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Architectural Design Competition  
for  
**Nalanda University Campus**  
Master Plan and Phase I Construction

**REPORT ON NET ZERO DESIGN  
APPROACH**



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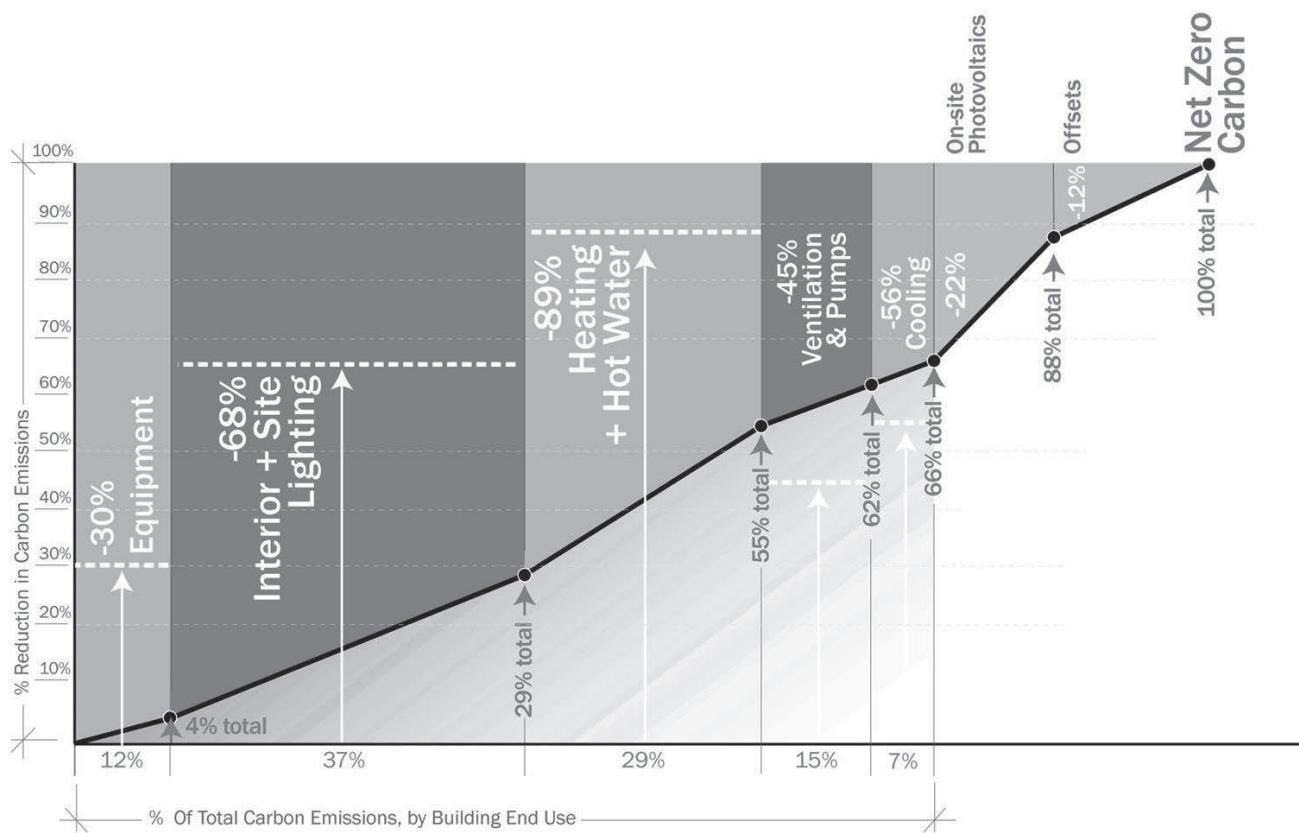
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# INTRODUCTION

The key ambition of the project is to produce a world class University Campus with sustainability as a priority and zero carbon, zero water and zero waste in particular as long term targets.

The history of the region and the durability and strength of the historic institution despite the difficult climate speaks volumes of the opportunity to develop a contemporary environmental response that is clearly rooted in the vernacular but which moves it on to embody the best of environmental thinking of the modern era.



Routemap to Zero Carbon



Recent efforts to rethink our effect on the environment have become known as "sustainability" and it is a key component of our project plan for the Nalanda Campus that the design should be developed with environmental and sustainability objectives as core elements. This extends from the way that the development sits on the site and interfaces with its neighbours through to the minutiae of decisions about materials and operation of the buildings that make up the proposal.

Conventional Environmental efficiency is about both doing more with less, using fewer resources, reducing pollution and waste and minimising damage to human health and the environment. But being less bad is not necessarily being good and an alternative approach, being "Eco-effective", is about aiming to understand and establish ways in which man can have a beneficial impact on the environment and how the implementation of sustainable strategies can have a very positive effect on the buildings and community that result.

In the vast array of issues that sit beneath the banner of sustainability, the importance of delivering "the real thing" is one of the most important to us. It is becoming commonplace for every development to claim itself to be "sustainable" when they in reality are anything but, often with a single idea, a micro-windmill or small PV cluster, as the emblem of their efforts. A movement towards real sustainable development requires thinking on a much broader scale and is altogether more challenging particularly with a masterplan for a campus of this ambition.

As well as giving detailed consideration to the physical requirements of sun, air, water and materials we must additionally give consideration to spirit, the ephemeral thing that defines the essence of a scheme in terms of its sense of place, its contribution to society and the broader community, heightening aspirations and pride in the place created. This is particularly a part of this project where the integrated activities on the site will result in it feeding back to the wider goals of the local society through a strong connection with the vernacular.

## INTRODUCTION

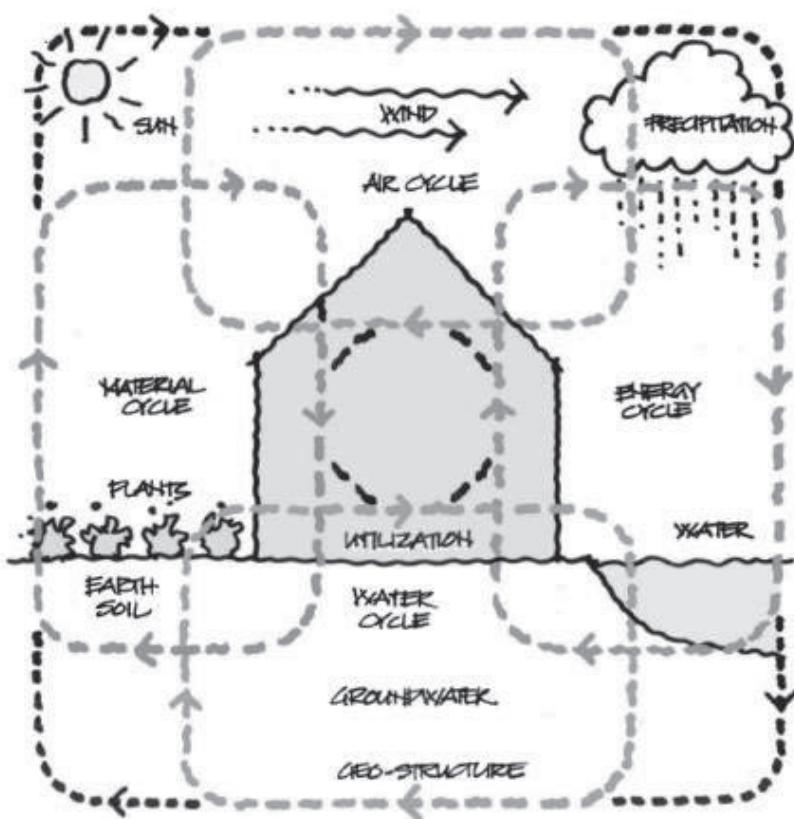
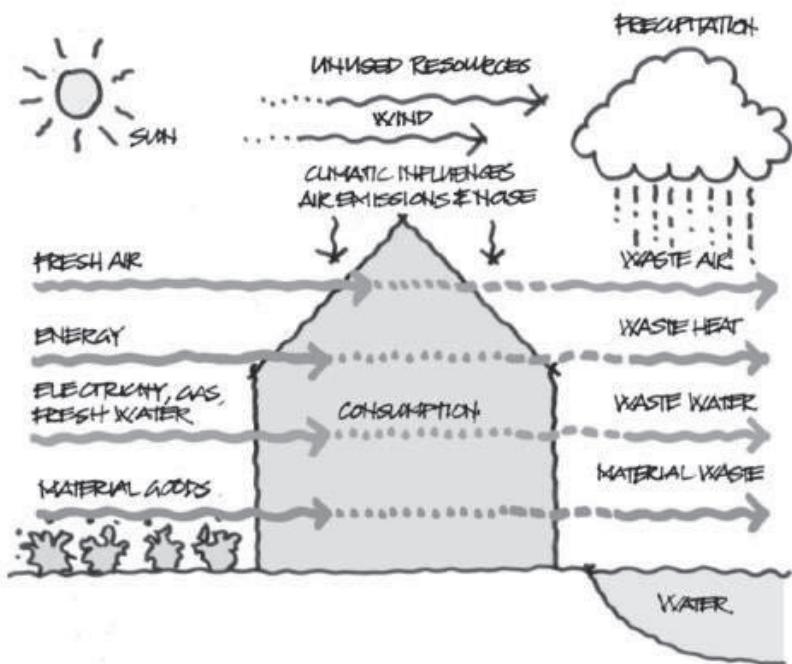
The brief has defined some of the key requirements and this statement is intended to respond to and expand upon the ambitions of the brief and to describe how the proposal will achieve the commitments and ambitions for the application of sustainable practices.

The climate of the region is challenging, characterised by long hot summers with high humidity that tend to define the environmental responses and by quite extreme wet and dry seasons that impact on both environment and water management. But high performance design is about more than designing for peak conditions. It is about making the most of the in-between and winter seasons and balancing supply and demand through attenuation, whether thermal or hydrological. Here for example the cold nights and warm day's outside the summer peak provide plentiful opportunities for simple passive design to minimise or eliminate energy demands for more than half the year.

Nonetheless, generating energy to meet the demands of lighting and plug loads and achieve the net zero carbon target is extremely challenging. Our approach has been to look to the wider region and to tap a waste stream in the form of waste cooking oil and other forms of biodiesel to power a zero carbon CHP plant, providing hot water throughout the year and cooling via absorption chillers in the summer via a Campus energy network.

In the time available for the competition it has not been possible to complete all of the calculations requested by the brief. This report however reflects the robust methodology that has been applied to the delivery of the high performance building proposal and we confident that the ambition of the project can be delivered.

Conventional model of consumption (l) and "Virtuous", closed loop cycles (r)



There are three very different but interdependent categories under which the issues of sustainable development can be addressed:

- Social sustainability
- Economic Sustainability
- Environmental sustainability

Environmental sustainability can be characterised by performing a hierarchy of actions:

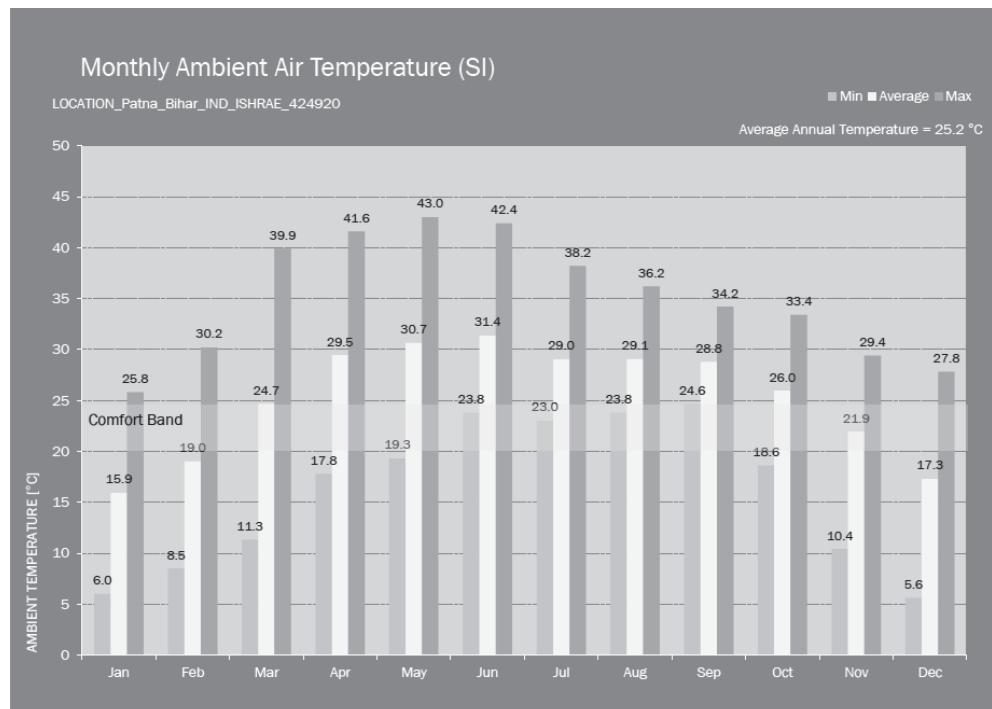
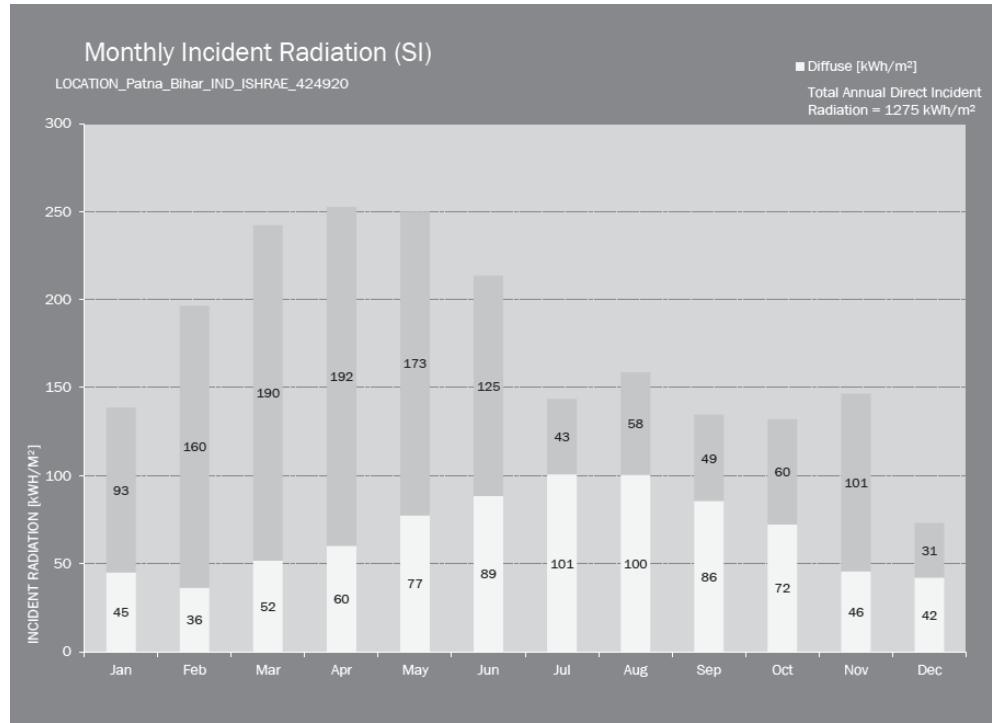
- i Displacing the need for the consumption of a resource through natural means,
- ii Utilising resources as effectively as possible and
- iii Generating resources renewably or reducing the sites existing impact on the environment.

A sustainability strategy is proposed that address energy consumption, transportation, materials used in construction, ecology, pollution and management issues surrounding the construction and maintenance of the buildings on the site. These areas will all be addressed following the hierarchy listed above.



As part of the design process the team have looked to investigate and incorporate the concept of "virtuous cycles" into the design. Conventional models of resource use are linear and follow an input-output-disposal process; with the virtuous cycle concept every process is examined for the opportunity that it might present for recycling or up-cycling. See the diagram below. This is a very familiar notion in contemporary Indian society, rather less so other cultures where conspicuous, and very linear consumption is the norm.

## Monthly Ambient Air Temperatures



# CLIMATE

## **Climate and Site Opportunities for Passive Design / Demand Reduction**

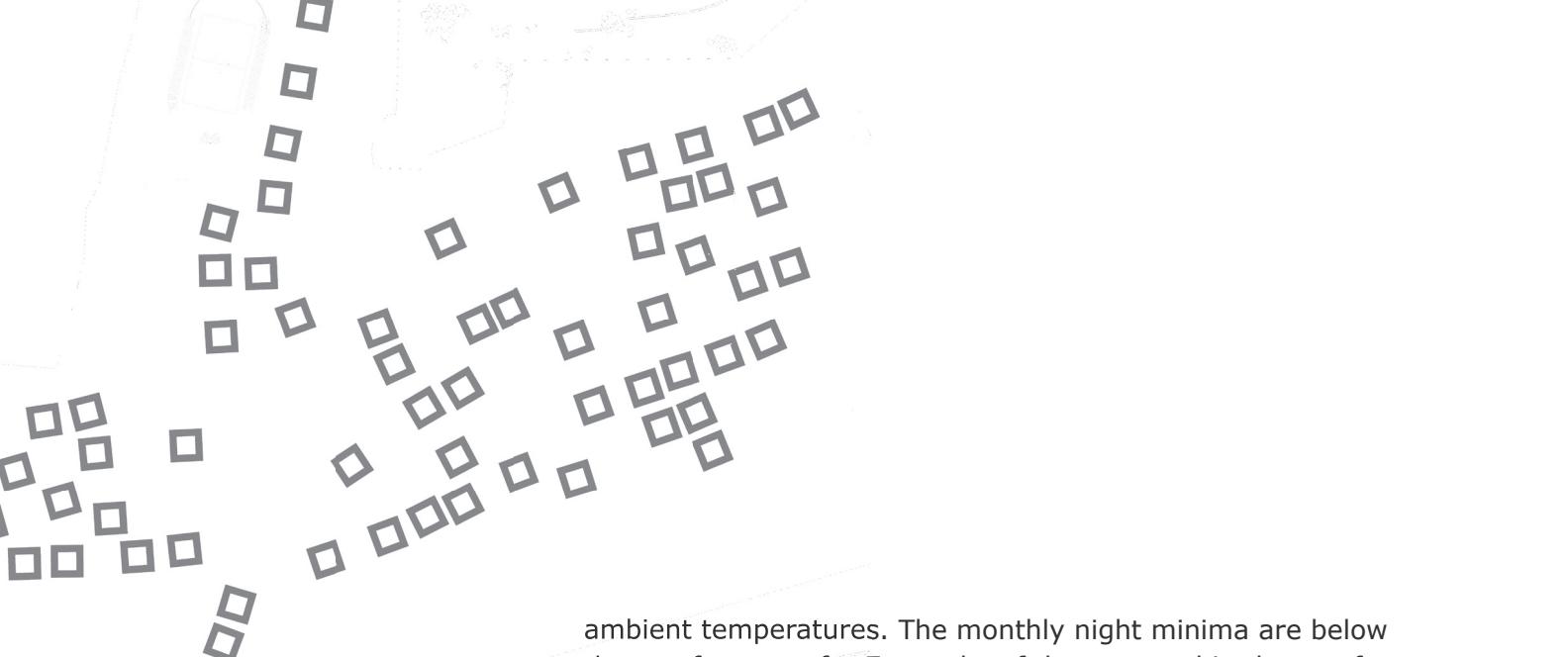
A key driver to the energy strategy for this site has been to reduce the energy demand associated with normal occupation. The thermal envelopes of the buildings have been designed to minimise the energy demands on systems and the use of fossil fuels. In undertaking environmentally responsive design for any climate the first step is to analyse the prevailing typical weather conditions for the site.

The brief describes the long hot summers and short winters in Rajgir with heavy rain common from mid-June to September. The design responds to the desirability for shade in summer and solar access in winter by the use of overhangs on roofs and shutters on glazing. The streets in the Masterplan have a strong N-S alignment, which will tend to ensure that the walkways are shielded from direct sun for much of the day.

A more detailed analysis of the local weather has been sourced to allow a clear understanding of diurnal temperature variations throughout the year and the opportunities for passive cooling in particular. To facilitate this analysis a full hourly weather data set consisting of 8,760 data points (one for each hour in the year) has been located for the airport at Patna Bihar, some 90km north of the site. This is the closest available full data set that is available for modelling purposes and it is envisaged that the climate will be very similar because the elevation above sea level is similar and other microclimatic influences will be small by comparison to the Himalayas to the North.

The monthly radiation graph clearly illustrates the impact of the heavy cloud cover through the rainy season from mid-June to October, with levels of direct solar radiation less than 30% of that experienced during the clear sky months during the early part of the year but with diffuse radiation coming through the clouds increased by 25 to 30%.

Peak temperatures climb quickly in the bright sunshine post February, as is illustrated by this chart of monthly average



ambient temperatures. The monthly night minima are below the comfort zone for 7 months of the year and in the comfort zone for all 12 months, suggesting that there are significant opportunities for passive night cooling. The diagram below illustrates a week in March and shows that with the application of appropriate thermal mass the opportunities exist for significant comfort improvement and/or cooling load reduction.

In the wet season the heavy cloud cover will tend to hold the moisture in and, along with the saturation from the rainfall, result in high humidity along with temperature. Annual temperatures and humidity are shown in the Psychrometric Chart below. Each dot on the chart represents an hourly value of temperature and moisture content. The shaded regions are the periods that are indicative of periods of good external thermal comfort and suitability for natural ventilation internally.

In the height of summer the diurnal temperature range is limited, largely due to the extreme cloud cover and the retained humidity. At this time the temperature variations are limited to +/- 6°C and the night-time temperature is rarely below 32°C, rendering it of limited use for night cooling.

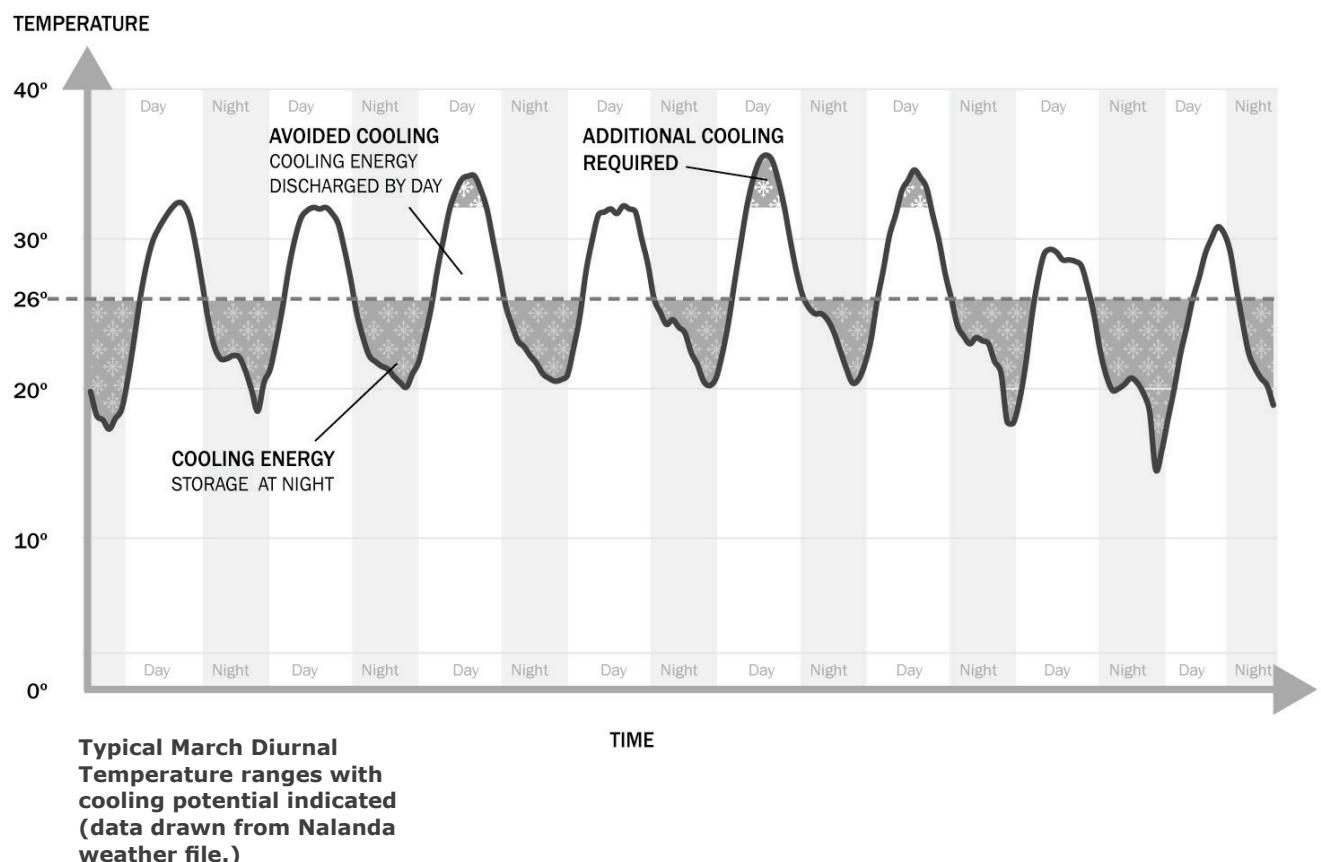
High humidity is a significant issue as the statistical analysis of these figures demonstrates that the moisture content exceeds 13g/kg of dry air (an upper level of typical human comfort in a conditioned space) for more than 4700 hours per year.

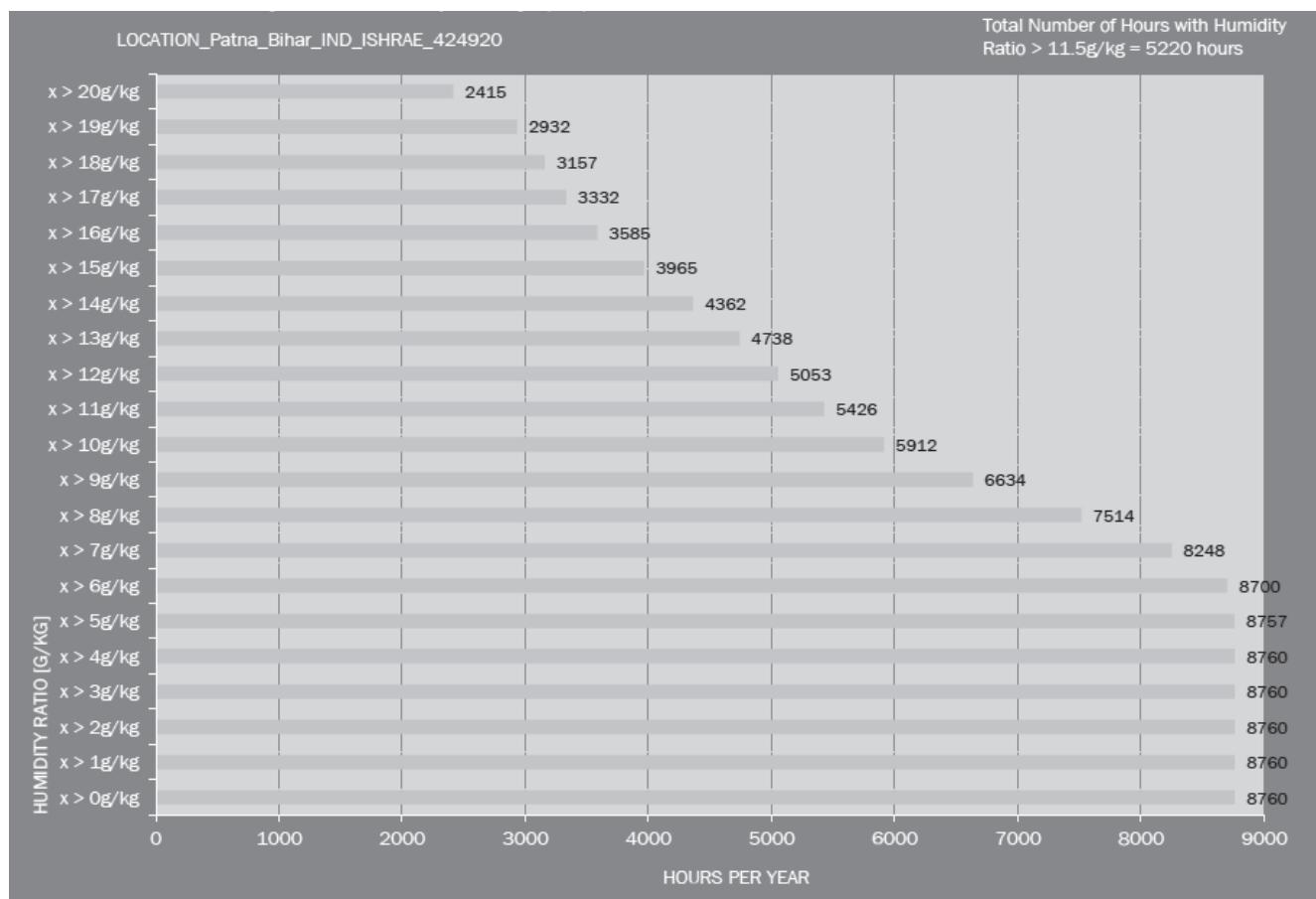
Removing moisture from the air is an energy intensive activity and, on the basis of the forgoing climate analysis the proposal includes a recommendation that the use of desiccants, in either liquid or dry form (depending on the application), be seriously considered for this location. A desiccant is a material that has a high affinity for water and is used as a drying agent. Desiccants can be repeatedly regenerated by exposure to heat (from Cogen systems or Solar panels) and are increasingly finding a place in low carbon conditioning systems in tropical and sub-tropical climates. They work particularly well with displacement conditioning systems where supply air temperatures can be close to the room condition and the use of desiccants avoids the need for sub-cooling to strip the

moisture from the air. The integration of desiccants into the proposed system is described in detail later in the report.

The modified Psychrometric chart below shows the potential impact of desiccants on the outdoor air. Typically desiccants will reduce RH from 100% to 30 % in a single process and the effect on reducing the enthalpy required in the cooling process is self-evident, particularly when considered with the higher supply air temperatures that accompany displacement-cooling systems as proposed.

From this analysis of the climate emerges a clear set of strategies that are appropriate to the masterplan and the buildings contained in the masterplan and which have been incorporated into the design described and illustrated below.

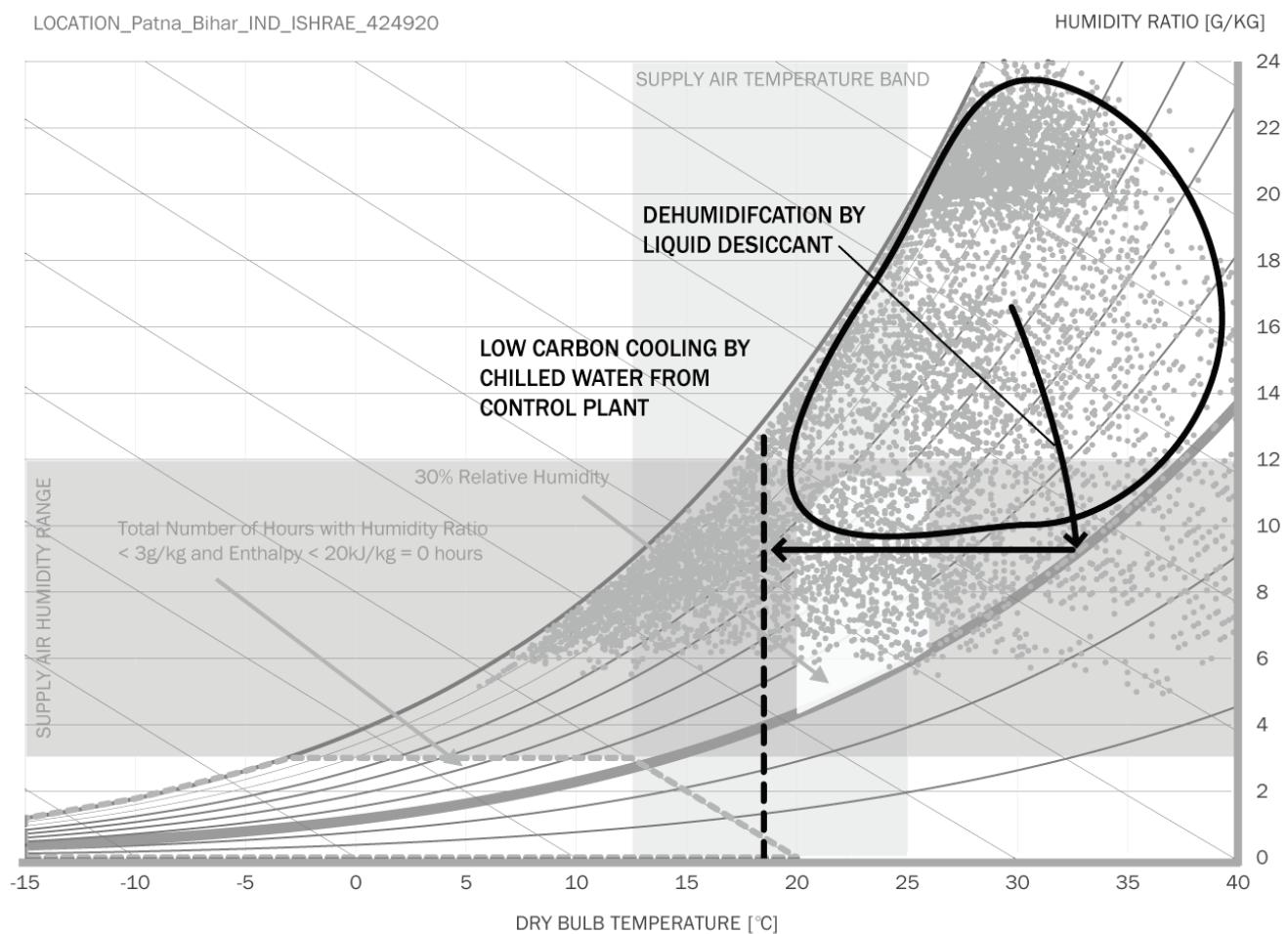




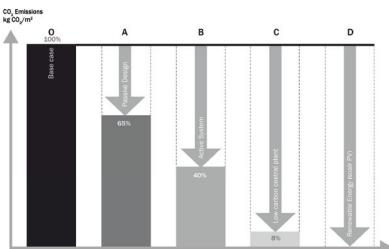
**Humidity Ratio  
frequency for Patna,  
Bihar**

## CLIMATE

LOCATION\_Patna\_Bihar\_IND\_ISHRAE\_424920



**Psychrometric Chart  
for Patna, Bihar**



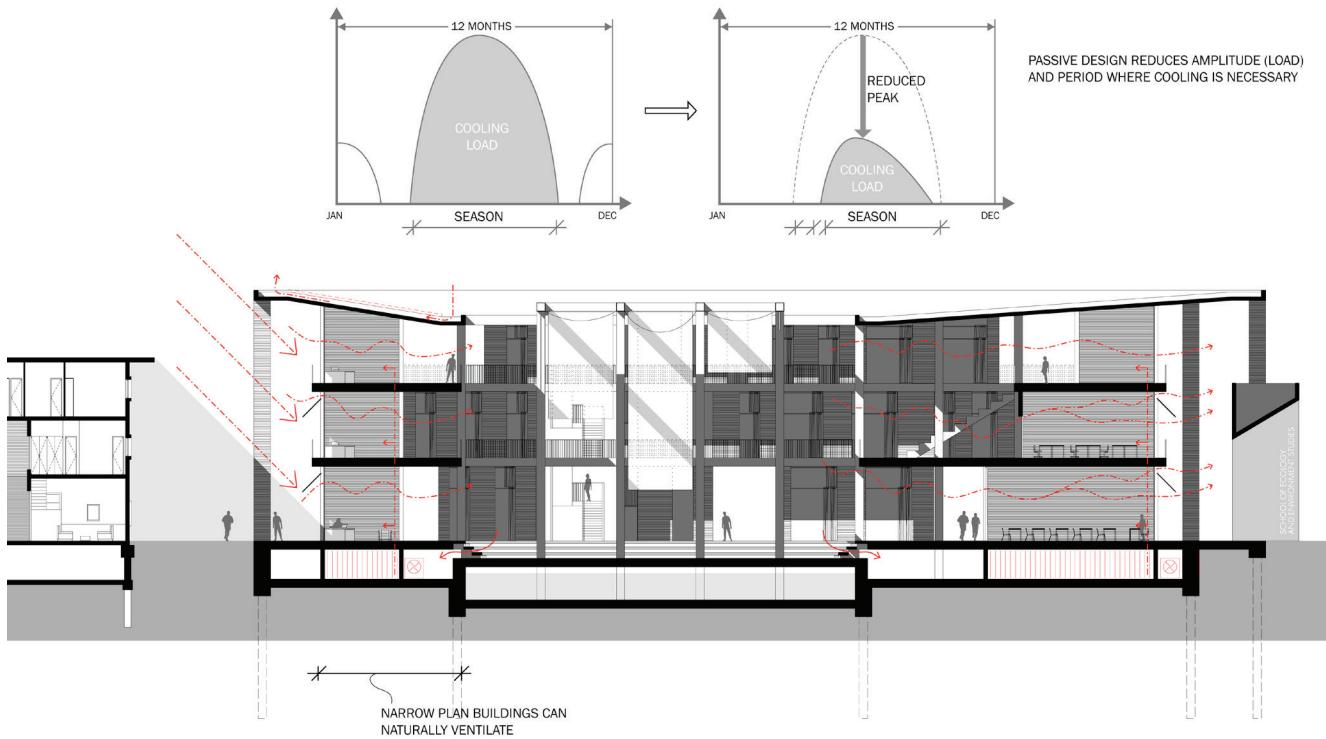
## Environmental Design

The design development has followed a path to high performance that is based broadly on the tenets set out previously and summarised in this route to zero carbon diagram below:

In developing the design for the Nalanda Campus this process has been carefully followed – first working to reduce the demands by closely integrating the environmental objectives with the architecture to control solar gain and daylight as illustrated in the section below. Next efficient and effective systems have been introduced to ensure that the energy that is required is used efficiently. Next the energy required will be produced by low and zero carbon central energy systems and finally the remaining demand will be met by more familiar PV and Solar Hot water systems. The target reductions for each step are indicated in the graph below.

- Passive Design**
- High sun angles protected by overhangs
  - Low sun angles protected by shutters/shades
  - Massing of buildings provides shelf shading and shaded walkable streets
  - Cool pools in courtyards help microclimate
  - Permeable structures and forms encourage cross ventilation
  - Thermal isolation in walls reduces conduction heat transfer in hottest/coldest weather
  - Thermal mass insures zero - energy comfort in winter and shoulder seasons

- Active Design**
- Labyrinth below buildings made of rammed earth blocks in void provides diurnal/seasonal energy storage for “free” cooling and shoulder seasons (when diurnal range is good)
  - PV panels on individual buildings offset Labyrinth fan energy
  - Central (zero carbon) cooling for peak months from CHP/Absorption cooling plant
  - Domestic hot water from waste heat



The resultant Architectural section for a typical Faculty building is shown below.

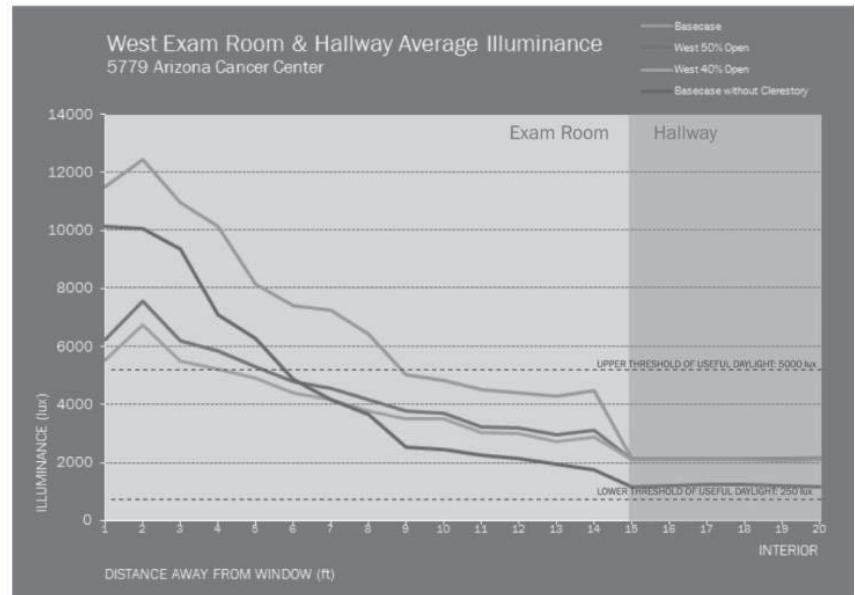
The masterplanning and Passive Design proposals to minimise energy consumption illustrated in this section include:

- Large overhangs to protect glazing and walls from high sun angles and provided shaded walkways and breezeways.
- Shutters and simple adjustable shades to protect from low sun angles
- Façades designed to make the most of useful daylight. These will be optimised in due course using the analysis set out below.
- The massing of buildings provides shelf shading and shaded walkable streets
- Cool water below courtyards helps microclimate
- Permeable structures and forms encourage cross ventilation
- Double roof structure with shading to reduce solar heat gains through roof
- Thermal insulation in walls reduces conduction heat transfer in hottest/coldest weather
- Exposed thermal mass ensures zero - energy comfort in winter and shoulder seasons

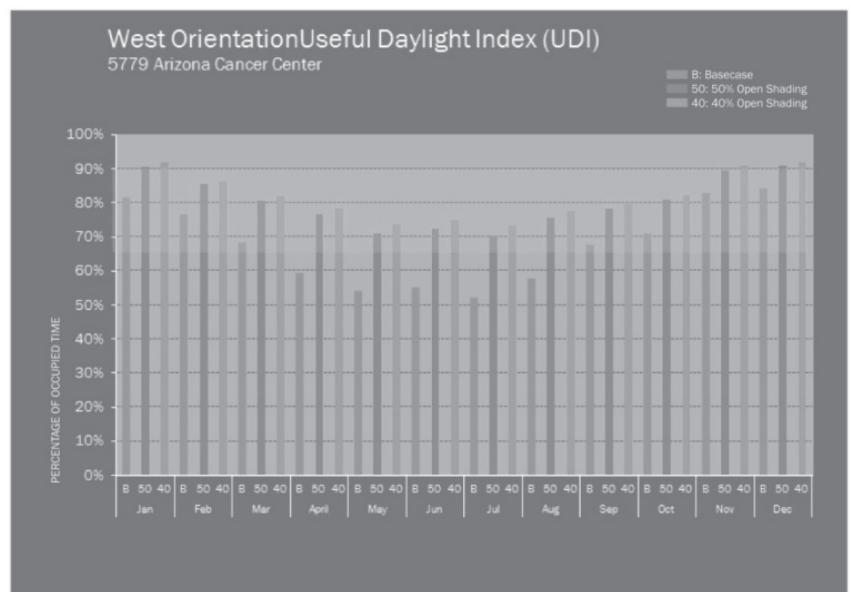
The daylight and glare performance of the lecture theatres and classrooms will be examined in more detail in the next stage of the design process and glazing areas optimised for best performance. On page 19 is a sequence of diagrams from the design for an Examination room in a college in Arizona, USA designed by Atelier Ten, which illustrates the design process explicitly.



**Daylight Distribution Analysis  
by Atelier Ten of an Exam  
room at Arizona University**



**Contrast and useful Daylight  
Analysis by Atelier Ten for an  
Exam Room at Arizona University**





The glazing proportion of the façade and glazing location has been designed to optimise the use of natural daylight to offset demand for artificial lighting and the form of the building with its massing, overhangs and integrated shading will ensure a very high degree of daylight autonomy with more than 90% of occupied spaces daylit in normal conditions (ie average DF>2.5). In many areas it will allow beneficial heat gains in winter to offset low temperatures and eliminate any heating need. Good day lighting design will be tied to active lighting control systems to ensure that unnecessary lighting is switched off when the day lighting is adequate or the rooms are unoccupied. We have targeted a 60% reduction in energy use for lighting compared to conventional buildings through the use of LED and other high performance light sources.

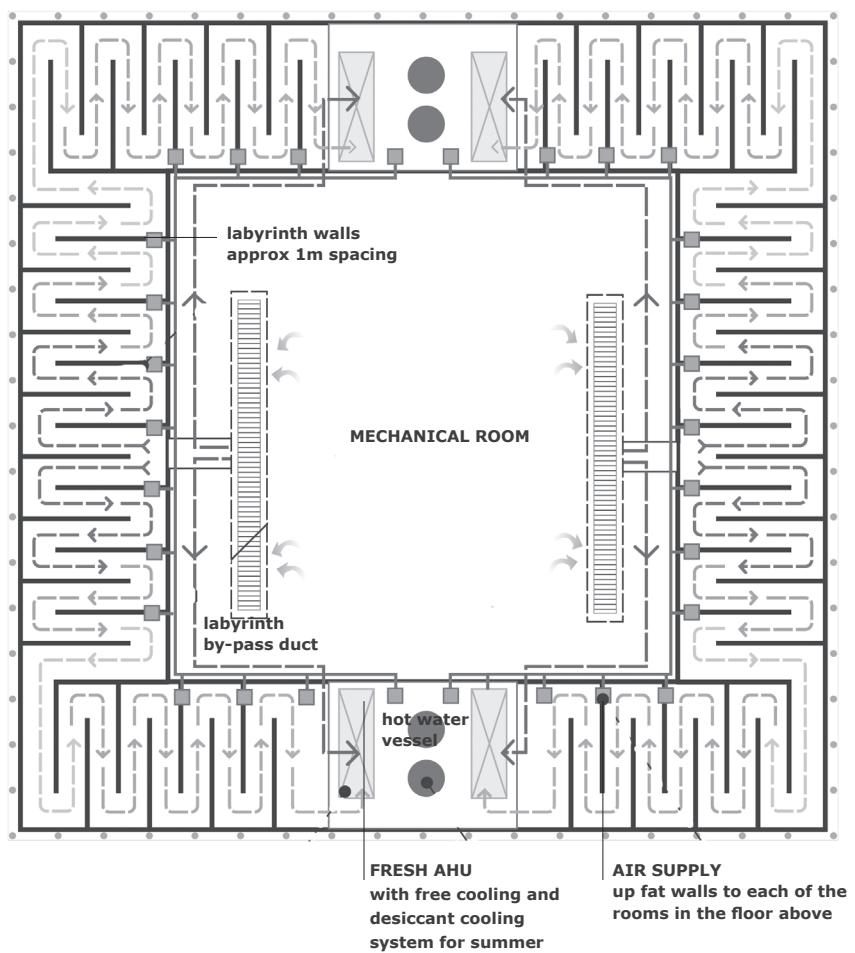
By reducing demand to a minimum in these ways it will be possible to have extended periods where the buildings will require no cooling, heating or background ventilation for most of the space types and simple natural ventilation through the building perimeter will suffice for good comfort. At the same time as being designed to maximise passive gains the façade will be designed to reduce thermal gains and losses through the use of good quality selective glazing and modest insulation levels to manage heat flows.

As the weather warms up in spring there will be a need for more shading from the facades and a certain amount of cooling. The high thermal mass of the rooms will be night cooled passively through open shuttered windows.

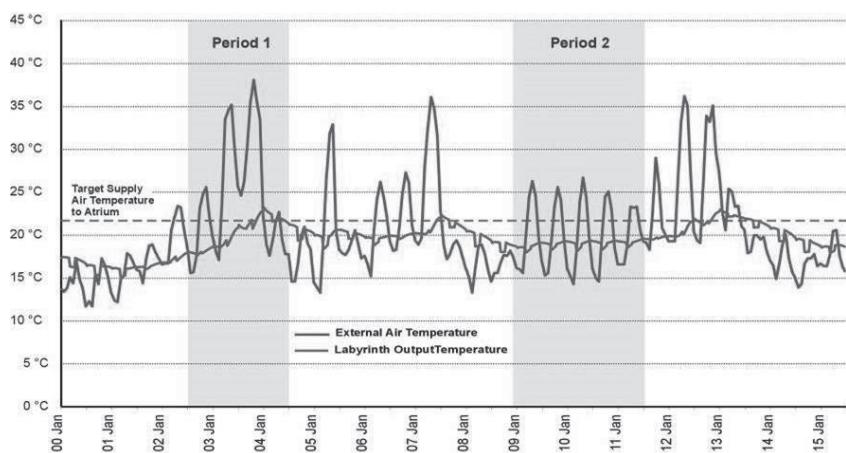
Each room will have a air supply connection fed from air handling units located beneath the building as shown in the section. The air will be supplied through low level displacement diffusers in the vertical "fat walls" that connect the upper level rooms to the basement at the corridor or external wall line. As the temperature increases further the mechanical system will run for longer hours and will draw air through an innovative passive decoupled thermal store called a labyrinth, which will be located beneath the building to precondition the incoming air.

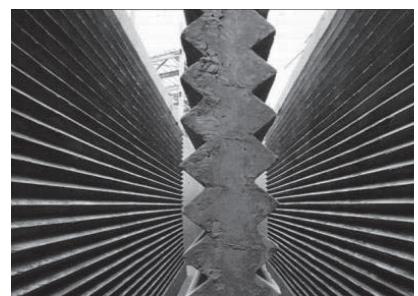
**The Labyrinth at Federation Square in Melbourne and a collection of the rammed earth bricks that are proposed here.**

**Diagram of Labyrinth proposed beneath one of the Faculty buildings.**



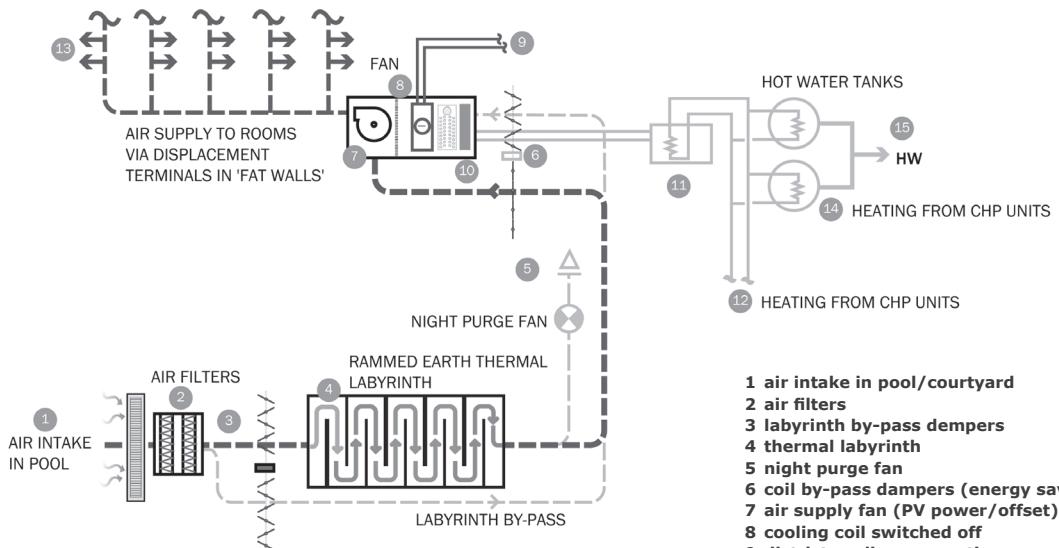
**Labyrinth performance as experienced in a hot period at Federation Square in Melbourne – the flatter line shows the output from the labyrinth.**





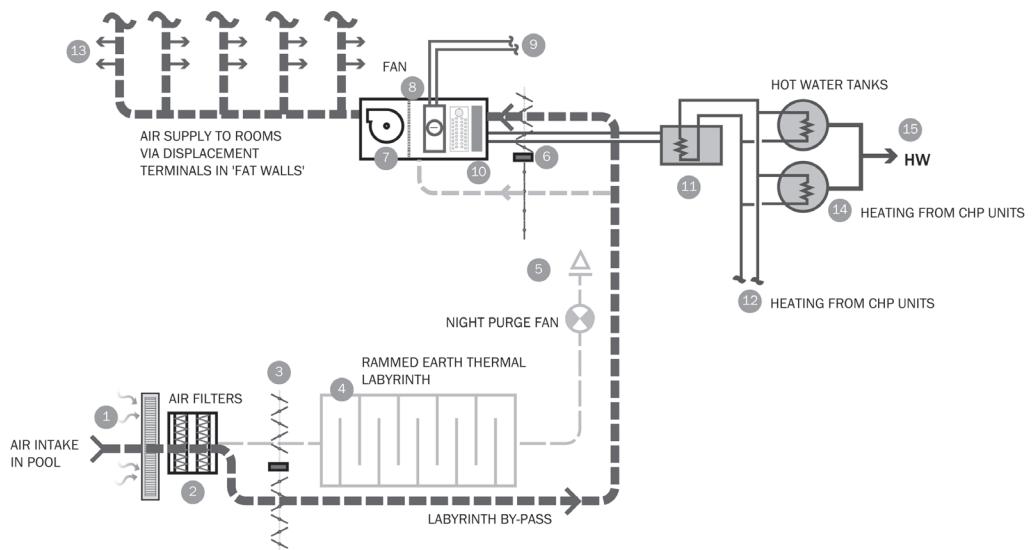
Labyrinths are a reinterpretation of a traditional form of ground coupled cooling and are increasingly being used to significantly alter the external air temperature to provide free cooling. With a labyrinth, the fresh outdoor air is drawn through a long winding tunnel where it is brought into contact with a large surface area of thermally massive material such as concrete or stone. This material will have been cooled overnight by cool external air and will therefore have the capacity to condition or pre-condition the air that will end up in classrooms, offices or even bedrooms. In our experience they can significantly extend the periods of the year where passive conditioning is sufficient.

The Labyrinth uses both the inherent mass of the material that it is constructed from as thermal storage and links to the constant cooler temperature of the ground to condition air supplied. The maze-like passageways in this proposal are proposed in rammed earth blocks, formed from the found materials on the site and dried in the sun, for the minimum environmental impact. The following images are of a large Labyrinth constructed in 2002 at Federation Square in Melbourne, Australia. The labyrinth has performed ahead of expectations and at peak conditions has provided more than 20oC of free cooling. The labyrinth here displaced 100% of the mechanical cooling load passively. This will not be possible in Nalanda as the nights in summer are warmer but the target will be to achieve passive cooling for 75% of the academic year. The longevity potential of this system is particularly important to recognise in the context of the Nalanda project, A labyrinth will last more than 100 years without replacement or significant maintenance, Air conditioning for many future generations.

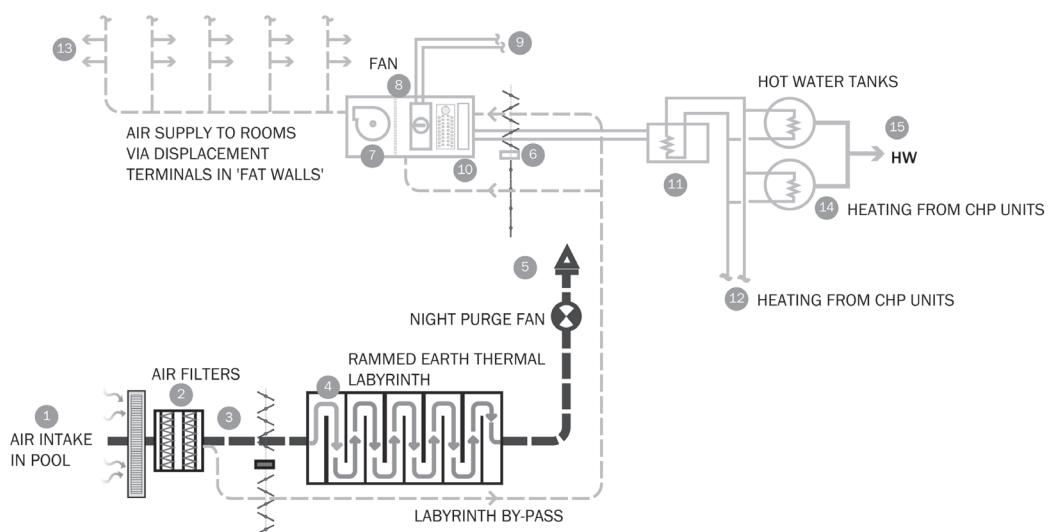


**Labyrinth and cooling system operation (typical) on a Spring/Autumn Day**

- 1 air intake in pool/courtyard
- 2 air filters
- 3 labyrinth by-pass dampers
- 4 thermal labyrinth
- 5 night purge fan
- 6 coil by-pass dampers (energy saving)
- 7 air supply fan (PV power/offset)
- 8 cooling coil switched off
- 9 district cooling connection
- 10 liquid desiccant pad
- 11 desiccant regeneration unit+store heated by 12
- 12 district heating connection
- 13 air supply to rooms via fat wall arrangement
- 14 hot water storage tanks (for residential units)
- 15 hot water supplies



**Summer day operation**



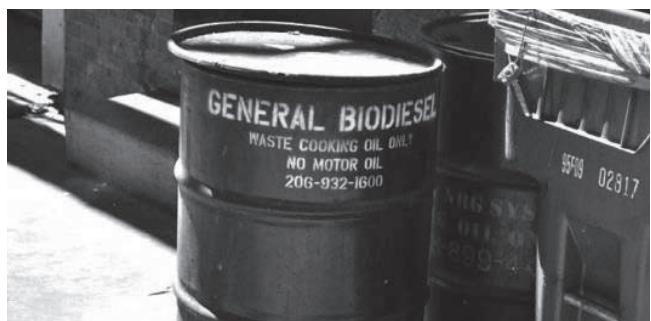
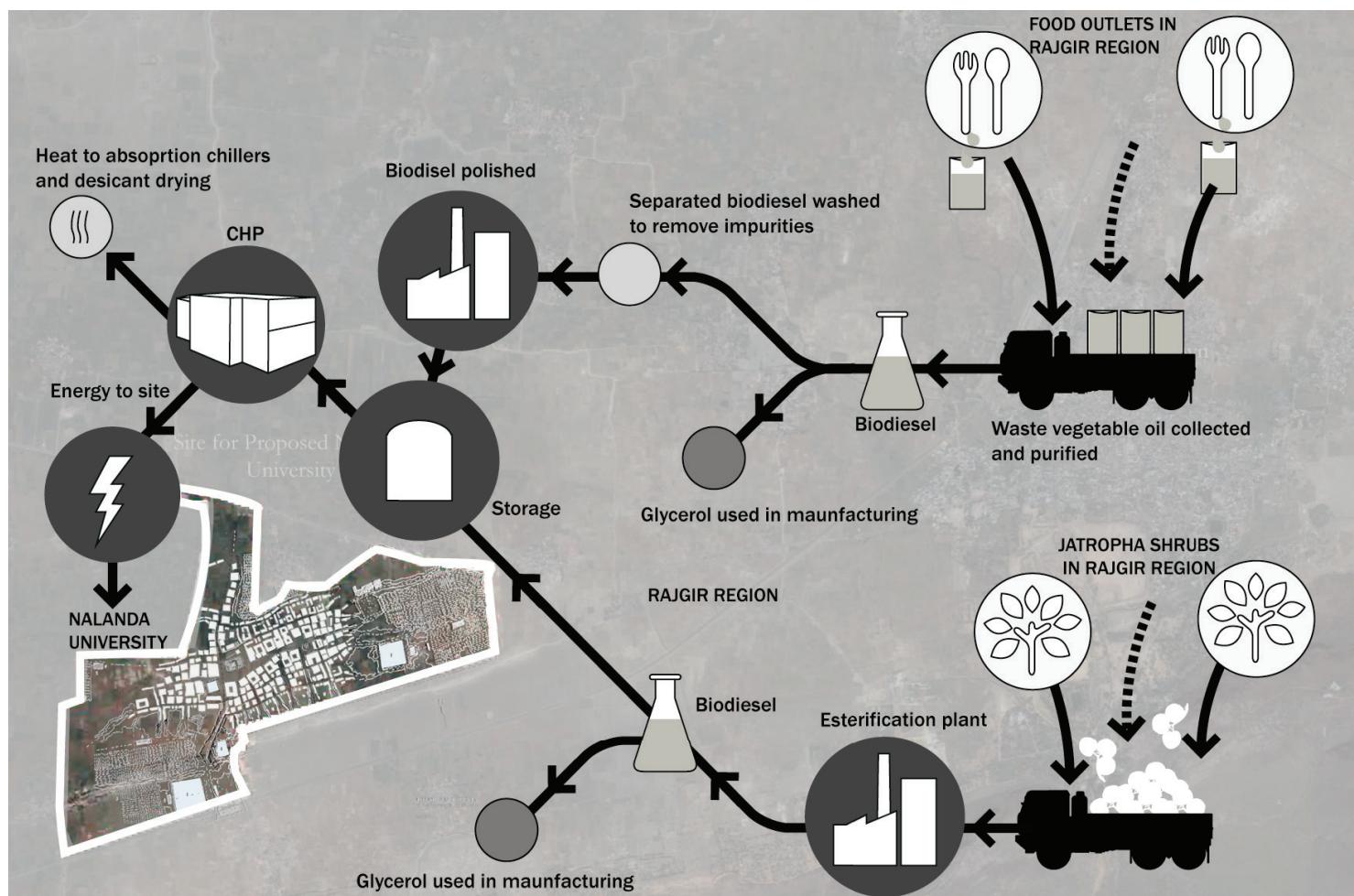
**Summer night operation**

The arrangement of plant is quite straightforward as shown in the operating diagrams on page 22. Intake air passes through a filter and via a face/bypass damper to either run through the labyrinth passageways or not, depending on the operating mode. On a spring/autumn day when labyrinth cooling is required to temper the fresh air, the air from the labyrinth bypasses the cooling coil and desiccant unit and feeds directly into the supply air fan and from there runs to the rooms.

In the summer months the labyrinth is only used when it can provide some useful pre-cooling and dehumidification of the incoming air. In all seasons the labyrinth can be purged at night using a simple by-pass fan as shown. On a summer day the air is drawn into the unit and passed first across the desiccant pads. These use a lithium chloride solution as a desiccant and reduce the RH of the outgoing air to 30-40% as required. The cooling coil is then connected to the district cooling system; and it cools the dry air to the desired supply temperature for displacement supply (c 18-20°C).

The weak lithium chloride solution from the desiccant unit is 'dried' by heating it in a regeneration unit fed from the district heating main that also feeds the domestic hot water systems in all of the buildings. As an alternative the systems could use dry desiccant in a hygroscopic wheel arrangement to achieve the same effect without the need for liquid based systems. A further study of the available technology in the Indian market would be carried out during the schematic design stage. In both cases the regeneration would be carried out using waste heat from the biofuel generators described below.

Each of the buildings will have a high degree of autonomy environmentally through these passive and semi-passive systems and would be able to function for much of the year without external inputs beyond power and heat for hot domestic water. Chilled water for cooling and heating water for domestic supplies and air conditioning will be generated at energy centres strategically located at the perimeter of the development. These are also described on page 22.

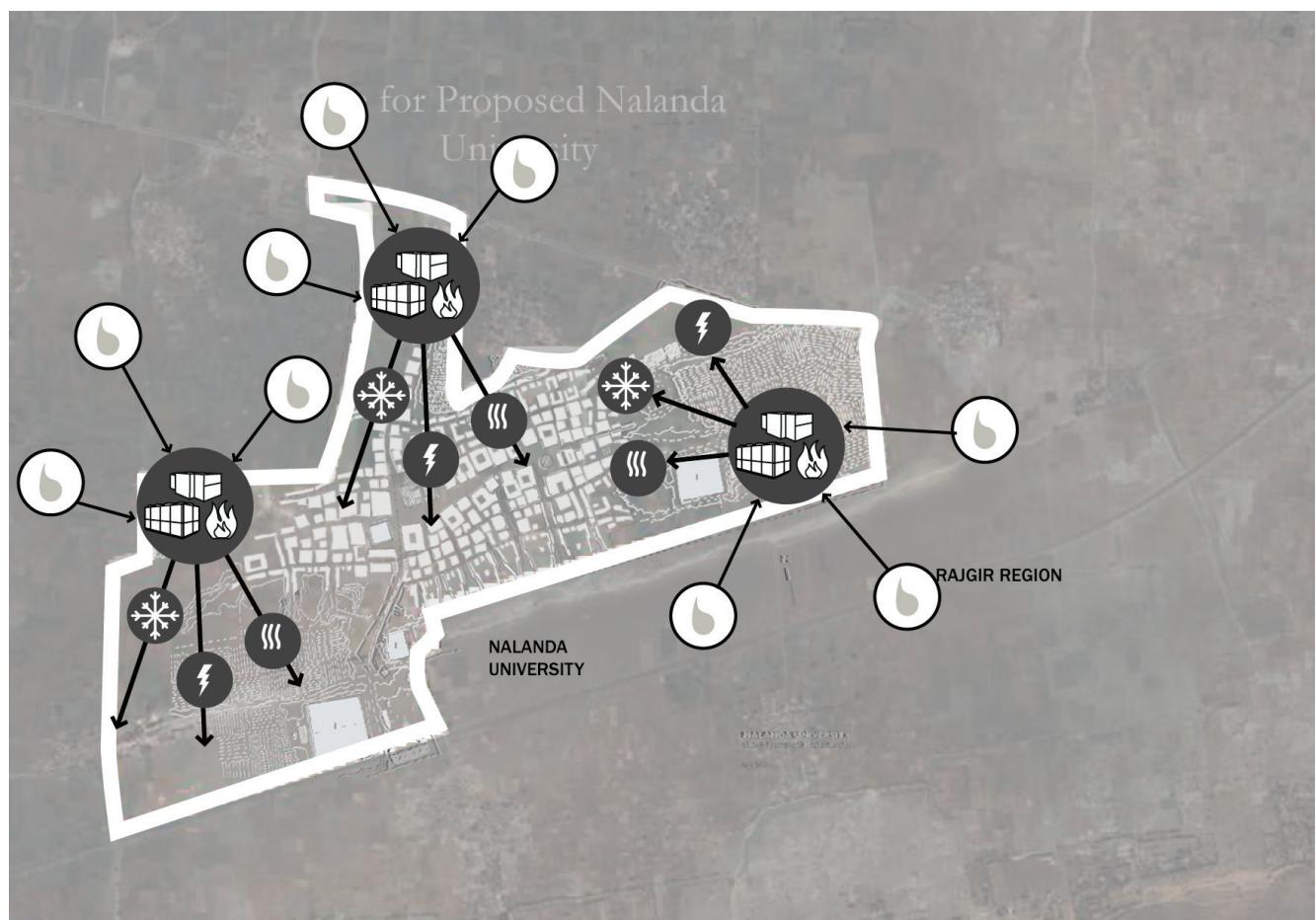
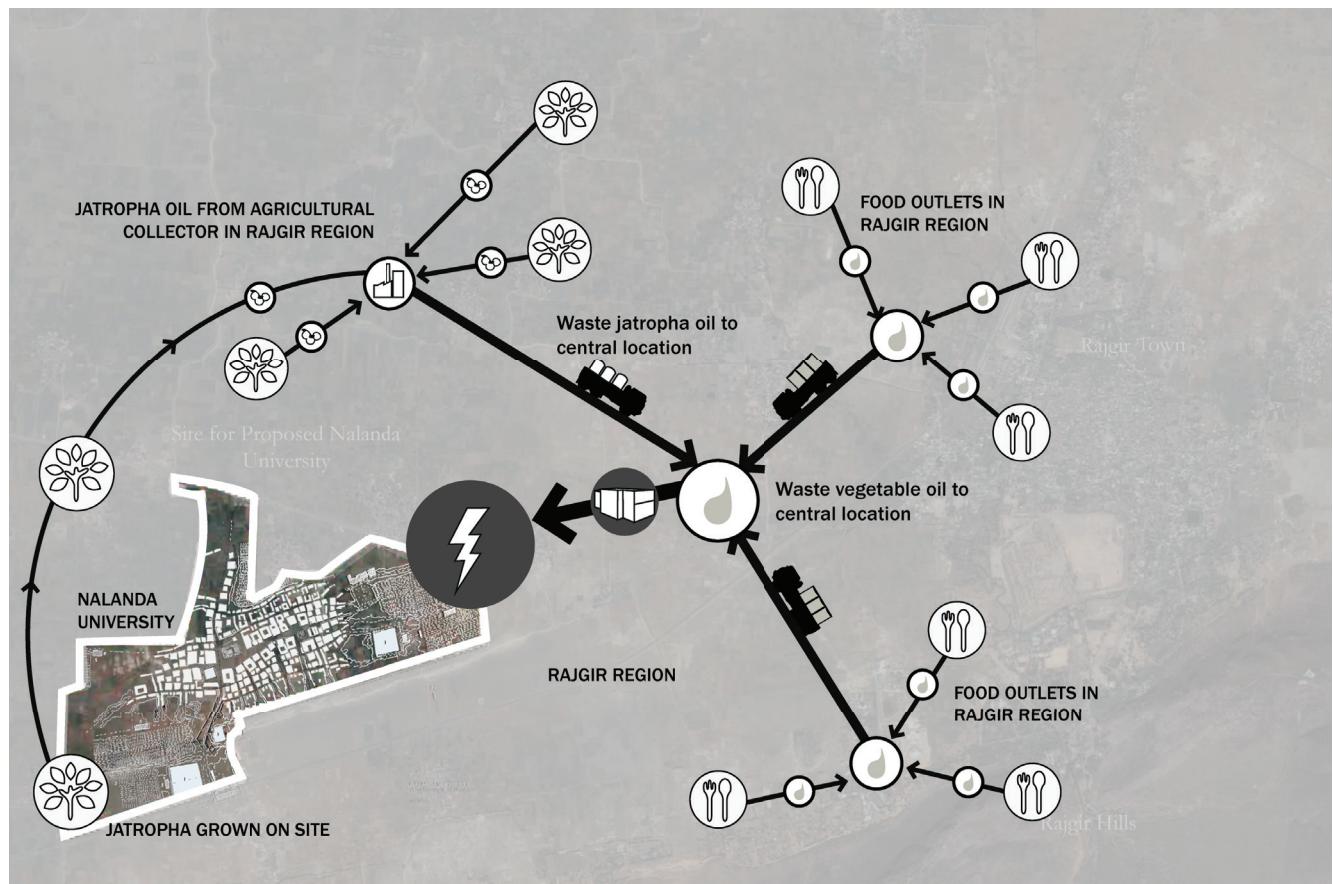


**Zero carbon biofuel from  
intercepted waste stream –  
used cooking oil and from  
Jatropha.**

## CENTRAL PLANT AND ENERGY SOURCES

The challenge of finding an affordable technology to deliver the ambition of a net zero carbon energy system for the campus is a significant one. The main demands for the operation of the buildings are electrical energy for lighting and plug loads, cooling and dehumidification for the hot seasons and heating for hot water for showers and other domestic water purposes. The lack of direct solar radiation in the rainy season suggests that a system based around solar energy, whether for electricity, heating or indirectly for cooling is unlikely to be successful. There is a rather limited wind resource on the site and generally the winds are quite light and so wind turbines would not consistently deliver the energy that is required to reliably support the campus.

The proposal is to develop a site wide energy grid based around a number of Cogeneration systems running on either a waste material supply or a biofuel or both. We have looked at waste to energy as one solution but from an initial appraisal the amount of waste required and the potential issues with the scale of deliveries, air quality and emissions would be a concern. We are therefore proposing a dual fuel strategy based around waste cooking oil recovery and processing and a biofuel such as Jatropha, which could potentially be grown and on site as well as being purchased as a fuel crop from farmers in the hinterland. Both of these fuel sources could potentially have a much wider social benefit than alternative imported fossil fuels in that their growth, harvesting, processing and management would provide useful inputs to the regional economy in both built up areas (waste oil) and rural areas (Jatropha).



**Processed Cooking Oil and Jatroha Oil**  
from the wider region is processed on  
or off site and delivered to three energy  
centres on the completed campus.

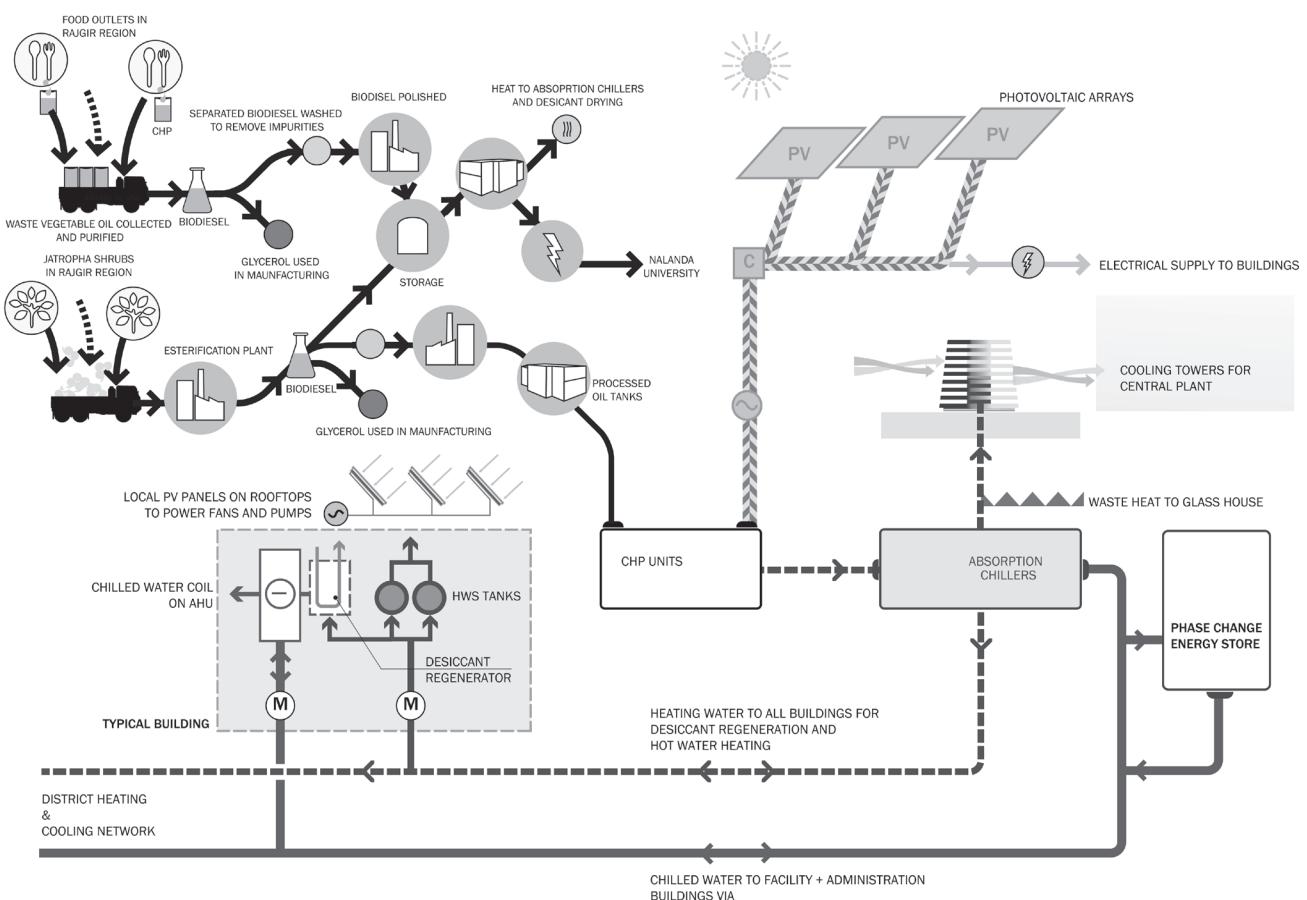
The collection and processing of waste cooking oil is a well-established industry in many cities of the world, as is the processing of Jatropha nuts into fuel stock. It is envisaged that the processing activities and bulk storage would be off site and that the on-site facility would be limited to short term storage and the cogeneration plant itself.

The proposed energy generation and distribution system is illustrated in the diagram on page 26. The biofuel is fed into a combined heat and power unit in one of three distributed but interconnected Energy Centres. Three Energy Centres are proposed initially to facilitate phasing, to reduce the scale of the individual infrastructure investment, to coincide with the likely substation locations and to provide resilience. The CHP unit will generate electricity and high and low grade heat in the form of hot water at two different temperatures. The 'high grade' hot water will be supplied to absorption chillers which will generate chilled water for building cooling while the lower grade heat (90°C) will be distributed in a district heating network to the individual buildings for hot water heating and desiccant regeneration. Supplementary electrical supplies will be drawn from PV panels located in a field next to the energy centre – these will be subject to a detailed affordability analysis during schematic design.

Thus the entire energy supply network within the site boundary could be close to zero carbon, depending upon how the energy used in transportation and delivery of the fuel stock is treated.

The opportunity also exists to increase the power output from the energy centres and to supply electricity to surrounding villages, thus rooting the university firmly in the community and bringing a wider benefit to the surroundings.

The importance of understanding the impact of human behaviour on the energy performance of the buildings in use cannot be overstated. The design can help facilitate low carbon usage, for example by providing suitable spaces for drying clothing and simple to understand lighting and other controls. More complex interfaces can also be helpful, for example these indicator lights at the Forestry School at Yale University which tell the students when the building is in 'Natural/Passive' or 'Mechanical' mode and one of the user interface screens that provide instantaneous telemetry on building performance.





**User interface and controls at Kroon Hall, Yale University**

To summarise the active and renewable energy systems proposed:

- Managed night cooling in winter and shoulder seasons uses room thermal mass to reduce cooling demand.
- Labyrinth below buildings made of rammed earth blocks in void provides diurnal/seasonal energy storage for “free” cooling in shoulder seasons (when diurnal range is good)
- Desiccants remove humidity from the air, regenerated with waste heat.
- Pumps and fans equipped with variable speed drives to match supply to demand.
- Smart user controls to inform faculty and students about building operating modes and performance.
- Central (zero carbon) cooling for peak months from CHP/ Absorption cooling plant
- Domestic hot water generated from waste heat of CHP system (Waste oil / biodiesel to energy)
- PV panels on individual buildings offset Labyrinth fan energy
- Option of centralised PV or solar concentrator array subject to detailed feasibility
- Potential to export surplus energy to the surrounding community.



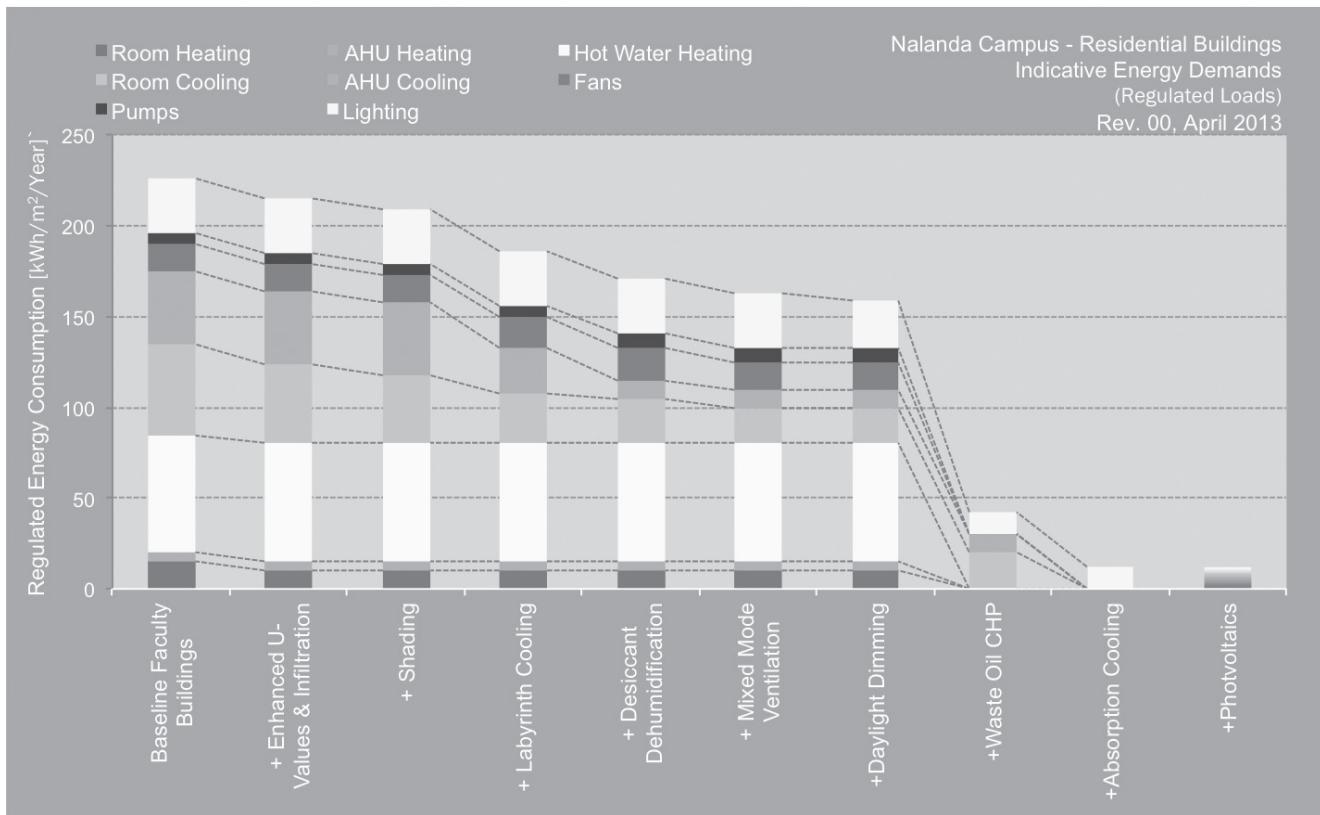
**A packaged biodiesel CHP unit**



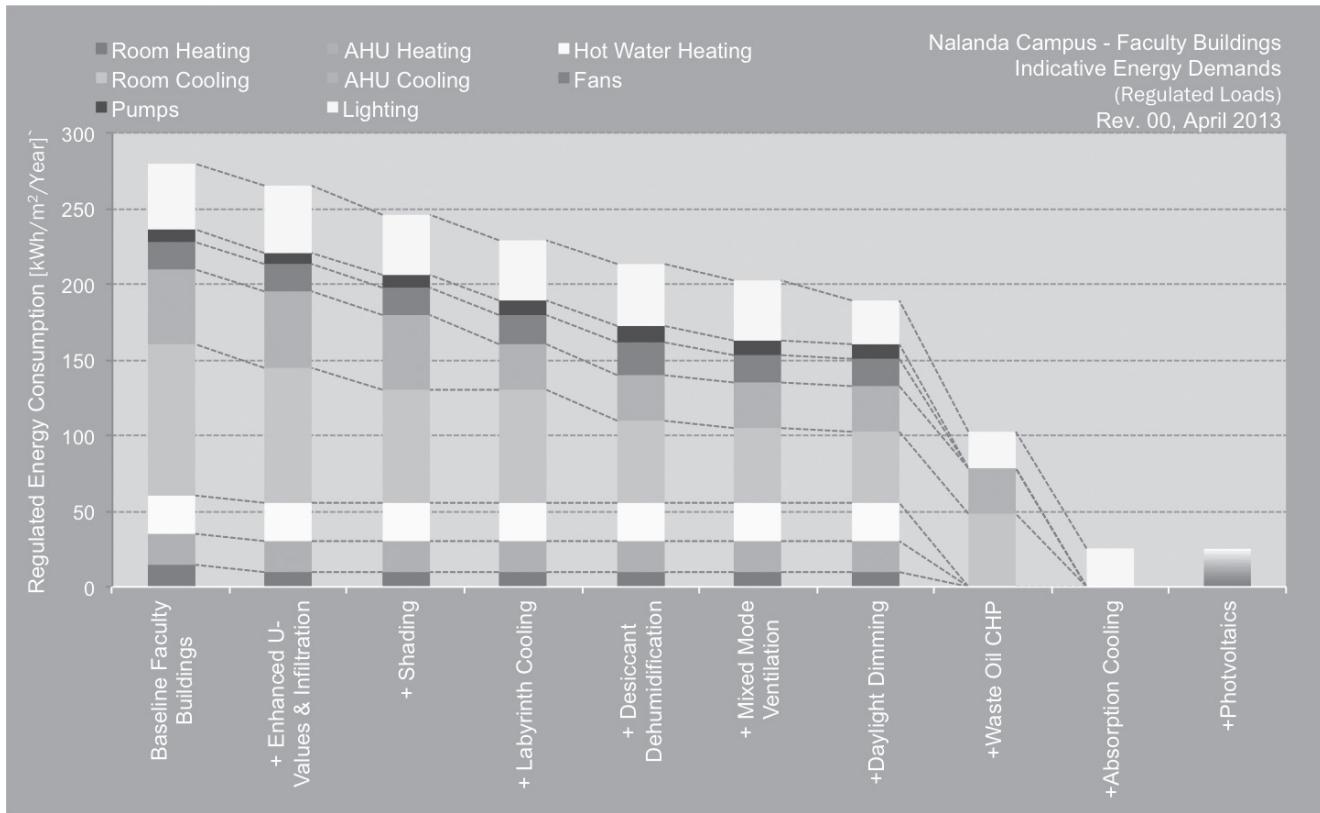
**(l) PV Panels providing shade to a car park, (r) a solar concentrator array**

The generation of detailed computer models to accurately forecast building and campus wide loads is an extremely lengthy and detailed process and cannot properly be carried out until the buildings are designed in more detail and equipment correctly sized. In this submission therefore we include analysis output based upon approximate calculations of demand and supply. These are included below for the residential and faculty buildings and they show the relative impact of the proposed sequential strategy on the various elements of the demand and the overall energy demand.

The graphs demonstrate the means by which the project could achieve net zero-carbon and be supplied with 100% of the required energy from renewable sources.

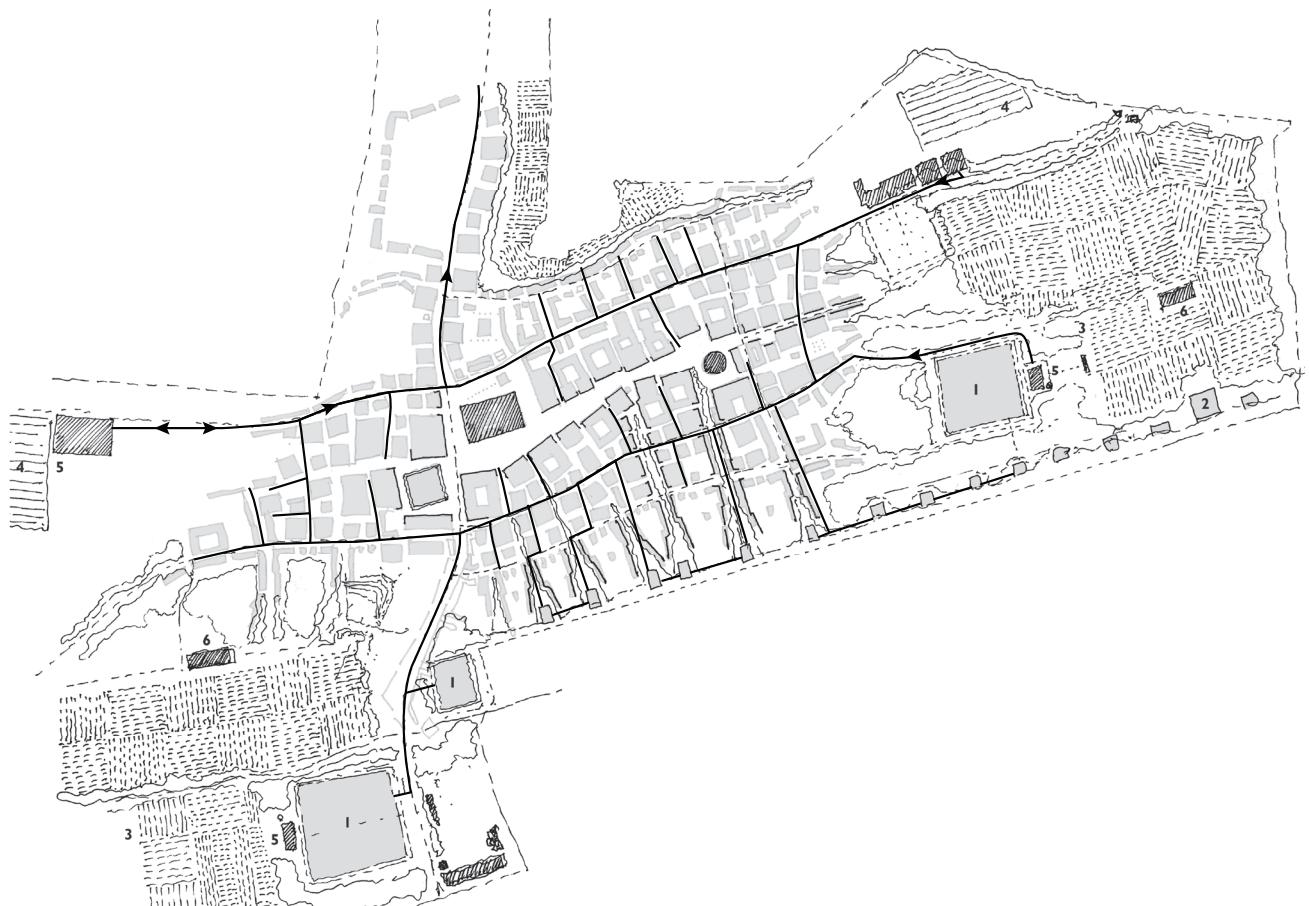


### Preliminary Energy Demand reduction assessment – Residential Buildings

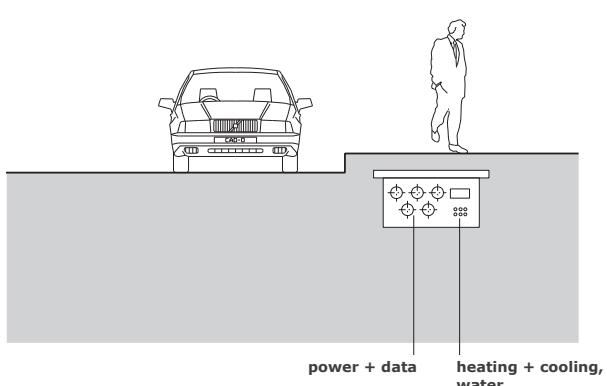


### Preliminary Energy Demand reduction assessment – Faculty Buildings

# SUSTAINABILITY

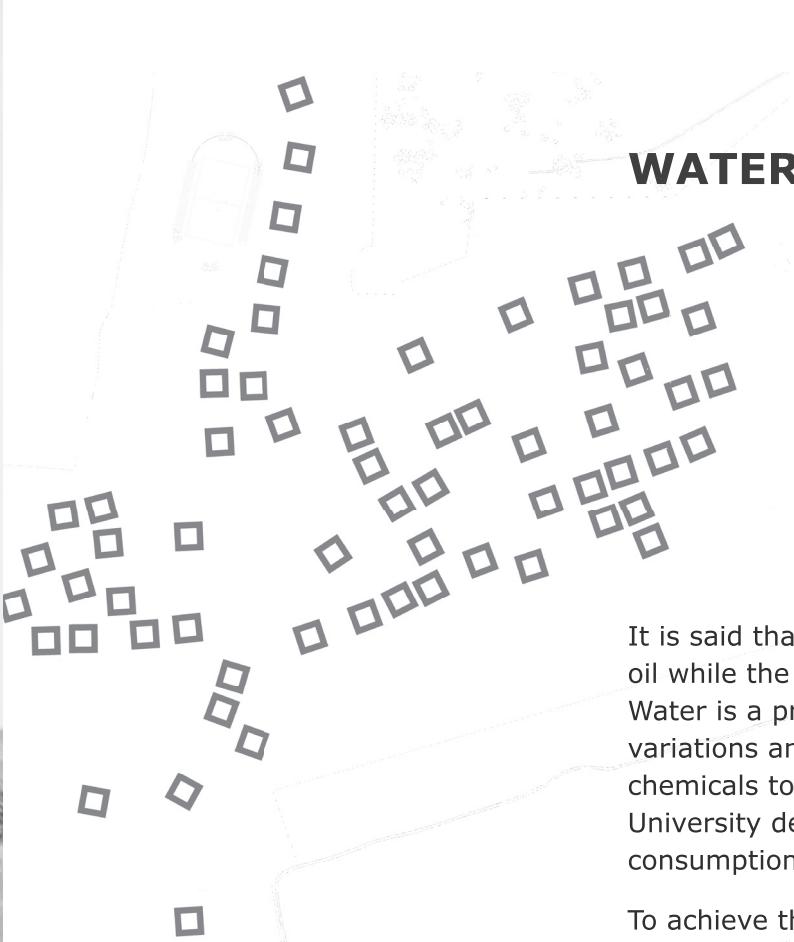


main distribution routes



- 1 Reservoir (storm water run-off)
- 2 Small collection tanks
- 3 Cultivation
- 4 Solar field + power plant
- 5 CHP
- 6 Greenhouse
- Primary distribution network (power, potable + rainwater)





# WATER STRATEGY

It is said that the wars of the 20th century were fought over oil while the wars of the 21st century will be fought over water. Water is a precious resource in India due to the seasonal variations and as it takes both energy and deleterious chemicals to purify water to a potable level. The Nalanda University development aspires to be self-sufficient in water consumption and achieve a net zero water target.

To achieve this target, we have followed a two-tier approach:

## **Minimise Water Use**

To achieve the required reduction in potable water usage, the development will incorporate a number of water saving measures. Aerated spray taps, dual flush WC's using grey water, waterless urinals and low flow aerated showers will be used to reduce the volume of water required for sanitary purposes. Drought resistant landscape design using native plant species with minimal requirements for irrigation has been incorporated in the university campus.

## **Maximise Water Collection and Recycling**

### Rain water

Rain water will be harvested directly via the roof structure and gravity fed into tanks underneath the buildings for local treatment. This water will be treated to potable water quality for human consumption, cooking, washing, bathing and educational purposes. By using water collected from roof and treating it to potable water use, least amount of energy will be expended in the process. Water collected from the hard landscaped areas will be diverted into on grade retention ponds which will be used for irrigation purposes.

### Grey water

Used water from wash hand basins, showers and treated water from the blackwater treatment plants will be used as grey water. The recycled water will be used to provide WC flushing water, cooling tower make-up water and landscape irrigation and the swimming pool.

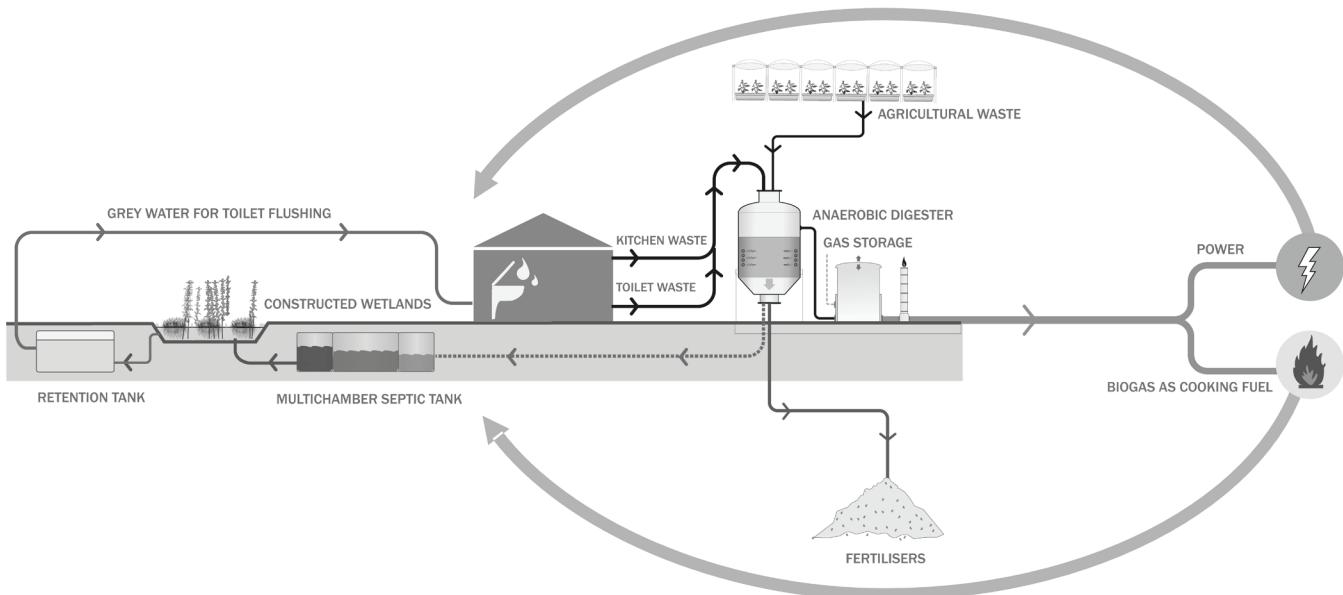
### Black water

All sewage from the development will be diverted into an anaerobic digester. Waste water from the digester will be collected in a bio-sewage treatment plant. The plant will consist of a gravity fed three tier sewage treatment tanks planted with reed beds and filters. The treated grey water will be stored and used to replace non-potable water use. The reedbeds will serve a dual purpose as a water feature in the landscape design as well as a water filtration system. Further information on specific plant species for this purpose is provided in the Landscape section in the design report document.

### Boreholes

Water from below ground reservoirs will be utilised to top up any potable water requirements that will not be met by precipitation.

Other water collection strategies integrated into the design includes collecting water from dew and condensate from mechanical cooling equipment.



# WASTE AND MATERIALS STRATEGY

A BMW is composed of 70% recycled materials while the average building consists of 1% recycled material. The intention for this project is to approach Nalanda University development with a BMW approach to the consumption of raw materials for construction. The University aims to be an exemplar sustainable development and the project should aim to reduce the use of virgin materials and conserve natural resources, reuse construction materials and reduce waste to landfill sites.

It seeks to use construction materials with a low environmental impact over the full life cycle of the building. A significant proportion of the construction materials should be locally sourced to reduce the environmental impact of their transportation. Where specific materials not available in India and needs to be imported from abroad, it is recommended to use means of transport with lower environmental impact such as train or ship for deliveries from neighbouring countries.

In the choice of construction materials and elements, consideration will be given to the robustness of the material to last the lifetime of the building as well as adequate protection of vulnerable parts of the buildings and

landscape, such as internal and external areas exposed to high pedestrian traffic and vehicular movements, to minimise the frequency of material replacement.

During construction a waste management procedure will be put in place to ensure that by products of construction are evaluated for re-use on site. If that is not achievable then they will be separated for off-site recycling. New materials used on site will be selected to have a high recycled content, be low VOC and FSC wood or other environmentally managed source. This will alleviate the wider impact on the environment as a result of the construction of this development.

Operational waste will be extensively recycled. The University aims to be net zero waste. Organic waste from sewage, kitchens and agricultural cuttings will be fed in anaerobic digesters and converted into cooking fuel, power and fertiliser and fed into a waste recycling virtuous cycle.

Recycling facilities will be provided on site to sort inorganic waste in several waste streams. This will be taken offsite for further reuse. Use of plastics would be restricted on the development with only recyclable plastic permitted. This will ensure minimal waste to be sent for incineration. All efforts will be made to ensure reusing or up-cycling of waste to minimize requirement for virgin materials.

Some common construction materials likely to be used for construction of Nalanda University have been listed below. These will be replaced or additives added to reduce virgin material quantities.

- Concrete: Additives will be selected so that the curing time and quantity of water needed to cure the concrete is reduced. Cement replacement material like GGBS, Pulverised Fly Ash, rice husks will be added to concrete to reduce the use of cement. Concrete waste will be crushed and used as aggregates while preparing concrete.
- Steel: Steel used in concrete construction will have a high proportion of recycled steel content.
- Timber: All timber used in the building will be sourced from sustainably maintained forests and should be either FSC certified or similar. Timber used in the construction or elsewhere in the building will not be hardwood sourced from ancient woodlands in tropical countries.
- Flooring: Flooring to use natural fibres or natural materials that can be rapidly grown like jute, bamboo, etc.
- Insulation: The use of thermal insulation products which have a low embodied energy relative to their thermal properties and responsibly sourced will be considered, e.g., insulation made from sheep's wool, cellulose,etc. The passive design's aim is however to avoid the use of insulation where possible.

# GRIHA EVALUATION

Further to the desired net-zero strategy for the campus as outlined on the previous pages, the competition entry intends to promote further enhancements, that emphasise the university's intention to 'reach beyond the norm'. This is important in particular, as the site is located on a Greenfield without any previous development. Preserving the natural state of the area as much as possible is important for a harmonic site in relation to its sensitive surroundings.

Therefore a GRIHA assessment was undertaken to define the measures that should be considered for the design and construction of the campus and each of its buildings. The schedule below should be understood as a generic outline, and will need to be applied to each building individually in the detailed design and construction phases, but the aim is to keep the final assessment as close to the proposed individual attempts.

Criteria	Points	Attempts
<b>1 Site Selection</b>	1	0
<b>2 Preserve and protect landscape during construction/compensatory depository forestation</b>	4	4
<b>3 Soil conservation (post construction)</b>	2	2
<b>4 Design to include existing site features</b>	4	4
<b>5 Reduce hard paving on site</b>	2	2
<b>6 Enhance outdoor lighting system efficiency</b>	1	1
<b>7 Plan utilities efficiently and optimize on-site circulation efficiency</b>	3	3
<b>8 Provide minimum level of sanitation/safety facilities for construction workers</b>	2	2
<b>9 Reduce air pollution during construction</b>	2	2
<b>10 Reduce landscape water demand</b>	3	3
<b>11 Reduce building water use</b>	2	2

<b>12</b>	<b>Efficient water use during construction</b>	1	1
<b>13</b>	<b>Optimize building design to reduce conventional energy demand</b>	8	8
<b>14</b>	<b>Optimize energy performance of building within specified comfort limits</b>	16	16
<b>15</b>	<b>Utilization of fly-ash in building structures</b>	6	5
<b>16</b>	<b>Reduction in embodied energy of the building</b>	4	4
<b>17</b>	<b>Use low-energy materials in Interiors</b>	4	3
<b>18</b>	<b>Renewable energy utilization</b>	8	8
<b>19</b>	<b>Renewable energy based hot water system</b>	3	3
<b>20</b>	<b>Waste water treatment</b>	2	2
<b>21</b>	<b>Water recycle and reuse (including rainwater)</b>	5	4
<b>22</b>	<b>Reduction in waste during construction</b>	1	1
<b>23</b>	<b>Efficient Waste segregation</b>	1	1
<b>24</b>	<b>Storage and disposal of wastes</b>	1	1
<b>25</b>	<b>Resource recovery from waste</b>	2	2
<b>26</b>	<b>Use of low-VOC paints/adhesives/sealants</b>	3	3
<b>27</b>	<b>Minimize ozone depleting substances</b>	1	1
<b>28</b>	<b>Ensure water quality</b>	2	2
<b>29</b>	<b>Acceptable outdoor and indoor noise levels</b>	2	2
<b>30</b>	<b>Tobacco and smoke control</b>	1	1
<b>31</b>	<b>Provide at least the minimum level of accessibility for persons with disabilities</b>	1	1
<b>32</b>	<b>Energy audit and validation</b>	0	0
<b>33</b>	<b>Operation and Maintenance</b>	2	2
<b>34</b>	<b>Innovation Points</b>	4	0
<b>Score</b>		100	96

With a successful implementation of the above outline assessment, the University would achieve the highest five star GRIHA rating.

Type of resource	Availability	Appliances	Visual impact	Costs	Other	Location	Result
<b>Wind</b>	Available in one main direction, but low speed and probably not sufficient for effective output	Energy	Sign for 'green' campus  Visible due to low rise campus	High installation plus maintenance	Noise	Along Road (north)	Unlikely due to low efficiency and high costs
<b>Geo thermal</b>	Readily available  Will work from November until June on its own, needs additional cooling with conventional means	Serves cooling, heating not required	None	Constructed as part of basement/ groundworks	High level of groundwater and aquifer could be beneficial to support cooling	Earth ducts/ Labyrinth below building footprint  Below every building	Suitable to site and can be constructed as part of buildings
<b>Solar hot water</b>	Roof space available, works with mild cloud cover	Hot water	Low	Low		Roofs, Residential buildings only	Suitable to site and can be constructed as part of buildings
<b>Solar</b>	Dependent on no cloud cover, may be difficult during monsoon period  Cloud cover between July and October (plus December)	Energy	On roofs of individual buildings, constructed as part of cool roofing systems  In clusters in landscape above water reservoirs to avoid evaporation	High installation, but low maintenance		Clusters integrated in Landscape design and on roofs	Possible, but not as only source for energy due to lack of output during second part of year. Could also feed into grid in first half of the year
<b>Central Plant/ Biomass</b>	Vegetable oil from greater area  Segregated compostable waste from site  Crops locally grown on fields (Jatropha)	Energy with heating and cooling as a by-product	Dedicated plant building as part of landscape. Building combined with water treatment, located next to reservoirs	Running maintenance costs	Mostly local biomass	3 Energy centres distributed on campus, towards the 'outskirts' along main access roads	Independent source of power and heating/ cooling

### Evaluation of Sustainable Resources



# SUMMARY

The design of buildings and masterplan has been developed in close collaboration with the Energy, Sustainability and Landscape specialist, to ensure that no considerations to minimise impact on the environment have been left untouched. Local climate and site specific conditions have been studied to ensure the right measures have been chosen with the intent to follow the principal of reducing the need for electricity, heating/cooling and water before trying to meet the demand with renewable sources. All possible sustainable energy sources have been reviewed and the most appropriate systems chosen based on local climate, site conditions and the universities requirements and intent.

The strategy has been implemented on each scale of the design. Whilst the whole campus can function as a closed system, each individual building has a degree of independence also (building specific shading, below ground labyrinth for cooling, water storage in every building etc.).

One of the most important aims is for people on campus (scholars, lecturers and visitors) to experience the measures taken at different scales, and in a way learn actively about sustainability by the use of buildings, without being compromised in comfort.

With all systems in place, the University could surpass their aim for a self sufficient net-zero (off-grid), and also feed into the surrounding local villages and support their infrastructure, and highlight its intention to act as a shining beacon for a sustainable building approach worldwide and set an example for future generations.





