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MINISTRY OF ELECTRICITY AND ENERGY
THE REPUBLIC OF YEMEN

RENEWABLE ENERGY STRATEGY AND ACTION PLAN

OFF-GRID RENEWABLE ENERGY DEVELOPMENT STRATEGY AND ACTION PLAN

FINAL REPORT

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List of Abbreviations

ALD	accredited local dealer
CFL	compact fluorescent lamp
DC	direct current
GPS	global positioning system
GTZ	German Technical Cooperation
MEE	Ministry of Electricity and Energy
MFIs	Microfinance Institutions
NMF	National Microfinance Foundation
PEC	Public Electricity Corporation
REA	Rural Electrification Agency
RES	Rural Electrification Sector
SHS	solar home system
SL	solar lamp
W	watt
Wp	watt-peak
YR	Yemen Rials

1 Executive Summary

1.1 Key rural electrification issue

- Access to electricity services in Yemen is among the lowest in the Arabian Peninsula. In 2005, only 39 percent of the households throughout the country are connected to national and rural electricity grids. At present, more than 1.7 million households have no access to modern electricity services[1].
- The Public Electricity Corporation (PEC), agency responsible for electricity distribution, commits to increase electricity access in rural areas through grid expansion. In its long term Electricity Distribution Expansion Plan 2006-2020, PEC targets to expand its services in 10 Governorates. At present, the Government have already secured funding for infrastructure investments until 2010 (Power 5 Project).
- In addition, the National Rural Electrification Strategy Study proposes the Government to establish 27 Service Territories in 12 Governorates to be achieved within 10 years.
- Despite of these, there are several districts in 11 Governorates that are not included in the PEC drawing board nor in service territory development of the National Rural Electrification Strategy for grid expansion.

1.2 Rural Electrification Policy

- The Rural Electrification Policy was proposed by the National Rural Electrification Strategy Study with the objective of assuring the necessary expansion of rural electric coverage, providing service to the maximum number of rural households at the lowest cost possible, consistent with the Government's aim to provide universal access to electricity services. This study highlights that the proposed expansion of rural electric coverage does not only include grid expansion but also off-grid provision of electricity services.
- The proposed Rural Electrification Policy recognizes the role of renewable energies in electricity service provision to remote communities. This is stated in the principles and components of the proposed Policy which are the following: i) establishment of a new and independent electrification agency, ii) establishment of commercially viable service territories, iii) assure community participation in provision of electric service, iv) assure program sustainability by setting tariffs to meet cost of service, v) REA expansion plan will be composed of projects that are economically viable, vi) renewable off-grid projects will be included in the national electrification expansion plan, vii) employment of new and least cost construction standards to maximize program impact and lower costs.

[1] PEC Commercial Activities Report 2005.

1.3 Off-grid rural electrification strategy

To provide energy services to the identified areas that will not be covered by grid expansion (not included in the PEC Distribution Expansion Plan and the proposed Energy Service Territories of the National Rural Electrification Strategy), this study proposes a strategy that removes barriers and stimulates the establishment of market-based and decentralized approach to off-grid rural electrification. The principles and components of this strategy are the following:

- Prioritize financially sustainable off-grid areas to kick-off national market for renewable energy technologies
- Ensure least cost supply option
- Establish decentralized and market-based off-grid energy service delivery strategy
- Introduce measures to remove investment barriers
- Provide funding to social infrastructures
- Protect consumer's welfare
- Promote the development of wind-diesel mini-grid systems
- Raise awareness and strengthen stakeholders' capacities

1.4 Off-grid areas and energy supply options

- The study identified areas that are not included in the current Distribution Grid Expansion Plan of the Public Electricity Corporation (PEC) as well as in the proposed Energy Service Territories of the National Rural Electrification Strategy. These off-grid areas are within 56 districts of 11 Governorates consisting around 1.6 million inhabitants in 2004 and representing around 8 percent of the total population.
- The resource assessment component of this study identified that only solar and wind energies have the potential to provide wide-scale energy services in these isolated areas.

1.5 Energy service delivery programs for rural households

- Off-grid areas identified by this study cover more than 6,200 villages in more than 50 districts in 11 Governorates throughout the country. With respect to the number of households, these marginal areas register more than 240 thousand households in 2005. To initiate a market-based approach to energy services through solar PV technologies, a number of villages need to be prioritized for development to operate as a market catalyst and to sustain the development of the solar PV market.
- The first screening criterion adopted by the study is the household density. Villages with less than 50 households are initially screened out for off-grid rural electrification due to high costs in the provision of services. On the other hand, villages with large number of households (more than 50) are given higher priority due to high economies of scale in the provision of support services.

Almost 180 thousand households in the identified off-grid areas are within villages with more than 50 households.

- The second screening criterion used in the study is the village poverty index level. Off-grid projects would be most likely to succeed and sustained in villages with higher ability to pay for energy services. Villages classified with Village Poverty Index Level 1, 2 and 3 were considered in the analysis while those with Poverty Index Level of 4 were excluded. Villages with 1, 2, and 3 ratings numbers around 101 thousand households in 2005.
- Based on household density and poverty criteria, the household energy market is classified also into solar home system (SHS) market and solar lamp (SL) market. The poorest households in villages with household density of more than 50 were considered for solar lamp market as well as all the households in low density villages (household density of less than 50). The rest is considered for the solar home system market.
- The lack of market development of solar PV technologies in Yemen is partly due to their high capital costs. A financing scheme is required in order to make these technologies affordable to a larger number of rural households. Another screening criterion is introduced to determine which households have access to financial services of the current financing institutions in the country. The fourth screening criterion used in the study is the proximity of off-grid areas with the financing institutions. Microfinance institutions, the CAC Bank and the Postal and Postal Savings Authority have expressed their interest to be involved with the delivery of off-grid energy services.
- Based on the current service profiles of the financing institutions, microfinance institutions and the CAC Bank can potentially served the solar home system (SHS) market while the Postal Service can potentially serve the solar lamp (SL) market. Off-grid areas within the 50 km zone of a branch of a financing institution are classified as Sector 1 which means areas that could be potentially served by financing institutions. Sector 2 consists of off-grid areas outside the 50 km zone of these institutions. Almost all off-grid areas are within the 50 km zone of Postal Service branches.
- With these, 8 programs were proposed to activate the solar PV market. These are categorized into the following:
    - Solar home system sales (cash and credit) program through financing institutions. Off-grid areas within the 50 km zone of a branch of a financing institution.
        - Program 1: Solar home systems (SHS) delivery to Al Mahwit, Hajja, Lahj, Raimah, and Taiz through credit and cash sales by financing institutions.
        - Program 3: Solar home systems (SHS) delivery to Abyan and Amran through credit and cash sales by financing institutions.
    - Solar home system fee-for-service program through local service providers. Off-grid areas outside the 50 km zone of a branch of a financing institution.

- Program 5: Solar home systems (SHS) delivery to Al Baida, Al Hodeidah and part of Amran
- Program 7: Solar home systems (SHS) delivery to Al Mahara and Hadramout

o Solar lamp sales (cash and credit) program through the Post and Postal Savings Authority. Low household density villages and poorest segments of the high density villages.

- Program 2: Solar lamps (SL) delivery to Al Mahwit, Hajja, Lahj, Raimah, and Taiz
- Program 4: Solar lamps (SL) delivery to Abyan and Amran.
- Program 6: Solar lamps (SL) delivery to Al Baida, Al Hodeidah and part of Amran
- Program 8: Solar lamps (SL) delivery to Al Mahara and Hadramout

1.6 Energy service delivery programs for social infrastructures

- Social infrastructures considered in the study are rural health centres, schools, mosques, and military checkpoints. The estimated market potential in off-grid areas for these infrastructures are the following: 570 for rural health centres, 2050 for rural schools, 9500 for mosques, and 200 military checkpoints.
- Following the sector and program classifications and implementation programs for off-grid rural household electrification (discussed above), the study estimated the market potential of each off-grid districts and governorates.
- Social infrastructures benefits members of the communities in off-grid areas. This study proposes a public funding model in providing energy services to these infrastructures using solar PV technologies. The public funding however will be derived from the budgets of specific ministries responsible for these infrastructures such as the Ministry of Education for schools, Ministry of Health for health centres, Ministry of Religious Endowment and Islamic Affairs for mosques, and Ministry of Interior for military checkpoints.
- PEC-RES/REA may however provide subsidies sourced from the Rural Electrification Fund or from other donor agencies channelled through the Fund.
- Four (4) programs were proposed to develop the social infrastructures in off-grid areas, and these are the following:
  - o Program 1 covering social infrastructures in Al Mahwit, Hajja, Lahj, Raimah and Taiz Governorates, as well as military checkpoints throughout the country
  - o Program 2 involving social infrastructures in Abyan and Amran Governorates
  - o Program 3 focusing on social infrastructures in Al Baida and Al Hodeidah Governorates

- Program 4 targeting social infrastructures in Al Mahara and Hadramout Governorates

1.7 Programs to promote wind-diesel hybrid systems

- Solar PV systems and wind-diesel systems do not compete but rather complement each other. Isolated networks of wind-diesel systems are financially feasible in areas where load demand is high (villages with more than 200 households). In villages with low household density, it may be financially viable to provide solar PV systems to each household.
- The study identified potential villages in off-grid areas (mainly along the coastal areas) where wind-diesel hybrid systems may be viable. More than 40 villages in 5 Governorates (Al Hodeidah, Taiz, Lahj, Abyan and Hadramout) could be possibly supplied with energy services through these systems.
- Resource measurement however needs to be carried out first in these villages to determine the availability of the resource and the technical and financial viability of wind-diesel systems. The study proposes 2 programs to promote the development of wind-diesel systems in off-grid areas.
  - Program 1. Preparatory program with activities covering wind resource measurement campaign, baseline market studies, feasibility studies and capacity building activities.
  - Program 2. Project implementation in identified areas
    - Program 2A – for feasible areas in Taiz Governorate
    - Program 2B – for viable areas in Al Hodiedah Governorate
    - Program 2C – for areas in Lahj, Abyan, and Hadramout Governorates.
- As an apex body for rural electrification, PEC-RES/REA could carry out the implementation of Program 1. Program 2 however should be implemented either by the private sector or the Public Electricity Corporation (PEC).

1.8 Off-grid rural electrification action plan

The study outlines an Action Plan to implement the proposed programs and estimates the cost of activities to be pursued by the Ministry of Electricity and Energy (MEE) and PEC-RES/REA. These are the following:

- Action plan to scale up off-grid rural electrification through solar PV systems
- Action plan to provide energy services to social infrastructures
- Action plan to promote the development of wind-diesel systems

The timeline of the programs is shown in *Figure 1-1*.

The cost of implementing the proposed activities amounts to almost US$ 20 million over the period of 10 years. An additional amount of more than US$ 91 million is needed for the purchase of renewable energy technologies. Some of these capital

investments however will be recovered particularly those allocated for solar home systems.

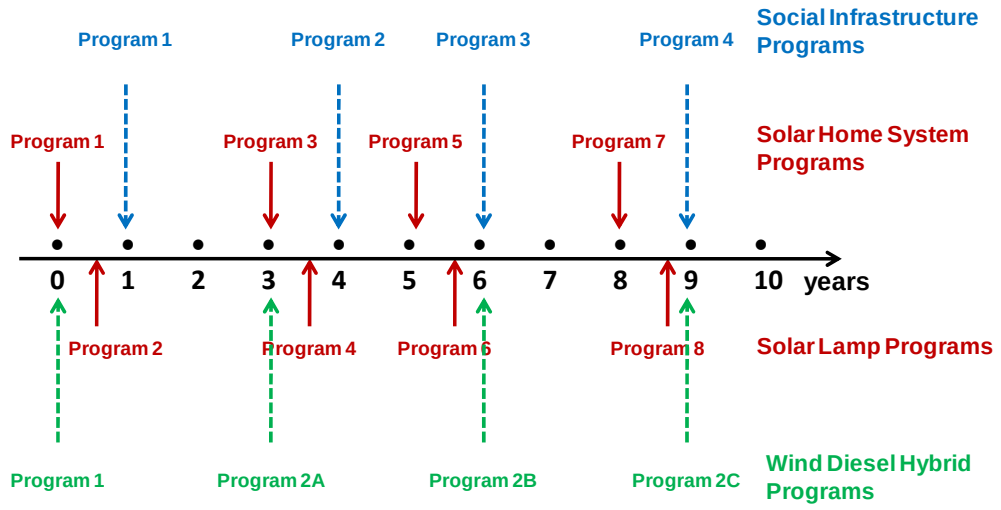

Figure 1-1: Off-grid rural electrification programs timeline

Table 1-1: Action Plan activities and cost estimates

Activities	Program Cost **USD (million)**	Hardware Financing Requirement **USD (million)**
1. ACTION PLAN TO SCALE UP RURAL ELECTRIFICATION THROUGH SOLAR PV **A. Solar Home System *Sales* Program**		
A. Financing institution preparation	-	
B. Local market survey and social preparation	0.050	
C. Awareness campaign	0.015	
D. Financing facilitation		
• Required subsidy (capital cost)		
Program 1*	4.188	
Program 3*	0.148	
• Initial funding (including subsidy)**		
Program 1 (10,000 units)	6.034	
Program 3 (2,000 units)	2.413	
• Hardware costs (total)		
Program 1		14.197
Program 3		0.888
E. SHS procurement	0.010	
F. Technician's training	0.020	
G. Formation of end-user's group	0.050	

H. End-user training	0.020	
I. Monitoring and evaluation	0.020	
Total	**12.968**	**15.085**
Total (without total program required subsidy)	**8.632**	
B. Solar Home System *fee-for-service* Program		
A. Baseline study	0.050	
B. Service provider selection	0.025	
C. Awareness campaign	0.015	
D. Financing		
• Required subsidy (capital cost)		
Program 5*	2.275	
Program 7*	1.526	
• Hardware costs (total)		
Program 5*		5.353
Program 7*		3.869
E. Technician's training	0.020	
F. End-user training	0.050	
G. Formation of end-user's group	0.020	
H. Monitoring and evaluation	0.020	
Total	**4.001**	**9.222**
Total (without total program required subsidy)	**0.200**	
C. Solar Lamp *Sales* Program		
A. Financing institution preparation	-	
B. Local market survey and social preparation	-	
C. Awareness campaign	0.010	
D. Financing		
• Required subsidy (50% of the market potential – all programs)	0.773	
• initial funding to be allocated for Program 2 and 4 (this amount will be recovered)	1.305	
• hardware cost (50% of the market potential – all programs)		4.641
E. SL procurement	0.005	
F. Technician's training	0.005	
G. Monitoring and evaluation	0.010	
Total	**2.108**	**4.641**
2. ACTION PLAN TO PROVIDE ENERGY SERVICES TO SOCIAL INFRASTRUCTURES		
A. Partnerships with concerned Ministries	-	
B. Baseline study	0.075	
C. Service provider selection	0.025	
D. Awareness campaign	0.015	
E. Financing		
• Program 1*		[11.07]
Health centers		1.24
Schools		3.55
Mosques		4.17
Check points		2.55
• Program 2*		[5.73]
Health centers		0.85
Schools		2.31

Mosques		2.57
• Program 3*		[3.24]
Health centers		0.49
Schools		1.29
Mosques		1.47
• Program 4*		[30.40]
Health centers		4.38
Schools		12.52
Mosques		13.14
F. Technicians' training and accreditation	0.030	
G. End-users' training	0.030	
H. Monitoring and evaluation	0.030	
Total	**0.205**	**50.08**
3. ACTION PLAN TO PROMOTE WIND-DIESEL SYSTEMS		
A. Wind Measurement (6 stations)	0.100	
B. Baseline Study (23 sites)	0.075	
C. Feasibility Studies (	0.075	
D. Capacity Building	0.030	
E. Program 2A		5.775
Program 2B		4.200
Program 2C		2.100
Total	**0.280**	**12.075**
TOTAL	**19.562**	**91.103**

2 Rural Electrification Policy

Access to electricity services in Yemen is among the lowest in the Arabian Peninsula. In 2005, only 39 percent of the households throughout the country are connected to national and rural electricity grids. At present, more than 1.7 million households have no access to modern electricity services.

The Government is committed to expand the provision of electricity services in rural areas. In 2006, the Government issued the Power Development Strategy Note which identifies the development of a National Rural Electrification Strategy as one of the main interventions to support medium- and long-term economic development.

In a recently completed National Rural Electrification Strategy Study, a National Rural Electrification Policy was being proposed, and currently, being considered by the Government. The aim of the of the Policy is to assure the necessary expansion of rural electric coverage, providing service to the maximum number of rural households at the lowest cost possible, consistent with the Government's aim to provide universal access to electricity services.

The principles and components of proposed policy are the following:

- establishment of a new and independent electrification agency
- establishment of commercially viable service territories
- assure community participation in provision of electric service
- assure program sustainability by setting tariffs to meet cost of service
- REA expansion plan will be composed of projects that are economically viable
- renewable off-grid projects will be included in the national electrification expansion plan
- employment of new and least cost construction standards to maximize program impact and lower costs.

As shown above, the proposed national rural electrification strategy recognizes the potential role of renewable energies in improving electricity services in rural communities in the country.

This study elaborates a national strategy for off-grid rural electrification with the objectives of increasing access to electricity services in off-grid areas and alleviating poverty and improving the quality of life of the population in remote communities in a least-cost and sustainable manner.

Key elements of the study are the following:

- identification of off-grid and marginal areas
- assessment of supply options in marginal areas
- elaboration of strategy promoting a market-based and decentralized approach to off-grid electricity services.

3 Rural Electrification Areas

Rural electricity markets in Yemen are categorized by the National Rural Electrification Strategy Study into the following:

- grid-connected areas served by providers other than PEC and large enough for the utilities to become financially viable,
- isolated, or off-grid, service areas that are either too small, too remote, or areas that are economically depressed and cannot be configured into financially viable service territories but could be best served by conventional energy systems; and,
- isolated, off-grid service areas that can only be served with renewable energy technologies.

This section focuses on the third market segment, electrification of rural areas by renewable energies. To demarcate off-grid areas from grid areas, the study reviews the current areas covered by the PEC Distribution Expansion Plan and the areas included in the 27 service territories to be established under the National Rural Electrification Strategy.

3.1 Grid areas

3.1.1 PEC Distribution Expansion Plan

The Public Electricity Corporation is the main agency responsible for power generation, transmission and distribution in the Republic of Yemen. In 2005, PEC serves more than 1.1 million consumers in 20 Governorates through centralized electricity supply or isolated generation systems accounting around 40 percent of total number of dwellings (*Table 3-1*).

At present, PEC is committed to increase access to grid electricity services of rural population in the country. In accordance to the Electricity Master Plan, PEC recently carried out a study to supply electricity in local areas either through isolated diesel power generation or distribution network expansion from 2006-2020. The Government has also secured financing for these rural electrification projects. This distribution projects will cover the following Governorates and areas as well as target number of consumers shown in *Table 3-2* and *Figure 3-1*.

Table 3-1: PEC consumers and electrification rate in 2005

Governorate	Consumers	% of consumers with respect to total number of dwellings
Capital city	221,323	87.23
Sana'a Gov.	52,312	44.56
Aden	111,065	122.39
Taiz	122,688	33.25
Hoddidah	85,797	24.58
Ibb	110,460	36.11
Dhamar	68,491	36.44
Sadah	11,396	13.38
Hajja	19,882	10.16
AL- Baida	31,342	46.49
AL- Mahweet	16,354	23.64
Mareb	7,216	25.79
Amran	23,048	21.65
AL-Jawf	847	1.35
Abian	34,942	59.43
Hadhramout	124,648	100.01
AL- Dhalae	25,040	41.79
Lahjj	26,546	25.17
Shabwah	21,302	40.04
AL- Maharah	6,988	48.94
Raimah	-	-
Total	**1,121,687**	**40.62**

Source: PEC Commercial Activities Report 2005

Table 3-2: PEC Distribution Expansion Plan 2006-2020

Governorate/Areas	Number of residential consumers to be connected
Ma'reb Governorate	14,810
Al-Jawf Governorate	18,250
Sa'adah Governorate	79,201
Al Baida	62,483
Al Dhalee	62,928
Shabwa Governorate	53,406
Al-Mahara Governorate	11,026
Habilin-Laboos	53,851
Central Tehama	149,824
Jabal Asharq District and Surrounding Areas (Dhamar Governorate)	63,744
Jabal-Habshi, Mowasit, and Maweah Districts (Taiz Governorate)	39,266
Power IV Project – Phase II (Amran Governorate)	28,123
TOTAL	636,912

Source: Distribution Projects NEPCO Report 2006.

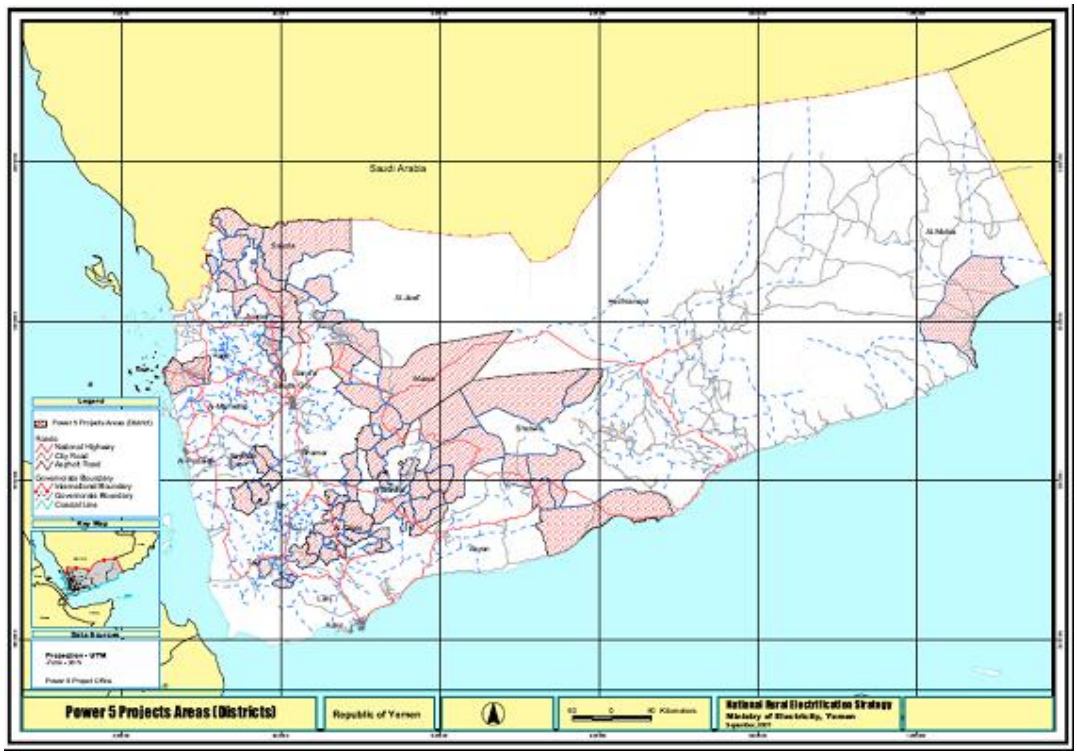

Figure 3-1: Areas to be covered by the distribution expansion plan 2006-2020

3.1.2 Grid-Based Service Territories

The National Rural Electrification Strategy Study identified and proposed the development of 27 grid-based service territories in 12 Governorates of the country. This proposed service territories are shown in *Table 3-3* and *Figure 3-2*.

Key criteria employed by the said study in the formation of service territories are the following: i) interconnection of existing rural electric systems to achieve a minimum of 10,000, but no more than 40,000 consumers, ii) immediate expansion of service territory to connect rural communities within a buffer of approximately ten kilometres, iii) consolidation of isolated distribution systems through interconnection, and to either provide power through interconnection to the national transmission system, or to consolidate power generation in a single, larger power plant, and, iv) creation, where possible, of no more than four service territories per governorate, unless the above criteria cannot be satisfied.

Two main screening criteria were used in the study to demarcate this market segment, and these are: i) load concentration, and ii) distance from the grid interconnection point.

Table 3-3: Proposed service territories and off-grid areas

Governorate	Number of Service Territories
Abyan	1
Aden	Urban-none
Amran	2
Al Baidah	2
Al Dhale	1
Al Hodeidah	3
Al Mahra	None
Al Mahweet	1
Al Jawf	None
Dhamar	2
Hadramout	None
Hajjah	2
Lahj	2
Ibb	4
Mareeb	None
Raimah	None
Sa'ada	None
Sana'a	3
Sana'a City	Urban-none
Shabwa	None
Taiz	4

Source: National Rural Electrification Strategy Study, NRECA, 2006.

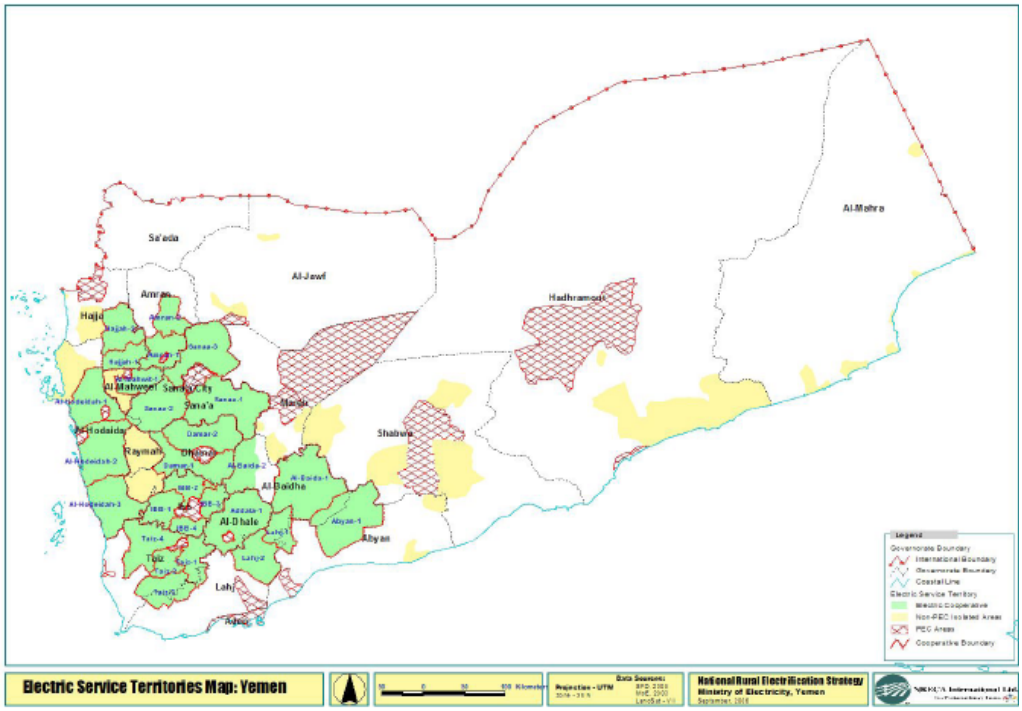

Figure 3-2: Proposed grid-based and off-grid service territories in Yemen

3.2 Off-Grid Areas

Based on the recommendations of the National Rural Electrification Strategy Study, off-grid areas in Yemen could be classified into the following:

- Un-served districts and villages of the proposed off-grid service territories in 7 Governorates
- Areas that will not be served under the proposed service territories in 12 Governorates

3.2.1 Off-Grid Service Territories

This consists of 7 Governorates that will not be covered by the proposed service territories. These Governorates are the following: Abyan, Al-Jawf, Al-Mahra, Marib, Shabwa, Hadramout, and Raymah. Some districts and large villages of these Governorates are however currently being served by either PEC or non-PEC isolated grids. The study focuses on unserved districts of these Governorates.

On the other hand, 5 of these governorates are also included in the PEC Distribution Expansion Plan programmed for the period 2006-2020. Districts that will not be supplied with grid electricity will be however relatively small. This is summarized in *Table 3-4*.

Table 3-4: Off-grid service territories and PEC Distribution Expansion Plan, 2006-2020

Governorate	Current Status	PEC Distribution Expansion Plan	Remarks
Al-Jawf	2 districts served by PEC 4 districts served by isolated non-PEC 6 districts are unserved	PEC plans to expand and develop the distribution network covering 5 main regions (Wadi Khabb, Rajozzeh, Assarhat, Alyoutmeh, and Hazem Al Jawf) covering around 358 villages and 18,250 households (2006 data)	Practically the PEC plan will cover all villages in Al Jawf Governorate. The SFD database shows that there are currently 366 villages in Al-Jawf Governorate.
Al-Mahara	6 districts are partly served by isolated non-PEC network 3 districts are unserved	PEC plans to expand electricity services in six districts, Qishn, Shahan, Sayhut, Hawf, Al Ghaydah and Huswain targeting a total of 11,026 households.	Three districts will not be covered by the grid expansion plan: Almasilah, Manar and Hat.
Hadramout	7 districts are served by PEC 5 districts are served by isolated non-PEC networks 18 un-served districts	None	Off-grid districts include the following: Adh Dhlia'ah, Al Abr, Al Mukalla, Amed, As Saoum, Broom, Daw'an, Hagr As Sai'ar, Hajr, Houdaibo, Qhail Ben Yameen, Qof Al Awamir, Qulansiyah, Rekhyah, Rumah, Thamud, Yabauth, Zamakh and Manwakh. Parts of Sah and Gail Ba Wazer will not be covered by grid electricity.
Marib	3 districts are served by PEC 3 districts are served by isolated non-PEC networks 8 districts are unserved	PEC plans to expand the distribution network covering all the districts and 440 villages with additional 14,810 target consumers.	The SFD database registers around 448 villages in Marib Governorate, thus the PEC will cover almost all of the villages.
Sa'dah	Isolated generation in some districts with large coverage in Sa'dah, Sahar and Qitabir	PEC's expansion plan covers almost all of the districts and targets around 79,000 consumers.	A small number of villages will not be covered by the plan but most of the districts will be included in the network expansion. The 2004 census registers 81,568 households in the Governorate.
Shabwa	3 districts are served by PEC	PEC programs to expand and provide grid-	The 2004 census registers 53,082

	7 districts are partly served by isolated non-PEC network 7 districts are unserved	connected electricity services to all 17 districts targeting around 53,406 consumers.	households in these districts. Thus, the PEC plan will cover most of the villages in the Governorate.
Raimah	Isolated generation systems are currently partly supplying electricity in 2 districts, As Salafiyah and Al Jabin.	Three districts will be covered by the PEC Distribution Expansion Plan, As Salafiyah, Al Jabin, Kusmah and Mazhar.	Two districts are not covered by the planned PEC expansion: Bilad at Ta'am, and Al Jafariyah.

3.2.2 Unserved Areas in Service Territories

Some of the proposed service territories under the National Rural Electrification Study could however not supply grid electricity services in all of the districts and villages within the specified territory. The Governorates with pockets of unserved areas are the following: Abyan, Al Baida, Lahj, Taiz, Al Hodeidah, Dhamar, Al Mahwit, Hajja, and Amran.

The current status, PEC Expansion Plan in these areas, and the proposed service territory coverage are summarized in *Table 3-5*. These could be targeted for rural electrification by renewable energies.

Table 3-5: Districts/villages that will not be covered in the proposed service territories

Governorate	Current Status and PEC Expansion Plan	Proposed Service Territory Coverage	Remarks
Abyan	Zungobar and Khanfir (partly) are served by PEC network while parts Ahwar and Al Mahfad are served by non PEC distribution systems.	4 districts (Jayshan, parts of Lauder, Al Wadea, and Modiyah) are to be covered by Abyan-1. 2 districts (Rosod and Sarar) will be served by Lahj-1.	Parts of Ahwar, Al Mafhd, Khanfir, Lawder as well as the whole districts of Sarar and Sibah will not be supplied under the proposed service territories and PEC.
Al-Baida	Isolated non-PEC distribution systems are currently serving major cities and towns	Al Baida-1 will cover 9 districts (Al Bayda, Azzaher, Asswadiyah, Asswmah, Attafah, Al Malajem, Thi Na'em, Radman, Al Bayda City) and Al Baida-2 will serve 5 districts (Al Ryashiyah, Al Arsh, Al Qorayshiyah, Rada'a, Sabah). The district of Mookayras will be part of Abyan-1.	5 districts (Ashsharyah, Maswarh, Natea, Noman, Wald Rabee) will not be covered by the proposed service territories.
Lahj	PEC distribution system is currently serving 2	Lahj-1 will cover Al Had, Yafaa, Al Muflehe and	4 districts (Al Qabaytah, Al Musaymer, Al Madaribah and Al Arah,

	districts (Al Hutah and Tebn)	Yaher, while Lahj-2 will serve Halmin, Habil Jabr, Radfan and Al Milah.	Toor Al Bahah) will not be covered by the proposed service territories.
Taiz	PEC is currently providing services in Al Qahirah, Al Muka, Al Mudafar, Salah. The PEC expansion plan will cover Al Mawaset, Jabal Habashi, Mawiyah.	Taiz-1 will cover Asselwo, Hayfan, Khadeer, Mawiyah. Taiz-2 will include Al Misrakh, Al Mafer, Jabal Habashi, Sa'me, Saber Al Mwadem, Mashra'ah and Hadnan. Taiz-3 will supply services to Ashshmayeetain, Al Mawaset, Al Waziyah. Taiz-4 wil cover Attaizyah, Shara'ab Arrawnah, Shara'ab Assalam, Makbanh, Mawza.	A number of villages in Al Mocha district as well as Bab Al Mandab are not served and will not be covered by the proposed service territories. Districts covered under PEC expansion will be integrated into the proposed service territories.
Al Hodeidah	PEC is currently serving parts of Al Hawak and Bajel. PEC expansion plan for Tehama includes Allohayah and Azohrah.	Al-Hodiedah-1 will provide service to Azzaydiyah Addahi Al Qanawes Al Mighlaf Bajel. Al-Hodiedah-2 will cover Addorayhimi Assokhnah Al Marawiah Al Mansuriyah Bara Bayt Al Faqih. Al-Hodiedah-3 will incldue Attahyta Al Jarahi Al Khokhah Jabal Rass Hayss Zabid.	Districts that will not be covered by electricity services are Assalif, Al Munirah and Kamaran.
Dhamar	PEC is currently supplying electricity services in Dhamar City. Programmed PEC expansion covers Jabal Asharq, Utmah, Wusab Assafil and Wusab Al A'ali.	Dhamar will be supplied by PEC (Dhamar City) and Dhamar-1 and Dhamar-2. Only 2 districts, Wusab Assafil and Wusab Al A'ali, will not be covered by the service utilities. These 2 districts however is included in the programmed PEC expansion.	All districts of Dhamar will be provided electricity services by PEC and the proposed 2 service territories.
Al Mahwit	Al Mahwit City is currently supplied with electricity services by PEC.	1 service territory is proposed for Al Mahwit covering 5 districts Arrojom, Attawilah, Hafash, Shibam	3 districts, Al Khabt, Milhan, and most part of Bani Sa'd will not be covered by be the proposed service

		Kawkaban, and Al Mahwit.	territory.
Hajja	PEC is serving the district of Harad. PEC programmes to increase services in Harad and expanding supply to Abs, and down to Aslm, Al Magrabah, Mabyan and Shars districts.	2 services territories are being proposed: Hajjah-1 and Hajjah-2 which covers around 23 districts. Most of the target districts of PEC expansion will be integrated in the proposed service territories.	5 districts will not be included in both PEC expansion plan and proposed service territories: Bakil Al Mir, Mustaba, Wash'hh, Qarah, Hayran, and Midi.
Amran	PEC is providing services to Amran City and Jaba Iyal Yazid. PEC Expansion Plan includes development from Habab, Raydah, Khammer, Houth and Harf Sufyan.	2 service territories, Amran-1 and Amran-2, are being proposed which covers 9 districts. Target districts of PEC Expansion Plan will be integrated in these 2 territories.	7 districts are designated as off-grid areas: Al Oshah, As Sudah, Al Madan, Shiharah, Suwayr, Thulymat Habur, Al Qaflah. Parts of Harf Sufian will not also be covered by grid-electricity.

3.2.3 Off-Grid Districts and Villages

Despite the proposed aggressive grid rural electrification in the country (combination of service territory development and PEC distribution network expansion), there remains around 54 districts in 11 Governorates that are not targeted for grid electricity services. These off-grid areas, shown in *Table 3-6* and *Figure 3-3* could be supplied with renewable energies.

These districts are estimated to have around 1.6 million inhabitants, representing around 8 percent of the total population of Yemen in 2004 (*Figure 3-4*). Governorates with high number of off-grid population are Hadramaut, Lahj, Al Mahwit and Amran.

At present, these areas encompass around 6,276 villages. As shown in *Table 3-7*, most of these villages have however low population density. More than 60 percent of the total villages have less than 50 households. Also, many larger villages with more than 100 households are already part of an urban agglomeration.

Table 3-6: Off-grid areas taken into account the proposed service territories and PEC Distribution Expansion Plan

Governorate	Off-Grid Districts
Off-Grid Service Territories	
Al-Mahara	Districts of Al Masilah, Manar, and Hat
Hadramout	Districts of Al Mukalla, Broom, Adh Dhlia'ah, Al Abr, Amed, As Saoum, Daw'an, Hagr As Sai'ar, Hajr, Houdaibo, Qhail Ben Yameen, Qof Al Awamir, Qulansiyah, Rekhyah, Rumah, Thamud, Yabauth, Zamakh and Manwakh. Parts of Sah and Gail Ba Wazer will not be covered by grid electricity.
Raimah	Districts of Bilad at Ta'am, and Al Jafariyah.
Service Territories	
Abyan	Districts of Khanfir and Sibah, although parts of Ahwar, Al Mafhd, Khanfir, Lawder not be supplied under the proposed service territories and PEC.
Al Baida	Districts of Ashsharyah, Maswarh, Natea, Noman, Wald Rabee
Lahj	Districts of Madaribah and Al Arah, Toor Al Bahah, Al Qabaytah, Al Musaymer
Taiz	A number of villages in Al Mocha and Bab A Mandab
Al Hodeidah	Districts of Assalif, Al Munirah and Kamaran
Al Mahwit	District of Al Khabt, Milhan, and most part of Bani Sa'd
Hajja	Districts of Bakil Al Mir, Mustaba, Wash'hh, Qarah, and Midi
Amran	Districts of Asswdah, Al Madan, Shiharah, Suwayr, Thulymat Habur, Al Qaflah. Parts of Harf Sufian will not also be covered by grid-electricity.

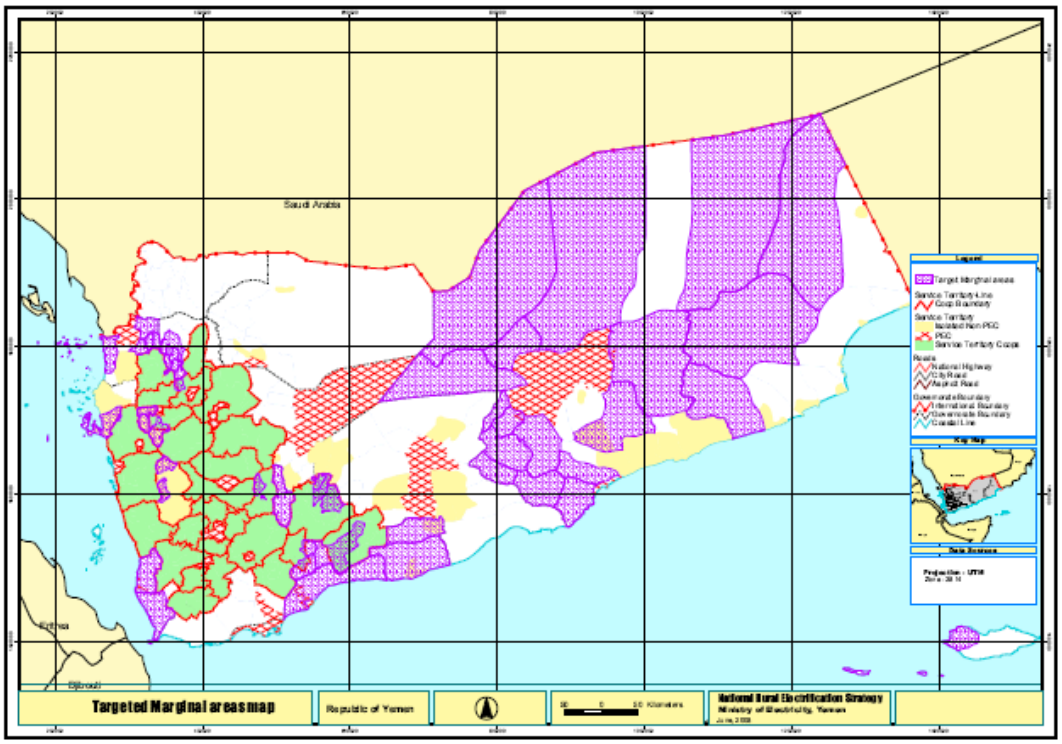

Figure 3-3: Off-grid areas

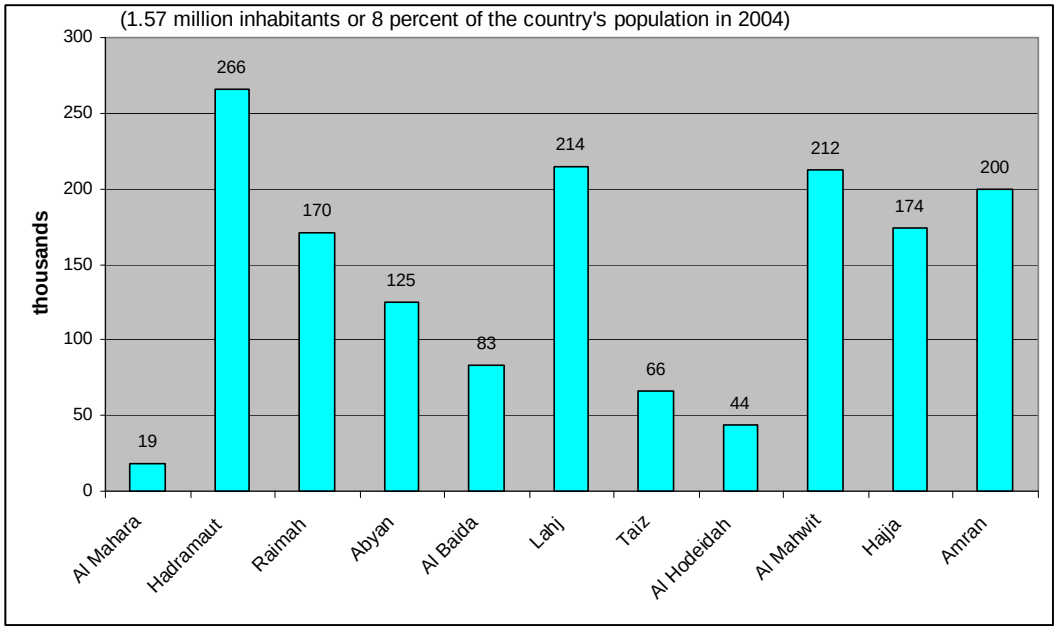

Figure 3-4: Off-grid area population in 2004

Table 3-7: Number of villages by household size distribution category

Governorate	number of villages by household size distribution						
	< 50	**50-100**	**101-150**	**151-200**	**201-300**	**301-450**	**> 450**
Al-Mahara	75	2	2	2	1	0	0
Hadramout	1783	138	41	13	17	5	2
Raimah	51	110	28	12	4	4	0
Abyan	298	15	6	0	1	0	1
Al Baida	223	63	13	2	3	2	0
Lahj	670	51	15	6	10	4	2
Taiz	8	2	4	1	7	6	12
Al Hodeidah	29	17	6	8	1	4	4
Al Mahwit	168	175	78	32	12	3	2
Hajja	386	101	12	12	5	7	5
Amran	286	139	339	166	376	180	8
TOTAL (percent)	**3977** (63%)	**813** (13%)	**544** (9%)	**254** (4%)	**437** (7%)	**215** (3%)	**36** (1%)

4 Energy Supply Options for Off-Grid Areas

4.1 Resources

Solar and wind energies, as presented in the resource assessment component of this study, are the two main renewable energy resources in Yemen that could potentially supply and sustain large scale energy services in the identified off-grid areas.

The resource potential for solar and wind energies are shown in Figures 3.2 and 3.3. Yemen's average solar radiation is ranges from 5.2 to 6.8 kWh/m^2/day. Solar energy resource in the country is not site specific and the average solar radiation is sufficient to power small-scale and individual solar energy technology systems.

Wind energy potential in Yemen is significantly high and, as discussed in the resource assessment study, can sustain large scale power generation. Wind energy resources in Yemen are however highly site-specific. Areas with favourable wind regimes are found mainly in the coastal areas and in the Highlands. These resources, however, need to be further investigated and validated on site. Additional wind measurement activities are needed to be undertaken in high potential villages and measurement stations must be erected in sites where wind power generation is to be located.

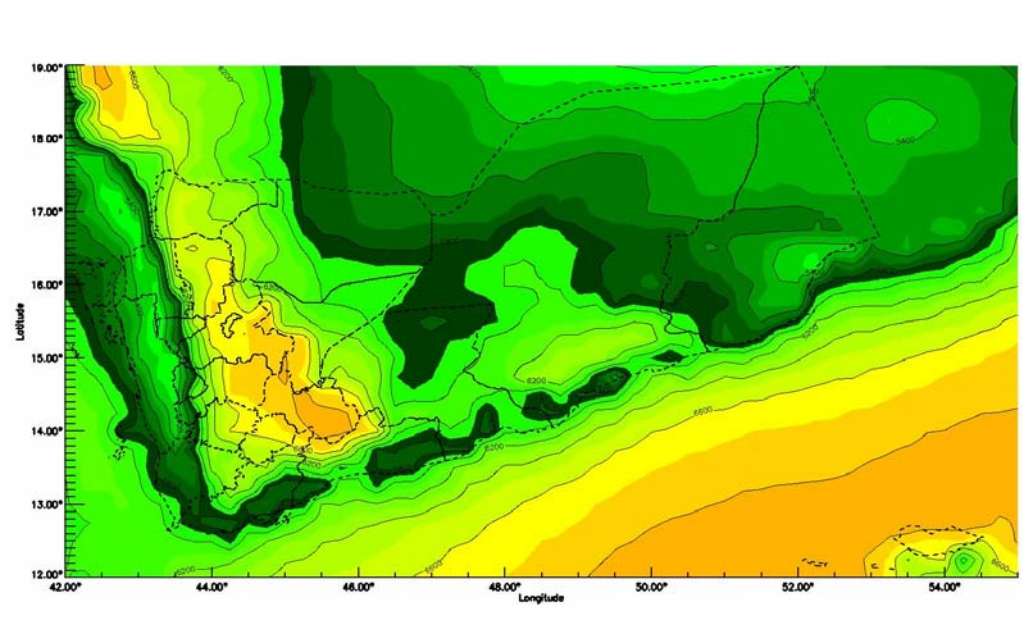

Figure 4-1: Average solar radiation in Yemen

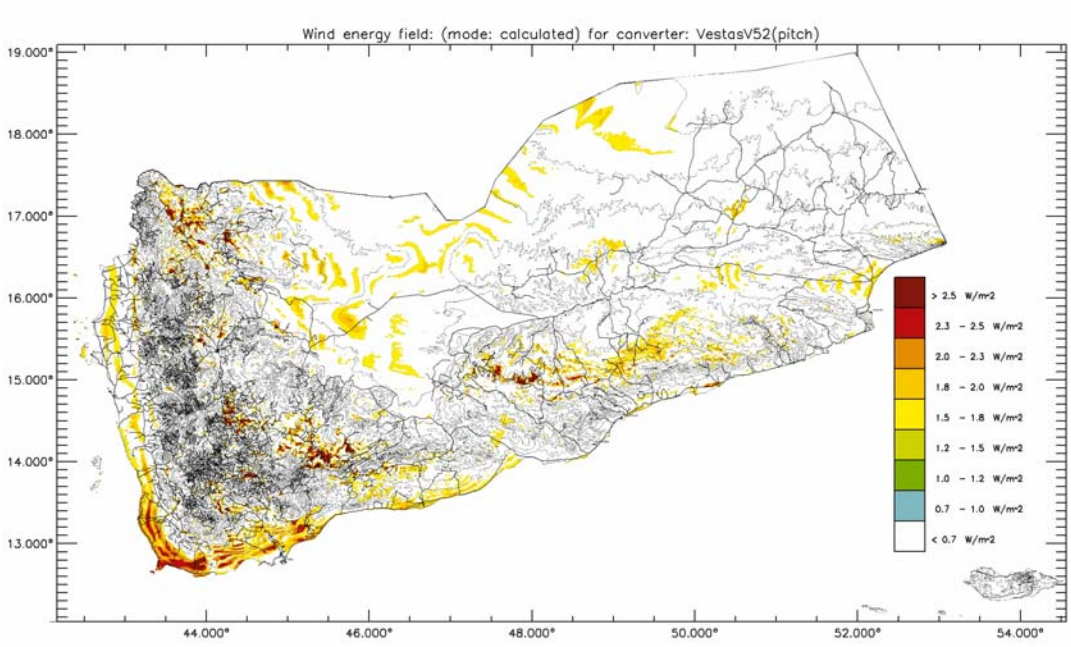

Figure 4-2: Wind energy resource potential

4.2 Technologies

This section reviews technical options for electricity services in the identified off-grid rural areas. The study focuses only on mature technologies that could be readily employed to provide services in these areas.

4.2.1 Solar Energy Technologies

Among the solar energy technologies, solar photovoltaic systems are the most appropriate and reliable technology for off-grid rural electrification. For residential sector, the solar home system (SHS) is the mainstay technology for remote communities.

The basic design of the SHS includes only a PV panel, a battery, wiring, and a few electric loads (e.g. fluorescent compact lights, radio and a TV). Often, but not always, systems also include safety features such as fuses and disconnect switches. Many systems also include a charge controller (to protect the battery from overcharging), low voltage disconnect (to protect the battery from damage by deep discharges), meters to measure current and voltage in the system, and other components. The typical system layout for SHS is shown in *Figure 4-3*.

SHS is sufficient to meet electricity needs for lighting and entertainment of individual households. This technology is also appropriate for villages with low population or household densities.

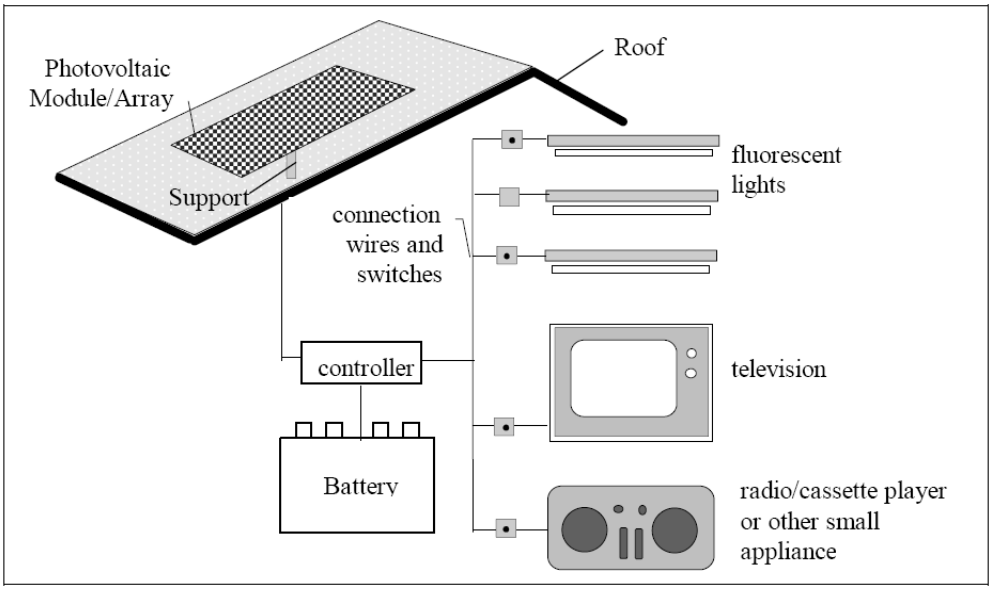

Figure 4-3: SHS Basic Layout

4.2.2 Wind Energy Technologies

The grid-based component of this study recommends large scale development of wind power generation using large scale wind turbine generators. For off-grid areas and remote communities, the most viable option for wind energy technologies is the stand alone wind hybrid systems.

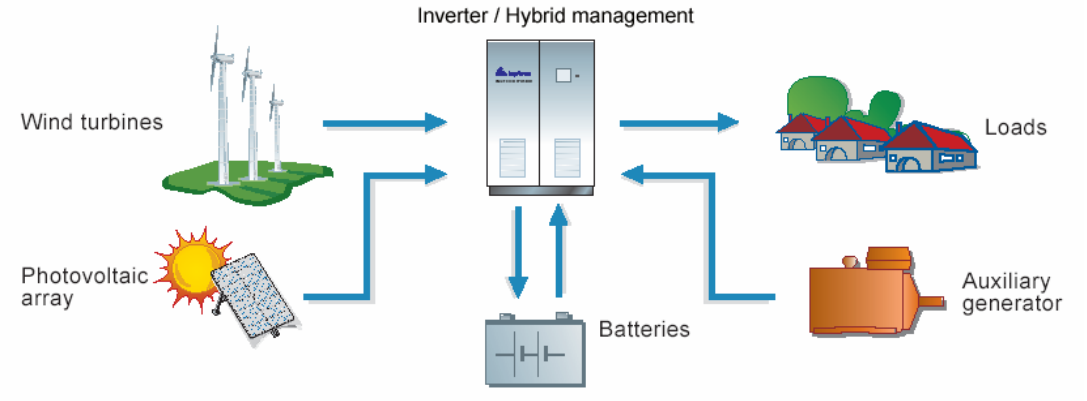

Figure 4-4: Stand alone wind hybrid system

An option for large villages in Yemen (with more than 400 households) is the installation of isolated stand alone systems including one or more wind turbines, a small sized diesel generator, and a battery bank for energy storage (*Figure 4-4*).

The wind diesel hybrid system is modular and extendable with regard to the basic energy need and the medium-term development of population and electricity consumption. An inverter with a flexible power range will manage the battery charging and the automatic regulation of the auxiliary generator.

4.3 Supply options

Based on the availability of renewable energy resource and technology, energy service supply options for identified off-grid areas in Yemen are summarized in *Table 4-1*. The table shows that solar energy is the most viable resource and solar PV systems, particularly the solar home systems which could be immediately exploited to provide electricity services in these areas.

Further investigations (wind measurements in specific areas) are needed to establish the viability of wind energy resource in the identified off-grid areas. In addition, taken into consideration the village size distribution of the off-grid areas, the market potential for wind hybrid systems in off-grid areas is very limited. This is shown in *Table 4-2*.

This study therefore recommends to immediately carry out provision of electricity services in off-grid areas using solar home systems. For areas with potential for wind hybrid options, additional wind measurement and verification campaign could be initiated.

Table 4-1: Resource and technology options for off-grid areas in Yemen

Off-grid Areas	**Renewable Energy Resources**		**Renewable Technology Options**	
	Solar	**Wind**	**Solar PV**	**Wind-Diesel Systems**
Al-Mahara				
• Al Masilah (w. coastal))	high	low coastal*	yes	not likely
• Manar, and Hat (inland)	high	-	yes	not likely
Hadramout				
• Al Mukalla, Broom (w. coastal)	high	medium to high*	yes	potentially*
• Adh Dhlia'ah, Al Abr, Amed, As Saoum, , Daw'an, Hagr As Sai'ar, Hajr, Houdaibo, Qhail Ben Yameen, Qof Al Awamir, Qulansiyah, Rekhyah, Rumah, Thamud Yabauth, Zamakh and Manwakh	high	low*	yes	not likely
Raimah				
• Bilad at Ta'am, Al Jafariyah and Mazhar (inland)	High	-	yes	-
Abyan				
• Khanfir (w. coastal)	high	medium to high	yes	potentially*

• Ahwar, Al Mafhd, Sibah, Lawdr and Sarar (inland)	high		yes	-
Al Baida • Ashsharyah, Maswarh, Natea, Noman, Wald Rabee (inland)	high	low highland*	yes	not likely
Lahj • Madaribah and Al Arah (w. coastal) • Toor Al Bahah, Al Qabaytah, Al Musaymer (inland)	high high	high medium	yes yes	potentially potentially*
Taiz • Parts of Al Mocha and Bab A Mandab (w. coastal)	high	high	yes	potentially*
Al Hodeidah • Assalif, Kamran and Al Munirah (w. coastal)	High	medium*	yes	potentially*
Al Mahwit • Al Khabt, Milhan, and Bani Sa'd (inland)	high	-	yes	-
Hajja • Bakil Al Mir, Mustaba, Wash'hh, Qarah, and Midi (inland)	high	low*	yes	not likely
Amran • Asswdah, Al Madan, Shiharah, Suwayr, Thulymat Habur, Al Qaflah (inland)	high	-	yes	-

Note: geographic location and resource matching were based on solar and wind atlas developed by the study.

* needs further wind measurement and investigation

Table 4-2: Village supply options

Marginal Districts	Number of Villages by Household Size Distribution						
	< 50	**50-100**	**100-150**	**150-200**	**200-300**	**300-450**	**> 450**
Districts with coastal areas (Al-Mahara, Hadramout, Abyan, Lahj, Taiz, Al Hodeidah, Hajja)**	3249	326	86	42	42	26	26
	Individual units (Solar Home Systems and Solar Lanterns)						Wind-diesel systems*
Inland districts (Raimah, Al Baida, Al Mahwit, Amran)	728	487	458	212	395	189	10
	Individual units (Solar Home Systems and Solar Lanterns)						Individual systems or isolated diesel-based network

* wind resources need further investigations and measurements

** some of the districts are situated inland, thus the number of villages that can be potentially developed for wind-diesel systems may be overestimated. Further analysis will be given in the following sections.

5 Market Potential for Solar Photovoltaic Systems in Off-Grid Areas

Resource and technology screening for the identified areas presented in the previous section indicates that solar energy resources and technologies are the most appropriate technologies for the remote and isolated villages. Some specified areas, wind-diesel systems may be appropriate but this requires further wind resource investigations and measurements. This Chapter proposes to focus electricity service provision in these areas through solar photovoltaic systems and estimates the market potential for these technologies.

5.1 Target households

5.1.1 Screen 1: Household Density

Of-grid areas, as identified in Chapter 3 of this study, cover more than 6,200 villages in more than 50 districts in 11 Governorates throughout the country. These areas constitute around 8 percent of the total population in 2004.

With respect to the number of households, these marginal areas register more than 240 thousand households in 2005. The total number of households by village size category in shown in *Figure 5-1*.

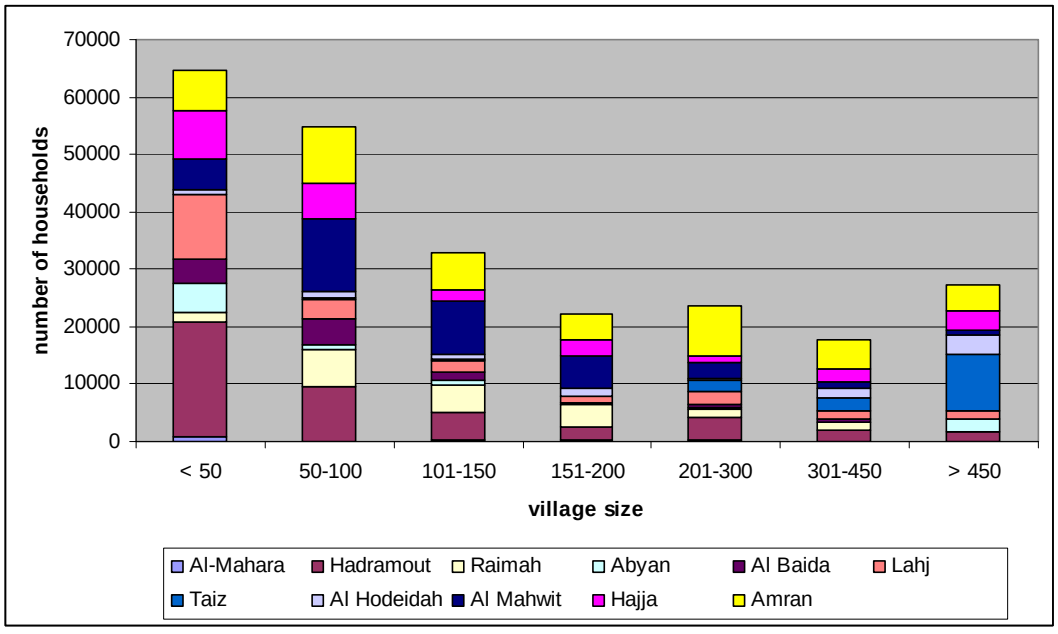

Figure 5-1: Number of households by village size

To initiate rural electrification by SHS in the off-grid areas, a number of villages need to be prioritized for initial development. The screening criteria to prioritize villages must be consistent with the overall goals of off-grid rural electrification. As defined earlier, one of the main objectives of off-grid rural electrification is to kick start a national market for SHS. Initial projects should operate as market catalyst and sustain the development of the solar PV market.

SHS projects do not only require technology dissemination but also support mechanisms such as awareness campaign, users and technician training, repayment collection set-up scheme, development of micro financing schemes, etc. This could be financially sustainable if the transactions costs in undertaking these support mechanisms are low. This could be efficiently carried out in high density villages (large number of households) than those with sparsely distributed households.

Villages with less than 50 households could be initially screened out for off-grid rural electrification due to high costs in the provision services. The total number of households in villages with household density of less than 50 represents only 27 percent of the total households (*Table 5-1*).

Villages with large number of households must be given higher priority due to high economies of scale in the provision of support services. The study recommends to target villages with more than 50 households. These villages represent more than 70 percent of the total number of households in the identified off-grid areas or almost 180 thousand households in 2005.

Table 5-1: Screen 1 - number of households by village size category

Governorate	number households						
	< 50	**50-100**	**101-150**	**151-200**	**201-300**	**301-450**	**> 450**
Al-Mahara	941	140	212	364	230	0	0
Hadramout	19835	9546	4889	2229	4114	1864	1577
Raimah	1610	6305	4836	3779	1236	1426	0
Abyan	5034	957	712	0	211	0	2453
Al Baida	4439	4363	1526	313	664	773	0
Lahj	11088	3468	1837	1055	2360	1331	1244
Taiz	172	145	461	188	1869	2316	9911
Al Hodeidah	794	1316	759	1435	272	1570	3252
Al Mahwit	5320	12573	9301	5521	2943	1014	905
Hajja	8311	6261	1841	2767	885	2489	3470
Amran	7227	9683	6541	4688	8751	4934	4464
TOTAL	**64771** (27%)	**54757** (23%)	**32915** (14%)	**22339** (9%)	**23535** (10%)	**17717** (7%)	**27276** (11%)

Note: households in villages with household density of less than 50 may be the least priority for solar PV rural electrification due to lack of economies of scale in the provision of services for repair and maintenance.

5.1.2 Screen 2: Poverty

Sustainability is one of the key objectives pursued in the National Rural Electrification Strategy Study. Economic and financial sustainability were the main criteria used in identifying and proposing grid-based service territories.

This objective is also crucial for the off-grid rural electrification since the nationwide replication of off-grid electrification projects hinges on successful implementation of initial or pilot demonstration projects.

Off-grid projects would be most likely to succeed and sustained in villages with higher ability to pay for energy services. Thus, in addition to high household clusters discussed earlier, candidate villages considered for initial development could be further screened out based on average income levels.

Villages with high average household income require minimal financial support. This financial support would most likely go to the poorer households in the village since affluent members have the ability to pay for their energy services. Also, villages with high share of affluent households could partially subsidize the ancillary services of poorer households.

After excluding the number of villages with less than 50 households, the study disaggregated the number of households according to village poverty index level. *Figure 5-2* shows the share of households by village poverty index level in each Governorate. Governorates with high rate of poverty (more than 50%) are Hajja, Al Mahwit and Taiz while Raimah and Amran have close to 50 percent share.

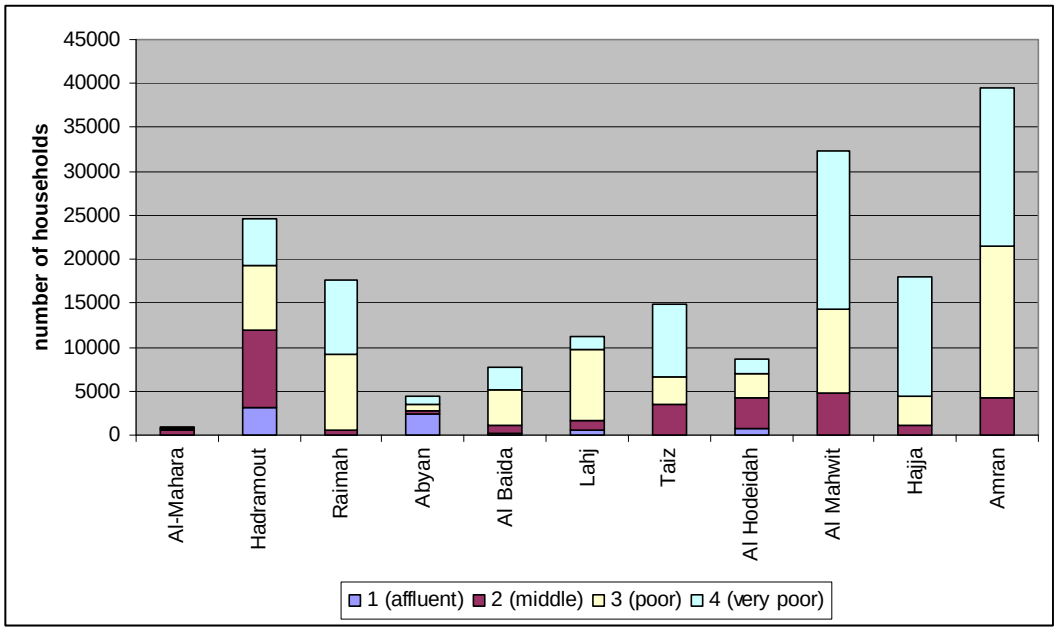

Figure 5-2: Number of households by village poverty index level

The total number of households in villages classified as very poor constitutes around 44 percent of the total number of households. The study recommends to focus the initial off-grid rural electrification activities to villages classified as affluent (1), middle (2) and poor (3). This represents 56 percent of the households or around 101 thousand households in 2005. This is shown in *Table 5-2*.

Table 5-2: Village poverty level

Governorate	**Village Poverty Index Level**			
	1 (affluent)	**2 (middle)**	**3 (poor)**	**4 (very poor)**
Al-Mahara	0	504	199	243
Hadramout	3052	8808	7378	5431
Raimah	0	462	8753	8367
Abyan	2453	283	727	870
Al Baida	177	868	4144	2450
Lahj	468	1251	8058	1518
Taiz	0	3517	3040	8333
Al Hodeidah	812	3431	2768	1593
Al Mahwit	0	4702	9588	17967
Hajja	0	1136	3237	13576
Amran	0	4209	17311	17991
TOTAL	**6962** (4%)	**29171** (16%)	**65203** (36%)	**78339** (44%)

5.2 Household Electricity Use and Solar PV Systems

5.2.1 Household Energy End-use and Expenditures

Household energy end-use in rural areas in Yemen can be broadly classified into cooking, lighting, refrigeration, TV and ventilation (*Table 5-3*). Except for cooking, all other household end-use activities can be supplied with electricity. In rural areas where the electricity network coverage is not extensive, households use electricity substitutes to fuel these socio-economic end-use activities.

Table 5-3: Household end-use activities and fuel supply in Yemen

End-Use Activity	**Fuel Supply**
Cooking	Biomass, kerosene, LPG
Lighting	Electricity, kerosene, LPG, battery, dry cell
Refrigeration	Electricity, LPG
TV	Electricity, battery
Ventilation (fan)	Electricity, battery

Summarized from *Household Energy Supply and Use in Yemen* ESMAP, 2005.

Energy expenditures of rural households are shown in *Table 5-4*. These expenditures represent around 9%, in average, of the total household income, though the lowest household income decile group spends around 15% of their income for energy while the highest decile group spends only 7% of their income.

In average, around US$14 are spent monthly by rural households for energy services. Half of the energy expenditure is spent on fuels for cooking while the other half for electricity and its substitutes.

Table 5-4: Rural household energy expenditures

	decile										
Fuel Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**average**
Electricity, Grid	50	56	126	189	187	318	425	288	679	1018	306
Battery charging	13	11	15	8	26	13	26	27	37	41	21
Dry Cell	127	193	233	252	219	220	324	285	369	388	253
LPG											
LPG lighting	33	63	103	129	103	121	162	132	139	186	112
LPG fridge	0	0	1	1	11	7	1	17	3	4	4
LPG: cooking	286	418	483	479	554	604	734	560	823	959	571
Total LPG	319	481	587	609	669	732	897	709	966	1149	688
Candles	22	21	65	37	52	41	62	64	77	149	56
Self-gen											
Self-gen fuel	0	0	25	79	100	9	243	277	841	311	169
Self-gen maintenace	0	0	82	59	51	3	217	108	418	417	123
Repairs [annual/12]	0	0	34	1	44	16	17	91	73	211	45
Total self-gen	0	0	141	139	195	29	478	476	1333	939	337
Purchased self-gen	44	35	256	116	110	82	130	166	90	153	118
Kerosene											
Kero: lighting	232	237	186	206	163	177	203	182	122	131	187
Kero: cooking	137	171	180	220	150	140	129	127	145	136	154
Total kerosene	369	408	366	426	313	317	332	309	266	267	340
Biomass											
Fuelwood	238	273	233	252	150	332	221	309	249	415	263
Charcoal	16	35	14	43	38	39	62	50	85	164	51
Crop residue	1	22	18	28	11	0	4	2	24	45	15
Dung	0	2	3	2	3	1	0	1	1	0	1
Total biomass	256	332	268	326	202	373	288	361	359	625	331
Diesel	19	30	140	178	215	117	377	357	790	1708	355
Total energy	1219	1567	2197	2280	2188	2242	3339	3042	4966	6437	2805
Income	8320	15565	18157	18930	22654	27596	33146	32967	48985	90407	29743
Energy as % of income	15%	10%	12%	12%	10%	8%	10%	9%	10%	7%	9%
Expenditure related to cooking											
YR/month	698	951	1072	1204	1133	1241	1529	1422	2120	3432	1415
Expenditure related to electricity and lighting											
YR/month	521	616	1125	1076	1055	1001	1810	1620	2846	3005	1390
$/month	2.6	3.1	5.7	5.4	5.3	5.1	9.1	8.2	14.4	15.2	7.0
$/year	31.6	37.3	68.2	65.2	63.9	60.7	109.7	98.2	172.5	182.1	84.2

Source: *Household Energy Supply and Use in Yemen* ESMAP, 2005.

5.2.2 Electricity Use, Aspirations, and Willingness to Pay

Electricity in the residential sector is mainly used for lighting, entertainment (TV), refrigeration, and ventilation (electric fans). The ESMAP Household Energy Demand Survey carried out in 2003 identified electricity uses by social category. For affluent households, electricity is used for lighting, TV and refrigeration though in urban areas and lowlands, electricity is also used for space cooling (air conditioning) and ventilation (electric fan). For poor households, electricity is mainly used for lighting and television. Most of the very poor households are not connected to electricity though in urban areas some of the very poor households are connected to the grid and the main electricity use is for lighting (*Table 5-5*).

The survey also revealed that most of urban and rural households aspire, whenever possible, to have access to electricity services. Electricity services improve the quality

of life of rural population through better lighting conditions and being able to watch television. Respondents also stressed that electricity was an investment in the future as it allowed children to study in the evenings. In areas without electricity, respondents also highlighted that it could generate employment for youths, for example as mechanics repairing cars and charging batteries in mechanized repair shops, or as technicians repairing television sets, generators, or x-ray equipment in health centres.

Table 5-5: Use of electricity (where available) by social category and purpose

Location	Well-off	Poor	Very poor
Rural highland	Main source of lighting Television Refrigeration	Main source of lighting Television	Not connected
Rural lowland	Main source of lighting Television Refrigeration Fans	Main source of lighting Television	Not connected
Urban	Main source of lighting Television Refrigeration Fans/air-conditioning	Main source of light Television	Some households connected, used for lighting

Source: *Household Energy Supply and Use in Yemen* ESMAP, 2005.

Household's aspirations however need to be matched with the actual economic circumstances of the rural households and their willingness to pay for electricity services. Household's willingness to pay however could not be easily determined since according to ESMAP study, it requires information related to energy expenditures before and after electrification.

Insights on household's willingness to pay could be made from their expenditures on substitutes for electricity. *Table 5-6* shows the average household spendings, both rural an urban, covered in the ESMAP survey. Even households connected to the national grid, they also spend on goods substituting electricity. This reflects the quality level of electricity services by the national grid. The ESMAP study shows a monthly average of YR 779 (US$3.9) is spent for electricity substitutes by households with no access to electricity services.

Table 5-7 shows average household income and average household expenditure related to electricity and lighting. The table compares data from ESMAP and GTZ survey studies. The ESMAP data covers electricity and lighting expenditures in rural areas including those with access to the grid or diesel generation. The GTZ data covers only un-electrified households.

The ESMAP data shows that the very poor households spent around US$3 per month for electricity and lighting, the middle income group spent twice as much, while the upper income group spent six times than those by the very poor. A similar pattern is also observed in the GTZ survey results but the disparity of the expenditure is not as high as in the ESMAP study. This is explained by the fact that the ESMAP study includes electricity consumption and lighting while the GTZ survey only expenditures for electricity substitutes.

Table 5-6: Household spendings on electricity substitutes

	total	kerosene		batterycharging		dryCell		LPG lighting		LPGfridge		candles	
	[YR/m]	[YR/m]	[%HH]	[YR/m]	[%HH]	[YR/m]	[%HH]	[YR/m]	[%HH]	[YR/m]	[%HH]	[YR/m]	[%HH]
PEC national grid	307	134	36%	212	1%	224	53%	204	18%	594	0%	119	58%
at PEC urban tariff													
at PEC rural tariff													
PEC isolated system	499	149	64%	353	1%	304	71%	265	48%		0%	84	28%
Coop	407	191	66%	314	1%	257	58%	244	19%	484	6%	98	19%
Private	1043	162	91%		0%	607	100%	198	100%		0%	141	64%
total grid/minigrid access	**328**	**141**	**40%**	**226**	**1%**	**234**	**54%**	**215**	**20%**	**512**	**0%**	**117**	**54%**
village/community gense	488	156	57%	314	4%	308	68%	247	31%	1159	1%	149	33%
relative/neighbor gense	575	257	41%	277	12%	372	66%	245	35%	1250	1%	185	25%
family genset	1365	306	43%	332	20%	716	80%	421	52%	918	2%	760	30%
other													
total with electricity acce	**418**	**160**	**42%**	**309**	**3%**	**287**	**58%**	**245**	**24%**	**703**	**1%**	**141**	**49%**
no access	**779**	**332**	**78%**	**354**	**8%**	**439**	**64%**	**401**	**34%**	**492**	**0%**	**197**	**22%**

Source: *Household Energy Supply and Use in Yemen* ESMAP, 2005.

Table 5-7: Energy expenditures by income group per month (US$)

Household Income Classification	ESMAP Database			GTZ Database	
	Average income	Average Energy Expenditure	Average electricity and lighting expenditure	Average income	Average lighting expenditure
Very poor (income decile 1)	42	6	2.6	-	-
Poor (income deciles 2-4)	88	10	4.7	75	3.5
Middle (income deciles 5-7)	139	13	6.5	128	4.0
High (income deciles 8-9)	205	20	11.3	221	5.3
Very high (income decile 10)	452	32	15.2	350	7.8

Summarized from ESMAP database (*Household Energy Supply and Use in Yemen, 2005*) and GTZ database (*Solar Lantern Study, 2008*)

5.2.3 Solar PV System Electricity Supply and Services

Electricity expenditures discussed above indicates that lighting is one of the basic services required by rural households with no access to grid electricity. In addition to lighting, the use of television is also high in the affluent and middle class households in rural and un-electrified communities.

These electricity services in rural communities could be met by solar pv systems. The study on 'Business Models and Financial Schemes for the Solar Home System Program of the National Rural Electrification Strategy in Yemen' funded by the GTZ recommended three solar home system sizes to be suitable for the rural off-grid electricity market in Yemen. These are small (20 Wp), medium (50 Wp) and large (120 Wp) solar home system units. In addition, solar pV lamps could also be suitable to some off-grid areas, hence included in the study analysis. The estimated electricity supply and services that could be provided by solar PV systems are shown in *Table 5-8*.

Table 5-8: Electricity supply and services of solar PV systems

Solar PV System Size (Supply)	Electricity Services (Demand Profile)
Solar lamp 5 W PV module	**Lighting** 4W/150 lumen bulb, 4-5 hours operation per day
Small, 20 Wp Electricity supply 20 W x 5 hrs [1] = 100 Watt-hrs	**Lighting** 3 CFL lamps (11 W), 3 hours use • 3 x 11W x 9 hrs = 99 Watt-hours
Medium, 50 Wp Electricity supply 50 W x 5 hrs [1] = 250 Watt-hrs	**For Highlands** **Lighting** 5 CFL lamps (11W), 4 hours use • 5 x 11W x 4 hrs = 220 Watt-hours
	For Lowlands **Lighting** 3 CFL lamps (11W), 4 hrs use • 3 x 11W x 4 hrs = 132 Watt-hours **Electric Fan** 20 W electric fan, 5 hours • 20 W x 5 hours = 100 Watt-hours
Large, 100 Wp Electricity supply 100 W x 5 hrs [1] = 500 Watt-hrs	**For Highlands** **Lighting** 5 CFL lamps (11W), 4 hrs use • 5 x 11W x 4 hrs = 220 Watt-hours **TV** 60 W AC color TV, 4 hours • 60 W x 4 hrs = 240 W-hrs
	For Lowlands **Lighting** 4 CFL lamps (11W), 4 hrs use • 4 x 11W x 4 hrs = 176 Watt-hours **TV** 60 W AC color TV, 4 hours

	• 60 W x 4 hrs = 240 W-hrs **Electric Fan** 20 W electric fan, 4 hours • 20 W x 4 hrs = 80 W-hrs

[1] estimated peak-sunlight hours – irradiation

5.3 Solar PV Market Potential

This section estimates the market potential of solar PV technologies in identified off-grid areas. In Section 5.1, villages with low household density were not included in the analysis due to very low economies of scale in providing energy services particularly by solar home system (SHS) technologies, but these villages could be optionally be the target for solar lanterns (SL). Thus, low household density villages are considered for solar lamps and battery charging market. This is shown in *Table 5-9*.

Table 5-9: Off-grid area solar PV technology options – low household density villages for solar lamp or battery charging market

Off-grid Districts	**Number of Households per Village Size Distribution**						
	< 50	**50-100**	**100-150**	**150-200**	**200-300**	**300-450**	**> 450**
Districts with coastal areas (Al-Mahara, Hadramout, Abyan, Lahj, Taiz, Al Hodeidah, Hajja)	Solar lanterns	Solar Home Systems and Solar Lanterns (to be further screened by poverty level – to be discussed in the next section)					Wind-diesel systems*
Inland districts (Raimah, Al Baida, Al Mahwit, Amran)	Solar lanterns	Solar Home Systems and Solar Lanterns (to be further screened by poverty level – to be discussed in the next section)					Individual systems or isolated diesel-based network

* wind resources in inland areas need further investigations and measurements

Additional assumptions were further made to estimate the market potential of each solar PV technology. Villages were earlier disaggregated into poverty index based on the Social Fund for Development classifications (the database used in this study is from the Social Fund). The study assumes a household income distribution for each poverty index level and this is shown in *Table 5-10*.

In addition, as observed in many villages in various districts in the country, some households are already connected to small diesel generators either run by local governments or private entrepreneurs. The study further assumes diesel penetration for each poverty classification level and this is shown in the table below.

The study also assumes the type of technology that is affordable for each household by income group. This is shown in *Table 5-11*.

Table 5-10: Village poverty classification and HH income distribution assumptions

Governorate	**Village Poverty Index Level**			
	1 (affluent)	**2 (middle)**	**3 (poor)**	**4 (very poor)**
Al-Mahara Hadramout Raimah Abyan Al Baida Lahj Taiz Al Hodeidah Al Mahwit Hajja Amran	HH income distribution High: 50% Medium: 25% Low: 15% Very Low: 10%	HH income distribution High: 15% Medium: 50% Low: 25% Very Low: 10%	HH income distribution High: 10% Medium: 15% Low: 50% Very Low: 25%	HH income distribution High: 5% Medium: 20% Low: 25% Very Low: 50 %

Potential diesel penetration: index level 1 – 20%; index level 2 – 15%; index level 3 – 10%; and index level 4 – 5%.

Table 5-11: Assumptions on affordability of available technologies by income group

Household Income Classification	**Solar PV Technologies**
Very poor income decile 1 (0-9000 YR/month)	Solar lanterns
Poor income decile 2: (9001-12000 YR/month) income decile 3: (12001-15000 YR/month) income decile 4: (15001-19800 YR/month)	20 Wp solar home system
Middle income decile 5: (19801-22500 YR/month) income decile 6: (22501-27000 YR/month) income decile 7: (27001-33000 YR/month)	50 Wp solar home system
High income decile 8: (33001-42700 YR/month) income decile 9: (42701-61000 YR/month) income decile 10: (61001>0 YR/month)	100 Wp solar home systems

Based on the above assumptions, the market potential for solar PV technologies are estimated by this study. The total market is more than 228 thousand units. This can be further disaggregated into solar home system (SHS) market and solar lamp and battery charging station (BCS) market.

The solar home system market has a market potential of more than 108 thousand units while that of the solar lamp and BCS is around 120 thousand units. The disaggregation of these market potentials are shown in *Table 5-12* and *Figure 5-3*.

Table 5-12: Market potential of solar PV technologies

Governorate	Household density					TOTAL
	High				Low	
	Solar Home System Market			Solar Lamp Market		
	100 Wp	50 Wp	20 Wp	Solar lamps	Solar lamps	
Al-Mahara	94	287	254	203	941	1 779
Hadramout	3 266	6 382	6 848	5 233	19 835	41 563
Raimah	1 244	2 968	6 024	5 983	1 610	17 829
Abyan	1 124	874	888	797	5 034	8 718
Al Baida	6 71	1 429	2 652	2 184	4 439	11 376
Lahj	1 144	2 002	4 309	2 678	11 088	21 220
Taiz	1 118	3 488	4 094	4 941	172	13 814
Al Hodeidah	1 087	2 297	2 450	1 736	794	8 365
Al Mahwit	2 316	6 706	9 581	11 091	5 320	35 015
Hajja	1 081	3 499	4 922	7 273	8 311	25 087
Amran	2 949	7 544	12 957	12 798	7 227	43 476
TOTAL	**16 093**	**37 477**	**54 981**	**54 918**	**64 771**	**228 241**
	108 552			**119 689**		

High household density village as discussed are those with more than 50 households while low household density means villages with less than 50 households.

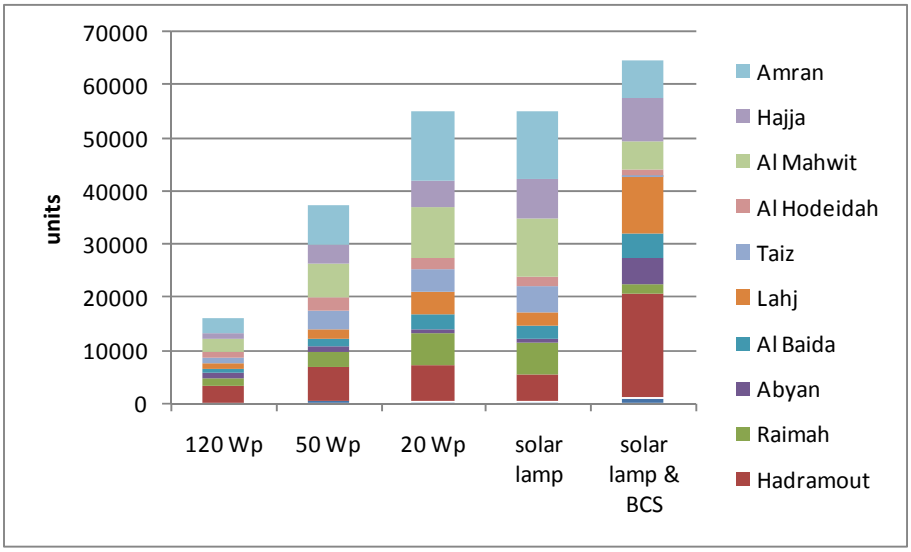

Figure 5-3: Solar PV market potential

6 Service Delivery Strategy

6.1 Service delivery mechanisms

6.1.1 Off-grid Energy-Service Delivery Strategy

Through various stakeholder consultations, the study 'Business Models and Financial Schemes for the Solar Home System' proposed a decentralized and market-based off-grid renewable energy delivery strategy.

Under this approach, the role of the Government (MEE and REA) is limited to program promotion, activation of the market system, and provision and financing of subsidies. Crucial to this approach is the activation of private sector rural energy service providers (*Figure 6-1*). The above-mentioned study identified 3 main entities that are already providing various services in the rural areas which could play the role of rural energy service providers. These are the following: i) CAC Bank, and ii) postal service, and iii) micro-financing institutions.

In reaching out the targeted households in marginal villages, the said study proposed a three-stage process: first, to focus on marketing the technology with the existing clients, then to expand through establishment of new branches, and to further reach out new markets through activation of local communities in remote areas. This is illustrated in *Figure 6-2*.

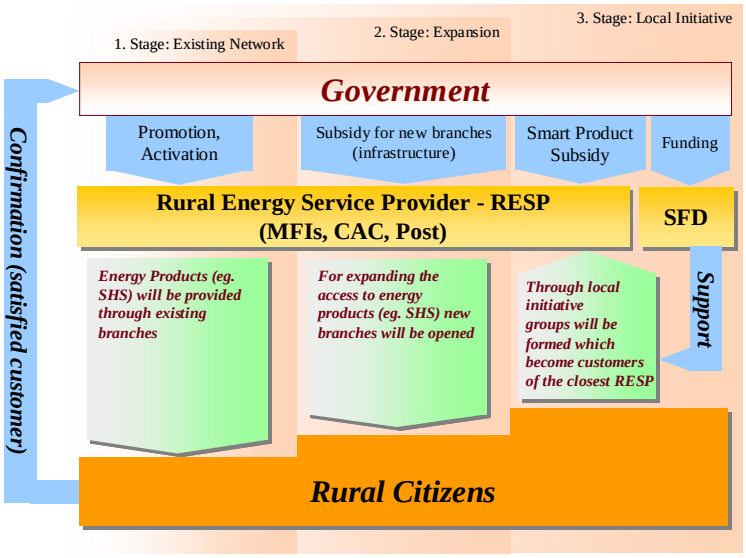

Figure 6-1: Off-grid service energy delivery strategy
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

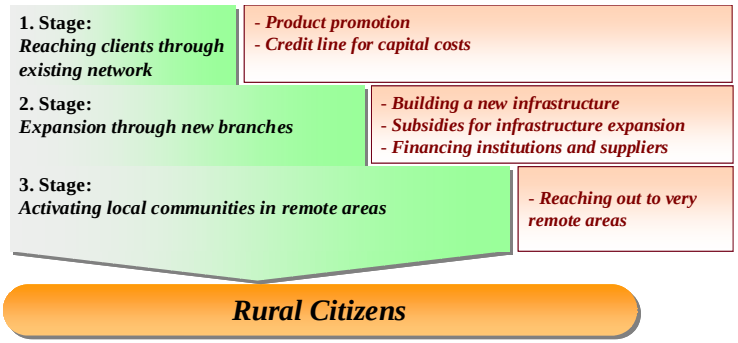

Figure 6-2: Three stage process in service delivery
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

6.1.2 Rural Energy Service Providers

As presented earlier, three main institutions, CAC Bank, postal service, and microfinancing institutions, currently serving the rural population through various services including financial services could act as rural energy service providers. Their number of branches, capacity to serve the rural population, existing services, and client profiles are shown in *Figure 6-3*, *Figure 6-4*, and *Figure 6-5*.

In the absence of these institutions in remote villages, it was also proposed that villages could be organized to form village associations. These associations could be linked up with the nearest rural energy service providers. The Social Fund for Development (SFD) has been involved in establishing and strengthening local structures in the villages. The formation of the associations in remote communities could be assigned to SFD. This is illustrated in *Figure 6-6*.

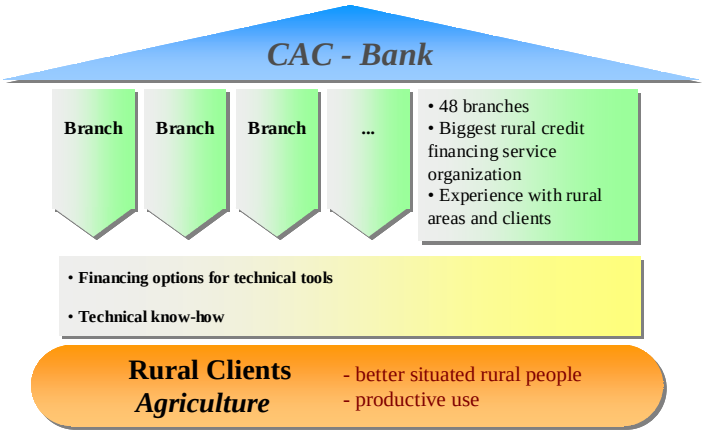

Figure 6-3: CAC Bank delivery model
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

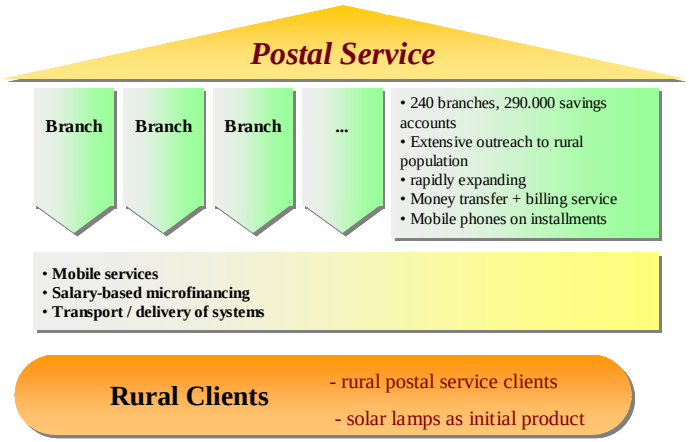

Figure 6-4: Postal service delivery model
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

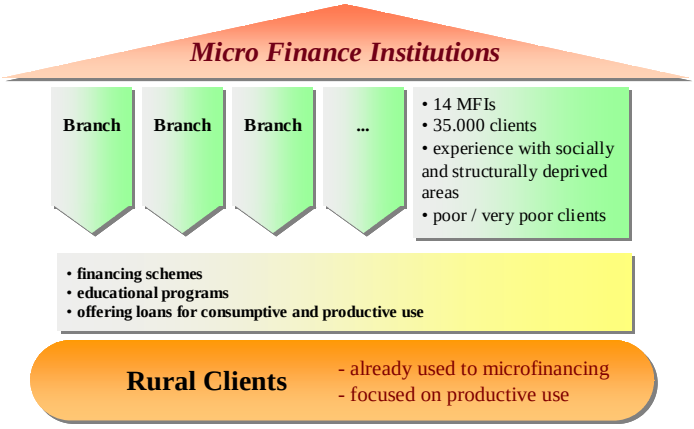

Figure 6-5: Microfinance institution delivery model
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

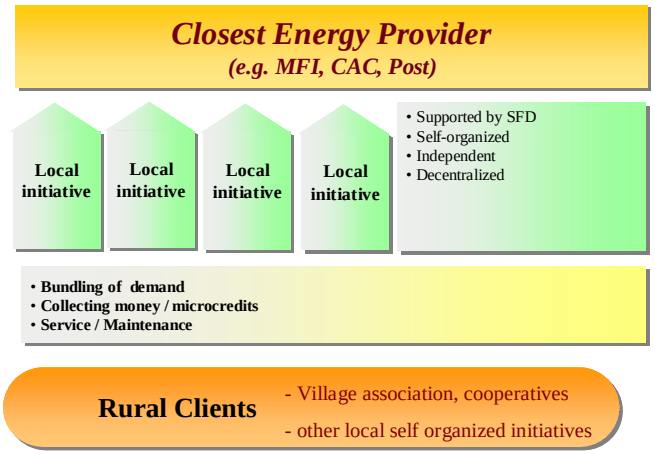

Figure 6-6: Local initiative delivery model
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

The activation of these three entities as rural energy service providers could cover most of the socio-economic sectors in rural areas since each of these entities targets different market segments. For example CAC Bank clients are involved in agriculture-related activities thus it can target productive applications of rural energy systems. Postal service clients are mostly employees of commercial and agricultural businesses, thus it can target mainly consumptive uses of rural energy systems. Microfinancing institutions, on the other hand, targets the rural poor and provide assistance for these clients to engage in productive activities. MFIs could target both the consumptive and productive uses of renewable energy systems. The energy needs that could be served by the potential energy service providers are illustrated in *Figure 6-7*.

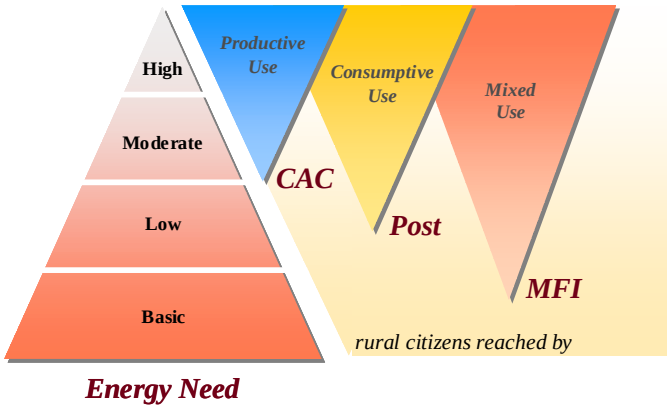

Figure 6-7: Rural customers reached by potential service providers
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

6.2 Energy service provision in target off-grid areas

6.2.1 Off-Grid Areas and Financing Institutions

Off-grid districts and villages identified in this study are relatively remote with depressed economic conditions. In many cases, CAC Bank, postal services and microfinance institutions are not operating in these marginal areas. *Table 6-1* shows the nearest branches of these institutions to the identified marginal districts. *Figure 6-8*, *Figure 6-9*, *Figure 6-10* also shows the potential coverage areas of branches of CAC Bank, Postal Service and Microfinance Institutions.

Table 6-1 also presents the districts where the decentralization process and local authority strengthening (Decentralization and Local Development Support Program or DLDSP) as well as intervention programs of the Social Development Fund (SFD) are currently implemented. The market-based and decentralized approach to off-grid rural electrification could be easily integrated in areas where there is an ongoing implementation of DLDSP and SFD programs.

Among the potential rural energy service providers, microfinance institutions are the most prepared entities to provide rural energy services in marginal areas. The socio-economic conditions of many marginal districts and villages are consistent with their target client economic profiles. In addition, the National Microfinance Foundation (NMF) expressed willingness and interest to expand their product portfolio to include provision of solar home system services. A Team of international, local consultants and representatives of NMF recently visited selected villages, and NMF expressed interest of expanding their operations in those areas.

CAC Bank, on the other hand, needs to change its Charter, before it can engage into rural energy service provision business. The change is however not difficult to implement particularly if it can be demonstrated that the market delivery approaches are profitable ventures for these financing institutions.

Table 6-1: Off-Grid Areas and nearest MFIs, CAC Bank and Postal Services, and Areas covered by DLDSP and SFD interventions

Target Marginal Districts	MFI	CAC	Post	DLDSP Coverage/ SFD Intervention
Abyan				
Ahwar	Zungobar	Zungobar	Ahwar	DLDSP
Al Mafhd	Zungobar	Zungobar	Ahwar	DLDSP
Khanfir	Zungobar	Zungobar	Khanfir	DLDSP
Sibah	Zungobar	Zungobar	Rosod	DLDSP
Lawder	Zungobar	Al Baidah	Al Wadea	DLDSP
Sarar	Zungobar	Zungobar	Khanfir	DLDSP
Al Baida	-			
Ash Sharyah	Lahj	Al Baidha City	Al Baidha City	
Na'man	Lahj	Al Baidha City	Al Baidha City	
Nata	Lahj	Al Baidha City	Al Baidha City	
Wald Rabia	Lahj	Al Baidha City	Al Baidha City	
Maswarh	Lahj	Al Baidha City	Al Baidha City	
Al Hodiedah				
Al Munira	Al Hawk	Al Hawk	Assalif	DLDSP
Assalif	Al Hawk	Al Hawk	Assalif	DLDSP
Kamran	Al Hawk	Al Hawk	Assalif	DLDSP
Al Mahara				
Al Masilah	Al Mukalla City	Qishin	Qishin	
Manar	Al Mukalla City	Al Gaidah	Al Gaidah	

Haat	Al Mukalla City	Al Gaidah	Al Gaidah	
Al Mahwit				
Al Khabt	Bajl	Al Mahwit City	Al Mahwit City	SFD
Milhan	Bajl	Al Mahwit City	Al Mahwit City	
Bani Saad	Bajl	Al Mahwit City	Al Mahwit City	
Amran				
Al Madan	Hajja City	Amran City	Al Madan	DLDSP
As Sudah	Hajja City	Amran City	As Sawd	DLDSP
Shiharah	Hajja City	Amran City	Al Madan	DLDSP
Asswdah	Hajja City	Amran City	Amran City	DLDSP
Suwair	Hajja City	Amran City	AL Madan	DLDSP
Thulymat Habur	Hajja City	Amran City	Thulymat Habur	DLDSP
Al Qaflah	Hajja City	Amran City	Al Madan	DLDSP
Hadramout				
Adh Dhlia'ah	Al Mukalla city	Al Mukalla city	Yabauth	DLDSP
Al Mukalla	Al Mukalla city	Al Mukalla city	Al Mukalla city	DLDSP
Broom	Al Mukalla city	Al Mukalla city	Al Mukalla city	DLDSP
Dawan	Al Mukalla city	Al Mukalla city	Yabauth	DLDSP
Hajr	Al Mukalla city	Al Mukalla city	Yabauth	DLDSP
Qhail Ben Yameen	Al Mukalla city	Al Mukalla city	Qhail Ben Ymn	DLDSP
Rekhyah	Sayun	Sayun	Wadi Al Ain	DLDSP
Yabauth	Al Mukalla city	Al Mukalla city	Yabauth	DLDSP
Al Abr	Sayun	Sayun	Al Abr	DLDSP
Amed	Sayun	Sayun	Al Huraidah	DLDSP
As Saoum	Sayun	Sayun	Tareem	DLDSP
Hagr As Saiar	Sayun	Sayun	Al Qatn	DLDSP
Qof Al Awamir	Sayun	Sayun	Tareem	DLDSP
Qulansiyah	Sayun	Sayun	Tareem	DLDSP
Rumah	Sayun	Sayun	Rumah	DLDSP
Zamakh and Manwakh	Sayun	Sayun	Al Abr	DLDSP
Hajja				
Mustabah	Abs	Abs	Harad	DLDSP
Bakil Al Mir	Abs	Abs	Harad	DLDSP/SFD
Wash'hh	Abs	Abs	Harad	DLDSP
Qarah	Abs	Abs	Harad	DLDSP
Midi	Abs	Abs	Harad	DLDSP
Lahj				
Al Madarib and Al-Ara	Radfan	Radfan	Al Qabaytah	
Al Musaymer	Radfan	Radfan	Radfan	
Al Qabaytah	Radfan	Radfan	Al Qabaytah	
Tawr Al Banah	Radfan	Radfan	Al Qabaytah	SFD
Raimah				
Al Jafariyah	Bayt Al Faqiah	Bayt Al Faqiah	Kusmah	
Bilad At Ta'am	Al Mansuriya	Al Mansuriya	Bilad At Ta'am	
Taiz				
Al Mocha	Al Khawkan	A Mocha	A Mocha	DLDSP
Dhubad	Al Khawkan	A Mocha	A Mocha	DLDSP

Red – outside 50 km
Blue – within 50 km

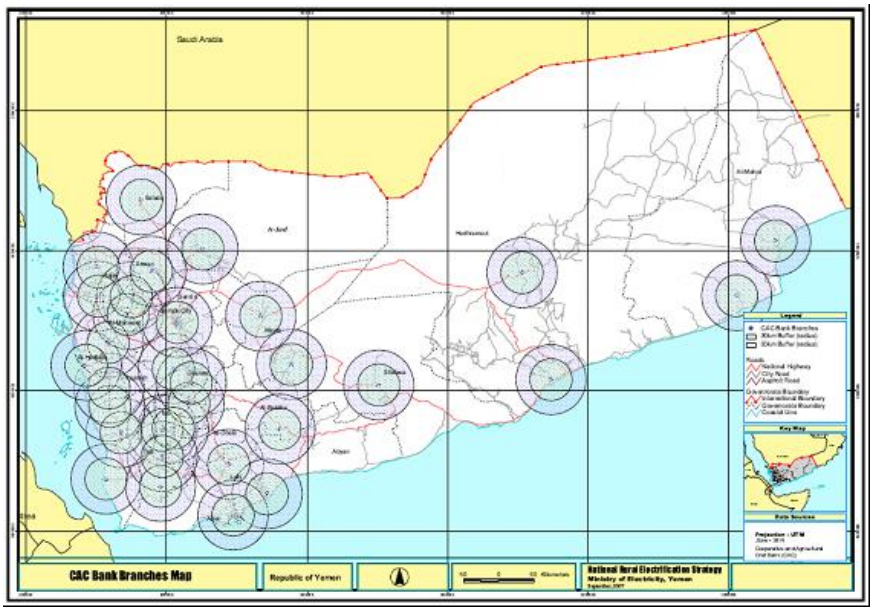

Figure 6-8: CAC Bank Branches and potential rural energy service coverage area
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

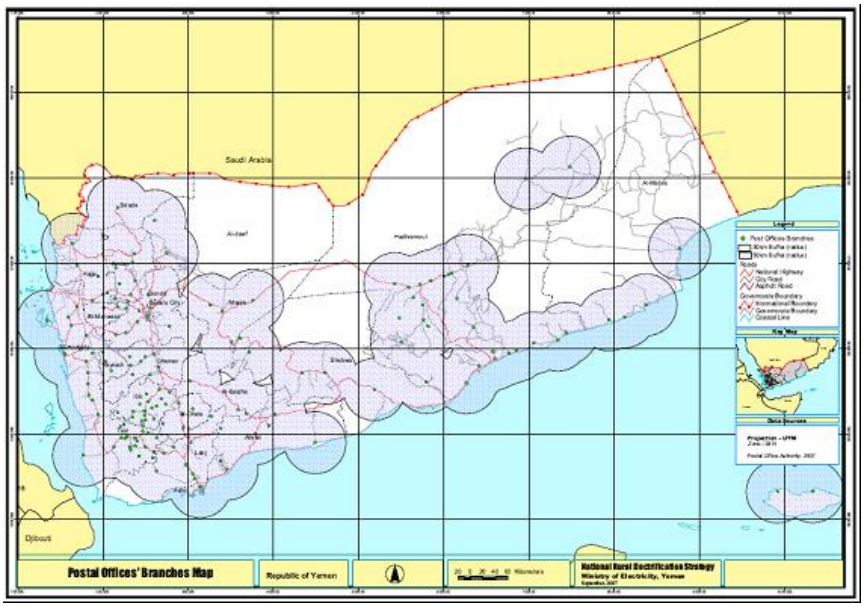

Figure 6-9: Postal Service Network and potential rural energy service coverage area
Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

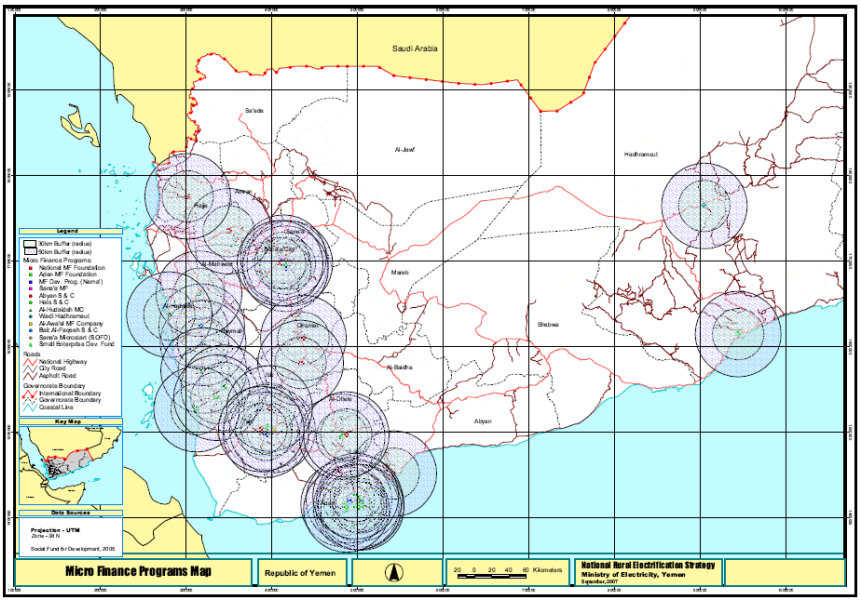

Figure 6-10: Geographic locations of microfinance institutions and potential rural energy service coverage area

Source: *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

Taking the 50-kilometer radius as the limit of operation of each local branch of a financing institution, off-grids areas in each district could be classified as those that are being served by financial institutions and those that are not. This categorization of off-grid areas by financing institutions could then be the basis for the prioritization of of-grid development. Off-grid districts categorized into solar PV technology market and presence or absence of financing institution is shown in *Table 6-2*.

Table 6-2: Availability of financing institutions in off-grid areas

	Solar Home System Market		Solar Lamp Market	
	SHS Sector 1 Microfinance Institution/CAC Bank	**SHS Sector 2 No Financing Institution**	**SL Sector 1 Postal and Postal Savings**	**SL Sector 2 No Postal Service**
Abyan				
Ahwar		X	X	
Al Mafhd		X	X	
Khanfir	X		X	
Sibah		X	X	
Lawder	X		X	
Sarar	X		X	
Al Baida				
Ash Sharyah		X		X
Na'man		X		X
Nata		X		X
Wald Rabia		X		X
Maswarh		X		X
Al Hodiedah				
Al Munira		X	X	
Assalif		X	X	
Kamran		X	X	
Al Mahara				
Al Masilah		X		X

Manar		X		X
Haat		X		X
Al Mahwit				
Al Khabt	X		X	
Milhan	X		X	
Bani Saad	X		X	
Amran				
Al Madan	X		X	
As Sudah	X		X	
Shiharah	X		X	
Asswdah	X		X	
Suwair	X		X	
Thulymat Habur	X		X	
Al Qaflah	X		X	
Hadramout				
Adh Dhlia'ah		X	X	
Al Mukalla	X		X	
Broom	X		X	
Dawan		X	X	
Hajr		X	X	
Qhail Ben Yameen		X	X	
Rekhyah		X	X	
Yabauth		X	X	
Al Abr		X	X	
Amed		X	X	
As Saoum		X	X	
Hagr As Saiar		X	X	
Qof Al Awamir		X	X	
Qulansiyah		X	X	
Rumah		X	X	
Zamakh and Manwakh		X	X	
Hajja				
Mustabah	X		X	
Bakil Al Mir	X		X	
Wash'hh	X		X	
Qarah	X		X	
Midi	X		X	
Lahj				
Al Madarib and Al-Ara		X		X
Al Musaymer				
Al Qabaytah	X		X	X
Tawr Al Banah	X	X		X
Raimah				
Al Jafariyah	X		X	
Bilad At Ta'am	X		X	
Taiz				
Al Mocha	X		X	
Dhubad	X		X	

6.2.2 Off-grid Area Sector and Phase Classifications

The presence of a financing institution is one of the main criteria for prioritizing the development of an off-grid area. Off-grid districts currently being served by microfinance institutions (or within 50 kilometers from a financing institution branch) will be classified as *Sector 1* of the off-grid rural electrification program, while those beyond the 50 kilometer distance from a branch of a financing institution will be considered as *Sector 2*. In addition, in each sector, off-grid areas could be further categorized into *phases* of development based on relative difficulty in developing the area. The classifications and their criteria are summarized in *Table 6-3*. *Table 6-4* shows the classification of off-grid areas (by Governorate) into market sector and phase of development.

Based on the above classifications, the market potential by phases and sectors for each solar PV technology can be estimated. The market potential for solar home systems in Phase A of Sector 1 is around 55 thousand units while in Phase B, it is around 26 thousand units. The total potential of Sector 1 is more than 80 thousand

units. The market potential details for both solar home systems and solar lamps are shown in *Table 6-5*. In addition, the study also estimated the market potential of solar PV lamps in villages with household density of less than 50. This is also shown in *Table 6-6*.

Achievability rate was also being considered in the estimation of market potential. For solar PV market in villages with household density of more than 50, an achievability rate of 75% was being used while in those villages with below 50, a very low rate, 25%, was being applied. These corrected figures are being used in the analysis throughout the study. These recalculated values are shown in *Table 6-7* and *Table 6-8*.

Table 6-3: Off-grid area classifications and phases of development

Sector	Phase	Criteria
Solar Home System (SHS) Market		
SHS Sector 1 within the 50 km zone of a branch of a financing institution (FI)	Phase A	within a microfinance institution and CAC (MFI) zone
	Phase B	within CAC Bank zone
SHS Sector 2 outside the 50 km zone of a branch of a financing institution (FI)	Phase A	geography 1 (Highlands, South and Western part)
	Phase B	geography 2 (Eastern Part of the country)
Solar Lamp (SL) Market		
SL Sector 1 within the 50 km zone of a branch of the Postal and Postal Savings Authority	Phase A	to follow the SHS 1 Phase A grouping plus certain considerations
	Phase B	to follow the SHS 1 Phase B grouping plus certain considerations
SL Sector 2 Outside the 50 km zone of a branch of the Postal and Postal Savings Authority	Phase A	geographic consideration 1
	Phase B	geographic consideration 2

Table 6-4: Solar PV market by sector and by phase of development

	Solar Home System Market				**Solar Lamp Market**			
	SHS Sector 1		**SHS Sector 2**		**SL Sector 1**		**SL Sector 2**	
	Phase A	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*
Abyan		X				X		
Al Baida			X				X	
Al Hodiedah			X		X			
Al Mahara				X				X
Al Mahwit	X				X			
Amran		X				X		
Hadramout				X		X		
Hajja	X				X			
Lahj	X				X			
Raimah	X				X			
Taiz	X				X			

Table 6-5: Solar PV market potential (villages with household density of more than 50)

	Solar Home System Market (high density villages)				**Solar Lamp Market (high density villages)**			
	SHS Sector 1		**SHS Sector 2**		**SLH Sector 1**		**SLH Sector 2**	
	Phase A	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*
Abyan		2 887				797		
Al Baida			4 752				2 184	
Al Hodiedah			5 834				1 736	
Al Mahara				635				203
Al Mahwit	18 603				11 091			
Amran		23 451				12 798		
Hadramout				16 495				5 233
Hajja	9 503				7 273			
Lahj	7 454				2 678			
Raimah	10 236				5 983			
Taiz	8 701				4 941			
TOTAL	**54 497**	**26 338**	**10 586**	**17 130**	**31 966**	**13 595**	**3 920**	**5 436**
	80 835		**27 716**		**45 561**		**9 356**	

Table 6-6: Solar lamp market potential (villages with household density of less than 50)

	Solar Lamp Market (low density villages)			
	SLL Sector 1		**SLL Sector 2**	
	Phase A	*Phase B*	*Phase A*	*Phase B*
Abyan		5 034		
Al Baida			4 439	
Al Hodiedah			794	
Al Mahara				941
Al Mahwit	5 320			
Amran		7 227		
Hadramout				19 835
Hajja	8 311			
Lahj	11 088			
Raimah	1 610			
Taiz	172			
TOTAL	**26 501**	**12 261**	**5 233**	**20 776**
	38 762		**26 009**	

Table 6-7: Solar PV market potential (villages with household density of more than 50) (75 % achievable rate)

	Solar Home System Market (high density villages)				**Solar Lamp Market (high density villages)**			
	SHS Sector 1		**SHS Sector 2**		**SLH Sector 1**		**SLH Sector 2**	
	Phase A	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*
Abyan		2165				598		
Al Baida			3564				1638	
Al Hodiedah			4376				1302	
Al Mahara				476				152
Al Mahwit	13 952				8318			
Amran		17588				9599		
Hadramout				12371				3925
Hajja	7 127				5455			
Lahj	5 591				2009			
Raimah	7 677				4487			
Taiz	6 526				3706			
TOTAL	40 873	19754	7940	12848	23975	10196	2940	4077
	60 626		**20 787**		**34 171**		**7 017**	

Table 6-8: Solar lamp market potential (villages with household density of less than 50) (25 % achievable rate)

	Solar Lamp Market (low density villages)			
	SLL Sector 1		**SLL Sector 2**	
	Phase A	*Phase B*	*Phase A*	*Phase B*
Abyan		1259		
Al Baida			1110	
Al Hodiedah			199	
Al Mahara				235
Al Mahwit	1330			
Amran		1807		
Hadramout				4959
Hajja	2078			
Lahj	2772			
Raimah	403			
Taiz	43			
TOTAL	6625	3065	1308	5194
	9 691		**6 502**	

6.2.3 Off-grid Area Development Program and Practicable Service Models

Based on the above sector and phase classifications, a program approach to develop the off-grid areas is being proposed in this study. Eight (8) programs are being identified, and the necessary actions required by the government, potential service delivery model practicable for each program, and program duration are shown in *Table 6-9*.

Practicable business models are functions of market institutions present in the target off-grid areas:

- for Sector 1 where financing institutions are present, sales approach (credit and cash sales) could be practicable,
- for Sector 2 where there are no market players in target areas, an alternative approach could be developed by MEE/PEC-RES/REA. This study proposes that for solar home system a fee-for-service approach with local service provider could be introduced, while for solar lamps, cash sales approach with local dealers could be launched.

Similarly, *Table 6-10* shows the program coverage by phase and by sector. The proposed off-grid project implementation schedule is shown in *Figure 6-11*.

Table 6-9: Off-grid programs, actions and practicable service delivery models

Sectors Phases	Actions	Financing Model Program period
Program 1 SHS Sector 1 Phase A	Overlapping presence of MFIs and CAC Bank in almost all districts • mobilize these institutions rapidly and designate market territories to each institution	**Cash and credit model with FI** 5 years – Hajja, Lahj, Raimah, Taiz, Al Mahwit
Program 2 SL (SLH and SLL) Sector 1 Phase A	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 1 (SHS Sector 1 Phase A)	**Cash and credit model with Postal Service** 5 years
Program 3 SHS Sector 1 *Phase B1* (part Amran covered by CAC Bank)	Presence of MFIs and CAC Bank in selected districts • mobilize MFI and CAC Bank in Abyan • mobilize CAC Bank in Amran • initiate after 3 years of Program 1	**Cash and credit model with FI** 5 years
Program 4 SL (SLH and SLL) Sector 1 Phase B	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 3 (or 1 year later)	**Cash and credit model with Postal Service** 5 years
Program 5 **Program 5.1** SHS Sector 1 *Phase B2* (part Amran not covered by CAC Bank) **Program 5.2** SHS Sector 2	No MFIs and CAC Bank branch operating in the area • convince MFIs and CAC Bank to expand • if not, mobilize local service operators for a fee-for-service approach • initiate after 5 years of Program 1	**Cash and credit model** (if MFIs and CAC Bank) **Fee-for-service model** (if local service models – most likely scenario) 5 years

Phase A		
Program 6 SL (SLH and SLL) Sector 2 Phase A	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 5 (or 1 year later)	**Cash and credit model with Postal Service** 5 years
Program 7 SHS Sector 2 Phase B	No MFIs and CAC Bank branch operating in the area • convince MFIs and CAC Bank to expand • if not, mobilize local service operators for a fee-for-service approach • initiate after 8 years of Program 1	**Cash and credit model** (if MFIs and CAC Bank) **Fee-for-service model** (if local service models – most likely scenario) 5 years
Program 8 SL (SLH and SLL) Sector 2 Phase B	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 7 (or 1 year later)	**Cash and credit model with Postal Service** 5 years

Table 6-10: Off-grid areas, sectors, phases and programs

	Solar Home System Market				**Solar Lamp Market**			
	SHS Sector 1		**SHS Sector 2**		**SLH Sector 1**		**SLH Sector 2**	
	Phase A	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*
Abyan		P 3				P 4		
Al Baida			P 5				P 6	
Al Hodiedah			P 5				P 6	
Al Mahara				P 7				P 8
Al Mahwit	P 1				P 2			
Amran		P3 (part) P5 (part)				P 4		
Hadramout				P 7				P 8
Hajja	P 1				P 2			
Lahj	P 1				P 2			
Raimah	P 1				P 2			
Taiz	P 1				P 2			

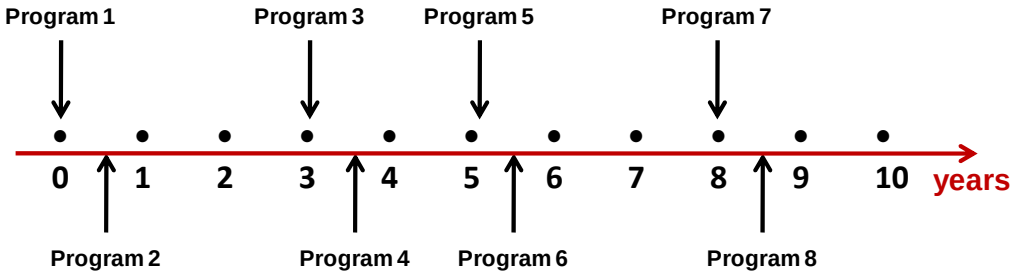

Figure 6-11: Project implementation schedule

7 Service Delivery and Financing Model Demonstration

Prior to the implementation of the off-grid rural electrification program, the proposed delivery and financing models needs to be tested and demonstrated that it is workable and feasible in Yemen given the diversity of socio-economic and cultural practices in the country. The German Technical Cooperation (GTZ) is currently preparing and supporting the Ministry of Electricity and Energy (MEE) in the demonstration of pilot projects. At present, 4 models have been identified and the implementation agreements between project partners are being discussed and negotiated. These models are the following:

- Solar home system (SHS) cash and credit sales by a microfinance institution
- Solar home system (SHS) cash and credit sales by a local service provider and a financing institution
- Solar lamp (SL) cash and credit sales by the Post and Postal Savings Authority
- Fee-for-service approach in partnership with Yemen LNG

7.1 SHS cash and credit sales by the National Microfinance Foundation

At present, there are 14 microfinance institutions (MFIs) in Yemen currently serving around 35,000 clients. These institutions are currently operating in the Highland Governorates and Western Coastal Areas. Among the MFIs, the National Microfinance Foundation (NMF) is the largest MFI in Yemen with 10,900 clients.

The National Microfinance Foundation (NMF) has expressed interest to become energy service providers in rural areas. This micro lending institution is the most prepared and ready to pilot test the energy service business. NMF have just recently signed an agreement with the Public Electricity Corporation–Rural Electrification Sector (PEC-RES) to implement the pilot demonstration project.

All of the National Microfinance Foundation's (NMF's) regional branches are closely situated with the identified rural electrification off-grid areas. The study selected the NMF's branch in Abs district of Hajjah Governorate to carry out the demonstration project for the feasibility of providing energy services through microcredit. NMF's Abs Branch is a strategic choice for project demonstration since some of its neighbouring districts such as Hayran, Mustaba, Washsh and Bakir Al Mir are identified as off-grid areas for rural electrification– meaning not being covered by the current PEC expansion distribution plan as well as not included in the proposed development of grid-based service territories of the National Rural Electrification Strategy.

The service delivery model is shown in *Figure 7-1* and describe below.

- The National Microfinance Foundation (NMF), who is interested to expand its services to energy service provision, promotes the solar home system (SHS) technology, and raises the awareness of the local community on the benefits of the technology.

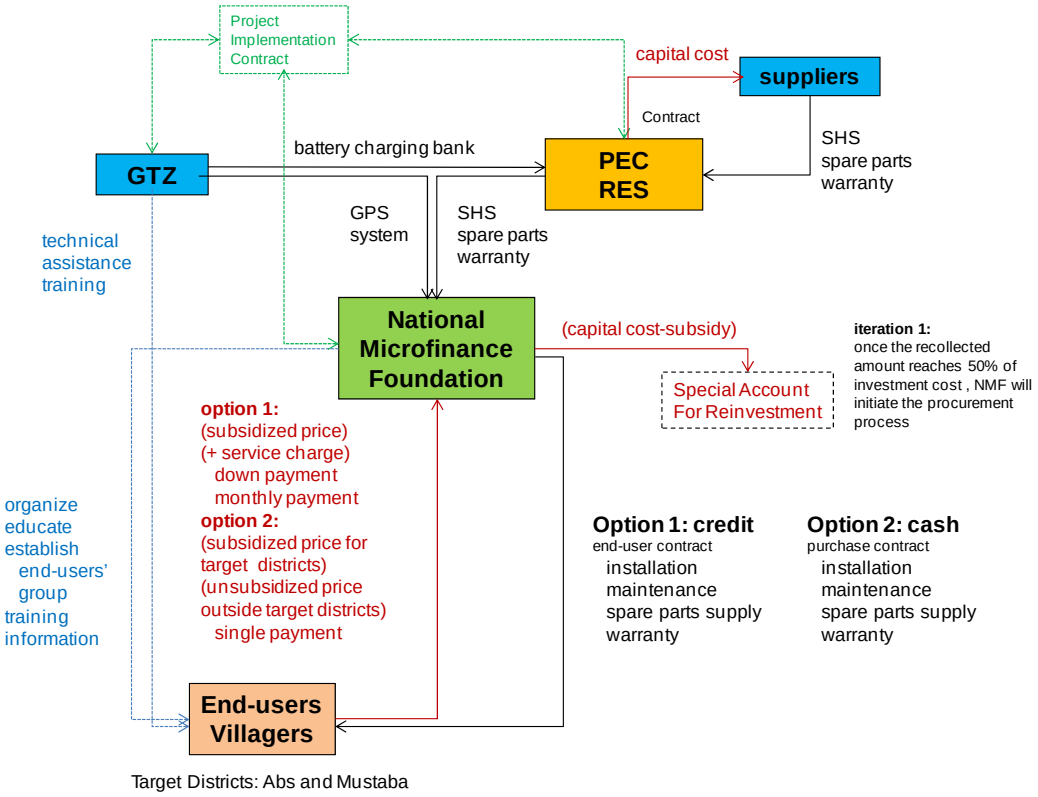

Figure 7-1: Energy service delivery by a microfinance institution (MFI)

- NMF offers micro-credit to villagers for the purchase of SHS. The villagers, who are interested to purchase the technology, sign a micro-credit contract with MNF, pay a small down payment, and pay monthly amortizations of the loan over the period of 3 years (payment is made directly to NMF).
- With the micro-credit contract, MNF installs the system at the premises of the end-user. As part of the purchase contract, NMF also supplies maintenance and repair services to the end-users.
- NMF also organizes an end-users' group to provide assistance and preventive maintenance, and act as focal point for complaints.
- One of the main barriers to this approach is NMF's lack of financial capital to initially purchase the systems and lack of technical expertise in the procurement of the technology. To address these issues, the Public Electricity Corporation–Rural Electrification Sector (PEC-RES) will provide initial capital and procure the technology in behalf of NMF.
- Another project barrier is NMF's lack of technical know-how in business promotion, awareness campaign, and organization of end-users' group as well as in providing repair and maintenance services. The German Technical Cooperation (GTZ) in partnership with the Ministry of Electricity and Energy

(MEE) will provide technical support and finance activities that mitigate these issues.

- The recovered capital investment from end-users' monthly payment will be placed in a special account and will be used for reinvestment.

7.2 SHS cash and credit sales by a local service provider and a financing institution

The German Technical Cooperation (GTZ) has identified and is currently negotiating with a Yemeni entrepreneur who has a local branch in the identified pilot project area, and who is willing to partner with GTZ and the Ministry of Electricity and Energy (MEE) to demonstrate the viability of this service delivery approach in providing energy services to off-grid areas in Yemen.

Similarly, the pilot area is also within the geographic scope of one of the Microfinance Institutions (MFIs) which provides micro-credit to rural communities. This Institution is also interested to team up with local dealers.

Among the identified off-grid areas being analyzed in this study, the above market institutional conditions appear to exist in the district of Tawr Al Baha of Lahj Governorate. Tawr Al Baha is one of the 15 districts of Lahj Governorate. Its total population in 2005 is more than 47,000 and almost 8,000 households. A private company based in the National Capital, is interested to expand its business into energy services and has a company branch in Tawr Al Baha.

Also, the district of Tawr Al Baha is within the geographic scope of the Lahj branch of the National Microfinance Foundation (NMF). This microfinance institution is also interested to participate in the proposed pilot demonstration project.

The delivery model is shown in *Figure 7-2* and described below.

- The Accredited Local Dealer (ALD), who is interested in developing a solar home system (SHS) business, teams-up with a microfinance institution (MFI) who will provide micro-credit to its potential clients in target areas.
- ALD procures the systems, promotes the technology, raises the awareness of the local community on the benefits of the SHS, and organizes an end-users' group in the pilot area. The Dealer also introduces potential clients to its partner microfinance institution (MFI).
- The financially qualified villagers, who are interested to purchase the technology, sign a micro-credit contract with the MFI, pay a down payment, and pay a monthly amortization of the loan over the period of 3 years.
- With the micro-credit contract, the MFI purchases the SHS from the local dealer and requires ALD to install the system to the premises of the end-user. As part of the purchase contract, ALD also provides maintenance and repair services to the end-users.
- One of the main barriers to this approach is the lack of technical know-how of ALD in business promotion, awareness campaign, organizing end-users' group and repair and maintenance. The German Technical Cooperation (GTZ) in

partnership with the Ministry of Electricity and Energy (MEE) will provide technical support and finance activities that address these issues.

- In order to make the systems affordable to a large number of potential end-users, the German Technical Cooperation (GTZ) will also provide a one-time capital subsidy to buy down the cost of the SHS.

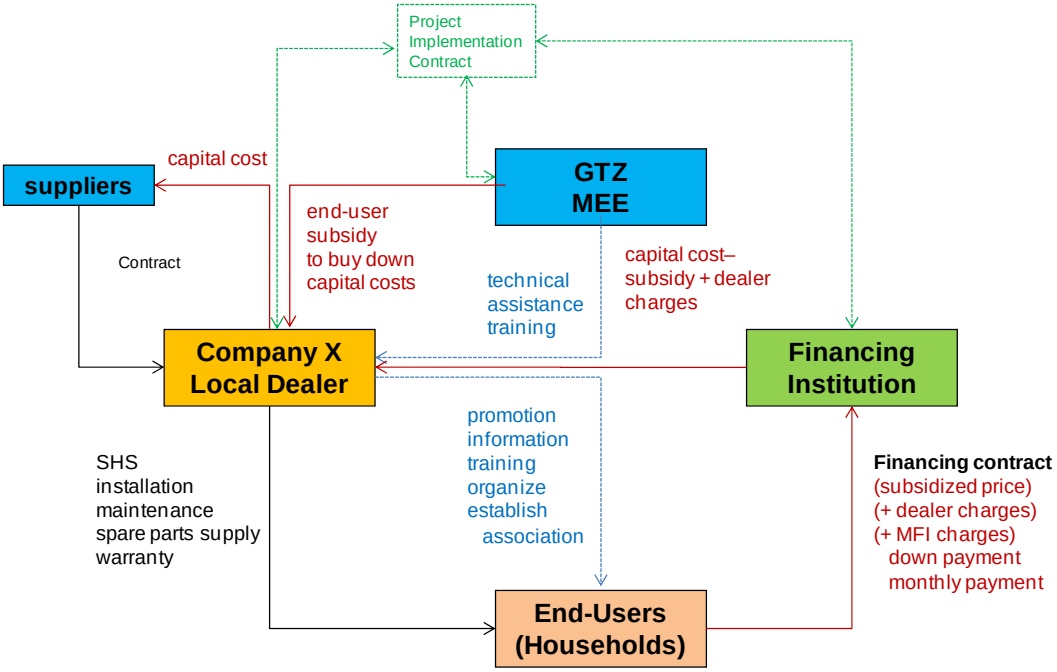

Figure 7-2: Energy service delivery by a local dealer and financing institution

7.3 Solar lamp (SL) cash and credit sales by the Post and Postal Savings Authority

The Postal and Postal Savings Authority of the Republic of Yemen, in addition to its traditional postal services, is involved in financing, banking, and other commercial services in the country.

- Financial and banking services are currently offered to around 290,000 clients with savings account with the Postal Service.
- Social welfare payments to 520,000 very poor citizens, salaries of 132,000 government employees, and pensions of 200,000 pensioners are channeled through this agency
- Banking services offered to private organizations and companies. These entities are currently having 82,000 accounts with the Postal Service.
- Utility and other bills are being paid though this agency.

- Mobile phones are also being sold through this agency, and offers mobile phone credit to those who channeled their salary/pensions through the Postal Service.

The coverage of the Postal Service is very extensive. With 240 branches all over the country, it claims to cover 70% of the national territory and 72% of the total population.

With this, the study 'Business Model and Financial Schemes for the Solar Home System Program of the National Rural Electrification Strategy in Yemen' recommends to take advantage of the Postal Service network in providing energy services to the rural and remote communities in the country particularly the poorest of the poor. The said study recommended to market solar lanterns through the Postal Service.

The proposed institutional arrangement of the pilot project is shown in *Figure 7-3*. The postal agency markets the solar lamps through its branches in targeted off-grid areas with the technical and financial support from the Public Electricity Corporation–Rural Electrification Sector (PEC-RES) and the German Technical Cooperation (GTZ).

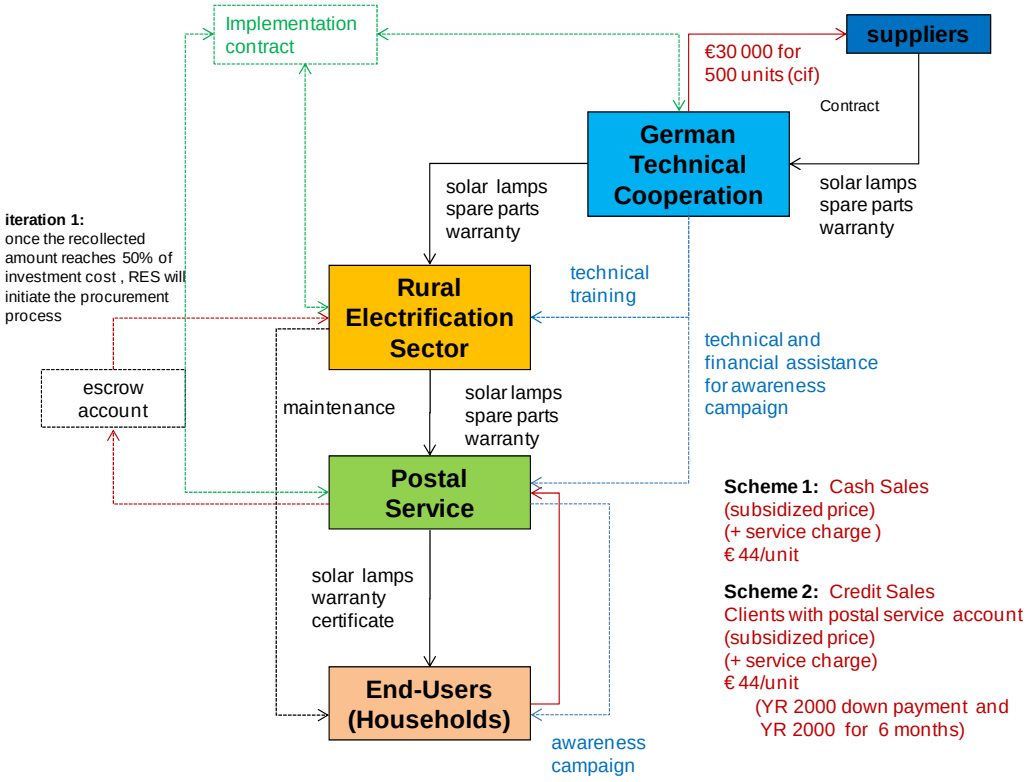

Figure 7-3: Solar lamp sales by Postal Service

Key aspects of the demonstration project are the following:

- The Postal Service either sells the solar lanterns on cash or credit basis (credit will be offered only to end-users who maintains savings account with the agency).

- The German Technical Cooperation (GTZ) will provide a grant to the Public Electricity Corporation–Rural Electrification Sector (PEC-RES) for the purchase of the solar lamps. The procurement of the systems will also be undertaken by GTZ.
- The systems will be transferred to the Public Electricity Corporation–Rural Electrification Sector (PEC-RES) which in turn hand over the systems to the postal agency.
- The German Technical Cooperation (GTZ) will also provide technical and financial assistance to both PEC-RES and the Postal Service for training and awareness and information campaign.
- PEC-RES, in case of system failures, will offer maintenance and repair services.

7.4 Fee-for-service approach in partnership with Yemen LNG

Yemen LNG, as part of its corporate social responsibility, is interested to be involved with the current rural electrification efforts of the Government. The company identified isolated fishing villages in Abyan Governorate with no modern energy services. It also appears that the identified villages will not be connected to the distribution grid in the long term.

The institutional arrangement of the approach is shown in *Figure 7-4* and briefly discussed below.

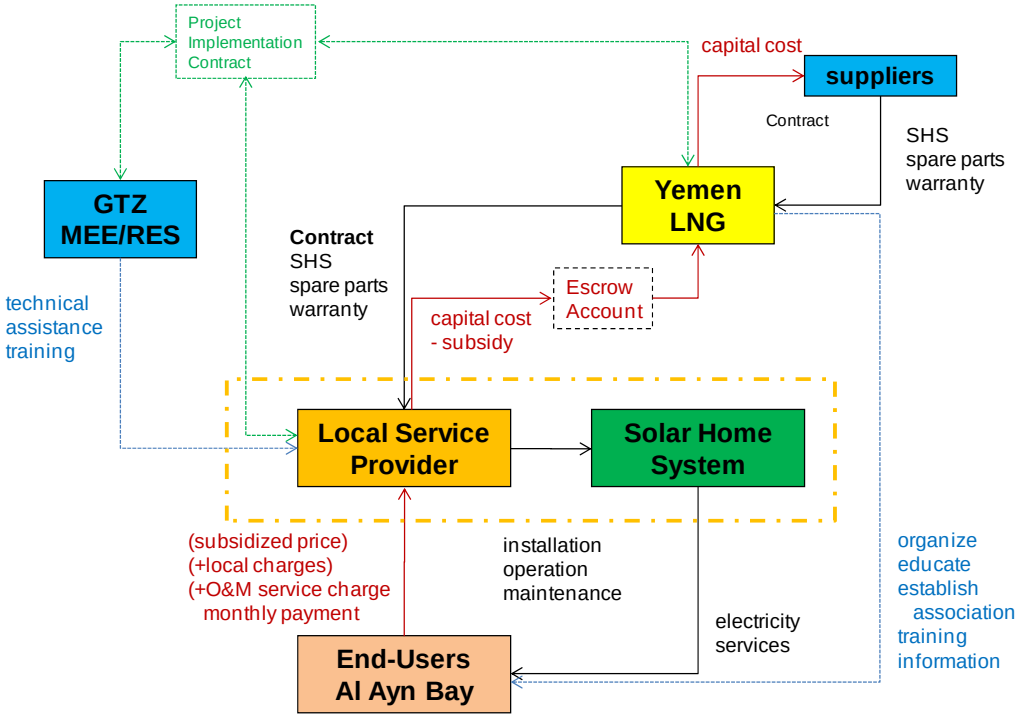

Figure 7-4: Institutional arrangement of fee-for-service model with support from Yemen LNG

- Yemen LNG, who is interested in supporting the rural electrification program of the Government as part of their corporate responsibility, identifies and engages (signs a contract agreement) a local service provider (LSP) to operate a fee-for-service scheme to the identified project area.
- Yemen LNG promotes the solar home system (SHS) technology, raises the awareness of the local community on the benefits of the technology, informs the community on the service provision plan, and establishes an end-users' group. The Company introduces the local service provider to the local community.
- Yemen LNG procures the solar home systems and transfers the acquired equipment to the local service provider (LSP). The Company also provides subsidy to end-users, and instructs the LSP to take into account the subsidies in the calculation of the monthly tariff.
- To address the lack of technical know-how barrier, the German Technical Cooperation (GTZ) in partnership with the Ministry of Electricity and Energy (MEE) provides technical training on SHS installation and maintenance to the LSP.
- The villagers, who are interested to receive energy services, select the size of the home systems based on the offered monthly tariffs, and sign a service agreement with the LSP.
- With the service agreement, the LSP installs the system to the premises of the end-user. The ownership of the system remains with Yemen LNG, and managed by the LSP.

8 Incentives Framework

8.1 Financial and economic viability

8.1.1 Solar Home Systems

The estimated ownership costs of different SHS units are shown in *Table 8-1*. The table presents various cost components to derive the retail price of SHS from hardware costs. Retail prices for SHS amounts to $261, $652 and $1564 for small, medium and large units, respectively.

Solar panel's technical life spans up to 20 years while some of solar home systems' components only last for a couple of years. SHS O&M costs are significantly influenced by the replacement costs of these components. *Table 8-2* shows the estimated O&M costs for different SHS units.

Table 8-1: Estimated financial costs of SHS in Yemen

			SHS Systems		
			Small	Medium	Large
System Configuration					
panel [Wp]			20	50	100
charge controller [A]			5	10	15
consumables/frame			1	1	1
Lamps			3	4	6
battery [Ah]			30	100	150
Hardware costs (purchase price)		**100%**	**$156**	**$390**	**$936**
	composition of purchase price				
Panel		58.8%	91.7	229.3	550.4
charge controller		3.1%	4.8	12.1	29.0
consumables/frame		0.1%	0.2	0.4	0.9
Lamps		8.6%	13.4	33.5	80.5
Battery		29.4%	45.9	114.7	275.2
Wholesale price		**100%**	**$190**	**$476**	**$1,141**
Commission		3.0%	6	14	34
Consignment		5.0%	10	24	57
Taxes		3.0%	6	14	34
Customs		5.0%	10	24	57
unpredictable costs		2.0%	4	10	23
purchase price		**82.0%**	**$156**	**$390**	**$936**
Retail Price			**$261**	**$652**	**$1,564**
wholesale price			190	476	1141

operational costs			65	162	388
	commission on sales(loan officer/local dealer/local staff)	1.0%	2	5	11
	strategy related additional costs		15	38	91
	general operational costs	25.0%	48	119	285
	OED-strategy related additional costs		**15**	**38**	**91**
		based on wholesale price			
	local transport	2.0%	4	10	23
	Maintenance	1.0%	2	5	11
	customer training	1.0%	2	5	11
	infrastructure/administration (branches)	4.0%	8	19	46
Profit		3.0%	6	14	34

Source: modified from *Business Models and Financial Schemes for the Solar Home System* Microenergy, 2007

Table 8-2: SHS replacement costs

Small (20 Wp)		**Medium (50 Wp)**		**Large (100 Wp)**	
Lamps	$16	Lamps	$ 41	Lamps	$98
Battery	$56	Battery	$140	Battery	$336
				Inverter	$150
Total	**$72**	**Total**	**$181**	**Total**	**$584**
Replacement every 3 years		Replacement every 3 years		Replacement every 3 years	

The financial benefits of using solar home systems are mainly those avoided expenditures related to grid electricity substitutes. Each solar home system unit avoids specific amount of expenditures. Based on the ESMAP survey data, shown in *Table 8-3*, and the income group classification used in Chapter 5, the first decile could be too poor to financially able to pay a SHS. The smallest solar home system unit (20 Wp) could be targeted for household group within the second to fourth deciles, while largest unit could be aimed for the eighth, ninth and tenth deciles. The medium solar home system could be marketed for the fifth, sixth and seventh deciles.

The corresponding benefits (monthly expenditures for substitutes) could range between $2.7-4.7 per month for 20 Wp system, $3.3-6.7 per month for 50 Wp unit and $6.4-10.6 per month for the biggest system. Since the survey and data used in the ESMAP analysis are for year 2003, the study adjusted these figures to reflect recent developments and price increases in the country. In the estimation of benefits, the study inflated these values by a factor of 1.25.

Table 8-3: Expenditures related to grid electricity substitute

Fuel Type	decile 1	2	3	4	5	6	7	8	9	10	average
YR/month	449	539	934	850	816	642	1323	1268	2090	1838	1028
$/month	2.3	2.7	4.7	4.3	4.1	3.3	6.7	6.4	10.6	9.3	5.2
$/year	27	33	57	52	50	39	81	77	127	112	63

Source of data: *ESMAP, Household Energy Supply and Use in Yemen, 2005.*

Based on the above system costs and benefits, the study estimated the financial impacts of solar home system ownership assuming that systems are purchased through cash sales. The cash flow simulation results show that only the 20 Wp SHS unit is cost effective taking into account the avoided expenditures for electricity and lighting. This means that rural poor households could be provided with better lighting services given their current expenditures for lighting substitutes (*Table 8-4*). The medium and large systems, on the other hand, are found to have negative net present values (NPV) and very low internal rate of return (IRR).

Table 8-4: Financial viability of solar home systems

Costs	Benefits	Financial Indicators
20 Wp **Capital cost** $261 per unit **O&M costs** $66, every 3 years	**Avoided costs** $4.88 per month	**NPV** = $85 **IRR** = 17%
50 Wp **Capital cost** $652 per unit **O&M costs** $181, every 3 years	**Avoided costs** $5.88 per month	**NPV** = - $440 **IRR** = very small
100 Wp **Capital cost** $1564 per unit **O&M costs** $585, every 3 years	**Avoided costs** $10.96 per month	**NPV** = - $1,737 **IRR** = very small

An economic analysis of the solar home systems was also carried out in the study. Financial costs were adjusted to exclude the transfer costs (taxes) while benefits were also rectified taken into account the subsidies on petroleum products. Similar to the financial analysis, with only the avoided economic costs taken as system benefits, only the small system (20 Wp) is economic in Yemen (*Table 8-5*). This result is also consistent with the study carried out by ESMAP in the Philippines (Economics of Solar Home Systems: Case of the Philippines, ESMAP 2003).

The study also simulated the improvement of economic indicators if the consumer surplus is added as economic benefits of the study. Consumer surplus represents the users' financial valuation of improved electricity services. With consumer surplus, the ESMAP study in the Philippines shows that the economic benefits of solar home systems have increased, in average, by around 50%. This study assumes an average increase of 40% to the economic benefits. The result shows that with consumer surplus as added benefits, both the small and medium-sized systems become economic while the larger system, 100 Wp, remain uneconomic. This is also shown in *Table 8-5*.

There are, however, other economic benefits that could be generated by the solar home systems such as the local environmental benefits, human health benefits, and global warming benefits. If the contribution of these benefits could further increase the

baseline benefit (avoided costs) by 25%, then all the systems are economic in the country. This is also shown in the table below.

The main issue is therefore not on whether indicators show economic efficiency and financial effectiveness, but rather on whether the rural households can afford to pay the high initial capital costs of solar PV technologies. The high capital investment cost of owning a SHS is the main barrier that prevents the development of SHS market in many developing countries including the Republic of Yemen.

Table 8-5: Economics of solar home systems

Costs	Benefits	Economic Indicators
20 Wp **Capital cost** $237 per unit **O&M costs** $72, every 3 years	**Avoided costs** $7.31 per month	**ENPV** = $383 **EIRR** = 49%
	Consumer surplus* $10.23 per month	**ENPV** = $682 **EIRR** = 99%
	Consumer surplus + externalities $12.06 per month	**ENPV** = $868 **EIRR** = 149%
50 Wp **Capital cost** $594 per unit **O&M costs** $165, every 3 years	**Avoided costs** $8.81 per month	**ENPV** = -$10 **EIRR** = 10%
	Consumer surplus* $12.33 per month	**ENPV** = $350 **EIRR** = 23%
	Consumer surplus + externalities $14.54 per month	**ENPV** = $575 **EIRR** = 32%
100 Wp **Capital cost** $1425 per unit **O&M costs** $533, every 3 years	**Avoided costs** $16.44 per month	**ENPV** = - $843 **EIRR** = very low
	Consumer surplus* $23.02 per month	**ENPV** = - $171 **EIRR** = 7%
	Consumer surplus + externalities $27.13 per month	**ENPV** = $249 **EIRR** = 14%

Note: Economic costs - import duty and sales taxes are excluded in the analysis; Economic benefits – petroleum subsidies are excluded in the analysis (an adjustment factor of 1.5 is used in the analysis); Consumer surplus analysis –an ESMAP study in the Philippines estimated an average increase of benefits, taken into account consumer surplus, by around 50%. This study assumes an increase of benefits by 40% to take into account the increase end-users welfare due to improved quality of services. Additional 25% is assumed in the study to include benefits from environmental externalities.

8.1.2 Solar Lamps

The cost of an imported solar lantern is estimated in *Table 8-6*. With assumed taxes and charges including dealer's margin, the cost is estimated to be slightly below US$ 120 per unit.

The solar lantern consists of a solar PV module, lamp, rechargeable battery, and electronic controller. The module can last for 20 years, while the lamp and battery needs to be replaced every 3 years. This is shown in *Table 8-7*.

Table 8-6: Financial costs of solar lamps

Import price (fob)	US$ 75
Customs (5%)	US$ 3.75
Sales tax (3%)	US$ 2.25
Commission (3%)	US$ 2.25
Consignment	US$ 15
Wholesale price	US$ 98.25
Dealers margin and other charges (20%)	US$ 19.65
Retail price	US$ 117.9

Table 8-7: Solar lantern replacement costs

Lamp	US$ 2.6
Battery	US$ 10.37
Replacement every 3 years	

Note: lamps – import price US$2, plus 8% customs and sales tax, plus 20% margin; battery – import price US$8, plus 8% customs and sales tax, plus 20% margin

Solar lanterns displace the traditional lighting technologies in rural areas. The avoided expenditures related to the use of these technologies represent the benefits of solar lanterns. Monthly expenditures related to lighting in selected villages in 7 Governorates were surveyed recently by a study commissioned by the German Technical Cooperation (GTZ). The study shows that an average household in off-grid areas spends US$ 4.72 per month for lighting. If kerosene consumption is only considered to be avoided by the solar lantern, the monthly benefit of the technology is US$3.71. This is shown in *Table 8-8*.

Financial impacts of owning a solar lantern was simulated given the system costs and benefits. The financial indicators are shown in *Table 8-9*. Even with the avoided kerosene consumption only, the financial impacts to end-users are positive. The net present value (NPV) is US$ 190 while the internal rate of return (IRR) is 44% which is significantly higher than the hurdle rate of 10%.

Similarly, the economic impact of solar lantern was also estimated in the study. The capital costs were corrected to remove the financial transfers (taxes) while the benefits were also adjusted to remove the subsidies to kerosene. An inflator of 1.2 is used to take into account the current subsidies. The results show that solar lanterns are economic in Yemen. The economic net present value (ENPV) is US$ 277 while the economic internal rate of return (EIRR) is 71% (*Table 8-9*).

Table 8-8: Household expenditures in target areas for solar lanterns

No	Gov	District	Monthly Lighting Expenses									
			Kerosene (Liters)	Monthly cost for Kerosene (Y.Rs)	LPGs Refiling Times	LPGs Refiling cost	Monthly cost for LPGs (Y.Rs)	Torch's Batteries	Monthly cost for Batteries (Y.Rs)	Candles	Monthly cost for Candles (Y.Rs)	Total cost
1	Rymah	Al-Gafriah	14	882	5	277	677	6	153	0	0	1,596
2	Al-Hodeda	Al-Marawah	20	979	13	20	133	9	176	43	319	1,662
3	Dhama'ar	Darawan Aanes	11	875	2		580	7	167	0	0	996
4	Lahj	Tor Al-Baha	14	543	0	0	0	0	0	0	0	543
5	Ibb	Al-Qafr	7	441	0	0	0	9	214	0	0	655
6	Al-Dala	Damt	7	213	1	102	108	5	118	10	69	466
7	Taiz	Khadeer	14	505	1	50	30	7	141	4	16	691
		Average	12.6	634	3.2	64	218	6.1	138	8.1	58	944

Source: Market Survey for Solar Lanterns, Report submitted to GTZ, 2008

1 US$ = YR 200

Table 8-9: Financial and economic viability of solar lanterns

Costs	Benefits	Indicators
Financial **Capital cost** $117.9 per unit **O&M costs** $12, every 3 years	**Avoided costs** $3.71 per month (kerosene consumption only)	**NPV** = $187 **IRR** = 44%
Economic **Capital cost** $111.9 per unit **O&M costs** $11.7, every 3 years	**Avoided costs** $3.96 per month (kerosene consumption only)	**ENPV** = $261 **EIRR** = 66%

8.2 Measures to remove investment barriers

As mentioned earlier, the key issue that prevents the development of solar PV market in Yemen is the high initial capital requirements of the solar PV technologies. This section presents measures to remove investment barriers such as subsidies and financing schemes.

8.2.1 Subsidies

One of the measures to reduce the investment costs is to provide subsidy in the purchase and operation of solar home systems. Financial costs of owning and operating a SHS can be categorized into several components. A typical solar PV cost breakdown is shown in *Table 8-10*.

To remove investment barriers, these cost elements could be used as target variables for subsidy policy. The following discussions focus on selected cost components that could be targeted for subsidy policy in Yemen.

Table 8-10: Solar PV financial costs

Capital costs	• Hardware costs (PV module, mounting frame and pole, battery, charge controller, lamps, and wirings and installations) • Dealer's gross margin (part of the dealer's gross margin are transfer costs) • Import duty and sales tax • Installation cost • Local transport
O&M Costs	• Hardware costs (battery, lamps, controller) • Sales tax • Local transport
Financing costs	• Interest on loans • Guarantee payments
Other transfer costs	• Income tax on dealer's profit • Income tax on financial institutions profit

Import Duty and Sales Tax Exemptions

The current import duty rate is around 5 percent of the equipment cost while the sales tax is 3 percent. Import duty and sales tax exemptions can contribute in lowering solar PV capital costs making it more affordable to rural population.

Interest Rate Subsidy and Guarantees

Under credit sales (dealer and end-user credit sales) in many developing countries, in addition to high interest rates for credits, financing institutions also require unrealistic collateral requirements from borrowers. In Yemen, microfinance institutions charge 18 percent interest rate for a US$ 100 credit which is payable within 18 months. Interest rates charged to higher amounts and for longer duration period are even higher and sometimes double the current rates. In addition, lending institutions may also require property ownership titles as collateral for loans.

In the case of the National Microfinance Foundation (NMF), the current charge for its group loans is around 27 percent per year.

Concessional finance and well as grants from donor governments and institutions channelled through the Rural Electrification and Renewable Energy Fund could be used to buy down interest rates and provide guarantees to local lending institutions.

Capital Cost Subsidies

Subsidies on taxes and transfers may not be sufficient to lower down the costs and improve financial viability of solar PV systems. In many developing countries, grants and government budget allocations are used to buy down solar PV capital costs.

The inverse Ramsey pricing principle could be used as basis in structuring capital cost subsidy for solar PV systems in Yemen. The rule states that products with highly elastic demand generate maximum market expansion per invested subsidy. Several studies also show that demand elasticity for smaller units is high compared with larger units. As also shown in the market assessment study, the potential market share of smaller units is higher than larger PV units. Subsides to smaller units generate higher national benefits, thus smaller PV units must be provided with higher subsidies than larger PV systems.

The proposed subsidies for different SHS units are the following:

- $5/Wp up to 20 Wp system
- $4/Wp from 21 Wp up to 50 Wp system
- $3/Wp from 51 Wp up to 100 Wp system

For solar lamps, the proposed subsidy is the following:

- $15 per unit

Proposed Subsidies

At the initial stages of project implementation, subsidies that could be easily and practically implemented are the following:

- import duty and sales tax exemptions
- one time capital cost subsidy as presented in the previous section

The estimated levels of subsidies are summarized in *Table 8-11*.

Impact of Subsidies

The proposed subsidies significantly reduce the capital cost of the systems and also improve the financial indicators of the systems. These subsidies, however, fail to raise the financial indicators of medium and large size solar home systems into positive levels. On the other hand, the subsidy improves significantly the financial indicators of solar lanterns. This is shown in *Table 8-12*.

Table 8-11: Subsidy Conditions and Estimated Subsidy Levels

Market Prices	Import Duty and Sales Tax Subsidy	Capital Cost Subsidy	Total Subsidy
20 Wp Capital cost $261 per unit	$15 per unit	$5/Wp ($100 per unit)	$5.75/Wp ($115/unit)
50 Wp Capital cost $652 per unit	$38 per unit	$4/Wp ($200 per unit)	$4.76/Wp ($238 per unit)
100 Wp Capital cost $1564 per unit	$91 per unit	$3/Wp ($300 per unit)	$3.91/Wp ($391 per unit)
Solar Lamps Capital cost $117.9 per unit	$ 6 per unit	$ 15 per unit	$ 21 per unit

Table 8-12: Impact of Subsidies on Financial Indicators

Market Prices	Import Duty and Sales Tax Exemptions	Import Duty and Sales Tax Exemptions + Capital Cost Subsidy
20 Wp NPV = $85 IRR = 17%	NPV = $124 IRR = 22%	NPV = $225 IRR = 58%
50 Wp NPV = - $440 IRR = very small	NPV = - $310 IRR = -4.14%	NPV = - $129 IRR = 1.0%
100 Wp NPV = - $1,737 IRR = very small	NPV = - $1,403 IRR = very small	NPV = - $1,131 IRR = very small
Solar lantern NPV = $187 IRR = 44%	NPV = $196 IRR = 48%	NPV = $209 IRR = 61%

Assumptions used are given in Table 8-11.

8.2.2 Solar Home System End-User Credit

In addition to subsidies, another measure that addresses the investment barrier is to provide a financing scheme for rural households.

A credit scheme for the dissemination of solar home systems in Yemen was recommended by the study 'Business Models and Financial Schemes for Solar Home Systems Program'. This model is being used in this study's simulation of the impact of subsidies on solar home system's the financial viability.

The above study recommended a 3-4 year loan terms for SHS. Loans provided by microfinance institutions in Yemen are, however, payable in one year. As mentioned in the previous chapter, if the marginal areas will be served by microfinance institutions, the credit term these institutions will most likely to offer will be one year. Having a loan term of one year defeats the financing purpose since the monthly amortization will remain unaffordable to majority of rural households. The Government should negotiate for longer payment terms (at least three years) and a lower financial charge.

The financing models for different SHS sizes are shown in *Figure 8-1*, *Figure 8-2*, and *Figure 8-3*. The analysis shows a 36-month payment period and a financial charge of 10% per year. The lower down payment and monthly dues make these technologies affordable to end-users at different income classes.

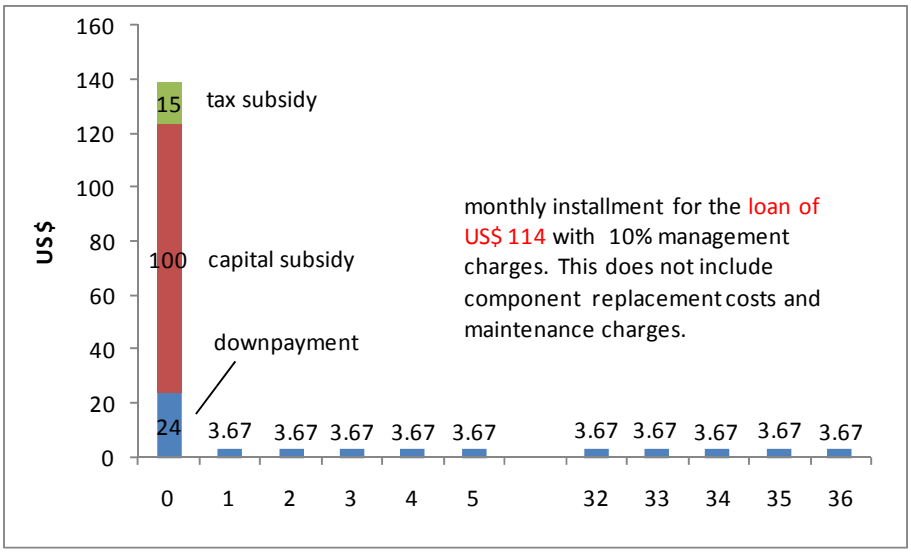

Figure 8-1: End-user financing scheme for 20 Wp Solar Home System

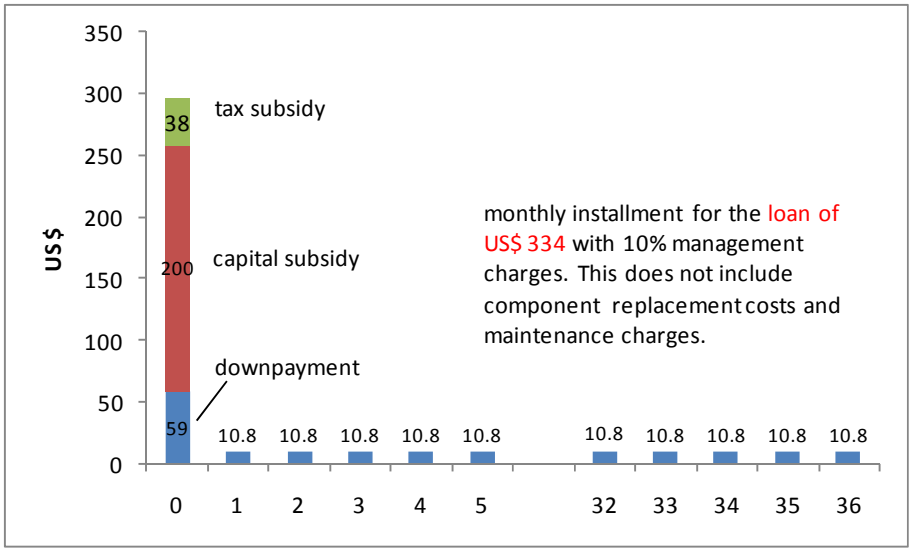

Figure 8-2: End-user financing scheme for 50 Wp Solar Home System

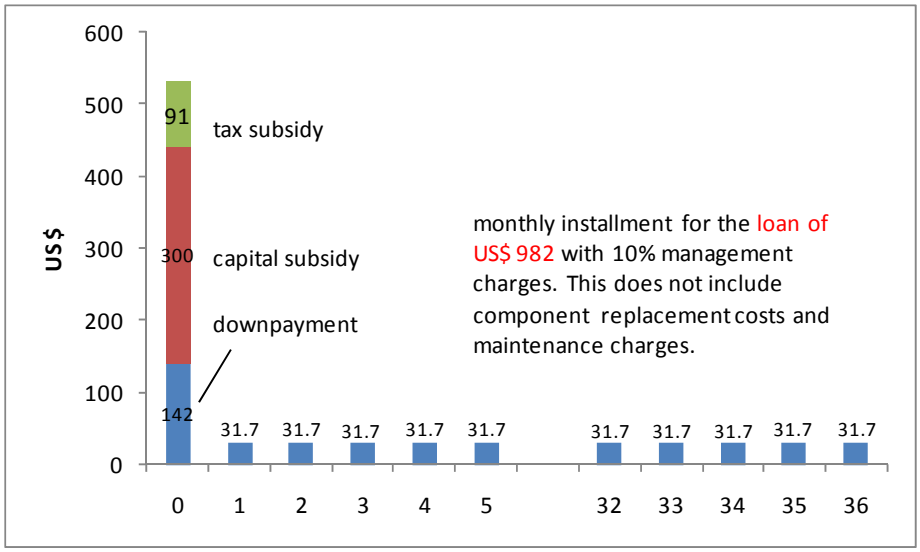

Figure 8-3: End-user financing scheme for 100 Wp Solar Home System

8.2.3 Solar Lamp End-User Credit

For solar lamps, it was recommended that the Post and Postal Savings Authority should provide credit to households which use the agency as the vehicle of their monthly salaries, pensions and other sources of income. At present, the Postal Service is currently providing credit services to its clients for the purchase of mobile phones.

Based on the study commissioned by GTZ, rural households expressed their willingness to purchase solar lamps at the price of around US$ 60 per unit. With a financing, most households can afford to pay for a US$10 down payment and monthly amortization of around US$10. Based on these survey results, the study designed a financing scheme for solar home systems given the estimated capital cost and proposed subsidies. The study also assumed an annual 10% credit charge. With US$10 down payment, the credit needed by each household is around US$71.9 and with 10% annual charge, a monthly payment of around US$10.6 is required over 9 months. This is shown in *Figure 8-4*.

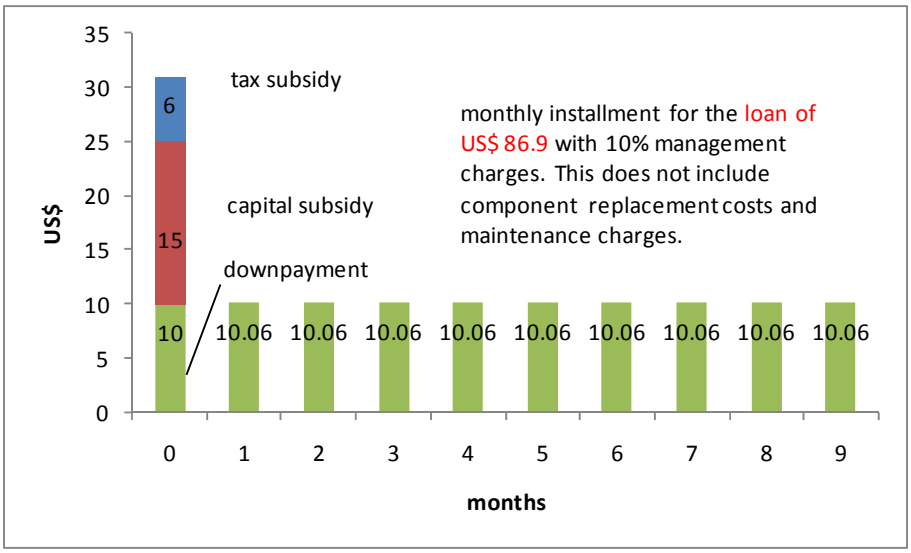

Figure 8-4: End-user financing scheme for solar lanterns

8.2.4 Solar Home System *Fee-for-Service*

For the fee-for-service model, as presented in Chapter 5 of this study, the private or the public sector provides capital fund for the purchase, installation and operation and maintenance of the systems. The end-users will pay an initial connection fee, and monthly payment for the services provided.

The study simulated the required monthly payment of each household given assuming the same subsidy levels are provided in the end-user credit. System component replacements over the period of 20 years are also included in the analysis. With assumed connection fees for each system and 10% discount rate, the estimated monthly payments are the following: US$2.54 for 20Wp systems, US$ 7.0 for 50Wp systems and US$ 24.5 for 50Wp systems. This consists only of the equipment costs and does not include management and maintenance charges. This is shown in *Figure 8-5*, *Figure 8-6*, and *Figure 8-7*.

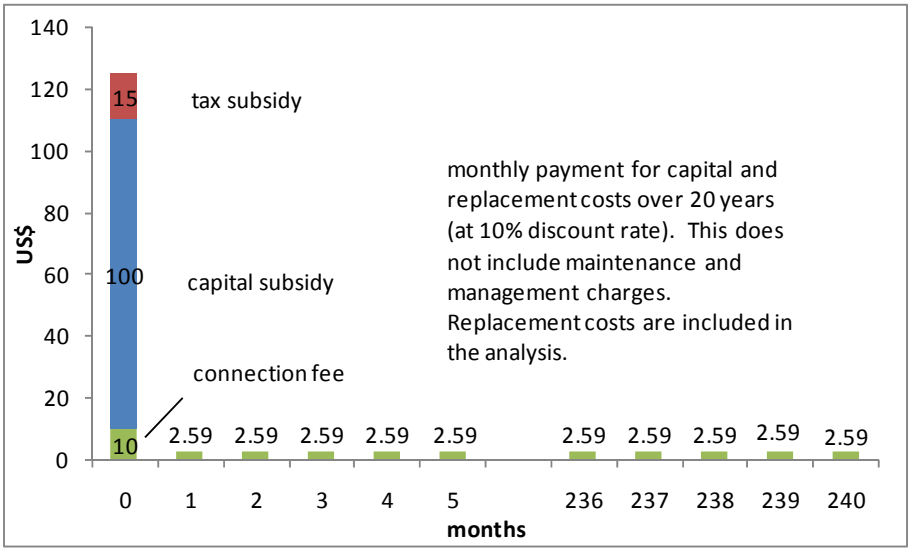

Figure 8-5: Monthly payment for 20 Wp systems under the fee-for-service approach

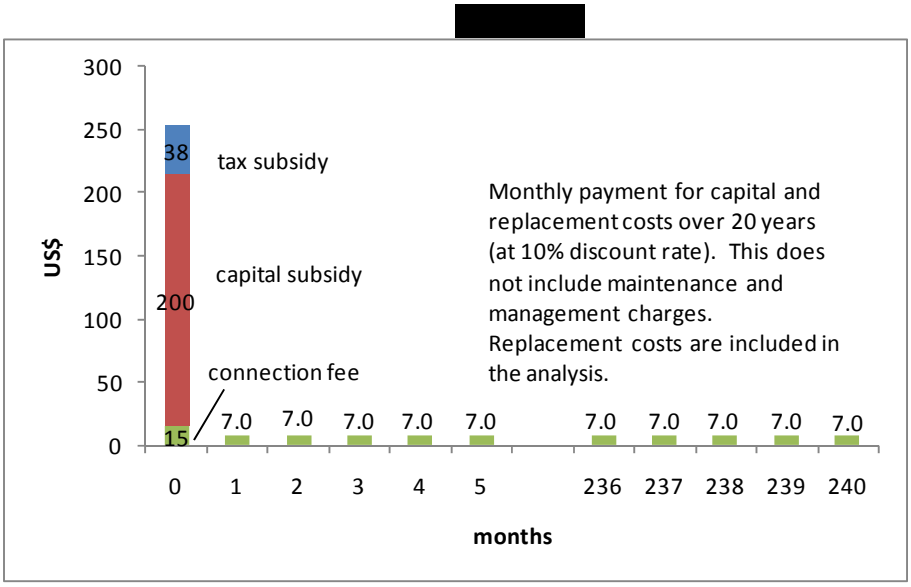

Figure 8-6: Monthly payment for 50 Wp systems under the fee-for-service approach

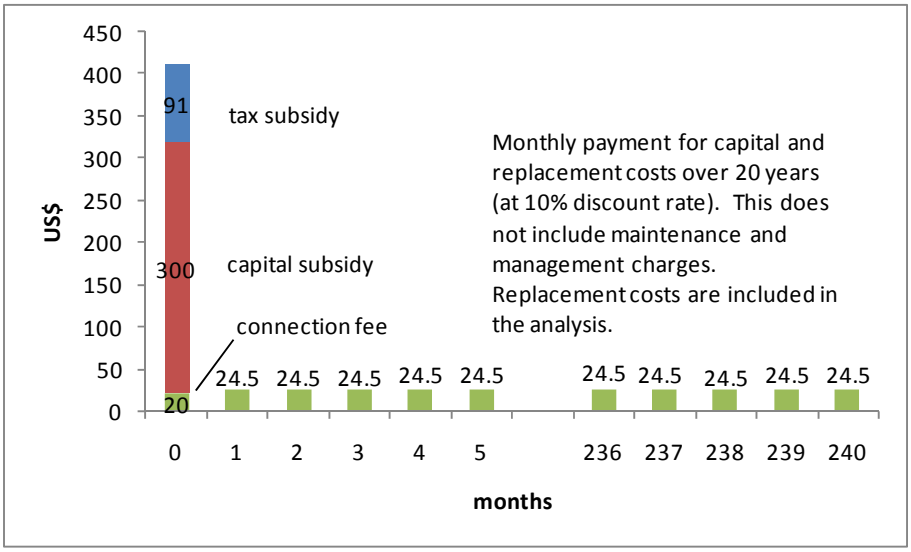

Figure 8-7: Monthly payment for 100 Wp systems under the fee-for-service approach

9 Financing Framework

9.1 Financing requirements

The previous Chapter presented measures to address investment barriers to solar home systems (SHS). These measures are the following:

- subsidies (one time capital cost subsidy and duty and sales tax exemptions),
- credit schemes to reduce the initial investment cost and increase affordability of the technologies, and
- third party capital investment through fee-for-service approach

Capital subsidy will be initially provided by the Public Electrification Corporation (PEC)-Rural Electrification Sector (RES) and at the later stage by the Rural Electrification Agency (REA) when this institution will be established. This subsidy could be sourced from the Rural Electrification Fund (REF). For duty and sales tax exemptions, this represents the foregone revenue of the Ministry of Finance.

Micro-credit will be supplied by the microfinance institutions under credit sales programs while energy service companies provide capital investment costs for fee-for-service programs. These entities however may need financing for the initial procurement of the solar PV technologies. These could be sourced from company's internal budget or from other sources such as the Rural Electrification Fund, Social Fund for Development and other financing institutions. This is shown in *Table 9-1*.

Table 9-1: Sources of Financing

	Institution	Source of Funding
Duty and sales tax	Ministry of Finance (foregone revenue)	
Capital cost subsidy	PEC-RES/REA	Government budget Rural Electrification Fund International donors
Hardware cost financing		
Credit schemes	Financing Institutions (FIs)	Internal fund Rural Electrification Fund Social Development Fund Other Financing Institutions
Fee-for-service	Energy Service Companies (ESCOs)	Internal fund Rural Electrification Fund Social Development Fund Other Financing Institutions

The estimated amount of subsidies and required financing for each program and for the whole off-grid rural electrification program are shown in *Table 9-2*. In total, import

duties and sales tax subsidies would amount to US$ 2 million, the proposed capital cost subsidy would reach around US$ 9 million while the capital requirement for hardware procurement would be more than US$ 23 million.

Moreover, the estimated annual requirements for subsidy and capital investments are shown in *Table 9-3*. These are derived from the assumption that each program target will be achieved in five years.

Table 9-2: Subsidies and investment capital requirement (50% penetration rate of market potential)

	Tax Subsidies (million US$)	**Capital subsidy (million US$)**	**Hardware costs (million US$)**
Solar Home System End-user Cash and Credit Sales with Microfinance Institutions			
Program 1			
Al Mahwit	0.30	1.50	3.45
Hajja	0.15	0.76	1.72
Lahj	0.12	0.43	1.38
Raimah	0.16	0.78	1.78
Taiz	0.15	0.72	1.68
Sub-total	**0.886**	**4.188**	**10.008**
Program 3			
Abyan	0.01	0.02	0.12
Amran (25%)	0.05	0.12	0.62
Sub-total	**0.06**	**0.148**	**0.74**
Total (SHS cash and credit sales)	**0.945**	**4.336**	**10.748**
Solar Home System Fee-for-Service with Local Service Providers			
Program 5			
Al Baida	0.08	0.38	0.88
Al Hodeidah	0.11	0.52	1.29
Amran (75%)	0.28	1.38	3.18
Sub-total	**0.47**	**2.27**	**5.35**
Program 7			
Al Mahara	0.01	0.06	0.13
Hadramout	0.32	1.47	3.74
Sub-total	**0.33**	**1.53**	**3.87**
Total (SHS fee-for-service)	**0.803**	**3.801**	**9.222**
Solar Lamp End-User Cash and Credit Sales with Post and Postal Savings Authority			
Program 2			
Al Mahwit	0.04	0.10	0.67
Hajja	0.03	0.09	0.55
Lahj	0.02	0.06	0.40
Raimah	0.02	0.05	0.33
Taiz	0.02	0.04	0.23
Sub-total	**0.14**	**0.34**	**2.19**
Program 4			
Abyan	0.01	0.02	0.16

Amran	0.05	0.12	0.80
Sub-total	**0.06**	**0.15**	**0.96**
Program 6			
Al Baida	0.01	0.03	0.21
Al Hodeidah	0.01	0.02	0.10
Sub-total	**0.02**	**0.05**	**0.32**
Program 8			
Al Mahara	0.002	0.01	0.03
Hadramout	0.05	0.11	0.73
Sub-total	**0.05**	**0.12**	**0.77**
Total (SL cash and credit sales)	**0.262**	**0.655**	**4.230**
TOTAL	**2.010**	**8.792**	**24.416**

Note: 1) Tax subsidies include import duties and sales tax. 2) Capital cost subsidy is one time capital subsidy for each unit: $5/Wp for 20 Wp system, $4/Wp for 50 Wp system, and $3/Wp for 100 Wp system. 3) hardware costs are retail price of SHS less subsidies.

Table 9-3: Annual capital subsidy and capital investment requirements

	Year												
	1	2	3	4	5	6	7	8	9	10	11	12	13
program 1													
capital subsidy	0.84	0.84	0.84	0.84	0.84								
hardware	2.00	2.00	2.00	2.00	2.00								
program 2													
capital subsidy		0.07	0.07	0.07	0.07	0.07							
hardware		0.44	0.44	0.44	0.44	0.44							
program 3													
capital subsidy			0.03	0.03	0.03	0.03	0.03						
hardware			0.19	0.19	0.19	0.19	0.19						
program 4													
capital subsidy				0.03	0.03	0.03	0.03	0.03					
hardware				0.19	0.19	0.19	0.19	0.19					
program 5													
capital subsidy					0.45	0.45	0.45	0.45	0.45				
hardware					1.07	1.07	1.07	1.07	1.07				
program 6													
capital subsidy						0.01	0.01	0.01	0.01	0.01			
hardware						0.06	0.06	0.06	0.06	0.06			
program 7													
capital subsidy								0.31	0.31	0.31	0.31	0.31	
hardware								0.77	0.77	0.77	0.77	0.77	
program 8													
capital subsidy									0.02	0.02	0.02	0.02	0.02
hardware									0.15	0.15	0.15	0.15	0.15
TOTAL	**2.84**	**3.35**	**3.57**	**3.79**	**5.31**	**2.55**	**2.04**	**2.90**	**2.85**	**1.33**	**1.26**	**1.26**	**0.18**
capital subsidy	0.84	0.91	0.94	0.96	1.42	0.59	0.52	0.80	0.79	0.34	0.33	0.33	0.02
hardware	2.00	2.44	2.63	2.82	3.89	1.95	1.52	2.10	2.06	0.99	0.93	0.93	0.15

9.2 Rural Electrification Fund

The establishment of the Rural Electrification Fund has been proposed in the National Rural Electrification Strategy Study to streamline national and international support to rural electrification activities in the country. In the study Renewable Energy Strategy and Action Plan, a joint Renewable Energy and Rural Electrification Fund was proposed to coordinate international assistance and rationalize subsidies to renewable energies and rural electrification in Yemen (*Figure 9-1*). As discussed in the previous section, subsidies to SHS can be sourced from RE/REN Fund.

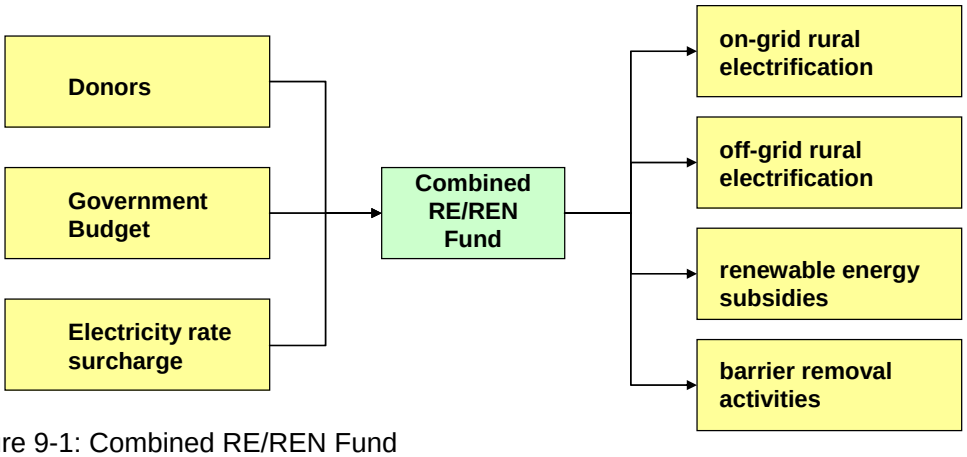

Figure 9-1: Combined RE/REN Fund

10 Social Infrastructures

Social infrastructures assessed in this study include health centres, rural schools, mosques and military checkpoints.

10.1 Market potential

The distribution of health centres and schools all over the country is shown in *Figure 10-1* and *Figure 10-2*. The estimated total number of these social infrastructures within the identified off-grid areas is summarized in *Table 10-1*. Currently, there are around 570 health centres, more than 2000 schools, and 9500 mosques in the identified off-grid areas. The Ministry of Interior on the other hand has planned to install around 200 mobile check points throughout the country.

Following the sector and program classifications and implementation programs for off-grid rural household electrification discussed in the previous chapter, the study estimated the market potential of each off-grid districts and governorates. The rational for following this classification is that off-grid activities, information and support infrastructure would have been carried out in those areas and that it would have been easier to integrate rural electrification programs for social infrastructures. The estimated potential for social infrastructures is shown in *Table 10-2* and *Table 10-3*.

Over the period of 10 years, PEC-RES/REA could however target around 50% of these market potential. These potentials are shown in *Table 10-4*, *Table 10-5* and *Table 10-6*.

The proposed implementation schedule for social infrastructure program is shown in *Figure 10-3*.

Table 10-1: Social infrastructure in off-grid areas*

	Highlands	Lowlands	Total
Health centres	480	90	570
Schools	1700	350	2050
Mosques			
Large	2900	900	3800
Small	3900	1800	5700
Checkpoints	150	50	200

Sources of data: health centres and schools – Social Fund for Development database; Mosques – based on IT Power estimation methodology, small mosques for villages with less than 20 households, 1 large and 1 small mosque for villages with 20-99 households, 2 large mosques for villages with 100-149 households, and 3 large mosques for villages with 150-200 households; checkpoints – estimated by PEC-RES.

* Off-grid areas as analyzed by IT-Power which closely approximates the off-grid areas considered in the study. The IT Power study considers off-grid areas as areas situated 50 km outside the existing grid and isolated grids, and 5 km outside the centre of big villages.

Market Assessment Report, IT Power, 2006.

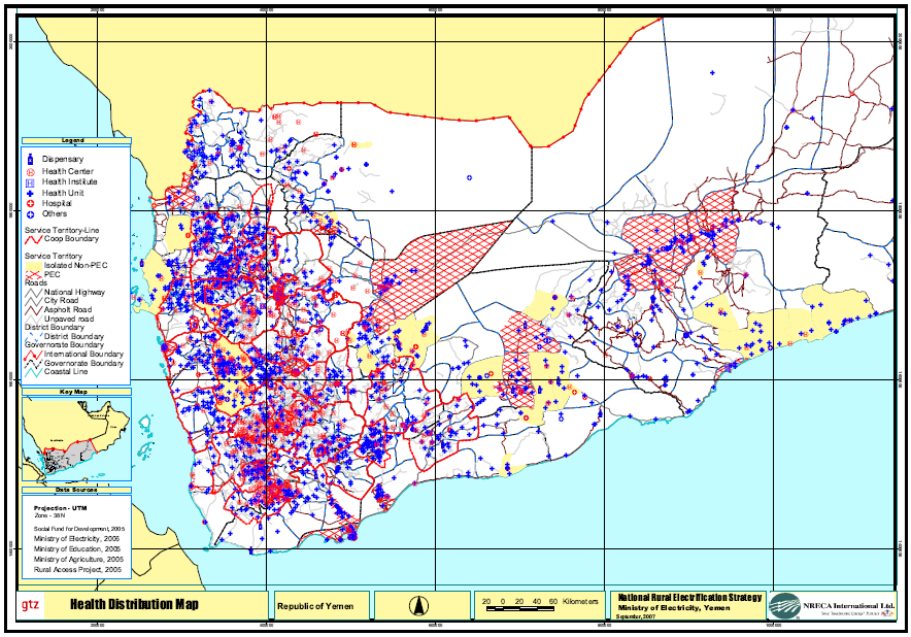

Figure 10-1: Geographic distribution of Health Centres

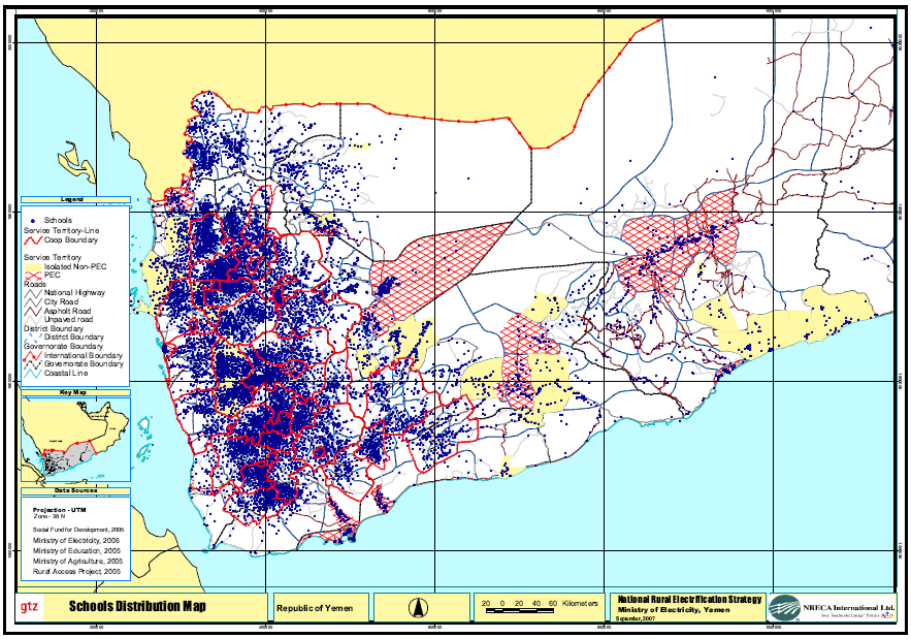

Figure 10-2: Geographic distribution of Schools

Table 10-2: Off-grid rural health centres and schools market potential

	Health Centres				Rural Schools			
	Program H1	*Program H2*	*Program H3*	*Program H4*	*Program S1*	*Program S2*	*Program S3*	*Program S4*
Abyan		61				220		
Al Baida			51				183	
Al Hodiedah			31				110	
Al Mahara				31				110
Al Mahwit	31				110			
Amran		71				256		
Hadramout				163				586
Hajja	51				183			
Lahj	41				146			
Raimah	20				73			
Taiz	20				73			
TOTAL	**163**	**132**	**81**	**193**	**586**	**476**	**293**	**696**

Table 10-3: Off-grid rural mosques market potential

	Large Mosque				Small Mosque			
	Program LM1	*Program LM2*	*Program LM3*	*Program LM4*	*Program SM1*	*Program SM2*	*Program SM3*	*Program SM4*
Abyan		407				611		
Al Baida			339				509	
Al Hodiedah			204				305	
Al Mahara				204				305
Al Mahwit	204				305			
Amran		475				713		
Hadramout				1086				1629
Hajja	339				509			
Lahj	271				407			
Raimah	136				204			
Taiz	136				204			
TOTAL	**1086**	**882**	**543**	**1289**	**1629**	**1323**	**814**	**1934**

Table 10-4: Target market potential (50%) for off-grid rural health centres and schools

	Health Centres				Rural Schools			
	Program H1	*Program H2*	*Program H3*	*Program H4*	*Program S1*	*Program S2*	*Program S3*	*Program S4*
Abyan		31				110		
Al Baida			25				92	
Al Hodiedah			15				55	
Al Mahara				15				55
Al Mahwit	15				55			
Amran		36				128		
Hadramout				81				293
Hajja	25				92			
Lahj	20				73			
Raimah	10				37			
Taiz	10				37			
TOTAL	**81**	**66**	**41**	**97**	**293**	**238**	**146**	**348**

Table 10-5: Market potential (50%) for off-grid rural mosques

	Large Mosque				Small Mosque			
	Program LM1	*Program LM2*	*Program LM3*	*Program LM4*	*Program SM1*	*Program SM2*	*Program SM3*	*Program SM4*
Abyan		204				305		
Al Baida			170				254	
Al Hodiedah			102				153	
Al Mahara				102				153
Al Mahwit	102				153			
Amran		238				356		
Hadramout				543				814
Hajja	170				254			
Lahj	136				204			
Raimah	68				102			
Taiz	68				102			
TOTAL	**543**	**441**	**271**	**645**	**814**	**662**	**407**	**967**

Table 10-6: Target market potential of social infrastructures

	Health Centres	Schools	Large Mosques	Small Mosques	Check Points
Program 1					
Al Mahwit	15	55	102	153	
Hajja	25	92	170	254	
Lahj	20	73	136	204	
Raimah	10	37	68	102	
Taiz	10	37	68	102	
Sub-total	**81**	**293**	**543**	**814**	**200**
Program 2					
Abyan	31	110	204	254	
Amran	36	128	238	153	
Sub-total	**66**	**238**	**441**	**407**	
Program 3					
Al Baida	25	92	170	153	
Al Hodeidah	15	55	102	814	
Sub-total	**41**	**146**	**271**	**407**	
Program 4					
Al Mahara	15	55	102	153	
Hadramout	81	293	543	814	
Sub-total	**97**	**348**	**645**	**967**	
TOTAL	**285**	**1025**	**1900**	**2850**	**200**

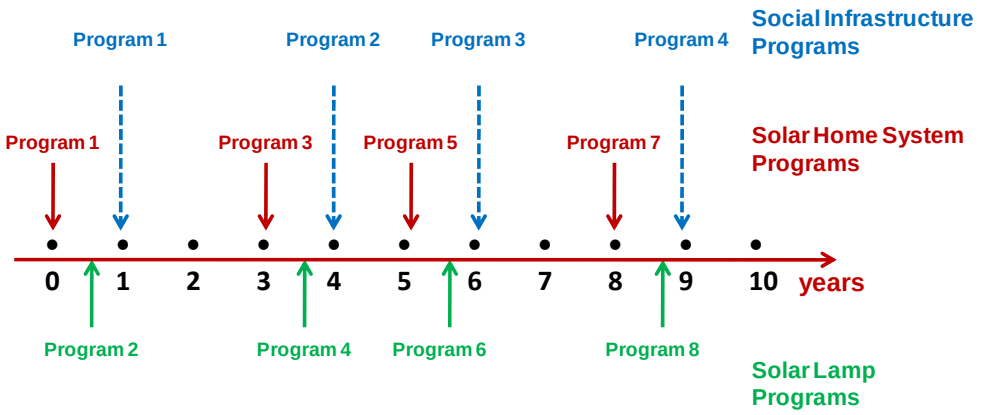

Figure 10-3: Proposed social infrastructures implementation schedule

10.2 Energy Demand Assessment and Systems Costs

Energy demand and supply assessments of the identified social infrastructures were carried out in the study Market Assessment for Solar PV.

For rural health centres, energy demand is classified into lighting and refrigeration for vaccines. Demand for mosquito killer lamps and ventilation are added to health centres situated in the highlands. The lighting systems for both highlands and lowlands were specified to be AC since this is the standard requirement for health units. The estimated solar PV system sizes required to meet the demand of typical health centres in the highland and lowlands is 490 Wp and 1120 Wp, respectively, with system costs amounting to US$ 7,910 and US$ 18,620. This is shown in *Table 10-7*.

Energy demand for rural schools is mainly for lighting. For schools situated in the lowlands, electricity load for mosquito killer lamps and fans are included. Solar PV sizes that meet typical rural school demand are the following: 280 Wp for schools in the highlands and 910 Wp for those in the lowlands. The estimated costs for these units are US$ 4760 and US$ 15470. This is shown in *Table 10-8*.

Energy services required by mosques are for lighting and for amplifier systems. Again, electricity load for fans and mosquito killer lamps are included in mosques situated in the lowlands. Also, large and small mosques are differentiated in the study. For large mosques, solar PV systems rated capacity that satisfy the energy requirement are 140 Wp and 280 Wp for highlands and lowlands respectively. Similarly, for small mosques the typical systems rated capacity are 60 Wp and 280 Wp. The demand requirements and unit costs of these systems are shown in *Table 10-9*.

For military checkpoints, the Ministry of Interior plans to install 200 units of mobile offices and checkpoints throughout the country. *Table 10-10* shows three modular designs developed by PEC-RES for mobile offices and checkpoints with specified equipment, rated power, array sizes and average unit system costs. The mobile office is equipped with 1200 Wp solar PV array, the mobile checkpoint 1 with 680 Wp and the smaller mobile checkpoint 2 with 480 Wp system. The average investment cost for each unit is the following: US$ 25,802 for the mobile office, US$ 14,621 for the medium-size mobile checkpoint 1, and US$ 10,321 for the smaller mobile checkpoint 2. Among these models, the popular model is the smaller mobile checkpoint 2. The study assumes the following market split of the three models: 10% for the mobile office, 20% for the medium size checkpoint 1, and 70% for the small size checkpoint 2.

Table 10-7: Rural health centres estimated energy demand, corresponding solar PV supply capacity and unit system costs

Energy Services	Highlands	Lowlands
Lighting and Air Cooling Systems		
Treatment rooms		
4 lamps x 18 W, 6 hours per day	432 Wh/day	432 Wh/day
Ancillary rooms		
5 lamps x 11 W, 5 hours per day	275 Wh/day	275 Wh/day
Fans		
4 x 50 W, 6 hours per day	-	1 200 Wh/day
Mosquito lamp		
1 x 50 W, 12 hours per day	-	600 Wh/day
Total daily load	**707 Wh/day**	**2 507 Wh/day**
Size of PV Array	**280 Wp**	**910 Wp**
Vaccine Refrigeration Systems		
Vaccine refrigerator/ice pack freezer	12V. 50 l	12V. 50 l
Size of PV array	210 W_p	210 W_p
Health Unit System (Combined)		
Size of PV array	490 Wp	1 120 Wp
Estimated system costs		
Including mounting systems, batteries, inverter and controller	US$ 7 910	US$ 18 620

Source: Market Assessment Report, IT Power, 2006

Table 10-8: Rural schools estimated energy demand, corresponding solar PV supply capacity and unit system costs

Energy Services	Highlands	Lowlands
Classroom lighting		
6 lamps x 11 W, 6 hours per day	396 Wh/day	396 Wh/day
Miscellaneous lighting		
4 lamps x 11 W, 5 hours per day	220 Wh/day	220 Wh/day
Fans		
6 x 50 W, 6 hours per day	-	1 800 Wh/day
Mosquito lamp		
2 x 50 W, 2 hours per day	-	200 Wh/day
Total daily load	616 Wh/day	2 616 Wh/day
Size of PV Array	280 Wp	910 Wp
Estimated system costs	US$ 4 760	US$ 15 470
(including mounting systems, batteries, inverter and controller)		

Source: Market Assessment Report, IT Power, 2006

Table 10-9: Rural mosques estimated energy demand, corresponding solar PV supply capacity and unit system costs

Energy Services	Highlands	Lowlands
Large Mosques		
Lighting		
5 lamps x 18 W, 3 hours per day	270 Wh/day	270 Wh/day
Water closet lighting		
2 lamps x 7 W, 3 hours per day	42 Wh/day	42 Wh/day
Amplifier		
1 x 50 W, 1.5 hours per day	75 Wh/day	75 Wh/day
Fans		
2 x 50 W, 3 hours per day	-	300 Wh/day
Mosquito lamp		
1 x 50 W, 2 hours per day	-	200 Wh/day
Total daily load	387 Wh/day	787 Wh/day
Size of PV Array	140 Wp	280 Wp
Estimated system costs (including mounting systems, batteries, inverter and controller)	US$ 2 240	US$ 4 760
Small Mosques		
Lighting		
2 lights x 18 W, 3 hours per day	108 Wh/day	108 Wh/day
Amplifier		
1 x 50 W, 1.5 hours per day	75 Wh/day	75 Wh/day
Fan		
1 x 50 W, 3 hours per day	-	150 Wh/day
Mosquito lamp		
1 x 18 W, 2 hours per day	-	36 Wh/day
Total daily load	183 Wh/day	369 Wh/day
Size of PV Array	60 Wp	140 Wp
Estimated system costs (including mounting systems, batteries, inverter and controller)	US$ 950	US$ 2 380

Source: Market Assessment Report, IT Power, 2006

Table 10-10: Mobile office and checkpoint - equipment, rated power, solar PV capacity and estimated unit costs

Equipment	Quantity	Rated Power
Mobile Office		
Indoor light	2 x 11 W	22 W
Outdoor light	1 x 11 W	11 W
Computer	1 x 400 W	400 W
Printer	1 x 100 W	100 W
Colored TV 14 inches	1 x 200 W	200 W
Telefax	1 x 220 W	220 W
Wireless telephone (CDMA)	1 x 70 W	70 W
Table fan	1 x 50 W	50 W
Blender	1 x 300 W	300 W
Non-froze refrigerator	1 x 200 W	200 W
Ventilating fan	1 x 20 W	20 W
Extra load for charging radio telephone	1 x 100 W	100 W
Size of PV array	*30 x 40 Wp*	*1200 Wp*
Batteries	*7*	*7 x 100 Ah 12 V dc*
Average mobile office unit cost	*US$ 25 802*	
Mobile checkpoint 1		
Indoor light	2 x 11 W	22 W
Outdoor light	1 x 11 W	11 W
Fax machine	1 x 220 W	220 W
Wireless telephone (CDMA)	1 x 70 W	70 W
Table fan	1 x 50 W	50 W
Non-froze refrigerator	1 x 200 W	200 W
Ventilating fan	1 x 20 W	20 W
Extra load for charging radio telephone	1 x 100 W	100 W
Size of PV array	*17 x 40 Wp*	*680 Wp*
Batteries	*3*	*3 x 100 Ah 12 V dc*
Average mobile checkpoint 1 unit cost	*US$ 14 621*	
Mobile checkpoint 2		
Indoor light	2 x 11 W	22 W
Outdoor light	1 x 11 W	11 W
Table fan	1 x 50 W	50 W
Non-froze refrigerator	1 x 200 W	200 W
Ventilating fan	1 x 20 W	20 W
Extra load for charging radio telephone	1 x 200 W	100 W
Size of PV array	*12 x 40 Wp*	*480 Wp*
Batteries	*3*	*3 x 100 Ah 12 V dc*
Average mobile checkpoint 2 unit cost	*US$ 10 321*	

Source: Personal Communications (Adnan Alakori), PEC-RES, 2008.

10.3 Investments and Sources of Funds

The total investment requirements for the target market potential in off-grid areas amount to more than US$ 32 million. This is shown in *Table 10-11*. Rural schools and mosques (large and small) have almost equal investment requirements and accounting around 86% of the total investments (more than US$ 12 for each infrastructure type). Health centres require more than US$ 4 million while that of military checkpoints is more than US$ 2.5 million.

Investment requirements for the first 3 years amount to more than US$2.2 million and this will rise to more than US$3 in the 4th to fifth years. *Table 10-12* shows the annual capital investment requirement for these infrastructures over the period of 13 years.

This study also indentified possible sources of funding for these infrastructures. The Ministry of Health could potentially allocate electrification funds for rural health centres. Similarly, the Ministry of Education and Ministry of Interior could provide funding for rural schools and military checkpoints.

PEC-RES/REA could also allocate subsidy for the implementation of these infrastructures. Subsidies could be sourced from the Rural Electrification and from other international donor agencies. The level of subsidy however will depend upon the availability of funding. This is summarized in *Table 10-13*.

Table 10-11: Investment requirements

	Health Centres	Schools	Large Mosque	Small Mosque	Check Points
Program 1					
Al Mahwit	0.12	0.26	0.23	0.15	
Hajja	0.47	1.42	0.81	0.61	
Lahj	0.38	1.13	0.65	0.48	
Raimah	0.08	0.17	0.15	0.10	
Taiz	0.19	0.57	0.32	0.24	
Sub-total	**1.24**	**3.55**	**2.16**	**1.57**	**2.55**
Program 2					
Abyan	0.57	1.70	0.97	0.73	
Amran	0.28	0.61	0.53	0.34	
Sub-total	**0.85**	**2.31**	**1.50**	**1.07**	
Program 3					
Al Baida	0.20	0.44	0.38	0.24	
Al Hodeidah	0.28	0.85	0.48	0.36	
Sub-total	**0.49**	**1.29**	**0.86**	**0.61**	
Program 4					
Al Mahara	0.28	0.85	0.48	0.36	
Hadramout	1.52	4.53	2.58	1.94	
Sub-total	**1.80**	**5.38**	**3.07**	**2.30**	
TOTAL	**4.38**	**12.52**	**7.59**	**5.55**	**2.55**

Subsidies could be provided by PEC-RES/REA through the Rural Electrification Fund. The amount of subsidy will depend upon the availability of financial resources. The subsidy can be estimated as percentage of the required investment cost by infrastructure type.

Table 10-12: Required investments per year (US$ million)

Subsidies could be provided by PEC-RES/REA through the Rural Electrification Fund. The amount of subsidy will depend upon the availability of financial resources. The subsidy can be estimated as percentage of the required investment cost by infrastructure type.

Table 10-13: Sources of Funds

Infrastructure	Main Source of Funding	Sources of Subsidy
Health Centres	Ministry of Health	Rural Electrification Fund, International Donors and Aid Agencies
Rural Schools	Ministry of Education	Rural Electrification Fund, International Donors and Aid Agencies
Mosques	Ministry of Religious Endowment and Islamic Affairs	Rural Electrification Fund, International Donors and Aid Agencies
Checkpoints	Ministry of Interior	Rural Electrification Fund, International Donors and Aid Agencies

10.4 Demonstration Projects

To establish partnerships with different government agencies responsible for the operations and functioning of the social infrastructures, PEC-RES/REA could initiate demonstration projects. The selection of project demonstration sites will be coordinated with concerned agencies. From economic point of view, it is desirable that these demonstration projects are to be implemented in areas where demonstration projects of solar home systems for rural households are also being carried out in order to exploit the economies of scale in the provision of support services and to create a critical mass for the solar PV market.

For the demonstration project, 20 solar PV systems for each social infrastructure could be installed (20 for health centers, 20 for schools, 20 for mosques and 20 for military checkpoints) or a total of 80 solar PV systems.

The institutional arrangement of the approach is shown in *Figure 10-4* and briefly discussed below. Further details of the model are presented below.

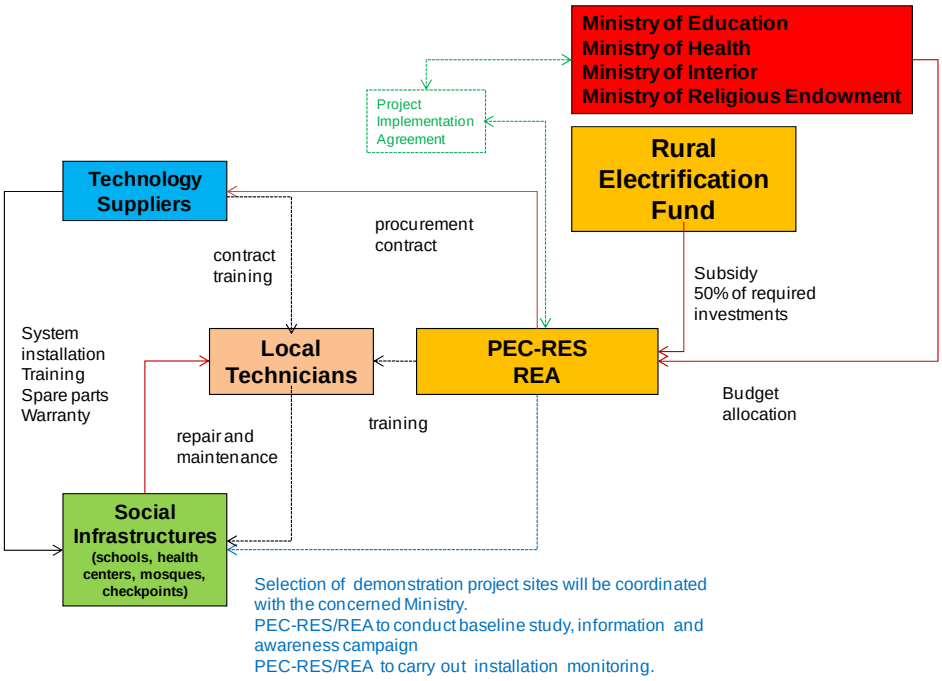

Figure 10-4: Institutional arrangement for energy service supply to social infrastructures

- PEC-RES/REA initiates contact, and negotiates with concerned government ministries for the supply of energy services of specific infrastructures in off-grid areas.
- Through the Rural Electrification Fund, PEC-RES/REA offers subsidy for the purchase and installation of the systems (subsidies could be as high as 50% of the system costs). PEC-RES/REA and the concerned Ministry sign a project implementation agreement.
- PEC-RES/REA in coordination with the concerned agencies will identify appropriate areas for pilot demonstration projects. PEC-RES/REA will carry out the baseline study for each identified project site.
- PEC-RES/REA together with the concerned agencies will carry out information and awareness campaign.
- The procurement of the solar PV systems through competitive bidding will be executed by PEC-RES/REA. Standards for solar PV systems and installation quality will be specified in the procurement process.

- The winning bidder will install the systems and provide training to personnel of each social infrastructure. As part of the contract, the winning bidder must provide after services for the period of at least 5 years through local technicians. These technicians could be a local technical person or an employee of the said social infrastructure. Training must also be provided by winning bidders for these local technicians. In addition, PEC-RES/REA will also conduct training for the accreditation of the technicians.
- PEC-RES/REA will carry out installation monitoring and the final payment to winning bidders will be dependent upon the compliance certification issued after the monitoring process.

11 Wind-Diesel Hybrid Systems

Chapter 4 of this report concludes that the government can immediately develop a full-scale rural electrification program using solar PV technologies while in parallel a full-scale investigation can be carried out for wind resource availability and for the viability of wind-diesel hybrid systems in off-grid areas. It must be noted also that, to large extent, solar PV systems and wind-diesel systems do not compete but rather complement each other. Isolated networks of wind-diesel systems are financially feasible in areas where the load demand is high (villages with more than 200 households). In villages with relatively low household density, it may be financially viable to provide solar PV systems to each household.

11.1 Market potential and development programs

Based on the information from the wind atlas, the study identified 8 off-grid districts in coastal areas of the country where the wind potential is relatively high. Villages with more than 150 households from these districts were considered as potential areas for wind-diesel systems. As shown in *Table 11-1*there are more than 40 villages that could be potentially supplied with energy services through stand-alone wind-diesel systems. Wind resources in these areas however need to be assessed and measured on site. Assuming that only 50% of these sites have favourable wind regimes, the total number of villages that could be developed with wind-diesel systems is only 23.

Key activities that could be pursued by the Ministry of Electricity and Energy (MEE) and PEC-RES/REA can be classified into the following programs:

- Program 1: Resource measurement and feasibility studies (to be implemented during the first 3 years)
    - Wind measurement campaign
    - Baseline market study
    - Feasibility studies
    - Capacity building activities
- Program 2: Project implementation in 23 sites (to be carried out within 10 years)
    - P2A – Taiz (11 systems)
    - P2B – Al Hodeidah (8 systems)
    - P2C – Lahj, Abyan, Hadramout (4 systems)

The proposed project implementation timeline is shown in *Figure 11-1*.

Table 11-1: Potential for wind-diesel systems (shaded columns)

Marginal Districts	Number of Villages by Household Size Distribution						
	< 50	50-100	100-150	150-200	200-300	300-450	> 450
Hadramout							
Al Mukalla	68	7	1	-	-	-	-
Broom	29	14	5	-	-	1	1
Abyan							
Khanfir	90	8	2	-	1	0	1
Lahj							
Madaribah and Al Arah	107	13	4	-	2	-	-
Taiz							
Parts of Al Mocha	3	1	-	1	5	6	9
Al Hodeidah							
Assalif	2	1	-	1	-	1	2
Kamran	1	-	1	-	-	-	-
Al Munira	26	16	5	7	1	3	2
TOTAL				9	9	11	15
TOTAL (50% of villages have feasible wind regimes)				5	5	5	8

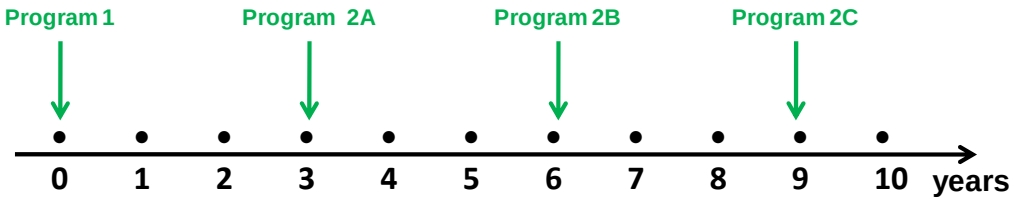

Figure 11-1: Implementation timeline of wind-diesel hybrid program

11.2 Electricity demand

The ESMAP study surveyed the electricity consumption by both rural and urban households by electricity supply system type. As shown in *Table 11-2*, rural electricity consumers connected to the national grid registered the highest consumption with an average of 101 kWh per month. Those connected to the PEC isolated systems consume around 74 kWh per month while those connected to private and cooperative systems use 45 and 45 kWh per month.

For rural households in off-grid areas, the study assumes an average consumption level of 37.5 kWh per month or an equivalent per household consumption of 1.25 kWh per day. For a typical rural village with more than 250 households, this translates to

around 120 MWh per year. An estimated distribution losses of 5% is included in the calculation. This is shown in *Table 11-3*.

The study calculated a typical wind-diesel system that satisfies the village electricity demand. This demand level could be met by the combination of a 75 kW wind turbines, 30 kW diesel generator and a storage system that can accumulate around 300 kWh of electricity. The technical parameters of the system are shown in *Table 11-4*.

Table 11-2: Rural household average monthly electricity consumption

Electricity PEC grid customers (kWh)	101
Electricity PEC isolated system customers (kWh)	74
Electricity cooperative customers (kWh)	44
Electricity customers of private suppliers (kWh)	45
Assumed average consumption of electricity per customer of wind-diesel systems in off-grid areas (kWh)	*37.5*

Source (non-italic): *Household Energy Supply and Use in Yemen* ESMAP, 2005

Table 11-3: Typical village electricity demand

Assumed average consumption of electricity per customer of wind-diesel systems in off-grid areas	37.5 kWh/month 1.25 kWh/day 456.25 kWh/year
Typical village size (isolated grid systems)	250 households
Total village electricity demand (+5% distribution losses)	120 MWh/year

Table 11-4: Wind-diesel system technical parameters

Wind turbine capacity	25 kW
Number of units	3
Total wind turbine capacity	75 kW
Hub height	25 m
Diesel generator capacity	30 kW
Diesel generator heat rate	3 kWh/liter
Diesel generator normal running time	2000 hours per year (10000 hours in 5 years)
Accumulator (battery) capacity	300 kWh

The energy production of the wind-diesel system will depend on the wind speed regimes in each site. This is the rationale why the study recommended that a wind measurement campaign for each site should be carried out.

Based on the data available from the wind information system, the study simulated 2 wind regimes with capacity factors of 10% and 15% or full load hours of 876 hours per year and 1314 hours per year, respectively. The corresponding wind energy production is 66 and 99 MWh per year.

As presented in *Table 11-5*, the diesel generation from the system depends on the level of wind energy production. The higher the wind capacity factor results in lower running hours of diesel engines. The diesel fuel savings are high in areas with high wind regimes.

Table 11-5: Energy production and diesel fuel savings (75 kW wind turbine and 30 kW diesel generator)

	Scenarios	
Wind turbine capacity factor	10 %	15 %
Wind turbine full load hours (hrs/year)	876 hrs/year	1314 hrs/year
Wind electricity generation (also demand covered by wind turbines)	66 MWh/year	99 MWh/year
Demand covered by diesel generation	54 MWh/year	21 MWh/year
Diesel generator running time	1802 hours	707 hours
Diesel fuel savings	21900 liters/year	32850 liters/year

11.3 System costs and tariffs

The turnkey investment cost of the specified wind-diesel system amounts to US$ 525,000. This is shown in *Table 11-6*. Components replacement and costs as well as operation and maintenance costs are also shown in the said table.

Table 11-6: System costs

Turnkey investment cost • 3 x 25 kW wind turbine • 1 x 30 kW diesel generator • 300 kWh accumulator • Inverter	US$ 525,000
Replacement costs • Diesel generator (every five years) 4 units in 20 years • Wind turbine (1 unit after 10 years) • Battery (1 unit after 10 years) • Inverter (1 unit after 12 years)	US$ 67,500 (US$16,875 per unit) US$ 75,000 US$ 36,000 US$ 42,000
O&M costs • Wind turbine (over 20 years), (US$750 per year) + (US$3000 after 10 years for bearing, seals, etc) + (US$ 4500 after 10 years for miscellaneous) • Diesel generator (US$2475 per year) • Battery (US$ 360 per year)	US$22,500 US$ 49,500 US$ 7200

For the wind-diesel systems, the average monthly tariff could be estimated for each household based on system costs. For full cost recovery of investments over 20 years at interest rate of 10%, the average tariff per household could amount as high as US$ 23 per month. If 50% of the capital cost is to be subsidized, the monthly tariff is only US$ 13.61 per month. If the households will only pay for the replacement costs (100% capital cost subsidy), the tariff will be US$ 4.27 per month. The analysis excludes management fees, diesel fuel costs, and financing costs. This is shown in *Table 11-7*.

Table 11-7: Average tariff based on system costs

	Average tariff per household per month
Full system costs	US$ 22.95
50% subsidy of capital costs	US$ 13.61
100% subsidy capital costs (household pays for replacement and O&M costs only)	US$ 4.27

Note: This excludes management fees, diesel fuel costs, and financing costs. 10% discount rate is used in the analysis.

11.4 Investment requirements

Capital requirements for the whole program to promote the development of wind-diesel systems are shown in *Table 11-8*. Program 1, the preparatory program, requires an investment of more than US$ 200 thousand while Program 2, the project implementation program needs more than US$ 12 million.

Table 11-8: Investment capital requirements

	US$ million
Program 1	
• Wind measurement campaign	0.100
• Baseline market study	0.020
• Feasibility studies	0.075
• Capacity building activities	0.030
Program 2	
• Program 2 A (Taiz)	5.775
• Program 2 B (Al Hodeidah)	4.200
• Program 2 C (Lahj, Abyan and Hadramout)	2.100
TOTAL	12.300

The annual capital requirements for the whole program is estimated and shown in *Table 11-9*.

The preparatory program (Program 1) will be carried out mainly by PEC-RES/REA while the project implementation (Program 2) should be carried out by an electric utility, in this case by the Public Electricity Corporation (PEC). The main funding source for Program 1 is PEC-RES/REA while for Program 2 the Public Electricity Corporation.

PEC-RES/REA may however provide capital cost subsidies for project implementation sourced from either Rural Electrification Fund or other donor agencies. This is shown in *Table 11-10*.

Table 11-9: Annual investment capital requirements

Program	year										
	0	1	2	3	4	5	6	7	8	9	10
Program 1	0.113	0.113									
Program 2 A				1.925	1.925	1.925					
Program 2 B							1.400	1.400	1.400		
Program 2 C										1.050	1.050
Total	0.113	0.113		1.925	1.925	1.925	1.400	1.400	1.400	1.050	1.050

Table 11-10: Sources of Funds

Program	Main Source of Funding	Source of Subsidy
Program 1	Rural Electrification Agency	Rural Electrification Fund, International Donors and Aid Agencies
Program 2	Public Electricity Corporation	Rural Electrification Fund, International Donors and Aid Agencies

12 Institutional Arrangement and Regulatory Framework

Off-grid rural electrification envisaged in this Renewable Energy Strategy and Action Plan Study (RESAP) and the Business Models and Financial Schemes for the Solar Home System Study are private sector driven. The role of the government is to establish enabling environment including regulatory frameworks to stimulate the private sector to engage in the supply of technologies and services as well as to protect the welfare of end-users and customers ensuring quality and affordability of services. The critical regulatory aspect concerning this model is consumer protection, ensuring customers of minimum solar PV technical performance. Quality standards are necessary in order to establish customer confidence on the technology and ensure long term sustainability of the PV market.

12.1 Rural electrification institutional arrangement

The National Rural Electrification Strategy study calls for the establishment of the Rural Electrification Agency (REA) to be the apex organization responsible for the administration of the rural electrification program (both grid and off-grid) of the government (*Figure 12-1*). This implies that REA will establish a sector focusing off-grid rural electrification by renewable energies. This agency will be responsible for program management (including technical oversight) and financing. The Ministry of Electricity and Energy will be mainly responsible for policy while the regulatory agency, the National Regulation Board, will be responsible for economic regulation (mainly tariff setting).

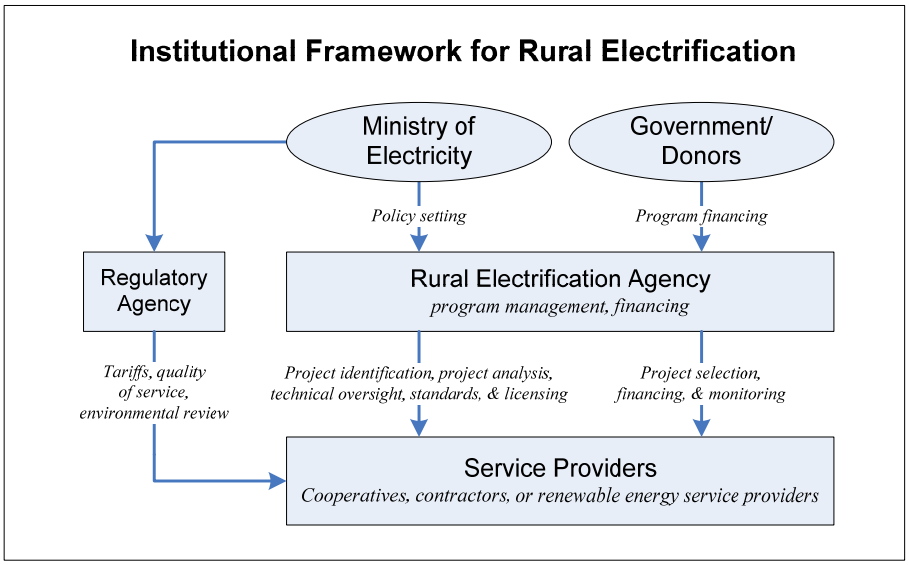

Figure 12-1: Rural electrification institutional framework
Source: *National Rural Electrification Strategy* NRECA, 2006

12.2 Regulatory agency

The draft Electricity Law specifies the establishment of the National Regulatory Board to be the main agency responsible for Electricity Sector Regulation covering both economic and technical regulation. At present, however, since the Board is not created yet, the economic regulation is being carried out by the Ministry of Electricity and Energy (MEE).

Technical regulation for off-grid rural electrification could be carried out by the REN Sector of MEE. At present, however, the off-grid rural electrification program is being carried by the Rural Electrification Sector (RES) of Public Electricity Corporation (PEC) and will be transferred to the Rural Electrification Agency (REA), once this institution is established by the Government.

Based on the experience in many several developing countries, it would be more effective as well to delegate the regulation of off-grid rural electrification sector to PEC-RES, and then to REA once it is created.

12.3 Quality regulation

12.3.1 Equipment Quality

The Ministry of Electricity and Energy (MEE) has to make sure that solar PV technologies available in the market or technologies used in the Solar Home System Programme comply with the national technical standards. In the absence of national standards, MEE can adopt international standards used by countries that successfully implemented a solar PV programme such as the standards recommended by the PV GAP and the World Bank.

These standards could be used in the technical specifications for technologies to be used in the proposed Solar PV Programme. The role of MEE, therefore, as a regulator is to specify technical specifications and warranties for PV systems components. Specifications and warranties required for solar PV units include the following:

- PV generator
- Module support structure
- Battery
- Charge regulators
- Loads (lighting fixture with fluorescent and ballast)
- Systems installation and wiring
- Grounding, lightning protection

In addition each unit must be accompanied by User's and Technician's Manual specifying installation, operation and trouble-shooting instructions as well as warranty conditions for major components and acceptance of test procedures.

12.3.2 Installation Quality

Similarly, MEE must also ensure that the installation of the PV equipment will be carried out according to international standards. This could be regulated through the following:

- Accreditation of technician's training
- Issuance of Code of Practice on system design, sizing and installation
- Commissioning of the installation by an accredited technician
- Installation inspection by MEE's expert's team

12.3.3 Program Regulation

As presented above, PEC-RES/REA should issue technical specifications and warranty for solar PV technologies and components. During the implementation, the agency should also carry out installation quality control through project site monitoring. The specific technical regulation requirement for each program is summarized in *Table 12-1*.

Table 12-1: Program Technical Regulation

Program	Service Provider	Technical Regulation
SHS cash and credit sales Program 1 Program 3	• Financing institutions (FIs) • Accredited local dealers	• Technical standards or specifications • Accreditation of installers and technicians • Monitoring of installation and operation
SHS fee-for-service Program 5 Program 7	• Local Energy Service Company (ESCO)	• Technical standards or specifications • Accreditation of installers and technicians • Monitoring of installation and operation
Solar lamp cash and credit sales Program 2 Program 4 Program 6 Program 8	• Postal and Postal Savings Authority • Local retailers	• Technical standards or specifications • Accreditation of repair technicians
Social Infrastructures Program 1 Program 2 Program 3 Program 4	• Local Suppliers	• Technical standards or specifications • Accreditation of installers and technicians • Monitoring of installation and operation

Note: Technical standards or specifications are issued as part of the tender documents. For the accreditation of installers and technicians, PEC-RES/REA will carry out standardized trainings and examinations systems for local technicians. For installation monitoring, this will be carried out by experts from PEC-RES/REA or hired local consultants.

12.4 Off-grid program institutional arrangement and regulation

Chapter 5 of this report presented the short-term (demonstration stage) institutional arrangement of each service delivery model while this section presents the long-term institutional arrangement and regulation.

12.4.1 SHS Cash and Credit Sales through Microfinance Institutions

The long-term institutional arrangement for SHS cash and credit sales through microfinance institutions (MFIs) is shown in *Figure 12-2*. In this model, MFIs provide both technical and financial services to off-grid rural communities.

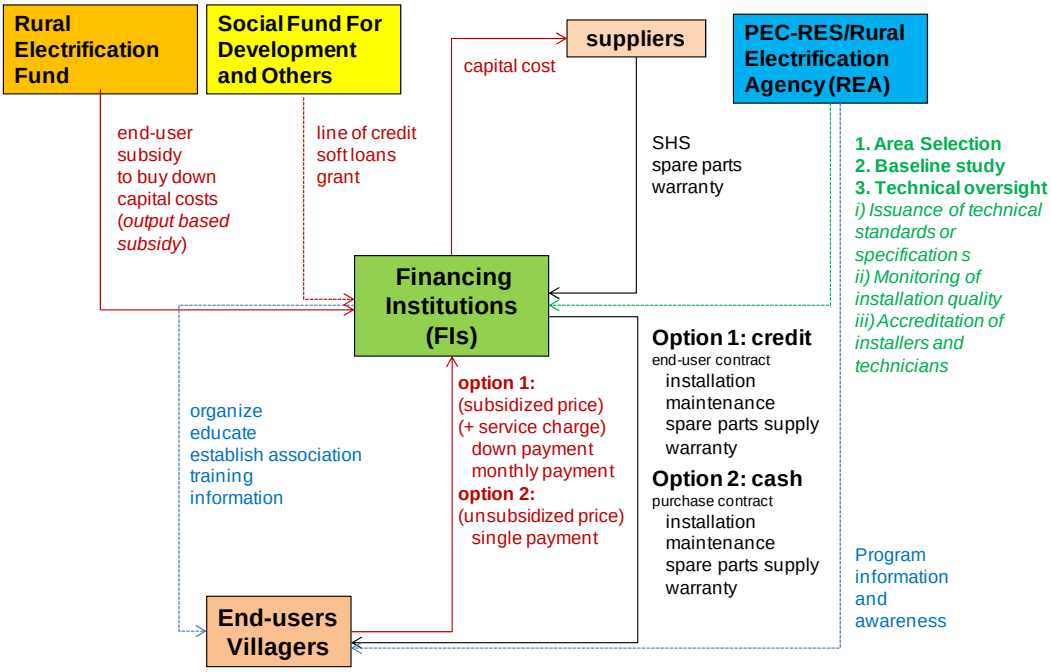

Figure 12-2: Long-term institutional arrangement for SHS cash and credit sales through a financing institution

Note: An output based subsidy means that the full amount of subsidy is only released when the system is installed and accepted by the monitoring team of PEC-RES/REA.

The brief summary of the delivery mechanism, regulation and information and awareness activities is presented below:

- PEC-RES/REA identifies the target areas and carries out market baseline study.
- PEC-RES/REA establishes partnership with microfinance institutions (MFIs) in providing energy services in these areas.

- MFI, as service provider, secures its own funding (from internal budget, credit from the Social Development Fund or from other sources) and carries out its own technology procurement.
- Other preparatory activities of the MFI include educating, organizing and mobilizing end-users, establishing an end-users group in target areas, and providing information about the technology, costs, and financing schemes.
- PEC-RES/REA carries out information and awareness campaign for the target district and at the same time assists the MFI in the information and awareness campaign for its target customers.
- MFI provides micro-credit to the end-users. Once the financial agreement with the end-user is finalized, the MFI installs the system and provides product warranty and after sales services.
- MFI, through its loan officers, collects the down payment and monthly dues.
- The Rural Electrification Fund provides capital cost subsidy to buy down the cost of the equipment and make the systems affordable to a larger segment of the society. The full amount of subsidy could only be released to the MFI once the installation is completed and accepted by the monitoring team.
- To ensure technical quality, PEC-RES/REA issues technical specifications to MFI prior to its procurement program, develop installation standards, conduct training and accredit technicians, prepare monitoring plans and carry out monitoring activities.
- Monitoring results provide the basis whether the final subsidy payment could be released or not.

12.4.2 SHS Cash and Credit Sales through Accredited Local Dealers and Microfinance Institutions

In the above model, energy services and micro-credit services are carried out by the microfinance institution while in this model these services are implemented by 2 different entities – the accredited local dealer (ALD) for the former and microfinance institution (MFI) for the latter.

The delivery mechanism, regulation and information and awareness are briefly discussed below and shown in *Figure 12-3*.

- PEC-RES/REA identifies the target areas and carries out market baseline study.
- PEC-RES/REA establishes partnerships with local dealers and microfinance institutions (MFIs) in providing energy and micro-credit services to identified households.
- The accredited local dealer (ALD) secures its own funding and carries out its own technology procurement.
- ALD promotes, provides information related to costs and available financing, markets the technology to the target households, and assists in the

establishment of end-users' group. ALD also introduces the villagers to MFIs who can provide micro-credit for the purchase of the systems.

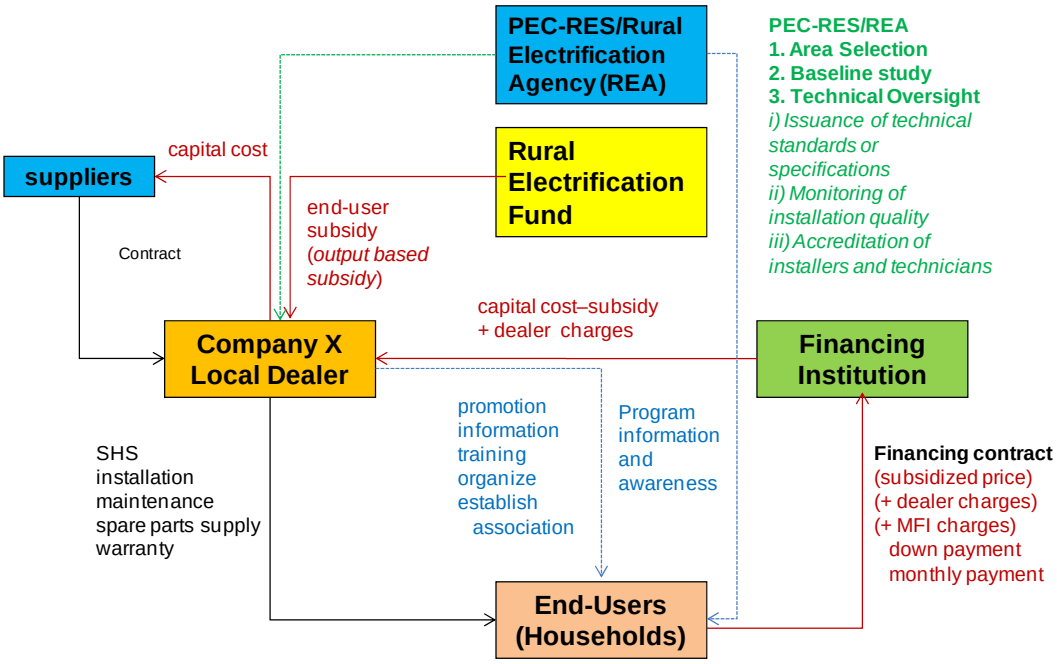

Figure 12-3: Long-term institutional arrangement for SHS cash and credit sales through a local dealer and a financing institution

Note: An output based subsidy means that the full amount of subsidy is only released when the system is installed and accepted by the monitoring team of PEC-RES/REA.

- PEC-RES/REA carries out information and awareness campaign for the target district and at the same time assist the ALDs in the information and awareness campaign for its target clients.
- End-users' apply for micro-credit from MFIs. MFIs screen applicants based on its microfinance screening criteria. Once the financial agreement with the end-user is finalized, MFIs purchase the system from ALDs at the capital cost rate minus the subsidy.
- ALDs install the system and provides product warranty and after sales services. MFIs, thought its loan officers, collect the household monthly payments.
- The Rural Electrification Fund provides capital cost subsidy to buy down the cost of the equipment and make the systems affordable to a larger segment of the society. The full amount of subsidy could only be released to the ALDs once the installation is completed and accepted by the monitoring team.
- To ensure technical quality, PEC-RES/REA issues technical specifications to ALDs prior to its procurement program, develop installation standards, conduct

training and accredit technicians, prepare monitoring plans and carry out monitoring activities.

- Monitoring results provide the basis whether the final subsidy payment could be released or not.

12.4.3 SHS Fee-For-Service

The institutional arrangement for SHS fee-for-service business approach is shown in *Figure 12-4*. The delivery mechanism, regulation and information and awareness are briefly discussed below:

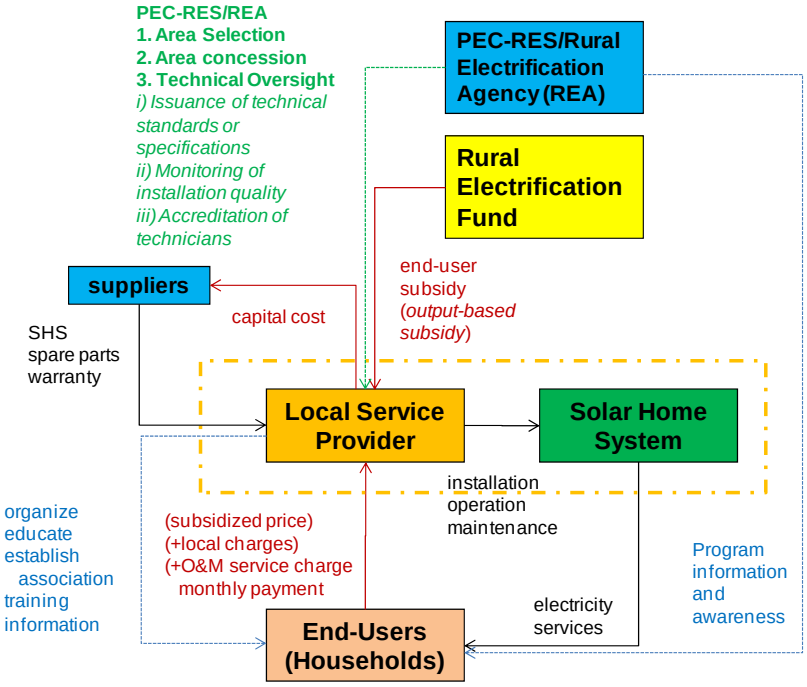

Figure 12-4: Long-term institutional arrangement for SHS fee-for-service

Note: An output based subsidy means that the full amount of subsidy is only released when the system is installed and accepted by the monitoring team of PEC-RES/REA.

- PEC-RES/REA identifies the target areas, demarcates it into concession areas and carries out baseline study for each concession area.
- PEC-RES/REA through competitive bidding select a local service provider (LSP) for each concession area.
- LSP educates, organizes, mobilizes end-users, establishes end-users' group, and provides information about the technology, costs, and financing schemes.
- PEC-RES/REA carries out information and awareness campaign for the target districts and at the same time assist the LSP in the information and awareness campaign for its target customers.

- LSP secures its own funding and carries out its own technology procurement.
- End-users select the size of the technology taken into account monthly dues and their ability to pay. The LSP installs the systems in their premises, collects the down payment and monthly dues, and operates and maintains the systems.
- The Rural Electrification Fund provides capital cost subsidy to buy down the cost of the equipment and make the systems affordable to a larger segment of the society. The full amount of subsidy could only be released to the LSP once the installation is completed and accepted by the monitoring team.
- To ensure technical quality, PEC-RES/REA issues technical specifications to LSPs prior to its procurement program, develop installation standards, conduct training and accredit technicians, prepare monitoring plans and carry out monitoring activities.

12.4.4 Solar Lamps Cash and Credit Sales through the Post and Postal Savings Authority

The institutional arrangement for solar lamps cash and credit sales through the Post and Postal Savings Authority business approach is shown in *Figure 12-5*. The delivery mechanism, regulation and information and awareness are briefly discussed below:

- PEC-RES/REA identifies the target areas and carries out market baseline study.
- PEC-RES/REA establishes partnerships with the Post and Postal Savings Authority for the sales (cash and/or credit) of solar lamps in target areas.
- The Post and Postal Savings Authority promotes and provides information about the technology, costs, and financing schemes to households with current savings account or monthly income channeled through the Postal Service.
- PEC-RES/REA carries out information and awareness campaign for the target districts and at the same time assist the Post and Postal Savings Authority in the information and awareness campaign for its target customers.
- The Post and Postal Savings Authority secures its own funding and carries out its own technology procurement from local suppliers. The local suppliers provide warranty to the Post and Postal Savings Authority which in turn passed the warranty to end-users.
- The Post and Postal Savings Authority provides credit sales to households with current savings account or monthly income channeled through the Postal Service. The monthly payment will be automatically deducted from the borrowers' bank accounts.
- After sales services (repairs) will be provided by local suppliers.
- The Rural Electrification Fund provides capital cost subsidy to buy down the cost of the equipment and make the systems affordable to a larger segment of the society. The full amount of subsidy could only be released to Post and Postal Savings Authority upon presentation of the sales documents of solar lamps.

- To ensure technical quality, PEC-RES/REA issues technical specifications to the Post and Postal Savings Authority prior to its procurement program, conduct training on repairs and accredit technicians of the local suppliers.

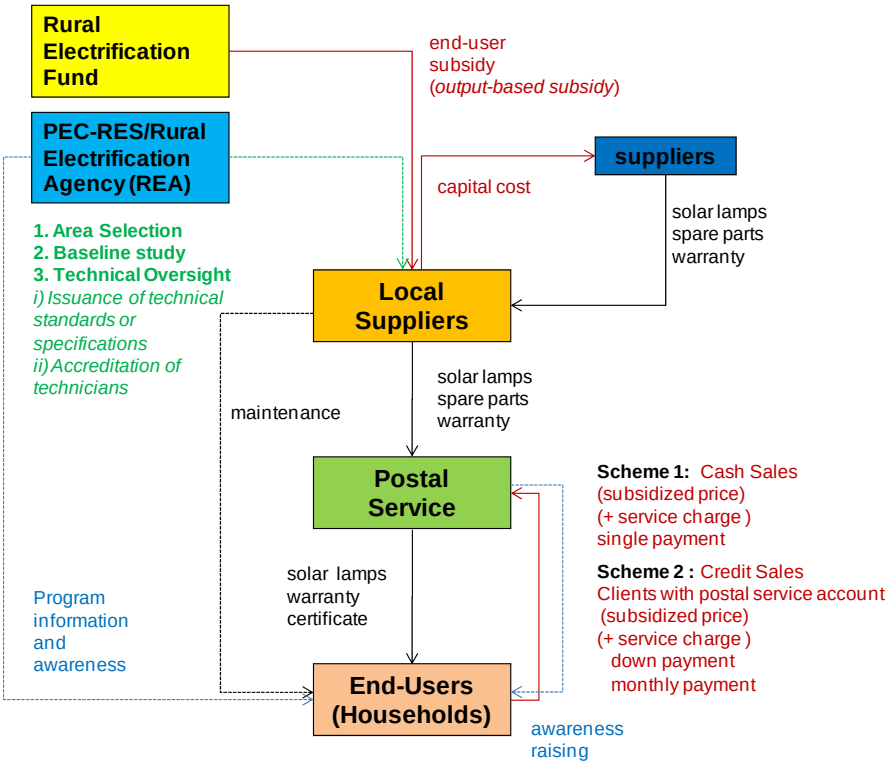

Figure 12-5: Long-term institutional arrangement for solar lamp (SL) cash and credit sales

Note: An output based subsidy means that the full amount of subsidy is only released when the solar lamps sales certificates are presented to PEC-RES/REA.

12.4.5 Public Funding for Social Infrastructures

The institutional arrangement for the energy service supply for social infrastructures is shown in *Figure 12-6*. The delivery mechanism, regulation and information and awareness are briefly discussed below:

- PEC-RES/REA identifies the target areas and carries out market baseline study.
- PEC-RES/REA establishes partnerships with the concerned agencies/ministries for the supply of energy service of social infrastructures in target areas.
- PEC-RES/REA in partnership with the concerned ministries carries out information and awareness campaign.

- Through the Rural Electrification Fund, PEC-RES/REA offers subsidy for the purchase and installation of the systems (subsidies could be as high as 50% of the system costs).
- The concerned ministries secure their own funding. PEC-RES/REA will carry out technology procurement through competitive bidding. Standards for solar PV systems and installation quality will be specified in the procurement process.
- The winning bidder will install the systems, make spare parts available, provide warranties and provide training to personnel of each social infrastructure. As part of the contract, the winning bidder must provide support services (repair and maintenance) for the period of at least 5 years through local technicians. These technicians could be a local technical person in the target area or an employee of the said social infrastructure. Training must also be provided by the winning bidders for these local technicians. In addition, PEC-RES/REA will also conduct training for the accreditation of these technicians.
- PEC-RES/REA will prepare monitoring plan, and carry out monitoring activities. The final payment to winning bidders will be dependent upon the compliance certification issued after the monitoring process.

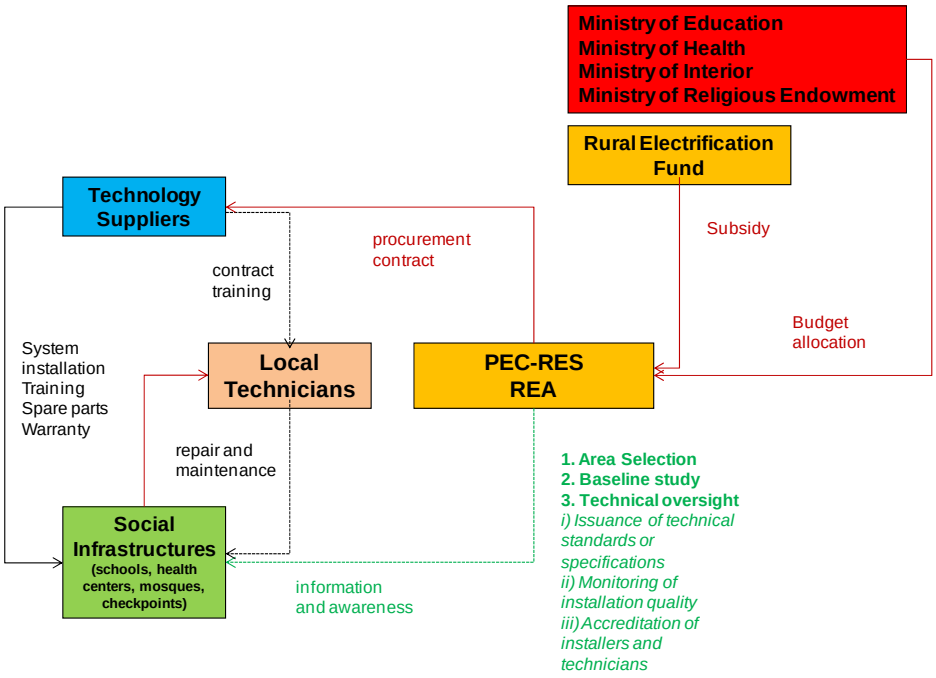

Figure 12-6: Long-term institutional arrangement for social infrastructures

12.5 Organization and staffing

Key activities of the Rural Electrification Agency (REA), as proposed in the National Rural Electrification Strategy, are promotion and development of grid-based service territories. This study proposes that REA should establish an Off-Grid Unit responsible for the promotion and development of off-grid areas. This unit will have five units namely,

- solar PV systems
- hybrid systems
- finance
- planning and database
- information and awareness

The department will be administered by a Director with a flat organizational structure. This is shown in *Figure 12-7*. Key functions of the units are summarized in *Table 12-2*.

Each unit will be supervised by a senior engineer with at least one junior engineer. This department will have, at least, 12 personnel. This unit is relatively small compared with the proposed 80 staff of the grid-based units of REA. The REA off-grid staffing is shown in *Table 12-3*.

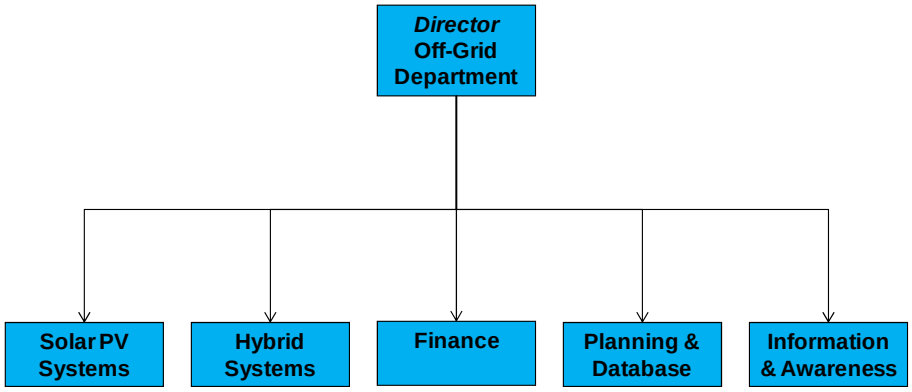

Figure 12-7: REA Off-Grid Unit Organizational Chart

Table 12-2: Off-Grid Department Functions

Unit	Responsibilities
Management (Director)	• Overall management and promotion of off-grid rural electrification • Identification and negotiations with service providers • Contract negotiations
Solar PV systems	• Solar energy resource assessment and measurement • Technical standards and specifications • Technical quality control, evaluation and monitoring • Training (installation and operation) and accreditation of technicians
Hybrid systems	• Wind resource assessment and measurement • Hybrid systems standards and specifications • Technical quality, evaluation, and monitoring • Training (installation and operation)
Finance	• Design of financing schemes and subsidies • Collaboration with financing institutions • Financial and economic analysis of projects and programs • Training (financial and economic analysis)
Planning and database	• Program planning and area identification • Energy demand and supply analysis • Database management • Preparation of tender documents and contracts • Training (demand and supply analysis)
Information and awareness	• Social preparation and surveys • Stakeholder mobilization and consultations • Information and awareness raising • Training (social component of projects)

Table 12-3: REA Off-Grid Unit Staffing

Unit	Senior Engineer	Junior Engineer	Administrative Staff	Total
Management (Director)	1		1	2
Solar PV systems	1	1		2
Hybrid systems	1	1		2
Finance	1	1		2
Planning and database	1	1*		2
Information and awareness	1	1		2
TOTAL	6	5	1	8

* Geographic information system (GIS) expert

13 Information and Capacity Building Framework

Lack of information and lack of human capacities are among the key barriers to market-based and decentralized off-grid rural electrification in Yemen. This chapter identifies measures to increase awareness, promote private sector provision of services and carry out capacity building activities.

13.1 Information and awareness raising

The Ministry of Electricity and Energy (MEE) as a policy making body and also responsible for renewable energy promotion in the country will be tasked to disseminate information and increase the level of awareness of key stakeholders to off-grid rural electrification. Key activities that will be carried out by MEE, in coordination with the Rural Electrification Agency (REA), are discussed below.

Information dissemination

The REN Sector of MEE should publish several primers related to SHS technologies, benefits, quality standards, service deliveries as well as the planned off-grid rural electrification program. These primers are aimed at target households and local officials in marginal districts and villages. In addition, brochures and posters will be produced containing summarized version of information and will be distributed in the target areas.

These information could also be uploaded in the REN website. A web page could be dedicated to off-grid rural electrification by solar home system in target marginal areas.

In addition, a radio/TV information program could also be developed aiming to reach the targeted remote communities.

Stakeholder Education

In addition to information dissemination, the REN Sector will be also responsible for educating key stakeholders. These stakeholders could be categorized into the following: i) local officials (governors and local council members) and other institutional stakeholders present in the target marginal areas, and ii) rural households.

For the first group of stakeholders, executive briefings could be carried out to explain the planned off-grid rural electrification strategy. For the second group, the rural households, public briefings will be carried out.

13.2 Training and capacity building

One of the most important components of off-grid rural electrification strategy is training and capacity building. The REN Sector of MEE, in coordination with the Rural Electrification Agency (REA), will be the main unit responsible for implementing the training and capacity building component of the off-grid rural electrification program.

In the design of the capacity building program, the REN Sector could pursue the following activities:

- Identify the stakeholders and their role in off-grid rural electrification
- Evaluate the existing knowledge and skill base
- Identify training needs
- Define training measures
- Implement capacity building activities

The key off-grid rural electrification stakeholders and their potential role in the off-grid rural electricity market are shown in *Table 13-1*.

The existing knowledge and skills base of market-based and decentralized approach to off-grid rural electrification in Yemen are very limited. The available capacity needs to be enhanced and strengthened.

Table 13-2 presents the capacity building measures required to strengthen the key roles necessary to operate a SHS market in Yemen. These roles include policy and planning; regulation; service provision and technology supply; information and public awareness; financing; training, and capacity building. These measures represent the capacity building requirements of key stakeholders necessary to establish a well functioning off-grid rural electricity market.

Table 13-1: Market roles of off-grid rural electrification stakeholders

Role	Stakeholders
Policy and Planning	MEE and REA
Regulation	National Regulatory Board, MEE and REA
Service provision, technology supply	Microfinancing institutions, CAC Bank, Postal Service, local international technology suppliers
Financing	Microfinancing institutions, CAC Bank, Postal Service, SFD
Information and awareness	MEE, REA, NGOs, local councils
Training and capacity building	MEE, REA, NGOs

Table 13-2: Capacity building measures

Role and Stakeholders	Capacity Building Measures
Policy, Planning (MEE, REA, local councils)	• Exposure to other successful programmes in other countries through visits and trainings (study tours) • Off-grid rural electrification policy, planning • Monitoring and evaluation of off-grid rural electrification projects • Interactive programs between national and local level government stakeholders to discuss energy issues. • Plan for financial co-operation with service providers • Inter-sectoral governmental (Electricity, Health, Education etc) workshops to discuss linkages of energy to health, water, and education specifically to address PRSPs, MDGs etc
Regulation (MEE,REA)	• Rural electrification regulatory and legal frameworks • Off-grid rural electrification pricing and regulation

	• Off-grid renewable energy technology quality standards • Monitoring and evaluation of off-grid rural electrification projects and programmes
Service Provision, Technology Supply (Microfinance Institutions, CAC Bank, Postal Service, technology suppliers)	• Resource measurement and data analysis • Training on installation, operation and maintenance • Study tours to countries that successfully implemented specific renewable energy projects • Vocational training for RE systems to be introduced to produce PV electrical technicians who will help for the sustainability of the systems.
Financing (Microfinance Institutions, CAC Bank, Postal Service)	• Introduction/sensitisation workshops, dialogues with energy stakeholders. • Specific training on linking finance and delivery of energy services, especially in the provision of credit services for higher risk projects. • Training women who lack basic skills in microfinance and financial analysis to work with women consumers. • Study tours to countries that successfully implemented SHS projects • Training sessions on technology, funds available, financing structures and mechanisms, delivery of energy projects • Development of Yemen specific indicators for funding, monitoring and evaluating energy projects and programs.
Information and Public Awareness (MEE, REA, NGO's, local councils)	• Specific dialogues, interactions and training programs to mobilise communities in rural areas in dealing with energy issues. • Training sessions on technology, funds available, financing structures and mechanisms, delivery of energy projects
Training, Capacity Building (MEE, REA, NGOs)	• Renewable energy policy, planning • Off-grid renewable energy regulatory and legal frameworks • Off-grid renewable energy technology quality standards • Resource measurement and data analysis • Renewable energy technologies, installation, operation and maintenance • Financing structures and mechanisms, delivery of energy projects

13.3 Program awareness raising and capacity building

The discussion of program awareness raising and capacity building were also covered in Chapter 10 during the presentation of the program institutional arrangement and capacity building.

For information and awareness, key targets are mainly the end-users in target areas. This activity will be carried out by both the service provider and PEC-RES/REA.

The target for training is i) the end-users, and ii) those who will be providing technical support to end-users such as service providers and local technicians. End-users' training will be implemented by service providers as part of their obligations, while PEC-RES/REA will be responsible to conduct trainings for service providers and local technicians.

Information and capacity building activities and responsible entities for each program are shown in *Table 13-3*.

Table 13-3: Information and end-users training

Program	Activity	Responsibility
SHS cash and credit sales (FIs) Program 1 Program 3	• End-users information • End-users training • Training of FIs, local technicians, end-users' group, others	• FIs and PEC-RES/REA • FIs • PEC-RES/REA
SHS cash and credit sales (ALD and FIs) Program 1 Program 3	• End-users information • End-users training • Training of ALD, FIs, local technicians, end-users' group, others	• ALD and PEC-RES/REA • ALD • PEC-RES/REA
SHS fee-for-service Program 5 Program 7	• End-users information • End-users training • Training of LSP, FIs, local technicians, end-users' group, others	• LSP and PEC-RES/REA • LSP • PEC-RES/REA
Solar lamps cash and credit sales Program 2 Program 4 Program 6 Program 8	• End-users information • Training of local technicians	• Post and Postal Savings Authority and PEC-RES/REA • PEC-RES/REA
Social Infrastructures Program 1 Program 2 Program 3 Program 4	• End-users information • Training of local technicians	• Service providers • PEC-RES/REA
Wind-diesel mini-grid systems	• Awareness raising of policy makers • Training of PEC, MEE, REA staff	• MEE • REA

SHS – solar home systems; FIs – Financing institutions; PEC-RES – Public Electricity Corporation-Rural Electrification Sector; REA – Rural Electrification Agency; ALDs – accredited local dealers; LSP – local service provider.

14 Off-grid Rural Electrification Strategy

Based on the analysis carried out in Chapters 3-13 of this document, an off-grid rural electrification strategy is being formulated. The components of the strategy are summarized below and discussed in the following sections.

- Prioritize financially sustainable off-grid areas to kick-off national market for renewable energy technologies
- Ensure least cost supply option
- Establish decentralized and market-based off-grid energy service delivery strategy
- Introduce measures to remove investment barriers
- Provide public funding to social infrastructures
- Protect consumer's welfare
- Promote the development of wind-diesel mini-grid systems
- Raise awareness and strengthen stakeholders' capacities

14.1 Prioritize financially sustainable off-grid areas to kick-off national market for renewable energy technologies

This study identified the off-grid districts and areas (areas not covered in the current PEC Distribution Expansion Plan and the proposed 27 Off-Grid Service Territories) which are situated in 9 Governorates (*Figure 14-1*). These areas consist of more than 240 thousand villages with around 1.6 million inhabitants and constitute around 8 percent of the total population in 2004.

These off-grid areas are composed of both low and high population density villages with economic conditions ranging from very poor to relatively better economic circumstances. Transactions costs in the provision of energy services are low in high population density villages due to economies of scale while high market penetration could be achieved in villages with low incidence of poverty.

The government's off-grid rural electrification program therefore focuses on areas with high population density and with better economic circumstances in order to ensure program sustainability and to kick-off the national market for renewable energy technologies (*Table 14-1* and *Table 14-2*). As of 2004, there were more than 100 thousand households in villages with more than 50 households and with poverty indicators ranging from poor to well-off (poverty index of 1, 2, and 3 based on Social Fund for Development poverty indicators) in the identified marginal districts and areas. These villages will be initially targeted for off-grid renewable energy service development in the next 10 years.

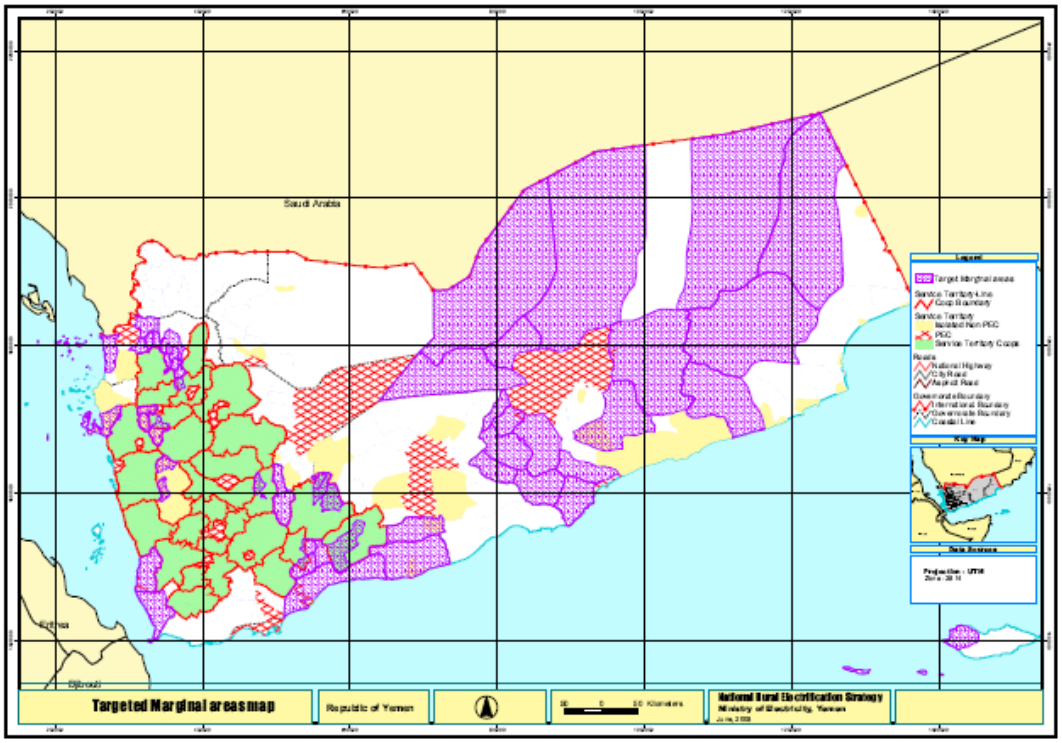

Figure 14-1: Off-grid Areas

Table 14-1: Number of households by village household density

Governorate	number households						
	< 50	**50-100**	**101-150**	**151-200**	**201-300**	**301-450**	**> 450**
Al-Mahara	941	140	212	364	230	0	0
Hadramout	19835	9546	4889	2229	4114	1864	1577
Raimah	1610	6305	4836	3779	1236	1426	0
Abyan	5034	957	712	0	211	0	2453
Al Baida	4439	4363	1526	313	664	773	0
Lahj	11088	3468	1837	1055	2360	1331	1244
Taiz	172	145	461	188	1869	2316	9911
Al Hodeidah	794	1316	759	1435	272	1570	3252
Al Mahwit	5320	12573	9301	5521	2943	1014	905
Hajja	8311	6261	1841	2767	885	2489	3470
Amran	7227	9683	6541	4688	8751	4934	4464
TOTAL	**64771** (27%)	**54757** (23%)	**32915** (14%)	**22339** (9%)	**23535** (10%)	**17717** (7%)	**27276** (11%)

Note: households in villages with household density of less than 50 may be the least priority for solar PV rural electrification due to lack of economies of scale in the provision of services for repair and maintenance.

Table 14-2: Number of households by village poverty index

Governorate	Village Poverty Index Level			
	1 (affluent)	2 (middle)	3 (poor)	4 (very poor)
Al-Mahara	0	504	199	243
Hadramout	3052	8808	7378	5431
Raimah	0	462	8753	8367
Abyan	2453	283	727	870
Al Baida	177	868	4144	2450
Lahj	468	1251	8058	1518
Taiz	0	3517	3040	8333
Al Hodeidah	812	3431	2768	1593
Al Mahwit	0	4702	9588	17967
Hajja	0	1136	3237	13576
Amran	0	4209	17311	17991
TOTAL	**6962** (4%)	**29171** (16%)	**65203** (36%)	**78339** (44%)

14.2 Ensure least-cost option

Villages in the identified off-grid areas could be potentially supplied with electricity services based on renewable energies such as wind and solar energies, as the RESAP study results indicated. Solar energy is available throughout the country while wind energy is, however, limited in the coastal areas and in specific sites in the highlands.

Off-grid energy technology options for these areas include small-scale wind-diesel systems, solar home systems, and small diesel generation sets (*Table 14-3*). The off-grid RE strategy ensures that off-grid electricity services to be provided to rural households will be the least-cost supply alternative.

Table 14-3: Village Energy Supply Options

Marginal Districts	Number of Villages by Household Size Distribution						
	< 50	50-100	100-150	150-200	200-300	300-450	> 450
Districts with coastal areas (Al-Mahara, Hadramout, Abyan, Lahj, Taiz, Al Hodeidah, Hajja)	3249	326	86	42	42	26	26
	Individual units (Solar Home Systems and Solar Lanterns)						Wind-diesel systems*
Inland districts (Raimah, Al Baida, Al Mahwit, Amran)	728	487	458	212	395	189	10
	Individual units (Solar Home Systems and Solar Lanterns)						Individual systems or isolated diesel-based network

* wind resources in inland areas need further investigations and measurements

Based on the available renewable energy resources in target areas, both solar and wind energies appear to complement rather than compete with each other. Wind-diesel systems are commercially viable in villages with high household densities. Also wind energy resources needs to be further assessed and measured in the identified sites.

For areas where solar energy technologies are obvious least-cost alternative, the study further identified these villages into potential solar homes systems and solar lamps market. Markets for solar home systems are those households in villages with density greater than 50 and those under the village poverty index of 1, 2, and 3. Potential markets for solar lanterns are those households in villages with household density below 50 and those in areas with high density but under poverty index of 4. This is shown in *Table 14-4*.

Table 14-4: Solar PV market potential

Governorate	Household density					TOTAL
	High				Low	
	Solar Home System Market			Solar Lamp Market		
	100 Wp	50 Wp	20 Wp	Solar lamps	Solar lamps	
Al-Mahara	94	287	254	203	941	1 779
Hadramout	3 266	6 382	6 848	5 233	19 835	41 563
Raimah	1 244	2 968	6 024	5 983	1 610	17 829
Abyan	1 124	874	888	797	5 034	8 718
Al Baida	6 71	1 429	2 652	2 184	4 439	11 376
Lahj	1 144	2 002	4 309	2 678	11 088	21 220
Taiz	1 118	3 488	4 094	4 941	172	13 814
Al Hodeidah	1 087	2 297	2 450	1 736	794	8 365
Al Mahwit	2 316	6 706	9 581	11 091	5 320	35 015
Hajja	1 081	3 499	4 922	7 273	8 311	25 087
Amran	2 949	7 544	12 957	12 798	7 227	43 476
TOTAL	**16 093**	**37 477**	**54 981**	**54 918**	**64 771**	**228 241**
	108 552			**119 689**		

High household density village as discussed are those with more than 50 households while low household density means villages with less than 50 households.

14.3 Establish decentralized and market-based off-grid energy service delivery strategy

Constrained with financial resources in the provision of energy services, the Government will rely on the private sector and the market in providing energy services in off-grid areas. Based on stakeholder consultations and with considerations on the institutional, economic as well as socio-cultural practices of the country, a decentralized and market-based approach is determined to be the most appropriate in delivering energy services in marginal areas.

Under this approach, the role of the Government will be limited to program promotion, activation of the market system, and provision and financing of subsidies. Crucial to

this approach is the activation of the rural energy service providers. Entities such as the micro-financing institutions, CAC Bank, and the postal service which are currently providing various services (particularly financing services) in the marginal areas will be tapped to become energy service providers in these areas. These institutions have also expressed interest to potentially become rural energy service providers. In the absence of these institutions in some areas, villages will be organized through Social Fund for Development to form village associations which could be eventually linked up with the nearest rural energy service providers and financial institutions.

Off-grid areas are further classified into sector and phases based on their proximity with financing institutions (*Table 14-5*). With these, appropriate financing models are identified (*Table 14-6*), and a program approach is being proposed (*Table 14-7*).

Table 14-5: Off-grid area sector and phase classifications

Sector	Phase	Criteria
Solar Home System (SHS) Market		
SHS Sector 1 within the 50 km zone of a branch of a financing institution (FI)	Phase A	within a microfinance institution and CAC (MFI) zone
	Phase B	within CAC Bank zone
SHS Sector 2 outside the 50 km zone of a branch of a financing institution (FI)	Phase A	geography 1 (Highlands, South and Western part)
	Phase B	geography 2 (Eastern Part of the country)
Solar Lamp (SL) Market		
SL Sector 1 within the 50 km zone of a branch of the Postal and Postal Savings Authority	Phase A	to follow the SHS 1 Phase A grouping plus certain considerations
	Phase B	to follow the SHS 1 Phase B grouping plus certain considerations
SL Sector 2 Outside the 50 km zone of a branch of the Postal and Postal Savings Authority	Phase A	geographic consideration 1
	Phase B	geographic consideration 2

Table 14-6: Sectors and financing models

Sectors Phases	Actions	Financing Model Program period
Program 1 SHS Sector 1 Phase A	Overlapping presence of MFIs and CAC Bank in almost all districts • mobilize these institutions rapidly and designate market territories to each institution	**Cash and credit model with FI** 5 years – Hajja, Lahj, Raimah, Taiz, Al Mahwit
Program 2 SL (SLH and SLL) Sector 1 Phase A	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 1 (SHS Sector 1 Phase A)	**Cash and credit model with Postal Service** 5 years
Program 3 SHS Sector 1 *Phase B1* (part Amran covered by CAC Bank)	Presence of MFIs and CAC Bank in selected districts • mobilize MFI and CAC Bank in Abyan • mobilize CAC Bank in Amran • initiate after 3 years of Program 1	**Cash and credit model with FI** 5 years
Program 4 SL (SLH and SLL) Sector 1 Phase B	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 3 (or 1 year later)	**Cash and credit model with Postal Service** 5 years
Program 5	No MFIs and CAC Bank branch operating in the area	**Cash and credit model**

Program 5.1 SHS Sector 1 *Phase B2* (part Amran not covered by CAC Bank) **Program 5.2** SHS Sector 2 Phase A	• convince MFIs and CAC Bank to expand • if not, mobilize local service operators for a fee-for-service approach • initiate after 5 years of Program 1	(if MFIs and CAC Bank) **Fee-for-service model** (if local service models – most likely scenario) 5 years
Program 6 SL (SLH and SLL) Sector 2 Phase A	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 5 (or 1 year later)	**Cash and credit model with Postal Service** 5 years
Program 7 SHS Sector 2 Phase B	No MFIs and CAC Bank branch operating in the area • convince MFIs and CAC Bank to expand • if not, mobilize local service operators for a fee-for-service approach • initiate after 8 years of Program 1	**Cash and credit model** (if MFIs and CAC Bank) **Fee-for-service model** (if local service models – most likely scenario) 5 years
Program 8 SL (SLH and SLL) Sector 2 Phase B	Presence of Postal and Postal Savings Authority • mobilize Postal and Postal Savings Authority • start simultaneously with Program 7 (or 1 year later)	**Cash and credit model with Postal Service** 5 years

Table 14-7: Off-grid areas, sectors, and programs

	Solar Home System Market				**Solar Lamp Market**			
	SHS Sector 1		**SHS Sector 2**		**SLH Sector 1**		**SLH Sector 2**	
	Phase A	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*	*Phase A*	*Phase B*
Abyan		P 3				P 4		
Al Baida			P 5				P 6	
Al Hodiedah			P 5				P 6	
Al Mahara				P 7				P 8
Al Mahwit	P 1				P 2			
Amran		P3 (part) P5 (part)				P 4		
Hadramout				P 7				P 8
Hajja	P 1				P 2			
Lahj	P 1				P 2			
Raimah	P 1				P 2			
Taiz	P 1				P 2			

14.4 Introduce measures to remove investment barriers

One of the main barriers to individual renewable energy technology systems such as the solar home systems (SHS) is the high initial cost of the technology, and most of the rural population, given their income profiles, could not afford to purchase these technologies.

The Government ensures to address this issue through subsidies and financing schemes to lower the capital cost and to make the systems affordable to villagers in marginal areas. The importation of the solar home systems will be exempted from import duties while the local sales of the technology will be exempted from government service tax. In addition, a one-time capital cost subsidy will be provided during the

purchase of the equipment. The combination of these subsidies reduces the capital cost of the systems.

On the other hand, one of the preconditions in selecting rural off-grid service providers is the ability and capacity to provide loans for rural energy systems to rural households in marginal areas. Service providers therefore are required to provide financing schemes to target rural households, thus reducing the initial capital outlay and making the renewable energy technology systems affordable. The identified service providers, such as the micro-financing institutions, CAC Bank and postal services are currently providing micro-finance services to various segments of rural population.

Capital cost subsidies will be sourced from the Rural Electrification Fund established under the Rural Electrification Strategy. The Fund could also provide soft loans to service providers as support in the procurement of renewable energy technologies. On the other hand, import duty and sales tax exemptions represent the Ministry of Finance's contribution in the form of foregone revenues.

The subsidy and annual capital requirement is shown in *Table 14-8*, while the annual budget over the program period is shown in *Table 14-9*.

Table 14-8: Subsidies and investment capital requirement (50% penetration rate of market potential)

	Tax Subsidies (million US$)	**Capital subsidy (million US$)**	**Hardware costs (million US$)**
Solar Home System End-user Cash and Credit Sales with Microfinance Institutions			
Program 1			
Al Mahwit	0.30	1.50	3.45
Hajja	0.15	0.76	1.72
Lahj	0.12	0.43	1.38
Raimah	0.16	0.78	1.78
Taiz	0.15	0.72	1.68
Sub-total	**0.886**	**4.188**	**10.008**
Program 3			
Abyan	0.01	0.02	0.12
Amran (25%)	0.05	0.12	0.62
Sub-total	**0.06**	**0.148**	**0.74**
Total (SHS cash and credit sales)	**0.945**	**4.336**	**10.748**
Solar Home System Fee-for-Service with Local Service Providers			
Program 5			
Al Baida	0.08	0.38	0.88
Al Hodeidah	0.11	0.52	1.29
Amran (75%)	0.28	1.38	3.18
Sub-total	**0.47**	**2.27**	**5.35**
Program 7			
Al Mahara	0.01	0.06	0.13
Hadramout	0.32	1.47	3.74
Sub-total	**0.33**	**1.53**	**3.87**
Total (SHS fee-for-service)	**0.803**	**3.801**	**9.222**
Solar Lamp End-User Cash and Credit Sales with Post and Postal Savings Authority			
Program 2			

Al Mahwit	0.04	0.10	0.67
Hajja	0.03	0.09	0.55
Lahj	0.02	0.06	0.40
Raimah	0.02	0.05	0.33
Taiz	0.02	0.04	0.23
Sub-total	**0.14**	**0.34**	**2.19**
Program 4			
Abyan	0.01	0.02	0.16
Amran	0.05	0.12	0.80
Sub-total	**0.06**	**0.15**	**0.96**
Program 6			
Al Baida	0.01	0.03	0.21
Al Hodeidah	0.01	0.02	0.10
Sub-total	**0.02**	**0.05**	**0.32**
Program 8			
Al Mahara	0.002	0.01	0.03
Hadramout	0.05	0.11	0.73
Sub-total	**0.05**	**0.12**	**0.77**
Total (SL cash and credit sales)	**0.262**	**0.655**	**4.230**
TOTAL	**2.010**	**8.792**	**24.416**

Note: 1) Tax subsidies include import duties and sales tax. 2) Capital cost subsidy is one time capital subsidy for each unit: $5/Wp for 20 Wp system, $4/Wp for 50 Wp system, and $3/Wp for 100 Wp system. 3) hardware costs are retail price of SHS less subsidies.

Table 14-9: Annual capital subsidy and capital investment

	Year												
	1	2	3	4	5	6	7	8	9	10	11	12	13
program 1													
capital subsidy	0.84	0.84	0.84	0.84	0.84								
hardware	2.00	2.00	2.00	2.00	2.00								
program 2													
capital subsidy		0.07	0.07	0.07	0.07	0.07							
hardware		0.44	0.44	0.44	0.44	0.44							
program 3													
capital subsidy			0.03	0.03	0.03	0.03	0.03						
hardware			0.19	0.19	0.19	0.19	0.19						
program 4													
capital subsidy				0.03	0.03	0.03	0.03	0.03					
hardware				0.19	0.19	0.19	0.19	0.19					
program 5													
capital subsidy					0.45	0.45	0.45	0.45	0.45				
hardware					1.07	1.07	1.07	1.07	1.07				
program 6													
capital subsidy						0.01	0.01	0.01	0.01	0.01			
hardware						0.06	0.06	0.06	0.06	0.06			
program 7													
capital subsidy								0.31	0.31	0.31	0.31	0.31	
hardware								0.77	0.77	0.77	0.77	0.77	
program 8													
capital subsidy									0.02	0.02	0.02	0.02	0.02
hardware									0.15	0.15	0.15	0.15	0.15
TOTAL	**2.84**	**3.35**	**3.57**	**3.79**	**5.31**	**2.55**	**2.04**	**2.90**	**2.85**	**1.33**	**1.26**	**1.26**	**0.18**
capital subsidy	0.84	0.91	0.94	0.96	1.42	0.59	0.52	0.80	0.79	0.34	0.33	0.33	0.02
hardware	2.00	2.44	2.63	2.82	3.89	1.95	1.52	2.10	2.06	0.99	0.93	0.93	0.15

14.5 Provide public funding to social infrastructures

Social infrastructures are vital to economic and social development of rural households in off-grid areas. Key infrastructures considered in the study include rural health centres, schools, mosques and military checkpoints. Currently, there are around 570 health centres, more than 2000 schools, and 9500 mosques in the identified off-grid areas. Moreover, around 200 mobile check points are being planned to be installed in the country. Following the geographic clustering in rural electrification by solar home systems presented earlier, four programs are being proposed for the development of the social infrastructures. This is shown in *Table 14-10*.

The development of these infrastructures requires a relatively significant level of financing. The total investment requirements for the target market potential in off-grid areas amount to more than US$ 32 million (*Table 14-11*). Investment requirements for the first 3 years total to more than US$2.2 million and this will rise to more than US$3 in the 4th to fifth years (*Table 14-12*).

Public investments to these infrastructures do not only improve the overall welfare of the rural population but also stimulate the national market for renewable energies. The required investments may not necessarily be sourced from the Ministry of Electricity and Energy (MEE) or the Rural Electrification Agency (REA) but will be allocated from the budgets of ministries responsible for these infrastructures (*Table 14-13*).

Table 14-10: Programs and target market potential* for social infrastructures

	Health Centres	Schools	Large Mosques	Small Mosques	Check Points
Program 1					
Al Mahwit	15	55	102	153	
Hajja	25	92	170	254	
Lahj	20	73	136	204	
Raimah	10	37	68	102	
Taiz	10	37	68	102	
Sub-total	**81**	**293**	**543**	**814**	**200**
Program 2					
Abyan	31	110	204	254	
Amran	36	128	238	153	
Sub-total	**66**	**238**	**441**	**407**	
Program 3					
Al Baida	25	92	170	153	
Al Hodeidah	15	55	102	814	
Sub-total	**41**	**146**	**271**	**407**	
Program 4					
Al Mahara	15	55	102	153	
Hadramout	81	293	543	814	
Sub-total	**97**	**348**	**645**	**967**	
TOTAL	**285**	**1025**	**1900**	**2850**	**200**

* 50% of the total market potential

Table 14-11: Investment requirements

	Health Centres	Schools	Large Mosque	Small Mosque	Check Points
Program 1					
Al Mahwit	0.12	0.26	0.23	0.15	
Hajja	0.47	1.42	0.81	0.61	
Lahj	0.38	1.13	0.65	0.48	
Raimah	0.08	0.17	0.15	0.10	
Taiz	0.19	0.57	0.32	0.24	
Sub-total	**1.24**	**3.55**	**2.16**	**1.57**	**2.55**
Program 2					
Abyan	0.57	1.70	0.97	0.73	
Amran	0.28	0.61	0.53	0.34	
Sub-total	**0.85**	**2.31**	**1.50**	**1.07**	
Program 3					
Al Baida	0.20	0.44	0.38	0.24	
Al Hodeidah	0.28	0.85	0.48	0.36	
Sub-total	**0.49**	**1.29**	**0.86**	**0.61**	
Program 4					
Al Mahara	0.28	0.85	0.48	0.36	
Hadramout	1.52	4.53	2.58	1.94	
Sub-total	**1.80**	**5.38**	**3.07**	**2.30**	
TOTAL	**4.38**	**12.52**	**7.59**	**5.55**	**2.55**

Subsidies could be provided by PEC-RES/REA through the Rural Electrification Fund. The amount of subsidy will depend upon the availability of financial resources. The subsidy can be estimated as percentage of the required investment cost by infrastructure type.

Table 14-12: Required investment per year

Subsidies could be provided by PEC-RES/REA through the Rural Electrification Fund. The amount of subsidy will depend upon the availability of financial resources. The subsidy can be estimated as percentage of the required investment cost by infrastructure type.

Table 14-13: Sources of funds

Infrastructure	Main Source of Funding	Sources of Subsidy
Health Centres	Ministry of Health	Rural Electrification Fund, International Donors and Aid Agencies
Rural Schools	Ministry of Education	Rural Electrification Fund, International Donors and Aid Agencies
Mosques	Ministry of Religious Endowment and Islamic Affairs	Rural Electrification Fund, International Donors and Aid Agencies
Checkpoints	Ministry of Interior	Rural Electrification Fund, International Donors and Aid Agencies

14.6 Protect end-users' welfare

One of the regulatory functions of MEE and REA is to protect the welfare of end-users and customers by ensuring quality and affordability of services. For both grid-based and off-grid RE programmes, MEE and REA will make sure that electricity services will comply with international quality standards.

Quality standards to be ensured by REA are the following: i) product quality which refers to renewable energy systems' meeting with the stipulated technical specifications, ii) service quality which relates to technology supplier's/service provider's training for end-users and annual visits to villages, and iii) commercial quality which refers to technology supplier's/service provider's response time to request for new service and to customer complaints as well as the employment of local technicians for every number of end-users.

A dedicated unit of REA's off-grid division will be established to ensure compliance with technical specifications, carry out technical inspections, and monitor service and commercial qualities of service providers. The regulation required for the programs are shown in *Table 14-14*.

Table 14-14: Program technical regulation

Program	Service Provider	Technical Regulation
SHS cash and credit sales Program 1 Program 3	• Financing institutions (FIs) • Accredited local dealers	• Technical standards or specifications • Accreditation of installers and technicians • Monitoring of installation and operation
SHS fee-for-service Program 5 Program 7	• Local Energy Service Company (ESCO)	• Technical standards or specifications • Accreditation of installers and technicians • Monitoring of installation and operation
Solar lamp cash and credit sales		

Program 2 Program 4 Program 6 Program 8	• Postal and Postal Savings Authority • Local retailers	• Technical standards or specifications • Accreditation of repair technicians
Social Infrastructures Program 1 Program 2 Program 3 Program 4	• Local Suppliers	• Technical standards or specifications • Accreditation of installers and technicians • Monitoring of installation and operation

Note: Technical standards or specifications are issued as part of the tender documents. For the accreditation of installers and technicians, PEC-RES/REA will carry out standardized trainings and examinations systems for local technicians. For installation monitoring, this will be carried out by experts from PEC-RES/REA or hired local consultants.

14.7 Promote the development of wind-diesel mini-grid systems

As mentioned earlier, solar and wind energies appear to complement rather than compete with each other. Isolated networks of wind-diesel systems are financially feasible in areas where the load demand is high (villages with more than 200 households). In villages with relatively low household density, it may be financially viable to provide solar PV systems to each household.

Based on the information from the wind atlas, the study identified 8 off-grid districts in coastal areas of the country where the wind potential is relatively high. Villages with more than 150 households from these districts were considered as potential areas for wind-diesel systems. There are more than 40 villages that could be potentially supplied with energy services through stand-alone wind-diesel systems.

The Ministry of Electricity and Energy (MEE) and PEC-RES/REA can carry out resource measurement (wind measurement campaign) and feasibility studies (baseline market study and feasibility studies) to assess the availability of wind resources and evaluate viability of the mini-grid systems.

14.8 Raise awareness and strengthen stakeholders' capacities

A dedicated unit of REA will be established to carry out education, information and training programmes. The specific off-grid solar PV information and capacity building program is shown in *Table 14-15*.

Education and information programmes

Education and information campaign programmes will be developed targeting relevant rural electrification stakeholders. Three separate awareness raising programmes will be developed to address the particular needs of different national RE stakeholders.

- Programme for policy makers and government officials. The main purpose of this programme is to inform, educate and elicit support from decision makers concerning the planned on- and off-grid rural electrification programmes.

- Programme for technology users/households (beneficiaries). This programme aims to educate users/households on the proposed decentralized market-based approach to off-grid rural electrification to address misconceptions about rural energy services.
- Programme for general off-grid RE stakeholders. Off-grid rural electrification programmes are complex which involve active participation not only from project beneficiaries but also from various stakeholders such as village associations, technology suppliers, service providers, local associations, etc. An information campaign will be designed to inform and educate these stakeholders on the planned off-grid rural electrification programme, their potential roles and corresponding obligations in project implementation.

Consultation meetings and workshops will be carried out while print and broadcast media as well as the internet will be employed to reach out the greatest number of target recipients.

Capacity building

Crucial to the successful implementation of the rural electrification strategy is the strength of human resources of implementing institutions and participating entities. Capacity building programmes will be developed and carried out targeting the following rural electrification strategy stakeholders:

- MEE and REA. MEE's capacity will be strengthened particularly in the areas of policy making and economic regulation. On the other hand, the organizational strength of REA particularly on project implementation and technical regulation will be reinforced.
- Off-grid service providers. Adequate training programmes on system installation, operations, maintenance, inspection, monitoring, economic and financial aspects, and management will be provided to rural energy service providers.
- General off-grid stakeholders. Various types and levels of training activities will be carried out targeting various stakeholders of the off-grid renewable energy service chain. These include basic RE system operations for project beneficiaries; installation and maintenance training for system suppliers and technicians; economic and technical aspects of RE systems for financial institutions, village associations, and other stakeholders.

Table 14-15: Program training and capacity building activities

Program	Activity	Responsibility
SHS cash and credit sales (FIs) Program 1 Program 3	• End-users information • End-users training • Training of FIs, local technicians, end-users' group, others	• FIs and PEC-RES/REA • FIs • PEC-RES/REA
SHS cash and credit sales (ALD and FIs) Program 1 Program 3	• End-users information • End-users training • Training of ALD, FIs, local technicians, end-users' group, others	• ALD and PEC-RES/REA • ALD • PEC-RES/REA
SHS fee-for-service	• End-users information	• LSP and PEC-RES/REA

Program 5 Program 7	• End-users training • Training of LSP, FIs, local technicians, end-users' group, others	• LSP • PEC-RES/REA
Solar lamps cash and credit sales Program 2 Program 4 Program 6 Program 8	• End-users information • Training of local technicians	• Post and Postal Savings Authority and PEC-RES/REA • PEC-RES/REA
Social Infrastructures Program 1 Program 2 Program 3 Program 4	• End-users information • Training of local technicians	• Service providers • PEC-RES/REA
Wind-diesel mini-grid systems	• Awareness raising of policy makers • Training of PEC, MEE, REA staff	• MEE • REA

SHS – solar home systems; FIs – Financing institutions; PEC-RES – Public Electricity Corporation-Rural Electrification Sector; REA – Rural Electrification Agency; ALDs – accredited local dealers; LSP – local service provider.

15 Off-Grid Rural Electrification Action Plan

This Chapter outlines the proposed Action Plan to be pursued by the Ministry of Electricity and Energy (MEE) and PEC-RES/REA. The Action Plan is developed based on the analysis carried out in the previous chapters of this study and summarized in *Table 15-1*.

Table 15-1: Off-grid rural electrification action plan

Action Plan	Sub-plan	Programs
1. Scaling-up off-grid rural electrification through solar PV systems	Solar home system *sales* program	Programs 1 and 3
	Solar home system *fee-for-service* program	Programs 5 and 7
	Solar lantern *sales* program	Programs 2, 4, 6 and 8
2. Provision of energy services to social infrastructures	Health centers Schools Mosques Checkpoints	Programs 1, 2, 3 and 4
3. Development of wind-diesel systems	Preparatory program Project implementation program	Program 1 Programs 2A, 2B and 2C

The implementation plan of these programs is shown in *Figure 15-1*.

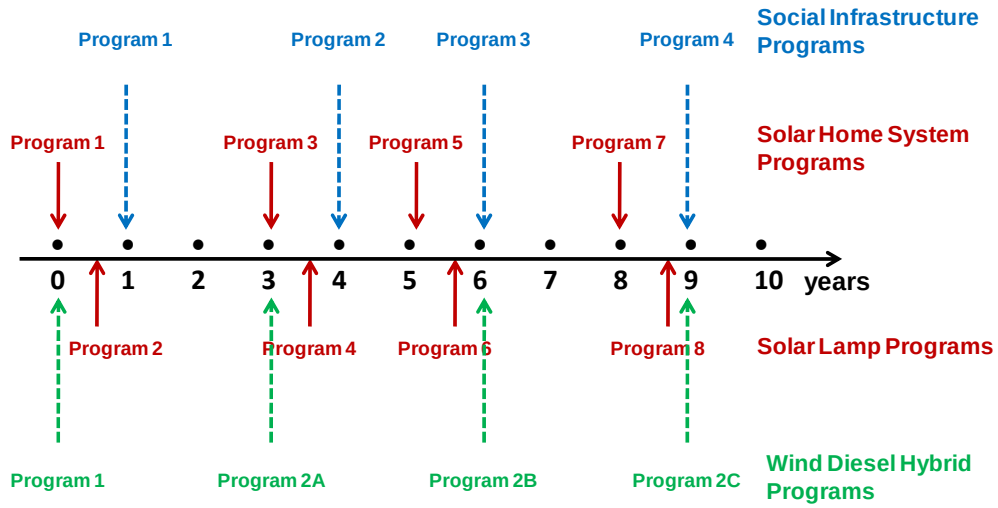

Figure 15-1: Off-grid rural electrification implementation plan

15.1 Action plan to scale-up off-grid rural electrification

15.1.1 SHS *Sales* Program Action Plan

Programs 1 and 3 are credit and cash sales program for SHS through financing institutions (MFIs and CAC Bank). As mentioned earlier, Program 1 covers the off-grid areas of Al Mahwit, Hajja, Lahj, Raimah, and Taiz with market potential of 40,000 households. Program 3, on the other hand, consists of off-grid areas in Abyan and a part of Amran Governorates with market potential of almost 11,000 households.

These off-grid areas are within the 50 km zone of a branch of a financing institution, either a microfinance institution or a CAC Bank, and it is proposed that these areas will be assigned for cash and credit sales of SHS through one of these institutions.

A. Preparation of financing institutions

The Ministry of Electricity and Energy (MEE) will locate, identify and mobilize the local branches of microfinance institutions and CAC Bank in each district of the target off-grid areas.

MEE together with PEC-RES/REA will present the overall plan of providing energy services to off-grid areas, convince them on the business opportunity, and invite these institutions to visit the on-going demonstration projects.

MEE will start to negotiate with these institutions for their rural electrification participation and discuss the terms and conditions of the project. Based on the results of the negotiations, implementation agreements will be drafted and finalized.

Some of the terms and conditions of the said agreement are discussed in the following sections.

B. Local market survey and social preparation

Using the result of this study, a local area market survey will be carried out by the PEC-RES (with the aid of local consultants and with representatives from the specific financing institution) to identify which specific off-grid village in each district will be prioritized first as well as to identify which villages a financing institution can start initially. The main output of this activity is the ranking of off-grid villages in specific district for development priorities, and socio-economic baseline conditions including end-users' willingness to pay.

As a social preparation, the market survey team will also conduct village consultations presenting the program, the technology and the financing scheme.

C. Awareness campaign

In addition to the consultations carried out in item B above, an awareness campaign will be carried out jointly by PEC-RES/REA and the assigned financing institution in each district area. This campaign is aimed to raise awareness of rural households for the whole target off-grid areas. Villagers need to be informed on the benefits and limitations of the systems and the proposed financing schemes. The approach carried out and the materials used in the on-going demonstration project will be used in this program.

D. Financing

Financing institutions (MFIs and CAC Bank) may need initial funding for the procurement of SHS technology. PEC-RES/REA may initially provide a soft loan (sourced from RE Fund or government budget allocation) to MFIs and CAC Bank.

The most realistic approach is that PEC-RES/REA will initially provide funding for 2,000 SHS units for each Governorate. The total number of units to be initially acquired is the following:

- Program 1: 10,000 units for 5 Governorates
- Program 3: 4,000 units for 2 Governorates

The amount used to procure these units will be recovered when the end-users' start to pay monthly dues. The recovered capital (capital cost minus subsidy) could be reinvested in the project until the initial capital amount will be depleted. After the depletion of the initial funding, it is expected that financing institutions could secure their funding from other sources, otherwise PEC-RES/REA may provide a second tranche of funding or provide a soft loan sourced from the RE Fund.

E. SHS procurement

SHS procurement includes preparation of tender documents, technical specifications and regulations, as well as solicitation for the SHS supply through competitive bidding. With the proposed initial funding from the Government, the first procurement could be done by PEC-RES/REA.

When financing institutions will reinvest the collected funds for the project, it is expected that they will carry out the tendering of the supply. PEC-RES/REA will provide technical assistance in the preparation of the documents and tendering process.

F. Technicians' training and accreditation

This covers training of technical staff of financing institutions, service providers and local technicians. PEC-RES/REA will provide training to these technical persons for installation and maintenance of the systems. The training consists of PEC-RES/REA standard procedures for installation and maintenance. For Program 1, 3 a series of training could be carried out during the project implementation. The first will be during the project initiation, second training could be implemented once the service provider starts to expand from one site to another site. Training manuals used in the demonstration projects will also be reproduced.

The culmination of the training is a practical examination for trainees. Those who passed the examinations will receive certifications as accredited technicians.

G. End-user training

This will be carried out by the service provider (financing institutions) during the installation of the equipment. PEC-RES/REA could provide assistance through the publication of end-user manuals. Experience learned in the end-user training during the demonstration project could be valuable in this Program.

H. Formation of end-users' group

The service providers (financing institutions) will be required to establish an end-users' group in each village or cluster of villages. In each group, some members could be trained as local technicians who could then be subcontracted to carry out maintenance services in the village. The end-users'-group will serve as the focal point for information as well as end-users' complaints.

Based on the experience gained in the pilot demonstration project, PEC-RES/REA could provide assistance in the social preparation and in the organization of the end-users in each village.

I. Monitoring and evaluation

The first project monitoring will be carried out one month after the installation of a specified batch of SHS units to ensure that the system installation is according to PEC-RES standards. Monitoring acceptance results will trigger the release of subsidy payments. For non-compliance, the service providers could be immediately notified after the monitoring visit and mitigation must be carried out within one month after the receipt of the notification.

A random monitoring and evaluation will be carried out by PEC-RES/REA every 6 months during the first 2 years of operation in each project site to ensure proper provision of after sales services by service providers. Again, actions to the identified technical issues must be carried out within one month.

Table 15-2: SHS Sales Program Action Plan and Cost Estimates

Activities	Program Cost **USD (million)**	Hardware Financing Requirement **USD (million)**
A. Financing institution preparation	-	
B. Local market survey and social preparation	0.050	
C. Awareness campaign	0.015	
D. Financing facilitation		
• Required subsidy (capital cost)		
Program 1*	4.188	
Program 3*	0.148	
• Initial funding (including subsidy)**		
Program 1 (10,000 units)	6.034	
Program 3 (2,000 units)	2.413	
• Hardware costs (total)		
Program 1		14.197
Program 3		0.888
E. SHS procurement	0.010	
F. Technician's training	0.020	
G. End-user training	0.050	
H. Formation of end-user's group	0.020	
I. Monitoring and evaluation	0.020	
Total	12.968	15.085
Total (without total program required subsidy)	8.632	

* 50% of market potential
** this amount will be recovered once the end-users start to pay monthly dues (amount to be recovered is initial funding minus subsidy).

Table 15-3: Program 1 Action Plan Timeline

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. FI preparation											
B. Local Market Assessment											
C. Awareness campaign											
D. Financing Facilitation											
E. SHS procurement (first tranche)											
F. Technicians' training											
G. Formation of end-users' group											
H. End-user training											
I. Monitoring and evaluation											

Note: This time schedule is only for Program 1. The same time schedule could be followed for Program 3 only that it will start 3 years later (in this case 2013).

15.1.2 SHS *Fee-for-Service* Program Action Plan

Programs 5 and 7 are fee-for-service programs through local service providers. Program 5 covers the off-grid areas in Al Baida and Al Hodeidah with market potential of more than 10,000 households. Program 7 on the other hand includes off-grid areas of Al-Mahara and Hadramout with total market potential of 17,000 households. The identified project sites are situated more than 50 kilometers from existing branches of financing institutions operating in the country. It was proposed that these areas will be provided with energy services through a fee-for-service concession model.

A. Baseline Study

For the fee-for-service model, a baseline market study is necessary to be carried out at the outset of the program preparation. This could be carried out by local consultants (or a team of international and local consultants). Key elements of the study are the following: identification and ranking of villages for program development; surveys to determine current household economic and social conditions, expenditures, and willingness to pay; market potential for each technology size, etc.

B. Selection of Service Providers

The selection of the provider will be executed through competitive bidding. Several activities need to be carried out prior to the selection of the service provider. These are the following:

- Finalization of the institutional framework. This defines the agencies responsible for granting the concession permit, determining tariffs, and providing subsidies.
- Preparation of tender documents. Tender documents will be prepared with inputs from the baseline study. Key elements include: definition of concession area, market and target potential, scope of services, technologies to be used, service charges, quality of service regulation (technical specifications and service quality), etc.
- Solicitation, evaluation, and selection. This includes call for bids, evaluation of bids based on defined criteria, and awarding of bids to service providers. Key parameters that could be included in the criteria are the following: number of households that could be covered in a given period of time, and repair and maintenance services, management fees, etc.

C. Awareness campaign

The awareness campaign will be jointly implemented by PEC-RES/REA and the selected service provider. This campaign will be aimed to raise awareness of the rural households for the whole target off-grid areas. Villagers need to be informed on the benefits and limitations of the systems and the proposed payment schemes. The materials used in the on-going demonstration project will be used in this program.

D. Financing

The target areas for fee-for-service model are among the difficult areas in the country. It may be hard to attract service providers if they will be required to provide capital investments. Eventually, the government will provide the program capital investments. On the other hand, the service provider may be asked to share the financial risks through an output-based subsidy approach. The service provider may receive an initial

amount for mobilization after signing the contract agreement with PEC-RES/REA. The full payment will be released only after the installation is approved by the monitoring team. The government may source the funds from the Rural Electrification Fund.

It is envisaged that the end-users' monthly payments will cover the management, operation and maintenance charges, and part of the capital costs.

E. Technician's training and accreditation

This covers training of technical staff of service providers and local technicians. PEC-RES/REA will provide training to these technical persons for installation and maintenance of the systems. The training consists of PEC-RES/REA standard procedures for installation and maintenance. A series of training could be carried out during the project implementation. The first will be during the project initiation, second training could be implemented once the service provider starts to expand from one site to another site. Training manuals used in the demonstration projects will also be reproduced.

The culmination of the training is a practical examination for trainees. Those who passed the examinations will receive certifications as accredited technicians.

F. End-users' training

This will be carried out by the service provider during the installation of the equipment. PEC-RES/REA could provide assistance through the publication of end-user manuals. Experience learned in the end-user training during the demonstration project could be valuable in this Program.

G. Formation of end-users' group

The service providers will be required to establish an end-users' group in each village or cluster of villages. In each group, some members could be trained as local technicians who could then be subcontracted to carry out maintenance services in the village. The end-users'-group will serve as the focal point for information as well as end-users' complaints.

Based on the experience gained in the pilot demonstration project, PEC-RES/REA could provide assistance in the social preparation and in the organization of the end-users in each village.

H. Monitoring and evaluation

The first project monitoring will be carried out one month after the installation of a specified batch of SHS units to ensure that the system installation is according to PEC-RES standards. Monitoring acceptance results will trigger the release of capital payments. For non-compliance, the service providers could be immediately notified after the monitoring visit and mitigation must be carried out within one month after the receipt of the notification.

A random monitoring and evaluation will be carried out by PEC-RES/REA every 6 months during the first 2 years of operation in each project site to ensure proper provision of after sales services by service providers. Again, actions to the identified technical issues must be carried out within one month.

Table 15-4: SHS Fee-for-Service Program Action Plan and Cost Estimates

Activities	Program Cost **USD (million)**	Hardware Financing Requirement **USD (million)**
A. Baseline study	0.050	
B. Service provider selection	0.025	
C. Awareness campaign	0.015	
D. Financing		
• Required subsidy (capital cost)		
Program 5*	2.275	
Program 7*	1.526	
• Hardware costs (total)		
Program 5*		5.353
Program 7*		3.869
E. Technician's training	0.020	
F. End-user training	0.050	
G. Formation of end-user's group	0.020	
I. Monitoring and evaluation	0.020	
Total	4.001	9.222
Total (without total program required subsidy)	0.200	

* 50% of market potential

Table 15-5: Program 5 Action Plan Timeline

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
A. Baseline study											
B. Service provider selection											
C. Awareness campaign											
D. Financing Facilitation											
E. Technicians' training											
F. End-user training											
G. Formation of end-users' group											
H. Monitoring and evaluation											

Note: This time schedule is only for Program 5. The same time schedule could be followed for Program 7 only that it will start 3 years later (in this case 2018).

15.1.3 Solar Lamp Sales Program Action Plan

Programs 2, 4, 6 and 8 will be replications of the currently being prepared cash and credit sales of solar lamp demonstration project through the Postal Service. Almost all of the target off-grid areas are within the 50 km zone of a branch of the Postal and Postal Savings Authority. These programs are to be implemented in the following regions:

- Program 2: Al Mahwit, Hajja, Lahj, Raimah, and Taiz (potential of 22,609 households)
- Program 4: Abyan and Amran (potential of 9,863 households)
- Program 6: Al Baida, Al Hodeidah and part of Amran (potential of 3,268 households)
- Program 8: Al Mahara and Hadramout (potential of 7,912 households)

For all these programs, PEC-RES/REA will be dealing only with one service provider, the Postal and Postal Savings Authority. The success therefore of the soon to be implemented solar lamp demonstration project will have crucial implications to these programs.

The phasing in of these programs is designed to be implemented almost simultaneously with the implementation of the solar home system programs (Programs 1, 3, 5, and 7) to take advantage of the economies of scale in end-users' mobilization, information campaign, training, and monitoring.

For example, during the social preparation phase of the solar home system (SHS) market, the poorest households who participated in the event will be offered right away with solar lamps as an option and be referred to the program being implemented by the Post and Postal Savings Authority.

A. Preparation of the Post and Postal Saving Authority

With the soon to be implemented demonstration project, the preparation needed to mobilize the Post and Postal Savings Authority would be minimal. This mainly involves the exposure of the branch managers to the pilot demonstration project. Similarly, once this Program (Program 2) has been initiated, it would be easier to negotiate with the Post and Postal Savings Authority for Programs 4, 6 and 8.

An implementation agreement for each program however needs to be defined and signed by each participating branch and PEC-RES/REA. The implementation agreement used in the demonstration project will be the basis for the new agreements.

B. Local market survey and social preparation

This activity will be integrated during the local market survey and social preparation for solar home system (SHS) projects (Programs 1, 3, 5 and 7). Thus, the target groups for solar lamps (the poorest member of the society) will be offered right away an option and be informed about the solar lamps projects of the Post and Postal Savings Authority during the consultation meetings.

C. Awareness campaign

Similar to the above activity, the awareness campaign related to solar lanterns (SL) will be incorporated in the same campaign for solar home systems (SHS): Program 1

awareness campaign with this Program (Program 2), Program 3 with Program 4, Program 5 with Program 6, and Program 7 with Program 8.

The materials used in the demonstration project will also be used in the awareness campaign of the new programs.

D. Financing

Similar to financing institutions (MFIs and CAC Bank), the Post and Postal Savings Authority may need initial funding to procure the solar lamps. PEC-RES/REA may initially provide a soft loan (sourced from RE Fund or government budget allocation) to the Post and Postal Savings Authority.

On the other hand, it is more realistic if PEC-RES/REA will initially provide funding for 500 units for each target district in Programs 2 and 4.

- Program 2 – 8,000 units at the beginning of the off-grid rural electrification program
- Program 4 – 6,500 units after 3 years of the initiation of Program 2

This amount will be recovered when end-users purchase the equipment either by cash or credit. The recovered capital (capital cost minus subsidy) could be reinvested in the project until the initial capital amount will be depleted.

After the depletion of the initial funding, it is expected that the Post and Postal Savings Authority will be linked to private suppliers through PEC-RES/REA. If private suppliers are not interested to participate in the Program, PEC-RES/REA may provide a second tranche of funding or a soft loan to procure additional supplies.

E. Solar Lamp Procurement

Solar lamp procurement includes preparation of tender documents, technical specifications and regulations, as well as solicitation for the solar lamp supply through competitive bidding. With the proposed initial funding from the Government, the first procurement could be done by PEC-RES/REA.

When the Post and Postal Savings Authority will reinvest the collected funds for the project, it is expected that the agency will carry out the tendering of the supply. PEC-RES/REA will provide technical assistance in the preparation of the documents and tendering process.

F. Training

The training will be intended for the Postal Service technical staff in each branch who will carry out technical checks and repair (in case of system failure). This training program will be implemented by PEC-RES/REA technical staff with the support from local experts.

G. Monitoring and Evaluation

Project monitoring and evaluation for all SL Programs will be incorporated in the monitoring for SHS Programs. In this case, random checks for SL will also be carried out every 6 months for one year. If issues are being reported, the Postal Service will be notified immediately after the monitoring visit and mitigation must be carried out within one month after the receipt of the notification.

Table 15-6: Solar Lamp Programs Action Plan and Estimated Costs

Activities	Program Cost **USD (million)**	Financing Requirement **USD (million)**
A. Post and Postal Savings Authority preparation	-	
B. Local market survey and social preparation	-	
C. Awareness campaign	0.010	
D. Financing		
• Required subsidy (50% of the market potential – all programs)	0.773	
• initial funding to be allocated for Program 2 and 4 (this amount will be recovered)	1.305	
• hardware cost (50% of the market potential – all programs)		4.641
E. SL procurement	0.005	
F. Technician's training	0.005	
G. Monitoring and evaluation	0.010	
TOTAL	**2.108**	**4.641**

Table 15-7: Program 2 Action Plan Timeline

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. FI preparation											
B. Local Market Assessment											
C. Awareness campaign											
D. Financing Facilitation											
E. SL procurement											
F. Technicians' training											
I. Monitoring and evaluation											

Note: This time schedule is only for Program 2. The same time schedule could be followed for Program 4, 6, 8.

15.2 Action plan to provide energy services to social infrastructures

Social infrastructures considered in this study include health centers, rural schools, mosques and military check points. At present, there are around 570 health centres, more than 2000 schools, and 9500 mosques in the identified off-grid areas. The Ministry of Interior on the other hand has planned to install around 200 mobile check points throughout the country in the next 5 years.

These infrastructures will be supplied with energy services following the area classifications and clustering of districts in the rural household electrification programs presented in the previous section. Four programs were designed for the provision of these services and these are the following: Program 1 (Al Mahwit, Hajja, Lahj, Raimah, and Taiz), Program 2 (Abyan and Amran), Program 3 (Al Baida and Al Hodeidah), and Program 4 (Al Mahara and Hadramout).

A. Partnerships with ministries responsible for social infrastructures

PEC-RES/REA initiates and negotiates with concerned government ministries for the supply of energy services of specific infrastructures in off-grid areas.

PEC-RES/REA will present the overall plan of providing energy services to rural infrastructures in off-grid areas and raise the awareness of these institutions on the benefits of the solar PV technology.

PEC-RES/REA will start to negotiate with these institutions for their rural electrification participation particularly in providing financing for social infrastructures and will discuss the terms and conditions of the project. Based on the results of the negotiations, implementation agreements will be drafted and finalized.

B. Baseline study

The baseline study will be carried out by PEC-RES/REA through its local consultants, in partnership with the concerned Ministries.

Key elements of the study are the following: identification and ranking of social infrastructures for program development in target off-grid areas; surveys to determine existing social services and its corresponding energy service requirement and technologies.

C. Service provider selection

The selection of the provider will be executed through competitive bidding. Several activities need to be carried out prior to the selection of the service provider. These are the following:

- Financing agreement. This defines the role of specific ministries in providing financing and subsidies that can be provided by PEC-RES/REA through the Rural Electrification Fund.
- Preparation of tender documents. Tender documents will be prepared with inputs from the baseline study. Key elements include: market and target potential, scope of services, technologies to be used, service charges, quality of service regulation (technical specifications and service quality), etc.

- Solicitation, evaluation, and selection. This includes call for bids, evaluation of bids based on defined criteria, and awarding of bids to service providers. Key parameters that could be included in the criteria are the following: number of infrastructures that could be covered in a given period of time, and repair and maintenance services, management fees, etc.

D. Awareness campaign

The awareness campaign will be jointly implemented by PEC-RES/REA and the concerned government Ministry. This campaign will be aimed to raise awareness of the end-users of the social infrastructures in target areas. End-users need to be informed on the benefits and limitations of the systems. The awareness campaign targeting social infrastructures can be integrated in the campaign targeting rural households. Materials used in the on-going demonstration projects will be used in this program.

E. Financing

Social infrastructures require public financing for the purchase and installation of solar PV systems. For operation and maintenance, however, this could be taken from the operational budget of the said infrastructures.

As discussed in Chapter 10 of this report, the main source of finance is from the budget allocation from each concerned Ministry. This could be supplemented by subsidies from the Rural Electrification Fund.

F. Technicians' training and accreditation

This covers training of technical staff of service providers and local technicians. Local technicians could include employees of a given social infrastructure.

The training consists of PEC-RES/REA standard procedures for installation and maintenance. A series of training could be carried out during the project implementation. The first will be during the project initiation, second training could be implemented once the service provider starts to expand from one site to another site. Training manuals will be developed.

The culmination of the training is a practical examination for trainees. Those who passed the examinations will receive certifications as accredited technicians.

G. End-users' training

This will be carried out by the service provider during the installation of the equipment. PEC-RES/REA could provide assistance through the publication of end-user manuals.

H. Monitoring and Evaluation

The first project monitoring will be carried out within one month after the installation of a specified batch of SHS units to ensure that the system installation is according to PEC-RES standards. Monitoring acceptance results will trigger the release of contract payments. For non-compliance, the service providers could be immediately notified after the monitoring visit and mitigation must be carried out within one month after the receipt of the notification.

A random monitoring and evaluation will be carried out by PEC-RES/REA every 6 months during the first 2 years of operation in each project site to ensure proper

provision of repair and maintenance services. Again, actions to the identified technical issues must be carried out within one month.

Table 15-8: Social Infrastructure Programs Action Plan and Estimated Costs

Activities	Program Cost **USD (million)**	Hardware Financing Requirement **USD (million)**
A. Partnerships with concerned Ministries	-	
B. Baseline study	0.075	
C. Service provider selection	0.025	
D. Awareness campaign	0.015	
E. Financing		
• Program 1*		[11.07]
Health centers		1.24
Schools		3.55
Mosques		4.17
Check points		2.55
• Program 2*		[5.73]
Health centers		0.85
Schools		2.31
Mosques		2.57
• Program 3*		[3.24]
Health centers		0.49
Schools		1.29
Mosques		1.47
• Program 4*		[30.40]
Health centers		4.38
Schools		12.52
Mosques		13.14
F. Technicians' training and accreditation	0.030	
G. End-users' training	0.030	
H. Monitoring and evaluation	0.030	
Total	0.205	50.08

* 50% of market potential

Table 15-9: Program 1 Action Plan Timeline

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. Develop partnerships											
B. Baseline study											
C. Service provider selection											
D. Awareness campaign											
E. Financing Facilitation											
F. Technicians' training											
G. End-user training											
H. Monitoring and evaluation											

Note: This time schedule is only for Program 1. The same time schedule could be followed for Programs 2, 3, and 4.

15.3 Action plan to promote decentralized wind-diesel systems

As discussed in Chapter 4 of this report and in the Renewable Energy Resource Assessment Study, wind energy potential is high in the coastal areas of the country. This wind resource potential however needs to be further verified through actual field measurements. Some off-grid areas in Al Mahara, Hadramout, Abyan, Lahj, Taiz, Al Hodeidah and Hajjah with high household density could be provided with energy services through wind-diesel systems. Areas with high potential, as indicated by the wind atlas, will be pre-selected and will be confirmed through site visits.

PEC-RES/REA, as an apex agency for rural electrification, does not have the capacity nor the mandate to develop the decentralized wind-diesel systems in selected areas. The projects could be implemented by the Public Electricity Corporation (PEC) or by the private service providers. PEC is, however, in the best position to carry out these activities.

The role therefore of PEC-RES/REA is to promote and to facilitate the removal of barriers to the development of wind-diesel systems in rural areas. The following activities are being proposed to be pursued by PEC-RES/REA in order to promote the development of wind-diesel systems in off-grid areas.

Program 1

A. Wind Measurement

From the pre-selected areas, at least 6 sites will be initially developed for pilot demonstration, and wind measurement stations will be installed in these sites. These new masts could be moved to other locations after at least 1-2 years of wind measurement campaign.

Wind measurement will be carried out by a team of international and national consultants with the support of the local staff from REA.

B. Baseline Study

During the period of the wind measurement campaign, a baseline market study of the selected villages could be carried out. This will be executed by a team of local consultants.

Key elements of the study are the following: demand analysis and forecasting, surveys to determine current household economic and social conditions, expenditures, and willingness to pay, etc.

C. Feasibility Studies

Based on the wind measurement results, feasibility studies will be carried out to evaluate the technical, economic and financial viability of wind-diesel systems in providing energy services in rural areas.

D. Capacity Building

1) Study visit. A study visit to countries (Europe or developing countries) where a wind-diesel system is successfully implemented (technical, financial and institutional). The study visit will be designed decision makers and top level managers of Ministry of Electricity and Energy (MEE), Public Electricity Corporation (PEC), Rural Electrification Agency (REA) with the objective of increasing their awareness and understanding of decentralized wind-diesel systems for off-grid rural electrification.
2) Resource assessment and measurement, and wind-diesel system operation training. This is designed mainly for the technical staff of MEE, PEC and REA. Three to four representatives will be sent overseas for training on resource assessment, measurement, wind-diesel system operation as well as in the use of computer softwares specifically designed for these activities.

Program 2

E. Project Implementation

As mentioned earlier, wind-diesel hybrid system project implementation could be best carried out by the Public Electricity Corporation (PEC). From the results of the studies carried out in Program 1, feasible projects will be implemented in Program 2. These projects could be grouped into the following:

- Program 2A – for feasible areas in Taiz Governorate
- Program 2B – for viable areas in Al Hodiedah Governorate
- Program 2C – for areas in Lahj, Abyan, and Hadramout Governorates.

Table 15-10: Decentralized Wind-Diesel Systems Action Plan and Estimated Costs

	US$ million
Program 1	
• Wind measurement campaign (6 stations)	0.100
• Baseline market study (23 sites)	0.075
• Feasibility studies	0.075
• Capacity building activities	0.030
Program 2	
• Program 2 A (Taiz)	5.775
• Program 2 B (Al Hodeidah)	4.200
• Program 2 C (Lahj, Abyan and Hadramout)	2.100
TOTAL	12.355

Table 15-11: Decentralized Wind-Diesel Systems Action Plan Timeline

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. Wind measurement											
B. Baseline studies											
C. Feasibility studies											
D. Capacity building											
E. Program 2A											
Program 2B											
Program 2C											