Green Power for Mobile

International Finance Corporation
World Bank Group

In Partnership with
the Netherlands

Green Power for Mobile Interactive Replication Guide: India Market Specific

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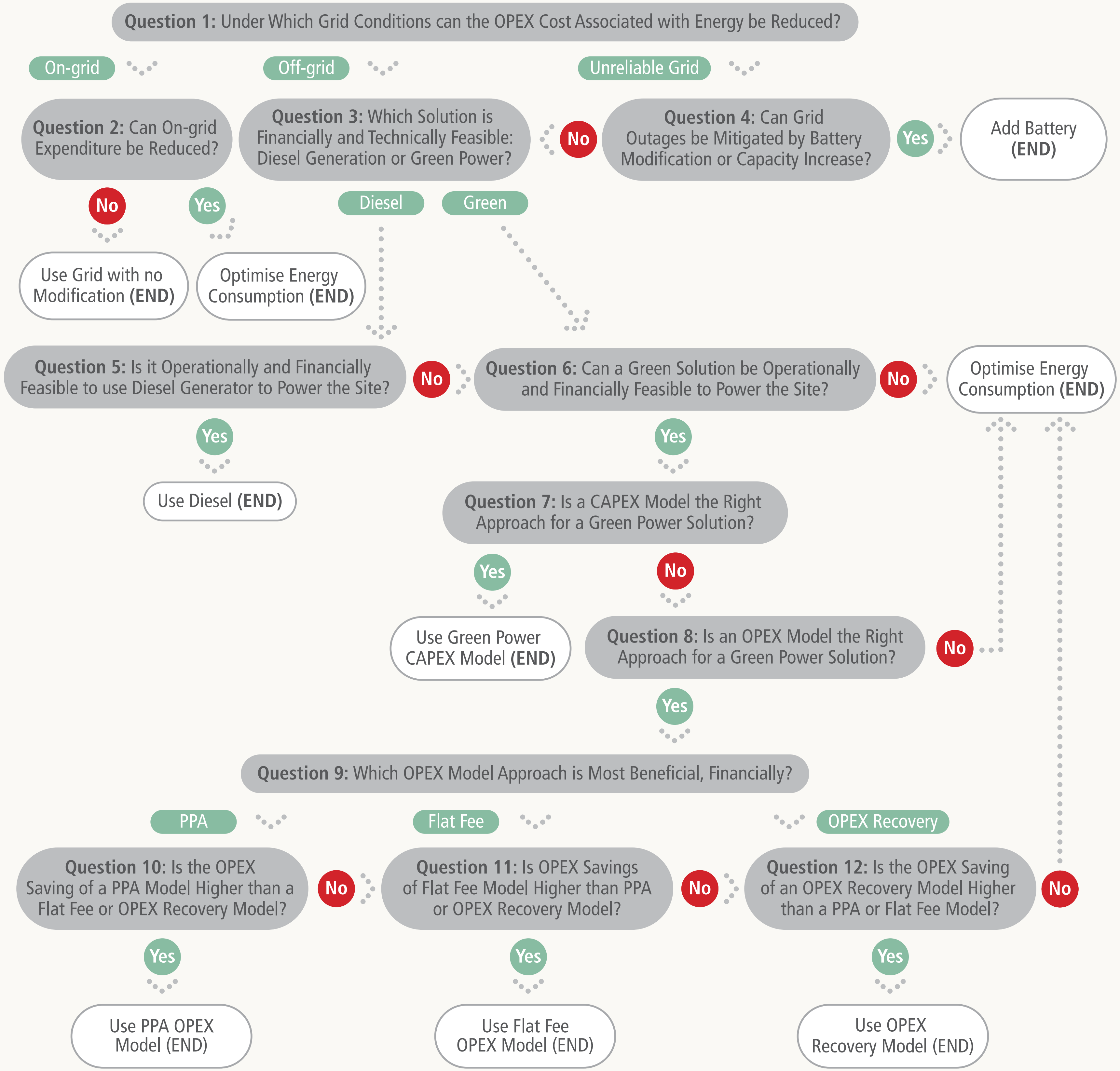
This Guide is intended to assist Mobile Network Operators (MNOs) and Infrastructure Providers (IPs) navigate through the decision making process of determining if a site is a suitable candidate for conversion into a renewable energy deployment.

This guide should not be read as a linear document. It has been designed as a decision tree, where the reader makes a series of choices after reading information sheets relevant to the questions posed by the tree.



Question 1:
Under Which Grid Conditions Can the OPEX Cost Associated with Energy be Reduced?

Key Points:

1. Definition of different grid conditions.
2. Energy OPEX of telecom tower.

Grid Definition

The telecom industry in India deals with three types of grid scenario:

- On-grid: A site that is connected to a commercial grid.
- Unreliable Grid: A site that is connected to a commercial grid but power availability is very low.
- Off-grid: A site that is not connected to a commercial grid.

Almost 82% of the existing telecom tower infrastructure in India is connected to the commercial grid. Yet 38% of the connected sites have issues with grid availability, and 18% of tower infrastructure is located at an Off-grid area. For further information, please read India Market Sizing and Forecasting Document on Energy for Telecom Towers.

Energy OPEX for Telecom Towers

The energy OPEX of a telecom tower depends upon two key questions:

- What is the power consumption of the telecom equipment at the tower location?
- What is the source of power for this telecom equipment?

The power consumption of telecom equipment varies greatly on subscriber handling capacity (number Of TRX). Also, if the telecom equipment is old, it is considered to be consuming more power than recent equipment of the same specification.

One of the major factors of a site's power requirement is whether it's an indoor or an outdoor site. In the case of an indoor site, it is a regular practice to use an air conditioner to maintain shelter temperature. Since the air conditioner itself consumes a great amount of power, the site's power requirement rises in tandem.

If the site is connected to commercial grid power, it is likely to be receiving energy in the most economical way already. However, if the site is connected with an Unreliable Grid, a diesel generator is often the preferred solution. Consequently, the site's energy cost increases markedly. If the site is not connected with grid power, a diesel generator running for long hours is the most widely-used power solution.

Question 2:
Can On-grid Expenditure be Reduced?

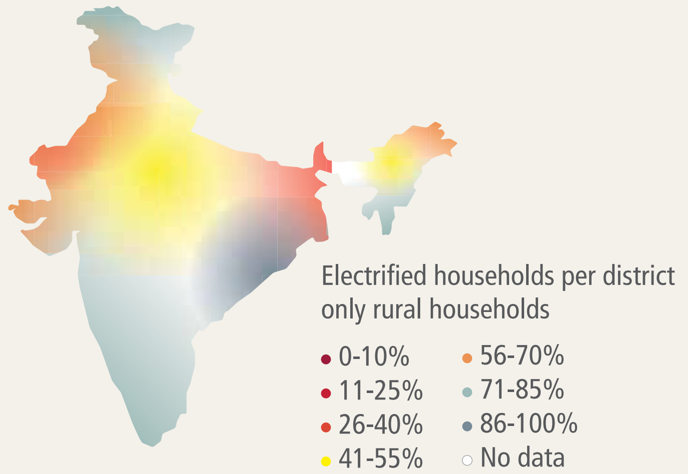
Key Points:

1. The distance from the base station site to the grid, along with local terrain, affects connection cost.
2. Grid reliability could be unstable in some regions causing frequent power outages.

Grid Availability

The availability of grid electricity varies dramatically between the different States of India. In India, the International Energy Agency states that around 65% of the population have access to electricity, 93% live in urban regions and 53% live in rural areas. In India, Jharkhand, Uttar Pradesh, Orissa and Madhya Pradesh are some of the States where a significant number (more than 10%) of villages are yet to be electrified.

Figure 1: Percentage of Electrified Rural Households per District



Calculations based on NSS data, round 55 (year 1999-2000)

If available, grid electricity is typically preferable to using diesel or Green Power Solutions. If grid electricity is available and inexpensive, it should be used as the primary source of power for the base station site. Using grid electricity has a number of benefits over diesel and Green Power Solutions:

- Lower CAPEX than Green Power Solutions.
- Lower OPEX than diesel generators.
- Minimal maintenance required.
- Ease of scalability of site to higher power consumption.
- Typically lower emissions than using diesel generators.

Grid Connection Lead Times

Even if a grid connection is possible and affordable, lead times may be a barrier to network expansion plans. Operators have stated grid connection lead times between 6-12 months are typical.

Grid Connection CAPEX

Grid connection CAPEX depends on the grid extension and connection charges. In urban areas, grid extension may not be required, but in most rural areas, the MNO/IP has to input CAPEX in order to extend the existing grid to get commercial power. MNO/IP typically report that the grid extension costs range between US$2,000 to US$10,000, depending upon the distances involved, whereas the connection fee for commercial power at India is only US$25.

Grid Connection OPEX

Using grid electricity to power base station sites is generally the lowest OPEX solution. The price of electricity fluctuates significantly between regions. However, the grid electricity prices are increasing every year.

Unreliable Grid Electricity

In the developed world, the electricity grid is typically very reliable with power outages (blackouts) occurring only rarely. In the developing world the grid is far less reliable and power outages are frequent. Grid outages need to be covered by some form of backup, either with diesel generators, batteries or Green Power Solutions.

Examples of Commercial Power Unreliability in the Developing World

Region	Commercial Power Unavailability
Nigeria	Available 75-85% of the time
Bangladesh	Urban: 4x 1hr outages / day
	Rural: 2x 4hr outages / day
Sri Lanka	Outages every day
Sumatra	4 hours outage / day
Pakistan	3,000-6,000 MW electricity capacity shortage
East Africa	Power outages one day a week; 4 hour rolling outages

Source: Operator interviews

India is no exception to this trend. In rural areas, the commercial power is unavailable for an average of ten hours per day and in urban areas, it can be unavailable for an average of two to four hours per day.

Impact on Network Performance

If the grid power supply to a base station site fails, and there is no backup source available, the base station will not function and network availability to end users will be adversely affected.

Remote Off-grid sites can sometimes be part of a network 'daisy-chain'. In this scenario it is vital that the backhaul operation continues in order to route network traffic to the remaining links in the chain. As the backhaul requires significantly less power than the full base station site, power loads can be reduced by allowing the backhaul to operate while turning off the rest of the BTS.

This form of intelligent switching is not recommended as part of the planning for the regular power charge/discharge cycle, as removing coverage is likely to breach operators' licence conditions. However, the technology is extremely useful when designing a network for resilience to unpredictable power disruptions (e.g. extreme weather). Intelligent switching technologies minimise the battery size required, with consequent CAPEX reduction.

Future developments in intelligent switching may allow transceivers to power down based on the energy available and battery level. Operators must consider the most appropriate balance of coverage and capacity in order to optimise profit from their network.

Future Trends in Grid Availability

In most developing countries, grid coverage is increasing as economic development and infrastructure improvements extend from cities to rural areas. However, in some regions of the world this extended coverage can be coupled with reduced reliability. Excess demand can lead to electricity grids introducing 'load-shedding' whereby power is rationed to particular areas of the country in order to prevent general brown-outs.

Question 3:
Which Solution is Financially and Technically Feasible: Diesel Generation, or Green Power?

In order to determine the most economically favourable power option it is useful to analyse the CAPEX and OPEX of the different options available – Green Power, diesel, and where relevant, grid.

The following pages provide information that will help you to answer these key questions:

- What is the CAPEX for Green Power Technology? Click for more info
- What is the OPEX for the Green Power Technology? Click for more info
- What Tools can I use to Check Financial and Technical Viability? Click for more info
- Where do I get Data Regarding Solar and Wind Resource Availability? Click for more info
- What are the CAPEX and OPEX to Install a Diesel Generator on the Site? Click for more info

Question 4:
Can Grid Outages be Mitigated by Battery Modification or Capacity?

Key Points:

1. Several types of batteries are available, each with specific advantages.
2. Open wet-cell batteries are suitable for easily accessed sites.
3. Flow batteries, which achieved significant price decrease in recent years, could offer an interesting solution as they maintain longer lifetimes regardless of charging regime.

In order to answer the question of whether grid outages can be handled by modifying/installing batteries, it is useful to examine what types of batteries can be used and what length of outages they can handle.

What Battery Types can be Used?
Key Points:

1. There are many battery types available each with specific advantages.
2. Open wet-cell batteries are suitable for easily accessed sites.
3. Flow batteries are a new technology, which maintain long lifetimes regardless of charging regime, but are currently significantly more expensive than lead-acid batteries.

Battery Requirements

Batteries are a key component of Off-grid and Unreliable Grid power solutions. They are also used in combination with Green Power Solutions.

Widely available lead-acid 'car' batteries are inappropriate for base station site-backup as they are designed to provide large bursts of energy. Instead, base station site systems require a battery that can withstand multiple charges and discharges over extended periods.

When using a Green Power Solution, battery type is even more important as different battery designs suit different power cycles. For example, because solar modules generate energy gradually during the day and use the stored energy overnight (i.e. cycle every 24 hours), batteries need to be designed to cycle a large number of times.

Types of Battery Technologies

Different types of battery technologies to be considered are open lead-acid wet-cell; absorbed lead-acid (or "gel") and flow batteries. Each of these technologies has a number of different materials and specifications, which, depending on the manufacturer may be more or less suitable to Green Power applications.

Batteries are rated at 25ºC. Above this temperature, the lifetime of the battery decreases significantly. A battery maintained at 35ºC will have 50% of the rated life. This applies to all lead-acid batteries. Flow batteries are designed to operate up to 40ºC. Above this temperature, the battery will temporarily stop working. Therefore it is very important to carefully control the environment of all battery types.

What Length of Outages can the Battery Handle? Key Points:

1. For grid outages of less than eight hours a day, batteries alone may be a suitable solution.
2. Repeated cycling of batteries can shorten battery lifetime.
3. Deep cycling batteries are an interesting solution as they can withstand longer regular power outage situations.

Grid Outages

In the developing world the grid can be unreliable with frequent outages (see further information on grid unreliability). This impacts the reliability of the base station site and the network coverage it provides.

Traditionally, outages are covered by diesel generators or batteries. Batteries are preferable to diesel generators as they do not need fuel to be kept on site, there are no emissions or noise, and they are easier to maintain. Similarly to Green Power Solutions, batteries have high CAPEX but low OPEX as there is no diesel cost. For grid outages of less than eight hours a day, batteries alone may be a suitable solution.

Impact of Battery Cycling

A lead-acid battery's lifespan is determined by the number of 'cycles' through which the battery is charged and discharged. Longer and deeper cycles mean heavily reduced lifetimes. As such, when an Unreliable Grid is supported by battery backup, the optimum battery size can be difficult to calculate.

Furthermore, lead-acid batteries require consistent (and often slow) charging regimes in order to re-establish a full charge. Therefore in some situations, adding a wind or solar generator to ensure batteries are not deep-discharged and are re-charged consistently, can greatly increase battery life and reduce operating costs.

Battery Comparison Table

	Maintenance	Lifetime	Controller	Cost
Open Lead-Acid Wet-Cell	**Requires maintenance** Top up with distilled water approximately every three months.	**Long life** Up to 2000 cycles for 80% rated capacity. Could last 15-20 years. Life reduces dramatically with temperature.	**Needs good charge controller** To limit gassing, stratification, and sulphurisation.	**Low Cost** <US$ 100-200/kWh.
Absorbed Lead-Acid (Gel)	**Maintenance free** Batteries are sealed.	**Shorter life than wet-cells** Up to 1600 cycles for 80% rated capacity. Could last 10-15 years. Life reduces dramatically with temperature.	**Less susceptible to charging problems**	**Mid priced** US$ 150-200/kWh.
Flow Batteries	**Low maintenance** Some maintenance may be required for fluid pumping system.	**Lifetime guaranteed for ten years** Recharge rate is up to four times quicker than other batteries. No degradation on deep cycling. Will not operate above 40°C.	**Integrated controllers manage charge/ discharge** To limit gassing, stratification, and sulphurisation.	**Expensive** ~US$ 1,000/kWh. But cost is being reduced. Potential two years ROI with latest products.

Question 5:
Is it Operationally and Financially Feasible to use Diesel Generation to Power the Site?

In order to answer the question of whether you can use diesel to power the site, it is useful to determine whether you can get diesel to the site, as well as to understand the risk of theft and the maintenance requirements.

Is it Possible to Get Diesel to the Site?
Key Points:

1. Availability of diesel varies regionally.
2. Distribution of diesel is dependent on transportation infrastructure and site location.

Availability of Diesel

Diesel is a refined fuel and requires transportation from production sites to consumption locations. Most locations covered by MNOs are able to source diesel. Cost is variable depending on transportation. Many locations in India suffer from an unreliable supply of diesel due to supply chain problems and seasonal accessibility restrictions.

Logistical Limitations of Delivering Diesel to a Site

Diesel consumption varies greatly based on the usage patterns of diesel generators as a power source. For remote sites relying exclusively on generators, typical fuel consumption for a base station generator (<=15kVA) is approximately 1,000 Litres per month. As such, generators require frequent and sizeable deliveries of fuel. There are several factors affecting delivery logistics:

- **Road access to site:** Site accessibility by road and distance to a fuel depot determine the ability to deliver diesel by conventional means (lorry).
- **Alternative methods of transportation:** Remote locations lacking road access (such as islands or mountain locations) require alternative means of transportation. These locations are often serviced by boat or aircraft. In extreme cases manual transportation (cart) has also been noted. Each of these methods limits the quantity of fuel that may be distributed in each visit and substantially increases cost.
- **Cost of distribution:** Fuel distribution can either be managed internally by MNO/IP or through an outsourced distributor. Most MNO/IP outsource to a fuel delivery company. Distribution costs are material and result in a substantial premium to regional ‘pump’ prices. In extreme cases the cost of distribution is similar to the price of diesel itself.
- **Security:** Diesel theft is one of the most critical problems for site operations in India. In some cases, 50% of fuel cost results from theft. Due to poor site security and local diesel mafia, thefts can occur internally due to collusion from the site technician, security guard or externally during transit.

Seasonal Variability on Diesel Availability

Heavy seasonal weather such as monsoon seasons and snowfall in some places, can severely restrict the supply of diesel to base station sites. This leads to increased distribution costs and reduced reliability of the base station site.

MNOs have cited that in some cases nearly 80% of aggregate network down-time is the result of diesel shortages at sites. Shortages are due to a number of factors including fuel availability and theft, but are amplified by seasonal variability in fuel supply.

What is the Risk of Theft of Fuel and Generator? Key Points:

1. Diesel theft is a significant problem in some regions.
2. Generator theft can also occur.

Diesel Theft

MNO/ IP in some regions are routinely affected by theft in their network fuel supply chains. Theft and tampering can occur at multiple points in the supply chain:

- Operationally by external distributors (tampering of fuel or incorrect book-keeping).
- Loss during transit.
- From site after distribution.

In some cases 50% of fuel costs are a result of theft, with the figure rising to 80% in extreme cases. The problem is only likely to increase with rising diesel prices.

Generator Theft

Generators used for telecommunications sites are large (typically 7kVA – 15kVA) and are deployed in heavy metal or concrete housing. Heavy lift equipment is required for the deployment of generators, but this does not always prevent theft in some problematic regions.

What are the Maintenance Requirements for Diesel Generators?

Key Points:

1. Diesel generators in constant use require technician visits every ten days, which is a substantial cost.
2. The more isolated a site is the higher the maintenance cost will be.

Maintenance Requirements

Diesel generators require regular engine maintenance including parts servicing and routine oil changes. Generator oil samples are also routinely collected to assess the health of individual site generators and forecast replacement requirements.

Generators require servicing at 250 hour runtime intervals. For sites relying entirely on generators for power, this represents a requirement for physical site access approximately every ten days. For extremely remote sites or low accessibility sites this can constitute a significant cost beyond routine maintenance costs.

Maintenance Costs

Maintenance costs include the cost of replacement parts and of a mechanic's time to carry out the replacement. Whereas parts can be treated as a fixed cost, the cost of the mechanic's time depends on many factors such as distance travelled to sites, hourly labour rate, and the skill of the technicians.

Scheduled Maintenance

Scheduled maintenance depends on how long the generator has been in service. In the early stages, fuel and air filters need replacing and oil levels need to be checked. In mid life, the generator will require an oil change and injector pumps and injection nozzles may need cleaning or replacing. At the end of life, maintenance requirements increase significantly, with major parts needing to be replaced.

Generators operating 16-24 hours/day will require replacement or complete overhaul approximately every 24 months.

Fuel and Oil Quality

The quality of the fuel and oil used can have a significant effect on the life of the generator. When fuel quality is low, filters, pumps and injector nozzles need replacing more frequently. In these cases, it may be worth considering treating fuel with additives to improve the quality, but this is generally only feasible where fuel can be stored and treated in bulk.

Question 6:
Can a Green Solution be Operationally and Financially Feasible to Power the Site?

In order to answer the question of whether you can use Green Power at the site, it is useful to explore the availability, price trends and import barriers for Green Power Solutions, as well as how you would select a solution provider and considerations around theft, maintenance and possible site sharing.

The following pages provide information that will help you to answer these key questions:

- How do I Select a Green Power Solution Provider? Click for more info
- Can you Protect Against Theft and Vandalism? Click for more info
- Can the Green Power Equipment be Maintained? Click for more info
- What are the Availability and Price Trends for Green Power Technology? Click for more info

Question 7:
Is a CAPEX Model the Right Approach for a Green Power Solution?

In order to answer the question whether a CAPEX Model is the right approach for Green Power Solution deployment, it is important to understand what the CAPEX Model is.

In the CAPEX Model, the capital investment for the Green Power Solution is made by the Infrastructure Provider (IP) or by Mobile Network Operator (MNO). The entire risk of the investment goes to IP or MNO. The Return on Investment (ROI) and OPEX saving is higher in a CAPEX Model, but IP or MNO has to invest the entire CAPEX in this model, which makes its scalability dependant on the funds the IP or MNO are able to allocate to the power solution. CAPEX Model is the most widely used model in the telecoms industry.

Hypothetical Example of CAPEX Model:

Let's consider an existing site with a load of 2kW that has a 15kVA DG which runs for 16 hours every day. Assuming current fuel cost is US$1.00/litre, fuel consumption for a DG is 2lt/hr. An estimated solar PV cost is $2.00/Wp. We can perform a technical dimensioning of the solar hybrid system using HOMER (HOMER is a software application for renewable solution dimensioning developed by National Renewable Energy Lab). For above requirement, HOMER proposed Solar PV of 5kW, Battery of one string 1000Ah OPzS series, 8kW converter and 120A controller.

PV (kW)	DG (kW)	GFMJ -10	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren Frac.	Diesel (L)	DG (hrs)
5.00	12	48	12	$27,340	4,502	$52,778	0.534	0.41	3,916	1,088
5.00	12	24	8	$21,920	5,521	$53,117	0.538	0.40	4,487	1,610
5.00	12	48	16	$27,840	4,493	$53,224	0.539	0.41	3,916	1,088

Using the previous estimates for the equipment and operating costs, the following results were calculated:

CAPEX Model Cash Flow

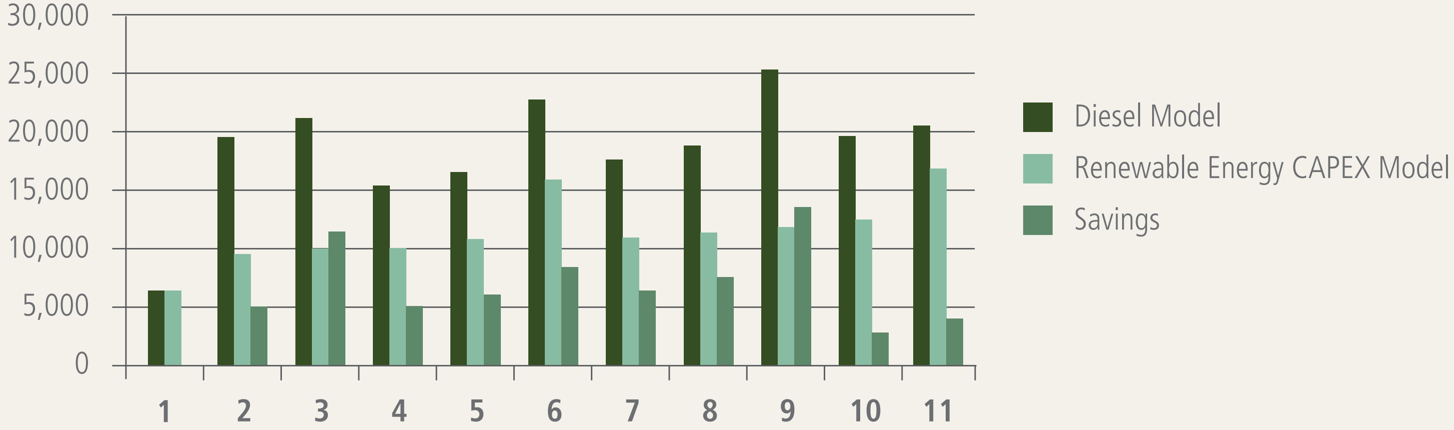
CAPEX	0	1	2	3	4	5	6	7	8	9	10
PV	9,000	0	0	0	0	0	0	0	0	0	0
Generator	2,000	0	0	0	0	0	0	0	0	0	0
Battery	4,920	0	0	0	0	4,920	0	0	0	0	4,920
Engineering Service	3,500	0	0	0	0	0	0	0	0	0	0
Energy Optimisation	0	0	0	0	0	0	0	0	0	0	0
Solar Controller	2,000	0	0	0	0	0	0	0	0	0	0
Total	21,420	0	0	0	0	4,920	0	0	0	0	4,920

OPEX	0	1	2	3	4	5	6	7	8	9	10
Site O and M Cost		1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
Site Security Cost		1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140	1,140
Generator Fuel Cost		4,487	4,725	4,987	5,286	5,583	5,894	6,209	6,563	6,971	7,356
Total		**6,828**	**7,067**	**7,330**	**7,630**	**12,848**	**8,240**	**8,556**	**8,911**	**9,320**	**14,626**

Financial Summary will be (all figures in US$):

Payback	**2.3 yrs**
ROI	33.47%
IRR	104.57%
NPV	34,708
Discount Rate	16%

If we compare the cash flow of Green Power CAPEX Model with the existing diesel solution, the Green Power CAPEX Model is proved to be a great OPEX saving solution for the IP or MNO.



Question 8:
Is an OPEX Model the Right Approach for a Green Power Solution?

In order to determine whether an OPEX Model is the right approach for a Green Power Solution, the idea of an OPEX Model should be clarified.

In an OPEX Model, the Green Solution infrastructure deployment and maintenance cost is born by a third party. The third party is called a Telecom ESCO (Energy Services Company). The Telecom ESCO is responsible for investment, power production and all necessary maintenance of the power equipment. The IP or MNO takes power from the Telecom ESCO at a site level. It helps the IP or MNO reduce dependency on diesel generators without having to invest the capital for the renewable energy solution. Since power generation and maintenance is not the core competency for the IP, outsourcing the power generation will help the IP to get rid of the challenges and risks associated with power. The concept of an ESCO has therefore been proactively introduced to the telecoms industry to facilitate the outsourcing model.

Question 9:
Which OPEX Model Approach is Most Beneficial, Financially?

To answer this question, it is important to understand different OPEX Models. In the current market, Power Purchase Agreements (PPA), Operating Lease or Flat Monthly Fee and OPEX Saving Recovery are the three approaches operating on OPEX Models.

A PPA Model is where the ESCO owns, installs and maintains the renewable energy power system and sells power to the IP or MNO at an agreed per kilowatt-hour rate. The main benefits of a PPA to the IP or MNO are that the payments for energy are an operating expense. The operator is only paying for the power they use and the financing of the power equipment is the responsibility of the ESCO. In this type of arrangement the IP must typically commit to a minimum take or capacity payment or otherwise assume the risks of energy load levels.

In an operating lease or monthly flat fixed fee structure, the ESCO would own, install, operate and maintain the renewable energy equipment and provide power to the operator's site for a fixed monthly cost. In addition to capital expense being the responsibility of the ESCO, it stabilises the IP's OPEX associated with power so it is no longer a variable part of the budget.

An OPEX saving recovery or ESA is where an ESCO installs the renewable energy system and operators pay based on a portion of verified energy cost "savings". The key component to the ESA is the operator payment formula which will determine how much of the saving will be passed through to the operator and how much will go to the ESCO to recover the capital cost of the equipment. This formula to split the saving will sometimes change at an agreed time during the term of the contract.

Power Purchase Agreement (PPA) Model:

The PPA is a more complicated model. In this model, the IP pays for power on a per kilo-watt hour (kWh) basis for the exact usage of power. The rate for per kWh may become more difficult to calculate as the market scenario will fluctuate over the ten years of the business case. The key to implementing this model successfully is aligning the per kWh price expectations of the IP with the rate the ESCO is able to provide. It should always be remembered that the kWh rate may not be as competitive as commercial grid power as the power generation is a renewable energy source. Due to the distributed model, and the O and M cost for ESCOs, it is costly to maintain the required uptime demanded by the telecoms industry.

Considering the same sample site again, with a 2kW load and the same technical solutions, the generic year-by-year cash flow for ESCOs will be:

	0	1	2	3	4	5	6	7	8	9	10
Total Cost for ESCO	-6,426	-9,481	-9,719	-9,980	-10,279	-15,497	-10,888	-11,202	-11,556	-11,964	-17,270
Power Requirement per annum (kWh)				**17,520**							

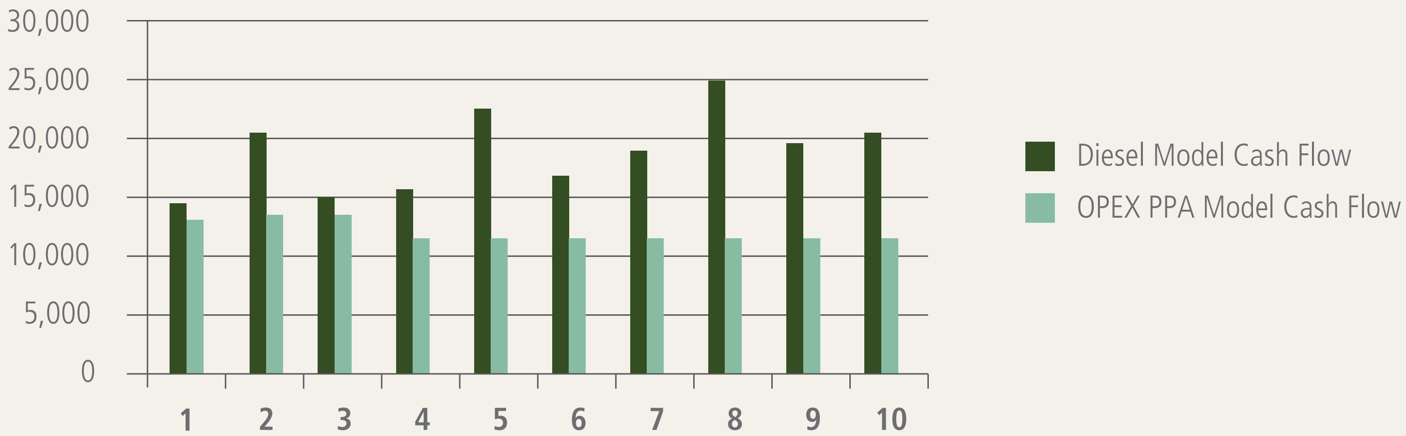
From an investment perspective, 20% is a desired IRR value. To achieve that, an estimated price for power will be: $0.72/kWh

The estimated cash flow for the IP will be:

	0	1	2	3	4	5	6	7	8	9	10
IP Cash flow	12,547	12,547	12,547	12,547	12,547	12,547	12,547	12,547	12,547	12,547	12,547

NB: The cash flow may be different if site load increases

If we compare the cash flow of Green Power OPEX PPA Model with existing Diesel solution, OPEX PPA Model will be proved a great OPEX saving solution for IP or MNO. A comparison is shown in the graph below:



From OPEX PPA Model, cumulative savings for IP will be:

	1	2	3	4	5	6	7	8	9	10
Cumulative Savings for IP	13%	29%	25%	25%	30%	29%	30%	33%	33%	34%

Operating Lease or Monthly Flat Fee Model:

In an operating lease, the ESCO bears the financial risk of OPEX increases for any of the power sourcing components. For any given power requirements the ESCO is required to provide uninterrupted power (99.95% power availability) for the entire duration of the contract. While calculating the monthly fee, the ESCO usually has an implied margin of 10% – 15% on its cost. In addition, the ESCO has to be careful while considering all possible operating costs as some can be unpredictable (i.e. diesel fuel cost). Since this model precisely triggers a specific power requirement of telecom equipments, the ESCO gets the monthly fee regardless of whether or not the telecom equipment consumes maximum power. For a similar sample site as before with 2kW power requirement the same technology and technical dimension will be the same as CAPEX Model and the year-by-year cash flow for ESCO will be the same of OPEX PPA Model.

	0	1	2	3	4	5	6	7	8	9	10
Total Cost for ESCO	-6,426	-9,481	-9,719	-9,980	-10,279	-15,497	-10,888	-11,202	-11,556	-11,964	-17,270

If we solve the financial figure on 20% IRR for ESCO, the operating lease or Monthly Flat Fee will be:

IRR	20%
Annual Fee	$12,547
Monthly	$1,046

Usually there will be no financial difference between a PPA and Flat Fee Model. In a PPA Model, the IP/MNO has to pay based on usage, whereas a Flat Fee Model does not deal with usage; rather, a flat monthly fee. However, Flat Fee Model restricts the maximum power consumption.

OPEX Saving Recovery or Energy Savings Agreement Model

In this model, a third party ESCO invests the CAPEX for a renewable energy solution and implementation programme. After the implementation, the ESCO measures how much the energy OPEX has been reduced due to renewable energy power implementation. The difference between the OPEX and current OPEX is calculated to determine the gross savings. The ESCO will receive a percentage of the OPEX savings value from MNO.

Some of the difficulties of this model are:

- It is challenging to identify actual OPEX savings. In order to do that, an ESCO must observe the current OPEX due to the diesel-based solution, and then observe the OPEX for a renewable solution.
- Sometimes unavailability of the current energy OPEX can lead to delays in deployment as progression cannot be made until the ESCO has examined the current energy OPEX.
- If the energy requirement at the site increases, it becomes very difficult for the ESCO to measure the OPEX saving.

Taking the CAPEX Model example again:

Diesel Model	0	14,392	20,976	15,089	16,233	22,909	17,119	18,364	25,147	19,469	20,832
Renewable Energy CAPEX Model	6,426	9,481	9,719	9,980	10,279	15,497	10,888	11,202	11,556	11,964	17,270
Savings	**6,426**	**4,911**	**11,257**	**5,109**	**5,954**	**7,413**	**6,231**	**7,162**	**13,591**	**7,504**	**3,561**

From the figures above, we can see that there is an OPEX saving each year. In an ideal case, if the ESCO returned 50% of the saved OPEX, the IP/MNO gets a net OPEX saving of:

	1	2	3	4	5	6	7	8	9	10
ESCO Revenue	3,213	2,456	5,629	2,554	2,977	3,706	3,116	3,581	6,795	8,550

Question 10:
Is the OPEX Saving of a PPA Model Higher than a Flat Fee or OPEX Recovery Model?

In order to answer the question, it is important to understand different OPEX Models and the cash flow implications of each.

The following links will assist your understanding:

- Which OPEX Model Approach is Financially more Beneficial? Click for more info
- The OPEX Savings of Different OPEX Models. Click for more info

Question 11:
Is the OPEX Savings of a Flat Fee Model Higher than a PPA or OPEX Recovery Model?

In order to answer the question, it is important to understand the different OPEX Models and the cash flow implications of each.

The following links will assist your understanding:

- Which OPEX Model Approach is Financially more Beneficial? Click for more info
- The OPEX Savings of Different OPEX Models. Click for more info

Question 12:
Is the OPEX Saving of an OPEX Recovery Model Higher than a PPA or Flat Fee Model?

In order to answer the question, it is important to understand the different OPEX Models and cash flow implications of each.

The following links will assist your understanding:

- Which OPEX Model Approach is Financially more Beneficial? Click for more info
- The OPEX Savings of Different OPEX Models. Click for more info

Optimise Energy Consumption

In order to understand whether existing site equipment should be replaced to improve energy efficiency; it is useful to evaluate the power requirements of the existing site, current equipment compatibility with Green Power, and the opportunities available to upgrade the current equipment, along with the economic viability of doing this.

Are the Power Requirements of the Current Site too High to use Green Power?

Key Points:

1. Old base station sites have higher power consumption.
2. The Internal Rate of Return for Green Power Solutions is higher than for modern, energy efficient sites.

Changes in Power Consumption

Energy use in mobile telecoms has only recently become a focus for MNO, IP and equipment providers. However, new technologies and base station designs have been introduced to reduce the power consumption of base station sites.

The most substantial change in recent years has been the removal of air conditioning. New, more robust electronics in telecoms equipment prevents the need for tightly regulated climate control. In some climates cooling is still required to maintain battery life, however significantly smaller (lower power load) systems can be used.

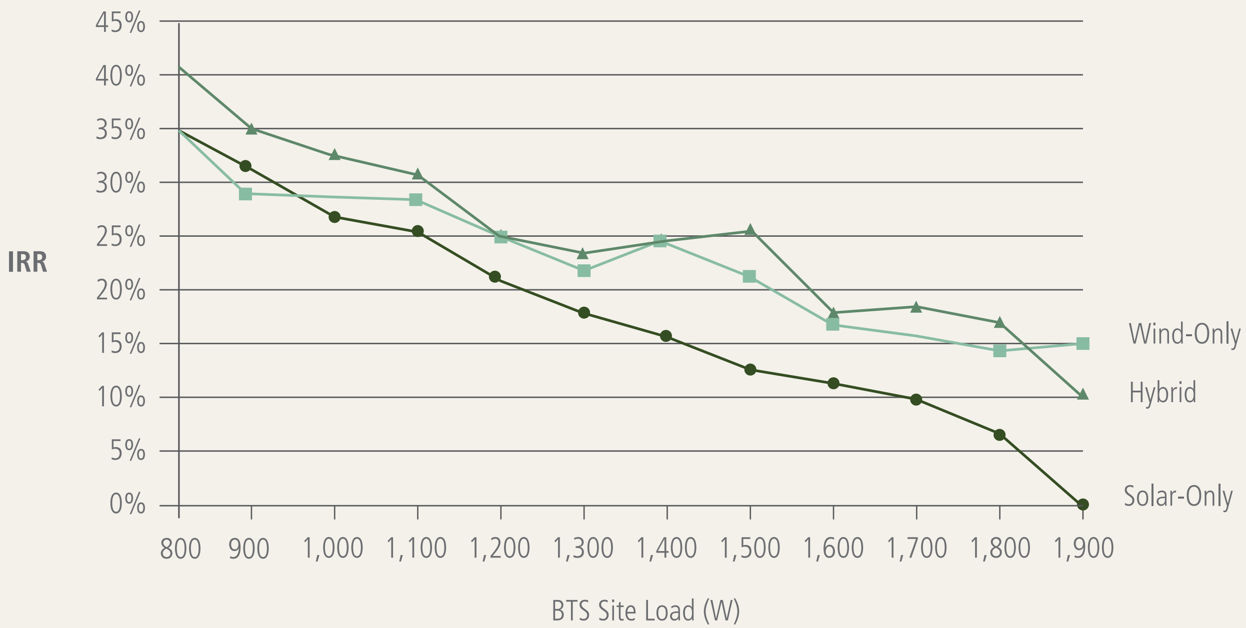
The power consumption of telecoms equipment at base station sites has fallen annually in an unbroken trend since 2005. As such, old sites typically have less efficient equipment and therefore have higher power consumption. These sites require larger specification Green Power Solutions, which will involve higher CAPEX.

Payback of Green Power versus Generators

A diesel-only solution will generally be based on an over-provisioned diesel generator (typically >10kVA).

As the generator is generally over-producing, the capital expenditure tends to be largely independent of site power consumption. Furthermore, fuel use for most generators of this size (10kVA) does not vary significantly for loads of less than half of the rated power. As a result the payback time of Green Power relative to a generator solution is longer for less power-efficient sites. The deployment of green power provides on average compelling returns on investment, particularly at lower loads - although solutions are extremely scenario-sensitive.

Base Station Site Load versus IRR (relative to diesel generator)



By reducing the amount of energy used at the base station site, the financial viability of Green Power increases substantially. See additional information on the economic attractiveness of upgrading old equipment to improve energy efficiency of the base station site.

Is it Economically Favourable to Replace Existing Equipment?

Replacement of existing telecom equipment is only valid for the MNO. Since the IP does not own the telecom equipment, the below discussion on telecom equipment replacement does not apply to them.

Key Points:

1. There is a strong business case for replacing existing equipment and diesel generators.
2. Replacements costs must be below $24k for a three year payback.

Changes in Power Consumption

Replacing existing equipment, whilst retaining a diesel generator as the power solution offers a potential business case for more established operators. By replacing old, energy inefficient equipment, the load requirements of the base station site are reduced and a more appropriately sized generator can be installed.

Larger AC generators use more fuel than smaller AC generators and for maintenance and functionality reasons, it is common for generators to be over-specified. Our interviews showed it is common to use 11-30kVA generators for a 5kW base station site. As the load on a generator decreases, the fuel consumption does not change significantly.

Using the latest equipment the following loads can be reduced:

1. Cooling – 2kW cooling load entirely removed in many climates. In high-temperature climates a much smaller, equipment specific and/or non-compressor cooling method can be used – at approx 200W.
2. Base Station Equipment – more robust (to prevent need for cooling) and reduction from 1.2kW to 1kW. With Remote Radio Heads this could be reduced further.
3. Other – reduction of other loads from 300W to 100W.

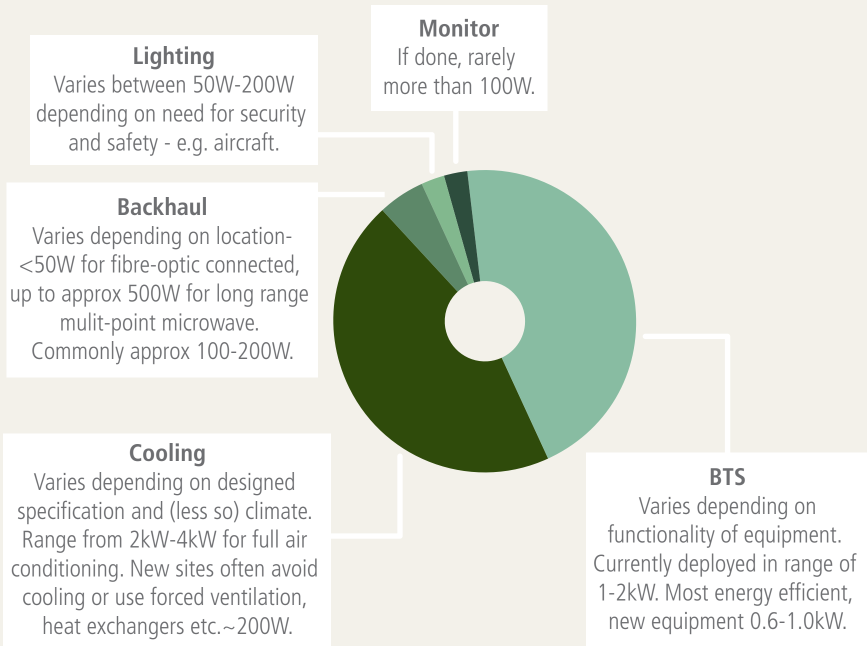
What are the Options to Upgrade Current Equipment?

Key Points:

1. Base station site power consumption is primarily from the base station equipment, active cooling, backhaul, lighting and monitoring.
2. There are numerous approaches to reducing power consumption.
3. Removal of active cooling and the use of Remote Radio Heads allow significant reduction in base station site power consumption.

Site Power Consumption

A typical base station site has a number of contributors to its total power consumption, as illustrated in the following graph:



Cooling

Cooling is a major contributor to power consumption at a base station site and can range between 2-4kW.

Cooling Telecoms Equipment

In the past, telecoms equipment providers specified operating temperatures up to 25°C, whereas 45°C is now typical for modern equipment. In hotter climates, maintaining 25°C requires active cooling, meaning large cooling loads. At 45°C, active cooling is not required providing enclosures allow, or force (with a low power fan) airflow and are in the shade.

Cooling Batteries

Batteries are adversely affected by temperatures above 20°C. Battery temperatures rise much slower than the air in the enclosure. Therefore providing the daily average temperature (including night time) does not exceed 25°C. Other – reduction of other loads from 300W to 100W. 25°C, active cooling is not required. New battery technologies are expected to be more robust in high-temperature environments.

Design Suggestions

In order to prevent overheating, enclosures must be designed to allow passive cooling and sometimes require forced airflow. Design suggestions include:

1. Batteries are often installed in separate/external cabinets, allowing good airflow.
2. Enclosures and equipment are often installed in the shade below solar panels.
3. For situations where the batteries still require cooling, small battery-specific cooling can be used (200W battery specific cooling, vs. 2kW air conditioning system for whole enclosure).

Since a battery is considered as passive equipment, the IP can implement the above battery cooling and design suggestions.

Base Transceiver Station (BTS)

Energy efficiency has only recently appeared on the design agenda for a number of network equipment providers. Gradual reductions in power consumption have occurred through component improvement. Substantial reductions in power consumption can occur through the use of Remote Radio Heads and Standby Modes.

Remote Radio Heads

Substantial reductions in BTS power draw could occur through the adoption of Remote Radio Heads. Typically half the emitted power from radio transmitters is lost in the feeders due to cables being several tens of metres long. This can be minimised by limiting the distance between radio units and antennas.

The reduced power consumption and remote location of Remote Radio Heads has further advantages: it is much easier to cool passively, thus eliminating the BTS cooling load. In a typical small site (e.g. a 2/2/2) the power draw is now split between four cabinets; a baseband unit at the foot of the mast, and three physically separated Remote Radio Heads at the mast top. None of these units generate sufficient heat to require active cooling. Power savings from the elimination of active cooling are in addition to the savings realised by the masthead location of the Remote Radio Heads.

Standby Modes

Intelligent low-traffic standby modes greatly reduce power consumption during off-peak times. BTS sites are dimensioned to cope with peak hours; during quieter periods standby mode could be used with no impact on service quality. This method can save approximately 20% of daily power load.

Backhaul

Power required for backhaul varies depending on the site's location and the method used. The most common method for Off-grid rural BTS backhaul is terrestrial point-to-point microwave radio-relay, with a range from 50-500W depending on distance and number of points connected. Reductions could be made by changing the high-level network plan. A fibre-connected site consumes very small amounts of power (< 50W). Alternative methods for backhaul include satellite-microwave, WiMax and copper wire (ADSL) which are less commonly used.

Lighting and Ancillary Equipment

Sites can also have a wide range of ancillary equipment. These highly variable loads are not important when using grid-electricity or an oversized diesel generator; however for a CAPEX-minimised Green Power Solution it can be significant and therefore the use / installation of these items of equipment should be carefully considered.

Ancillary equipment includes:

1. Tower-top aircraft warning systems/mast-lights.
2. Flood lighting systems for security.
3. Ancillary lighting for equipment maintenance (low power CF or LED lights can reduce this load).
4. Spare electrical sockets for maintenance equipment (often abused – e.g. kettles/heaters).

Monitoring

Operators can monitor the sites for power usage in order to address problems with generation and loads. Previously monitoring of power consumption was a low priority due to the use of grid-electricity or oversized generators. With movement to a CAPEX-minimised Green Power Solution, which is affected by the weather, monitoring of power use will become more important.

Is the Current Equipment Compatible with Green Power?

Key Points:

1. Key equipment may need upgrading/modifying to be compatible with Green Power Solutions.

If the installation is at an existing site the Green Power Solution may affect the operation of the current equipment and certain considerations need to be made. Below is a list of equipment that could be affected by a Green Power Solution installation and also any particular considerations:

Battery – A Green Power Solution will require additional batteries to be installed. Batteries should be specified based on the specific wind and solar conditions, site power consumption and autonomy (i.e. power system failure) requirements. The key to a robust Green Power Solution lies in the selection and sizing of batteries. For a site without a backup diesel generator, the battery may be the only power source during night-time and / or non-windy parts of the day and therefore is a critical component. Batteries suited to Green Power Solutions, for example a daily charge / discharge for solar applications, have much longer life-times (up to eight years) than general purpose batteries (one-two years).

Diesel Generator – Installation of a Green Power Solution will reduce the load requirements of the diesel generator. It may be required to switch to a smaller, more efficient (at smaller loads) diesel generator that is more suited to operate as a backup rather than 24/7.

Enclosure – The enclosure may need to be enlarged to accommodate additional batteries and control equipment. In order to reduce the cooling load, an alternative enclosure can be used which allows for passive and/or forced ventilation.

Power Controllers – The existing generator controller cannot be re-used for Green Power. Both solar and wind power controllers should be designed specifically to suit the combination of panels/turbines, weather and battery size. A well designed controller will increase the amount of power captured during sunny/windy days and drastically increase battery life. When using a 'hybrid' configuration with more than one source of energy (e.g. solar + wind, wind + generator etc.), the design of a controller becomes even more important.

Power Inverters – Battery strings provide a DC power source, whereas generators provide an AC power source. Rather than upgrade the inverter, it is far more energy efficient to run the site directly on DC power, removing the need for a DC – AC inverter and an AC-DC rectifier.

What is the CAPEX for Green Power technology?

Key Points:

1. Green Power CAPEX is formed from equipment costs, battery and controller costs and additional civil works.
2. Solar Solutions work best for small loads due to the CAPEX increasing with load requirements.
3. Wind Solutions have a lower CAPEX than Solar Solutions and are particularly suitable for high load requirements.
4. Batteries can represent a significant part of the overall CAPEX.
5. Combined solutions (e.g. wind and solar) can be the most cost effective, as they increase the reliability of power generation by combining independent power sources, thus reducing required battery capacity.

Elements of Green Power CAPEX

Green Power Solutions typically have higher CAPEX than diesel generators. The CAPEX is formed from three key elements: Green Power equipment (e.g. solar panels, turbines and generators), batteries/controllers, and additional civil works.

Green Power Equipment

Green Power equipment, such as solar panels and wind turbines, is costly in comparison to generators. Solar panels are expensive. Their cost is effectively linear to load requirements and is therefore very expensive for high load requirements. Wind turbine costs scale at a lower than linear rate. Wind is therefore more cost effective than solar at higher load requirements.

Batteries and Controllers

To provide sufficient backup for periods when Green Power equipment is not able to generate electricity, for example dark or still days, battery backup is required, which can form a large component of CAPEX – particularly at higher loads. The required battery load will also depend on the expected duty cycle of the batteries: solar arrays are a more reliable source of energy than wind turbines as some power will be generated even on overcast days, whereas wind turbines generate no power until a start-up wind speed (typically 5m/s) is reached. Wind turbines generally require larger battery banks than solar arrays. In many scenarios, combined wind and solar power systems provide the most cost effective solution.

In the calculations of batteries and control-gear in the tables below batteries are conservatively specified to provide three days autonomy. Significant savings can be made on this cost if lower autonomy is required from the batteries.
To control the energy-generation equipment and to ensure maximum power output, sophisticated controller mechanisms are required, which carry an additional cost.

Additional Civil Works

Green Power Solutions can have a large area footprint at the site and this carries an additional CAPEX cost for civil works. Solar Solutions, due to their large area requirements have very high civil works costs for high load sites.

Examples of Green Power CAPEX

The following CAPEX examples are for different sites, each one being meteorologically suitable for the solution (i.e. there is significant solar and wind resource).

Solar CAPEX

The Solar Solution works best for small loads due to CAPEX increasing with load, while generator CAPEX hardly increases (due to over sizing).

CAPEX on a Hypothetical Solar Solution Base Station

BTS Site Load	1,000W		2,000W		3,000W	
Location-Northern India	**Diesel**	**Solar**	**Diesel**	**Solar**	**Diesel**	**Solar**
Capital Expenditure	**US$'000s**					
Solar Panels and Generator	4	6	4	9	4	12
Batteries and Control-gear	2	4	2	6	2	10
Additional Civil Works	0	3	0	5	0	6
Total	**6**	**13**	**6**	**20**	**6**	**28**

Source: Site Analysis at India

Wind CAPEX

The Wind Solution has a lower CAPEX than the Solar Solution and is more suited to high load requirements.

CAPEX on a Hypothetical Wind Solution Base Station Site

BTS Site Load	1,000W		2,000W		3,000W	
Location-Northern India	**Diesel**	**Wind**	**Diesel**	**Wind**	**Diesel**	**Wind**
Capital Expenditure	**US$'000s**					
Wind Turbine and Generator	4	15	4	20	4	N/A
Batteries and Control-gear	2	4	2	6	2	N/A
Additional Civil Works	0	4	0	4	0	N/A
Total	**6**	**23**	**6**	**30**	**6**	**N/A**

Source: Northern India Site Analysis

Hybrid CAPEX

The hybrid solution gives a strong combination of the benefits of wind and solar technologies. At high load requirements CAPEX is not as high as for the solar only solution. The use of solar in the solution reduces the impact of the particular issues with a wind only solution (see GPM point of view on Wind Solutions).

CAPEX on a Hypothetical Wind/Solar Solution Base Station Site

BTS Site Load	1,000W		2,000W		3,000W	
Location-Northern India	**Diesel**	**Hybrid**	**Diesel**	**Hybrid**	**Diesel**	**Hybrid**
Capital Expenditure	**US$'000s**					
Solar Panels, Turbine and Generator	4	21	4	29	4	N/A
Batteries and Control-gear	2	6	2	9	2	N/A
Additional Civil Works	0	7	0	9	0	N/A
Total	**6**	**34**	**6**	**47**	**6**	**N/A**

Source: Site Analysis for India

What is the OPEX for Green Power technology?

Key Points:

1. Green Power Solutions can have substantially lower OPEX than diesel generators.
2. The key elements of Green Power OPEX are fuel costs, Green Power maintenance/replacement and battery maintenance/replacement.

Green Power OPEX

Green Power Solutions can have substantially lower OPEX than diesel generators. Generators have high OPEX from fuel and maintenance costs. Green Power Solutions have low OPEX formed from three key elements: maintenance/replacement costs and battery maintenance/replacement and where used, fuel costs for a backup generator.

Elements of Green Power OPEX

Diesel Costs

If the Green Power Solution requires no backup generator because batteries provide sufficient reliability, the fuel costs will be zero. Some Green Power Solutions will require a small generator as additional backup. However, if Green Power equipment is well specified, the renewable resource remains consistent, and batteries are suitably dimensioned, then diesel consumption should be minimal. See further information on diesel OPEX.

Green Power and Generator Maintenance/Replacement Costs

Green Power Solutions have minimal maintenance costs (see further information on maintenance). Also, due to the long lifespan of Green Power Solutions there are minimal replacement costs.

Battery Maintenance/Replacement Costs

Green Power Solutions require significant battery capacity to provide power when Green Power technology is not able to produce enough electricity, for example on still or cloudy days. Battery maintenance costs are a small contribution to Green Power OPEX, but battery replacement costs are significant due to the comparatively (compared with the Green Power equipment) short lifespan of batteries. If batteries are poorly maintained or mis-used their lifespan will shorten and Green Power OPEX will increase.

Solar OPEX

Technical OPEX for Pure Solar is very small. Since PV has a long life span, there may not any replacement required in ten years. However, as battery comes as an essential element for Solar Solution, battery OPEX should be considered as Solar OPEX. If battery is stored in a temperature controlled environment with a proper maintenance, a deep cycle good quality VRLA battery can last for five years.

If Diesel cost is $1/lt, for the additional CAPEX for a Solar Solution of a 1kW load roughly has a payback of two years. If the diesel cost increases, the Payback reduces significantly.

Wind OPEX

At a diesel cost of US$ 1.2/Litre the Wind Solution pays back the additional CAPEX in roughly 2.5 years for a site in Northern India. With high diesel costs at US$ 2.4/Litre, the wind-only system could pay back in approximately 12 months.

Hybrid Solar/Wind OPEX

At a diesel cost of US$ 1.2/Litre the hybrid solar/Wind Solution pays back the additional CAPEX in less than three years for a site in India. With high diesel costs at US$ 2.4/Litre, the hybrid system could pay back in approximately 24 months.

What Tools can I use to Check Financial and Technical Viability?

Key Points:

1. HOMER is suitable for specifying Green Power Solutions at specific sites.

Suggested Tools.

HOMER is a comprehensive tool for designing small scale Green Power Solutions. The tool was developed by the US National Renewable Energy Laboratory (NREL) and is widely considered the most suitable tool for specifying Green Power Solutions for base station sites.

HOMER
What is HOMER?

HOMER is a tool that is recommended to conduct site specific technical and financial viability of Green Power Solutions in comparison to diesel or grid options. HOMER, the micropower optimisation model, simplifies the task of evaluating designs of both Off-grid and grid-connected power systems.

When you design a power system, you must make many decisions about the configuration of the system:

- What components does it make sense to include in the system design?
- How many and what size of each component should you use?

The large number of technology options and the variation in technology costs and availability of energy resources make these decisions difficult. HOMER's optimisation and sensitivity analysis algorithms make it easier to evaluate the many possible Green Power Solution configurations.

When Should HOMER be used?

HOMER is an advanced and comprehensive tool, and is commonly used in a number of industries including telecoms for Green Power Solution design for base station sites. Due to the level of complexity it is not recommended that it be used without a solid understanding/experience of the process of specifying Green Power Solutions for base station sites. Operators who are new to using Green Power Solutions should seek guidance to specifying sites from Green Power vendors (see further information on Green Power vendors).

How do I use HOMER?

To use HOMER, you provide the model with inputs, which describe technology options, component costs, and resource availability. HOMER uses these inputs to simulate different system configurations, or combinations of components, and generates results that you can view as a list of feasible configurations sorted by net present cost.

HOMER also displays simulation results in a wide variety of tables and graphs that help you compare configurations and evaluate them on their economic and technical merits. You can export the tables and graphs for use in reports and presentations.

Where do I get Further Information Regarding HOMER?

HOMER is available for free at:
https://analysis.nrel.gov/homer/default.asp

Where do I get Data Regarding Solar and Wind Resource Availability?

Key Points:

1. Assessing renewable energy resource is a critical step in site planning.
2. Wind resource is highly variable and localised.
3. There are numerous sources of public domain and fee based data services.

Renewable Resource Impact

For a Green Power Solution to be successful it requires a suitable solar or wind resource at the location. The size of the required solution depends on the load requirements of the site and the amount of solar or wind resource available. The size of the required solution directly affects CAPEX and therefore the payback period.

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Differences Between Solar and Wind Resource

There are significant differences between the solar and wind resource.

The solar resource is evenly spread over the local geography, for example, ignoring effects of shade. There is little effect from topography, such as hills and man made structures, on the strength of incident sunlight.

This is in contrast to the wind resource, which is greatly affected by local topography and even local vegetation and land use, for example forests greatly reduce down-wind wind speed.

SWERA	Local Specific Maps	3 Tier	Local Met Office	Local Assessment
■ NASA and NREL data. ■ Low resolution. ■ Global. ■ No cost.	■ SWERA, NREL, JRC data. ■ Improved resolution (various). ■ Country and regional maps. ■ No cost.	■ 3Tier data. ■ Resolution: 5km wind, 10km solar. ■ Global (staggered rollout till 2010). ■ Fee paying.	■ Local met office data. ■ High resolution. ■ Availability - various. ■ Cost - various.	■ Locally collected data. ■ Very high resolution. ■ Availability dependant on time and cost. ■ Cost - various.

SWERA (Solar and Wind Energy Resource Assessment)

The SWERA Programme provides easy access to high quality renewable energy resource information and data to users all around the world. The SWERA Interactive Mapping System (IMS) is an online Geographic Information System tool for viewing renewable resource data. Through this interactive system, users can view several renewable resource datasets available through SWERA. SWERA provides a global view of renewable resource.

SWERA IMS uses datasets from a number of sources including the US National Renewable Energy Laboratory (NREL) and NASA. The NREL datasets are typically of a higher resolution and accuracy but are only available for specific countries. The NASA dataset that SWERA IMS uses is at a resolution of one degree latitude and longitude and is based on satellite observations. For the wind dataset there is no consideration of local topography or surface affects. Due to this reason and points detailed in section 'Differences between Solar and Wind Resource' data confidence is higher for the solar NASA data than for wind.

SWERA Interactive Mapping System

SWERA also has high resolution maps for specific countries; see the section below on 'Local Specific Maps'.

Local Specific Maps

Following a high level view of resource availability, it is recommended to assess whether there are any higher resolution maps available for your specific region. These maps should be used to confirm the data from SWERA and obtain greater accuracy due to improved resolution.

3TIER

3TIER offers a fee-paying online renewable energy resource mapping tool built into a Google maps interface. The tool provides both wind and solar data and they offer a variety of services as explained below. 3TIER are a new service and are rolling out the data availability by regions up to 2010.

See further information on the 3TIER solar data source and resolution. See further information on the 3TIER wind data source and resolution.

3TIER FirstLook Service provides information from the map-based viewer, such as average annual wind speed, which is free to all registered users. There are also two fee rate options depending on the detail of information required. Green Power for Mobile recommends the 'Standard' report, which contains enough detail for assessing renewable resource for base station sites. See further information regarding the report features (FirstLook Report >> Feature Matrix).

3TIER FullView Service provides highly customised, high-resolution information about specific wind resources at any global location, scalable from project sites to entire countries. This level of detailed report is more applicable to On-grid, large scale wind farms and would be prohibitively expensive and excessively detailed for use in assessing individual base station site locations.

Local Meteorological Office

To further validate the data provided by the tools above it is recommended to contact the national meteorological office to see if they have any further local data. Universities and research institutions could also be contacted for this purpose.

Site Specific Assessment

Due to the local variability of wind and the sensitivity of wind turbines to variance in wind speed it may be appropriate to conduct a local site assessment. Usually this will be based on a local installer's experience in the area, rather than a long-term weather monitoring survey. It is rare for long-term weather surveys to be economically viable for single base station sites. Instead collaboration with installers, universities or other third parties are recommended.

What are the CAPEX and OPEX to Install a Diesel Generator on the Site?

Key Points:

1. Diesel CAPEX is typically lower than for Green Power Solutions.
2. Diesel costs are rising rapidly due to increases in oil price.
3. Delivery of diesel to remote and inaccessible site locations can be a major contributor to OPEX.
4. Maintenance and replacement costs for diesel generators are significant.

Diesel Generator CAPEX

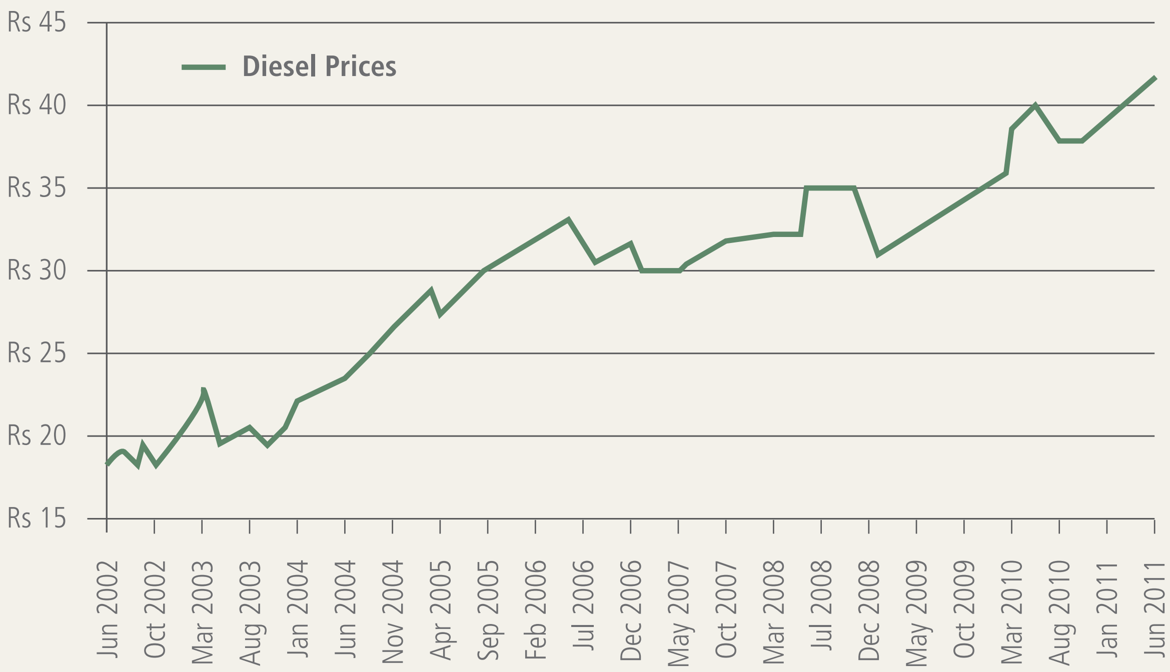
Diesel generators typically have low CAPEX in comparison to Green Power Solutions even though two are usually installed at each site (for redundancy). Larger generators require industrial transportation and equipment to mount on the site. This significantly increases CAPEX if road access is poor.

Diesel Generator OPEX

Diesel generators typically have substantially higher OPEX than Green Power Solutions. Generator OPEX has three key elements: diesel price, diesel delivery price and maintenance/replacement costs.

Diesel Price

Diesel prices have risen significantly in the past few years. It is estimated that over the next few years, it will have a continuous 5% - 10% price hike of diesel.

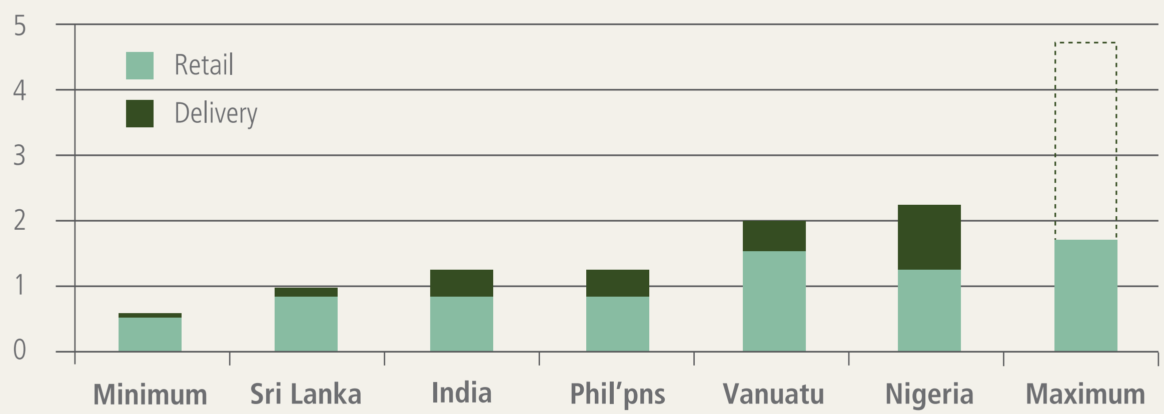


Source: http://www.mypetrolprice.com/diesel-price-chart.aspx

Diesel Delivery Price

Fuel transportation costs can form a significant component of generator OPEX. Isolated Off-grid sites with long transport distances will have particularly high delivery prices.

Lack of road access to sites and difficult terrain, such as mountains or islands will increase delivery price. Some regions will have delivery issues at certain times of the year due to seasonal weather causing access issues.



Source: Operator interviews

Maintenance and Replacement Costs

Generators have significant maintenance requirements (see further information on diesel maintenance requirements). They also have short lifespans of between three-five years, which raises replacement costs. Similarly to delivery cost, the cost associated with maintaining a generator will depend on the accessibility of the site. Base stations on remote islands, mountainous regions and the like will have substantially higher maintenance costs.

How do I Select a Green Power Solution Provider?

Key Points:

1. The Green Power value chain in mobile telecoms is complex.
2. There are various types of players within the value chain.

Solution Provider Requirements

The value chain for Green Power Solutions within the telecoms industry is complex with a number of different types of players. In order to be successful, Green Power Solution providers must do more than simply supply the equipment. They should also offer essential planning and support services including network and site optimisation, supply of Green Power specific controllers, solution dimensioning and weather assessments.

Green Power in the Telecoms Value Chain

The various players in Green Power in the telecoms value chain are identified below, together with a brief description of their business focus:

Clean Tech Equipment Vendor	Power Solutions Provider	Systems Integrator	Telecoms Equipment Vendor	Installer	Operator
Manufacturer of Green Power equipment, serving a variety of industries.	Manufacturer and installer of power solutions, including Green Power.	Niche players who design and manufacture solutions tailored for mobile networks.	The “Big 5” manufacturers and providers of mobile telecoms infastructure.	Local companies that traditionally install generators and carry out civil works.	Operators that procure Green Power Solutions from suppliers, self-assemble and deploy.

Operator Considerations When Selecting a Vendor

- What is my overall Green Power strategy (e.g. size of roll-out, locations and topographies)?
- What Green Power Solutions can my current Equipment Vendor(s) supply?
- What local Green Power expertise and support can my current Equipment Vendor provide?
- Do I want to develop internal Green Power expertise or is outsourcing more appropriate?
- What Systems Integrators have a presence in my region and should be explored?
- Do I want to maintain the Green Power equipment or outsource this activity?

Can you Protect Against Theft And Vandalism?

Key Points:

1. Theft of solar equipment is an issue in numerous regions.
2. Theft of wind equipment is rare.
3. There are numerous technical and community based approaches to theft prevention with varying degrees of success.

Green Power Equipment Theft and Vandalism

Theft and vandalism are key concerns of operators and are issues in numerous regions. The issues are far more widespread for solar than for Wind Solutions.

Solar

Theft and vandalism is a major issue for Solar Solutions. There is a strong second hand market for solar panels in numerous regions and there are also examples of their use in non-generating purposes, such as roofing and coffee tables.

Wind

Theft and vandalism are far less of an issue for wind than they are for solar. This is due to the height, weight and risk of electrocution when removing the equipment, as well as a smaller second hand market in most regions.

Prevention Measures

There are numerous prevention measures of varying success, which include both technical and community ownership approaches. The most successful measures seem to have at least an element of community ownership.

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Technical Prevention Measures: Fencing, Lighting, Cameras and Alarms

There is a range of standard security measures that can be used to protect a site including electric fences, security lighting, camera monitoring and alarms. There are issues to each of these approaches. First, many sites are in remote regions where there is no-one to observe or react to standard security measures. Second, electrical methods raise power consumption of the site, which increases the size of the Green Power Solution and raises CAPEX. Finally, the security systems themselves increase CAPEX of the site.

Preventing Access to Panels

One option is to raise panels a few metres from the floor so they cannot be reached. Unfortunately this is only possible with small systems as mounting large numbers of panels on raised platforms is difficult and expensive. Some vendors use special screws that can only be unscrewed with tools that have limited availability. Both approaches have been reported with mixed success.

Resale Prevention

Other theft prevention measures are focused on preventing the resale of panels through a number of techniques. Operators report using marking measures including putting company names on the back of panels using specific colour schemes, and using miniature serial numbers ('micro-dots') on the equipment. Again these approaches have been reported with mixed success.

Guarding

Another common solution is to post guards at the site. The issues with this approach are both cost and the susceptibility to corruption. In regions where guards are posted to protect telecoms equipment, this will be a default option.

Community Prevention Measures

Community based approaches all have an element of local involvement in the prevention of theft. Educating local people to understand the implications of panel theft on the mobile network they use reduces the risk of theft.

Some operators assign a local 'minder' who is responsible for preventing theft from the site. There are financial rewards and penalties for the individual and/or the community dependant on the prevention of theft.

A different approach is to have a small shop at the site, for example a shop selling pre-pay phone cards. The shopkeeper who lives and works at the shop protects against theft as it directly affects his income. Although not widespread these approaches have been reported to have some success in the prevention of theft and vandalism.

Can the Green Power Equipment be Maintained?

Key Points:

1. High quality Green Power equipment can operate without substantial maintenance for upwards of ten years - batteries, inverters and connections require more maintenance than Green Power equipment.
2. The skills required to maintain Green Power equipment are available globally.

Green Power Equipment

Solar and Wind Solutions typically have far lower maintenance requirements than diesel generators (see further information on generator maintenance).

Solar

Solar panels do not contain moving parts and as such have minimal maintenance requirements. A typical maintenance programme would involve cleaning the panels and checking electrical connections to batteries and control equipment, every three to four months.

Inclining the solar panels allows rain to wash any dirt/sand off the panels. The incline of solar panels should be set to your latitude (e.g. 25 degrees North, include the panels at 25 degrees to get the highest output). However, you need at least a 15 degree inclination for the rain to clean the panels. Major manufacturers of solar modules warranty their products for 20 to 25 years (for 80% of rated output).

Wind

The highest quality wind turbines are designed to work without major maintenance for ten years. As a precautionary measure, many operators recommend annual inspections for damage. For some turbines this visit may coincide with minor maintenance such as replacing 'leading-edge' tape, etc.

Turbines outside of the top-tier often require scheduled replacement of consumable parts including bearings, springs, etc. every three-five years. After five-ten years there may be a requirement to replace major parts such as the fan or tail due to damage.

Approaches to Maintenance

Unskilled local workers can be used for simple routine maintenance such as checking the wind turbine for damage or cleaning solar panels. For more substantial maintenance tasks, trained and experienced technicians must be used to prevent damage to the machine. Our interviews showed there is good access to these skills throughout the developing world.

What are the Availability and Price Trends for Green Power Technology?

Key Points:

1. Wind turbine manufacturers are expanding production capacity close to developing world demand centres, and lead times are not currently an issue. Prices are expected to stay stable.
2. Solar modules are a commoditised product and prices are expected to fall in the next couple of years.

Wind

There is currently only a handful of top-tier, small wind turbine producers and unlike solar panels the products have different design characteristics from large-scale centralised electricity production, and therefore are less commoditised. Current aggregated production is in the 1000's per year.

Most small wind turbine manufacturers are expecting rapid growth in the next few years and are ramping up production planning capacity to meet demand. Most manufacturers are planning new production sites near developing world demand centres. Lead times are currently not a major issue for wind turbines suitable for base station sites. Inaccessible locations and trade restrictions aside, lead time is typically under four weeks.

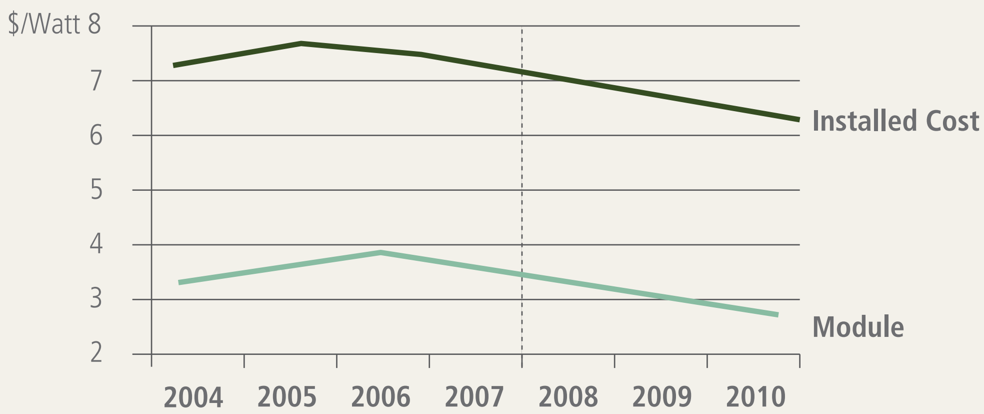
The capacity of small wind manufacturers should scale with increased demand and therefore lead times should not be affected in the short term. However, due to the current scale of the industry, any demand shocks created by increased subsidies for micro-generation in developed countries could change this dynamic. Demand increasing more rapidly than supply is the biggest risk to price and availability.

The components in a wind-turbine are mature technologies, with only-incremental improvements expected. Improvements are likely to be in increased reliability from materials and implementation improvements.

Solar

Solar panels are a commoditised product and are widely available in most regions. There has been a supply constraint on solar panels due to a lack of high-grade refined silicon. This silicon supply shortage is largely regarded as having been overcome. Recently and in the next couple of years the top-tier solar companies are installing significant production capacity and are vertically integrating upwards in the supply chain to secure silicon supply mines. Therefore most manufacturers are expecting the price of solar panels to fall in coming years, which it did by ~30% or more in many cases for year 2010-2011. Although rises in other commodities and energy, for example oil, glass, aluminium and steel, which input into solar panel production, may offset expected price falls.

Global Average Price Trends

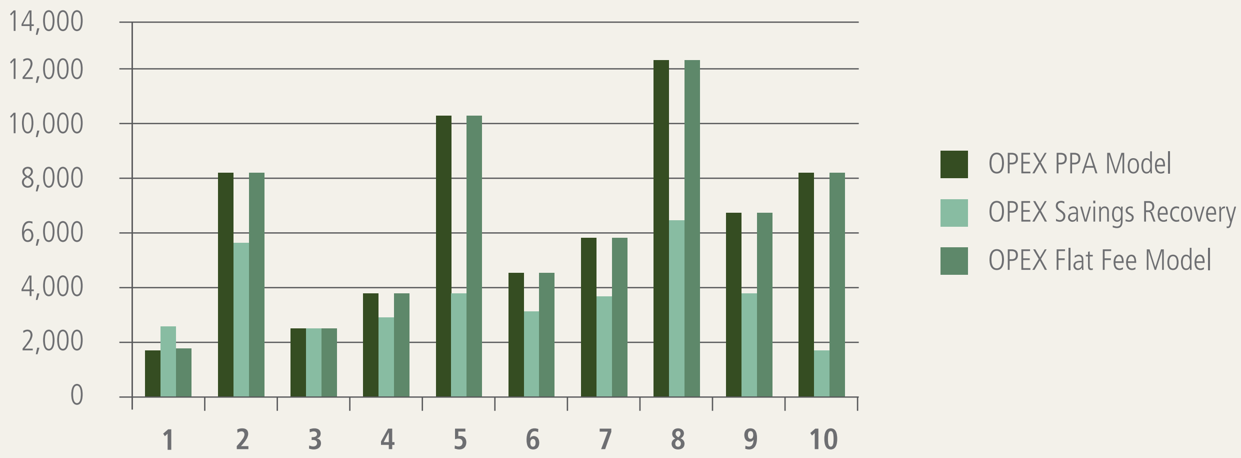


Source: BizEsp

OPEX Savings of Different OPEX Models:

To compare the OPEX saving data, we can go back to the earlier question and collect OPEX saving data from there. From the models we described, below is the OPEX saving for each of the models:

PPA Model	1,845	8,429	2,542	3,686	10,362	4,571	5,817	12,599	6,921	8,284
OPEX Recovery	2,456	5,629	2,555	2,977	3,707	3,116	3,581	6,796	3,752	1,781
Flat Fee Model	1,845	8,429	2,542	3,686	10,362	4,571	5,817	12,599	6,921	8,284



Use Grid with no Modification

Optimised Energy Consumption

Add Battery

Use Diesel

Use Green Power CAPEX Model

Use PPA OPEX Model

Use Flat Fee OPEX Model

Use OPEX Recovery Model