eS-tudio

A Journey Towards Neutrality

TEAM INFO

Victoria Molina
4th Year Architecture
Undergraduate Student

Tafadzwa Bwititi
1st Year Architecture
Graduate Student

INTRODUCTION

While designing a net zero energy and carbon neutral building, many variables came into play. Throughout the design process, we tried to tackle all of these issues through basic design strategies as well as choices of materials, products, etc. to improve the overall quality of the building to reach our goals.

To begin with, it was important to consider the location of the building on the site. After analyzing the program requirements, we thought that the location of the building should not only address design issues, but also find a way to improve the building's general performance. With these thoughts in mind, we decided to place the building on the SE corner, enhancing that part of the block and allowing the building to receive daylight from all four sides.

Second, we decided to have a modular floor plan, basing the span on a regular steel-frame structure. Therefore, our building was designed to have four floors to fit all the program requirements for the project. The rest of the lot is used for ground level parking, drop-off areas, and green spaces.

Moreover, we decided to incorporate an atrium running along the middle of the building in an East-West direction. The main purposes of this feature were to enhance the importance of the entrance and lobby spaces and provide an additional source of daylight for the interior spaces. By implmenting this feature we could greatly reduce the effect of lighting on the energy consumption of the building.

Furthermore, we designed a double skin façade with PV cells incorporated into the exterior glazing and evacuated tubes to heat water. By doing this we intended to reduce the heating and cooling loads, offer a stronger barrier against thermal exchange, and provide an extensive source of energy production (through the evacuated tubes and PVs).

We implemented a ground source heat pump system to cool and heat the building. As a result of these measures, the energy consumption was significantly reduced, allowing us to get closer to our final goal of net zero energy and carbon neutrality.

Finally, we incorporated a green roof structure and PV panels. The green roof allowed us to reduce the cooling and heating loads through the envelope (in this case, the roof). The PV panels represented one of the most important elements in our design, allowing the building to produce its own energy.

To test these design moves, we estimated the performance of the building and did some analysis to verify the carbon neutrality and net zero energy goals. We went back and forth between doing estimates and adjusting design moves in order to come up with more precise and reliable results. Even though we do not have definitive answers, the demonstration below shows a very close result for this schematic design effort.

INTENTS and CRITERIA

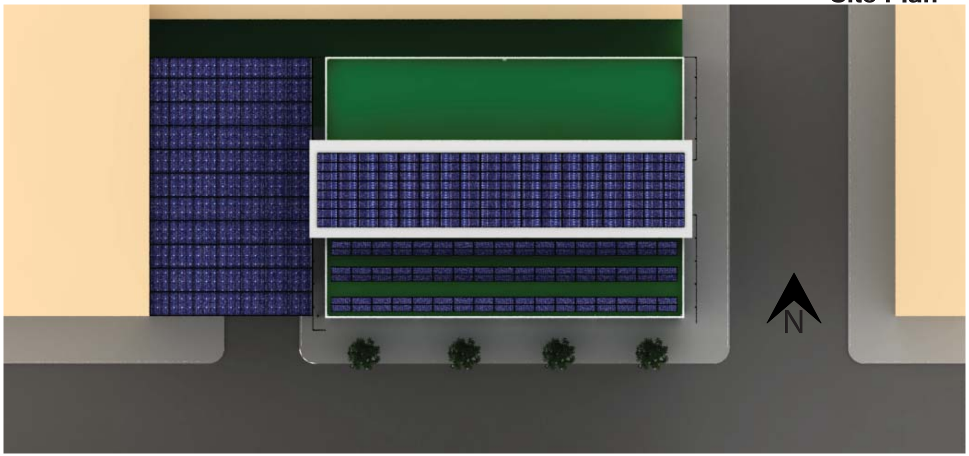
After in class class discussion, this is the final list of optional and mandatory intents and their corresponding criteria:
* = MANDATORY

INTENTS	CRITERIA
Meet the program*	Follow the program list of requirements
Adhere to conventional codes*	Fulfill restrictions from Indiana Building codes, etc.
Provide a healthy and comfortable environment*	Follow ASHRAE 62.1 rules
Operate at net zero energy*	Minimize operational level on site source, organizational, construction, materials, etc.
Archieve carbon neutrality*	Minimize operational level
Be a Green building*	Become a “LEED GOLD BUILDING”
Have a Low operation cost	At least 50% less than other buildings with the same size and function
Recieve peer recognition	Win the AIA regional and/or national award
Make building as a teaching tool	“Explicit technology”, guided tours, etc.
Mitigate embodied energy from construction and materials	20% reduction [in each case]
Develop contextual identity	Relate to surrounding buildings in size/scale
Improve productivity	20% more than other buildings with the same size and function

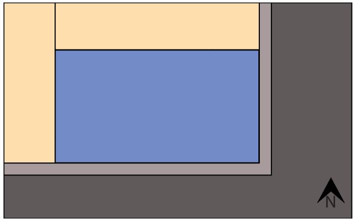
Design Development

The initial design steps were important and needed to be thought out throughly. These steps played a pivotal role in later design development stages because they dictated many opportunities and constraints that will came out as the design process continued.

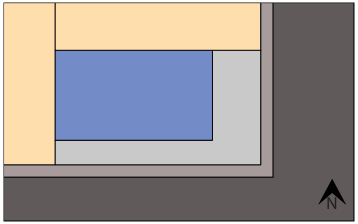
Site Plan



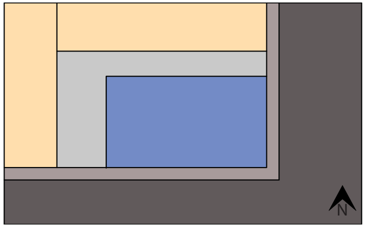
Building Footprint Development



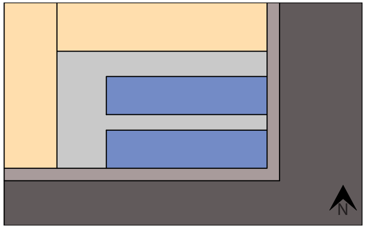
1. Building footprint covers whole site. Thermal gain/loss on western and northern facade not an issue. Light coming in from southern and eastern facades



2. Building footprint covers most of site. Building becomes more vertical. Thermal gain/loss on western and northern facade not an issue. Light coming in from southern and eastern facades

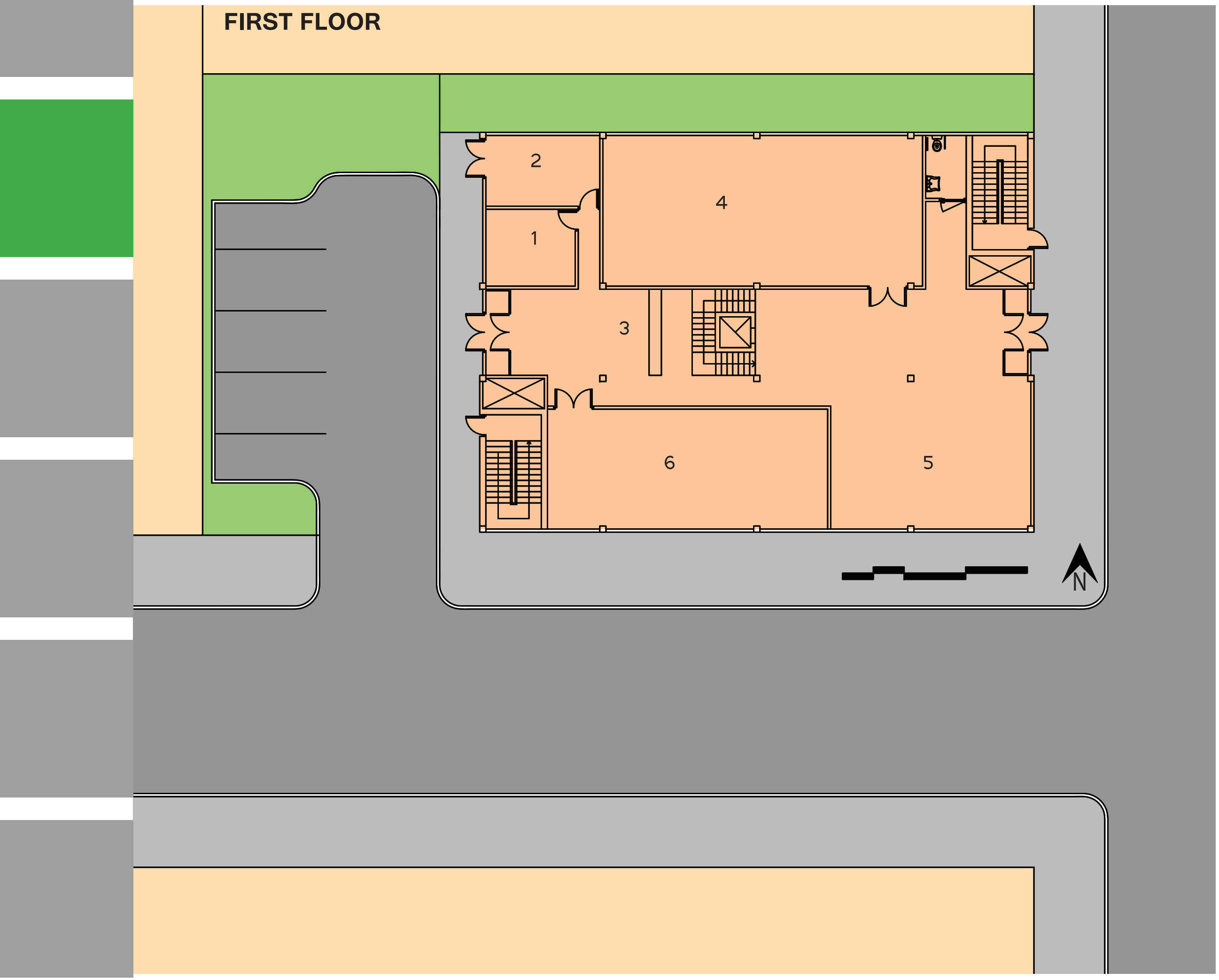


3. Building footprint covers most of site but offset from surrounding buildings. Thermal gain/loss is from all facades. Light coming in from all facades



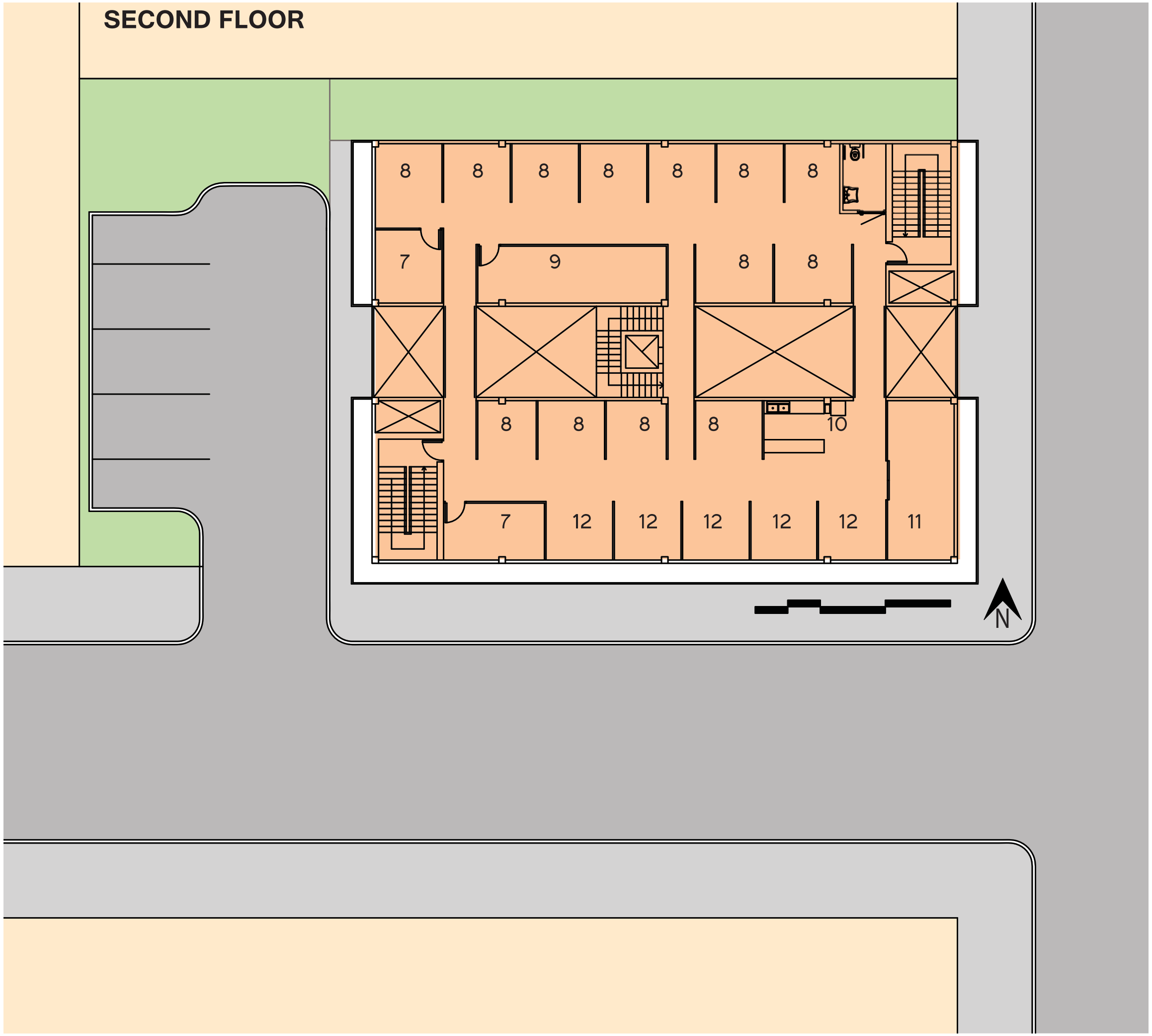
4. Building footprint covers most of site but offset from surrounding buildings. The building is split into two sections around a central atrium space. This allows for more daylight to enter into the building (from the center and all facades.) Thermal gain/loss is from all facades.

FLOOR PLANS

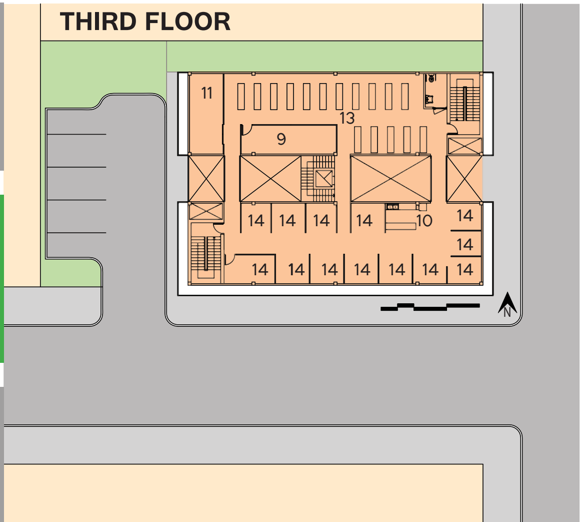


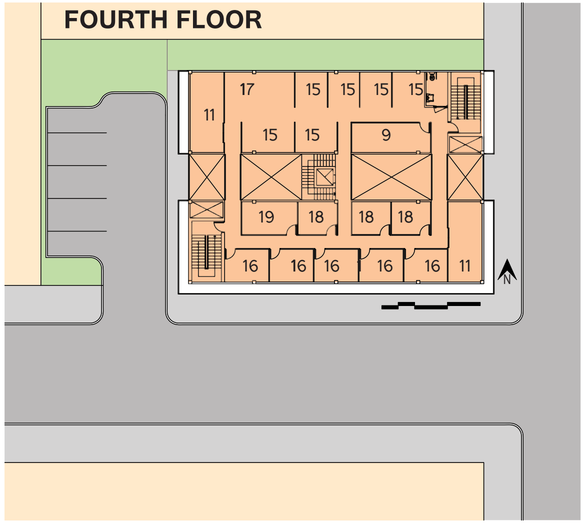
The building has an open plan design and the client can arrange the spaces to suit thier needs. The following floor plans show an example of how the floors could be laid out.

1. Recycling Area
2. Shipping And Receiving
3. Reception
4. Large Conference Room
5. Gallery
6. Education Classroom



7. Manager's office
8. Architect's cubicles
9. Filing and Cabinet Area
10. Kitchenette
11. Conference Room
12. Interior Design cubicles





13. Samples and Resources Library
14. Enginneering Cubicles
15. Staff Support
16. Principal Offices
17. Central Copier, Printer and Plotter Area
18. Centrual Filing Area
19. Accounting Office

Interior Perspective currently been made

TOWARDS NET ZERO ENERGY

Using Indianapolis' data as reference for our design, we established that a regular office building in the area consumes ***100,000 Btu/sf/yr.*** With that base point, we implemented a series of moves in order to reduce that number to zero.

1. ASHRAE CHECKLIST (AEDG)

According to the principles of this checklist, a building that follows all the precepts would reduce their energy consumption by 30%.

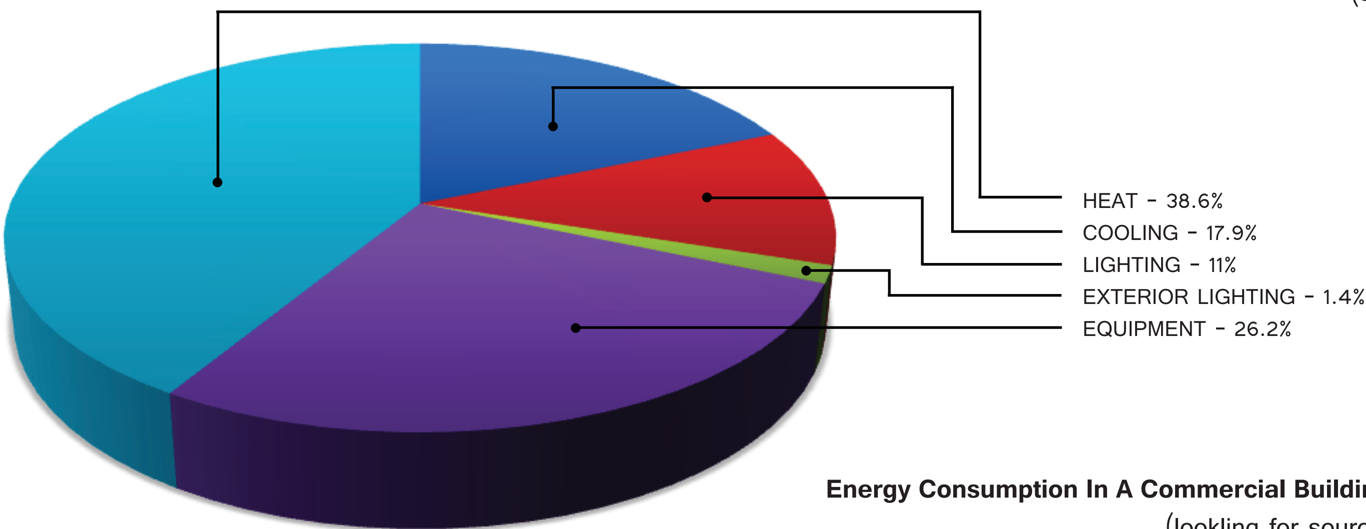
Taking into account that our building AT LEAST follows this guideline in order to reach the net zero energy goal, the amount of energy needed is immediately reduced to ***70,000 Btu/sf/yr.***

Climate Zone 5 Recommendation Table

	Item	Component	Recommendation	How-To's in Chapter 4
Envelope	Roof	Insulation entirely above deck	R-20 c.i.	EN2, 17, 20-21
		Metal building	R-13 + R-19	EN3, 17, 20-21
		Attic and other	R-38	EN4, 17-18, 20-21
		Single rafter	R-38 + R-5 c.i.	EN5, 17, 20-21
		Surface reflectance/emittance	No recommendation	
	Walls	Mass (HC > 7 Btu/ft^2)	R-11.4 c.i.	EN6, 17, 20-21
		Metal building	R-13 + R-13	EN7, 17, 20-21
		Steel framed	R-13 + R-7.5 c.i.	EN8, 17, 20-21
		Wood framed and other	R-13 + R-3.8 c.i.	EN9, 17, 20-21
		Below-grade walls	R-7.5 c.i.	EN10, 17, 20-21
	Floors	Mass	R-10.4 c.i.	EN11, 17, 20-21
		Steel framed	R-30	EN12, 17, 20-21
		Wood framed and other	R-30	EN12, 17, 20-21
	Slabs	Unheated	No recommendation	EN17, 19-21
		Heated	R-10 for 36 in.	EN14, 17, 19-21
	Doors	Swinging	U-0.70	EN15, 20-21
		Non-swinging	U-0.50	EN16, 20-21
	Vertical Glazing	Window to wall ratio (WWR)	20% to 40% maximum	EN23, 36-37
		Thermal transmittance	U-0.42	EN25, 31
		Solar heat gain coefficient (SHGC)	N, S, E, W - 0.46 N only - 0.46	EN27-28
		Window orientation	$(A_N * SHGC_N + A_S * SHGC_S) > (A_E * SHGC_E + A_W * SHGC_W)$	A_x–Window area for orientation x EN26-32
		Exterior sun control (S, E, W only)	Projection factor 0.5	EN24, 28, 30, 36, 40, 42 DL5-6

Note: If the table contains "No recommendation" for a component, the user must meet the more stringent of either Standard 90.1 or the local code requirements in order to reach the 30% savings target.

Building Footprint Development
(source from walter)



Energy Consumption In A Commercial Building
(loolking for source)

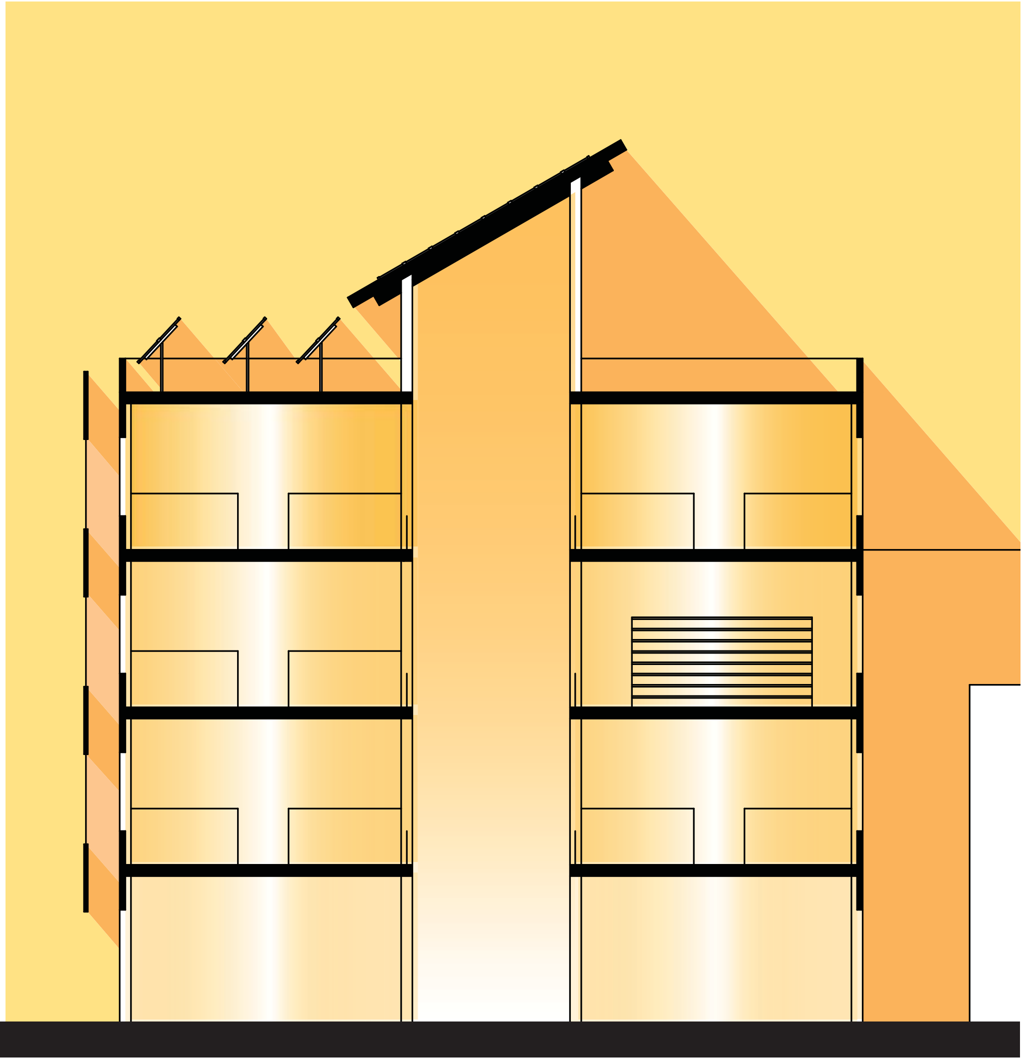
2. DAYLIGHTING

Lighting represents 18% of the energy use of a typical office building. By implementing several different design moves (locating working areas next to windows, creating an atrium in the middle of the building, strategic location of unused spaces in dark areas), we will reduce the energy needed for daylighting by AT LEAST 80%. So:

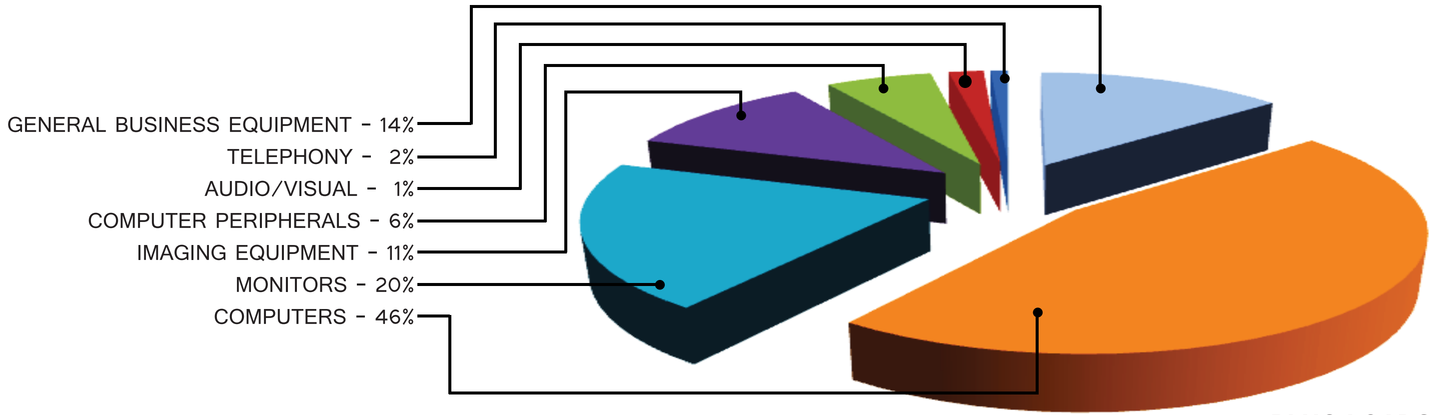
18% of 70,000 Btu/sf/yr
= 12,600 Btu/sf/yr

80% of 12,600 Btu/sf/yr
= 10,080 Btu/sf/yr

70,000 Btu/sf/yr
– 10,080 Btu/sf/yr
= 59,920 Btu/sf/yr



Daylight Diagram



PLUG LOADS

3. PLUGLOADS

Plug loads are one of the biggest portions of the pie chart: 26% of energy use goes to these electrical loads. It is also one of the hardest consumptions to control, since not many design moves can address this problem. However, we came up with a set of rules (applicable to the employers and employees of the firm) in order to tackle this issue:

a) Only 3 plugs per cubicle: According to our calculations, this number of plugs is sufficient for a worker to complete regular tasks.

b) Only 4 plugs per office: considering that these offices would need, for example, a fax machine.

c) A plug load monitoring system connected to the network server: this system would determine regular use vs. excessive use and immediately send out warning messages to those who exceed the norm. This system would also keep a record of usage in order to reward or punish employees according to their energy usage.

d) Night-time sensors: areas where a plug load is not critical (offices, cubicles, meeting rooms) would shut down after 30 minutes of inactivity.

e) Occupancy and light sensors: to establish the need for task lighting (light levels needed when a person is working).

f) We estimate that by implementing these measures, the energy consumption can be reduced by 25%.

26% of 70,000 **Btu/sf/yr**
= 18,200 **Btu/sf/yr**

25% of 18,200 **Btu/sf/yr**
= 4,550 **Btu/sf/yr**

59,920 **Btu/sf/yr**
- 4,550 **Btu/sf/yr**
= 55,370 **Btu/sf/yr.**

4. HEATING

Heating is the biggest portion of the energy consumption. In a typical Middle West office, it is 40% of the total (28,000 Btu/sf/yr). To address this problem, we incorporated a series of technologies available in the market, as well as design moves, to reduce the heating load as much as possible.

a) Double skin façade: The incorporation of a double skin in the project was a key energy saver for the building. If we analyze its effects on the heating loads, having a third layer of glass (with PVs) between the interior and the exterior is the same as having a triple glazing window. To make an assumption of the implied reduction, we compared u-values of double glazing vs. triple glazing to find out the percentage of improvement.

U-value of double glazing window : 2.2
U-value of triple glazing window: 1.4
That is a decrease of 63%.

Assuming that window conduction represents 30% of the heating load, we reduced that number by 63%.

***40% of 70,000* Btu/sf/yr**
***= 28,000* Btu/sf/yr**

***30% of 28,000* Btu/sf/yr**
***= 8,400* Btu/sf/yr**

***63% of 8,400* Btu/sf/yr**
***= 5,292* Btu/sf/yr**

***55,370* Btu/sf/yr**
***– 5,292* Btu/sf/yr**
***= 50,078* Btu/sf/yr.**

b) Evacuated tube solar collectors: we incorporated evacuated tubes on the Southern façade in order to heat water for plumbing uses. Along our façade we located several modules which contain in total 405 tubes that would produce a total of 5491 Btu/sf/yr and 19.7% of the energy needed. The information for our calculations was taken from the solar hot water system webstie

405 tubes
= 32m²

32m2 of tubes
= 87.7 kW /day

[87.7 kW /day]
/ 1,850m2 (building area)
= 0.04 kW/m2/day

[0.04 kW/m2/day]
x 317.1
= 15 Btu/sf/day.

15 Btu/sf/day
= 5,491 Btu/sf/yr.

50,078 Btu/sf/yr
– 5,491 Btu/sf/yr
= 44,587 Btu/sf/yr.

Evacuated tubes solar collectors

5. COOLING

If we analyze cooling, it represents 11% of the building's energy consumption (7,700 Btu/sf/yr). However, through the different strategies explained above, this load is greatly reduced. As seen in the chart below, the cooling load is divided into sub-loads. If each of these is reduced, the total will be as well.

i. Equipment and plug loads (22%): as mentioned above, we intend to reduce the plug load up to 25%. So,

22% of 7,700 Btu/sf/yr
= 1,694 Btu/sf/yr

25% of 1,694 Btu/sf/yr
= 423.5 Btu/sf/yr

44,587 Btu/sf/yr
– 423.5 Btu/sf/yr
= 44,163.5 Btu/sf/yr

ii. Lighting(19%): if we take into account that the lighting load is going to be reduced by at least 80%, we can say that:

19% of 7,700 Btu/sf/yr
= 1,463 Btu/sf/yr

80% of 1,463 Btu/sf/yr
= 1,170.5 Btu/sf/yr

44,163.5 Btu/sf/yr
– 1,170.5 Btu/sf/yr
= 42,993 Btu/sf/yr

iii. Roof: By using a green roof, the reduction of incoming load is 30%

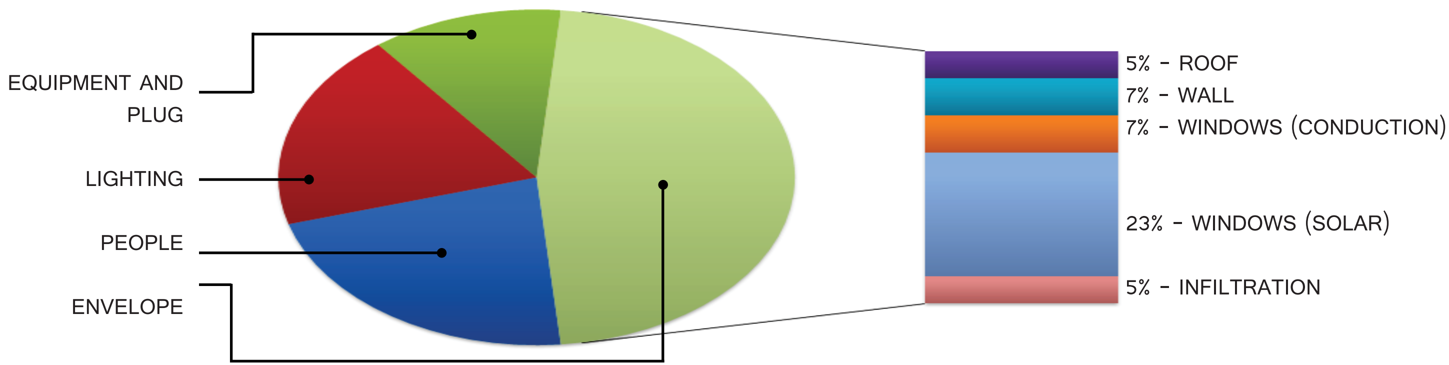
5% of 7,700 Btu/sf/yr
= 385 Btu/sf/yr

30% of 385 Btu/sf/yr
= 115.5 Btu/sf/yr

42,993 Btu/sf/yr
– 115.5 Btu/sf/yr
= 42,877.5 Btu/sf/yr

iv. Walls: besides the 30% initial reduction following the ASHRAE AEGD, no more moves were taken to reduce this value.

42,887.5 Btu/sf/yr
– 0 Btu/sf/yr
= 42,877.5 Btu/sf/yr



COOLING LOAD COMPONENTS FOR A TYPICAL 10,000 SF OFFICE BUILDING

v. Windows (conduction): with the double skin façade, we estimate to reduce the conduction gain by 63%.

7% of 7,700 Btu/sf/yr
= 539 Btu/sf/yr

63% of 539 Btu/sf/yr
= 339.5 Btu/sf/yr

42,887.5 Btu/sf/yr
– 339.5 Btu/sf/yr
= 42,548 Btu/sf/yr.

vi. Windows (solar): our building has a double skin covered with PV panels incorporated in the glass. Therefore, the shading of the glass will increase as much as the surface covered by those PVs (50%). So:

23% of 7,700 Btu/sf/yr
= 1,771 Btu/sf/yr

50% of 1,771 Btu/sf/yr
= 885.5 Btu/sf/yr

42,548 Btu/sf/yr
– 885.5 Btu/sf/yr
= 41,662.5 Btu/sf/yr

vii. Infiltration: other than the 30% initial reduction following the ASHRAE AEGD, no other moves were taken to reduce this load.

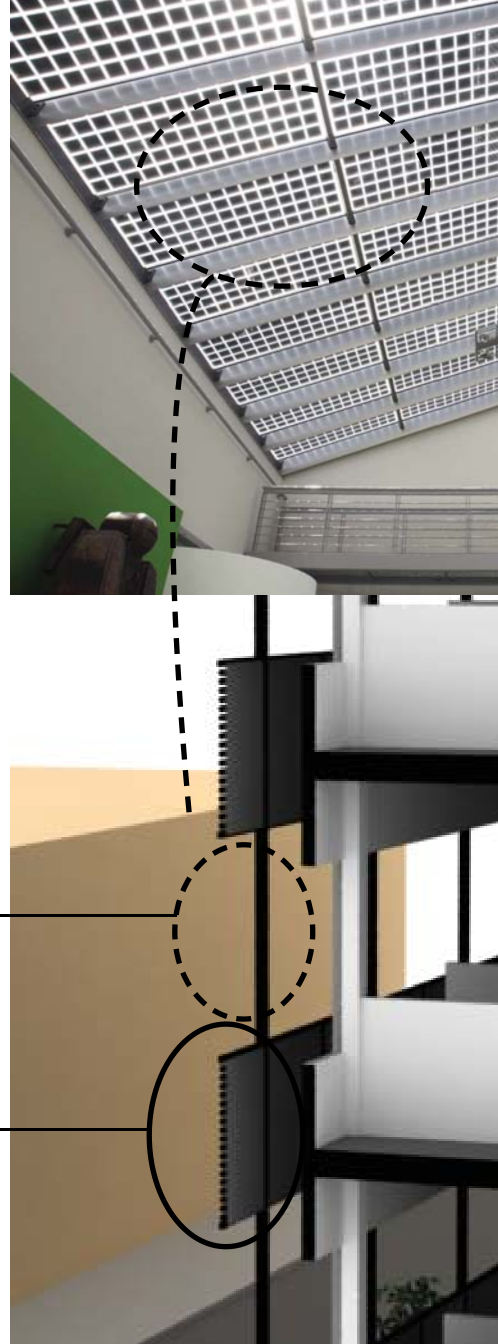
5% of 7,700 Btu/sf/yr
= 385 Btu/sf/yr

41,662.5 Btu/sf/yr
– 0 Btu/sf/yr
= 41,662.5 Btu/sf/yr

viii. People: from a design perspective, there is no way we can reduce this load.

12% of 7,700 Btu/sf/yr
= 924 Btu/sf/yr

41,662.5 Btu/sf/yr
– 0 Btu/sf/yr
= 41,662.5 Btu/sf/yr



Pv Cells at as a means of shading

evacuated tube panel act as a shading device.

we got confused on the calculations for this part please can you explan again then we can finish the calculations

GROUND SOURCE HEAT PUMP

To tackle both numbers (heating and cooling) we proposed a ground source heat pump system, considering that the Midwest is one of the most ideal places for implementing this system.

According to the The Architect's Studio Companion, a regular office building of this size needs 40 tons of cooling/heating. However, in this building that number is clearly reduced. First of all, when implementing the ASHRAE checklist for the building, we increase the efficiency of the building by 30%. That is to say that those 40 tons get reduced to 28 tons. Second, as shown above, the loads for heating and cooling have been reduced between 30% and 40%. Therefore, only 19.6 tons need to be produced by the heating/cooling system chosen.

Comparing the energy efficiency of a regular system to a ground source heat pump system, we can see how the energy consumption is greatly reduced.

COP of regular heating/cooling system: 1 (100%)

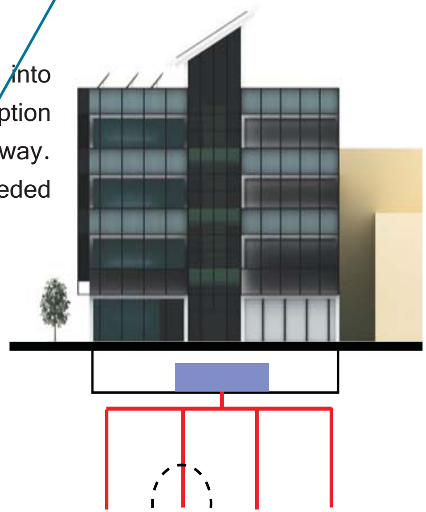
COP of Ground Source Heat Pump system: 3.5 (350%) (average between highest and lowest system)

Therefore, we could assume that if we consume 19,353 Btu/sf/yr to heat the building at a COP of 1, we would reduce that number by a factor of 3.5. Thus,

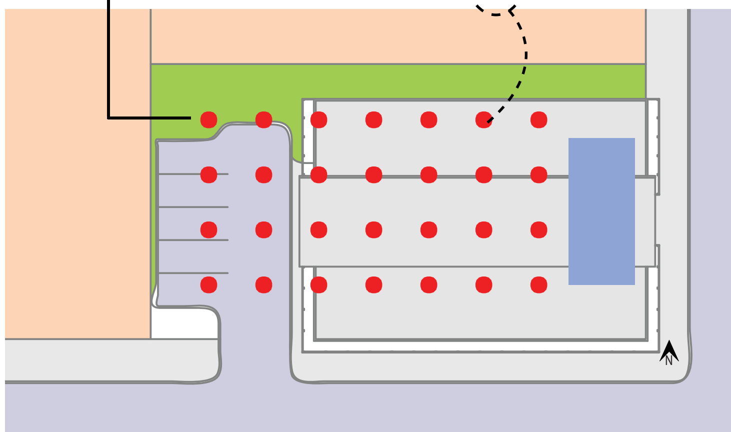
[19,353 Btu/sf/yr]/3.5 (COP)
= 5,529 Btu/sf/yr

This COP also translates into the cooling energy consumption in a proportional way. Consequently, the Btus needed for cooling reduce to:

[4,641.6 Btu/sf/yr] / 3.5
= 1,326 Btu/sf/yr



Red dots are ground source wells spaced 15ft apart.



FINAL COUNT AND PVs

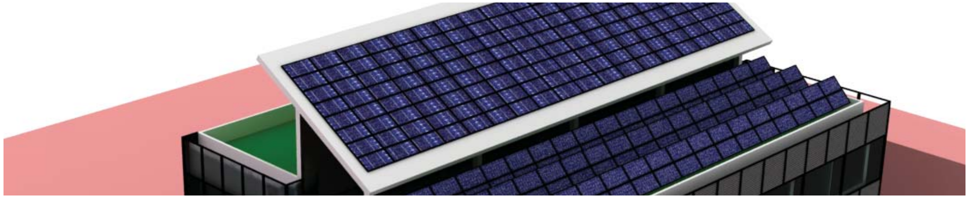
After reducing these numbers individually, the final amount of Btus/sf/yr to be tackled is:

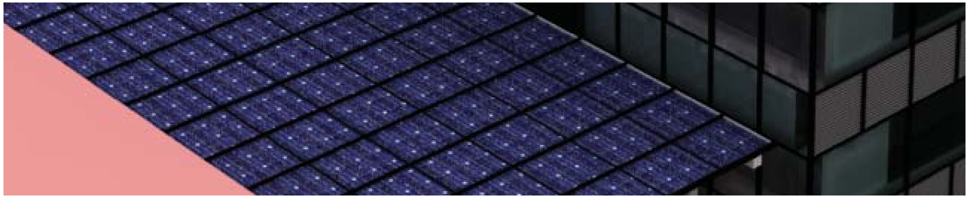
***2,506** Btu/sf/yr [daylight] + **13,755** Btu/sf/yr [plug loads] + **5,529** Btu/sf/yr [heating] + **1,326** [cooling]*
***= 23,116** Btu/sf/yr*

According to our PV calculation, the amount of energy produced on site by the current PVs is 381,269,612 Btu/yr, that is to say 19,179 Btu/sf/yr. So,

***23,116** Btu/sf/y r- **19,179** Btu/sf/yr*
***= 3,937** Btu/sf/yr*

With all the measures explained above, we could reduce the original energy consumption from 100% to only 3,94%.





Surface	PV (kWh)#	Btu#	Area	TOTAL Btu production
Southern on Double Skin	3,079	10,505,548	1,500	**2,352**
East on Double Skin	3,079	10,505,548	1,321	**2,071**
Atrium	4,551	15,528,012	2,068	**4,793**
Above Parking	4,312	14,712,544	2,550	**5,600**
Slanted	4,895	16,701,740	1,750	**4,363**
			TOTAL Btu prod	**19,179**

Conclusion

Considering that our numbers were based on a preliminary design and some modest assumptions, we believe that the final building could largely achieve the net zero energy goal. In the same way, understanding that having such a low energy consumption generated by renewable sources of energy only, the building is also in the run for carbon neutrality. Confidently, we believe that in a more advanced stage of development, the building will achieve net zero energy and carbon neutrality in its performance.

Sources

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