LP Gas Markets

Guidelines for LP Gas Use in Rural Energisation

WORLD LP GAS ASSOCIATION

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Design : CEP - St-Pierre-des-Corps (Tours - France)

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Acknowledgements

These guidelines were developed with the support of the following WLPGA members who generously shared their time, talent and wisdom.

Bruno de Calan	Totalgaz
Thierry Genthialon	SHV Gas
M. L. Jain	Indian Oil Corporation
John Venn	Caltex

The major work was performed by C.I.Services Ltd who prepared the initial draft and successive versions of the document. Jim O'Driscoll, John Dunne and Jim Sherry were instrumental in bringing their vast LP Gas experience to these pages. Chris Hazard of PN Energy Services Limited also provided valuable insights. Their sharing is greatly appreciated.

Robert Myers of WLPGA coordinated this project.

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Executive Summary

Purpose

The purpose of these **Guidelines** is two-fold. The first is to give World LP Gas Association (WLPGA) members a tool to help assess the market for rural energy in a given region or community. The second purpose is to inform planning and policy officials about the role LP Gas can play in bringing modern energy to those without current access. This LP Gas role can be either in the form of direct power, or as a back up to other energies including renewables such as wind and solar.

The first purpose is not necessarily limited to developing countries. Some developed countries are experiencing power shortages and lack, or very high cost of, grid extensions. The need for reliable power upon which so many computer driven and telecommunication applications rely increases daily. And the "quality" of this power imposes requirements that even some of the most reliable grids cannot meet. For example, fallen power lines due to storms are phenomena for which even the best of plans cannot always compensate. To hedge against such an event, on-site LP Gas power generation is an attractive option for homes, businesses and industry alike even if only in a back up mode.

The second purpose, and clearly the dominant thrust of these **Guidelines**, is to inform decision makers about LP Gas as they make plans and policies in order to bring modern energy to rural areas. This second purpose is driven by the converging need to raise the quality of life for one-third of the world's population and the availability of the technology to do so. But it makes little difference whether LP Gas is supplying basic cooking and lighting needs in a rural African or Asian village, or supplying hybrid power generation (combination of LP Gas and renewable energy) to a household in Norway. The role for LP Gas is clear. Both applications are discussed herein.

The narrative reflects a strong conviction that to be helpful the message must be objective and candid. We are also keenly aware that an energy plan or policy must be sustainable. Simply stated, a sustainable energy strategy is one that provides the kind of energy people want, when and where they want it, and is consistent with the broader agenda for economic and social development. Sustainability is the subject of a World Bank/WLPGA publication, ***"The Role of LP Gas in Meeting the Goals of Sustainable Development"***, and should be read as a companion to these **Guidelines**.

The benefits of LP Gas for energising rural areas are many and real. Yet, LP Gas is not a panacea to every country or region's energy challenges and we say so. Over the past several decades billion of dollars equivalent have been spent on myriad well-intentioned projects devoted to bringing modern energy to those without it. Much of this money focuses on renewables such as biomass, wind and solar. Too frequently customer expectations rise only to dwindle into failure for equally myriad reasons. We discuss some of the "lessons learned" so that mistakes can be avoided.

The Role of Renewables


Pole mounted solar panel.

In developing countries particularly, there is a strong emphasis on using renewable energies such as biomass, wind and solar in lieu of traditional fuels. In developed countries the role of renewables is aimed at replacing fossil fuels. Many think these energies are essentially "free", therefore cost-effective, because there is no cost to the basic energy supply. However, every source of energy whether fossil fuel, nuclear, hydro, biomass, solar or wind has benefits and limitations. There is no "one-size-fits-all" solution. Although the energy may be free or low cost, the lack of capital for equipment, installation and maintenance can and does defeat many projects. Moreover, the absence of an effective local community mechanism for operating and fee collection also defeats many projects.

The Challenge of Providing Energy

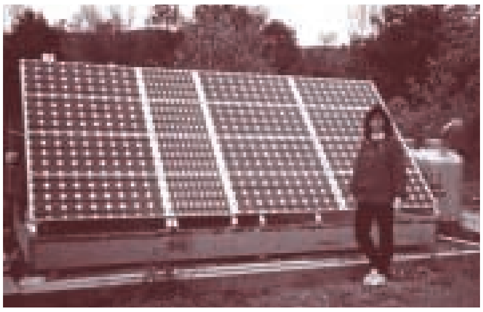
The immediate challenge is to match the customer or community needs and expectations with the fuel and technology in the most cost-effective, environmentally benign, and sustainable manner possible. The daunting challenge is to repeat that "match" for two billion people.

An insightful publication, ***"Energy as a Tool for Sustainable Development"*** (1999, Reference 52) by the European Commission and the UN Development Programme, puts into context the scope of the problem.

> "The need to move fast and think big is most evident in the context of electrification, and can be illustrated through a simple calculation. In 1990 only 8% of rural people and 38% of urban dwellers in Sub-Saharan Africa had electricity connections. An ambitious growth target might be to increase access to 50% of rural and 75% of urban populations by 2025. Achieving this goal would require a five-fold increase in rates of new connections per year in urban areas, and a seven-fold increase for rural areas, relative to the rates achieved in the 1980s. Nearly 720 million people would need to be connected, 60% of them (430 million) in urban areas. Yet, despite this huge acceleration of efforts and investment, in 2025 the absolute number of Africans without electricity would be higher than today: 470 vs 420 million".

The Role for LP Gas in Providing Rural energy

How to reverse that dynamic is far beyond the scope of these **Guidelines**. But we suggest to at least "start simple". In communities historically dependent on traditional fuels such as charcoal, wood, dung and grass "starting simple" means replacing the traditional cooking fuel with a cylinder of LP Gas attached to a simple burner. As customer expectations are met and familiarity with this new energy increases, a single LP Gas powered light can be added. The next step can involve installing a cooker inside the home with the gas supplied from a cylinder outdoors. Hot water heating and/or refrigeration can be added to this basic system if affordable and desired.



A solar photovoltaic array / LP Gas hybrid. LP Gas tank shown in background.

Electricity to power lighting and residential appliances can operate from an LP Gas powered generator. Later, several homes and even an entire community can be supplied modern energy from a piped gas system fed from central fuel storage. All of this in a graduated, evolving level of sophistication depending on customer expectations and economic wherewithal. This incremental development is graphically shown in Figure 3.1. The stages of evolution are not specific plans, only options, and with LP Gas they can be tailored to the consumer's needs. This approach is demand driven, or "market pull" rather than supply driven, or "energy push" (energy source dictated by others).

There is another fundamental economic rationale to this approach. Frequently consumers expect, and governments promise, access to major electricity or natural gas grid systems. Investors, however, are reluctant to risk capital where there is no existing demand. Availability of grid supply is no guarantee of sustainable demand. By building a solid base of LP Gas users throughout a community, the demand is already in place and quantifiable, thus limiting the risk for the potential utility grid. LP Gas is portable. It can either find other markets in the community or move on to the next community. Above all, LP Gas can bring modern energy to rural communities *now*, and do it with private capital. There are no long deliberations awaiting investor approval, no long wait for sufficient demand to justify grid construction.

The role of LP Gas in rural energisation can be characterized both as "direct power" and/or "hybrid". Hybrid is the term commonly used to define a combination of two energy sources complementing each other such as an LP Gas powered generator supplying electricity when there is insufficient wind or solar power. Direct power means LP Gas provides power and heat independently of other energies. Both strategies are discussed. However, it must be stressed that LP Gas is widely used throughout the world already in supplying essential energy for residential, commercial, agricultural, industrial and transportation sectors. In developing countries it is often the dominant modern energy for cooking.

Some would argue diesel powered generators should be replaced with LP Gas. We point out that although a diesel generator's original cost is more than a comparable LP Gas one, generally the cost of the fuel and lower maintenance cost over the life of the engine will favour diesel. That dynamic changes when environmental concerns are an issue since particulate and NOx emissions, and soil and water pollution threats, favour LP Gas. Also, the use of diesel is generally limited to providing electric power whereas LP Gas can provide electricity in addition to basic cooking, heating, water heating, refrigeration and drying needs. However, diesel powered generators are a reliable proven means of generating electricity, and they are the only source of modern energy for many communities. It makes little sense to replace one type of generator with another when the real challenge is to increase the total number of generators.

Introduction to Rural Energisation

The term "rural energy" is a popular label used by a diverse group of people including development agencies - both governmental and private, community planners, energy providers, economists, and equipment manufacturers each with a slightly different perspective depending on the area of interest. To some the term encompasses that broad and complex series of issues and challenges associated with developing countries of bringing modern energy to the two billion people of the world without current access. To others in developed countries "rural energy" means a reliable source of power and heat that may not be consistently available from the traditional natural gas and electricity grids. Our definition is more general: by "rural energy" we mean energy for those users without a source of clean, reliable, portable, affordable and available power and heat regardless of geography or economic status.

These **Guidelines** are not intended to be an engineering manual on how to evaluate, design, construct and operate a rural energy system. Yet, they describe the components of a variety of systems in which LP Gas may be used for direct power and heat, or integrated into hybrid applications.

The emphasis on the role of renewable energies is deliberate. The **Guidelines** go into some detail in describing each of the most prominent renewable sources, how they function, their costs, benefits and limitations. Most importantly, the detail describes how they can be integrated into an LP Gas system. Tools for evaluating various rural energy systems are described. The expectation is that the curious reader will be motivated to look further into how these tools may be useful. Finally, in Appendix III, a case study of a variety of rural energy programs in South Africa is discussed. Some of these programs involve LP Gas, others not. But each of them provides insight into how a concerned government working in partnership with industry can focus talent and resources into offering modern energy to those who have long sought its benefits.

The role of subsidies in providing modern energy to those severely in need is not discussed, yet it can be a significant factor in introducing modern energy. (For a discussion of the subsidy issue, see the World Bank/WLPGA's publication, **The Role of LP Gas in Meeting the Goals of Sustainable Development**). In principle, WLPGA does not favor direct subsidies for purchasing energy. Energy pricing should reflect true costs or at least move toward that objective so that consumers can make informed decisions. The plain fact is that some people cannot afford LP Gas. But some technologies and some energies require subsidies or incentives for some period so that they can take a foothold. Without sheltering some of the inherent risk for investors in new energy paradigms, and without the economic stimulus for consumers to abandon traditional fuels, the chasm between the "haves" and the "have nots" only continues to grow. Without modern energy in rural areas, people gravitate to urban areas further compounding already severe economic and social conditions. The cost of social and political unrest in response to this urban migration must be weighed against any form of subsidy or incentive to improve the quality of life in order to keep rural dwellers rural.

It is somewhat ironic that the discoverer of LP Gas ninety years ago had the same motivation. Concerned that young people were leaving farms and rural values for the attraction of the city "bright lights", the very first use of LP Gas was to provide a steady and brighter light than was possible with kerosene or paraffin. Those without modern energy yearn for its benefits, yet are frequently least able to afford it. And they are too remote from seats of central power and administration to collectively influence policy makers.

Today there is merit in considering a results-based strategy involving commercial interests that are willing to invest their own capital. LP Gas can clearly demonstrate it is an energy carrier with unique and valuable features making it a profound "development energy".

LP Gas will not solve all the inherent and terribly complex issues of rural energy. But it can be part of the solution as discussed in the pages that follow.

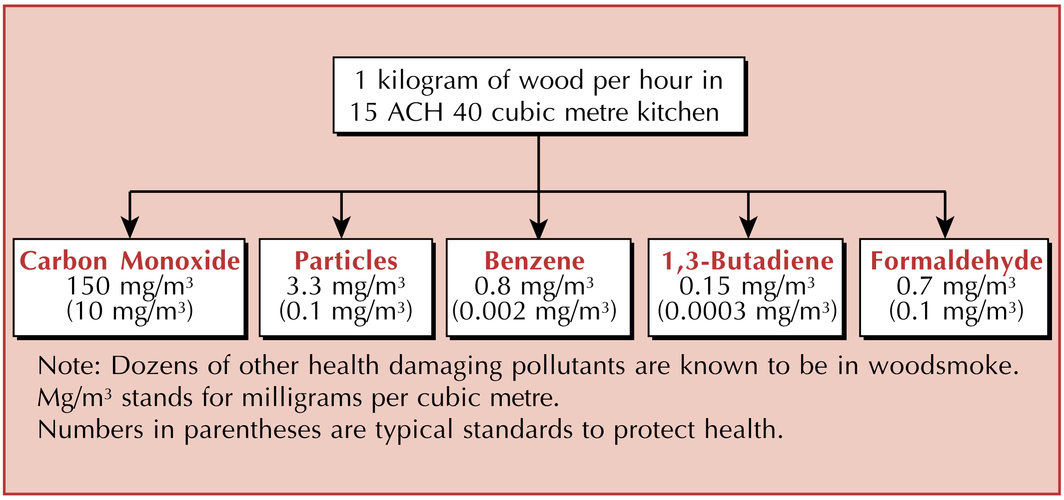
Introduction

1.1 Energy

Energy is sometimes referred to as an "endless growth" industry with an insatiable appetite for natural and financial resources. Despite sustained and targeted efforts - including technological development - it is estimated that up to two billion people do not enjoy access to modern energy, and that a further half-to-one billion have only limited access. This problem has been addressed in many ways for many years but is far from resolution.

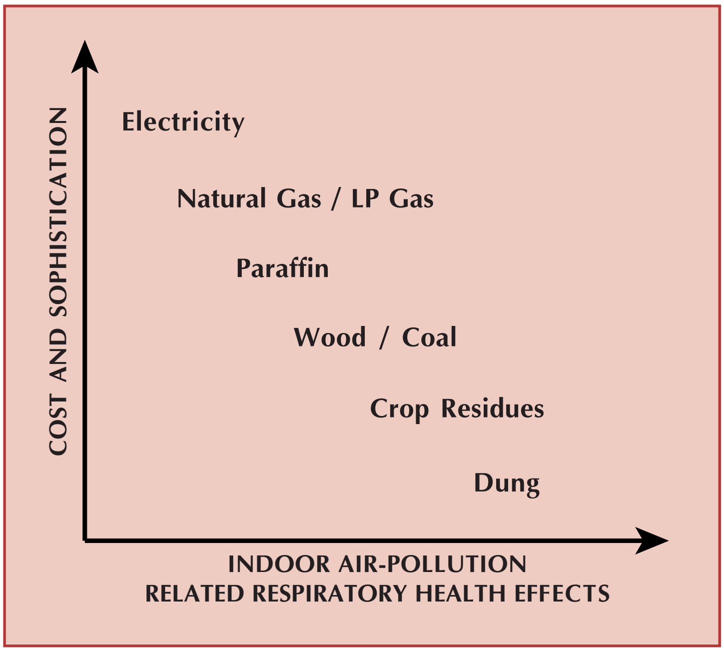
Energy demand generally increases with population but in many developing countries the rate of population growth has exceeded the rate of increase in modern energy provision. Further, as countries' economic development proceeds, their per capita rate of commercial energy consumption generally increases, adding to the problems of supply. Per capita energy consumption in the United States, for example, is eighty times higher than in Africa and fifteen times higher than in East Asia.

Inadequate energy markets restrain economic growth, hinder development and keep living standards low. High-tech industrial processes and telecommunication systems require large amounts of electricity of consistent quality, delivered with total reliability. The provision of western-style healthcare is crucially dependent on the availability of modern energy at hospitals and rural clinics. Household use of biomass fuels has been linked with the incidence of respiratory illness and as a factor in infant mortality in several countries. Figure 1.1 dramatically shows the pollution effects from cooking with wood. Figure 1.2 indicates the health benefits to be gained in moving to modern energy supply.



Source: UNDP (Document 50)

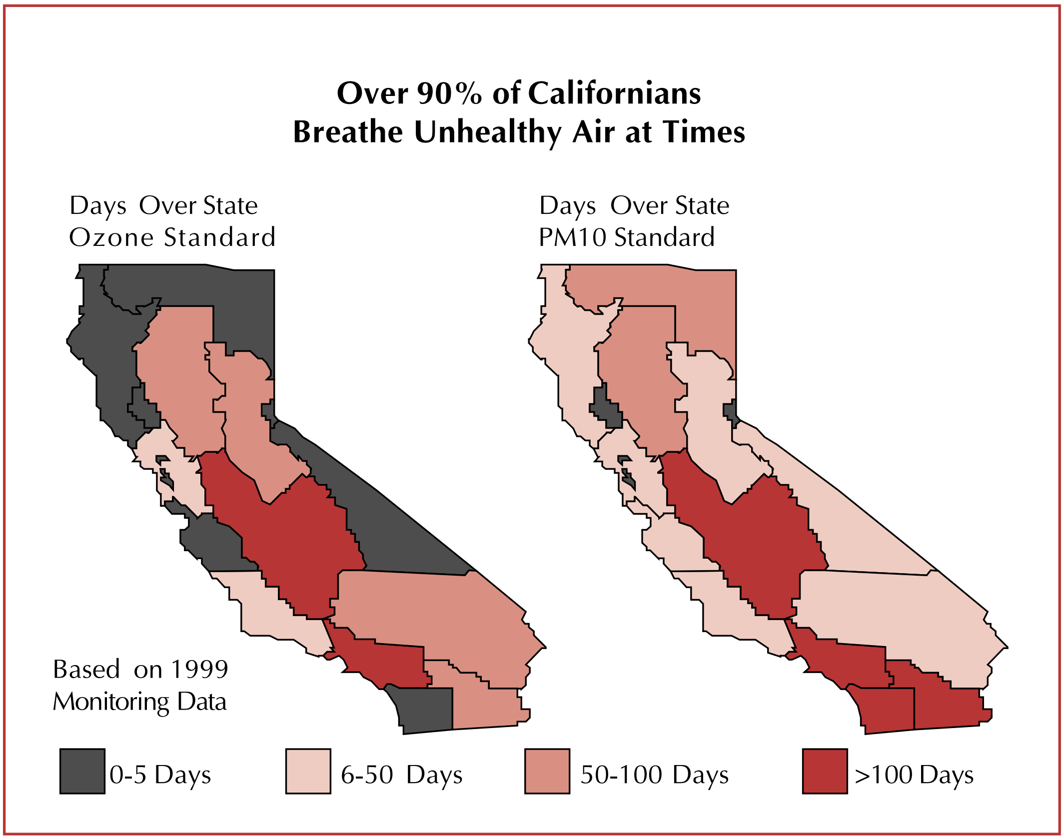
Figure 1.1



Source: CSIR and EMSA (Pty) Ltd. (Document 54)

Figure 1.2

Developing countries are frequently but unfairly singled out as having the most severe air pollution problems. However, in California (if it were a single country it would be the 7th largest economy in the world) 90% of the population is exposed to unhealthy air at times, as indicated in Figure 1.3. One major difference between California and the rural areas of many developing countries is their lack of basic modern conveniences afforded by modern energies.



Source: CARB (Document 51)

Figure 1.3

While there is a tendency to identify modern energy with grid-based electricity, the reality in the developed world is a mix of energy based on such considerations as availability, suitability, consumer preference and cost. Natural gas and LP Gas feature prominently in the mix, whether used directly or as the primary fuel in conventional electricity generation. Natural gas, and in some areas nuclear energy, has largely displaced coal and oil in new power generation projects. Such diversity of energy supply and usage is desirable for security, environmental and economic reasons.

Energy demand may vary greatly on an hourly, daily and seasonal basis, and readily-storable fuels cope better with such variation than does electricity. The cost and environmental impact of providing conventional, grid-based electricity for every energy demand would be unsupportable, even in economically-advanced countries. Awareness of the possibilities and limitations of different energy sources, and how they are best matched to energy demand, is fundamental to sound energy policy.

1.2 The Rural Energisation Process

Energisation is a process whereby communities progress from a restricted to a broader range of energy options: from dung, crop residues and woodfuel (commonly referred to as "traditional fuels") to liquid fuels (diesel, kerosene), LP Gas, natural gas and electricity. For rural dwellers, the step to liquid fuels or gas represents progress to modern commercial energy. Even limited access to modern energy can have profound and beneficial effects on the quality of rural life. For example, a household refrigerator reduces food spoilage and the associated health risk. One downside: woodfuel is largely consumed in towns - often as charcoal - and represents a sizeable business. This trade may be one of very few year-round cash generators for rural dwellers. Projects that seek to accelerate, or change the direction of, the energisation process must therefore take account of the multi-faceted nature of traditional energy practices, in addition to the yearning for amenities linked to modern energy.

The economics of supply often mean that rural communities are denied grid-based energy - electricity and natural gas. Their needs are met by biomass, traditional fuels and commercial fuels such as LP Gas, perhaps augmented by locally generated, non-grid electricity. The poorest, most remote communities may be wholly dependent on biomass. The combination of population growth and deforestation usually means that more and more time is spent on gathering fuel.

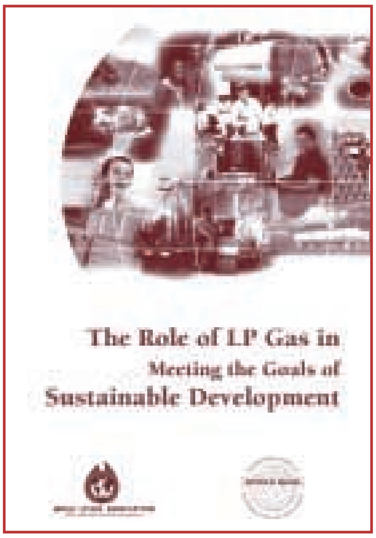
While LP Gas is ideal for thermal energy applications, electricity is preferred for lighting and for educational/recreational applications such as computers, radio and television. Thus electricity is associated with "the bright lights" and a modern lifestyle. Understandably, rural dwellers want these amenities and many rural upliftment programmes seek to provide them.

Upliftment programmes promoted by international development agencies, such as the World Bank, usually have an environmental and sustainable livelihood dimension. In the energy sector this dimension is often reflected in such terms as "Renewable" and "Sustainable". Energy sources such as wind, wave, solar, hydro and certain kinds of biomass are considered to be renewable.

Technologies for supplying electricity exclusively from renewable energy sources have their own problems, including cost, capacity limitations and technical complexity. Often, electricity supply from renewable energy sources such as wind and solar is reliable only in "hybrid" form meaning some sort of back up from non-renewable sources. Rural communities in developing countries, eager to progress to modern energy, may reasonably ask for simpler and more affordable alternatives.

The principal barriers to rural energisation are economic and institutional. Modern energy provision is expensive - perhaps impossibly so for the very poor in the remotest areas - although costs vary widely with location, scale and technology. Even a modest electricity supply requires a significant capital outlay, especially if derived from renewables. Energy supply derived from liquid fuels and LP Gas may require lower initial investment but involve higher ongoing distribution and operating costs.

Rural energisation programmes require robust institutional frameworks for delivery and sustainability. The literature reviews undertaken in preparation of these **Guidelines** describe rural energisation projects of various kinds and in different countries but revealed a disappointing success rate. Failure to identify and manage key stakeholders is a recurring theme. Even the less ambitious programmes to improve utilisation and sustainability of traditional fuels experienced difficulties when they failed to take sufficient account of local preferences and practices. One WEC/FAO paper noted (in the context of rural energisation) that "the costs of electrification were underestimated while its benefits were overstated". Initial cost and lack of affordable credit reduce take-up rates that, in turn, tend to undermine the viability of projects requiring high initial investment. Equally crucial to project success is the need for balanced demand and supply side solutions. Community involvement and "buy-in" are essential: rural people best understand their energy needs. Their involvement in planning, implementation and upkeep are crucial for sustainable energisation.



Rural energisation programmes - like so many upliftment programmes - may be put at risk by excessive, unwarranted optimism. The results may be judged to be good or bad depending on the expectations of the participants.

Rural Energy Options

2.1 Energy Needs

Rural energy use revolves primarily around household needs - cooking, water heating, power generation, refrigeration and lighting. Lighting facilitates study, entertainment, greater security and a cleaner and safer environment. In colder climates, space heating will often be a significant need and may influence cooking methods. In warmer climates, indoor cooling will feature in the mix of energy demand. Overall demand will be met, to a greater or lesser extent, depending on availability and on consumers' ability to pay for the commercial component of energy supply. Figure 2.1 denotes the energy use of various household appliances.

TYPICAL APPLIANCE ENERGY USAGE	
APPLIANCE	**ENERGY CONSUMPTION Watts**
Minimal Lighting	150
Additional Lighting	400
Radio	6
Television	100
Refrigerator	90
V.C.R.	50
Sewing Machine	95
Hair Dryer	1,400
Electric Stove	1,500
Electric Kettle	1,500

Source: C.I.Services Ltd.

Figure 2.1

Agricultural activity is both a producer and consumer of energy. Much of the energy produced may be low-grade in the form of dung and crop residues, but certain large-scale farming activities can be a viable source of biogas, i.e. fuel gas, the useful energy component of which is methane. In developing countries, much of the energy input to agriculture may be in the form of manual and animal labour. Much of the potential gain from rural energisation is in the form of reduced physical labour, higher productivity and reduced deforestation.

Seasonal changes in household energy demand may relate to climate and are dealt with, where possible, by storage of biomass fuels, coal etc. Irrigation and harvesting can create peaks in farm energy demand and put pressure on liquid fuel and electricity supply systems. Electricity, whether supplied directly or through storage batteries, is indispensable for media, communication and certain lighting needs. In the absence of modern energy, certain types of demand, e.g. electrical motive power, will not arise or will remain unsatisfied.

2.2 Energy Sources

About one third of all energy supply in developing countries (not just the rural areas) comes from biomass fuel. Demand for wood fuel has resulted in deforestation around areas of heavy energy demand. Forest regeneration has proved very difficult in the face of growing demand and the commercialisation of woodfuel. Renewable energy in the form of solar and wind power is not yet a significant contributor while nuclear power is generally out of favour. Liquid and gaseous fuels are - and seem likely to remain - essential energy sources. LP Gas, when available, remains a key component of modern rural energy supply.

2.3 Renewable Energy

Of the renewable energy sources, solar/photo-voltaic, wind and hydro have been brought into practical and widespread use. Wave power has progressed more slowly. Thermal springs (geothermal) and rocks are useful sources of thermal energy but do not occur very widely. Solar provides both thermal and electrical energy.

Technical and practical aspects of relevant renewables - micro-hydro, solar and wind - are discussed in the following paragraphs. The economics of modern energy supply, based on renewables and on LP Gas, are discussed in Chapter 5.


Solar panel array with LP Gas back up.

Wind and sunlight are variable and their electrical energy output, based on current technologies, comes largely in response to influences not directly related to demand, i.e., sunlight and wind are neither continually available nor predictable. These limitations are an impediment to "sustainability" since the energy is not necessarily available when it's needed. A reasonable level of consumer service requires energy storage of some kind typically in battery banks and/or generator back up. Many renewable energy installations are "hybrid", e.g. solar/photo-voltaic (or PV) and/or wind turbine generator (WTG) with stand-by or back up conventional generator. While solar and wind turbines may be environment-friendly, the same cannot be said of lead-acid batteries and diesel-fuelled generators.

Hydro

Hydro is long-established as a source of both mechanical and electrical energy. In recent years, hydro technology has been successfully adapted to small-scale power generation, often feeding electricity into local, or mini, grids. Micro-hydro systems (< 100kW) are available in capacities ranging from 125W upwards. The water resource of a micro-hydro plant may be subject to seasonal weather extremes such as drought or freezing. Outside these extremes, a micro-hydro plant can produce electricity continuously unlike wind and solar. With continuous production, a small installation can produce large amounts of energy.

It is generally not easy to extend the civil works for a micro-hydro project once constructed so the design, including land requirements, must take account of the long-term power demand. Because of their small scale, micro-hydro systems cause less environmental concern than traditional large-scale hydro. Well-maintained micro-hydro installations can last for a long time, perhaps as much as 50 years. Back up power generation may be required if adequate water flow is not available on a year-round basis.

Solar/Photo-Voltaic

The basic component is a collecting panel or module, multiples of which are referred to as arrays. Solar modules (also known as PV modules) are rated in peak watts (Wp) according to peak output capacity under standard conditions. They perform best at times of high insolation (bright sunlight) but lose efficiency in poor light and in high temperatures. Modules appropriate for rural energisation are available in a wide range of rated capacities up to 300Wp. To allow for periods of reduced light intensity and to provide light when it is needed, most solar systems include storage in the form of 12 volt battery banks. Electricity derived from sunlight through solar modules is direct current (DC), often requiring conversion to alternating current (AC) - and voltage step-up - in order to power conventional appliances. If AC (alternating current) power is required, the system will require an inverter. The capacity of solar systems can be boosted by increasing the number of modules and connecting the electricity supply to an increased number of batteries, in series or in parallel, as appropriate.

The cost of a solar system depends largely on the price of modules, that, although declining in recent decades, remains relatively high. The capital cost increases more or less directly with capacity and economies of scale are minimal. However, the modules themselves are durable and require little maintenance. Solar can be an attractive option, especially for smaller loads. However, it must be stated that solar will have little effect, if any, on deforestation. Solar provides electricity and is generally not effective for cooking, a major motive for cutting down trees.

Wind Turbines

Wind turbine generators (WTGs) come in various sizes and offer economies of scale. They operate within specified wind-speed envelopes and, as power output can fluctuate widely with changes in wind, controls are needed to keep a turbine within acceptable limits. WTGs are usually equipped with braking mechanisms to prevent potentially destructive damage from operation at times of excessive wind speed.

Wind Turbine generators (WTG).

WTGs need more maintenance but in moderate winds they typically produce more energy than a similarly priced solar array. However, WTG installations of similar size can vary significantly in capital cost. Price differences among turbine manufacturers vary widely as do the costs of transporting the equipment to the site and erection costs. Electrical output may be AC or DC and battery storage would again be the norm with inverter/rectifier for DC/AC or AC/DC conversion, as appropriate.

Batteries

Energy storage is an inescapable part of electricity supply from solar and wind-power and typically comprises banks of 12 volt batteries. While the fixed battery banks support the base installation, portable batteries can also be re-charged there, thus extending the system utilisation and the availability of electricity.

A life of five years is usually quoted for good quality re-chargeable, lead-acid batteries. However, this life is dependent on careful management and use including the correct timing of re-charging. In practice, useful life may be as little as one year, adding unexpected costs and increasing disposal requirements. Batteries need to be handled, transported and disposed of in an environment-sensitive fashion. Rural communities may understand this need but lack the required facilities.

Inverters/Rectifiers

Inverters convert direct current (DC), the form of electrical output from solar modules, batteries and most small WTGs, to alternating current (AC), the form required for many common electrical appliances and devices. Rectifiers convert AC to DC.

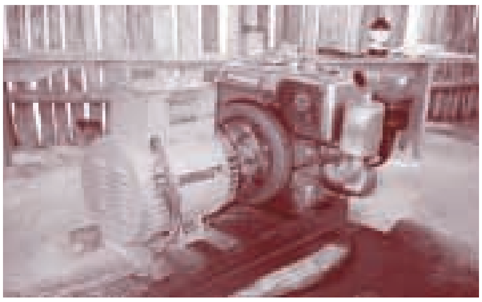
2.4 Hybrid Systems

Solar or wind turbine systems can each bring service to communities remote from the grid. Combining solar and wind can enhance and extend that service. However, providing electricity on a 24-hour basis and in useful quantities normally requires conventional generator back up. The integration of electricity supply from different sources making up hybrids - and possibly a generator - adds to the complexity of such systems. In an ideal hybrid system, the renewable components minimise the generator running time, keeping operating costs to a minimum, while the generator reduces the required size of the renewable components.

Generators

Generators may be used as "stand-alone" providers of electricity, as stand-by to grid supply, or as back up to renewables. They may be liquid or gas-fuelled and are usually designed to operate at a constant speed producing higher-voltage AC electricity.

Generators can be run "on-demand", to feed the loads as required. However, if the load balance dictates, it may be more economical to provide battery storage for some of the load, e.g. to supply a water pump for short periods and lighting for extended periods. The generator can feed the pump and batteries for the short periods and the batteries then provide lighting for the extended periods.



Typical electric generator.

Currently, purpose-built LP Gas-fuelled electricity generators are not generally available below about 5kW but smaller gasoline units are readily converted to operate on LP Gas. Diesel generators are generally more expensive to purchase than gasoline/LP Gas generators, but are more durable and cheaper to operate and maintain. Their wide availability and well-deserved reputation for reliability have won diesel generators a dominant position in the stand-by/back up market. Diesel generators are available in sizes from 1.5kW upwards and gasoline generators in smaller capacities, down to 0.5kW.

The principal advantage of generators is their ability to provide electrical power on demand, a feature that can help avoid over-sizing the renewable component. The disadvantage can be high operating costs in fuel and maintenance. Diesel fuel has the additional disadvantage of pollution in handling and use. In an optimally-sized hybrid system, the renewable components minimise the generator running time, keeping operating costs to a minimum while the generator reduces the required size of the renewable components. This makes it essential that systems be properly sized for the intended power demand. (see Figure 4.2).

Other advanced technology power "generators" include micro-turbines and fuel cells. Micro-turbines are essentially small jet engines which are gas fuelled and are designed to be more efficient and less polluting in operation than conventional reciprocating engine power generators. However, the technology is still developing with production or development models in the range 30-200kW. Preliminary industry figures estimate an LP Gas consumption rate of 0.75 litres for each kW of power delivered, comparable to the consumption rate of small conventional LP Gas-fuelled generators. However, when anticipated future efficiencies in micro-turbines materialise, and capital costs reduce, they will be worth considering for community-scale use.

Fuel cells are electro-mechanical devices that convert chemical energy into electrical energy without combustion or rotating machinery. While this technology is very promising for the future, initial costs are currently high and thus fuel cells are not yet considered economically viable.

2.5 Energy/Fuel Mix

Consumers - urban and rural - in developed countries typically have access to a variety of energy sources and opt for a mix of fuels. The choice is influenced by such considerations as availability, user preference and cost. The availability of electricity does not mean abandoning other sources of energy. Rural communities in developing countries may have fewer options than those in developed countries but may still opt for a mix of fuels.

The LP Gas industry acknowledges the superiority of electric lighting but would argue in favour of LP Gas for thermal loads such as cooking, heating, water heating, drying and refrigeration. LP Gas is a cleaner alternative to diesel for back up power generation where pollution is an issue, and as a cleaner alternative for transportation fuel - autogas. Nor should we forget that rural dwellers often need portable lighting where light intensity may be less important and for which LP Gas is ideal.

While limited availability may be a constraint, the emphasis should be on matching premium energy to uses for which it is best, or uniquely suited, e.g. electricity for critical lighting and media, LP Gas for thermal use where its clean-burning qualities and speed are valued.

LP Gas

3.1 The LP Gas Industry

LP Gas is a hydrocarbon product of the oil and gas industry. Its markets are in the energy and petrochemical sectors. In these **Guidelines**, we are concerned with the energy sector only where LP Gas is normally a liquid during storage and transportation, but is readily transformed to gas at the time of use. This property means that LP Gas is ideal for rural energisation applications.

Within the LP Gas industry worldwide, more than 200 million tonnes are used each year. During the past 10 years supply has grown roughly 5% per year.

LP Gas supply begins with the producers - the oil and gas industry. LP Gas marketers may be oil or gas company affiliates or independent businesses whose scale of operation may range from local to multi-national. LP Gas moves from the point of production to the ultimate user in a sophisticated transportation and distribution system. This takes place through a combination of ships, pipelines, rail cars, barges, truck transports and local bulk or cylinder delivery trucks. Regional and seasonal fluctuation in supply and demand have led to the development of an international trade in LP Gas (mainly water-borne in refrigerated ships) and of businesses participating in and servicing that trade.

Cargo ship delivering LP Gas as part of the international distribution chain.

Generally, consumers are served by local LP Gas distributors and retailers who may also supply, install and service appliances. Empty LP Gas cylinders are re-filled at purpose-built "bottle filling" stations that, together with a stock of cylinders, trucks and retailers' storage constitute the basic distribution infrastructure. In some countries these filling stations also supply the autogas market. This sector attracts many private entrepreneurs and provides employment to the local economy.

In addition to LP Gas supply, prospective users need appliances, i.e. the gas consuming equipment that actually provides the required amenity - heat, cold, light, etc. While appliance manufacture and LP Gas supply are very different activities, the products are often sold through the same retail outlets thus offering customers the opportunity of one-stop shopping.

The simplest LP Gas supply system comprises a gas cylinder to which an appliance is fitted directly or connected through a flexible hose, and a pressure regulator. Such systems can be extended by adding appliances and cylinders and, possibly, fixed pipe work. In "bulk" supply, cylinders are replaced by storage tanks and are replenished by tank trucks. "Piped supply" may serve separate or multi-occupancy buildings or even entire communities from common storage, normally with individual metering. (See also 3.4 Incremental Development and LP Gas).

A clean, bright consistent flame - typical of LP Gas.

3.2 The Product

LP Gas is a gas at normal temperature and pressure. When subjected to modest pressure or cooling it liquefies making it possible to transport large quantities of energy cost effectively since roughly 270 units of gas can be compressed into a single unit of liquid. Yet, when ready to provide heat or power at the "burner tip" it reverts to a gas.

"Stored energy" is one of the benefits of LP Gas. It is not dependent on electricity or natural gas grids, nor subject to the uncertainties of wind and solar availability. Customer storage can be as large as required or as small a practical. Worldwide, the most popular storage for small domestic usage is 6 to 20 kilogram cylinders or "bottles". Tens of millions of customers who depend on LP Gas for cooking are already familiar with this storage. But LP Gas is not limited to cooking.

Other popular home and commercial business uses includes hot water heating, clothes drying, space heating and refrigeration. Portable lighting and cooking are also popular uses. In agriculture and horticulture industries LP Gas is used for greenhouse heating, flame weeding, crop drying, waste incineration and powering of equipment. Numerous industries rely on LP Gas for heating, drying, thawing, glazing, process heating, powering portable generators and industrial forklift trucks.

LP Gas cylinder distribution depot.

LP Gas is also the world's most widely used alternative transportation fuel with over 7 million vehicles currently using it instead of petrol or diesel. Its clean burning characteristics contribute to abatement of urban air pollution problems.

LP Gas has some special attributes for rural communities, which have earned it ready acceptance and a prominent position in rural energisation. Those benefits include:

- ***Availability.*** There is nothing exotic to invent or improve. The transportation system that moves it is in place, the tanks to store it are available, the appliances and equipment that provide heat and power are "on the shelf".
- ***Portability.*** LP Gas can be stored, easily transported and used virtually anywhere from downtown urban areas to remote regions of the globe. It is not dependent on natural gas or electricity grid systems.
- ***Indefinite shelf life.*** LP Gas does not deteriorate over time unlike some other liquid fuels that gel, stratify or evaporate. In the context of rural energy shelf life is critical. Traditional fuels can have a short shelf life and must be protected from the weather to prevent deterioration.
- ***Energy density.*** Compared to traditional fuels in terms of weight equivalency, LP Gas has ten times the energy.
- ***Temperature control.*** LP Gas appliances and equipment allow easy and instantaneous adjustable flame temperatures to suit the consumer's needs. LP Gas refrigerators do not have temperature control limitations such as are common with kerosene refrigerators thus maintaining the "cold chain" essential for critical vaccines used in primary health care.
- ***Friendly to the environment.*** LP Gas burns cleanly without smoke or residual ash thus avoiding the health hazards associated with indoor use of traditional fuels. In the event of a leak LP Gas does not contaminate the soil or aquifers.
- ***Compatible and flexible.*** LP Gas is not only compatible with renewable energies as discussed herein but also with new technologies such as fuel cells and microturbines.

Fundamental to understanding the role for LP Gas in rural energy is that LP Gas can fulfill the essential needs of heat and power either directly or as a partner with renewable energies.

Most importantly, LP Gas lends itself readily to "incremental development". Rural consumers can begin by using LP Gas to fuel basic cooking devices and progress to more sophisticated applications. LP Gas supply can develop in parallel from single-cylinder to bulk and piped-in systems.

LP Gas may represent an introduction to modern energy for rural dwellers in developing countries. In developed countries, however, LP Gas remains an ongoing important energy source not only for household uses but also for many commercial and industrial applications.

3.3 LP Gas and Rural Energy

Consumer attitudes toward LP Gas are positive and enduring, especially among those freed from the labour and dirt associated with biomass and some liquid fuels. Typically, LP Gas finds its first application in household cooking where it can reduce dramatically the incidence of illness associated with smoke from traditional fuels and the time spent on collecting woodfuel and preparing meals. Many kinds of food benefit, in terms of flavour and nutritional value, from the faster cooking possible with LP Gas.

However, rural energy needs extend well beyond households and LP Gas shows its versatility in satisfying many of them. The product is usually familiar and trusted for household use and is readily accepted for commercial applications as farming becomes industrialised.

While electricity is preferred for critical lighting needs, LP Gas can be a viable alternative for lighting where lower intensity is acceptable and where portability is an advantage.

All energy is potentially hazardous, including LP Gas. Those not already familiar with LP Gas' benefits, and long dependent on traditional fuels, may find useful WLPGA/UNDP's ***"Guidelines for Good Safety Practices in the LP Gas Industry"***. National LP Gas associations and marketers also produce safety guidance for their customers.

Initial costs for new LP Gas consumers, i.e. the cash outlay for a cylinder and appliance, are significant for poorer communities. This investment in modern energy will not be forthcoming unless prospective consumers have confidence in the availability, continuity and affordability of LP Gas supply. LP Gas marketers and their distributors must make wholehearted efforts, and put in place the necessary infrastructure, to ensure service levels in line with consumers' needs in order to develop and maintain long-term trading relationships.

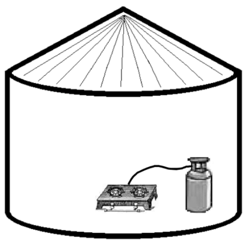
LP Gas cooker / cylinder providing clean portable heat.

3.4 Incremental Development and LP Gas

"Incremental development" is a useful concept in discussing rural energisation. It refers to steps in the progress from biomass to modern energy. The first approach looks at the incremental development of a basic LP Gas system, as graphically shown in Figure 3.1. Figure 3.1 shows in Stage 1 a basic simple system of providing fuel for cooking, a cylinder of LP Gas connected to a two burner hot plate inside the home. This system is widely used throughout the developing world today. Stage 2 adds a light and refrigerator and the cylinders are moved outdoors. Stage 3 introduces electricity from an LP Gas generator and adds a hot water heater. Due to the increased demand for fuel a larger tank is installed. The generator powers electric lights and other electric appliances inside the home. All of these essential needs are accomplished through a single source of LP Gas.

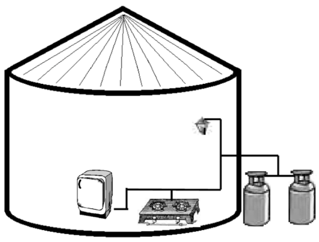
LP Gas Incremental Development

Stage 1



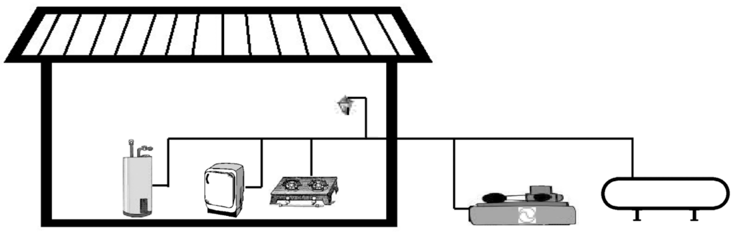
- LP Gas cylinder inside, feeding stove.

Stage 2



- LP Gas cylinders outside, piped inside to feed stove, refrigerator and light.

Stage 3



- LP Gas bulk tank feeding stove, refrigerator and water boiler, and fuelling LP Gas generator.

Figure 3.1

Source: CI Services

Note: The placement of appliances in relation to the LP Gas cylinders and tank are for graphic purposes only. Actual placement is subject to applicable codes and regulations and should be checked carefully to ensure compliance.

The second approach, as denoted in Figure 3.2, shows the integration of renewables (solar and wind) into the basic LP Gas system. In successive stages a number of consumer energy needs are satisfied by an equal mix of energies. From the basic cooking needs (Stage 1) to a fully integrated system that can supply several homes and even community facilities services (Stage 5), the flexibility of LP Gas in responding to the needs and affordability of the consumer is dramatically shown.

LP Gas can fuel cooking from simple household needs to commercial and institutional catering. It provides space heating and water heating in various modes and quantities. LP Gas refrigerators use absorption rather than compressor technology, minimising the number of moving parts thus enhancing reliability and making them silent in operation.

LP Gas is used to fuel electricity generators from the smallest portable units to large generators for community and commercial supply. Modern micro-turbine generators are designed for gaseous fuel, including LP Gas. The efficiency of generators can be enhanced in Combined Heat and Power (CHP) systems. CHP, in addition to generating electricity, recovers heat from that process and utilises it to meet thermal energy needs.

The incremental concept is obviously useful in describing progression in LP Gas supply systems - from cylinder to bulk and to an entire piped network.

LP Gas in a Hybrid System

Stage 1

Fuel Input

- Biomass.

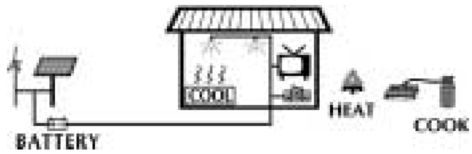
Comments

- Fetch water.
- Biomass heating.
- Biomass cooking.
- Cool by water evaporation.

Stage 2

Fuel Input

- Biomass.
- Wind.
- Solar.
- LP Gas.



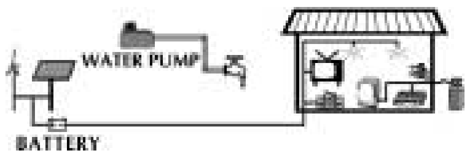
Comments

- Fetch water.
- Biomass heating.
- Basic light and media via solar or WTG.
- Upgrade cooking using LP Gas.
- Cool by water evaporation.

Stage 3

Fuel Input

- Wind.
- Solar.
- LP Gas.



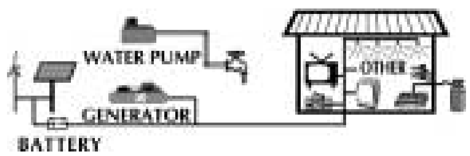
Comments

- Water pumped to standpipes using LP Gas powered pump.
- Basic light and media using solar or WTG.
- Upgrade cooking with internal stove using LP Gas.
- Basic refrigeration using LP Gas.
- Upgrade heating option using LP Gas space heating.

Stage 4

Fuel Input

- Wind.
- Solar.
- LP Gas.



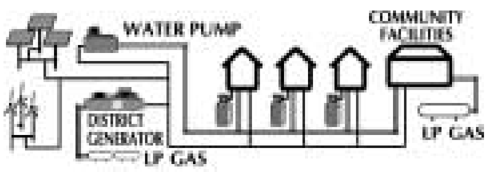
Comments

- Water pumped to standpipes using LP Gas powered pump.
- Hybrid system using solar / WTG along with generator set fuelled by LP Gas.
- Refrigeration / additional lighting / media / other appliances off hybrid system.
- Cooking and heating using LP Gas.

Stage 5

Fuel Input

- Wind.
- Solar.
- LP Gas.



Comments

- Water pumping using LP Gas powered pump, piped to standpipes / houses.
- Community hybrid system using solar / WTG energy farm along with generator set fuelled by LP Gas.
- Mini-grid electrical supply reticulation to community houses, school, clinic, micro-enterprise, workshops etc..
- Cooking and heating using LP Gas.

Figure 3.2

Source: CI Services

LP Gas and Renewable Energy Partnerships

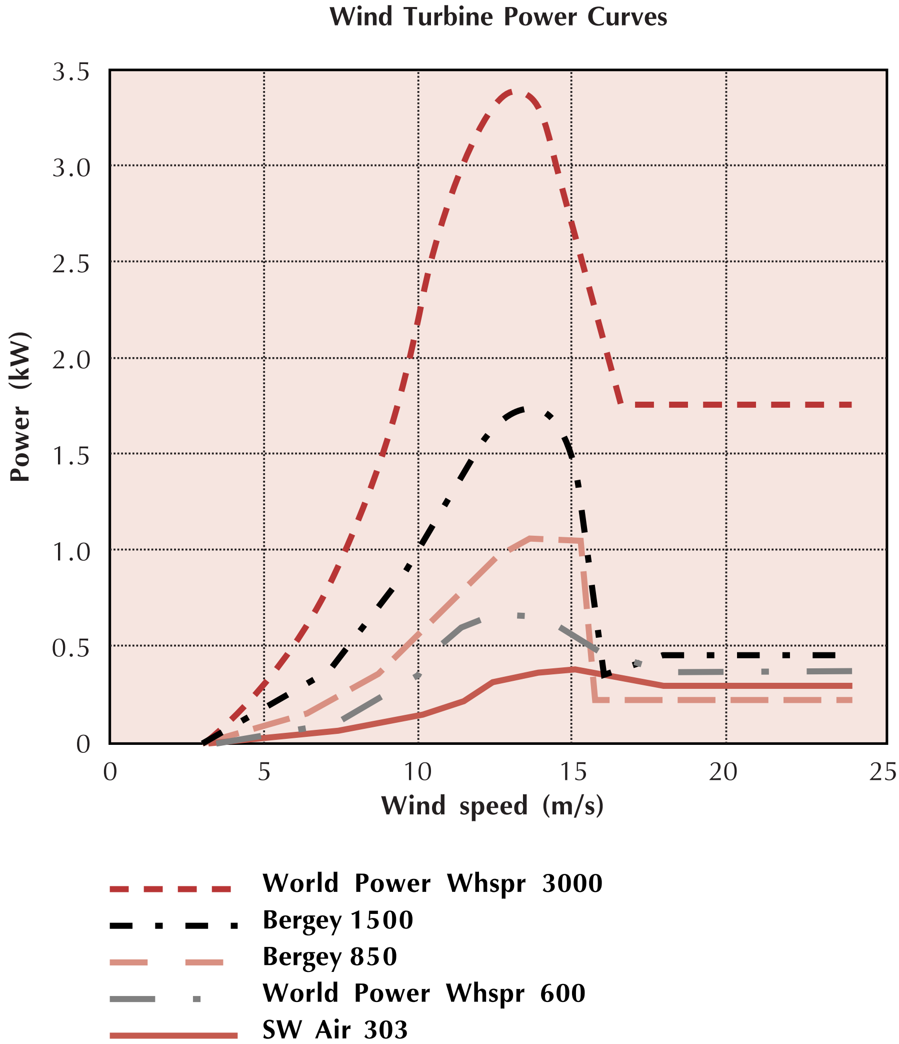
4.1 Renewables: Operational performance and limitations

Renewable energy systems for power generation include hydro, wind and solar. All three are viable technologies but each has its limitations. Wind and solar produce electricity under suitable conditions but lose capacity and reliability in unfavourable conditions. Figure 4.1 denotes typical wind turbine power curves. Experience with renewable energy systems, especially in rural energisation programmes, suggests that hybrid systems and/or back up from other energy sources are required for continuous supply of useful amounts of electricity. Figure 4.2 indicates the technological selection of renewables plus generator.

Wind Turbine Generators (WTG)

A wind turbine's performance is characterized by its power curve, which is the relationship between the wind speed and the turbine power output. Power curves for several manufacturers and sizes of turbines are shown in Figure 4.1. Before producing power the turbine must reach a minimum speed. For small turbines that "cut in" wind speed is typically 3 to 4 m/s (metres per second). After reaching minimum speed the power accelerates rapidly with increasing wind speed until reaching peak power at which time the turbine "cuts out" to protect it from over spinning. This usually occurs at wind speeds of 14 to 18 m/s. Power generation doesn't stop at cut out but continues at 30%-70% of rated power. Thus wind turbines are rated by their power output at a specified wind speed.

As is readily seen in Figure 4.1 it is difficult to predict long-term performance of a wind system. This puts additional emphasis on properly sizing the storage (battery bank) system in order to have steady electric power.



Source: NREL (Document 9)

Figure 4.1

Solar/Photo-Voltaic

Solar (also known as photo-voltaic or PV) modules convert sunlight directly into direct current (DC) electricity. Unlike wind turbines with rapidly moving parts, solar modules have no moving parts, adding to their longevity. Manufacturers claim high reliability and solar systems require little maintenance although some projects report that maintenance is higher than promised. Solar modules can also be easily assembled into "arrays" to accommodate any size load.

Solar modules consist of individual cells electrically connected together to produce a desired voltage and current. Cells are usually encapsulated in a transparent protective material and housed in a light weight frame. The type of technology used to make the modules dictates the cost.

Solar modules are rated in terms of peak watts (Wp) or peak kilowatts (kWp), a function of size and efficiency. This makes it easy to compare costs based on the rated Wp. The rating is an indication of the amount of power that the module will produce under standard conditions. The intensity of sunlight (called "insolation") at noon on a clear summer day might approximate to 1 kilowatt per square metre of module at 20 degrees C. Thus, a module rated at 50 Wp will produce 50 watts of power when the temperature is average. Modules are available in a wide variety of ratings up to 100 Wp but larger modules are also manufactured. Modules can be connected in a series to increase the voltage, or connected in parallel to increase the current.

Solar modules are mounted facing the sun either on fixed or tracking mounts. Fixed mounts at an optimal angle are more common and are widely used in rural energy projects. Tracking mounts enable the module to follow the sun.

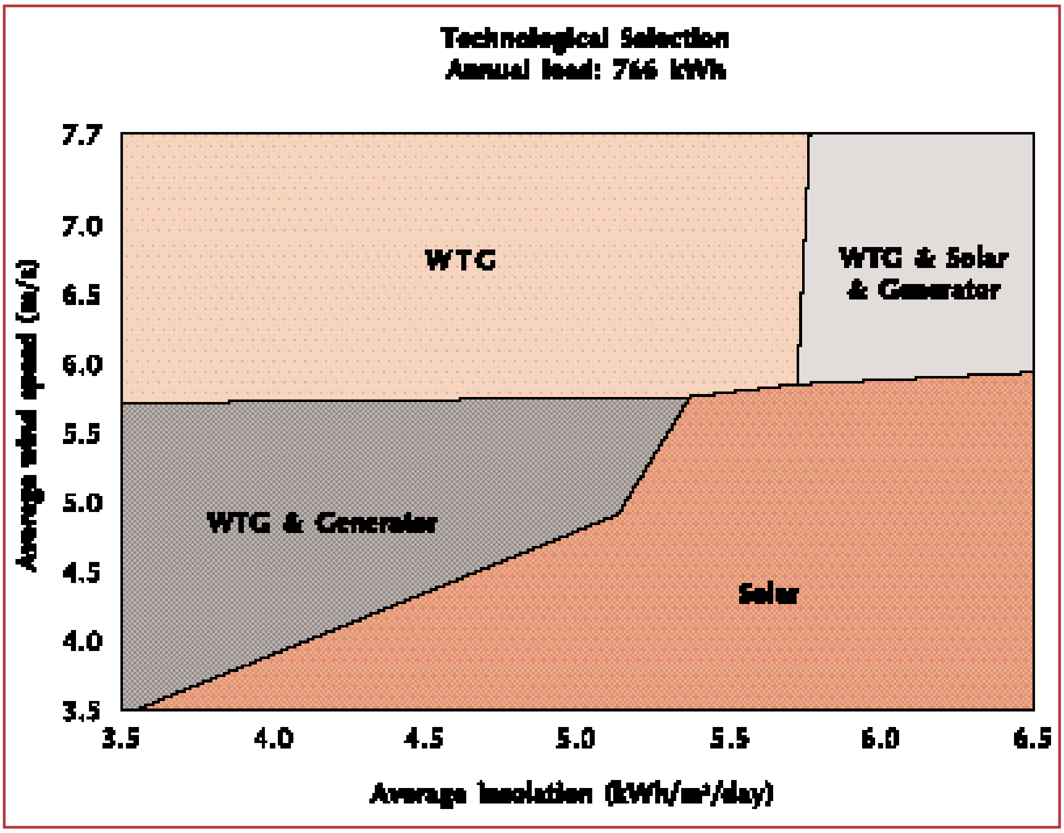
The energy from solar modules can be used directly or indirectly. Most modules are designed to charge 12 volt battery banks (indirect use) but larger off-grid systems may power other DC applications.

Combined Wind Turbine Generators and Solar

Depending solely on the natural occurrence of wind and sunlight for steady electricity is obviously risky and fraught with limitations. Using the two renewable energies in tandem can increase the reliability of power but still leave the consumer with an intermittent shortfall. A battery bank is therefore essential. However, the optimum system may well consist of a wind turbine, a solar array and a back up generator. This selection virtually assures power whenever needed. Such a system, however, increases the costs and introduces a range of mechanical devices all of which at one time or another will require service and maintenance. However, the generator eliminates the cost of a battery bank. Optimising this hybrid system can be challenging. Figure 4.2 is a helpful guide in determining *the lowest cost system* depending on the availability of solar and wind resources. Figure 4.2 does not purport to be a sizing guide.

Wind / solar / battery installation.

Note that when the average wind speed is less than 5.6 metres/second, and there is inadequate solar insolation, a generator combined with the wind turbine generator is the *lowest cost option*. As solar supply increases it becomes the lowest cost option. However, even when both resources are optimized there is still a shortage of power in meeting the demand of 766 kWhr annual load, thus the need for a back up generator.



Source: NREL (Document 9)

Figure 4.2

4.2 Limited/Mini-Grid Electricity

Limited grid comprises extending the regional or national grid to local communities but with a capacity to deliver only small quantities of electricity, say 1 to 3 amps, to each customer. The utility recognises its inability to deliver sufficient power to give all customers a "full" supply. Instead it delivers to each customer "essential electricity" to typically power lighting and media, thus providing an increment of development to the community, usually a township not too remote from the main grid. LP Gas is an ideal partner for limited grid supplies with its ability to efficiently provide the required thermal energy for cooking and heating, thus complementing the "essential electricity".

Mini-grid comprises installing a modest generating capacity, sufficient for full supply to a small community or limited supply to a larger community. In developed countries, small island communities are typically supplied by mini-grid, this being more cost effective than connection to the main grid. LP Gas can be used in mini-grid electricity generation and/or in reducing the electricity demand by providing thermal energy.

In South Africa experience indicates that, under the right circumstances, costs of electrical supply for 1 to 3 amp connections was lower than solar solutions. Typical costs were $250 to $400 per connection, depending on the housing density.

4.3 Village Power Programmes

Many national and international agencies have rural energisation programmes incorporating renewable energy systems. The National Renewable Energy Laboratory of the United States (NREL) through its Village Power programme has demonstrated a variety of systems in widely dispersed locations. These and other programmes provide valuable insights to rural energy needs and the challenge of incorporating renewables into rural energisation. Appendix III gives details of rural energy programmes in the Republic of South Africa.

4.4 Lessons Learned

Typical solar powered home project.

Among the lessons learned from developing countries, and reported by NREL and others, was the need to adapt rural energy planning methodology to accommodate renewables and to consider options, including the enhancing of existing energy delivery. Quality of service was found to be very important and, while electricity is preferred for lighting, 24 hour service is preferred to a 4 to 6 hour service. Differences in quality of service should be reflected in comparisons of alternative solutions to the challenge of rural energisation. Controls and conversion equipment are essential parts of renewable energy technology but are also the least robust of system components. Community involvement and "buy-in" are essential. The effort required to develop and support maintenance programmes should not be under-estimated.

Other lessons learned include:

- Within governments the responsibility for rural energy development is fragmented among several agencies or departments with no clear agendas.
- Reliance for development is left mainly to the private sector but with no safeguards to minimize risk or to protect investments.
- Rural energy strategies need to be sensitive and responsive to other rural development needs such as clean water, health services and education. Rarely do energy programs succeed without integrating other key priorities.
- Renewable energies are not generally conducive to improving agricultural practices, the basic economic activity for rural dwellers.
- "Improved efficiency" technologies developed in the laboratory often fail in practical service.
- Financing schemes for purchasing and using modern energies are frequently ignored.
- Some advertised benefits of renewables have failed to materialize due to higher initial costs, service and maintenance expense, or lack of trained technicians.

4.5 Partnership Opportunities

At present, renewable energy sources such as solar and wind make a tiny contribution to rural energy supply, but as the technologies develop and unit capital costs decline, their contribution seems likely to increase. When renewables form part of energy supply, their contribution should be integrated with other sources in a cost-effective manner.

LP Gas has an established role in rural energisation and typically makes a sizeable contribution to supply, being the preferred fuel for many applications. Environmentally it is preferable to liquid fuels in power generation. Advanced micro-turbine generators can be LP Gas-fuelled.

When used directly in thermal application and indirectly for power generation, LP Gas can provide all the modern needs of rural dwellers. Where they are technically feasible, i.e., with adequate insolation and/or suitable winds, renewables may replace liquid and gaseous fuels in power generation. In practice, solar and wind systems need generator back up in order to maintain a reasonable level of service.

LP Gas is usually sold at a premium compared with liquid fuels such as diesel and kerosene, partly because of its attributes but also because its distribution tends to be more expensive. At a certain stage of economic development, rural dwellers welcome the superior qualities of LP Gas and accept a price premium over biomass and liquid fuels.

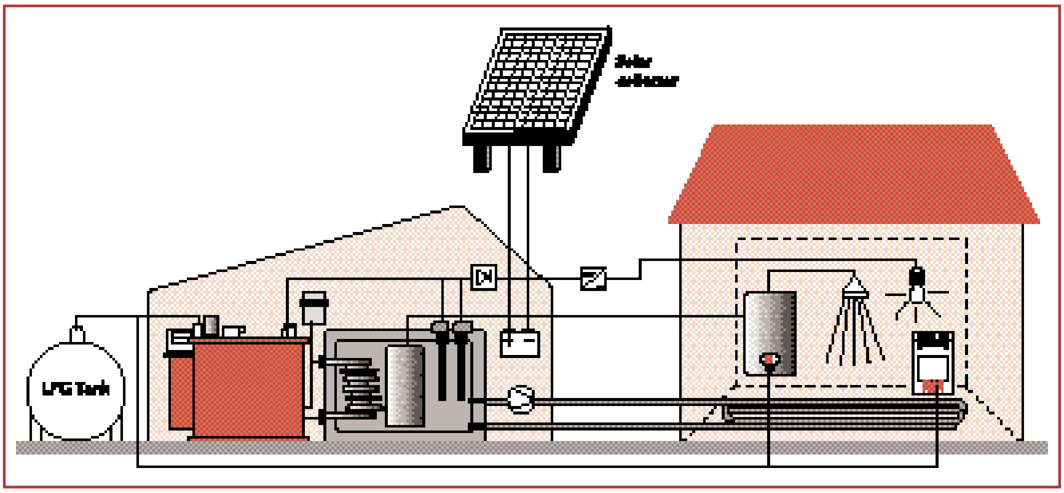
LP Gas is the ideal fuel to work in partnership with renewables, fuelling thermal loads that may be beyond the capacity of the renewable system and/or fuelling back up power generation in order to maintain a desired level of service, and cleanliness.

4.6 Advanced LP Gas and Solar Hybrid Example

As mentioned in the introduction the primary focus of these **Guidelines** considers the rural energy requirements in developing countries, where the prime energy source is biomass or traditional fuels with few options available. However, even in rural areas in developed countries a combination of renewable energy and LP Gas can effectively be used.

The Norwegian Water Resources and Energy Directorate has, in conjunction with other partners, developed a stand-alone system to meet all the energy needs of an ordinary family house remote from the electricity grid. The system employs LP Gas and solar modules as the primary energy sources. It comprises:

- LP Gas-fuelled CHP (combined heat and power) generator
- Solar array
- DC / AC inverter to 220V
- Electricity storage battery unit
- Hot water storage tank.



Source: CADDET (Document 17)

Figure 4.3

In addition to fuelling the electricity generator, LP Gas is used directly in, for example, the cooker and water heater.

Electricity produced by the CHP unit and solar module array is not used directly but stored in the battery unit while heat recovered from the CHP unit is stored in the water tank.

The solar elements of the system are sized to supply the summer electrical load. In winter the solar contribution is negligible and electricity is produced solely by the CHP generator while its heat contributes to the space heating demand.

In remote areas of Norway, connection to the electricity grid is expensive and it can be difficult to ensure continuous service, especially during winter. In Norwegian conditions, and year 2000 costs, the stand-alone system is competitive for a single dwelling where the distance from the electricity grid is greater than 2km. Figure 4.3 denotes the layout of the Norwegian Hybrid Energy System for a single household.

It is therefore worth noting from this example that the need for rural energy also exists in developed countries, and LP Gas has a role. There are many remote areas where extension to a national electricity grid is expensive. LP Gas can be used for the thermal needs of cooking and heating, and to fuel a generator providing part or all of the electricity needs. There are also areas where reliability of the electricity grid poses problems, especially in winter. An LP Gas powered generator, with a small storage tank, provides an ideal back up solution.

Economics of Rural Energisation

5.1 Renewable System Components and Costs

Costs of energy systems vary widely, partly because the components and capacities - especially for hybrids - are variable and also because costs tend to be location-specific. One study noted that the actual delivery costs of a renewable energy system to a remote rural location could account for as much as 25 per cent of the initial system cost. Land acquisition and civil works feature prominently in hydro schemes and are location-specific. (All monetary values shown in $US).

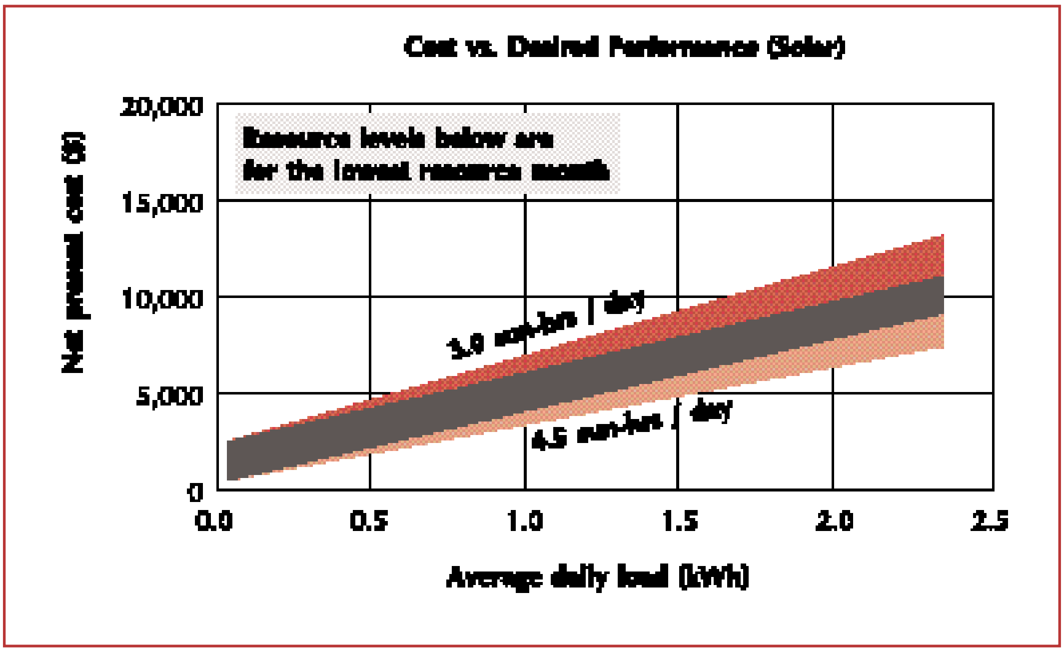
In general, the overall cost of delivering electricity via small renewable energy systems to rural communities is substantially in excess of the cost of grid electricity where that grid electricity is already available. Figures 5.1 and 5.2 indicate the cost of typical small solar or wind turbine systems. However, the use of small renewable systems can make economic sense in remote areas by circumventing the need to make large investment in extending the national electricity grid. Larger modern wind turbine systems can be complementary to conventional oil or gas-fuelled power generation.

Micro-Hydro

Capital costs ranging from $1,000 - $4,000 per kW have been reported underlining the extent to which the initial costs of small hydro schemes vary between locations. Hydro schemes are characterised by long life and minimal operating costs with annual maintenance at about 3 per cent of capital cost.

Solar

The cost of a solar/photo-voltaic system depends largely on the cost of its modules that, although declining in recent decades, remain relatively expensive. Retail prices for small modules in 1998 were approximately $5,500 per kWp, with some reductions possible for bulk purchases. Costs for mounting, wiring and installation are typically $1,000 - $1,500 per kWp. Other system equipment - batteries and inverter (if AC is required) - and controls will add further to the initial cost. Figure 5.1 denotes Cost versus Desired Performance for solar systems.

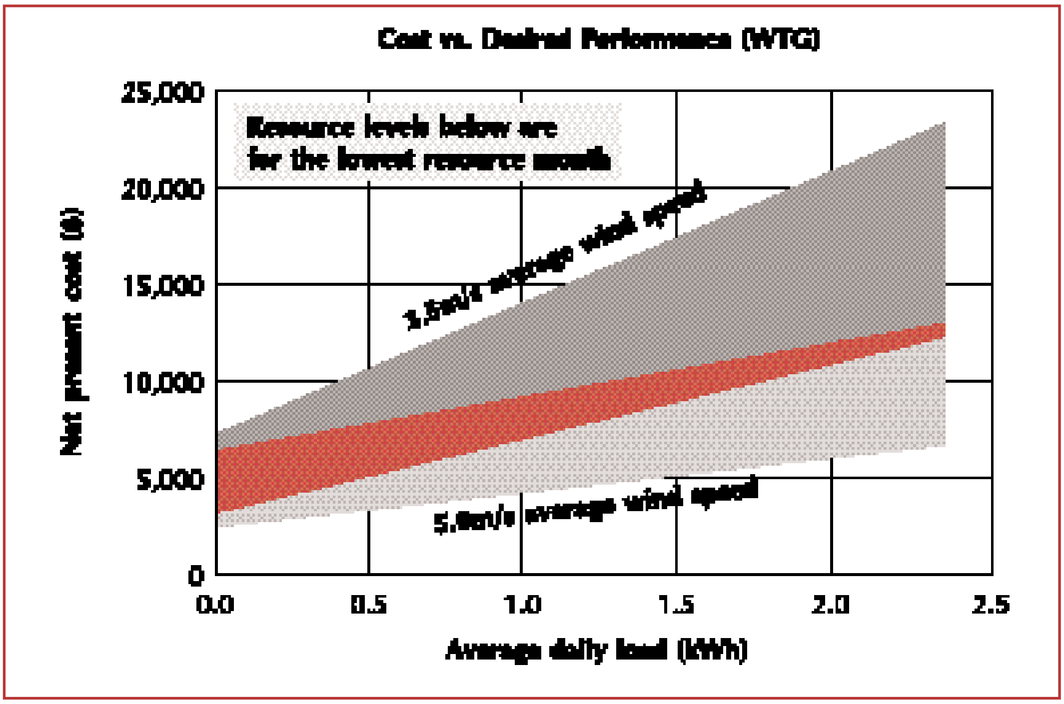


Source: NREL (Document 9)

Figure 5.1

Wind

Wind turbine prices are more variable than solar module prices. Similar sized turbine installations can differ significantly in cost because of pricing differences between manufacturers and widely varying tower costs. Installed cost for small systems ranges from $2,000 - $6,000 per rated kW and, with economies of scale, larger wind turbine generators generally cost less per kW. A unit capable of producing about 500 kWh per month at an average wind speed of six metres per second will typically have an installed cost of $3,000 - $5,000. Figure 5.2 denotes Cost versus Desired Performance for Wind Turbine Generated (WTG) systems. Thus a WTG system capable of handling an average daily load of 1.0kWh, in a location with worst-month average wind speed of 5 m/s is expected to have a 25-year net present cost of between $4,000 and $8,000.



Source: NREL (Document 9)

Figure 5.2

Batteries

Individual batteries used in renewable energy systems are available in capacities from 0.5kWh to several kWh. Typical battery costs are in the range $70 - $100 per kWh of storage for batteries with lifetimes of 250 to 500 cycles, or a useful lifetime of three to eight years. Performance is adversely affected by extreme temperature and batteries may need to be enclosed in an insulated box. There will be additional set-up costs for wiring, housing, etc., along with terminal disposal costs.

Inverters

DC/AC inverters vary in cost depending on capacity and the quality of AC output required which, in turn, depend on the particular application. High quality inverters cost $500 - $1,000 per kW. Small (100 - 200 W) inverters capable of handling simple applications cost about $100. Inverters with a capacity in excess of 5kW become more expensive per kW of capacity.

Generators

Diesel generators are initially more expensive than gasoline or LP Gas generators of comparable capacity but are generally more durable and cheaper to operate. While generators have significant operating costs, they provide electrical power in AC form on demand. Their inclusion in a hybrid system not only provides continuity of supply but also can be used to avoid over-sizing the renewable components. Figure 5.3 denotes the indicative comparative costs of small diesel, gasoline and LP Gas fuelled generators. It indicates that, for generators with a 5 kW output, the relative capital costs are: Diesel = $5,000; LP Gas = $3,500; Gasoline = $1,750.

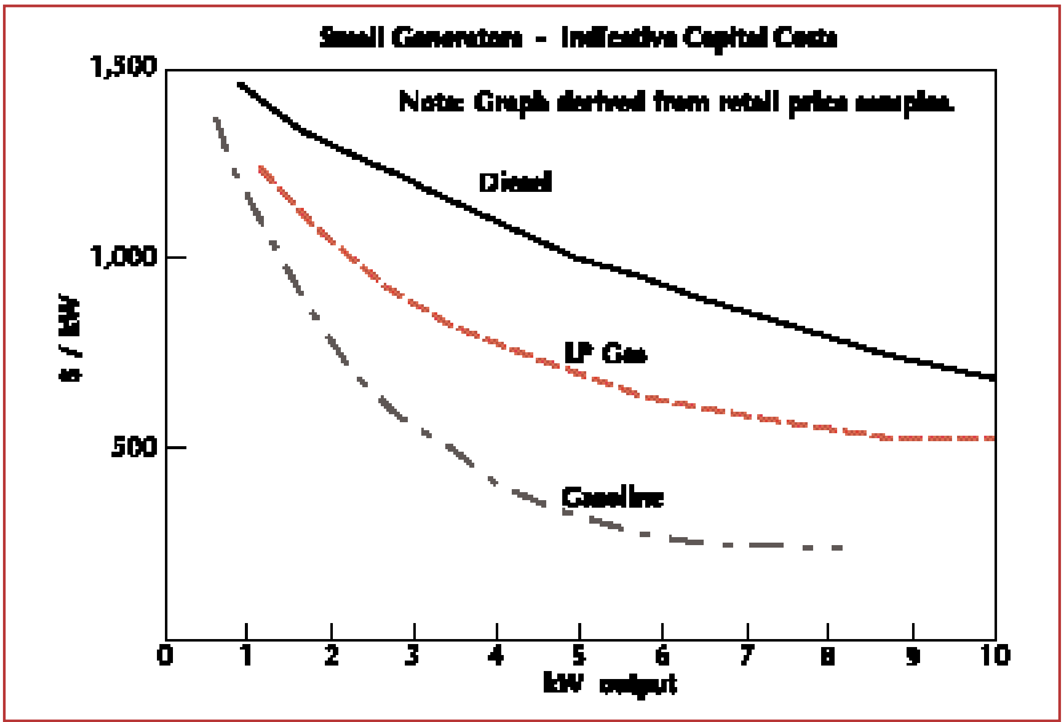


Figure 5.3

Source: NREL (Document 10)

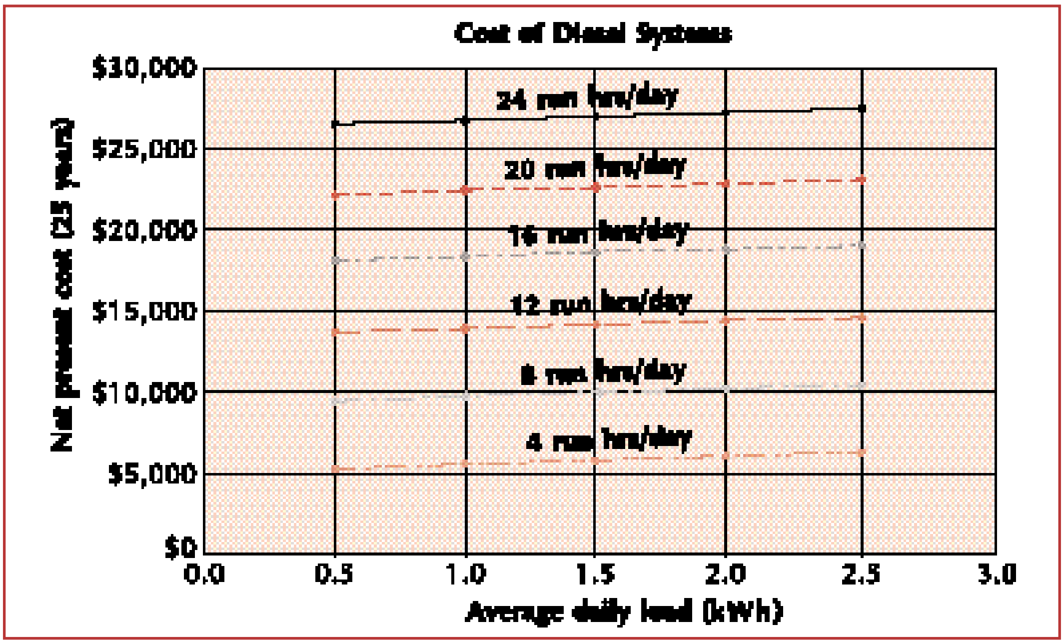


Figure 5.4

Source: NREL (Document 9)

Figure 5.4 shows the twenty-five year net present cost of a 2.5kW diesel generator and average daily running hours. Note that costs vary only slightly with load but escalate rapidly with increased running hours. It shows the importance of correctly sizing the generator for the required load. To run a 2.5kW generator, capable of handling an average load of 1.2kW/hr, for 24 hours per day just to deal with a daily load of 2.5kW is very inefficient.

If the number of operating hours is low, a single generator providing electricity directly in response to demand can be a cost-competitive source of energy. In an ideal hybrid system, the renewable energy components minimise generator operating costs and the generator reduces the required size - and cost - of the renewables.

5.2 LP Gas Supply Infrastructure Costs

Large LP Gas storage tanks at distribution center.

The economics of LP Gas supply to rural communities depend on product cost, the scale of operations and the cost of distribution. Assuming access to an existing source of supply and cylinder filling facilities, the additional investment is in cylinders - one or two per household and sufficient circulating reserve cylinders to ensure continuity of supply. Growth in demand will, in time, warrant additional cylinder filling capacity at the existing facilities and, ultimately, an additional filling plant. LP Gas cylinders are normally distributed on a flat-bed truck, secured by rails or in cages. As the supply system develops to include fixed customer tanks, LP Gas road tankers augment the cylinder trucks. The investment in this infrastructure is usually undertaken by the LP Gas marketer or distributor and is phased in as the market grows. The consumer may purchase his cylinder or, more often, is given the use of the marketer's cylinder in return for a cash deposit or a rental charge.

A full graphic depiction of the entire LP Gas distribution chain can be found in Appendix IV.

Costs

An estimate of the cost of supplying additional LP Gas infrastructure and equipment is shown in Figure 5.5.

LPG INFRASTRUCTURE COSTS		
Item	**Capacity**	**Cost $US**
Additional cylinder filling capacity in an existing facility.	100 fills/day @ 12.5kg each	$2,500 - $3,500
Small LP Gas road tanker.	6 - 7 tonnes	$60,000 - $70,000*
Storage tank (at end-user site).	1 tonne.	$1,000 - $2,000

* Costs can vary widely depending on the equipment and the specific country. For example, in India a 15 tonne road tanker costs approximately $15,000.

Figure 5.5

LP Gas cylinders come in various sizes: a household size cylinder - 12.5kg capacity - from a reputable manufacturer costs about $15 - $20. The incremental cost of additional cylinder filling capacity in an existing facility is about $2,500 - $3,500 per 100 fills per day. A small LP Gas road tanker of 6 - 7 tonnes capacity suitable for multiple deliveries costs about $60,000 - $70,000 (in U.S./Europe) and a 1 tonne capacity tank suitable for fixed installation costs $1,000 - $1,200 plus delivery and installation.

LP Gas supply comes at a relatively low initial capital cost to the consumer since the supplier finances the infrastructure. However, the consumer must pay for the energy consumed. The LP Gas industry sometimes uses a rate of one fill per month (150 Kg per annum) as a measure of household consumption for cooking only. However, this crude rule-of-thumb takes no account of family size or cooking methods.

LP Gas is an internationally traded product the price of which generally reflects the prevailing price of oil and natural gas, with regional and seasonal variations. In domestic markets insulated from international prices, the market price of LP Gas, in common with other conventional energy, may be subject to other influences, not least the cost of transportation. Government policy often determines the price at which LP Gas is sold and its price relative to other fuels. In some counties, fuel prices are subsidised directly, but selectively.

In a recent study of the West African market, the WLPGA and the World Bank found significant differences in retail LP Gas prices between neighbouring countries, arising in part from subsidies (see Figure 5.6 below).

WEST AFRICA LP GAS PRICING ($US / Tonne)

	Cameroon (12.5 Kg)	Cote D'Ivoire (6 Kg)	Cote D'Ivoire (12.5 Kg)	Ghana (14.5 Kg)	Senegal (6 Kg)	Senegal (12.5Kg)
Ex-refinery Price	150.0	235.0	235.0	264.2	306.8	306.8
Shipping	9.2					
Port Charges	6.0	2.0	2.0			
Taxes and Duties	1.7	4.7	4.7	39.6		
Stabilisation (Tax)						81.8
Storage and Filling Margin	207.6			103.8	134.7	183.5
Distribution Margin	89.0	268.8	218.6		52.8	30.4
TVA					44.1	49.0
Transport Equalisation	29.8	6.4	6.4			
Subsidy		(100.2)			(202.0)	
Consumer Price	493.3	416.7	466.7	407.5	336.4	651.5

Source: World Bank / WLPGA (Document 53)

Figure 5.6

A 1999 survey of tax-inclusive prices of residential fuels in the Americas also showed wide differences in the cost of LP Gas and in the relative cost of LP Gas with competing liquid fuels (see Figure 5.7 below).

Clearly, economic evaluation of rural energisation programmes based on LP Gas, or with an LP Gas component, must include an informed assessment of local LP Gas prices and of relevant government policy.

EXTRACT FROM SURVEY OF TAX-INCLUSIVE PETROLEUM PRODUCT PRICES

RESIDENTIAL FUELS				
Country	Light Fuel Oil	Kerosene	LP Gas	LP Gas
	Prices in US $ Per Gallon			$/Kg
United States	1.26	1.07	0.63	0.29
Argentina	0.56	2.01	2.08	0.96
Brazil	0.65	1.14	1.64	0.75
Chile	0.69	1.00	1.48	0.68
Bolivia	1.20	1.03	0.66	0.30
Jamaica	0.69	1.65	1.35	0.62
Barbados	0.53	0.98	0.85	0.39
Trinidad and Tobago	0.52	0.70	0.77	0.35
Venezuela	0.22	0.48	0.66	0.30

Source: EIA (Document 48)

Figure 5.7

5.3 Tools for Comparison of Systems and Costs

Because of the many variables, useful cost comparison of alternative system options is effectively site-specific. Tools to assist with making such comparisons are identified in Item 5.5. below, and expanded on in Appendices I and II. However, Figure 5.8 illustrates how the net present costs will vary depending on energy demand, technology chosen and financing terms. The system with the lowest net present value of life-cycle costs is highlighted. In this illustration, solar is the most economical option for small loads. As the load size increases, a WTG or diesel generator/battery system becomes more economical than solar. If the cost of capital (COC) is 25% per year, the diesel generator/battery system is more economical because of its low initial costs compared to the WTG, whereas if the cost of capital is 10% per year the WTG system will make more sense because of its lower operating costs. It is interesting that Note 6 to this figure indicates that a solar module/LP Gas generator is optimal for the 25kWh/month system.

Cost Comparison Chart					
Technology			Energy Demand (kWh / month)		
		COC	25	200	800
Solar at 5 kWh / day	Initial Investment		$3,200	$19,800	$80,400
	Annual Operating Costs		–	–	–
	Net Present Value	10%	2,400	15,300	61,800
		25%	3,000	18,600	74,300
	Annualized Capital Costs	10%	400	2,500	10,100
		25%	2,500	5,200	2,500
Diesel Battery Hybrid at $0.28 / litre	Initial Investment		$400	$4,200	$4,500
	Annual Operating Costs		700	500	2,200
	Net Present Value	10%	5,400	9,300	30,700
		25%	3,600	6,100	19,900
	Annualized Capital Costs	10%	900	1,500	5,000
		25%	2,500	2,000	2,500
Wind Hybrid at 6 m/s	Initial Investment		$3,800	$9,800	$21,500
	Annual Operating Costs		100	200	900
	Net Present Value	10%	3,400	6,500	20,200
		25%	4,000	9,100	21,900
	Annualized Capital Costs	10%	600	1,400	3,300
		25%	2,500	2,500	6,100

Assumptions

1 Project life = 10 years.
2 Solar. Inverter and battery maintenance costs depend on local labour costs, present a marginal increase in costs and are not included here.
3 Solar system (modules and mounting structure) : Linear depreciation over 20-year life.
4 Diesel System : Linear depreciation over 2500 hour life.
5 Wind system (turbine and tower) : Linear depreciation over 12 or 16 year life (depending on turbine size) represents the system of choice for each load size and discount rate.

Notes

1 "COC" is the cost of capital, or real discount rate.
2 Solar costs will vary linearly with resources.
3 Diesel costs will vary linearly with cost of fuel.
4 Wind costs will vary exponentially with resources.
5 The system configuration is held constant at COC comparisons. In the case of the 800 kWh load, the optimal system at a 25% COC, a hybrid system using less wind and more diesel is not represented.
6 Solar/LP Gas hybrids are not presented here. For the 25 kWh system, a Solar/LP Gas generator hybrid is optimal.

Source: NREL (Document 9)

Figure 5.8

5.4 Financing and Cost Recovery

Paying for rural energy hardware, maintenance, and the energy itself is a crucial factor in any rural energy project. Only a small percentage of rural households can afford to pay for rural energy systems with cash, but credit or rental options can expand the market significantly. Micro-finance programs have proven to be one effective means. One estimate of the proportion of end users that can afford solar under different purchasing options is:

- Cash sales 5%
- Credit 15 - 20%
- Fee-for-service 18 - 25%
- Not able to afford solar 50%.

Thus, some form of credit or rental option will obviously be required to facilitate rural energisation at a basic level. To provide such credit or rental options, a well designed financial plan will be required, geared towards the householder's ability to repay and recognising the logistics involved in large numbers of small creditors.

The World Bank has initiated a proposed pilot project in Mexico to improve access to electricity in off-grid rural areas. The project concept recognises the difficulty in attracting private sector investment without substantial support from government, but notes that previous government efforts that did not provide for some means of cost recovery have not been sustainable and benefited only a few. The project seeks to find a middle ground, providing first cost subsidy against monthly payments set at "willingness to pay" levels, with an expectation that once a critical mass is achieved, private sector participation would be forthcoming.

For LP Gas, an example is an initiative by ENPRO, a subsidiary of the Ghanaian National Petroleum Corporation, recognising the environmental benefit of LP Gas, to make low-cost, small stoves and cylinders available to civil servants with interest free credit, and recovering the cost from their ongoing salary payments.

Three different approaches that have been used for financing rural energy systems are:

- End-user finance. Each business or residence has a separate system. End user credit can be provided, either through grants/subsidies or micro-finance loans.
- Community based system. Rural energy systems are used to power a local mini-grid. End users are metered. Community and individual credit again can be provided either through grants/subsidies or micro-finance.
- Energy entrepreneur. The community-based entrepreneur is responsible for provision of the service, and charges users on a fee-for-service basis. His start-up and operating capital may be provided by micro-finance.

These three approaches are compared in Figure 5.9

COMPARISON OF THREE INSTITUTIONAL APPROACHES			
Institutional Approach	**Role of Micro-finance**	**Role of Micro-enterprise Support**	**Role of Upstream Finance**
End-User Finance	• Fixed - asset credit for RE System • Fixed-asset or working capital for productive uses • Finance for a package that includes an emergency system, tools and working capital.	• Target income generation • Packaging generators and applications	• Capitalize revolving credit fund • Provide working capital for supplier-run credit program
Community Based System	• Fixed-asset or working capital for productive use	• Business incubator services • Promoting productive uses	• Fixed asset lending for community energy system
Energy Entrepreneur	• Working capital for energy entrepreneur • Fixed-asset lending for RE system • Productive use lending for community members	• Evaluate the covenant between the community and the entrepreneur	• Capitalize a revolving credit fund or bank program

Source: NREL (Document 9)

Figure 5.9

5.5 Economic Models

Various life-cycle cost analysis models for rural electrification projects are available in the public domain. Appendix I provides outline information on Hybrid 2, RREAD, SAFIRE and HOMER. For specific site locations, these enable the user to determine the most appropriate energy hybrid. The models are useful for economic evaluation of alternative electricity supply options based on renewables, with diesel generator back up, in particular locations. Results from one location are of little value in another location. The currently available models are geared toward electricity supply options rather than dealing with an overall energy mix. They have not been designed with LP Gas fuelled generators in mind, but some limited extrapolation is possible by substituting LP Gas generator and fuel cost data in place of diesel.

The Enpower tool, to be available by the end of 2002, includes LP Gas in its fuel options and therefore will probably be the most appropriate in the context of LP Gas use in Rural Energisation. Enpower is designed to facilitate the derivation and selection of the best compromise approach to introducing modern energy services to poor communities in a way that provides them with sustainable balance energy solutions. It assesses the existing energy use and service provision, and makes energy service comparisons based on received output, taking account of perceived non-financial benefits of different appliances and fuels, affordability, local community aspirations and expected price sensitivities. Potential solutions are listed on either a supply side or demand side value basis and offered to the community and other stakeholders. The process is refined until a practical and pragmatic final approach to the required energisation has been determined. A more detailed description of the Enpower tool is contained in Appendix II.

Conclusions and Recommendations

6.1 Conclusions and Recommendations

These **Guidelines** demonstrate that LP Gas has an essential role in providing modern energy to rural areas of the world whether in developing or developed countries. The prime focus, however, is developing countries. Regardless of the economic status of the country or community the benefits are the same: LP Gas is a clean, portable, cost-effective and reliable form of energy. LP Gas can be a partner with renewable energy, or provide heat and power independently.

These **Guidelines** are intended to enhance the understanding of LP Gas distributors of the challenges and opportunities in rural energisation. An equally important reason for these **Guidelines** is to assist those charged with the responsibility of rural development in understanding how LP Gas can be a solution to the complex issues they face. These **Guidelines** will be useful if the following recommendations are taken.

- LP Gas distributors should carefully read the document so that they understand the basics of renewable energies, and how LP Gas can partner with renewables.
- LP Gas distributors should make sure local and national authorities responsible for rural development receive a copy of these **Guidelines**. A face-to-face meeting is preferable so that dialogue can be established.
- Rural planning officials and policy makers should review the document so that the option of LP Gas is given serious consideration in their planning process.
- Governmental officials must create and support a business climate where those willing to risk private capital are given an opportunity to earn a return on their investment.
- The collaborative effort of the LP Gas distributor and the rural planner should lead to a well designed, implemented, and monitored project involving the local community leadership.

Communication site powered by solar with LP Gas back up.

Appendix I: Life-cycle Cost Analysis Models for Rural Electrification Projects

The following life-cycle cost analysis models for rural electrification projects are available in the public domain.

Hybrid2

Hybrid2 is a user-friendly tool to conduct detailed long-term performance and economic analysis on a wide variety of hybrid power systems. Systems are based on three bus configurations (three power sources) containing multiple wind turbines, PV arrays, diesel generators, battery storage, power converters and a dump load. The on-line library of approximately 150 different commercial equipment systems and data files allows the user to create project and power systems, and resource data files. All components are easily defined from manufacturers specification data so that the user can enter components not included in the library. A detailed economic analysis allows the user to analyse a wide variety of inputs from taxes to load information. Hybrid2 is available from the National Energy Research Library, USA, for a $100 registration fee.

RREAD

RREAD is a spreadsheet-based model to evaluate the energy and economic performance of PV, wind turbine and PV/wind hybrids. RREAD processes resource, economic and financial data, in combination with inputs on technology configurations and relevant policy factors, to provide the user with an analysis of the energy output and economic value of user-specified renewable energy applications. RREAD can conduct sensitivity studies that allow the user to examine the impacts of technical, economic and policy changes on the performance of off-grid renewable energy systems. RREAD was developed by the Center for Energy and Environmental Policy, University of Delaware, USA.

SAFIRE

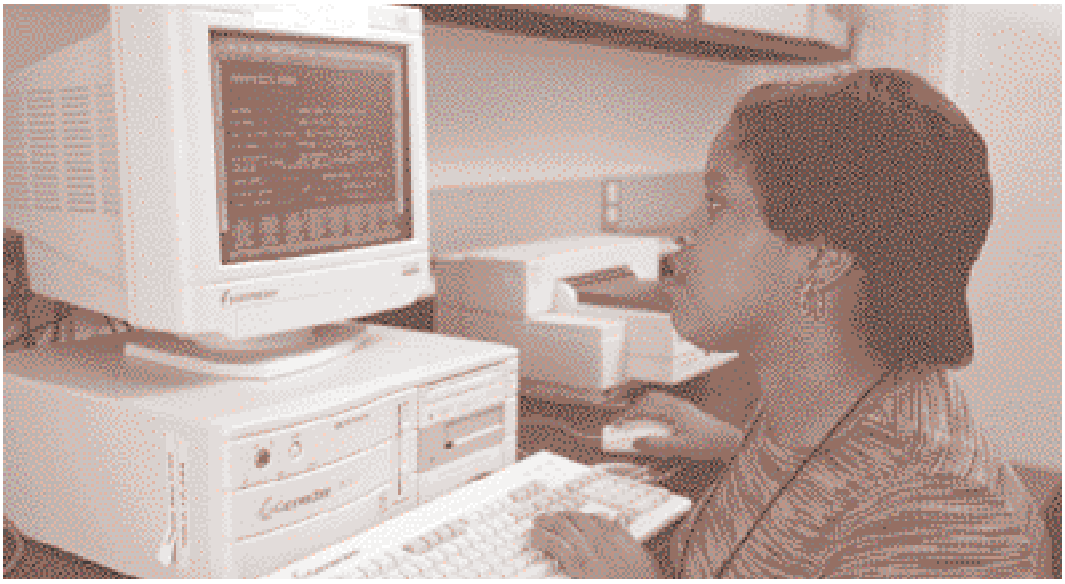
Solar array with LP Gas back up.

SAFIRE is an engineering-economic bottom-up model, designed for the assessment of first order impacts of renewable and non-renewable energy technologies on a national, regional or local level against a background of different policy instruments and scenario assumptions. SAFIRE assesses the impact of energy technologies and associated policies on a number of economic indicators i.e. investment costs, pollutant emissions, environment and health costs, net employment creation, net value added, government expenditure and import dependency. The SAFIRE database currently covers 32 countries in Europe and a further eight world wide, and thus is more appropriate for developed countries rather than developing countries. More information is available from ESD Limited in the UK.

HOMER

Homer is an optimisation model for designing stand-alone hybrid electricity power systems. With an input of electrical loads, solar and wind resources, and performance and cost data for various components, HOMER will design the optimum hybrid power system to serve those loads. HOMER can model any combination of wind turbines, PV modules, diesel generators and battery storage. One positive attribute of HOMER is the level of detail at which it runs. Simple spreadsheet models are useful for financial analysis, but cannot reliably predict the performance of hybrid systems with intermittent resources and storage because they do not consider the temporal patterns of loads and resources. Detailed engineering models such as Hybrid2 above are time consuming to set up and run. They are useful for evaluating the performance of specific well-defined systems, but are of limited use in determining the optimum system. HOMER fills the large gap between these two types of models. It is sophisticated enough to consider the hour-by-hour performance of the system, but not so complicated that the design process gets bogged down in details. HOMER is available from the National Renewable Energy Laboratory web site. Note that the model can take a number of hours to complete one run.

While HOMER does not specifically consider LP Gas generators, a simplified assumption of factoring the diesel cost by 1.5 will reflect the running cost of an LP Gas generator, and the smaller capital cost can also be input. If more detailed fuel consumption data is available for a proposed LP Gas generator, then a specific fuel curve can also be used.



Computer generated models can aid in sizing rural energy systems.

Appendix II: The 'Enpower' Energy Appraisal Toolkit for Poor Communities

The aim of this project is the development and demonstration of the 'Enpower' tool. The Enpower tool is designed to facilitate the derivation and selection of the best compromise approach to introducing modern energy services to poor communities in a way that provides them with sustainable balanced energy solutions. The need for such an approach exists since at present no practical model exists that can capture energy developmental needs from a demand side perspective (i.e. an approach that gives the needs of the community a voice) and then show how these might be converted into appropriate, sustainable, supply solutions. In addition the Enpower tool demonstrates how stakeholders' interests are affected by each possible combination of fuels and appliances.

The Enpower tool assesses the existing energy use and service provision, and models the potential benefits of alternative energy supply solutions. It has three basic components:

- ***Energy service comparisons*** based on received output. Methods of comparison are presented that use, as a comparative basis, the actual benefit enjoyed by the end user for each energy service (meals cooked, time spent cooking, hours of light etc.). This approach is more realistic than a simplistic comparison based on the relative cost between fuels, adjusted to consider efficiencies. The output of this component is therefore a sound basis for economic comparison between the existing and alternative solutions for the community (incuding data and modelling at the individual appliance level).
- ***Perceived non-financial benefits*** of different appliances and fuels. The decision to purchase one option over another is not based solely on the relative economic cost. The other influence is the complex area of perceived performance. A method has been developed that measures and quantifies the relative performance between appliances based on a set of dimensions for each energy service (e.g. ease of use, quality of output, cleanliness, risk of theft, etc.).
- ***Affordability, aspirations and expected price senstivities*** are used in assessing the benefits of alternate options from a community perspective. Specifically all new energy services may require a change in spending patterns and hence require assessing and factoring into the analysis.

The Enpower tool then integrates these three components to give relevant insights into the perceived value to the customer while simultaneously taking price sensitivity into account. The schematic at the end of this Appendix shows how the Enpower tool facilitates an interative interaction with the local community. Enpower is designed on a modular basis and the logical structure of the modules allows a structured process of analysis and benefit determination.

The modules contained in the Enpower tool are described below:

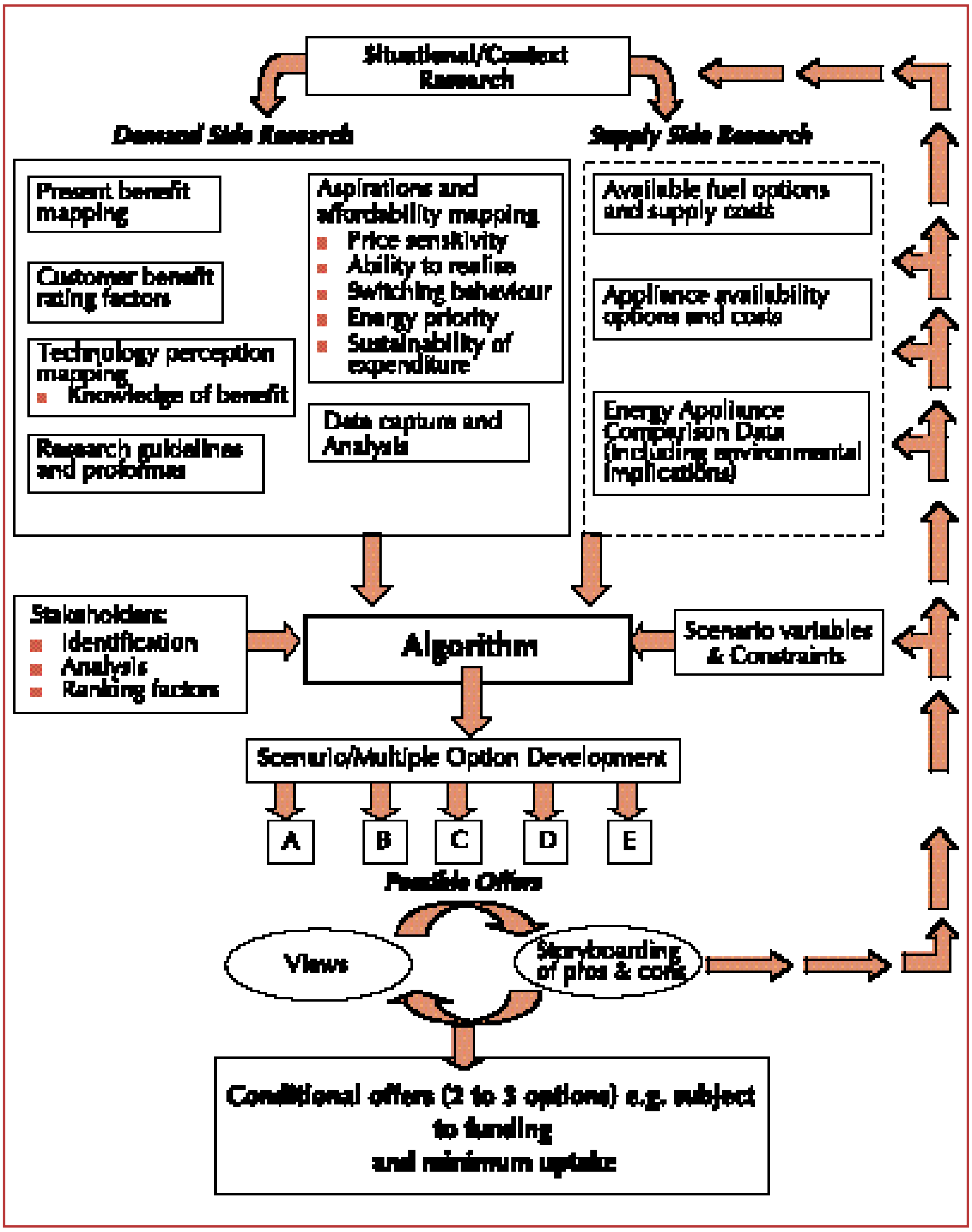
- ***Situational research***, where the user needs to collect and understand data that defines the broader context within which the intervention is to be made.

- ***Structured mapping of the present patterns of energy usage*** (by fuel as well as by service received from this fuel use) and the benefits perceived by the community as arising from this energy use pattern. This involves gathering of data on the supply side options available (including local fuel resources) to the community. There may be a regional dimension to this, depending upon exactly where the community is situated. Attitudes to particular technologies and the perceived level of service associated with their deployment will also be explored. Thus if supply options are not currently available they can still be part of the offer, but the cost of making the new fuel available is clearly identified and made visible.
- ***Aspiration mapping*** in order to set out a framework for determining the expectations of the community from increased access to modern energy services. This mapping effectively contains an estimate of the latent potential for growth in demand for energy services within the community, as well as their ability to assimilate and exploit the energy service provided in the medium term.
- ***Analysis of the gathered information***. This is carried out in two steps; basic processing and validation of field data, and final processing against pre-programmed logic.
- ***Testing the data*** against a number of predetermined scenarios. These will be crafted so as to show the impact of external constraints on individual stakeholding groups (and as such highlight where these may benefit or be disadvantaged under any given scenario).
- ***Presentation of outputs***. The outputs from the Enpower tool are presented in the form of appliance/fuel options and a series of 'stakeholder matrices', structured to highlight the pros and cons of the various solutions. This approach shows, as clearly as possible, the sort of 'trade offs' that will have to be made by each party in order to arrive at final offer(s). A potential final offer could be centralised solar battery charging for lighting and entertainment needs and LP Gas for thermal needs.
- ***Determination of solutions***, by selection of potential offerings on either a supply or demand side value basis. These solutions can then be offered to the community and other stakeholders and the process refined until a practical and pragmatic final approach to energy upliftment has been determined.

The Enpower tool is structured to set out clearly the benefits accruing to different stakeholders and to identify where there are conflicts (e.g. local vs. global environment, women vs. village, household vs. community), and hence provide a tool that can help manage stakeholder expectations. It is designed to be in practice a simple tool that suitably trained non-energy experts can use to help explore how demand for services can be met in a practical and sustainable manner. This requires that the data collection process is simplified so that non-energy experts can collect information while carrying out rural appraisals (e.g. via production of data collection guides specially designed for use by field workers).

The Enpower toolkit will be completed and be available in the public domain by 31 December 2002. Further information is available from PN Energy Services in South Africa, at e-mail chris@pn.co.za. PN Enegy Services is a company owned jointly by Eskom of South Africa and EDF of France.

Schematic Representation of the Enpower Logic & Module Structure



Appendix III: Case Study - South Africa

1. Overview

Eskom, the South African Electrical utility has spearheaded one of the most successful electrification programmes in the world, bringing grid electricity to over half of the South African population. However, while some 80 percent of urban areas have been connected to the grid, around 54 percent of rural areas remain unconnected. Furthermore, those rural villages, schools and clinics located far from the existing grid infrastructure are unlikely to be electrified due to the very high cost of connecting to the grid.

Eskom, having been mandated by government with the task of bringing grid electricity to all areas in South Africa, was faced with the reality that for certain rural locations other solutions had to be found. In 1997, Eskom therefore initiated the "Rural Energisation" project with the aim of finding alternative ways of providing a combined energy package for the upliftment of specific rural areas.

2. The Energisation Project

The Energisation Project had the following three fundamental aims:

- To devise a range of technical, institutional, financial and political solutions for sustainable energy upliftment for over 2 million rural households in South Africa.
- To highlight the plight of the rural poor in South Africa in order to influence government energy policy, and attract the international energy industry to participate in a a co-ordinated rural energy programme.
- To create an energisation pilot project in a rural community to test and demonstrate the above aims and to provide a documented and replicable case study.

The energisation elements were to be affordable, fit for purpose, environmentally benign and were to exploit the high level of sunlight available in South Africa using proven household renewable energy technology. It was necessary at the early stages to establish the principle of co-operation between energy suppliers that normally compete with one another.

3. Project Approach

The three critical elements to any energisation project are (a) a combined energy package of essential electricity and a thermal supplement, (b) the energy modelling to derive and select the optimum energy mix for specific rural communities and (c) the best institutional (government, industry, and community organisations) arrangements to suit local circumstances for effective implementation and sustainability.

For the Energisation Project, as originally envisaged, the energy modelling took into consideration the following:

- Energy service comparisons based on perceived output focussing on actual benefits enjoyed by the user (e.g., time spent cooking, hours of light etc.) rather than a mere comparison of relative costs between fuels.
- Perceived non-commercial benefits of different fuels and appliances e.g., cleanliness, safety, risk of theft, quality of output etc.
- Affordability, aspirations and expected price sensitiveness were used in assessing the benefits of alternative options from the rural community perspective.

Energisation in this context involves the packaging of essential electricity provided from various sources of solar, generator sets, batteries etc., with a thermal supplement for cooking and water heating.

In order to test and demonstrate the whole energisation approach, a pilot project was chosen, the Emzweni Village Energisation Demonstration Project. This is described in more detail hereunder.

4. Other South African Rural Energy Schemes

It should be noted that various other rural energy schemes have been undertaken in South Africa and it is worth outlining and commenting in general on some of these schemes.

Solar Home Systems (SHS) Pilot Project.

Located in KwaZulu Natal this small pilot project, initiated in 1995, has provided solar powered basic electricity to 50 households and a local school. The package consists of a 50-55 Wp solar module plus battery to provide basic electricity for 3 lights, radio and monochrome TV. The commercial approach was on a lease-purchase basis with a 10% deposit and monthly repayments over 36 or 48 months. Eight SHS's have been repossessed due to non-payment. Some technical problems have occurred with the original batteries and ballast inverters/fluorescent tubes. The original projections were to have 1,000 households supplied with SHSs. It is now expected that the project will form part of a concession area for non-grid electrification as part of the Department of Minerals and Energy's (DME) latest programme. No thermal supplement was supplied.

Solar Home Systems Utility.

Located in Eastern Cape Province this is the latest pilot project initiated by Eskom/Shell SHS (Pty) Ltd in 1998, to supply SHSs to off-grid communities. The package consists of a 49Wp pole-mounted solar module plus battery to provide basic electricity for 4 lights, radio and monochrome TV. A total of 6,000 systems had been installed by the end of 2000 with the final projected number of installations of 50,000 making this scheme (known as the "Powerhouse" project) one of the largest commercial solar rural electrification projects in the world. The commercial basis is on a "fee-for-service" concept with an initial connection fee and a monthly fee for the power supply. The average monthly fee of R47 is comparable with the normal expenditure by a household for candles, paraffin and batteries for lighting, radio and TV. It covers the cost of essential electricity only and no thermal fuel is supplied.

National Schools Non-Grid Electricification.

This nation-wide scheme was initiated in 1994 with Eskom as the implementing agent on behalf of the Department of Minerals and Energy (DME). The projections are that 16,000 schools will require non-grid electrification. Installations are progressing steadily with over 1,852 schools connected to-date. The electrification package consists of a solar system that provides 2.8kWh per day employing DC supply for internal and external lights and AC supply via an inverter for the use of overhead projectors, monitors and VCR/TV. The cost per school in the initial phase was R75,000 which included the provision of the necessary electrical appliances. Funding has been from a variety of sources (European Union, NORAD, Netherlands, RDP Fund and Eskom) as direct fiscal applications or grants.

National Clinics Non-Grid Electrification.

This nation-wide scheme was initiated by the Independent Development Trust (IDT) in 1994 with the projection that 2,000 clinics need to be supplied with non-grid electrification. The electrification package consists of a solar system that provides AC power for internal and external lights as well as power for a vaccine refrigerator, a medical examination light and radio communications where no telephone lines are available. The cost per clinic is R95,000 including equipment. 180 clinics have been completed to-date. All funding has been direct fiscal applications or grants through IDT.

Rural Energisation Utility.

This project is located in northern KwaZulu, Natal Province, and was one of the first pilot locations for rural energisation, using solar as the electricity source and other fuels (LP Gas and paraffin) to provide the thermal needs of rural households. The project was initiated in 1999 by Eskom, BP Southern Africa and Emtateni, a local service company. The energisation package consists of a 49Wp solar module plus battery, and a two-plate gas stove (with two 4.5kg cylinders) to provide electricity for 4 lights, radio and monochrome TV. LP Gas is used for cooking and water heating. A total of 20 systems had been installed at the end of 1999. The commercial basis was on the “fee-for-service” concept with an initial connection fee of R150 along with a monthly payment of R68. This project has now been discontinued.

Observations on these Schemes.

- In relation to the relatively high costs involved, solar systems provide a limited electricity supply in comparison to a grid connection.
- Solar systems do not address the other important energy needs of cooking, water and space heating, and cooling.
- Communities apparently felt quite strongly that the basic solar system is a poor alternative that would deny them the chance of ever getting connected to the national grid.
- Most rural households cannot afford to pay anything additional to what they pay at present for energy such as candles, batteries and fuel wood. In reality, therefore, rural communities have little choice but to accept the minimum solar energisation type package or remain as they are.

- On a cost benefit analysis basis the electrification of community facilities such as schools or clinics is one of the most effective ways to initiate a rural energy programme. Providing a combined energisation package such as solar/LP Gas can greatly enhance the impact. For example, by providing the nursing staff with gas cooking and refrigeration such better living conditions can attract staff to remote locations.
- One particular rural school with a progressive dynamic headmaster has vastly improved the basic solar package supplied, adding more solar modules and an LP Gas fuelled electricity generator. This has been used to power a photocopier and a computer centre with 20 computers. The school is now linked to the Internet and to the learning channel in Johannesburg. The combination of basic facilities and effective education is attracting pupils back from urban schools to this rural school.
- A coherent and sustainable government energy policy that addresses rural energy and a transparent and fair regulatory framework and authority are vital aspects of any Rural Energisation programme. The need to involve the rural communities directly in the decision-making regarding their energy mix requirements also cannot be over-emphasised.
- Other critical issues are (a) practical measures to deal with theft, (b) providing the crucial customer after-care services and (c) a reliable revenue collection, banking and management system.

5. Emzweni Village Energisation Demonstration Project

Emzweni village is a rural community located in the heart of KwaZulu Natal. The village has a school, a modest clinic and 250 households. The average income is R600 per month per household and an average of 7 persons per household.

The basic energisation package, payable over a period of three years, consisted of an LP Gas/solar system as follows:

- Two 4.5kg LP Gas filled cylinders
- 2-plate gas stove with connections
- 49W solar panel, roof or pole mounted
- battery with regulator
- wiring for two 9W low consumption, high output, wall-mounted lights, later 3 lights
- outlets for a black and white television set and radio
- a possibility of a black and white TV set, depending on product compatibility (not included due to the poor quality of signal in the area).

After allowing for a government subsidy, the cost to the consumer was an initial deposit of R140 and R65 or R55 per month depending on whether the solar module was pole-mounted or roof-mounted. For the fixed monthly payment the consumer was entitled also to a refill of one cylinder per month. While Eskom promoted the Pilot Scheme, TOTALGAZ, of TotalFinaElf, was the main implementation company responsible for the project. The first 40 units were installed in 1998 and by mid-2000, 100 units were installed, with 125 operating to-date.

A local Energy Agent was appointed and his responsibilities are the installation of equipment, conducting ongoing maintenance, dispensing LP Gas, providing safety advice and providing spares. He also collects monthly repayments and deposits these with the local development bank.

Problems with the strength of the TV signal as well as the licensing costs resulted in this part of the package being withdrawn. This halved the number of interested parties applying for the package.

An independent customer satisfaction survey denoted the following perceived main advantages of the package:

- there were no power failures
- the lighting was bright
- cooking was quicker and easier
- the house was clean from soot
- it was affordable
- gas and services from the Energy Agent were nearby and convenient.

It should also be noted that LP Gas sales were far above expectations. This was despite the community being unused to LP Gas. The key to this is the local availability of LP Gas whereas before the consumer had to travel 30 or more kilometres.

The basic cost of the solar package was R3,500 and the LP Gas equipment was R380. A subsidy of between R1,700 and R2,200 was required to maintain the repayments at an acceptable level.

6. The Current Non-Grid Electrification Programme

After months of recent deliberation, the South African Government, Department of Minerals and Energy and the other ministries along with Eskom, local authorities and rural energy concessionaires have just embarked on the Non-Grid Electrification Programme to bring improved energy provisions to 2.2 million rural households.

The proposed geographic concession areas and supply consortia are as follows:

Consortium	Concession Area
Eskom-Shell JVC	Eastern Cape: Eastern Transkie
Renewable Energy Africa Group	Eastern Cape: Southern Transkei
EDF - TotalFinaElf	KwaZulu Natal: Midlands
Nuon RAPS Utility (Pty) O Ltd	KwaZulu Natal: North
Solar Vision Group	Northern Province

The first phase of the programme will target 50,000 households in each of the geographical concession areas shown above.

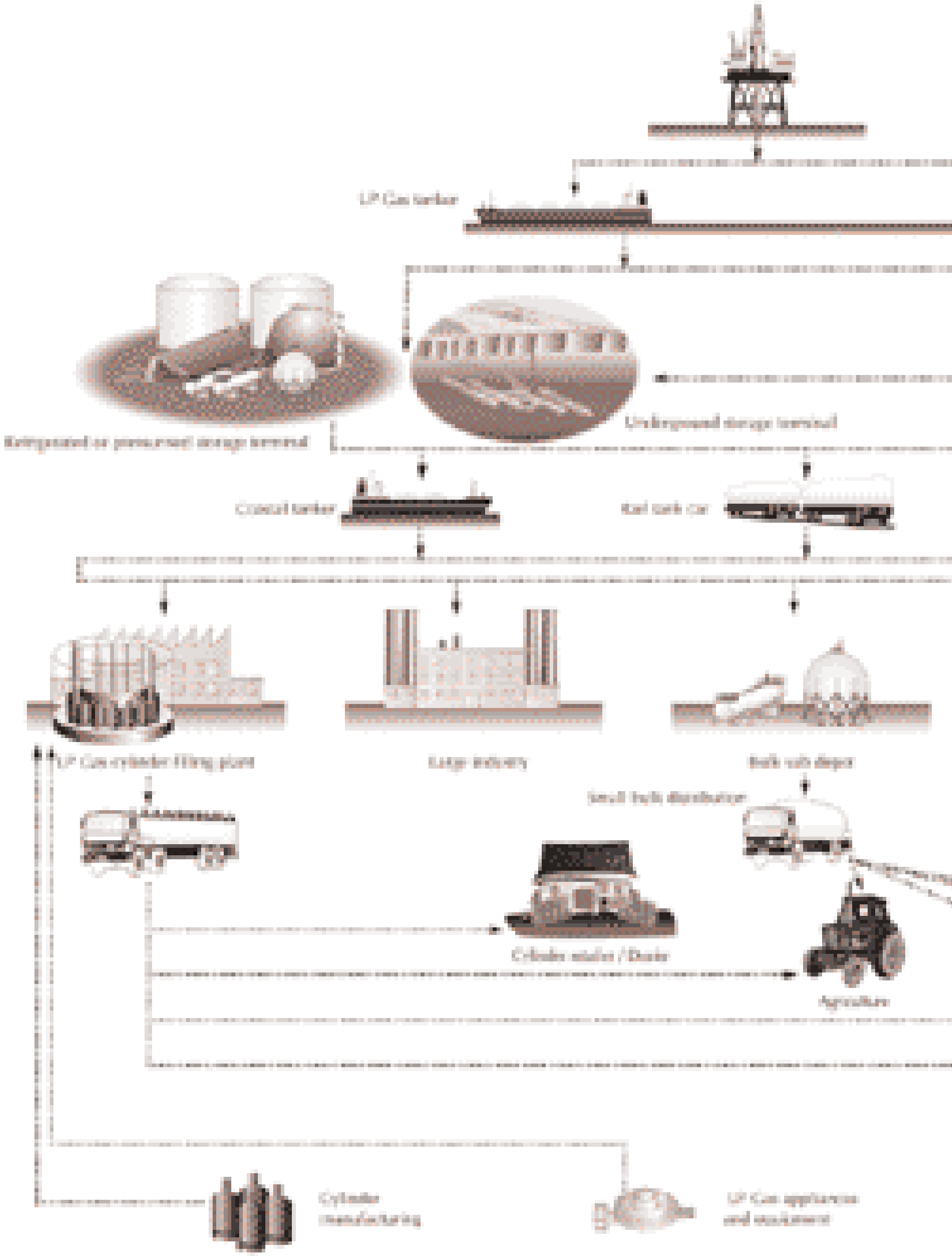
In the past the non-grid electricity supply only provided for a basic service. It is a requirement of participation in the current programme that concessionaires also provide a thermal element such as LP Gas or paraffin and related appliances to meet cooking and other energy needs through their local agency outlets.

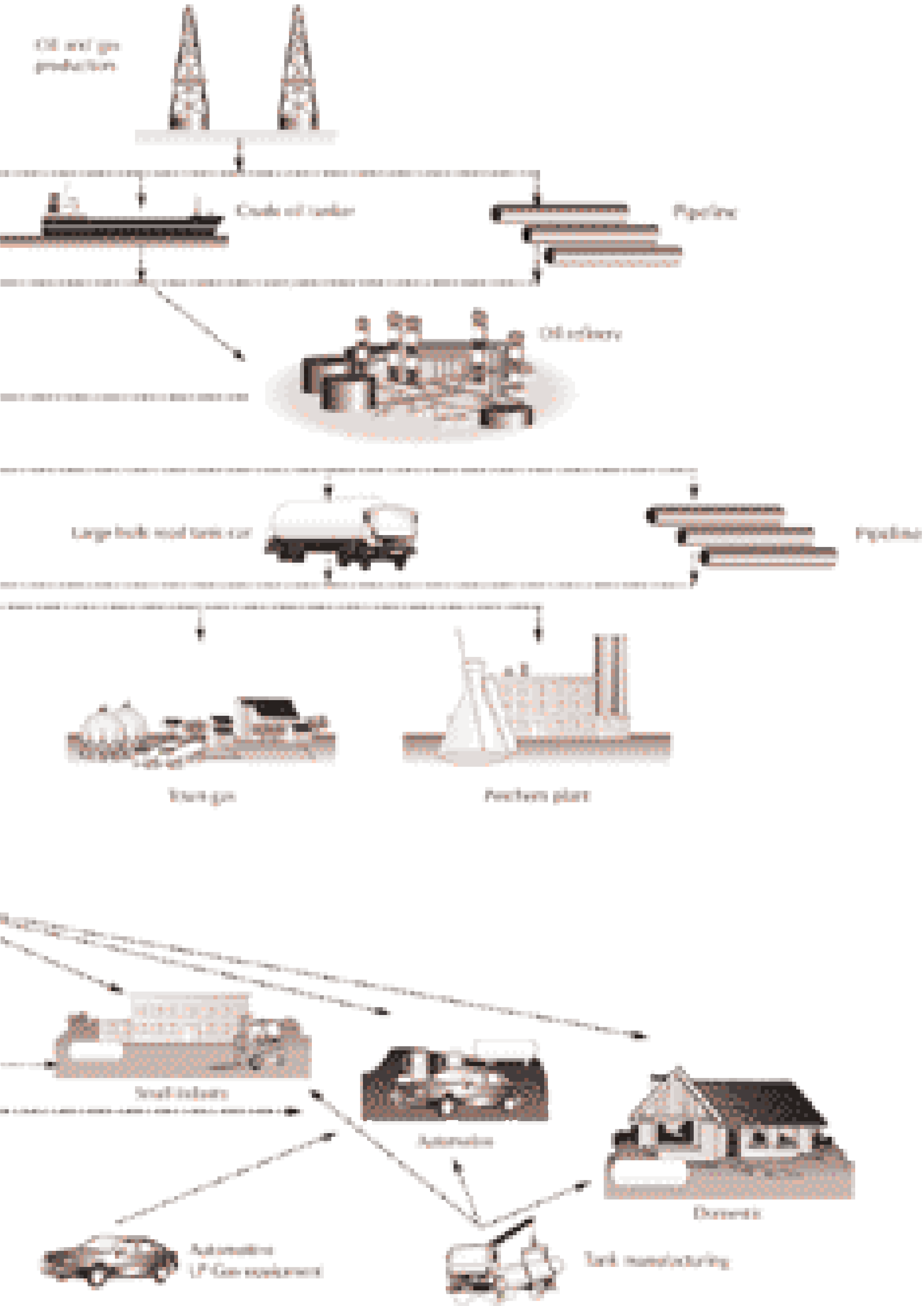
It should be noted that Eskom, one of the main drivers of the original pilot schemes, has dropped the inclusion of LP Gas in their projects as they feel it is too expensive and have decided to opt for IP (Illuminating Paraffin/Kerosene). They argue that local communities are familiar with IP, it is readily available, cheaper than LP Gas and the appliances are very cheap.

On the other hand, the South African Government is openly stating that LP Gas is the preferred fuel of choice both from its health and its safety aspects.

Because IP is so extensively used by the poorest of the rural communities, the government is keeping the price down and has it zero-rated for VAT. The South Africa LP Gas Association is taking its own initiatives to try to redress this imbalance.

LP Gas Distribution Chain




Oil and gas production
Crude oil tanker
Pipeline
Oil refinery
Large bulk road tank car
Pipeline
Town gas
Petrochem plant
Small industry
Automotive
Domestic
Automotive LP Gas equipment
Tank manufacturing

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5.	Towards a Sustainable Energy Future.	IEA/OECD	2001
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Useful 'first contact' internet addresses for access to some of the above documents or contact with the relevant organisation are:

World Bank	http://www.worldbank.org/
IEA/OECD	http://www.iea.org/
FAO/WEC	http://www.fao.org/
WLPGA	http://worldlpgas.com
ESD	http://www.esd.co.uk
CADDET	http://www.caddet-re.org
ESKOM	http://www.eskom.co.za/
TERI	http://www.teriin.org
AREED	http://www.areed.org
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CAPSTONE	http://www.microturbine.com
AGIP Gas	http://www.agipgas.it/
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CARB	http://www.arb.ca.gov/homepage.htm
NREL	http://www.rsvp.nrel.gov/rsvp/ http://www.nrel.gov/international/

Glossary

Absorption - The process of using latent heat of evaporation to effect cooling.

Alternating Current (AC) - Electric current in which the direction of flow oscillates at frequent, regular intervals.

Ampere (A) - Unit of electric current measuring the flow of electrons per unit time.

Ampere-Hour (Ah) - The quantity of electrical energy equal to the flow of current of one ampere for one hour.

Annualized Cost - The equivalent annual cost of a project if the expenses are treated as being equal each year. The discounted total of the annualized costs over the project lifetime is equal to the net present cost (NPC) of the project.

Array - A mechanically integrated configuration of PV modules together with support structure, designed to form a DC power-producing unit.

Battery - Two or more "cells" electrically connected for storing electrical energy.

Battery Capacity - Generally, the total number of ampere-hours that can be drawn down from a fully charged cell or battery. The energy storage capacity is the ampere-hour capacity multiplied by the battery voltage.

Biogas - A fuel gas produced from biomass, the useful energy component of which is methane.

Biomass Fuels - Solid fuels such as wood, crop residue, dung, etc.

Cost of Capital (COC) - The rate at which the future expense cash flows are discounted is usually set at a cost of capital.

Current - The flow of electric charge in a conductor between two points having a difference in potential (voltage).

Direct Current (DC) - Electric current flowing in one direction.

Dump Load - A standby load demand to ensure that a generator can at all times operate against a load.

Grid - The network of transmission and distribution lines used in central power or gas systems.

Hybrid - An energy system, which draws power from more than one source, such as PV plus generator.

Hydro - Hydro installations convert the kinetic energy of moving or falling water into electricity.

Insolation - The solar radiation incident on an area. Usually expressed in Watts per square metre (W/m^2).

Inverter - A solid-state device that changes a direct current (DC) input to an alternating current (AC) output.

Kilowatt (kW) - One thousand Watts.

Kilowatt Hours (kWh) - One thousand Watt hours.

Life-Cycle Cost - An estimate of the cost of owning and operating a system for the period of its useful life; usually expressed in terms of the present value of all costs incurred over the lifetime of the system.

Load - The amount of electrical power being consumed at any given moment. Also, any device or appliance that is using power.

Module (Panel) - A predetermined electrical configuration of solar cells laminated into a protected assembly.

Net Present Cost - The value in the base year (usually the present year) of all expenses associated with a project.

Nominal Voltage - A reference voltage used to describe batteries, modules, or systems (i.e., a 12-Volt or 24-Volt battery, module or system).

Peak Load - The maximum load or electrical power consumption occurring in a period of time.

Peak Watt (W_p) - The amount of power a photo-voltaic device will produce during peak sunlight and optimum temperature.

Photo-Voltaic (PV) Cell - A photo-electric cell that generates electrical energy when irradiance falls on it.

Photo-Voltaic (PV) System - An installed aggregate of solar array, power conditioning and other subsystems providing power to a given application.

PV - Photo-Voltaic.

Rectifier - A rectifier converts alternating current (AC) to direct current (DC).

Solar Cell - see Photo-voltaic cell.

Thermal Energy - Heat.

Transformer - Converts the voltage at which an electric system operates.

Volt, Voltage (V) - A unit of measurement of the force given to electrons in an electric circuit; electric potential.

Watt, Wattage (W) - Measure of electric power. Watts = Volts x Amps.

Wind Turbine Generator (WTG) - A device that converts the energy of moving air into electricity.

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