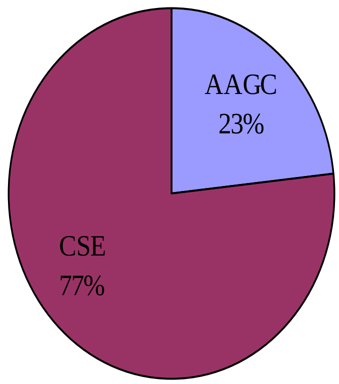
Building Operations

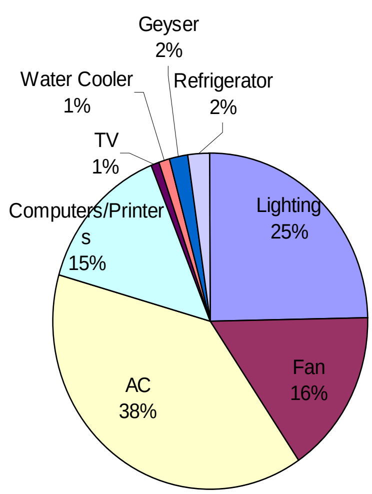
Energy Consumption Pattern

The Energy Audit is conducted on December 2010 for both buildings, and it is estimated that the total use of energy-mix in the buildings is optimally contributed to overall energy consumption demand. The building AAGC and Main CSE building has 98.39 kW and 89.30 kW sanctioned load from the grid supply respectively. The annual electricity bills for buildings, diesel and solar energy generation data collectively finds that Main CSE building's (77%) share in total energy consumption was more than three times that of AAGC (22%) building (see Graph 01).



Graph 01: Total Share of Energy Consumption of both Buildings annually

The annual energy consumption of AAGC is 44,750 kW, where as main CSE building is 146,833 kW. Graph 01 shows the average monthly energy consumption pattern for various electrical appliances exhibited in both buildings. However, we have made a separate auditing for both building to distinguish and identify the nature of energy losses in overall buildings operation. The system level auditing (electrical appliance load) and area-based approach (energy consumed per m^2) to find out the relative energy performance index for both the buildings.

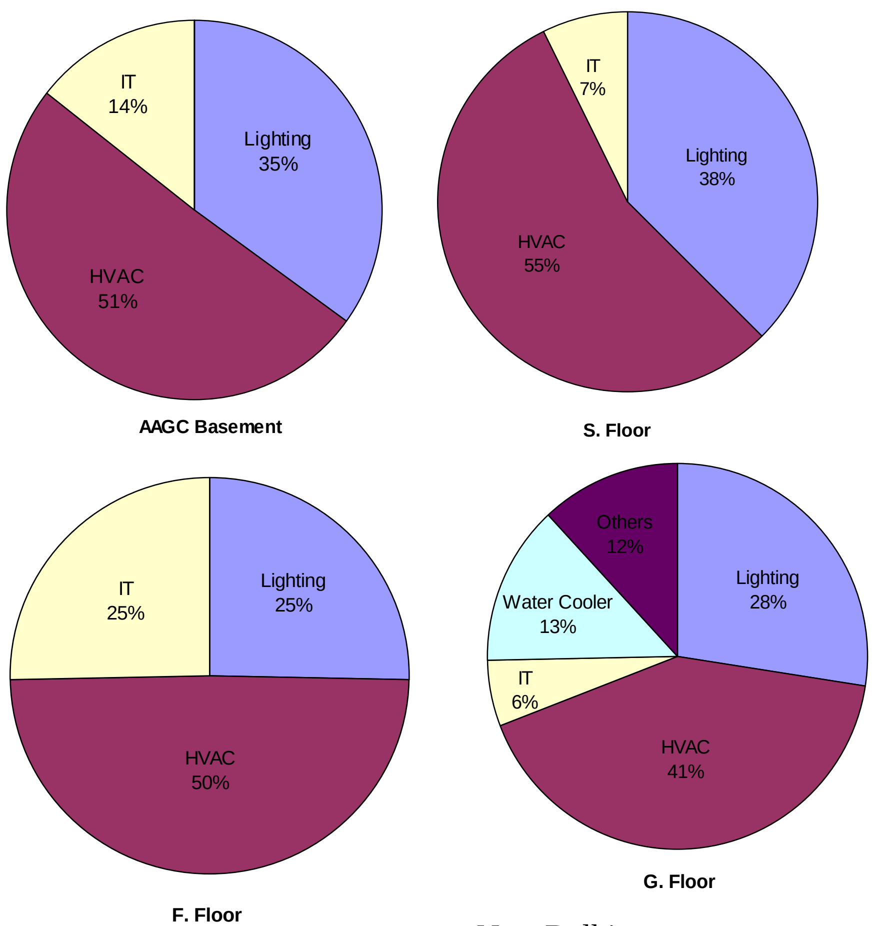


Graph 02: Total share of Annual Electricity Consumption in both Building

On an average, the energy utilized in buildings through connected appliances and seasonal energy demands shows the 54% (*38% + 16%, see Graph 02*) energy is used for active and evaporative cooling the indoor-air for both the buildings having less than 50% conditioned space of total built up area, during peak months (May-Oct). On the contrary, analysis shows that the non-peak months (November-April) utilizes 16% for cooling and remaining (38%) load is not required. Main CSE buildings and AAGC has differential consumption patterns that suggest the functions and operational behavior of the building. However, we have found that the buildings with its innovative design in treating building envelope facing south-west direction, greening open areas, and sustainable site-planning measures have maintained the optimum indoor temperature.

Energy Audit for AAGC

The building having 1196.33 m^2 of total built up area used for environmental education and training program for most of the time. The floating population during education and training program requires indoor-units to respond to the occupants requirements. We have analyzed the consumption pattern in active and passive mode of building cooling, air ventilation, lighting, IT requirements and other activities.



Graph 03: AAGC Floor-wise Energy Consumption

AAGC	Energy Consumption (kWh/annum)					
	Lighting	**HVAC**	**IT**	**Water Cooler**	**Others**	**Total**
Basement	7331.3	10570	2995.2	0	0	20896.5
G. Floor	4179.46	6326.4	864	2016	1810	15195.86
F. Floor	4124.16	8006.4	4101.12	0	0	16231.68
S. Floor	608.256	892.8	115.2	0	0	1616.256
Total	16243.176	25795.6	8075.52	2016	1810	53940.296

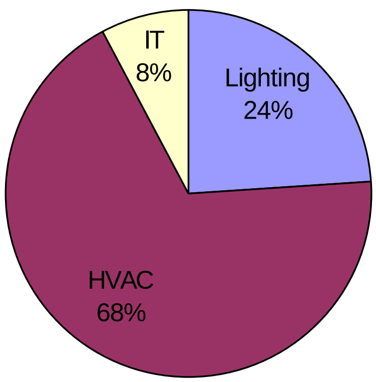
Table 01: Floor-wise Energy Consumption (kWh) in AAGC

AAGC	Connected Load (kWh/annum)	Total Area (m^2)	AC area (m^2)
Basement	20896.5	333.52	290.22
Ground Floor	15195.86	165.83	129.12
First Floor	16231.68	131.74	141.17
Second Floor	1616.26	83.79	56.25
Total Area		715	
Annual Consumption (Billed)		44,750 kWh	
EPI		**63 kWh/m2/year**	

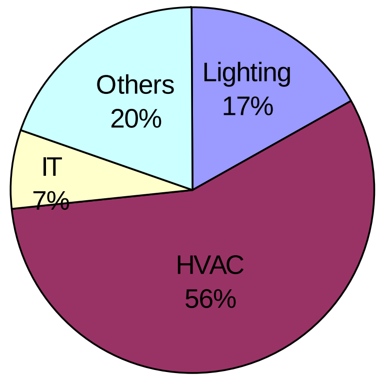
Table 02: Energy Performance Index for AAGC

Energy Audit for CSE Main Building

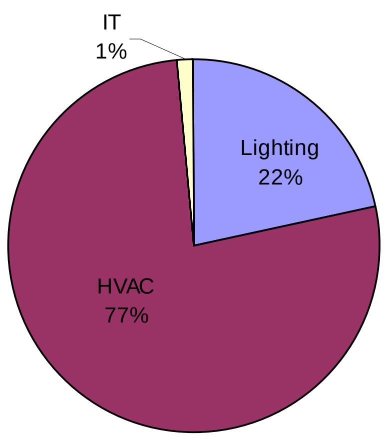
This building having built up area of 1250 m^2 with less than 50% air conditioned space. Each floor acts as a working station and research department having decentralized functions. The building is facing south direction with its main entrance and the building openings on North and East side which minimizes direct solar heat gain in the indoor environment. However, we have found the AC units along west wall need to be covered or relocated on northern wall façade for better performance.



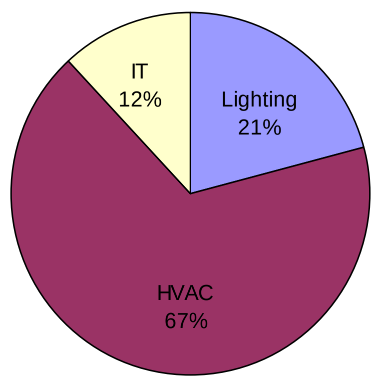
Basement (Marketing)



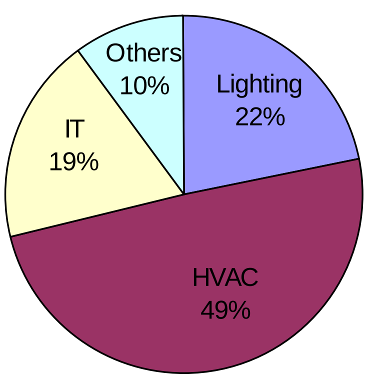
G. Floor (APC)



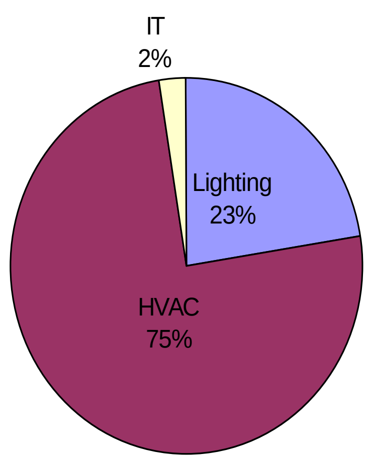
F. Floor (DTE)



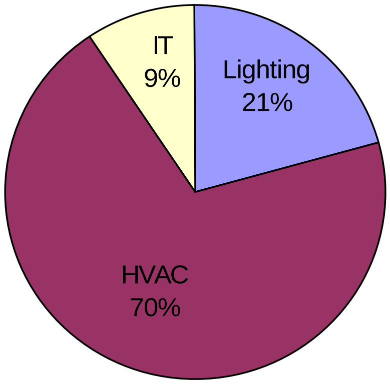
Second Floor (DTE+HR)



Terrace Floor (Canteen)



Third Floor (WATER)



Graph 04: Floor-wise Energy Consumption in CSE Main Building

Area	Lighting	HVAC	IT	Others	Total
Basement	4707.07	13384.8	1555.2	0	19647.07
G. Floor	4922.5	16251.84	2003.04	5698.94	28876.32
F. Floor	5681.66	20131.2	360	0	26172.86
S. Floor	6132.1	19838.4	3491.52	0	29462.02
T. Floor	4893.7	16329.6	518.4	0	21741.7
4th Floor	5436.29	18302.4	2453.76	0	26192.45
Canteen	561.02	1267.2	480	259.2	2567.42
Total	32334.34	105505.4	10861.92	5958.14	154659.8

Table 03: Floor-wise Energy Consumption (kWh) in CSE Main Building

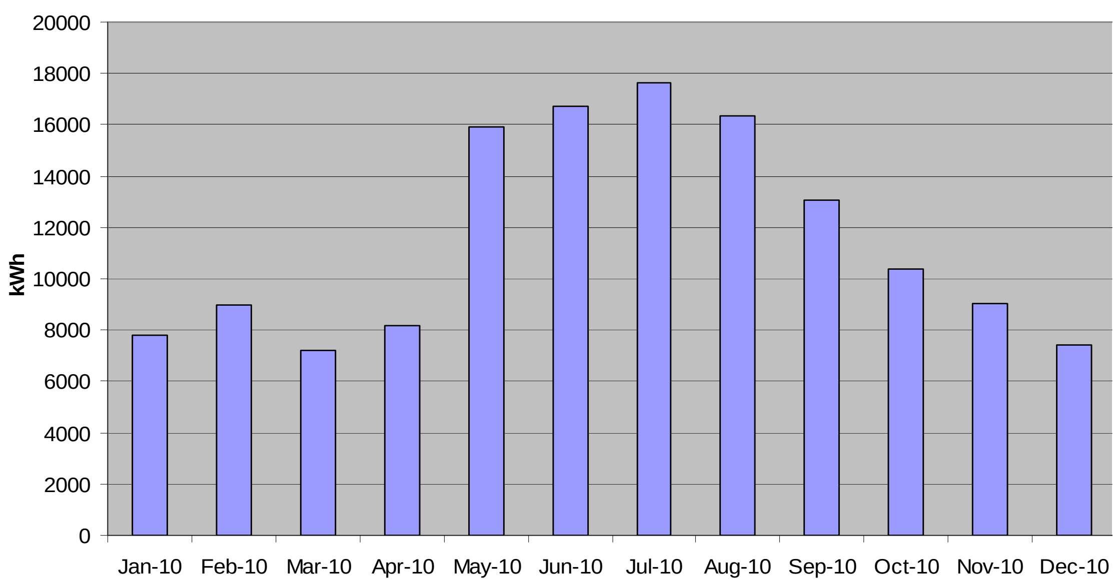
CSE	Connected Load	Total Area	AC Area
Basement	19647.07	211.035	192.485
G. Floor	28876.32	213.8086	136.04
First Floor	26172.86	197.906	131.932
Second Floor	29462.02	169.814	108.04
Third Floor	21741.7	155.994	100.24
Fourth Floor	26192.45	147.105	107.08
Canteen	2567.42	147.105	110.22
Annual Consumption (Billed)	146833	1242.7676	
EPI	**118 kWh/m^2/year**		

Table 04: Energy Performance Index for CSE Main Building

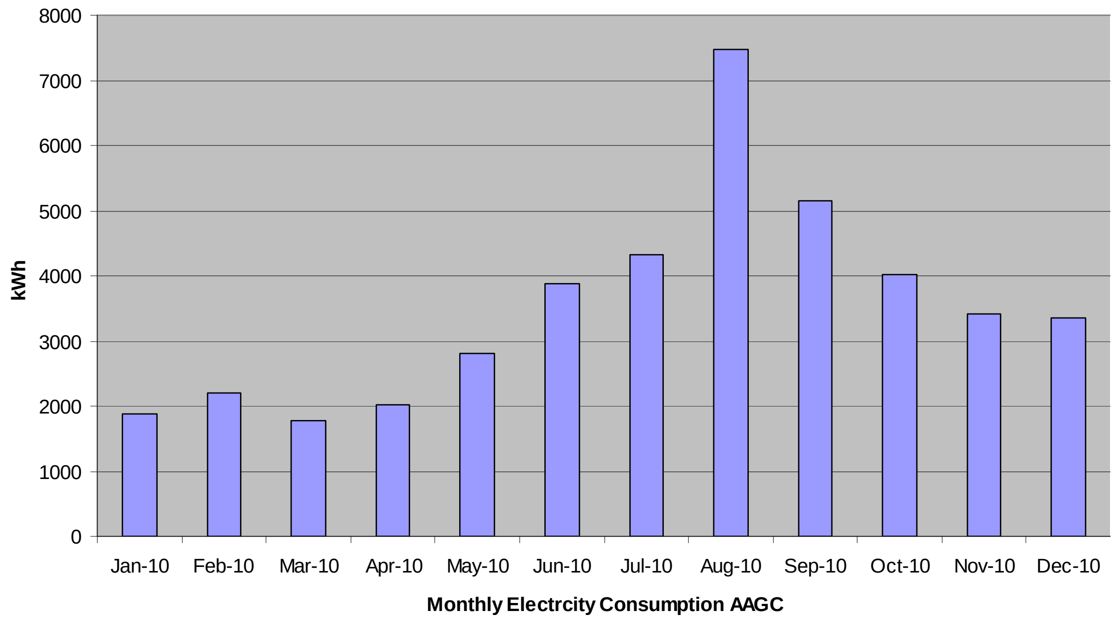
The average energy consumption on floor-wise reflects upon the energy intensity nature, type of connected load (equipment size), and emerging pattern of energy consumption in the AAGC building (see Table 01). The graph shows that as the building floors increase the HVAC requirement is increasing as a result the required level of comfort is achieved through additional air conditioning units. Interestingly, second floor required highest air conditioning due to its expose to exterior climate condition. The low level of occupancy rate at first and second floor seems to be the energy loss in these flowers contributing to excess energy consumption.

It is evident that the building located in composite climate will have higher levels of energy consumption in the month of May to September due to varying degree of changes in the outdoor temperatures. During the same period, the indoor ambient temperature of CSE main building, having less than 50% air-conditioned space, consumes maximum amount of energy consumption. However, we found the Energy Performance Index (EPI) of the building is still relatively closer to the baseline of conventional energy intensive office building (National benchmark 180 kWh/m^2/ year, *source BEE*).

The energy consumption per capita based on total occupancy rate on annual basis is worked out. Occupants include employees, housekeeping staff and volunteers were calculated which forms the organization's SEC and was taken as reference for comparison between year 2009-10. The annual energy consumption is 191,583 kW computed from total energy supply for total 135 employees. The SEC for 2009-10 was 1420 kWh/capita/year and energy cost spent is about Rs. 8067/ capita/ year.



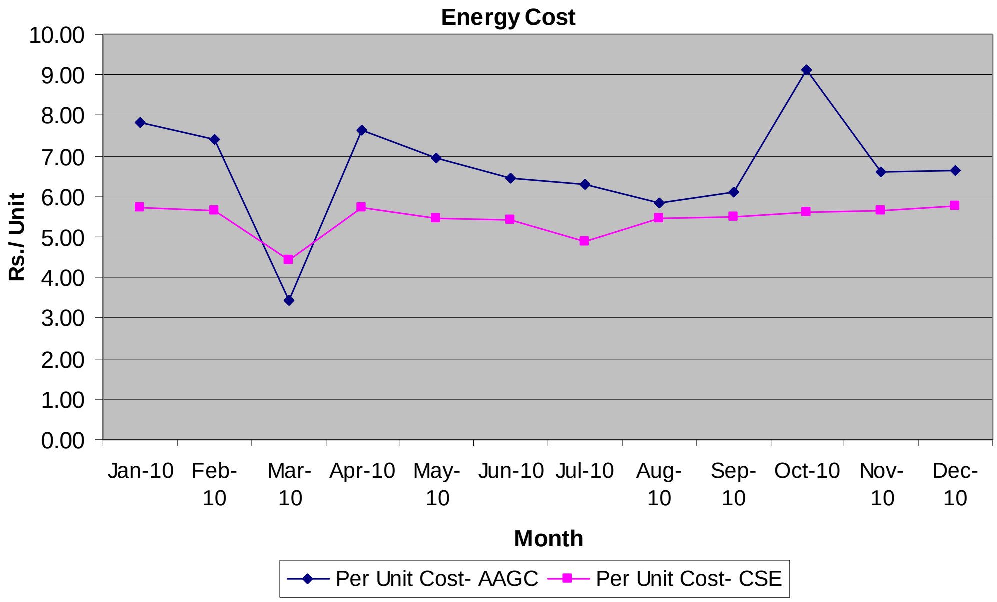
Monthly Electricity Consumption, Old CSE



Graph 05: Annual Energy Consumption in CSE.

The annual energy consumption is not consistent over the entire year. The graph 05 reflects the two major peak months as May- September in hot summer season, and October-April in winter season. The peak summer season has high energy intensive consumption level due to HAVC requirements observed in both buildings. The energy cost parameter for both building is consistent on an average Rs. 6.6/ unit. The last energy bill audited for AAGC shows fluctuating energy price in the range between Rs. 3.43 to Rs. 9.11 per unit (kWh). Results shows BSES Rajdhani, utility supplier, has kept the energy prices reasonably high during peak summer month when the energy demand is high. Whereas, energy bill audited results for CSE main building represents consistent energy price Rs. 5.42/ unit. Both results are the important consideration to implement effective energy conservation measures to minimize annual energy cost for overall

CSE buildings.



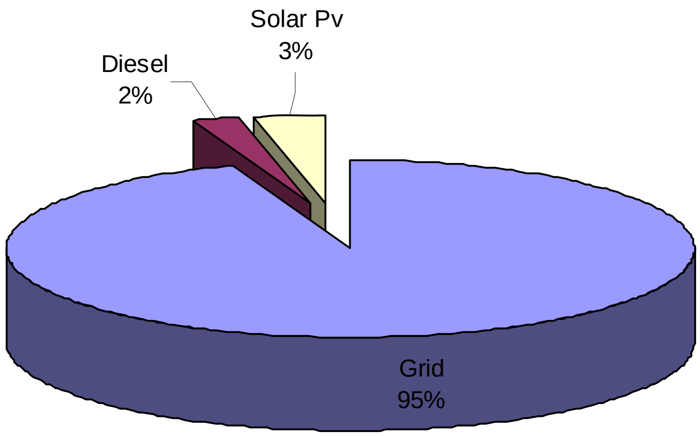
Graph 05: Average Energy Cost (2009-2010)

AAGC has 98.39 kW and CSE has 89.5 kW of sanctioned load, consuming total units of 191,583 kW connected load annually on a total built up area of 1958 m^2 from grid supply. The building has roof-top Solar Photovoltaic (SPV) mounted for CSE main building. The total output renewable energy utilized for running PCs and Printers in both buildings. The SPV has integrated in to building design with Power Converting Unit (PCU) and battery bank at the basement. This represents an effective Energy Performance Index (EPI) of 82kW/m^2/year for entire building.

Indicator	**Quantity**
Annual Energy Consumption CSE	146,833 kWh
Main CSE Built-up Area	1243 m^2
Energy Performance Index (<50% AC)	118m^2/year
Annual Energy Consumption AAGC	44750 kWh
AAGC Built-up Area	715 m^2
Energy Performance Index (<50% AC)	63 kWh/m^2/year
Total CO2 Emission	
Annual CO2 Emission	95,791 kg
	149,435 kg of CO2

Table 02: Energy Consumption Profile of Building (as per Audited Bill)

Apart from the conventional grid supply of energy building has energy consumption from Solar Photovoltaic installed over the roof. The end-use appliances such as computers and some emergency lighting in the corridors is connected through solar power generation grid and integrated in both the buildings. The Solar Photovoltaic (SPV) is 140 in numbers connected in series of 10 each into 14 blocks producing close to 10.5 kW of energy.



Graph 06: Energy-mix Consumption Pattern for the main CSE and AAGC Buildings

Following table 04 measures the energy-mix supply utilized in the buildings. It is evident that the grid supply is a major source of electricity supply followed by solar energy. The diesel contribution is less due to random hourly operation of diesel generating set. DG set is used in power shortages and during load shading from utility suppliers. The Power Factor (PF) recorded for AAGC is 0.54 and in Main CSE building is 0.84, as per utility supplier BSES Rajdhani.

Building	**Energy Supply (kWh)**			
	Grid	**Diesel**	**Solar**	**Total**
AAGC	42300	920	1530	44750
CSE	138632	3080	5121	146833
Total	180932	4000	6651	**191583**

Table 02: Energy-mix Supply in Buildings for 2009-10

Area	**Total kWh**	**Cost (Rs)**
AAGC (Grid)	42,300	280,767
Main CSE (Grid)	138,632	750,731
Diesel	4000	24,338
Solar PV	6651	33,250
Total	**191,583**	**1,089,086**

Table 03: Total Annual Energy Cost, 2009-10

AAGC building has its own convective, mechanism, illustrated in figure 01 to maintain the indoor air-quality, temperature and daylight illumination levels. The building also consists of Solar Chimney which basically works as air flow channel to remove hot air bringing in fresh air through sill and clear story level openings, resulting into maintaining optimum level of indoor air temperature and quality of air. A simple fenestration treatment over wall façade and exposing office designated areas to the window, increases sufficient lighting during peak office hours. However, building does not have insulation on wall, window and roof, and the design to bring insulation in the buildings is under consideration.

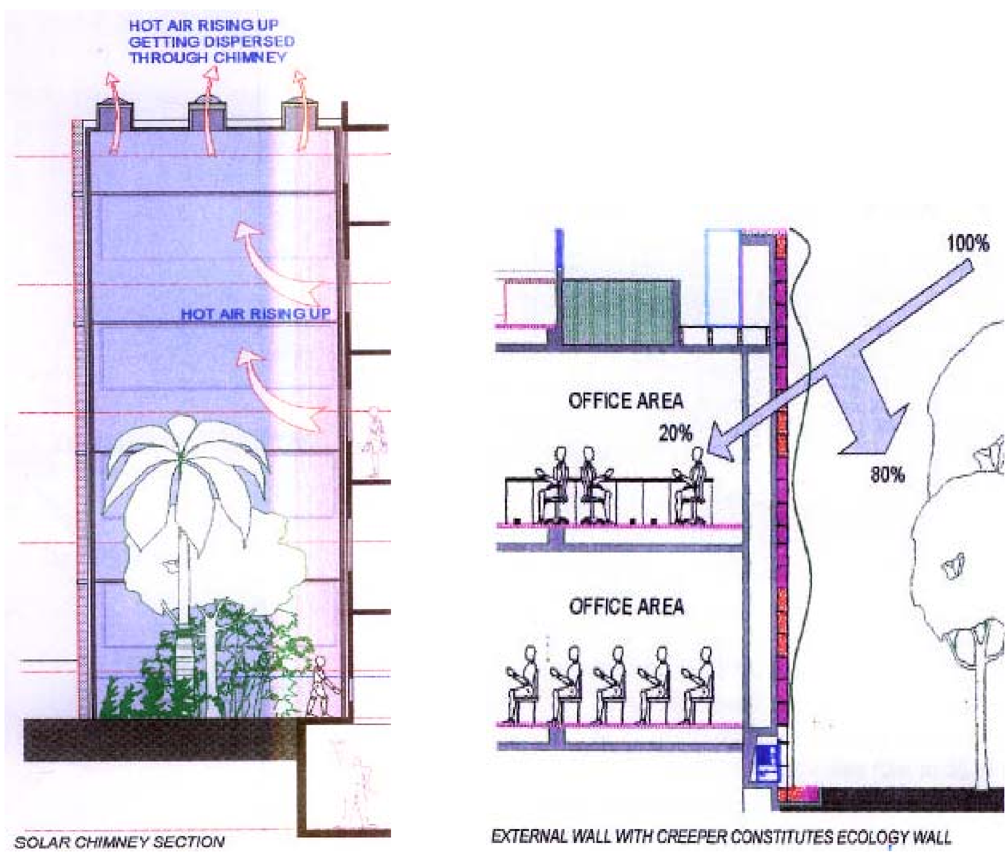
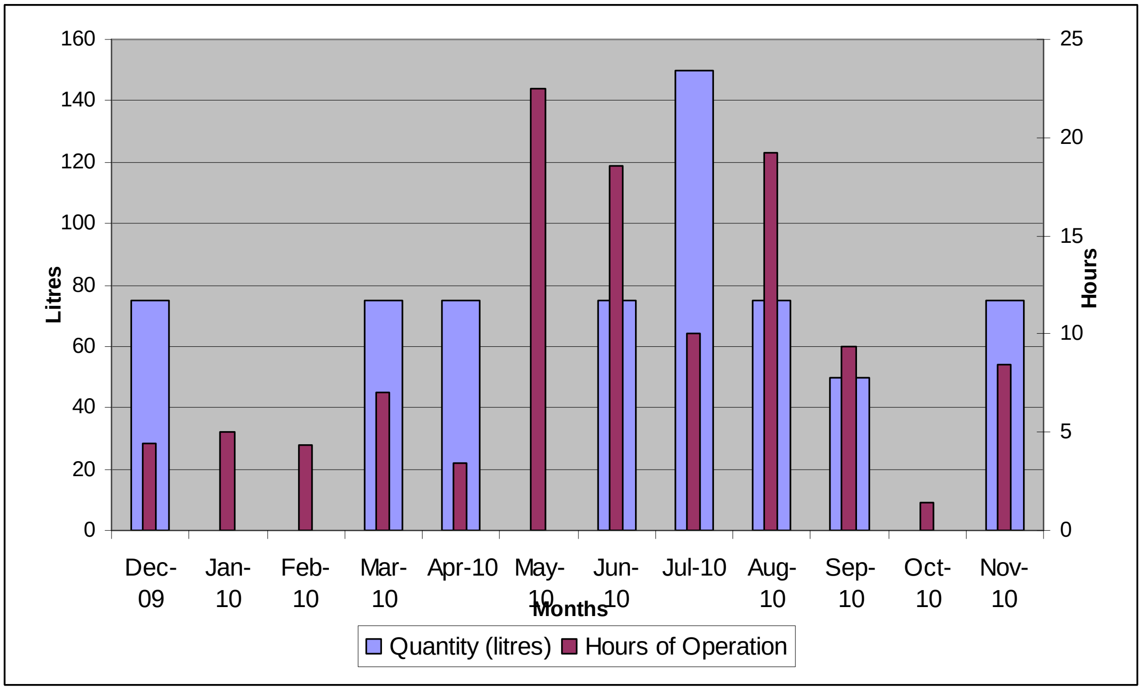


Figure: 01 Convective Mechanism for Air ventilation in AAGC

A solar chimney which is still functioning- earlier designed for the air-removal and maximizes day-lighting function at the southeast corner of the building. It is designed in glass and metal with mechanical louvers at the top to facilitate the air-flow movement. From the initial estimates the chimney helps in reducing the requirement for artificial lighting and need for air conditioning at office hours (8 hours daily). It is saving energy from grid source of about 61,152 kWh annually.

Energy Audit: Diesel Generating Set

The 40 kW installed capacity DG set in CSE campus is a major captive generation power supply for both the buildings. The output power is connected to internal IT equipments and emergency lighting areas. The audited result shows that the diesel consumption and associated emission is maintained optimum. Graph 07 represents the diesel consumption and the operating hours on a monthly basis contributing to the building operation during grid supply failure. The connected load under DG set is a major source where the energy can be saved.



Graph 07: Energy Audit for DG set

A typical energy balance in a DG set indicates following break-up:

Input: 100% Thermal Energy	100%
Outputs: Electrical Output	35%
Alternator Losses	4%
Stack Loss through Flue Gases	33%
Coolant Losses	24%
Radiation Losses	4%

Table 04: Energy Balance of DG Set

Waste Heat Recovery (WHR) Potential of DG set were not audited for the same year.

Energy Audit for Solar Photovoltaic

The hybrid solar power system in the Centre for Science and Environment acts as an on-line uninterrupted power supply (UPS) system, providing stable power to all the electronic appliances. 120 solar modules are mounted on a space frame over the front twin-pillar supported pergola of the CSE building. The remaining 20 are installed over the CSE canteen roof.

Components

The 10 kilowatt power (kWp) photovoltaic power plant in CSE comprises the following components:

- Solar modules
- Power conditioning unit (PCU)
- Battery bank

Peripheral components

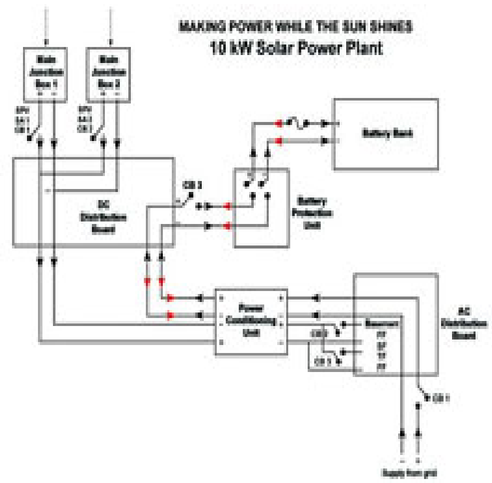
- Data logging system with personal computer (PC)/printer
- Direct current (DC) and alternating current (AC) distribution boards
- Earthing kits and electricity distributing cables

Solar modules

Solar cell or photovoltaic (PV) cell is composed of semiconductor materials – silicon wafers. Photovoltaic cell, as the word implies (photo = light, voltaic = electricity), converts sunlight directly into electricity. Several PV cells go into the making of a solar module. CSE solar PV array comprises 140 solar modules – 10 modules connected in series and 14 in parallel – of 75 watts (W) and 12 volts (V) each. The 10 kilovolt ampere (kVA) PCU of 120 V DC and 230 V AC acts as inverter – converting DC to AC –as well as solar charge conditioner – controlling current for efficient and optimal battery charging. It is connected to 220 V AC grid supply.

Battery bank

Sixty PV batteries of 120 V, 2-1,200 ampere hour (Ah) are the energy reservoirs.



Power from the Sun

- Electricity generated (DC at a rate of 75 W per hour) by the solar modules travels through the DC distribution board (DCDB) to PCU.
- After the battery bank is fully charged the excess energy is converted to AC. This is distributed to the load points through AC distribution board (ACDB) via copper cables
- When the battery is fully charged, the excess power generated, feeds the load.
- When the AC mains fail, solar energy and the battery feed the load. When the mains resume, the battery is charged by mains as well as solar power.
- The system can be viewed, controlled and monitored by a data logging system and a PC-based software.
- Solar modules, with efficiency greater than 12 per cent, are estimated to last for more than 30 years.

THE COST FACTOR

Sl.No.	Item	Units	Total Cost in Rs
1.	Solar Module TBP – 1275	140	15,96,000
2.	Module Mounting Structure	122	77,000
3.	Power conditioning Unit (PCU) – 10 KVA	1	8,50,000
4.	Array & Main junction box	7 + 2	25,230
5.	DC, AC & Floor Distribution box	1+1+6	1,00,600
6.	PV Battery with accessories	60	6,79,590
7.	Data Logging system with PC & Printer	1	1,49,000
8.	System Accessories	Lot	1,10,580
9.	Overheads		67,000
	Grand Total		36,55,000

How CSE benefits?

- The cost of installation of the system (Rs 36.55 lakh) can be recovered in two years, if the gross savings are taken into account.
- Every month, CSE saves about Rs 8000- 10,000 on its electricity bills.
- 10,000 on its electricity bill.

- Solar power helps in saving approximately Rs 20 lakh per annum if we assume that it takes 35-minutes of rebooting daily and 5-7 power outages a day leading to a loss of Rs. 50 in the output of each employee.
- CSE never shuts down. Its critical appliances are connected to the 24-hour solar energy back up.
- Steady power supply prevents damage to computers and loss of precious data. It reduces dependence on the diesel generator.
- With all its electronic appliances connected to solar energy, CSE has managed to dispense with the UPS and associated recurring costs.
- In the event of both mains and power backup failing, solar system is capable of supplying six hours of instant and uninterrupted power.

Building Envelope

The building envelope or external façade is characteristic of low-energy-embodied building material used during construction of both buildings. The CSE's overall commitment to optimize energy is evident in careful selection of building materials which requires less energy to manufacture and passive-techniques as design feature.

The CSE Main building having basement, ground and four floors with an average height of 19.2 meter including canteen and machine room on terrace, has building envelope designed with appropriate vertical fenestration. The building envelope consists following energy efficiency components to be looked upon:

- Insulation materials and specified R-values
- Fenestration U-factors, Solar Heat Gain Coefficient (SHGC), Visual Light Transmittance and Air Leakages
- Over Hang and side fins
- Envelope Scaling details

Building is designed on south facing plot with major chances of solar heat gain occurred on west and south west window openings. Due to sustainable site-planning features the excess heat gain is avoided and the openings are opened on the North facing wall connecting to the AAGC building. The insulation of 230 mm brick cement plastered wall with single glazed window has following technical specifications observed in both buildings:

Building	Window to Wall Ratio (WWR)	**Building Envelope**				
		Frame Type	Glazing Type	U-factor (w/m2.K)	SHGC	VLT
CSE	15%	MS Metallic Sash Window	Single Glazing	7.1	0.82	0.72
AAGC	27%	Aluminum Window	Single Glazing	7.1	0.82	0.68
AAGC stair-case	>60%	Aluminum Window	Single Glazing	7.1	0.82	0.92

Table 05: Observed R and U-values for Building Envelope

		WWR≤40%	40% <WWR≤60%
Climate	Maximum U-factor	Maximum SHGC	Maximum SHGC
Composite	3.30	0.25	0.20
Hot and Dry	3.30	0.25	0.20
Warm and Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51

Table 06: U-factor and SHGC requirements of the rated fenestration for two WWR ranges according to code compliance given in Table 4.3 of ECBC.

Lighting Power Density (LPD)

As per the Energy Conservation Building Code specifies the LPD for various building typologies. Based on the recommended value, the energy consumption at CSE main building and AAGC found to be higher.

It is found that the range of LPD in both buildings is substantially higher than the recommended values in the energy conservation measures. In CSE main building the average LPD on all the floors is touching as high as 36 W/m^2, whereas the AAGC building which is partly occupied with library in the basement consumes LPD up to 31 W/m^2. The figures are audited on floor-area-wise basis. The LPD is a major indicator in evaluating the energy performance of the building in terms of lighting efficiency. We have found the connected lighting fixtures are operated through single switch. It does not allow for design based on desk-task-lighting concepts. The desk-task-lighting system allows for larger efficiency and targets particular task and required level of illumination at a given location to use the energy more efficiently. The day-lighting is most areas are restricted due to inappropriate furniture layout design and positioning of lighting fixtures.

CSE	Lighting (kWh)	Total Area (m^2)	Lighting Power Density (kW/m^2)
Basement (Admin)	4707	211	22.31
G. Floor	4922.5	214	23.00
First Floor	5681.66	198	28.70
Second Floor	6132.1	170	36.07
Third Floor	4893.7	156	31.37
Fourth Floor	5436.29	147	36.98
Canteen	561	147	3.82

Table 07: Lighting Power Density for CSE main Building

AAGC	Lighting (kWh)	Total Area (m^2)	Lighting Power Density (kWh/m^2)
Basement (Library)	7331.3	333.52	21.98
Ground Floor	4179.46	165.83	25.20
First Floor	4124.16	131.74	31.31
Second Floor	608.256	83.79	7.26

Table 08: Lighting Power Density for AAGC Building

CSE-Green Building

CSE main building having 128 kWh/m2/year, with more than 50% air conditioned built-up space of office category, stands in ***3-Star*** of BEE's energy efficiency bandwidth for Buildings. Whereas AAGC having 63 kWh/m2/ year, with less than 50% air-conditioned built up space office, stands in ***2-Star*** rating as per BEE's Building Energy Star Program. However, energy performance indices allows for lot of scope to implement energy conservation measures. Further, the building represents an interesting best practice in office category of Sustainable Habitat paradigm, and opens an array of learning outcomes embodied in its design performance. Given the baseline performance measures, there are considerable opportunities to measure, report and verify energy and water consumption of the overall building assembly.

The compliance mechanism of both the buildings matches with the various green building criteria of the prevailing voluntary Green Building Rating system, such as GRIHA or LEED in India, is adopted in the built environment. The CSE buildings contribute to the message of sustainable habitat including natural resource optimization and energy conservation. It also defines one of the best practices for healthy and livable office built-environment.

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