Energy Efficient Buildings in Hot Arid Climates

Micro Campus Design for San Carlos Community College

by

Meghana Singaraju

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved October 2022 by the
Graduate Supervisory Committee:

Wanda Dalla Costa, Chair
Claudio Vekstein
Paul Coseo
Kristen Parrish

ARIZONA STATE UNIVERSITY

December 2022

ABSTRACT

This is an applied research paper, where a micro campus was designed for the San Carlos Apache Community with a goal of meeting requirements for at least three petals of Living Building Challenge. The end goal was to submit recommendations for attaining the petal certifications. The process of design not only included following spatial requirements of designing the building, but also including a wider perspective of construction and energy management in it. The first step of the research was getting to know the community and their requirements and priorities. This was done in 1st semester as a part of an applied class Indigenous Project Delivery. The second part of the research was to design a micro campus for the community that is in sync with the main campus. The intent of design is to respect the community's culture and help them pass it on to the next generation while abiding by the Living Building Challenge standards. The third step of this research was to back up the design with recommendations for petal certifications.

TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

CHAPTER Page

LIST OF FIGURES

Figure Page

CHAPTER 1

CULTURAL CONTEXT

1.1 Introduction

San Carlos Apache is a part of Apache Nation bands & was established on Aug 9th,1871. The San Carlos Apache college at present has +/- 130 students and is planning to build a new campus on a previous air mile strip near the current campus location, adding a micro-campus at Bylas site located 24 miles away from the current campus location.

The community engagement performed by IDC in September ’21 revealed a lot about the community, importance of the ‘place’, their value priorities, and their expectations of the future campus as a community.

1.2 Community Assets

Land, Lifeways, People, Activity and Climate are established as the common cultural assets by the community. Further diving into it, research was done by the class of Fall’21 as a part of Indigenous Project Delivery, which covered various topics like Buckskin, Crown Dance Regalia, Wickiup, Basketry, Pottery, etc. to learn about their cultural traditions and relate them to bio-climatic design response strategies.

1.3 Cultural Elements

1.3.1 Camp Dress – It was a two-piece shirt and skirt worn by Apache women, which was first made from buckskin and leather and later, when trade routes opened with Mexico was made from cotton. They often include geometric shapes (Jenn Walker, 2013)

1.3.2 Crown dance Regalia - The dance was taught to the Apache by the mountain spirits as a way of healing. The crown dancers (5 in number) in the ceremony are the mountain spirits and they believe that Usen, the creator, sent the mountain spirits to teach them harmony. (Jeff Goss, 2016)

1.3.3 Tufa Stone – Tufa is a variety of limestone. It is a type of sedimentary rock formed by calcium carbonate precipitates. Tufa stone is found abundantly in the San Carlos Apache community, and they have exclusive rights to evacuate the rock quarry on the reservation.

1.3.4 Artist integration – Artist integration is one of the major ways of treasuring and passing down culture to the younger generations. Not only having art by local artists, but also holding art exhibitions and educational art events is of utmost importance.

1.3.5 Wiki Up - A wickiup is built by creating a wood base and attaching tiny trees together, then wrap it in animal hide or brush It produces a dome form, and depending on the season, animal hide/brush provides protection, ventilation, and warmth.

Figure 1: Wiki Up

The plan of the building is inspired by the shape of wiki up, that is, a circle. But to avoid negative space in the building, caused due to the shape of the building, the shape of the plan has been changed into an octogen. This shape also provides design flexibility for developments in the future with respect to community suggestions without disturbing the shape of the plan much, just by shuffling the spaces unless the area of the spaces change. This way the calculations done in this paper will hold true to provide base values for estimation. The spaces in the building are designed and places with compliance to the circle of life principle followed by the community, standing true to the policy of teaching the next generation students, the San Carlos way of life and culture. This building is designed not only to teach a way of life but also be energy efficient.

1.3.6 Waffle Agriculture

Figure 2: Waffle Agriculture

The San Carlos Apache Tribe relied heavily on hunting and gathering because the men hunted both big and small game. Women gathered by gathering fruit, nuts, and seeds. Later, agriculture was introduced as they farmed to what they call the Three Sisters, which are corn, squash, and zucchini. The most traditional method was the waffle garden. This agriculture type slowly faded due to various reasons. The integration of this agriculture type in the campus, not only is a way to teach the historical way of life to students, but also a way to give back to the community.

The water flowing to and through this community garden, can be an element to connect the building to the nature around the building. The pattern of waffle agriculture can be a repetitive design element, while exploring the elevation design of the building in the future.

1.4 Value Priorities

Identity, Welfare of the community, acceptance, power, and engagement were elected as value priorities from the community engagement. Portraying and including these priorities as a part of building design using cultural traditions by relating and incorporating them in design is the way to rich value-based design.

For the micro campus, camp dress, tufa stone construction, crown dance regalia, agricultural methods followed by San Carlos Community and local art were incorporated into the design.

CHAPTER 2

MICRO CAMPUS DESIGN

2.1 Site Details

Site Location – Near Mt. Turnbull Elementary School

Co-ordinates - 33.09625, -110.11669

The site area is around 27 acres and is only 1.7 miles away from the nearest elementary school (Mt. Turnbull Elementary School). It currently has water, electricity, gas, sewer connections available. The Bylas District has a population of 2,781. A micro campus is being established here to cater to the students of the Bylas community attending San Carlos Apache Community College, since main campus is 27.8 miles away from the site.

Figure 3: Site Location

2.2 Site Surroundings

Figure 4: Site View – East

The East Side of the site is a beautiful view of the mountains and also entry of the site.

Figure 5: Site View – North

The North Side of the site receiving indirect sun and having view of the current site expanding up to 1000 feet

Figure 6: Site View – West

The West Side of the site receiving maximum sunlight and having mountain view. Also, the prevalent winds are from west to east.

Figure 7: Site View – South

The South Side of the site has a main road running alongside of the site and there is a water tank right opposite to the planned entry to the site.

Figure 8: Stone found on site

Stone found on site and can be used for construction. The site has red dry sand on the surface.

Figure 9: Natural Landscape of site

There are two washes present in the site area. Almost 70 feet wide and 12 feet deep, covered with natural vegetation.

2.3 Soil Test Analysis

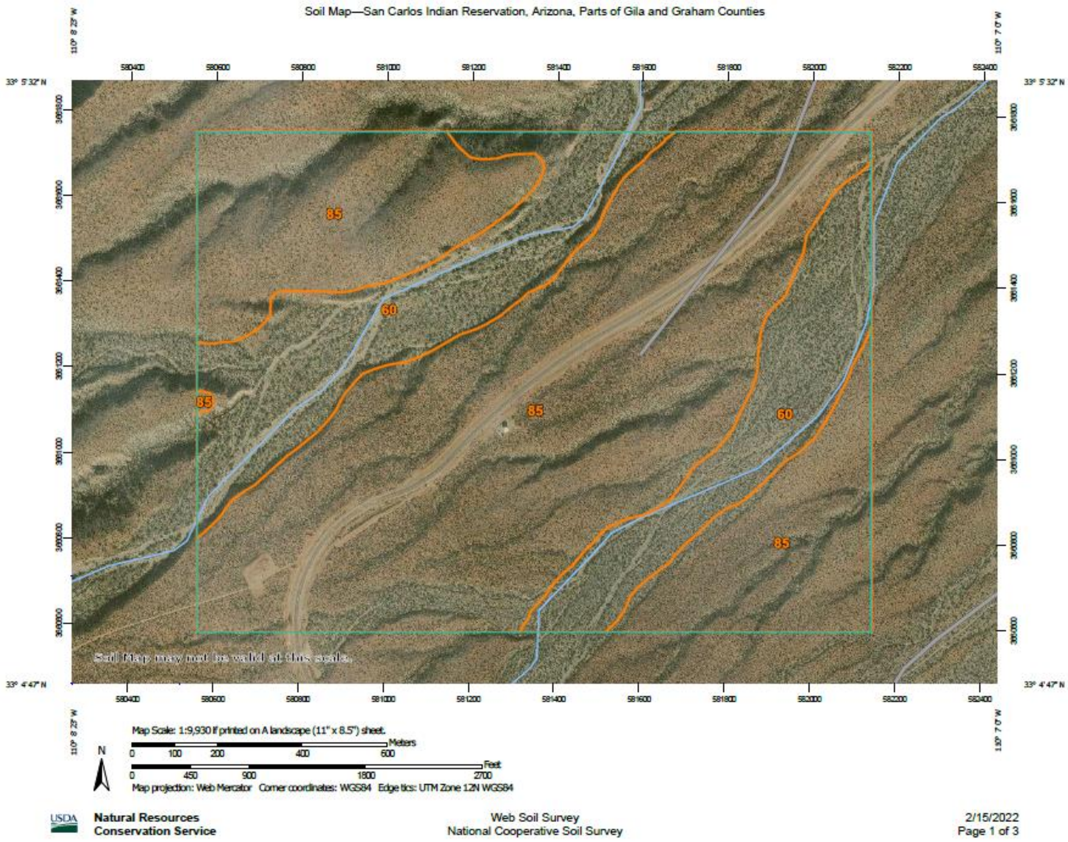


Figure 10: Soil Profile

1. There are no canals on the site, and it has no dramatic contours, other than the slight natural slope towards the washes.

2. Typical Soil Profile

   A - 0 to 1 inches: very gravelly sandy loam

   Bt1 - 1 to 11 inches: very gravelly sandy clay

   Bt2 - 11 to 34 inches: very gravelly sandy clay

   2Btk - 34 to 60 inches: very gravelly sandy loam

3. Slope:3 to 15 percent

4. Drainage class: Well drained

5. Runoff class: Low

6. Since the soil is clay as we dig deep into the site, pile foundations need to be constructed for the stability of the structure. Although, materials like stone found on site, adobe, wood can be used as materials for construction, it is essential to use concrete for the construction of foundations and they need to be waterproofed.

2.4 Music School Case Study

The intention behind studying Music School was to observe and analyze the south courtyard. Since the music school also acts as a micro campus, plans of the campus have been redrawn to understand the scale and concept of the school in depth. This courtyard was created to establish and act as a bridge between the existing building and the extension of music school around 1989.

Figure 11: ASU Music School Courtyard

The courtyard has a waterbody on the curve of the building as opposed to the usual placement of fountains in the center. This gave a lot of space for circulation and since it was place in a strategic position for the prevailing winds to pass through the pool, as it is placed between two corridors (openings).

Figure 12: ASU Music School Entrance

The openings are lined with elements liked columns and overhead mounted railings, so are the walls along the corridor leading to courtyard and the courtyard itself. This is helping shift the point of sight to a much higher level than the existing doors and openings.

2.5 Design – Concept

What is a micro campus?

A micro campus is a building that has all the facilities provided in a college campus but caters for much smaller number of students. Micro campuses not only act as miniature campuses, but an extension of the original campus itself.

For the same reason, the design of this micro campus is as much in sync with the original campus design as necessary, after which it was targeted to have a character of itself. This way while being an extension of the original campus the micro campus will have a chance to tell its own story to everyone who visits.

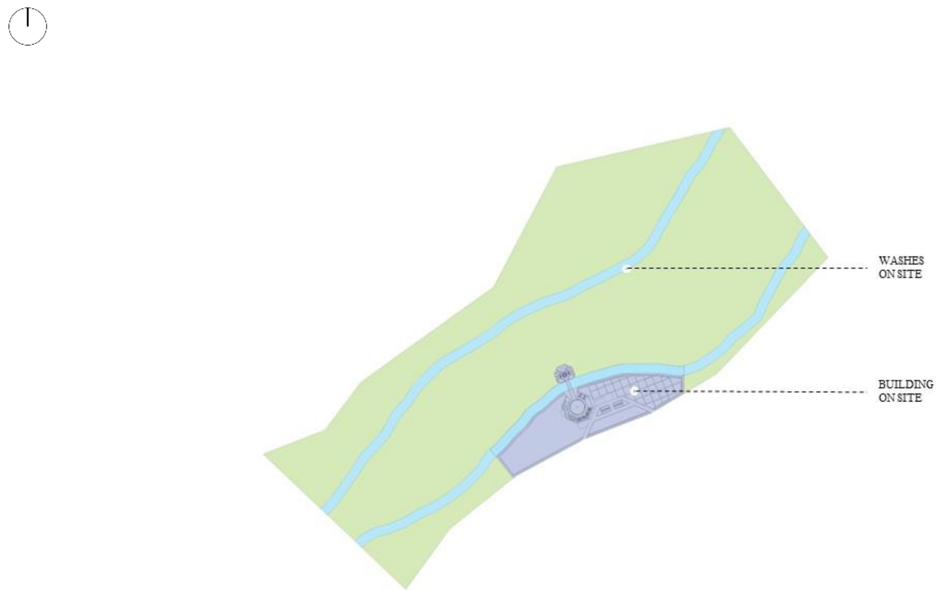


Figure 13: Building Location on Site

The total area of the campus building is 39,950sft including the courtyard, the bridge, and the pathway around it. Since this only a small part of the total site, the wash along the building on site is maintained to contain the rainwater, throughout the year.

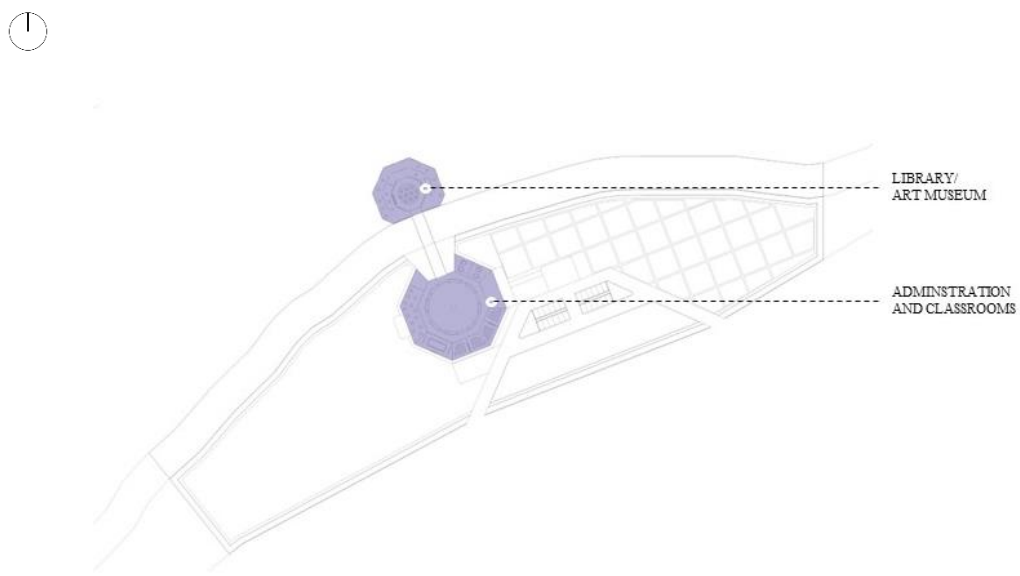


Figure 14: Building Concept

The entry to the site is on absolute east, respecting the principle of circle of life followed by the community.

The building is designed with utmost respect towards the site and culture of community and with the aim to be a part of site, rather than a building on site.

As a part of this effort, the building has been designed using the wash as a guiding line, with an intention to make it a part of the building and as an effort to eventually make the building self-sufficient.

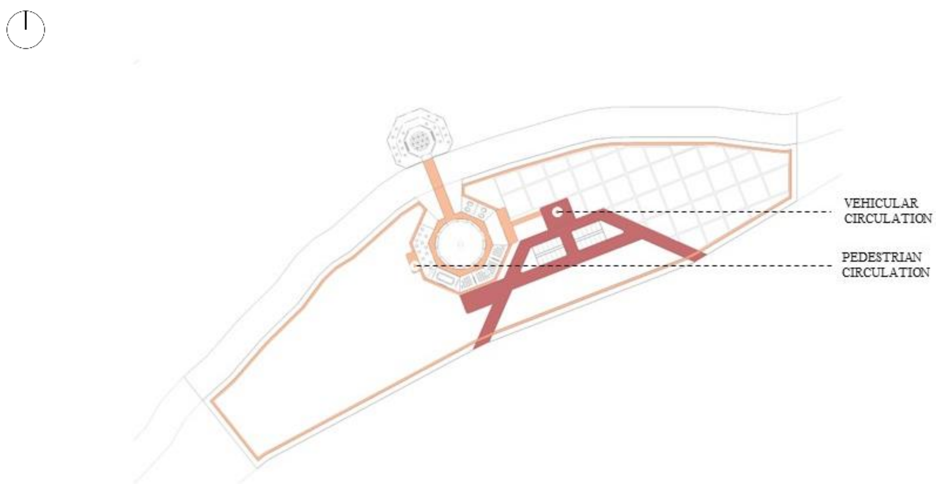


Figure 15: Vehicular and Pedestrian Circulation

The parking and the road leading to the building is designed with an intention to use as less asphalt as possible on site.

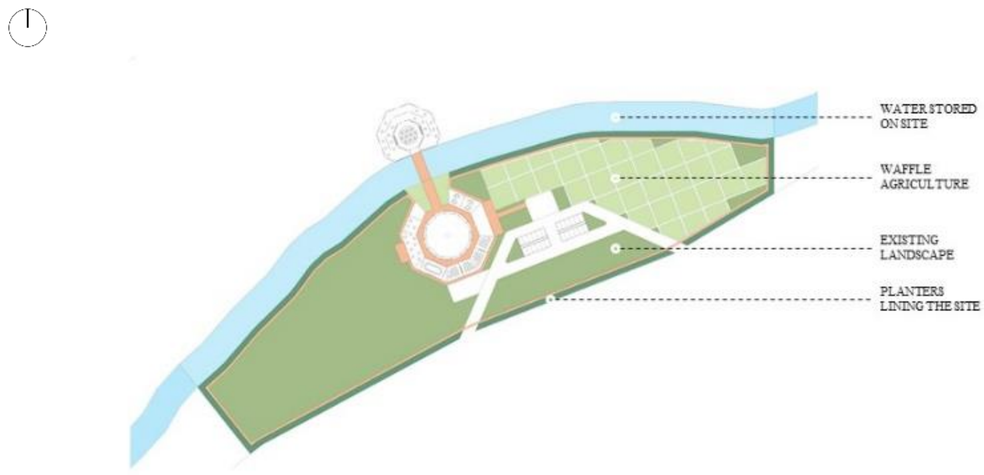


Figure 16: Landscape on site

Furthermore, the natural vegetation in the site will be maintained and promoted as a part of landscape design, intervening as less as possible with the existing site conditions. Since this only a small part of the total site, the wash along the site is maintained to contain the rainwater, throughout the year.

2.5 (a) Building Section – Air flow in building

Following is the section cut through dining area and lobby of micro campus, depicting the air flow.

Figure 17: Sections

Hot air blows into the building through southwest, it cools down after entering the building, due to the already existing natural landscape on site and the evaporative cooling mechanism established in the building. This cool air stays cool due to the courtyard and the water body established as the center of courtayard, while hot air naturally goes up. The cold air passing through the courtyard, will leave the building as cold air and stays cold, due to the waffle agriculture set up on the front side of the building.

2.5 (b) Roof of the building

Figure 18: San Carlos housing in 1900

The roof for this campus is inspired from the San Carlos office quarters that was turned into housing in 1900 when the army abandoned its camp, which was taken over by San Carlos Indian Agency.

2.6 Plan and Program

The plan is oriented towards north - east ensuring utmost amount of indirect sunlight gracing the whole building with the courtyard in between creating a microclimate of itself for gathering and ultimately cooling down the whole building.

1.	Financial aid and Staff room	1724.5 sft
2.	Classrooms	851 sft (x4)
3.	Conference Room	1759.5 sft
4.	Food Court	3516.7 sft
5.	Library	2835 sft
6.	Tribal Museum	7465 sft

Bigger part of the building encompasses spaces such as classrooms, financial aid and staff rooms, conference hall and food court, while the smaller part of the building consists of library and surrounding it is the tribal museum/exhibition

Inspired by the ‘crown dance regalia’ the administration, education, food, museum and library act as 4 sacred dancers while, the 5th dancer, the one who drove away evil spirts, is the building envelope.

2.7 Relatability of building elements to cultural elements

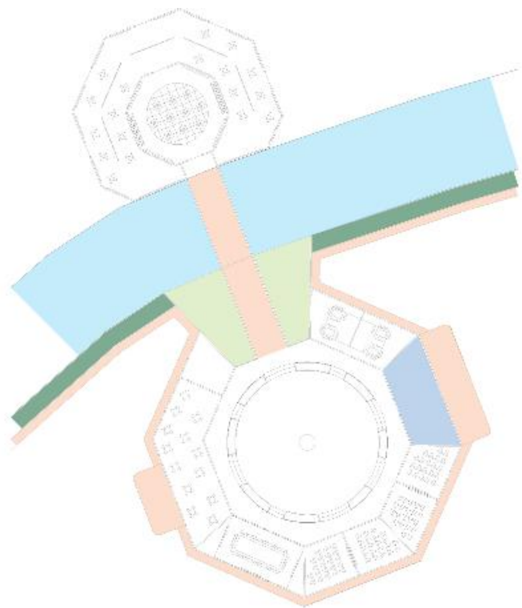


Figure 19: Entrance Lobby

The entrance to the main building, encompassing the basic functions of a campus. The entrance of this building is to the east of the site. The basis of the functionality and circulation of the building is not only based on the climate and site orientation, but also the principle of ‘circle of life’ the community follows.

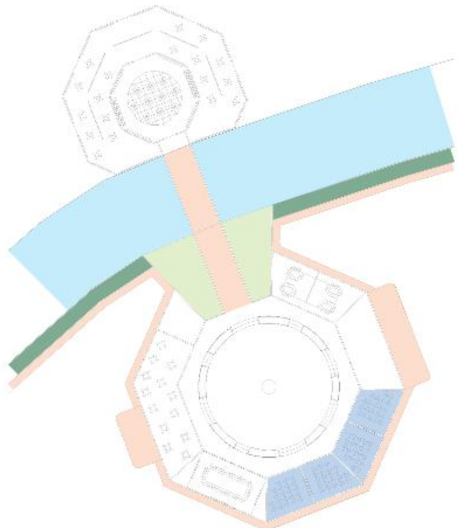


Figure 20: Classrooms

Classrooms are situated in the south – east, although, according to the circle of life the admin and finance rooms should be present there. This classroom placement is to protect the spaces from any kind of external noise, without completely cutting them off from the exterior spaces.

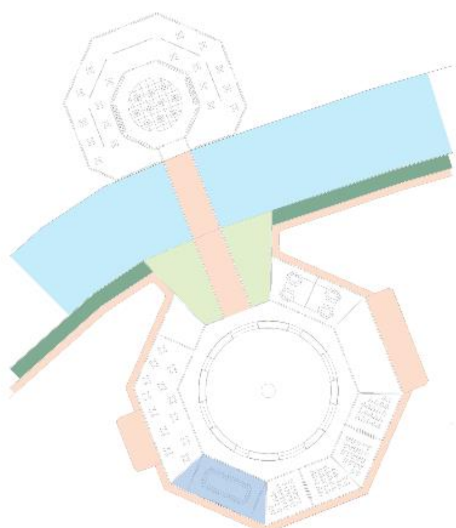


Figure 21: Conference Room

The conference hall is situated in between the classrooms and dining, this way it will act as a formal gathering space while being accessible to everyone and while following the principle of circle of life.

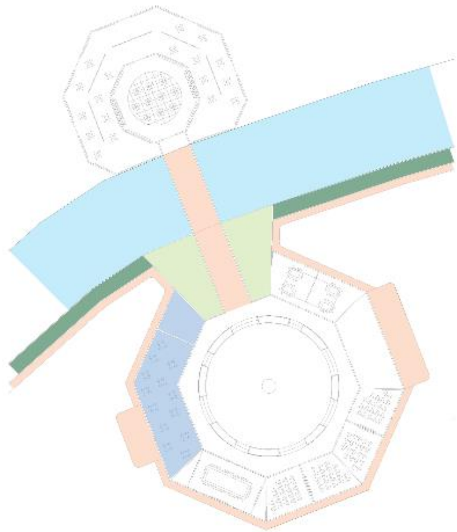


Figure 22: Kitchen and Dining

Kitchen and dining are towards the west, according to the principle of circle of life and in the best possible vicinity of kitchen garden.

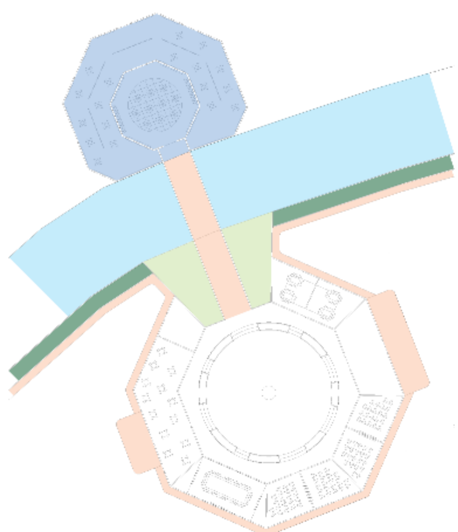


Figure 23: Library and Tribal Museum

The library and the kitchen are meant to be used as community spaces, so is the courtyard which can be used as community gathering area. The goal of this campus will not only be to educate the students at this college but also the community as a whole, especially regarding the culture and roots of the community.

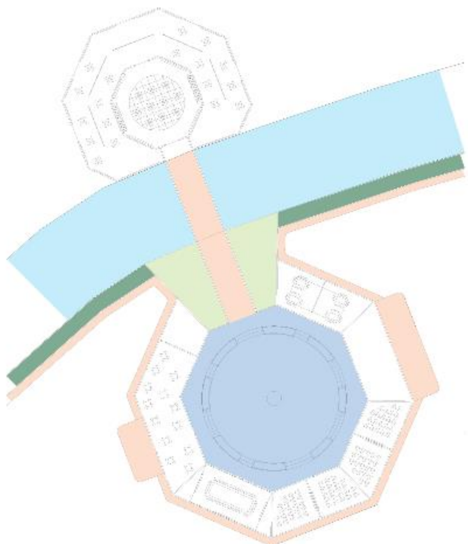


Figure 24: Courtyard and atrium

This micro campus is not only meant to act as a campus building for the students residing in Bylas, but also an inspiration for students at the elementary school encouraging them to pursue higher education. The courtyard is not only meant for students at this college, but also for the students of the elementary school. This not only acts as a breakout space/ extension, but also as a space of gathering.

Agriculture is being included as a part of the design with an intention to return waffle agriculture into practice.

CHAPTER 3

LIVING BUILDING CHALLENGE

3.1 What is living building challenge?

For this project, Living Building Challenge has been established as a guiding design principle and target to be achieved.

‘The living building Challenge consists of 7 performance categories, which are also known as petals: Place, Water, Energy, Health + Happiness, Materials, Equity and Beauty’ (LBC 4.0, 2019). Through this design, the target is to achieve certifications for Place, Material and Energy Petals.

3.2 Place Petal

3.2.1 ‘Intent’

The Place Petal's aim is to realign people's understanding and relationship to the natural environment that nourishes us. To preserve, safeguard, and improve the story, the built environment must reconnect with the ecology of place and the features inherent in each community. The Place Petal clearly articulates where it is permissible for people to construct, how to conserve and repair a developed place, and how to stimulate the formation of communities that are built on the pedestrian rather than the vehicle. These communities, in turn, require the support of a network of local and regional agriculture that promotes the consumption of local, fresh, and seasonal food (LBC 4.0, 2019).

3.2.2 Place Imperative 1 - Core – Ecology of the place

The Imperative's purpose is to maintain wild and ecologically significant places while simultaneously supporting natural restoration and better community and project function.

Prior to starting construction, all project teams must document site and community conditions, including establishing the project's "reference habitat(s)." All project teams must investigate the community's cultural and social equity aspects and requirements, and utilize the knowledge gained to drive design and process decisions (LBC 4.0, 2019).

3.2.3 Place Imperative 2 – Urban Agriculture – Scale Jumping Permitted

All projects must devote a portion of their total project area to growing food or devote a smaller portion of their total project area to growing food while also directly providing weekly community access to healthy local food that meets a community need, via farmers markets, CSA programs, or other local food producers.

Scale jumping can be utilized to improve the availability of healthy, local food to a specific demographic or the community through an off-site venue such as a food bank, school, or other community resource.

Resilience Strategy - In the event of an emergency, all projects (except residential developments) must provide food for 75 percent of FTE inhabitants for at least three days (LBC 4.0, 2019).

3.2.4 Place Imperative 3 – Habitat Exchange

The purpose of this Imperative is to protect land for other species as more land is developed for human use.

All projects must set aside land comparable to the project size (or 0.4 hectares/1 acre, whichever is greater) in perpetuity, either through an approved Land Trust organization or the Institute's Living Future Habitat Exchange Program. (LBC 4.0, 2019).

3.2.5 Place Imperative 4 – Core – Human Scale Living – Scale Jumping Permitted

The purpose of this Imperative is to assist in the development of walkable, pedestrian-oriented communities that reduce the use of fossil fuel transportation. All developments must keep or increase site density while simultaneously promoting a human-powered lifestyle.

- Implement at least four of the recommended practices listed below:

a. Examining and improving pedestrian paths, including weather protection on street frontages.

b. Community advocacy to encourage the use of human-powered and public transportation.

c. A transportation subsidy for all project inhabitants.

d. Assistance with carpool coordination.

e. Access to subsidized car sharing and/or hybrid or electric fleet vehicles.

f. Conduct regular polls of residents to ascertain current fossil fuel-powered SOV journeys (LBC 4.0, 2019).

3.3 Place Petal Recommendations

3.3.1 Place Imperative 1 - Core – Ecology of the place

1. Site Documentation

2. Protection of Natural Vegetation

3. Minimum interference of non-ecological materials and respect or site.

4. Preserving natural vegetation/wildlife on site

5. Design respecting and following cultural preferences and traditions

All the above stated recommendations were followed in the design process. The site was documented. The natural vegetation is included in the landscape of the building. The building is located on the site in a way that as less asphalt can be used as possible and the materials follow material petal requirements, helping keep the site as is, as much as possible. The design is following the principle of circle of life followed by the community and is respecting the land and place as the community does.

3.3.2 Place Imperative 2 – Urban Agriculture – Scale Jumping Permitted

1. Include Agriculture as a part of design

2. Distribute it with the help of school or micro campus.

3. Use the kitchen as community kitchen while using on site agricultural produce

Having a waffle agriculture as a part of campus will not only be a way of introducing community culture and cultivation to the younger generation, but also will be a way of giving back to the community in times of need. Using the school kitchen as a community kitchen is one of the many ways in which a sense of community and responsibility can be induced in students who are the next generation of the community.

3.3.3 Place Imperative 3 – Habitat Exchange

1.Setting aside land equal to the project size on site.

There is land set aside as much as the building footprint and some more as a way of respecting and preserving the natural environment. Apart from this there is a lot of land left for future development.

3.3.4 Place Imperative 4 – Core – Human Scale Living – Scale Jumping Permitted

Following are the four best practices recommended best for the school that are financially achievable

1. Consideration and enhancement of pedestrian routes, including weather protection on street frontages.

2. A transit subsidy for all occupants of the project.

3. Carpool coordination assistance.

4. Regular survey of occupants to determine current fossil fuel-based SOV trips.

The pedestrian routes have not only been designed just around the building, but also around the wash where water is being reserved and in between the waffle agriculture. This way the students and anyone who visits the school can get an essence of the building.

3.4 Materials Petal

3.4.1 Intent

The Materials Petal's mission is to help establish a non-toxic, ecologically friendly, and transparent materials economy. This section's Imperatives aim to eradicate the most severe known infringing materials and behaviors, as well as to drive industry toward a truly responsible materials economy. The Red List has transformed the building industry over the previous decade, from one in which materials were kept hidden to one in which openness is the new normal (LBC 4.0, 2019).

3.4.2 Materials Imperative 12 – Core – Responsible Materials

The purpose of this Imperative is to provide a foundation for all future activities in terms of transparency, sustainable extraction, help to local industry, and waste diversion. This Imperative does not need to be documented when a project is striving for all Materials Imperatives because all needs are superseded by Imperatives 13-16 (LBC 4.0, 2019).

3.4.3 Materials Imperative 13 – Red List

The purpose of this Imperative is to foster a transparent materials economy free of poisons and hazardous chemicals. In 90 percent of their new materials, all projects must avoid the following Red List chemical classes. "In situ" materials do not need to be removed or tested for Red List chemical categories (LBC 4.0, 2019).

3.4.4 Materials Imperative 14 – Responsible Sourcing

This Imperative's purpose is to encourage sustainable material extraction and product labeling.

- The establishment and approval of third-party validated criteria for sustainable resource extraction and fair labor practices for the extraction of rock, metal, minerals, and timber by all projects.
- All dimension stone quarries and/or producers utilized in the project must be certified under the Natural Stone Council (NSC) 373 Standard.

All projects must incorporate two Declare branded items for every 200 sq m of gross building space or project area, whichever is smaller, for a total of forty products, and all manufacturers who are not Declare members must register their products in the Declare database. Every 1,000 square meters of project space must incorporate one Living Product Challenge-certified product (LBC 4.0, 2019).

3.4.5 Materials Imperative 15 – Living Economy Sourcing

The purpose of this Imperative is to assist local communities and companies while decreasing transportation impacts. The project must integrate site-specific solutions while also contributing to the development of a regional economy based on sustainable practices, commodities, and services.

‘Manufacturer location for materials must adhere to the following restrictions:

• 20% or more of the materials construction budget must come from within 500 kilometers of construction site.

• 30% of the total materials construction budget must come from within 1000 kilometers of the construction site or closer.

• An additional 25% of the materials construction budget must come from within 5000 kilometers of the construction site.

• The remaining 25% of materials may be sourced from any location.’ (LBC 4.0, 2019).

3.4.6 Materials Imperative 16- Net Positive Waste

The purpose of this Imperative is to include waste reduction into all phases of projects and to encourage innovative usage of salvaged "waste" materials. Every 500 square meters of gross building area must use at least one salvaged material or be an adaptive reuse of an existing structure.

‘All projects must develop a Materials Conservation Management Plan that shows how the project optimizes materials in each of the phases listed below:

• Design Phase, which includes deconstruction and adequate durability in product parameters.

• The construction phase, which includes product optimization and waste material collecting for reuse or recycling.

• The operation phase, which includes a plan for collecting additional consumables and durables.

• End-of-Life Phase, which includes a strategy for flexible reuse and deconstruction.’ (LBC 4.0, 2019).

3.5 Material Petal Recommendations

3.5.1 Materials Imperative 12 – Core – Responsible Materials

1. Source from vendors in the local industry as much as possible.
2. Reuse materials extracted from site

Tufa stone is the material available abundantly in the community and is the recommended material for the external walls of the building. This way the community can abide by the imperative while respecting and preserving the vernacular materials and way of construction.

3.5.2 Materials Imperative 13 – Red List

1. Use materials on site and ecologically friendly materials.
2. Try and use only concrete, glass, and steel, apart from other ecologically friendly materials and use them as less as possible

While we are using tufa stone as a major building material, we will still need glass, steel and concrete for windows, skylights, reinforcements, and frames. Since Tufa stone is already available in community, using steel, concrete and glass sold and installed by community contractors, will not only abide by the imperative but also empower local contractors and ensure the growth of community economy.

3.5.3 Materials Imperative 14 – Responsible Sourcing

1. Select manufacturers and vendors from the Declare brand list
2. Select LPC certified products

It is also recommended that the contractors in the community get registered as a ‘declared brand’ by LPC. This way the business can stay in the community.

3.5.4 Materials Imperative 15 – Living Economy Sourcing

1. Use as less transportation as possible to get materials on site. In other words, use materials closest to the site

2. Use the distance mapping picture to determine the vendors in sync with this imperative, adding to the afore mentioned imperatives.

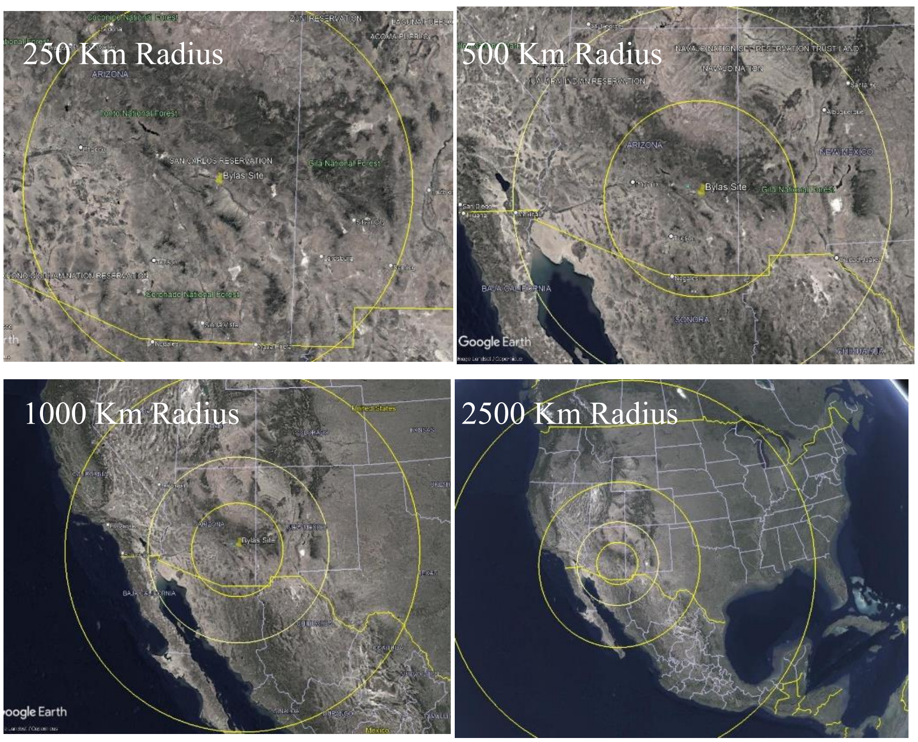


Figure 25: Radius mapping for materials imperative 15

3.5.5 Materials Imperative 16- Net Positive Waste

1. Since there are no salvaged materials from previous construction, use salvaged materials from excavation of site in the construction of new building.

2. Include optimization and reusing and responsible usage of materials as a part of building making process in all stages.

3.6 Energy Petal

3.6.1 Intent

The Energy Petal's purpose is to create new renewable energy sources that will allow projects to function year-round in a robust, pollution-free manner. Furthermore, the Energy Petal stresses energy efficiency as a technique for decreasing wasteful energy, resource, and capital expenditures. The Energy Petal envisions a new paradigm for humans' relationship with energy, in which the places we live, work, and play act as catalysts for a healthy and resilient future (LBC 4.0, 2019).

3.6.2 Energy Imperative 7 – Crore – Energy + Carbon Reduction – Scale Jumping Permitted

Building projects, whether new or existing, must demonstrate a 20% reduction in raw material embodied carbon when compared to an equivalent baseline. Existing structures may use in-situ materials to meet the 20% requirement.

For product categories where embodied carbon data is readily available, all projects (excluding Landscape + Infrastructure) must employ interior materials with a lower carbon footprint than the industry average (LBC 4.0, 2019).

3.6.3 Energy Imperative 8 – Net Positive Carbon – Scale Jumping Permitted

All developments must be "zero ready," which involves strategies like designating areas and pre-installing wiring and connections for both electric car charging and future renewable energy system installation.

This Imperative's purpose is to encourage the development and use of carbon-free renewable energy resources while reducing the negative repercussions of fossil fuel use, notably emissions that contribute to global climate change.

On a net annual basis, all projects must supply 100% of their project's energy consumption using on-site renewable energy that does not utilize combustion.

By utilizing carbon-sequestering materials and/or obtaining a one-time carbon offset from an ILFI-approved carbon offset provider, all projects must account for the total embodied carbon emissions (tCO2e) from construction (including energy expended during construction) (LBC 4.0, 2019).

All projects must design and contain a resilience strategy that permits the building to be livable for one week or to engage in disaster assistance for the local community through the use of batteries, storage, and other similar means (LBC 4.0, 2019).

3.7 Energy Petal Recommendations

3.7.1 Energy Imperative 7 – Crore – Energy + Carbon Reduction – Scale Jumping Permitted

1.Calculate the decrease in 20% carbon compared to baseline

This building is designed to be a self-sustainable building on many levels if not a net zero one. Following is the information acquired from the energy model of the building.

Assumptions made for this model are as follows.

a. Materials used will be tufa stone and wood for walls, concrete wherever necessary for support. Clay tiles for roof with reinforced concrete base.

b. Evaporative cooling and electric heating are used.

c. Working hours of the school are 8am to 5pm during spring and fall semesters and 9am to noon during summer.

d. Full attendance is accounted for during peak seasons and 50% while summer.

e. Evaporative cooling is not only used to cool the rooms, but also semi covered courtyard and bridge.

f. Roof insulation is brought up to R-30 and exterior wall insulation is R-19. Therma cork is considered as the best option for insulation since it has R-4 resistance per inch and is not toxic.

3.7.1 (a) Calculating Baseline

‘Colleges and universities in the U. S. spend an average of $1.10 per square foot (ft2) on electricity and 18¢/ft2 on natural gas annually.’(M. Jafary, et.al, 2016)

APS charges 0.13 cents per kwh. If universities spend $1.10 per sft per annum, they use 1.10/0.13 = 8.46 kwh per sft per annum.

This implies, our baseline is 8.46*23160 = 1,95,933.6kwh per annum.

Our target is to reduce use 20% less than that baseline; meaning, our energy target is 1,56,746.28kwh per annum.

3.7.1 (b) Lighting and Energy Model Calculation

There has been a modification to the energy model, where only conditioned built area is accounted for roof insulation has been increased to R-34.

According to the energy model total energy used per year is 238430 kwh, out of which more than 50% is accounted for area lighting, which is not the actual scenario. The software equest has been crashing multiple times, because of which .sim file were not getting generated. Hence, energy used by lighting is calculated manually below.

According to the California’s Title 24, the Lighting Power Allowance (LPA), that is the maximum allowed watts per square feet is 0.65 watts as of now and 0.6 watts starting 2023 for all non – residential buildings. California Title 24 is being considered because that is the has most strict regulations ASHRAE 90.1 2007 – 2019, 2019 Building Energy Efficiency Standards, 2018 Washington State Energy Code, NYC Energy Conservation Code, 2020 Vermont Commercial Building Energy Standards. (Alcon Lighting, 2022)

Energy Required for lighting per annum

The total built and conditioned area – 23160 sft

Watt per sft – 0.6

Kwh per sft – (watt* number of hours)/1000 (0.6*1)/1000 = 0.0006

No. of working hours per day during spring and fall semesters – 8

Considering there is 8-hour usage of all lights per day

Total energy consumed per day for lighting is – kwh per sft*total area*total number of hours = 0.0006*23160*8 = 111.168kwh

Total energy consumed in fall and spring semesters = 111.168*275 = 30,571.2kwh

No. of working hours in summer semesters – 5

Considering there is 5-hour usage of all lights per day.

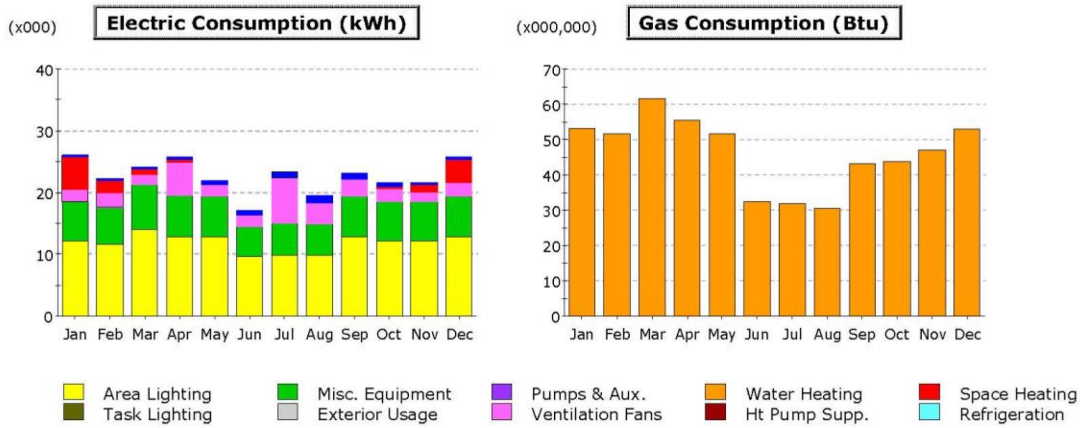
Total energy consumed per day for lighting is – kwh per sft*total area*total number of hours = 0.0006*23160*5 = 69.48kwh

Total energy consumed in summer semesters = 69.48*90 = 6,253.2kwh

Total energy consumed by lighting per annum = 30571.2+6253.2 = 36,824.4kwh

Following is the report generated by Equest

Project/Run: SCAC trail 4 - Baseline Design　　Run Date/Time: 10/23/22 @ 01:48



Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.21	0.31	0.39	0.43	0.53	0.56	1.00	1.08	0.85	0.55	0.32	0.21	6.44
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.83	1.76	0.70	0.24	-	-	-	-	-	0.20	1.37	1.90	8.00
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	0.5	0.67	0.49	0.97	0.37	0.4	0.67	0.7	0.6	0.4	0.39	0.52	6.68
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	6.34	6.02	7.29	6.65	6.65	5.01	5.17	5.17	6.65	6.34	6.33	6.65	74.28
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	12.23	11.62	14.07	12.84	12.85	9.54	9.86	9.86	12.84	12.24	12.23	12.85	143.03
Total	31.96	24.10	26.13	23.63	23.89	19.20	23.34	23.97	26.60	23.64	24.24	29.63	238.43

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	53.37	51.53	61.67	55.33	51.59	32.49	31.89	30.50	43.17	43.75	46.89	52.88	555.08
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	53.37	51.53	61.67	55.33	51.59	32.49	31.89	30.50	43.17	43.75	46.89	52.88	555.08

eQUEST 3.64.7130　　Monthly Energy Consumption by Enduse　　Page 1

Figure 26: Energy Model Report

After replacing the lighting energy in the above simulated report with the lighting calculated, following is the total energy used.

(6.44+ 8+ 6.68+74.28+36.82)*1000 = 132220kwh

So the total KWH used per annum, by the whole campus is 132220kwh which is 15.6% lower than our targeted energy use. This implies that the building is consuming 35.6% energy lower than the base model.

3.7.2 Energy Imperative 8 – Net Positive Carbon – Scale Jumping Permitted

1. Install cabling and connectors for charging electric vehicles.
2. Installation of solar panels/canopies
3. Calculate the energy consumption of the whole building and produce by solar panels
4. The community should decide on purchasing carbon offset from IFLI approved carbon offset provider
5. Calculate the energy produced by solar canopies and install more if necessary.

3.7.2 (a) Generating electricity on site

Per design, 216 monocrystalline solar panels have been installed in the form of solar canopies over the parking lots.

Following is the energy generated by the panels per annum

Power output per panel – 2kwh per day (Catherine Lane, 2021)

Number of solar panels present – 216

Energy generated per day – 216*2 = 432kwh

Energy generated per annum = 432*365 = 1,57,680kwh

Considering 30% energy loss = 110056

Even after considering 30% energy loss, the solar panels are catering for 83% of the energy required by the campus per annum.

Although it is a requirement by LBC to have renewable energy onsite to cater for energy requirements of the campus, it is of utmost importance to calculate the return on investment for the solar panels.

3.7.2 (b) Return on Investment

Upfront cost for installation of solar panels – $2.65 per watt

Cost of one panel that produces 2kwh – 2*2.65*1000 = $5300

Cost of 216 panel installation = 5300*216 = $11,44,800

Energy required by campus = 132220kwh

Assuming APS is the provider , it costs 13.47 cents per kwh

Total utility charge by APS per annum = 132220*0.13 = $17,188.6

Total number of years required to pay back the installation cost in terms of aps utility charges = 17188.6/1144800 = 66.7 years.

Since, the payback period is that long, installation of the panels can be done in phases. But until the energy required is generated 100% on site the Energy Imperative 08 would not be achieved.

3.7.2 (c) Federal Policies for encouraging solar panel installation

While there are a number of policies for installation of solar panels in residential buildings, there are very few policies supporting large scale solar panel installation for nonresidential buildings especially educational buildings. While few of these policies are financially rewarding, there are few for standard regulations such as,

- Solar Design Standards for State Buildings (DSRIE, 2020)

According to this state policy, comprehensive measures should be taken to ensure that all technologies being used are up to standard which will given them a certification of the code compliance they are following.

Following are the financially and technically rewarding federal policies which provides incentives for tribal communities with regards to clean energy. Following are few grants specific to solar energy.

- National Community Solar Partnership – Funding type – Technical assistance
- Tribal solar accelerator fund – funding type – financial assistance for new solar projects.

Ongoing policies for clean energy in Indian communities will be found in the following website.

Energy.gov - Office of Energy Policies and Programs -

https://www.energy.gov/indianenergy/ongoing-funding-opportunities

CONCLUSION

According to the current design and financial situation, while Place and Material petal are attainable certifications, Energy Petal needs more financial backing, or it needs the community to agree to the payback period.

Even if the community does not agree to the solar panels, the design as is saving 35% energy when compared to the average baseline according to the primary design concept. This can further be improved based on design revisions provided by the community. The current shape of the plan caters to reshuffling of the spaces without effecting the total area of the building, unless the community decides on reducing the area of the courtyard, library, and museum.

FUTURE RESEARCH

Following are the points that need to be further researched

1. How can we reduce the energy consumption while constructing the building?
2. The policies available for installation of solar panels or financial programs available to support the construction of educational buildings are very less. Few of them are listed above, but compared to the policies available to residential sector, these are very less. Further study should be done about the policy strategy and recommendations to help increase the number of policies available to encourage the installation of solar panels.
3. How to reduce the solar energy loss happening on hot days? ASU is already researching about this.
4. Is there an energy modelling method/software efficient for modeling the building at a conceptual design stage?
5. The design of the building of westside can be explored in a lot of ways, further down the design development stage. Mediterranean and Spanish architecture needs to be studied, to understand the volume and height play of west side of the buildings. In the same manner, multiple designs of the courtyard need to be explored and implemented in the design, per the design requirements of the community.

REFERENCES

1.Jenn Walker (2013), The Woman Who Wears the Dress, Global Miami Times.
https://www.globemiamitimes.com/the-woman-who-wears-the-dress/

2.Jeff Goss (2016) Cultural Creative: Festival of Native Peoples, The Goss Agency, Inc.
https://thegossagency.com/2016/09/20/cultural-creative-festival-native-peoples/

3.Living Building Challenge, 4.0, 2019

4. Alcon Lighting (2022) 2023 U.S. Commercial Lighting Energy Standards Primer
https://www.alconlighting.com/blog/learning-lab/commercial-lighting-regulations/

5. M. Jafary, M. Wright, L. Shephard, J. Gomez and R. U. Nair, "Understanding Campus Energy Consumption -- People, Buildings and Technology," 2016 IEEE Green Technologies Conference (GreenTech)

6. Catherine Lane, 2021, How much energy does a solar panel produce?, Solar Reviews.
https://www.solarreviews.com/blog/how-much-electricity-does-a-solar-panel-produce

7.DSRIE, 2020, Solar Design Standards for State Buildings.
https://programs.dsireusa.org/system/program/detail/316/solar-design-standards-for-state-buildings