

**ABSTRACT**

Sudan like most poor countries suffers from a deficiency in the supply of electrical power, especially for rural areas. Less than 10% of the total population, can benefit from the national grid connection.

This paper evaluates the economic, environmental and social issues associated with electrification in western Sudan for rural and nomadic peoples, by assessing three different systems for off-grid electricity supply; stand alone systems powered by diesel generator (gen-set), photovoltaic cells, and a larger distributed generator system (mini-grid).

The study indicates that, although photovoltaic might be the best source of electricity from an environmental and social view, unfortunately it currently cannot compete economically. The research identified that Sudanese customs and tax policy adds a significant cost to PV, making diesel generators the best power choice for rural and nomadic regions in Sudan. Other important factors include fuel supply problems and availability of spare parts for generators.



Figures 1-5: Scenes from Al Kababish area, lowest one shows wood market

**AIMS OF STUDY**

The aims of the study were to try and assess 3 types of electricity sources in terms of their economic, environmental and social benefits and dis-benefits for the Al Kababish people of west, central Sudan, the area they live in is shown in pictures in figures 1 – 5 and on the map in figure 6.



Figure 6: Al-Kababish area in north Kurdufan and nomadic routes in red

**METHOD**

- A flow chart of the model used to assess these sources is shown in figure 7.
- Villagers were interviewed to find out their current usage of electricity; various agencies and sources were used to gather other information for the model.
- 3 types of electricity generators were considered;
  - stand-alone PV modules (50 Wp);
  - 3 load scenarios (A – low), (B – mid), (C - high)
  - imported gen-sets (two capacities 0.5kW, 2.4 kW)
  - small mini-grid system (313kW peak)



Figure 7 : Flow chart of model used to make economic, environmental and social assessments of three types of electricity sources.

**OVERALL RESULTS**

- Economic results: levelised cost results for each system are shown in figure 8. Situations with each system with different loads and with and without fuel subsidies are considered.
  - PV systems are the most expensive option even without fuel subsidies.
  - Mini-grid system is the best.
- Environmental results: (carbon dioxide emissions, CO<sub>2</sub>)
  - PV solution was the best option.
  - Mini-grid at part load was the worst solution
- A table comparing centralised and distributed energy sources is given in Table 1. Finally, social concerns were also considered, these are more complex to disentangle, each system has some benefits and dis-benefits, these are listed in detail in the section to the right of this poster.

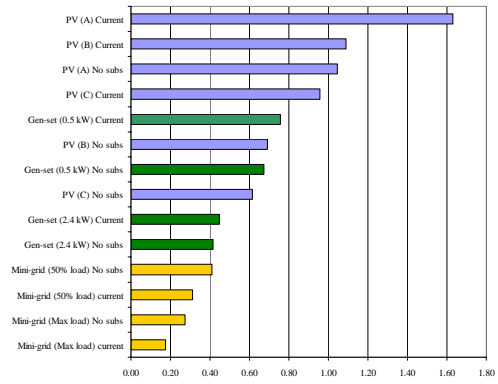


Fig. 8: Levelised economic cost for each system with and without subsidies, custom and taxes.

**STRATEGIES AND POLICIES**

- In a poor country like Sudan where there are no sustainability policies, big energy projects can be a great risk. A stand-alone system does not need a lot of supervision and maintenance, and could be more acceptable than a central system which belongs to the government and needs continuous supervision and maintenance.
- Sudanese policy towards rural electrification is encouraging the use of central power stations as the price of fuel is subsidized. Sudan now has oil and is a local source of energy.
- Renewable energy is considered as a new technology and has high duties; about 60% of the price of the product. For a diesel gen-set the total duty is 32% including customs 22% and taxes 10%. Thermal power station is beyond the remit of custom and tax as it is considered a public project and attracts no duties or taxes. Solar electricity depends totally on expensive imported products from industrialized countries. PV, can have estimated taxes of 100% of the import price.
- Adapting a strategy to use PV modules could lead to economic benefits, and build up local knowledge of the technology, which in turn would improve operation, maintenance and troubleshooting.
- Developing countries should encourage local participation to ensure the requirements of communities are met and ensure local adaptation of technology to protect the environment and resource base. Industrialised countries should provide overseas development, financial and technical assistance in a responsible and sustainable manner.
- Technologies for electricity generation should be evaluated economically, environmentally and socially before choosing, ignoring one of these elements leads to one or more of the following problems;
  - failure of the project,
  - failure of electrification programmes in nearby villages,
  - social and economical problems at the national level.
- Also, developers must have a future view for the village. If they are looking for rapid improvement in living standards and want the village to be a service centre the mini-grid system could be the best solution. But, if they want to develop the local community without changing the living pattern, stand-alone systems might be better.
- A larger study of environmental and social benefits should be carried out to evaluate the development that can be achieved at the national level by the removal of taxes from renewable resources.

Table 1: Comparison between grid system and decentralised energy resources

Grid System	Distributed Energy Resources (DER)
1- The installation of the system could take a long time.	1- The most important value of Distributed Grid (DG) is the short time in which the system can be installed. The speed of implementation and the modular nature of this technology allow developing countries to efficiently invest in power generation as the population grows.
2- Typical large central plants must be over-designed to allow for future capacity and consequently they must run most of their life in very inefficient manner	2- Mini-grid & stand-alone systems are designed according to the local needs.
3- Great transmission losses, due to the length of the line.	3- Less transmission losses.
4- The majority of these plants are prepared for a huge electricity demand (greater than 10 MW) making them relatively large in both physical size and facilities requirements, and often making the site selection and the procurement a real challenge.	4- DG suits the small demand (less than 10MW) that needs small plants.
5- It needs a significant infrastructure both to get fuel and supplies to the plant and for transmitting and distributing the power once it is generated.	

**DETAILED ECONOMIC ASSESSMENT**

- To let PV compete with the other sources of electricity, customs and duty should be removed and soft loans given to the users.
- Even without the extra taxes, PV has some advantages, namely:
  - fuel can be unavailable for part of the year, or more expensive in the rainy season,
  - regular maintenance for generators can be difficult because of a lack of spare parts and technicians.
- Economies of scale are not considered for the stand-alone PV as most small villages just need lights for the primary school, the club, the mosque, the church and the clinic. This low demand increases the popularity of using stand-alone PV systems, as they do not need fuel and regular maintenance.
- The comparison between the three systems is complicated by their different capacities. Large PV power stations would be more cost effective than those considered here, and smaller gen-sets would be less cost effective.
- PV users must accept that load and activity demand depends on electricity availability.
- Conventional systems are easy to maintain due to experienced technicians. Failures could be a large problem with the PV system, but generally they need low maintenance and are expected to have a long life.
- A very attractive solution may fail as a result of a vague operation and maintenance strategy.
- Current concerns about the price of oil will only serve to make PV a more attractive option economically.

**DETAILED SOCIAL AND ENVIRONMENTAL ASSESSMENT**

- PV is the best environmental solution in terms of CO<sub>2</sub> emissions, and is silent.
- Use of the PV system forces people to choose high efficiency lamps (compact fluorescent). Subsidised electricity leads to use of cheaper but less environmentally friendly tungsten lamps.
- Making a good rural electrification plan could reduce the problem of deforestation since lighting is a major firewood consumer.
- PV users must accept that load and activity demand depends on electricity availability.
- Ignoring cultural aspects leads to the failure of projects. A stand alone system that belongs to a household could work better and survive longer than a central system.

**FUTURE IMPACT OF PROJECTS**

- All electrification systems could provide significant benefits, especially for women and children, as they mainly will be used for lighting for studying and housework purposes. Also could lead to creation of micro-enterprises that improve livelihood and income.
- PV can improve health in the village.
- The questionnaire indicates women indeed have an important role to play in sustainable energy development. They take care of the modules and that makes them responsible for the lighting in the house, and improves their self-confidence.
- Rural electrification encourages people to contact each other. This contact is very important in Sudan that consists of so many tribes. It has been found that the PV technology increases this contact more than the other two systems.
- The cost of one mini-grid system could be the cost of installing hundreds of small stand-alone systems in public buildings in many villages. This might lead to better health, education and social services in many villages, with lower quality services to many villages instead of high quality services to one village. This could decrease the amount of migrants.
- The Kababish people are unlikely to change their lifestyle and stay in one or two places to benefit from a power station. PV could be the best solution for them as it is portable, provides a constant amount of electricity all around the year and is silent. However as a result of needs discovered by using electricity and their contact through TV and radio with other cultures, they might tend to settle or become semi-nomadic tribes.