Team Connect the Zot's

Autonomous Sustainable Building

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Overview

Located in the UC Irvine Campus next to the prestigious Engineering department, the design of the wood-frame autonomous administration building is a quality representation of innovation, design integration and environmental sustainability. The building is composed of a concrete first floor lobby that is 14 feet with high ceilings for aesthetics and room for harnessing any design systems. The other floors are composed of a glue laminated wood-frame structure, raising 12 feet each story. Each floor will contain a total area of 2880 square feet, providing administrative utility parcels, such as office spaces and conference rooms. The important features of the new autonomous building is its self-healing concrete, fire resistivity, and a passive heating/ cooling system. The self-healing concrete minimizes the formation of cracks, preventing the need for maintenance in the future. Glue-laminated recycled wood is used for fire resistivity and its stronger nominal capacity. The passive cooling/ heating system will be using 28 solar power integrated windows called SolarWindows™ for better energy storage and leverage natural elements. The cost and budgeting was also calculated to be less costly and more environmental friendly to construct than a steel frame structure. Indeed, there is a urgent need for new clean, renewable energy sources.

Current energy sources are outdated while many have negative impacts on the environment. The goal of this project is to implement a molten salt tower to provide eco-friendly power. Molten salt towers have already been successfully implemented in several locations including Nevada, China, Spain, and Germany. This system uses the sun's energy, molten salt technology, and thermal storage to generate clean renewable energy. In addition to building the molten salt tower, passive stack ventilation will be used to ventilate the building using little power. Evaporative coolers will be used in conjunction with the passive stack ventilation in order to cool the building when outside air is not enough to cool the building. The main challenge of this project is finding land large enough to build the tower on. To overcome this challenge, the tower will be scaled down to fit in the lot behind Vista Del Campo, while maintaining maximum efficiency and the ability to produce >4000W. At the same time, incorporating the different electrical systems requires a highly sophisticated device control.

The device control system incorporates Fault Detection and Diagnostic (FDD) systems with an array of sensors that are connected to a Programmable Logic Computer (PLC). This will

autonomously collect measurements and follow smart pathways to respond to certain situations. The computer considers the location of the sensors, severity of the situation, and follows smart pathways to ensure the most effective solution to the situation. A server connected to the PLC communicates with employees through an app. By incorporating location in the output of the sensors, the building will run more sustainably and efficiently. The use of an app will streamline every day office tasks and communicate with employees in case of an emergency. Also, delivering day-to-day mail can be incorporated by the smart autonomous Destixign interior delivery system. Destixign has a system that will not only save a client's time and money in the long-run, but will provide safe, efficient, and reliable delivery within the building. In this design report, the team introduces the mechanical, innovative and economic advantages with their system. Destixign still engineered their project in a way that meets all the requirements and has a low budget which will attract more customers. As delineated before, the team's design uses the universal law of magnetism to transport a package. This allows for a system which will be economic, durable and best, innovative.

Goal

The entire goal of the of the whole project is to build and develop a smart, autonomous, and self-sufficient building that will incorporate all four universal engineering concerns.

By providing a sustainable clean energy source to power the Zero-Waste Building, that will result in zero carbon emission and waste and a ventilation network that can freely change the inside temperature. Implement and construct the passive and civil-related aspects of the autonomous building that leverages solar energy and uses recycled material.

Also, considering the plethora of electrical components in the building, a powerful device control system must be implemented. The device control system focuses on the the (1) safety in the building utilizing Fault Detection Diagnostics (FDD), (2) efficient energy consumption via smart allocation of utilities, and (3) use of a mobile application for users to interact with the smart components in the building and notifications.

A interior delivery system user interface is a key aspect that harnesses the sheer “autonomous” aspect of the building. The primary goal of the delivery system is to provide a safe, efficient, and reliable delivery system within the smart building by designing a system that saves clients’ time and money. By implementing package security procedures, it is ensured to deliver the package uninterrupted and undamaged.

Objectives

Establish and build an autonomous building that will be equipped with the latest technologies and the most revolutionary ideas from the ground up.

Eco-Friendly Power System

- Create a sustainable clean energy source that provides >4000W of power
    - Use of sun tracking mirrors heats molten salt adding large amounts of heat which can be turned into energy.
- Maximize power and cost efficiency
    - Molten salt has a high heat capacity, giving it a high energy density.
- Provide ventilation to the building
    - Use of passive stack ventilation allows a low energy solution towards ventilating the entire building.
- Limit carbon footprint and waste
    - Molten Salt and water are recycled in the system, reuse can continue for upwards of 30+ years until the salt needs replacement.

Zero Waste

- The structural components of the design will be seismically conservative.
    - Lead rubber bearings underneath building allow for building to withstand substantial lateral loads
- Live Loads are to be taken as 100 psf to accommodate for the large conference rooms and flexibility of room arrangements.
- Incorporated Solar Integrated Glass Windows to maximize the natural lighting within the building
- Make building structurally stable and capable of handling vertical dead and live loads
    - Glulam beams are stronger than steel and versatile, allowing for a dynamic range of spans

Device Control

- Improve the interaction of people with office components (lights, AC, coffee maker, etc…) to increase comfort and productivity through app.
- Accurately detect problems within the HVAC (Heating, Ventilation, Air Conditioning) and other utilities through the use FDD(Fault Detection Diagnostics).
- Cyber related safety measures.

Delivery System

1. Deliver a maximum 10” x 10” x 10” & 9 kg package
    - With the use of the universal law of magnetism, the package will be able to travel through 4 floors at a rate of 2 m/s
2. Minimize power consumption
    - Based on our calculations, we will consume 1.5 kW which is less than our 2000 W maximum
3. Justify superiority with an engineering approach
    - With the first of its kind, we were able to push boundaries while meeting the established interior delivery agenda
4. Maintain a budget less than $80,000
    - While being innovative, we were able to meet our objective of minimizing our budget by nearly $46,000

Design & Layout Specifications

Eco-Friendly Power Supply

The system works by positioning about 44 mirrors arranged in a circle aimed at a solar tower. On the ground there is a reservoir that holds the cooled down molten salt. The salt is pumped up the tower which heats the salt at the top where the mirrors are pointing. Once the salt is heated to about 500 Celsius, it is sent down the tower into another reservoir that stores the hot molten salt. This tank will keep the molten salt hot enough for about 1.5 hours. This is useful because on cloudy days, energy can still be produced for a certain amount of time. The salt from the hot reservoir is sent through a heat exchanger in a pipe surrounded by water. The heat from the salt will vaporize the water which will be sent into a steam turbine. The cooled molten salt from the heat exchanger will go back to the cool molten salt reservoir. The energy made from the steam turbine goes into a generator and the vapor goes through a condenser. The now liquid water returns to a reservoir to cool the water and brings it back to the heat exchanger. There are two backup flow streams. One is a water reflux stream coming out of the heat exchanger. This ensures that if the water fails to completely evaporate, the water will be returned into the water stream. The second stream is from the water reserve tank, placed next to the main water tank supply, which will provide a backup water supply if water is lost through pressure relief valve or the condenser.

Below are a couple of calculations that were performed in the design. The first calculates the amount of heat transfer rate that must be transferred to the salt to liquify it based on the the desired mass flow rate.

$$Q_{in} = \alpha\sigma T_{surr}^4 A$$

$$Q_{out} = \varepsilon\sigma T_{surf}^4 A$$

$$Q_{rad} = Q_{in} - Q_{out}$$

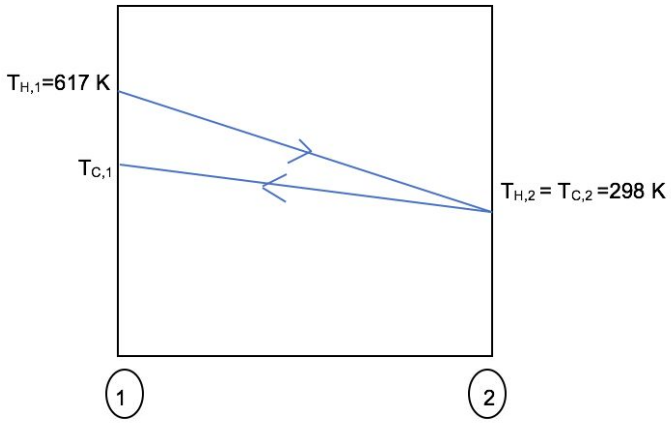
$$Q_{rad} = A\sigma(\varepsilon T_{surf}^4 - \alpha T_{surr}^4)$$

$$Q_{salt} = \int_{298K}^{617K} Cp\, m dT \; + \; mH_{fus}^{\circ}$$

$$Q_{salt} = (1560\tfrac{J}{kg^{\circ}C})(617\ K - 298\ K)m + m(161\tfrac{kJ}{kg} * 100\tfrac{J}{kg})$$

$Q_{salt} = 65840 \ \frac{J}{kg} \ m$

The second calculation models the counter flow heat exchanger and solves for the amount of heat absorption rate of the water on the assumption of a salt mass flow of 2.0 kg/s. It is important to note that these calculations are based off of ideal situations and in reality, there will be heat dissipated into the environment.



$q = \ m_H C_{pH}(T_{H,i} - T_{H,o})$

$q = \ (2.0 \ \frac{kg}{s}) \, (1560 \ \frac{J}{kg*K})(617K - 298K)$

$q = 9.95 * 10^5 W$

The ventilation system uses a passive ventilation system that allows the building to remain ventilated without the use of energy. Each floor has vents near the floor that is distributed around the building that allows air from outside to go inside the building. With the difference in temperature within the air, using the principles of stack ventilation and Bernoulli's principle, the air inside the building moves and regulates the interior temperature without additional energy. This makes the building environmentally sustainable. While passive ventilation is cheap, it is not as efficient in controlling temperature but has retractable ducts that allows for greater control in temperature. However, the passive ventilation system is supplemented when 3 evaporative coolers are installed to further regulate interior temperature and prevents the building to overheat. Evaporative coolers is the preferred method of cooling in the hot and dry climate of southern California, and has little carbon dioxide emissions. As the

use of the evaporative is not the default action to regulate the temperature, the ventilation system still remains environmentally clean.

Zero-Waste

Leveraging Solar Energy

For the building Solar Windows™ will be used as a form of solar energy. Solar Windows™ are more cost effective than common PV Solar Panel Units since there is a cost reduction and a financial payback that can be seen within one year of use. The Solar Windows™ provide low cost manufacturing and are also able to perform under natural, shaded and indoor light meaning they can be applied to any side of a building. The use of a single solar window can “avoid 2.2 million miles of carbon dioxide vehicle pollution; [which is] twelve times more than solar.” as stated on the solar window website. The building will be placed facing slightly east to west in order to accomodate for efficient insulation and windows will be placed on the north and south sides of the buildings since there is more heat gain in those locations. Plants will also be integrated in the design of the building as a way to make insulation more efficient, as well as collect Carbon Dioxide emissions. According to the Environmental Pollution publication by H. Akbari, experiments with tree planting programs documented about 30% in cooling-energy savings(equivalent to about 4 kilowatt-hour per day). Based on such findings the north and south sides of the 1st floor will have vines hanging on the exterior walls while the other floors will have plant vines on the sides of the balconies on the second and fourth floor will integrate plants. Angled windows will also be incorporated in the designs of the balconies to minimize reflection.

Recycled Material

The first floor of the building will incorporate self-healing concrete due to increased permeability that comes with micro cracks in concrete. The concrete’s self-healing ability is given by bacteria present in the concrete, this allows the concrete to regenerate itself in the cracks. The leading rubber bearing isolators are able to enhance the performance of structures at any hazard level. The Glulam beams are able to provide dimensional layered and laminated pieces of durable lumber that are moisture resistant. In addition, glulam itself has a capacity to withstand heat temperatures for longer durations in comparison to steel. This is due to the

unique property of glulam as it burns, for it develops a char that carbonizes the wood and effectively creates a layer that insulates the rest of the beam. It allows for the beam to withstand exposure to fire for upwards of two hours. In terms of cost, glulam beams, which are similar to that of wood, is inherently cheaper than steel. Despite it being higher maintenance than steel, glulam is extremely practical and efficient in its application, as its lightweight and strong integrity allows for it to be cut in to many spans, as opposed to steel, which is tailored to specific dimensions and is not so easily cut.

Device Control

The system utilizes variety of sensors to maintain a safe and productive environment. It includes 54 energy meters, 37 heat sensors, 14 laser sensors, 8 raspberry pi units, 24 light dependent resistors (LDR), 2 handprint readers, 32 security cameras, 57 gas detector sensors, 1 moisture sensor, 4 thermometer, in addition to one PLC. The main goal of the system is to provide both a safe physical environment as well as a cyber secured one. Moreover, the system integrate all of its features by connecting everyone in a smart grid which shows the updates by a mobile application.

Heat and Laser Sensors

For light automation, the heat sensor will play the great part there. Every single door in the building (except for the bathrooms) has a heating sensor. The heating sensor is capable of measuring the temperature as well as the number of people going in and out. It projects a heat map of the people who enter or exit the rooms. This can be done by calculating the time difference between the front and back of the door (when someone goes through the two sides of the door). In order not to invade anyone’s privacy, the heat sensors should be in the top of the door where they can detect everyone down only. This will make the sensor project the heat map of a person as dot from above (so that everyone’s privacy is secured).

For the bathroom, the system have laser sensors and LDR, which are controlled by raspberry pi, which behave almost the same as the heat sensor. Thus, when someone enters the bathroom,

it will show that the bathroom is not available in the mobile application as well as an LED in the bathroom's door (red for full and green for available).

Security Devices

The system has four cameras in each floor (a total of 16 in the building). These ones are simple security cameras, which is a hybrid system since it involves human reaction as well. It is hybrid because there are two handprint readers in the two frontal gates, very safe and reliable security devices.

Gas Leakage

In case of any gas leaks, there are a total of 57 infrared (IR) Gas Detectors. These are very advance detectors. The detector/sensor shoots rays and these rays will refract and reflect in a way depending on the concentration of the gas. For instance, if there is a hole in the pipe, a gas will start leaking and the concentration of the gas will drop. The detector here will distinguish the difference in concentration of the gas which will notify everyone by an alarm of a potential leak. This detector has a great advantage since it does not need to be connected directly to the pipe to detect leaks like vibrational or pressure sensors.

Energy Monitoring

There are a total of 54 energy meters. 50 out of them are smart outlets which report the energy consumption through the grid. The other 4 are meters for the four AC units in the building.

Moisture Control

The moisture sensors integrates the device control team with the zero waste team. It senses when the plants need water. If they need water, the water sprinklers will turn on.

Integration between teams

Refer to the smart pathways in System Connectivity under Device Control team.

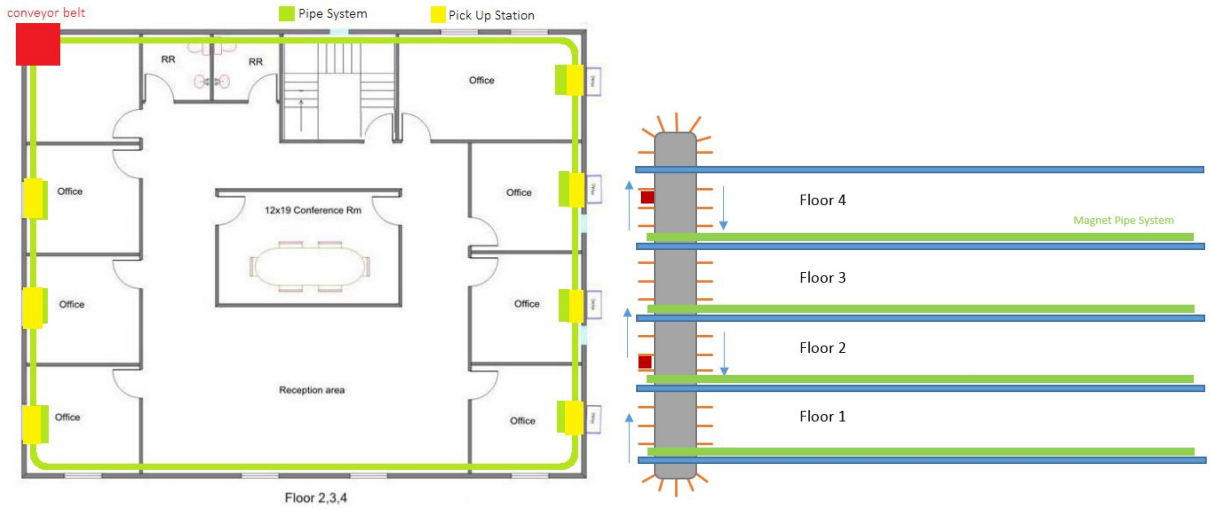
Delivery System

Movement of Capsule

There is two main modes of transportation, a conveyor belt that lifts the capsule vertically to different floors, and electromagnetic tubing that branches the capsule throughout the floor, distributing through the designated room.

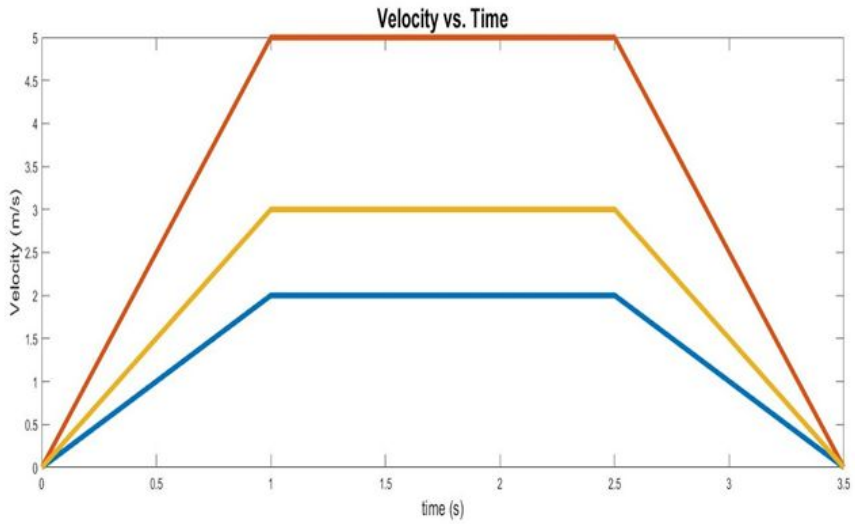
Electromagnetic Tubing System

The package moves throughout the floor through one main tubing system that traces the outer lining of the floor plan. When near the designated room, a signal is called to decelerate the capsule using the eddy current braking system, slow it down without damaging the package and/or capsule. After the capsule is slowed down, it will be pushed upward to a stationary pickup location in each room, where it awaits till the package is removed from the capsule without disrupting the flow of the pipe. Upon completion, the user will be able to push the capsule back into the main magnetic pipeline, and go along its path toward the conveyor belt to be brought back to the main floor.



The pipe system will allow the package to travel in magnetically influenced capsule through an electromagnetic corridor. The pipe will be embedded with copper coils and will be pulsed with the movement of the package to maintain momentum in the tube, saving both energy and power costs. Once the capsule passes through every feet of coil, the current

running through those coils will be turned off. Our design is similar to the pneumatic tube transport system used. today in banks and hospitals.



Graph 1: This MATLAB simulation shows the effect on acceleration and travel speed of the capsule based on the power of the magnetic force propelling the package. We deduced that the lowest accelerating force (blue line) is most optimal to avoid risking damage to the package.

Conveyer Belt:

To determine the power output necessary for the conveyor belt to spin at a constant linear velocity of 2 m/s constant, first, calculate the torque required to rotate the shaft at such speeds…

Force applied on the pulley = mass of the package × acceleration due to gravity

F = 10 kg × 9.8 m/s^2 = 98 N

Torque on the pulley of the conveyor belt is the Force applied on the pulley × radius of the pulley

Torque = 98 N × 0.25 m = 24.5 Nm

Angular velocity = $\sqrt{angular\ acceleration\ \div\ radius}$

Angular acceleration = (2 × F) ÷ (mass of the package × radius)

Angular acceleration = (2 × 98) ÷ (10 × 0.25) = 78.4 rad/s^2

Angular velocity = $\sqrt{78.4 \div 0.25}$ = 17.71 rad/s

Power = Torque $\times$ Angular velocity = 24.5 $\times$ 17.71 = 433.86 W

NOTE: Using calculations derived from Faraday's Law and Lorentz's Law, we can calculate the exact power needed to supply the electromagnets to provide the requisite force for the capsule. Due to time constraints we have approximated this value to a value of around 500W to 1kW.

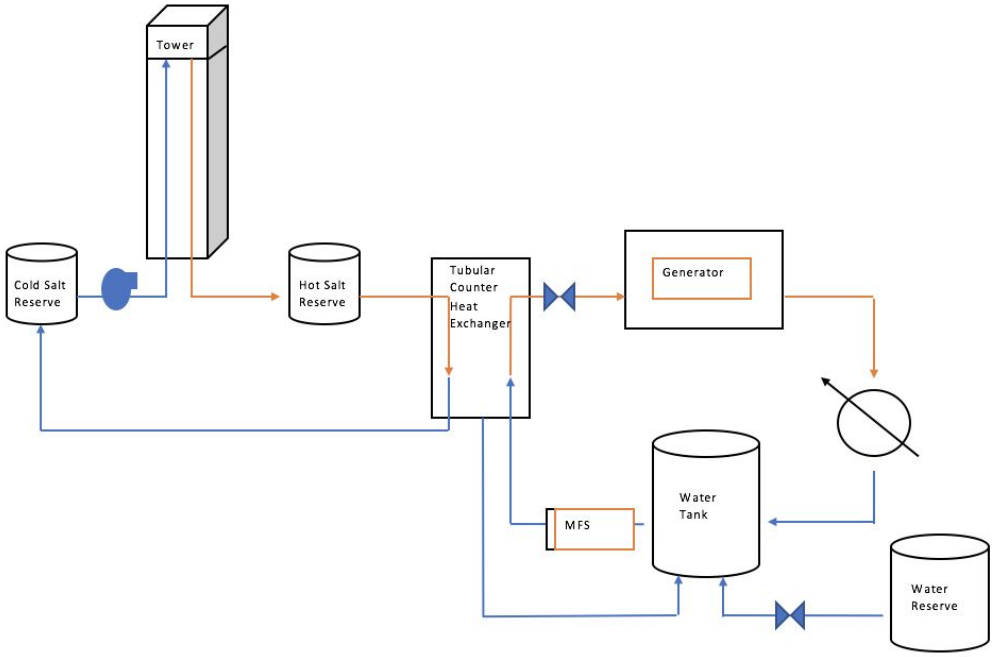
Total estimated power usage: 1433.86W → 1.5kW

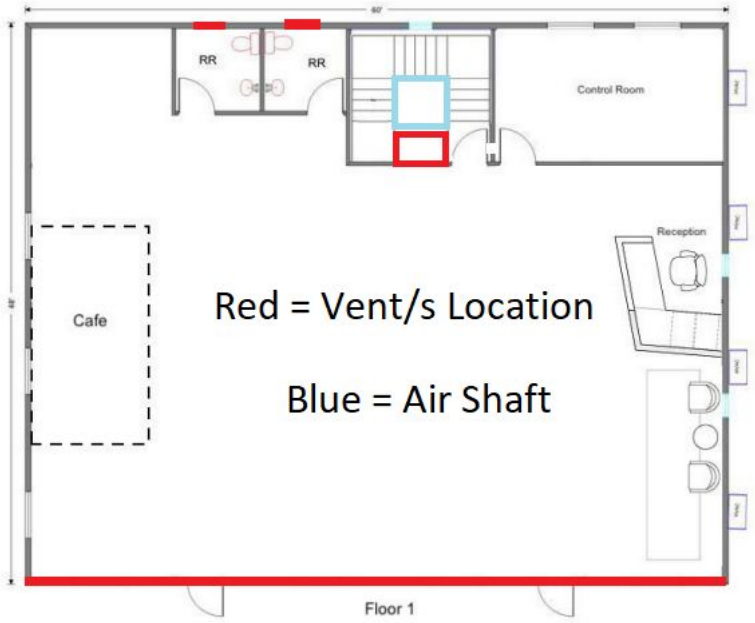
System Connectivity

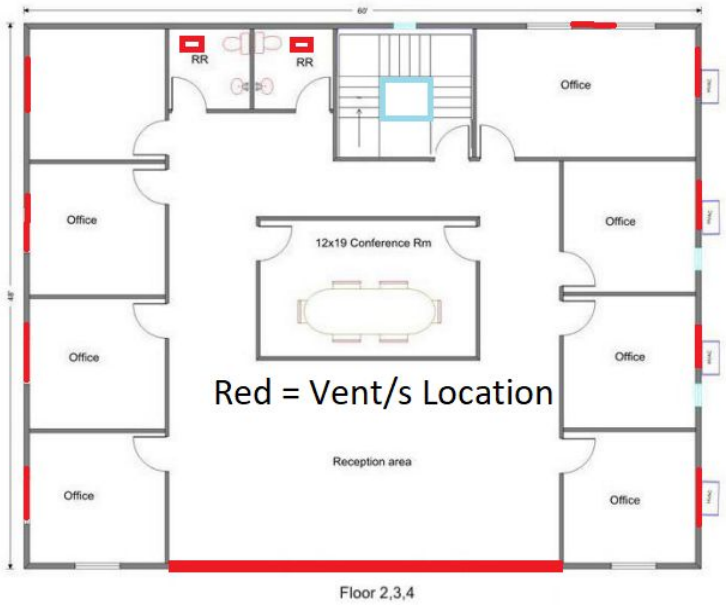
Eco-Friendly Power Supply

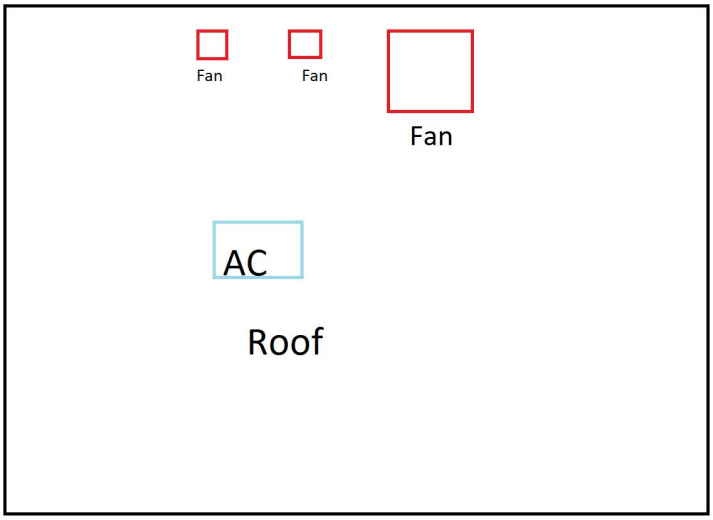
316-steel wires pipes are used to connect the cool molten salt throughout the design. The 316-stainless steel pump propels the salt up the tower and then it goes down the tower into the tank. From the tank it stays in a pipe until it goes back to the original tank. The water uses pipes as well to go from the reservoir to the heat exchange, condenser, and back. Regarding energy, the power generated by the steam will be passed through power lines to distribute to the building.

For the Passive Ventilation system, vents joining the outside air is connected into the inside of the building. For larger red lines in the first and second diagrams, there is suffice space to install multiple vents on the same wall. The bathrooms in all floors have a vent in both the top and bottom of the room that allows them to have more ventilation without connecting the bathrooms into the rest of the structure. In the same diagram, the blue box acts as a chimney where the air inside will escape. For the final diagram, all the red boxes are the chimneys in which air escapes the building. The AC box is the location of the installed AC units.


Tower
Cold Salt Reserve
Hot Salt Reserve
Tubular Counter Heat Exchanger
Generator
MFS
Water Tank
Water Reserve


RR
RR
Control Room
Reception
Cafe
Red = Vent/s Location
Blue = Air Shaft
Floor 1





Zero Waste

The Building will have a concrete first floor which consists of self-healing concrete only on the first floor. Our second, third and fourth floors will consist of glulam timber already coated with Permapost K-8 in order to avoid water and contact with electricity. To allow structural components of the design to withstand seismic activity lead rubber bearings are installed. On the outsides of our first and second floor the walls will be lined with plants as a way to ensure

efficient insulation. In order to ensure we maintain the plant growth a sensor will be installed to know when to water the plants and a camera will be installed to detect when it will be necessary to trim the plants. With the use of the Salt Tower power supply the plants would eventually be able to use the fertilizer for the plants. Solar Windows will be integrated which will also go into providing power to the delivery system.

Below are the coordinates of the building site, as well as the seismic factors provided by the USGS calculator, including the seismic acceleration. The building was categorized as a Risk III building due to it being four stories high.

	Reference Document	ASCE 7-10 Standard	
	Risk Category :	III	
	Site Coordinates:	33.64755	degrees North
		117.84226	degrees West
	Site Soil Classification:	Type D - "Stiff Soil"	
	Seismic Parameters		
	Ss :	1.585	g
	Sms:	1.585	g
	S1:	0.579	g
	Sm1:	0.868	g
	Sds:	1.057	g
	Sd1:	0.579	g
	Seismic Base Shear Coefficient		
	R:	1.5	
Importance Factor	I:	1.25	
	Cs	0.8808333333	
Upper Limit	Csmax	1.283	
Lower Limit	Csmin	0.058135	
Design Spectrum	Ts:	0.5478	s
Fundamental Period	Ta:	0.376	s

Parameters: Since the building parameters is limited to 2880 SF, floor heights have been chosen to harness new design systems and have a higher floor aesthetics. The wall depths are chosen based on most commonly used wall depths, to keep the building in standard size. Floor gravity loading was dependent on the weight of each story, to find the seismic factor, Cs, in each floor. Then the base shear was calculated for each story and it came out to be approximately 520 kips.

Building Parameters			Floor Heights		
Length	48	ft	Height		
Width	60	ft	Main	14	ft
Floor Area	2880	sf	2nd	12	ft
Wall Area	10800	sf	3rd	12	ft
			4th	12	ft

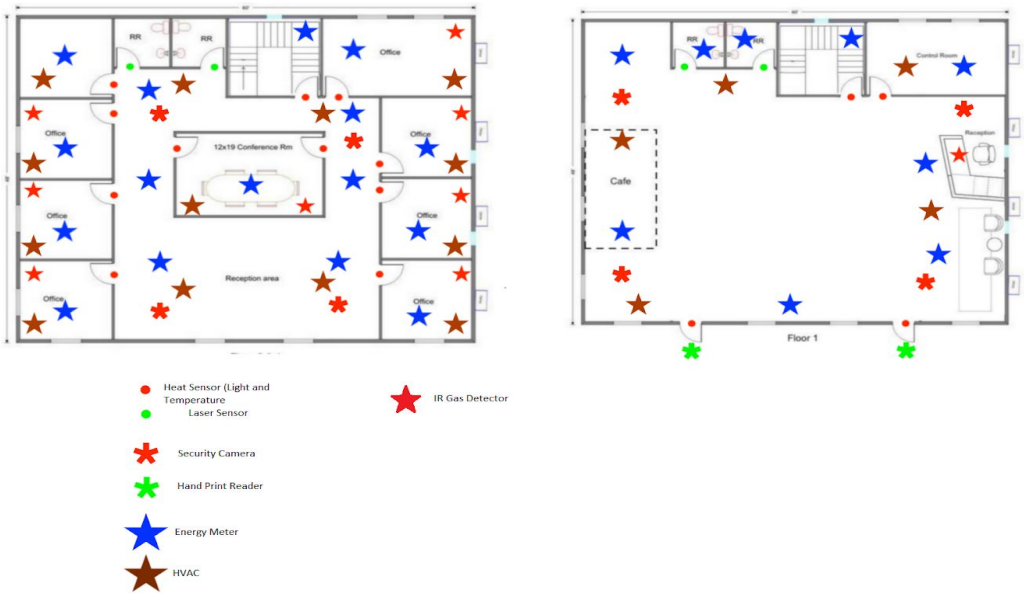
Self-Weight			Loads Used		
Timber	35	pcf	Roof	100	psf
Wall Depth	8	in	Dead Load	25	psf
Wall Load	25	psf	Live Load	80.0	psf
Concrete	150	pcf	Roof Live Load	20	psf
Wall Depth	12	in			
Wall Load	25	psf			

Height			Floor Load (lb)	Wall Load (lb)	Total Load (lb)	Base Shear (kip)
Main	14	ft	72000	75600	590400	520.004
2nd	12	ft	72000	64800	442800	390.031
3rd	12	ft	72000	64800	295200	260.021
4th	12	ft	72000	64800	147600	130.01
		Load Total	288000	270000	590400	520.004

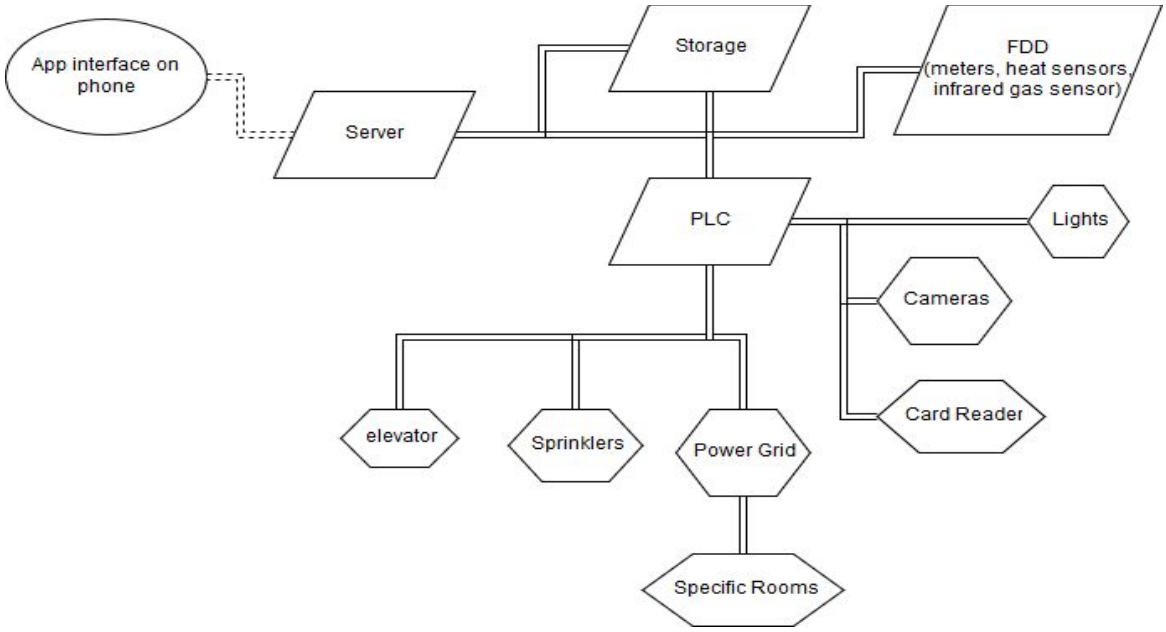
Height	Hx			Timber Walls			
Roof	50			Wall Thickness	Wall Length	Wall Area	c
4	38		Main(concrete)	12"	36.11138889	505.56	w
3	26		2nd	8"	115.991683	1391.9	
2	14		3rd	8"	77.32788781	927.935	
			4th	8"	38.66379521	463.97	

Device Control

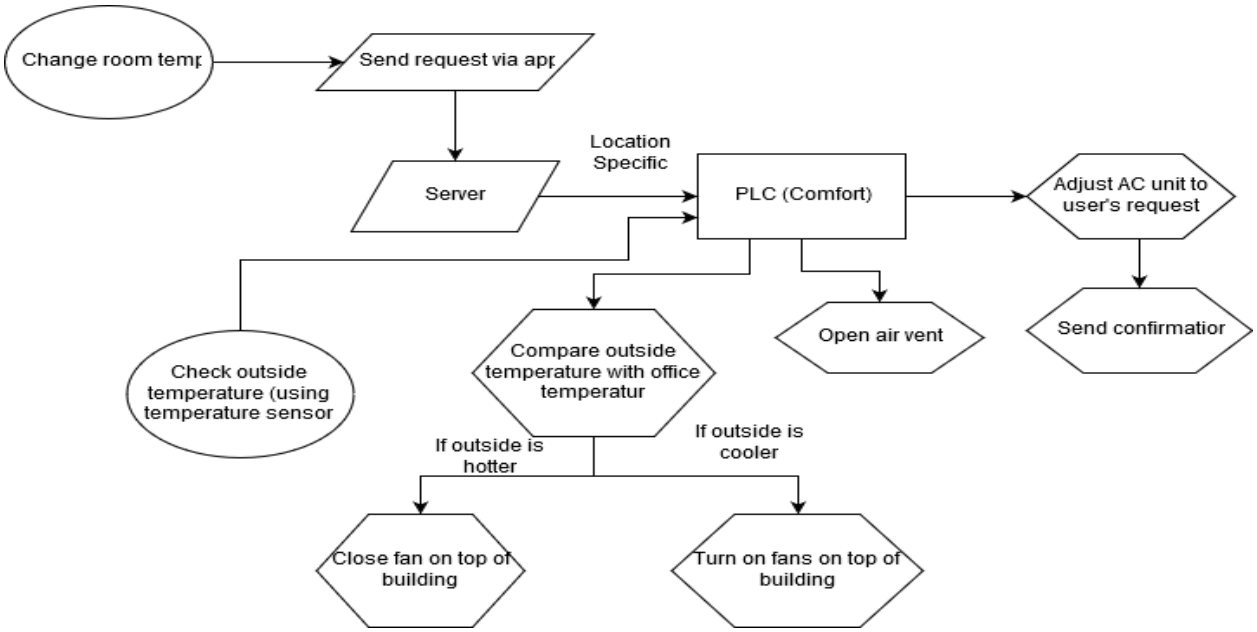
The overall system has many sensors, meters, and security cameras that collect a lot of data. The data sent to the server which send them to the main computer (PLC) to process the data and send a feedback order to control the system as needed. The smart pathways below illustrate how the many components of the system are connected with each other and their desired functionality.



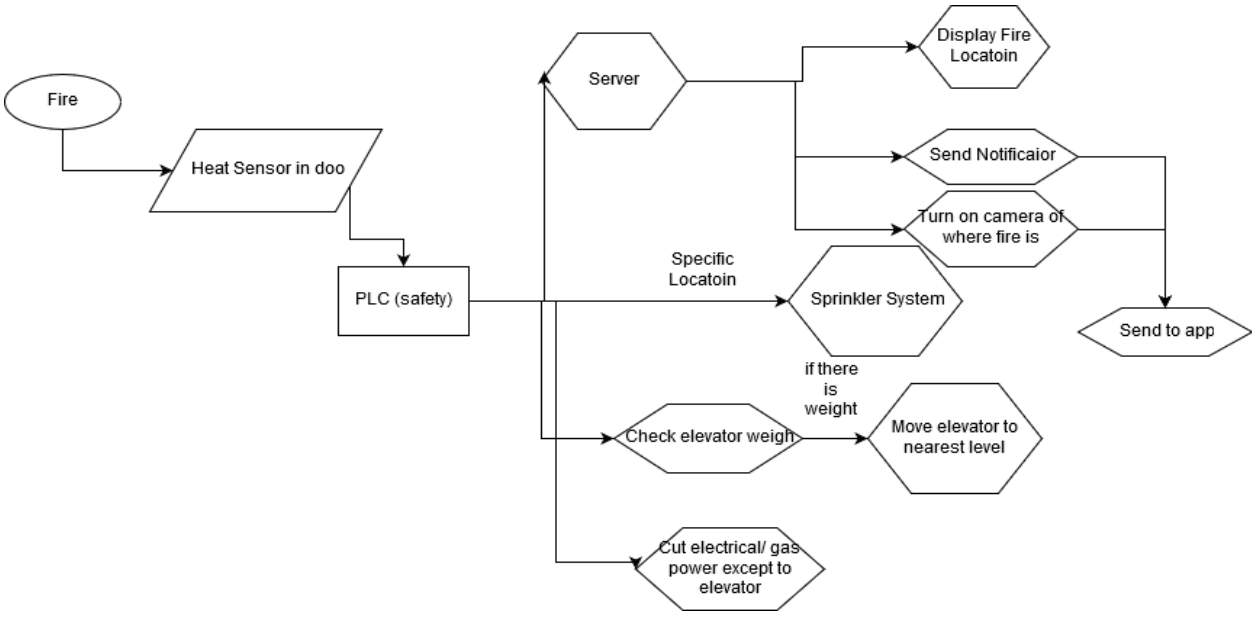
1. The diagram below explains the pathway of the mobile app and how it works with the whole system



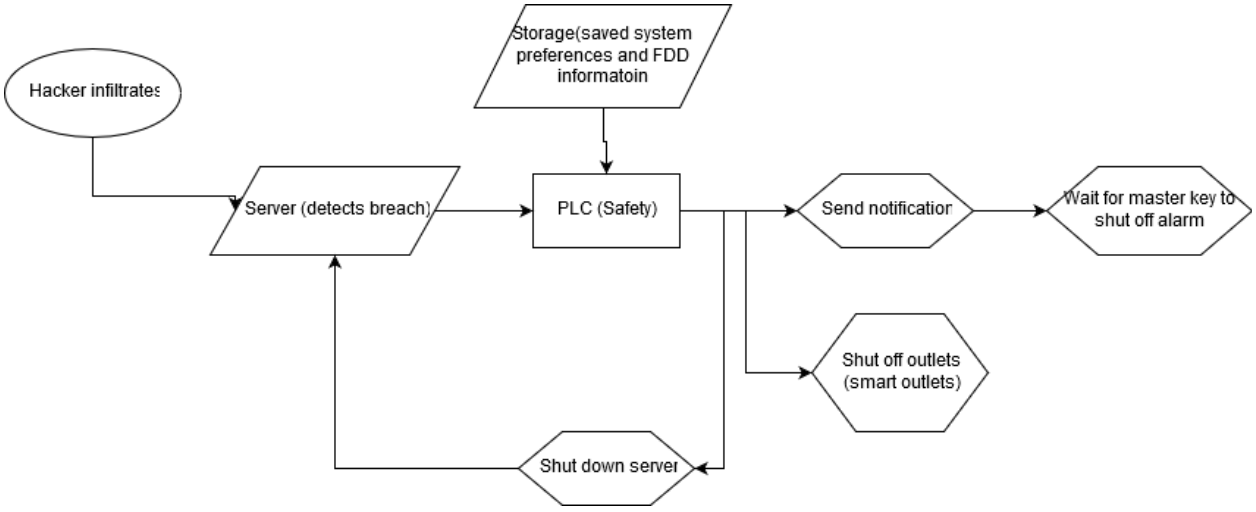
2. This diagram explains how the ventilation and temperature works to deliver the right amount of heat



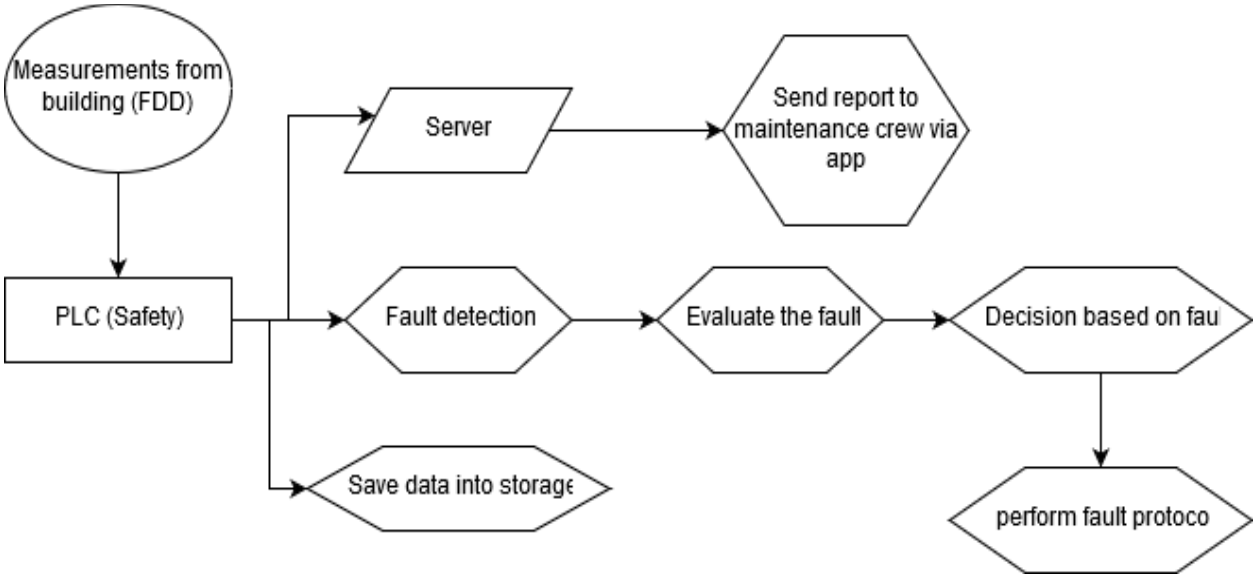
3. This diagram shows the counter measurements in case fire happened



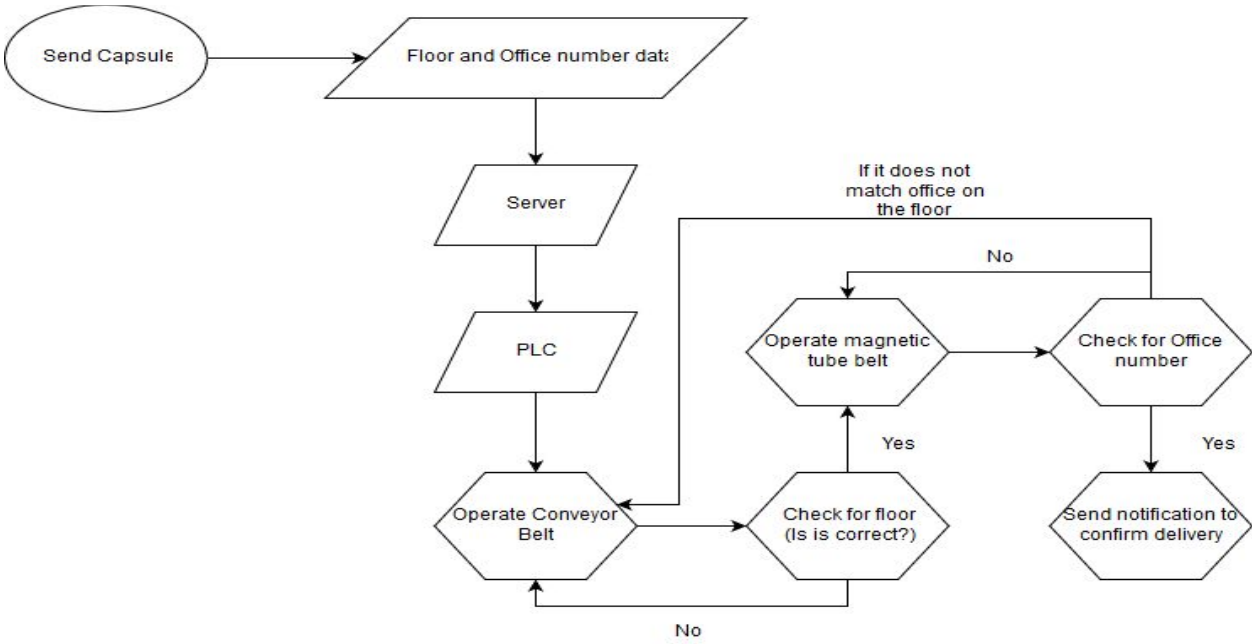
4. The diagram explains how the system behaves when a hacker infiltrate and how to stop the virus from propagating.



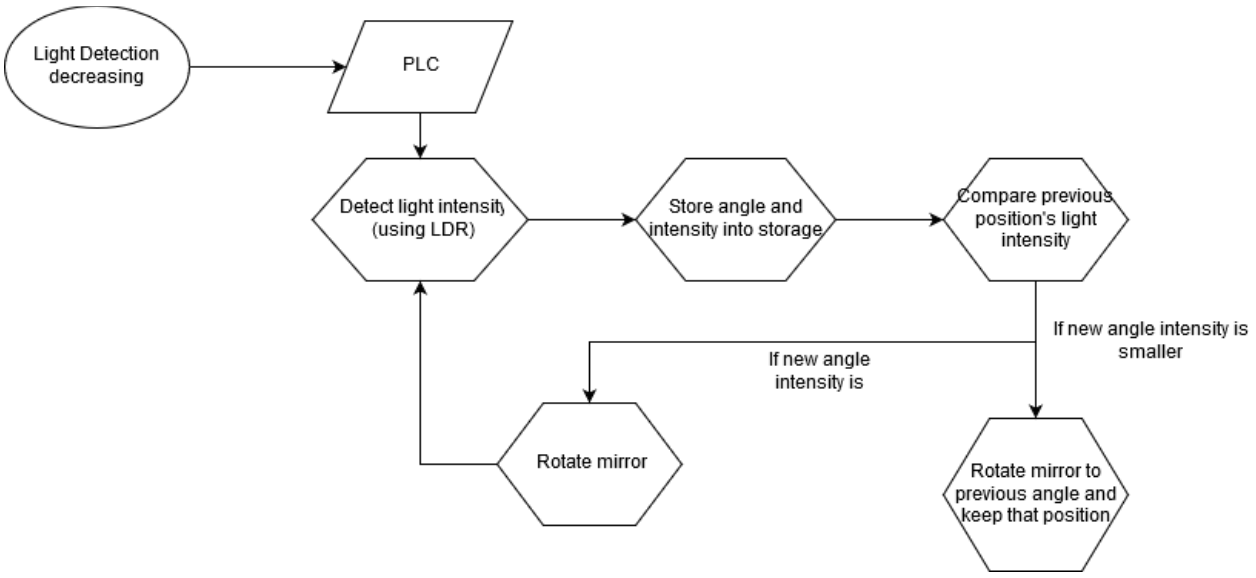
5. FDD contributes to making the building autonomous. The system will detect faults based on the data collected from the sensors (i.e. infrared, laser, heat) and meters utilized in the system and evaluate the faults.



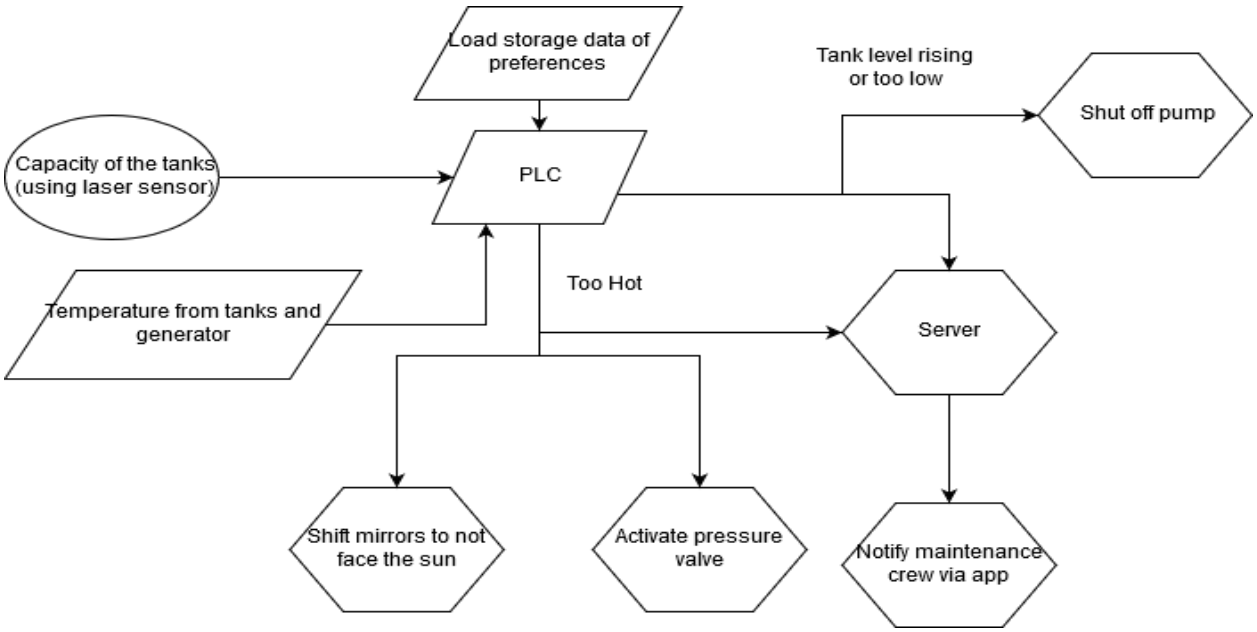
6. This diagram shows how the system tracks the path of packages needed to be delivered using the electromagnetism.



7. This diagram shows the control of the mirror that reflect sunlight into the salt power system. To maximize the heating of the molten salt (refer to Eco-Friendly Power Supply section under System Connectivity), the control will ensure the mirrors aim the sunbeam at the target, which is the top of the tower.



8. Laser sensors will be used to detect the overflow of water in the heat exchange component of the salt system (Refer to the Eco-Friendly Power Supply section under System Connectivity.)



Delivery System

Connectivity is made throughout the coiled pipe system. When the capsule in the pipe reaches its office of destination, it would be slowed down by eddy currents which are forces that occur when non-magnetic metals move through magnetic fields. Then, the package would be pushed into the office since the magnetic plate in front of the wall of that office will repulse it. The employee will after claim their package and take it out of the capsule that will be returned to the pipe system.

The magnetism within the coils of the piping uses electricity that can be produced using either energy stored from the solar windows or the salt powered heat turbine system. Within the delivery system, coding is needed to decipher where the package will end up. Right now, capsule has a controller to find signal specific to a office using a one way system. This can be done using the app using the user interface.

Bill of Materials

Eco-Friendly Power Supply

Item	***Description***	***Manufacturer***	***Price per unit***	***Quantity***	***Total price***
Molten Salt Tower					
KNO_3	60% of the reaction	Unibrom corp	$750	1 ton	$750
$NaNO_3$	40% of the reaction	*Qingdao Ever Century Trading Co., Ltd.*	*$400*	*1 ton*	*$400*
Mirrors	What are heating up the receiver at the top of the tower	Fab Glass and Mirrors	*$863.51*	*44*	*$37994.44*
Water	Water for reservoir	IRWD	$0.95	748 gallons	$1.59
316 stainless steel	Used to make the pipes		$28.80	8”	$25920
316 stainless steel	Used to make tanks holding salt		$156.28	36in x 12in	$1250
Galvanized Steel Sheet	Tower material	Cut 2 Size Metals	$16.74	36 x 48 in	$1321.38
Condenser	Condenses steam to	*acwholesalers*	*$1079/unit*	*1*	*$1,079*

	liquid water				
High Viscosity Electric Drum Pump	Pumps molten salt	*Uline*	*$1499*	*2*	*$2,998*
Turbine	To generate energy from steam (we are sizing down the condenser by making our own)	*ebay*	*<$17500*	*1*	*$17,500*
Heavy Duty Highhead Pump	Pumps water	*AMT Pumps*	*$1952*	*1*	*$1,952*
Heliostat Motor	Rotates the mirrors throughout the day to angle the sun	*SAT Control*	*$4135*	*44*	*$181,952*
Ventilation System					
Industrial Evaporative cooler	AC units used	*Indoor comfort supply*	*$3549/unit*	*4*	*$14,196*
Louvre exhaust duct	Duct door separating both sides of the building	*Gamut*	*$96/unit*	*49*	*$4,709*
Air Ducts	Air Ducts used to move air around	*Fixr*	*$4.5/unit*	*2000*	*$9,000*
Grand Total	$301,023.41				

Zero Waste

Budget Estimation Sheet					
Item	**Description**	**Manufacturer**	**Quantity**	**Unit Cost (per unit)**	**Total Cost**
Glue-Laminated Wood	Utilized for structural support on floors 2, 3, and 4	Rosboro	1855.87	66.62	123,638.07
Self-Healing Concrete structure)	Serves as the base of the structure	Basilisk Concrete	505.54	84.81	42,874.85
Lead-Rubber Bearing	Structure's primary means of handling lateral loads and resisting seismic forces	Dynamic Isolation Systems	25	800	20,000
Solar Integrated Glass	Utilized in insulating and collecting solar energy	SolarWindow	12	265	25,440.00
			16	265	29,680
Structural Steel	Used to reinforce concrete base	Schnitzer Steel	758.31 lb	22.26	16,879.98
Labor Cost (30%)					102,120.7
Contingency (5%)					17,031.7

Total					377,665.3

Device Control

Item	***Description***	***Manufacturer***	***Price per unit***	***Quantity***	***Total price***
Smart Outlet	*It turns itself on or off when needed. Also, it monitors the consumption of energy. It also monitor the consumption for the AC units.*	*TP-Link*	$29.27	*54*	$1580.58
Infrared (IR) Gas Detector	*Detects Leakage of gases by rays*	*FLIR*	*$949*	*20*	*$18980*
Security Camera	*Cameras for surveillance for safety purposes*	*eLinkSmart*	*$39.99*	*32*	*$1279.68*
Handprint Reader	*It allows people to pass using their handprints*	*Timedox*	*$159*	*2*	*$318*
Heat Sensor	*Project or show heatmap of people entering or*	*FLIR*	*$199.99*	*37*	*$7399.63*

	exiting rooms.				
Raspberry Pi 3 Model B	Microcontroller for bathroom availability	Raspberry Pi	$34.99	8	$279.92
PLC	The main brain of the system	Allen-Bradley / Rockwell Automation	$5819	1	$5819
LDR	Detects Laser	Fluke	$89.99	24	$2159.76
Laser Pointer	Shoots laser into the laser detector to sense when people go into or out of the bathroom	_____	$12.99	14	$181.86
Moisture Sensor	Measures the moisture of the plant to know when to turn the water sprinklers on	Koubachi	$143	4	$572
Thermometer	Measures temperature	Morpolit	$43.99	4	$175.96
Grand Total	$38,746.39				

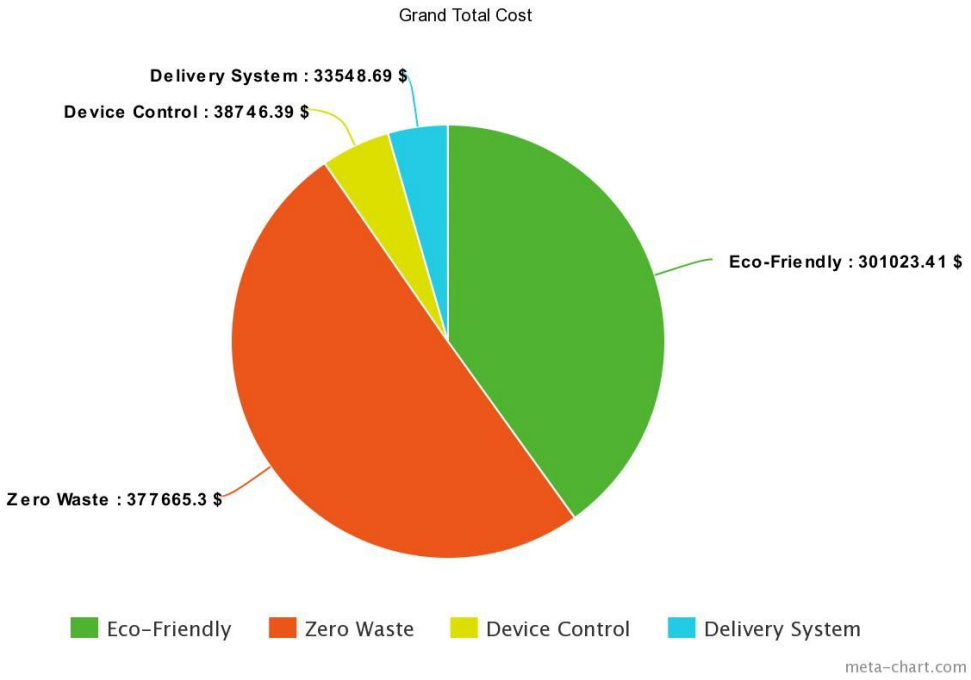
Delivery System

Item	Description	Manufacturer	Price per unit	Quantity	Total price
Capsule (1)	This is the item used to transport	Aaron Metals	Steel (outer	Steel(3.6 kg)	$232.24

Capsule (2)	*the package. It's composed of the following:* • *Steel* • *Aluminum* • *Charcoal*		*layer/tips) - $1.68 USD/lb* *Aluminium (inner layer) - $1.09 USD/lb* *Charcoal Foam Sheets - $4.58 per capsule*	*Aluminum (5.4 kg)* *Charcoal Foam Sheets (15" x 22")* *8 Capsules*	
Nickel - Copper Alloy (80:20) *Nickel-Copper Alloy (80:20)*	*The Nickel -Copper alloy is used as an electromagnet and is in the form of plates.*	*Metal Supermarkets*	*$5.89 USD/lb*	*648 ft*	*$5,333.04*
PVC Piping 16" Diameter	*The PVC Piping is used as a main form of transportation channel for the capsule with the package.*	*Lowes'*	*$711.54 per 20 ft PVC*	*648 ft*	*$23,053.90*
Conveyor Belt	*The conveyor belt is used to carry the capsule vertically and controls which*	*Bastian Solutions*	*$4,929 per Conveyor Belt*	*1*	*$4,929.51*

	floor level it goes to.				
Mu Metal	*The Mu Metal will be used to protect sensors from the electromagnetic field generated by the coil*	*Mouser Electronics*	*$6.83 per roll*	*2*	*$13.66*
Grand Total	*$33,548.69*				

Total cost: $750,983.79



Conclusion

The entity of the project is to construct from the ground up a highly innovative, sophisticated autonomous building.

Integration -

- Zero Waste 1
    - How is it related to Device Control System
        - *Physical sprinkler system detects when plants need to be watered*
        - *Immediately contacts fire department if fire detected (sensor)*
        - *Detect if plants need to be trimmed*
    - How is it related to Eco-Friendly Power Supply
        - *Provide salt for fertilizers*
        - *Heat rises so it does not affect plant*
    - How is it related to Interior Delivery
        - *Moving loads and dead loads added to seismic calculation*
        - *Cooling for magnetism movement of capsule*
        - *Paint wall with waterproof coating to avoid water and electricity*
        - *Solar system to charge battery, energy cost lowered*
- Eco Friendly Power Supply 2
    - How is it related to Device Control System
        - *DCS controls the ventilation designed by salt tower*
        - *Monitor power coming into the building (power usage)*
    - How is it related to Interior Delivery
        - *Powering the conveyor belt and current going through coil*
        - *Ventilation fixes heat problem caused by magnetism*
    - How is it related to Zero Waste
        - *(Mentioned above)*
- Device Control System 3
    - How is it related to Eco-Friendly Power Supply
        - *Monitoring of the structural integrity of building (FDD)*
    - How is it related to Interior Delivery
        - *(mentioned above)*
    - How is it related to Zero Waste
        - *Mentioned above*

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