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Non-conventional energy options for rural electrification in Pakistan

By

Engr. Mushtaq Ahmad Bhatti

B.Sc. Elect. Engg. (UETL) ; Post Graduate (USSR)

P.E., M.I.E.E.E. (USA) ; M. Inst E.E. (Pak)

Principal Engineer & Project Manager, NESPAK Lahore

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NON - CONVENTIONAL ENERGY OPTIONS FOR RURAL ELECTRIFICATION IN PAKISTAN

MUSHTAQ AHMAD BHATTI *

SYNOPSIS

About 72 percent of the total population of Pakistan is settled in rural areas, which provide the essential agricultural base to the urban population and the industry. Low per capita income in rural areas is the main cause of overall low standard of living at the national level, which can be raised through rapid rural development. Electricity, undoubtedly, plays an important and positive role in this regard.

Because of acute power shortage which is likely to persist for quite sometime and on account of rising costs of fossil fuels, the traditional solutions for electrification of rural areas will not be able to satisfy the energy needs of the rural masses, especially, living in remote areas. The paper presents non-conventional renewable energy technology options for rapid rural electrification in Pakistan.

1. PERSPECTIVE

The economy of Pakistan continues to be dominated by agriculture. About 72 per cent of its population is inhabited in rural areas, which provide the essential agricultural base for the urban population and the industry. According to the

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* B.Sc. Elect. Engg: (UETL); Post Graduate (USSR); P.E; M.I.E.E.E (USA); M. Inst. E.E. (PAK).
PRINCIPAL ENGINEER & PROJECT MANAGER, NESPAK, LAHORE.

latest statistics available, the Gross Domestic Product (GDP) in the country rose by 8.4% during 1984-85, as compared with the growth rate of only 3.4% during 1983-84.

Similarly the per capita income increased by over 4.1% during the last year in contrast to a marginal decline of 0.1% in 1983-84. This has been attributed to a sharp rise of 9.9% in agricultural production, during the last year, ending June 30, 1985. This implies that overall standard of living at the national level cannot be raised without changing the fortune of the rural masses. Thus if social strains and stresses creating economic imbalances are to be avoided while planning any strategy for economic growth of the country, the energy needs of rural development can hardly be overlooked. This requires establishment of infrastructure facilities in the rural areas and electricity, undoubtedly, plays an important and positive role in this regard. This calls for investing increasing financial resources into rural electrification programme. The initial low financial returns deserve tolerance because the programme, when viewed in the perspective of overall development of the country, promises lots of economic returns on the national scale, in the long run. Apart from that, certain non-quantifiable but qualitative inputs of rural electrification in the overall social system of the country are beyond measures.

Because of acute power shortage which is likely to persist for quite sometime and on account of rising cost of fossil fuels, the traditional solutions of providing power to rural areas, viz. through rural mains, from an integrated power network or through small diesel-fuelled engines, as prime movers, will not be able to satisfy the energy needs of the rural population, particularly the areas which are located very far away from the electricity generation centres or distribution network.

In this connection, the production of energy from non-conventional sources for electrification of rural areas meets with growing interest, espacially if looked at in a future perspective.

The paper identifies the limitations and constraints with the present-day conventional methods of rural electrification in Pakistan and discusses the renewable energy technology options for rural areas, viz.

- Nuclear
- Biomass
- Wind
- Solar

2. PRESENT POWER SUPPLY SITUATION

The present and near future power supply situation in the country can be best appraised by studying the Supply-Demand Balance position on WAPDA System. The power generated by WAPDA is pre-dominantly from Hydel energy. It, therefore, seems realistic to study the power supply position under the worst conditions i.e. during the lean hydel periods. Table-1 presents such position during January -- February 1985, which shows a deficit of 694MW — 19.2 percent of the peak demand on the system.

The future generation expansion programme of WAPDA till the year 1990 is shown in Table-2. Even with such an ambitious expansion programme, the Supplv — Demand position, as estimated by the Planning Department of WAPDA, will still worsen by January -- February 1990, with a deficit of 939MW, as shown in Table-3.

Out of a total number of about 45,000 villages in Pakistan, only 19,269 villages (43%) were electrified by June, 1985. (Refer Table-4). It has been estimated that about 1000MW of additional power will be needed to meet electricity requirements of private households, community centres, commercial consumers, public lighting, irrigation tubewells and lift pumps in the remaining non-electrified villages. The corresponding annual energy requirement is estimated to be around 5256 million KWh.

TABLE – 1

WAPDA SUPPLY – DEMAND BALANCE

LEAN HYDEL PERIOD

(January – February, 1985)

Installed Capacity (MW)		Firm Capacity Available (MW)	Peak Demand (MW)	Surplus/Deficit (MW)	%
Hydel	2870	1790	3609	–694	–19.2
Thermal	1419	1125			
Total	4289	2915			

TABLE – 2

GENERATION EXPANSION PROGRAMME (1986-90)

WAPDA SYSTEM

Sr. No.	Station Name	Unit No.	Installed Capacity (MW)	Expected date of Commissioning
1.	300MW Gas Turbine at Guddu	3	75	Jan. 1986
2.	300MW Gas Turbine at Guddu	4	75	Feb. 1986
3.	Guddu	4	210	Feb. 1986
4.	300MW Gas Turbine at Guddu	1	75	Mar. 1986
5.	300MW Gas Turbine at Guddu	2	75	Apr. 1986
6.	Kot Addu Gas Turbines	1 & 2	200	Aug. 1986
7.	Kot Addu Gas Turbines	3 & 4	200	Oct. 1986
8.	Combined Cycle Steam, Guddu	5	75	Jul. 1987
9.	Combined Cycle Steam, Guddu	6	75	Oct. 1987
10.	400MW Gas Trubines at Lahore	1 – 4	400	Sep. 1988
11.	Jamshoro Oil Fired	1	250	Dec. 1988
12.	Low Head Hydel	1	35	Jul. 1989
13.	Mangla	9 & 10	200	Sep. 1989
14.	Tarbela	11	432	Sep. 1989
15.	Tarbela	12	432	Dec. 1989
16.	Jamshoro Oil Fired	2	210	Dec. 1989
17.	Multan	1	210	Dec. 1989
18.	Tarbela	13	432	Mar. 1990
19.	Tarbela	14	432	Jun. 1990
21.	Multan Oil Fired	2	210	Jun. 1990
21.	Multan Oil Fired	3	210	Dec. 1990
22.	Jamshoro Oil Fired	3	250	Dec. 1990

TABLE – 3

WAPDA SUPPLY – DEMAND BALANCE

LEAN HYDEL PERIOD

(January – February, 1990)

Installed Capacity (MW)		Firm Capacity Available (MW)	Peak Demand (MW)	Surplus/Deficit (MW)	%
Hydel	5200	2529	6818	–939	–13.8
Thermal	4324	3350			
Total:	9524	5879			

TABLE – 4

PROVINCE-WISE NUMBER OF ELECTRIFIED/NON-ELECTRIFIED VILLAGES

Province	Total No. of Villages.	Present Electrification Status.		Villages to be Electrified.
		Villages Electrified upto June, 1985	%	
Punjab	25,382	9,771	38	15611
N.W.F.P.	7,949	4,915	62	3034
Sind	5,587	3,753	67	1834
Baluchistan	6,163	830	13	5333
Total:	45,081	19,269	43	25812

It is evident that in view of the power shortage which is likely to persist for a number of years to come, it is difficult to provide electricity to rural areas, from the existing power supply network in the country.

The other option is to electrify the rural areas with small diesel fuelled engines, as prime movers. In view of high cost of energy available from this source, as compared to the average cost per KWh on the WAPDA System, it is not economically feasible to opt for such an expensive proposition, on a large scale. The cost analysis of one KWh generated from a small diesel generating set is presented in Appendix-I.

From the preceding discussions it is clear that non-conventional sources of power generation will have to be exploited very soon for rapid electrification of rural areas, if the overall living standard of the nation is to be raised.

3. NON-CONVENTIONAL ENERGY OPTIONS

3.1 Nuclear Energy.

This is a capital cost intensive proposal and requires many years from planning to final commissioning of the plant, with relatively low availability during its first years of operation. This alternative involves Geo-political problems and difficulty in acquiring appropriate nuclear plants. Apart from other operational problems, such plants pose hazards to human-life because of difficulty in disposing off of nuclear-wastes. Whereas, this alternative may possibly be considered as a long-term energy option for the country, it may not be totally banked upon for immediate rural electrification requirements.

3.2 Biomass Energy

The production of energy from 'Biomass' meets with growing interest. Biomass comes from regenerative sources and in many cases, in the processing of

natural products, it occurs as waste such as sawdust, barks, rice-husks, cotton-sticks/bolls, nut-shells, straws and animal-dung or virtually any organic-combustible material. These waste materials offer a source of energy which has not been effectively utilised so far.

The main Biomass Conversion routes are as follows:

3.2.1 Biogas

The fermentation of wastes such as animal-dung, sewage or food production residues under anaerobic conditions can produce a smokeless & low calorific value fuel gas mixture of mainly methane and carbon dioxide, known as 'Biogas'. The effluent from the fermentation unit is rich in nitrogen and has valuable properties as a fertiliser and soil conditioner. This is a further factor in promoting the use of Biogas plants.

Biogas is obviously an ideal choice for rural areas where it is easier to obtain the animal-dung. Biogas can be used for the purpose of cooking, lighting and also for heating houses in winters. The Government of Pakistan has already launched a campaign to promote the installation of Biogas Units in rural areas, utilising cattle-dung. It plans to set-up about 7000 Units by the end of 1987.

The data available from PCSIR Laboratories shows that a 'Biogas Plant' with 2 cubic metres gas storage capacity needs about 40 Kg of cattle dung every day (i.e. 4 to 5 cattle heads). The optimum efficiency of the system is obtained at around 35°C. At temperatures lower than 15°C, the process of evolution of gas decreases considerably. A study shows that there are about 3.3 million animals in 'BARANI' areas of Pakistan, sufficient to produce about 1.5 million cubic meter of gas every day and

about 4.4 million metric tonnes of manure annually. Thus a consi derable potential exists for promotion of 'Biogas' in rural areas.

'Biogas' has been a great success in China and India. The Chinese have applied the technology very widely in certain provinces with mild winters, such as 'Sichuan'. Several million family size biogas units are in use in China. In India about 36,000 Biogas units are operational. Apart from other noteworthy benefits, such units have surprisingly brought some physiological advantages to the rural population in India. It has been observed that, with the use of Biogas units the rate of 'CATARACT' dropped by 80% in comparison with those using cattle dung directly as a source of combustion. The direct use of cattle-dung is widely in vogue in Pakistan as well. The application of Biogas in rural areas, can thus bring about an improvement in the existing health standards, which is also an additional plus point.

Unfortunately Biogas, in Pakistan, has not achieved the desired amount of success which was expected of it, mainly due to the following factors:-

i) Poor public response because of aesthetic reasons, as the plant requires regular cleaning of the digester, and painting to avoid corrosion.

ii) Lack of education of the users regarding the operation of the unit itself, such as varying the amount of dung-water ratio, with the changing atmospheric temperature, for optimal operation.

iii) Lack of co-operation between the donors of animal-dung.

The use of 'Biogas' can, however, be promoted through public education

and training.

Biogas is also a clean fuel for engines and can replace upto 75 percent of the diesel-fuel needs of an unmodified compression – ignition engine. It has good anti-knock properties and can be used in very high compression ratio engines, giving good efficiency, and low maintenance requirements. Unfortunately, the rate of production of gas is usually very low and the economic storage of biogas, in sufficient quantity, for all except rather small scale application presents difficulties. That is why 'Biogas' is not feasible for power production on a relatively larger scale. It is rather more beneficial to use it for direct combustion.

3.2.2. Combustion of Biomass

Burning is the obvious way to process biomass provided the fuel is reasonably dry. Steam engines were the main mechanical prime-movers for over a hundred years. They are in a sense technological extinct species. But recently due to the scare of 1973 oil embargo and the decreasing oil-reserves, efforts have again been started for giving the steam engines a respected place by making them techno-economically feasible. Recent advancements have been made to upgrade engineering in steam engine technology to improve performance and lower operational costs. Biomass energy systems have been developed to produce process steam for operating the steam-engine generators. The biomass fuel can consist of rice husks, wood chips, saw dust, barks, cotton bolls, nut-shells, straws or virtually any organic combustible material.

One of the main disadvantages previously have been the problem of fuel which was not dry. But with recent system, the waste steam is used to pre-heat the fuel which is then put into the boiler. This system also provides simplicity of operation, long-system life of about 30 years and

a very low maintenance cost. A typical system schematic diagram is illustrated in Figure-I to explain the working principles involved in the system.

The heart of this system is a steam-generator which provides the following advantages over steam turbines.

1. Steam engines use approximately 40% less steam than turbines and are not as sensitive to the quality of the steam in terms of such factors as moisture content.

2. Steam engines have a higher efficiency across their normal power range than turbines.

3. Steam engines are more tolerant of chemical contamination in boilers.

4. The normal horse power rating of steam engines can be increased up to 20% without negative effect and can be sustained continuously, again without negative effect.

The combustible fuel is pre-heated first through the forced draft of Airflow Chamber. The fuel is then put in Storage Area where it is further dried with the help of steam from the Airflow Chamber. The moist-free fuel is then placed manually or automatically in Firebox/Grate. From the combustion of fuel, the water in the boiler is heated to a level which produces steam and this steam drives the Steam-Engine during its course. Steam-Engine is coupled with a generator, which in turns produces electrical energy. However, the steam continues its journey towards, Heat Exchanger/Condenser from where by virtue of condensation of steam, water is collected and reaches the Feedwater-Tank, through Transfer Pump. In Feedwater-Tank, Chemcial Feed

is also introduced for water softening. The cycle is completed through Feedwater Pump, when water from Feedwater-Tank reaches back to the Boiler for production of steam.

A cost analysis was done to find out the economic viability of this system. For this purpose, a comparison was made between a Diesel-Generating System and the Biomass Energy System.

An analysis of the 'Rural Electrification Master Plan in Pakistan', prepared by the author, shows that the average peak load per village ranges between 30 to 80KW in different provinces. But for comparison purposes a load of 30KW per village has been considered to meet the elctricity requirements of private households, community centres, small commercial units, small industrial units, tubewells/lift pumps and public lighting etc. (Refer Appendix-1).

The analysis presented, therein, shows that the cost per KWh of electrical energy through the Biomass Energy System is around Rs. 0.55 which is considerably lesser as compared to Rs. 1.84 per KWh through Diesel-Generating set of the same size.

Infact the energy cost produced through Biomass Energy System is comparable with the average supply cost per KWh at the WAPDA System.

In veiw of these findings, it is felt that the use of such Biomass Energy Plants should be systematically promoted, particularly in those rural areas where the Biomass wastes are abundantly available to fulfill the need of sustained requirements for power generation.

3.2.3. Gasification/Pyrolisis

Biomass gasification technology centres on attempts to develop

techniques that can produce a substitute natural gas. The aim is to alter the ratio of hydrogen to carbon of the biomass feedstock, which involves adding hydrogen to make hydrogen/carbon ratio more like that of natural gas. The hydrogen can be made by reacting steam with hot biomass is a series of reactions that add up to the overall reaction:

$$2C+2H_2O \rightarrow CH_4+CO_2$$

An alternative to adding hydrogen to biomass carbon is to remove some of the carbon. This can be achieved through 'Pyrolisis' which is no more than the process of heating the biomass without letting any air or steam into the system. 'Pyrolisis' is conceptually simple but, however, an inefficient way of converting the biomass chemcial energy into gaseous energy. Only a quarter of the energy present in the biomass feedstock is retained in the gas produced.

The gas which is produced can be used in many ways, chiefly as fuel for internal combustion low-compression engines, with little modification. Modern internal combustion engines with high compression ratio are often not very tolerant of this aggressive but low calorific value fuel. Acids and tars can cause premature wear, alongwith a need for much more frequent cylinder maintenance.

This option of utilising energy from biomass gasification for running gas engines is not likely to meet with growing interest in Pakistan, as compared to the biomass combustion system discussed in para 3.2.2.

3.3. Wind Energy

Wind is a free-occuring natural form of diffused energy available on earth. According to World Energy Conference, the total power of the wind in the

entire atmosphere is estimated to be about 2600×10^{12} gigawatt-hour/year of which about one quarter is over the land.

The power extracted from the wind is given by the formula;

$P\ (KW) = 0.00035\ n\ AV,^{3}$ where

A= Area in m^2 swept by the turbine blades

V= Wind speed in m/sec.

n= Efficiency of the system (≤ 0.6)

Generation of electricity from wind power can be done competitively through the use of a wide selection of commercially available systems. That is why wind power is finding greater application in the present days for use even by large electricity generating utilities, including CEGB, England, who commissioned their first 200 KW units at Carmarthen Bay in 1982.

The wind generators of 50 to 100KW, particularly suitable for our rural areas, are very easy to get in the international market. Such generators become significantly cheaper than solar photovoltaic system (Refer para 3.4.2) for similar duties, with mean wind speeds exceeding 4.5 m/sec. The 3.0 to 4.5 m/sec. range is a 'grey area' for which other factors must be weighed in choosing between solar and wind systems. Average wind intensity is generally much higher in coastal regions than inlands.

In view of limited coastal areas in Pakistan and the prevailing wind conditions, the use of wind energy may find application mostly in the lower Sind and the coastal areas of Baluchistan only.

3.4. Solar Energy

Solar energy is considered, at present, a very promising and limitless source for

meeting the energy requirements in remote rural areas. Solar power could also eliminate most of the serious environmental problems associated with fossil fuel and nuclear power because chemical air pollution and dispersion of radio-active particles could be minimized.

Pakistan lies entirely in the high solar radiation belt between 40°N and 40°S and has abundance of sunshine throughout the year. Studies show that solar energy received in the country is around 2000 KWh/m^2 during the whole year.

There are two primary solar energy conversion techniques, thermal and photo-voltaic.

3.4.1 Solar Thermal System

This system employs conversion of the suns' radiations into useful heat for raising steam to run the steam engine generators. Despite the long history of solar steam engines, the solar thermodynamic process to generate high grade mechanical or electrical power still remains technically unviable. The Second Law of Thermodynamics poses formidable hinderances to the success of this technology. The difficulty is neither in the total supply of solar energy nor in the lack of energy conversion devices. The problem is that solar energy is relatively diffuse and the cost of collection is high; the cost of concentration to temperatures appropriate for heat engines is still very high.

For solar thermal plants, temperatures well above 300°C would be required. These plants would need relatively expensive focussing collectors and sun-tracking mechanism as well. A typical form of concentrator-collector is shown in Fig. 2. A heat transfer fluid flows in the receiver, whose axis is to be oriented to track the sun throughout the day.

The cost analysis for a solar thermal system is presented below:

–	Concentrating solar collector built to track the sun and to withstand wind loads		$\$100/m^2$
–	Average power density available		$0.03KW/m^2$
–	Plant cost	100/0.03 =	\$ 3333/KW

This means a plant of 30KW will cost \$100,000 and will cover an area about 1000 m^2. This does not take into account the capital cost of energy transfer, conversion machinery, storage, energy loss due to storage and the high cost of land required for this system.

The approximate cost figures cited above suggest that solar thermal power is far from competitive, as compared with fossil fuels. There is little doubt that it is technically feasible but not economically viable for adoption in rural areas of Pakistan, at the moment.

3.4.2 Solar Photovoltaic System

A Solar Photovoltaic cell for electrical power generation is made of a single crystal of silicon into which a doping material is diffused to form a semi-conductor that generates electricity when it absorbs light. As photons are received, free electrical charges are generated that can be collected on contacts applied to the surface of silicon-cell. Because solar cells are not heat engines, and therefore, do not need to operate at high temperatures, they are adapted to the weak energy flux of solar radiations. The operating efficiency of this system is about 12 to 15 percent and decreases fairly rapidly with increasing temperatures.

The electric energy produced by photovoltaic cells is stored by

means of batteries, and whenever electricity is needed as an alternating current, for ordinary motors, or electronic devices, etc., necessary equipment is to be provided to convert DC into AC power. (Refer Schematic diagram at Fig. 3) This conversion is costly both in terms of capital expenditure and power dissipation.

Though silicon is one of the earth's most abundant material, it is expensive to extract (from sand) and refine to the purity required for solar cells.

The great barrier to solar cell application lies in the cost of the cells themselves. There are signs that the price is ready to drop in the coming years through expansion in production of mono-crystalline silicon cells, more competition, better manufacturing techniques etc.

Economic studies recently carried out for rural areas in Pakistan show that, at present, solar plants, because of their high cost, are not competitive when compared with conventional sources of energy. But in the near future (say within 5_10 years) these plants may become economically feasible because of lowering of their costs and because of the increase of the prices of conventional energy sources, particularly oil.

A cost comparison for electrification of a village through two alternatives namely;

i) A 30KW Solar Photovoltaic Plant installed in a village.

ii) Supply from existing WAPDA network.

is presented in Appendix-2. The comparison shows that the annual costs for the two alternatives become equal when the distance of the villages is about 36 Km from the existing network of WAPDA beyond which electrification from solar photovoltaic system is economical.

4. CONCLUSIONS

1. Low per capita income in rural areas is the main cause of overall low standard of living at the national level, which can be raised through rapid rural electrification.

2. Nuclear energy exploitation may be considered as a long-term energy option for the nation but may not be totally banked upon for immediate rural electrification requirements.

3. Whereas, the use of biogas from cattle-dung should be further promoted in rural areas for lighting, cooking and heating through direct combustion, its use for power generation on a relatively larger scale is not feasible because of very low rate of production of gas and difficulties of economic storage of gas in large quantities.

4. Power generation from biomass fuel e.g. wood chips, saw dust, rice husks, barks, cotton bolls, nut-shells, straws or virtually any organic combustible material, through the 'Biomass Energy System' should be systematically promoted, particularly in those rural areas where the Biomass wastes are abundantly available.

5. The gasification of biomass fuel is not likely to meet with growing interest in rural areas of Pakistan, owing to the unsuitability of the gas for the modern internal combustion engines, with high compression ratio.

6. The use of wind energy is envisaged mostly in the Lower Sind and the coastal areas of Baluchistan.

7. Solar Thermal System for running of steam-engine generators in rural areas is far from competitive as compared with fossil fuels and hence not recommended.

8. Solar Photovoltaic System for rural electrification is likely to become competitive within a period of 5-10 years because of the expected decrease in solar cell prices and relative increase in the cost of oil.

9. Solar photovoltaic system is, at present feasible for electrification of those remote villages which are at a distance of 36 Km or more, from the existing integrated electricity network.

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APPENDIX – I

COST PER KWH GENERATED DIESEL VS BIOMASS ENERGY SYSTEM

		Diesel	Biomass Energy System
Comparison Factors:			
Engine Rating		30KW (Maximum	30KW
2-Hour Overload		Not Advised	38KW (Maximum)
Fuel		Light Diesel Oil	Any Organic Combustible matter
Low Heat Value (BTU/Kg)		41,162	21,560 (Average)
Fuel Cost (Kg)		$0.30	$0.003
Operating Factors			
1.	Installed Cost	$13,000	$35,000
2.	Expected Plant Life (Years)	15	30
3.	Annual Depreciation	$867	$1167
4.	B.T.U./Hr	350,650*	694,000**
5.	Fuel Kg/Hr	8.52	32.19
6.	Fuel Kg/Year (@ 60% load factor)	44,774	169,190
7.	Fuel Cost per Kg	$0.30	$0.003
8.	Fuel Cost per Year	$13,432	$508
9.	Lubricants etc.	$1,800	$800
10.	Operation & Maintenance Cost per Year	$2,000	$3,000
11.	Total Annual Cost (3) + (8) + (9) + (10)	$18,099	$5,475
12.	Kwh Generated per year	157,680	157,680
13.	Cost/KWh Generated	$0.115 (Rs. 1.84)	$0.035 (Rs. 0.55)

* Thermal efficiency : 29%

** Thermal efficiency : 15%

N.B.: Average supply rates at 0.4KV WAPDA System = Rs. 0.50 approx.

APPENDIX–2
1 of 2

COST COMPARISON FOR RURAL ELECTRIFICATION THRU SOLAR PHOTO-VOLTAIC SYSTEM VS WAPDA NETWORK

A. SOLAR PHOTOVOLTAIC (PV) SYSTEM

1.	Installed Power	30 KW
2.	PV Cells Cost	
i)	Material Cost @ 7$/watt	$ 210,000
ii)	Transportation & Erection @ 15%	$ 31,500
iii)	Civil Works incl. battery room etc.	$ 6,000
	Sub-Total	$ 247,500
iv)	Average Life	40 years
v)	Annual Depreciation Cost	$ 6,188 ..... (a)
3.	Storage Battery Cost	
i)	Cost of storage battery, incl. Charge Regulator.	$ 45,000
ii)	Transportation & Erection @ 15%	$ 6,750
	Sub-total	$ 51,750
iii)	Average Life	8 years
iv)	Annual depreciation cost	$ 6,469 ..... (b)
4.	Total annual cost (a)+(b)	$ 12,657
5.	Operation & Maintenance @ 10%	$ 1,266
	Total annual cost	$ 13,923

B. SUPPLY FROM WAPDA NETWORK

Let the village be 'x' Km from the existing WAPDA network.

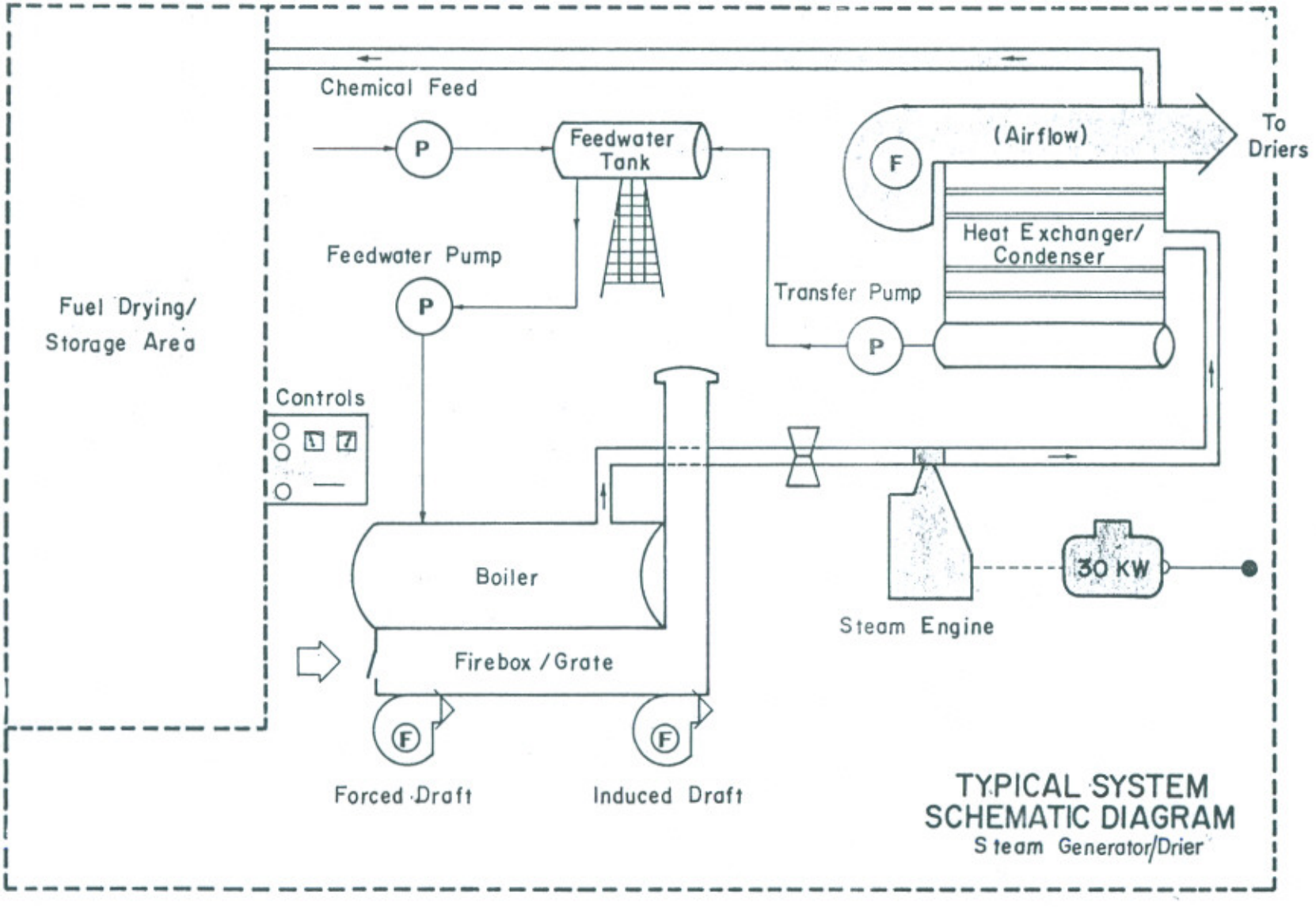
i)	Cost of 'x' Km of 11 KV lines @ $ 3,500 per Km	$ 3,500x
ii)	Cost of Step-down Transformer. Substation, 11/0.4 KV, 50 KVA	$ 1,600
	Sub-total	$ (3500x+1600) ..... (a)
iii)	With Construction & Erection Cost etc. @ 26.5% of (a), total cost	$ 1.265 (3500x+1600)
iv)	Average life of the equipment	20 years
v)	Annual depreciation cost	$ $\frac{1.265}{20}$ (3500x+1600)
		= $ 0.063 (3500x+1600) ... (b)
vi)	Annual Energy requirement @ 60% load factor	30x8760x0.6=157,680 KWh
vii)	Cost of supply @ $ 0.0375 KWh	$ 5,913 ..... (c)
viii)	Total annual cost (b) + (c)	$ 0.063 (3500x+1600)+5,913

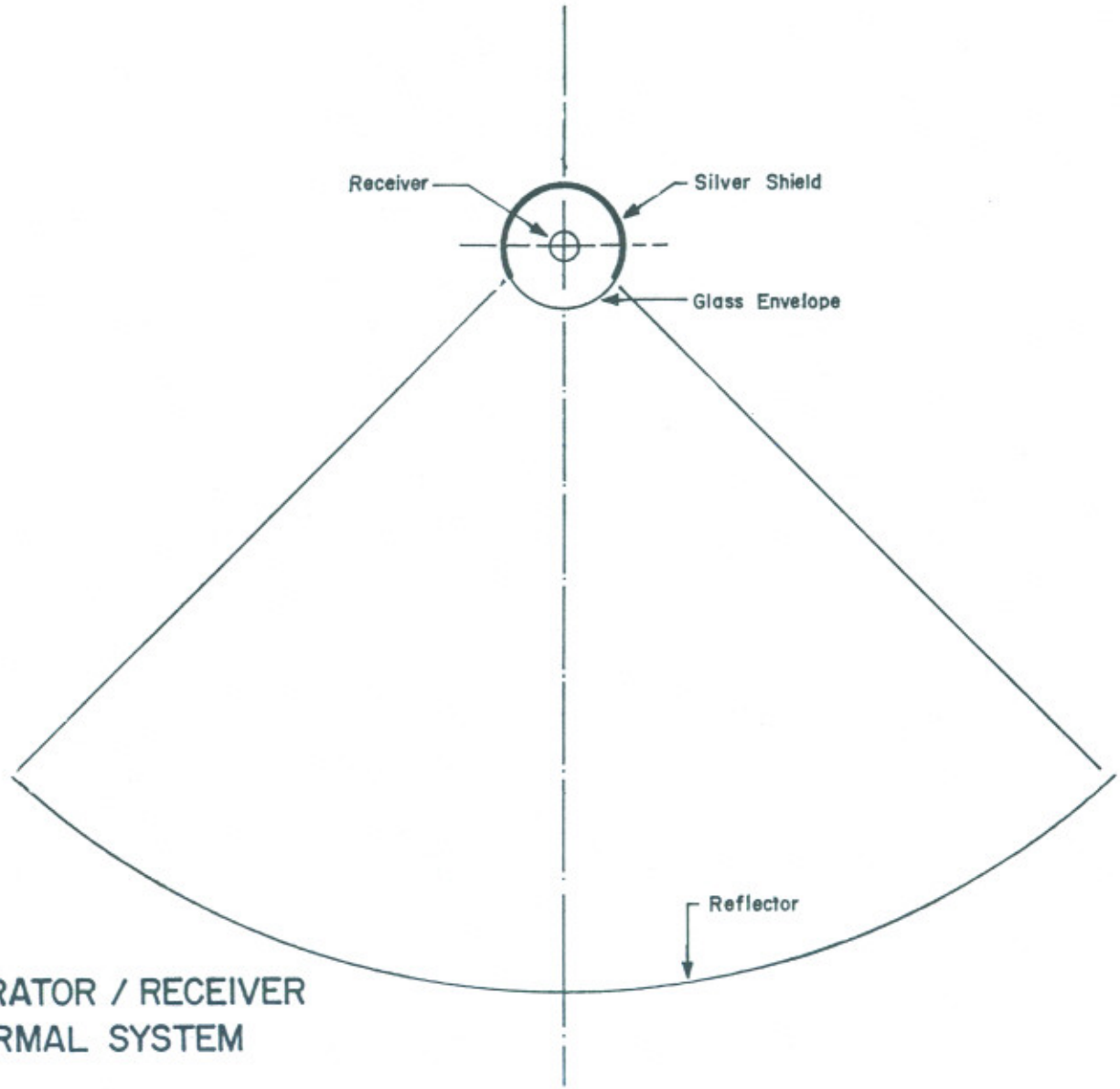
C. FOR BREAK EVEN ANNUAL COST

Annual cost with WAPDA Network	=	Annual cost with Solar Photovoltaic System
0.063 (3500x+1600) + 5,913 from where x = 36 Km.	=	13,923

D. CONCLUSION

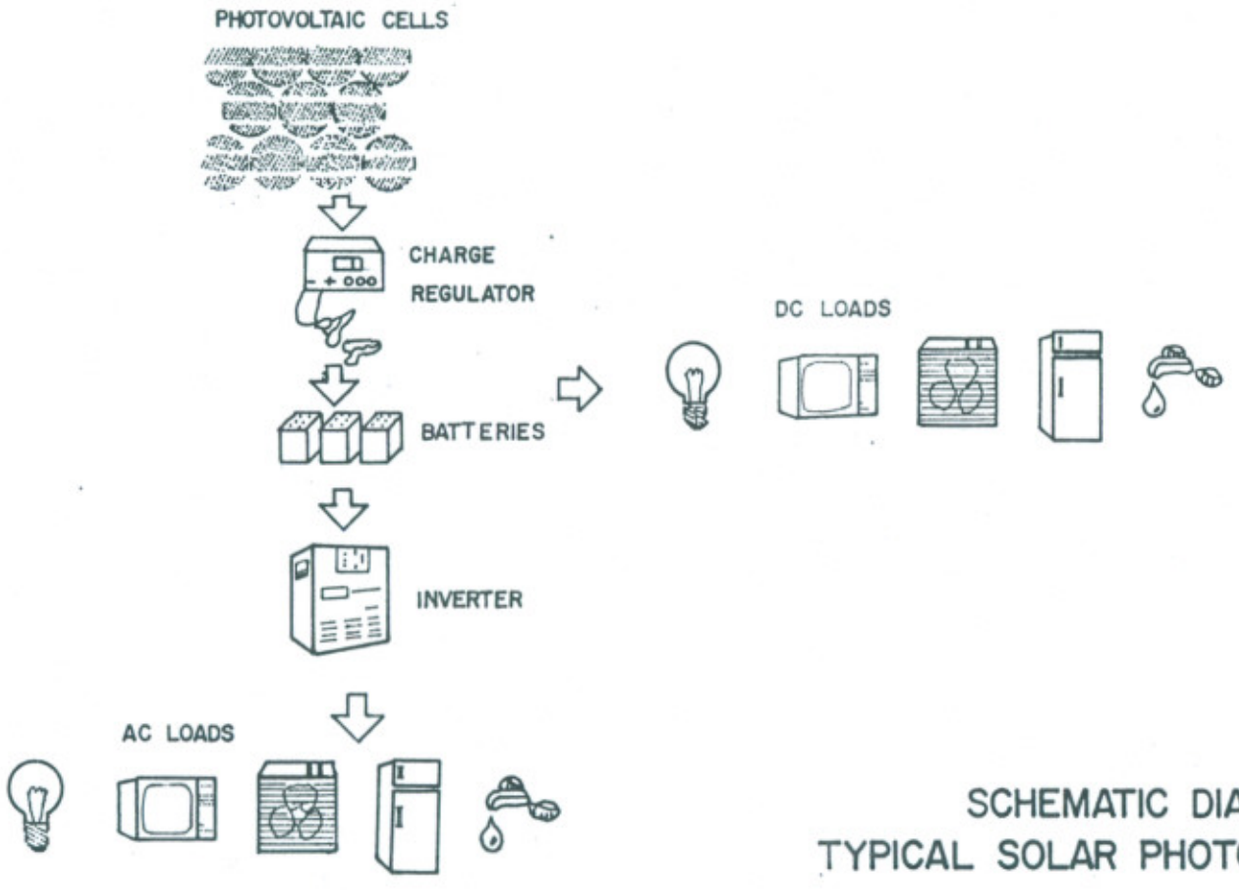
This means that to electrify those villages, which are away from the existing power supply network of WAPDA by 36 Km or more, it is economically more feasible to supply from 'Solar Photovoltaic System' rather than providing them from the existing power network.


Chemical Feed
P
Feedwater Tank
(Airflow)
F
To Driers
Heat Exchanger/ Condenser
Feedwater Pump
P
Transfer Pump
P
Fuel Drying/ Storage Area
Controls
Boiler
Firebox / Grate
30 KW
Steam Engine
F
F
Forced Draft
Induced Draft
TYPICAL SYSTEM SCHEMATIC DIAGRAM
Steam Generator/Drier



TYPICAL CONCENTRATOR / RECEIVER
FOR SOLAR-THERMAL SYSTEM

FIG. 2



SCHEMATIC DIAGRAM FOR A
TYPICAL SOLAR PHOTOVOLTAIC SYSTEM

FIG - 3