PV Toolkit for Community Facilities: Guidance for Sustainability

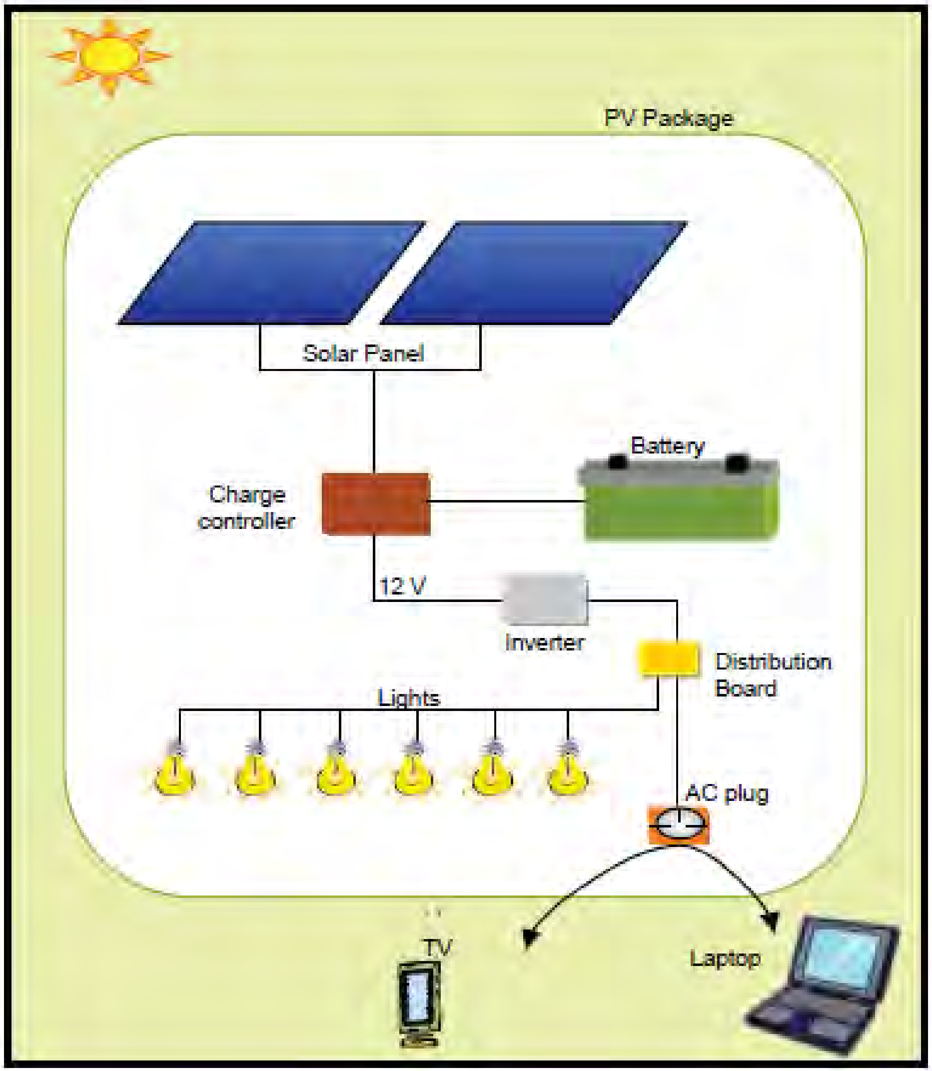
Outline

- Motivation for the Toolkit
  - Why solar PV as an energy source
  - Problems with sustainability
- Roadmap of the Toolkit
  - Rapid assessment
  - Preparation of implementation plan
  - Procurements and contract management
  - Long-term operation
- Where to find the Toolkit and how to use it

Solar PV can be a good match for rural facilities

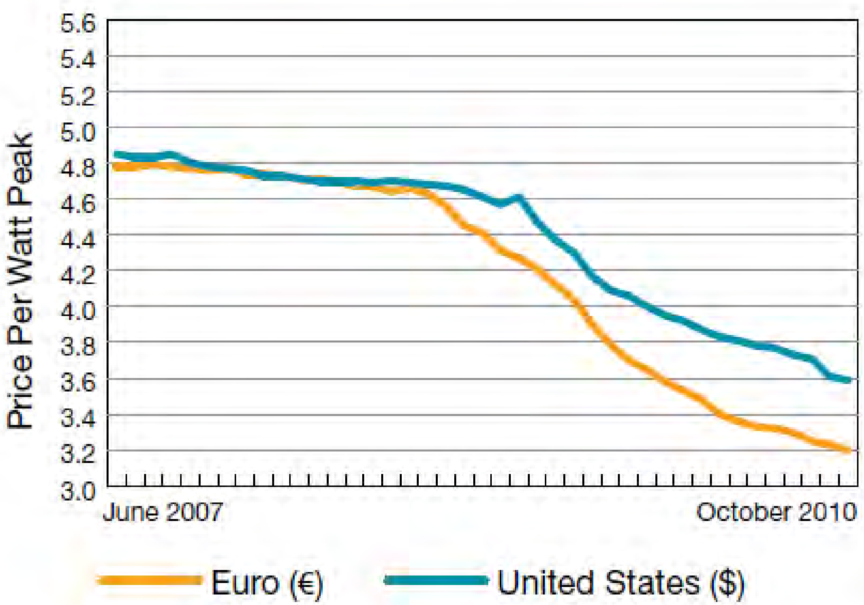
- Least cost electricity solution for many remote facilities
- Can be deployed quickly
- Reliable, predictable solar resources
- Reliable, modular technology, components and systems can be standardized for easy procurement and management
- Low recurrent costs
- Simple to operate, less trouble than diesel, no moving parts
- Minimal servicing, suitable for hard to reach communities
- Low environmental impact with quiet, safe operation

PV System Configuration



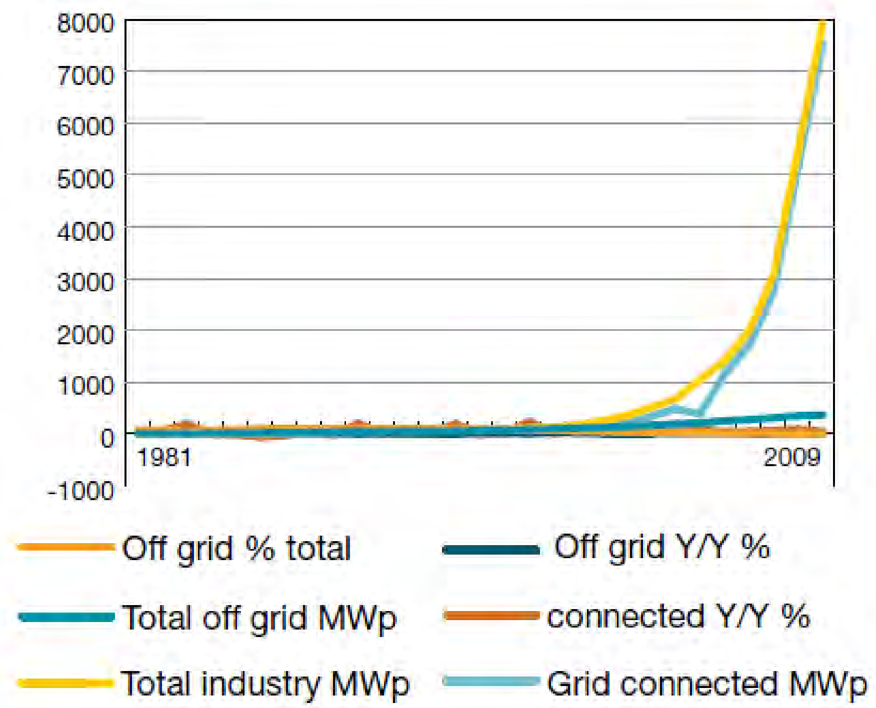
PV market trends making it more affordable to use solar

FIGURE 1: DECLINING COSTS OF PV MODULES



Source: www.solarbuzz.com/Moduleprices.htm

FIGURE 2: PV INDUSTRY GROWTH SHOWING MWP SALES, 1981-2009



Source: www.navigantconsulting.com/downloads/FinalSupplyNums2009.pdf

Problem – low system sustainability

- Many of the PV systems installed in off-grid rural community facilities not working after 3 to 5 years
- During preparation, issues of ownership, maintenance, component replacements, budget support are treated too lightly
- After installation, institutional weaknesses lead to misuse, maintenance failures and weak supervision, leading to system shutdowns and loss of investment.
- Maintenance and system reliability are rarely tracked; project monitoring does not report on performance of the PV systems
- Low sustainability approaches are replicated

Challenge of sustainability

Off grid planning – PV meets grid

Motivation for the Toolkit: Reversing low sustainability

- Sizing, configuring and specifying PV systems is fairly straightforward given requisite technical expertise. PV technology itself is mature: robust, well designed, correctly installed systems will work.
- However, the systems will work over expected lifespan only if placed within equally robust institutional arrangements.
- Establishing strong institutional arrangements for post project ownership and maintenance funding is the main issue.
- Maintenance continuity is the *sine qua non.*

Risks and Guidance

Risk	Guidance
Wrong technology choice, (trading current low costs of diesel generator against high future costs). Sudden, unexpected grid extension and energization.	Compare life-cycle costs (not only initial capital costs) of alternatives. Determine whether communities can receive electricity from the grid. Rural electrification plans are famously uncertain (e.g., when communities are connected, they may be subject to local and national politics or decisions of external donors). Bringing a "connection" is not synonymous with "bringing electricity."
Procurement and implementation rollout delays.	Involve/build PV procurement capacities of lead organization and funder early on and persist throughout the design and preparation stages. Design contracts with detailed technical specifications and strong certification, warranty, and commissioning conditions. Standardize to as few "building blocks" as possible. Closely supervise equipment supply and installations.
Poor-quality, inefficient designs and equipment. Over- or under-investment in wrongly-sized systems of too high or low quality.	Ensure technical system design by well-qualified PV specialists aware of current best practices and not linked to potential suppliers. Consult with off-grid PV specialists and seek independent review. Design PV systems via an iterative process, considering: • current and near-term energy use (the introduction of electricity may result in such unanticipated demands as extended TV viewing or cell-phone charging); • best available solar resource data from vicinity or databases that extrapolate resources; • energy-efficient lights and appliances (but do not set the number of lights or lighting quantity or quality too low); • good-quality components, using international or equivalent standards for panels, batteries, controllers, and energy-saving lights (don't skimp); • budget capacities to meet the recurrent costs of maintenance, repairs, and component replacements; and • local O&M capacities, including suppliers and maintenance providers at central, regional, and local levels.

Risks and Guidance

Lack of funds for battery replacements result in system shutdown. Misuse, poor maintenance, and lack of maintenance or troubleshooting skills. "Sudden" failures due to lack of system performance tracking and supervision.	Include community participation in preparation. Establish system ownership. Secure firm commitments for recurrent budgets for maintenance and component replacements. Consider beneficiary participation in funding O&M. Decide on in-house or outsourcing maintenance, and build local-service capabilities accordingly. Fix and enforce rules for system use and maintenance. Be clear on the limitations of PV systems (e.g., they are not for ironing, cooking, or heating). Ensure user training in appropriate use and load-management practices. Track PV system maintenance and performance to anticipate and address problems before failures occur. Closely supervise contract implementation, maintenance, and performance.
Adverse environmental impacts. Theft and vandalism.	Arrange recycling or disposal of light bulbs (e.g., CFLs or fluorescent tubes that use mercury) and lead-acid batteries. Identify any security risks and mitigating measures. Consult and create strong awareness to align community and staff expectations with sustainability of PV systems.

Outline of Toolkit: Preparation to operation

1. Rapid assessment (one week)

   Result is concept and preparation plan

2. PV implementation plan preparation (1 - 3 months)

   Covers same questions as the rapid assessment, but in much more detail. Result is the implementation plan.

3. Procurements and implementation (1 year to contract effectiveness)
   - Procure, roll out supply and installation of PV systems, build capacities, verify, manage contracts
   - Initial maintenance may be included in contract

   If PV supply and installations are successful

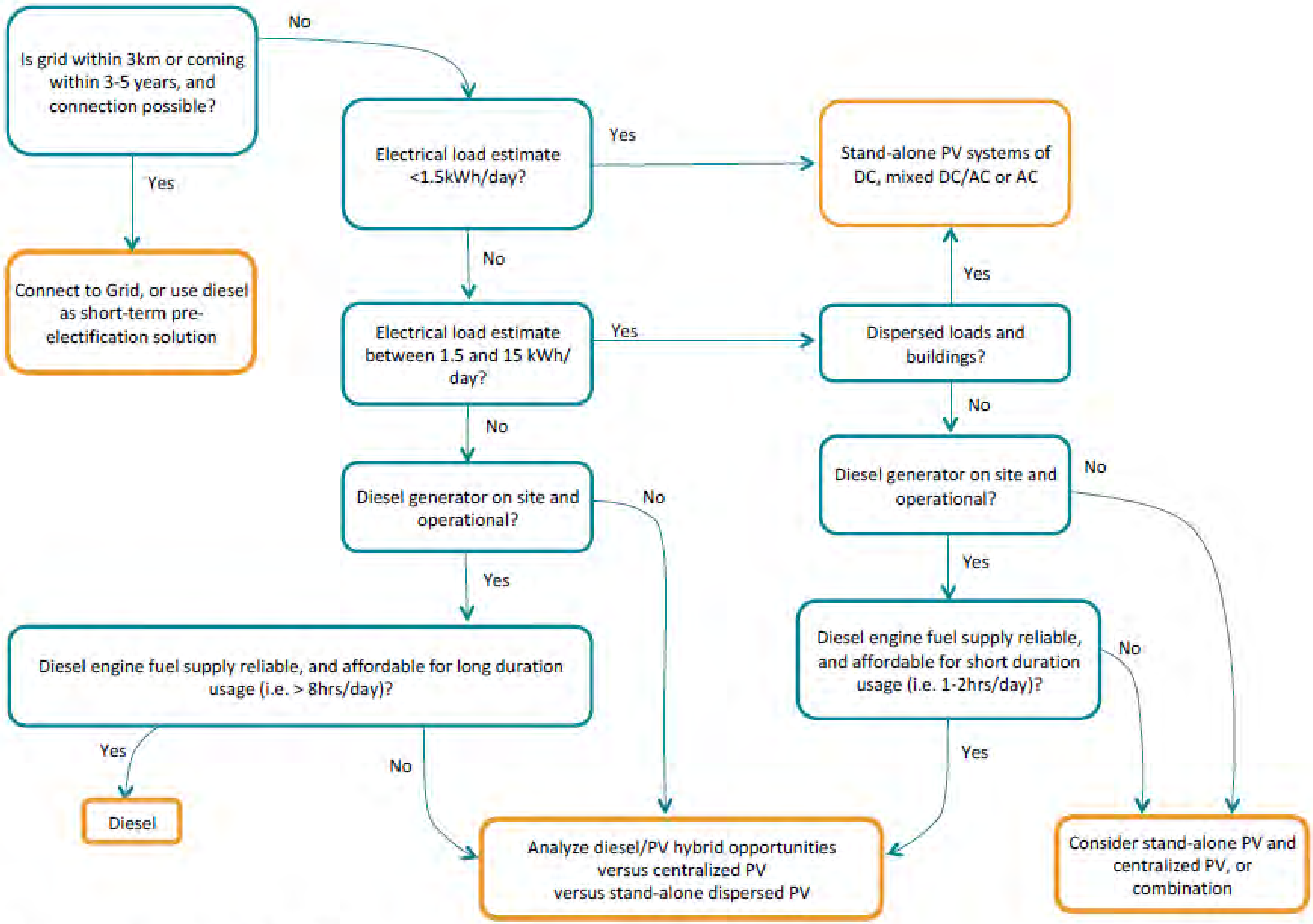
   - Maintain, track performance, supervise (up to 20 years)

Key steps in rapid assessment

1. **Assess why PV systems are being considered.** Are there existing facilities without electricity access, new facilities yet to be constructed, high costs of operating existing diesel generators, new services that require electricity to be introduced, or difficulties in recruiting and retaining staff without electricity?
2. **Determine which, where, and how many facilities and which services to cover.** Develop concept and initial scope based on discussions with main stakeholders and reviews of readily available data. Assess quality of information and identify data gaps. If water pumping services are considered, separately estimate their requirements, costs, and possible implementation models.
3. **Determine the energy requirements and PV system sizes.** Estimate energy demand using country and international norms for main strata of facilities. Assess available information on country experience. Source solar-resource data from websites or maps; use month of least sunlight as the design month. Estimate system sizes using basic conversion ratios and estimating factors.
4. **Estimate PV system costs and least-cost option.** Calculate investment costs using broad ranges (e.g., US$14–19 per Wp) based on recent national or regional procurements. Estimate operating costs as a fixed proportion of investment costs. Determine the least-cost solution, comparing life-cycle costs per kilowatt hour (kWh) of PV systems against grid extension and diesel generators, using standard cost curves.
5. **Decide on implementation model and institutional and technical details.** Identify initial implementation options for supply, installation, and operation with key stakeholders. Estimate total costs by applying margin to estimated investment costs. Agree on project preparation strategy, responsibilities, requirements, and timing. Consult with independent specialists, including off-grid renewable energy specialists.

Source: Authors' recollections, 2010.

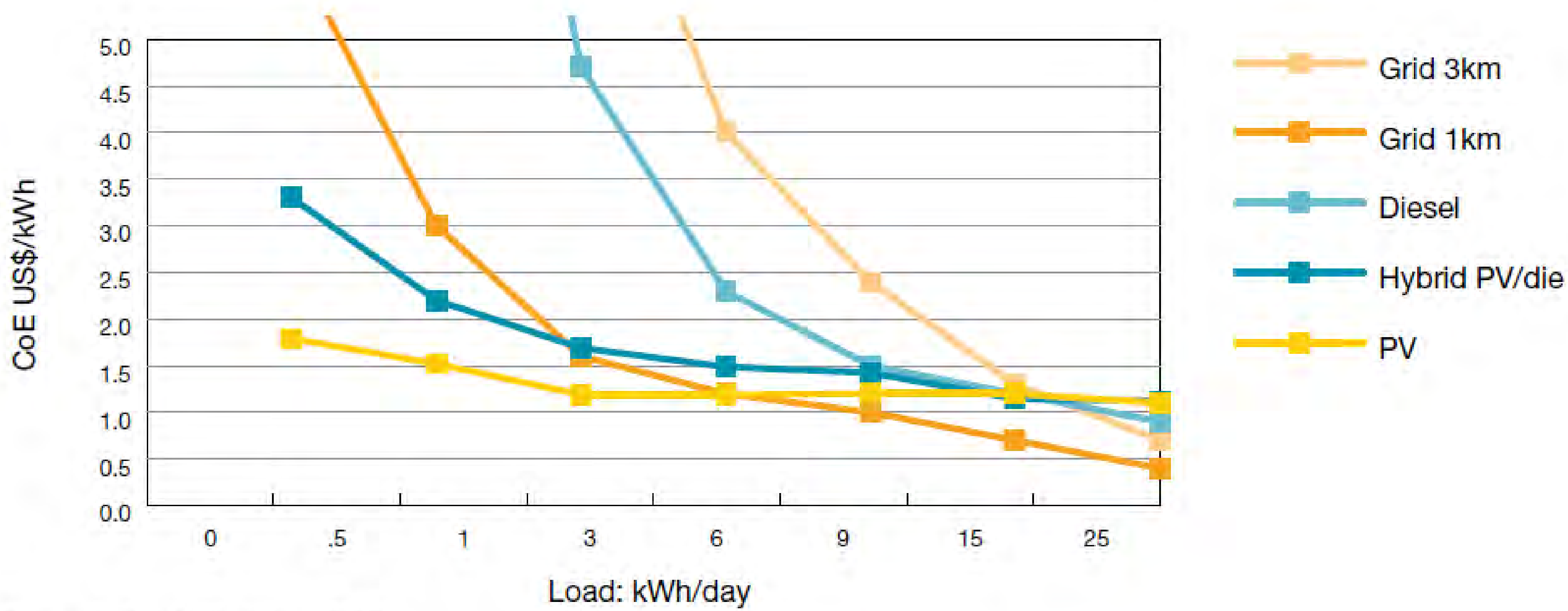
Technology choice decision tree



Source: Authors' schematics, 2010.

Compare cost of technologies

Solar PV is most attractive where load is fairly low. In some cases, diesel or grid will be the best choice if it is possible to have a regular supply of fuel.



Source: Authors' calculations, 2010.
*6% DR; 20 yer life; diesel US$1.1/litre delivered; grid extension at US$15,000/km; grid elect US$0.22/kWh

Preparing implementation plan

1. **Gather information and conduct field surveys.** Collect data on numbers, locations, physical layouts, and energy requirements for types and levels of facilities. Assess institutional and market capacity (Annex 3). Conduct wide stakeholder consultations and field surveys at representative facilities. Review sector priorities and policies and grid extension plans.
2. **Update rapid assessment data on facilities and prioritize services.** Deepen and update information from the rapid assessment on numbers and types of facilities. Rank energy requirements by the priority of the services they support, with rankings determined by sector policies and likely impacts. (If PV water pumping is included, conduct separate site-by-site assessments guided by water specialists).
3. **Refine energy requirements and size and configure PV systems.** Calculate requirements through several iterations comparing use and configuration options, considering country experience and international best practice. Refine solar-resource estimates with disaggregated data, including regional and seasonal patterns. (National meteorological office may have detailed data.) Size and configure systems with engineering design methods simulating component and installation options with reliability/cost and other trade-offs.
4. **Construct cost estimates and fine-tune least-cost option.** Build up investment and operating estimates with unit cost data for components, shipping, local taxes and handling, installation labor and logistics, maintenance, and component replacements. Run iterations comparing technical and organizational design options. Consider PV procurement cost trends. Customize least-cost assessments and simulations with data on specific technologies and locations.
5. **Decide on implementation model and institutional and technical details.** Identify opportunities to cooperate with other projects and organizations. Conduct multiple consultations with stakeholders, including PV specialists, on all aspects. Agree on responsibilities for supply and installation, maintenance, financing, ownership, and any links with market development. Determine procurement methods. Build up project budgets, schedules, and draft procurement packages, including technical specifications and terms of reference for capacity building, implementation support, and system performance tracking (Annex 4). Consult with independent specialists, including off-grid renewable energy specialists.

Source: Authors' recollection, 2010.

Market and institutional assessments

- Market capacities and barriers
  - size and performance of local PV market, including prices, quantities, quality; local capacities to support PV, including number and track records of local and international companies operating in local PV market, organizations, and specialists; PV-related capacities in communities near the targeted facilities.
- Grid extension plans , costs, tariffs
- Diesel prices, supply reliability in targeted communities
- Country PV experience—local experiences, including those of targeted communities; implementation models used; results; sustainability track records of facilities in public sector, for-profit, and non-profit sectors.

Market and institutional assessments

- Institutional capacities (design, procurement, supervision, training, ownership, operation, maintenance):
  - lead organization
  - likely facility owner
  - others - e.g., central government ministries, local governments, technical institutions, NGOs, private firms
- Cooperation opportunities with other projects, organizations:
  - PV market development projects underway or planned
  - possible links with activities to sell and finance PV systems for households
  - possible inter-agency coordination, collaboration
- Framework opportunities, issues and barriers:
  - regulations, standards, and enforcement
  - duties and taxes and customs practices
- Maintenance capabilities—maintenance experiences and capabilities, especially for long-term arrangements

Choosing the implementation model

- Who will fund the investment?
- Will implementation focus on a single sector, is it feasible to cover facilities across multiple sectors within an area?
- Will there be linkages with market capabilities or other projects?
- Who will be the lead organization for implementation of supply and installations?
- Who will own the PV systems once installed?
- Who will be responsible for maintenance?
- Will maintenance be done in-house or contracted out?
- Who will fund the recurrent costs of operation?

Prepare institutional details

- Design details for procurement, contract management, ownership, post project maintenance and recurrent funding
- Prepare capital and recurrent cost budgets and schedule
- Secure firm commitments for recurrent funding
- Design security package – structure of payment schedule, payment retentions, warranty and performance securities, liquidated damages provisions
- Identify Plan B
- Identify measures to address identified framework barriers
- Build capacities of procurement officials
- Prepare and begin capacity building for contract management of roll out of installations and initial operation, maintenance and supervision

Design issues (selected)

Issue		Guidance
What are the service requirements?	Decisions about which services to support directly impact PV system costs.	Prioritize services, design accordingly to control costs.
How critical is uninterrupted service?	Designing for no interruptions for all services can be expensive. Some services are critical, others are not.	Differentiate between critical, moderate and tolerant systems.
Lighting and appliances – how efficient shall we be?	Inefficient lighting design and appliances increase system costs. However, the most efficient lights and appliances may not be locally available or supported.	Efficient lighting design easily achievable. Efficient appliances decisions may depend on local situation.
Should a contract to supply PV systems include the supply of the appliances?	Bundling appliances in the PV contract ensures that they are supplied in phase with the PV systems. However, adds to contractual complexity, cost to project, equipment support issues.	Depends on local situation. Generally procure lights, vaccine refrigerators and pumps as part of PV packages. Other DC/AC appliances may need special consideration.
How should PV systems be provided for staff?	May be important for staff recruitment and retention. There are several ways to provide PV systems for staff. There are questions of cost, ownership, affordability, maintenance and component replacement contributions and responsibilities.	Depends on local situation. Liaison with sectors and staff necessary, as well as local PV market support mechanisms.

Prioritization of loads

Purpose/location	Service	Priority ranking (example)
Cold chain and Expanded Program on Immunization (EPI) refrigeration	Vaccine refrigeration	High
External lighting	Security lights at all main doors	High
	Security lights around buildings, front gate streetlight, outside toilet block lighting	Low
	Veranda lights	Medium
Outpatient department (OPD) lighting and appliances	Laboratory lights and appliances (list)	High
	OPD lights and medical appliances (TV, list others)	Medium
Maternity and Mother Child Health (MCH) lighting and appliances	Maternity and MCH lights	High
	Medical appliances (suction, ceiling fan, list others)	High
Office lighting, appliances, and communications	Cell phone charger, TV	High
	Office appliances (computer, printer), office lights, and ceiling fan	Medium
Operating theatre (OT) lighting and appliances	OT lights	Not applicable for this typical site
	OT appliances (list them)	Not applicable for this typical site
Ward and patient kitchen lighting and appliances	Ward lights	Medium
	Ward appliances (list them)	Low
	Kitchen lights	Low
Staff housing lighting and appliances	Staff lighting	Medium/high
	Appliances (TV, radio, ceiling fans, and cell phone charger)	Medium/high
General purpose	Water pumping	Medium
	Refrigerators	Medium
	Cooking for institution	Medium
	Sterilization	High

Source: Authors' calculations, 2010.

Ownership – maintenance - financing

- The problem:
  - responsibilities for recurrent costs frequently not firmly set
  - projects close down before issues of ownership, maintenance and operational funding begin to affect sustainability.
- Good practice
  - clearly establish ownership; this will frame maintenance options
  - align responsibilities for recurrent funding and maintenance with ownership
  - decide details, e.g., who buys new lights, who buys replacement batteries, who fixes broken switches, who provides the funding?
  - if facility staff and community are to contribute to recurrent costs, consult with them in determining feasibility, before deciding
  - settle how recurrent costs are financed, before any procurement
  - settle any ownership and funding issues before systems are installed

Contract maintenance or do it in-house?

- How will post project maintenance be funded? You get what you pay for.
- What are the local experiences, in-house and with private firms, in maintaining PV systems in remote facilities; what are the track records; what looks promising?
- Will in-house or private firms be more cost-effective and deliver better results?
- Will area-based clustering of maintenance services be more cost effective?
- Should maintenance be part of supply-and-installation contract or would separate, annual or longer-term maintenance contracts be more cost-effective?
  - single contract for supply, installation and maintenance (e.g., five years with an option to extend) puts full responsibility on one contractor.
  - supply and install contractor may have limited on the ground maintenance capability
- If in-house:
  - how will budgeting and maintenance management be handled?
  - how will maintenance performance be tracked and supervised?
- How will facility staff, who will change over time—be trained and retrained (staff turnover) and know to get help for system performance problems or failures?

Procurement and contracting

Certification of major equipment

- Clarify outstanding issues and items.
- Get overall signed Declaration of Compliance, if not already provided.

Equipment samples for approval

- Get airfreight samples, as necessary, to expedite approvals and ordering; these include CFLs, light fittings and reflectors, medical lamps, reading lamps, inverters, battery enclosures, battery fuses, lightning surge arrestors, and other equipment.

System technical reviews

- Check system sizing offered and drawings; check component matching.
- Make corrections to components, and, if needed, propose changes to standardize equipment.
- Add lightning protection to new specification and as per new drawings (at cost).

Schedule of price variations (if not already included in contract price schedules); obtain for:

- Cabling between buildings (per meter).
- Cabling strain relief ends (supply and install per pair).
- Lamp and switch (supply and install).
- Distribution board (supply and install with main 2-pole CB and 2 x 1-pole CB).
- Lightning protection (supply and install).

Schedule of equipment delivery; obtain for:

- Blueprint equipment and installation.
- Major equipment for main rollout.

Installation program

- Get blueprint schedule and confirm site selection.
- Obtain main rollout plan, including number of teams, supervision, and detailed rollout program per team.

Revised handover and payment proposal

- Confirm practical completion and provisional acceptance stages (with minor snags) with supervision consultant, and confirm payment amount.
- Confirm final acceptance stage requirements, confirm payment amount.

Supervision of responsibilities (may be role of Supervision Consultant)

- Supervise site visits and due diligence.
- Reallocate sites that do not meet PV electrification criteria (e.g., too close to grid).
- Reallocate packages among sites (if numbers of buildings at site do not meet standards).
- Allocate additional lights per package to meet lighting design requirements, with at least one light per room and passage.
- Cable between buildings, with additional DBs.
- Determine array and battery locations in each building.
- Instruct contractor on all of the above items.
- Change order and check pricing based on the variation price schedules provided.

Source: Authors' recollections, 2010.

Procurements, supply and installation

- Finalize procurement packages, with technical specifications
- Launch informational activities to create awareness among as large a pool as possible of qualified bidders
- Implement capacity building for installers, local experts, standards and testing entities, project staff and others
- Conduct the procurement (example contracts in annex)
- Ensure:
  - bidders are qualified
  - equipment is compliant with specifications. Vet certifications. Test as necessary.
  - installations are compliant. Verify, commission and issue acceptance.
- Disburse

Procurement method and process

- Standard bidding documents (SBD)
- International competitive bidding (ICB)
- Prequalification of bidders The SBD for goods, different from the ones for plant and works, is not intended for prequalification of bidders, although it is sometimes done (e.g., Tanzania SSMP). Without prequalification, some potential credible bidders may be deterred by high costs of preparing bids, particularly for installations and related services in remote off-grid communities, especially if they are concerned that some firms without good capability will under bid. Increases need to generate interest with good advance publicity and information and to reduce any perception of risk by establishing clear criteria for post-qualification.
- Clarifications and pre-bid conference For innovative projects, provide at least three months for the clarification process and pre-bid conference. A bidders' conference, conducted in the field in a representative community, can provide vital information about the sites, distances and logistics, organizational and environmental conditions.

Additional resources in the Toolkit

Where to find the Toolkit

- Online: http://siteresources.worldbank.org/EXTENERGY2/Resources/PVToolkit.pdf

- Hard copies available in French and English

Donors

Africa Renewable Energy Access Program (AFREA)

1818 H Street, N.W.
Washington DC 20433, USA
Internet: www.worldbank.org/afr/energy/afrea
Email: africaenergyunit@worldbank.org

ESMAP
Energy Sector Management Assistance Program

1818 H Street, N.W.
Washington DC 20433, USA
Internet: www.esmap.org
Email: esmap@worldbank.org

THE WORLD BANK

1818 H Street, N.W.
Washington DC 20433, USA
Internet: www.worldbank.org/afr/energy
Email: africaenergyunit@worldbank.org