waste, straw etc. Upon delivery, the materials are first weighed, and then put into storage.

ii. Biogas production

Biogas is produced by fermenting substrates with the exclusion of air to generate a combustible gas containing between 40% and 75% methane. That makes biogas, which primarily comprises methane, a high value source of energy. The quantity of biogas generated depends on factors such as: temperature, residence time and the composition of the substrate in the fermenter.

iii. Biogas utilization

Raw biogas has to undergo further processing before it can be used. The automation technology has to be designed to match the way the biogas is going to be used. The gas will be burnt in a power plant to generate electricity.

iv. Residue Handling

Fermentation residues remaining after the fermentation of biomass in a biogas plant are either liquid or solid residues. Because of its high concentration of nutrients, it will be used as agricultural fertilizer.

v. Maintenance of Biogas Plant

Maintenance is the key factor for the successful operation of any Plant. A biogas plant has to be monitored and controlled. As well as accounting for all the quantities of materials brought in and produced, it is particularly important to fulfill the documentation duties for the gas and energy production. A certain degree of automation ensures profitable and trouble-free operation of the plant.

3.12.3 Process Flow Diagram of Solar-Biogas Plant

In operation phase of the Solar-Biogas Plant, the project will involve a set of processes which will convert solar energy and biogas into electricity. Process flow diagrams for both solar and biogas plant are given as under:

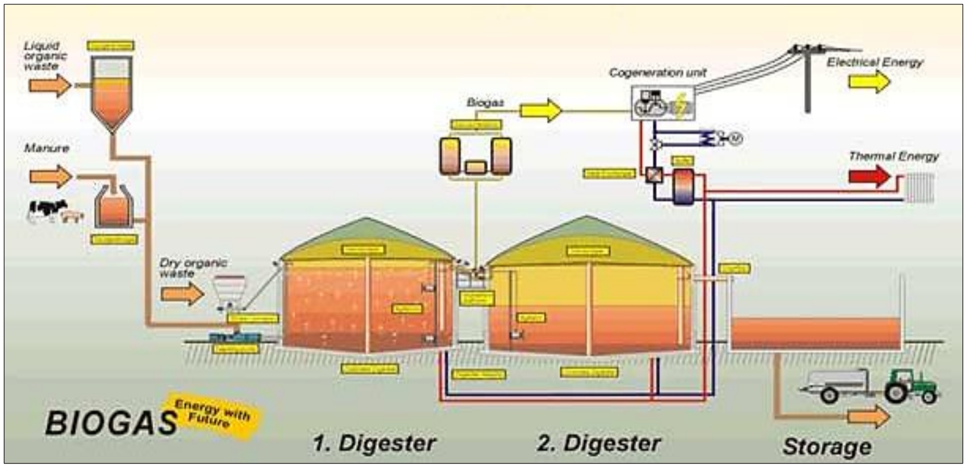


Figure 3.2: Process Flow Diagram of Biogas Plant

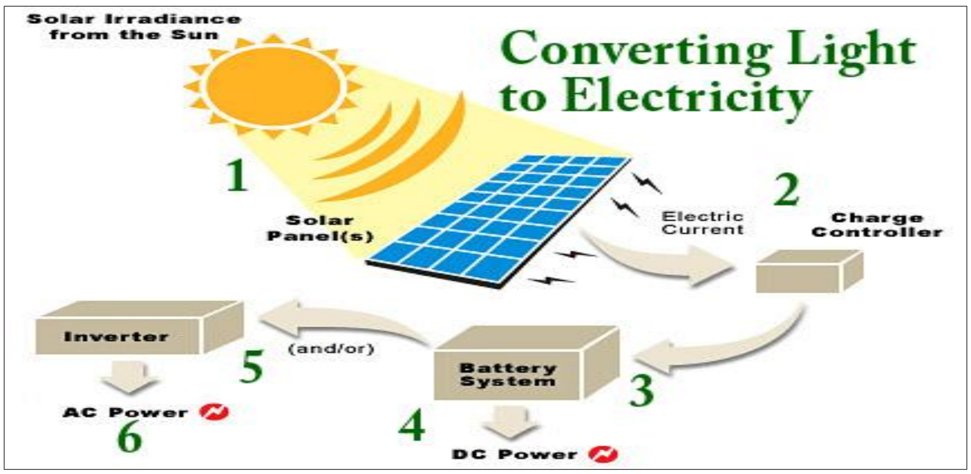


Figure 3.3: Process Flow Diagram of Solar Plant

3.13 Restoration and Rehabilitation Plan

After completion of the construction work all the disturbed sites will be changed into conditions as they were prior to the commencement of the project or better than that. The area will be planted with indigenous vegetation. All the concrete will be broken and disposed of according to the rehabilitation plan. To improve the environmental and aesthetic value or visual quality of the site once construction ceases, the proponent will carry out landscaping and tree planting. The fences will be removed, the burrow areas will be leveled and top soil will be restored after the construction.

3.14 Government Approvals

Approvals from all the concerned departments will be provided by the client.

4. APPROACH AND METHODOLOGY

This chapter deals with technical approach and study methodology applied for evaluating the potential environmental impacts which has been conducted in accordance with Environmental Protection Agency Punjab Guidelines 2000. This study aims at finding out the possible ways for the protection, conservation of the environment to mitigate the impacts from the construction of proposed Project. Initial Environmental Examination (IEE) study is a formal procedure for investigating, analyzing and presenting the environmental implication of a proposed development and identifying mitigation measures required to trim down the adverse environmental impacts by taking it to acceptable levels. In so much that Initial Environmental Examination (IEE) shall have to be carried out to ensure issues associated with the project foreseen and potential benefits brought to light prior to implementation in an objective way, considering regional development issues, as well as legislative and institutional aspects.

4.1 Study Area

An area around the project can be considered as influence zone and hence it has been taken as Study Area (SA) to collect the primary data related to physical, ecological and socio-economic environment.

4.2 Project Area

The boundary of that specific area where the project is going to be established is taken as Project Area

4.3 Technical Approach

A typical technical approach followed in conducting the IEE study is given as under:

- Prepare the project specific Questionnaire and checklist to conduct the baseline data collection of the study Area.
- Carry out the baselie survey of the Study Area which is supposed to be influenced by the proposed Project.
- Carry out baseline evaluation to identify the present environmental conditions in the Study Area on the basis of available data field investigation and monitoring.

- Invite experienced environmental experts to discuss and examine the environmental impacts and major environmental issues in the light of Project scheme and present environmental setting.
- Predict the environmental impacts caused by the Project upon special study and simulation incorporating experts' opinions.
- Evaluate the environmental impacts caused by the Project according to relevant laws, regulations, standards and the predicted results
- Put forward remedial measures to assess the residual impacts and evaluate whether they meet the relevant policies and standards or not.
- Make environmental monitoring plan to evaluate the actual environmental impacts and the effectiveness of the remedial measures.

4.4 Adopted Procedure

The IEE approach, methodology and procedure were generally followed according to the provisions of the PEPA Act, 1997. Field survey was conducted on 23 July, 2017 by professional team of the ECCS to collect the Socio-Environmental baseline data of the Study and Project Area. The following procedure is adopted to carry out the IEE study:

- Desk Analysis
- Collection and review of secondary sources of information
- Preparation of Project Specific Checklist
- Field Survey
- Compiling and collection of Existing Information
- Impact Identification and Mitigation Measures
- Environmental Management and Monitoring Plan
- Conclusion and Recommendations
- Compilation of final IEE report according to EPA guidelines

4.5 Survey of the Study Area

A multi-disciplinary team visited the Study Area of which the Project Area makes an integral part for updating/verification of the baseline information on physical, biological, socio-economic and cultural environment to evaluate the anticipated environmental impacts and propose the practical mitigation measures.

Following team of professionals was responsible for data collection, field study, analysis and report writing:

1. Mr. Noman Ashraf, Environmentalist, recorded baseline data of physical, ecological and socio-economic environment through structured Socio-Environmental checklists and also helped out other team members in record keeping.

2. Mr. Arslan, Enumerator, recorded village profile i.e. demographic, social and economic information of the village through structured questionnaire.

3. Ms. Farwa Batool, Environmental Engineer, Prepared project specific questionnaires, analyzed and compiled the baseline data of the Study Area, determined the sources of impacts and suggested mitigation measures to reduce potentially adverse environmental impacts to protect and preserve water, air and soil by keeping them free of contaminants and pollutants. After determining the severity of impacts she devised the EMMP and prepared the detailed IEE report according to guidelines of EPA.

4.6 Mitigation Measures and Monitoring Plan

Mitigation and monitoring prescriptions were developed having based on the identified impacts their nature, extent and magnitude. A realistic approach was applied for the application of the mitigation measures in the local context. Environmental monitoring plan was developed to assess the effectiveness of the mitigation measures and implementation status.

4.7 Structure of Report

This IEE Report reviews information on existing environmental attributes of the Study Area. In which geological, hydrological and ecological features, air quality, noise, water quality, soils, social and economic aspects and cultural resources are included. The report predicts the probable impacts on the environment due to the proposed sub-project enhancement and expansion. This IEE Report also proposes various environmental management measures. Following this introduction, the report includes:

- The environmental and social regulations which are pertinent to the proposed Project
- Description of Project
- Description of Environmental and Social Baseline Conditions
- Assessment of Environmental Impacts and Mitigation Measures
- Environmental Management and Monitoring Plan
- Recommendations and Conclusions

4.8 The Final Report

The IEE report was prepared by untiring efforts of above mentioned study team. After reviewing the final IEE report according to TOR, it will be submitted to Environment Protection Agency (EPA) through client for approval.

5. SOCIO-ENVIRONMENTAL BASELINE CONDITIONS

5.1 General

This section describes the existing environmental conditions around the proposed Project Area. Information that has been collected from different sources including public literature, reports of other studies conducted in this area, knowledge with the proponent and the concerned government departments and the first-hand surveys and field measurements has been presented in this section. This encompasses all the important aspects of local environment; such as Physical, Ecological and Socio-economic resources.

5.2 Study Parameters

The existing information to establish a database for the IEE of the proposed project was collected from different government departments; review of previous studies and through the site visits carried out in the Project Area. To comprehend the existing environmental conditions, a site survey was conducted and salient observations were duly noted. The pertinent data were also collected from the Census Report of Vehari District. In addition to the Census Report, relevant government departments were also consulted for related data.

The Social Assessment of the proposed Project Area was conducted through consultation with the community. Area residents were interviewed to get their opinions and views regarding the construction of the proposed Project.

5.3 Physical Environment

This part examines the physical resources such as Geography, Geology and Soils, Topography, Land use, Climate, Surface and Ground water resources and quality and Ambient Air quality of not only the project site but also the village as a whole to assess whether the project under assessment can have any adverse impact on any of these parameters. Following is a brief description of various physical resources of the Study Area, of which the Project Area makes an integral part.

5.3.1 Geography

The Vehari District is located between 29°36′ N 71°44′ E and 30°22′ N 72°53′ E and borders with Bahawalnagar and Bahawalpur on the southern side, with Pakpattan on the eastern, with Khanewal and Lodhran on western and with Sahiwal and Khanewal on northern side. The total area of the district is 4,364 square kilometres (1,685 sq mi). It is about 93 kilometres (58 mi) in length and approximately 47 kilometres (29 mi) in breadth and it is sloping gently from North-East to South-West.[2]

The coordinates of the proposed Project Site are 30° 04′ N and 72° 30′ E.

5.3.2 Geology and Soils

Geologically the lands constituting Vehari are made of sedimentary rocks of quaternary types. The soils of the district are quite fertile. This fertility is reflected in the vast agricultural lands that dominate the scenes in the district. The soils in the district have been deposited by the rivers - River Beas which used to flow in the northern part of the area which now forms the district and River Satluj that flows in the south. The soils lying in the belt that borders River Satluj are those which are found in the active or young flood plains. The soils in the rest of the district are those that are found in the older flood plains.

5.3.3 Topography

Topography of Vehari is flat. There is not much diversity in the physical features of the district and the area appears to be monotonous.

5.3.4 Land Use

In terms of use of land, much of the district is now composed of arable lands dotted with human settlements. The district is covered with a vast network of canals. Two main canals, Mailsi and Pakpattan with their networks irrigate the district. Total number of canals including their minors in the district is 119 with total length of 1380 km approximately.[3]

[2] District Vehari Hazard, Vulnerability and Development Profile; Published by: Rural Development Policy Institute (RDPI), Islamabad 2010

[3] District Vehari Hazard, Vulnerability and Development Profile; Published by: Rural Development Policy Institute (RDPI), Islamabad 2010

5.3.5 Climate

Climatically Vehari is hot, arid and very dry as it receives less than 125 mm of annual rainfall. May, June and July are the hottest months and the mean maximum and minimum temperatures for these months are 42°C and 28°C respectively. The winters are mild and January and February are considered to be the coldest months and mean maximum and minimum temperature during these months are recorded to be 22°C and 8°C respectively. Dry, hot and dusty winds are common during summers. The district receives its share of rains mostly in the monsoon from July to September and very little rainfall during winters[4]. The details of climatic parameters are further discussed below:

a. Temperature and Precipitation

The average annual temperature and precipitation data is shown below in Table 5.1:

Table 5.1: Average Temperature and Rainfall for Vehari District[5]

Month	Temperature °F		Average Rainfall (mm)		Average snow days	Average Fog days
	Average		Daily	Monthly		
	max	min				
January	54.1	41.9	0	0	0	7
February	57.7	39.9	0.1	3	0	3
March	56.7	42.3	0	0	0	1
April	64.0	41.9	0	0	0	0
May	64.0	51.6	0.1	3	0	1
June	64.4	52.0	0	0	0	0
July	54.1	55.4	1.5	45	0	0
August	71.4	53.6	0.2	6	0	0
September	59.7	50.7	0	0	1	0
October	71.6	58.5	0.3	9	0	0
November	60.8	51.4	0.1	3	0	1
December	56.7	46.6	0.1	3	0	7

[4] [Cited 01 Aug, 2017]; available from (https://www.meteoblue.com/en/weather/forecast/modelclimate/vehari_pakistan_1162813)

[5] [Cited 01 Aug, 2017]; available from (https://www.meteoblue.com/en/weather/forecast/modelclimate/vehari_pakistan_1162813)

The average annual trend for temperature and precipitation is shown below in Figure 5.1:

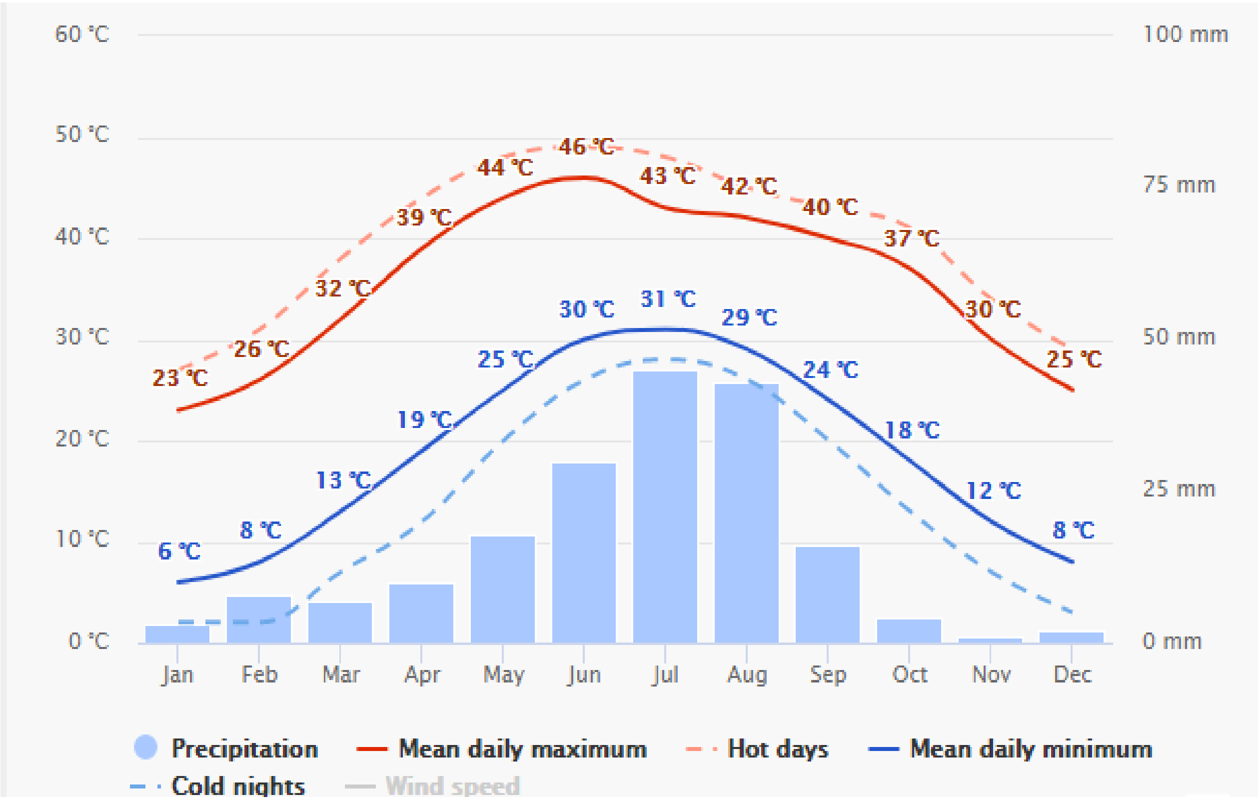


Figure 5.1: Average Temperatures and Precipitation

The "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Faisalabad. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years.[6]

b. Wind Speed

Wind speed of Vehari District varies throughout the year. Maximum wind speed recorded in July that is 14 km/h and minimum in October to December that is 7 km/h.

6 [Cited 02 Aug, 2017]; available from (https://www.meteoblue.com/en/weather/forecast/modelclimate/vehari_pakistan_1162813)

Average speed for whole year is 9.9 km/h. Following Table 5.2 shows the average wind speed for each month.

Table 5.2: Wind Speed[7]

Month	Average Wind Speed (km/h)
January	8
February	9
March	10
April	10
May	11
June	13
July	14
August	13
September	10
October	7
November	7
December	7
Average for whole year	**9.9**

The following figure shows the Maximum, Minimum and Average wind speed for each month.

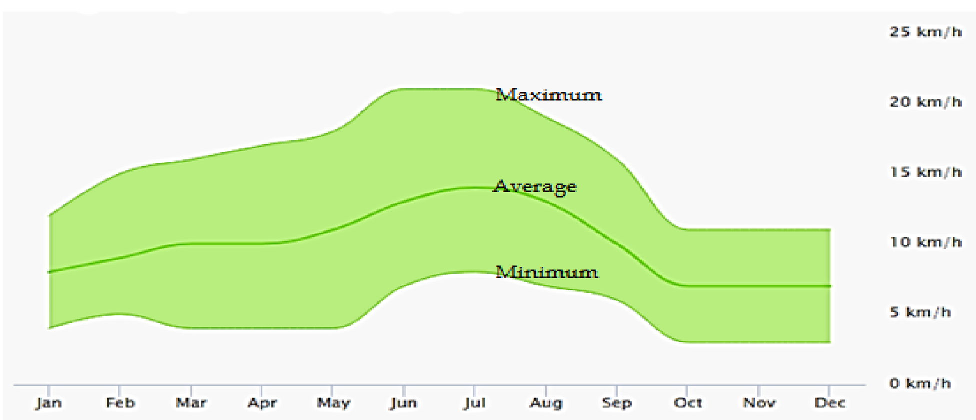
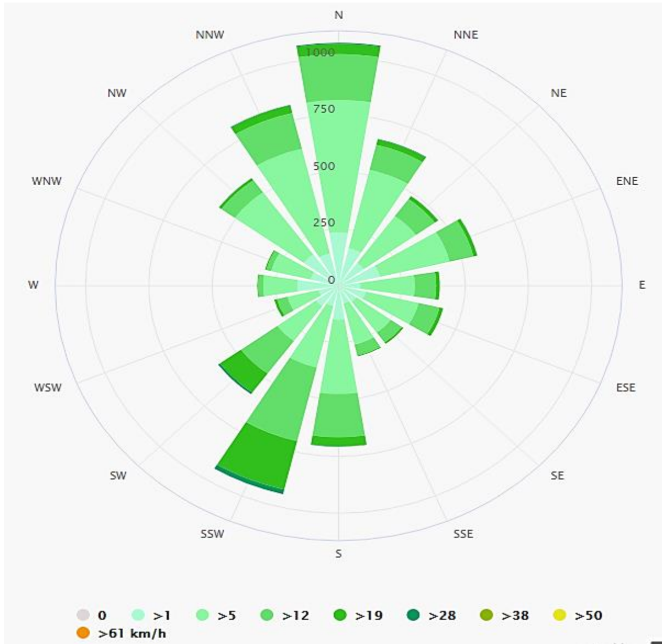


Figure 5.2: Average Wind Speed

[7] [Cited 19 Aug, 2017]; available from (https://www.meteoblue.com/en/weather/forecast/modelclimate/vehari_pakistan_1162813)

c. Wind Direction

Wind rose diagram of District Vehari is shown below[8]. Wind rose for Vehari shows for how many hours per year the wind blows from the indicated direction. For example, SW means the wind is blowing from SW to NE.



d. Sunshine

The sunshine patterns for a specific area vary accordingly. For each month, the number of sunny and cloudy days of Vehari District is shown below in Figure 5.3[9]:

[8] [Cited 19 Aug, 2017]; available from (https://www.meteoblue.com/en/weather/forecast/modelclimate/vehari_pakistan_1162813)

[9] [Cited 02 Aug, 2017]; available from (https://www.meteoblue.com/en/weather/forecast/modelclimate/vehari_pakistan_1162813)

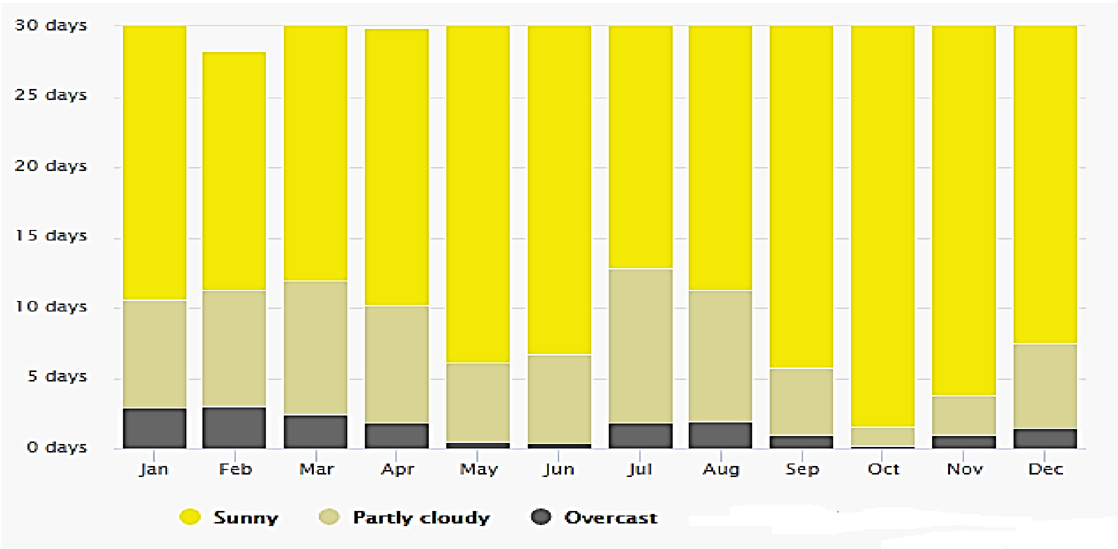


Figure 5.3: Average number of Sunny and Cloudy Days

The graph shows the monthly number of sunny, partly cloudy and overcast days. Days with less than 20% cloud cover are considered as sunny, with 20-80% cloud cover as partly cloudy and with more than 80% as overcast.

5.3.6 Ambient Air Quality

The monitoring of air has been conducted to analyze the ambient air quality of the Study Area. Equipment used for monitoring was Haz Scanner HIM 6000 Air Quality Monitoring Station. The results of which are shown below:

Table 5.4: Ambient Air Quality

Parameter	Observed Value	NEQS	Unit
Carbon Monoxide	0.0	10	mg/m^3
Sulphur Dioxide	3.80	120	$\mu g/m^3$
Nitrogen Dioxide	27.40	80	$\mu g/m^3$
Particulate Matter	82.0	150	$\mu g/m^3$

The results of monitoring shows that the major air pollutants i.e. carbon monoxide, sulphur dioxide, nitrogen dioxide and particulate matter are within NEQS.

Noise level was also measured on Project site, the noise level recorded at project site was 74.2 dB which is within NEQS (75 dB).

5.3.7 Water Resources

a. Surface Water

As stated earlier, the district is covered with a vast network of canals. Two main canals, Mailsi and Pakpattan with their networks irrigate the district. Total numbers of canals including their minors in the district are 119 with total length of 1380 km approximately.

b. Ground Water

Vehari is a plain with a minor slope of its general area towards North South. It lays between Sukh Bias; non perennial Nala and River Sutlej.[10]The shallow sub soil water of Vehari is brackish and unfit for human consumption. However the water at deeper depth is of good quality. Present source of water supply system is with deep Tube wells installed at depth of 400ft. Water table is at 60-65 feet.

Laboratory monitoring of ground water of Project site was conducted in order to analyze its quality. The results of which are shown below in Table 5.3:

Table 5.5: Ground Water Quality Analysis

Sr. No.	Parameter	Units	WHO Guidelines	Concentrations	Methods
1	pH	-	6.5-8.5	7.35	pH Meter
2	Total Dissolved Solids	mg/l	1000	952	Evaporation
3	Iron Total	mg/l	0.3	0.05	Atomic Absorption
4	Calcium Hardness	mg/l	-	220	Digital Titrator
5	Magnesium Hardness	mg/l	-	140	Digital Titrator
6	Total Hardness	mg/l	-	354	Digital Titrator
7	Sodium	mg/l	200	169.3	Flame Photometer
8	Potasium	mg/l	-	4.9	Flame Photometer
9	Arsenic	mg/l	0.01	0.03	Atomic Absorption
10	Chloride	mg/l	250	184	Digital Titrator
11	Flouride	mg/l	1.5	0.60	Spectrophotometer
12	Sulphate	mg/l	250	150	Spectrophotometer
13	Nitrate	mg/l	50	20	Spectrophotometer
14	Total colony count	cfu/ml	500	>1500	Culture
15	Total Coliforms	cfu/100ml	0	0	Culture
16	Faecal E. Coli	cfu/100ml	0	0	Culture
17	Feacal Enterococci	cfu/100ml	0	0	Culture

[10] Punjab Municipal Services Improvement Project (PMSIP) Planning Status Report – Vehari

The results of ground water quality analysis shows, almost all the parameters are within safe limits of WHO.

5.4 Ecological Environment

The ecological environment of an area is generally considered sensitive to large-scale developments. Disturbances and imbalances in the ecological environment can adversely affect the biodiversity features of an area. The biodiversity of an area generally reflects the abundance and richness of the biological and or the ecological resources.

5.4.2 Flora

a. Forests

The study area is devoid of any specific or major plantation except a few ordinary trees. There is no major forest plantation within the zone of influence of the project.

b. Trees

The diversity and distribution of plant species within the Vehari district depends upon the availability of water and the underlying geology. The trees existing in the Study and project Area mostly consist of Neem, Taali, Keekar etc. The botanical names of trees present in study area are shown below in Table 5.2:

Table 5.2: Trees present in Study Area

Sr. No.	Local Name	Botanical Name
1	Neem	Azadirachta indica
2	Taali	Dalbergia sissoo
3	Keekar	Vachellia nilotica

c. Grasses

Some of the common grasses present in Study and Project Areas are Boi Grass, Dab Grass and Gorkha Grass. The botanical names of above stated grasses are shown below in Table 5.3:

Table 5.3: Grasses present in Study Area

Sr. No.	Local Name	Botanical Name
1	Boi Grass	Cyperus
2	Dab Grass	Desmost Achya
3	Gorkha Grass	Elionurus Hirsutus


Figure 5.4: Major Grasses of Study Area

d. Shrubs and Herbs

The shrubs and herbs provide nutritious supplemental feed to livestock during lean period because they are perennial and have depth root systems. Some of the common Shrubs and Herbs present in Study and Project Area are Karer, Jand, Aak, Kana and Lana; Botanical names of which are shown below in Table 5.4:

Table 5.4: Major Shrubs and Herbs of Study Area

Sr. No.	Local Name	Botanical Name
1	Karer	Capparis Decidua
2	Jand	Prosopis Cineraria
3	Aak	Calotropis Procera
4	Kana	Sueda Fruiticosa
5	Lana	Saccharum Munja


Figure 5.5: Major Shrubs and Herbs of Study Area

e. Endangered Floral Species

No such plant species is encountered at Study Area that is endangered or declared protected under national, provincial or local government definitions as well as international agreements/protocols ratified by Government of Pakistan.

5.4.3 Fauna

The study on terrestrial fauna in the Study Area is based upon the field investigation and reports of Forest Department. A variety of animals is found in Study Area which is categorized as Mammals, Birds, Reptiles and Amphibians.

a. Mammals

Some of the common Mammals found in Study Area are Jackal, Dog and Monkey. Following Table gives the Common and Zoological names of Mammals:

Table 5.5: Mammals present in Study Area

Sr. No.	Common Name	Zoological Name
1	Jackal	Canis Aureus
2	Dog	Canis Lupus Familiaris
3	Monkey	Macaca Fascicularis

Figure 5.6: Major Mammals present in Study Area

b. Birds

Native species of birds present in Study Area are Pigeon, Sparrow, Crow, Dove, Quail and Grey Francolin. Common and Zoological names of birds are given in Table 5.6:

Table 5.6: Major Birds present in Study Area

Sr. No.	Common Name	Zoological Name
1	Pigeon	Columbidae
2	Sparrow	Passeridae
3	Crow	Corvus
4	Dove	Columbidae
5	Quail	Coturnix Coturnix
6	Grey Francolin	Francolinus Pondicerianus

c. Reptiles and Amphibians

The native species of Reptiles and Amphibians observed in Study Area are Snake, Lizard and Frog.

Table 5.7: Reptiles and Amphibians of Study Area

Sr. No.	Common Name	Zoological Name
1	Snake	Serpentes
2	Lizard	Lacertilia
3	Frog	Anura

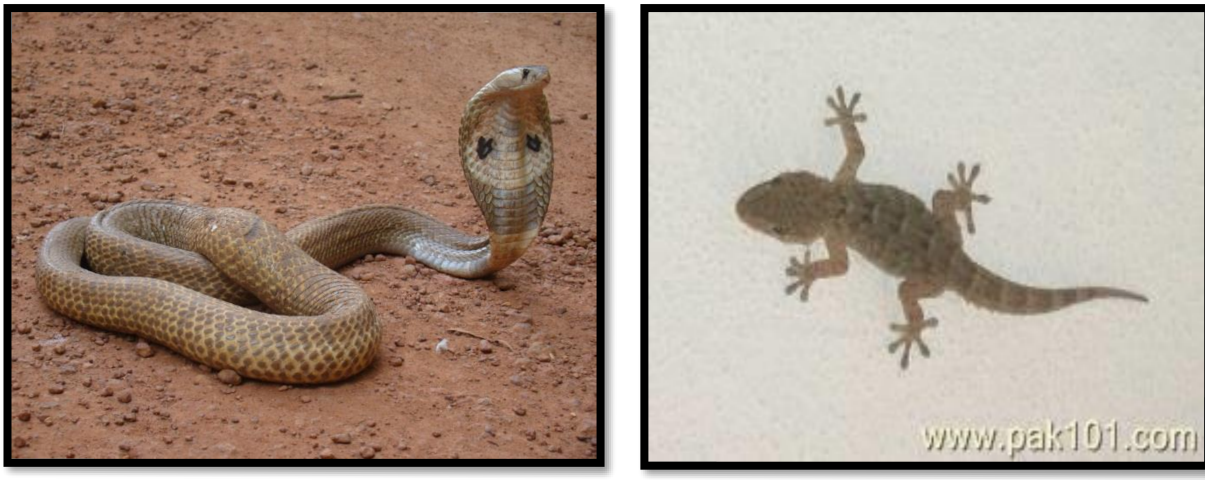


Figure 5.7: Common Reptiles and Amphibians in Study Area

d. Endangered Faunal Species

None of the faunal species encountered at Study Area is endangered or declared protected under national, provincial or local government definitions as well as international agreements/protocols ratified by Government of Pakistan.

5.5 Socio-Economic Environment

This section provides an overview of the baseline information relating to the socio-economic environment of the Study Area. The information collected from the respondents comprised their occupation, civic facilities, educational and health facilities, agricultural status including livestock population.

5.5.1 Demographic Profile

Vehari is a populous district. It is estimated that by the year 2006, the population of the district had reached 2.5 million. Like the uniformity in the area, the population within the district also appears to be somewhat evenly distributed among the three tehsils of this district. During last one decade the population growth rate is estimated to have reduced from 2.7% recorded for the period 1981-98 to 2.23% during the period 1998-2006. However despite this reduction in the population growth, the rate is still higher than the national and provincial level population growth rates (Pakistan: 2.14% and Punjab: 2.0% for the period 1998-2006). Since 1981, there has been an increase of 87.7% in the population of Vehari and from 1951 to 2006, there was 347% increase in the population.[11]

Table 5.8: Population Statistics of Vehari District[i]

District/Tehsil	Population (Thousand Persons)				
	1951	1961	1972	1981	1998
Tehsil Burewala	200	265	369	473	730
Tehsil Mailsi	185	226	342	442	705
Tehsil Vehari	173	213	317	414	655
Vehari Distt.	558	704	1028	1329	2090

In terms of population balance or male female sex ratio, an improvement has been made. From a male-female sex ratio of 112 recorded in Census 1981, the ratio was noted to have improved to 108 in 1998.

Table 5.9: Male Female Ratio

District/Tehsil	Sex Ratio (Males per 100 Female)	
	1981	1998
Tehsil Burewala	111	107
Tehsil Mailsi	111	108
Tehsil Vehari	112	108
Vehari Distt.	112	108

Vehari is rural in nature as the vast majority of its population lives in rural areas. In 1998, the population living in the urban settlements of the district was recorded to be 16% of the total population of the district. Burewala is the most urbanized (urban population 21%) and Mailsi is the least urbanized (12% urban population).[12]

[11] District Vehari Hazard, Vulnerability and Development Profile; Published by: Rural Development Policy Institute (RDPI), Islamabad 2010
[12] District Vehari Hazard, Vulnerability and Development Profile; Published by: Rural Development Policy Institute (RDPI), Islamabad 2010

Table 5.10: Comparison of Urban and Rural Population

District/Tehsil	No. of UCs			Population(as per 1998 census)			1998 Urban Proportion (%)
	Total	Urban	Rural	Total	Urban	Rural	
Tehsil Burewala	32	6	26	730	152	578	20.8
Tehsil Mailsi	31	5	26	705	89	616	12.6
Tehsil Vehari	26	4	22	655	94	561	14.4
Vehari Distt.	89	15	74	2090	335	1755	16.0

5.5.2 Demographic Information of Project Area

The village present in the vicinity of Project Site is "Chak No. 563 EB, Vehari". The project area was surveyed by Professional Environmentalists of ECCS on 23 July, 2017. According to the information collected from survey, the approximate population of the village is 1500 persons. The village comprises of total 350 houses approximately. The major languages spoken are Punjabi, Saraiki and Urdu. The accessibility to village is through metaled road. The results of socio-economic baseline survey have revealed that on overall basis 10% of population is of Project Area is Illiterate, 30% Primary, 25% Matric, 20% Inter, 10 % Graduate and 5 % Masters. The major occupation of the residents is Agriculture.

5.5.3 Physical Structures

According to information collected through survey, a number of structures are present like houses, shops, primary schools, deeni madrassa and community place.

a. Religious Structures

In the surveyed areas, mosques, shrine and graveyard are present. the mosques present in area are Jamia Masjid Qubba, Panjtan Pak Masjid and Ahle Bait Masjis. The shrine of Baba Wali Muhammad Chisti Sabri is present in the village under study.

b. Protected Structures

There is no protected site, present in the Project Area.

c. Historical and Cultural Heritage

The project area does not have any cultural and historical heritage.

5.5.4 Education

Poor educational facilities are available in the village. Two primary schools are present; one for girls and other for boys but the quality of education and facilities is very unsatisfactory.

5.5.5 Health

The village is lacking the basic health care facilities; no hospital or dispensary is present in the area, only one rural health center is present having insufficient facilities and poor standard.

5.5.6 Civic Facilities

According to survey, majority of the area is entertained with the basic facilities like water supply, drainage system, electricity, telephone, livestock market, grocery shops and play grounds. The village is lacking the Gas supply system which is crucial need of the residents.

5.5.7 Welfare Organizations

Local and international NGOs are working for the welfare of local community. Plan Pakistan which is an international donor NGO and Islahi Taraqqati Tanzeem which is a local organization are present in the village.

5.5.8 Agriculture

a. Prevailing Crops

Majority of the population is associated with Agriculture. The main crops which are being cultivated in the area are Wheat, Cotton and Sugarcane. These crops are cultivated and harvested in their respective seasons and after harvesting, products are sold to market to earn profit.

b. Prevailing Livestock

Common domestic livestock is found in area. The prevailing livestock is Buffalo, Goat Sheep and Cow. These animals are reared to get milk and meat; which are then supplied to nearby area to earn livelihood. Following Table gives the Common and Zoological names of Livestock animals present in Study Area:

Table 5.5: Common Livestock present in Study Area

Sr. No.	Common Name	Zoological Name
1	Buffalo	Bubalus Bubalis
2	Cow	Bos Taurus
3	Goat	Capra Aegagrus Hircus
4	Sheep	Ovis Aries

Figure 5.6: Common Livestock present in Study Area

5.5.9 Occupation of Population

Most of the people of the area are linked with Agriculture. Minority of population is associated with Government and Private Jobs.

5.5.10 Common Diseases

In this area, common diseases are Common Cold, TB (Tuberculosis), Typhoid, Malaria, Goiter, Dysentery and Hepatitis.

5.5.11 Quality of Life Values

People of the proposed area have non-nomadic life style and are living here from times of their ancestors. Both Family Systems (Joint and Nuclear Family System) are found in the proposed area. The major occupation of the people, residing in the proposed area, is agriculture.

5.5.12 Favor of Proposed Project

Almost 100% of the village population is in favor of the project and are also willing to provide animal dung, crop residues and other waste i.e. poultry excrements for the Biogas plant.

5.6 Lab Reports of Environmental Analysis

Laboratory testing of environmental parameters i.e. ambient air quality, ground water quality, noise level has been carried out by certified Environmental Lab. Results of laboratory analysis has been annexed as Annex E.

6. ANTICIPATED ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

6.1 General

The progress of any task surely carries variation in native environment with respect to biological, physical and socio-economic facets. The influences created in these phases leave a positive or negative effect. This Chapter identifies the potential impacts due to the implementation of project "Energy Solutions using indigenous resources in villages" on the physical, ecological and social environment of Project Area. The chapter also identifies measures that will help mitigate the Project's adverse environmental effects and enhances positive impacts.

During manufacturing and subsequent operational stages, every single environmental finding (possible effects) has been assessed with respect to their present situation. That's why these impacts have been identified in terms of their interval, extent and magnitude.

6.2 Impact Prediction Methodologies

To identify or resolve the main impacts, various practices were used. These can be based on:

- Professional judgment with adequate reasoning and supporting data. This technique requires high professional experience
- Experiments or tests but these can be expensive
- Numerical calculations and mathematical models which can require a lot of data and competency in mathematical modeling without which hidden errors may arise
- Physical or visual analysis and detailed description is needed to present the impact
- Geographical Information Systems (GIS)
- Risk assessment
- Economic valuation of environmental impacts

6.3 Impact and Mitigation Management

Purpose of mitigation is to evade, reduce or balance the expected antagonistic effects in suitable way, to integrate these into environmental managing strategy or plan. At every stage of the project, mitigation plan for all the adverse impacts should be predictable and coasted to find out the best alternatives. The objectives of mitigation are to:

- Invent best substitution, means of better alternatives and ways of doing things
- Improve the environmental and societal payback of the project
- Prevaricate, remedying or reduce, provocative impacts
- Certify that remaining negative influences are kept within permissible limits

6.4 Purpose of Mitigation Measures

Purpose of mitigation measures includes that what is the problem, when the problem will occur, when, where and how the problem should be addressed. The answers to these questions are given below:

a. What is the Problem

As the project is the establishment of Solar-Biogas Power Plant so the problem will be the impacts that will likely to cause from the activities involved in construction and operation phase of the project i.e. air pollution, noise pollution, solid waste, wastewater generation etc.

b. When Problem will occur and when it should be addressed

Problem will occur during construction and operational phase when different activities will be done through machinery or manual work. These problems may include noise, solid waste, liquid waste etc. These all problems should be addressed on the spot to avoid the adverse impacts.

c. Where Problem should be addressed

As the problem is generating from the construction and operational of the project so it should be addressed on source i.e. site of the project.

d. How the Problem should be addressed

Proper mitigations measures will be provided according to the nature of the impacts/problems. Details of mitigation measures are further discussed in this chapter.

6.5 Ways of Achieving Mitigation Measures

a. Changing in Planning and Design

Any change in project planning and design i.e. change of technology and location will require revision in mitigation measure accordingly. Since the Project is supposed to be established as it is planned as per feasibility study so there will be no need to revise mitigation measure due to changing in planning and design of the Project.

b. Improved Management & Monitoring Practices

Improving activities will be carried out for betterment while monitoring will also be conducted to keep environment friendly throughout the project construction and operation of the project.

c. Compensation in Money Terms

There will be no damage of fauna, flora or any other resource. So, compensation in money will not be needed.

d. Replacement/ Relocation/ Rehabilitation

Proposed project is located in open land where there is no sensitive area, population or natural resource. So, replacement, relocation and rehabilitation are not required.

6.6 Beneficial Impacts of the Project

6.6.1 Environment Friendly

The project will generate electricity using renewable energy sources i.e. solar and biomass thus having negligible Green House Gas (GHG) emissions thus the projects seems to be environment friendly. Generating electricity from renewable energy rather than fossil fuels offers significant public health benefits. The air and water pollution emitted by coal and natural gas plants is linked to breathing problems, neurological damage, heart attacks, and cancer. Replacing fossil fuels with renewable energy has been found to reduce premature mortality and lost workdays, and it reduces overall healthcare costs.

6.6.2 Uninterrupted Power Supply

The project will supply the electricity to the local grid station and the villagers will enjoy the continuous power supply in order to fulfill their daily tasks in much better way than before. In this way the standard of living will improve and economic condition of the area will rise. Continuous availability of electricity to educational institutes and health care facilities will augment the standard of education and health of the area.

6.6.3 Employment Opportunity to Local People

This new project will affect local community for longer run as providing them supplementary new sort of additional jobs for shorter period of time in construction phase and some for longer period of time in operation phase as well. The poor slum residents and villagers depend on local livestock for their livelihood, generation of edible and medicinal plants. This impact will lead to a significant effect on earnings of local community and thus is considered as positive.

6.7 Impacts Associated with Project Location

As the selected site of the proposed Project is open and barren having no settlement so the project will have no adverse impacts regarding its location.

6.8 Impacts Associated with Project Design

In design phase no considerable impacts will occur on land, soil, topography, ground water, and on people of the area. However in pre-construction phase a management system should be provided at design level so that the possible impacts can be reduced. Design of project will adhere to all standard technical requirements in order to avoid impacts on environment and human health.

6.9 Impacts Associated with Construction Phase and their Mitigation Measures

6.9.1 Topography and Soil

a. Impacts

The construction phase of the solar-biogas project will not have any significant impact on the topography of the area. However, some minor changes in topography are expected due to excavation of pits and other construction works during the construction phase. Improper storage and disposal of construction spoils and unusable wastes can contaminate soil and land.

b. Mitigation Measures

There will be careful handling and minimization of waste as well as stacking of materials and equipment near the construction site of proposed Project. Proper housekeeping will be ensured during the construction phase. All the construction wastes generated will be recycled or will be properly disposed of at the location identified by the PMU in the village. No heavy earth moving machines will be used to minimize impacts to environment.

6.9.2 Rural Services

a. Impacts

During the construction phase there can be some minor impacts in the form of inconvenience to the villagers due to transportation of construction materials. Proper scheduling of transport of construction materials will be able to reduce the inconvenience to the villagers. The particular households where construction of solar-biogas plant will be aware of schedule of construction and will therefore adjust their routine for the small duration of construction. The other utilities such as water supply and electricity supply are not anticipated to be impacted due to construction activities.

b. Mitigation Measures

The construction materials will be transported by forming a proper schedule in the area to avoid inconvenience to the village community.

6.9.3 Surface Water Sources

a. Impacts

No adverse impact on surface water quality is anticipated during the construction phase. The likely expected problems associated during the construction process can be kept under control by adopting proper mitigation measures.

b. Mitigation Measures

During the construction the concerned farmer and construction crew will ensure that construction materials like earth, stone or gravel are disposed off in a way not to block the flow of water of any water course (in the vicinity) and to prevent temporary or permanent flooding of the site or any adjacent area. The water required for construction will be utilized from the allocated domestic supply.

6.9.4 Ambient Air Quality

a. Impacts

Some emissions of dust are anticipated due to transportation and handling of construction materials. Some gaseous emissions may also be generated from vehicle exhausts during transportation of construction materials to solar-biogas plant sites. In case these are transported through animal carts then there will be no generation of gaseous emissions. Pollutants of primary concern at this stage include Particulate Matter (PM) and gaseous emissions. The impacts at construction stage will be temporary and restricted to the close vicinity of the construction site.

b. Mitigation Measures

The ambient air quality impact identified during construction phase is generation of dust. This dust will be suppressed through water spray at regular intervals at the construction site. The project management unit will formulate a water spray schedule and instruct the construction crew and farmer to adhere to this schedule for the suppression of dust.

6.9.5 Noise Levels

a. Impacts

During construction phase, some noise will be generated from the various construction activities like construction works, operation of construction equipment and vehicles engaged in transportation of construction materials. The transportation of construction materials will be organized by the contractor one time only therefore no impacts will be felt on account of this every day. The increase in noise levels is expected to be marginal (between 5 - 10 % of existing ambient noise levels). But these levels will be confined within the premises of construction site and will be limited during day time only. No construction works will be carried out in Night hours.

b. Mitigation Measures

In order to minimize the noise level impacts no construction activity will be taken up during night time.

6.9.6 Debris/ Solid Waste Generation

a. Impacts

During construction phase there will be generation of surplus excavated earth due to creation of pits and left over construction materials that may cause hindrance to the smooth transportation of the villagers if left unattended. Solid waste may also cause blockage in flow of water courses present in the vicinity of project site.

b. Mitigation Measures

The surplus earth, stone grit etc. may be utilized for backfilling of excavation pits. In case it is not required for leveling it will be disposed off at low lying area in the vicinity.

6.9.7 Wastewater Generation

a. Impacts

The contractor's camp will generate wastewater that may contaminate the surface and ground water sources if not disposed of properly.

b. Mitigation Measures

Septic tanks of appropriate design should be used for sewerage treatment and outlets should be released in soakage pit. Ensure that the outlets released into soakage pits must not make a pond of stagnant water. The soakage pit must be of absorbent soil. Effective drainage must be placed at site.

6.9.8 Impact on Flora and Fauna

a. Impacts

The construction activity will be carried out in the proposed site for the Project which is almost open and barren having no significant flora and fauna, therefore, no adverse impact on fauna and flora is anticipated due to the proposed activity. There will be no cutting of any trees. There will be removal of grass and weeds from the location of solar-biogas plant site.

b. Mitigation Measures

No mitigation measures are warranted as no adverse impacts have been identified during construction phase.

6.9.9 Health and Safety

a. Impacts

During construction phase no adverse impacts on health are anticipated due to generation of dust and emissions. The chances of accidents will be there in the initial construction phase when excavation is done for pits. The cattle and passerby will be susceptible to fall in the pits if these are not properly fenced. Other than this no risk is anticipated during the construction period. The construction labors may be prone to some injuries due to non-compliance of personal protective practices.

b. Mitigation Measures

Regular water spray will be taken up to avoid any dust generation and indirect impact on health of construction crew. Ensure the availability of safe drinking water to the workers. During construction phase the excavated pit will properly be fenced, for this project management unit will provide necessary training to the construction crew so that no accident occurs due to falling in the pits. Safety signage must be provided on project site in order to avoid accidents. Proper use of PPEs (details of PPEs will be provided in section 6.11) must be ensured by the crew in order to avoid possible injuries due to the use of construction equipment and machinery.

6.9.10 Socio-economic Conditions

a. Impacts

The implementation of the proposed Project will not involve dislocation or involuntary resettlement of people. The primary benefit of the project would result in overall improved environmental conditions of the village thereby leading to better quality of life. Positive impact is anticipated in terms of employment opportunity as many skilled, semi-skilled and un-skilled personnel will get direct and indirect employment during construction phase.

b. Mitigation Measures

During construction phase no adverse impacts on socio-economic conditions have been identified rather positive impacts are envisaged, therefore no mitigation measures are warranted.

6.10 Impacts Associated with Operation Phase and their Mitigation Measures

6.10.1 Topography and Soil

a. Impacts

During operation phase of the proposed solar-biogas hybrid project, topography will not be affected, therefore no impact is anticipated. During operation phase there will be generation of organic manure as by-product from biogas plant. This manure will be in semi dry form and will be stored in the vicinity of plant in an underground pit. Hence no impact is anticipated on soil of the area. There will be positive impact on soil as farmers will apply this manure to their agriculture fields which will enhance crop productivity.

b. Mitigation Measures

No impacts have been identified on the contrary positive impact on soil has been identified due to generation of organic manure.

6.10.2 Rural Services

a. Impacts

During operation phase there will be positive impact on rural services as villagers may use electricity generated from solar and biogas resources. Therefore a positive impact is anticipated on rural services during operation phase.

b. Mitigation Measures

During operation phase no adverse impacts on rural services have been identified therefore no mitigation measures are warranted.

6.10.3 Surface and Ground Water Contamination

a. Impacts

No impact on surface water sources is anticipated during operation phase. No surface water consumption is anticipated for the operation of solar-biogas plant. The water will be utilized for making the slurry of cattle dung for feeding the biogas plant from the allocated domestic supply. The ground water may get contaminated if there is leakage of biogas slurry from biogas digester. Since, water is used only for the cleaning purpose of solar PV modules to remove dust from it. The discharge water does not include any chemical or hazardous material.

b. Mitigation Measures

Leakages from biogas plant can be restricted by making foundation of biogas digester impervious and concrete lining must be provided in order to avoid possible spills from the plant.

6.10.4 Water Resources and Water Sharing

a. Impact

Solar energy power plant is considered to be an environment friendly technique but water will be used for plant washing and by labor that may put stress on scarce groundwater resources in the vicinity of Noorsar village. There are chances of arguments on equally used or shared water for domestic purpose.

b. Mitigation

Efficient management and utilization of groundwater resources may solve the problem. The generated wastewater will be disposed off directly by using septic tanks and the groundwater resources will be replenished.

6.10.5 Ambient Air Quality

a. Impacts

During operational phase no dust generation is likely. However, there may be accidental leakage from biogas plant if the supply pipe gets ruptured due to any reason. In such situation also no adverse impact is anticipated as methane gas being lighter than air will disperse very fast. Air quality will not be degraded due to solar PV panels as there will no emissions.

b. Mitigation Measures

The quality management staff of the project will ensure the timely maintenance of plant to avoid any potential accidental leakages. Regular maintenance of biogas plant must be guaranteed to identify the technical disruptions on time so that the management actions would be taken.

6.10.6 Noise Levels

a. Impacts

During the operational phase, no impact is anticipated on the noise levels. Therefore, no mitigation measure is required.

b. Mitigation Measures

No mitigation measures are warranted as no impacts have been identified.

6.10.7 Impact on Flora and Fauna

During operation phase no impact on flora and fauna is anticipated as there will be no generation of pollutants from the operation of solar-biogas plant.

b. Mitigation Measures

No mitigation measures are warranted as no impacts have been identified during operation phase.

6.10.8 Debris/ Solid Waste Generation

a. Impacts

During operation phase there will be generation of organic compost which is a by-product from biogas plant. This compost will be reusable as organic manure. The manure produced will need to be properly handled and utilized else it will impact aesthetics of the area and will become the home for flies and mosquitos that may damage the health of villagers.

b. Mitigation Measures

The organic manure will be lifted at regular intervals for utilization in the agriculture farm or house garden/ community plantation.

6.10.9 Accidents and Risks due to Implementation of Biogas Plant

a. Impacts

During operation phase no accidents are anticipated except fire. It may cause if biogas leakage takes place and there is some ignition source close to this leakage.

b. Mitigation Measures

The project management or quality management unit will provide proper training to the maintenance staff for maintenance of biogas plant. The connecting pipe and other appurtenances will be regularly checked to avoid any leakage of the biogas.

6.10.10 Health

a. Impacts

Chances of generation of flies, insects and other worms are there if cattle dung is stored in open for long time due to nonoperation of plant.

b. Mitigation Measures

The chances of formation of insects, worms and flies resulting from cattle dung not being used if the biogas plant is not working can be mitigated effectively. Some of the key components of the proposed Solar-Biogas Hybrid Plant are (i) strict quality control of the plant construction to minimize the need for repair and maintenance, and (ii) provision of trained personnel to ensure timely repair and maintenance to minimize down time of the plant.

6.10.11 Socio-economic Impact

The project will create business opportunities for supply, installation, services of biogas plants and spare parts. It will provide an innovative way of minimizing and managing cattle dung in an environmentally and economically beneficial manner.

6.11 Details of Personal Protective Equipment

There are different types of PPE's available for each type of hazard. Use of PPE's should be ensured for safety of the workers during construction and operation phase of the project. Details of PPEs for each type of hazard are given below in Table 6.1:

Table 6.1: Details of PPEs

Organ	Hazards	PPEs
Eyes	• Dust • Gas and vapors	▪ Goggles ▪ Face screens ▪ Face shields ▪ Visors ▪ Safety spectacles
Head and Neck	▪ Impact from falling or flying objects ▪ Risk of head bumping ▪ Hair getting tangled in machinery ▪ Climate or temperature	▪ Safety helmets ▪ Bump caps ▪ Hairnets ▪ Firefighters' helmets
Ears	• Noise – a combination of sound level and duration of exposure, very high-level sounds are a hazard even with short duration	• Earplugs • Earmuffs • Canal caps
Hands and Arms	• Abrasion • Temperature extremes, • Cuts and punctures • Electric shock • Vibration	• Gloves • Gloves with a cuff • Gauntlets a • Sleeves that covers part or all of the arm
Feet and Legs	• Wet, hot and cold conditions • Slipping • Cuts and punctures • Falling objects • Heavy loads	• Safety boots and shoes with protective toecaps and penetration-resistant • Mid-sole wellington boots and specific footwear, e.g. foundry boots and chainsaw boots
Lungs	• Oxygen-deficient atmospheres Dusts • Gases and vapors	• Fresh-air hose • Compressed airline • Self-contained breathing apparatus

6.12 Decommissioning Phase

The decommissioning process for the biogas plant would consist of the following steps:

6.12.1 Biogas Plant Decommissioning

a. Vessel Emptying and Cleaning

- Remaining silage on the bunkers would be sold to local farmers as cattle feed and transported off site. Alternatively it could be spread on nearby farm fields if its quality was unsuitable for cattle feed. Any solid manure would be loaded and spread on farm fields. The receiving of input material would be halted. All material in the input tanks would be pumped into the plug flow digester and the inside of the input tanks pressure washed. The wash water will be pumped into the secondary digester. The heat in the receiving tank would be turned off. When the retention time in the plug flow digester has been achieved, the material can be pumped into the secondary vessel, the interior can be pressure washed and the wash water added to the storage vessel. The heat in the plug flow digester would be turned off.
- When the retention time in the secondary digester has been achieved, the digestate can be pumped into the tertiary digester, the interior can be pressure washed and the wash water added to the digestate storage vessel. The heat in the secondary vessel can be turned off.
- When the retention time in the tertiary digester has been achieved, the digestate can be pumped into the digestate storage vessel, the interior can be pressure washed and the wash water added to the digestate storage vessel. The heat in the tertiary vessel can be turned off. The engine can be shut down to cease heat production. Any remaining biogas can be flared.
- When field application can be undertaken, the material in the storage vessel should be sold and applied to a farmer's field as fertilizer. All separated solids should be transported off site and sold as solid fertilizer.

b. Equipment Removal

Much of the equipment on site such as engines, pumps, valves and mixers have residual value and can be sold and re-located off site for reuse. Other custom built equipment such as switchgear, heat manifolds and control systems contain parts and materials that can be re-used and would be salvaged. Piping, ducting, electrical cabling and similar materials can be recycled

c. Above Ground Structure Decommissioning

Metal buildings will be removed and recycled, cladding can be recycled and the insulation removed and disposed of. When the digesters and storage vessels have been stripped, the concrete structure as well as all of the other concrete tanks can be demolished and the concrete crushed and re-used.

When the engine/ control room has been stripped, the building can be demolished. Most of the materials can be recycled or re-used. The concrete floor can be broken up and recycled. The security fence can be removed and re-used. Note that silt fencing should be attached to the security fence at the beginning of demolition and not removed until vegetative ground cover is re-established. The transformer can be salvaged and re-used.

d. Below Ground Structure Decommissioning

All of the below ground concrete associated with the vessels and tanks can be demolished and removed for recycling. All underground wiring can be pulled out of their ducts and recycled. All underground piping can be re-excavated and disposed of. Site gravel can be taken up and reused off site.

6.12.2 Solar Panels Decommissioning

Typical activities during the solar energy facility decommissioning are given below:

a. General Removal Process

Effectively, the decommissioning of the solar plant proceeds in reverse order of the installation.

- The PV facility shall be disconnected from the utility power grid.
- PV modules, from First Solar, shall be disconnected, collected and returned
- Site aboveground and underground electrical interconnection and distribution cables shall be removed and recycled off-site by an approved recycling facility.
- PV module support wooden beams and aluminum racking shall be removed and recycled off-site by an approved recycler.
- PV module support steel and support posts shall be removed and recycled off-site by an approved metals recycler.
- Electrical and electronic devices, including transformers and inverters shall be removed and recycled off-site by an approved recycler.
- Concrete foundations shall be removed and recycled off-site by a concrete recycler.
- Fencing shall be removed and will be recycled off-site by an approved recycler.

b. PV Module Collection and Recycling

The PV modules will be carefully collected and will be sold to the relevant module manufacturing company. The module recycling program includes the glass and the encapsulated semiconductor material, with over 90% of the material recovered for future use.

6.12.3 Site Restoration Plan

Site Restoration when all of the structures and underground piping has been removed, the site can be graded back to its original grade. As no material was removed from the site for the construction of the plant, all of the native material is available for restoration. Topsoil should be added to the site and seeded with a mix of native species. No impact on ground or surface water is anticipated. The future use of the site would in all likelihood be for agricultural purposes as permitted by the municipal Official Plan consistent with surrounding uses.

6.13 Potential Environmental Enhancement Measures

Several measures have been proposed for enhancing the environment and social aspects. These measures include planting of trees, flowering beds, grassy lawn and shrubs beyond that is required according to the law, construction of retaining walls and guardrails, providing sign boards. The project is itself environment friendly due to zero greenhouse gas emission, therefore no significant damage to environment is foreseen due to this project.

6.13.1 Tree Plantation Plan

Consultant has prepared Tree Plantation Plan for Proposed Project as part of environment enhancement measure. It will help enhance the environment, moreover will work as a noise and dust barrier. Straight line and Circular plantation will be carried out. These rows will cover boundary wall of Project Area. The detailed plan is given below:

Table 6.2: Estimated Tree Plantation

Sr. No.	Particulars	Numbers
1	Total Plantation	100
2	Tree Spacing (m)	5 m
3	Tree Survival Rate	50%

Following plants species may be suitable to be plant in the Project Area:

Table: 6.3: Trees to be Planted

Sr. No.	Scientific Name	Local Name
1	Acacia Karoo	Kikar
2	Erythrophleumsuaveolen	Tali
3	Eucalyptus Globus	Safaeda
4	DalbergiaSissoo	Sheesham

6.13.2 Area Development Program

Area development projects are small scale additional projects which can be offered to the community as a part of enhancement measures. These projects may include health care facilities, parks, clean drinking water and vocational training centers. These projects will uplift the socio-economic conditions of the area.

7. ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

7.1 General

This Chapter presents the implementation mechanism in the form of an Environmental Management and Monitoring Plan (EMMP) for the environmental and social mitigation measures identified during the present IEE and reported in Chapter 6 of this document. Existing environmental regulations in Pakistan are complied with and potential adverse environmental impacts resulting from the project activities are minimized as practicably as possible. These are achieved through appropriate project planning and methods of Project operation. Implementation of ongoing environmental monitoring programs will enable the assessment and modification, if required, of the Environmental Management Plan. This EMMP provides the delivery mechanism to address the adverse environmental as well as social impacts of the proposed Project during its execution, to enhance project benefits and to introduce standards of good practice to be adopted for all project works.

Environmental management and monitoring is carried out in all stages of the Project namely; pre-construction, construction and operational phases. The EMMP of the identified environmental impacts associated with this Project consists of three main components:

1. Implementing the Impact Mitigation Plan
2. Monitoring the implementation of the EMP
3. Institutional Framework for Monitoring, Reporting and Supervision of EMP

7.2 Objectives of EMMP

This Environmental Management and Monitoring Plan (EMMP) aims at ensuring the application of the mitigation and monitoring measures, needed to reduce and control the various environmental and social impacts associated with the implementation of the proposed Project. The key objectives of the EMMP are summarized below:

- Define roles and responsibilities for the Project proponent, contractors and construction supervision consultants for implementation
- Provide mechanism for unanticipated environmental situation

- Identify training requirements at various levels

7.3 Components of EMMP

The EMMP consists of the following components:

- Institutional arrangements
- Mitigation plan to reduce the severity of associated impacts
- Monitoring plan to monitor the impacts and their severity
- Environmental and social trainings to raise awareness

7.4 Institutional Capacity

Environmental management is basically the institutional arrangement which delegates some specific assigned responsibilities and those responsibilities are to be monitored properly. For this purpose, a good and functional institute must be present in order to reduce adverse socio-environmental effects of the proposed project. This process requires proper monitoring in order to report performance of mitigation measurement of adverse impact generated by proposed project. The solar-biogas plant will be implemented and monitored by the Project Management Unit (PMU) of "Energy Department, Government of Punjab" which is the proponent of the proposed Project.

Environmental Management Plan (EMP) will be a part of training program to be given by the PMU to the Masons and labors to be employed for construction of the Project.

7.5 Training Schedule

To enhance the capacity of the Proponent as well as the Contractor, training will be imparted related to the environmental and social issues of the project implementation of mitigation measures and the monitoring protocols and reporting mechanism. The training will be conducted by PMU of the Project. Project will ensure in-house training for the Project staff i.e. labor, masons etc., Contractor, and the Supervisory staff through the provision of one day basic training and one day advanced training, covering environmental and social aspects of the Project with emphasis on the roles and responsibilities of the Proponent and the Contractor's staff while executing the

Environmental Monitoring Plan in particular. The training protocols will include the following aspects:

- Procedures for monitoring the air quality parameters and measures to be adopted for avoiding or minimizing air pollution, particularly from the concrete batching plant, haul-trucks, etc.
- Procedures for monitoring water quality parameters and measures to be adopted for avoiding or minimizing water pollution, particularly from the wastewater effluent generated from the workshops, machinery washing yards and other obnoxious chemicals;
- Safe waste disposal practices
- Safe noise levels from the construction machinery etc.
- Safety measures against hazards for workforce and the local communities arising from the construction activities
- Use of safety gadgets by the workforce

7.6 Environmental Management Plan

The Environmental Management Plan is meant for mitigation, management, avoidance of the adverse impacts. For each mitigation measure to be taken, its location, timeframe, implementation and overseeing /supervising responsibilities are listed in the EMP. The identified impacts and suggested mitigation measures with institutional responsibilities are tabulated in Table 7.1:

Table 7.1: Environmental Management Plan

Anticipated Environmental Issues and Impacts	Proposed Mitigation Measures	Measurement Frequency	Institutional Responsibility	
			Implementation	Supervision
Construction Phase				
Disposal of waste material and excess earth from construction sites	Construction wastes and excess earth shall be collected and disposed in low lying areas. But these will not be disposed off in water courses and connecting roads to village	Once after construction is over	Construction Crew	PMU
Use of water for construction	The proponent will make arrangement for water required for construction from his allocation of water supply and will not tap water from natural Ground/Surface water sources	During Construction period	Construction crew	PMU
Contamination of Water Sources from Construction Wastes	Measures shall be taken to prevent the wastewater Generated in construction from entering directly into river or other natural water sources	During Construction period	Construction crew	PMU
Dust generation	The construction crew will take all necessary measures to suppress dust generation. For this water spray will be carried out each day at least twice i.e. morning and evening	During Construction period	Construction crew	PMU
Noise from Construction sites	The construction works will be taken up in Day time only	During Construction period	Construction crew	PMU
Operation Phase				
Generation of flies, worms,	The maintenance staff will be given training by	As required	Maintenance Staff	PMU

insects and mosquitoes due to improper handling of cattle slurry and digested sludge	the PMU to properly operate and maintain the biogas plant. In case of any malfunctioning not in control of staff will be rectified by the Masons			
Possible Leakage of Biogas from pipes, and biogas plant	The Maintenance staff of biogas plant will be provided training by the PMU for proper upkeep of connecting pipes and replacement of these at every 5 years. The villagers will be made aware of possible occurrence of fire in case of leakage and necessary fire prevention measures to be taken by them in the event of occurrence of such incident	Monthly	Maintenance Staff	PMU
Odor problem from biogas plant	In order to mitigate odor problem the leakage from biogas digester should be restricted. For this purpose effective maintenance of biogas plants is needed.	Every day during operation and utilization of biogas	Maintenance Staff	PMU
PMU: Project Management Unit				

7.7 Environment Monitoring Plan

To ensure the effective implementation of mitigation measures and environmental management plan, during construction and operation phase of the Project, it is essential that an effective Environmental Monitoring Plan be followed as given in Table 7.2:

Table 7.2: Environmental Monitoring Plan

Environmental Component	Parameter	Location	Duration / Frequency	Responsibility
Air Quality	Dust Generation at construction site	Construction site	Once during construction	EMC of PMU
Noise	Noise Level (dB)	Construction site	Once during construction	EMC of PMU
Surface and Ground Water Quality	Construction waste disposal,	Construction site and nearby	Once during	EMC of PMU

	Water Quality measurement using standard methods.	water bodies	construction	
Hygiene at Biogas plant and surroundings	Proper training in maintenance to avoid Generation of insects, worms, flies, and mosquitoes	Biogas plant site	Monthly during Operation Stage	Quality control officer
EMC: Environmental Management Committee, PMU: Project Management Unit, dB: decibel				

7.7 Equipment Maintenance Details

7.7.1 Maintenance of Biogas Plant

When the biogas plant has started its operation; daily, monthly or yearly measures are necessary for control and maintenance. Most of the controls may be done continuously by control and monitoring systems (like temperature of the reaction, the amount of substrates, the quantity of gas/electricity/heat produced, etc.) but others might require expert support e.g. resolve liquid leakage at pumps, oil changing, small repairs etc. the details for each equipment used in biogas plant are given below:

a. Spare Part Management

- Keep strategic spare parts and wear parts on stock.
- Strategic spare parts can be foreseen to be needed to keep vital functions running and/or parts with long delivery time
- Wear parts are parts which can be foreseen to wear out periodically, to be able to schedule service without need to wait for parts
- Update relevant spare and wear parts to have on stock according to experience
- Remember to replenish stock as soon as spare parts are used
- Consider to refurbish replaced equipment to keep as emergency spare units

b. Pre-digester Pit

Depending on the type of agitator, maintenance can be undertaken outside the pre-digester pit or the digester, without process interruption. If the design lacks provision for removing settlement layer material, this material has to be removed manually. Apart from this, virtually no maintenance outlay; maintenance of the various technical items of equipment is described in the corresponding sections.

c. Digester

- At least one manhole is necessary so that the interior of the reactor can be accessed in the event of a breakdown.
- Comply with applicable health and safety regulations for working inside the digester

7.7.2 Maintenance of Solar Panels

There are different steps of PV maintenance procedures:

- Perform Visual Inspection
- Verify System Operation
- Perform Corrective Actions
- Verify Effectiveness of Corrective Actions

Maintenance details for equipment used in photovoltaic solar panels are given below:

b. Array Maintenance

- Module inspection
- Shade control / soiling
- Debris removal
- Array mount inspections

c. Shade Control

- Perform regular shading analysis of array(s)
- Inform villagers about impact of shading and recommend regular tree trimming where necessary if they are causing shading on the panels.

d. Electrical Equipment Maintenance

- Visual inspection of inverters, transformers, and other electrical equipment.

- Inspect all wiring, conductors, terminators, conduit and junction boxes
- Disconnects, fuses and circuit breakers checked for proper operation
- Exposed conductors checked for insulation damage, clean and secure terminals, adequate strain relief, and properly connected and supported conduits

7.8 Environmental Budget

The environmental cost has been worked out (Table 7.5) which covers the environmental monitoring, tree plantation cost, social cost, environmental auditing, environmental training etc.

Table 7.5: Environmental Budget

Sr. #	EMP Parameters	Unit Cost	Before Construction		During Construction		After Construction		Total (m PKR)
			Times	Cost	Times	Cost	Times	Cost	
	Environmental Monitoring	0.075	1	0.075	1	0.075	1	0.075	0.225
1	Internal Environment Auditing	0.05	0	0	1	0.05	1	0.05	0.1
	Social Cost (meeting, visit, tour etc.)	0.05	2	0.05	2	0.05	1	0.05	0.125
2	Environmental Training	0.25	1	0.25	1	0.1	0	0	0.35
3	Tree Plantation Plan	0.0012	0	0	0	0	500	0.6	0.6
4	Environmental reporting & review	0.1	0	0	3	0.3	3	0.3	0.6
Total									2
Operation & Maintenance (5%)									0.1
Contingencies (10%)									0.2
Grand Total									**2.3**

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Based on the environmental and social impacts assessment of the proposed Project, it is concluded that Project will have short term and reversible adverse impacts with moderate to minor magnitude. Implementation of the proposed Project will alleviate/offset the power crisis with the arrangement of cheaper and uninterrupted energy supply which will provide electricity to their nearby grid station and supplied to the community. The major findings of the Project are summarized as under:

- The construction activities of proposed Project will not involve cutting/ removal of any trees
- All the other impacts like soil erosion, soil contamination, solid waste generation, high noise level, etc. will be of temporary nature and can be controlled and mitigated through good engineering practices.
- No protected forest area or wildlife sanctuary or any other environmentally sensitive site exists within the Project Area of influence and around it.
- A comprehensive EMP has been developed identifying the impacts, mitigation measures, agencies responsible for implementation and monitoring of the proposed measures. EMP also describes the environmental and social monitoring responsibilities.
- The total estimated cost for the environmental and social management comes to about PKR. 2.3 million.

In the light of above discussion, it may be concluded that most of the above-mentioned impacts are of temporary nature rather manageable through proper planning/execution and good engineering, furthermore, none of these are irreversible, therefore proposed Project is environment friendly and will have the least adverse impacts on the area in terms of social and environmental settings.

8.2 Recommendations

Although comprehensive mitigation measures have been proposed in the report to minimize offset the adverse impacts and enhance the positive impacts of the Project, however, major recommended measures are summarized as under:

- The contractor should plant at least 100 trees as part of environment enhancement measures.
- Solid waste management and high noise levels should be controlled with the use of good engineering practices.
- The contractor will have to adopt suitable timing for the construction activities so as to cause the least disturbance to the local community particularly women considering their peak movement hours.
- Contractor should take due care of the local community and its sensitivity towards local customs and traditions.
- Locals should be preferred for the job opportunities during construction/operation of the Project.
- EMP proposed in Chapter 7 should be implemented in its true spirits.
- Strengthening of road network, education facility and health improvement system may be enhanced as Area Development Plan.
- The Proponent must apply for Environmental Approval (NOC) to EPA, Punjab before proceeding further into the Project implementation.