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Draft Final Report

Deployment of Renewable Energy Technologies (RETs) to Enhance Teacher Training Effectiveness in Bihar

Technical Assessment and Design of Solar Technology Deployment

The World Bank

January 2014

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Abbreviations

AC	Alternating Current
ACDB	AC Distribution Board
BRC	Block Resource Center
BSEIDC	Bihar State Education Infrastructure Development Corporation
CEA	Central Electricity Authority
CRC	Cluster Resource Center
c-Si	Crystalline Silicon
DC	Direct Current
DCDB	DC Distribution Board
DG	Diesel Generation Set
DIET	District Institute for Education and Training
DoD	Depth of Discharge
EDI	Education Development Index
EMI	Electromechanical Interface
GoB	Government of Bihar
IEC	International Electromechanical Standards
IS	International Standard
ISI	Indian Standards Institute
JNNSM	Jawaharlal Nehru National Solar Mission
kW	Kilo Watt
LaBL	Lighting a billion lives
LGBR	Load Generation Balance Report
LoI	Letter of Intent
MNRE	Ministry of New and Renewable Energy
MPPT	Maximum Power Point Tracking
MS	Mild Steel
MU	Million Units
NABARD	National Bank for Agriculture and Rural development
PCU	Power Conditioning Unit
PTTEC	Primary Teacher Training and Education Center
RE	Renewable Energy
RET	Renewable Energy Technology
RFID	Radio Frequency Identification
RTE	Right to Education
SCERT	State Center for Education Research and Training
SPV	Solar Photovoltaic
SS	Stainless Steel
TF	Thin Film

Executive Summary

The World Bank is assisting Bihar State Education Infrastructure Development Corporation (BSEIDC) in development of overall education infrastructure in Bihar. The improvement of training infrastructure for the teachers is one of the recognized goals. The projects targets at providing information and communication technologies (ICT) equipment across teachers training infrastructure in the state. As part of the enabling infrastructure, there is a need to provide a reliable and a cost-effective energy source for energizing ICT equipment. The proposed World Bank program is expected to provision the same by supporting deployment of renewable energy technology at the teacher training institutes. In this context, this study has been conducted to assess available renewable energy technologies in Bihar and their suitability with ICT load requirement. The selected RET is to be implemented in a phased manner across institutes.

The present study has adopted a graded evaluation approach to assess and evaluate all the possible renewable energy technologies and filter out the most feasible ones through a three step process involving (1) the assessment based on state wide renewable resource potential availability, (2) evaluation of suitability of infrastructural conditions and (3) Technology Management, Supply Chain & Cost Parameters. A mix of secondary desktop research and primary research through site surveys for 24 shortlisted locations has been carried out. The data and information collection through both secondary and primary research has been used for the first two stages of elimination. In the ultimate analysis, biomass and solar technologies were the two RE technologies shortlisted for the third stage. These have been assessed by developing a technology selection matrix comprising of three parameters viz. technology acceptability, applicability and technology management & cost.

Based on the analysis, the solar PV technology is found to have greater acceptability and technology adaption for the requirements of teachers training infrastructure spread all over the state. The technology enjoys policy and fiscal benefits from both central and state government making it more cost competitive in the market.

A detailed technical analysis for the SPV design shows that the crystalline silicon (c-Si) is more appropriate as compared to the Thin Film (TF) technology as it requires less area per kW and is also a more commercially established technology. The proposed technical design is based on solar grid hybrid with storage and manual switchover facility for DG set option. This has been proposed based on the conditions at the sites where the grid connected and un-interrupted power supply is not available.

The proposed design of the system also addresses certain critical issues unique to the local conditions in the state. This includes threat of theft and vandalism, lack of training and knowledge about SPV for the field education department staff. These concerns have been mitigated through appropriate technology solutions and practices. The training needs are proposed to be addressed through involvement of the project implementer who would undertake the training as part of project implementation.

In addition, the local staff on expiry of the annual maintenance contract (AMC) will manage the operation & maintenance of SPV systems with the project developer. Thus, the project developer would be required to provide requisite training to local staff.

An assessment of daily energy requirement of ICT loads has been carried out based on the equipment loads and numbers per installation and assuming seven hours of daily operation. The daily energy requirement for various categories of institutions varies from 5.3 kWh for BRC/CRC, DIET/ PTTEC 23.8 kWh and 32.6 kWh for SCERT.

The solar PV capacity has been assessed based on the solar irradiation data available for Bihar and estimating the solar PV system capacity for different categories of training institutes. A total solar PV capacity of 607 kW is estimated for the pilot phase of project implementation which will cover SCERT and 150 additional sites. For the recommended option of solar grid hybrid with seven hours of battery backup configuration, the procurement cost has been estimated be Rs 10.62 crore (USD 1.77 million) without capital subsidy and Rs 7.43 crore (USD 1.24 million) with capital subsidy.

The capacity for entire program covering 1,201 teachers training institutes will be 2,600 kW and the procurement cost has been estimated at Rs 25.92 crore (USD 4.32 million) without capital subsidy and Rs 18.12 crore (USD 3.02 million) with capital subsidy.

Under the proposed business model, the BSEIDC will procure the solar PV project installation under World Bank program for education department. The project can avail a maximum of capital subsidy of 30% from MNRE available under JNNSM Off-Grid SPV scheme. The subsidy however is subject to approval and availability of funds. Additionally, incentives available from the state government, if any, may be availed by the project developer. The World Bank will fund the remaining project cost including the AMC for a period of 5 years. The proposed project bid process shall be managed by BSEIDC. The selection of solar PV project developer will be selected through an open competitive bidding process which will include the capital subsidy provided by MNRE for solar PV projects. The successful develop would be expected to implement the project and also be responsible for the operation & maintenance of the SPV system for a period of minimum 5 years. The period can be extended by BSEIDC or fresh bids invited for the annual maintenance contract (AMC) at the end of 5 year period.

1 Introduction

1.1 World Bank's program for education sector in Bihar

Bihar is the third largest state in India in terms of population. More than 190 million students are enrolled in the elementary and primary education and gender parity has been achieved in the state recently. In spite of the recent improvements in the access to education and retention, the state is still ranked 35th in the country in Educational Development Index (EDI). Most of the districts of state are in bottom quartile of EDI distribution for the country.

The quality of education is a major issue that needs immediate attention. Achievement of quality education will be dependent upon recruiting well-qualified teachers and providing them with effective pre-service training. Moreover, it is important to ensure continuous professional development of teachers to raise their quality.

The state government in Bihar has initiated efforts in this direction and is embarking on major project to upgrade the teachers training infrastructure with help of the World Bank. The project would be providing Information and Communication Technologies (ICT) equipment at teacher training institutes and 1201 Teachers Training Institutes have been identified for this purpose. These institutes are spread across all the 38 districts of the state covering urban, semi-urban and remote areas.

The existing teachers training infrastructure in the state is old and has challenges in access to energy supply which is both reliable and cost-effective. Currently, the state of Bihar faces issues in reliability of energy supply as well as access in several rural areas. A large number of institutes in Bihar are not connected to the grid supply and have to rely on expensive diesel-based power generating sets to meet the electricity requirement. In order to make the ICT equipment functional in the existing as well as new teacher training infrastructure under the program, a reliable energy source needs to be identified.

1.2 Teachers Training Infrastructure in Bihar

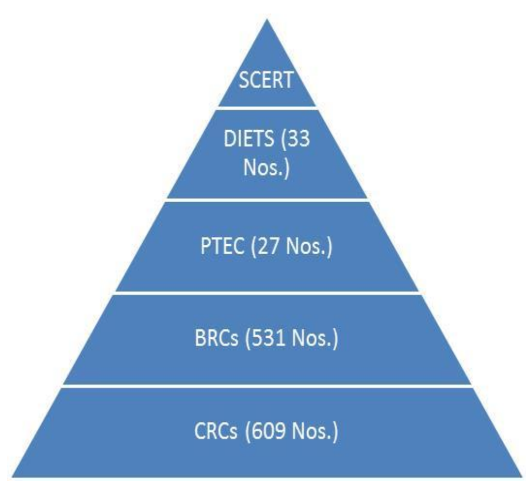
The state of Bihar has a large teacher training infrastructure covering 1,201 teachers training institutes and one State Centre for Education Research and Training (SCERT).

The teacher training infrastructure covers all the 38 districts of the state. Training institutes are located in every district and block of the state. To strengthen the access to training in the state, several Cluster Resource Centers or CRCs have also been established in remote and far-flung areas. The teachers training infrastructure in Bihar comprises of the following institutes:

State Council for Educational Research (SCERT) is the central facility located in Patna and is the hub and repository center to train and develop teachers in the state. It is the core center to train the lead trainers who work in their areas of districts or blocks level.

District Institute for Education and Training (DIETs) and **Primary Teacher Education Colleges (PTECs)** are the district level training centers with the training staff providing a range of training to secondary

Figure 1: Teachers Training infrastructure in Bihar



Source: The World Bank and BSEIDC

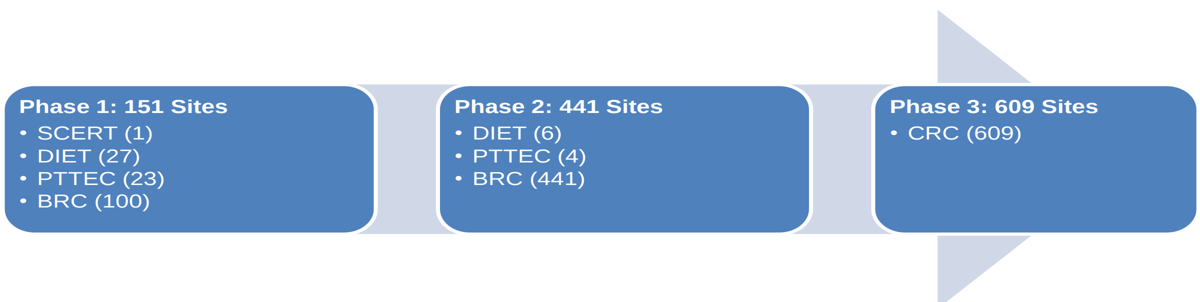
Block Resource Centers (BRCs) are located at the block level to increase the reach of training centers and train the local teachers working at block level.

Cluster Resource Centers (CRCs) are located in remote areas and cater to the training and development needs in far-flung areas. There are a total of 609 CRCs in the state at present. These institutes provide training to teachers teaching students in elementary and primary level.

1.3 Implementation plan

The selected RET is proposed to be implemented in a phased manner for energizing the 1,201 teachers training institutes across Bihar. The initial phase will be a pilot project covering only 151 sites in the state. This will be followed by second phase covering all of the remaining sites except Cluster Resource Centers (CRCs). In the final phase, all of the CRCs will be covered or energized through SPV systems. Implementation of second and last phase is completely dependent upon the results of implementing the first phase or pilot project. The figure below shows the implementation plan that the state government plans to follow for implementation.

Figure 2: Project implementation plan



The detailed list of 151 sites under phase 1 (pilot phase) is provided in

1.4 Objective of the assignment

The state of Bihar has reasonable renewable energy potential especially for technologies of solar energy, biomass and micro-hydro. The use of renewable energy to energize the ICT equipment provides can provide an environment friendly alternative to meet the electricity requirement for these institutes.

In this context, the study has been formulated with the objective of assessing the applicability of renewable energy technologies for the teachers training institutes in Bihar. The study coverage includes the following

- Assessment of locally available renewable energy sources
- Assessment of suitability of technologies in meeting ICT load for the teachers training infrastructure. RE Technologies have been compared on important parameters like technology acceptability, technology applicability and technology management & cost
- Recommendation on specific RE technology that can be used for meeting the electricity requirements of ICT equipment to be installed in various teachers training institutes in Bihar
- Finalization of recommended RE technology through stakeholder consultation including addressing their specific concerns
- Preparation of detail design for the proposed RE technology

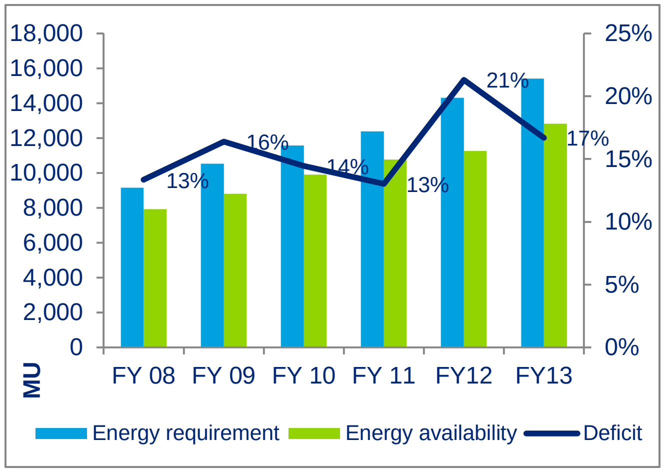
2 Overview of Bihar's power sector

The state of Bihar has been witnessing a huge gap between the power demand and supply for more than a decade. The per capita power consumption at the end of FY 13 was around 117 units as compared to national average of 813 units.

The annual energy deficit in Bihar during the 6-year period from FY08 to FY13 has been in the range of 13% and 21%. While the energy requirement has grown at a CAGR of 11%, the energy available from various generation sources has grown at 10%.

During the same period, the peak deficit in Bihar has been in the range of 14% to 34%. The state's peak demand during FY14 is projected to be 2,750 MW.

Figure 3: Bihar Power Sector scenario



Source: CEA (Load generation balance reports)

The state power sector is in dire need of revival and development to increase the reach of energy access to the population which is essential for all-inclusive economic and social development.

As per the 18th Electric Power Survey (EPS), the peak demand for power in Bihar is projected to be 5,018 MW by FY 2017-18 while the energy requirement will be 29,539 MUs. The survey committee has forecast a CAGR of around 15% for the period starting 2009-10 to 2016-17 and of 12% for period 2017 to 2022 for the state.

Figure 4: Peak Load Requirement

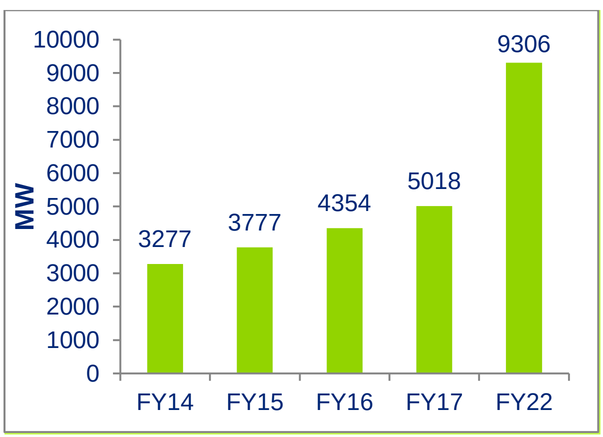
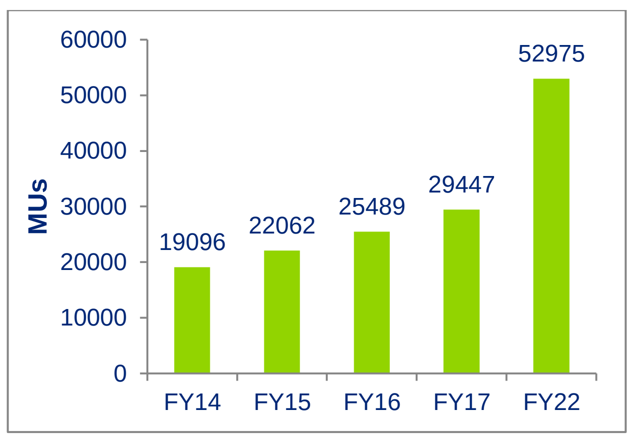


Figure 5: Energy Requirement



Source: Deloitte research and analysis

2.1 Planned Generation Capacity Addition in Bihar

The state has elaborate generation expansion plans to expand its power generation base by adding capacity from central sector thermal and hydro power plants. The state government of Bihar plans to spend Rs 9,200 Crore (USD 1533.33 Million) on the power sector alone out of the total central special package of Rs 12,000 crore (USD 2000 Million) available to state during the 12th five year plan.

The total power available including the private and central allocations to the state of Bihar is projected to reach around 5,300 MW in FY 16 from current level of around 2,300 MW.

Table 1: Planned power capacity addition

Source	FY 13	FY 14	FY 15	FY 16
NTPC	1,694	1,694	2,199	2,549
Railway & BSEB				50
NHPC	129	129	129	129
PTC	340	340	340	340
DVC		100	100	100
IPP	200	200	650	1,283
State Generation	210	493	493	875
Total	**2,573**	**2,956**	**3,911**	**5,326**

Source: CEA/Deloitte research and analysis

Bihar has a large population that does still not have access to the grid supply. As presented in the table below, around 83% of the households are un-electrified in the state. Most of these households are in remote or far-flung areas.

Table 2: Electricity access status in Bihar

Households	Numbers
Total number of households	1,89,40,629
Households having electricity access for lighting	30,98,435
Households using kerosene and other sources for lighting	1,56,12,491
Households using solar lighting systems	1,09,389
Households with no lighting source	15040
Total un-electrified households	1,57,32,805
Share of un electrified households	83%

Source: India Census 2011

Given this scenario, the grid electricity would have challenges in reach as well as availability at least in the short to medium term. Decentralized electricity generation through renewable energy resources would be more efficiently and effectively serve to energy access issues in the state. Although, the state has significant amount of renewable energy potential especially in form of solar and biomass energy, renewable energy does not presently hold a substantial share in the state's energy mix.

2.2 Renewable sector development in Bihar

The state government notified a policy on 24th June 2011 on 'Promotion of New and Renewable Energy Sources'. The policy has following provisions:

- Agriculture land can be used for project development after a sanction

- Grid interfacing and evacuation of power from grid-connected plants to be arranged by project developer
- Developer is allowed to sell power as third party sale or as captive use
- Incentives applicable to RE projects are as follows:
  - Exemption of electricity duty on power being consumed
  - Exemption of entry tax for the power plants equipment to be procured
  - Eligible for incentives under State Industrial Incentive Policy notified by Government of Bihar
  - In addition to state incentives, all the benefits or incentives that are made available by MNRE is also applicable to renewable energy technologies in Bihar.

Bihar state has good potential in renewable energy especially in technologies including biomass, solar and micro hydro. WISE study (2012) has estimated the renewable potential for both grid–connected and off–grid in the range of 5,000 to 18000 MW (around 7300 MW is exclusively from off grid). Tapping such a huge RE potential seems to be an appropriate solution to meet Bihar's increasing future energy demand and to enhance the energy security for the state. According to the Indian Wind Atlas (published by the Centre for Wind Energy Technology), Bihar lies in low wind zone area, with very few areas having wind power density even in the range of 100-200 W/m^2.

There are two government agencies in the state responsible for development of renewable energy technologies. Bihar State Hydroelectric Power Corporation (BHPC) has been established to harness the hydroelectric potential in the State. The BHPC conducts survey for this purpose and prepares the schemes on hydroelectric power generation. Bihar Renewable Energy Development Agency (BREDA) is involved in promoting development of other non-conventional energy sources.

2.2.1 Current status of Renewable Energy

The state has an installed capacity of around 70 MW of small hydro out of total assessed potential of 250 MW. The state government has also initiated efforts to develop the biomass and solar technologies. Around 700 MW of biomass projects have been approved in the state. In solar, Government has planned for 150 MW of solar photovoltaic (PV) based projects which are to be set up on the 'chaur'/pond where pisci-culture is being undertaken.

The state already has some experience in development of renewable energy resources and the state institutions like BREDA are working for propagation of these technologies. The RE technologies, particularly, solar PV and biomass has wide acceptance amongst the rural population and few local entrepreneurs have also come up in the state to provide services for these technologies.

BREDA has initiated pilot projects for rooftop solar PV and has installed a 50 kW system at Chief Minister's residence. Further, solar power system of capacity of 22 MW has also been installed at headquarters of East Central Railway (ECR) at Hajipur and a 25 MW plant is planned to install at Samastipur Railway division[1]. BREDA has also recently issued bid invitation for installing solar rooftop systems of 100 kWp at Buxar Open Jail and 50 kWp rooftop Solar PV plant at Abhilekh Bhavan (Archive Building) in Patna. A detailed list of solar projects implemented or currently under implementation in Bihar is provided in Annexure 2.

[1] http://www.dnaindia.com/india/report-bihar-govt-devises-policy-to-encourage-use-of-solar-energy-1769244

Several private sector players like L&T, Coenergy etc. are involved in development of off-grid PV projects and mini-grids in the state while players like Claro energy are developing solar PV irrigation pump-sets. TERI and SELCO have been actively involved in developing solar PV off-grid market in the state. TERI through its Lighting a Billion Lives (LaBL) program is active in more than 15 districts of Bihar. SELCO, in association with SEWA Bharat (micro financing organization) and NABARD, has been providing solar home systems in few districts of Bihar. In addition, various Non-Government Organizations (NGOs) are also involved in developing renewable energy technologies in the state, especially in decentralized mode.

The experience with solar PV stand-alone and off-grid systems as well as biomass has been quite successful in Bihar and market acceptance of this technology is high.

2.2.2 Incentives to solar energy in Bihar

As mentioned above that both central and state specific incentives all applicable to renewable energy in Bihar. In terms of solar energy overall benefits includes - Jawaharlal Nehru National Solar Mission (JNNSM) of central government and Bihar state policy on promotion of renewable energy.

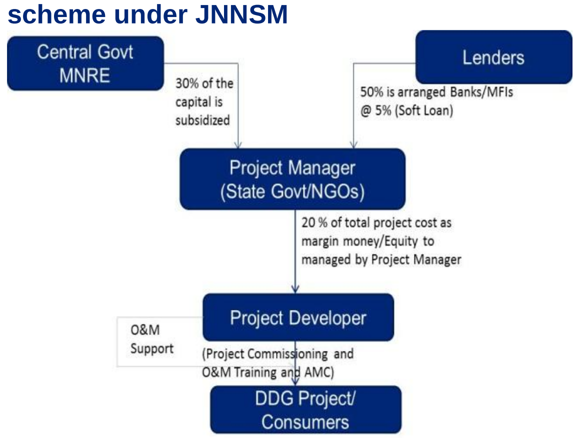
These incentives help in bringing down the initial high cost of solar PV technology and thus the technology becomes cost competitive in comparison to other renewable energy technologies. The following section will provide the details about the incentives available for solar PV technology.

Off-grid SPV systems in state of Bihar will get an exemption in entry tax for the equipment and building materials from the state government and will be getting a capital subsidy from MNRE.

Project Structure – MNRE Off-grid SPV Scheme

The following figure shows the capital subsidy model followed by MNRE for SPV off-grid systems. A project manager gets 30% capital subsidy from MNRE and arrange for a loan of around 50% of capital cost from market lenders. Indian Renewable Energy Development Agency (IREDA) may re-finance this market loan at a soft loan rate of 5%. The project manager/project developer or consumers themselves arrange for margin money or equity of 20%. As per this model, the project developer provides operation and maintenance training and AMC services for three years.

Figure 6: Capital subsidy model for off-grid PV scheme under JNNSM



Source: MNRE

3 Renewable Energy Technology Selection Framework

3.1 Overall Approach

The key objective of this study is to evaluate various RET options for supporting the education program and recommend the most appropriate and cost effective solution for energizing ICT equipment across 1201 teachers training institutes in Bihar. This has been undertaken through a mix of the primary and secondary research. The overall renewable resource availability and potential assessment has been undertaken through secondary information compilation and analysis. In addition, primary research has been undertaken through site visits for a representative sample covering 24 locations across all the categories of training centers (BRC, CRC, DIET, PTTEC). The shortlisting of sites was done in consultation with the Bihar State Education Infrastructure Development Corporation (BSEIDC). In addition to primary and secondary research, extensive stakeholder consultations have been conducted throughout this exercise of technology selection.

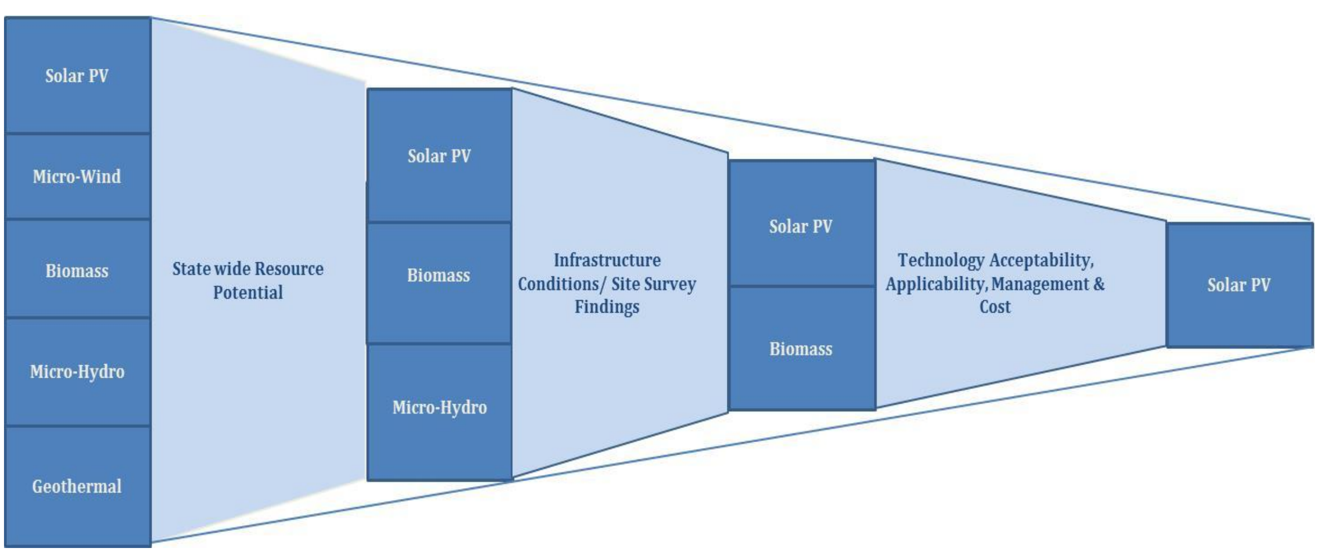
A stepwise RET evaluation and filtering approach has been adopted to select the most appropriate RET suitable for implementation. At the end of each step in the process, the RETs which are found to be inappropriate for the purpose are filtered out and remaining technologies are further evaluated.

The following five RE options have been assessed for their suitability:

a) Solar PV
b) Biomass
c) Wind
d) Small and Micro Hydro
e) Geothermal

The figure below highlights the study approach & methodology:

Figure 7: Study Approach and Methodology



1 State wide renewable resource potential availability

As a first step to the study, the five potential RE options have been evaluated based on the overall renewable resource availability within the state. This has been undertaken through secondary research using the past studies and available database of various RE resources.

2 Suitability for teachers training infrastructure conditions

The suitability of RETs for use in the teachers training institutes has been evaluated. This has been achieved through site surveys across 24 locations in the state (refer to Annexure 5). These sites have been assessed for renewable energy resource potential considering certain base parameters for technology feasibility.

3 Technology management, supply chain & cost analysis

A technology selection matrix has been designed to select the most suitable technology considering technology cost and other site-specific critical factors affecting technology success.

The following sections describe the various steps in detail.

3.2 Renewable Energy Technology Assessment

3.2.1 State wide resource potential assessment

The resource potential data for the identified RE technologies (wind, biomass, solar PV and micro-hydro) have been evaluated for all the districts in the state to understand the extent and suitability of these resources for state wide deployment. The following table provides the renewable resource potential mapped for districts in Bihar.

Table 3: Renewable Technologies Resource Potential in Bihar

S No	District	Wind (m/s)	Biomass - Rice Husk (MT/Year)	Solar (kWh/m2/day)	Micro-Hydro (MW)
1	Araria	0.90	10,595	4.92	42.05
2	Arwal	NA	5,849	NA	NA
3	Aurangabad	1.20	41,789	5.04	NA
4	Banka	1.60	4,670	4.94	NA
5	Begusarai	0.90	485	4.90	NA
6	Bhagalpur	1.30	4,729	4.87	NA
7	Bhojpur	0.90	24,489	4.94	NA
8	Buxar	1.00	23,634	4.99	NA
9	Darbhanga	0.80	2,582	5.04	NA
10	East Champaran	0.80	5,602	5.16	13.20
11	Gaya	1.20	14	5.02	NA
12	Gopalganj	0.80	7,220	5.14	NA
13	Jamui	1.40	7,709	4.97	NA
14	Jehanabad	1.00	9,592	4.94	NA
15	Kaimur	NA	NA	NA	NA
16	Katihar	1.20	10,299	4.82	28.00
17	Khagaria	0.90	3,089	4.90	0.00

S No	District	Wind (m/s)	Biomass - Rice Husk (MT/Year)	Solar (kWh/m2/day)	Micro-Hydro (MW)
18	Kishanganj	0.90	8,324	4.87	11.50
19	Lakhisarai	1.00	9,204	4.94	NA
20	Madhepura	0.80	14,701	5.02	2.00
21	Madhubani	0.80	9,095	5.11	0.65
22	Munger	1.00	5,244	4.92	NA
23	Muzaffarpur	0.80	1,302	5.04	NA
24	Nalanda	0.90	9,239	4.94	NA
25	Nawada	1.20	14,735	4.99	NA
26	Patna	0.90	7,875	4.97	NA
27	Purnia	1.00	15,645	4.82	20.00
28	Rohtas	1.20	40,946	5.04	NA
29	Saharsa	0.80	25,010	4.90	1.20
30	Samastipur	0.80	1,532	4.94	NA
31	Saran	0.90	12,050	4.97	NA
32	Sheikhpura	NA	5,141	NA	NA
33	Sheohar	NA	874	NA	NA
34	Sitamarhi	0.80	5,461	5.18	NA
35	Siwan	0.80	11,516	5.06	NA
36	Supaul	0.80	7,936	4.94	6.00
37	Vaishali	0.80	2,783	4.97	NA
38	West Champaran	0.90	9,222	5.21	142.50

Sources: NASA, Bihar Agriculture Department, CWET

In addition to the above RE resources, the potential of geothermal energy for Bihar has been assessed based on the Geothermal Map of India (refer Annexure 4).

3.2.2 RE Technology selection based on RE resource potential

From the above assessment, the following conclusions can be drawn

- Solar resource potential is adequate across the state for the purpose of installation of PV projects
- Bihar state has reasonable biomass potential spread across various regions within the state
- Wind resource potential is not adequate for statewide implementation. As per MNRE guidelines for installation of aero-generators, the sites should have minimum wind speed of 4.17 m/s at 20 meter hub height. As per CWETs wind assessment report, Bihar lies in the low wind zone. In addition, the data analysis for the sites shows that wind speed at these sites is very low, with most of them falling well below 4.17 m/s at 20 m hub height.
- Geothermal potential sites identified in India fall in five provincial regions namely Himalayan Province, Cambay Province, West Coast Province, Sonata and Godavari region. The state of Bihar does not fall in any of the identified regions/province. Further, geothermal technology is still in experimental stage in India and building geothermal generating systems of micro capacity to serve ICT load would not be a feasible option.

Based on the above*, geothermal and wind energy technologies are found to be unsuitable for the requirements at teachers training infrastructure spread across the state of Bihar. These renewable resources have not been taken up for further analysis.*

3.2.3 Infrastructure Conditions/ Key Survey Findings

The primary surveys of the shortlisted sites have been conducted to find out and assess various factors that may affect technology selection decision. Twenty four (24) sites have been covered in the sample survey (details are provided in Annexure 6). The sample has representation of all the categories of the teachers training infrastructure as provided below

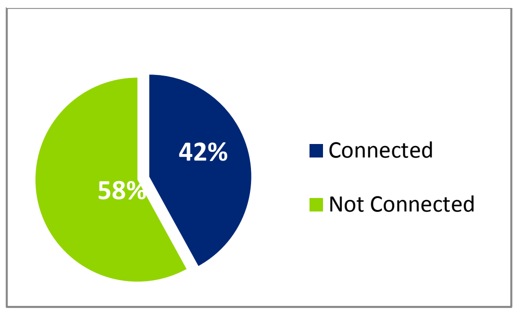
- SCERT 1 No
- PTTEC 3 Nos
- DIET 7 Nos
- BRC 8 Nos
- CRC 5 Nos

The key findings from the site surveys are analysed below:

1 Grid connectivity is not available at most sites

Only 42% of the institutes surveyed are grid connected or have electricity connection. Further, the connected sites also face issues of erratic electricity supply due to frequent shutdowns and outages. These institutes have to rely on diesel generator sets for meeting their electricity requirements. The situation is not likely to improve in short term, given the huge demand supply gap existing in the state. This calls for assessing the suitability of renewable energy based decentralized system for the sites.

Figure 8: Grid connection status

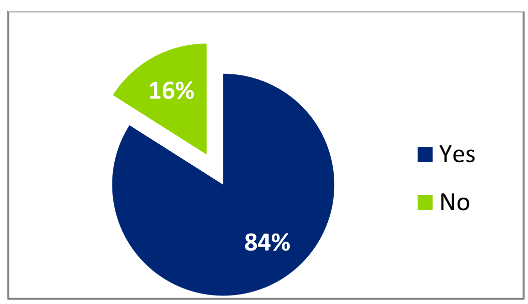


Source: Deloitte research and analysis

2 Most sites have space available for installation of solar PV systems

Around 84% of the surveyed sites have space availability (either on the rooftop or on the ground) for the installation of solar PV systems.

Figure 9: Space availability for SPV

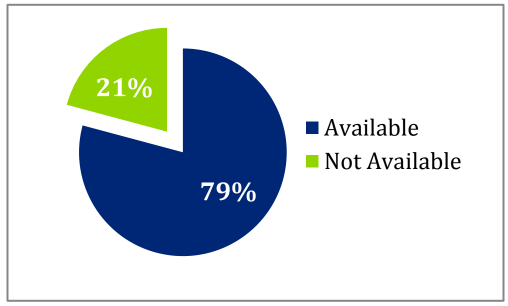


Source: Deloitte research and analysis

3 Availability of Night guards for security

The security of stand-alone systems in remote areas is a matter of concern in the state of Bihar. In this context, it has been felt that availability of night guards at the sites would be desired for protection of the RE equipment. Around 80% of the sites surveyed have been found to have night guards which can mitigate the risk of thefts and wilful damages to the equipment during the non-operational hours.

Figure 10: Availability of Night Guards



Source: Deloitte research and analysis

4 Space availability for installing biomass gasifier is limited

A biomass gasifier requires space for erection of gasifier, placement of engine set and construction of biomass fuel storage facility. Only around 60% of the sites have been found to have space facilitating installation of 10 kW capacity biomass gasifier systems.

5 Non availability of workforce for operating biomass gasifiers

Biomass gasifier operation requires activities like biomass fuel collection, storage, drying, gasifier feeding, etc to be carried on regular basis. Thus, a dedicated work force is required for operation of biomass gasifiers. During the site surveys, requirement of such a work force has been assessed. Only in 4% of the surveyed sites, the respondents believe that guards available at the sites can perform biomass gasifier operational activities.

6 Limited micro hydro sites in the vicinity of teachers training institutes

The micro hydro resources are not available in the vicinity of any of the institutes covered in the survey. While the micro-hydro potential exists in Bihar, it is confined to few districts and given the location specific nature of this resource; it would have limited applicability for statewide implementation.

3.2.4 Technology filtering based on infrastructure conditions

The infrastructure conditions in terms of space availability, technical feasibility of installing systems, safety concerns etc. do not favor selection of micro hydro technology as none of the sites surveyed had any available micro hydro resource in the vicinity. Further, there could be issues in carrying the construction materials to undertake the civil works for micro hydro projects to the remote sites in absence of proper road infrastructure. Though the state as a whole has potential for mini and micro hydro technology (Annexure 4), but for the purpose of supplying electricity to the institutes dispersed over a wide geographical area in the state, this single technology will be able to cater to a very limited number of teachers training institutes. Hence, mini hydro technology would not be appropriate RE technology for statewide deployment and have not been evaluated further.

Hence, the Solar PV and Biomass based RETs are found to be suitable for application across teachers training institutes and have been shortlisted for further evaluation and selection.

3.2.5 Technology Selection Matrix

A technology selection matrix has been developed to evaluate the shortlisted RETs viz. Solar PV and biomass technologies have been compared under following three broad categories

1 Technology acceptability

The two technologies have been evaluated on parameters of resource accessibility, space availability for technology system installation, technology awareness and its likely impact on surroundings. The solar PV technology fares significantly better when compared to biomass technology:

- Biomass technology requires constant monitoring and developing a dedicated supply chain for fuel transportation, whereas solar is relatively hands free and omnipresent.
- While considering technology impact on surroundings, though both are renewable energy technologies, biomass technology can still create certain degree of noise pollution and visual impact on the surrounding.
- In terms of technology awareness of the two, the rural populace has high awareness and acceptability of solar PV. The populace is equally aware of biomass technology but shows lower acceptability of the same.
- Both technologies have same issues as far as space availability is concerned. Biomass plant has specific space requirements and requires separate set up; solar has flexibility of being mounted on rooftop or on ground but requires a little more space.

2 Technology applicability

Technologies have been rated on their applicability at sites considering their suitability for ICT equipment for the Teachers Training Infrastructure.

- Majority of the ICT equipment utilizes DC power. The solar PV technology produces DC output, thus solar PV technology is rated higher for technology suitability with ICT operation.
- Biomass power plant once established would be difficult to relocate while solar systems are comparatively easier to install and dismantle. SPV has better mobility and flexibility.
- Associated infrastructural requirements are higher for biomass as compared to solar PV. Biomass plant needs erection of gasifier and engine in addition to construction of fuel storage facility while solar PV would require setting up mounting structures that is comparatively less tedious.
- With no requirement of fuel supply chain, solar plants have lower operational requirement. Whereas, biomass technology is fuel dependent and supply chain is a major issue across India. Further, with no mechanical equipment, solar has lower maintenance requirements.
- Solar PV systems have been rated lower while comparing on security standards. Theft of solar panels is an area of major concern in Bihar. However, there are certain anti-theft and safety features which can be provided to improve the security of solar systems. Simple improvisations like providing locking system and stronger riveting can be used
- Solar is modular in nature and hence the scalability and flexibility in design is higher. Biomass gasifiers running only on biomass fuel performs better at a capacity of more than 10 kW. Below this threshold capacity, the efficiency of gasifiers goes down and there are several operational issues to be addressed for this operation. Thus, biomass has design flexibility issues.

3 Technology management & cost analysis

- Market studies have shown that the equipment and services market for both the technologies are quite mature in the state of Bihar. Thus, both the technologies are on an equal footing when compared on this parameter.
- However, while looking for availability of standardized equipment in the state, it has been observed that Biomass gasifiers operating without diesel support and below 10 kW capacities are not easily available.

- With mobile panels, there is no requirement for extensive civil works. The solar plants can be easily installed in a very short time-span.
- Solar projects require inverters (12-13 years) and battery (6-7 years) replacement on periodic basis. Thus, they have been rated lower when compared to biomass systems having no such frequent replacement requirements.
- A life cycle cost analysis has been done to determine the present value of the two. With lower per kW levelized cost and tariff per kW, solar PV technology has been rated higher.

The table below shows the comparative evaluation of both the technologies (solar and biomass)

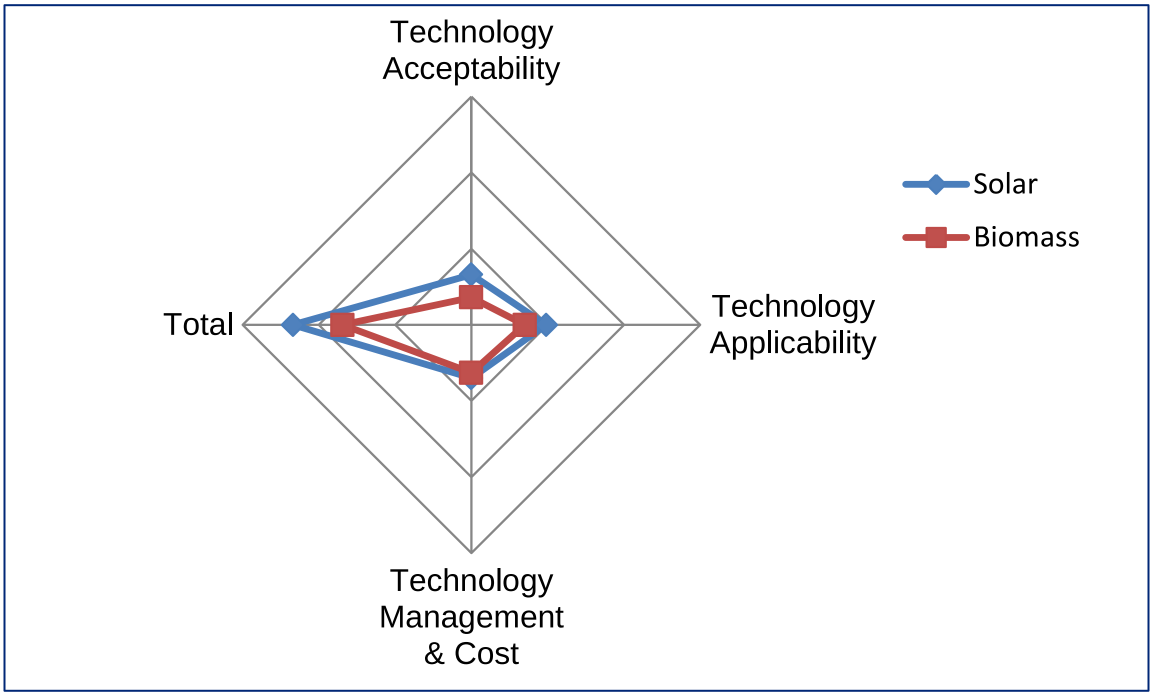
Table 4: Technology Selection Matrix

S No	Parameter	Solar PV	Biomass
1	**Technology Acceptability**		
1.1	Resource Accessibility		
1.2	Space Availability for system installation		
1.3	Impact on surroundings		
1.4	Technology Awareness		
	Technology Acceptability - Overall		
2	**Technology Applicability**		
2.1	Suitability with ICT operation		
2.2	Mobility of Device/Equipment		
2.3	Requirement of additional infrastructure		
2.4	Operational & Maintenance Requirement		
2.5	Security of equipment and installations		
2.6	Scalability and flexibility in design		
	Technology Applicability - Overall		
3	**Technology Management & Cost**		
3.1	Equipment & Service providers		
3.2	Ease of Installation and gestation period		
3.3	Equipment replacement requirement		
3.4	Equipment Standardization		
3.5	Lifecycle Cost of Technology		
	Technology Management & Cost - Overall		

Legend: High, Medium, Low

The following figure shows the comparative scores for the two technologies and the overall score.

Figure 11: Comparison between Solar PV and Biomass



The solar PV as technology solution is appropriate for supporting the teachers training infrastructure requirement

3.3 Proposed RE Technology solution and benefits of technology

Technology selection matrix results suggest that the solar PV technology is technically more feasible and also has greater acceptability as compared to other renewable technology options in the state. Hence the solar PV technology would be the most suitable RET option for teachers training institutes in Bihar.

There are certain other considerations that support this conclusion as indicated below:

Technology Commercialized and widely acceptable

With a total installed capacity of more than 1.6 GW across country, solar PV is a well-established and proven to be commercially viable technology for India. The state of Bihar itself has some experience in the off grid and individual systems, particularly in rural India. There is high degree of awareness and acceptability amongst the local populace. In addition, the state has active MNRE channel partners and other active solar developers (more than 10 players active in state). The state has already initiated pilot projects for solar rooftop installation

Ease of Technology Management

Solar PV systems are modular and enjoy high level of device mobility as compared to other technology systems. Solar RE systems can be rapidly deployed as decentralized units to yield benefits in short period of time. With no supply chain for the fuel and other operational needs, the systems have minimal daily operational requirements as compared to other technology systems that require dedicated man-force for operation. Ease of technology management is a major advantage SPV systems enjoy over other technologies particularly for operations in remote areas.

Appropriate for ICT load requirement

SPV systems generate DC power and most of the ICT equipment requires DC power input. SPV systems are modular and scalable with most optimized and efficient design capabilities to suit the ICT load requirements. Moreover, the load at these institutes may increase in the future and the modular nature of solar PV technology makes it easier to upgrade the capacity of systems in future.

The Teacher Training Institutes are mostly located in remote areas with no manpower available to handle system O&M. With low maintenance requirements, SPV systems are most suited for the same. With availability of night guards at most locations and strong riveting, security concerns can also be overcome.

Policy and fiscal benefits available for solar

Federal government structure in India allows twin benefits (both central and state) to be applicable to various industries. Emerging industries like renewable energy gets capital subsidy from The Ministry of New & Renewable Energy (MNRE) and additional state incentives in terms of subsidies, feed-in-tariff etc.

According to the state policy on ‘Promotion of Renewable Energy in Bihar (Nov 2011)’, solar energy will be getting all kind of incentives notified by Central and State Government to the power generated from renewable energy sources. Apart from this, other incentives include exemption from electricity duty, exemption from registration and entry tax for the equipment and building materials. The applicable incentives and benefits for solar projects have been discussed in Section 2.2.2.

4 Solar PV Technology – Detailed Analysis

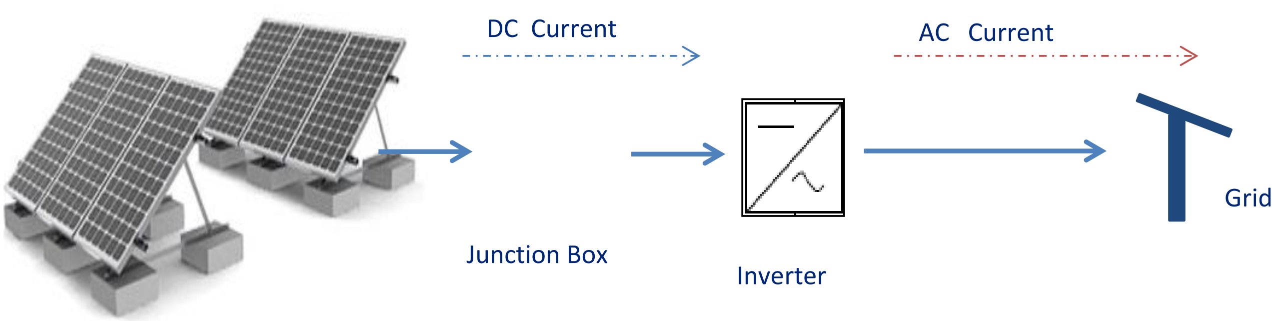
4.1 Solar PV (SPV) System Components

The solar radiation falling on the solar modules is converted into electricity based on photovoltaic principle. The energy generated is maximum when the solar insolation is maximum. The energy generated by the modules is stored in the battery bank by charging the batteries. A solar charge controller is required to perform this operation. The solar charge controller charges battery bank and prevents battery from being over-charged or over-discharged.

The battery bank is sized to support each day's energy requirement as the solar modules would charge the battery bank every day. However, battery capacity can be upgraded to store sufficient energy supporting the load during low or no insolation days. Generally, this period is assumed to be 3 days and is known as System Autonomy. In any case, the battery bank will be discharged only up to 80% of full capacity. This is known as DOD (Depth of Discharge).

The energy stored in the battery bank is DC type. This DC energy is converted into AC supply using an inverter. The inverter is to invert DC voltage to generate output of 230 VAC, 50 Hz. The inverter output is directly fed to the load. The inverter has built-in protective features for output short circuit, over-load and battery low/high conditions. In most cases, the inverter also has a facility to use grid power to charge battery in case of insufficient solar energy. In such cases, it is common to call this as power conditioning unit (PCU) and this may house charge controller within the same enclosure. The inter-connecting cables are used to interconnect the Solar Modules, Junction Boxes, Solar Charge Controller, Battery Bank, Inverter. The following figure shows a typical solar PV system:

Figure 12: Typical solar PV system



Source: Deloitte research

A typical SPV system has following components:

Table 5: Technical details and specifications of major components in the SPV system

Component	Description
Solar Modules	PV modules with performance warranty of 25 years and expected life of over 30 years

Component	Description
Module mounting structure	Galvanized Iron (GI) or Mild Steel (MS) painted structure; Suitable for flat roof mounting; Divided into number of mountings for 4, 6, 8 or 10 or more number of modules
Solar Charge Controller	Efficient charger of batteries; has all protection to safeguard battery as well as loads; Could be housed in the PCU or separately
Battery Bank and Accessories	Photovoltaic battery; deep discharge, lead acid, tubular, low-maintenance battery; requires topping up only twice in a year;
Power Conditioning Unit (Inverter)	This is to invert stored DC power from battery into AC power that can be used for all the appliances. It also has a facility to use main grid as additional source of energy in case solar not being sufficient
Cables and accessories	DC and AC cables with appropriate conduits wherever necessary as per site and location conditions;
Connection hardware	Includes Junction boxes; Distribution Boards, etc. as per the site conditions

Source: Deloitte research

4.2 Solar PV technology options

There are two types of PV technologies: crystalline silicon (cSi) and Thin Film. In a c-Si PV system, slices (wafers) of solar-grade (high purity) silicon are made into cells that are assembled into modules and electrically connected. TF PV technology consists of thin layers of semiconducting material deposited onto inexpensive, large-size substrates such as glass, polymer or metal. The crystalline silicon PV is the oldest and currently the dominant PV technology with more than 80% of the global PV market share.

The choice of solar PV technology for installation is often based on a trade-off between investment cost, module efficiency and electricity tariffs. Compared with c-Si-based PV systems, the production of TF PV system is less energy-intensive and requires significantly less active (semiconducting) material. TF solar PV is therefore generally cheaper, though significantly less efficient and requires substantially more surface area for the same power output, than c-Si-based systems. TF PV has experienced tremendous growth a few years ago, more recently its market share is decreasing and the current outlook for further growth in the deployment of this technology is uncertain and will depend heavily on technology innovation.

A comparison table of c-Si and Thin Film technologies is as below:

Table 6: PV Technology comparison: c-Si vs Thin Film

Parameter	Crystalline Silicon	Thin Film
Key characteristics	Proven technology, modular, high capacity to area ratio, relatively higher efficiency vis a vis thin films, losses efficiency at high DNI levels and high temperatures.	Recently developed technology and still in process of stabilization; modular; low capacity to area ratio; works in diffused light; gains efficiency at high temperatures
Efficiency	14 – 17%	6 to 13%
Status of local supply chain development	Mature and developed	Mature and developed
Changes in capital cost	15 to 25% reduction in last 5 years	15 to 25% reduction in last 5 years
State of technology development	Very High	High
Value Proposition	Very high (in present circumstances) – however correction likely to happen in near future	Relatively low – higher efficiency (energy and land) as well as relatively lower costs of cSi leading to contraction of TF market
Key Merits	• Higher efficiency • Longer track record than thin films • Lower area/ land requirements • Lower BoS requirements	• Improved operation under diffused light • Lower efficiency loss at higher temperatures • More efficient material usage

Source: Deloitte research

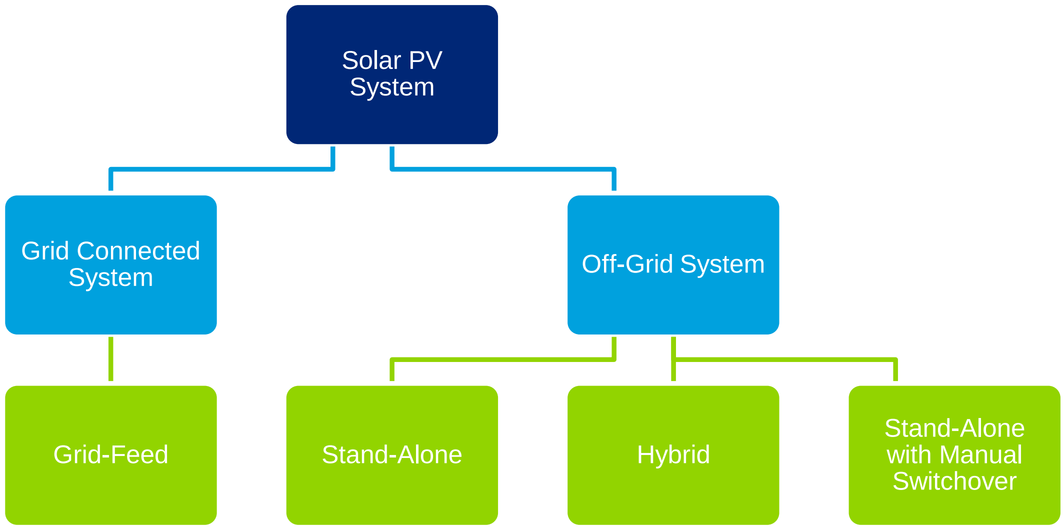
Though there is no substantial price difference between the two types, TF can be available at a slightly lower price per Wp. However, this difference in price is generally offset by increased cost of mounting structures and cables in case of TF.

Crystalline Silicon (cSi) technology has proven track record over last 30 years and has greater suitability for energizing ICT equipments at teachers training institutes, given the lower area requirement and the service requirements. *Crystalline Silicon (cSi) technology is thus proposed for implementation under this project.*

4.3 SPV system configuration options

There are various configurations of SPV systems which can be considered for this project as shown below.

Figure 13: SPV system configurations



Source: Deloitte research

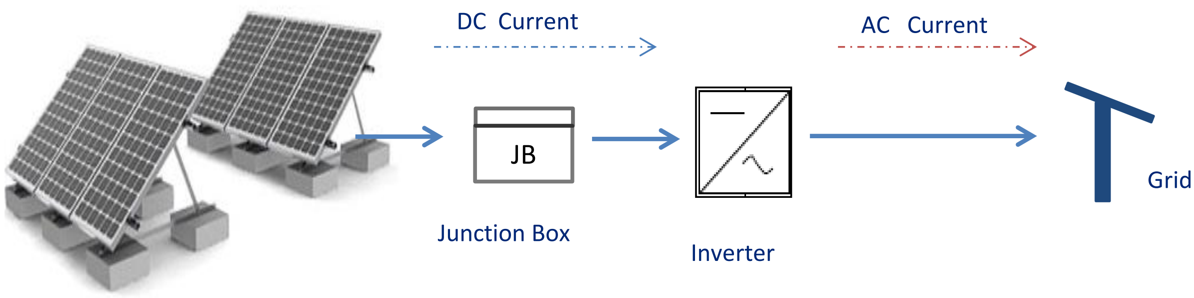
The various PV configuration options have been evaluated below in terms of their suitability for the project.

4.3.1 Grid connected or SPV system without storage

The grid connected systems are also known as SPV systems without storage. The energy generated is directly fed to the grid and thus it is essential that power grid must be charged to receive the generated energy. The grid acts as a battery for these systems and thus there is no requirement of battery in grid connected SPV systems.

The analysis of our field survey data shows that majority of the teachers training institutes in Bihar are currently not connected to grid and very few grid connected institutes (mostly in the urban areas) have continuous power supply. Most of these get erratic supply with no power availability during the daytime or operational hours of the training centers. Hence, it would not be technically feasible to install SPV system without storage in these centers under this program. Further, the solar radiation varies throughout the day and absence of any storage device between the generation and equipment which would use the energy would expose this equipment to the voltage and current fluctuations. These could be harmful to the equipment and reduce its life in case of severe fluctuations in output. Therefore, installing SPV system without storage is not an option under this program. The following figure shows a typical grid connected system:

Figure 14: Grid connected SPV system layout



Source: Deloitte research

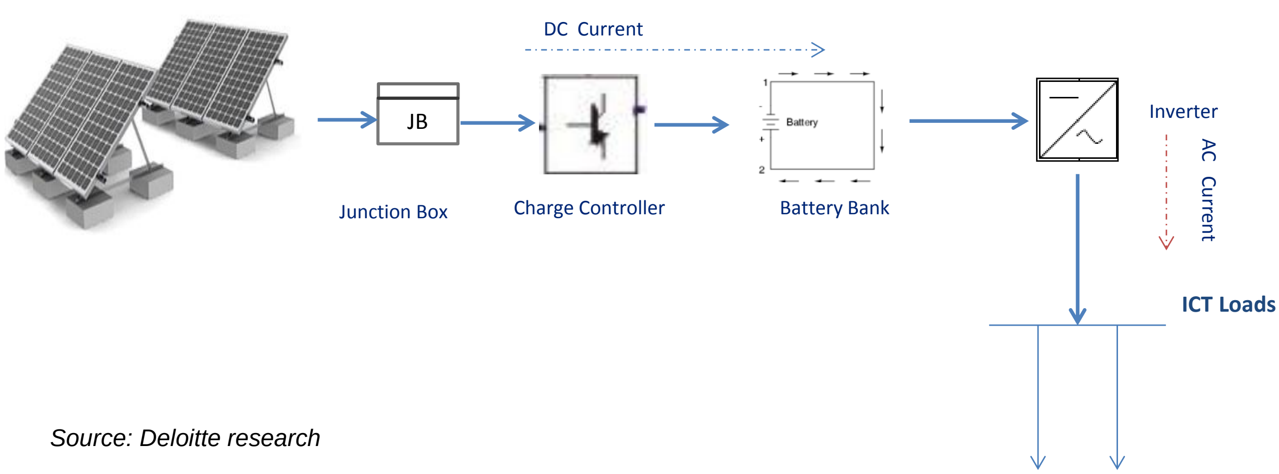
4.3.2 SPV with storage

SPV off-grid systems can work on stand-alone basis or as hybrid systems. In these systems, the generated DC power by the solar modules is stored in a battery and then used whenever required by converting it to AC using an inverter.

In addition to the energy storage, the battery also works as a buffer for energy fluctuations so that inverter is always fed with power within their limits and can work efficiently without interruptions. The battery capacity depends on the load wattage as well as daily energy requirement of the equipment to be energized with SPV system. While designing the battery, various losses are also to be considered so as to provide sufficient energy to the loads.

The batteries are designed to support the load for those days when there is no energy generation or battery charging due to weather conditions. This is called as battery 'system autonomy'. One-day autonomy means that battery has a built-in capacity to support designed load for one day even when no new charging is possible. Similarly, there can be two days or three days autonomy in SPV off-grid systems.

Figure 15: SPV with storage layout



Source: Deloitte research

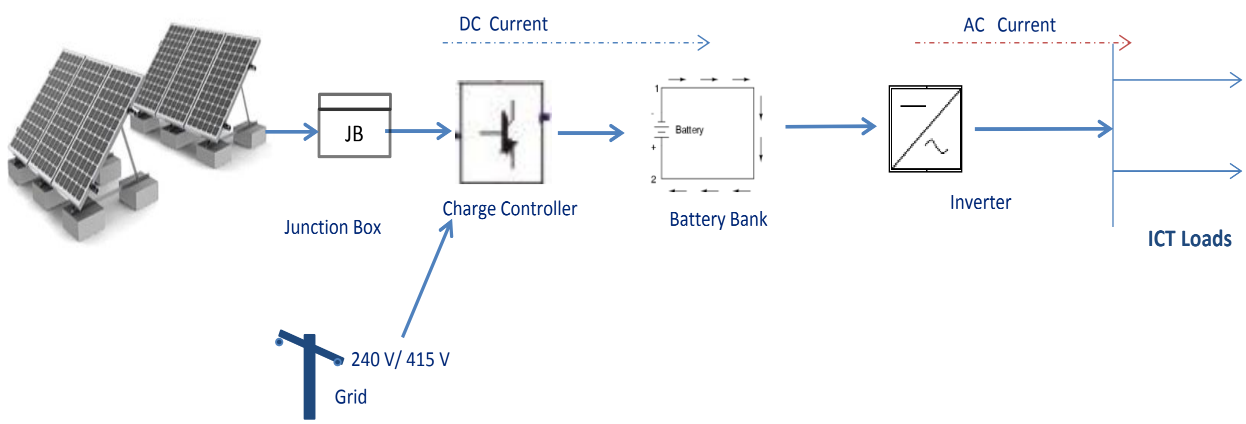
4.3.3 SPV with storage and hybrid with grid

The operation of SPV hybrid with either grid or DG set is similar to the SPV system as described above. The difference is in use of source for charging the battery bank. In hybrid system, the electronics of power conditioning unit, as a replacement of standard inverter allows using different sources for battery charging. The priorities can be designed and normally would be Solar- Grid - Diesel so that cost is minimized and clean sources are optimally used. There are built-in controls to avoid using grid or DG set to charge full battery and leaving SPV as stand-by.

In such cases, the systems are usually designed in a way that solar module capacity can be reduced to decrease the system cost. This is because battery can be charged by another source in addition to solar. For instance, a 60% solar hybrid system (wherein the modules capacity is reduced to 60%) would charge only up to 60% of the required battery charging and balance would be charged by another source. However, it is essential that the second source is available daily for necessary time.

In such hybrid systems a charger facility is required that allows the charging of battery using one source out of multiple sources. Generally, this charge is housed inside the power-conditioning unit (PCU) that replaces simple inverter.

Figure 16: SPV with grid hybrid layout



Source: Deloitte research

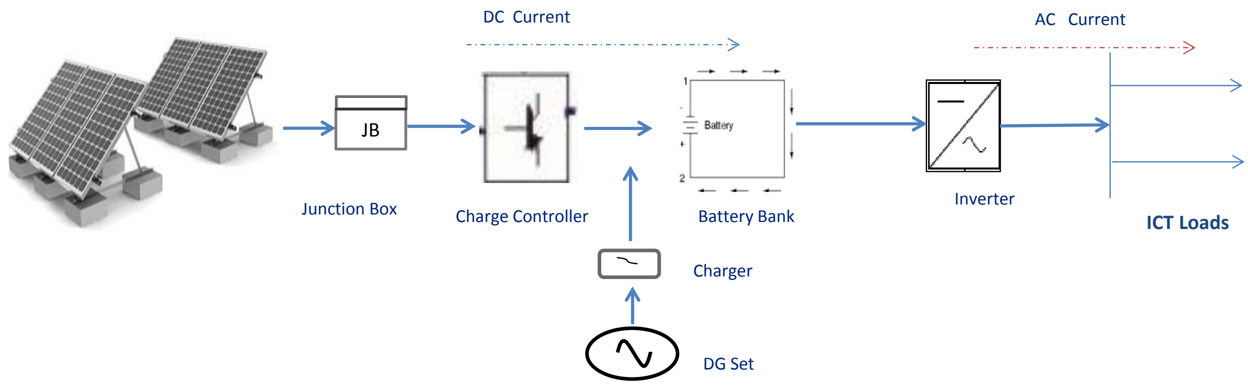
4.3.4 SPV with storage and hybrid with diesel generator

Technical design of this system can be similar to one explained above. However, as diesel generation is noisy and polluting, mostly the use of diesel is restricted to starting the system and supporting the load directly rather than charging the battery.

This mainly depends on whether the available DG set is a dedicated one for this system or being used for other loads outside the system loads. In case of dedicated DG set for the SPV system, the electronics necessary to be incorporated in the PCU are expensive and complicated.

Thus, for this project, it is suggested that instead of a SPV-DG set hybrid a simple DG set should be used as an alternate option for non-sunny days. This should work with a manual switchover to diesel.

Figure 17: SPV system with diesel hybrid



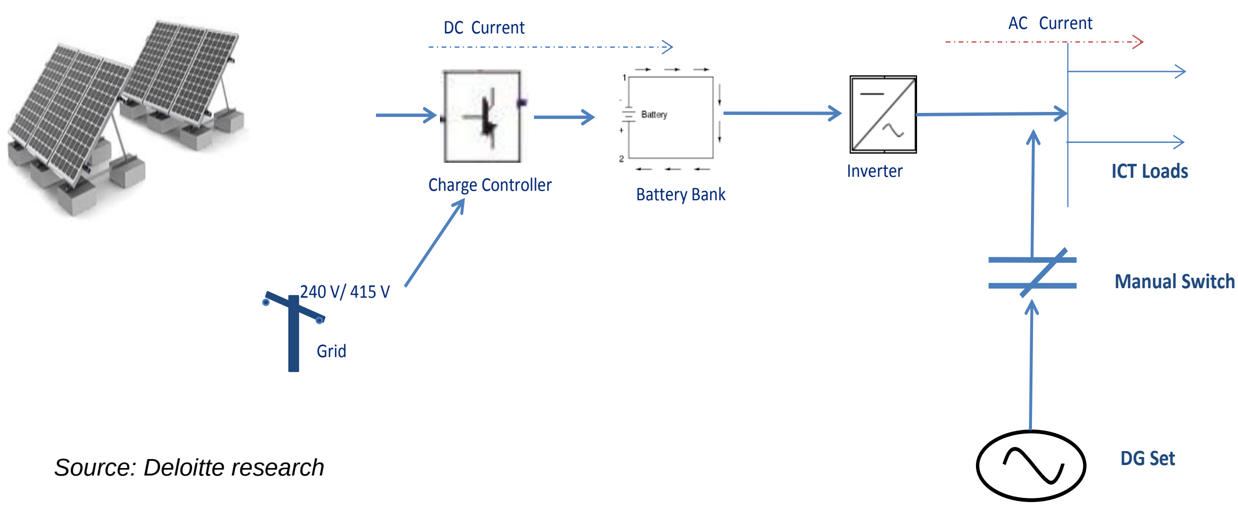
Source: Deloitte research

4.3.5 SPV with manual switchover to grid or diesel

In case of any stoppage or mal-functioning of SPV system, manual switchover can help in bypassing the load on the other source.

In this project, such manual switchover switch would be provided so that the DG set can support loads wherever necessary. At all the centers in the project there is a provision of DG set for supporting loads that are not on the SPV system. Therefore, a DG set is to be available at each center and hence it is advisable to have a switchover facility to make use of this DG set when the SPV system fails and the connected load is to be operated.

Figure 18: SPV system with grid hybrid and manual switchover to diesel



Source: Deloitte research

4.4 Rooftop suitability and area considerations

The suitability of a rooftop site is a fundamental pre-requisite from the perspective of installation of rooftop solar PV systems and power generation. Solar system installations have to account for collateral development in the vicinity and the effects of shading from trees, nearby buildings, water tanks and other obstructions.

The rooftop area requirement for installation of rooftop solar PV system can vary from 12 square meters per kilo watt to 15 square meters per kilo watt depending upon the shadow free area available. The architecture of the building itself can impact the shadow free area due to the use of elements like parapets, varying roof levels for instance, resulting in a large part of the rooftop being unusable for solar installation.

The strength of the rooftop or terrace should be capable enough to bear the load of system. The cemented grouting of mounting structures is required for erection of SPV system and thus the strength of roof/terrace is very important. It also needs to be ensured that the mounting frames and other structures should transfer dead loads directly to roof structural members. Any roof-mounted concentrated loads, such as batteries, should be designed on structures that distribute their weight over a large enough area.

4.5 SPV technical design considerations

Based on the above evaluation, the following technical specifications are recommended for inclusion in the SPV system design:

- SPV technology option: crystalline silicon (c-Si) PV technology
  - Site survey results have shown that availability of shadow free area can be an issue for certain sites due to various factors such as trees, other buildings, and roof condition etc. Thus, it is recommended that c-Si technology be used because the overall area requirement per kW installation of c-Si modules is lower than that for Thin Film technology. Moreover, c-Si is more commercial technology having a share of 75% global PV installations.
- SPV system configuration: Solar grid hybrid with storage (battery) and manual switchover facility for DG
  - Around 50% of teachers training institutes in Bihar are connected to the grid and more will get electricity connection in future. Thus, a hybrid system allowing battery charging with grid is desirable. Moreover, energy requirement at teachers training institutes is basic and continuous power supply without interruptions is not desirable there. Thus, a manual switchover to DG set has been proposed. The manual switchover does not add any cost to overall capital cost of system.

4.6 Technical details and specifications for key SPV components

4.6.1 Solar Panel/ Module

The total of solar PV array capacity should not be less than the specified power pack capacity mentioned for each type of building and should comprise of solar mono / multi crystalline modules of minimum 100 watts. The Photo Voltaic modules must be tested & approved by one of the IEC authorized test centers and module type must be qualified as per IEC 61215 (Second

Edition). In addition, PV modules must qualify to IEC 61730 Part-I and Part-II for safety qualification testing. SPV module conversion efficiency should not be less than 14.0% under standard test conditions[2].

The module shall have warranty of 25 years with degradation of generated power not exceeding 10% of the minimum rated power after 10 years period and not exceeding 20% over the 25 years period.

The modules shall be battery charging type and values V_{oc} and V_{pm} should be such that battery of suitable capacity can be charged fully only on modules.

Identification and Traceability**:** Each PV module used in the solar power project must use a RF Identification Tag (RFID), which must contain the following information. The RFID can be inside or outside the laminated module, but must be able to withstand harsh environmental conditions.

- Name of the manufacturer of PV Module
- Name of the manufacturer of solar cells
- Month and year of manufacture (separately for solar cells and modules)
- Country of Origin (separately for solar cells and modules)
- I-V Curve for the module
- Peak wattage, I_m, V_m and Fill Factor (FF) for the module
- Unique Serial No and Model No of the Module
- Date and Year of obtaining IEC PV module qualification certificate
- Name of the test laboratory issuing IEC certificate
- Other relevant traceability of solar cells and modules as per ISO 9000 series

4.6.2 Battery and Accessories

One set of storage battery bank of specified necessary capacity for each type of power pack must be provided with each power pack for storage of energy generated by the solar array.

- The battery shall be a photovoltaic battery of flooded electrolyte, low maintenance, deep discharge Lead acid type with hard rubber container
- Storage batteries should conform to IEC 61427 / IS 1651 / IS 133369 as per specifications
- The batteries shall use 2V cells and battery capacity is to be designed at C10 rate with end cell cut off voltage of 1.85 V per cell
- Battery terminal shall be provided with covers
- Batteries shall be provided with micro porous vent plugs with floats
- Charging instructions shall be provided along with the batteries
- Suitable carrying handle shall be provided
- A suitable wooden battery rack with interconnections & end connector shall be provided to suitably house the batteries in the bank
- The batteries shall be suitable for recharging by means of solar modules via incremental / open circuit regulators
- The batteries shall be designed for operating at ambient temperature at sites in the state of Bihar
- The self-discharge of batteries shall be less than 3% per month at 20 deg. C and less than 6% per month at 30 deg C

[2] Standard test condition is a normal temperature and pressure condition at which tests are done.

- The charge efficiency shall be more than 90% up to 70% state of charge
- The topping up frequency shall be 6 – 12 months
- The batteries shall consist of individual cells, which can be carried separately with ease while transporting
- Offered batteries shall comply minimum to the following:
  - 10 % of DOD: 7200 cycles
  - 50 % of DOD: 3000 cycles
  - 80 % of DOD: 1200 cycles

4.6.3 Power Conditioning Unit (PCU/Inverter)

The power conditioner unit of suitable capacity as mentioned for each type of power pack should be provided to convert DC power produced by SPV modules into AC power. In addition to high efficiency pure sine wave inverter, the PCU shall house MPPT (Maximum Power Point Tracker), an interface between solar modules and battery and inverter, to maximize solar energy input to the system.

PCU refers to the combination of charge controller, inverter and AC charger and can be supplied as integrated unit or separate units. Some of the key features for PCU are

- PCU to be used in solar photovoltaic energy system should have high operational efficiency. The idling current at no load must not exceed 2% of the full-load current
- The PCU shall include appropriate self-protective and self-diagnostic features to protect itself and the PV array from damage in the event of PCU component failure or from parameters beyond the PCU's safe operating range due to internal or external causes
- The self-protective features shall not allow signals from the PCU front panel to cause the PCU to be operated in a manner which may be unsafe or damaging. Faults due to malfunctioning within the PCU, including commutation failure, shall be cleared by the PCU protective devices and not by the existing site utility grid service circuit breaker
- The PCU shall not produce Electromagnetic Interference (EMI) which may cause malfunctioning of electronic and electrical instruments including communication equipment, which are located within the facility in which the PCU is housed
- The PCU shall have an appropriate display on the front panel to display the instantaneous AC power output and the DC voltage, current and power input. The display shall be visible from outside the PCU enclosure. Operational status of the PCU, alarms, trouble indicators and AC and the DC disconnect switch positions shall also be communicated by appropriate messages or indicator lights on the front cover of the PCU enclosure
- The PCU shall include an easily accessible emergency OFF button located at an appropriate position on the unit
- The PCU shall include ground lugs for equipment and PV array grounding. The DC circuit ground shall be a solid single point ground connection in accordance with WEC 69042
- All exposed surfaces of ferrous parts shall be thoroughly cleaned, primed, and painted or otherwise suitably protected to survive a nominal 30 years design life of the unit
- The PCU enclosure shall be weatherproof and capable of surviving climatic changes and should keep the PCU intact under all conditions in the room where it will be housed. The PCU located indoor should be floor mounted/ wall mounted. Moisture condensation and entry of rodents and insects shall be prevented in the PCU enclosure
- Components and circuit boards mounted inside the enclosures shall be clearly identified with appropriate permanent designations, which shall also serve to identify the items on the supplied drawings

- The design and fabrication of the PCU should be carried out considering site temperature (0^o to 70^0 C), incident sunlight and the effect of ambient temperature on component life. Consideration shall also be given to the heat sinking and thermal effect for blocking diodes and similar components

Operating Modes

The following operating modes are to be made available:

- Night or Sleep mode: Where the inverter is almost completely turned off, with just the timer and control system still in operation, losses should not exceed 2 watts per 5 kilowatt.
- Standby mode: Where the control system continuously monitors the output of the solar generator until pre-set value is exceeded (typically 20 watts)
- Operational or MPP tracking mode: The control system continuously adjusts the voltage of the generator to optimize the power available. The power conditioner must automatically re-enter stand-by mode when input power reduces below the standby mode threshold. Front Panel display should provide the status of the PCU, including AC Voltage, Current, Power output & DC Current, Voltage and Power input, Battery voltage and fault Indication (if any)

Codes and Standards

The quality of equipment supplied shall be controlled to meet the guidelines for engineering design included in the standards and codes listed under relevant ISI and other standards as:

- Inverter must conform to IEC 61683, IEC 60068 as per specifications
- MPPT must conform to IEC 62093, IEC 60068 as per specifications
- IEEE 928 Recommended Criteria for Terrestrial PV Power Systems
- IEEE 929 Recommended Practice for Utility Interface of Residential and Intermediate PV Systems
- IEEE 519 Guide for Harmonic Control and Reactive Compensation of Static Power Controllers
- National Electrical NEPA 70-(USA) or equivalent national standard
- National Electrical Safety Code ANSI C2- (USA) or equivalent national standard
- JRC Specification 503 (Version 2.2 March 1991) or JPL Block V standard for PV modules

Data Monitoring and Display

Digital Energy Meters to log the actual value of AC/ DC Voltage, Current & Energy generated by the PV system shall have to be provided for each SPV Power Plant.
All major parameters should be available on the digital bus and logging facility for energy auditing through the internal microprocessor and can be read on the digital front panel at any time the current values, previous values for up to a month and the average values. The following parameters should be accessible via the operating interface display.

- AC Voltage
- AC Output current
- Output Power
- DC Input Voltage
- DC Input Current
- Inverter Status

Protective function limits (Viz-AC Over voltage, AC Under voltage, Over frequency, Under frequency ground fault, PV starting voltage, PV stopping voltage, Over voltage delay, Under voltage delay over frequency, Ground fault delay, PV starting delay, and PV stopping delay).

Important Features / Protections required in the PCU

- Standard protections including Short Circuit protection, Over-charge and Over-discharge protections, Battery reverse polarity protection
- Authentic tracking of solar arrays' maximum power operation voltage (MPPT)
- Array ground fault detection
- Automatic fault conditions reset for all parameters like voltage, frequency and/or black out
- MOV type surge arresters on AC and DC terminals for over voltage protection from lightning-induced surges
- PCU should be rated to operate at 0 to 55 deg. Centigrade above ambient temp
- Over load capacity (for 30 seconds) should be 200% of continuous rating for battery invertors
- Inverter output power factor of 0.8 lag
- Stand alone and Hybrid modes of operation
- Rated for continuous operation at full load
- Type: Self commuted, current regulated, high frequency, IGBT based. Dual input type – solar or AC mains grid
- Output voltage single phase / three phase, 230 V / 415 V AC (+12.5%, - 20% V AC)
- AC charger input: 240 V AC, 50 Hz from AC mains grid
- Frequency: 50 Hz ±0.5 Hz
- Continuous rating: Suitable for each type of building and power pack
- DC input voltage Operating: 0 V to 400 V nominal range
- Total Harmonic Distortion: less than 3%
- Operating Temperature Range: 0 to 55 Degree Centigrade
- Housing cabinet PCU to be housed in suitable switch cabinet, IP 30 / IP 65 degree of ingress protection as per indoor / outdoor installation requirements
- Inverter overall efficiency:
  - Greater than 90% at full load
  - Greater than 85% at partial load (50% - 75%)

4.6.4 Junction Boxes

The junction boxes shall be dust, vermin and waterproof and made of FRP / Thermo-Plastic. The terminals shall be connected to copper bus bar arrangement of proper sizes. The junction boxes shall have suitable cable entry points fitted with cable glands of appropriate sizes for both incoming and outgoing cables. Suitable markings shall be provided on the bus bar for easy identification and cable ferrules shall be fitted at the cable termination points for identification. Each main junction box shall be fitted with appropriate rating blocking diode. The junction boxes shall be of reputed make and should be as per IP 65 (for outdoor), IP 21 (for indoor) & as per IEC 62208. The junction boxes shall have suitable arrangement for the following:

- Combine groups of modules into independent charging sub-arrays that shall be wired to the controller.
- Provide arrangement for disconnection for each of the groups.
- Provide a test point for each subgroup for quick fault location.
- To provide group array isolation.
- The rating of the JB's shall be suitable with adequate safety factor to inter-connect the Solar PV array.

4.6.5 Mounting Structures

- Suitable number of PV module structures shall be provided. Structures shall be of flat-plate design with combination of I, C and L sections as per structure design requirement.
- Structural material shall be corrosion resistant and electrolytically compatible with the materials used in the module frame, its fasteners, nuts and bolts
- Galvanizing should meet IS 1477 Part 1 with thickness of 70 microns as per IS 5905
- Structures shall be supplied complete with all members to be compatible and to allow easy installation and easy replacement at the rooftop sites
- The structure should have angle of inclination as per the site conditions to take maximum insolation
- The structures shall be designed for simple mechanical and electrical installation. There shall be no requirement of welding or complex machinery at the installation site
- The array structure shall support SPV modules at a given orientation to absorb and transfer the mechanical loads to the rooftop columns properly. All nuts and bolts shall be of very good quality stainless steel SS 304 except foundation bolts which can be of MS (GI Coated)
- The structure should be non-penetrating and of low height. The foundation for the structures shall be 1:2:4 PCC construction. The minimum clearance between roof surface and bottom edge of modules shall be 500 mm
- No damage in any way should be caused to the building while installation of SPV Power Plant

4.6.6 DC Distribution Board (DCDB)

DC Distribution Board (DCDB) should be provided for each site to receive DC output from the array field. It shall have MCBs of suitable rating for connection and disconnection of array sections. DCDB should be fabricated from CRC Sheet to form enclosure of dust and vermin proof confirming to IP-65 Standard.

4.6.7 Common AC Distribution Board (ACDB)

Common ACDB shall have the arrangement for measuring all electrical quantities such as Voltage, Current and Frequency of different feeder lines and energy supplied to different feeders. Common ACDB shall have sheet iron enclosure of dust and vermin proof & shall have adequate cooling arrangement. The bus-bars are to be made of copper of desired size.

4.6.8 Cables

- All cables should be as per IEC 60189 / IS 694 / IS 1554 or IS / IEC 69947 and should have proper current carrying capacity
- All cables, whether indoor or outdoor, needs to be laid using casing capping. As and when necessary flexible conduits can be used
- ISI marked PVC insulated copper conductor cable should be used of suitable sizes, as per design, for connections between modules / arrays and junction boxes; junction boxes and DCDB (armored); DCDB and inverter and inverter and ACDB (armored)
- Wires: Only copper wires of appropriate size and of reputed make shall be used. In the DC side only Solar Cables of required specifications and tested by MNRE approved laboratory shall be used. Cables of size less than 4 sq. mm shall not be used
- Cables Ends: All connections are to be made through suitable cable lug / terminals and should be crimped properly with use of glands
- Cable Marking: All cable / wires are to be marked in proper manner by good quality ferules or by other means so that the cables can be easily identified

- Cables sizes shall be selected based on efficient design criteria such that overall energy loss in any section of cable / wire is less than 3% under standard operating conditions

4.6.9 Lightening Protection

A number of suitable lightning arrestors shall be installed in the array area. Lightning protection shall be provided by the use of metal oxide arrestors and suitable earthing such that induced transients find an alternate route to earth. Protection should be in compliance with relevant codes and standards.

4.6.10 Earthing Protection

Each array structure of the PV yard should be grounded / earthed properly as per IS: 3043-1987. Adequate provisions have to be made for shorting and grounding of the PV array at the time of maintenance work. All metal casing / shielding of the plant should be thoroughly grounded in accordance with Indian Electricity Act / IE Rules. Earth Resistance should be tested and reported at the time of commissioning of the each system. PCU, ACDB and DCDB should also be earthed properly.

4.6.11 Electrical safety and protections

- Internal Faults: In-built protection for internal faults including excess temperature, commutation failure, overload and cooling fan failure (if fitted) is obligatory
- Galvanic Isolation: Galvanic Isolation is required to avoid any DC component being injected into the grid and the potential for AC components appearing at the array
- Over Voltage Protection: Over Voltage Protection against atmospheric lightning discharge to the PV array is required. Protection is to be provided against voltage fluctuations in the grid itself and internal faults in the power conditioner, operational errors and switching transients
- Earth fault supervision: An integrated earth fault device shall have to be provided to detect eventual earth fault on DC side and shall send message to the supervisory system
- Cabling practice: Cable connections must be made using PVC Copper cables, as per BIS standards. All cable connections must be made using suitable terminations for effective contact. The PVC Copper cables must be run in GL trays with covers for protection
- Fast acting semiconductor type current limiting fuses at the main bus-bar to protect from the grid short circuit contribution

4.6.12 Battery and Inverter Stands

A suitable Battery and Inverter stand shall be provided. The battery and inverter are fully accommodated in the stand for outdoor application.

4.6.13 Manual Switch for putting the load on the DG set circuit

A manual switch of suitable size and capacity should be provided in the system so that the supported loads can be transferred to the existing diesel generator manually. This will bypass the complete system and DG set shall directly support the designated loads along with other electrical loads at the site.

4.7 Issues and Concerns regarding SPV installations in Bihar

This section identifies the key issues and concerns related to installation and operation of SPV systems across state of Bihar. Some of the mitigation measures for the issues highlighted are referred below.

4.7.1 Key concerns

A detailed stakeholder consultation was organized in Patna to understand, amongst other things, the key concerns and risks perceived by the education department personnel in operation and maintenance of the SPV systems. Based on the inputs received during the consultations and other discussions with the stakeholders, the following key issues and concerns emerged;

1 Safety and security of PV panels, batteries and other accessories from theft

2 Risk of vandalism and destruction of PV panels by monkeys

3 Operation and maintenance of solar PV systems in the long term

Theft is a social issue and completely addressing this with technology is not possible. There are certain improvisations and technology features which can help in significantly restricting the events of thefts. Similarly, the threat of vandalism can also be addressed to an extent. The operation and maintenance concerns can be mitigated through training and ensuring onsite servicing through appropriate contracting mechanism.

4.7.2 Key mitigation measures

1 Safety and security of PV panels, batteries and other accessories from theft

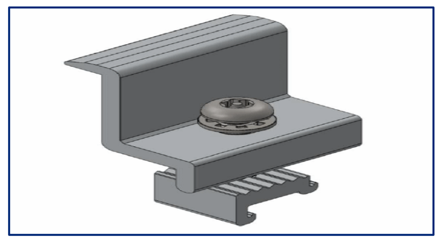
Incidences of theft of PV panels and balance of systems are reported from across the globe and the entire PV industry is taking on this challenge of stopping it. According to a recent study by US specialist insurer SolarInsure, the past few years has seen a significant increase in solar panel robbery. Solar thefts grew by 15% in 2009 compared with the previous year and some believe that figure has risen by 15% each year since 2002.

Although manufacturers offer warranty for solar panels and can even guarantee their electricity generation, these do not protect customers from theft occurrences. Hence some form of physical protection that prevents panel from removal must be provided. In developed markets like the United States (US), insurers are present to provide insurance against theft. But, they have also started demanding security measures to be in place before covering an installation.

Security measures that are being practiced across the globe are as follows:

- One of the basic practices is to install the system at a place that is not accessible easily. For instance, instead of ground the system can be mounted on rooftops
- It is important to not provide unguarded easy access to the place of installation. This can be done by not leaving ladders against walls and locking access doors to terraces
- Further, building a reinforced concrete wall around the panel mountings, so preventing access to the supporting structure and its bolts can be practiced. The only accessible part of the array is then the upper glass side of the PV modules and access for maintenance is via a door in the wall
- Mounting structures legs should be grouted well to the terrace / roof surface
- ‘Tighten-and-break’ anti-theft screws that fasten panels to mounting frames are a straightforward way to increase security. When these screws are fastened and applied tightening torque reaches a critical value, the hexagonal head of the nut breaks off completely, leaving a conical head that no wrench can grip

- An alternate way is to use snap-off headed bolts. These bolts must be drilled out to remove the module frame clamps.
- Another option is from some companies where special end-clamps are available in anti-theft versions, which use a pin Torx fastener instead of the standard socket head cap screw. The pin Torx fastener is generally manufactured from grade A2 (304) stainless steel.



- Connecting wires to each panel in an array to form simple electrical loops is one solution. When the cables are cut during a robbery, the current in the loops drops to zero. This change can be used to trip an alarm or trigger a message via a mobile transmitter, so giving the signal for security intervention by police or others. However, this kind of feature will add to the overall cost of the system.
- The inverter / PCU and the battery bank should be housed in the enclosure that has lock and key arrangement and could be sealed without hindering the necessary maintenance requirements
- All the cables and wires are to be laid through casing and capping and should be fixed

However, it should be noted that screwing into the module frame (or engraving) may void module warranty. Therefore, anti-theft solutions that use either different types of nut-bolts or screws or use special end clamps are recommended rather than any other method where module frame will be involved in a way other than standard recommended practice by the manufacturer.

2 Risk of vandalism and destruction of PV panels by monkeys

It is a general belief that presence of monkeys is a threat to the performance of SPV system. However, the recent technology advancements have sought to dispute this. Any IEC 61215 certified PV modules passes, among other tests, two tests for its mechanical strength; one is mechanical load test and another is hail impact test. After each of these tests the module is checked for electrical performance like maximum power and electrical insulation and also for any mechanical damage. Only on passing these tests the modules are certified with IEC 61215.

The hail impact test comprises of ice balls of different diameters launched on 11 spots on the module surface at various velocities. Balls of 12.5 to 75 mm diameter can be used as per the standard the most commonly used are 25 mm diameter 7.53 grams balls launched with 23 meter per second speed. Laboratory statistics shows very low failures due to this.

More important test is mechanical load test where modules are mounted as per manufacturer's instructions and then the modules are subjected to mechanical loads. Here 2400 Pa load which is equivalent to 130 KMPH wind speed is applied for one hour to the installed modules. Once modules withstand this load it is increased to 5400 Pa in the last stage.

Both these tests certify that modules installed properly can withstand static and dynamic loads and impacts on the glass surface without hampering its life and performance.

3 Operation and maintenance of solar PV systems in the long term

The SPV systems are easy to maintain and operate due to absence of any moving parts. There is no wear and tear of any component in the system and performance is dependent upon regular monitoring and replacement of equipment only.

For best daily operation, it is necessary that maximum possible solar radiation falls on the surface of the module and most of it is transmitted to the cells below the glass. This is achieved simply by observing that no shadow falls on the module surface and by periodically cleaning the module's glass surface.

Similarly, for long-term operation, it is necessary that other components are checked regularly and any action as necessary is taken immediately upon identifying any possible or occurred problems. The typical maintenance schedule for the SPV system is as follows:

Table: O&M activity schedule

O&M Activity	Schedule
Cleaning of surface of solar modules at the site	Weekly or Fortnightly depending on dust factor
Topping up of battery	Once in six months with distilled water
Checking all cable terminals	Once in a year
Checking module mounting structure for corrosion	Once in a year

Source: Deloitte research

The life of a well-maintained battery would be about 4 to 5 years. As these systems would be using tubular lead acid deep discharge batteries these will have better life and hence these will be required to be changed after 5 years. Similarly, the inverter life is about 10 years and this also will be required to be replaced after 10 years. The costs have been factored in the lifecycle cost.

Training needs

In order to ensure proper maintenance of the SPV system, especially after the AMC period, it is required that staff at institutes is acquainted in the basic operation and maintenance activities. The private developer installing the SPV system (AMC will also be part of the contractual obligation) have to provide following training to identified representative of staff. The developer must provide training on at least these components at the time of completion of project implementation phase

- PV system configuration

- Role of main components
- PV module function – frequent change in module power output, shadow and damage effect
- Correct module orientation
- Operation and maintenance – over charge protection, over discharge protection, over load protection, overuse effect
- Periodic check and maintenance- Checkpoints for each component and maintenances, Skill to check PV system condition, Periodic module cleaning requirements and procedures, Periodic checking importance for problem prevention, How to check, maintain and handle battery bank, charge controller, cables and lighting systems

These training requirements can be incorporated in the procurement guidelines to be finalized under the world bank contract.

5 Load assessment for Teachers Training Infrastructure

5.1 Information and Communication Technologies (ICT) Infrastructure

An ICT infrastructure covers following equipment

- **Thin-Client Network:** A thin client network link individual work stations to a host computer. The works stations are in effect intelligent clusters of monitors and other hardware that use the processing power of the host computer to perform tasks. Thin client networks used in the training centres at SCERT, DIETs, PTECs, BRCs, and CRCs will all share the same architecture, but will vary in size according to specific needs
- **Host computer**: A host computer is required to run network of work stations in a thin client. The host computer allows multimedia and video to run optimally across work stations. The host computer should have; 64 bit processor (8 Core preferable); minimum speed 2.0 GHz; RAM 8 GB
- **Keyboards**: Keyboards are used to type. An English/Hindi keyboard will be required as part of the thin-client network set up
- **Monitors**: Energy efficient LCD monitors with 15" screens
- **Headphones:** Headphones helps the users to interact with audio multimedia. One headphone is required with each work station in a thin client
- **Printer/Scanner/Copier**: A printing device should be added to each network to allow for small runs of paper-based documents for classroom use
- **Monitor/Projector**: In order to allow the students and mentors to refer to digital resources a ceiling- or wall-mounted 55" LCD monitor should be mounted and connected to the thin client network. For study centres that host 20 or more students, a data projector will be required in place of a wall monitor
- **Netbook**: All teacher educators in various locations are proposed to be provided with a Netbook, to ensure that they have full-time access to the courseware, facilitation notes, and resources. They will be able to use the centre connectivity to access the SCERT server

5.1.1 ICT load and basic lights only

In order to assess the SPV capacity required for various categories of teachers training institutes, the overall energy requirement for the proposed equipment have been taken. This energy requirement is to be assessed using the typical load (Watt) of these equipment and the hours of operation. Based on the information available with BSEIDC and earlier studies conducted by World Bank under the ongoing Bihar education sector project, the following ICT equipment list for various categories and the typical load capacity of ICT equipment has been taken below:

Table 7: ICT load and Equipment requirement per installation

ICT Equipment	Typical Load	No of Equipment per Installation				
	kW	SCERT	DIET	PTTEC	BRC	CRC
Thin Client Network (30 terminals)	1.8000	0	1	1	0	0
Thin Client Network (40 terminals)	2.1600	1	0	0	0	0
Netbook	0.0120	0	0	0	3	3

ICT Equipment	Typical Load	No of Equipment per Installation				
	kW	SCERT	DIET	PTTEC	BRC	CRC
Printer	0.0240	2	2	2	1	1
Photocopier	0.3360	2	0	0	0	0
PSP Combo	0.0070	0	0	0	1	1
LCD	0.0940	1	1	1	1	1
DLP Projector	0.4200	2	2	2	1	1
ADSL Modem	0.0156	3	1	1	1	1
CFL Light	0.0240	4	4	4	2	2

Source: BSEIDC and the World Bank

Further, the total load at each type of building is calculated as shown in table below:

Table 8: Total load for each type of building

ICT Equipment	Building Load (kW)				
	SCERT	DIET	PTTEC	BRC	CRC
Thin Client Network (30 terminals)	-	1.800	1.800	-	-
Thin Client Network (40 terminals)	2.160	-	-	-	-
Netbook	-	-	-	0.036	0.036
Printer	0.048	0.048	0.048	0.024	0.024
Photocopier	0.672	-	-	-	-
PSP Combo	-	-	-	0.007	0.007
LCD	0.094	0.094	0.094	0.094	0.094
DLP Projector	0.840	0.840	0.840	0.420	0.420
ADSL Modem	0.047	0.016	0.016	0.016	0.016
CFL Light	0.096	0.096	0.096	0.048	0.048
Total (Rounded off)	**3.957**	**2.893**	**2.893**	**0.644**	**0.644**

Source: Deloitte analysis

5.2 SPV capacity assessment

There are different categories of teachers training institutes that are to be energized using the solar off-grid systems. These categories are – SCERT, PTTEC, DIET, BRC and CRC. The design and cost of SPV systems will vary depending on the category as connected loads vary across these categories. The ICT equipment requirement differs among these institutes and thus the overall load to be catered.

5.2.1 Assessment of daily energy requirement

Based on the interactions and the survey undertaken, following key assumptions have been taken for estimating the daily energy requirement.

- Assumption of 7 hours of operation
- Equipment load factor of 85%

The daily energy requirement calculations are provided in table below:

Table 9: Daily energy requirement

Parameter	Units	SCERT	DIET	PTTEC	BRC	CRC
Typical Load per building	kW	3.957	2.893	2.893	0.644	0.644
Daily Operation	Hours	7	7	7	7	7
Electricity Consumption per Day	kWh	27.69	20.25	20.25	4.51	4.51
Load Factor of Equipment	%	85%	85%	85%	85%	85%
Daily electricity input required per Building	**kWh**	**32.60**	**23.80**	**23.80**	**5.31**	**5.31**

Source: Deloitte analysis

5.2.2 Assessment of battery size

The size of batteries at each category of teacher training institute is dependent upon the load requirement that has been assessed above. Using the load requirement, the battery sizing assessment is shown in the table below.

Table 10: SPV Battery sizing

Battery Sizing	SCERT	DIET/PTTEC	BRC/CRC
Load wattage	3,956	2,893	644
System Voltage	96.00	96.00	48.00
Current in Amperes	41.21	30.14	13.43
Operation hours per Day	7.00	7.00	7.00
Required AH per day	288.49	210.96	93.98
Battery Depth Of Discharge	0.80	0.80	0.80
Battery Efficiency	0.85	0.85	0.85
Temperature losses	0.85	0.85	0.85
Wiring losses	0.98	0.98	0.98
Total Efficiency Factor	0.57	0.57	0.57
Required AH per day	509.30	372.44	165.90
Autonomy	1.00	1.00	1.00
Total AH of Battery selected	**500.00**	**400.00**	**150.00**

Source: Deloitte analysis

As can be seen in the table above, the battery designing assessment has considered various losses and efficiency factors. Standard values for these factors have been undertaken during the assessment.

It is important to mention that an autonomy (that is storage capacity of battery) has been taken as 1[3]. This means that battery has energy storage capacity for maximum of one day or 6 to 7 operational hours. The autonomy can be increased but that will increase the cost of battery.

5.2.3 Assessment of SPV system capacity

The daily energy requirement is used to find out the capacity of SPV system that can generate equivalent energy. The actual energy generation per kWp of SPV system is initially carried out using the monthly average solar radiation and the loss factors. The table below shows the solar potential data for Bihar

Table 11: Monthly average solar radiation in Bihar

Boundaries	Location	Horizontal (kWh/sqm-d)	Tilt angle 25 degrees (kWh/sqm-d)
North-West	Bettiah	5.27	5.69
North-East	Kishanganj	5.27	5.72
South-East	Bhagalpur	5.15	5.52
South-West	Bhabhua	5.03	5.34
Capital	Patna	5.21	5.60
Average		**5.19**	**5.57**

Source: NASA

The monthly average solar radiation in Bihar is estimated to be around 5.57 kWh/m^2/day. In addition, the system losses are to be factored in the system design.

Table 12: Total losses in SPV systems

Loss Factors in Solar PV Systems	
Wire losses	0.98
Battery depth of discharge	0.80
Battery efficiency	0.85
Soiling (Dust) losses	0.98
Inverter Efficiency	0.90
Temperature coefficient	0.98
Module derating	0.90
Total loss factor	**0.52**

Source: Deloitte analysis

The SPV system losses are around 52% as shown in the table above.

Based on the estimated solar insolation and SPV system loss data, the energy generated per KW is assessed and same is hence utilized to estimate the required capacity of SPV system. This is shown in table below.

Table 13: Pilot project capacity assessment (in kW)

Solar PV Capacity Required	SCERT	DIET	PTTEC	BRC	CRC	TOTAL

[3] Based on discussions with BSEIDC personnel

Usable energy per kWp (kWh)	2.9	2.9	2.9	2.9	2.9	
System Capacity per building (kWp)	11.3	8.2	8.2	1.8	1.8	
Pilot (kW)	**11.3**	**223**	**190**	**184**	**0**	**607**

Source: Deloitte analysis

Around 600 kW capacity has been estimated for the pilot phase of the program.

6 SPV system cost estimation

6.1 Cost estimates for typical layouts

The cost estimates have been worked out based on the market data available for Q4 2013 in India. Based on the above capacity estimates, the following system cost has been considered for the project.

Table 14: SPV system cost for SCERT building

S No	Particulars	Type/Model	Cost (INR)	Cost (USD)
1	Solar Module	11300 Wp	770,000	12833
2	Module Mounting Structure	LS; GI Fixed type	70,000	1167
3	Battery	96 V 500 AH	340,000	5667
4	Power Control Unit	Hybrid Inverter cum Charger; 4 kW	340,000	5667
5	Battery Rack / Enclosure	Fiber	50,000	833
6	Cables, Connectors, etc.	Solar Grade	65,000	1083
	Equipment Price		**1,635,000**	27250
7	Transport, I&C		60,000	1000
	System commissioning cost		**1,695,000**	28250
8	O&M for 5 years		280978	4683
	System Price in the Project		**19,75,978**	32933

Source: Deloitte analysis on market trend

Table 15: SPV system cost for DIET/PTTEC building

S No	Particulars	Type/Model	Cost (INR)	Cost (USD)
1	Solar Module	8200 Wp	558,000	9300
2	Module Mounting Structure	LS; GI Fixed type	49,000	817
3	Battery	96 V 400 AH	246,000	4100
4	Power Control Unit	Hybrid Inverter cum Charger; 3 kW	246,000	4100
5	Battery Rack / Enclosure	Fiber	40,000	667
6	Cables, Connectors, etc.	Solar Grade	45,000	750
	Equipment Price		**1,184,000**	19733
7	Transport, I&C		46,000	767
	System commissioning cost		**1,230,000**	20500
8	O&M for 5 years		203896	3398
	System Price in the Project		**14,33,896**	23898

Source: Deloitte analysis on market trend

Table 16: SPV system cost for BRC or CRC building

S No	Particulars	Type/Model	Cost (INR)	Cost (USD)
1	Solar Module	1800 Wp	122,000	2033
2	Module Mounting Structure	LS; GI Fixed type	11,000	183
3	Battery	48 V 150 AH	52,000	867
4	Power Control Unit	Hybrid Inverter cum Charger, 0.75 kW	52,000	867
5	Battery Rack / Enclosure	Fiber	8,000	133
6	Cables, Connectors, etc.	Solar Grade	10,000	167
	Equipment Price		**2,55,000**	4250
7	Transport, I&C		15,000	250
	System commissioning cost		**270,000**	4500
8	O&M for 5 years		44758	746
	System Price in the Project		**314758**	5246

Source: Deloitte analysis on market trend

In off-grid SPV systems, it is always advisable to have a business model under which the project developer is bound to operate and maintain the systems after installation. Industry practice is 5 year of annual maintenance and contract (AMC). Thus, in addition to capital cost of equipments, 5 years AMC cost is mentioned. The O&M cost under AMC is 3% of initial capital cost for first year and an escalation of 5% every year for next 4 years.

6.2 Project Cost Estimates

6.2.1 Pilot Phase

The estimated procurement cost for the project is dependent upon the final component design selection. All the design options with their estimated procurement cost are mentioned in above section. The procurement cost covers both the equipment cost and AMC cost for 5 years.

Table 17: SPV procurement cost for pilot phase under program

S No	Option	Buildings covered (Nos)	Procurement Cost without Subsidy Rs Crore (USD Million)*	Procurement Cost with Subsidy Rs Crore (USD Million)*
1	Solar only (with 7 hours of battery backup)	151	9.91 (1.65)	6.94 (1.16)
2	Solar grid electricity hybrid (with 7 hours of battery backup)		10.62 (1.77)	7.43 (1.24)
3	Solar- Diesel hybrid (with 7 hours of		12.74 (2.12)	8.92 (1.49)

	battery backup)			

*Conversion Rate: 1 USD = Rs 60

Source: Deloitte analysis

For the pilot project phase, the estimated procurement cost with capital subsidy would be in the range of USD 1.16 million to USD 1.49 million. For the recommended option of solar grid hybrid (with 7 hours of battery backup) configuration, the estimated procurement cost would be Rs 10.62 crore (USD 1.77 million) without capital subsidy or Rs 7.43 crore (USD 1.24 million) with capital subsidy.

6.2.2 Entire Program

For the same technical configuration system, the procurement cost covering 1,200 teachers training institutes and 1 SCERT for the state is estimated to be as follows:

- Rs 25.92 crore (USD 4.32 million) without capital subsidy
- Rs 18.12 crore (USD 3.02 million) with subsidy.

Table 18: SPV procurement cost for entire program

S No	Option	Number of buildings	Procurement Cost without Subsidy INR Crore (USD Million)*	Procurement Cost with Subsidy INR Crore (USD Million)*
1	Solar grid electricity hybrid (with 7 hours of battery backup)	1201	25.92 (4.32)	18.12 (3.02)

Source: Deloitte analysis

7 Proposed Implementation Model for SPV System

The proposed project for energizing the ICT equipment in various teachers training institutes across Bihar is an energy project that has to be managed by the education department of Bihar. The World Bank would fund the capital cost of the project for both pilot and subsequent phases. The pilot project would be taken up immediately and accordingly the energy requirements for the institutions would need to be met through proposed RET.

The establishments which would be energized are located in remote areas and also the local staff would not be acquainted with the operations and maintenance of the equipment. Accordingly, the operation or maintenance requirement under this project for a reasonable period of time needs to be met by the developer responsible for the project implementation. This could be accomplished through building in an Annual Maintenance Contract for a minimum period of 5 years as part of the original bid. Further, a minimum response time can also be included which would ensure a state wide servicing infrastructure to be provided by the successful bidder.

An important consideration is the cost of the proposed energy solution to be provided. Since the major thrust of the program is on the education infrastructure and energy sourcing is incidental to overall needs, the capital cost of proposed solution should be reasonable. The project would eligible for availing the capital subsidy from MNRE under the solar off-grid scheme under JNNSM. A maximum of 30% capital subsidy on benchmark capital cost as notified by MNRE can be availed under the scheme. The scheme details and funding pattern is provided in Annexure 7. However, it is important to mention that subsidy from MNRE is subject to approval and availability of funds. The subsidy is disbursed after the project commissioning and the selected project developer can himself receive that from MNRE but it is recommended that an approval be sought initially to avoid any risk during or after project commissioning.

BSEIDC must set the process in motion to obtain the subsidy approval before initiating the process for selecting the project developer.

There are sufficient number of private players in the solar PV space in India who would be interested in the project. The list of MNRE certified channel partners/SPV project developers (

Annexure 8) can be targeted as potential participants in the bid process. Moreover, they develop project using MNRE certified quality equipments.

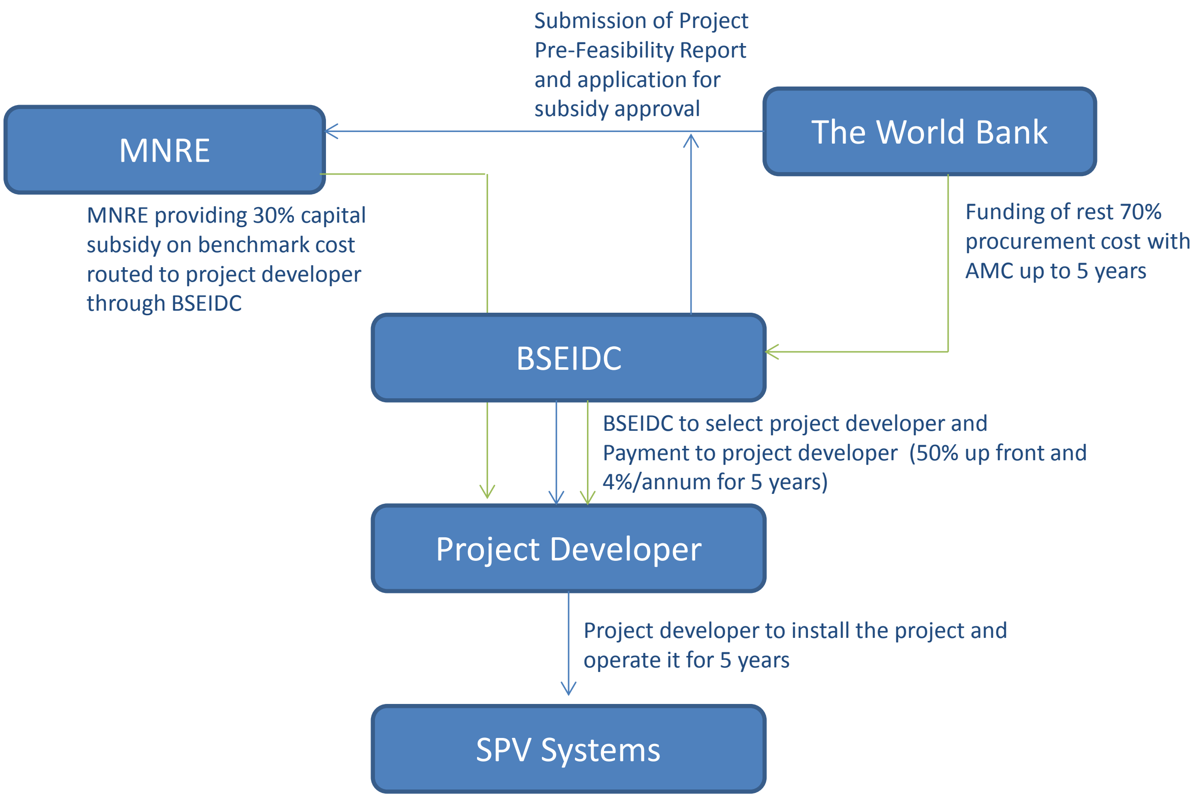
The Bihar State Education Infrastructure Development Corporation (BSEIDC) may become the project coordinator with responsibility to conduct the procurement exercise and selection of project developer(s). The project developer can be selected through an open capital cost based bidding. As the World Bank would be involved in funding part of the capital cost, it is recommended that BSEIDC should adopt relevant procurement guidelines of the World Bank.

Under this model, the project developer will be responsible for implementation of project and receiving the capital subsidy from MNRE. Upon approval of the capital subsidy and after project commissioning, the MNRE will release funds in favor of BSEIDC. BSEIDC will then transfer the capital subsidy to project developers.

The World Bank will be funding the remaining 70% of capital cost (including AMC) and all the funds will be provided to BSEIDC during the project implementation phase. It is also recommended that BSEIDC pay project developer in tranches linked to AMC in order to avoid the risk of project developer not maintaining the projects post installation.

Annual Maintenance Contracts (AMC) will also be responsibility of the project developer and the term of AMC can be at least 5 years and extendable for a period of further 5 years. BSEIDC can also invite fresh bids at the end of 5 year tenure for the AMC contract. The project developer will also be responsible for availing the applicable state government incentives if any to SPV off-grid systems.

Figure 19: Possible business model for solar PV project



Key considerations under the business model:

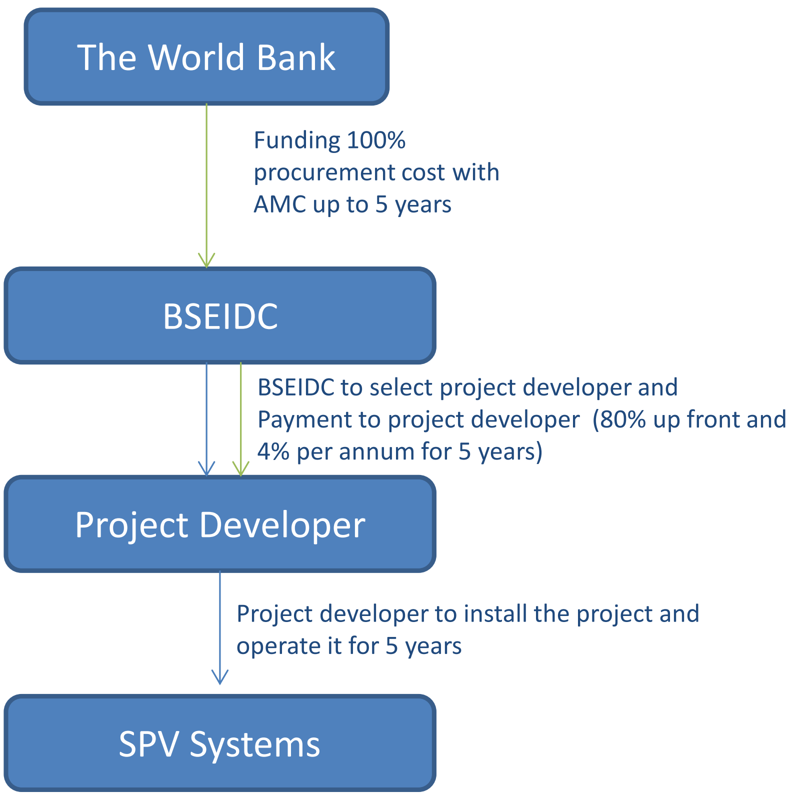
- The project can leverage the capital subsidy provided by the MNRE, however initiating the project development process without prior approval of subsidy from MNRE may pose as a big risk as subsidy is subject to funds availability with MNRE.
- It is recommended that project developer selection guidelines include the SPV system operation and maintenance requirements and also includes specific condition on project developer's obligation to have service centers across the state in order to ensure timely maintenance of systems.
- AMC contract must clearly define the O&M and replacement schedule (as specified in earlier section) and penalty must be imposed on the project developer if he fails to adhere the schedule.
- The project developer must also be required to provide basic training on operation and maintenance of the system
- Experience of developing and maintaining the solar PV stand-alone systems in India and specifically in Bihar or nearby states must be put as qualification criteria for project developer selection

The World Bank or BSEIDC will also have to initially decide upon the project sanction boundary conditions. The overall capacity of the pilot phase (600 KW) is not very high and one project developer can easily develop the same. However, considering the number of smaller systems that sums this capacity (151 buildings) and the geographical spread of them, it may be required to distribute the total capacity between two or more players.

It is recommended that the World Bank and BSEIDC conduct a pre-bid meeting with the project developers to understand their viewpoint in this respect.

In case the capital subsidy is not available for the project, the following model would apply:

Figure 20: Alternate business model for solar PV project (without capital subsidy)



8 Annexures

Annexure 1: List of sites covered under pilot phase

S No	District	SCERT	DIET	PTTEC	BRC	Total
1	Araria		1	0	4	**5**
2	Aurangabad		1	1	2	**4**
3	Banka		1	0	5	**6**
4	Begusarai		1	1	8	**10**
5	Bhagalpur		1	2	4	**7**
6	Bhojpur		1	1	5	**7**
7	Buxar		1	0	5	**6**
8	Darbhanga		1	1	4	**6**
9	East Champaran		1	1	4	**6**
10	Gaya		1	1	1	**3**
11	Kaimur		1	0	4	**5**
12	Katihar		1	1	4	**6**
13	Khagaria		1	0	3	**4**
14	Lakhisarai		1	0	0	**1**
15	Madhepura		1	1	2	**4**
16	Muzaffarpur		1	3	5	**9**
17	Nalanda		1	0	4	**5**
18	Nawada		1	0	2	**3**
19	Patna	1	1	5	0	**7**
20	Rohtas		1	1	4	**6**
21	Samastipur		1	1	7	**9**
22	Sheikhpura		1	0	1	**2**
23	Sheohar		1	0	1	**2**
24	Sitamarhi		1	0	1	**2**
25	Siwan		1	1	4	**6**
26	Vaishali		1	1	8	**10**
27	West Champaran		1	1	8	**10**
Total			**27**	**23**	**100**	**151**

Annexure 2: Solar off-grid/rooftop PV projects in Bihar

List of solar off-grid/rooftop PV projects installed/planned in Bihar by Bihar Renewable Development Agency (BREDA)

S.no	Project Capacity (kW)	Location	Total Capacity (kW)	Status
1	100	Chief Minister house, Patna	100	Operational
2	100	Vidyut Bhawan, Patna	100	LoI to be issued
3	50	Governor House, Patna	50	LoI to be issued
4	60	Chief Justice House, Patna	60	LoI to be issued
5	100	Canal top based project	100	LoI to be issued
6	25	Collector house in 38 Districts	950	LoI to be issued
7	25	Circuit house in 38 Districts	950	LoI to be issued
8	25	District Hospital in 38 Districts	950	LoI to be issued
Total			**3260**	

Annexure 3: Stakeholder consultations

Apart from face to face consultations with all the key stakeholders in Bihar including BSEIDC, BREDA, education department, a stakeholder consultation workshop was organized was on 3rd Dec 2013 in Patna to discuss the key findings of the study and take specific inputs on the implementation plan for the RE based solution for teachers training institutes. The consultation was chaired by BSEIDC with participation from Bihar state government (education department), representatives from teachers training institutes, private players in solar PV segment, procurement consultants and technical consultants.

Key points which were discussed are as follows:

- Power supply position in Bihar to improve -- Urban locations in Bihar shall have 24 hour uninterrupted power supply in future- Phased manner increase in power availability from this year
- Solar PV and systems needs more security measures to be implemented successfully in Bihar
- CRC may be very remote and more vulnerable to theft issues
- CRCs to be covered in subsequent phases and not in pilot phase
- After pilot phase, all BRCs to be solarized
- BRCs may have land limitations and thus rooftop model is more optimum for these locations
- Guards will be deployed for security and safety of these systems
- Operation and maintenance of the systems will be key issues and private developers must provide long term maintenance contracts (AMC)
- Private developers need to set up service centers across the state
- AMC up to 10 years is feasible can be provided for longer term also (Jain irrigation systems)
- In order to have optimum quality of equipment/systems, in addition to component wise specifications of the systems in the bid document sample testing both pre and post-dispatch must be practiced (BREDA)
- Performance guarantee, Output monitoring, Complaint system- SCADA features may also be used to ensure quality of projects
- PV system service may be provided within 2 days of complaint in any part of the state (Jain irrigation system)
- Panel theft is not very major issue can be easily addressed through double side riveting
- Monkeys nuisance can’t damage the panels (consultants)

List of Participants for the stakeholder consultation workshop

S. No.	Name	Organization
1	Mr. A.K. Sinha	IAS, Principal Secretary, Education Department, GoB
2	Mr. Sanjiwan Sinha	Director, BSEIDC
3	Mr. Niraj Kuma Verma	BRCC Fatuha Education Department
4	Mr. Pramod Kumar	BRCC State Education Department
5	Mrs. Manju Kumari	BMR Training College
6	Mrs. Kiran Kumari	DIET, Patna
7	Mrs. Nirupa Kumari	PTEC, Mahendru
8	Mr. Shyam Mohan	Block Education Officer, Barh, Patna
9	Mr. Shishu Pal Kumar	BEO, Mokaroma, Patna
10	Mr. Manoj Kumar	BRCC
11	Mr. Guddu Kumar Singh	BRCC, Patna,
12	Mr. Dhiraj Kumar	Block Education Officer
13	Mr. Arun Kolsur	World Bank
14	Mr. Karthik Kamath	Ernst & Young LLP, New Delhi
15	Mr. Ishad Akhtar	BREDA
16	Mr. Vijay Biloria	BREDA
17	Mr. Sujeet Kumar	Jain Irrigation Systems Ltd.
18	Mr. Sanjeev Kumar	TERI
19	Mr. Sanjay Pandey	EKP
21	Mr. Shailesh Kumar	Nawada
22	Mr. D.K Singh	S.G Enterprises, Ranchi
23	Dr. S A Moin	SCERT, Patna

Annexure 4: RET Resource Potential in Bihar

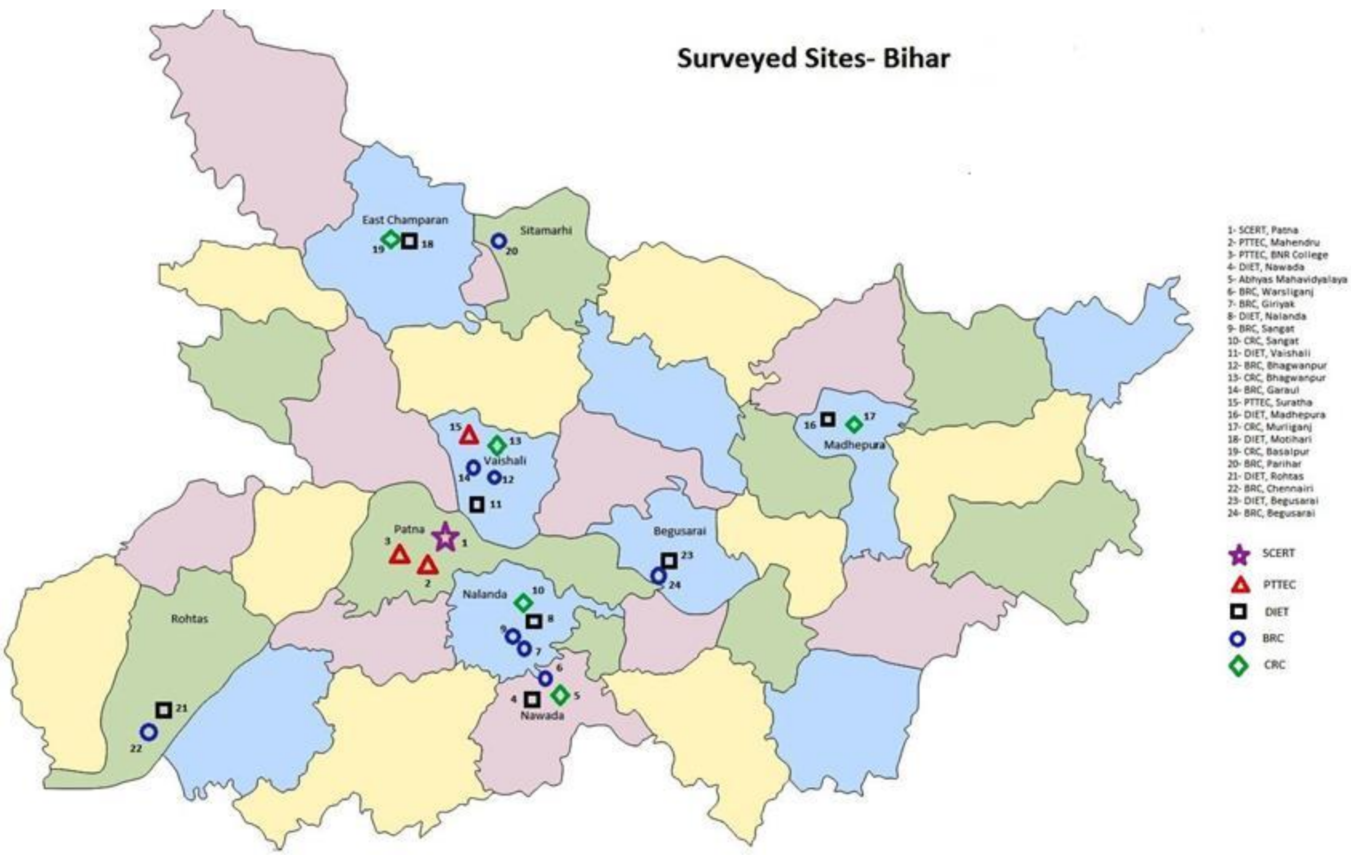
Geothermal

The highlighted area in the map shows the regions having geothermal potential in India

Annexure 5: Field survey coverage

The study team collected field information from 24 teachers training sites in Bihar during September 2013 to evaluate the infrastructure suitability and on-ground assessment of the RE technologies available. The sample sites were finalized in consultation with BSEIDC and have adequate coverage of various categories of the present teachers training infrastructure in the state.

The following map provides the overview of locations selected for site assessment



Annexure 6: Key Survey Findings

S No	Category	Assessed ICT Load Requirement	Name of Site	District	Grid connectivity Status	Rooftop space available for SPV	Ability to support rooftop solar	Space for Installing SPV on Ground	Space availability for solar PV	Assessed SPV Rooftop Potential (KW)	Availability of Night Guards	Space Availability for Installing Biomass	Availability of work force for biomass collection and gasifier operation	Micro Hydro Resource in Vicinity
1	SCERT	0.1	SCERT Patna	Patna	Connected	Yes	Yes	Yes	Yes	16	Yes	Yes	Yes	No
2	PTTEC	0.1	PTTEC Mahendru	Patna	Not Connected	No	No	No	no	0	Yes	Yes	No	No
3	PTTEC	0.1	PTTEC BNR College	Patna	Connected	Yes	Yes	No	Yes	8	Yes	Yes	No	No
4	DIET	0.1	DIET, Nawada	Nawada	Not Connected	Yes	Yes	No	Yes	7	Yes	Yes	No	No
5	CRC	0.05	Abhyas Madhya Vidhalaya	Nawada	Connected	Yes	Yes	Yes	Yes	7	No	Yes	No	No
6	BRC	0.05	BRC, Warsliganj	Nawada	Not Connected	Yes	Yes	No	Yes	7	Yes	No	No	No
7	BRC	0.05	BRC, Giriyak	Nalanda	Connected	Yes	Yes	No	Yes	7	Yes	No	No	No
8	DIET	0.1	DIET, Nalanda	Nalanda	Connected	Yes	No	No	No	7	Yes	Yes	No	No
9	BRC	0.05	BRC, Sangat	Nalanda	Not Connected	Yes	Yes	No	Yes	7	Yes	No	No	No

S No	Category	Assessed ICT Load Requirement	Name of Site	District	Grid connectivity Status	Rooftop space available for SPV	Ability to support rooftop solar	Space for Installing SPV on Ground	Space availability for solar PV	Assessed SPV Rooftop Potential (KW)	Availability of Night Guards	Space Availability for Installing Biomass	Availability of work force for biomass collection and gasifier operation	Micro Hydro Resource in Vicinity
10	CRC	0.05	CRC, Sangat	Nalanda	Not Connected	Yes	Yes	No	Yes	3	Yes	No	No	No
11	DIET	0.1	DIET, Vaishali	Vaishali	Connected	Yes	Yes	Yes	Yes	10	Yes	Yes	No	No
12	BRC	0.05	BRC, Bhagwanpur	Vaishali	Not Connected	Yes	Yes	No	Yes	3	No	No	No	No
13	CRC	0.05	CRC ,Bhagwanpur	Vaishali	Not Connected	Yes	Yes	No	Yes	7	No	Yes	No	No
14	BRC	0.05	BRC, Garaul	Vaishali	Not Connected	Yes	Yes	No	Yes	7	Yes	Yes	No	No
15	PTTEC	0.1	PTTEC, Suratha	Vaishali	Not Connected	No	No	Yes	yes	8	Yes	Yes	No	No
16	DIET	0.1	DIET, Madhepura	Madhepura	Connected	No	No	Yes	yes	8	Yes	Yes	No	No
17	CRC	0.05	CRC, Murliganj	Madhepura	Not Connected	Yes	Yes	No	Yes	6	No	No	No	No
18	DIET	0.1	DIET, Motihari	East Champaran	Connected	Yes	Yes	No	Yes	10	Yes	No	No	No
19	CRC	0.05	CRC, Basalpur	East Champaran	Not Connected	No	No	No	no	0	Yes	No	No	No

S No	Category	Assessed ICT Load Requirement	Name of Site	District	Grid connectivity Status	Rooftop space available for SPV	Ability to support rooftop solar	Space for Installing SPV on Ground	Space availability for solar PV	Assessed SPV Rooftop Potential (KW)	Availability of Night Guards	Space Availability for Installing Biomass	Availability of work force for biomass collection and gasifier operation	Micro Hydro Resource in Vicinity
20	BRC	0.05	BRC, Parihar	Sitamadi	Connected	Yes	Yes	Yes	Yes	NA	Yes	Yes	No	No
21	DIET	0.1	DIET, Rohtas	Rohtas	Not Connected	Yes	Yes	Yes	Yes	NA	Yes	Yes	No	No
22	BRC	0.05	BRC, Chenairi	Rohtas	Connected	Yes	Yes	No	Yes	3	No	Yes	No	No
23	DIET	0.1	DIET,Begusarai	Begusarai	Connected	Yes	Yes	No	Yes	NA	Yes	No	No	No
24	BRC	0.05	BRC, Begusarai	Begusarai	Connected	Yes	Yes	No	Yes	3	Yes	Yes	No	No

Annexure 7: Fiscal incentives available for solar PV projects

MNRE provides a capital subsidy of 30% on benchmark capital cost for off-grid solar photovoltaic systems. The benchmark capital cost is revised by the MNRE every year. Amended benchmark capital cost for off-grid SPV systems with and without storage for the year 2013-14 are as follows. Also present is the maximum available capital subsidy from MNRE for each category of SPV system.

Table: Benchmark cost for solar PV systems

S No	SPV System	Capacity	Benchmark Cost (Rs./ kWp)	Maximum MNRE Subsidy (Rs/kWp)
1	SPV Power Plants (With Battery Bank)	>300 Wp to 1 kWp	210	70
		>1 kWp to 10 kWp	190	63
		>10 kWp to 100 kWp	170	56
2	SPV Power Plants (Without Battery Bank)	Up to 100 kWp	100	33
		>100 kWp to 500 kWp	90	30

Source: MNRE

General funding under MNRE's capital subsidy scheme

- Funding under the scheme is done in Project mode, i.e. there must be a project report including technical & financial details about the project, O&M and monitoring arrangements etc. that need to be submitted to MNRE
- The total project cost shall be funded through a mix of debt and incentives where the promoters' equity contribution would be at least 20% (unless otherwise specified). Techno-economic specifications for a minimum cut-off level for the requirement of the project mode would be specified by MNRE
- MNRE may also provide 5% interest bearing loans to the project developers
- There would be a provision for channel partners, operating in the market mode to access a combination of capital subsidy and a low cost interest for the end consumer provided they can tie up with a lending institution

Release of funds

- The release of funds for the project shall be back ended as reimbursement on completion and verification thereof. However, MNRE may provide front ended funds also but only in case of actual need from project developers.

Approval Mechanism

- The project proposals shall be considered and sanctioned by a Project Approval Committee (PAC). This committee would provide approval and will also review progress. The entire process of receiving proposals, processing them and giving approvals is IT enabled. The committee frame rules and prescribe formats etc., for project approval, within the overall framework of this scheme to make the process transparent

Annexure 8: List of SPV players/ Channel Partners

MNRE has list of accredited channel partners for the solar PV technology. There are more than 196 solar energy System Integrators and 2 Renewable Energy Service Companies (RESCOs) across India. These agencies have been accredited latest till 31st March 2015. The accredited scale ranges from 1A to 3C with 1A being the best category.

The latest list of MNRE channel partners can be found at:

http://mnre.gov.in/file-manager/UserFiles/list_channelpartners_sp_jnnsm.pdf