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A Review of Distributed Generation Technologies And Their Applicability in Ethiopia

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EXECUTIVE SUMMARY

This study has four parts. The first part reviews the current energy and electricity situation in Ethiopia by examining the consumption and supply patterns of energy in general, and the electricity sector in particular.

The second part explores Distributed Generation, its definition and the reasons for its current popularity as the emerging electric power generation paradigm.

The third part evaluates makes a preliminary financial analysis of the "Mega" hydro electricity vs Distributed Generation electricity.

Finally, the concluding section summarizes the different issues raised, and comes up with a few recommendations.

1. INTRODUCTION: ETHIOPIA'S ENERGY PICTURE

Mekonnen Kassa of the Ethiopian Rural Energy Development and Promotion Center provides a succinct summarization of the energy situation in Ethiopia. The first few paragraphs of his paper "AN OVERVIEW TO THE ENERGY SITUATION IN ETHIOPIA" are quoted as is.[1]

Total final energy consumption in 1988 E.C. was estimated at 723 Peta Joules or about 50 million tones of wood equivalent (or and is characterized by a high dependence on biomass fuels […]. Firewood and charcoal combined met more than 77 per cent of the final consumption and agricultural residues (dung and crop residues) an estimated 15.5 per cent. The contribution of the modern component of the sector (i.e., petroleum and electricity) was no more than 6%.
The supply of petroleum products is met entirely by importation and has claimed 15-20% of imports in recent years. Petroleum fuel consumption in 1988 amounted to about 870 thousand tonnes and contributed approximately 4.8% of total final consumption. The transport sector accounted for more than 51% of the consumption of petroleum products, among which diesel oil (46%), kerosene (20%) and gasoline (18%) predominate.

1 Mekonnen Kassa, "An Overview to the Energy Situation in Ethiopia", Economic Focus, V3 No. 5

Electricity generated amounted to 1,563,415 MWh (96.4% from hydro and 3.6% diesel) and covered less than 1% of final consumption but absorbs over 90% of energy sector investment programme. Energy consumption consisted of approximately 89 per cent by households (83% by rural and 6% by urban households), 4.6% by industry, 2.5% by transport and 3.6% by the services sector. Energy used in the agricultural sector represented merely 0.1% of total consumption and 2.3% of petroleum products.
The energy consumption pattern reveals that energy distribution and consumption is biased with electricity and petroleum fuels hardly flowing to rural areas indicating energy consumption inequality in the form of energy being used. Urban households consumed 79.9% of biomass fuels and 20.1% of modern fuels whereas the rural households' energy consumption was almost entirely of biomass fuels (99.92%), petroleum products contributed merely 0.08%.

While understanding the fact that most of the energy demand and supply in Ethiopia revolves around rural bio-fuel, this paper focuses on the electricity sector.

The electricity market has so far been dominated by what used to be called EELPA, but is now known as EEPCO (Ethiopian Electric Power Corporation). The name change is not just cosmetic; it denotes a restructuring of the energy industry under a new energy policy instituted in 1994, and the creation of the Ethiopian Electric Agency by Proclamation No. 86/1997. Under this restructuring, EEPCO becomes a state owned commercial supplier of electric power, while EEA has responsibilities to "…promote the development of efficient, reliable, high quality and economical electricity services…"[2] Essentially, the EEA is to be responsible for issues that face any and all entities engaged in the production, sale and distribution of electricity. Examples of such issues are pricing policies and technical standards.

Data[3] for 1995 indicates that EEPCO markets electricity to over 500,000 commercial and residential customers through what are called Inter Connected Systems (ICS) and Self Contained Systems (SCS). The ICS refers to the main national grid fed by six main hydroelectric power stations (Koka, Awash II and III, Tis-Abbay I, Finchaa and Melka-Wakena) and two diesel (Dire Dawa and Alamaya) power plants. The total installed capacity of the system is 378.1 MW. Of this total capacity, only 6.5 MW is from the diesel sources. In terms of total installed capacity in the country, the ICS represents about 93% of the total. ICS also serves 92.2% of EEPCO's customers.

The SCS serves 7.8% of EEPCO's customers and comprises of local generation plants serving small isolated loads through local sub-transmission and distribution networks. Even though mini hydro plants do exist in the SCS,

2 http://www.ethioinvestment.org/petrol/energy/subsector.htm
3 ibid.

the supply is primarily based on diesel generation. The system has an aggregate capacity of 32.9 MW of which 6.3 MW represents the mini hydro contribution, the remaining 26.6 MW being diesel. The SCS comprises 7% of the total installed capacity.

The following table provides the installed capacity in MW of the two systems, i.e., ICS and SCS.

TABLE 1:EEPCO's Generating Capacity

Source	ICS (MW)	SCS (MW)	Total
Hydro	371.6	6.3	377.9
Diesel	6.5	26.6	33.1
Total	378.1	32.9	411.0

Transmission voltages of 230 KV and 132 KV and sub-transmission voltages of 66 KV and 45 KV in both the ICS and SCS are used to transfer energy. The 45 KV level is being abandoned in favor of 66 KV. The present network consists of 4,945 Kms of transmission lines in total.
Power distribution occurs at 15 KV primary and 380/220 V secondary voltage levels. The two systems consist of roughly, 7,770 km of the 15 KV lines, 4,162 distribution transformers, and 5,880 km of 380 V low voltage lines. The following table provides a breakdown of the distribution network for the ICS and SCS.

Table 2: EEPCO's Transmission and Distribution Network

System	15 KV Lines	Transformers
ICS	6,835	3,836
SCS	935	336
Total	7,770	4,174

Such transmission and distribution however, comes at a cost. System losses, as determined from generation and sales figures, stand at 19%, which is roughly 271 GWh. Losses in the ICS and the SCS are 18% and 28%, respectively. The figures represent both technical and non-technical losses and the major percentage is attributed to the distribution network. These T & D losses are quite high when compared to what are accepted as “typical” such losses of 7% in the US for example.

The aforementioned energy policy has as its major objectives the following,

- Place high priority on hydropower resources development,
- Shift from traditional energy fuels to modern energy fuels,
- Establish standards and codes for efficient energy use,
- Develop human resources and establish strong energy institutions, and

- Pay due and close attention to ecological and environmental considerations during the development of energy projects.

The policy statement indicates a recognition of the need for developing sustainable and long-term energy solutions, primarily looking at the possibilities of hydro-electricity. Additionally, the environmental impact of too much reliance on traditional fuels such as wood is found in the stated need to shift from traditional to modern energy “fuels”.

With this background, we want to look at the possibility of pursuing a distributed generation approach to providing a more cost-effective method of achieving rural electrification, and higher urban electric power reliability. Successful distributed power generation can make electricity more accessible to rural areas and potentially replace bio-fuels at least partially. We also explore the potential for replacing bio-fuels in cooking by using alternative technologies. The concluding section will try and discuss distributed generation with respect to the Energy Policy goals.

2. DISTRIBUTED GENERATION

2.1. DEFINITION:

Distributed Generation is power generation technology that is close to the point of use, as opposed to the centralized production of energy. The scale of the generated power is significantly lower, as the generator is usually designed to service a home, a building, a manufacturing plant or commercial facility or a small community. Distributed generation systems may be independent, connected to a pre-existing grid, or be connected to other independent distributed generation facilities to create what are called “micro-grids”.

2.2. WHY NOW?

Stand-alone generators are not new, however there is a qualitative difference. Distributed generation has received a new emphasis in the industrialized economies because of the following three major factors.

2.2.1. Increased Demand for More Electricity

This is mostly a result of the telecommunication and computing industry’s explosion. Servers, cell phone towers and similar facilities of the information age cannot afford to be off-line. Not only is the availability of electricity important, the quality of power is also critical. Voltage spikes and power interruptions can ruin expensive electronic equipment.

2.2.2. Power Industry De-regulation

The US power industry has been deregulated due to a 1979 law called PURPA, allowing smaller generating companies to enter an industry formerly reserved for giant utilities. Such de-regulation is also becoming more common in other countries. This competition is forcing potential entrant to review capital requirements. Smaller scale generation that avoids high transmission and distribution costs becomes more attractive.

2.2.3. Environmental Regulations

Increasing penalties for emissions of CO_2 and other combustion gases is forcing the development of environmentally friendly electricity generation technologies. The prospect of severely negative environmental impact of electricity production by newly industrializing countries using "old" technologies is an additional stimulus.

2.3. DISTRIBUTED GENERATION BENEFITS,

2.3.1. Deferral of new transmission and distribution (T&D) capital investments

Electricity generated close to the point of use does not require miles of high power copper wires, nor a transformer station. Estimates for adding a mile of new wire in the US range from $5,000 to $40,000 per mile. Preliminary data for Ethiopia indicates that an international class grid extension can cost as high as USD$108538.35 per KM[4].

2.3.2. Elimination of T&D electrical line losses

It is generally accepted that around 7% of the electric power generated is lost during transmission from the central generation source to the final point of use. Electricity generated at a centralized station has to be stepped up for high power transmission, sent through miles of copper wire, then stepped down before being delivered to the end user. Each step has unavoidable inefficiencies in it that eventually build up to significant losses. In Ethiopia these losses are much higher and range from 18% to 28%.

2.3.3. Improved power quality and reliability

As discussed above, power quality is another benefit of distributed generation. For some applications, power interruption, voltage spikes, "brown-outs" and other power quality disruptions are simply unacceptable. Last year (2000) the drought so severely affected the hydroelectric power delivery in Ethiopia that EEPCO instituted electricity rationing throughout the country. Besides affecting the quality of life of ordinary electricity consuming citizens, such blackouts have affected manufacturing industries. One commentator has described the effect on the Mugher cement factory, and the result that had on the price of cement.[5]

2.3.4. Reduction in energy ($/kWh) and electric demand ($/kW) charges

Peak shaving - choosing to get off the grid at times of peak demand when charges are high, or base loading - using your own DG resource to meet most of your needs and using grid supply for peak demand times only, are some of the strategies used to reduce overall utility electric bills. Electricity charges

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4 "Electricity Deal Signed With Sudan And Djibouti", UN Integrated Regional Information Network, April 25, 2001

5 "Pessimism in Ethiopia Over Energy Crisis", Ethiopia: Seven Days Update (Addis Ababa), July 12, 2000

for Ethiopian residential customers move in bands of 0-50, 50-100, 100-200, 200-300 and >300 kWh, each band demanding higher per kWh charges.[6]

2.3.5. Combined heat and power application for high energy-efficiency

In the process of converting fuel into electricity, a large amount of heat is created (on average 2/3 of energy content of the fuel). Customers can utilize this heat if a power generation system is located on-site or near the customer's facility. By using CHP, customers can increase efficiency, lower greenhouse gas emissions, and lower power costs. CHP is best suited for mid to high thermal use customers, such as process industries, hospitals, prisons, health clubs, and laundries.

2.3.6. Self-reliance: potential source of emergency and high reliability standby power.

Beyond the reliability issues, locations that are far from a grid are better off generating their own power rather than facing the stiff capital costs associated with connecting to a remote grid line. Locations that ARE connected to the grid have the additional benefit of having reliable, high quality back up.

2.3.7. Environmental Cleanliness

DG technologies are generally designed from the ground up to be environmentally more benign, with little to no impact on air quality when compared to current centralized generation. For companies that can be exposed to stiff penalties due to pollutant emissions, this becomes an economic issue.

2.4. DISTRIBUTED GENERATION TECHNOLOGIES

Distributed generation technologies can be roughly divided into two: generation and storage.

2.4.1. Power Generation

Overall, the power generation technologies can be divided into combustion, chemical conversion, and renewables.

2.4.1.1. Combustion Technologies

In these technologies, fuel is burnt, converting the chemical energy of the fuel into thermal energy, which is then converted to mechanical work, and then into electricity. The classics are the old standby reciprocating diesel and gasoline engines. The new one here is microturbine technology.

2.4.1.2. Direct Chemical Conversion

This really refers to the emerging field of Fuel Cells, which are devices that convert the chemical energy of a fuel directly into electricity, bypassing the thermal and mechanical stages of the combustion technologies. There are different variants of this technology, but the chemical reaction is essentially the combination of hydrogen gas with oxygen to create heat, electricity and

6 Personal communication with Bethlehem Mengistu

water vapor. The efficiency and the environmental-friendliness of the technology is pushing a lot of development work.

2.4.1.3. Renewables

These are DG technologies essentially tied, directly or indirectly, to solar energy. These include solar technologies such as photovoltaics and solar-thermal application. There is also wind energy. And finally, micro-hydropower is included.

2.4.2. Energy Storage

Energy storage issues are becoming critical as the various DG technologies mature. The relevant approaches can be summarized into the following: Chemical storage, Mechanical and Grid

2.4.2.1. Chemical Storage

2.4.2.1.1. Fuel

In the combustion technologies, the fuel that is not burnt, such as natural gas, or propane, IS the stored energy. The same can be said of the Fuel Cell technologies, which really use Hydrogen as fuel, but have to rely on reforming a more classic hydrogen-rich fuel such as Methanol or natural gas.

2.4.2.1.2. Electro-chemical Battery

Excess energy is used to charge the battery that rely on the chemistry of its contents. The downside is that batteries are environmental problems, and require replacement every two years.

2.4.2.2. Mechanical Battery

This refers to flywheel systems that retain the energy in the kinetic rotation energy of an enclosed mass. New flywheels are designed to work at very high rotations (in the scale of 10000RPM). The designs are simple, have no hazardous chemicals, and can be buried and forgotten for as long as 20 years.

2.4.2.3. Grid

DG facilities that are connected to the grid do not need to bother with storage issues as the grid itself serves as "virtual" storage. Typically, excess energy is sold to the utility that owns the grid, and it is bought back when needed. Interconnection standards are the technical issues here, while policy issues such as the electricity selling and buying rates have to be considered.

2.5. COST COMPARISON OF DG TECHNOLOGIES

The installed and operating costs of the various technologies are presented below. It is important to note that the cost estimates and numbers vary from source to source, but we have chosen to use this relatively more comprehensive summary. It should be noted that these costs do not factor indirect costs such as environmental impact. Considering such factors would make clean technologies more attractive.

Table 3: Cost Summary of Distributed Generation Technologies7

Product	Diesel Engine	Gas Engine	Simple Cycle Gas Turbine	Micro-turbine	Fuel Cell	Photovoltaics	Wind Turbine
Rollout	Commercial	Commercial	Commercial	Commercial	1996 – 2010	Commercial	Commercial
Size Range (kW)	20 – 10,000+	50 – 5,000+	1,000+	30 – 200	50 – 1000+	1+	10 kW - 1MW
Efficiency (HHV)	36 –43%	28–42%	21– 40%	25 – 30%	35– 54%	N/A.	25% - 40%
Genset Package Cost ($/kW)	125 –300	250–600	300 – 600	350 –750*	1500 – 3000	N/A.	
Turnkey Cost- no heat recovery ($/kW)	350 –500	600–1000	650 – 900	600 –1100	1900–3500	5000 – 10000	1,000
Heat Recovery Added Costs ($/kW)	N/A.	$75–150	$100 – 200	$75 – 350	incl.	N/A.	N/A
O&M Cost ($/kWh)	0.005–0.010	0.007–0.015	0.003 – 0.008	0.005 – 0.010	0.005 – 0.010	0.001–0.004	0.01

2.6. ENVIRONMENTAL IMPACT

The environmental impact of the new distributed generation sources is best captured in the following table

7 SOURCE: Gas Research Institute, http://www.gri.org/pub/solutions/dg/distgen.pdf, Wind column added by authors.

Table 4: Environmental Impact Comparison of Generation Technologies

EMISSIONS for Uncontrolled electric generators sized under 1 MW							
		Eff	**Emissions in lb./MWh**				
DEVICE	**Fuel**	**% at HHV**	**CO2**	**NOx**	**SO2**	**CO**	**PM-10**
ICE	Diesel	33 - 42	1300 - 1700	10 - 41	0.4 - 3	0.4 - 9	0.4 - 3
ICE, stoic	NG	33-42	950-1,200	18-53	negl.	1-6	~0.6
ICE, LE	NG	35-41	980-1,100	0.3-6.0	negl.	2-9	~0.6
Microturbine	NG	22-30	1,300-1,800	0.2-1.4	negl.	0.3-1.8	>0.03
Fuel Cell	H from NG	29-50	800-1,400	<0.05	0	0.01-0.12	Negl.
Biomass	Gas/wood	30 –41	0 -2300	0.3 – 6.0	< 0.3	2 - 9	0.6 -4
Photovoltaic	Sunlight	N/a	0	0	0	0	0
Wind	Wind	N/a	0	0	0	0	0

(SOURCE: Derived from http://www.distributed-generation.com/Library/Emissions.PDF)

As this table indicates, PV and Wind technologies are the true green alternatives. While microtubines and fuel cells are not as clean as PV and wind, they represent significant improvements in SOx, NOx and Particulate emissions when compared to traditional internal combustion engines. CO_2 emissions are in some instances comparable, but when viewed in terms of the improved efficiencies, they demonstrate net improvements.

Comparing between the Fuel cells and microtubines, we see fuel cells produce $1/3^{rd}$ less CO_2, $1/10^{th}$ the NOx, and ½ the CO of a Microturbine. This seems to indicate that fuel cells are the preferred environmental choice, but cost may be a barrier to their acceptance with respect to microturbines at this point.

2.7. BARRIER

There are a number of significant technical, economic and institutional barriers that hinder the deployment of distributed power technologies. Leaving aside the different technical issues for the different generating technologies, the following are the important barriers to the spread of DG as a concept.

2.7.1. Interconnection with the grid

This is essentially an issue of technical standardization, or rather the lack of standards for independent, but grid connected generators to connect to the grid. This does not seem to have been looked at in Ethiopia.[8]

2.7.2. Utility pricing practices and tariff structures

Current utility use tariffs and rate design as a rule do not price distribution services to account for system benefits that could be provided by distributed generation. A grid connected generation facility in Ethiopia has to sell the electricity at prices set by EEPCO, since EEPCO owns the grid.

2.7.3. Siting, permitting and environmental regulation

Regulatory processes can both delay and increase the costs of distributed power projects. In general, distributed power technologies are not covered in national building, electrical, and safety codes. We do not believe this issue has been explored in Ethiopia

2.7.4. Current business models and practices

Existing business practice and business models often reflect the old regulated electricity industry dominated by vertically integrated utilities and central station power plants. New business models are needed to capture the values of non-utility owned distributed power in delaying or avoiding transmission and distribution system upgrades, the use of distributed power for ancillary services and for improving system reliability, power quality and reducing line losses.

3. ETHIOPIAN DISTRIBUTED GENERATION POWER ECONOMICS

3.1. RELATIVE COSTS

To do a valid financial analysis of the possibility of Distributed Generation applicability in Ethiopia, we have referred to the table we showed earlier in Table 3, and added a column for hydroelectricity costs (see Table 5 below).

TABLE 5: ELECTRICITY GENERATION TECHNOLOGIES ECONOMIC COMPARISON[9]

Product	Diesel Engine	Simple Cycle Gas Turbine	Micro-turbine	Fuel Cell	Photovoltaics	Wind Turbine	Hydro Electricity 10
Size Range (kW)	20 – 10,000+	1,000+	30 – 200	50 – 1000+	1+	10 kW – 1MW	
Turnkey	350 –500	650 – 900	600 –1100	1900–	5000 –	1,000	$1,700-

8 Personal communication with Alemayehu Negash of Ethiopian Renewable Energy Society

9 Derived from Table 3

10 US DOE, "Hydro Power R&D – Partnership with the Environment", http://hydropower.inel.gov/hydror&d/hydror&d.pd)

Cost- ($/kW)				3500	10000		2,300
O&M Cost ($/kWh)	0.005–0.010	0.003 – 0.008	0.005 – 0.010	0.005 – 0.010	0.001–0.004	0.01	0.007
Service Life	20 years	20 Yrs	20 yrs	20 yrs	20 yrs	20 yrs	50+ years
System Efficiency (%)	30 - 35	30 -35	30 – 35 ~50% w/CHP	40 – 50 ~75% w/CHP	~24%	~40%	80% plus

The value for hydroelectricity is taken from the US Department of Energy's Hydropower Website, hardly a source of biased information. As can be evident here, at least a couple of the DG technologies already cost lower on a per kW basis than typical Hydroelectric establishments.

3.2. COST ELEMENTS

The basic elements that affect the cost of electricity (in fact for any business) are:

a) Capital cost
   i) Basic System Cost:
      - wind turbines, PV panels, fuel cells
   ii) Balance of System Costs:
      - typically about half of total capital cost for most systems
      - Inverters, rectifiers, housing, wiring, support structures, housing, construction, land rent, set up manpower
b) Operating and Maintenance Cost, which includes:
   i) Scheduled repairs
      - Cleaning, lubricating, replacing minor components
   ii) Unscheduled repairs
      - Replacement of major components
      - (perhaps also include costs due to lost income)
   iii) Manpower
      - Customer service, sales and marketing
   iv) Services fees, taxes etc..
   v) Fuel
c) Financing Cost (which is influenced by interest rates and amortization period)

On top of these costs, what must be taken into account is the avoided cost of setting up a transmission and distribution infrastructure, and associated losses.

TABLE 6: US vs. ETHIOPIA GRID EXTENSION COSTS

	US	ETHIOPIA
T & D Losses	7%	18% – 28%
Per Mile Grid Extension	USD 5,000 – 40,000	@ USD 174,825[11]

Typical transmission and distribution losses for the US are frequently given as 7%, while similar losses for Ethiopia are given as 18% and 28% for the ICS and SCS. The reason for this huge disparity is not known, nevertheless, it does point to the significant economic losses incurred with the adoption of a centralized power system in Ethiopia.

The per mile grid extension number for the US is a range that was derived from many resources on the web. While the average US value may be around $15,000, even the high end of this range, the $40,000 per mile figure, pales in comparison with what EEPCO is budgeting to sell electricity to Sudan and Djibouti. The validity of this number is still questionable.

3.3. ELECTRICITY CONSUMPTION AND GENERATOR SIZING

To answer the question of what typical residential and commercial electricity demands in Ethiopia are, data was collected from EEPCO[12], as well as from the electricity bills of a "high-end" residential user. Accordingly,

Typical Household Consumption:
ICS: 1055 kWh/yr
Rural: 304 kWh/yr

"High –End" Urban Household Consumption per Month: 250kWh

Cost per kWh:
ICS: ETB 0.06/kWh
SCS: ETB 0.34/kWh

Typical Commercial Consumer:
143Gwh/year (Gigawatt hour per year).

Sizing these consumption rates into the generator power rating is difficult, but the following process was followed. The annual consumption rates were

11 This data is taken from the grid extension budget of EEPCO for selling electricity to Sudan and Djibouti. The numbers provided were for a 691 km grid extension costing USD$75,000,000

12 Communication from Bethlehem Mengistu

divided by 12 to give the monthly rate. The number of total hours in a month were calculated using 30x24, and that came out to be 720. Then an assumption was made into how much of that monthly consumption could be distilled into a period of constant peak power demand (thus the heading Peak Usage Rate %). This number is based on what the authors assume to be is a reasonable usage rate, i.e. a house will probably have its peak electricity usage during a few hours in the evening (hence 25%), while a business will use peak power during the working day. Peak power requirement was then calculated by dividing the monthly consumption (in kWh), by the product of number of total monthly hours and the peak usage rate (i.e. 720 times the Peak Usage Rate). The latter figure gives a result in hours, allowing the "hr" expression in the "kWh" number to be cancelled out and providing the peak power requirement in kW.

TABLE 7: POWER REQUIREMENT SIZING FOR TYPICAL ETHIOPIAN USERS

	Annual Consumption (kWh)	Monthly Consumption (kWh)	Peak Usage Rate (%)	Peak Power Requirement (kW)
High End Urban[13]		250.0	25.00%	1.39
Average Urban	1055	87.9	25.00%	0.49
Average Rural	304	25.3	25.00%	0.14
Average Commercial	143000000	11900000	40.00%	41319.44

For fulfilling residential needs, we can assume two scenarios. One would be if a household decides to power itself exclusively. The second is if a small private enterprise invests in power generation equipment to sell electricity to its small town and village consumers. We believe the first scenario is unrealistic, and so have focused on the second.

This analysis suggests that the electricity needs of a rural town of 100 households can be met by the production of 20kW of power. The 20kW number is not too far from an actual example of a 30KW PV village electrification for Mitto (population 300 households) 1987 – 1989 by the Ethiopian National Energy Committee (ENEC) and the Ministry of Agriculture. The plant provided 4- 5 hours of nighttime lighting, powered the village borehole pump and flour mill. [14]:

While a similar calculation can be made for urban settings, it can fairly reasonably be assumed that larger towns and cities can and already are served

13 Communication from Le'aelaf Mengistu

14 email interview with Ato Yonael Teklu (former ENEC engineer) October 1995

by the grid-supplied hydro-electricity. EEPCO anticipates the blackouts and power rationing of the year 2000 due to drought could be eliminated when an additional 46% of new generating capacity is brought in-line within the next four to five year period.

So, the question becomes, what are the financial issues related to setting up a 20kW generating facility, and selling electricity produced through it.

3.4. FINANCIAL ANALYSIS MODEL

A very simple spreadsheet program was set up to see the financial viability of the implementation of one of the DG technologies discussed. The program takes into account the following: Capital cost per kW, Operating and Maintenance Costs per KWh, interest rate, loan repayment period, exchange rate, peak power generating capacity, number of users and percent of peak power usage time. The numbers that were found were then compared to EEPCO's rural or SCS rate of ETB 0.34 per kWh.

For the "sample" example cited earlier (i.e. 100 users), a distributed generation facility with a 20kW, at 10% interest, 20 year loan period and an O&M cost of US$0.01was evaluated. For those terms, a technology selection that costs US$700 per kW is a better investment than EEPCO's rate of 0.34 per kWh. This indicates that low end wind, microturbine and diesel systems will be financially appropriate technologies. PV is still the costliest alternative, with Fuel Cells coming a distant second.

3.5. "MICRO" LEVEL DISCUSSION

The above example shows that a rural electrification scheme with distributed generation technologies can be applied with prices that are currently being charged by EEPCO. The initial investment costs can be expected to keep going down in US dollar terms as technical improvements and global manufacturing volumes go further.

However, the question of whether or not it is possible to attract private investors to this sector will depend a lot on the capital cost, stability during the loan repayment period and exchange rates for inputs such as fuel.

A financing arrangement that can be worked out with the government with T & D deferral costs in mind, can help bring down the capital costs for the producer. So can significant domestic input in terms of capital costs, as well as (potentially) domestic fuel sources.

If electricity prices can include the true price of fuelwood, which is expected to steadily go up as deforestation and population increase, then the price the market will be willing to pay may be higher.

3.6. "MACRO" LEVEL DISCUSSION

A distributed generation approach can have significant positive impact when the following are considered.

3.6.1. Scale, Scope and Speed of Power Generation Deployment

One of the biggest problems associated with rural electrification in Ethiopia is the extreme dispersal of the rural population, complaints often being that settlements do not typically have a large enough population close enough to make economic sense for electricity deployment.

Distributed generation technologies can be much better scaled to local electric power requirement. Photovoltaic technology is especially noteworthy in this regard, as PV panels can be bought to meet village energy demand right now, and easily added on in the future. Some of the other systems can be similarly scaled for small towns that have no current dependable, or sufficient electricity. Such scaling opportunities mean that many small (perhaps even economically viable) generation facilities may be installed, thereby expanding the scope of the electricity reach. Finally, the modest scale of such facilities means that the probability of such installations being quickly deployed is quite high when compared to the several decades mega scale hydro facilities require from inception to generation.

3.6.2. "Balance-Of-System" Opportunities

For much of the systems discussed, the balance-of-system (BOS) costs are about half of the indicated per kW costs. There is a "non-equipment" part of the BOS costs which includes inputs such as land, consulting, construction, taxes and fees. The "equipment" half of the BOS is usually composed of support structures, wiring, inverters and storage.

The non-equipment part of BOS expenses indicate opportunities for economic activities in construction, consulting and other services, all of them targeted in the rural areas.

Much of the "equipment" half of the BOS indicate opportunities for local manufacturing. Supporting frames, wiring, housing and similar components can, even today, be implemented with significant local input. When one takes into consideration the generic role inverters play in any type of DG facility, it is not hard to imagine that the promise of the sheer volume of such installations can create incentives for investors who would wish to manufacture such component.

3.6.3. Foreign Exchange

As a follow-up to the above discussions, an important point that has to be underlined is the role foreign exchange has in electricity generation in the centralized system and the DG system. Centralized generation systems are highly engineered because of the scale of power they generate. Almost by definition, they have to be imported into the country lock, stock and barrel, in foreign exchange, under international financing terms. If projects like Gilgel Gibe and Melka Wakana are to be appropriate guides, then it will be many, many years before they are completed and deployed. In the meantime, the clock is ticking on the loan repayment, which invariably is in US dollars. So is the exchange rate, which always is on a downward valuation trend vs. the dollar, and can rationally be expected to be so for the foreseeable future. Again, when the Gilgel Gibe and Melka Wakana projects were initiated, the country's official exchange rate was at ETB2.07 for every USD. Today, some fifteen years later, the rate hovers around ETB8.50, with not a single Watt of power having yet to be generated. We do not know the terms of the loans for those projects, but when one considers that typical capital financing loans are for thirty years, some of the irrationalities of the "centralized" approach will be fairly obvious.

On the other hand, a distributed generation approach that can be quickly deployed, and can have significant local input can be a great relief on the country's foreign exchange requirements and indebtedness.

3.6.4. Local Expertise

Large installations are highly engineered, and require significant technical knowledge for installing and deployment, invariably of foreign origin. Once they are deployed, they require a relatively few persons, typically highly trained, to run them. The opportunities to develop local capabilities in associated technical knowledge is few, far in between, and perhaps even hard to justify considering the lack of "economy of scale".

Many local companies, in the business of deploying many generation facilities all over rural Ethiopia, must necessarily have a large pool of local expertise to draw on. The constant push to drop costs and increase profits also means that the requirement for local expertise can extend into the affiliated BOS activities.

Such need based technical expertise, once developed for the electricity generating business, can flow into other industries, perhaps electric equipment design, manufacture and sales.

An additional dimension of this is the support rural electrification can have on the electric equipment manufacturing industry.

4. BACK TO BASICS: THE REAL ENERGY NEED

The foregoing sections looked at the various technologies associated with electricity generation at scales that are close to what actual customers need, and at locations close to where these customers are. It would be remiss if we did not go back and see the real energy need in Ethiopia, especially the vast rural untouched sections that will see many years before electricity becomes part of their daily life.

4.1. ENERGY SOURCE AND CONSUMPTION

The following table summarizes the national energy consumption by source

TABLE 8: ETHIOPIAN NATIONAL ENERGY SOURCES[15]

SOURCES	PERCENT AGE
Fuel wood	69.9%
Dung and Crop Residue	14.9%
Oil Products	4.2%
Electricity	0.5%

The dependence on firewood has had some dire consequences. With an agriculture based economy, one of the most pressing issues facing Ethiopia today is that of an alarming rate of deforestation and resulting soil erosion. At the turn of the century, 70% of Ethiopia was covered by forest, today this has been reduced to less that 3%. The resulting has been devastating with an estimated one million tons of soil lost to erosion every year. One of the major reasons for deforestation is the eternal search for firewood.

In addition, while oil imports contribute a mere 4.2% to the national energy consumption, the value corresponds to 40-48% of Ethiopia's total exports. Use of dung and crop residue for energy generation means that the land is deprived of useful mineral nutrients. The result is that farm yield is reduced by 2% which translates to a loss of 1.5 million tons of grain.

Households account for the vast majority of energy consumption contributing a whopping 82 % to total final energy consumption (Agriculture, Industry, transport, Public and Commercial account for the rest). Rural peasant settlements account for 87.8% of all domestic energy consumption. Of this rural energy consumption, a minute 0.02% comes from modern fuels. This means that when the country is considered as a whole, almost all consumption of energy is derived from traditional fuels. It should also be noted that 75% of Ethiopia's regions experience fuel wood shortages.

As mentioned in the introduction, rural households account for up to 83% of energy consumption in Ethiopia. In addition, an estimated 77% of the total energy consumption in Ethiopia is for cooking, the vast majority of which is provided by firewood. This means that rural cooking accounts for the majority of energy consumption in Ethiopia. An associated interesting statistic is the amount of energy estimated to be used in the making of Injera, which Yacob[16] cites Cecelski as having estimated to be 62,500 kJ of energy per kg of injera. This was about 40 times and 20 times more than the energy required to bake the same quantity of chapati and boil one kg of rice, respectively. This is a shocking number by any stretch of the imagination,

[15] Samson Tolessa "Photovoltaics, Country Profile – Ethiopia"

16 Yacob Mulugetta, "Energy In Rural Ethiopia: Consumption Patterns, Associated Problems And Prospects For A Sustainable Energy Strategy"

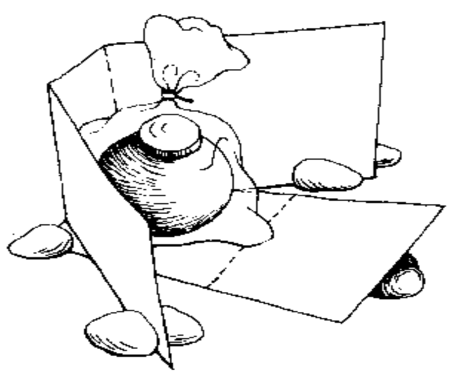
and points to the need for engineering better cooking technologies, if one is to have immediate and significant impact on the energy and deforestation issues.

According to Ian Brooks of UNICEF17 women carrying heavy loads of firewood on their backs suffer from spinal deformation, and the smoke from the burning wood causes upper respiratory related problems. Thus a clean, renewable and readily available alternative energy for cooking is an urgent need.

4.2. NEW TECHNOLOGIES IN THE KITCHEN

In fact, such activities have been taking place. A new injera mTad called "Mirt Mitad" has been on the market since mid 1995 and is now manufactured at dozens of locations throughout the country. Data printed in 1998 indicates that 50,000 have been sold just between April 97 and April 98 alone[18]. The traditional mitad design used to waste over 93% of the energy generated, while this new design is said to reduce fuelwood requirement by 50%. Another technical improvement is the now ubiquitous "Lakech" charcoal stove.[19] Charcoal use if quite high for boiling, cooking and just heating applications in Ethiopia.

There has to be however, a shift from making better use of fuelwood as a cooking resource, to not using wood as a cooking resource at all. In this respective the technological shift for non-electrified areas should move towards the use of solar cookers.



Solar cookers come in three basic categories: box cookers, panel cookers and parabolic cookers but they all operate using the same principle. Reflective surfaces (such as mirrors or even aluminum foil) are used to concentrate the sun's heat onto a dark pot that is places in the middle of the reflector.

The simplest and cheapest one is the panel cooker which can be made from cardboard covered with aluminum foil for less that $2 US. The pot is put in a plastic cooking bag that retains the heat. The solar panel cookers are being used by about 5400 families in the

17 Phone interview with Ian Brooks, UNICEF Copenhagen, May 1995

18 http://info.tve.org/ho/doc.cfm?aid=240

19 Communications from Alemayehu Negash of ERES.

Kakuma Refugee Camp in Kenya. They have also being used in the Aisha Refugee Camp in Ethiopia[20].

There have been recent efforts in producing and promoting solar cookers. For example Selam Technical and Vocational Center has been designing parabolic and box solar cookers. It is also encouraging to see private businesses moving into this space. Bereket Solar, a company started recently by a graduate of Selam manufactures these solar cookers.[21] However compared to neighboring countries such as Kenya the penetration of such alternative cooking technologies is low.

4.3. SOLAR COOKING RECOMMENDATION

As far as solar cookers are concerned we propose two main recommendations. First there is the need to improve solar cookers locally and make them appropriate to local conditions. Second it is critical to formulate a good plan to ensure that the target population embraces this technology.

The success of solar cookers in Ethiopia will be determined by how well these cookers are able to meet the needs of the target population, as well as how accessible they are. This means that the design of the cookers has to be such that they are easily made from locally available material, and they meet the cooking needs of the population. One of the obvious disadvantages of current solar cookers is the inability to cook at night. There has been some interesting work at universities in the US to design modules made of cement or clay that can store heat from the sun during the day and release it for cooking at night. There should be a concerted effort to encourage Ethiopian academic/technical institutions as well as entrepreneurs to work closely with such researchers in the West as well as elsewhere in the world, to develop even more efficient solar cookers that can be produced locally.

Even with some of their obvious disadvantages, current solar cookers by virtue of the fact that they are easily and cheaply made, as well as effective during daytime hours, have the potential to make a significant impact. However the success of this technology will be determined by how well the local population embraces it. Cooking is a very traditional task and the idea of using the sun to cook is a significant cultural shift especially as no flames are involved. To diffuse this technology successfully it is critical that key and respected members of the community are first targeted and educated regarding the benefits of solar cookers. The cookers and perhaps even some trial food to be cooked should be provided for free. It is also very important that their feedback is incorporated in improving the cookers. Once these key community members embrace solar cookers they can be the evangelists for the technology in the community. It is critical that a well-thought out plan for

20 (Solar Cookers International East Africa Update http://solarcooking.org/scrdec99.htm#East Africa Update)

21 email interview with Alemayehu Negash March 2001

diffusing this technology in the target population be put in place because if the cookers are introduced without considering this issue and they fail, the chance of this technology ever being embraced in that community in the future will have been significantly reduced.

5. CONCLUSIONS AND RECOMMENDATION

Based on what we have looked at, the following can be concluded.

- When grid extension costs and current grid transmission losses are taken into account, the distributed generation approach shows high promise as a cost-effective method of rural electrification.
- The amount of investment needed for producing and selling electricity at the scale of tens of kilowatts, as opposed to hundreds of megawatts, is attractive to private investors of relatively modest means.
- Current anticipated growth in fuel prices, combined with the continuing steep drop in PV and wind system costs, will continue to make ever more compelling business cases for the commercial exploitation of electricity produced using these methods.
- For absolute power dependability in areas that are not grid connected, the drop in purchasing prices, and the low O&M costs for Fuel Cells and Microturbines will eventually, (perhaps within the coming 5 years) make these technologies viable alternatives to diesel generation.
- In many cases, each of the different technologies can be implemented in a complementary fashion, for example, low solar radiation during the rainy season can be complemented by higher wind speeds during the same period. Also, microturbines that are more flexible in terms of fuel selection can be used as backups rather than diesels.

There are additional benefits to pursuing the Distributed Generation approach.

- Consistent with the government's energy policy of developing institutional capabilities, small-scale electrical energy companies that pursue opportunities throughout rural Ethiopia will result in the formation of technically competent organizations. This will happen because they will be motivated to protect their investment while maximizing their return.
- The spread of DG electricity in the rural areas will help support a budding local electrical equipment industry, by opening up the hitherto untouched rural market for things like light bulbs, radios, TVs, electric cookers, etc…
- The Balance-Of-System costs in most DG applications account for half or more of the system. Implementing DG can help create manufacturing opportunities for domestic companies that make the various components in the balance-of-system, saving foreign exchange and developing domestic talent. Examples would be inverters that can work for almost any DG application, towers for wind turbines, PV panel frames, etc…

- The adoption of DG technologies in the cities can help support urban electricity demand for periods when low rainfall cuts down on the capabilities of hydroelectric dams.
- DG technologies are designed from the ground up with the environment in mind. This sensitivity to the environment is also one of the stated goals of the energy policy.

For DG to be widely accepted, the following are recommended.

- Detailed energy potential information on as many sites as possible in Ethiopia need to be carried out by a central entity. This refers to wind and solar energy specifically. This is a task better done by governmental organizations.
- Financing incentives should be pursued. The government should take a second look at the international loans it gets for the energy sector, and carefully balance its stated need to generate mega hydro-electricity, the costs associated with transmission and distribution of that electricity, the overall savings in DG supplied rural electricity, the development of technically capable local generating companies, the support of indigenous electrical equipment manufacturers, and the rapid electrification of the rural areas.
- Local electrical equipment manufacturers could perhaps be brought into the picture to look at designing equipment that can work at (perhaps) lower voltages or currents than the standard urban 220V 50Hz AC system. These can help make the cost of electricity usage low and manageable for the typical rural user, helping generating companies get customers, as well as opening further markets for the manufacturer. In this regard, perhaps further re-design for improved efficiency of the standard electric mitad used in the cities could be carried out so that electricity instead of fuelwood can be used in urban as well as rural areas for cooking.
- The success of DPG in Ethiopia will depend on the development of local technical expertise and industry to support it. Local design, manufacture and distribution of the components and subsystems of DPG solutions are necessary for the sustainability of these projects. Joint ventures with firms in neighboring countries and the west should be encouraged and tax incentives should be provided to allow such a local industry to develop.
- A “net-metering” policy would encourage a few urban residents/businesses to generate at least some of their own electricity using PV modules. Net-metering is a way of giving consumers electricity credits for power they have generated via their PV systems. Excess electricity generated can be fed into the main grid for credit for future electricity consumption.