INTERNATIONAL SOLAR ALLIANCE

Module Outline

PV PROJECT ECONOMICS

Disclaimer

Relevance and Background

Solar PV is capital intensive unlike conventional sources of energy. A major part of lifetime costs of solar PV is upfront. Due to this, the economics of solar PV are different from conventional sources of energy, and hence a different approach for designing and deploying solar PV is required.

Solar PV can be deployed across several applications ranging from off-grid to grid-connected utility-scale. Also, solar PV can be deployed across scale from kW to GW. Considering the landscape for solar PV applications, the economics of solar PV varies considerably.

Basis the energy needs, customized solar PV solutions need to be designed. Cost of generation can vary with the level of customization needed. Since a large portion of expenses is upfront, the utilization factor also plays a major role.

It is important to understand the major components of solar economics that can influence the cost of generation and profitability. This will help in designing better solar solutions and business models based on the needs.

Theme – Financing
Competency – Business Models and Financing
Code of the Module – T04C09M24

Learning Outcomes

At the end of the presentation, participants will be conversant with:

- Major components of solar economics
- Identifying metrics for assessing solar economics
- Understanding sensitivity analysis
- Requirement for financial incentives
- Need for different business models.

The module will throw light on the factors influencing the economics of solar PV and assessing the feasibility of solar PV applications.

Finally, the participants will evaluate a solar PV project through a case study.

Method of Delivery

Duration	Resource Code	Resource Delivery
45 min.	M24 L01	Lecture on PV Project Economics
15 min.	M24 C01	Case Study

M24 L01: Lecture Presentation

The MS PowerPoint presentation will present the capital costs and their breakup along with cost trends across various countries.

This will be followed by a discussion on equity and debt, which are used to fund the project cost of solar PV. Both costs and revenue sources for solar PV will be presented along with different ways of assessing project feasibility. Major components have also been identified that impact the project feasibility assessment.

Basis the feasibility, the need for various policy interventions like capital subsidy have been highlighted.

M24 C01: Case Study

The trainer is recommended to develop the feasibility assessment for any project from the country of the trainees and present it as part of the lecture. The case study should also demonstrate the sensitivity of solar feasibility on key components of solar economics.

Key Topics to be Covered

1 Project Cost
2 Illustrations of Project Costs and Variations
3 Sources of Funds
4 Revenue
5 Financial Assessment
6 Tax Incentives
7 Impact of Key Components on Economics
8 Using Project Economics to Develop Appropriate Interventions

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1 Project Cost

For solar projects, a major part of the lifetime expenses is project cost, which is upfront in nature. These are required to develop the project. Project cost constitutes more than 50-75% of the lifetime costs, while the rest is the cost of operations and maintenance (O&M) - usually about 1-2% of the project cost on an annual basis.

1.1 Cost of Plant and Machinery

Plant and machinery are the highest contributor to a solar project's cost. Since solar is deployed for several applications, the cost of plant and machinery changes with the configuration of the project. Therefore, factors influencing the project cost are:

- Configuration of the solution - The system components change with the need of the application.
- Size of the plant - The project cost of large-capacity plants like utility-scale solar is low due to the economies of scale. On the other hand, distributed solar solutions usually cost more on a per kW basis.
- Project design - All components have several technological options available with varying costs. For example,
  - Solar PV modules - thin film, mono and poly crystalline, PERC
  - Inverters - central, string and micro inverters
  - Module mounting structure - fixed, single-axis, double-axis trackers[1]
  - Batteries - lead acid and lithium-ion[2]

Decisions for the selection of technology are based on economics (like a decrease in the cost of generation due to an increase in generation) as well non-economic factors (like lack of alternate technologies for the requirement).

1.2 Cost of Land

A solar PV plant would need a land area of about 4-5 acres (16,000-20,000 square meters) per MW. Purchase and lease[3] are the usual methods of acquiring land for the project.

[1] Floating solar projects would need special mounting structures and platforms to keep panels afloat.
[2] Lead acid batteries are cheaper vis-à-vis lithium-ion batteries; however, lead acid batteries also need a greater number of replacements during the life of the project making cost of generation from lithium ion batteries lower.
[3] Lease fee can be a one-time fee, a periodic fee and/or a combination of both.

1.3 Installation Costs

Costs for installing plants and machinery include the cost of human resources (unskilled, semi-skilled and skilled) and the equipment used for installation.

1.4 Soft Costs

Soft costs include:

- Design costs
- Fee for licensing and permissions
- Interest during the construction
- Cost of fund-raising
- Cost of consumer acquisition

There are other factors that influence the project cost, such as:

- **Country and Region** - The local cost structures, especially of labor, vary for each country and region. These cost structures influence both hard and soft costs.
- **Import Duties** - Many countries depend on the import of critical components. The import duty regime of the country directly impacts on the hardware cost.
- **Licensing and Permissions** - Each country or region has their own requirement for licenses and permits and their respective fees.

2 Illustrations of Project Costs and Variations

2.1 Utility-Scale Projects

The project cost of utility-scale varies between USD 596/kW to USD 1,900/kW depending on the country, with the major part being contributed by solar PV modules and inverters. The project cost breakup also varies with the country. The presentation will discuss a detailed breakdown of utility-scale solar PV total installed costs by country, using 2020 data[4].

2.2 Mini Grids in Nigeria

For a mini-grid, the battery is the highest contributor to the project cost, unlike solar PV modules for utility-scale projects. Distribution infrastructure also adds to the cost of mini-grids. The presentation describes an example from Africa of the break-down of the cost of mini-grids designed for Nigeria with a generation capacity of 125 kW[5].

[4] Source: International Renewable Energy Agency
[5] Source: Rocky Mountain Institute

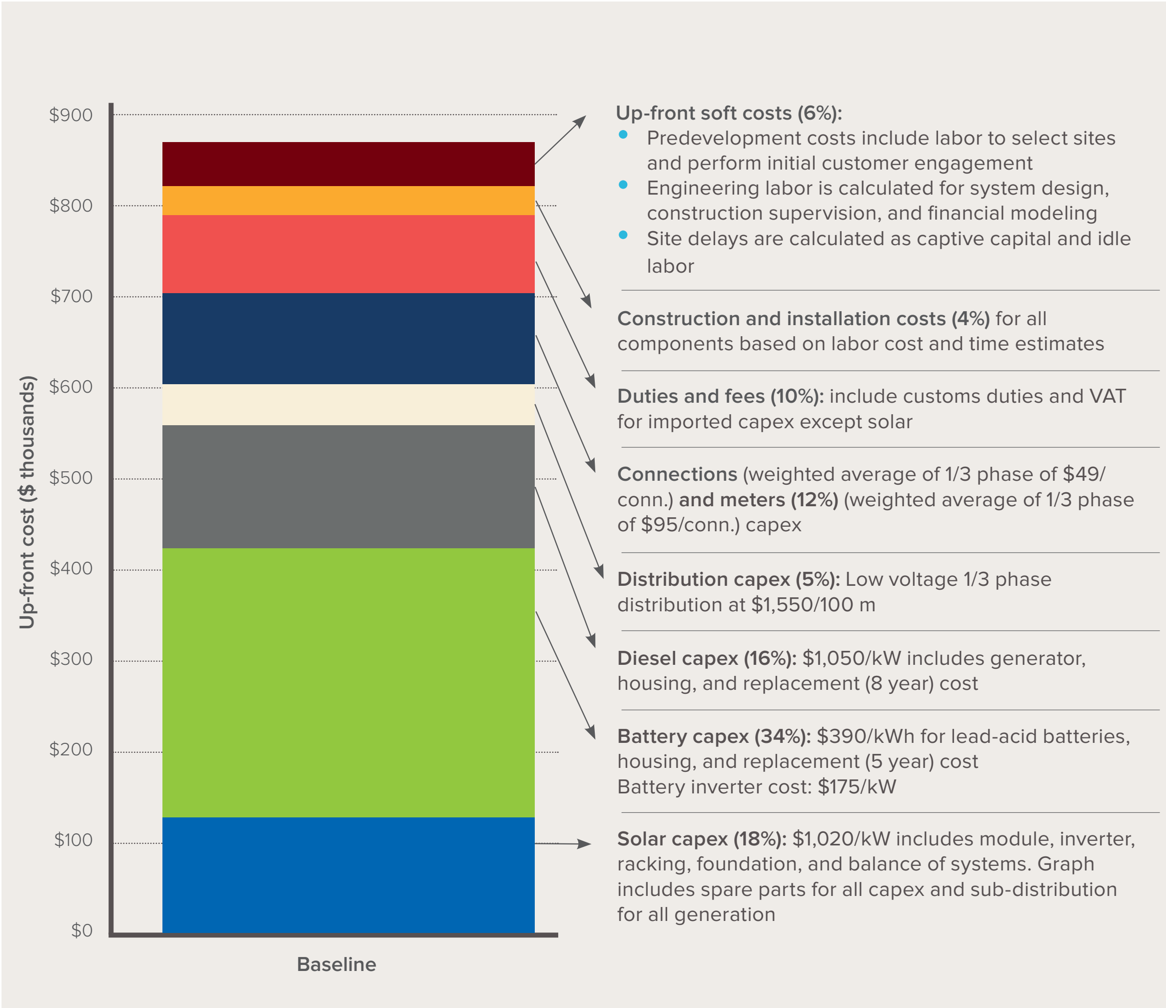

Figure: Break-down of cost of mini-grids designed for Nigeria with a generation capacity of 125 kW[6]

[6] Source: Rocky Mountain Institute

2.3 Floating Solar

Floating solar has high project costs vis-à-vis ground-mounted utility-scale solar. The same is reflected in the cost of generation.

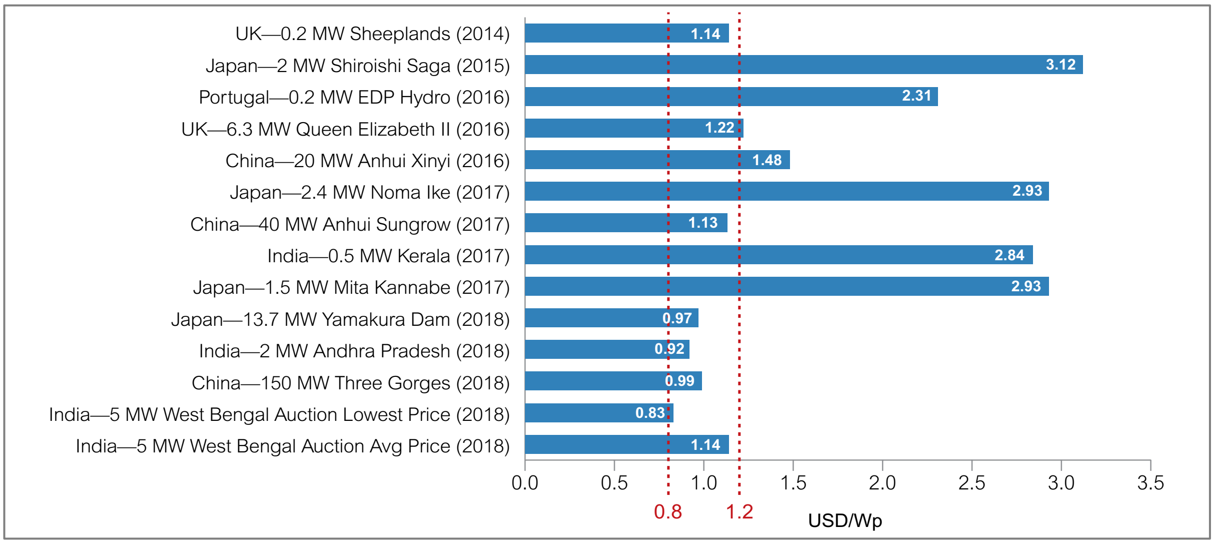

Figure: Investment costs of floating PV in 2014–2018 (realized and auction results)[7]

	Ground-mounted PV (fixed tilt)	Floating PV (fixed tilt)
Electricity produced (first year), GWh	75.8	79.6
Increase in performance from ground-mounted fixed tilt		*5%*
LCOE (U.S. cents/kWh)		
at 7% discount rate (base case)	5.0	5.6
at 8% discount rate	5.2	5.7
at 10% discount rate	5.4	6.0

Source: Authors' compilation.
Note: GWh = gigawatt-hour; kWh = kilowatt-hour; LCOE = levelized cost of electricity; MWp = megawatt-peak; PV = photovoltaic.

Figure: Comparing the levelized cost of electricity from a 50 MWp floating with that from a ground-based PV system[8]

3 Sources of Funds

Projects are usually funded through equity, debt, and capital subsidy. Their respective share and the required returns influence the economics of the project.

3.1 Equity

Equity is sourced from the project owners, also known as developers. Developers deploy their own capital or the capital of their investors as equity. The equity investors can claim only the residual cash flow[9] as the returns on their investment from the project. Due to this claim, equity is considered to have the highest risk among the three sources. The expected return on equity is highest due to the high risk.

Developers have a requirement for a minimum RoE or IRR to make any investment. Solar PV projects should be able to generate such return rates for investors to be interested in solar PV projects. Developers also use simpler metrics like payback periods for assessing the project and equity viability.

3.2 Debt

Debt is usually in the form of term loans from commercial banks, multilateral agencies like the International Finance Corporation and Asian Development Bank (ADB) and other financial institutions. The major aspects of debt are the interest rate and repayment terms. Debt service is an obligation and lenders can act as per the debt terms and local law of the country. The project needs to generate at least the money needed for debt service.

3.3 Capital Subsidy

The capital subsidy is usually provided by the government to reduce the cost of the project and improve its economics. This is not required to be paid back to the government.

[9] Residual cash flow is the cash flow after meeting all the operational expenses, payments to the lenders, and taxes.

4 Revenue

For consumer-owned models, savings for the consumers from the use of solar energy can be considered revenue for the project. For the other models, revenue is generated from the sale of energy to the utilities and consumers. Other revenue streams for projects can be:

- Sale of surplus energy to utilities (in case of net metering/billing projects)
- Carbon credits
- Renewable energy certificates

5 Financial Assessment

Different metrics are used for assessing the financial viability of solar PV. Levelized cost of energy (LCoE), Equity IRR, Payback period, and Debt service coverage ratio (DSCR) are the most prominent ones.

5.1 Levelized cost of Energy

LCoE is used to understand the cost of generation on a per kWh basis. It is generally used by policymakers and regulators to compute solar tariffs for the sale of electricity to utilities. LCoE is also used by consumers to compare their current cost of energy vis-à-vis investing in solar. Annual estimated expenses and generation for project life are discounted to estimate LCoE, which includes the following components:

- Project cost
- Debt equity ratio
- Annual depreciation (derived from project cost)

- O&M cost
- Interest payments (derived from term loan, repayment schedule and interest rate)
- Annual return on equity (pre-tax)
- Generation
- Annual discount rate

LCoE can also be used to understand the breakup of project costs, which can help in designing interventions to reduce costs.

5.2 Equity IRR

Unlike LCoE, equity IRR considers revenue and targets to estimate the return to the equity investment from free cash flow to equity through the life of the project. Equity IRR is an important tool for the equity investors to make an investment in solar PV projects.

5.3 Payback Period

Payback period measured in years estimates the time taken for recovery of the investment (project cost or equity) from the cash flows generated by the project. Payback, due to its simplicity in calculation and usage, is generally used by consumers for assessing the viability of the project for self-consumption.

5.4 Debt Service Coverage Ratio

DSCR is the ratio of cash flow after meeting operational expenses and annual debt service. It is used to assess the ability of the project to service interest payments and repayment.

6 Tax Incentives

Besides capital subsidies, governments also provide tax incentives to developers to improve the project viability. Commonly used tax incentives are:

- **Tax Credits** - The developer avails tax credits on a part of the project cost and uses them to service taxes from their other businesses. Tradable tax credits can provide additional revenue sources for the developers.
- **Tax Holiday** - Income tax is waived for solar projects for the first few years.
- **Accelerated Depreciation** - Developers are allowed to book a higher depreciation on solar assets, thus reducing their tax.

7 Impact of Key Components on Economics

As explained above, the key components that impact the economics of solar PV projects are:

- Project cost
- Equity (amount of equity and returns expected)
- Debt (amount of debt, interest rate and repayment schedule)
- Power generation
- Tariff/savings
- O&M cost

Sensitivity analysis needs to be carried out to understand the impact of these key components on the feasibility of solar projects.

The trainer should develop a few scenarios to illustrate their impact on the project feasibility for the trainees. Indicative scenarios could include:

- Impact of decrease in tariff by 10% on Equity IRR and DSCR
- Impact of decrease in generation by 10% on Equity IRR and DSCR
- Impact of increase in project cost by 10% on LCoE and Equity IRR
- Impact of increase in equity by 10% on Equity IRR and LCoE
- Impact of decrease in debt by 10% on LCoE, Equity IRR and DSCR
- Impact of increase in O&M cost by 10% on LCoE, Equity IRR and DSCR

The tools listed in the reading material below can be used to carry out the sensitivity analysis.

8 Using Project Economics to Develop Appropriate Interventions

The LCoE of a solar PV project should be lower than the cost of replaced energy for a consumer or the declared tariff for a developer to develop a project. In case LCoE is higher than the cost of replaced energy/declared tariff, governments can provide capital subsidy to bridge the gap.

A higher interest rate and shorter repayment period would need the project to generate higher returns and thus require higher tariffs/savings. By reducing the interest rate and prolonging the repayment period, the need for higher returns and this requirement for higher tariffs/savings can be reduced. Providing loans with lower interest rates and longer repayment periods or interest rate subvention can be used to address this.

Cost of capital for consumers and small investors is high. It is difficult to reduce the cost of capital for these investors. Alternatively, capital subsidy can be used to reduce the quantum of investment and thus reduce the cost of capital in absolute terms. Another alternative can be to allow large investors, who have access to low-cost capital, to build, own and operate the systems to sell energy to the consumers.

Revenue from the sale of energy at the declared tariff or savings from replaced energy might not be adequate to generate the required returns. Additional sources of revenue can help improve the feasibility of the project. Carbon credits, renewable energy certificates, and/or tradable investment credits can be offered to the developers/consumers to improve the feasibility of the solar projects.

Cost of smaller systems are higher on a per-kW basis. These costs can be reduced by procuring in bulk. The reduced cost of the systems can make them more attractive to consumers. Government can design programs to procure and install systems in bulk on behalf of the consumers. Alternatively, governments can also aggregate many small systems and invite developers to build, own and operate the systems to sell energy to consumers.

Reading Material

1. *Generic Tariff Order for Grid Interactive PV Solar Energy Generating System (GISS) dated 22-10-2021 by Tamil Nadu Electricity Regulatory Commission, India (http://www.tnerc.gov.in/Orders/files/TO-Order%20No%20251020211341.pdf) The document can be referred to understand how LCoE is computed for solar PV*
2. *LCoE Calculator by U.S. Environmental Protection Agency (https://www.epa.gov/sites/default/files/2016-02/webinar_20140416_calculator_0.xlsx)*
3. *Levelized Cost of Electricity in Indonesia - Understanding The Levelized Cost of Electricity Generation by Institute for Essential Services Reform (IESR), Jakarta (https://iesr.or.id/wp-content/uploads/2020/01/LCOE-Full-Report-ENG.pdf)*
4. *CREST Model for Solar by National Renewable Energy Laboratory (https://www.nrel.gov/analysis/assets/docs/nrel-crest-solar.xlsx). This Excel-based model can be used to assess the feasibility of solar PV projects.*
5. *Renewable Power Generation Costs in 2020 by International Renewable Energy Agency (https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf)*
6. *Minigrids in the Money - Six Ways to Reduce Minigrid Costs by 60% for Rural Electrification by Rocky Mountain Institute (https://rmi.org/wp-content/uploads/2018/12/rmi-seeds-minigrid-report.pdf). The report can be referred to understand the project and generation cost breakup of a mini-grid and ways to reduce the cost*
7. *Cost and Returns of Renewable Energy in Sub-Saharan Africa: A Comparison of Kenya and Ghana by Institute of Development Studies (https://core.ac.uk/download/pdf/43542198.pdf). The report can be referred to understand the impact of costs on IRR and LCoE*
8. *Developmental Case Study - Central Solar de Mocuba Mozambique by Norfund (https://www.norfund.no/app/uploads/2020/02/Mocuba-Case-Study.pdf). The report discusses how a combination of financial assistance mechanisms like development finance, equity and credit guarantees are used to develop a solar PV plant*
9. *Where Sun Meets Water by World Bank (https://documents1.worldbank.org/curated/en/579941540407455831/pdf/Floating-Solar-Market-Report-Executive-Summary.pdf) This report can be used to understand the economics of floating solar*

Annexure 1

Tamil Nadu Electricity Regulatory Commission (TNERC) released order on Generic Tariff Order for Grid Interactive PV Solar Energy Generating System (GISS) dated 22-10-2021. Following are the LCoE calculations carried out by TNERC to declare solar tariff.

Tariff Calculator **151-999 kW**

LCOE Calculations [description]

Inputs			**Unit**
1	Solar PV system capacity	1.00	kW
2	MNRE benchmark cost	-	INR / kW
3	Gross capital cost before subsidies	39,080	INR / kW
4	MNRE subsidy	0.00%	%
5	Government of Tamil Nadu subsidy	0.00%	%
6	Equity (% of net capital cost after subsidies)	30.00%	%
7	Return on equity	14.00%	%
8	Interest on loan	9.50%	%
9	Loan tenure	10	Year
10	Loan moratorium	1	Year
11	Solar PV system CUF	21.00%	%
12	Daytime grid availability	98.00%	%
13	Average annual solar panel degradation	0.75%	%
14	O&M (percentage of capital cost)	1.40%	%
15	O&M annual increase	5.72%	%
16	Insurance (% of depreciated asset value)	0.35%	%
17	Annual depreciation	3.60%	%
18	Depreciation on net capital cost after subsidies?	Y	Y/N
19	Working Capital - O&M	1	Month
20	Working Capital - receivables	2	Months
21	Interest on Working Capital	10.00%	%
22	Discount factor	8.67%	%
23	Economic life of system	25	Years

Results / Outputs

	Funding		
	MNRE benchmark cost for installed capacity	-	INR
	Gross capital cost ***before subsidy***	39,080	INR
	Capital cost eligible for subsidy	-	INR
	MNRE subsidy (INR)	-	INR
	Capital cost ***after MNRE subsidy***	39,080	INR
	Government of Tamil Nadu subsidy	-	INR
	Capital cost ***after MNRE subsidy and GoTN subsidy***	39,080	INR
	Equity	11,724	INR
	Loan	27,356	INR

	Total Funding Check - % of *Gross* Capital Cost		
	MNRE contribution	0.00%	%
	Tamil Nadu Government contribution	0.00%	%
	Equity	30.00%	%
	Loan funding	70.00%	%
	Total Funding (% of gross capital cost)	**100.00%**	**%**

	Total Funding Check - % of *Net* Capital Cost		
	Equity	30.00%	%
	Loan funding	70.00%	%
	Total Funding (% of net capital cost)	**100.00%**	**%**

For the abovesaid order refer http://www.tnerc.gov.in/Orders/files/TO-Order%20No%202510202113341.pdf.

Solar Energy Generation

Year-->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Solar energy generation (kWh)	1,803	1,789	1,776	1,763	1,749	1,736	1,723	1,710	1,697	1,685	1,672	1,660	1,647	1,635	1,622	1,610	1,598	1,586	1,574	1,563	1,551	1,539	1,528	1,516	1,505	41,238

Cost of Solar Energy Generation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Return on equity	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	1,641	41,034
Interest on Loan	2,599	2,599	2,310	2,021	1,733	1,444	1,155	866	578	289	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15,593
Operation and Maintenance (O&M)	547	578	612	646	683	723	764	808	854	903	954	1,009	1,067	1,128	1,192	1,260	1,332	1,408	1,489	1,574	1,664	1,759	1,860	1,967	2,079	28,860
Insurance	137	132	127	122	117	112	107	102	97	92	88	83	78	73	68	63	58	53	48	43	38	33	28	24	19	1,942
Depreciation	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	35,172
Interest on O&M Working Capital	5	5	5	5	6	6	6	7	7	8	8	8	9	9	10	11	11	12	12	13	14	15	16	16	17	241
Sub-total	**6,336**	**6,362**	**6,102**	**5,843**	**5,587**	**5,333**	**5,081**	**4,831**	**4,584**	**4,340**	**4,098**	**4,148**	**4,201**	**4,258**	**4,318**	**4,382**	**4,450**	**4,522**	**4,598**	**4,679**	**4,765**	**4,856**	**4,952**	**5,055**	**5,163**	**122,842**
Interest on Receivables Working Capital	106	106	102	97	93	89	85	81	76	72	68	69	70	71	72	73	74	75	77	78	79	81	83	84	86	2,047
Total cost	**6,441**	**6,468**	**6,204**	**5,941**	**5,680**	**5,422**	**5,165**	**4,912**	**4,660**	**4,412**	**4,166**	**4,217**	**4,271**	**4,329**	**4,390**	**4,455**	**4,524**	**4,597**	**4,674**	**4,757**	**4,844**	**4,937**	**5,035**	**5,139**	**5,249**	**124,889**
Total cost per kWh	**3.57**	**3.61**	**3.49**	**3.37**	**3.25**	**3.12**	**3.00**	**2.87**	**2.75**	**2.62**	**2.49**	**2.54**	**2.59**	**2.65**	**2.71**	**2.77**	**2.83**	**2.90**	**2.97**	**3.04**	**3.12**	**3.21**	**3.30**	**3.39**	**3.49**	75.65

Levelised cost of Energy

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Discount Factor	1.00	0.92	0.85	0.78	0.72	0.66	0.61	0.56	0.51	0.47	0.44	0.40	0.37	0.34	0.31	0.29	0.26	0.24	0.22	0.21	0.19	0.17	0.16	0.15	0.14	0.44
Present Value	3.57	3.33	2.96	2.63	2.33	2.06	1.82	1.60	1.41	1.24	1.08	1.02	0.96	0.90	0.84	0.79	0.75	0.71	0.66	0.63	0.59	0.56	0.53	0.50	0.47	1.36

Levelised cost of energy INR	**3.10**	***per kWh***

Depreciation calculation

Year-->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Depreciation on gross capital cost	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	35,172
Depreciation on gross capital cost - cumulative	1,407	2,814	4,221	5,628	7,034	8,441	9,848	11,255	12,662	14,069	15,476	16,883	18,289	19,696	21,103	22,510	23,917	25,324	26,731	28,138	29,544	30,951	32,358	33,765	35,172	35,172
Depreciation on net capital cost after subsidies	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	35,172
Depreciation on net capital cost after subsidies - cumullative	1,407	2,814	4,221	5,628	7,034	8,441	9,848	11,255	12,662	14,069	15,476	16,883	18,289	19,696	21,103	22,510	23,917	25,324	26,731	28,138	29,544	30,951	32,358	33,765	35,172	35,172

Working Capital Calculation

Year-->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
O&M Working Capital	46	48	51	54	57	60	64	67	71	75	80	84	89	94	99	105	111	117	124	131	139	147	155	164	173	2,405
Interest on O&M Working Capital	5	5	5	5	6	6	6	7	7	8	8	8	9	9	10	11	11	12	12	13	14	15	16	16	17	241
Receivables Working Capital	1,056	1,060	1,017	974	931	889	847	805	764	723	683	691	700	710	720	730	742	754	766	780	794	809	825	842	861	20,474
Interest on Receivables Working Capital	106	106	102	97	93	89	85	81	76	72	68	69	70	71	72	73	74	75	77	78	79	81	83	84	86	2,047

Debt Servicing

Year -->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Debt opening balance	27,356	27,356	24,316	21,277	18,237	15,198	12,158	9,119	6,079	3,040	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27,356
Debt repayment	-	3,040	3,040	3,040	3,040	3,040	3,040	3,040	3,040	3,040	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27,356
Debt closing balance	27,356	24,316	21,277	18,237	15,198	12,158	9,119	6,079	3,040	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest	2,599	2,599	2,310	2,021	1,733	1,444	1,155	866	578	289	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15,593
Total debt service	**2,599**	**5,638**	**5,350**	**5,061**	**4,772**	**4,483**	**4,195**	**3,906**	**3,617**	**3,328**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**42,949**