

Hybrid Energy Deployment

What to consider when enabling alternative energy sources at the cell site

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Executive Summary

There are 5.3 billion mobile subscribers (that's 77 percent of the world population)¹ and this number is growing every day. The cost of and demand for energy is on the rise, but stable utility power is not always available, especially in remote and underdeveloped parts of the world. Despite these challenges, demand for wireless solutions around the world is increasing, prompting service providers to seek and wisely use multiple energy sources. Hybrid energy technologies are emerging as an answer, but there are many options available with a host of technical complexities to consider.

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Introduction

Estimates suggest telecommunications networks already are consuming nearly one percent of the energy used worldwide, and continuing service expansion is increasing those energy demands. To mitigate increasing demand, carriers and providers are making power efficiency in their networks a higher priority. However, power is not always readily available or predictable, and the costs of traditional power continue to rise.

Recently in the telecom industry, hybrid systems using local energy are starting to play a larger role in reducing operating costs and expanding market coverage. In addition to available grid power, hybrid systems are designed to manage multiple energy sources including active generators, batteries, fuel cells, wind and solar technologies. Hybrid energy sources engage active power devices, as opposed to standby power devices where power is used only when the primary source fails. These active power devices provide primary power against a defined algorithm, where usage is predictable and frequently called upon.

Not only technologies, but logistics, setup and operation should be considered when exploring what energy source to employ in a hybrid energy site solution. There is no one-size-fits-all solution. Differences in climate, social environments, site objectives, and usage expectations often differ from one site/region to the next, and thus, what works well in one application may be inadequate for another.

Energy vs. Power

Because energy has been readily available, virtually unlimited and low-cost for more than half a century, the need to distinguish *power* from *energy*, outside of looking at the utility bill, has been lost. However, hybrid energy sources typically do not provide continuous, constant and uninterrupted power. Solar, wind, battery, and even active generators limited by size, type and fuel reserve fall into this category. As such, energy needs to be embraced as a performance metric.

This also applies to the load. Understanding energy demand is key. Power consumption can be proportional to energy when the drain is constant and spikes are limited, but power will provide a misleading estimate of energy, when demand is cyclic or fluctuates from use. Basically, the greater the energy need, the larger the energy device and associated real estate required. Understanding peak power ensures the solution is properly sized for safety and no nuisance faults, but understanding energy demand provides the knowledge to ensure a good financial investment that will provide continuous, predictable operation.

Does AC equipment need to be enabled?

For the most part, the telecommunications industry runs on DC power with DC batteries as backup. Solar panels and hydrogen fuel cells are also native DC energy sources. When the grid is unavailable, DC is the dominant local energy source regardless of how it is delivered. If an AC device remains, the question of how and when it is powered must be answered. An inverter is possible, but costs rise, efficiency drops and operational risks grow. DC loads always are preferable to the use of AC devices. Employing a DC generator or, just as efficiently, a standard AC generator with a feed into a high-efficiency DC rectifier are reasonable options.

Steps to avoid or mitigate these issues:

- Eliminate the AC convenience outlet in a cabinet. Most technical tools, if powered, are battery operated. If an AC generator is on-site, it probably has an AC outlet. Technician tools can be updated such that they have a portable inverter for small loads, or a portable generator.
- Implement DC lighting, DC LED lighting, DC tower strobes, etc.
- Migrate to DC power heat exchangers that operate more efficiently than AC power air conditioners. If an air conditioner is necessary, a DC air conditioner is suggested.
- Utilize DC heaters for deployment at cold sites.

Batteries

Over the years, the standard telecom battery has been refined and developed primarily as a standby source of power – a common-format, front-terminal battery with low cyclic life, low maintenance and low cost. While standby batteries provide excellent return on initial investment (CAPEX), the batteries' operational life will be exhausted quickly in most off-grid situations that require high-cycle performance. Since most off-grid hybrid applications require a larger reserve than traditional installations, more batteries are required. With that in mind, including operating expense (OPEX) when evaluating batteries is necessary. The primary TCO (Total Cost of Ownership) drivers become battery life, autonomy, performance and efficiency.

Battery life is a function of many variables, including the actual discharge rate (steady or variable), whether the battery needs to service the load before full recharge (partial state of charge, or PSOC), and how deep the battery discharges before recharging begins (depth of discharge, or DOD). The deeper the discharge, the greater the loss of battery life. The shallower the discharge, the more energy needed to operate, thus requiring an expansion of both batteries and real estate to maintain the same autonomy.

Autonomy, defined by the number of hours/days that a site can operate on battery power alone, drives both OPEX and CAPEX. As autonomy increases, we need to expand the battery plant and the equipment needed to recharge this reserve. Adding an active generator to share autonomy responsibility will minimize this compound effect, but minimum fuel capacity reserves and procedures for refueling must be included as part of the design.

Performance and efficiency of the battery and supporting equipment are used to determine how long a generator must be used, the number of solar panels required to recharge batteries, etcetera. Beyond a datasheet and quote, any quality proposal needs to include:

- A definition of the operational use of the reserve and relationship to other energy sources, articulating limits tied to DOD, state of charge (SOC) and PSOC, plus a representative operational simulation
- The algorithm for recharge (explaining efficiency) and related operating cost
- Controls and limits for temperature control
- An explanation of how battery life is determined and managed

The ultimate battery solution should include battery monitoring, which extends the OPEX investment without sacrificing loss of service or large fuel consumption increases.

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Hydrogen Fuel Cells (HFCs)

Hydrogen Fuel Cells represent a stable technology for power generation. However, this technology is not deployed frequently, nor is it aggressively expanding, as the supply chain for fuel creation and delivery is still emerging. Supply chain issues are typically hampered by the availability of hydrogen itself (produced or captured), delivery of fuel to remote locations, limited suppliers, and local training and certification requirements of the technicians who manage the system and refuel the sub-systems.

With the deployment of HFC solutions, providers need to define site capacity while acknowledging the supply chain performance for fuel delivery. Given the emerging nature of this fuel source, providers may be required to enable a ready supply of hydrogen, create the supply chain agreements and procedures for refueling, and define performance requirements that support forecasted disturbances (for example, how to “top-up” for approaching hurricanes) and recovery from local disasters.

Furthermore, local acceptance of hydrogen storage may be stigmatized by vague recollections of the Hindenburg disaster. Hydrogen is a stored energy, and all stored energies do carry some risk. Perhaps acceptance requires the education of local municipalities, including fire departments, and the creation of local codes for storing hydrogen. The good news is that the number of HFCs is growing, and with it, the understanding and acceptance of hydrogen.

Actually, a segment of the industry has responded to the challenge of capturing and producing hydrogen by providing reformers — devices that extract hydrogen from a hydrocarbon fuel, such as gasoline, diesel, ethanol, methanol-water, etc. A common solution focuses on the single carbon bond of hydrocarbon methanol-water. While reformers mitigate the issues of hydrogen delivery, it creates another sub-system to manage that consumes energy and also generates low emissions at the site. Depending upon the reformer’s fuel needs, it may still require the development of a supply chain, with all the associated issues of performance related to inventory and replenishment.

None-the-less, HFCs are an intriguing solution for remote sites because they provide hours of stable backup power, release low emissions on site, and are a low-risk choice in terms of potential theft.

Wind

Wind has been used for centuries as a free, renewable source of energy. Today, small wind turbines — typically less than 10KW — are used to provide energy for telecommunications networks. The question of wind’s viability comes down to both quantity and quality. A site may seem to have enough wind, but it must be “good” wind — i.e., laminar wind, not turbulent. Turbulent air is a poor source for the transfer of energy. A visual comparison is that of a river, where turbulent air equates to boiling rapids, providing an inconsistent, choppy flow, with eddies, as opposed to the laminar effect of a free-flowing steady stream from one direction.

The initial consideration is whether the region and locale provide good wind. A region reflects the area and general wind patterns, while the locale refers to the site with performance either limited or enhanced by immediate geography, vegetation, etc.

Wind maps, typically available through government agencies, provide substantial information on whether a given region is suitable for a wind turbine.

With the deployment of HFC solutions, providers need to define site capacity while acknowledging the supply chain performance for fuel delivery.

As a rule of thumb:

- If the average wind speed is below 11.4 mph at 98' (Class 1, $160\text{W}/\text{m}^2$, 5.1m/s) the locale is probably not a good candidate.
- If the average wind speed is between 11.4 and 13.2 mph at 98' (Class 2, $160\text{-}240\text{W}/\text{m}^2$, $5.1\text{-}5.9\text{m/s}$), it may be worth investigating the locale.
- If the average wind speed is above 13.2 mph at 98' (Class 3 or greater, $240\text{W}/\text{m}^2$, 5.9m/s), there is good probability that good wind is available at the locale.

In investigating a locale, start with the question, “does the site provide an unobstructed view?” If there are substantial topography obstructions or rough terrain, the value of a wind solution is substantially reduced.

If a detailed numerical validation is required, the provider needs to work with a consultant or a wind/meteorological service that supports wind energy.

Beyond simple availability, there are additional considerations when evaluating wind as a power source and tools available to help make the decision and ultimately advance good wind solutions. They include:

- Obstruction Clearance
- Wind Rose and a Compass
- Height of Turbine Installation
- Wind Energy Distribution
- Size and Type of Turbine
- Safety – Axial Loads, Dump Load and High Winds.

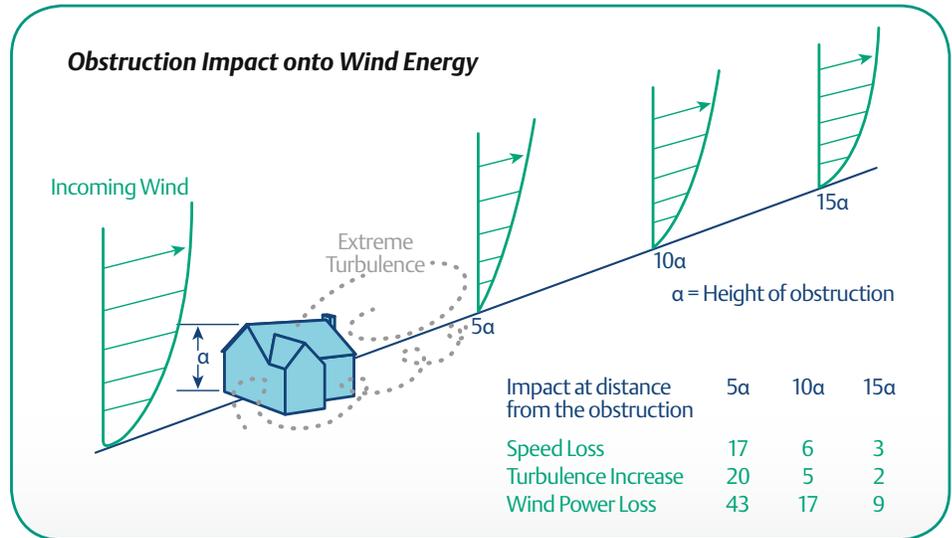


Figure 1. Obstruction Impact onto Wind Energy, Source: NREL – National Renewable Energy Laboratory Wind Resource Assessment Handbook Reference TAT-5-15283-01, Published April 1997.

Obstruction Clearance: The impact of obstructions depends upon many variables, but the following model [Figure 1], courtesy of the Department of Energy’s National Renewable Energy Laboratory (NREL), illustrates the substantive effect of obstructions. While acknowledging that obstructions may be unavoidable, a planner with a Wind Rose should give priority to sites that minimize any obstructions to the dominant incoming winds.

A common rule of thumb is that the swept area of a small turbine should be a minimum of 30' higher than the nearest obstruction within a 300' radius (as stated above, attention must be paid to the dominant direction of the wind). Buildings interject significant turbulence and power loss, therefore mounting a turbine immediately on a roof is of diminished value.

Wind Rose and Compass: If wind energy is considered in any region-locale, a Wind Rose and Compass [Figure 2] should be used by the planners to help select sites that are free and clear of obstructions. Wind Roses come in different formats and presentations, but what the planner must know is the direction and associated strength of winds in all directions.

Using the above Wind Rose as an example, a site with good clearance to the West and South is desired. Conversely, given there is little wind energy available from the Northwest to East, there is little harm in placing a turbine whose free clearance is limited in those directions.

Height: The negative effects of turbulence and aerodynamic drag from the surface are reduced as the height of the installation increases (the few exceptions that exist usually are associated with dramatic geographic features preceding the turbine). The effect of drag is called wind shear and often is expressed as a function to the seventh root.

Available wind power is a function of wind velocity to the “cube.”

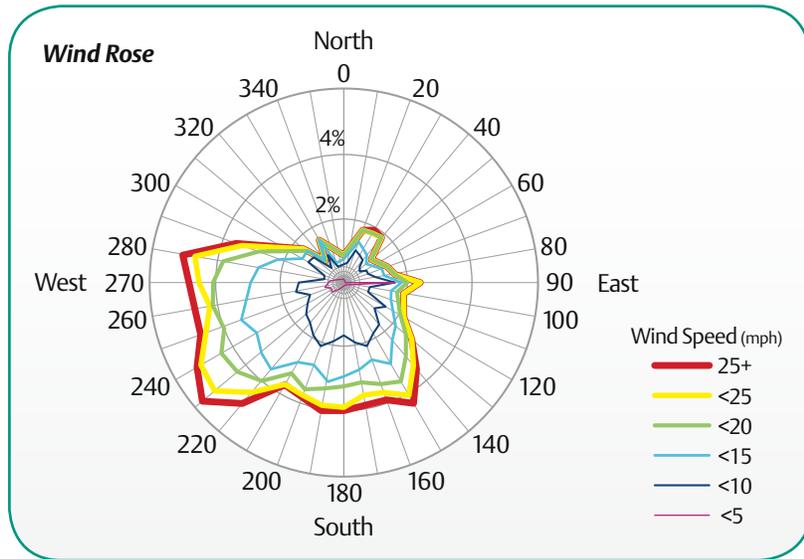


Figure 2. Wind Rose

Thus, by doubling the height and using the 1/7 power rule (guideline), wind speeds will increase by 10 percent, but the wind energy gain will be 35 percent. Small improvements in velocity have larger gains in power. Beyond the benefits of reducing drag, the actual gain likely will be greater

given the reduction of turbulence seen with height and minimizing the impact of radiative heating-cooling during day-night.

As a general rule of thumb, higher is substantially better.

$$V_1 = V_{\text{known}} \times \left[\frac{H}{H_{\text{known}}} \right]^a$$

Where **a** is typically 0.143 (1/7) (range from 0.1 (beach) to 0.5 (forest))

$$P = 1/2 \times Be \times D \times A \times V^3$$

Where **Be** is performance coefficient and related to the efficiency of energy transfer limited to 0.56 by Betz’s law, with **D** as air density and **A** is swept area of the turbine. **V** is wind velocity.

Wind Energy Distribution (Weibull):

Wind Energy often is expressed in the form of a Wind Rose and reference to a Weibull Distribution [Figure 3]. Weibull is similar to the bell curve, a probabilistic distribution used to describe events, quality, school grades, etc., but a bell curve is a symmetrical shape. Weibull is more complex in that it is an asymmetrical distribution that can approximate distribution of wind speed (energy) at a site, and thus be used to simulate and model the amount of energy a turbine can collect at a site.

The standard (default) Weibull distribution used to describe the wind is the Raleigh Distribution, which is a defined shape parameter (Gamma or 'K') of 2, with the Mean Wind Speed anchoring its position on the X-Axis (Wind Speed). As illustrated by the plot in Figure 3, the actual distribution of power (wind velocity to the third power) will shift significantly by definition-assump-

tion of 'K'. As the value 'K' is reduced for any given Mean Wind Speed, the available wind power is significantly reduced.

There are many studies that validate the strengths and weaknesses of using a Weibull Distribution to predict energy delivered. These studies have shown the actual best-fit 'K' extends beyond the illustrated range of 1.5 to 2.5 in Figure 3.

Nevertheless, Weibull is a valid tool to provide a fair comparative analysis of solutions and provide an estimate of energy available without extensive site surveys. Acknowledging the many compromises when locating a telecom site, a provider may be better suited to predict extended energy delivered with a more conservative wind distribution profile of 'K'=1.5.

Size and Type of Turbine and Its Relationship to Power:

As illustrated in a previous formula, size has a significant impact on energy capture (defined by the windswept area). One large turbine typically will outperform two small turbines. With that in mind, the investment should be directed to a single large turbine, limited of course by local regulations, neighborhood acceptance and safety considerations.

Acknowledging the cube relationship of velocity to power available, velocity of wind has a profound impact on power provided and the energy stored. What determines the effectiveness (energy generated) of a wind turbine is how the turbine behaves at wind velocities normally expected at the locale.

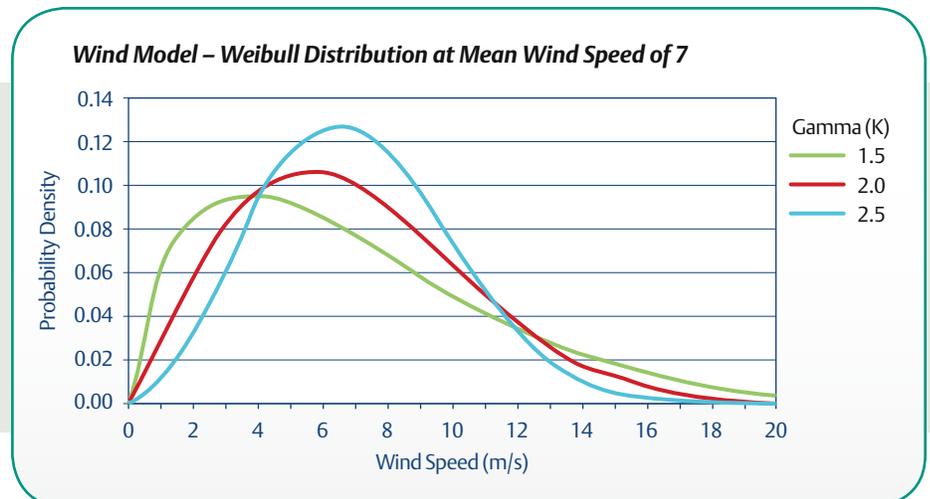


Figure 3. Weibull Distribution with a Mean Wind Speed of 7 m/s.

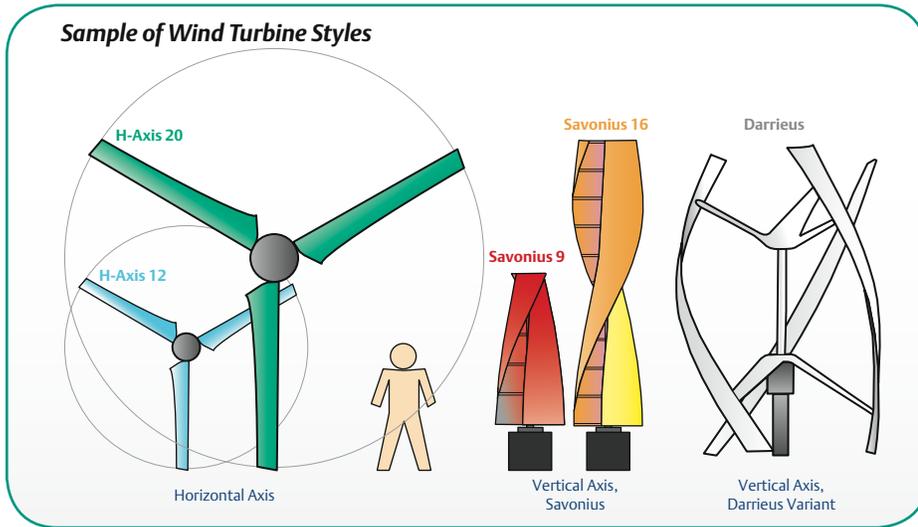


Figure 4. Sample of Wind Turbine Styles

Note:

While solar panel performance reporting is highly standardized and self-regulated, this is not so with wind turbines. Some manufacturers highlight low wind cut-in speed, and yet little wind energy is really available. Others promote high power numbers, but at very high winds that are not common. Energy delivery numbers often are optimistic, based on good winds with good high velocity wind distribution.

The only established standard enabling an effective datasheet comparative review is being administered by the British Wind Energy Association (BWEA). Other certification-test programs are emerging.

On initial glance at the scale drawing in Figure 4 and the comparative Power Curve (10-40mph) in Figure 5, it appears the larger Savonius, given its high power output (nearly 10KW), and small physical footprint (compared to the H-Axis 20) is the best choice. It isn't quite that simple.

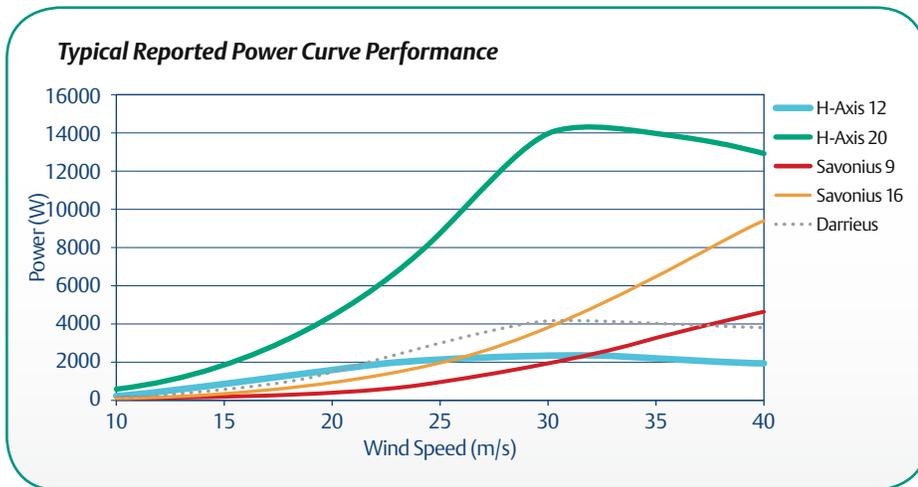


Figure 5. Typical Power Curves for Different Turbines

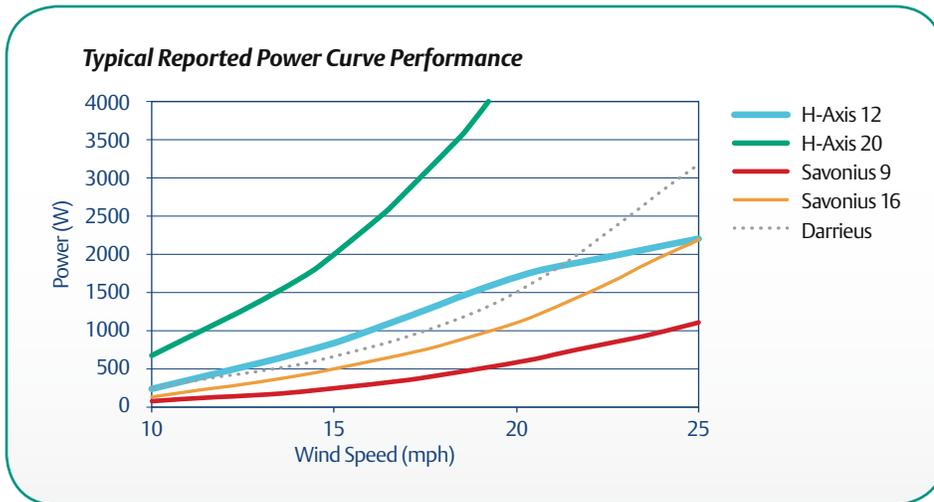


Figure 6. Typical Power Curves for Different Turbines at Lower Speeds

In focusing on the common wind speeds [<20 mph, shown in Figure 6], the Savonius units will provide substantially less power than the sampled Horizontal Axis Wind Turbine (H-Axis 20) and Darrieus units. Looking even closer, comparing the smaller H-Axis 12 against the Darrieus, the latter unit provides substantial power gain after the wind exceeds 21mph. So if the site has substantial high winds for extended periods, the Darrieus is expected to provide more energy. Otherwise, the nod goes to the H-Axis 12.

An accurate quantitative analysis of energy provided by a turbine requires review of the associate power curve of the turbine against the actual (or simulated [Weibull]) wind distribution at the site. Given small changes can have substantial impact on energy delivery, and acknowledging power is a function of velocity to the third power, the accuracy of the prediction is limited by the accuracy and assumptions of expected wind distribution.

The size and style of a turbine may be limited by regulations or neighborhood acceptance, but, again, size does matter, and the energy collected is a function of the turbine’s power curve (and efficiency) mapped against the actual wind distribution at the site.

For safety and efficiencies, most turbines are designed for a “sweet spot,” and then limit or brake their turbines at high speeds. This is seen in the above power curves, where the power begins to level off or drop as the wind increases.

Safety and Maintenance: Many providers are well versed in the issues associated with tower planning from height restrictions, lighting, stress and axial loading, wiring in a tower, lightning, grounding, etc., and the steps required to obtain approvals. Acknowledging this, here are some additional considerations that need to be thought out prior to deploying small wind solutions that depend upon the turbine in use:

- What are the procedures to address high wind survivability? Some solutions expect the site to be manned, and provide manual intervention.
- How is a dump load from electrical braking addressed (if one exists)? Many solutions provide electrical braking at high winds to maintain integrity, but how is this additional load diverted?
- How is the turbine maintained? Access to service, access to replacement parts must be a part of the overall plan.
- Will the turbine interfere in normal service operations?

Why Wind? The deployment of wind energy subsystems invokes many considerations and adds an element of unpredictability, but a good locale and installation provides a sizable renewable energy source that does not consume vast real estate.

Solar

Solar cells arranged in photovoltaic modules transform the sun's rays into electricity and provide a viable energy source in areas where direct sunlight is ample throughout most of the year. In areas such as the American southwest, it is reliable; in the northwest, less so. Internet resources exist to access regional availability of solar energy to help determine the energy available, as illustrated in Figure 7 as an annual summary:

Or, by month and installation format, as seen in Figure 8:

Many agencies, such as NASA's Surface Meteorology and Solar Energy Group and Canada's RETScreen International provide tools and information usable for all regions, where feasible.

Solar is an effective technology that will outlast most communications' subsystems, but there are several basic and profound considerations that must be managed and planned for:

- **Low Density Energy Source:** Solar requires substantial real estate to generate enough energy to be a significant option for most telecom installations. As it is a low density energy source, consideration to pair solar with other sources should be given, i.e., wind and/or a generator.
 - Illustration of power density: A typical 230W panel is 1.7m x 1m (or 18.3 ft²) in area, effectively delivering 12W/ft². But, these accurate performance numbers are generated in a lab, under conditions defined as STC (Standard Test Conditions) where insolation and cell temperature is 1000W/m² and 25°C, respectively. Solar insolation is more likely to peak below 800W/m² at most good sites (a reduction of approximately 20%) and power performance degrades

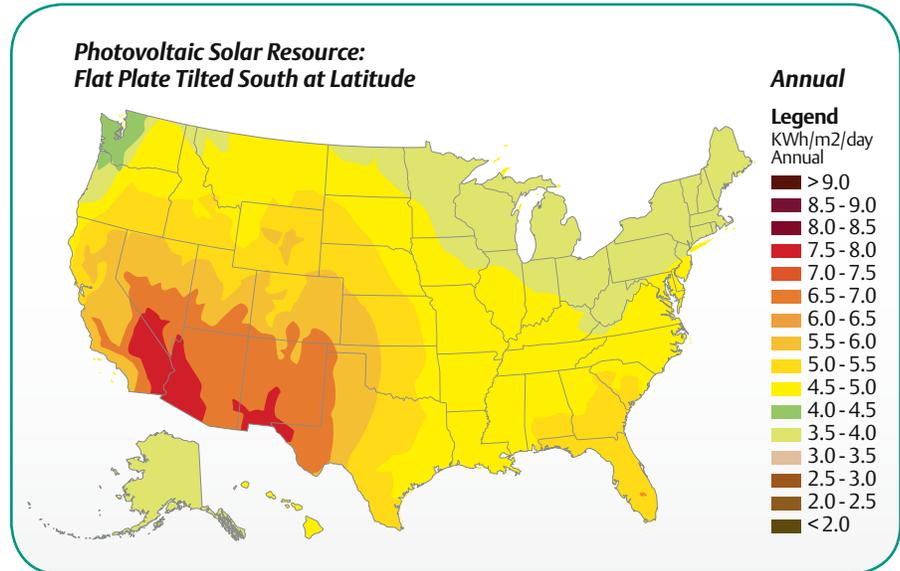


Figure 7. US Solar Availability, Annual Summary, with Fixed Panel Tilt to Latitude
Source: National Renewable Energy Laboratory, <http://www.nrel.gov/gis/solar.html>

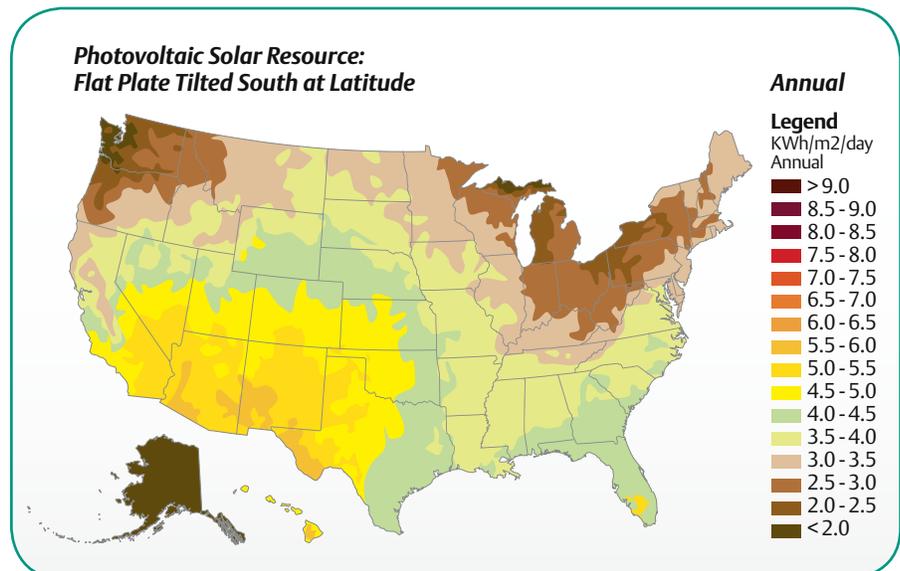


Figure 8. US Solar Availability, January, with Fixed Panel Tilt to Latitude
Source: National Renewable Energy Laboratory, <http://www.nrel.gov/gis/solar.html>

as temperatures rise by 0.45%/°C. Estimating a delta of 30°C between ambient and cell temperature, the actual peak power output of this typical panel in Southern United States on a warm sunny day will be an approximate 9 W/ft².

- A solar array is not about how much power it can deliver, but how much energy it can collect.
- The solar industry has well-established criteria for standardized testing and reporting for solar panels. Though these lab conditions are optimistic compared to actual sites, the industry is very open about reporting performance that is likely to be seen in the field and enabling good modeling and prediction.

■ **Theft and Security:** Solar panels are an attractive target for theft. The risk and (convenience) of theft can be reduced by permanently identifying and marking panels (rear), raising the panels, use of security cameras (real or not), alarm removal sensors, using security head screws, and by creating a secure compound for installation.

■ **Obstructions and Landscaping:** When sighting a location, no southerly obstructions from the east to the west that can cause shade should be present.

- The probability of shading can be reduced by placing the array high, as a solar canopy on a roof or above cabinet. This will also reduce the solar load (heat) onto the infrastructure below, reducing cooling costs.
- Physical tools (tied to analysis software) exist that will assist in determining if trees and other obstructions will interfere with availability of the sun.

Numerical Study of Monthly Solar Energy Available in Central California

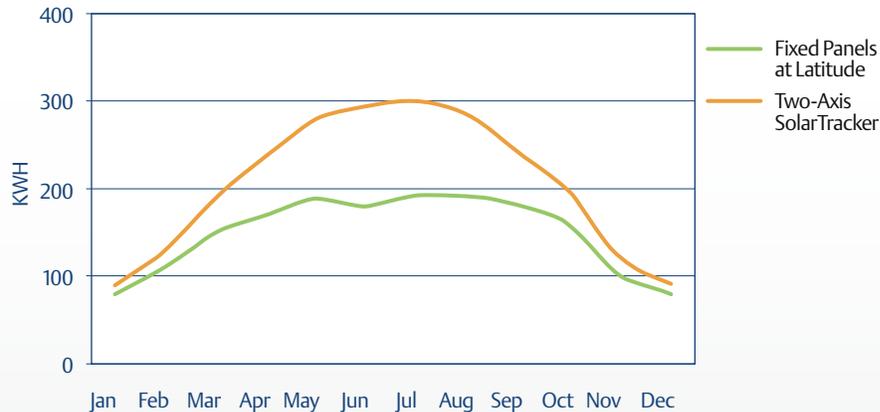


Figure 9. Numerical Study Illustrating Benefits of a Solar Tracker.

- Where snow is a consideration, racking should have a clean bottom edge (no lip or obstructions) and space below the panels, allowing snow to slide off freely once the sun returns and temperatures rise.

■ **Racking:** There are many commercially available racking solutions for open fields and traditional roofs, but many telecom applications do not provide an ideal terrain or the need to place the array above cabinets. As such, the provider may need to define and develop with their partners a custom solution for the local installation (ideally for the region), often requiring a professional engineer signoff for local acceptance addressing conditions such as wind loading.

- Large Pole Mount, typically seen with tracking solutions, may be the best answer on ridges.

- The greatest benefit of solar tracking comes at sites with unimpeded access to the sun and when the sun moves dramatically across the sky (for example, in the Northern U.S., summer vs. winter). If the site can benefit significantly from the increase in energy during the summer by a tracker, such as a Grid Connect FIT (Feed In Tariff) installation, the additional cost and maintenance can be justified. Most studies and implementations illustrate a substantive benefit in the summer, but actual gains are dependent upon locale/regional conditions, and may be less than that of the study in Figure 9.

■ **Tilt:** For fixed mount solutions, the default answer is to adjust the angle of the array (tilt) to the latitude at the site, which may not address weather conditions or specific objectives driven by electrical rates or neighborhood acceptance. Some cases to illustrate how other variables that can drive an alternate mounting angle include:

– **Remote Off-Grid Site in the Pacific Northwest Coastal Region:**

where winters are dark and wet, and the amount of solar collection in this period is poor, the application may call for wind energy and a generator in winter, tilting the panels lower to maximize energy collected in summer.

– **Remote Off-Grid Site at High Attitudes:**

where winter prevents access to refuel a generator, the application may require a large fuel reserve or placing the panels at a high tilt to reduce buildup of snow and ice, and enable maximum energy collection in winter.

– **On-Grid Electrical Savings for TOU (Time of Use) Billing in Southern Units:** where a solution is on the grid to reduce electrical demand and costs, panels should be placed at a lower angle to collect more energy in summer, when electrical rates are at the seasonal highs.

With an understanding of the locale-regional availability of energy, a provider can make the best decision on how to mount the panels, given the objectives and limitations. As an example, the graphical summary in [Figure 10](#) allows the provider to decide and predict the amount of energy for a fixed tilt panel array, and to make the decision of best-fit for the business objective [such as, whether the panel array addresses TOU utility cost reductions (on-grid consideration) or to normalize energy through the year (a desired outcome for off-grid solutions)].

What is the industry trend for solar panels? Though, small efficiency gains are constant, the industry recognizes solar as a low density energy source and the fundamental need is to reduce cost. While a market exists for “higher” efficiency solar panels, the primary need is to reduce the cost per watt. As a reference, [Figure 11](#) charts the best gains in solar by technology for the past 35 years.

Generator

Standby Generators are a familiar technology to most providers. The following discussion relates to those issues associated with deploying generators as an active energy (power) device. In this transition to being an active source, the generator run-time will rise and its operational performance (efficiency) gains importance in determining the providers’ TCO and assurance of service availability. Given this new focus, the need to evaluate a generator migrates from a best CAPEX answer to the best TCO (CAPEX and OPEX) answer. Therefore, operating performance, maintenance service periods and contracts, performance tracking and alarms, maintenance and monitoring of the starter battery, sizing and storage of fuel is now important evaluation criteria in selecting the best solution.

Another consideration that results in this transition is emissions acceptability – acoustics and air pollution – for the region and locale (neighborhood). With respect to air pollution, the type and availability of fuel (for example, diesel versus propane) needs to be measured against emissions and generator efficiency, i.e., the cost to operate at the expected loads.

The traditional AC generator feeding into a DC telecom rectifier is a good solution. The AC generator can provide an AC convenience outlet for tools and construction, when necessary for the occasional need. The high- efficiency DC rectifier can provide known, clean (electrical noise) power. DC generators are not as common, but are viable, although most DC generators do not have the DC Voltage Controls expected from traditional DC telecom solutions.

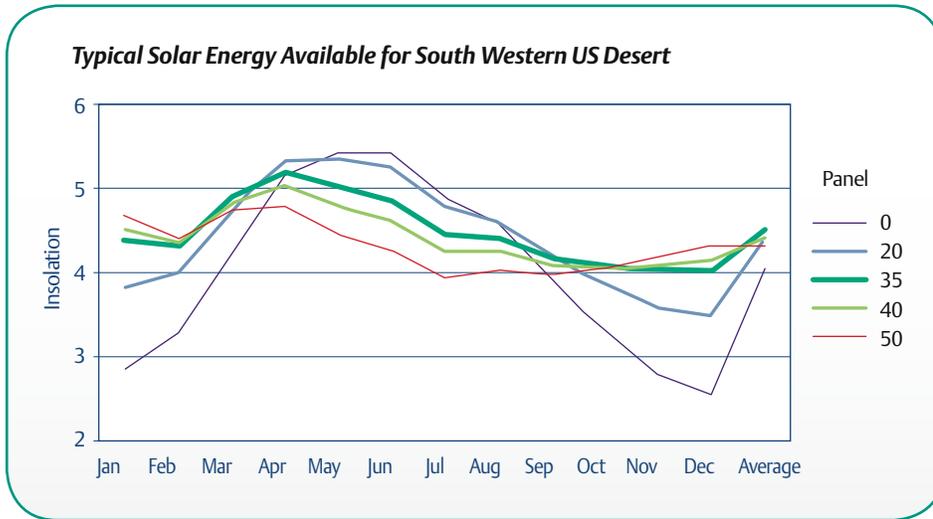


Figure 10. Southern US Insolation for a Fixed Tilted Solar Array

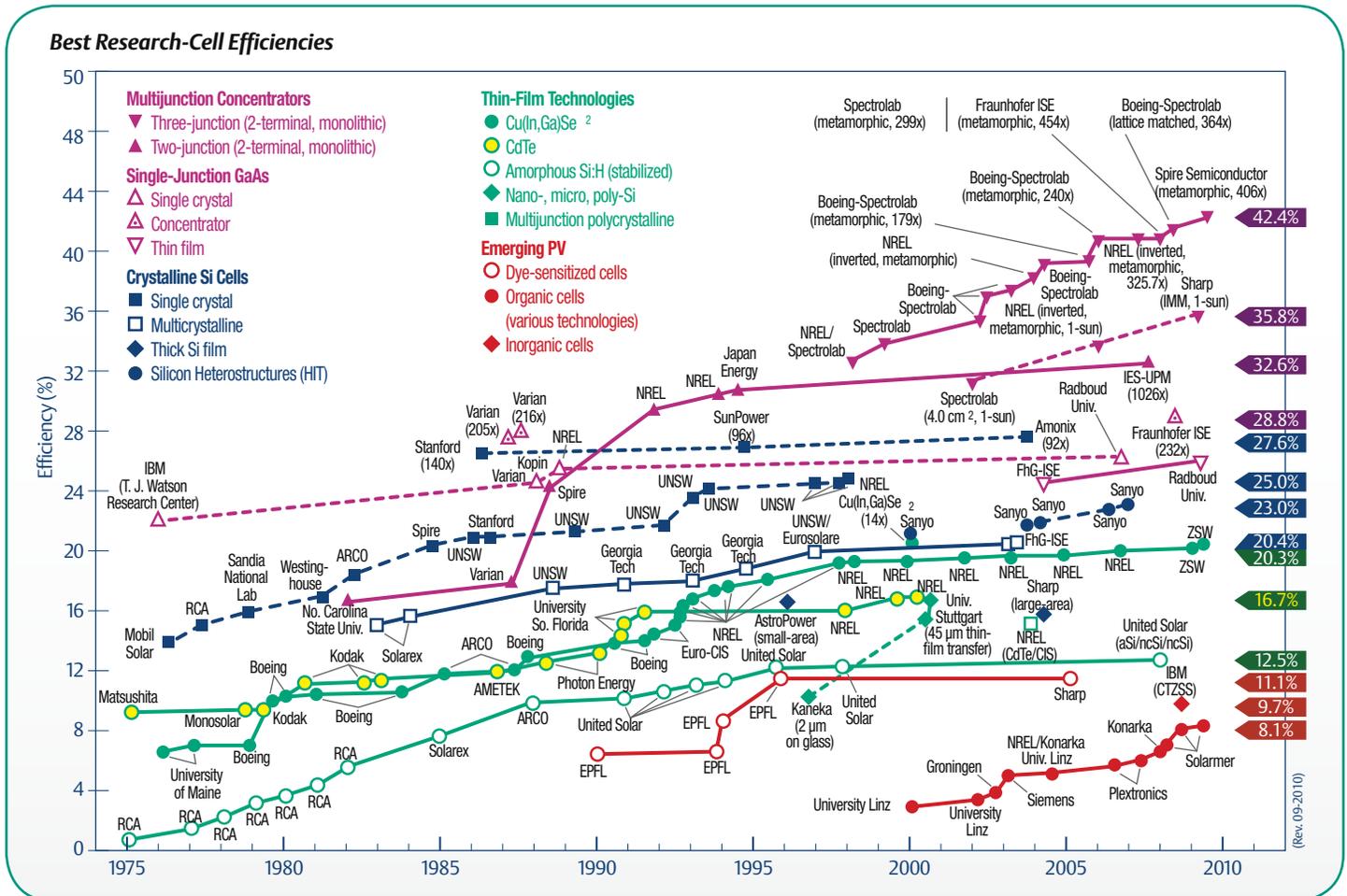


Figure 11. NREL Tracking of Solar Technology and Efficiencies. Source: National Renewable Energy Laboratory, <http://www.nrel.gov/>

As discussed in the battery section for off-grid solutions, consideration should be given that the generator is not just another energy source, but is paired with the battery to provide extended autonomy. As the battery capacity is sized for active use, the fuel capacity must be sized as an active energy source with consideration for access and restrictions (such as seasonal road conditions).

The generator and associated DC output should be sized to manage the full telecom load and enable a rapid efficient recharge of batteries, with system efficiency (or TCO) defined as a function of generator fuel consumption and supporting equipment. Large generators providing substantially more energy than required are inefficient and smaller generators require longer operational times, representing another probable inefficiency.

For example, given an 80A load and the batteries' efficient recharge current is 320A, the generator and matching DC delivery should be sized to provide 400A at the generator's best fuel efficiency. As it pertains to rectifier sizing, we are not looking at N+1 where the N satisfies the load, but N+R, where N represents the load and R represents the battery recharge.

A generator is a high-density energy device, and thus, with batteries, can provide a low CAPEX solution that may be deployed in a small foot-print in off-grid locations.

Grid

When the grid is both stable and available, it is virtually an infinite source of energy with very low real estate impact. When connecting renewable sources to a stable grid, the purpose will drive the best fit solution:

- **Feed-In-Tariff (FIT)** Using renewable energy to put energy back into the grid and be paid for it.
 - FIT, unlike reverse metering, invokes two meters and two payment plans, the traditional consumption meter paying for energy used, and a FIT meter that allows the provider to be paid for energy provided back to the utility (often at a higher rate than the consumption rate).
 - In the FIT solution, the provider typically delivers renewable energy back to the utility as an AC source, which requires inverters but eliminates the need to invest in additional local storage, such as batteries.
- **Reduce Grid Reliance**
Also known as “peak-shaving” or “energy saving,” energy consumption from the grid is reduced at peak usage times.
 - The traditional telecom design and infrastructure remains, but solar and wind energy is delivered in parallel with traditional rectifier(s) onto the DC load bus, sharing the responsibility to provide power.

- Another option is to disconnect from the grid at peak times and run solely on solar, wind and batteries. Then, during off-peak times, return to the grid and recharge. Since batteries are now being used cyclically, a battery plant update may be necessary to meet capacity demands and ensure a reasonable operational lifespan.
- **Grid as a Backup Device**
The Grid replaces the generator as a backup device and is used to deliver standby or recharge energy when requested.

If the grid is available, but not stable, it is viewed as an unpredictable energy source, like wind. A generator is the traditional bridge for these off-periods, but batteries and other sources may be used.

When the grid is available, whether in North America or Africa, it can be used as a cost efficient high density energy source, but its role depends upon the objectives of the provider.

Real Estate Needs

Throughout this paper, the various energy sources have been linked to density, i.e., the amount of real estate the solution will consume.

The energy demand of most telecom equipment is high, relative to most residential and commercial real estate properties, but fortunately, the utility provides a high density energy source that is usually available in these areas. When considering other energy sources, the actual density diminishes, requiring planners to think more about space and needing more space. Actual density of energy sources will vary significantly by region, seasons and type.

For purposes of comparison by type, a high-density Utility Transfer Switch can provide 576KWH per day (100A 120-240V service) in a few square feet, approximating 100KWH per day per square foot; but a low-density solar array may provide 0.1KWH per day per square foot.

The effective implementation of other energy sources is linked to real estate planning, location and size.

Comparing the hybrid technologies:

- **Generator** – A well known entity with providers. If there are any changes, it is when a generator becomes an active source, not just standby. In this transition, the need to model and understand fuel consumption is important in determining size of the fuel tank to enable a balance of refueling costs and space. As these solutions are often deployed in remote and difficult-to-access locations, additional considerations should be given to surcharges and seasonal limits; for example, access could be delayed by a rainy season or blocked for extended periods by severe winter weather.

- **Hydrogen Fuel Cell** – Similar to the generator discussion above, but as discussed earlier, there may be additional demands placed upon the provider for safety and training, to achieve approvals for installation.
- **Batteries** – Another well known source of power, but in the transition to active energy source, typically the demand for more space will grow and size of investment rises. Given the greater investment, and acknowledging traditional battery chemistry life, operation is dependent upon the temperatures it resides in. Active efforts should be taken to moderate temperature. Air conditioners and heaters may be used to moderate temperatures, but can efficient passive measures be used to moderate the battery cabinet? For example, the battery cabinet can be placed under a solar panel canopy to shade it in summer and expose it to the sun in winter.
- **Wind** – Real estate issues were discussed earlier, but the key is to understand if wind is viable in the region and then utilizing a Wind Rose and Compass to evaluate and select a locale that provides few obstructions for the prevailing winds. Big and tall (within reason) are usually the best options, with the realization that such may not always be accepted by local authorities and neighbors.

- **Solar** – Represents the lowest density power solution, and thus requires the greatest space to deploy. Real estate demands can be reduced by augmenting with Generator-HFCs and Wind, as appropriate. Still, solar consumes significant space and the long-axis of any property allocation should be oriented south to enable the most cost effective structure. In locations where terrain is rough, mono-pole mounts may be the best answer.

While solution providers may feel the need to access and solve each locale, they should be able to offer solutions that support a region under a common load window. There may be differences and comprises, but an expert team that establishes a good dialogue with the planners can create a package that ably supports a region.

Landscaping protocols, often done to hide sites or appease neighbors, may require adjustments such that they do not block light to solar panels or create obstructions in front of a wind turbine.

As solutions are deployed in unmanned sites, security measures must be considered. Many thefts are based on “convenience,” and a remote site can provide a sense of cover. The use of DC lighting, security cameras (real or not), large-pad mounted generators, alternate fuel-based sites, etc., will all reduce the convenience and probability of theft. Proximity alarms on solar panels to detect removal are also recommended.

Energy Manager

Energy management is moving beyond a simple rectifier controller hanging off the grid with standby batteries and/or generator. A true solution involves the cost and operational management of many energy sources. The integrated actions of any solution will depend upon the time and day of need, the energy sources available, and the reserve associated with each source. An effective solution is one that provides control of the multiple energy sources, in accordance to site requirements and the provider's objectives.

Once operational, the solution should provide clear and concise operational management and reporting. As an example, the system should monitor batteries and indicate when they are approaching exhaustion, extending the investment in the batteries to the maximum without increasing consumption of fuel. The solution should provide answers that indicate the renewable source is functioning well and taking advantage of trends.

With consolidation of local sources of energy, the provider becomes the energy manager, needing tools and support to set up the site, and concise reports to manage the site.

Conclusion

With the introduction of multiple energy sources at the cell site, the complexity of design and management has risen. This multiplicity drives the need to refine objectives for deployment and operation, and involves the introduction of new technologies and procedures, from those engaged in the management of the technology to those who manage the real estate and landscaping.

Developing individual solutions for each site is not the answer. Instead, assess the region, work with local authorities and planners, and create new industry standards if need be. Through diligence and perseverance, common integrated network solutions can be established, deployed and effectively managed as traditional solutions. Expect no less.

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[1] "The World in 2010." The International Telecommunication Union (October 2010).