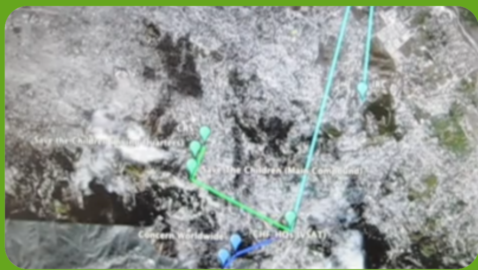



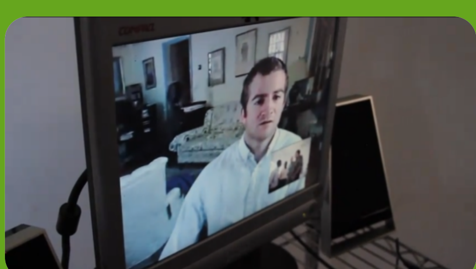

Buyers' Guide to Sustainable ICT Infrastructure in Low Resource Settings

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inveneo

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Intro

This document is intended to serve as a sort of “buyers’ guide” for those planning to deploy information and communications technologies (ICTs) in low resource settings – i.e., communities lacking basic support infrastructure, such as grid power and broadband connectivity, and where computer skills among users and facilities managers are often limited. It highlights the most important considerations in the selection, design, deployment and support of general facilities, ICT tools and supporting power systems. We have intentionally not addressed the complicated issue of mobile computing devices (perhaps a topic for another “buyers’ guide”), opting instead to focus on the challenges facing those planning to deploy and operate “shared access computing facilities” such as school computer labs, community knowledge centers (CKCs), process outsourcing facilities, etc.

This paper is divided into two sections. Part 1 covers the key factors to consider in selecting major infrastructure components, from buildings and facilities to computers, peripherals, software and connectivity. Part 2 discusses infrastructure support and logistical issues around deployment.

Because there are many topics to cover, and to keep this resource as short and accessible as possible, each section starts with a brief introduction, followed, where appropriate, by a simple bullet list of key points to consider. We invite you to provide your feedback on this document and ideas for improving it via email at info@inveneo.org.

Part 1: Choosing the Right Infrastructure

ICTs do not exist in a vacuum. Computers, radios, software and other ICT tools rely on a range of supporting infrastructure. In low resource settings, these supporting components can greatly impact the sustainability of ICT systems themselves. Part 1 discusses each of these component systems, starting with physical facilities, then ICTs themselves and finally power systems.

Buildings/Facilities

Key considerations in selecting the best facility for your project include location, layout, construction and security. The relative importance of each factor will depend on the project specifics, but facility design/selection is particularly important for the success of shared computing projects.

Location

Once situated, a facility is difficult and costly to move and your options for expansion may be limited. Consider the following factors when selecting a specific location for your project:

- *Traffic/demand* - Situate your facility carefully and with attention to issues such as foot traffic. For some, close proximity to complementary facilities/destinations (e.g., school, church, etc.) can help to deliver clientele. For others, relative isolation may be preferable.
- *Connectivity options available at prospective sites* – Assuming your project will rely on connectivity, either with the Internet or with other facilities [?], its location can greatly impact your options and related costs.
  - Which providers offer wireless broadband in the area?
  - Which providers offer VSAT in the area?
  - Which providers offer Internet over the GSM network?
- *Power options* - Is there grid power? If not, and if solar is used, it is important to plan for sufficient sun-facing[1] roof space for the solar array. Make sure the rooftop (or wherever the array will be located) is not shaded by trees, other buildings, etc.
- *Security* – Relatively public locations can help minimize theft, but only if solid basic protections are in place. Locating near another facility requiring security (e.g., microfinance banks) can mean reduced (or shared) security costs.
- *Ability to expand* – For shared computing projects where demand is unknown, it is often a good idea to start with a relatively basic (but expandable) facility and infrastructure before investing in additional infrastructure. Expanding is much easier when it can be done in the original location, either by moving into existing adjacent space or buildings.

[1] The sun-facing roof is the south facing in the northern hemisphere; north facing in the southern hemisphere. In locations on or near the equator, any slight angle will work.

Layout

Especially in shared computing environments, physical layout can greatly impact the user experience, the type and amount of services you can support as well as comfort for end users. Here are the main factors to consider:

- *Consider room layout carefully* – for example, in a school setting simultaneous classes may require multiple/separate rooms. Does the center manager need a separate office?
- *Assign dedicated space for power and server equipment* – this space should be ventilated, at least to the rest of the interior space and, if possible, to the exterior (if possible without compromising security), for improved cooling. The best solution is a lockable internal room/closet that is vented externally.
- *Consider cultural and religious context* – do children and adults need separate rooms for learning? Men and women? Or will holding their classes at separate times suffice (depending on the culture and religious restrictions)?
- *Design for airflow* – both building design and location – this helps with comfort as well as cooling of equipment. If the facility is not comfortable, it will struggle to attract users.
- *Supervision* - If you plan to run computer-based education, design the classroom so that the instructor can easily supervise what students are doing on the computers. For instance, consider placing monitors on walls facing inward, or in a single direction, rather than outwards around a large table). Mirrors can also be used strategically to enhance supervision.
- *Privacy* - At the same time, users have a reasonable expectation of privacy, particularly from their immediate neighbors. When space is tight, dividers between computers can help ensure reasonable privacy.
- *Access Control* - Position the facility manager near the main entrance to control access.
- *Multiple Users* - Consider providing enough space for two chairs per computer to enable shared learning and maximize the use of scarce computers.

<u>Construction</u>

In general, it's important to conform to local design principles and use local materials in all new construction. This will help reduce building efforts as well as operating/maintenance costs. In addition, purchasing key inputs locally can also help to ensure local support for the project from the very start. Design the facility with the following construction factors in mind:

- *Computers must be in buildings that are in good repair* - The building should not have leaks in the roof and doors and windows should be lockable and able to block rain. All electronic equipment must stay dry during a storm. In addition, dust can interfere with the operation of computers and printers in particular, so measures should be taken to keep as much dust as possible from getting into sensitive equipment.

- *Security* - some projects require significant investment to protect ICT and power infrastructure, while others do not. Consider the context: only local knowledge can guide this decision. Here are some general factors to consider
  - Security should be as "passive" as possible (e.g., bars vs. locking shutters).
  - Metal, locking doors and bars on all windows.
  - Avoid glass, especially at ground level.
  - If the design includes multiple interior rooms, doors should be lockable to improve security when rooms are not in use.
  - Solar arrays should be secured with locking and welded frames. Based on local conditions, wire mesh or other screening may be required to protect glass from rocks, etc.
  - Widespread community support for the ICT system and/or the services they support can help to minimize the likelihood of theft or vandalism.
- *Roofing* - The roof should be engineered to support the solar array (as needed) as well as potential future expansion. For new or existing structures, avoid roof pitches that are too flat or too steep to maximize solar exposure on the panels.
- *Conduit* - If building from scratch, install plenty of chases for electrical and/or Ethernet wiring to get through cinderblock or concrete walls. If using solar power, remember to install a steel conduit run for the electrical drop from the roof array.
- *Internal dividers* - If using WiFi for LAN networking, avoid metal wire or mesh barriers, which can block wireless signals. Is a mast needed for mounting radios? If so, designing a waterproof conduit run through roofing eaves can help minimize retrofit costs.

ICT Infrastructure

This section lays out a step-by-step process for deciding which computers, software, peripherals and connectivity solutions are right for your project, with an emphasis on shared computing projects. Note that appropriate ICT infrastructure must be considered in tandem with the power systems that will be used to support it (see next section) since these two systems are mutually interdependent. Both systems, however, should be planned based on a clear understanding of your requirements.

Step 1- Define your requirements

Before selecting the right ICT equipment, it's important to think very carefully about your needs. Inveneo recommends thinking in terms of "use cases," or descriptive stories about how users will interact with the equipment. These use cases can then be used to define a set of technical requirements at a level of detail that, along with other factors, will drive the equipment selection process.

For example, you may decide that users should be able to take, edit and print digital pictures. A number of questions arise: Will users have access to a camera? What level of editing do you envision users doing? What size prints are needed? Once fully elaborated, this use case yields a list of specific requirements, e.g., you might require 1) one or more digital cameras with at least 6 megapixels image quality, 2) workstations with at least 15 inch monitors, 3) dedicated photo editing software, 4) a printer with sufficient resolution to print quality color images up to 8.5x11.

There are many possible service offerings that may be needed in shared computing facilities and the options are likely to increase with time. In our experience, the most common ICT uses in shared computing environments fall into the following general categories:

- Basic computing
- Internet access
- Computer/applications training
- Educational apps/content
- Standard printing/copying
- Photo and video editing
- Skype calling/video conferencing
- Gaming
- Community events such as movies

Step 2 - Select your computing platform(s)

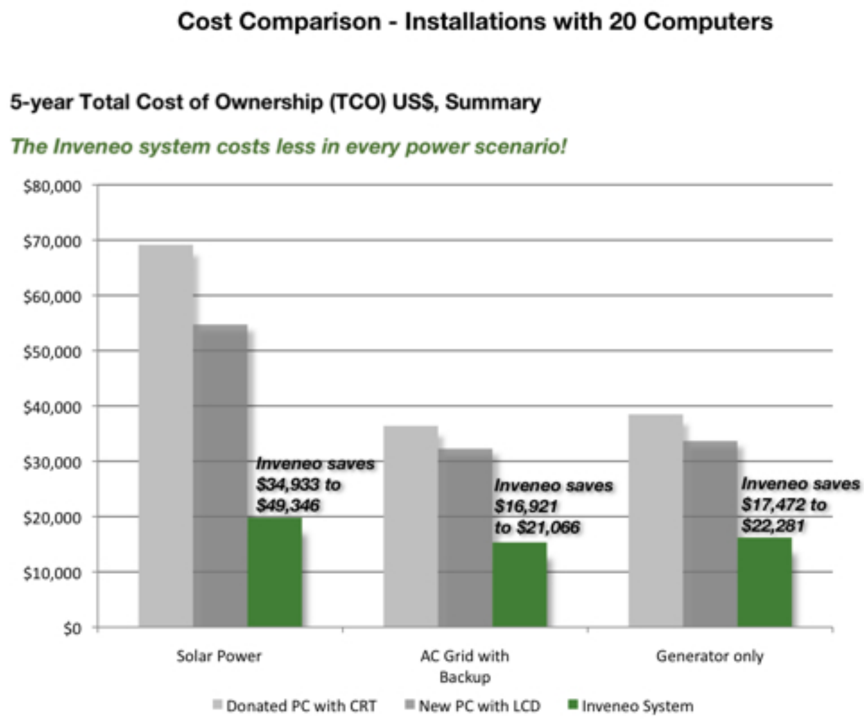
The next step is to determine what type of computers, peripherals and software will best meet your defined IT requirements. This process is relatively complex and involves a number of factors.

Computer Types

There are many types of computers available in the market with many configuration options from which to choose. Which devices are appropriate for your project – desktops, laptops, thin-client, etc. – is primarily a function of the requirements you've identified and the specific constraints imposed by other factors, such as the cost of power. Key considerations include the need for mobility, processing power, screen size requirements, the size and layout of the facility and need for special hardware, such as touchscreens. ***It is critical to assess not just the upfront costs of the equipment, but the "total cost of ownership" (TCO), which factors in operating and support costs as well.*** Pros and cons for the major platforms are discussed below.

Desktops

Desktops are the most common computer for shared computing environments. Individual components, such as keyboards or mice can be replaced easily and inexpensively when they break, whereas laptops, with integrated components, are more expensive to repair. Desktops typically offer the highest performance to up-front-cost ratio, although higher performance means higher operating costs in off-grid settings. If power is cheap and reliable, free desktop computers are often available from groups that refurbish and distribute used computers. Be careful, however, to assess the state of these machines prior to accepting the donation. Aside from the (often high) cost of powering them, donated PCs can be costly to maintain and have shorter service lives. In off-grid settings, and where heat and dust are a problem, power efficient desktops with hardened hardware and software are the best option. The Inveneo High-Performance Computing Station consumes approximately 10% of the power of a normal desktop and, therefore, offers excellent performance with a very low 5-year Total Cost of Ownership (TCO). Figure 2 shows estimated TCO for donated computers with older CRT (cathode ray tube) monitors, new desktops with LCD (liquid crystal display) monitors and power-efficient computers from Inveneo running on different power sources.



5-year Cost of Ownership (TCO) US$, Details

	Solar Power	AC Grid with Backup	Generator only
Donated PC with CRT	$69,133	$36,398	$38,482
New PC with LCD	$54,720	$32,273	$33,673
Inveneo System	**$19,787**	**$15,332**	**$16,201**

TCO includes original capital cost of computers and power equipment, plus operating costs such as maintenance, generator fuel or, for AC grid source, power company charges per KW/Hr.
Cost comparison are based on these assumptions:
1 - Donated PC with CRT display, $50 cost, typical power consumption: 175W (PC=100W, CRT=75W)
2 - New PC with LCD display, $400 cost, power 120W (PC=90W, LCD=30W)
3 - Inveneo System, $600 cost, power 20W (PC=12W, LCD=8W)

SEE NOTES PAGE FOR MORE DETAILED EXPLANATIONS

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Figure 1: TCO analysis for 20-computer CKC

Thin Client

The Thin Client model combines multiple CPU-less workstations (clients) with a single central PC (server) to provide computing power to all workstations. Each workstation has an LCD monitor, keyboard and mouse, but receives all data and graphics from the central server through a USB or network cable. Because thin clients use a single server to support multiple screens, the hardware cost per user can be lower than if a separate computer is purchased for each user. On the downside, thin client systems are less flexible than either PCs or laptops. With a thin client system the power of the single server must be shared among all the users, so graphics performance, in particular, is the lowest of the three types. Certain types of thin client setups are the least flexible in terms of space/mobility since the distance between the clients and the PC server is strictly limited (usually about 3m). Other types of thin clients are network connected and space/mobility requirements are less restrictive. Finally, a single server with many shared users represents a single point of failure, whereas with multiple low cost desktops, if one PC fails, the others can continue operating.

Laptop

Small and light, with integrated screen, keyboard and battery, laptops are designed for maximum portability and require much less power than do standard PCs. At most price-performance levels, laptops are more expensive than desktops. The smallest and most affordable laptops, often called "netbooks," offer the best battery life but have lower processing power than do standard laptops or desktops. Netbooks offer about the same power draw and performance as power-efficient PCs (see above) but in a smaller form factor (including much smaller screens).

The laptop's mobility comes at a cost. Despite their (often) "ruggedized" construction, laptops can be dropped which makes them prone to damage. Because of the integrated components, they are also more expensive to service when and if something breaks. Although adequate for many tasks, their small screens (typically 10-12 inches) are not great for Internet browsing. Finally, their mobility makes laptops especially vulnerable to theft. [And may put individual users at personal safety risk if they are required to carry laptops to and from a facility each day, as with a one-to-one computing model.]

If mobility is an absolute requirement, there are several options now available that minimize the likelihood of damage and theft. In particular, Intel's Classmate line of laptops are "ruggedized" and can be dropped from desk height without damage. Designed primarily for use in schools, the Classmate's software offers great functionality for training, allowing the instructor to monitor each user's computer screen or to project it for the entire class as well as administer tests over the local network to each computer. Finally, the Classmate also has a theft deterrent system allowing an administrator to fully disable individual computers that do not "check in" on the local network within a specified period of time thus deterring potential thieves.

Tablets

Tablets are portable computers typically equipped with a touchscreen interface. Interest in this relatively new product class has increased greatly in recent years as the number of tablet computing devices has grown tremendously. Tablet strengths are similar to those offered by laptops. Performance is, at best, similar to that offered by the least powerful netbook computers but battery life is significantly better than most laptops.

Computer Type	Initial Cost	Off-grid TCO	Durability/ reliability	Mobility	CPU	Power Draw	Security
Standard Desktop	$-$$$	$$$	XX	X	XXX	XXX	XXX
Low-Power Desktop	$$	$	XXX	XX	XX	XX	XX
Thin Client	$$	$	XX	X	XX	XX	XXX
Laptop	$$	$$	XXX	XXX	XX	XX	X
Tablet	$$	$$	XX	XXX	X	X	X

Table 1: comparison of computer hardware

Servers

In many settings a server is required to provide:

- Shared Internet access
- Dynamic Host Configuration Protocol (DHCP)
- Bandwidth and user management tools
- User file sharing
- Processing for client devices (under thin client model)
- Data backup (RAID)

Servers come in many shapes and sizes. They can be purpose-built, dedicated machines or deployed on a standard desktop or even laptop. Inveneo's R4 server provides these services from a low-power, compact platform.

Configuring Hardware

Once you have selected the *types* of computers you will use, you will need to decide on the best configuration for each component.

CPU Speed

In solar powered settings, where grid or generator power costs are relatively high, CPU speed should be kept as low as possible because processor speed is generally proportional to power consumption. In Inveneo's experience, the Intel Atom platform offers an excellent performance-to-power-consumption ratio, but these processors are generally not capable of supporting CPU-intensive uses, such as video editing or high definition playback. Consider whether heavy processing applications are needed on every machine or whether one or two more powerful desktops can be designated for these applications.

Storage

Storage can be located both on computers accessed by users and on a central server. Dynamic content that must be accessible to users should be stored on a central server. More static content, especially that which is related to specific client applications, can be stored on client devices.

- Think about the storage your content/apps require
- Plan to size your web cache based on the connectivity available
- RAID[2] is important and provides cheap insurance against hard disk drive failure by backing up data on redundant disks.
- Only consider Solid State Disk Drives (SSD) for the most extreme environments.
- User storage is usually best left on USB sticks, assuming adequate virus protection is in place.
- Costs for storage fall quickly, so don't buy much more than you need.

Screen size

Screen size is important because the screen can be the greatest power consumer within a computer. LCD monitors with LED backlighting are the most energy efficient but may cost more. Ironically, smaller screen sizes (e.g. 15 inches or less) often cost *more* than larger screens due to their lower production volumes. In off-grid settings, you will need to weigh the lower power consumption and operating costs for smaller screens against potentially higher initial costs. Consider dedicating a set of computers with larger monitors to uses that benefit from the larger screen size. If operating from solar power or battery backup power, under no circumstances should you use older glass CRT-based monitors of any size, as these older displays can use many times the power of the computer itself!

Local Networking

The decision about how to connect computers in the local network (LAN) usually boils down to WiFi (WLAN) or Ethernet. This decision is made based on the facility's layout, distances between computers and servers and the likelihood of needing to move computers. There is no "correct" answer, but for most scenarios we have found that wireless/WiFi connections are usually cheaper to install (no need to run CAT5 cable and cable runs) and more flexible overall. On the downside, WiFi can be more susceptible to interference. Ask yourself:

- Are computers in a single room or adjacent rooms?
- Will computers need to be moved in the future?
- Is the current or planned construction likely to impede wireless signals?
- Will WiFi be needed for other purposes (e.g., wireless peripherals or to allow access to those with WiFi enabled devices?)

If you choose to go with Wifi for the LAN network, here are some tips:

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[2] RAID ("Redundant Array of Inexpensive Disks") provides on-site data storage protection by writing data to more than one disk at a time so that no data is lost if a single disk fails. When a failed drive is replaced, the array will repair itself. There are many different "levels" of RAID based on the number of drives used and what degree of protection is required.

- Select an access point (AP) that uses 2.4mghz unless you have problems with interference from other wireless devices.
- Make sure your AP supports the latest WiFi protocol (802.11n) to ensure compatibility with external devices and improve performance.
- Assuming you only need a few Ethernet ports (for non-WiFi-enabled devices), consider buying an integrated switch/AP/Router to save money.

There is, of course, no reason that *both* WiFi and Ethernet cannot be used together.

If, on the other hand, you stick with Ethernet, use only shielded CAT5 cable for all outdoor cabling and make sure that administrators are trained to test and repair cables as needed. Damaged or unplugged Ethernet cables are a common cause of problems; one that often leads so significant downtime in the absence of basic troubleshooting and repair skills.

- If you have a larger area to cover, or if your construction poses a challenge for standard APs, consider buying a separate AP with more transmit [transmission?] power, such as those offered by Ubiquiti.

Step 3 - Select Software

Software can be usefully discussed in terms of three categories: operating system (OS), user applications and utility tools.

Operating Systems - Windows vs. Linux

Although Microsoft's Windows faces growing competition, it remains the dominant operating system in the private sector and is often deemed a requirement for organizations with existing Microsoft investments and those seeking to increase employment options for their constituents. Using only Windows also simplifies administration.

However, where IT administrators have sufficient skills and/or when training of IT professionals and alternative operating systems is a priority, then more than one OS may be required. If you are considering using a Linux-based operating system:

- There are many versions of Linux available, but in our experience, Ubuntu provides the most intuitive experience for those familiar with Windows.
- Consider Linux/Ubuntu for computers that will support a single purpose only (e.g., "kiosk" functions).
- Non-Windows machines can be deployed separately or on "dual boot" machines, which run more than one operating system.
- *Wherever* Windows is used, solid virus and malware protection is critical (see below).

User Applications

The number of potential user applications is essentially limitless, but here are some considerations:

- Do not select applications that require more Internet bandwidth or processing power than is available.
- When possible, test the applications on your selected hardware before deploying.
- Use open source and free applications wherever possible to keep costs low. For example, Open Office is free and provides most of the functionality offered by Microsoft's Office Suite.
- Select applications that match *known* community needs. Applications that are not used just take up space and complicate administration.
- Think carefully before introducing complex software (e.g., video editing software), as it can be difficult to train on and frustrating to use without adequate instruction. Be mindful that most manager/administrators are NOT able to provide technical support for complex applications.
- To simplify deployment and support, consider building a custom image that can be applied to all machines.

Inveneo has created a "Community Center Software Collection" of free and open source applications for the Windows (XP and 7) operating system that has been tested to perform well on Inveneo's power-efficient computing platforms. For a list of included applications see the Inveneo Wiki.

Administrative Tools

In addition to user-facing applications, IT managers need a range of tools to help them do their jobs. These include, but are not limited to, the following:

Anti-virus - Viruses are a major cause of system failure in computers running Windows. This is especially true where connectivity is limited and where USB sticks are in widespread use. There are two main ways to protect against viruses. First, anti-virus software, both free and paid, can protect against known viruses so long as there is adequate Internet connectivity for virus threat updates. AVG and Avast both offer excellent and free anti-virus software and many other options are available.

Another approach is to use a tool to allow administrators to "lock down" computers and to restore them to a known virus-free state with a simple reboot. These applications are typically used in shared computing environments in order to simplify administration and prevent user mis-configuration – accidental or otherwise – of computers. In this category, Inveneo often recommends Deep Freeze, a commercial application from Faronics that is easy to deploy and use. Once systems are "frozen," no additional software can be installed. System administrators must "thaw" computers in order to perform updates or install new software and then "refreeze" them in their new, virus-clean state. Because systems must be thawed in order to perform updates, including virus definition updates, Deep Freeze is generally not used together with virus protection tools.

As a final backup, a system image taken with imaging tools like Clonezilla can be a useful recovery tool, allowing managers to restore computers to their original state through manual re-imaging of each machine.

Internet Cafe Software – If you intend to charge for access to the Internet, you'll need a system for managing payments. There are many applications available, some free and open source (FOSS). Cyber Cafe Pro is one of the best free café software packages we've found. This client-server application runs on all versions of Microsoft Windows and provides a rich feature set. HandyCafe is another free application which runs on Windows, is compatible with Deep Freeze and very simple to use.

In addition to café management and anti-virus, IT managers may benefit from additional tools. Here's a list of the server-based tools Inveneo bundles on our R4 server:

- Bandwidth management software – allows managers to control their bandwidth at both the user and application level (MasterShaper)
- User and Share management – lets managers control user access to content on the server with password
- Whitelist/blacklist – allows managers to control the Internet content that is accessible to users SquidGuard, OpenDNS)
- Network management – general management of the devices connected to the local network
- Time management – helps keep all the computers connected to the network on the same timestamp

Step 4 - Select peripherals

Peripherals can be as, or even more, important than computers themselves. Deciding on peripherals depends first and foremost on a clear understanding of your requirements, which, if you are operating a shared computing facility, should be based on on-the-ground research. Here are some of the peripherals that are most commonly deployed in shared computing settings:

- Printer/copier – These are often the true workhorses of many public access projects, and can be an important income earner, so it's important to select a model that can stand up to plenty of use but does not draw too much power (if you are off the grid). A well-built inkjet printer can provide reliable service at much lower power consumption than laser printers. However, wherever heavy printing is expected a laser printer's ruggedness and longer lasting toner cartridges may offset the extra power draw and related costs. Compare prices for replacement ink cartridges to get a sense for operating costs before you buy.
- Digital still/video camera – These can be made available free of charge or rented for special events.
- Webcam – Used for video conferencing/Skype
- Headset – Provide for private audio/music listening as well as less intrusive conferencing. Consider locating a small number of computers in a relatively private setting if you plan to offer video/audio conferencing.
- Projectors – Used for community events and group meetings. Depending on the use requirements, there are several models of projector that use LEDs for the light source and therefore draw very little power.
- Audio equipment – USB speakers are cheap and can be useful for background music or for special events, but cannot provide quality audio to larger events in large spaces. A low power class-D music amplifier and external speakers offer an affordable alternative in cases where more sound is needed.

Internet/Data Services

ICT projects, including shared computing facilities, do not necessarily *require* Internet connectivity. Many valuable resources can be made available locally on cheap storage in ways that simulate Internet access. It's clear, however, that affordable broadband data connectivity is often at the heart of many ICT projects. This section covers some of the key factors to consider in selecting a suitable connection and negotiating with service providers.

Choosing your connection

A slow (or no) Internet connection may be acceptable for users in a very remote area, but not if there's a much faster connection nearby. For a 20-seat computer center, we suggest a minimum connection speed of 512Kbps down/256Kbps up (preferably 1Mbps down / 512 Kbps up or better) with unlimited data for basic web surfing. Wherever possible, it is best to secure a dedicated connection as opposed to "shared" service, which often become congested due to over-subscription.[3] Sometimes real bandwidth may actually be better with a slower, but *non-shared* connection, than with a supposedly faster, but *shared* connection. Many real time applications, including video and voice conferencing, will perform best over a "symmetrical" connection (i.e., same upload and download speeds). Aside from connection speed, the *type* of connection can greatly impact for cost and performance:

- *Wired Broadband* – These include DSL, ADSL, cable and fiber connections. Wired broadband is the most reliable service type, but is NOT available in most rural, low-resource settings.
- *Point-to-point WiMax and WiFi* – Wimax and WiFi wireless links provide reliable and high-speed services. WiMax offers excellent performance but is typically available only in urban and peri-urban settings. Because the equipment is much cheaper and because it relies on open unlicensed frequencies, WiFi is sometimes available in less densely populated and rural areas (See Inveneo's Haiti Rural Broadband Initiative). Both WiFi and WiMax can offer dedicated bandwidth at high data rates, usually with symmetrical service.
- *Cellular* (GSM – 4G) – Cellular Internet services are widely available but their speed and quality varies greatly based on the technologies behind them. Older GSM, GPRS and EDGE technologies (original GSM, 2G, and 2.5G respectively) can support basic data exchange but are not sufficient to support multiple Internet users. 3G service, the first mobile technology to reach what many consider "broadband" speeds (typically ~200kbps but potentially higher),[4] is usually sufficient for 1-3 concurrent users, sometimes more depending on the specific standards and equipment being used. 4G networks (mobile WiMax, LTE, HSPA, etc.) are starting to reach a few parts of the developing world, but are not yet widely

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[3] In most remote settings Internet connections will be shared, regardless of how the service is marketed. This is ok, so long as you have a clear understanding regarding the connection speeds you will receive on average and a way to track what speeds you are actually getting.

[4] While the UN/ITU and others have moved toward much higher speeds for broadband, the OECD has defined broadband as at least 256kbps in at least one direction. Clearly, "broadband" is a moving target.

available outside of urban areas. The battle over what technologies fall into which service category is contentious and confusing (by design), so don't put too much stock in the "xG" attached to a specific connection type. Instead, focus on the data transmission rate you are quoted and make sure you're actually getting it.

- *VSAT* – The most expensive and sometimes the least reliable broadband option. VSAT is often highly oversubscribed (i.e., high contention rates), especially in Sub-Saharan Africa, which reduces bandwidth below promised service levels. Cost for equipment is high (especially "C band" equipment) and bandwidth costs are also high (especially "Ku Band" equipment) when compared with alternatives. Regardless of the band type used, high latency (due to distances to satellites) makes real-time applications (e.g. Skype) difficult to use. C-band can be quite reliable and provide higher performance, but older (K-band) systems perform poorly during bad weather.

Dial up – not available in most low-resource settings and not sufficient to support a multi-seat computer lab.

VSAT Type	**C-Band**	**Ku-Band**
Frequencies	3.7 - 4.2 Ghz for downlinks and 5.9 - 6.4Ghz for uplinks	11.7 - 12.2Ghz for downlinks and 14.0 - 14.5Ghz for uplinks
Pros	Relatively reliable in poor weather Wide service coverage	Dedicated satellite frequencies so no interference from terrestrial microwave systems Smaller dish size due to more powerful and focused signal Less expensive equipment (typically ½ of c-band cost)
Cons	Susceptible to interference from terrestrial microwave systems Expensive equipment (2x Ku –band) and fees	Sometimes unreliable in poor weather More limited coverage area

What Table 2: Comparing VSAT technologies

What future options are likely?

Find out about any future plans for network service/upgrades. Consider statements from providers about timeframe for new/faster service as a “best case” scenario, especially if there’s not direct evidence that a service rollout is underway (e.g. service reaching neighboring areas with similar demographics)

- Will cellular providers be upgrading their infrastructure to support 3G (or even 4G) service?
- If it is not possible to partner, determine the cost of current or upgraded services.

Other options?

- Is it possible to extend broadband to your location over private wireless link? Low cost wireless technologies make it possible to install and maintain a long distance (up to 80km+) high bandwidth (20 Mbps+) wireless link with relative ease. If a broadband provider has an Internet connection at a nearby tower, it may be possible to build your own “last mile” link, and to have the provider deliver service at the tower to your equipment.
- Is there sufficient nascent demand in the area to entice a service provider through a joint purchase/contract?

Contracting and bandwidth management

Once you’ve identified the best option for Internet connectivity, here are some tips to help ensure you get what you’re paying for and are using it wisely:

- Make sure your contract is crystal clear regarding both bandwidth (speed of connection) and the total data allowed. Wherever possible, avoid contracts with limited monthly data limit and/or a so-called Fair Access Policy (FAP)[5].
- Make sure that the term of your contract does not extend much beyond expected arrival time for better connectivity options, if you believe they will truly become available in future.
- Use simple QoS (Quality of Service) bandwidth tools to manage available bandwidth optimally. These tools allow administrators to prioritize Internet traffic for specific uses/applications (e.g., Skype calling) or individual machines or users. Many easy-to-use bandwidth management tools can be installed on home quality routers. Examples include DD-WRT, m0n0wall, and pfsense. A number of Linux tools exist with easy to use web interfaces that can be run on small Linux-based network gateways. MasterShaper is one example.
- Use simple tools to independently measure the quality of service provided by the Internet Service Provider. Providers often deliver poor quality service, expecting users not to notice. Websites like speedtest.net and pingtest.net allow end users to test their own Internet connections. If you’re seeing a problem, take screenshots of results with the timestamp to show your service provider.

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[5] A “FAP” is the primary way in which VSAT providers seeks to limit their customers’ use of shared bandwidth. Typically, the FAP will throttle the users connection speed, often to an extremely low (often virtually unable) data rate,

Power Infrastructure

An ICT system is only as reliable as the power system that supports it. Since power systems can represent the single largest component of capital costs, the right solution will be based on:

1. Your total power requirements (based on the offerings you plan to make available)
2. What is currently available at potential locations
3. What may be available in the near to mid-term.

For example, if there is no grid power, but is planned in the near to mid-term (and you *believe* it!), it may be wise to use a generator initially to avoid the higher initial capital costs of solar power. This same generator can then be used for backup power if, as often happens, the new grid has routine outages. On the other hand, if grid power is not likely to arrive anytime soon, then solar power is generally the most reliable, sustainable and low-cost system. This approach is only possible, however, *if* power requirements can be kept very low. See ICT Infrastructure (prior section) for a discussion of how to define your ICT requirements.

This section provides general advice about implementing solar, generator and hybrid solutions with primary focus on solar power solutions for off-grid settings.

Solar Power Systems

While initial costs are relatively high compared with most alternatives, photovoltaic (PV) power's operating costs are very low and there are NO routine inputs required, which makes solar an economically attractive and reliable power source for computer labs with generally low power needs. In addition, in most (developing world0 settings solar is a more consistent power source than is, for example, wind or hydropower.

This section presents the key considerations in deploying PV power systems. For a more detailed discussion of solar power systems, see the Inveneo Solar Power Deployment Guide.

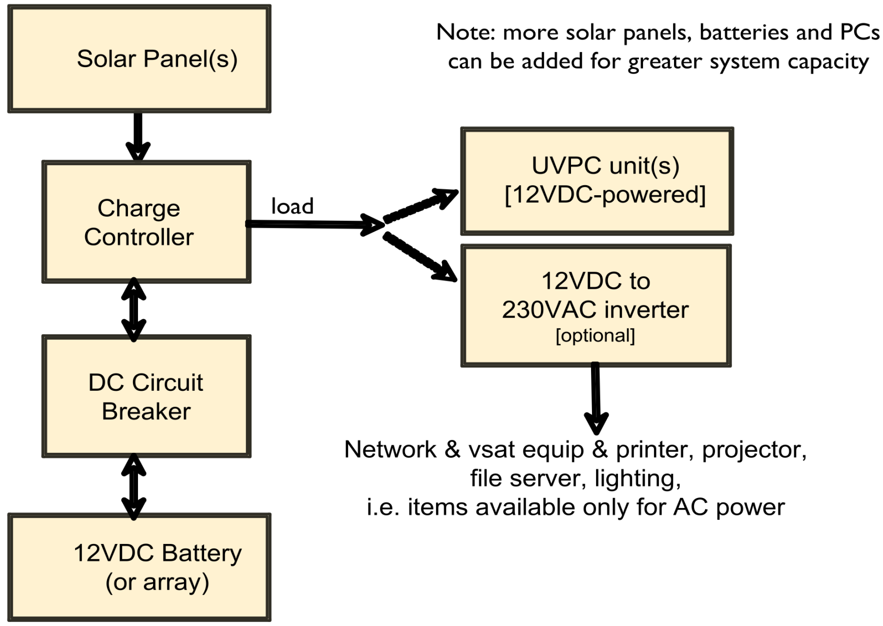

Figure 2: Components of a typical solar power system

Solar Power (PV) System Components

Solar Panels

Solar panels – or “modules” – are typically the most expensive component of a solar power system. It’s important to purchase from a reputable company, preferably one that will provide warranty and support services as well. Key factors to consider in purchase and installation include:

- *Selecting panels* – typical solar modules house many individual “solar cells,” which are made from either polycrystalline, monocrystalline silicone or “thin film.” Monocrystalline solar cells are somewhat more efficient (and costly) than polycrystalline, but both are equally durable. If panel space is limited, you may need to use monocrystaline panels to get enough power. Thin film panels are essentially silicon sprayed onto a panel. They are less efficient, therefore larger, but much less expensive so if they are available and roof space is not limited, thin film could be the best choice. All solar cells lose efficiency over time, but quality panels will still put out at least 80% of their rated power after 20 years of use. It is highly likely that more efficient alternatives will be available within that timeline. Buy the highest quality panels your budget will allow from a vendor that is likely to honor the product’s warranty, which should be *at least* 15 years. Whichever panel you select should be certified by industry standards organizations.[6]
- *Placement* – On pitched roofs, make sure panels have the right orientation based on your site’s geo-coordinates but are not laid flat, which can reduce efficiency as dirt accumulates. Panel efficiency decreases significantly in high temperatures, so it’s important to situate panels such that they are cooled as much as possible by wind flowing around them.
- *Maintenance* – The only maintenance panels should need is regular cleaning (to keep their efficiency high). During the dry season, when dust is higher, cleaning should be more frequent.
- *Security* – Because they’re expensive and useful, panels are commonly targeted by thieves. Solutions include steel frames around panels, mounting using concrete in a way that requires breaking the concrete to remove, locating the panels out of sight from the ground (assuming roof mounting) and other means of denying access. Quality panels are very hard to break by accident or even with a thrown object. Breakage is most likely to occur during an attempted theft.

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[6] Certifiers include Underwriters Laboratories (UL), Factory Mutual Research (FMR) and others. Common certifications include IEC 61215 / EN 61215 IEC 61215 Ed. 2, IEC61646, IEC 61730 / EN 61730, IEC 60364-4-41, IEC 62108 and IEC 61701. Your vendor should be able to provide proof of certification.

Figure 3: A well-protected PV array. Note that metal frame enclosures extend downward on the sides and are not easily removable from the top.

Batteries

Batteries are a key component of virtually every alternative power system. Choosing the right batteries is crucial for system performance and sustainability.

- *Battery type* – Where possible, use maintenance-free, sealed lead-acid gel (SLA), preferably “AGM reinforced” or “Gel” batteries. These are somewhat more expensive than the "wet" or "flooded" cell batteries that require regular maintenance and checkups, but are much more reliable in the long term. Always use “deep cycle” (designed for repeated discharge of a significant percentage of their stored power) batteries, as opposed to starter or regular car batteries, which are not designed for power backup purposes, and are damaged quickly when used for deep cycle applications.
- *Battery care* – Make sure that batteries are rarely discharged much below 50% to maximize their service life using a reliable charge controller (see below). If using wet-cell batteries for backup power, make sure to use ONLY distilled water in maintenance.
- *Protection* – All batteries should be properly protected in a well-vented enclosure. Care should be taken to cover batteries to avoid the possibility of dropping metal objects such as tools on battery contacts, causing a short.

- *Heat* – Like solar panels (see above), battery performance is significantly impacted by temperature. Lead-acid batteries lose much of their storage capacity at low temperatures, in particular near or below freezing. Each battery manufacturer gives its own specification for temperature coefficient. However, if that information is not available, a factor of 1% per °C below 20°C (68°F) should be subtracted from the battery's rated capacity.
- *Sourcing and Replacement* – Batteries are almost always too heavy to import in low quantities, so plan to purchase locally wherever possible. Plan to replace batteries every five years or so, depending on battery quality and usage.

Figure 4 - Typical deep-cycle battery

Charger/Controller

The charge controller manages the flow of power between panels, batteries and your electronic equipment. Most charge controllers have additional important features besides just charging the batteries, for example:

- *Load Switching* – with this the controller can act as a master power switch to shut off power to all the attached equipment
- *Low voltage disconnect (LVD)* – if the batteries are drained excessively for any reason, LVD will shut off the output current to all the equipment.
- *Reverse polarity protection* – prevents damage if the batteries or solar panels are connected by mistake with positive and negative terminals reversed.
- *Static and over-voltage protection* – in hot, dry environments in particular, the internal electronics can be damaged by static electricity. This feature can also protect against nearby lightning strikes.

There are several different kinds of charge controller, but Multi-Point Power Tracking (MPPT) is the latest and most efficient charging technology. MPPT uses clever algorithms and a DC-DC converter to match the optimum voltage and current from the solar panels to the battery array's state-of-charge. In non-technical terms: it's smarter than a standard charge controller, can be as much as 98% efficient and panel output voltage does not need to match the battery voltage. As a result, wiring between the panels and the controller can be much smaller (i.e. larger gauge number or smaller diameter in mm), assuming panels are wired in series to yield higher voltages, which can save on costs.

Whichever controller you chose:

- Make sure the charge controller is set to the appropriate battery type and to prohibit battery discharge below 50% of total battery capacity.
- Minimize the distance between solar panels and the charger/controller and especially between the controller and batteries. Make sure the gauge of wiring is appropriate for the distance (larger wire – i.e., smaller gauge # – is needed for longer runs).
- For safety, look for models that protect against low voltage, overcharge and reverse polarity.

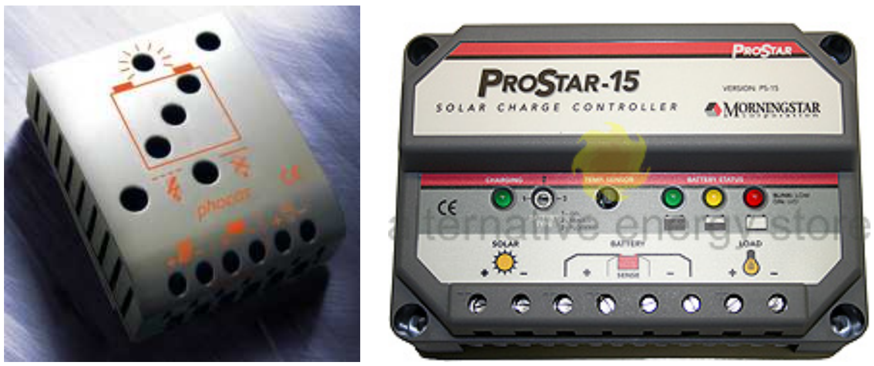

Figure 5 - Low cost, easy-to-use PWM solar charge controllers

Inverters

Inverters electronically convert the battery's DC voltage to a higher AC voltage. The quality of the AC waveform output is the primary differentiator among inverters, as normal AC grid power is a "pure sine wave" with a stable frequency of 50 or 60Hz, depending on country standards.

- Very small and cheap inverters output AC voltage in a "square wave," which may be ok for use with light bulbs. However, this type should not be used with electronic equipment or appliances that use AC motors.
- The "modified sine wave" output inverter is relatively inexpensive to manufacture and can be used with most electronic devices.
- "Pure sine wave" gives an AC output that is closest to high quality grid power. Pure sine AC power can be used with any type of equipment, and is recommended for appliances with motors, such as refrigerators, air conditioning, fans or washing machines. This is the most expensive type of inverter.

Inverters can be purchased stand-alone or are available in combination units that include charge controller functionality.

Figure 6 - Pure sine wave 12VDC to 230VAC inverter

Design and Installation Considerations

Now that you understand a bit about the main components of a solar power system, here are some factors to consider in evaluating bids.

To ensure safety, use a skilled electrician with experience installing solar power systems

When designed or installed improperly, all power systems can be dangerous for people and systems alike. ***This section is NOT intended to provide a guide for do-it-yourself electrical installation.*** Always find a qualified electrician with solid experience with solar power and check references. Unless they have proven competence, avoid using an ICT professional to install your power system. However, it is always a good idea to make sure your ICT contractor works closely with you and your electrician during design.

Build around locally available power components wherever possible

As with ICT components, parts that are not readily available locally tend not to be replaced or are replaced more slowly when they fail. If you select components that are not locally available, consider purchasing spares and ask your vendor about how to expedite delivery of replacements. Your vendor should be willing to commit to a standard service level for replacement of these components. Develop relationships with several suppliers of high quality batteries, chargers, solar panels, etc.

Sizing

A full explanation of how to determine the appropriate size for the solar power system is beyond the scope of this document. It is important to work with a power provider that has direct experience in the design and deployment of solar solutions. Keep the following sizing factors in mind when assessing vendors' proposals. It is always a good idea to compare multiple bids.

- *Know your real "load"* – Once you have defined the electronic equipment that will be used, size your solar system based on *actual* power draw, or "load," NOT on device labels (which generally show max, versus average, power requirements). Ask manufacturers for accurate power draw figures or use a simple and relatively inexpensive watt-meter to test yourself. Make sure you include all of your equipment, including lighting if the facility will be used at night, fans, etc. in your calculation of total power load. Low wattage CFL or LED lights initially cost more than standard incandescent bulbs but will cost far less to operate.
- *Know your usage* – Two factors – operating power and power-on time (or "duty cycle") – are multiplied together to calculate a design goal in Watt-hours (abbreviated as "Whrs" or "Wh"). It is the sum of these Watt-hour requirements for each piece of equipment that primarily determines the size and number of solar panels and batteries needed. Think conservatively about how many hours each piece of equipment will operate each day. Table 1 shows a sample power budget calculation based on power draw and daily usage. In addition to the total daily watts required, it's important to understand the maximum instantaneous load (ie,

the total power draw when every piece of equipment that could possible be used simultaneously is "on"), which will determine the maximum current (in Amperes) that the system will need to support.

- *Know your solar power factor* – Make sure to use actual "insolation"[7] values and to account for microclimates or other factors (e.g., vegetation coverage) that might reduce this value. Talk to others in your area about their solar power systems (and vendors) to understand what issues they've encountered.
- *Balance usage & reliability* – Balancing reliability/availability and total cost is an important design decision. Some facilities may need 100% reliability even during prolonged bad weather while others will not. Where possible, significant savings can be realized by allowing for shorter equipment working hours during prolonged cloudy weather. At the beginning of the design process, it is up to the system designer and client to decide on the appropriate balance between cost, reliability in varying conditions, and system size.
- *Protect against theft and misuse* - Design systems so that *unintended* power draw (any power draw that the system is not sized to support or that is highly variable) is minimized. This means minimizing the number of free outlets and monitoring users closely. If possible, size the system to support phone charging stations, electric lanterns or other community needs (especially if you can charge for this service). Low amperage circuit breakers can be a good guard against unintended power draws.
- *Pad your power budget* – As a rule of thumb, we advise that you budget 10-20% "headroom" over and above your initial sizing for minor expansion, unplanned overuse, prolonged bad weather and gradual loss of efficiency in panels and batteries.

List of equipment items	Typ. Power each (W)	Qty.	Total Instant Power (W)	No. hours operating/day	Watt-hours
Low-power Server (e.g. Inveneo® R4)	28	1	28	6	168
Low-power PC (e.g. Asus® EB1007 with Inveneo® 15" LCD monitor)	22	5	110	6	660
Intel®-powered classmate PC or similar netbook	15	1	15	6	90
VoIP Phone	3	0	0	0	0
Long-range WiFi radio (e.g. Ubiquiti® NSM5)	7	1	7	6	42
Network Equipment (e.g. Cisco Linksys® LAN switch)	5	1	5	6	30
Misc. Equip (ink-jet multi-function printer, etc)	20	1	20	2	40
Light bulbs (e.g. high-efficiency 12VDC CFL)	11	3	33	2	66
				Total Watt-hours per day for battery only operation:	***1096***
				Minimum Watt-hours per day of power during Insolation peak (4 hours):	***730***

Table 3 - Sample Power/Hours of Battery Operation per day List. For a detailed guide to solar power sizing and installation, see Inveneo's Solar Power Whitepaper

[7] Insolation is the minimum direct solar exposure at a given set of geo-coordinates expressed in peak hours/day, or in $kW/m^2/day$.

AC vs. DC power

Alternating Current (AC) power is what comes out of standard wall outlets (generally at 120VAC-240VAC) whereas Direct Current (DC) power typically comes from batteries (usually 12, 24, or 48VDC). Your project may rely on AC, DC or some combination of both to power electrical equipment. Here are some factors to consider:

- *Equipment power input* – Most standard computers require non-standard voltages, but some run on 12v battery power directly.[8] Powering computers directly with DC offers maximum efficiency (there is a loss of approximately 5% efficiency when inverting DC to AC power) and can help avoid power theft from standard AC outlets.
- *Wiring length* – Since DC voltage drops rapidly over standard gauge wiring, DC powered systems are only possible in relatively small facilities with short wiring runs (<10m is a good rule of thumb). As a rule of thumb, if the distance between the charger and computers or other loads is greater than approximately 8m, inverting to AC is usually the best choice.
- *Safety* – Using DC power requires the use of non-standard wiring systems and should be implemented by an electrician with experience in designing DC systems.

Protecting the system

In an "all solar" system, surge and voltage stabilization are generally not a concern as they are in generator or partial grid-power systems. However, the system will still require adequate protection:

- *Lightning protection* – To protect against damage from lightning strike, use quality lightning arrestors and shielded/grounded Ethernet cabling for all external radios, especially those located high on towers. Towers or masts also should be grounded directly.
- *Proper Grounding* – At a minimum this includes a properly installed grounding rod set in alternating layers of charcoal, rock salt and earth (with water) to a depth of approximately 2m. Cold water piping can be used instead of a grounding rod, if available.
- *Circuit Breakers* – Breakers help protect equipment and can also help guard against power theft of misuse. Make sure these are sized appropriately.

Generators

In general, we recommend against relying on a fueled generator as a primary source of power. Fuel and maintenance costs add up quickly and inability to source fuel or replacement parts can leave you without power for an extended period. However, if heavy power loads are anticipated in an off-grid setting, or where solar is not possible for other reasons, a generator may be the only option.

Selection

There are far too many generator types to review them here. A few key points are worth mentioning, however:

[8] See http://www.inveneo.org/desktops2 for examples of 12vdc solutions from Inveneo.

- *Size* – Select a generator with a rated output (in KW) that is adequate for your total load (see above).
- *Type* – In general, diesel powered generators are more reliable and efficient and last longer than petrol versions. Propane generators perform well but will make you dependent on a reliable source for propane, which can be hard to source.
- *Support* – Purchase the generator from a vendor that can support the warranty and service the unit.

Maintenance

If using a generator, routine preventive maintenance is key since unplanned outages generally cost more than scheduled service and can result in lost business. IT managers can perform basic maintenance, but a trained mechanic should perform major scheduled maintenance. Plan ahead to avoid system downtime during operating hours.

Fuel

In addition to regular maintenance, ensuring access to fuel is critical, especially if a generator is your only power source. Here are some factors to consider:

- *Storage* – Make sure storage is adequate for your supply situation but use fuel stabilizer for fuel that will be stored for more than a month before use.
- *Quality* – Make sure fuel is clear (not cloudy) and light colored when purchased. Cloudy or dark colored fuel may run the generator, but will reduce performance and increase the need for servicing and maintenance. In many places it may be difficult to find diesel fuel that has NOT had water added to it (or which has picked up water through condensation during transport). Storage tanks can be designed to allow removal of this water through a sloping bottom from which water can be drained through a valve at the lowest point.

Hybrid systems

Hybrid systems employ more than one source of power to run equipment. Hybrid systems are more complicated to deploy, but the redundancy makes them more reliable. Depending on the circumstances, hybrid systems can sometimes actually reduce initial capital costs by, for example, avoiding the need to design a solar solution that will provide reliable power through extended bad weather.

The most common hybrid systems are:

Grid with battery backup

This is the simplest and lowest cost hybrid solution. Grid power is used when available and a battery backup is used to store enough power to allow for normal operations during grid outages. It is important to have a clear understanding of grid power availability in order to design these systems properly. These systems are most reliable when grid power outages are relatively short and follow a consistent pattern.

Generator and battery backup (with or without intermittent grid power)

Though not optimal, this may be the best solution available in off-grid locations where there is not sufficient insolation (or power draws are too high) to make solar power economical. When power goes out for several days at a time, battery backup systems are generally not capable of providing sufficient power to keep the facility running. In general, battery backup systems, which can minimize fuel use and generator run times, are economical only when low-power computing solutions are used.

Solar and backup generator

In off-grid settings, solar and battery systems can be supplemented by a generator power during the rainy season or when heavy power loads are expected. This system makes the most sense when augmenting an existing generator with solar power for lower operating costs. It can also make sense when there is a seasonal need for increased power during extreme weather conditions.

System Protection

Both generator and partial grid power solutions can produce power spikes that will damage computers and networking equipment. Lightning is also a perennial threat to radios and other exterior/outdoor equipment. Equipment that protects against these threats is relatively inexpensive, readily available in most places and offers cheap insurance against damage to costly equipment.

- *Surge protection* – Make sure that surge protectors with circuit breakers – the least expensive protective equipment – are located as the *first* line of defense (we routinely find them placed further down the line, leaving all the equipment upstream exposed). “Passive” surge protectors (simple mechanical devices) are best in places with poor power, since “intelligent” or “active” protectors may not function at all if AC power is not stable.
- *Voltage stabilizers* – A voltage stabilizer is also required to ensure the load voltage remains within operational levels. This component should always be used with AC power sources such as grid and generator. A stabilizer is not needed with solar-powered installations.
- *Lightning protection* – To protect against damage from lightning strike, use quality lightning arrestors and shielded/grounded Ethernet cabling for all external radios, especially those located high on towers. Towers or masts also should be grounded directly.
- *Proper Grounding* – At a minimum this includes a properly installed grounding rod set in alternating layers of charcoal, rock salt and earth (with water) to a depth of approximately 2m. Cold water piping can be used instead of a grounding rod, if available.

Part 2: IT Deployment, Training and Support

Choosing appropriate infrastructure will greatly simplify both deployment and support but no system, however robust, can install and maintain itself. Careful planning will help you avoid most common problems encountered before and during installation and well conceived IT training and support policies help ensure that administrators are equipped with the skills and external resources they need keep your systems running. This chapter offers recommendations around deployment of ICT infrastructure, administrator training and ongoing support.

Deploying the Computer Lab's ICT Infrastructure

Depending on the country and location, getting equipment into the country and then up and running can be a challenge in itself. Here are some tips to help avoid the most common problems:

Before Deployment

- Purchase gear through a local installer – If contracting with a local firm to provide installation, we recommend letting *them* handle customs clearance (unless you have experience importing ICT equipment).
- Purchase local inputs well in advance of deployment. Having all your imported equipment arrive only to find that you must wait on local inputs (e.g., power equipment) can be frustrating and costly. Inveneo has a policy of not sending staff to perform a deployment until power systems and other required supporting infrastructure are fully deployed and tested.
- Know whether "pre-inspection" is required – In some countries, tariffs are significantly higher for goods that arrive without pre-inspection.
- Know customs duties/tariffs and determine whether your organization may be exempt.
- Are Declarations of Conformity required for the equipment you're using? DoC are most often required for radios and other communications equipment. Regulations are usually available through the national Communications Commission (or similar).
- If importing the equipment yourself (vs. purchasing from a local vendor), always request that the shipper take pictures of the equipment before it is put into transit. This can be useful should equipment "go missing" in customs.
- If equipment is missing on arrival, report it to authorities and to the vendor immediately.
- If your project includes deployment of wireless networking equipment that extends beyond your local facilities, understand wireless regulations and what equipment certifications (ie declarations of conformity, or "DoCs") may be required (e.g., CCK in Kenya requires CE DoCs for all radio equipment in their "type approval").
- Buy spares for hard-to-get but critical equipment (e.g., printers, which are important, difficult to locate in-country and usually cheap).

During Deployment

- Involve local manager(s) in the deployment process so that they understand the power and ICT equipment. Better yet, set aside a day or two specifically to train managers in the use of the new equipment and how to get support.
- Make sure that installers leave manuals for all equipment.
- Prior to final payment, do a formal "check off" with installer to make sure that everything was delivered safely and functions properly.

System Administrator and User Training

While it's seldom possible to have a dedicated, full-time system administrator, *someone* (usually the IT manager) must be clearly responsible for IT administration, including basic troubleshooting and knowing how to get outside help when needed. This section presents key points to impart during training for IT administrators.

Password and Security Management

- Protect all systems with strong passwords
- Train all personnel *not* to share system passwords
- Train IT administrators to change passwords periodically

Hardware and Power Support

- Create "cheat sheets" to help administrators troubleshoot common problems
- Have a clear plan for escalating problems to the next tier of support
- Make sure managers know how to switch between power sources (e.g. solar/battery to generator)
- Explain the importance of keeping solar panels clean and preventing unplanned power draws (ie, use of devices that the system was not designed to support).

Content Management

- General awareness of what is available locally on the server
- Discourage use of client hard drives for personal content (USB keys or sticks or Server)

Bandwidth Management

- Cache as much as possible when bandwidth is scarce
- Use tools to optimize the use of scarce bandwidth (e.g. OpenDNS, etc.)
- Do all computers need Internet? If not, don't connect them

User Training

In places where the Internet is completely new, a single online scam can damage the community's willingness to use shared computing resources. It's therefore important to ensure that new Internet users receive basic training on the risks/dangers involved in using the Internet and how to avoid them. This training can be performed in various ways, but we recommend making basic Internet orientation a prerequisite of web access at shared computing facilities. Key topics include:

- General awareness of common online scams
  - 411
  - Phishing
  - Identity theft
- Making sure users log out of personal accounts after use
- Not sharing passwords
- How to identify whether a web transaction is "secured" ("https")

For more on Internet safety, see http://techtips.salon.com/tips-use-internet-safely-10138.html

ICT Support

Lack of IT support capable of fixing even relatively minor problems is often the single greatest threat to sustainability, especially in remote areas. It is imperative to have a support plan (and budget) that is appropriate to your IT manager's skill level and location and that can resolve problems in a reasonable timeframe.

- Set expectations – It is critical that the IT administrator understands that problems will arise, that they will not be held responsible for equipment problems they did not create and that it is their responsibility to seek support in a timely manner.
- Source locally – As stressed in Part 1, select equipment that can be supported locally wherever possible. Also determine whether replacement parts and supplies are available locally and at what cost? (e.g. toner)
- Tiered support – Assuming you do not have fully training in-house IT support, define a tiered support process and contract with a capable provider, preferably the same company that installed the systems.
- Be proactive – Contract for pro-active support visits (we suggest quarterly visits for the first year) as well as "on call" remote support.
- Admin Training – Select a supplier that can provide basic user training for management/staff.

Conclusion

In low resource settings, ICT infrastructural components should be selected based on a clear understanding of both user-level requirements and the constraints imposed by physical, budgetary and other factors. There is no single correct solution; different computers, power systems and software will be needed depending on a range of factors. Regardless of the project's objectives, we hope that increased awareness of the main challenges and trade-offs involved will lead to more reliable, affordable and impactful ICT projects.