National Institute Of Science Education
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Environment and Economic Impact Assessment on Electricity Consumption

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INTRODUCTION

The changes brought about by previous civilisations were sometimes large but occurred very slowly so there was time to assess them. The environmental impacts of their actions also tended to be localised and limited in impact. Today it is possible to pollute whole oceans and even the earth's atmosphere with materials that will persist long into the future.

Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse, to facilitate collection of environmental data and preparation of management plans, guidelines have been evolved and circulated to the concerned Central and State Government Departments. EIA has now been made mandatory under the Environmental (Protection) Act, 1986 for 29 categories of developmental activities involving investments of Rs. 50 crores and above.

The aim of Environmental Impact Assessment is to protect the environment by ensuring that a local planning authority when deciding whether to grant planning permission for a project, which is likely to have significant effects on the environment, does so in the full knowledge of the likely significant effects, and takes this into account in the decision making process. It also ensures that the public are given early and effective opportunities to participate in the decision making procedures.

METHODOLOGY

Since **NISER** is an 850 crores campus, EIA for this campus is of paramount importance. In our project, we focussed only on the EIA due to electricity consumption. We have discussed the rules and regulations that concern electricity consumption and saving. Then, the consumption details of NISER is discussed along with their economic implications. Further, the future estimates of consumption have been analysed from both economic and environmental standpoints. Finally, we have discussed in details various alternatives and their economic and environmental viability in NISER.

*We have used the data from **NISER Works' Department** and adjusted all the rates for future inflation, thereby deducing the costs.*

1. Rules and Regulations regarding energy conservation
2. Current scenario in **NISER**
3. Future estimates and analysis of cost in **NISER**
4. Environmental impact of electricity usage at **NISER**
5. Conservation of Electrical energy and alternative energy resources

RULES AND REGULATIONS REGARDING ENERGY CONSERVATION

The Energy Conservation Act was enacted on 1st October, 2001 with the objective of providing necessary legal framework for promoting energy conservation measures in the country, and Bureau of Energy Efficiency (BEE) was created under its provision. The act provides a policy framework and direction to national energy conservation activities. It aims to coordinate policies and programs on efficient use of energy with stakeholders, establish systems and procedures to verify, measure and monitor EE improvements, leverage multilateral, bilateral and private sector support to implement the EC Act and demonstrate EE delivery systems through public-private partnerships.

Some of the important features of Energy Conservation Act are Energy Conservation Building Code (ECBC), Standard & Labeling, Demand Side Management (DSM), Bachat Lamp Yojana (BLY), Promoting Energy Efficiency in Small & Medium Enterprise (SMEs) and certification of Energy Managers & Energy Auditors etc. There are provisions for minimum energy consumption and performance standards for notified equipment & appliances (e.g: BEE rating), and prohibit non-conforming goods. According to Energy Conservation Building Codes (ECBC) is mandatory for commercial buildings having connected load of $\geqslant$ 500KW or contract demand of $\geqslant$ 600 KVA or air-conditioned area of $\geqslant$ 1000 sq.mt. Energy Conservation Fund has also been set up for promotion of Energy Service Companies, Research & Development demonstration, creation of testing facilities and awareness creation.

The Role of BEE is to prepare standards and labels of appliances and equipment, develop a list of designated consumer, specify certification and accreditation procedure, preparing building codes, maintain central EC fund, and undertake promotional activities in co-ordination with central and state level agency.

Central Government notifies rules and regulation under various provisions of the ACT, provides initial financial assistance to BEE and EC fund , coordinates with various State Government for notification, and decides penalties and adjudication. State government can amend ECBC to suit the regional and local climatic condition, designate state level agency to coordinate, regulate and enforce provisions of the ACT and constitute a state Energy Conservation Fund for promotion of energy efficiency. Non-Compliance by a person can amount not exceeding Rs.10,00,000/- for each offense. On continuous non – compliance an additional penalty up to Rs.10000/- per day.

In addition to the Act, there are a number of initiatives adopted by the Government to reduce electricity usage and environmental detriment. Some of these schemes are UJALA (Unnat Jyoti by Affordable LEDs for All), under which around 10,21,04,276 numbers of LEDs have been distributed, saving 3,63,28,701 KWh of energy per day, thereby reducing 29,426 ton of CO_2 emission per day; Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY), which has electrified 98.1% of villages, with preference to non-conventional sources. [1] Rs. 21.73 Crore has been sanctioned for "Green Cities" project, which seeks to promote solar energy in 55 cities across India. [2]

CURRENT SCENARIO

We have evaluated the economic implications of the current elctricity consumptions based on the data from the monthly elctricity bills of NISER for 3 months(containing 9 months' data from April 2015 to December 2015).

We wanted to have a complete idea of the exact way in which electricity consumption charges are applied for NISER. This required some understanding of a few concepts that will be elucidated first.

[1] http://www.powermin.nic.in
[2] http://mnre.gov.in/schemes/decentralized-systems/solar-cities/

What are we paying for?

The electricity chrages can be classified into three separate heads viz:

1. **TOTAL ACTIVE ENERGY CONSUMPTION:** This is the total energy expended by the institute over a month and measured in units of kWh. The energy meter is installed at a central location from where the power is distributed to various parts of NISER.Total cost due to energy consumption is calculated based on a slabwise standard rate system fixed by the electricity supply board.

2. **MAXIMUM DEMAND POWER(active)**: This is the maximum power utilisation of the institute as recored over a month's duration and measured in units of kW.If the actual MD crosses the earlier Contracted MD, then extra charges are imposed on the difference. If actual MD comes out to be less than contracted, rebate is given with rate fixed by the concerned electricity supply board.

3. **POWER FACTOR**: This is a measure of the wastage of the total supplied power as reactive power(unusable form). It takes a value between 0 to 1 and closer it is to 1, the better is this wastage controlled.
   The charges on power factor are a little different. It is not a standard charge, but imposed on the basis of % change in PF over a month.
   As of April 2015, Odisha Electricity Regulatory Commission has revised the retail supply tariff system. It has the following ponits on power factor charges:

(xv) Power factor penalty shall be

i) 0.5% for every 1% fall from 92% upto and including 70% plus

ii) 1% for every 1% fall below 70% upto and including 30% plus

iii) 2% for every 1% fall below 30%

The penalty shall be on the monthly demand charges and energy charges

There shall not be any power factor penalty for leading power factor. (Please see the detailed order for the category of consumers on whom power factor penalty shall be levied.)

(xvi) The power factor incentive shall be applicable to the consumers who pay power factor penalty in the following rate:

The rate of power factor incentive shall be 0.5% for every 1% rise above the PF of 97% up to and including 100% on the monthly demand charges and energy charges.

Figure 1: Excerpt from CESU Tariff Notification Document dated 23.03.2015

RETAIL SUPPLY TARIFF EFFECTIVE FROM 1ST APRIL, 2015

Sl. No.	Category of Consumers	Voltage of Supply	Demand Charge (Rs./KW/ Month)/ (Rs./KVA/ Month)	Energy Charge (P/kWh)	Customer Service Charge (Rs./Month)	Monthly Minimum Fixed Charge for first KW or part (Rs.)	Monthly Fixed Charge for any additional KW or part (Rs.)	Rebate (P/kWh)/ DPS
	LT Category							
1	Domestic							
1.a	Kutir Jyoti <= 30 Units/month	LT	FIXED MONTHLY CHARGE-->			80		
1.b	Others							10
	(Consumption <= 50 units/month)	LT		**250.00**		20	20	
	(Consumption >50, <=200 units/month)	LT		**420.00**				
	(Consumption >200, <=400 units/month)	LT		**520.00**				
	Consumption >400 units/month)	LT		**560.00**				
2	General Purpose < 110 KVA							10
	Consumption <=100 units/month	LT		**530.00**		30	30	
	Consumption >100, <=300 units/month	LT		**640.00**				
	(Consumption >300 units/month)	LT		**700.00**				
3	Irrigation Pumping and Agriculture	LT		**150.00**		20	10	10
4	Allied Agricultural Activities	LT		**160.00**		20	10	10
5	Allied Agro-Industrial Activities	LT		**420.00**		80	50	DPS/Rebate
6	Public Lighting	LT		**560.00**		20	15	DPS/Rebate
7	L.T. Industrial (S) Supply <22 KVA	LT		**560.00**		80	35	10
8	L.T. Industrial (M) Supply >=22 KVA <110 KVA	LT		**560.00**		100	80	DPS/Rebate
9	Specified Public Purpose	LT		**560.00**		50	50	DPS/Rebate
10	Public Water Works and Sewerage Pumping <110 KVA	LT		**560.00**		50	50	10
11	Public Water Works and Sewerage Pumping >=110 KVA	LT	200	**560.00**	30			10
12	General Purpose >= 110 KVA	LT	200	**560.00**	30			DPS/Rebate
13	Large Industry	LT	200	**560.00**	30			DPS/Rebate
	HT Category							
14	Bulk Supply - Domestic	HT	20	**430.00**	250			10
15	Irrigation Pumping and Agriculture	HT	30	**140.00**	250			10
16	Allied Agricultural Activities	HT	30	**150.00**	250			10
17	Allied Agro-Industrial Activities	HT	50	**410.00**	250			DPS/Rebate
18	Specified Public Purpose	HT	250	**As indicated in the notes below**	250			DPS/Rebate
19	General Purpose >70 KVA < 110 KVA	HT	250		250			10
20	H.T Industrial (M) Supply	HT	150		250			DPS/Rebate
21	General Purpose >= 110 KVA	HT	250		250			DPS/Rebate
22	Public Water Works & Sewerage Pumping	HT	250		250			10
23	Large Industry	HT	250		250			DPS/Rebate
24	Power Intensive Industry	HT	250		250			DPS/Rebate
25	Mini Steel Plant	HT	250		250			DPS/Rebate
26	Railway Traction	HT	250		250			DPS/Rebate
27	Emergency Supply to CGP	HT	0	**720.00**	250			DPS/Rebate
28	Colony Consumption	HT	0	**470.00**	0			DPS/Rebate
	EHT Category							
29	General Purpose	EHT	250	**As indicated in the notes below**	700			DPS/Rebate
30	Large Industry	EHT	250		700			DPS/Rebate
31	Railway Traction	EHT	250		700			DPS/Rebate
32	Heavy Industry	EHT	250		700			DPS/Rebate
33	Power Intensive Industry	EHT	250		700			DPS/Rebate
34	Mini Steel Plant	EHT	250		700			DPS/Rebate
35	Emergency Supply to CGP	EHT	0	**710.00**	700			DPS/Rebate
36	Colony Consumption	EHT	0	**460.00**	0			DPS/Rebate

Figure 2: The Tariff System,laid down by Odisha Electricity Regulatory Commission as of 23.03.2015

The following schematic gives a mathematical description of power factor.

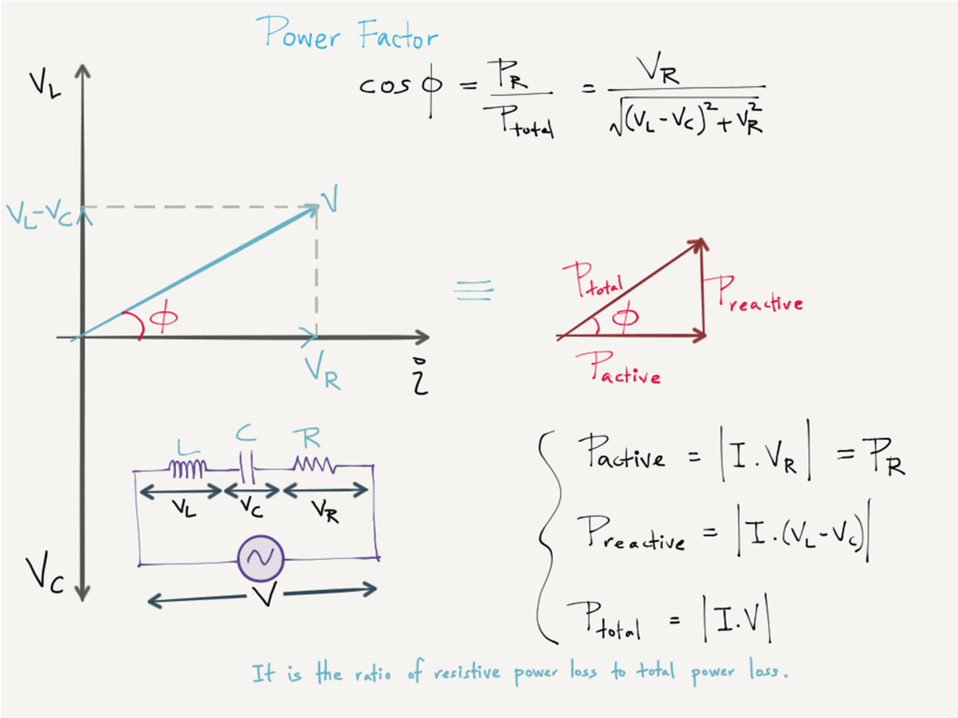

Figure 3: Power Factor Schematic

ELECTRICITY DISTRIBUTION IN NISER

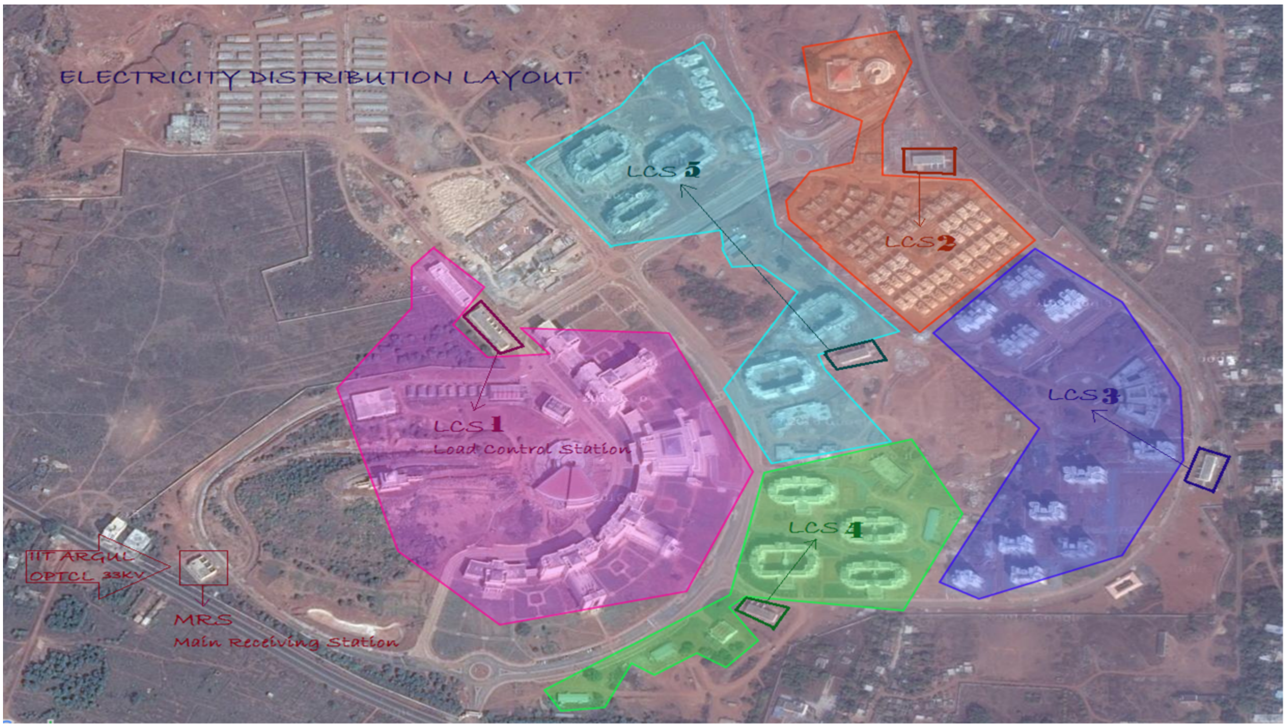

Figure 4: Power Distribution Layout in **NISER**

HOW GOOD ARE NISER'S CURRENT FIGURES?

From the monthly electricity bills, we found that:

- RATE FOR ENERGY CHARGES: ₹5.25 per kWh.
- RATE FOR POWER CHARGES: ₹250 per kW.

Table 1: DATA FROM MONTHLY ELECTRICITY BILLS

Month	kWh Consumed(active)	Cost of Energy Consumption(in ₹)=Units × Rate
Apr-15	6	31.5
May-15	11394	59818.5
Jun-15	220200	1156050
Jul-15	158400	831600
Aug-15	312000	1638000
Sep-15	395400	2075850
Oct-15	398130	2090182.5
Nov-15	398640	2092860
Dec-15	401400	2107350

Table 2: DATA FROM MONTHLY ELECTRICITY BILLS

Month	Actual MD(in kW)	Contracted MD(in kW)	Cost of power consumption(in ₹)=Units × Rate
Oct-15	1500	1800	375000
Nov-15	1500	1800	375000
Dec-15	1440	1800	360000

Table 3: DATA FROM MONTHLY ELECTRICITY BILLS

Month	Power Factor(PF)
Oct-15	0.9203
Nov-15	0.9294
Dec-15	0.9383

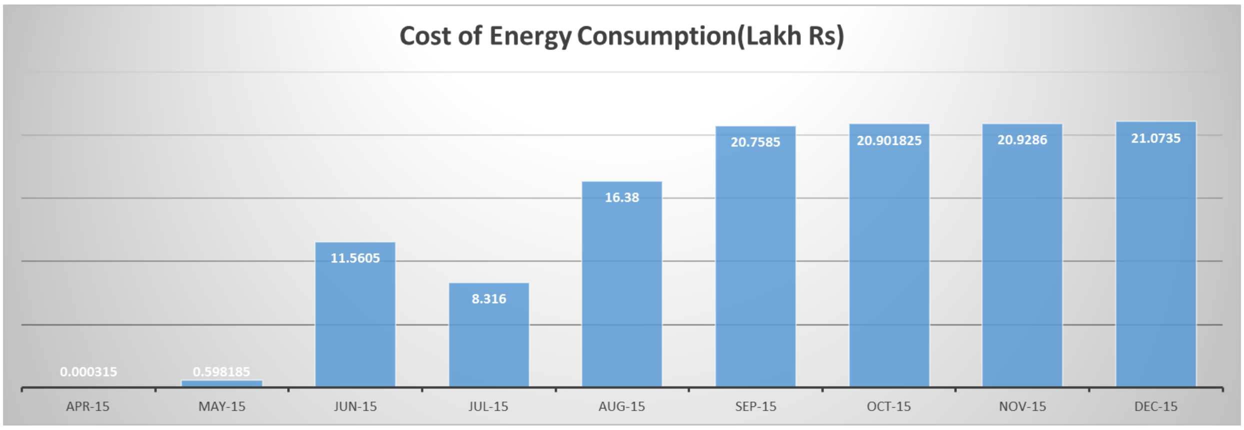

Figure 5: Consumption Pattern of Energy in NISER

ANALYSIS OF THE DATA AND COMMENTS ON EXISTING CONDITIONS

(a) **Actual MD is well below Contracted MD**(1800 kW). This means that the power consumption i.e. energy consumption per unit time is under control.

(b) The power factor has increased by **0.98 % from October to November,2015** and thereafter by **0.96 % from November to December,2015**. This is excellent sign of the fact that the **transmission losses are being minimzed and quality of transformers are being improved**.This reduces loss of energy in in the form of reactive power.
In fact ,if we can reach the 0.97 value and still continue to increase PF at rate of 1 % **NISER can get incentives on both power and energy charges**.

(c) The consumption of energy units per month is around **4 lakh kWh** at the current operational conditions. It is sure to increase in future.Among others ,whole residential areas are going to be fully operational.

(d) Apart from power and energy charges, there are two other charges of significant amount that contriubte to the total bill:

- **ELECTRICITY DUTY**:

  2. The Electricity Duty levied by the Govt. of Odisha under the Odisha Electricity (Duty) Act, 1961 and any other statutory levy/duty/tax/cess/toll imposed under any law from time to time shall be charged, over and above the tariff payable by the consumers in accordance with the law.

  Figure 6: Excerpt from CESU Tariff Notification Document dated 23.03.2015

  For NISER the duty amount was(data from months Oct,Nov,Dec 2015): **₹ 1,60,000**

- **TOD INCENTIVE**:

  The TOD rate charges a premium for electricity during periods of high demand on the electrical system, and offers a discount rate during off-peak hours. TOD allows the customer the choice of when to use electricity to do everyday tasks. The rate incentive encourages the customer to do their tasks, such as water heating, laundry, cooking, etc., during the off-peak, lower rate periods, with the reward being a lower monthly electric bill.

  (xii) Drawal by the industries during off-peak hours upto 120% of Contract Demand without levy of any penalty has been allowed. "Off-peak hours" for the purpose of tariff is defined as from **12 Midnight to 6.00 A.M.** of the next day. The consumers who draw beyond their contract demand during hours other than the off-peak hours shall not be eligible for this benefit. If the drawal in the off peak hours exceeds 120% of the contract demand, overdrawal penalty shall be charged over and above the 120% of contract demand. When Statutory Load Regulation is imposed then restricted demand shall be treated as contract demand.

  Figure 7: Excerpt from CESU Tariff Notification Document dated 23.03.2015

  For NISER the TOD Incentives for 3 months are as follows:

Table 4: DATA FROM MONTHLY ELECTRICITY BILLS

Month	TOD Incentive(in ₹)
Oct-15	2940
Nov-15	27060
Dec-15	14880

So in this front as well **NISER seems to be doing well, by reducing pressure on power during peak hours**.

FUTURE ESTIMATIONS AND ANALYSIS OF COST

In this section, We provide future estimates for:

- **Power Estimates**
- **Energy Estimates**
- **Cost Estimates**

Power Estimates:

Here, we present the estimated power that will be consumed when the NISER Campus will be fully functional.[3]

Table 5: **Normal Supply and Emergency Supply** Data for various Buildings:

Buildings Normal Supply	**C.L** (kW)	**M.D** (kW)	**Buildings** Emergency Supply	**C.L** (kW)	**M.D** (kW)
Admin	200	160	Admin	80	70
Chemistry	520	207	Chemistry	725	388
Biology	290	133	Biology	196	92
Library	262	132	Library	345	197
Physics	330	137	Physics	28	17
Maths	526	273	Maths	232	152
SOHs	660	595	SOHs	275	250
DOHs	456	408	DOHs	212	188
A	838	410	A	60	46
B	978	480	B	60	48
C	1150	564	C	58	48
D	2680	1400	D	120	100
Flats	235	115	Flats	30	24
SUM	**9125**	**5014**	Street Lights	200	99
			Green House	120	42
			SUM	**2741**	**1761**

Here,
$\Longrightarrow$ **C.L : Connected Load**
$\Longrightarrow$ **M.D : Maximum Demand**

$$\text{Total Future M.D Power} = 5014 + 1761 = \ \mathbf{6775} \ kW$$

We can see that a huge percentage of power $\approx$ **64 %** is consumed by the A,B,C,D and E type buidings. These bulidings are not fully functional now, but will be in the future and thus will form a major part on the cost of consumption as we will see further. This is illustrated in the pie chart:

[3] `Source:`NISER Works Department.

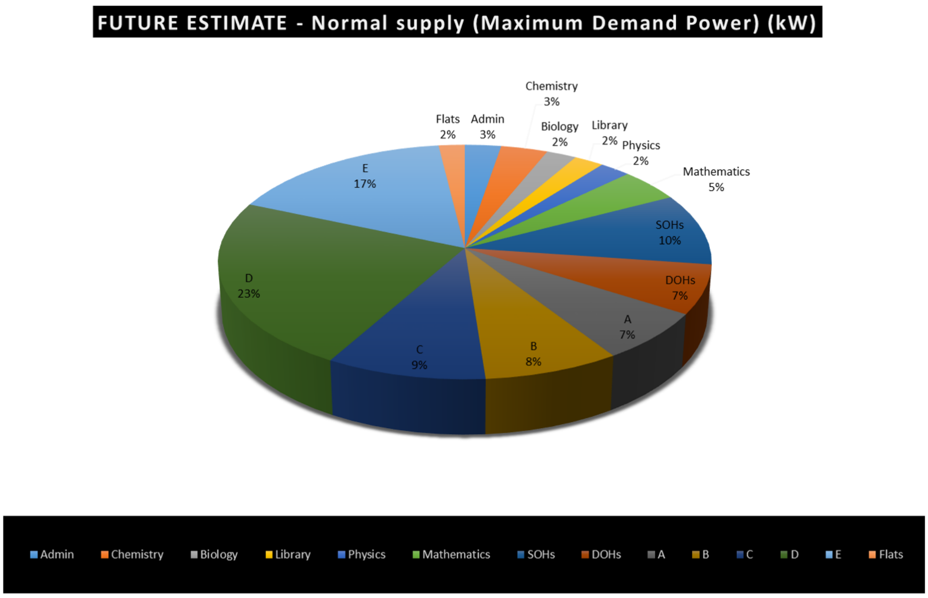

Figure 8: Future Estimate of M.D. for Normal Supply

Bar Graphs of Power Supply:

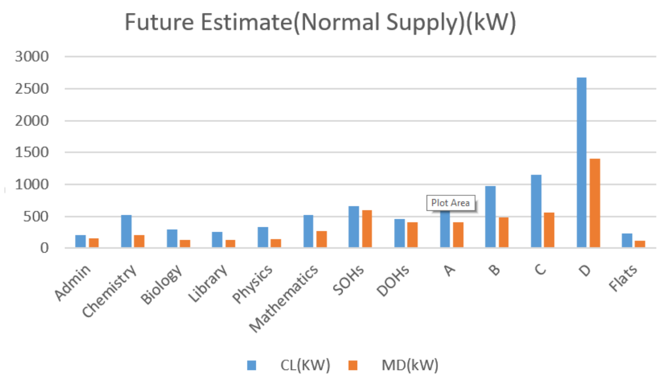

Figure 9: Bar graph of C.L and M.D for Normal Supply

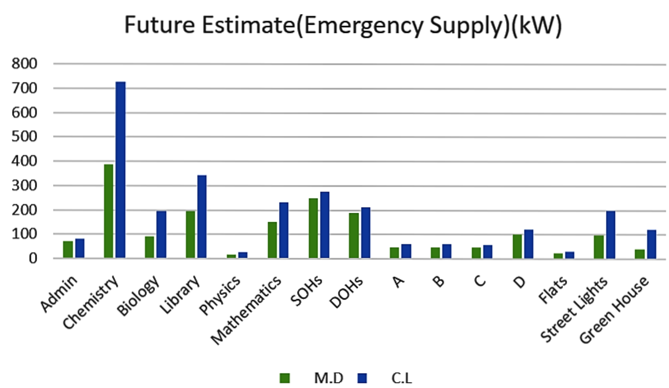

Figure 10: Bar graph of C.L and M.D for Normal Supply

ENERGY ESTIMATES:

We make estimations of future consumption of Energy Units using the data obatained from the electricity bills of NISER for the months of October, November and December 2015.
We know that

$$\text{Power} = \frac{\text{Energy Units Consumed}}{\text{Time of Consumption}}$$

Here we have the data for the Energy Units units consumed and M.D Power required as follows

Table 6: Estimation of Energy units consumed at full functionality of campus

Month	Energy Consumed (kWH)	Hours at MD power. $T_m = E/P_{M.D}$ (hr.)	Days $T_m/24$ (day)	Future Enrgy units(kWH) $E_F = P(M.D)_{total}.T_m$ (kWH)	Increased Folds E_F/E
Oct-15	398130	265.42	11.05917	1798220.5	4.516667
Nov-15	398640	265.76	11.07333	1800524	4.516667
Dec-15	401400	278.75	11.61458	1888531.25	4.704861
Avg:	**399390**	**269.9767**	**11.24903**	**1829091.917**	**4.579398**

Time at M.D power consumption(T_m):

Here we define a quantity called Time at M.D power consumption(T_m). This means that the time(in hours) when the system is operating at the *Maximum Demand Power*.

$$\mathbf{T_m} = \frac{\textbf{Energy Consumed}}{\textbf{Power at Maximum Demand}}$$

This means that if the system is operating continuously at a constant power consumption , then T_m will the time required for it to consume the given quantity of the Energy units.

Example(See table 6) For NISER, The $T_m \approx 267$ hrs. i.e. ≈ 11.25 days.This means that when the campus will operate at maximum power for 11.25 days continuously and stay in Blackout for the remaining days of the month, The Energy Units consumed(in kWH) will be same as in Normal Mode of Operation

Future Energy Units($\mathbf{E_F}$) :

Once we get the time of consumption at M.D (T_m), We obtain the Future Energy Units as follows:

$$\mathbf{E_F(\textbf{Future Energy Units}) = \textbf{Future M.D power} \times T_m}$$

We have, **Future M.D Power= 6775 kW** (See Table.5)

Thus , we obtain the Future Energy Estimates as given in the table.6 We observe that the future Energy Consumption increased approximately 4.6 folds as compared to present.

Future M.D Cost Estimates :

- Rate of per unit of Power consumption(kW)= ₹ 250
- Rate of per unit of Power consumption(kW)= ₹ 259.5. Considering Inflation Rate of 3.8 % for year 2020. We get value of ₹ 250 as:[4]

$$\text{Value of ₹ 250 in the year 2020} = \left(1 + \frac{3.8}{100}\right) \times \text{₹ } 250 = \text{₹ } 259.5$$

[4]Source: `http://www.tradingeconomics.com/india/inflation-cpi/forecast`

Table 7: **Cost of Future Estimate of M.D**

Buildings	Emergency Supply MD_E(kW)	Normal Supply MD_N(kW)	Total MD(kW)	In Rupees (at present rate)	In Rupees (at 3.8 inflation rate for year 2020)
			$M.D = MD_E + MD_N$	MD× ₹250	MD× ₹259.5
Admin	70	160	230	57500	59685
Chemistry	388	207	595	148750	154402.5
Biology	92	133	225	56250	58387.5
Library	197	132	329	82250	85375.5
Physics	17	137	154	38500	39963
Mathematics	152	273	425	106250	110287.5
SOHs	250	595	845	211250	219277.5
DOHs	188	408	596	149000	154662
A	46	410	456	114000	118332
B	48	480	528	132000	137016
C	48	564	612	153000	158814
D	100	1400	1500	375000	389250
Flats	24	115	139	34750	36070.5
Street Lights	99	NA	99	24750	25690.5
Green House	42	NA	42	10500	10899
			Total	**₹1693750**	**₹1758112.5**

- **Assumption**: We assume that the NISER Campus will be fully functional by the year 2020. Thus, we have calculated the cost using the M.D data for the Fully functional Campus. If case the campus is not fully functional by the year 2020. We can adjust the inflation rate upto that year eg. say 202x and do the cost estimate analysis in a similar manner.

- **Future Total M.D cost:**

$$\text{Future Total M.D cost} = \sum_{i:buildings} M.D_i \times \text{Rate ₹}$$

$$\therefore \text{Future Total M.D cost} = M.D_{total} \times \text{Rate ₹}$$
$$= 6775 \times ₹259.5 = ₹\ \mathbf{1758112.5}$$

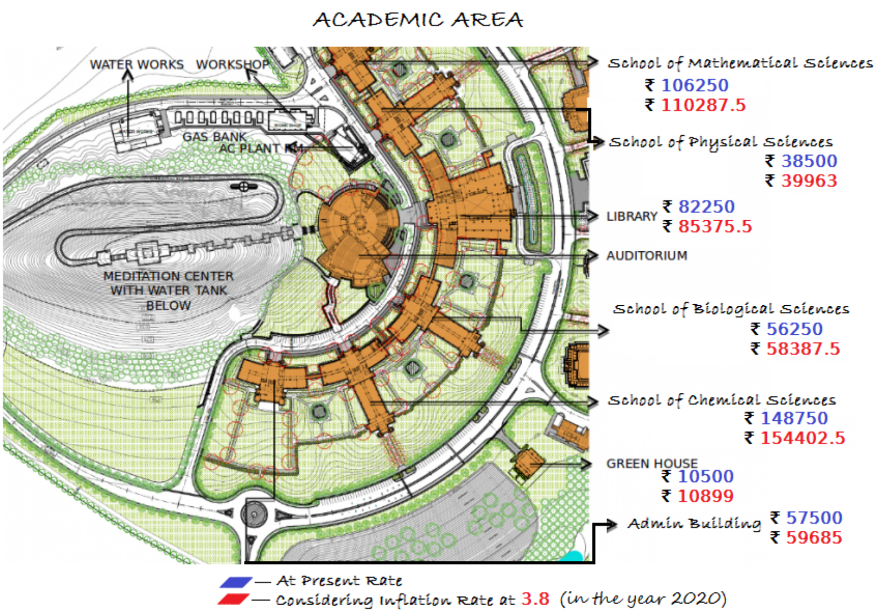

Figure 11: Schematic Map of Future cost of M.D at present rate and Inflated Rate for Academic Area

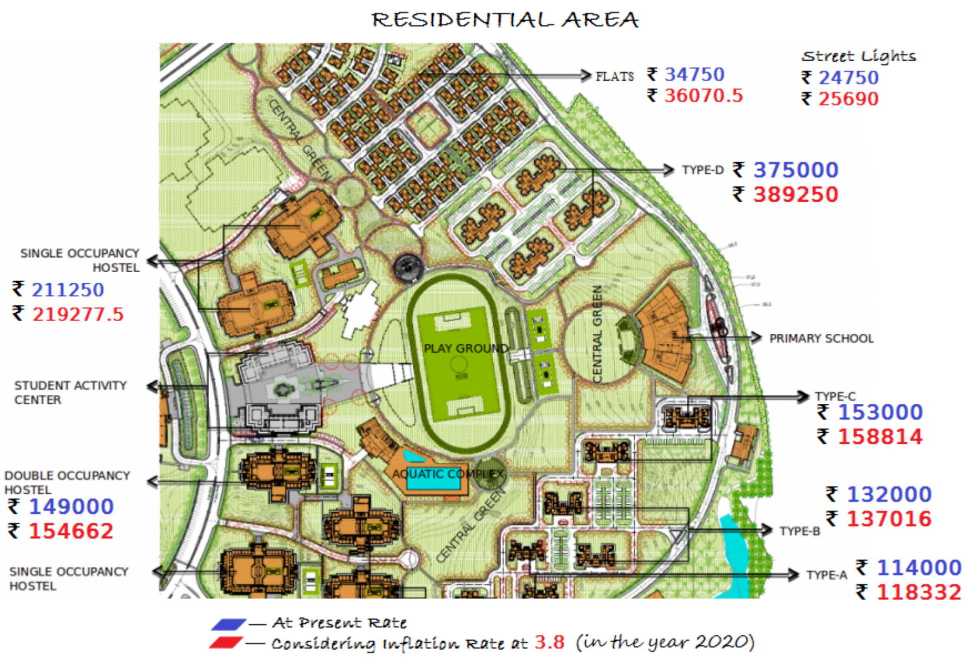

Figure 12: Schematic Map of Future cost of M.D at present rate and Inflated Rate for Residential Area

Figure 13: Overall Estimate Of Future Cost of M.D

Future Energy Cost Estimates :

Using the Future Energy Estimates as calculated in the Table.6

We can calculate the cost of energy by:

$$\textbf{Cost of Future Energy units} = \textbf{Future Energy units} \times \textbf{Inflated Rate}$$

$$\textbf{Inflated Rate} = \left(1 + \frac{3.8}{100}\right) \times ₹5.25 = ₹\mathbf{5.45}$$

Table 8: **Future Total Energy Cost:**

Month	**Energy units present** (kWH)	**Present cost** ₹	**Future Energy** (kWH)	**Estimate for 2020 at rate** ₹5.45	**MD total** future ₹	**Total cost** due to **Energy+MD**
Oct	398130	2090182.5	1798221	9799402.615	1758112.5	11557515
Nov	398640	2092860	1800524	9811955.538	1758112.5	11570068
Dec	401400	2107350	1888531	10291551.05	1758112.5	12049664
Avg ₹:		**2096797.5**		**9967636.4**		**11725749**

Thus we see that in future, total cost incurred due to Energy Units and Future M.D is:

Total Cost in Future ≈ 1.17 Crore.

ENVIRONMENTAL IMPACT OF ELECTRICITY USAGE AT NISER:

Electricity, by itself, is a clean form of energy. The environmental detriment caused by electricity comes chiefly from the footprints of the sources. Therefore, to evaluate the environmental impact of electricity usage at NISER, we chiefly focus on the environmental externality caused at the sources, the impact of in-campus generators and the problems posed by the transmission and other electrical components.

ENVIRONMENTAL IMPACT AT THE SOURCES:

How electricity reaches NISER?
Electricity is produced in Odisha by many Government of India owned agencies (e.g. Central Thermal Stations-NTPC, Central Hydro Stations etc.), Government of Odisha owned agencies (e.g- OHPC), Private/Public Sector Companies (Renewable resources, IPPS) etc. These are received and distributed by GRIDCO and OPTCL to distributors like WESCO, NESCO, SOUTHCO, CESU etc. CESU supplies the electricity at NISER.

The prominent sources of electricity at NISER are NTPC-Talcher and Hirakud Hydel Plant. Since NISER draws only a minuscule part of the electricity generated at the sources, we shall present the impact of a few selected sources.

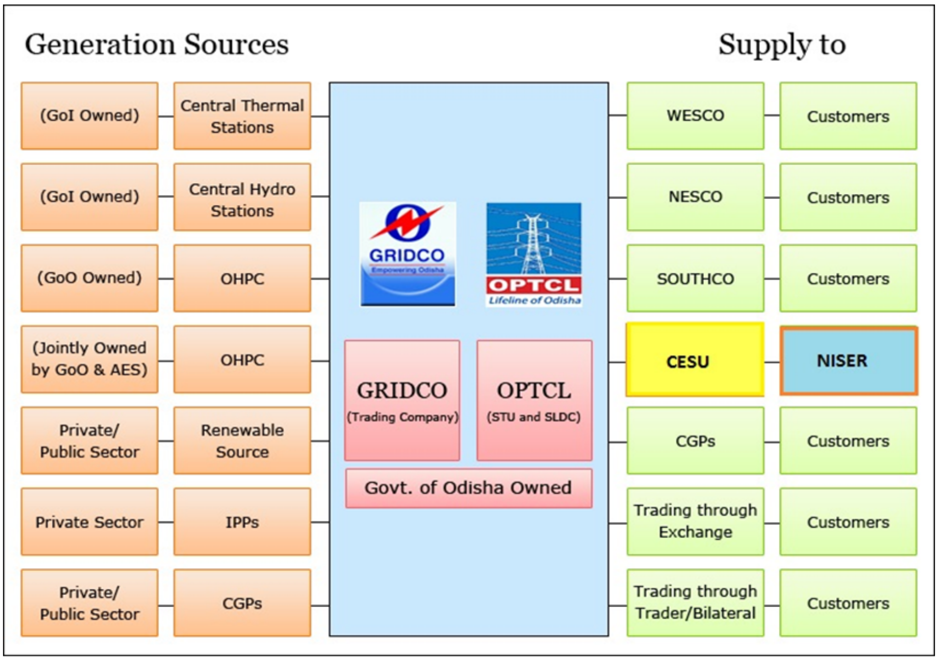

Figure 14: How electricity reaches **NISER**

IMPACT OF THE THERMAL PLANTS:

The installed capacity of the Thermal Power Plant at NTPC-Talcher is 1000 MW. Here is a rough computation of the amount of coal consumed by a 1000 MW plant, under certain standar assumption.

Energy content of coal is given in terms of KiloJoules (kJ) per Kilogram (kg) of coal as the Gross calorific value (GCV) or the Higher Heating value (HHV) of coal. This value can vary from 10500 kJ/kg to 36000 kJ/kg depending on the quality and type of the coal. Since, most of the coal found in Odisha is Bituminous [5], the HHV value of the coal produced is taken to be around 30,000 kJ/kg.

Efficiency:

Energy conversion takes place in two stages.

1. The first part of the conversion is efficiency of the boiler and combustion. Assuming a well-optimized power plant, the efficiency is around 88%.
2. Second part is the steam cycle efficiency. Modern Rankine cycle, adopted in coal fired power plants, have efficiencies that vary from 32 % to 42 %, depending on steam pressure and temperature parameters. A value of 38% has been chosen for the plant

The overall conversion efficiency then is (38% x 88%) 33.44 %.

Heat Rate:

Heat rate is the heat input required to produce one unit (1 kW-h) of electricity. Therefore for a 100% efficient plant would require 3600 kJ per hour to produce one unit of electricity. As per the assumed conversion efficiency in the power plant, we require an heat input of (3600 / 33.44%)$\approx$10765 kJ/ kw hr.

Coal Quantity

Since coal has a heat value of 30,000 kJ/kg, for producing one kW-hr, we require (10765 / 30000)$\approx$ 0.358 kg of coal. This translates to (0.358 x 3000 x 1,000) 107400 kg/hr (107.4 T/hr) of coal for an output of 3000 MW plant.

Coal Cost

Basic cost of coal depends on the market conditions, Transportation costs, regional influences and government taxes etc. We take a coal price of around Rs. 2,400-3,400 / Ton. [6] The cost of coal consumed by 3000 MW power plant is (107.4 $\times$ 3000) 322,000 Rs/hr.

However the amount and cost of coal consumed can be higher than this estimate. The environmental, ecological and health-related hazards have been computed from various sources using this estimate. Since NISER will have a power demand of $\approx$ 6.5 MW in future, it will contribute around 0.2% of the pollution.

EXTERNALITIES DUE TO THERMAL POWER PLANT:

1. Causes air pollution by emission of CO_2, NO_x, ash, particulate matters etc.
2. 1 MJ of heat input produces 0.1 kg of CO_2.
3. Sulphur in coal ranges from 0.1 % to 3.5%, releasing equivalent SO_2, causing acid rain, chlorosis in plants, health hazards like Pulmonary oedema, Corneal haze etc in humans and much more
4. 3000 MW plant produces around 12 million tons of ash in five years, increases particulate matter in air of size less than 2.5μm.
5. Adverse effects on health, agriculture, livestock
6. Local and global warming
7. Increases temperature of nearby water bodies by 2-3 ° C, decreasing O_2 level in water, thus disturbing the aquatic ecological balance
8. Land pollution by ash decreases fertility. There has been estimated loss of yield in agriculture $\approx$ 65-70% within 10 km radius

[5] Geography of India By Husain, Majid, http://www.importantindia.com/4603/classification-of-coal-in-india/

[6] http://www.business-standard.com/article/economy-policy/global-coal-prices-inche-closer-to-cils-cheer-to-ipps-115011600744_1.html

IMPACT OF HYDRO POWER PLANTS:

Though Hydro Electric (Hydel) Plants seem benign, there are a number of adverse environmental, ecological and social externality caused by Hydro projects, which become evident after long time.

Environmental Externality:

- Emission of methane and CO_2, due to anaerobic decay of vegetation. This emission much more than gas power plants, when cumulated over time.
- Deposition of silt near the dam area, affecting soil quality and fertility.

Ecological Externality:

- Forest areas equivalent to 370 NISER campuses (453 sq. Km) vanished
- Disturbed ecological balance
- Diverted natural waterway
- Nitrogen level increase affected fish reproduction

Social externality:

- Nearly 150,000 people were affected, and 22,000 families were displaced

These are some estimates of the impact at sources.

IMPACT DUE TO IN-CAMPUS ELEMENTS:

Several in-campus factors like generators, various transmission components etc also have adverse impacts.

Generators:

The in-campus Generators and emergency power supply systems use diesel-like fuel. They also have several adverse impact on both NISER Campus residents and outsiders.

Air pollution:

- They emit harmful gases.
- Externality such as health hazards on both outsiders and campus residents
- These should be replaced by renewable resources

Noise pollution:

- These machines produce continuous noise while operating
- These can be placed in soundproof/closed buildings

IMPACT OF TRANSMISSION COMPONENTS:

Various components used for distribution and transmission of electricity involve environmentally hazardous materials. For instance, plastic insulation on cables are not bio-degradable. Transformer oil contains non-biodegradable petroleum-based mineral oil materials. Generally used oil contains *hydro-treated light naphthenic petroleum distillate*, a confirmed carcinogen. These materials when not disposed properly, can have serious consequences.

CONSERVATION OF ELECTRICAL ENERGY AND ALTERNATIVE ENERGY RESOURCES

GREEN BUILDING CONCEPT

Green building (also known as green construction or sustainable building) refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition.
NISER construction has taken into account several concepts of green building like designing of hostels and departmental class-rooms which makes use of natural light. In terms of electricity consumption there is a scope of reducing electricity usage in the Library and Lecture Hall complex (where ventilation is only through AC). To prevent direct glare of sunlight partially reflective shades and reflective glass panels must be installed.
Other points which can make a building energy efficient are listed below:

1. Power can be conserved by reducing the usage of all high power rating appliances at the same time as it increases the MD(Maximum Demand)
2. Also from a monetary point of view, we should-not use such appliances in the peak hours as cost incurred during those hours is more.
3. In AC circuits, the power factor is the ratio of the real power that is used to do work and the apparent power that is supplied to the circuit. It takes value from 0 to 1.
4. Adjustments in the electrical circuit should be such that power factor hovers around 1 and power loss is minimized.

BEE STAR RATED APPLIANCES

Figure 15: BEE Star Rating Logo

BEE Star- Rated appliances should be promoted as a replacement of no star appliances. Government of India (Bureau of Energy Efficiency, Ministry of Power) introduced the Standards and Labelling Program in May 2006. Under this program the manufacturers are required to place a label showing how much electricity the appliance will consumer under certain conditions. The labels contain "Stars". More is the no. of Stars, more efficient is the appliance.

LED LAMPS FOR STREET LIGHTING

With leap and bound advancements in semi-conductor devices LEDs have become an effective lighting devices on a large scale. Before moving on to the cost part first let us consider some the other aspects of LEDs. that can emit light from 50 nm to $\geq$1000 nm. There are several features of LEDs that make them attractive alternatives to high-pressure sodium (HPS) lamps. First, LEDs can produce narrow-spectrum light at wavebands useful for plant growth and development, including blue (450 nm) and red (660 nm). Additionally, LEDs currently have a luminous efficiency of 38 percent (red) to 50 percent (blue) in converting energy to light and an estimated life of 50,000 luminous hours or more.

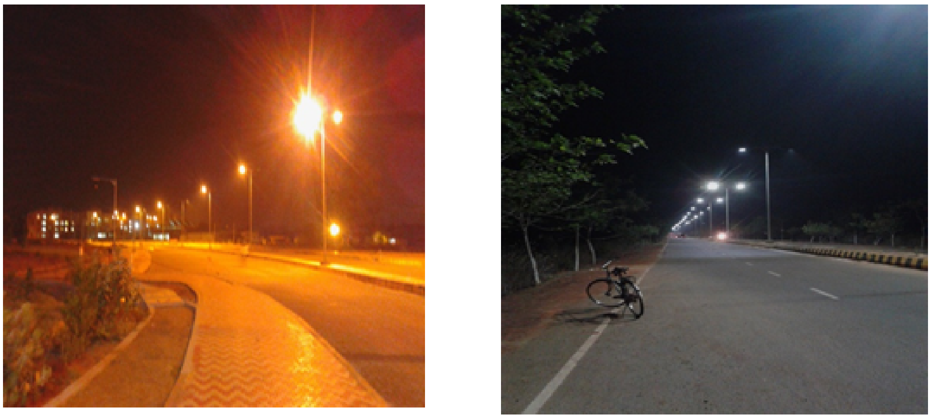

Figure 16: Street Lighting: A comparison a) On the left is the lighting scenario in NISER b)On the right is the lighting scenario of the road leading to IIT BHUBANEWSWAR.

Although the initial installation cost is high we have many advantages in terms of ignition time, lumens per watt, and most importantly lifetime. Since we are getting better luminosity at a lower wattage, we are saving electricity, thus saving money. Also increased lifetime means lower maintenance cost. Also, the light emitted from the LED lamp is directed downwards, spread throughout the entire area it covers. This means that a lower amount of light is needed to properly illuminate the area. This also dramatically reduces light pollution, which affects the mood of human beings, navigation in birds and insects, mating behavior in animals and flowering in plants.

SMART LIGHTING

Smart lightning is the good way which enables to minimize and save light by allowing the householder to control remotely cooling and heating, lighting, and the control of appliances.

Time Scheduling Device

The advent of embedded systems has given a scope to make programmable devices such as the timer circuit to control the power supply. The device is programmable and each day's time table can be fed into it. The device will operate the power supply only when there is a lecture and otherwise switched off, thus, operating on a pre-determined schedule. A brief analysis that follows is for NISER, Jatni.

Energy Management Devices using Image Processing

The lighting and power supply can be controlled by occupancy sensing.The feature of this device is that it controls the power supply of any place by sensing occupancy by any human. The distinguishing feature is that only human occupancy is detected. This device uses image processing and pattern recognition. This device is found to be an efficient method to implement energy management that too at a low cost. As per the ECBC user guide, there should be an occupancy sensor in all classrooms and conference halls.

PHOTOVOLTAIC

In view of the energy crisis of the present day scenario, we need to look forward towards harnessing alternative energy sources. As we are in India, one of best alternatives at our disposal is solar power.The average sunshine hours in Bhubaneswar is depicted in the figure below:

Number of lectures per day per course	**4**
Number of lectures per week per course	20
Number of classes running in a day	60
Duration of each lecture	50 min
Average load per class	460 W
Average electricity loss per day	4.6 kWhr
Loss per month	92 kWhr
Loss per year (assuming 250 working days)	1150 kWhr
No. of computers in CC	53
Average load per computer	130W
Average electricity loss per year (taking Sat. and Sun)	17197 kWhr
Total electricity loss	18347 kWhr
Cost of electricity that can be saved per year (with Rs.5.25per unit)	Rs. 96,000

Figure 17: Calculation For Time Scheduling Device

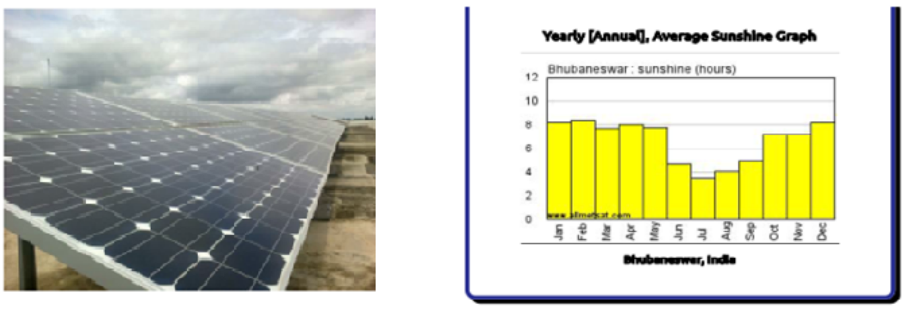

Figure 18: a) On the left are the solar panels b) On the right is the Yearly Average Sunshine

We start out with an estimate that we will be installing around 150 solar panels .The installation cost of these amounts to Rs 16,50,000. The total cost takes into account the cost of battery used for energy storage. We will be using around 100 batteries which amounts to Rs 15,00,000 bringing the total cost to Rs 31,50,000. In addition to that 20% batteries have to be replaced every 4 years. Thus additional maintenance cost taking into account the batteries, solar panels and other machinery amounts Rs 5,00,000 in four years. A total of 150 panels generate power of 34.5 KVA. With this output we will be saving around 4200 units of electricity per year. This when converted to money in term of commercial units amounts to Rs 23000 per month.This implies a saving of Rs 2,90,000 in a year. Although it seems that we are incurring losses. But after few years of installation we can really appreciate its benefits.

At present it may seem that opting for conventional energy sources might be more feasible and cost effective but we have to keep in mind that the cost of conventional energy sources like coal will be increasing in the near future and these renewable forms of energy will gain prominence.

SOLAR THERMAL ENERGY

Solar thermal energy can also be a good alternative. In this method, the sunlight is concentrated using mirrors to heat molten salt to high temperatures (around 500° C) and then it is pumped to a steam generator. The steam drives a turbine to generate electricity. There are many types of solar plant like Parabolic Trough system, Solar Dish system, etc. This method can also be applied to get hot water.

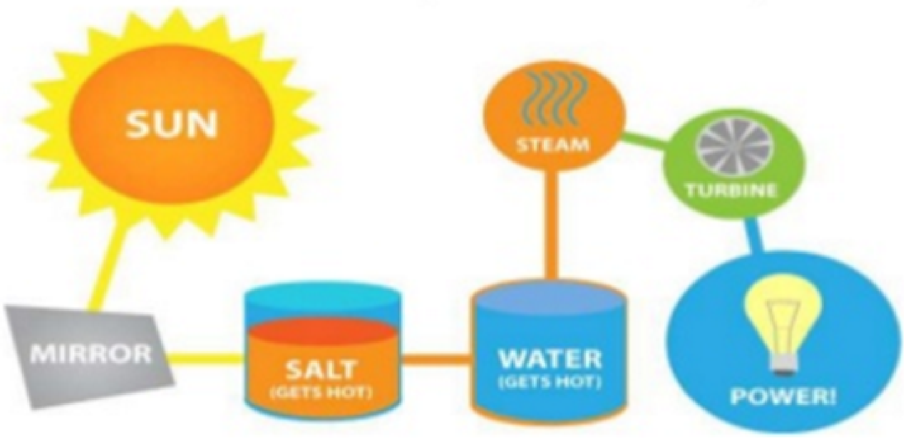

Figure 19: Solar Thermal Energy Generation

WIND ENERGY

NISER is situated in Jatani whose average wind speeds round the year falls within the window that is optimal for energy production. This average wind speed over 60 years is depicted in the graph below: For power generation we

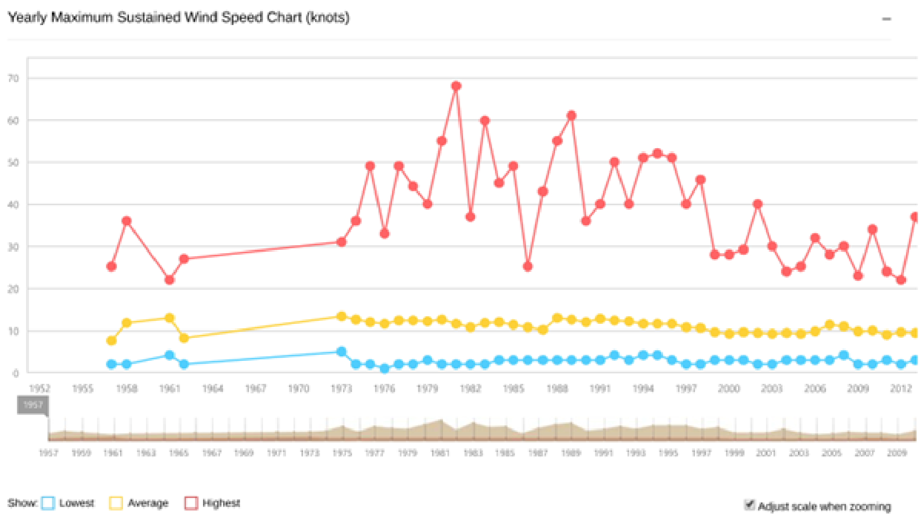

Figure 20: Wind speed chart of Jatni

need a steady speed of around 10 knots and Jatni clearly satisfies that criteria. Small sized turbines can set up in open spaces and certain amount of renewable energy can be derived from it.

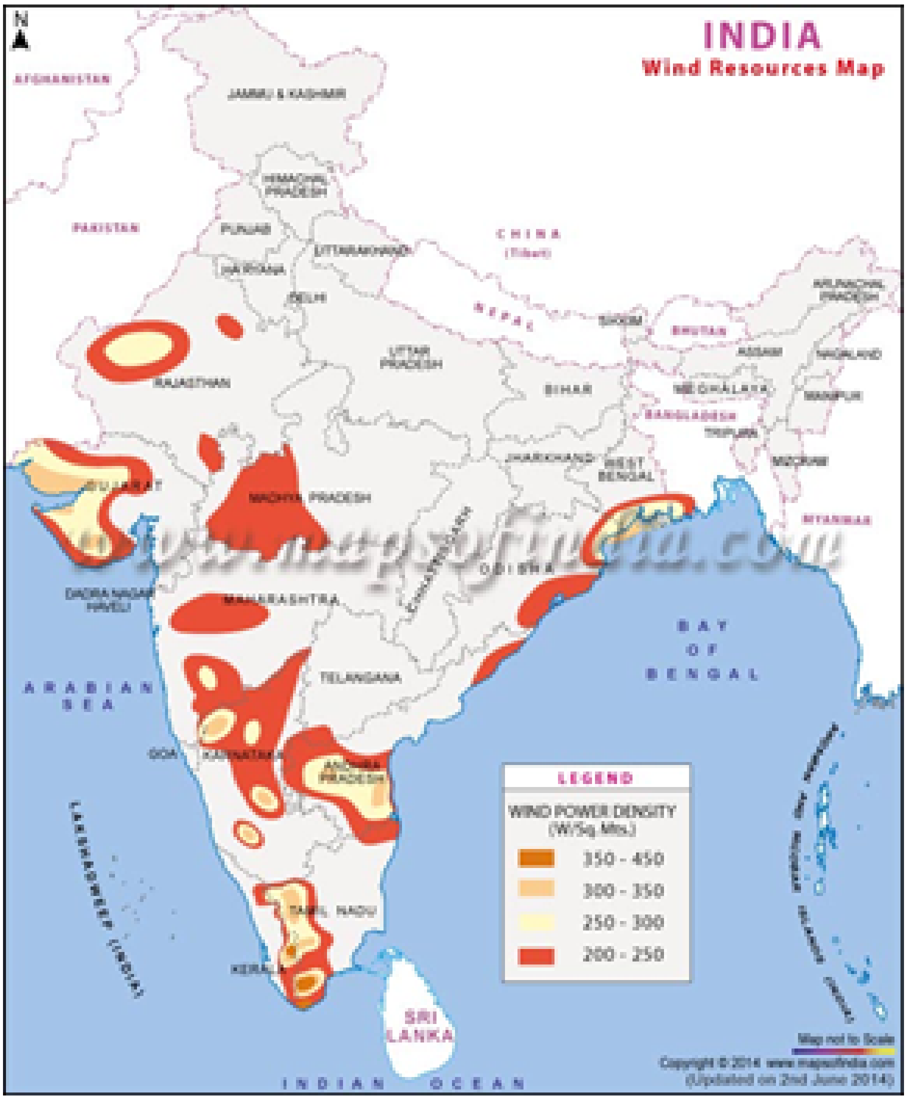

Figure 21: Wind Power Density graph of India

Several such turbines can be installed in roof tops of academic buildings where there are no solar panels installed. Wind turbines under 100 KW costs between Rs 2,00,000 and Rs 5,00,000. Total installation cost may range between Rs 33,00,000 and Rs 53,00,000. The total returns from the project will depend on the number of wind turbines installed which is difficult to predict at present due on going construction work.

CONCLUSION

NISER is one of the premier research institutes in the country and is expected to be in service of the nation for many more years to come. Viewing the current problem of energy crisis in the world, **NISER** should set an example for being a self sustaining and energy efficient institute in India. We are faced with an uphill task for reducing current consumption of electricity, making the already available alternatives cost effective and continuously searching for cleaner technologies. Since, we are a new campus, we still have a lot of opportunities to be a zero-emission campus and that is possible only when we switch to the viable energy alternatives available to us. That said, a lot of work has already been done but it's never enough.

Here's us concluding the assessment with a hope that it will help **NISER** be a green and energy efficient campus.