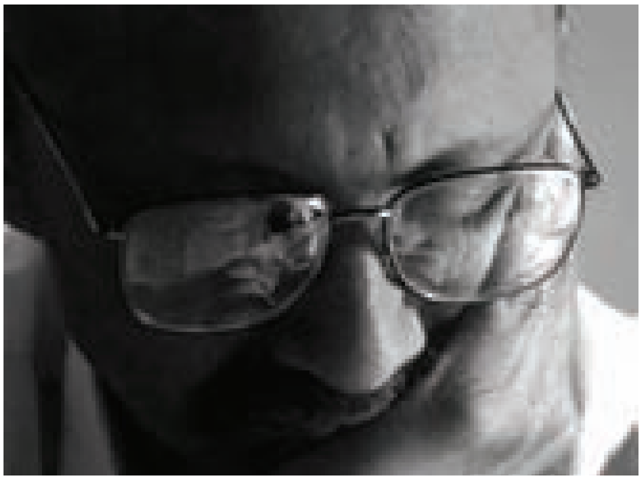
WALKING THE TALK

MAKING OF A SUSTAINABLE CAMPUS

THE ANIL AGARWAL ENVIRONMENT TRAINING INSTITUTE

AAETI



THE ANIL AGARWAL ENVIRONMENT TRAINING INSTITUTE (AAETI)

AAETI is a project of the Centre for Science and Environment (CSE). A learning, training and innovation centre designed to find appropriate and affordable solutions to some of the most pressing problems faced by the global South — from climate change, air pollution and urban mobility to water and waste management and environmental degradation.

The institute has been named after the late Anil Agarwal, CSE's founder-director and a leading figure in India's environmental movement.

The Institute will conduct its courses on this campus through six schools of learning. The faculty will comprise some of the foremost experts in their fields — from India and other countries. It aims to build capacities of a range of audiences – regulators, lawmakers, communicators, professionals, students, civil society members and administrators.

Currently, the campus can house some 100 guests and some 40-50 permanent staff. The cafeteria has a sitting capacity of 150 people. The academic block has 6 classrooms of various sizes with their capacities ranging from 35 people to 124. The campus also houses CSE's pollution monitoring laboratory, which is designed as India's first faecal sludge testing laboratory.

We hope you will enjoy our campus. It is our dream to make it a living laboratory of ideas and practice and a place where deliberations, dialogue and dissent can thrive.

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ANIL AGARWAL ENVIRONMENT TRAINING INSTITUTE

Location
Nimli, Rajasthan

Climate zone
Composite (Extreme summer and winter with warm-humid monsoons)

Typology
Institutes

Site area
39,090 sq.mt (9.66 Acres)

Gross area (including basement)
9,800 sq.mt

Air conditioned area
2,900 sq.mt

Cost
₹40 crores

Occupancy schedule
24 hours: residential
8 hours: academic and administration

Owner
Center for Science and Environment, New Delhi

Architecture, landscape and interior design
Pradeep Sachdeva Design Associates

Structural design
Arvind Gupta Consultants

Water and wastewater
Krim Engineering Services

HVAC and electrical consultants
McD Built Environment Research Laboratory Pvt Ltd

Energy consultants
Environmental Design Solutions Pvt Ltd

Civil structure and finishes contractors
M/S Chawla Techno Construct Ltd

Electrical services contractors
M/S Vijay Technical Services & Const. Pvt Ltd

Plumbing services contractors
M/S Yash Plumbing Engineers

HVAC contractors
M/S Adhunik Vatanukool Pvt Ltd

With collaboration from
CSE's energy, water, buildings, wastwater and solid waste management teams

02

OBJECTIVES OF AAETI'S GREEN CAMPUS

When we began working on AAETI we had a lot of ideas about what 'green' meant. But as we have worked on these concepts and put them in practice, we have learnt a lot of what works and what does not. We are presenting this documentation of our sustainability plan, not because we believe this is the best or the final word on green buildings. But because we need to use each such learning to build a community of practice of green architecture. We need to do and we need to measure what we have done and why.

But firstly, what have we tried to put into practice. What is a green building?

Energy: Materials, insulation and appliances

1. Minimise the footprint of the building so that it is as compact as possible and utilise maximum daylight. We have designed our building in such a way that maximum daylight is achieved and at least usage of artificial light is required.
2. Build to optimise on the local ecology and climate – build around the sun and the wind. This practice of passive architecture brings down the energy footprint.
3. Insulate as best as possible – the choice of building material is important.
4. Shade the building so that direct sun is avoided and ventilate so that wind becomes important for 'comfort'.
5. All this done, choose the most efficient heating, ventilation and air conditioning system (HVAC), which is best for long term energy use. Decide on temperature in building so that it is not too cold or too hot. Dress for the season and for comfort. Make sure there is ventilation and that there are fans – comfort is not only about temperature but about the design for air in the room and on our bodies.
6. Choose efficient appliances – use this to reduce energy use futher.
7. When all has been done to reduce energy demand, then plan for the energy generation (as much as possible) to be from renewable sources.

Water-waste

8. Make the campus water neutral – take less from groundwater then what you put back.
9. Ensure all sewage is treated locally.
10. Ensure that all treated sewage is re-used and the wastewater is recycled.

Garbage

11. Fullly segregate at source.
12. Minimise the use of plastics and non-biodegradables in the campus – move towards zero-plastic use over time.
13. Reduce food waste – educate people about taking only as much as they need.
14. Compost all biodegradable waste on site.
15. Recycle all other waste – segregate and plan its reuse. Work towards no waste for landfill.

Monitor all the above, after the building is commissioned. Report and revise goals. Must know what is working and what is not.

Connect the design building and operational performance so that sustainability goals are met.

The sustainable CAMPUS

Site Planning
• Respond to topography and site features
• Optimise building footprint
• Retain trees - native landscaping
• Grow your own food

Materials
• Use material high on insulation for building envelope
• Use recycled waste based products
• Reuse construction waste

Energy Use
• Day lighting
• Natural ventilation
• Energy efficient equipment
• Climate responsive architecture for thermal comfort
• Renewable energy

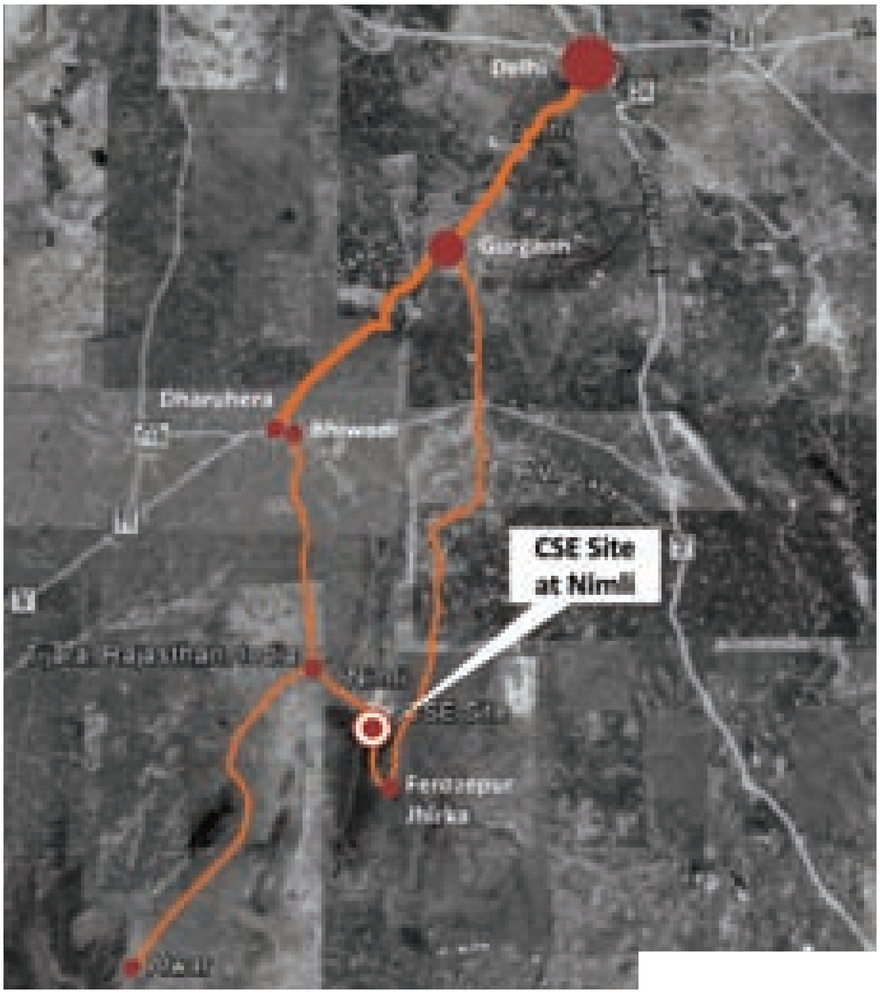
Water and Wastewater Management
• Harvest rainwater – recharge groundwater
• Revive water bodies
• Reduce need for irrigation
• Water efficient fittings and fixtures
• Treat and reuse wastewater

Waste Management
• Segregate at source
• Compost
• Minimise use of plastic and non-biodegradable products
• Reuse and re-cycle

03

UNDERSTANDING THE SITE

The project site is semi-arid and highly undulated with a seasonal stream (nallah) cutting through the plot. Topographically, the site is a shallow valley with the nallah being the lowest point, and the highest points located along its eastern and western edge.



Location

Nimli Village, Tehsil Tijara, Alwar, Rajasthan

KEY DISTANCES

Delhi (via Bhiwadi)
121km

IGI Airport (via Bhiwadi)
111km

Gurgaon (via Bhiwadi)
86km

Gurgaon (via Ferozepur Jhirka)
108km

Bhiwadi
46km

Alwar
62km

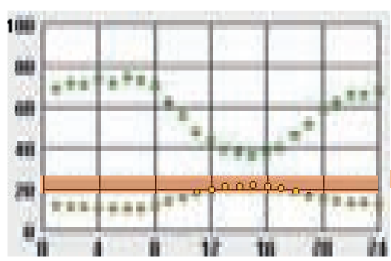
Tijara
15km

Ferozepur Jhirka
11km

DIURNAL VARIATIONS FOR DBT & RH

The Diurnal variations for dry-bulb temperature (DBT) is 8-15°C and relative humidity (RH) is 30-40%

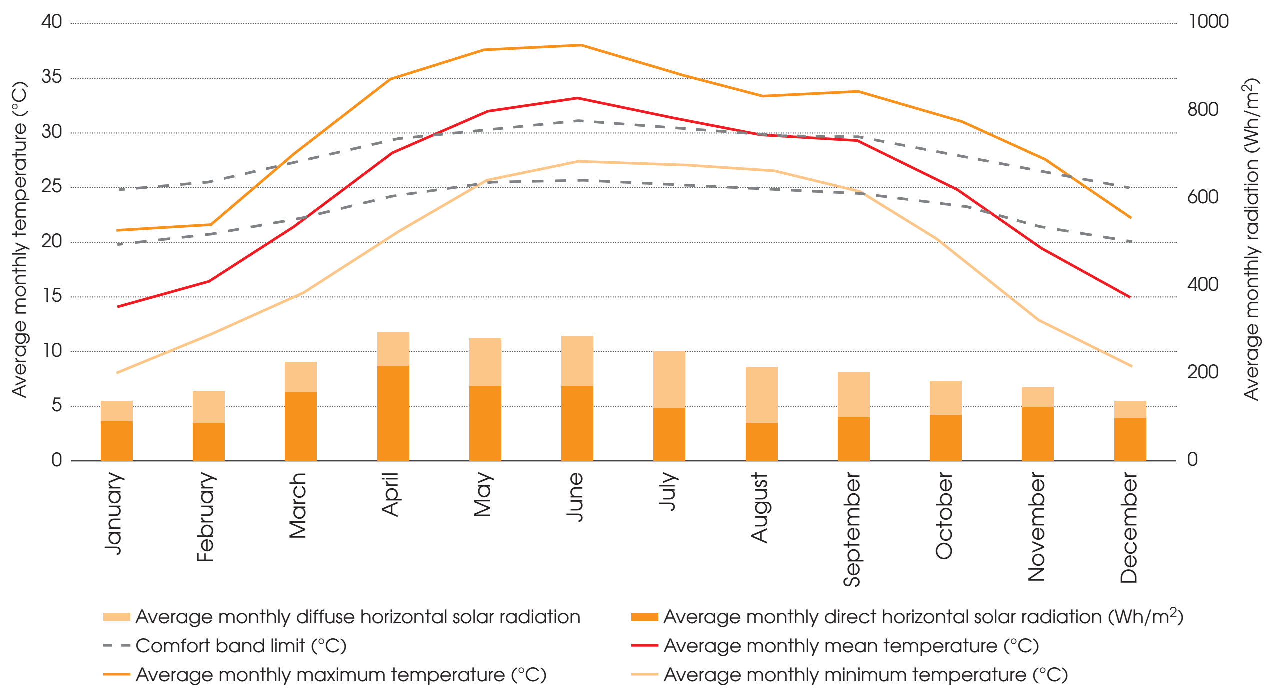
Hourly DB Temperature (deg C

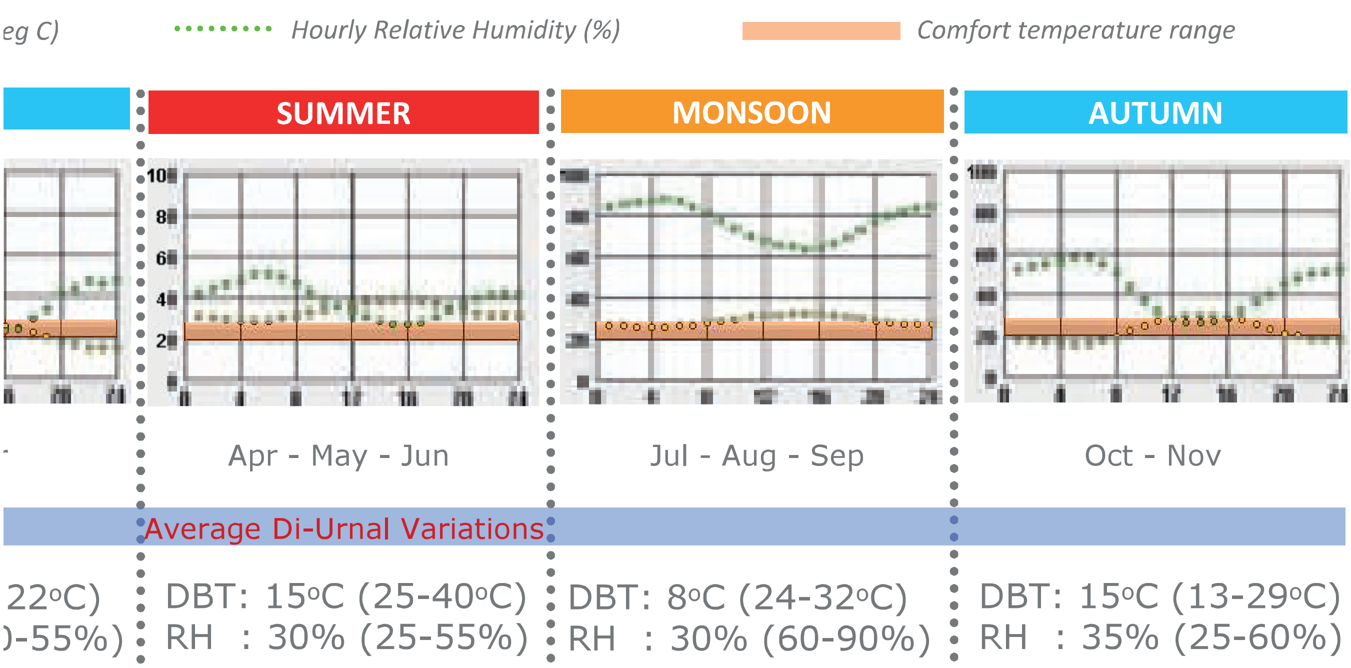
WINTER	SPRING
	
Dec - Jan	Feb - Mar
DBT: 14°C (7-21°C) RH : 40% (35-75%)	DBT: 15°C (7-22 RH : 35% (20-5

CLIMATE

Extremes: Winter, summer and monsoons

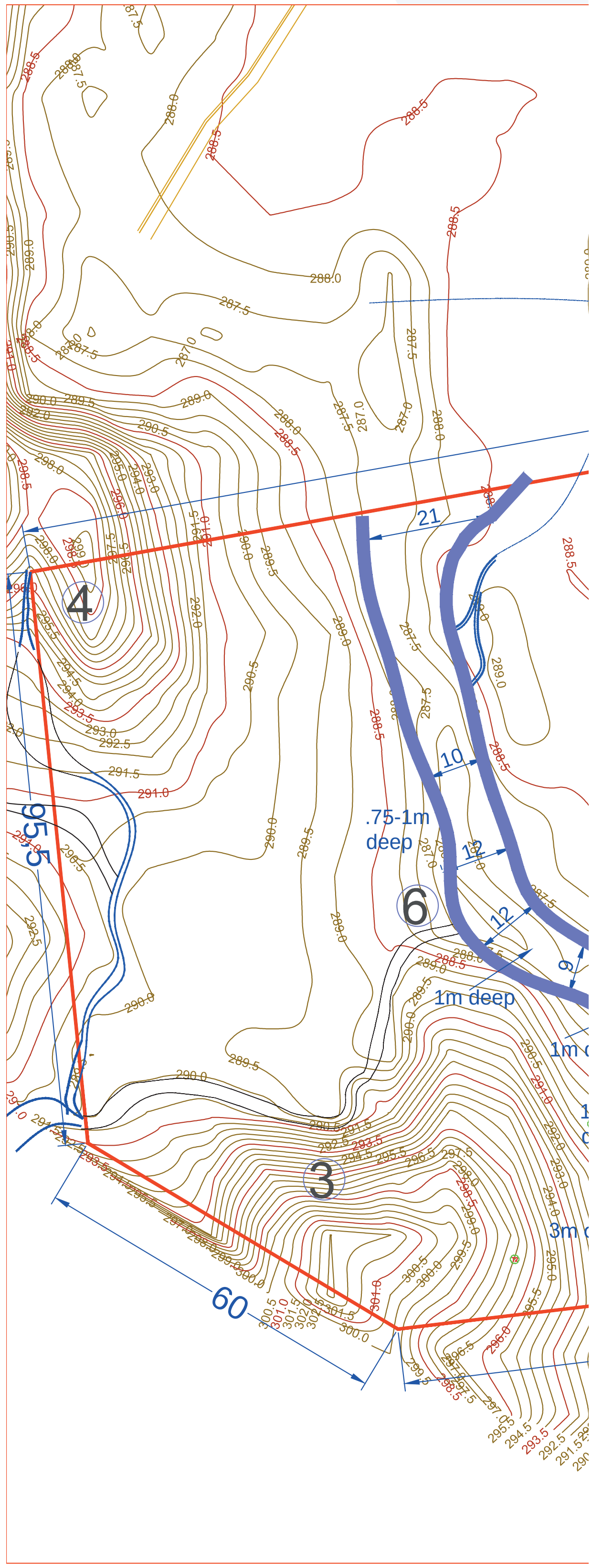
Climate summary | New Delhi



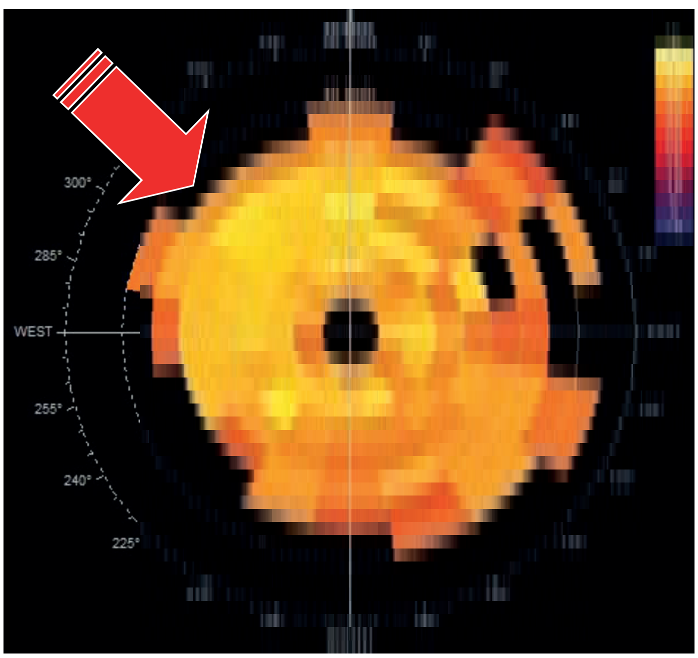


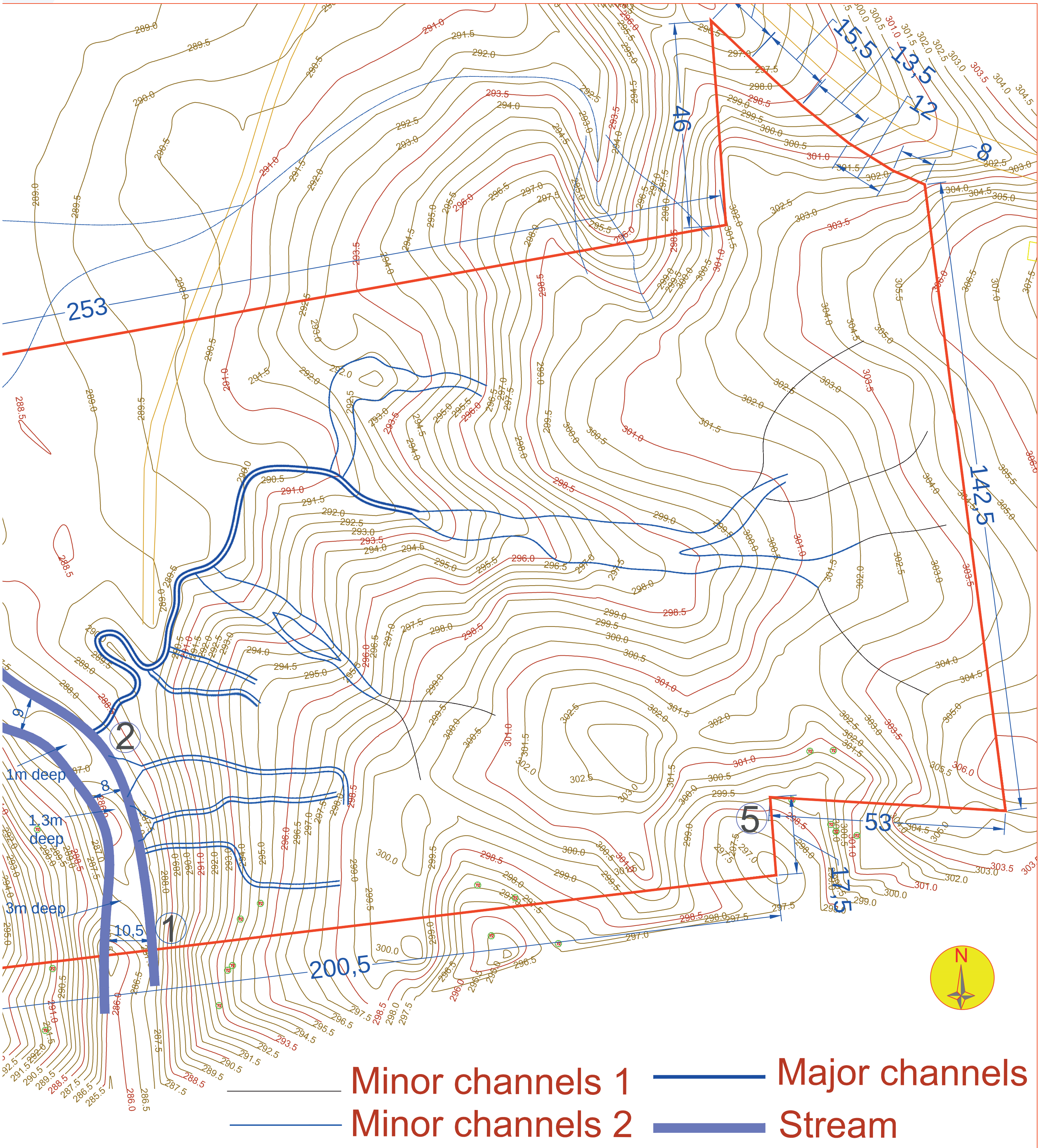
DRAINAGE:
Map of drainage and topography of the area

The site is part of the larger natural drainage pattern of the area, the nallah (seasonal stream) cuts through the site; and the catchment is vast. If not planned carefully the campus would be flooded during monsoons and would have water scarcity in the rest of the season.



Buildings need to be protected from hot summer winds that predominantly come from north-west.





253
46
15,5
13,5
12
8
142,5
53
17,5
200,5
10,5
1m deep
1.3m deep
3m deep
1
2
5
N
Minor channels 1
Minor channels 2
Major channels
Stream

04

UNDERSTANDING WHAT WE MEAN BY 'COMFORT'

What is comfort?

In Neemli, the average peak summer temperature reaches 44°C and drops to 7°C. During the monsoons, humidity can be as high as 80-100 per cent, making for unbearable heat. The advantage we have is our 'microclimate' – shrub-forests surrounding the campus and a seasonal wind regime. Buildings can be designed and air conditioning and heating provided to maintain certain temperature and humidity conditions.

But first we needed to agree on the room temperature that makes us comfortable?

There are standards that define indoor comfort conditions but their relevance to Indian environment is questionable. When CSE was deliberating this, the National Building Code (NBC) prescribed 25-30°C for naturally ventilated buildings and 21-23°C for air-conditioned buildings independent of weather conditions outdoors. In 2016, NBC revised its comfort conditions, based on adaptive comfort model developed by the Ahmedabad based CEPT university. This new approach recognizes that people's thermal comfort needs depend on their past and present context and that these needs vary with the outdoor environmental conditions of their location. Under this model, there are three different typologies for buildings; naturally ventilated (19-35°C); mix-mode building (23-28°C) and air conditioned building (24-26°C). AAETI would fall under mixed-mode, where we use air conditioning in limited areas and for limited period of the year.

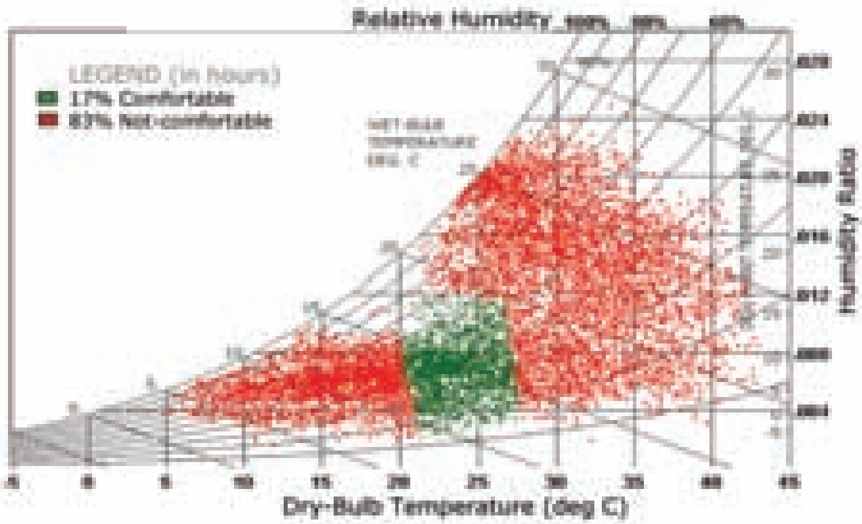
But what is the right temperature for comfort? To put the confusion to test, CSE carried out an "unscientific survey" of its staff to figure out what temperature conditions they felt comfortable working in, to help establish a comfort range. CSE office space is equipped with room air-conditioners, ceiling fans and openable windows, and staff is regularly found to playing around with a mix of these three to make themselves comfortable. When questioned most people said they are comfortable at 23-24°C. But when the temperature was actually measured at their workstation, we found that most did not complain of discomfort unless the temperature climbed above 28-29°C.

What is clear is that our 'sweet' temperature zone will define sustainability of the project. This means that we need to also ensure that we dress for climate – adopt Japan's famous bushshirt rule so that clothing would be local climate appropriate – no ties, suits in summer.

We agreed our campus buildings would be designed for thermal comfort conditions of 26 ± 2°C for summer and 18°C for winter.

ASHRAE standard 55 comfort model for air-conditioned spaces

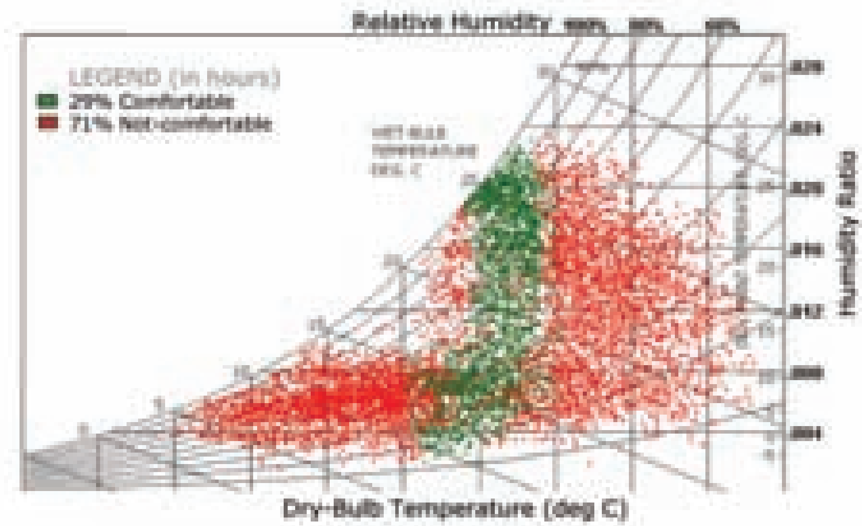
Details of ASHRAE standard 55 confort model



- This model of thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic rate (met), air velocity, humidity, and mean radiant temperature.
- Dry Bulb temperature from 20-27°C is considered comfortable
- Annually, only 17% out of 8760 hours are comfortable without any air-conditioning as per this comfort model.

ASHRAE standard 55 comfort model for non air-conditioned spaces

Details of ASHRAE standard 55 adaptive confort model



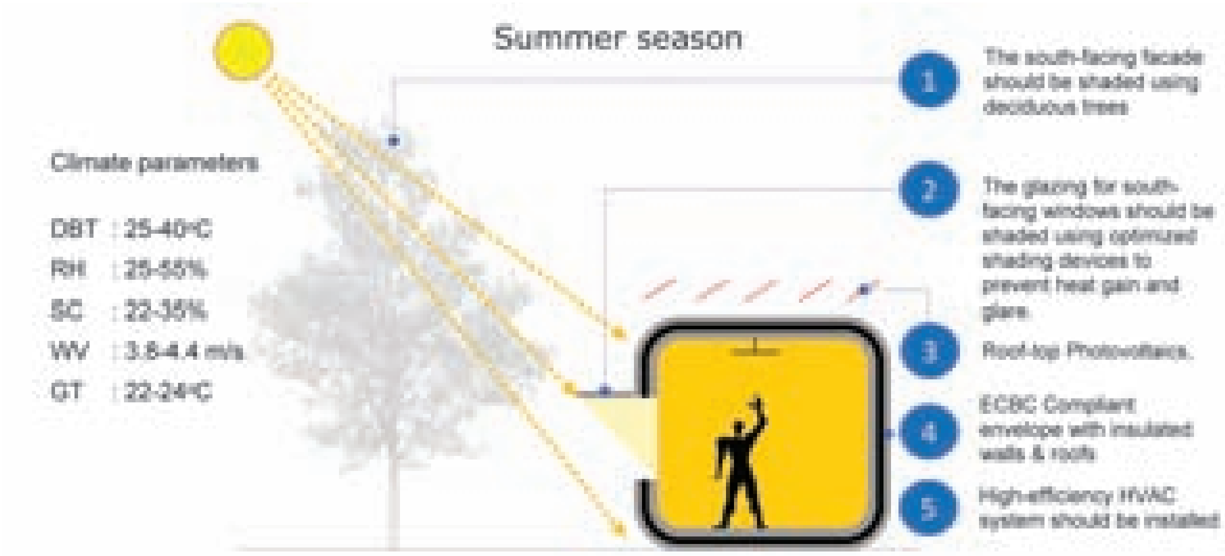
- This model assumes that occupants adapt their clothing to thermal conditions, and are sedentary (1.0 to 1.3 met). There must be no AC System.
- Dry Bulb temperature from 20-30°C is considered comfortable
- Annually, about 29% out of 8760 hours are comfortable without any air-conditioning as per this comfort model.

DESIGNING FOR THE CLIMATE: PASSIVE ARCHITECTURE

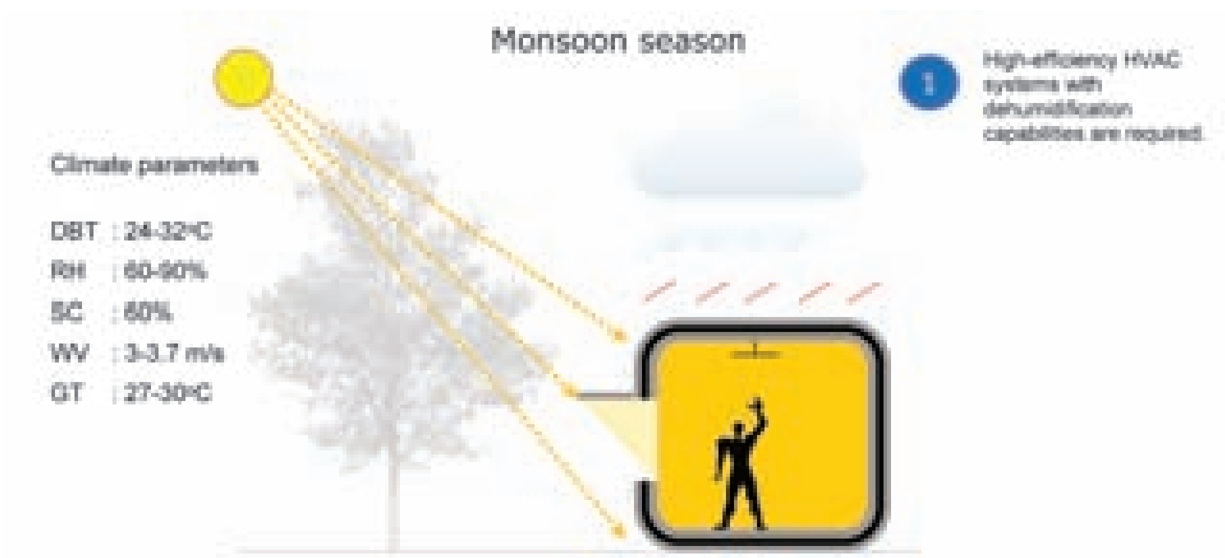
Rajasthan's traditional architecture has mastered the modern art of passive building design – dense, compactly built structures with narrow passages that minimise direct exposure to the sun and the use of wind for ventilation. We learnt from this and practiced this and more at AAETI.

We found that we needed to design for the sun.

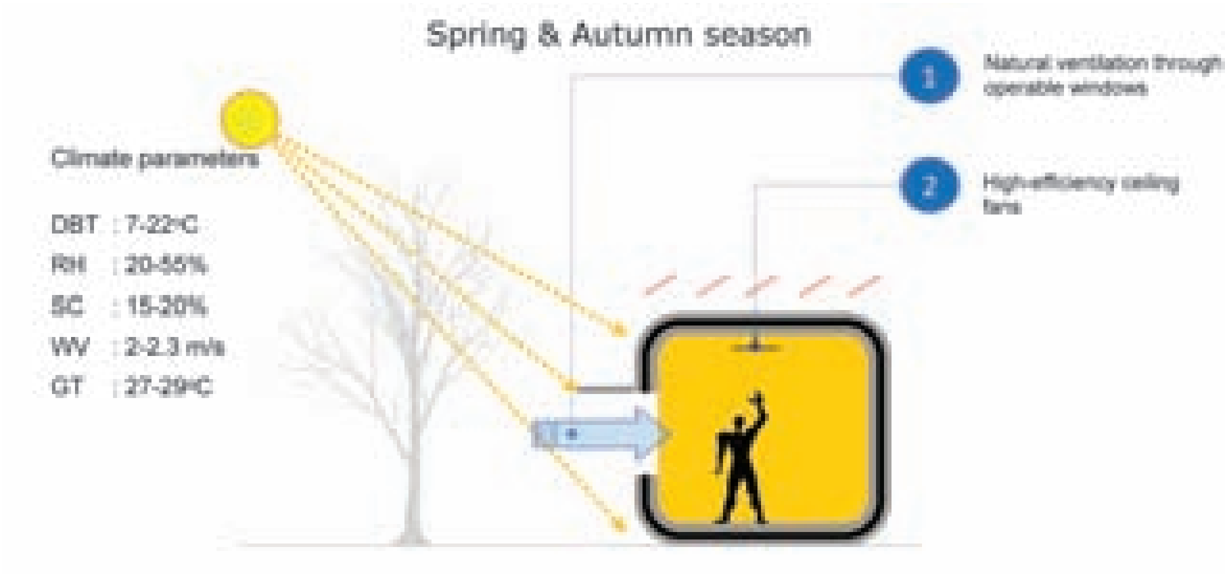
Envelope shading, window shading, highly efficient envelope & HVAC



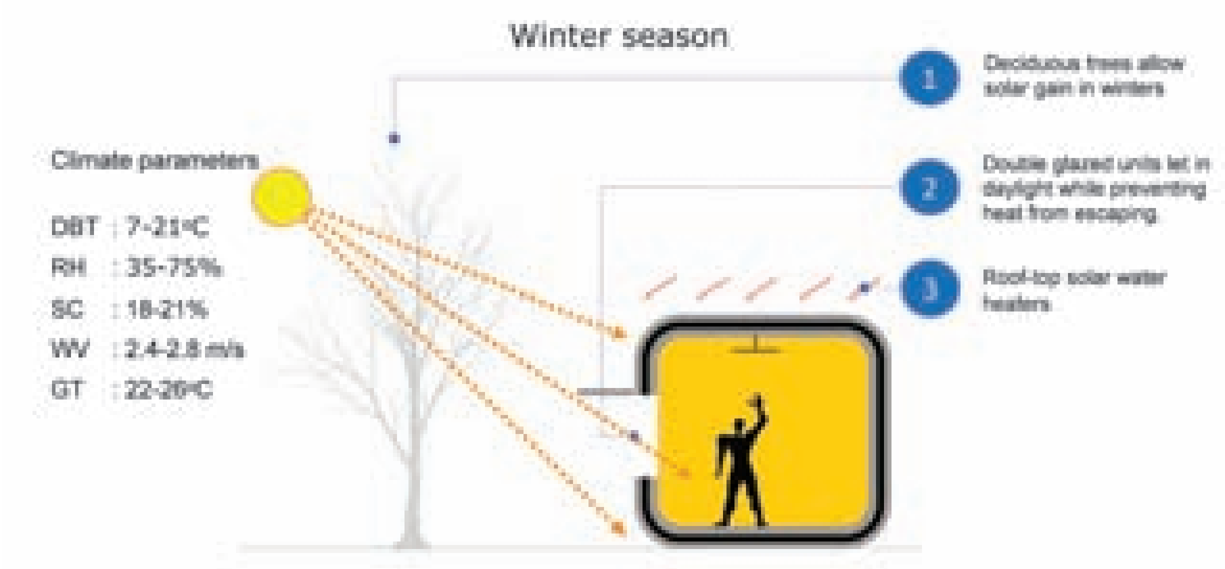
High-efficiency HVAC with dehumidification



Natural ventilation and indoor air movement



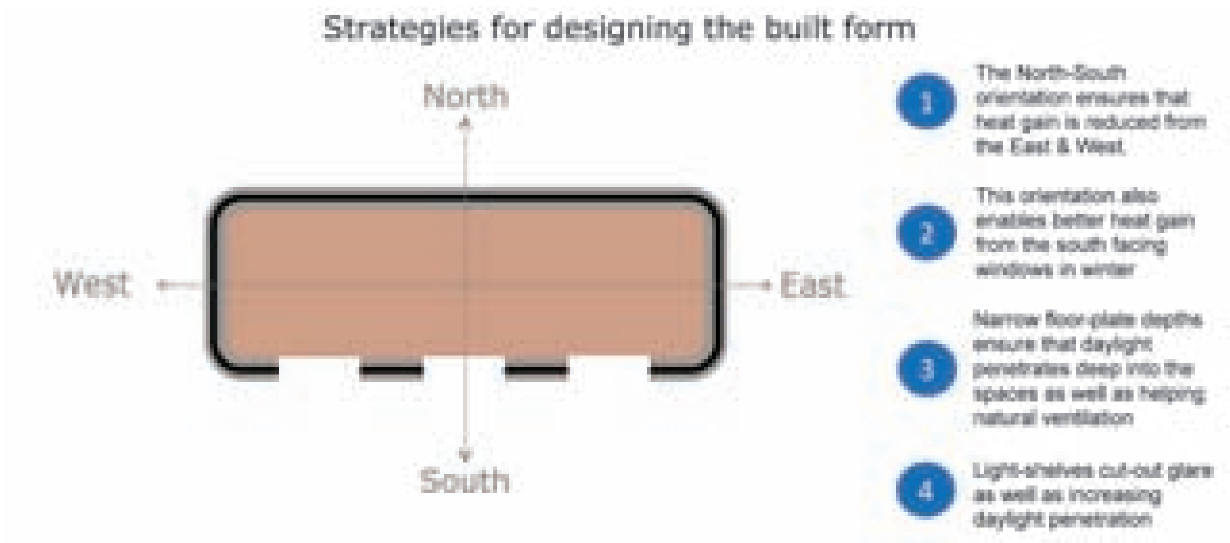
Passive solar gains, High thermal mass & Glare prevention with shading devices



First, we have oriented most of our buildings in the east-west direction, which reduced exposion to the harsh summer sun – or in other words, our building are facing north-south. Where we could not do so (canteen and guest house) we introduced special design interventions.

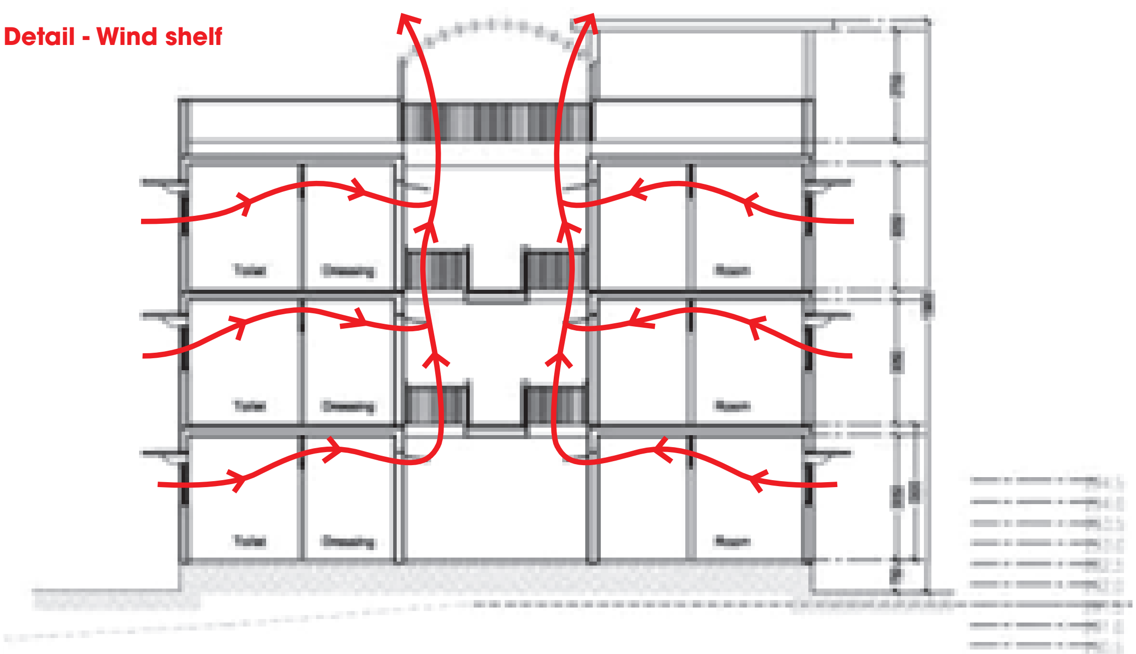
Now roughly 90 per cent of the windows and ventilators (fenestrations) open in the north or south direction.

North-South orientation, less than 30% Window Wall Ratio, narrow floor-plate depth & light shelves



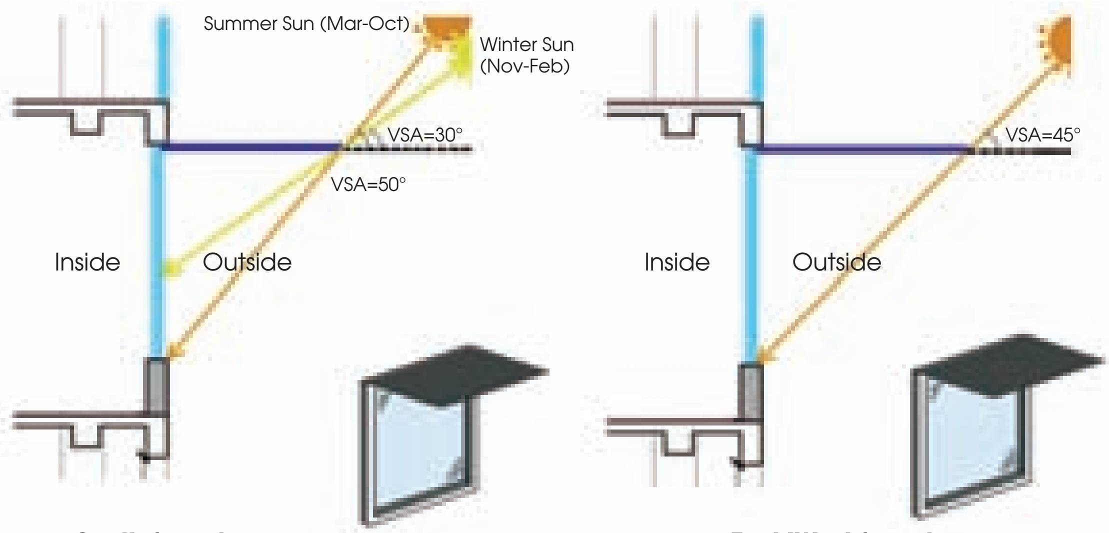
Second, buildings are designed with courtyards or cut-outs to provide natural ventilation and day-lighting. The student housing block has a double loaded corridor design (a single central corridor with student rooms flanking on both side) which made it tricky to have cross-ventilation as windows in the rooms had access to outdoors only in one direction. This has been solved with introduction of special wind shelves in the corridors that allow the hot air from building to escape facilitating cross ventilation in all rooms. It also helps bring in natural light to the corridor as well.

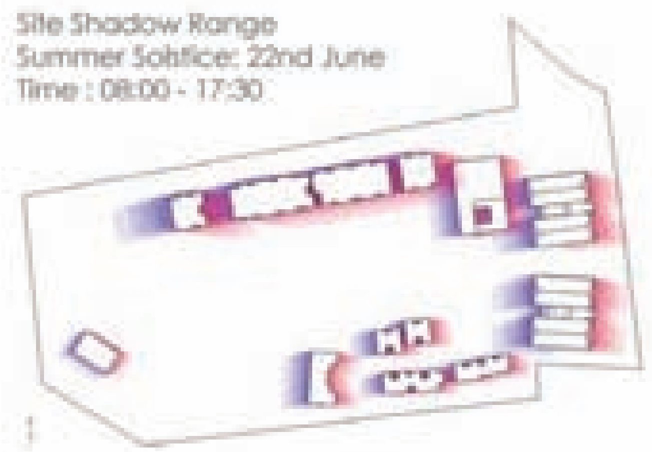
Detail - Wind shelf



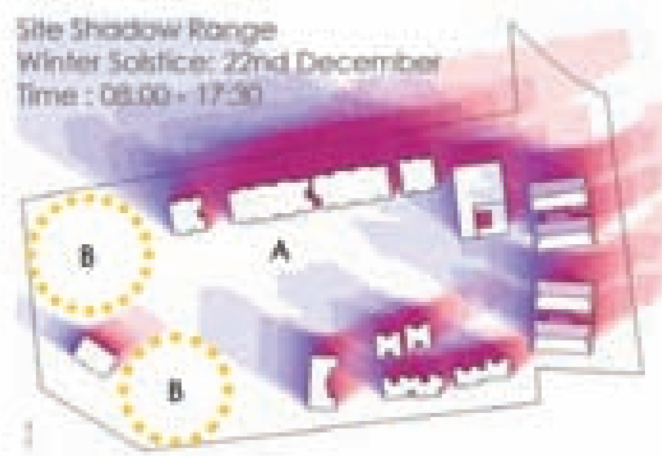
Third, most importantly, we have extensive and deliberate use of chajjas – horizonal sunshades – on all windows to further cut down exposure to direct sunlight.

Facade specific shading recommendations





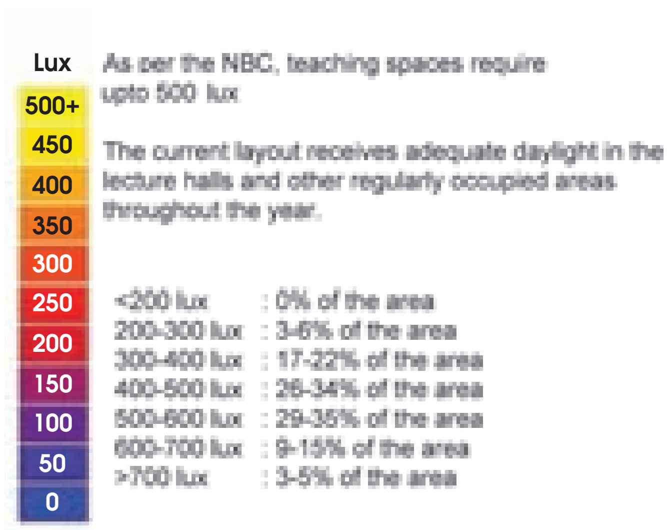
Strategy
Outdoor Thermal Comfort
- Shaded courtyards
- Shaded pavenets & parking
- Shaded OAT
- Sit-outs and Outdoor activity zones in shaded areas between buildings.

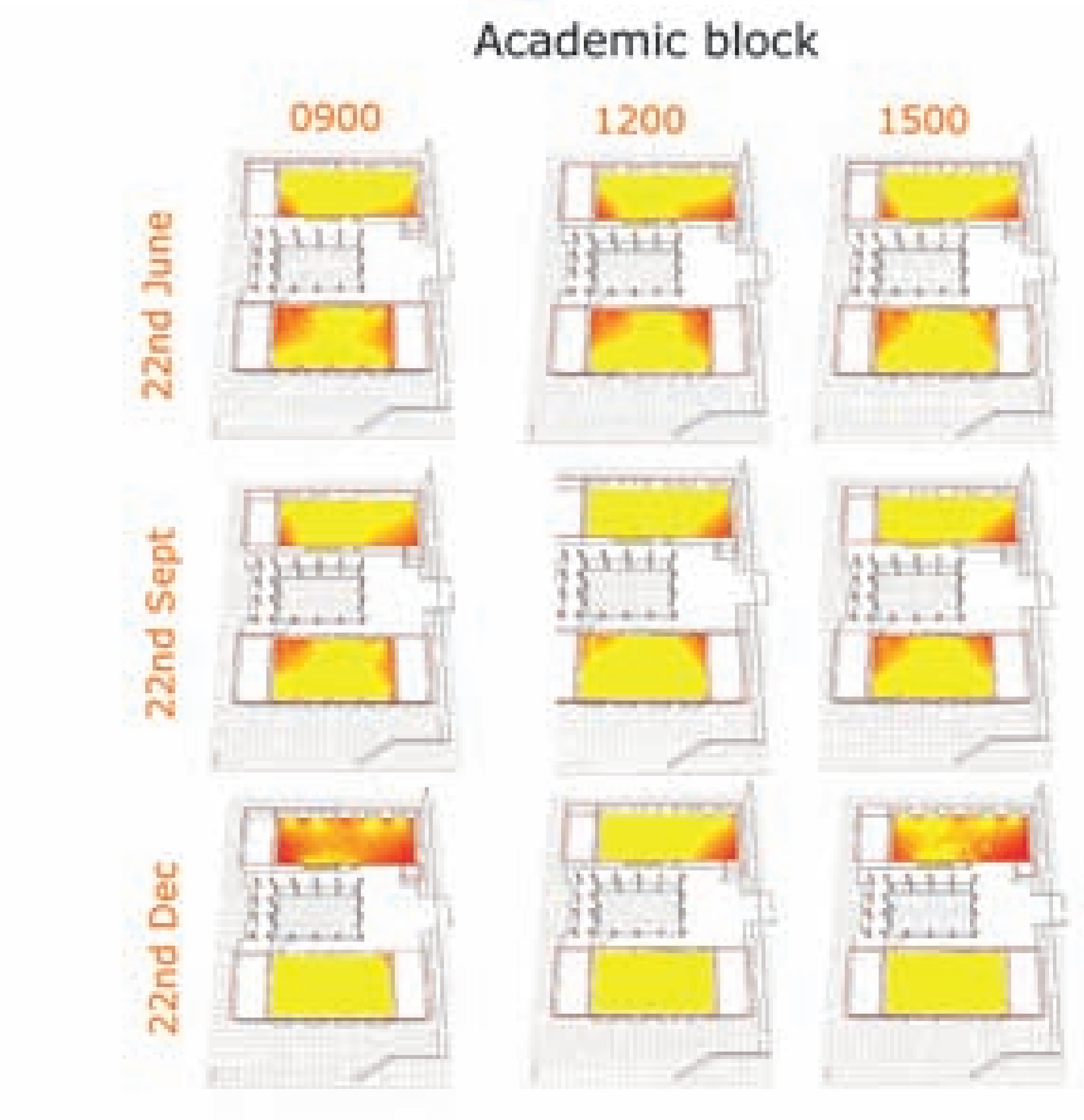


Strategy
Bright sunny winter spaces
- The central open space (A) receives adequate sunlight during winters.
- Locate ground-based solar PV arrays in areas (B) receiveing adequate sunlight even in winters.

Fourthly, cross-ventilation is ensured in all spaces including the ones not meant for regular human habitation (the monkey problem is making us close some of these spaces, but we are trying to find ways to balance the ventilation requirements).

Adequate daylight levels are achieved in 100% of the regularly-occupied areas





06

FINDING THE RIGHT BUILDING MATERIAL: FOR EMBODIED ENERGY AND INSULATION

Architectural design with elements like courtyards and fenestrations help a building to breathe and regulate internal comfort conditions. But a building's ability to achieve and retain these thermal conditions is governed by the material used in the building envelope.

Further, as manufacturing of building materials is also associated with massive environmental degradation (stone and sand mining) and greenhouse gas emissions, we need to find the right building material with the least embodied energy and the highest insulation (and of course cost, today and tomorrow).

The measure used to calculate the material's insulation is U-value – the amount of thermal energy that the material allows to pass through. The lower the U-value the most insulating is the material. Our energy consultants helped to map the U-value of different building materials:

Different U-Value of material

External wall assembly and insulation	Total thickness (mm)	U-value (W/ sq.mt/K)	Cost (INR/ sq.mt.)	HVAC energy savings (%)	HVAC plant downsizing (%)
230mm brickwall + 50mm insulation + external cladding	**395**	**0.46**	900 + cost of external cladding	**13.3**	**13**
230mm brickwall + 50mm insulation + 115mm brickwall	**395**	**0.42**	**1,075**	**14.5**	**13.9**
200mm Cement Stabilized Earth block wall + 50mm insulation + 100mm Cement Stabilized Earth block	**365**	**0.43**	**1,300**	**13.9**	**13.5**
200mm flyashbrick wall + 50mm insulation + external cladding	**250**	**0.44**	1,050 + cost of external cladding	**13.9**	**13.5**
200mm Hollow Concrete block wall + 50mm insulation + external cladding	**225**	**0.40**	1,200 + cost of external cladding	**14.5**	**13.9**
200mm AAC block + 50mm insulation + external cladding	**225**	**0.36**	1,450 + cost of external cladding	**15.4**	**14.7**
200mm AAC block + 25mm insulation + 100mm AAC block	**325**	**0.42**	**1,625**	**14.5**	**13.9**
300mm AAC block	**300**	**0.47**	**1,350**	**13.3**	**13**

Based on the above we narrowed down our search to the following:

Composite walls of brick, hollow concrete & AAC blocks XPS insulation were compared to evaluate which wall section is best suited to the needs of the project

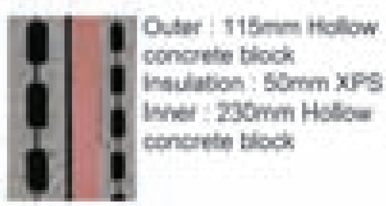
Options for external wall sections

Wall-section: Option 1

U-value: 0.42 W/sq.mt/K

Total thickness: 395mm
Cost: ₹3,000 per sq.mt

Wall-section: Option 2



U-value: 0.40 W/sq.mt/K

Total thickness: 395mm
Cost: ₹3,000 per sq.mt

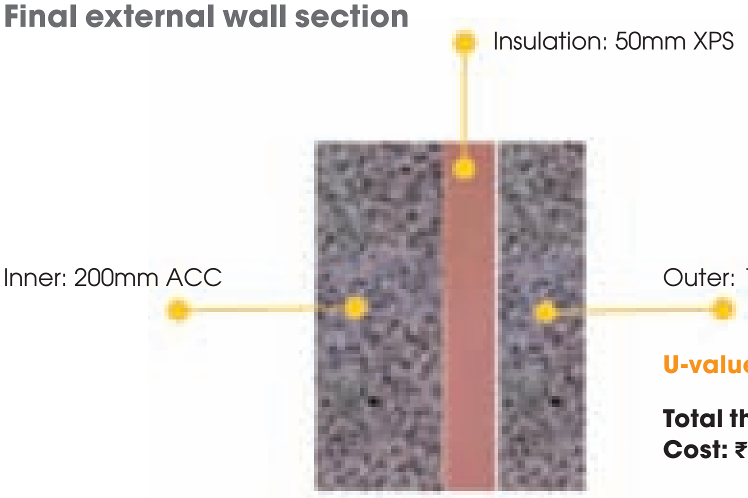
Wall-section: Option 3

U-value: 0.42 W/sq.mt/K

Total thickness: 325mm
Cost: ₹2,200 per sq.mt

We finally agreed on this option:

Final external wall section



U-value: 0.36 W/sq.mt/K

Total thickness: 350mm
Cost: ₹2,600 per sq.mt

We decided to use 50mm XPS sandwiched between a 200mm and a 100mm AAC block walls.

This was the most insulating walling combination with a U-value of 0.30 W/sq.mt./K which is considerably better than the prescribed standard of 0.44 W/m2K by the energy conservation building code (ECBC). Now the ECBC prescribes 0.40 W/sq.mt./K.

The Aerated Autoclave Concrete (AAC) block were used because they are manufactured using high recycled waste (flyash) and provide better insulation. Flyash bricks were used for non-structural work and partition while ACC blocks are used in the envelope owning.

Initially we were sceptical as XPS is a petroleum based product with high embodied energy and pollution. But comparative data showed us that improveed insulation would reduce energy requirements of the building and this would outstrip the embedded energy and pollution of XPS.

Roof:

Huge energy losses happen here. So, it was decided to use a combination of 100 mm XPS with 100 mm RCC on the roof. We also used the "cool roof" technique to reflect solar heat. At AAETI, broken white and recycled ceramic tiles of 13 mm thickness are used on the roof to reflect the heat.

Windows: Plugging the leakage

Windows though strategically located for maximum daylight and cross-ventilation are still major medium for heat gain/loss in the building.

To minimise this we used windows with double glazing with a U-value of 2.8 W/m2K and effective solar heat gain coefficient (SHGC) of 0.25 -- direct solar heat penetrating through glass. This low level of SHGC has been achieved with the use of high performance glass, combined with heavily shaded windows. Without the shading, we would have had to use darker tint glass, which would have reduced the visual light into the interiors.

To ensure quality daylight, window glass with visual light transmittance (VLT) of 81 per cent is used at AAETI.

Our estimate is that the investment in insulation and materials would bring down the energy demand of the building by over 20 per cent as compared to a conventional building.

This is the biggest investment at AAETI. We have to now see how it works to reduce our energy demand and to make the building comfortable for all.

07

HEATING AND COOLING: FINDING A SYSTEM LOW IN ENERGY AND YET COMFORTABLE

Our climate is about the extremes – very hot and very cold and very humid. In conventional buildings we move from using air conditioners to space heaters for most of the year, adding to energy bills and all the environmental impact that goes with it.

Active `cooling' to ensure thermal comfort is needed in the months of May to July (3 months) and active heating for 1 month, mid-December to mid-January.

So, we began discussions on the ideal Heating, Ventilation and Air Conditioning (HVAC) system, keeping in mind that we wanted a system that could be powered by solar energy – we wanted to plan for a campus that could go completely off-grid in the future. We met people; travelled to different projects where alternative HVAC systems had been installed; studied the economics and finally looked at the data:

Comparison for different systems which was proposed for the finalization of system

Description	VRF	3 stage evaporative cooling with decentralised heat pump	3 stage evaporative cooling with central heat pump	Radiant cooling system with central heat pump	Radiant cooling system with central VAM
Load or Capacity	72 TR	56,000 CFM + 56 TR	56,000 CFM + 27 TR	46TR	47 TR
Peak power demand kW	86.40	66.36	43.2	32.20	12.4
Capital cost (lakhs)	50.40	123.20	107.60	142.17	250.4
Per unit cost ₹/kWh	8.00	8.00	8.00	8.00	8.00
Operating cost (lakhs)	16.35	9.55	10.51	9.61	5.7
Pay back		10.72	9.80	13.62	18.8
Demand kWh/day	1,617.41	588.00	588.00	803.71	309.5
Solar PV	269.57	98.00	98.00	133.95	51.6
Total capex (lakhs)	346.92	231.00	215.40	289.52	307.1
PV area required in sq.mt	2,156.54	784.00	784.00	1,071.62	5,702.7

The decided to invest in a 3-stage evaporative cooling system but we decided to implement the system so that it was decentralised – different buildings would have their own version of the system, based on their requirements.

The system was selected for the following reasons:

a. The energy consumption would be almost half as compared to the other best systems

b. The overall capital cost would be lower, if we accounted for the generation of electricity through solar or wind. The objective for planning was to try and make the campus off-grid.

c. The choice of a modular and decentralised system would allow us to innovate and to monitor energy use in different conditions.

d. We also decided to avoid compressor/refrigerant based cooling for major duration of the year and yet we could make the spaces comfortable.

As we implemented the scheme, we have made changes – based on our learnings of our needs and what we could afford.

08

AAETI'S HVAC SYSTEM – OPTIMISING FOR CLIMATE AND ENERGY REQUIREMENTS

The campus has five different systems – we want to see how these work and what is the energy-comfort quotient that we can monitor and then build upon or better.

Student/Guest Housing (SH1 and SH2)

TOTAL BUILT AREA
4,493 sq.mt.

3-stage evaporative cooling system with heat pump-chiller

The system is primarily based on moving air – large quantities through the ducts and during the period when we need heating or cooling, the heat pump chiller kicks. It's a system based on the old-fashioned desert cooler, but made more efficient through its direct and indirect technology of cooling air. When the heat-pump chiller is operational for de-humidification (during monsoons), the system also provides hot water as a by-product.

In the first stage, the air is cooled indirectly by pipes carrying water which is humidified in the second stage through direct evaporation. This is an improved version of classic desert cooler and is perfect for hot and dry season which is the dominant weather in Rajasthan.

The third stage which uses the refrigerant for cooling instead of water kicks in only when the ambient air has too much humidity rendering evaporative cooling redundant. This system restricts the use of energy intensive to 2-3 months of monsoon.

Hot-water provided as the by-product of the system is used to meet hot water requirements of the campus. Additionally, it doubles up as space heating in winters.

All rooms are provided with ceiling fans to serve as the first means to tackle rising heat as they most efficient and prudent means to get cool if the temperature is off by a few degrees only.

SH1: Unit 1 serves the top 2 floors and is installed on the roof and its capacity is
12,500
Cubic Feet Minute (CFM)

SH1: Unit 2 serves 3 floors, basement, ground, first and its capacity is
15,000
CFM

SH2: 1 unit and its capacity is
15,000
CFM

The heat pump-chiller is installed on the roof of the cafeteria, provides space heating and space cooling and domestic hot water.

When the chiller is working then the air-handling system (AHU) operates at 50 per cent capacity in terms of the volume of air that is handled.

Operations: Guidance

1. For most of the year, we plan to use only air-cooling. Even in the peak summer months, we would like to use the air-cooling system, with fans and open windows for ventilation.
2. We have controls on each floor and the unit can be switched off manually. The administration needs to accommodate people in the building so that the air-handling unit of unoccupied areas can be switched off.
3. In the air-handling unit, we have used variable frequency drive so that the system automatically increases and decreases the cooling capacity depending upon demand.
4. We get hot water as a by-product of running the chiller. In rooms we have insulated hot water tanks.
5. The HVAC system will work between 18-26°C.
6. The system will turn on the hot air (heating) when the ambient temperature is 18°C and below
7. The system will turn on the cold air (cooling) when the ambient temperature is 26°C and above and the humidity is roughly 70 per cent.
8. Administration can check this through the humidity sensor, which is in the air-handling unit, which is displayed on the programme logic controller.
9. The opening of windows is bad when the heat-pump chiller is working as it will make the system inefficient and even lead to its collapse, as it will have to keep working to provide temperature control. Think of it like your home AC/heater working overtime to control temperatures, if you have opened doors or windows.
10. However, it is good to open doors and windows when only evaporative cooling (air-handling unit) is working, as it will improve ventilation and air-flow.
11. Hot water is a by-product of the heat-pump chiller and is not the primarily reason for its operations.
12. We have not installed individual room temperature control devices, partly because of the expense. We have the following options
    - **a.** Put thermo-meters in all rooms (with guidance on when to open windows)
    - **b.** Install manual air flow, which requires administration to open and close the vents entering each room (₹ 9,000 + civil work for damper)
    - **c.** Install individual switch off in all rooms (₹ 40,000 per room)
13. The hot water through the heat-pump is more efficient option than the boiler-type geysers. But at a later stage we may want to consider increasing the efficiency of our system by installing hot water systems based on solar energy.

Cafeteria

We use a variation of the 2-stage evaporative cooling system.

The main dining hall and serving area is on air-cooled system (13,500 CFM); for temperatures above 26°C.

We have a provision to add a cooling coil in the air-handling unit, which would make it 3-stage evaporative system.

The current heat-pump chiller has been designed to provide for cooling/heat with the additional installation of cooling coil. We will monitor the 'comfort' levels of this system and then decide.

We have installed a hot water system using solar energy for exclusive use of the kitchen.

Academic Block

We use another variant of the 3-stage evaporative system but this time with the use of water-cooled chillers.

Two air handling units of 15,000 CFM and 12,500 CFM each.

The air-handling unit is attached to a water-cooled chiller (30 tonnes). This will give us cooling in classroom in peak summer/high humidity periods.

There is no space heating in the academic block, because the building is highly insulated and most times the classrooms are used during day time with high-occupancy density (human heat).

There is no hot water here.

Laboratory

Lab system is separate (independent VRV 18 hp or roughly 15 tonnes). This gives heating and cooling. The Variable Refrigerant Flow (VRF) system in Air Conditioners (AC), is an advanced split AC system which can have more than one indoor outlets for each compressor unit installed outdoors. Further, this system varies the flow of refrigerant to indoor units based on demand and the outdoor unit has one or more compressors that are inverter driven. In short, VRF is the most efficient version of conventional room AC system.

Also we have separate ventilation machine for 6 hp fresh air and carbon and fine-filter exhaust for septage and microbacterial laboratory.

Guest-house

We use the conventional room air conditioner (11 ACs of 1.5 tonnes), but these come with R 290 refrigerant gas – ozone and climate friendly gas.

Support Housing

2-stage evaporative system.

Air handling unit of 12,500 CFM for all floors.

We have a provision for installing water or air based chiller with heat pump in future.

Gym/fitness centre

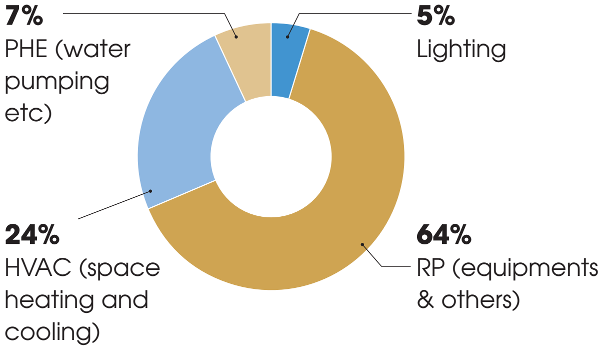
Five ACs of 1.5 tonnes each with R 290 refrigerant gas.

ESTIMATING ENERGY USAGE

We needed to see where we used electricity before we would monitor or reduce.

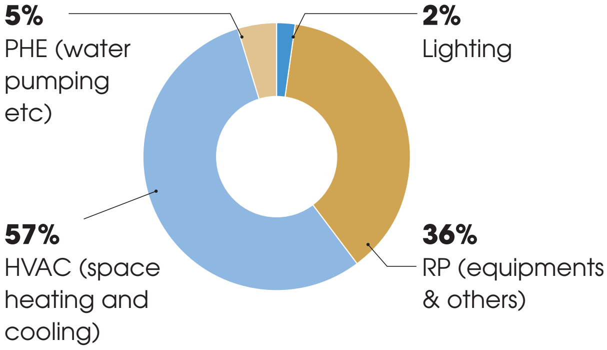
Electrical Demand Load (kW)

Total
284 **kW**

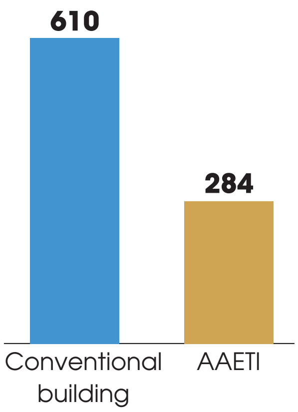


Energy Demand (kWh/day)

Total
2,382 **kWh/day**



Comparison of electrical load (kWh)



Based on the load and energy demand of different buildings, we calculated how much solar PV would be required to meet full demand and also the area required to install the system. According to this estimation, our total connected load is 473 kW, Peak Demand Load will be 284kW; consumption would be 2,382 kWh/day and for this demand we would require a solar PV system of 310 kWp, which in turn would require some 2,790 sq. mt. of land area (rooftop and surface).

However, we as you will find later, we have not installed the full solar system yet and because of the requirements of our laboratory (which was planned subsequently), we will have higher consumption.

10

SMART APPLIANCES: REDUCE ENERGY USE FURTHER

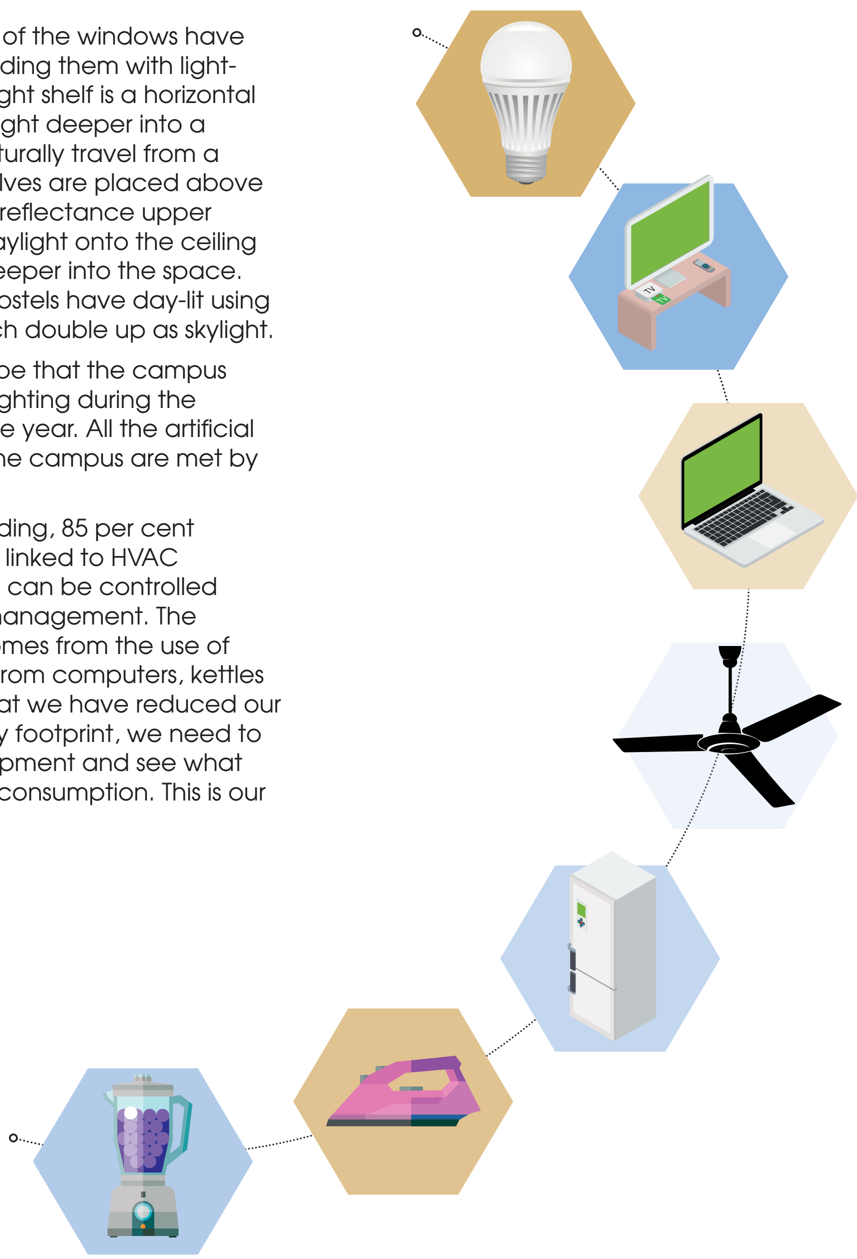
We have installed energy efficient fans that use only 28W, one-third of a conventional fan.

The objective is to reduce lighting needs though use of flitered sunlight as much as possible. The campus is designed to filter in day light into the interiors after cutting out heat and glare. Windows have been limited to just 30 per cent of the wall area and strategically located for maximum daylight.

Day-lighting potential of the windows have been enhanced by providing them with light-shelves in classrooms. A light shelf is a horizontal surface that reflects daylight deeper into a building than it would naturally travel from a typical window. Light shelves are placed above eye-level and have high-reflectance upper surfaces, which reflect daylight onto the ceiling which further reflects it deeper into the space. Corridors in the student hostels have day-lit using special wind shelves which double up as skylight.

With this done, we hope that the campus doesn't require artificial lighting during the daytime for majority of the year. All the artificial lighting requirement on the campus are met by energy efficient lights.

In a conventional building, 85 per cent of energy consumption is linked to HVAC and lighting usage which can be controlled by design and building management. The remaining 15 per cent comes from the use of appliances – everything from computers, kettles and refrigerators. Now that we have reduced our HVAC and lighting energy footprint, we need to monitor use of other equipment and see what we can do to rationalise consumption. This is our operational step.



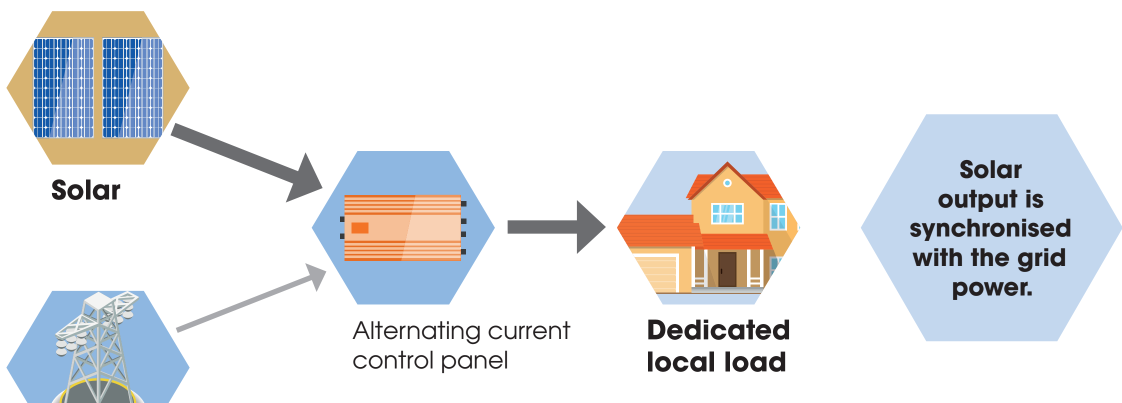
SOURCING RENEWABLE ENERGY

Now that the campus energy requirement has been reduced, the next step is to generate energy from renewable sources. Our objective to go completely off-grid over time. This will depend on how efficiently we can use our systems and to see how we can make our laboratory more energy efficent.

Currently, we have installed a solar system to meet our primary needs and the rest comes from the grid. Our solar system is grid-interactive so what we do not use we will feed into the grid.

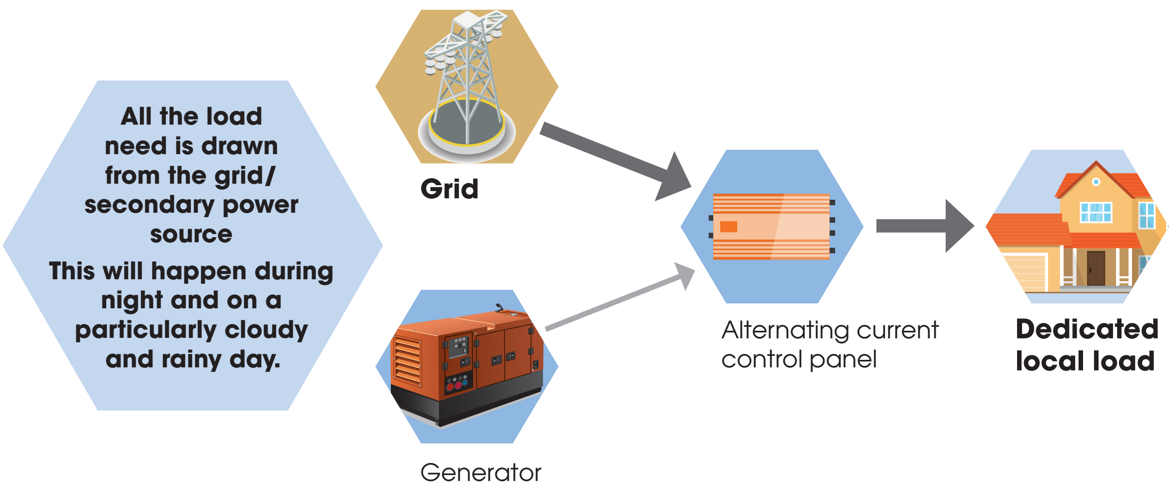
Operation of on-grid solar power plant

SCENARIO 1 -
Grid & solar are available

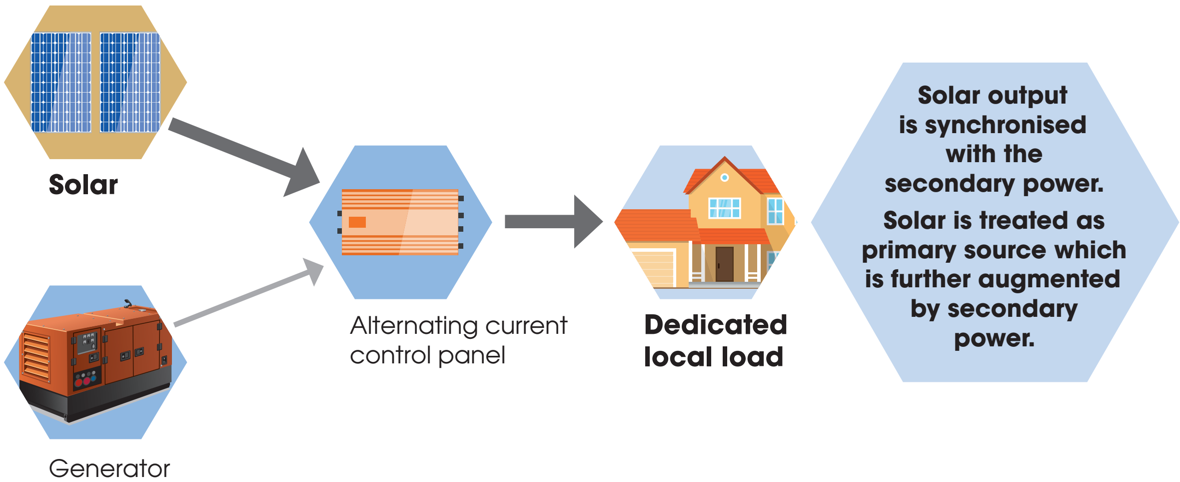


Solar is treated as primary source which is further augmented by grid if solar is insufficient.

SCENARIO 2 -
Solar is not available.



SCENARIO 3:
Secondary power & solar are available



Currently, the campus has 70 kWp of solar PV system in place which is capable of meeting 20-25 per cent of our projected energy demand. This will be scaled up in phased manner to meet the entire energy requirement. The connection to the national grid also eliminates the need for battery bank to store the harvested solar energy while providing opportunity to sell the excess solar energy that campus will eventually generate.

CSE has signed an agreement under RESCO model so that we will pay a flat rate of Rs 5.50 per unit for 12.5 years for the entire system. There is no tariff revision provided.

The company is responsible for the design, supply, installation and commissioning as well as the O&M of the 70 kWp of solar power. After 12.5 years, the plant will be transferred to CSE.

The cost of power we buy from Rajasthan state electricity board is ₹ 8 per unit; therefore, we are saving ₹ 2.5 per unit and also get power from our own rooftop.

We still require generators and UPS for backup for our computers and lighting needs during power-outages.

12

CALCULATING AAETI'S ENERGY BENCHMARK

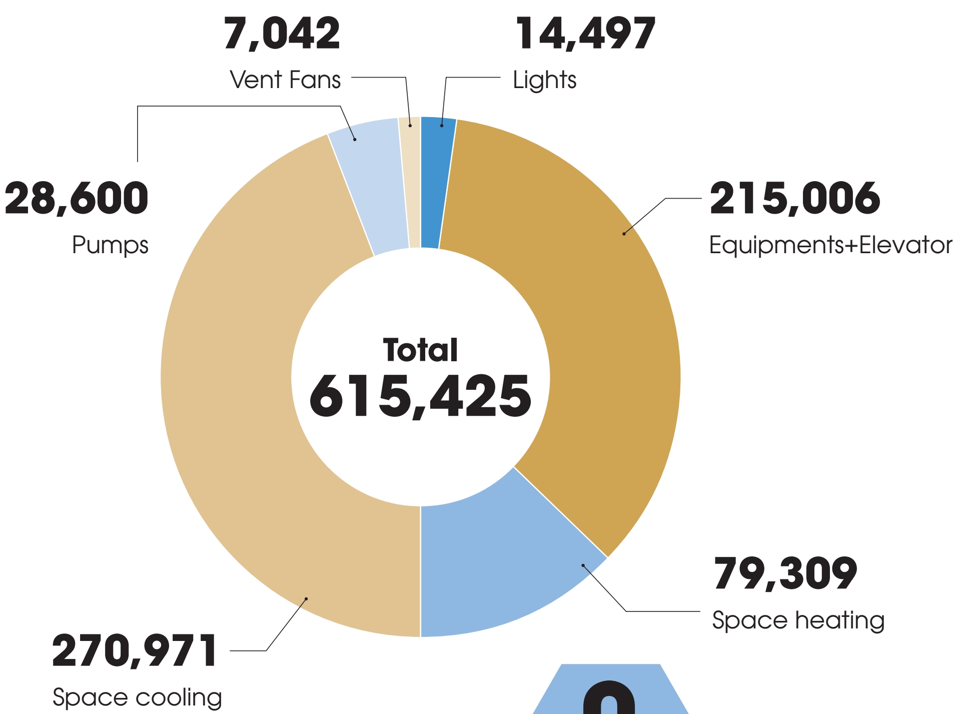
Based on design and implementation it is estimated that the 9,800 sq.mt. campus would consume about 62.7 kWh/sq.mt./year of energy once fully operational. This is 49 per cent lower than the energy efficiency requirement an institutional building under ECBC. This is also 46 per cent lower than the UNDP-BEE energy benchmark of 117 kWh/sq.mt./year for institutional buildings in composite climate.

AAETI's energy summary

Annual energy usage (kWh/year)
615,425

Energy performance index (kWh/ sq.mt./year)
62.7

AAETI Design (kWh/year)



0
Hot water

13

BUILDING A WATER NEUTRAL CAMPUS: TAKING LESS THAN WHAT WE GET FROM NATURE

Preserving natural drainage

AAETI is surrounded by Aravallis and this means that the catchment of water is huge – the hills drain into the plains. We also have a seasonal water channel that flows through our campus. The first task we had was to map the rainwater channels and then to estimate our water needs. The objectives for water management were:

a. To augment water availability by ensuring that we could channelise the flowing water to improve recharge and to store rainwater for our use.

b. To minimise water demand through careful budgetting.

c. To ensure that all wastewater – sewage and greywater from use – was treated for re-use.

d. To regularly monitor groundwater levels to ensure that we would not deplete our aquifers.

e. To regularly monitor quality of water supplied for use in the campus.

Overall less than nine percent of the land is utilized for construction, which allows us space for green and other environmental functions.

Rainwater harvesting and groundwater monitoring

It is estimated that the site has a rainwater harvesting potential of about 11,400 Kilo Litre (KL) annually. Due to the terrain of the area it is further estimated that the site will be able to collect and recharge additional run-off from the surrounding areas of around 12,000 KL annually.

To harvest this rainwater, we have done the following:

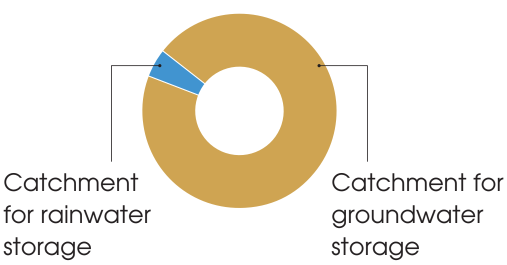
a. Built two underground rainwater storage tanks with combined holding capacity of 200 KL under the academic block and cafeteria. Based on the average rainfall of the area, the combined roof area will harvest roughly 913 KL annually. These would meet all the water requirement of the cafeteria for 190 days during the non-monsoon season. Currently, we have a provision to pump this stored water directly to our drinking water system. To ensure the quality of water, we have first a bypass for the first rain; de-silting chamber and after the rainwater tanks we have a disc-filter (sand-filter) and then in addition we have aquaguard with UV. We will regularly monitor the quality of drinking water in our lab.

b. Built eight re-charge wells in different locations so that rainwater used to augment groundwater aquifers.

c. We will also build more gabion and checkdams in the campus over time as we begin to understand water flows and can hold, recharge and drain rain.

With this done, we will recharge our groundwater and also ensure that when it rains, we do not flood.

Total area of the Site: 39,100 sq.mt.



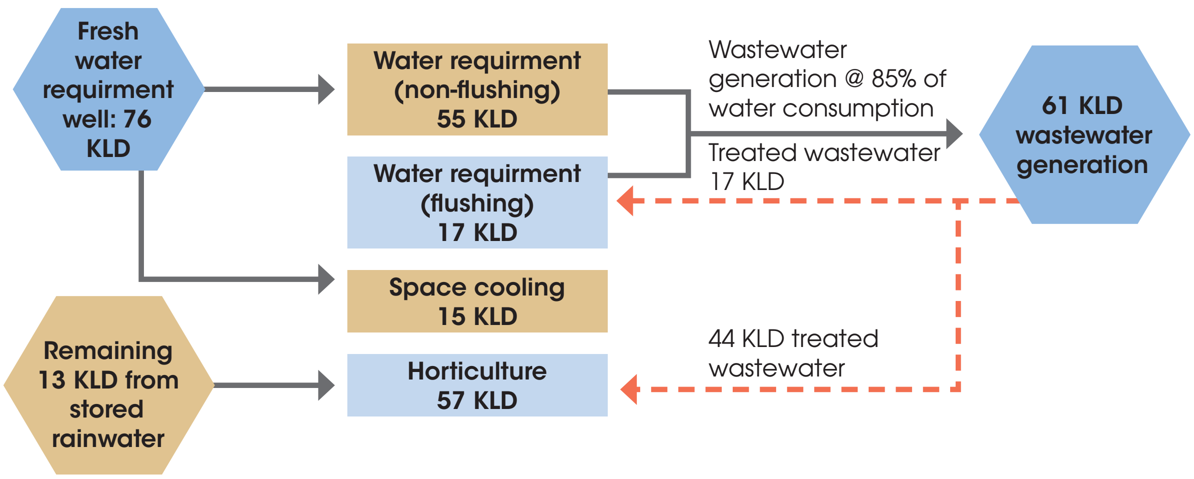
Rainwater storage

Building	Roof Area (Sq.M.)	Collection potential Yearly (KL)
Academic Building	604	380.52
Cafeteria & recreation	845	532.35
Total	**1,458**	**912.87**

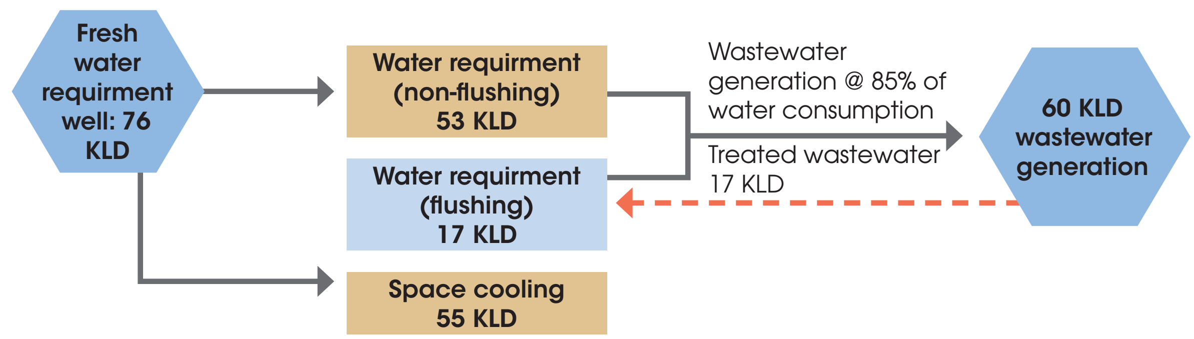
Water budget

The campus is estimated to extract a maximum of 76 KLD/day for all its flushing and non-flushing purposes, during non-rainy days. The extraction of water through the borewell is being monitored by the flow meter attached to the borewell. To measure the impact of the recharge of rainwater in the ground, two piezometers have been installed to measure the impact in the first two levels of aquifer – one piezometer is near the natural stream and the other near the entrance. This will allow us to monitor our usage and take corrective steps. Efficient water fixtures and conservation has help in bringing down water consumption of the campus by about 36 per cent. Water consumption is pegged at 86 LPCD as against standard 135 LPCD.

Daily water consumption balance chart (non-rainy days)

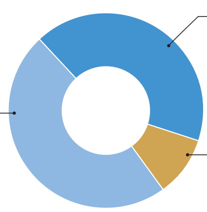


Daily water consumption balance chart (rainy days)



Note: 2 KLD of canteen water will be supplied from stored rainwater. Hence the fresh water demand in rainy days come down from 55 KLD to 53 KLD

Water requirement at AAETI (in KLD)



14

DECENTRALISED SYSTEMS FOR SEWAGE: RECYCLING AND REUSING

The objective is to use and demonstrate decentralised sewage technologies at AAETI. The total wastewater generation is estimated at 61 KLD, when the campus is fully operational.

Given this we have designed four separate systems for wastewater treatment at the campus, adding up to 30 KLD roughly.

1. **Decentralised wastewater system (DWWTs)** is designed to take the sewage of the academic building and faculty housing. The system design is for 8 KLD. This system is based on an anerobic system, where the sewage passes through settler, baffled reactor and then treated in an aerobic polishing pond. The quality of treated water is fit for horticulture (SEE CHART). CSE will be regularly collecting samples from the inlet and outlet as well as from different parts of the wastewater treatment system to check on its efficiency of treatment.

2. **Soil Biotechnology based wastewater treatment system**, which is designed to take the wastewater from the cafeteria and the student housing and support staff. This system is 20 KLD. This is a patented technology of IIT-Mumbai and here wastewater is treated through various layers of the bioreactor. The treated wastewater from this system is designed to be used for flushing. The treated water from this system will be pumped to an overhead tank and from here it will be pumped to the flushes in the academic block, student housing, cafeteria and the support housing (SEE CHART). CSE will also regularly collect samples from 3 points of this system – inlet, outlet and mid-way to check on quality.

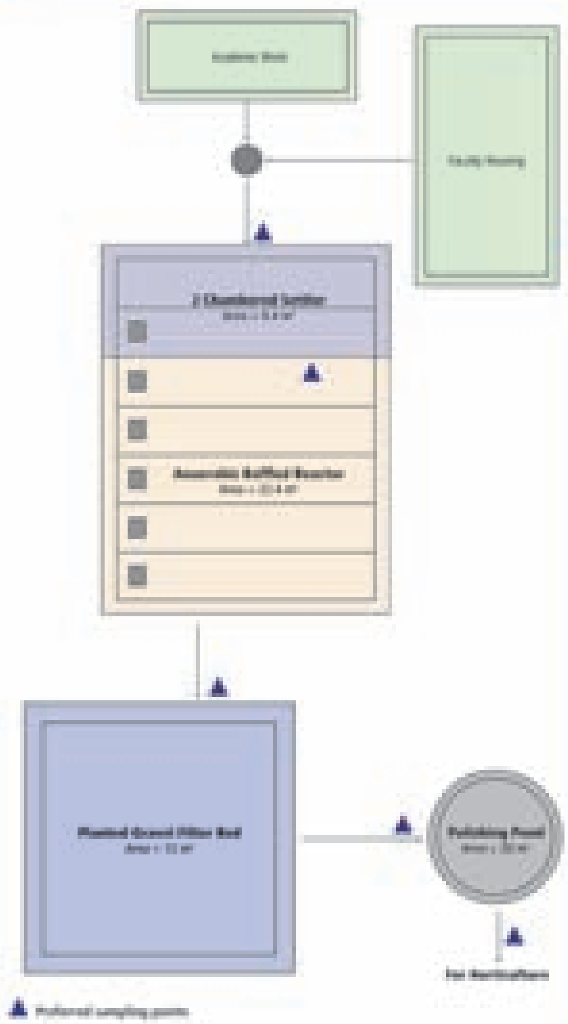
3. **Improved septic tank**, which is designed to take the wastewater only from the guest house. This system is small, only 1 KLD. But the objective is to see how we can improve a conventional septic tank system, which is widely used across India and other parts of the developing world. In this case, the septic tank is 3-chambered (as against the widely used 2 chamber system). The first and second chamber is for settling and the third chamber improves the quality of sewage through bio-degradation. The treated waste is then passed through a soak pit and discharged into the ground. CSE will develop a protocol to check on the quality of treated wastewater septic tank.

4. **Prefabricated septic tank** for the Gym – to test how such a system will work. This has two-chambers and treats on-site.

The CSE lab wastewater is treated separately. The chemical and wet waste from the laboratory is disposed into a lined tank, where it will be neutralized with lime. We have two tanks of which only one will be functional at a time. The capacity of each tank is 1,000 litres.

Decentralised wastewater system

LAYOUT



Section View

Treatment Scheme

Settler
It is a two chambered unit which offers primary treatment by removing settleable solids.

Anaerobic Baffled Reactor
It treats the wastewater that flows from the settler, by passing through 5 chambered ABR with filters (gravels and pebbles) in the last two chambers. It helps in degrading the organic content of the wastewater and reduces BOD by 70-90%.

Planted Gravel Filter Bed
PGF offers further treatment to purify wastewater coming from ABR. PGF consists of crushed stones, pebbles and wetland plant–Canna indica, which offers treatment by reducing BOD and removal of nutrients–Nitrates and Phosphates.

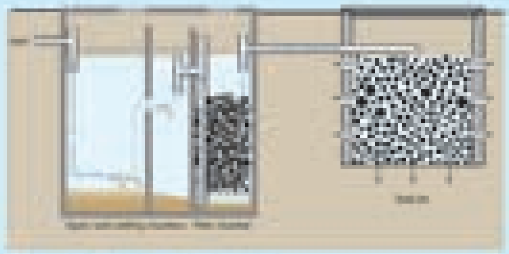
Polishing Pond
This unit removes pathogen and odor with the help of natural aeration and sunlight. The treated water is pumped for horticulture purposes.

Improved septic tank

LAYOUT

Preferred sampling points

Section View



Treatment unit

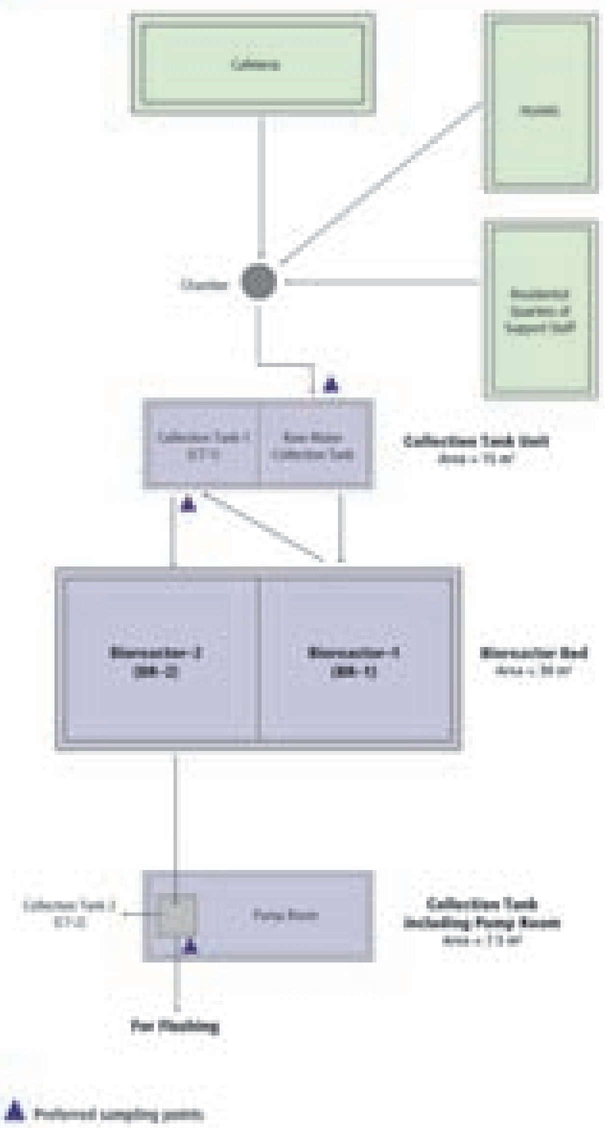
Septic tank
The first two chambers of the septic tank are designed to separate the settable solids by allowing them to settle down.

Filter Chamber
The effluent from the second chamber enters the filter chamber. The filter is of crushed stones. As the effluent passes through the filter layer, it undergoes anaerobic biodegradation. The anaerobic microbes that are attached to the filter layers play important role in reduction of organics and further removal of solids.

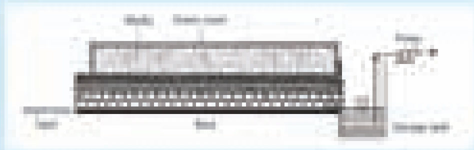
Soak Pit
A soak pit is a covered, porous-walled chamber that allows water to slowly soak into the ground. Treated effluent from the improved septic tank is discharged to this chamber from which it infiltrates into the surrounding soil.

Soil Biotechnology System

LAYOUT



Section View



Treatment Unit

Raw Water Collection Tank
Wastewater from cafeteria, hostels and residential quarters of support staff is collected in the tank.

Bioreactor Bed
There are two bioreactors (BR-1 & BR-2) that consists of various layers of crushed stones, jute bags, crushed bricks with media which supports microbial growth.

Collection tank
The treated water from the bioreactor bed (BR-1) gets collected in a collection tank (CT-1). Further the treated water gets collected in another collection tank (CT-2).

Overhead Tank
The treated water is stored in the overhead tank and further distributed for flushing in toilets.

15

WALKING THE TALK ON SOLID WASTE MANAGEMENT

Our objective is to move towards a 'Zero Waste Campus'

This requires us to do the following:

1. Ban certain non-recyclable material from entry into the campus – plastic carry-bags, pet bottles and other materials, which are disposed off in our orange and red box.
2. Find alternatives to material, which is not recyclable, for instance, tea bags, shampoo and soap sachets, food packed in multi-layered packaging (chips, biscuits etc).
3. Segregate all material at source.
4. Compost all biodegradable material on site.
5. Reduce food wastage – in the first year, we want to reduce wastage to half (please help when you take your food).
6. Recycle all other material through informal recyclers.

The detailed plan for solid waste is given in the "Walking the Talk" volume 2.

But please look out for the following bins and help us minimize and segregate, segregate and segregate.

Waste generated

Segregation at source

Waste type	Bin	Disposal
Wet waste- kitchen/ horticulture	Green bin	In situ composting/ biogas plant
Plastic waste recyclable	Blue bin	Stored and given to an authorised vendor/ dealer at regular intervals
Plastic waste non-recyclable	Orange bin	Stored and given to an authorised vendor/ dealer at regular intervals/ options to eliminate
Paper/ cardboard	Yellow bin	Stored and given to an authorised vendor/ dealer at regular intervals
Metal/ glass	Black bin	Stored and given to an authorised vendor/ dealer at regular intervals
Any other waste- textile rubber, markers, hazardous waste	Red bin	Stored and given to an authorised vendor/ dealer at regular intervals
Sanitary waste	Grey bin	Sent to the common bio-medical waste treatment facility (CBMWTF)
E-waste	Brown bin	Stored and given to an authorised collector
Inert/ residue- dust/ hair	Stored seperately on the campus	

16

MONITORING FOR GREEN PERFORMANCE

We have invested into a green building. But we know that "green" is as "green" does in daily life. In other words, the actual performance of the building in terms of reduction of energy, water and waste will hugely depend on how consciously we use AAETI and how we make it a 'living machine'. For this we need to live the change.

But first, we need to monitor the usage of resources carefully in the building and then use this to improve our performance.

We will do the following:

Monitoring protocol for AAETI: what to monitor; why and from where the sample/data will be collected

Objectives		Location	Periodicity/ reading
Energy: to ensure we keep to design level of EPI	Meter 1	Entry Gate	
	Meter 2	Canteen basement	
	Meter 3	Academic Building ground floor	
	Meter 4	Student Housing 1 ground floor	
	Meter 5	Student Housing 2 ground floor	
	Meter 6	Support Staff Housing ground floor	
	Meter 7	Fitness Centre ground floor	
	Meter 8	Guest House ground floor	
	Meter 9	Support Staff Housing ground floor	
Water levels: to ensure that water levels do not decline but get augmented	Piezometer 1	Entrance	
	Piezometer 2	Stream	
	Water Meter	At the bore well	

Objectives		Location	Periodicity/ reading
Drinking water quality: ensure there is no contamination	Aquaguard 1	Academic building	
	Aquaguard 2	Cafeteria	
Wastewater	DWWTS:	Inlet of settler	
Ensure effective treatment and no contamination		Inlet to ABR	
		Inlet to planted gravel filter	
		Inlet to polishing pond	
		Final outlet	
	Soil Biotech	Inlet to raw water collection tank	
		Collection tank 1	
		Final outlet	
	Septic tank	Developing protocols	
Solid waste			
Reduce food wastage to half	Cafeteria	Where food plates are emptied	
Eliminate 'Orange' plastic – non-recyclable	Orange box		
Weather station (the RainWise Portable Weather Logger (PORTLOG) operates as a completely self contained system. No power is required. The solar/battery supply will power the system continuously)	1. Wind speed 2. Wind direction 3. Temperature 4. Humidity 5. Dew point 6. Barometer 7. Rainfall 8. Solar radiation	Next to site-office huts	

17

LIVING THE CHANGE: WHAT WE NEED TO DO

None of this is possible, without your active engagement.

We have to be the change. We have to live the change.

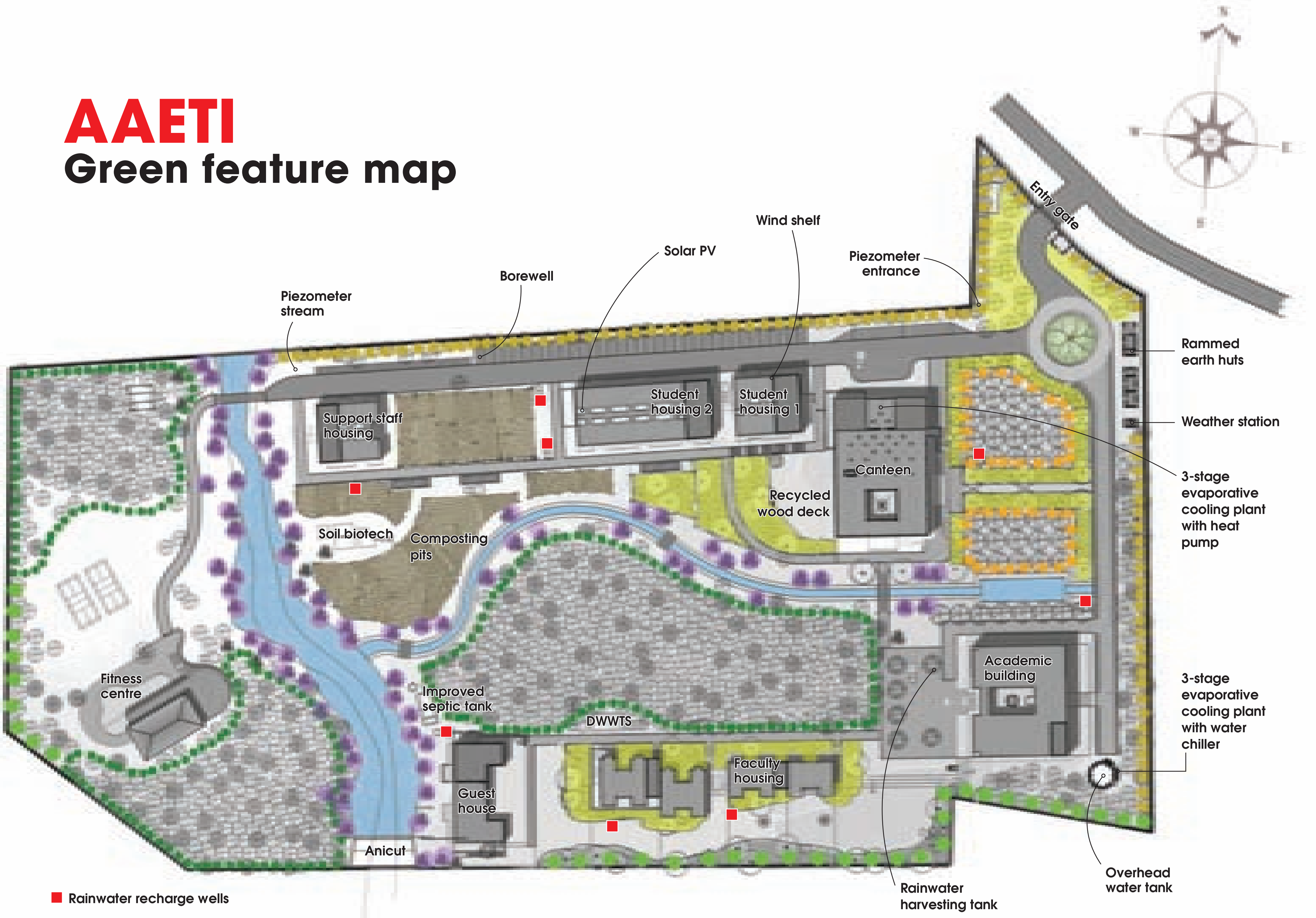
Please, please help us make AAETI a green campus by doing the following:

1. **Do not open your windows and doors, when the air-conditioning is on** – our heating and cooling system is based on a heat-pump chiller and it will have to over-work and over-use energy if you open windows or doors. Do use your fan when air conditioning is on as it will give you maximum 'comfort' conditions.
2. **Do enjoy the windows or use the balcony (but protect yourself from monkeys please) when the air-cooling system is on.** Our building is designed so that you can enjoy ventilation.
3. **Wear climate-appropriate clothing so that we do not have to over-heat or over-cool our campus.** Our temperatures are set at 26°C for summer and 18°C for winter.
4. **Take your water bottles and fill them up at our water dispensers so that we do not have to use bottled water.** We are checking the quality of drinking water regularly.
5. **Do not waste food please.** We have made this an objective of our campus. Please take only as much as you will eat.
6. **Segregate your waste** – read the waste manual for details
7. **Do not bring non-recyclable plastic** – particularly pet bottles into the campus and all other materials we are trying to eliminate, which are not recyclable.

Enjoy the campus and tell us what more we can do to improve its facilities and your experience.

From all of us at CSE

AAETI
Green feature map



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Centre for Science and Environment is a public interest research and advocacy organisation, which promotes environmentally-sound and equitable development strategies. The Centre's work since its establishment in 1980 has led it to believe and argue, both nationally and internationally, that participation, equity and community-based natural resource management systems alone will lead the nations of the world towards durable peace and development.

As a public interest organisation, the Centre supports and organises information flow in a way that the better organised sections of the world get to hear the problems and perspectives of the less organised. Environmental issues are seen in an anthropocentric perspective that seeks to bring about changes in the behaviour of human societies through appropriate governance systems, human-nature interactions, and the use of science and technology.

Though the public awareness programmes of the Centre have been its key strength and focus of work, it has endeavoured to move into associated areas of work like policy research and advocacy. Learning from the people and from the innovations of the committed has helped the Centre spread the message regarding environment without its normal association with doom and gloom. Rather, the effort of the Centre is to constantly search for people-based solutions and create a climate of hope.

The Centre has always been, and will continue to be, editorially independent of interest groups, governments, political parties, international agencies and funding sources. It never accepts funding to push a donor's viewpoint. All its outputs are available for public dissemination.

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