sustainable master planning

sustainable communities

energy management

water management

material

Waste Management

solar thermal & solar PV

wind turbines

MILESTONE ecofirst
Sustainable by design

FINAL REPORT

for

INTEGRATED ENERGY MANAGEMENT

to

ZANIRA PROPERTY PVT. LTD.

for

VACATION HOME PROJECT AT KARJAT

(29TH OCT, 2010)

Milestone Ecofirst Advisory Services (I) Pvt. Ltd.

602, Hallmark Business Plaza, Sant Dyaneshwar Marg, Opp. Guru Nanak Hospital,

Bandra (E), Mumbai 400 051

Tel: +91 22 4235 7000 Fax: +91 22 4235 7077

Contents

Executive Summary

In line with their vision for the creation of a sustainable neighbourhood, Zanira Property Pvt. Ltd. employed Milestone Ecofirst Advisory Services (I) Pvt. Ltd. to forge an “Integrated Energy Management” plan for their vacation home project, “Tattva” at Karjat. This report is the final energy report towards that end.

The ambit of this report extends to a review of the load calculations and transformer sizing for the project, reduction of the load through energy efficiency and renewable energy measures, resizing of the transformer after accounting for the energy efficiency and renewable energy measures and preparation of a backup strategy for the project.

The client has applied to MSEDCL for a 500 kVA transformer. Our calculations indicate that this transformer will be insufficient to cater to the load for the entire township and the actual requirement is around 1100 kVA. After incorporating energy efficiency measures and renewable energy technologies, the load can be brought down to 800 kVA. Hence a transformer of around 325 kVA should further be acquired to satisfy the entire load.

In terms of energy efficiency measures, we have recommended the use of LED street lights for the roads and energy efficient fans, lights and ACs for individual houses. These will provide an energy saving of 220 MWh or Rs. 11 Lakh per year. Solar water heaters have been recommended to cater to the entire water heating requirement. These affect a saving of 75 MWh or around Rs. 4 Lakh per year. Together, solar water heaters and the energy efficient equipments will also affect a 250 kVA reduction in transformer size required i.e. a reduction of Rs. 5 Lakh in transformer cost.

For the backup, we have recommended the installation of a solar photovoltaic (PV) farm which when compared to a diesel generator (DG) which would conventionally have provided the same function, saves more than 10,000 litres of diesel fuel per year. The report also provides a detailed analysis of three different backup options:

a. Solar PV farm
b. Diesel generator the entire backup
c. Diesel generator for common amenities in combination with individual inverters for each house

Chapter 1: Project Background

Current development is sprawling over 25 acres area near village Pinglus in Block Karjat of Alibagh district of Maharashtra, located at the confluence of two rivers, Pingles and Schillar. The project, positioned as 'Vacation Home Project', envisages having 58 villas with area of each villa between 1750 to 2200 sft. Additionally, 40 terrace houses are also part of the development plan. In spite of such positioning, occupancies are expected to be high during festival season and summer/winter vacations due to its proximity to Matheran hill station. Developer, Zanira Property Pvt. Ltd., wishes to incorporate sustainability principles and features in the project and has invited Milestone Ecofirst Advisory Services (MEAS) to prepare the energy management plan for the project. Scope of work and deliverables for energy management is as follows:

1. **Review of existing load calculations, transformer sizing details and renewable energy systems (e.g. solar system):**
    a. Firstly existing load calculation will be reviewed. Necessary assumptions will be made to arrive at the expected load per house.
    b. To decide whether the proposed infrastructure is sufficient/over-designed

    <u>Deliverables:</u>

    a. Load calculation based on time and use model
2. **Optimization of renewable energy systems:** Following renewable energy systems would be explored to see their impact on energy demand, cost and energy saving etc.
    a. Solar Water Heater System
    b. Solar Street-light

    <u>Deliverables:</u>

    a. Cost-benefit analysis of renewable energy systems
    b. Review of current solar lighting configuration
    c. Single Line Diagram of proposed renewable energy systems
3. **Incorporation of energy efficiency features:** Following energy efficiency measures would be explored to see their impact on energy demand, cost and energy saving etc.
    a. Energy Efficient Lights
    b. Energy Efficient Fans
    c. Energy Efficient Air-conditioners

Deliverables:

a. Cost-benefit analysis of energy efficiency features

4. **Reworking of energy demand per house after incorporation of energy efficient and renewable energy features**
    a. To decide whether the proposed infrastructure is sufficient/over-designed after incorporation of energy efficiency and renewable energy measures
    b. Way forward

Deliverables:

a. Revised load calculation based on time and use model

5. **Energy efficient power distribution planning including backup power:** Following power distribution and backup power options would be explored.
    a. Automatic Power Factor Controller
    b. 100% DG-set back up
    c. Partial DG-set back up and inverters for individual houses
    d. Photovoltaic cells based power generation as back up

Deliverables:

a. Cost-benefit analysis of power back-up options and recommendations
b. Single Line Diagram of recommended power back-up options

The purpose of this report is to review and comment on the existing load calculation & renewable energy systems and to conduct a feasibility analysis of different renewable energy and energy efficiency features for the development. The report also calculates revised loads after accounting for the energy efficiency and renewable energy features.

This, the final energy report, covers the following:

1. Review of existing load calculations, transformer sizing details and renewable energy systems (e.g. solar system)
2. Incorporation of energy efficiency features
3. Recalculation of energy demand after incorporation of energy efficient and renewable energy features
4. Creation of an electrical backup strategy for the entire development including a centralized solar facility and as well as a diesel generator (DG).

Chapter 2: Review of Existing Calculations

2.1 Current Scenario

The original project envisaged having 66 villas with area of each villa between 1750 to 2200 sft. Now the plan has been changed to comprise 58 villas and 40 terrace houses. The project is positioned as a 'Vacation Home Project'. The load calculation as per the original load application submitted to MSEDCL is shown below.

Particular	**Value**	**Unit**
No. of residential plots	66	Nos
Load estimated per house	8	kW
Total load for houses (villas)	528	kW
Load estimated for club house	10	kW
Load estimated for restaurant	10	kW
Load estimated for swimming pool	5	kW
Load estimated for common area lighting	10	kW
Load estimated for pumping	20	kW
Total load	583	kW
Diversity Factor	0.7	
Power factor	0.9	Lag
Total load in kVA	453	kVA
Transformer required	500	kVA

2.2 Review of existing load calculations

The current development spreads over 25 acres area near the village Pinglus in Block Karjat of the Alibagh district of Maharashtra. Being near Matheran Hill Station, *it can safely be assumed that* occupancy can go up-to a maximum of 70% in vacations especially during festival season and in summers. Load analysis for a typical villa (3-BHK) and a typical terrace house (2-BHK) is presented below.

The following assumptions were made to estimate the load per unit:

1. The target segment is looking for a luxury, high-end second home with all the comforts and appliances of modern life
2. The appliance wattages are assumed according to conventional models available in the market.

2.2.1 Review of residential load calculations

Table 2.1 Typical (Major) Loads for 3BHK

3 BHK			
	Nos	kW per Appliance	Total (kW)
Washing Machines	1	0.4	0.4
Water Heaters	1	3	3
TV	2	0.15	0.3
Toaster	1	1	1
Mixer	1	0.4	0.4
Microwave	1	1	1
Exhaust fan	4	0.1	0.4
Air-conditioners (1.5 Ton)	4	2.25	9
Electric Iron	1	1	1
Laptop Computer	1	0.1	0.1
Refrigerator	1	0.2	0.2
Lights	21	0.052	1.092
Fans	7	0.08	0.56
Garden Mower	1	0.2	0.2
Total			**18.7**

Table 2.2 Number of lights and fans in a 3 BHK setup

3 BHK – Number of Lights and Fans				
Lights			**Fans**	
Room type	**Nos**		**Room type**	**Nos**
Bedrooms	6		Bedrooms	3
Hall	3		Hall	2
Kitchen	2		Kitchen	1
Store/Study	1		Store/Study	1
Porch	2		Porch	
Bathrooms	3		Bathrooms	
External	4			
	21			7

MILESTONE ecofirst
Sustainable by design

Table 2.3 Calculation of Operating Load based on Time and Use Model for a 3 BHK setup

Villas - 3 BHK Calculation

Time ->	**0 to 3**		**3 to 6**		**6 to 9**		**9 to 12**		**12 to 15**		**15 to 18**		**18 to 21**		**21-24**	
Major Loads	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW
Water Heaters	0	0	0	0	1	3	1	3	0	0	0	0	1	3	0	0
TV	1	0.15	0	0	1	0.15	1	0.15	2	0.3	1	0.15	2	0.3	2	0.3
Toaster	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0
Light	6	0.31	6	0.31	8	0.42	10	0.52	5	0.26	8	0.416	16	0.83	16	0.83
Mixer	0	0	0	0	1	0.4	1	0.4	1	0.4	1	0.4	1	0.4	0	0
Microwave	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Domestic Fans	3	0.24	3	0.24	5	0.4	5	0.4	5	0.4	2	0.16	2	0.16	2	0.16
Exhaust fan	0	0	0	0	4	0.4	4	0.4	2	0.2	1	0.1	3	0.3	3	0.3
Air-conditioners	2	4.5	2	4.5	2	4.5	2	4.5	3	6.75	3	6.75	3	6.75	2	4.5
Electric Iron	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0
Laptop Computer	1	0.1	0	0	2	0.2	2	0.2	1	0.1	2	0.2	2	0.2	1	0.1
Garden Mower	0	0	0	0	0	0	1	0.2	1	0.2	1	0.2	0	0	0	0
Refrigerator	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2
Sum		5.50		5.25		12.67		12.9		10.81		9.58		**15.1**		7.39

Table 2.4 Total Load per 3 BHK

Peak Requirement	**15.14**	**kW**
Villa diversity	0.85	
Peak villa load	12.87	kW
Diversity across different villas	0.8	
Average peak load per villa	10.297	kW
Average peak load per villa (rounded)	11	kW

Table 2.5 Typical (Major) Loads for 2 BHK

2 BHK			
	Nos	kW per Appliance	Total (kW)
Washing Machines	0	0.4	0
Water Heaters	1	3	3
TV	2	0.15	0.3
Toaster	1	1	1
Mixer	1	0.4	0.4
Microwave	1	1	1
Exhaust fan	3	0.1	0.3
Air-conditioners (1.5 Ton)	3	2.25	6.75
Electric Iron	1	1	1
Laptop Computer	1	0.1	0.1
Refrigerator	1	0.2	0.2
Lights	18	0.052	0.936
Fans	6	0.08	0.48
Garden Mower	0	0.2	0
Total			**15.5**

Table 2.6 Number of lights and fans in a 2 BHK setup

2 BHK				
Lights			**Fans**	
Room type	**Nos**		**Room type**	**Nos**
Bedrooms	4		Bedrooms	2
Hall	3		Hall	2
Kitchen	2		Kitchen	1
Store/Study	1		Store/Study	1
Porch	2		Porch	
Bathrooms	2		Bathrooms	
External	4			
	18			6

Table 2.7 Calculation of operating load on the basis of time and use model for a 2 BHK setup

Time ->	0 to 3		3 to 6		6 to 9		9 to 12		12 to 15		15 to 18		18 to 21		21-24	
Major Loads	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW
Water Heaters	0	0	0	0	1	3	1	3	0	0	0	0	1	3	0	0
TV	1	0.15	0	0	1	0.15	1	0.15	1	0.15	1	0.15	1	0.15	2	0.3
Toaster	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Light	4	0.208	4	0.208	6	0.312	7	0.364	7	0.364	12	0.624	15	0.78	15	0.78
Mixer	0	0	0	0	1	0.4	1	0.4	1	0.4	1	0.4	1	0.4	0	0
Microwave	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Domestic Fans	3	0.24	2	0.16	4	0.32	5	0.4	6	0.48	6	0.48	6	0.48	4	0.32
Exhaust fan	0	0	0	0	3	0.3	3	0.3	3	0.3	3	0.3	3	0.3	3	0.3
Air-conditioners	2	4.5	2	4.5	1	2.25	1	2.25	2	4.5	2	4.5	2	4.5	2	4.5
Electric Iron	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Laptop Computer	1	0.1	1	0.1	2	0.2	2	0.2	2	0.2	2	0.2	2	0.2	1	0.1
Garden Mower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2
Sum		5.398		5.168		10.132		10.26		9.594		9.854		13		7.5

Table 2.8 Total load per terrace house

Peak Requirement	13.01	kW
Apartment diversity	0.85	
Peak apartment load	11.06	kW
Diversity across different apartments	0.8	
Average peak load per apartment	8.84	kW
Average peak load per apartment (rounded)	9	kW

The maximum possible peak load based on load model is 13 kW for terrace houses and around 15kW for Villas. However, there will be two levels of diversity in this peak requirement. One comes from the usage pattern within the unit and the other comes from usage pattern across the units. Assuming load diversity to be 0.9 in the terrace houses and 0.85 within the villa, the load requirement per terrace house falls to 11.7 kW for terrace houses and 12.9 kW for villas. Assuming diversity across units to be around 0.8, the average peak load per terrace house will be 9.37 kW and 10.3 kW per villa. The load estimated per house in load application to MSEDCL is 8 kW, which is lower than either of these.

2.2.2 Review of other load calculations

Other loads are estimated as follows:

Table 2.9 Estimation of loads in common areas

Load Centre	Area (sqft)	W/sqft	Value	Unit
Club House	4000	8	32	kW
Load estimated for party area	2500	5	12.5	kW
Load estimated for swimming pool	-	-	5	kW
Load estimated for common area lighting	-	-	8	kW
Load estimated for pumping	-	-	15	kW

Light Load Estimation

For common area lighting, existing plan is as follows:

a) 81 nos. of 80 W Metal Halide lights atop 8m poles
b) 40 nos. of 36 W CFL lights atop 4m poles

These two types of lights will account for approximately 8 kW load in all

2.3 Review of transformer sizing:

As per above calculation, the load requirement will be as depicted on the next page

The revised calculation shows that transformer load will be around 840 kVA and to cater to this load, a transformer of around 1100 kVA would be required.

Since the estimated load is more than 500 kVA, the following options may now be considered:

1. A transformer or set of transformers be acquired to cater to the entire 1100 kW load.
2. Energy efficiency and renewable energy features be incorporated into the design to reduce the load requirement as far as possible, thereby:
   a. Reducing the size of any additional transformers needed to a minimum
   b. Ensuring that the need for an additional transformer occurs as far in the future as possible

Table 2.10 Total load estimations at the site level

Site Level Load Estimations								
Item	**Load per unit After Accounting for diversity (KW)**	**Number of units**	**Total load due to this unit type (KW)**	**Site Level Diversity**	**Total Load Contribution After Site Diversity (kw)**	**Power Factor**	**Load After Accounting for Power factor (kVA)**	**Transformer Load @ 80% Loading (kVA)**
Villas	11	58	638	0.7	446.6	0.9	496.22	620.28
Apartments	9	40	360	0.7	252	0.9	280	350.00
STP	10	1	10	0.7	7	0.9	7.78	9.72
Pumping	15	1	15	0.7	10.5	0.9	11.67	14.58
Club House	32	1	32	0.7	22.4	0.9	24.89	31.11
Swimming Pool	5	1	5	0.7	3.5	0.9	3.89	4.86
Party Area	12.5	1	12.5	0.7	8.75	0.9	9.72	12.15
Street Lighting - Wide road	0.03	81	2.43	1	2.43	0.9	2.70	3.38
Street Lighting - Arterial roads	0.04	40	1.44	1.00	1.44	0.90	1.60	2.00
Total					786.67		**843**	**1,048.08**

2.4 Review of renewable energy system (solar street-light)

'*Tattva*' is also planning to power all streetlights (40 nos. of 36 W CFLs for arterial roads and 81 nos. of 80 W Metal Halides for the main roads) by solar energy (photovoltaic energy). It is also the developer's intention that these be powered by solar energy with grid power acting as a back up in the absence of sunlight.

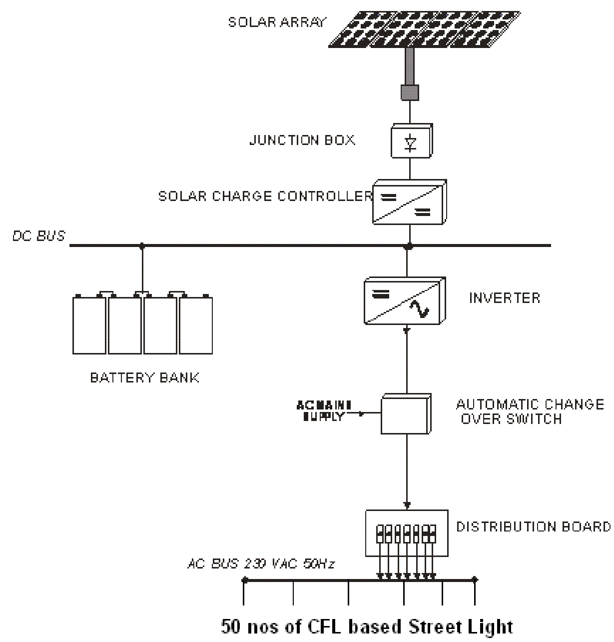


Figure 1. Schematic of the solar PV system for streetlights

The advantages of the proposed system are

a. **Hybrid mode:** The proposed system envisages having grid electricity as back-up, which would increase the systems reliability. Whenever solar energy is not available, especially during monsoon season, the grid electricity would power the street-lights.

b. **Centralized PV:** It is planned to have centralized photovoltaic (PV) panels, which would generate electricity to charge the battery and power the streetlights. Centralized PV panels are good choice if there are chances of shading on streetlight poles and standalone solar street-light becomes nonfunctional.

However the proposed system has several drawbacks also, which are mentioned as below:

a. **Reliability:** There is provision of grid electricity supply whenever solar energy is not available for longer periods. However during bad weather periods, especially in monsoon, when availability of both solar energy and grid electricity is unreliable, system may not function on few occasions. In order to improve the reliability, it is suggested to have a grid electricity back-up for inverter and battery system. The proposed change would ensure the charging of battery when solar light and grid electricity is available intermittently.

b. **Overdesigned back-up:** As mentioned already, the proposed system has grid electricity back-up also. In such scenario, battery back-up of two-days is redundant as grid electricity can power the street-lights whenever batteries are not charged. It is suggested to have one-day battery back-up instead of two. It would reduce the size of PV panel also and thus saving the capital cost.

c. **Use of LED instead of CFL:** The solar street light proposal envisages installing CFLs, however CFLs have less luminous efficacy than T5 and LED lights. Use of T5/LED would reduce the size of PV, battery and inverter system for a similar service quality and thus reduce the cost.

Chapter 3: Introduction of Renewable Energy Systems

Without the incorporation of renewable energy and energy efficiency features the load of the project will be far higher than 500 kVA. In this section, we will discuss renewable energy measures that can bring down the load.

3.1 Solar Water Heating System

To bring down the overall load from the grid through the renewable energy measures, it is suggested to install solar water heaters. In the proposed configuration, one solar water heater per house is suggested. The proposed system not only reduces the capital expenditure upfront but also brings down the annual operational cost for the project. The cost benefit analysis for the same is presented in the following table.

Table 3.1 Analysis of Solar Water Heater vs. an Electric Geyser

Item	Electric Geyser	Solar Water Heater	Unit
Capacity	125	125	LPD
Capital cost	4000	22500	Rs
Days of operation	300	240	Days
Electricity consumption for a day of functionality	3.23	0	kWh
Annual electricity usage (accounting for bad sunlight days also)	968	194	kWh
Electricity price per unit	5	5	Rs/kWh
Annual electricity cost	4,838	968	Rs
AMC cost @4%	160	900	Rs
Total operational cost	4,998	1,868	Rs

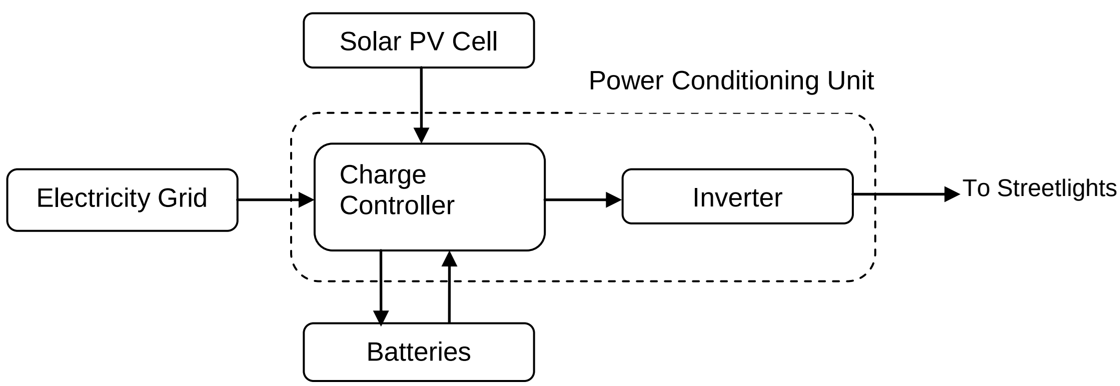
Table 3.2 Cost Benefit Analysis of Solar Water Heater vs. an Electric Geyser

Comparative Analysis		
Incremental capital cost due to SWH	18500	Rs
Avoided capital cost of transformer due to solar water heater	4,444	Rs
Net capital cost increase	14,056	Rs
Operational cost saving due to SWH	3,130.37	Rs
Payback	4.49	Yrs

3.2 Solar Street Light

Review of existing solar street light system has already been done in section 2.4. Following were the limitations of existing system.

a. **Reliability:** it is suggested to provide grid electricity charging for batteries to improve their reliability. Schematic diagram of proposed system is presented below:



b. **Overdesigned back-up:** With the grid electricity as backup option, two days storage capacity is redundant. It is suggested to have one day battery backup capacity. It would reduce (~ by 50%) required PV size also.

c. **Use of CFL instead of T5-FTL/LED:** Luminous efficacy of CFL is almost half of T-5 tube-lights or LED lights. Almost similar lux levels can be achieved by using 30 W LEDs (replacing 80W metal halides) for the main roads and 20 W LEDs (replacing 36 W CFLs) for the arterial roads. The overall power consumption of these lights will be significantly lower.

Chapter 4: Incorporation of Energy Efficiency Features

In this section, we will analyse energy efficiency measures that can bring down the load.

4.1 Energy Efficient Fans

Incorporation of energy efficient fans will reduce the average load per residential unit and thus reduce the overall load and transformer sizes. Cost benefit analysis for the same is provided below. Providing for energy efficient fans for each unit will reduce the operational cost and provide a payback period of around six months. The analysis for the same is provided in the table on the next page

The incorporation of energy efficient fans will bring down the transformer load by 10.25 kVA thereby reducing the capital expenditure to the developer by Rs.20,000. Moreover, since fans are part of the provided back up provided to the users, efficient fans will bring down the size of the backup provided.

Table 4.1 Cost Benefit Analysis for Energy Efficient Fans

	3BHK			2 BHK		
	Conventional Fans	Energy Efficient Fans		Conventional Fans	Energy Efficient Fans	
Particular	**Value**	**Value**	**Unit**	**Value**	**Value**	**Unit**
Number	7	7	Nos	6	6	Nos
Average operation hours	12	12	Hr	12	12	Hr
Wattage	80	50	W	80	50	W
Annual days of usage	150	150	Days	150	150	Days
Total annual energy use	1,008	630	kWh	864	540	kWh
Electriciy price	5.00	5.00	Rs/kWh	5.00	5.00	Rs/kWh
Total annual cost of electricity	5,040	3,150	Rs	4,320	2,700	Rs
Cost of fan	1,600	1,750	Rs/unit	1,600	1,750	Rs/unit
Capital cost	11,200	12,250	Rs	9,600	10,500	Rs
Total annual operational cost	5,040	3,150	Rs	4,320	2,700	Rs
Comparative Analysis						
Incremental capital cost		1,050	Rs		900	Rs
Reduction in operational cost		1,890	Rs		1,620	Rs
No of houses		58	Nos		40	Nos
Total operational cost reduction		109,620.00	Rs		64,800.00	Rs
Total kW saving per unit		0.2	kW		0.2	kW
Total kW saving		5.8	kW		3.6	kW
Transformer load reduction		6.44	kVA		4.03	kVA
Capital expenditure avoided due to transformer size reduction		12,884	Rs		8,064	Rs
Total incremental capital cost		60,900	Rs		36,000	Rs
Net Capital Expenditure Increase		48,016	Rs		27,936	Rs
Payback period		0.44	Yrs		0.44	Yrs

4.2 Energy Efficient Lights

Incorporation of energy efficient lights will also reduce the average load per unit and thus reduce the overall load and transformer sizes. Cost benefit analysis for the same is provided below. Providing for energy efficient lights for each unit will reduce the operational cost with a payback period of less than two years. The analysis for the same is provided in the table on the next page.

The incorporation of energy efficient lights will bring down the transformer load by 22.6 kVA, thereby reducing the capital expenditure to the developer by Rs. 45,000. Moreover, since lights are part of the provided back up provided to the users, efficient lights will bring down the size of the backup provided.

Table 4.2 Cost Benefit Analysis for Energy Efficient Lights

	3 BHK			2 BHK		
	T8 Lights	T5 Lights		T8 Lights	T5 Lights	
Particular	**Value**	**Value**	**Unit**	**Value**	**Value**	**Unit**
Number	21	21	Nos	18	18	Nos
Average operation hours	6	6	Hr/day	6	6	Hr/day
Wattage	52	30	W	52	30	W
Annual days of usage	150	150	Days/yr	150	150	Days/yr
Total annual energy use	983	567	kWh/year	842	486	kWh/year
Electricity price	5.00	5.00	Rs/kWh	5.00	5.00	Rs/kWh
Annual cost of electricity	4,914	2,835	Rs/year	4,212	2,430	Rs/year
Cost of lighting fixture and lamp	300	500	Rs/unit	300	500	Rs/unit
Cost of lamp	200	250	Rs/unit	200	250	Rs/unit
Capital cost	6,300	10,500	Rs	5,400	9,000	Rs
Life of the lamps	5,000	5,000	Hrs	5,000	5,000	Hrs
Replacement cost of lamps	36	45	Rs/yr	36	45	Rs/yr
Total annual operational cost	4,950	2,880	Rs	4,248	2,475	Rs
Comparative Analysis						
Incremental capital cost		4,200	Rs		3,600	Rs
Reduction in operational cost due to transformer size reduction		2,070	Rs/yr		1,773	Rs/yr
No of houses		58	Nos		40	Nos
Total operational cost reduction		120,060.00	Rs/Yr		70920	Rs/Yr
Total kW saving per house		0.5	kW		0.4	kW
Total kW saving		12.8	kW		8.0	kW
Transformer load reduction		14.2	kVA		8.9	kVA
Capital cost avoided		28,344	Rs		17,741	Rs
Total incremental capital cost		243,600	Rs		144,000	Rs
Net capital expenditure increase		215,255	Rs		126,259	Rs
Payback period		1.79	Yr		1.79	Yr

4.3 Energy Efficient Air-Conditioners

Similar to energy-efficient lights and fans, installation of energy efficient air-conditioners will further reduce the average load per unit and thus reduce the overall load and transformer sizes. Cost benefit analysis for the same is provided below. Providing for energy efficient air-conditioners for each unit will reduce the operational cost with a payback period of less than a year and a half. The analysis for the same is provided in the table on the next page.

Additionally, incorporation of energy efficient ACs will bring down the transformer load by 129 kVA, thereby reducing the capital expenditure to the developer by Rs. 2.57 Lakh.

Table 4.3 Cost Benefit Analysis for Energy Efficient ACs

	3 BHK			2 BHK		
	Conventional ACs	Energy Efficient ACs		Conventional ACs	Energy Efficient ACs	
Particular	**Value**	**Value**	**Unit**	**Value**	**Value**	**Unit**
Number	4	4	Nos	3	3	Nos
Average operation hours	6	6	Hr	6	6	Hr
Wattage	2,250	1,650	W	2,250	1,650	W
Annual days of usage	100	100	Days	100	100	Days
Total annual energy use	5,400	3,960	kWh	4,050	2,970	kWh
Electricity price	5.00	5.00	Rs/kWh	5.00	5.00	Rs/kWh
Total annual cost of electricity	27,000	19,800	Rs	20,250	14,850	Rs
Cost of air conditioner	19,000	22,000	Rs/unit	19,000	22,000	Rs/unit
Capital cost	76,000	88,000	Rs	57,000	66,000	Rs
Total annual operational cost	27,000	19,800	Rs	20,250	14,850	Rs
Comparative Analysis						
Incremental capital cost		12,000	Rs		9,000	Rs
Reduction in operational cost		7,200	Rs/yr		5,400	Rs/yr
No of houses		58	Nos		58	Nos
Total operational cost saving		417,600	Rs/yr		313,200	Rs/yr
Total capital investment		4,408,000	Rs		3,306,000	Rs
Total kW saving per unit		2.40	kW		1.80	kW
Saving in transformer load		73.62	kW		55.22	kW
Capital expenditure avoided due to transformer size reduction		147,242	Rs		110,432	Rs
Net capital expenditure increase		548,757	Rs		411,568	Rs
Payback period		1.31	Yr		1.31	Yr

4.4 Energy Efficiency in Street Lighting

The developer has planned to install 81 nos. of 80 W Metal Halide street lights atop 8m high poles along the main roads and 40 nos. 36 W CFL lights atop 4m high poles along the arterial roads. The measure explored is that these be replaced with 30 W and 20 W LEDs respectively. This measure will have a dual effect. It will

1. Reduce the development's energy consumption
2. This in turn will ensure that the Solar PV system being proposed to power (or battery and inverter set to backup) the street lights will also be of a significantly smaller size.

The table on shows that LED lights have a payback period of four years when compared to Metal Halides whereas they payback after nineteen years when compared to CFLs. Importantly, the combined payback due to replacement of all lights by LEDs is just around five years. Moreover, the impact of installing LED street lights is relatively small on the cost of each unit (Rs. 8,800 extra) and LEDs provide a significant reduction (4.7 kW on a base value of 8kW) in the power consumption due to street lights. They also have a much longer life (~ 11 yrs) compared to Metal Halides and CFLs which have a life of ~ 1 year.

The reduction in connected load due to efficient street lighting is calculated on the next page

Table 4.4 LED Cost Benefit Analysis

	LED vs. Metal Halide			LED vs. CFL		
	Metal Halide	LED	Unit	CFL	LED	Unit
Wattage	80	30	W	36	20	W
Number	81	81	Nos	40	40	Nos
Total wattage	6480	2430	W	1440	800	W
Cost per fixture	2000	9,750	Rs/piece	600	6,500	Rs/piece
Total cost of lights	162,000.00	789,750.00	Rs	24,000	260,000	Rs
Cost of lights per saleable unit	1,653.06	8,058.67	Rs	244.90	2,653.06	Rs
Energy use daily	77.76	29.16	kWh	17.28	9.6	kWh
Energy use annually	28,382	10,643	kWh	6,307	3,504	kWh
Price of electricity	5	5	Rs/kWh	5	5	Rs/kWh
Annual energy cost	141,912	53,217	Rs	31,536	17,520	Rs
Light life	1	11	Yr	1	11	Yr
Light replacement cost annually	141,912	69,182	Rs	21,024	22,776	Rs
Total operating cost	283,824	122,399	Rs	52,560	40,296	Rs
Comparative Analysis						
Incremental cost of LED lights		627,750.00	Rs		236,000	Rs
Capital expenditure avoided due to transformer size reduction		8100	Rs		1280	Rs
Net capital increment		619,650	Rs		234,720	Rs
Operating cost saving due to LED		161,425	Rs/yr		12,264	Rs/yr
Payback period		4	Yr		19	Yr

4.5 Combined Effect of Energy Efficiency Measures

We can now analyze the impact of all the energy efficiency measures as a whole. When solar water heaters and energy efficient fans, lights (including street lights) and ACs are installed, the load calculations will be as follows:

Table 4.5 Revised Typical (Major) Loads for 3 BHK

3 BHK			
	Nos	kW per Appliance	Total (kW)
Washing Machines	1	0.4	0.4
Water Heaters	1	1	1
TV	2	0.15	0.3
Toaster	1	1	1
Mixer	1	0.4	0.4
Microwave	1	1	1
Exhaust fan	4	0.1	0.4
Air-conditioners (1.5 Ton)	4	1.65	6.6
Electric Iron	1	1	1
Laptop Computer	1	0.1	0.1
Refrigerator	1	0.2	0.2
Lights	21	0.03	0.63
Fans	7	0.05	0.35
Garden Mower	1	0.2	0.2
Total			**13.6**

Table 4.6 Revised Calculation of Operating Load based on Time and Use Model for a 3 BHK setup

Villas - 3 BHK Calculation

Time ->	**0 to 3**		**3 to 6**		**6 to 9**		**9 to 12**		**12 to 15**		**15 to 18**		**18 to 21**		**21-24**	
Major Loads	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW
Washing Machines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Heaters	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0
TV	1	0.15	0	0	1	0.15	1	0.15	2	0.3	1	0.15	2	0.3	2	0.3
Toaster	0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0
Light	6	0.18	6	0.18	8	0.24	10	0.3	5	0.15	8	0.24	16	0.48	16	0.48
Mixer	0	0	0	0	1	0.4	1	0.4	1	0.4	1	0.4	1	0.4	0	0
Microwave	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Domestic Fans	3	0.15	3	0.15	5	0.25	5	0.25	5	0.25	2	0.1	2	0.1	2	0.1
Exhaust fan	0	0	0	0	4	0.4	4	0.4	2	0.2	1	0.1	3	0.3	3	0.3
Air-conditioners	2	3.3	2	3.3	2	3.3	2	3.3	3	4.95	3	4.95	3	4.95	2	3.3
Electric Iron	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0
Laptop Computer	1	0.1	0	0	2	0.2	2	0.2	1	0.1	2	0.2	2	0.2	1	0.1
Garden Mower	0	0	0	0	0	0	1	0.2	1	0.2	1	0.2	0	0	0	0
Refrigerator	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2
Sum		4.08		3.83		9.14		9.4		8.75		7.54		**10.9**		5.78

Table 4.7 Revised total load per villa

Peak Requirement	**10.93**	**kW**
Villa diversity	0.85	
Peak villa load	9.2905	kW
Diversity across different villas	0.8	
Average peak load per villa	7.4324	kW
Average peak load per villa (rounded)	8	kW

The maximum possible peak load based on revised load model will be around 11 kW. Accounting for the diversities within the villa and across the villas, the average peak load per villa comes to around 8 kW.

Table 4.8 Revised Typical (Major) Loads for 2 BHK

2 BHK			
	Nos	kW per Appliance	Total (kW)
Washing Machines	0	0.4	0
Water Heaters	1	1	1
TV	2	0.15	0.3
Toaster	1	1	1
Mixer	1	0.4	0.4
Microwave	1	1	1
Exhaust fan	3	0.1	0.3
Air-conditioners (1.5 Ton)	3	1.65	4.95
Electric Iron	1	1	1
Laptop Computer	1	0.1	0.1
Refrigerator	1	0.2	0.2
Lights	18	0.03	0.54
Fans	6	0.05	0.3
Garden Mower	0	0.2	0
Total			**11.1**

Table 4.9 Revised Calculation of Operating Load based on Time and Use Model for a 2 BHK Setup

Flats - 2 BHK Calculation

Time ->	**0 to 3**		**3 to 6**		**6 to 9**		**9 to 12**		**12 to 15**		**15 to 18**		**18 to 21**		**21-24**	
Major Loads	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW	No. ON	kW
Washing Machines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Heaters	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0
TV	1	0.15	0	0	1	0.15	1	0.15	1	0.15	1	0.15	1	0.15	2	0.3
Toaster	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Light	4	0.12	4	0.12	6	0.18	7	0.21	7	0.21	12	0.36	15	0.45	15	0.45
Mixer	0	0	0	0	1	0.4	1	0.4	1	0.4	1	0.4	1	0.4	0	0
Microwave	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Domestic Fans	3	0.15	2	0.1	4	0.2	5	0.25	6	0.3	6	0.3	6	0.3	4	0.2
Exhaust fan	0	0	0	0	3	0.3	3	0.3	3	0.3	3	0.3	3	0.3	3	0.3
Air-conditioners	2	3.3	2	3.3	1	1.65	1	1.65	2	3.3	2	3.3	2	3.3	2	3.3
Electric Iron	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Laptop Computer	1	0.1	1	0.1	2	0.2	2	0.2	2	0.2	2	0.2	2	0.2	1	0.1
Garden Mower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerator	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2
Sum		4.02		3.82		7.28		7.36		8.06		8.21		**9.3**		5.85

Table 4.10 Revised total load per terrace house

Peak Requirement	**9.3**	**kW**
Apartment diversity	0.85	
Peak apartment load	7.90	kW
Diversity across different apartments	0.8	
Average peak load per terrace house	6.32	kW
Average peak load per terrace house (rounded)	7	kW

The maximum possible peak load based on revised load model will be around 9 kW. Accounting for the diversities within the houses and across the houses, the average peak load per terrace house comes to around 7 kW.

Recalculating the transformer size required after these changes have been made (table on next page). From the table, it is clear that with the energy efficiency and renewable energy measures, the transformer size needed will go down from 1100 kVA to 800 kVA. The street lighting loads have been regarded as zero since it is proposed that they be run entirely on solar power with the grid acting only as a backup for those times of the year when sunlight is not available.

It is apparent from the table that despite the energy efficiency and renewable energy measures, a transformer of 500 kVA is still insufficient to cater to the entire load. Therefore, it is recommended that an additional transformer of 325 kVA be installed at a later date when the need for it arises.

Table 4.11 Revised load estimate at the site Level

Site Level Load Estimations								
Item	**Load per unit After Accounting for diversity (KW)**	**Number of units**	**Total load due to this unit type (KW)**	**Site Level Diversity**	**Total Load Contribution After Site Diversity (kw)**	**Power Factor**	**Load After Accounting for Power factor**	**Transformer Load @ 80% Loading**
Villas	8	58	464	0.7	325	0.9	361	451.11
Apartments	7	40	280	0.7	196	0.9	218	272.22
STP	10	1	10	0.7	7	0.9	8	9.72
Pumping	15	1	15	0.7	10.5	0.9	12	14.58
Club House	32	1	32	0.7	22.4	0.9	25	31.11
Swimming Pool	5	1	5	0.7	3.5	0.9	4	4.86
Party Area	12.5	1	12.5	0.7	8.8	0.9	10	12.15
Street Lighting - Wide road	0	81	0	1	0	0.9	0.00	0.00
Street Lighting - Arterial roads	0	40	0	1	0	0.9	0.00	0.00
Total					573		**637**	**796**

4.6 Energy Efficiency in Common Loads

Besides the overall load, Special emphasis should be laid on energy efficiency in common amenities and utilities. In view of this the following guidelines should be adopted

1. The transformer should be as per ECBC norms with expected allowable losses
2. Common area lighting and pumps should meet BEE energy efficiency criteria
3. For the on-grid common area and street lights, timers must be used to cut unnecessary usage.

4.5 Energy Efficiency Measures in Building Envelope Design

In addition to the energy efficiency measures in appliances, it is extremely useful to take advantage of various passive measures which reduce the heat load in the houses and hence reduce the amount of air conditioning needed to cool the houses. The following is a set of goals, which if followed in the construction of the building envelope, will affect a major energy saving.

1. 100% of the wall construction will have a U – Value (thermal performance indicator) of 1.25 W/sqmK. This can be achieved by providing polystyrene (EPS), 200 mm AAC blocks, air gap in the wall construction by way of rat trap type brick bonding or an assembly of 40mm ferro-cement + 40mm airgap + 40 mm ferro cement

2. 100% of the roof construction will have a U – Value (thermal performance indicator) of 0.5 W/sqmK. The roofing assembly for all the buildings should be designed for appropriate thermal insulation. As per the Energy Conservation Building Code of India the recommended U- Value for Warm and Humid locations is 0.5 W/sqmK. This can be achieved by many strategies such as the use of 2 inch thick expanded polystyrene (XPS) or provision of an air gap by way of hollow blocks or by 3 mm of Sunsulate insulation product.

3. 100% of the glazing will have a U – Value (thermal performance indicator) of 5 W/sqmK

4. 100% of the fenestration will have SHGC value (solar heat gain coefficient) of 0.38 (for window to wall ratio <20%) or 0.30 (for window to wall ratio 20-30%)

    - The U- value of the window glass needs to be 5.0 W/sqmK
    - The shading coefficient needs to lowest possible with a maximum of 0.86
    - The visible light transmission should be higher than 45

Chapter 5: Backup Power Strategy

Tattva is planning to back-up not only the common amenities and essential services, but also the residential units to a limited extent (around 1 fan and 2 lights per room).

Table 5.1 List of loads to be backed up

Load Center	Back Up	Total Power needed (kW)
Apartments - 2BHK	5 Lights 3 fans 1 Refrigerator	13
Villas - 3BHK	7 Lights 4 fans 1 Refrigerator	23.5
Club House	100% Backup	16
Swimming Pool	100% backup	5
Party Area	100% Backup	8.8
Street Lighting - Wide road	100% operation through solar PV	2.4
Street Lighting - Arterial roads	100% operation through solar PV	0.8
STP	100% Backup	10
Pumping	100% Backup	15

5.1 Option 1: Central Solar PV Farm + Diesel Generator

Under this option, it is suggested that the residential units and common amenities be backed up through a centralized solar PV. If required, the essential services (STP and Pumping) may be placed on a Diesel Generator (DG). The developer has already acquired a 75 kVA DG, which will suffice to backup the STP and Pumping systems which need 25 kW in all.

The solar PV system has been detailed on the next page.

Table 5.2 Calculation of Solar PV farm size

Load Center	Back Up	Backup Load per unit (kW)	Diversity	No Of Units	Total Power needed (kW)	Average running hours per day	Design Storag e for (days)	Total kWh storage needed	Correspond ing Panel Size (kWp)
Apartment - 2BHK	5 Lights 3 fans 1 Refrigerator	1	1	40	13	4	1	53	3
Villas - 3BHK	7 Lights 4 fans 1 refrigerator	1	1	58	24	4	1	94	6
Club House	100% Backup	32	1	1	16	4	1	64	14
Swimming Pool	100% backup	5	1	1	5	4	1	20	9
Party Area	100% Backup	13	1	1	9	4	1	35	8
Street Lights - Wide road	Continuous running on Solar	2	1	1	2	12	1	29	13
Street Lights - Arterial roads	Continuous running on Solar	1	1	1	1	12	1	10	4
Total					**70**			**305**	**58**

As can be seen in the table, a PV system of 58 kWp is required to cater to the entire load. The system has been sized keeping in mind that the street lights need to be used every day but the residential units will have heavy usage primarily during the weekend. This is premised on the assumption that being a second home or vacation home complex, the primary energy usage in residential units will occur on the weekends.

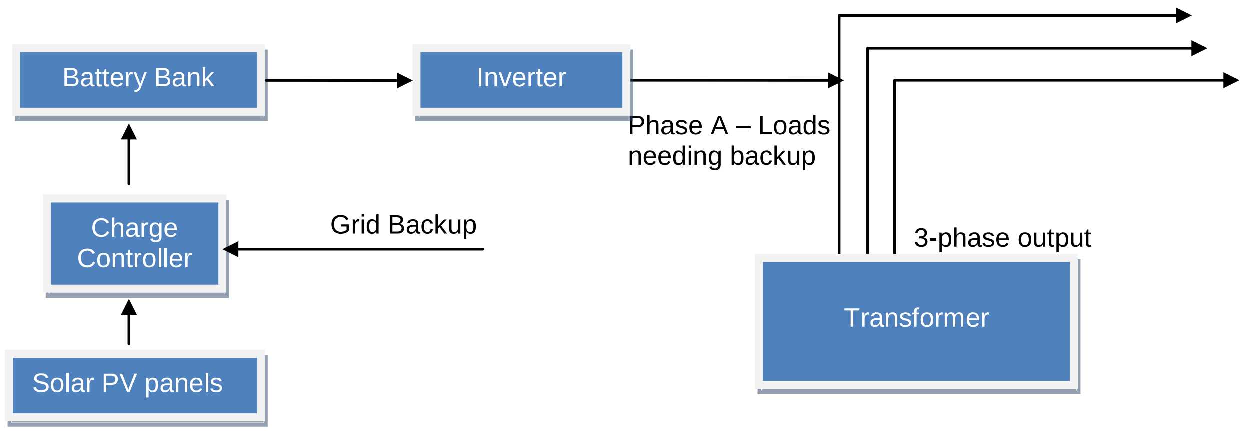


Fig 2. Schematic of Solar PV backup system

The cost and area needed for the Solar PV are detailed below:

Table 5.3 Details of PV farm

As depicted in the system diagram, the solar PV farm shall utilize a battery bank. This battery bank needs to be sized according to the storage requirements. An efficiency of 75% has been assumed for the batteries. From the table below, it is clear that we will need around 600 batteries of 150 Ah each.

PV Sizing		
PV kWp required	58	kWp
Area of PV farm	803	sqm
Cost of PV farm	17,283,796	Rs
Cost of 75 kVA DG set	900,000	Rs
Total cost per saleable unit	185,549	Rs
Subsidy (if available)	90	Rs/Wp
Total subsidy available	5,185,139	Rs
Subsidised cost of farm	12,998,657	Rs
Subsidised cost per house	132,639	Rs

Table 5.4 Battery Bank Sizing

Battery Bank Sizing		
Energy storage required	305.07	kWh
Efficiency of inverter	0.95	
Efficiency of batteries	0.75	
Total storage required	428	kVAh
Battery voltage	12	V
Ampere hours required	35,681	Ah
Battery capacity	150	Ah
Depth of discharge	40%	
Number of batteries required	595	Nos

The system diagram also depicts an inverter system. This inverter is sized in line with the peak power passing through it.

Table 5.5 Inverter Sizing

Inverter Sizing		
Peak power requirement through the solar farm	70	kW
Inverter efficiency	0.95	
Power requirement in kVA	73	kVA
Safety margin to cater to initial surge in power	1.5	times
Inverter size required	110	kVA

5.2 Option 2: 100% of all backup requirements are catered to by a Diesel Generator

This option explores the possibility of a single large diesel generator catering to the backup requirements of the entire development. The scenario is analysed on the next page.

It needs to be noted that if diesel generator is the only form of backup provided then the street lights will run on grid power during the hours when grid power is available and use the diesel generator only during power cuts.

Table 5.6 Diesel Generator Backup Requirement

Load Center	Back Up	Backup Load per unit (kW)	Diversity	No Of Units	Total Power needed (kW)	Backup running hours per day
Apartment - 2BHK	5 Lights 3 fans 1 Refrigerator	0.50	0.67	40	13	4
Villas - 3BHK	7 Lights 4 fans 1 refrigerator	0.61	0.67	58	24	4
Club House	100% Backup	32.00	0.50	1	16	4
Swimming Pool	100% backup	5.00	1.00	1	5	4
Party Area	100% Backup	12.50	0.70	1	9	4
Street Lights - Wide road	100% Backup	2.43	1.00	1	2	4
Street Lights - Arterial roads	100% Backup	0.80	1.00	1	1	4
Total					**70**	

Table 5.7 Diesel Generator Sizing

Diesel Generator Sizing		
Power requirement	70	kW
Power factor	0.8	Lag
Diesel generator size required	87	kVA
Cost of diesel generator*	1,047,116	Rs
Capital cost per unit	10,685	Rs
Efficiency of generation	3	kWh/litre of diesel
Daily hours of operation	4	Hr
Energy requirement per day	86	kWh
Fuel requirement per day	29	lit
Price of diesel	40	Rs/lit
Daily fuel cost	1,151	Rs
Annual fuel cost	420,098	Rs
AMC	52,356	Rs
Total annual operating cost	472,454	Rs
Operating cost per villa	5,204	Rs/yr
Operating Cost Per Terrace House	4,266	Rs/yr

**Of this, around Rs. 9 Lakh would have already been spent on the 75 kVA diesel generator*

5.3 Option 3: Common amenities backed up by a diesel generator and houses have individual inverters

This option explores the possibility of having a common diesel generator to cater to the common amenity loads while the individual units are backed up by personal inverter cum battery systems. The scenario is analysed below.

Table 5.8 Loads catered by common DG

Club House	100% Backup	32.00	0.50	1.00	16	4
Swimming Pool	100% backup	5.00	1.00	1.00	5	4
Party Area	100% Backup	12.50	0.70	1.00	9	4
Street Lighting - Wide road	100% Backup	2.43	1.00	1.00	2	4
Street Lighting - Arterial roads	100% Backup	0.80	1.00	1.00	1	4
Total					**33**	

Table 5.9 Common DG sizing

Diesel Generator Sizing		
Power requirement	33	kW
Power factor	0.8	Lag
Diesel generator size required	41	kVA
Cost of diesel generator*	900,000	Rs
Capital cost per residential unit	9,184	Rs
Efficiency of generation	3	kWh/litre of diesel
Daily hours of operation	4	Hr
Average energy requirement per day	82	kWh
Average fuel requirement per day	27	lit
Price of diesel	40	Rs/lit
Average daily fuel cost	1,099	Rs
Annual fuel cost	401,111	Rs
AMC	45,000	Rs
Total annual operating cost	446,111	Rs
Operating cost per villa	4,552	Rs/yr
Operating cost per terrace house	4,552	Rs/yr

**This is the cost of the 75 kVA diesel generator which has already been purchased*

Table 5.10 Inverter sizing for individual houses

Inverters - 1 per House			
	Villa	Terrace House	Unit
Power requirement	0.61	0.50	Kw
Power factor	0.80	0.80	Lag
Total power required	762.50	625.00	VA
Inverter size recommended	800.00	800.00	VA
Hours of backup per day	4.00	4.00	Hr
Storage required	3,050	2,500	Vah
Battery voltage	12.00	12.00	V
Battery capacity	150	150	Ah
Depth of discharge	0.50	0.50	
Batteries required	4	3	Nos
Inverter cost	4,250	4,250	Rs
Battery price	7,500	7,500	Rs/Battery
Total battery cost	30,000	22,500	Rs
Cost of system	34,250	26,750	Rs
Battery life	4	4	Yr
Annual battery replacement cost	7500	5625	Rs
Annual energy consumption due to battery charging	178	104	kWh
Electricity price	5	5	Rs/kWh
Annual energy cost	890	520	Rs
Total annual operating cost	8,390	6145	Rs

Table 5.11 Overall cost impact on houses

Overall Cost For Houses			
	Villas	Terrace Houses	
Capital cost upfront	43,434	35,934	Rs
Annual operating cost	12,943	10,697	Rs

5.4 Comparison of Different Backup Options

The following table compares the capital costs and operating costs of each of the backup options per house.

Table 5.12 Comparison of costs per house for different backup options

	Villas		Terrace Houses	
	Capital cost	Operating cost	Capital cost	Operating cost
Solar PV	185,549	6,451	185,549	6,451
100% DG	10,685	5,685	10,685	4,747
DG + Inverter	43,434	13,424	35,934	11,178

Chapter 6: Conclusions

After reviewing the various aspects of the electrical infrastructure, each element is summarized along with our recommendations below.

6.1 Load estimation and transformer sizing

After reviewing the load calculations and transformer sizing, it was concluded that in the current scenario, the transformer requirement was around 1100 kVA, implying that the proposed 500 kVA would be insufficient to cater to the entire load from the development. After incorporating numerous energy efficiency measures and renewable energy technologies, the overall expected demand was brought down to around 800 kVA. This in turn, means that the 500 kVA transformer is insufficient despite energy efficiency and renewable energy measures. Thus it is recommended that the developer install another transformer of around 325 kVA in addition to the current 500 kVA.

6.2 Energy Efficiency Measures

Through our calculations, we have analysed various energy efficiency measures namely efficient lights (T-5), fans and ACs (BEE 3 star) for the residential units and street lights for the common areas. For the residential appliances, the payback periods have been extremely good i.e. all of them are less than two years. For the street lights, the payback period is slightly higher, around five years, but is still very lucrative. Additionally, the LED street lights suggested have additional benefits in terms of longer life and a significant reduction in size of solar PV system needed to power them.

In light of the above, it is recommended that energy efficient lights, fans and ACs be installed in individual houses and that LED street lights be used for road lighting. The installation of energy efficient lights, fans and ACs will be easily possible for those houses where the interiors are being done by the developer's team itself. However, in houses which the interiors are not being done by the developer, it is important to create a scheme where the appliances chosen are energy efficient. This may be done through a contractual or incentive based process.

6.3 Renewable Energy Technologies

The options to get hot water entirely from solar water heaters have been explored. The solar water heaters pay back in less than five years and hence we strongly recommend their installation enmasse.

After analyzing the backup requirements, the second and third options for backup (100% diesel generator and diesel generator plus household inverter) seem more lucrative than the solar option. However both are very low on sustainability and create considerable emissions through the use of a diesel generator and greater grid power than the solar option. They have other negatives as well. Firstly, they do not affect a reduction in transformer size while the solar option does. Moreover, the ever increasing price of diesel and electricity ensures that they will be progressively more expensive to operate.

The option to power street lights entirely on and providing backup to houses and common amenities using Solar PV has also been analysed. While this may seem like a far less lucrative option, its benefits need to be looked at more holistically. First, the cost impact of the farm per saleable unit is quite small compared to the overall sale price, less than Rs. 2 Lakh per house. Secondly, being a very visible and significant sustainability initiative, it strongly affirms the commitment of the developer towards a sustainable neighbourhood. Thirdly, the solar PV farm reduces the transformer size required and eliminates the requirement for a new diesel generator (in addition to the 75 kVA DG already purchased). Finally, post the initial investment (which may well be borne by the buyers), the solar farm reduces electricity costs in as far as replacing grid electricity for street lights and reduces fuel cost in as far as eliminating diesel costs for the diesel generator.

Hence, we recommend the installation of a solar PV farm serving as the primary source of power for street lights and as a source of backup for the residential units and common amenities. The recommendation is despite the financial unattractiveness since the initiative entails a small cost per end user and a clearly visible sustainability initiative.