The Revolution of Smart Environments:

A responsive architecture to the natural and social changing environment

PASSIVE/ACTIVE APPROACH

Vladimir Alvarado

May 2010

Submitted towards the fulfillment of the requirements for the Doctor of Architecture Degree.

School of Architecture
University of Hawai'i

Doctorate Project Committee

Clark E. Llewellyn, Chairperson
Raymond Yeh
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We certify that we read this Doctorate Project and that, in our opinion, it is satisfactory in scope and quality in fulfillment as a Doctorate Project for the degree of Doctor of Architecture in the School of Architecture, University of Hawai'i at Manoa.

Doctorate Project Committee

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Clark E. Llewellyn, Chairperson

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Raymond Yeh

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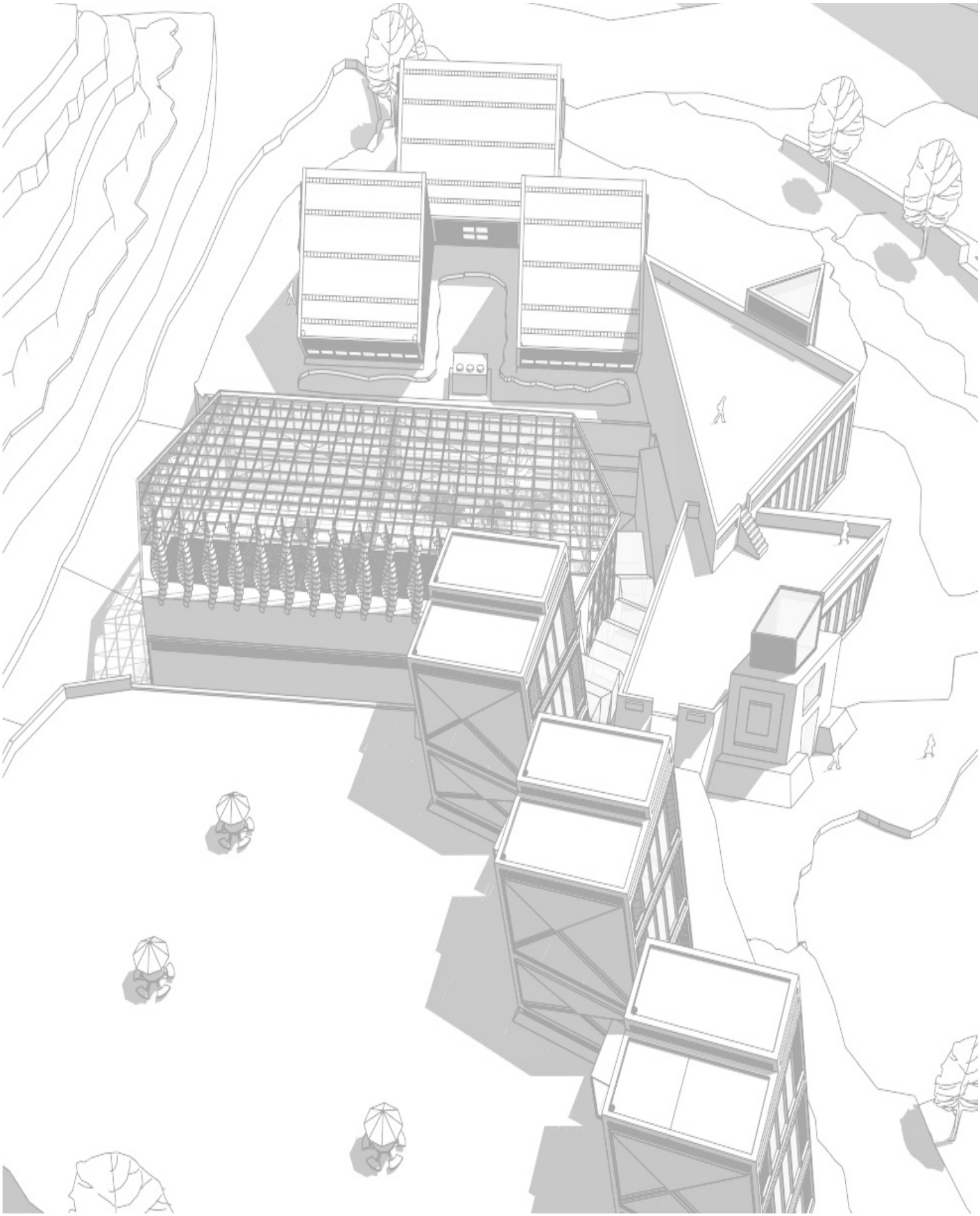
Farshad Rajabipour

In remembrance of my dear father Hernan Alvarado for his spatiotemporal footprint left as an expression and reflection of uninhabited environments.



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PASSIVE/ACTIVE APPROACH

Research/Design D-Arch Project

Prepared by **Vladimir Alvarado**

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PART I

1. INTRODUCTION

1.1 Concern

Climate change is the unintentional effect and insensitive approach from traditional technology to the environment. Traditional technology had set the foundations to superior outcomes such as better transportation, buildings, appliances, and much more. Nevertheless, traditional technology by itself has down side effects to the environment just as any pharmaceuticals have adverse reactions when responding to human body conditions. However, technology and science work together to find new solutions where traditional approaches cannot, in which certain limitations and boundaries are becoming thing of the past. We as human beings will always strive for new solutions and alternatives in response to cause and effect as part of our cognitive learning.

Technologies increases in response to radical social behaviors, natural disasters, and climate change as a way to find answers for comfort, security, and healthy environment.

Society had been threatened from social behaviors by radical extremist in whom we had developed new security systems to provide the necessary protection from unwanted threats just like:

- Oklahoma city bombing 1995
- September eleven attacks 2001
- Nerve gas attack on Tokyo subway 1995

We have experienced natural disasters like massive earthquakes, tsunamis, wild fires, droughts, heat waves, and air contamination from volcanic activities. From here, we had developed new construction materials, design approaches and the use of active systems to response to certain natural disasters and protect lives at all cost.
Our major concern is climate change at present times due to the devastated chain reaction of natural threats.

Climate change is the major course of unpredictable weather conditions in which this adverse reaction started to happen for instance:

Rise of Sea Level

Water contamination

Acid rain

Extreme droughts, heat waves

The change of our ecosystem and much more.

Greenhouse effect is the number one cause on climate change due to the release of CO2 and other harmful gasses into the atmosphere. We can pinpoint now the sources that have greater effects to the environment. According to IPCC (Intergovernmental Panel on Climate Change) fuel sources like coal, petroleum, the production of electricity, and other gases are the primary source of pollution into the atmosphere. We also know that the major consumers of energy are buildings starting from the assembly of buildings up to the services that these buildings need to provide in order to be fully functional and be occupied by people. Therefore, what makes buildings more energy efficient than others?

2. THE EVOLUTION OF BUILDINGS

Originally, our concept of buildings was no more than the enclosure of spaces which provided permanent or temporary shelter or settings for humans. From here we move to a more passive approach by redefining the design approach for buildings. Technologies now allow us to introduce new construction materials for better performance and to expand our traditional visualization and capabilities from interior to exterior construction elements.

The cause and effect circumstance in social life has forced us to adapt at moments, be flexible at times, and respond to events and more.

We have moved from static architecture to organic, from firmness to flexible, from brutal to responsible, and from uniformity to integrated systems. Buildings have become more complex and building systems now allow us to redefine our conventional approach of passive design.

Passive design has moved to the next level. It has become more dependent from technology than before. The focus is to move from passive to active design, but still there are variables that need to be analyzed and test its feasibility depending on cost, maintenance, and other variables.

The next generation of buildings should focus on the pure performance capabilities based on the integration of intelligent systems into building enclosures that respond to some stimuli. We can compare the complexity of building systems and functions to the human anatomy both are integrated systems that work perfectly together as one to perform multitask at once. Smart buildings can adjust and respond to the environment conditions, they could even respond to the presence on humans accordingly. We can say that smart buildings are observed as the science of artificial intelligence for the creation of smart environments.

3. GREEN TECHNOLOGY

3.1 What is Green Technology?

What do we know about Green Technology? What is it? The term green has grown popularity now on days thanks to the media and the market. Green Technology is the application of environmental sciences to preserve the natural environment for been maltreated from human involvement. Sustainable development is the basis of environmental technologies. These technologies are the answers to reach the environmental equilibrium and find alternatives to reverse somehow the ecological effect that now on days we started to perceive.

We have set projections to succeed in this none battles war against contamination and to preserve our natural resources and stop for polluting our precious planet as much as green technology allow us to do. Green technology is also known as clean technology; it gives us hope and makes our planet healthier and safe to humans, animals and all species including other important natural elements vital to humans like soil, air, and water.

3.2 When did it start?

The major event that rushed to environmental pollution was the industrial revolution. We can't denied that the industrial revolution broth us good and bad things. Technology was indeed the one that set the course of the chain reaction of many good products like new construction materials, computers, new and faster automobiles, airplanes, and others. On the other hand, at the same time an environmental movement arose at a lower degree in many parts of the world.

In the United States, there are traces of an environmental movement as far back as 1739 when History tell us that Benjamin Franklin and other activists petitioned the Pennsylvania Assembly to stop waste dumping and remove tanneries from Philadelphia's commercial district (Chris).

Later on in the 1916 the National Park Service was found by President Woodrow Wilson to preserve endangered species.

One of the most environmental influential books written in history was by Aldo Leopold called: A Sand County Almanac and his believe to have moral respect for the environment, and that it is unethical to harm it (Leopold). Another books in the environmental influence is Silent Spring by Rachel Carson a biologist which emphasizes in environmental impacts of the indiscriminate spraying of DDT in the US and questioned the logic of releasing this chemical into the environment without fully understand its effects on ecology and human health (Carson).

Other activists like the Chipko movement in the 1970s were formed in India influenced by Mahatma Gandhi in conservation of natural resources like forestry.

3.3 What was its motive?

People felt that they were on the edge of environmental catastrophe in the late 1970s and started to take some radical environmental theories such as deep ecology.
In 1979 former NASA scientist James Lovelock and his book, A new look at life on Earth understanding life as a single organism, which later on became an important part of the Green Ideology (Lovelock).

Now on days environmentalism has also changed to deal with new issues such as global warming and genetic engineering.

Environmentalist action has led to the development of a new subculture which is mainly composed of educated middle and upper-class. This subculture offers alternative products of general consumption as a way to offer recyclables products that does not harm in the long term ecology. There is a lot of marketing now on days about products that claim to be environmental safe but in the beginning they did not provide much information about its product content and ways to recycle it until we started to reinforce the manufactures to provide specifications of such products.

According to Encarta encyclopedia online Contemporary environmentalist is split into three groups: Dark, Light and Bright Greens. These groups have one thing in common “Save the Earth” and they can be slight different than each other. Light Greens protect the environment first as a personal responsibility in contrast with the dark greens they believe that environmental problems are a just part of industrialized capitalism, and seek radical political change. Lastly, the third movement the Bright Greens this group believes that radical changes are needed in the economic and political operation of society in order to make it sustainable but that better design, new technologies and more widely distributed social innovations is the means to make those changes. They strongly think that environmentalism is less about the problems and limitations we need to overcome that the “tools, models, and ideas” that already exist for overcoming them (Encarta).

3.4 Priceless Earth

As population grows worldwide, the need for new infrastructures, power plants, housing, commercial areas have become almost inevitable; it needs to happen. The use of the land is much the same as it has always been, using more land, more water, more soil, and more nonrenewable energy at a pace that can't be sustained no more. Subsequently, reducing the quality of life and having a major ecological impact to future generations.

People are moving from rural to suburban areas on account of population growth and pollution but soon these suburban areas will become much like cities on its own by reason of the demand of primary needs and so forth. As a result, how much do we care for this planet Earth that provide for every single human need?

Therefore, what are we doing to stop polluting our land and give back to our priceless mother Earth that cares so much for all of us?

According to AIA Architects and Climate Change, the major source of green house emissions and energy consumption are buildings with a 48%, industry with a 25% and transportation with the third major pollutant of 27%. It is projected to the US alone to increase its energy consumption by 37% and greenhouse emissions by 36% over the next

twenty years at an annual rate of 54% over the same period. This tell us clearly that the major consuming of energy are the buildings in general so there is a great responsibility among architects, designers, engineers, and all groups involved in the construction business to willingly help with this major greenhouse gas producer (AIA). Therefore, what are we going to do about it?

4. AN ENVIRONMENTAL REVOLUTION

4.1 How to approach it

Seventy five years ago we showed the world that we had the necessary technology and the best approaches to win World War II, even though we lost some battles like Pearl Harbor and Vietnam, but we never stop there, we continue to develop new technology which gradually helped us became a superpower nation in the world. Wars in general are political conflicts that cannot be solved with diplomacy so that is to say why we had to interfere intelligently in this environmental pollution and greenhouse effect as the only solution for the well being of mankind.

The twentieth century, has been giving us so much technology that now on days we can't live without them. It is a commodity that makes our lives pleasant, with more accuracy and innovation. We can't deny that we learn and gain so much during and after the two World Wars especially in technology. This is why our economy grew by reason of technology itself.

So is the way we been living for the last 75 years. In Order to sustain ourselves, we use technology to our advantage but at the end we found that some technologies have adverse effects into the environment. Like nuclear power plants, we claim to be safe, but we do not know how to dispose nuclear waste? We dig so dip in the ground to constantly obtain every natural resource and precious stones at all cost, we transport oil across the sea and contaminate alone the way when spills occurred.

These and many other examples are the products of the vast technology spillovers that had occurred and are happening right in front of our eyes. The major spillover in carbon monoxide which we all participate in spilling is, with the production of buildings and the consumption of energy that makes these buildings need in order to function.

Therefore, architects and other professionals in the construction business can gradually help reduce the carbon monoxide spill by sustainable approaches. Some of these approaches are:

- Intelligently meet the needs of society without disrupting natural resources.
- Help manufactures to meet with sustainable solutions and create products that can be consumed and reclaimed.
- Innovating alternatives in technology reducing fossil fuel and chemical use.
- Support new investors in this green technology carefully study all sustainable solutions in the market to offer green products available to everyone.

Green revolution main objectives:

- Offer alternatives fuels and energy efficiency.
- Building green meaning offering diverse of green products for the consumption of green buildings.
- Chemical alternatives to reduce or eliminate the consumption of hazardous materials.
- Federal support to all market available in sustainable solutions to stop environmental impact.
- Study of future technologies like nanotechnology.
- Create smart environments utilizing responsible systems.

4.2 Sustainability and Green Design

Daniel E. Williams wrote on one of his books “Sustainable Design: Ecology, Architecture, and Planning” to start solving common issues of sustainability, we need to gather many thinkers to give form and pattern to multiple issues and solve them simultaneously. Sustainable design must be capable of functioning “unplugged”.

In other words, sustainable buildings should be composed of technological systems that allow them to be functional without been connected to public services like

water, electricity, and or sewer systems. If designers start to address the challenge idea of been detached from services, then we can start seeing some real sustainable results.

Sustainable design is meant to last, to be flexible at times, and be sustained by renewable sources to survive extreme weather conditions, black outs, and or natural disasters, and remain standing fully functioning without major impacts.

On the other hand, Green Design is an ingredient of sustainable design. As a result, we can say that green design is different than sustainable design because green design integrates recyclable materials ecologically sensitive without living a trail of CO2 down the path during and after the building process and sustainable design is the integration of systems alone with green building materials that make it functional without been connected to nonrenewable sources.

Green design is composed of friendly technology materials, but it can be still attached by nonrenewable energy. As for Green Sustainable Buildings, we should consider them as intelligent living blocks that provide ideal environments to humans attached to a region acting as an integrated ecological system.

4.3 The Birth of Green Products

There is a great benefit of using Green materials, mainly because they are environmental friendly, they certainly have higher percentage of recyclable content, and better yet they are made consciously to reduce green house effects. Green products are natural, organic, nontoxic therefore reduce indoor pollution like allergies, headaches, nausea, rashes, and asthmatic attacks cause by high content of harmful chemical products.

This is why many people are choosing to move to green approaches to fight back this new illness cause by none responsible ordinary methods of choosing construction materials.

Those necessities gave birth to new technologies creating green products for green solutions.

4.4 Objectives

Building products make green building more affordable, functional, and beautiful. The demands for these products are rising dramatically because people begin to understand the ecological impact and the benefit that these new technological materials offer, appreciating more and more the use of such green products.

History in architecture taught us the way indigenous people approached sustainable solutions by the way they utilized regional materials in different geographical conditions.

During the Stone Age builders crafted stones and turned them into sculptured monuments that have lasted for thousands of years. Almost at the same time the new era of woodwork rose where in some cultures they master the craftsmanship turning buildings into art pieces. Even the era of making concrete out of volcanic ashes mixed with limestone was meant to be sustainable but not the way we process it now on days. Technologically, we showed that we master the making of concrete by making it stronger, but we forgot or denied to see that we contaminate the environment alone by the way we process it.

Other examples of sustainable approaches that we need to revisit are how ancient techniques adopted in cold and rainy weather conditions utilizing regional construction materials with new sustainable approaches were the way they built roofs with high pitched to drain water and or to avoid the accumulation of snow on roofs. One true example of the integration of sustainable approaches in ancient times was the application of heating floor systems to change the indoor environments as well as reducing or thickening walls to allow or prevent heat into rooms.

These and others were the initial approaches of sustainable solutions with regional materials; they even tested the strength limits on vegetable fibers to build tensile bridges

like, they did in South America. Revisiting sustainable approaches in ancient times, help us see how far we came in sustainable solutions. Unfortunately, we have not gone far because of the misconception of previous technologies that force architects to think in mass production instead of quality and performance.

For most indigenous communities geographically spread in all continents respected the land that provided to them in their daily needs without creating ecological effects on their lands.

That is to say not true now on days, ironically during and after the industrial revolution with new technologies we knew little of using such products like coal and oil. We kept using them to extreme conditions that now we see its side effects spreading an ozone layer at a distance of 10 to 50 km composed of three oxygen atoms which filter ultraviolet light into our planet and the lower ozone layer which is the reaction of sunlight on the ozone layer at a lower level. This lower level ozone makes it harmful to humans and animal, even disrupt the production of agricultural yields due to the increased ground level ozone and pollution which interferes with photosynthesis and stunts overall growth of some plant species. However, now on days green technology offers free education on these products, its benefits and the integration of green products in systems that willingly help achieve sustainable solutions on our green buildings.

4.5 Green Buildings an Architects Masterpiece

Green buildings have shown a tremendous growth over the last 10 years. Now we seen Large and small projects from educational, government, health care, and other institutions benefit from resource efficiencies, commodity, and lightness.

According to Alexis Karolides, on her article for Green building: Project Planning & Cost Estimating, “Green building is a way of enhancing the environment. Done right, it benefits human well-being, community, environmental health, and life cycle cost. This means tailoring a building and its placement on the site to the local climate, site conditions, culture, and community in order to reduce resource consumption, augment

resource supply, and enhance the quality and diversity of life. More of a building philosophy than a building style, there is no characteristic “look” of a green building. While natural and resource-efficient features can be highlighted in a building, they can also be invisible within any architectural design aesthetic.”(Means).

As Karolides continues on her article, buildings are more than just a recollection of green products; it should be a holistic approach to programming, planning, designing, and construction. It is this critical thinking of connecting a series of green systems to the region (Means).

Some of the questions rising now on days are how green building can be less costly. The main reason behind is that most of these new environmental friendly materials are not consumed by the majority forcing the market rise the cost of production. Consequently, the solution is simple the more architects now on days start to integrate green building products and the application of new and innovating systems until then the market will start reducing its cost base on demand. But for now green buildings and its initial cost will remain above average base on the demand of such products.

The bottom part is that green buildings is the product of a rationality responding to a particular region utilizing green technology and innovated green building systems. The product is an efficient masterpiece design to reduce or stop the heat flow, used of fossil fuels as the main energy consumption, and use techniques to utilize the natural environmental in the region to accommodate the interior building environment suitable and healthy for humans. Achieving this, becomes an Architects masterpiece for the benefit of the occupants and to the environment, that is to say doing the right thing is fitting a good fight in this green environmental revolution.

5. WORLD’S WORST ENEMY

5.1 Pollution

Everybody knows about pollution, we seen it, we feel it, we are so custom to live side by side to pollution that we take for granted what our natural environment is doing to protect us from pollution, but not for long. Because our planet it is not handling with this mass production of greenhouse effect. So what is Pollution? What do we know about it? How can we stop it?

Pollution is the contamination of the earth's environment reducing the quality of life and the natural function of ecosystems. Surely, we know that the increase of population is the reason behind because as we mention earlier the increase of technology to supply with this growth leave us with some technologies that benefit us in a way, but it has it side effects contaminating our path. So what do we have to say about this real problem we are living with? Certainly, we all agree that pollution is wrong and it must be prevented. But it does not end there; what are we actually doing to prevent it? What is the degree of pollution around the glove? We as human know that we can't turn it off just like that. It takes more than that, we need to re-educate ourselves about pollution; where is it coming from and where do we go from now, so we can start seeing all source of contamination with a naked eye so we can approach them properly.

5.2 Types of Pollution

There are two types of pollution natural and man-made. Natural pollution has its natural process which nature itself takes care of it through time. Meanwhile man-made pollution is caused by the chemical reaction of certain elements of grate toxicity content like the burned of coal, oil and its branches making it hard to get rid of.

Technically there are six man made types of pollution that we need to understand at a broader sense:

5.2.1Air Pollution
5.2.2 Water Pollution
5.2.3 Land Pollution
5.2.4 Noise Pollution
5.2.5 Radioactive Pollution
5.2.6 Thermal Pollution

5.2.1 Air Pollution

Ozone layer is an after effect of global warming, as well as acid rain. If we have time to observe what happens in our daily lives we can see that there are major sources of air pollution these are:

- **Vehicles**
  - Combustion of fuel to the production of oxides of lead, nitrogen and sulphur.
  - Oxides of lead, nitrogen and sulphur dissolve in water vapor and altering its pH and causing it more acidic.
- **Industrial**
  - Production of thick black smoke without a proper filtering system lead to an increase of carbon emission
  - Production of nitric acid through Ostwald process involves a series of combustion
- **Fertilizers Plants**
  - Emission of corrosive byproducts like sulphuric acid by contact process and hydrochloric acid which increase the acidity of water vapor in the atmosphere
  - Over production of ammonia for fertilizer production, which are not contained in a proper manner may increase alkalinity of atmosphere

- **Building demolitions**
    - Crumbling rubble and debris which floats and settles n the atmosphere, causing haze and smog like benzene, asbestos, beryllium, inorganic arsenic.
- **Solid Waste Disposal**
    - Accumulation of waste leads to production of strong smell and humidity,
    - Radioactive and hazardous waste not disposed in enclose area will cause the release of radioactive vapors or substances into atmosphere.

- **Solvent evaporation**
    - Vaporization of complex organic solvents which are non biodegradable
    - Organic vapors reacting with chemical compounds in atmosphere which acts as insulator earth, thereby producing greenhouse effects
- **Fuel production**
    - Fractional distillation of crude oil to produce kerosene, gasoline, and refinery gas by the cracking process called pyrolisis which involves the use of high heat energy
    - Fuel extraction, processing refining and distribution add an additional percentage of carbon dioxide emissions
    - Some 30% of hydrocarbon emissions are released through evaporation, which occurs from both fuel tanks and gasoline tanks
- **Roadway construction**
    - The construction process using vehicles
    - Asphalt fumes which are bothersome and toxic, which involves the release of both particulate benzene soluble organics and individual aromatic hydrocarbons
- **Electrical Components manufacturing**
    - Process of making semiconductors involves the usage of hazardous metals
    - Emission of toxic byproducts into river and atmosphere.

- **Extraction of metals**

    - The process involves the heating of carbon which produce carbon dioxide and carbon monoxide
- **Forest fires**
    - Release of particulates into atmosphere causing smog and haze into poor vision of sight in the area and since trees absorbers carbon monoxide during its life cycle if is burned it releases back to the atmosphere
- **Agriculture**
    - Improper sanitation results in the accumulation of feces and urine causing strong odor contaminating the area

5.2.2 Water Pollution

Water pollution is the contamination occurred in the ocean, rivers, underground water by toxic chemicals, pathogenic germs, and substances that require more oxygen to decompose. This contamination occurred in the water usually settles on the bottom causing excessive algae growths which reduces the content of oxygen.

Water in the earth has its cycle and is used and reused time and time again. This cycle involves the following transformations: Evaporation, transpiration, condensation, and precipitation.

- **Petroleum products**
    - Sources of contamination from manufacture of plastics, lubricants, distillation of crude oil, cars, solvents, synthetic fabrics and others.
    - Cause by spills in land or sea, improper refinery processes, and faulty equipments.
- **Synthetic Agricultural chemicals**
    - Cause by pesticides, herbicides, insecticides, fungicides
- **Metals**
    - Sources from mining, automobile exhaust, semiconductors, batteries from leak pipes, industrial discharge, etc
- **Hazardous wastes**
    - Radioactive, reactive, corrosive and ignitable materials
- **Excessive organic matter**

    - From animal waste, sewage sludge which stimulate algae growth
- **Sediment**
    - Soil erosion cause by floodwaters, storms which sediments accumulates contaminating waters.
- **Air pollution**
    - Cause by greenhouse effect can affect aquatic ecosystem
- **Thermal pollution**
    - Can warm water which will alter the water composition and levels of oxygen

5.2.3 Soil Pollution

Soil pollution starts by loosing millions of hectares per year due to people buying land and build on it, meaning loosing billions of tons of topsoil per year. On the other hand, another way of contaminating hectares of land is by malpractice on farming methods and improper irrigation practices.

Besides these malpractices there are other sources that lead to land pollution such as:

- **Agriculture**
    - Accumulation of animal manures, chemical fertilizers, illicit dumping.
- **Sewage sludge**
    - Improper sanitation systems
- **Dredged spoils**
    - Improper method of dredging at fertile land causes soil infertility
- **Demolition and construction**
    - Non biodegradable rubbles or debris which are not cleared settled in the soil undergo chemical settled in the soil increasing its toxicity

5.2.4 Noise Pollution

This is another way of pollution because now on days with the use of heavy equipment or vehicles on industrials zones, near airports, highways, and train stations. Sounds are produce at every moment of the day but when it reaches a high intensity can cause disturbances to our ears. Noise levels are measured by decibels (db) for instance, the threshold of hearing is 0 db, normal conversation 60 db, Motorcycle nearby at 85 db plus, subway inside around 94 db, mower 110 db, and a jet plane taking off depending on the size of turbines 130 db plus(Wikipedia).

We can also consider noise pollution indoors near rooms that noise can be transferred very easily by the improper sound proof aids.

5.2.5 Radioactive Pollution

The nuclear era reached its peak during WWII and according to scientist nuclear energy was recognized as clean energy. Mainly, because it does not release an atmosphere pollutant but it is not entirely true even though scientist claim to handle it properly it produces nuclear waste extremely harm to the environment and to humans and animals as well. Nuclear plants claim that they have reduced the amount of greenhouse gas emission but if a nuclear waste spill occurred it will cause death in the long run to those expose to such as radiation emitted by such waste.

There are three known types of radiation:

- Alpha particles can be stopped with a sheet of paper even human skin.
- Beta particles can be stopped by glass or metal but can penetrate skin.
- Gamma rays can be stopped only by a massive concrete wall and can penetrate skin damaging everything on its path.

This radioactive waste can be obtained from nuclear power plants, nuclear weapons, uranium mining but the most important to not forget is that radioactive waste have half life meaning that required about 10,000 years or more to disintegrate of half the atoms in a sample imagine large quantities (Wikipedia).

5.2.6 Thermal Pollution

Thermal Pollution is a combination of green house effect and the globalization. Nevertheless, one major producer of heat energy comes from heavy industries.
The major sources of this thermal pollution are power plants creating electricity from fossil fuels, water as a cooling agent to industrial facilities, deforestation of the shoreline, and soil erosion.

- **Power plants** which creates electricity from fossil fuels store energy creates a heat flow that drives turbine, these turbines generate electricity creating an excess heat because of the unnatural process.
- **Water as cooling** especially in heat exchangers from factories which needs heat and others that generates heat. The evaporation cooling or cooling by condensation generates a great amount of waste heat. Cooling comes from evaporation because ambient air is not saturated with water. Air discharged from cooling tower is a direct contribution to global warming
- **Deforestation of shoreline** contributes to the problem by aggravating soil erosion activity, and increases amount of light that strikes the water.
- **Soil erosion** sedimentation at lakes and streams makes the water muddy which lowers the clarity of water, containing microbes and other dissolves minerals which increase the light absorption from the atmosphere rising the temperature of water from the heat energy of light.

5.3 Measuring Carbon Footprint

We have mention that the major source of green house emissions and energy consumption are buildings with a 48%, industry with a 25% and transportation with 27%. At the same time we have identified sources of pollution which we can consider them as

raw technologies because we used them without refine them and understanding its major implication on polluting our environment.

Holistically climate change is a series of cause and effect which our current lifestyle affects on. These lifestyles are truthfully a big contribution to greenhouse effect, but we see them as a problem for others to deal with. One way to see our contribution to the greenhouse gas effect is to measure our carbon footprint as a tool to evaluate our contribution to climate change.

Carbon footprint is measured by units of carbon dioxide in representation of the effects of human activities. For example, every gallon that a car burned to produce carbon of Carbone dioxide so is every product in the market. There are many carbon footprint calculators online available to help us understand approximately the percentage of carbon by tons we may consume for each year. The ideal objective is not to find the major consumers and producers of carbon dioxide but is about a personal call to understand that we all are in the same boat, so we all contribute to that expense.

There is also an ecological footprint that some environmental groups offer to find in depth how much land and water is needed to produce all the resources a person consumes and disposes. For example, Redefining Progress estimates that the typical American uses 25 acres to support his or her lifestyle, almost five times more than is sustainable.

5.4 Does it matter?

Some people believe that climate change is a topic we shouldn't worry about because we won't see major changes in the next one hundred years. We can keep arguing that climate change it is not happening now, and that it does not pertain to responsible people who stay away from contaminated areas. If everyone strongly thinks that I don't contaminate the environment I just work here, and consume their products, then we are participants in the greenhouse gas effect as well.

So whose responsibility is it to begin with? Who's going to do something about it? “Is not my fault it is yours” If that is the case we are going to see major climate problems before we start to assume responsibility. Climate change is happening now and the next generation will see its radical results and so forth. Our grandkids will have to live with major consequences because this present generation did not want to assume responsibility and do something immediate to help our grandkids and to offer them quality lifestyle and enjoy it as much as we are doing now on days.

Of course it matters what we do now on days it is all about a positive attitude and responsibility to protect what is most valuable to us.

5.5 Are we consuming too much Natural Resources?

We know that in order to survive, we need natural resources for our coexistence, this Earth we live in, provide to us for all the things that we need whether are renewable and nonrenewable that can be used to produce goods and services, including but not limited to land, water, animals, minerals, trees, climate, soil, fire, seeds, grain and fruits.

Geographically speaking every country has its own natural resources unique to the region. Some countries lack of natural resources, but we always manage to reach a balance to satisfy our needs and consume them and its products.

Indeed there are areas where the major problem is not that people are consuming too much it is that people don’t have enough to consume like in third world countries. The problem is not that they lack of resources is that they don’t invest enough for future generations. So what we do now it has an effect later on whether we sit and do nothing and see the next generations starve to death or face unstable weather conditions due to climate change, or we can invest now for future generations and give them hope to live and enjoy life as we all do now on days.

It turns out that even with our SUV’s, AC’s we are participating in this greenhouse effect, but we can say we are not consuming too much, as long we are investing enough in the future to ensure that futures generation will enjoy technology and

their living standards will be as high as ours but instead of polluting, they will utilize renewable sources for their consumption.

Jon Christensen on his article Are We Consuming Too Much Vol. 6, No2 wrote: Economist tend to believe that, if we run out of some environmental resources or find better or cheaper substitutes, we will simply switch from horsepower to gasoline or from gasoline to hydrogen. The economic argument is typically that increases in knowledge and in manufactured and human capital will enable societies to substitute their way out of economic problems," he continues with the argument that "Ecologists, on the other hand, tend to believe that we are running out of environmental resources and some environmental resources cannot be replaced, like the dodo or the passenger pigeon."

Some countries have been abundant of natural resources, or we can say natural capital; some countries do not depend of natural capital for their economy like the USA, Japan, Germany and other countries. On the other hand, some countries are consuming their natural capital, but they are not investing in the loss of it. This is where the problem is, we need to invest for future generations and that starts with investing in new technology that is to say appropriate for future generations, technology where does not have adverse effects.

Certainly there are places were natural resources are not deploying as fast as we need them but this is where we need to interfere in helping our neighbors to find alternatives for those resources in danger of extension.

6. ENERGY

6.1 Where does it come from?

Energy can be found in many things and takes many forms. Kinetic energy makes objects to move. There are many ways of energy to travel, from a form of electromagnetic waves, such as heat, light, radio, and gamma rays. Humans and animals use metabolic energy from food sources. There is a mechanical energy that turns into heat energy.

Energy can change form but where did that energy really comes from? If we trace back the cycle of energy, we can track it back to the sun; so how much solar energy comes from the sun?

Energy is measured by Btu/sq. ft/hour or Watts/sq. meter. The pure light source from the sun is around 1,350 Watts/sq meter or 429 Btu/sq. ft/hour. Of course we do not receive that amount of energy from the sun because solar energy is interrupted for our benefit by different conditions. These conditions reduce the light intensity if light encounters any material. When that happens light can be reflected, absorbed, or transmitted in different rates levels depending of the source (Wikipedia).

The first thing the light encounters are the atmosphere in which 19% out of 100 % of sunlight is absorbed by the components of the atmosphere. The rest continues to travel to the Earth surface but is interrupted again when it reaches the tropopause because of the content of clouds. The average percentage that the clouds reflects back to space is around 25% depending in the geographical location for example New York and Hawaii that percentage increases if the accumulation of clouds and the angle from the sun to the region varies so the maximum percentage of reflectance can be 50% from the 100% of pure sunlight. So what that means is that we may receive a percentage of 30% of sunlight in New York and around of 45 to 50% in sunlight in Hawaii. Translated to 400 Watts/sq. meter or 130 Btu/sq. ft/hour in New York and more in Hawaii depending of the cloud concentration. This is without the interference of the greenhouse effect.

History tell us that in 1816, thousands of miles away from the US a volcanic explosion occurred which cause millions of tons of find dust particles shot up into the air causing a fine cloud in the sky and blocking the sunlight during summer which resulted that the US had no summer during that year and snow fell around the States even in July and August. In addition to that, back in time around 600 AD similar cause and effect broth severe cold weather in Europe and possibly around the globe where crops all failed and starvation was severe for several years (Epic Disasters).

In this general aspect, greenhouse effect is doing a similar effect just because most of the power plants are generated by nonrenewable sources adding with the automobile industry that both together dump to our atmosphere around 144 trillion cubic feet of carbon dioxide per year.

In other words, the greenhouse effect is the accumulation of carbon dioxide in the ozone layer creating a blanket effect because some of the 43% or more reflectance back into space is trapped by this blanket effect making the atmosphere becoming heated up by the addition of this extra absorbed energy.

So there we have it, the increase of temperature is really happening as we speak because of the polar ice melts making our oceans raise as it melts. However, Antarctica represents a far bigger disaster in the worst if it all melts because of the millions of square miles of ice ocean surface. So what are we doing to stop this greenhouse effect? Are we going to let this blanket effect to destroy our precious planet by heating it up and change dramatically our life cycle? We already identified that buildings are the major source of energy consumption and because of our nonrenewable sources we are adding more carbon dioxide to this blanket effect. So we need to identify the problem of energy consumption in buildings to start interfering in this carbon spill before our eyes.

6.2 Three environments that energy gets affected.

James Marston Fitch quotes on his seminal book American Building: The Environmental Forces that Shape it. “The ultimate task of architecture is to act in favor of man: to interpose itself between man and the natural environment in which he finds himself, in such a way as to remove the gross environmental load from his shoulders”.

Architects have a big responsibility in the built environment because of them energy gets affected in various forms, in thermal, luminous, and sound conditions. Michelle Addington and Daniel Schodek on their book Smart Materials and Technologies identify these problems as environmental conditions where thermal, luminous and sound of energy conditions gets affected.

No doubt that architects with the help of science have refined healthier environmental conditions in challenged spaces. One of the architect strengths is the sensibility to the built environment which makes her/him aware of natural conditions as a learning process to solve the challenge of creating environments free from pollutions.

There is a great responsibility to architects to study and be familiar with construction materials and its behaviors expose to different environmental conditions and find sustainable solutions and solve the challenges of energy consumption in buildings.

The way the interior environment is perceived by people will affect people’s behaviors by improving or not the quality of life.

The enclosure designs affect dramatically the interior environment. Therefore, is different as designing environments. Smart Materials and Technologies by Michelle Addington and Daniel Schodek wrote:

“All environments are energy stimulus fields that may produce heat exchange, the appearance of light, or the reception of sound. Rather than characterizing the entire environment as being represented by a bulk temperature, or a constant lux level of illuminance, we will define the environment only through its energy transactions or exchanges across boundaries, including those of the human body. This approach is

consistent with the current understanding of the body's sensory system. Whether thermal, aural, or optical, our body's senses respond not to state conditions – temperature, light level, etc. – but to the rate of change of energy across the boundary."

Once the human body enters an interior room it is sensing its body temperature constantly to the stimuli of the surrounding environment, and its reaction to that stimuli will contribute to the increase of thermal heat in that particular environment. How so?

6.3 The Thermal environment

We know how that heat transfer from high temperature to low temperature, but does not give us specifics how, so at the end we do not much how heat behaves as mention on Smart Materials by Michelle Addington.

Michelle continues with the argument that even in a control environment with a constant room temperature we can experience an umbrella of thermal behaviors. "Multiple types of heat transfer, laminar and turbulent flows, temperature/density stratifications, wide-ranging velocities – all occurring simultaneously." Michelle compares this thermal indoor behavior with the human body, and she realizes that there is a more complex thermal exchange of mechanism happening simultaneously in the human body.

The complexity goes beyond our comprehension of simultaneous stimuli happening at the same time with the indoor environment acting with the reflectance of thermal behaviors to different interior materials and unique characteristics of such. Michelle and Daniel realized that the heterogeneity of the different thermal behaviors, clearly offers a good potential to study the design process of choosing materials and analyze the exchange of thermal heat transfer.

Heat can transfer by conduction, convection, and radiation at a rate of its own unique conductivity qualities of each material, this thermal transfer acting with the human body can affect the way we perceive indoor environments.

There is a scientific explanation of such as thermal conductivity and its natural convection; it conserves its mass and energy according to its specific heat properties. The emissivity of heat transfer can be done by absorption, reflectivity, and transmissivity according to its own unique materials characteristics. This is where architects need to understand and apply new technologies to not only solve this thermal behavior but to create healthier indoor environments.

6.4 The Luminous environment

Light is a thermal energy, and it is considered as electromagnetic radiation because it moves through space back and forth or changes electric and magnetic disturbances (Wikipedia).

Light travels in a straight line between two points and when it reaches a surface it can be absorbed, transmitted, or reflected. It all depends of the surface characteristics. If it is reflected it will reflect from the surface at the same angle but in the other direction.

It can also be defused depending on the irregularity of the surface. If light is transmitted, it will refract at an angle related to the ratio of the refractive indices of the two media. Different materials reflect light very different increasing or decreasing the intensity of light. The intensity is the amount of photons per unit area in a particular direction. Our visual system adapts to the intensity of light reflected on a surface in relation to its surroundings.

The sun is the primary source of energy and light for us and light is what makes everything to come alive reflecting its color or changing it depending of the wavelength or bandwidth which it travels. From this we can infer that color is to light and light is to energy. The energy level tells us how bright, the wavelength tells us which hue, and the bandwidth tells us with what saturation.

When it comes to interior design and choosing the appropriate light source we are delivering a specific mood to the environment because of the intensity of wavelength of the source. For example light sources for a food store varies from a gallery because in the deli department light source should be with ling wavelength because we want to enhance the natural colors of the vegetables as for the gallery we choose short wavelength source to show more the canvas and the prism of pigments by doing it so we need to understand light and its behavior with the medium spectrum profile.

This visual system and its understanding have great implications for designers and for architects.

6.5 The Acoustic environment

Sound is another thermal energy that can travel by short and long wavelength. Sound is produced by mechanical energy which is propagated through an elastic medium by vibration of the molecules of the medium. Sound can be absorbed, reflected, and transmitted all depending of the characteristics of the surfaces (Addington).

We have been studding its behaviors since ancient times more than thermal and light. But nut until the beginning of the twentieth century we begin to master the science of acoustics and its limitations.

Room proportions directly determine the loudness of sound, and materials determine its clarity. The sound intensity is proportional to the amplitude of the pressure difference above and below the undisturbed atmospheric pressure. The material property of absorptivity affects the intensity levels.

We often find that materials that are good insulators are also good acoustics absorbers. These sound absorbers can be porous absorbers and resonant absorbers. The porous absorbers reduce the sound energy and resonant absorbers reflect it back at a particular frequency.

The characteristics that we as designers are interested in are how the ear spatialize sound. A big percentage of our awareness comes from the sound environment.

Modern science of acoustics was the discovery by Wallace Sabine that material absorptivity impacted the reverberation time of a room. The amount of time that a sound persists is known as the reverberation time. The reverberation time is the amount of time that elapses before there is complete silence after a 60db sound has stop.

Michelle Addington adds on her book that "Smart materials, in the form of piezoelectric, are already playing the central role in sound design, but the potential of designing the acoustic environment, as well as the thermal and luminous environments, directly may well be the most provocative application of smart materials in the design field."

6.6 Green Power and Technology

Green power is a renewable source of energy as an alternative to reduce energy consumption within a building, or it can function as the primary source of energy. There are many renewable sources available now on days to help architects and investors to achieve sustainability. By all means green power stops the carbon spill as the only appropriate technology to help global warming.

For the purpose of studying, we are going to look at green power starting as the only alternative to switch to because nonrenewable power plants are the number one source of carbon producers therefore if we need to stop faster this carbon spill we need to invest big and look big.

Some of the alternatives of green power plants at a **large scale** are:

- **Wind Power** it is been there for a long time. Is 100% renewable and carbon free technology. We started to see its initial power source in Europe to pump water and grind grain. Now on days the wind power industry spreads around the globe. Europe has shown a big interest in such as renewable source becoming the leader

in wind power. China started to invest on wind power and claims that it is possible to generate 250 GW by the year 2020.

- **Photovoltaic cell is** 100% renewable can be used in large concentration like California has shown an investment of many acres. Some countries have invested on PVs to achieve economies of scale, Germany been on the lead, the USA and Japan. The production of PVs in these three nations will contribute to drop prices down and be more available to the consumer around the globe.
- **Geothermal Power** is a renewable source of energy that exists under us and is generated by decaying radioactive isotopes within the Earth's mantle. Geothermal active areas can increase dramatically. Electricity generation mainly involves conventional steam turbines which operate at a minimum of 150 degrees Celsius. It is almost impossible to produce and transform energy without emitting some amount of carbon dioxide. But if it is combining with solar power or others it will be true 100% renewable.
- **Wave and Tide Power** The UK, Portugal, Scotland, and Norway are the countries investing in this type of clean energy generating enough electricity to small cities. There are a lot of wave and tide opportunities around the glove like Canada, China, Hawaii and many others which governments need to invest as opportunities to produce carbon free electricity.
- **Anaerobic Digestion Power** One solution to take care of two problems at the same time is to process waste and turn them into electricity. The process, wet waste comprising dung or sewage is transformed into slurry with about 95% water content. This mixture is fed to a sealed digester where the temperature can be controlled. The digestion process involves the breakdown of bacteria of organic material into sugars and then into various acids. These decompose to produce the final gas. Germany with 1500 small farms- based digestion plants, and Demark are among the leaders. The process requires various treatments but the final product can benefit cities from building landfills, it can produce biofuel another alternative for automobile source of fuel, and can feed gas engine and turn it into electricity.
- **Solid oxide fuel cell** is expected to have the widest range of applications. For large industries, commercial, and domestic usage generating electricity and heat.

It is fuel by natural gas. Its main manufacture is in the USA and its applications on large scale in Netherlands.

There are others types of green power but are categorized at a **small scale** these are:

- **Photovoltaic cells** there are various types available on the market for commercial, residential, and industrial use. Monocrystalline made from Monocrystalline silicon substrate, has relatively higher efficiency than polycrystalline or amorphous cell, Polycrystalline made from polycrystalline silicon substrate with square shape, and amorphous cells are made with layer of thin film amorphous silicon deposited onto a glass surface.
- **Micro-hydro** this type of generator works best for small communities in third world countries because of the unavailability and accessibility to remote areas.
- **Small scale wind turbine** most of small systems have a direct-drive permanent magnet generator which limits mechanical transmission losses. The most common and reliable are with horizontal axis. Some of the disadvantages are: It needs high winds, stronger foundation support, not suitable for wind changes.
- **Phosphoric acid fuel cell** it employs a phosphoric acid proton conducting electrolyte and platinum or platinum-rhodium electrodes and uses liquid electrolyte. This technology is popular in Japan. The largest installation to date for Tokyo had an output of 11 megawatts until expired. It is likely that its future lies in stationary systems.
- **Alkaline fuel cell** this type of energy was use d in the Apollo spacecraft program. It employs an alkaline electrolyte such as potassium hydroxide set between nickel and precious metal electrodes. Its operating temperatures are about 70 degrees Celsius. Can be use for small usage as an alternative for small jobs.

Fuel alternatives for **vehicles** consumption are the followings but not limited to:

- **Fuel cells there are** many types of fuel cells available, like Hydrogen which consumes hydrogen and others like, molten carbonate fuel cell, tubular solid oxide fuel cell, and planar solid oxide fuel cell. They need to be study and tested as alternative fuel for automobiles.

- **Bioenergy** most commonly used in Europe is a renewable energy made available from materials derived from biological sources. We can obtain biomass fuels from wood, wood waste, manure, sugar cane, corn and others.
- **Microgeneration and combined heat power**
- **Electric cars** produce zero carbon dioxide emissions. New battery technology gives full function to electric cars of 90 to 130 miles before it needs to be charge again.

6.7 Twenty First Century Master tools

Now on days architects depend from the latest technology to achieve what was impossible to achieve in previous times. Technology is definitely the primary tool for designers because with it we understand the capabilities of construction materials and products and its limitations. We often test materials to evaluate its thermal capabilities to transmit or repel heat, we look at fireproof materials to protect us from fire accidents, we look at material to achieve good acoustical environments, and so forth.

Some of the new challenges now on days are how materials can reduce the carbon production starting from their manufacturing up to the installation without spilling or reducing the trail of carbon monoxide a long the way. So in fact, we can say that green technology is the safest way to accomplish our goals and the best way to evaluate if a technology is appropriate or not is to look at its technical specifications, scientific approaches, and if it is offered at study cases to evaluate the specific functions of the merging technology.

6.8 The Architect's role

Architects need to rethink the conventional approach of design: we just don't need to design something functional, esthetic, structural stable according to codes. But we need to be more sensitive to our surroundings, to the environment, and to provide healthier buildings environments that have a little impact or no impact at all into our

environment. This is another responsibility that we have to add on besides just making buildings work for the client. We have a responsibility primarily to the environment and to the client as well.

Architects worry about the esthetics of green buildings to be lack of that visual look that makes building attractive. So this is the responsibility now on days to make things work, appealing to our eyes and primarily responsibly to the environment. Creativity does not end with sustainability, is where starts.

This are the new challenges that now architects face on. We cannot afford to think in a square box and forget that buildings do not contribute to ecological effects we are facing on climate change.

So let’s be responsibly intelligent and our creativeness will start facing these new challenges that has been added on to us because as architects we can take the lead in this green environmental revolution, and if we want to start, we need to rethink the choices we make in selecting environmental friendly materials.

7. GREEN MATERIALS

7.1 What are green materials?

Green materials are materials that use natural resources in a responsible way. They work on a cycle from production manufacturing, to consumer and proper dispose of the material. Green materials are natural, organic, and nontoxic therefore supports healthy environments.

Green building materials help in a responsible way to provide indoor air quality because of the way they were processed.

According to Ross Spiegel and Dru Meadows and their book “Green Building Materials”, to select a green product goes through a selection process step:

- Identify material categories
- Identify building material options
- Gather technical information
- Review submitted information for completeness
- Evaluate materials
- Select and document choice

Once the product is selected there are considerations for quality, performance, aesthetics and cost of each and it is added to the green list.
Spiegel also mentions that green products follow certain standards for qualification:

- E1971 Standard guide for stewardship for the cleaning of commercial and institutional buildings
- E1991 Standard guide for environmental life cycle assessment of building material products
- E2114 Standard terminology for sustainability relative to the performance of buildings
- E2129 Standard Terminology for data collection for sustainability assessment of building products (Spiegel).

7.2 Green Products from the Green Specification division

There is lot of help available about online and books to inform designers about the new responsible approaches in material searching. BuildingGreen.com offers a green specification guideline and product list as follows:

01: General Requirements

02: Existing Conditions

03: Concrete

04: Masonry

05: Metals

06: Wood, Plastics, and Composites

07: Thermal and Moisture Protection

08: Openings

09: Finishes

10: Specialties

11: Equipment

12: Furnishings

13: Special Construction

14: Conveying Equipment

22: Plumbing

23: Heating, Ventilating, and Air Conditioning (HVAC)

26: Electrical

27: Communications

28: Electronic Safety and Security

31: Earthwork

32: Exterior Improvement

33: Utilities

34: Transportation

35: Waterway and Marine Construction

42: Process Heating, Cooling, and Drying Equipment

44: Pollution control Equipment

This information is very valuable because designer need to get inform about specifics of products but also how to minimize labor, transportation, which will add to the carbon footprint in the process of building green. This paper will not get in to every green product available in the green market and look at its specifications in detail but rather inform to others of the most ecological friendly products and point out that green technology has set its foundation and that there are many products that offer good alternatives to switch to. There are many technologies out there but green technology is the most friendly and appropriate to reduce carbon spill.

If we look at construction materials and their manufactures we will find out that the ones that have a big ecological impact are the maker of Portland cement and its products so let's just look at alternatives for cement.

According to News brief from Environmental Building News there is "New Energy Performance Indicator for Cement Plants".
"Even with flyash and other cement-reducing additives, Portland cement is still required to make concrete for most projects. Nevertheless, now there might be a way to specify that the cement comes from a relatively efficient plant.

The U.S. Environmental Protection Agency (EPA) has announced a program to help increase the energy efficiency of cement plants and recognize the most efficient among them. The Energy Performance Indicator (EPI) for cement plants includes a spreadsheet that computes the efficiency of a facility based on the type and amount of energy it uses and the amount of cement it produces. The tool then compares the plant's efficiency to the national average. EPA classifies plants that score in the top 25% as "energy efficient." The EPI for cement plants was created with technical support from Argonne National Laboratory and the Portland Cement Association." This information tells us that they are not reducing carbon monoxide in the environment, the approach is to make more effective the production of cement, but they are not doing anything to help out with the spill of greenhouse effect. One has to think not only to the benefit of the

manufactures but to look at alternatives to improve the make and actually reduce the spill of carbon monoxide.

There are also other manufactures like TecEco from Australia which offers sustainable approaches in the maker of cement. Tec-cement is an alternative cement product which incorporates magnesia, encourages the use of pozzolans and flyash. It harden more quickly without loosen its strength and captures CO2 in the environment.

Their mission is to reduce greenhouse effects in the process of making eco-cement but also to provide a product that helps absorbed carbon monoxide in the environment. This is what we really need to manufactures to invest in other solutions at the same time testing its products and make available to the public such alternatives with all the specifications.

Tec-Cements are more complex to understand than Enviro and Eco-Cements but like them are relatively low alkali and therefore can be used as a repository for a large range of waste materials some of which can contribute properties to the resulting composites.

The reactive magnesium oxide used in Tec-Cements is currently made from magnesite (a carbonate compound of magnesium) found in abundance. TecEco hope to make Tec-Cement using magnesium from sea water and carbon dioxide produced by power stations.

BuildingGreen.com makes available some products I which the Woodlands, Texas makes available Masonry cement minus the Portland. It uses coal fly ash to replace some of the Portland cement in concrete mixes is standard practice in many places, but the fly ash rarely comprises more than 25% of the cementations materials. On Type-C fly ash for its hydraulic properties. MRT E-Z Joint Masonry cements consist of about 85% fly ash, combined with various additives. In the Atlanta area, where is it produced, MRT E-Z Joint products are cost-competitive with standard masonry cement. As the company expands into additional locations, more projects will have the option of building masonry

walls without the environmental burdens (primarily high embodied energy) of Portland cement.

Making an environmental responsible concrete will be a great thing for the environment and for architects that look for such responsible approaches. We need to join forces with engineers, physicist, and other scientist, to better approach our needs in solving the problem of greenhouse effect.

Next is an example of a contractor that joined forces with designers and engineers whom invented CFMU in order to solve efficiency thermal problems by minimizing the conducting of moisture, air, and heat through the wall. CFMU has high R- values, high recycle content materials, longevity, and reduces noise pollution, with less environmental impact. There are other investors and companies are moving from conventional making products to more responsible ones. These investors in new green technology need our support and from other experts to refine their products to more environmental friendly ones.

8. RESPONSIVE MATERIALS

8.1 Smart Materials

Smart materials are materials that respond internally or externally to certain stimuli in which their properties change because of heat, moisture, magnetic fields, or stress. Scientists have made amazing developments with materials that change the way we perceive our environment. Some materials can change shape or size by adding a little of heat, or change from liquid to solid form. Conventional materials serve one specific purpose and their properties remain static. Science and technology are working closely to introduce materials that not just serve one or many functions but materials that actually adapt to our natural and social environment.

The extent of these new science technologies are enhancing our awareness about smart products in which they transform our physical environment and the way we respond to such. These wide new ranges of product bring new opportunities to anyone that wants innovation and interaction with our surroundings. Not all new products are considered smart but they have new properties that challenge our visual perception.

How this new innovations of materiality came about? The industrial revolution brought new possibilities but at a very rough stage. Indeed we can say that another revolution in materiality came because of the NASA effect as Blaine Brownell points out on his book Transmaterial. Indeed, the aerospace and defense applications broth this exited possibility of materiality. Blaine categorized these new materials in seven applications:

- **Ultraperforming** are materials in which can be stronger, lighter, more durable, and more flexible than their conventional corresponding materials.

- **Multidimensional** materials are those three dimensional collection of flat planes that define space and function.

- **Repurposed** are materials that are use to replace others in conventional used in an application. It offers several benefits such as replacing raw materials with less precious or plentiful ones, less toxicity, waste and the most important point to increase the awareness of our limited resources.

- **Recombinant** materials are combined with different materials in harmony to create a product that performs greater. They are called hybrid materials and some are made of recyclable materials as filler. Another example is reinforced concrete.

- **Intelligent** materials as mentioned earlier are the ones that respond to their environment by some stimuli like heat, humidity, magnetic field, light conditions, and stress.

- **Transformational** materials undergo a physical metamorphosis based on environmental stimuli. Such change can occur automatically or driven by an additional stimuli. Some benefits of transformational materials are: reduce of waste, solar control, illumination benefits, and some interesting visual effects.

- **Interfacial** materials are virtual instruments that control material manufacturing, or physical manifestations of digital fabrications such as digital imaginary within physical objects, and in some cases making the invisible visible (Brownell).

Smart materials performed the followings:

- They respond to the environment
- They respond to a moment in time
- They respond internal rather than external
- Its response is selectively and predictable

- They respond local to particular events

New industries emerge from the outcome of new technologies in respect to materiality. This rapid growth forces technology to search for more and more solutions in respect of smart materials. People need to know about this new era of responsiveness to start utilized them as such. Because once we try them out new opportunities arise. Technologies go through a continuous cycle of evolution as part of natural growth of science. In architecture the use of materials go through long lifecycles all determined by the longevity of such materiality.

Some downsides of new technology, especially in the construction field are that new technology has to be verified by the industry before architects can rationally use them. So when do we can start utilized them? Architects are the ones that make the choice of select them for their design. So there is a risk involved when selecting new smart materials in a selected project in which architects need to know their properties, limitations, possibilities, expansions, and much more. The utilization of smart materials is the gate of virtual explorations. By doing it so there is no risk at all except gaining knowledge about our explorations with smart environments.

8.2 Types of smart materials

There are many materials that are considered smart because they undergo through a physical or visual change. Michelle Addington and Daniel Schodek categorized smart materials according to their physical change in two types to better studying them.

Types A are materials that absorb the input energy and the material itself goes through a physical change such as:

- **Thermochromic** are materials that based on the stimuli heat alter its physical structure at a molecular level. Once change into the new molecular change the structure possesses a different spectral reflectivity changing it's material color. There are two subcategories under thermochromic materials **liquid crystal** and **leuco dyes**. Liquid crystals are generally used for higher applications common

used in thermometers, stress testers, aquarium thermometers, and other applications. Leuco dyes are less precise and commonly used for art applications because their response temperatures cannot be controlled as well as liquid crystals for example battery testes, coffee mugs, plastics toys and others (Addington).

- **Magnetorheological** materials are materials whose rheological properties may be rapidly varied by the application of electric or magnetic fields. The reaction to these stimuli can occur in lapse of milliseconds. Therefore, potentially applicable to structures and devices when a tunable system response is required. When incorporated into an adaptive structural system, they can yield higher variations in the dynamic response of the structure as Qing Sun states on his/her article "An adaptive beam model and dynamic characteristics of Magnetorheological materials".
- **Thermotropic** materials are change by a thermal energy and/or radiation in which its micro-structure through a phase change. Thermotropic polymer may have new possibilities for the development of intelligent sun protection glazing. In comparison to synthetic polymer systems biopolymers offers substantial benefits. (Schneider).
- **Shape memories** are materials that after they go through a physical change, they remember their original shape and return to it when heated. Some applications include shape memory stents, and surgically like tube threaded into arteries that expand on heating to body temperature to allow increased blood flow (Addington).

Type B materials are the materials that does not change in physical conditions but rather transform the energy input to output energy in another form such as:

- **Photovoltaic** generally speaking have input of radiation energy in which it is converted to energy.
- **Thermoelectric thermoelectricity** is produced when you heat one end of a wire; electrons will move to the colder end, carrying electrical charge with them and producing a current. Otherwise, you can apply a current to the wire to carry heat away from a hot section to cooler areas. NASA has used this effect since the 1960s to generate electricity for spacecraft too far away from the sun for solar

cells to operate. The materials first application could be a device for siphoning off electrical power from the heat in automobile exhaust. Eventually, such a device could be used to supplement power from electric and fuel cell engines or provide a conventional vehicle with most of its electricity needs, running everything from its radio to its air conditioner. Scientist envisions materials use in microelectronics. The heat buildup in today's ultrafast microchips is, in particular, a problem in making smaller and faster devices. Tiny patches of the films precisely positioned on microelectronic chips could be used to spot-cool only the components that needs it (Aichele).

- **Piezoelectric** The piezoelectric effect describes the relation between a mechanical stress and an electrical voltage in solids. It is reversible: an applied mechanical stress will generate a voltage and an applied voltage will change the shape of the solid by a small amount. In physics, the piezoelectric effect can be described as the link between electrostatics and mechanics.

  A mechanical stress was applied on crystals such as tourmaline, tourmaline, topaz, quartz, Rochelle salt and cane sugar, electrical charges appeared, and this voltage was proportional to the stress. First applications were piezoelectric ultrasonic transducers and soon swinging quartz for standards of frequency (quartz clocks). An everyday life application example is your car's airbag sensor. The material detects the intensity of the shock and sends an electrical signal which triggers the airbag. The piezoelectric effect occurs only in non conductive materials. Piezoelectric materials can be divided in 2 main groups: crystals and ceramics (Sumitomo)
- **Photoluminescent** materials are materials that accumulate light energy when exposed to natural or artificial light sources**.** Then it gradually releases this energy in the form of visible light in the dark. These materials are made of Aluminum oxide in combination with other oxide and rare earth elements (Windle).
- **Electrostrictive** is the application of a current which alters the inter-atomic distance through polarization changing the shape of the material (Ludlow).

8.3 Properties of materials

Materials are known by their properties. They could be intrinsic and extrinsic. An intrinsic is determined by the molecular structure of the material. For example, strength is related to the interatomic forces within the molecule in combination with the intermolecular forces: the higher the forces, the greater the strength and hardness of such. The change of properties produced either by an alteration of the composition or by the microstructure of the material. All energy stimuli are the result of difference. A difference in temperature produces heat; a difference in pressure produces mechanical work. Properties are what mediate that difference.

This is why the properties of materials determine how a material will behave when subjected to a mechanical or load stimuli. Mechanical properties are described by specific measures. Strength is a measure of the materials resistance to forces. Stiffness is a measure of the stress deformation characteristics of the material. Electrical properties and important factor to measure whether the material has conductivity or resistivity (Ludlow). A thermal property measures the materials thermal conductivity and chemical properties measure materials reactivity, valence and solubility.

8.4 Nanotechnology

According to Center for responsible nanotechnology, nanotechnology is the engineering of functional systems at one to one hundred billionths of a meter. It is ability to construct items from the very bottom up, using now on days technology to make high performance products.

It started to conceptualize as early 1959 by the physicist Richard Feynman. “I want to build a billion tiny factories, models of each other, which are manufacturing simultaneously… The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is no an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big”.

According to Mike Roco of the U.S. National Nanotechnology initiative illustrates four generations of nanotechnology development:

1. **Passive nanostructures** are the current era in which materials are to perform one task.
    a. Dispersed and contact nanostructures like aerosols, colloids.
    b. Products incorporating nanostructures like coatings, nanoparticle reinforced composites, nanostructured metals, polymers, and ceramics.
2. **Active nanostructures** in which we are just entering to perform multitask.
    a. Bio-active for health effects meaning for drugs
    b. Physico-chemical active for transistors, amplifiers, actuators, adaptive structures.
3. **Systems of nanosystems** meant for 3D networking and new hierarchical architectures, robotics, evolutionary.
4. **Molecular nanosystems** meant for molecular devices by design, atomic design, emerging functions.

New technology has its down sides one down side of nanotechnology is because of the scale. As of today's the risks are nanoparticle toxicity because of biological warfare and it can create health risk if it is not handled properly. This and much more is thing that needs to be address, but they offer different problems therefore required new solutions.

8.4.1 Application on materiality

Applications of nanotechnology for smart buildings are becoming more acceptable now on days. It does not just offers economic opportunities and the industry but the most important to improve human conditions, and environmental health. It has slowly introduced with the use of nanocoatings for insulating, self cleaning, UV protection, corrosion resistance, and waterproofing. Many of these coatings incorporate titanium dioxide nanoparticles to make surfaces not only self-cleaning but also depolluting, able to remove pollutants from the surrounding atmosphere as Dr George Elvin asserts on his paper nanotechnology for green building.

The demand for nanotechnology is increasing everyday especially in building materials and its current applications.

- **Insulation**
  - Aerogel is an ultra-low density solid, a gel in which the liquid component has been replaced with gas. It is formed by 5% solid and 95% air in which it becomes so light because of its composition. As an insulator, aerogel panels can offer an R-value of R-28. it can be applied in windows, skylights, and translucent wall panels.
  - Thin-film insulation is nanocoatings applied in thin films to glass and fabrics. For example Masa Shade Curtains contains a thin film coating of stainless steel in which absorbs infrared rays blocking sunlight. Another product is the Nansulate Home Protect this coating application can provide corrosion, thermal and mold protection. Another one is HPC HiPer Coat Extreme meant for heat management, corrosion resistance, friction reduction, color appearance. NanoPore is another thermal insulation porous solid composed with silica, titanium and/or carbon in a 3-D can reach an R-value of R-40/inch.
- **Coatings**
  - Self-cleaning coatings are photocatalytic coatings containing titanium dioxide at a nanoscale. These particles initiate photocatalysis, a process by which dirt is broken down by exposure to the sun's ultraviolet rays and washed away by rain. It can transform any surface into anti-bacterial, anti-fungal, anti-fog, mold free surface in which purify the surrounding air where it was applied.
- **Adhesives**
  - Nanoglue is a method to bond materials that don't normally stick together. These materials are also self-cleaning, leave no residue, and are bio-compatible. There is another type of glue that imitates a gecko's foot by aligned multiwall carbon nanotube setae and spatulas. It can stick and unstuck repeatedly.

- **Solar energy**
  - Organic solar cells are not as efficient as silicon cells, but they can supply the power for small application like MP3 and others.
- **Lighting**
  - Organic light emitting diodes (OLED), are films of organic molecules that create light with the application of electricity. OLDEs emit light in a similar manner to LEDs, through a process called electrophosphorescence.

  There are several types of OLEDs:

  - Passive-matrix OLED cell phones, PDAs, MP3s
  - Active-matrix OLED computer monitors, large-screen TVs, and electronic signs or billboards
  - Transparent OLED for heads-up displays
  - Top-emitting OLED
  - Foldable OLED
  - White OLED

- **Air and water filtration** Nano enhanced water works at the atomic level. The chemical properties of basic elements tend to be different and easier to manipulate at the molecular level. Applications are going into the water treatment industry. There is a SpiraSep membrane filter used in Lee County, Florida, to collect rainwater from landfill leachate, the dirtiest of all waters.
- **Structural materials**

  Material strength is critical in a building, defining its structure, longevity, and resistance to gravity, wind, earthquake and other loads that act to tear it down strength is equally important in non-structural components like windows and doors for security and durability. A load-bearing structural material's strength/weight ratio is particularly important because stronger.
  - **Concrete** is the world's most widely used manufactured material. The merge of nanotechnology is leading to new cements, concretes, admixtures, low energy cements, nanocomposites, and improve particle

packing. When adding nanoparticles improves its durability through physical and chemical interactions such as pore filing, example, Nanocrete by EMACO.

- **Steel** is a major component in reinforced concrete construction as well as a primary construction material. Conventional steel has yield strength of 60 ksi grades 60 and MMFX recently received ASTM specifications of 100 ksi grade 100. Now engineers can design structures with less congestion based on the new yield strength.
- **Wood** nanotechnology is fundamentally changing the way materials are produced in the future. The ability to synthesize nanoscale building block with precisely controlled size and composition and then assemble them into larger structures with unique properties and functions will revolutionize the materials producer industries. These products will have strength properties now only seen with carbon-based composites materials. These new hyper performance bioproducts will be capable of longer service lives in severe moisture environments. Enhancements to existing uses will include development of resin-free biocomposites or wood-plastic composites having enhanced strength and serviceability because of nanoenhanced and nanomanipulated fiber-to fiber and fiber to plastic bonding. Nanotechnology will allow the development of intelligent wood and biocomposite products with an array of nanosensors to measure forces, loads, moisture levels, temperature, pressure, and chemical emissions.

- **Non-structural materials**
  - Glass- In this technology, matts, membranes and nonwoven textiles formed from fibers can reversibly change color depending on the wavelength of light they are exposed to. Nanotechnology enables glass to reach undreamed properties by using nanocoatings, films, gels and other combinations to exceed its properties. Thermochromic laminated glazing enables to regulate daylight automatically adapting dynamically to the continuously changing climatic conditions, aids in reducing the energy needs of a building and

providing thermal comfort. Novel Fire-Resistant glazing focuses in safety glazing with a multifunctional range of glass products.
SageGlass electrochromic glass switches from clear to darkly tint at the push of a button reducing undesirable effects such as fading, glare and excessive heat without losing views and connection to the outdoors.

8.5 Elements and control systems

Control systems are devices to manage, command, direct or regulate the behavior of materials or systems. The most common ones are:

- Sequential controls or logic controllers respond to switches, light sensors, pressure switches and others.
- Linear controls use linear negative feedback to produce a control signal. The output from a linear control system into the controlled process may be in the form of a directly variable signal.
- Proportional control manipulates the control by open or close gradually depending of the feedback.

Many of smart materials can adopt different forms and serve many purposes without having sensors or controls to trig them; but they do so within the material itself. So these behaviors are almost identical to what we classically defined as sensors, transducers and actuators. The intended purpose of smart materials is to assembling them to serve as sensors, transducers or actuators to produce an interconnected whole system that can be activated or controlled to produce an overall intended action or to process desired response characteristics as Michelle Addington asserts on her book Smart Materials and Technologies.

It is obvious that sensors, transducer, and actuators are tools of more interest for the engineer nevertheless architects and designers started to integrate them in such a way to deliver a specific use and connection between materiality and the users.

- **Sensor** is a device that measures a physical quantity and converts it into a signal in which the observer reads it. A sensor always interacts with the stimulus field.

There are a wide range of sensors available but we will be looking at sensors that may be useful in the creation of smart environments:

- **Chemical sensors** this type of sensors are meant to check for oxygen, ion, pH glass electrodes, redox electrodes, carbon monoxide and a wide variety of gases and its chemical components.
- **Magnetic sensors** do not directly measure the physical property of interest. Magnetic sensors, on the other hand, detect changes, or disturbances, in magnetic fields that have been created or modified, and from them derive information on properties such as direction, presence, rotation, angle, or electrical current. The output signal of these sensors requires some signal processing for translation into the desired parameter. Although magnetic detectors are somewhat more difficult to use, they do provide accurate and reliable data without physical contact.
- **Electromagnetic sensors** measures the spatial distribution of electromagnetic field EMF strength surrounding operating equipment
- **Mechanical sensors** for measurement of mechanical parameters: acceleration, position, pressure, knock, rotation, etc
- **Thermal sensors** detect changes in the thermal environment which include thermometers, thermocouples, thermistors and others.
- **Acoustic sensors** sound proofing and acoustic materials are used to attenuate, deaden, or control sound and noise levels from machinery and other sources for environmental amelioration and regulatory compliance. It helps design rooms, buildings theaters, churches, courthouses and schools by paying attention to the reflection of sound waves.
- **Biological sensors** typically a sensor with associated components that can convert the sensor's raw signal to usual be information on a biological organism. These may be stand alone instruments or a sensor module for incorporation in a more comprehensive system.
- **Air velocity flow sensors** measure air velocity or volume flow using insertion probes or capture hoods.
- **Humidity sensors** measure the absolute humidity, relative humidity, or dew point in air.

- **Touch sensors** touch-sensitive and tactile operate by touching or pressing to make a connection. Touch-sensitive switches are touch-operated switches that do not have moving parts, while tactile switches are electromechanical and provide tactile feedback.
- **Position sensors** one type of position sensor is the hall effect position sensor in which are noncontact devices that function via an electrical potential (for example, a voltage) that is developed across an axis perpendicular to an applied current flow and the presence of a magnetic field. Another type of position sensor is the magnetostrictive position sensor in which is non-contact linear position sensors that use the momentary interaction of two magnetic fields to produce a strain pulse that moves along a waveguide. One field is from a magnet that moves along the outside of the waveguide. The other field is from the waveguide itself.
- **Proximity sensors** may be contact or non-contact. Proximity sensors are of many technology types:
    - **Eddy current** sensor electrical current are generated in a conductive material by an induced magnetic field. Interruptions in the flow of the electric currents (eddy currents)
    - **Inductive** are identical in configuration to the variable reluctance type and generate the same type of signal. However inductive pickoff coils have no internal permanent magnet and rely on external magnetic field fluctuations, such as a rotating permanent magnet in order to generate signal pulse.
    - **Photoelectric** devices are used to detect various materials at long range, using a beam of light. They detect either the presence or absence of light and use this information to read the data from the output transistor.
    - **Ultrasonic** sensor emits an ultrasonic pulse, which is reflected by surface and returned to sensor. Speed can be determined by measuring frequency difference.
    - **Hall Effect** sensing element is a semiconductor device which, when electrical current is sent through it, will generate an electrical

voltage proportional to the magnitude of a magnetic field flowing perpendicular to the surface of the semiconductor.

        - **Captive** utilize the face or surface of the sensor as one plate of a capacitor and the surface of a conductive or dielectric target object as the other.
    - **Motion sensors** are usually used in security purposes. These types are based on the use of infrared technologies, and thus primarily detect heat differential in moving objects.

- **Transducers** are devices in which converts mechanical or other measurable phenomenon into an electrical one or vice versa. Examples of transducers are microphones, loudspeakers. From this material, we know that it is important to chose transducers that have the desired frequency, bandwidth, and focusing to optimize inspection capability. Most often the transducer is chosen either to enhance the sensitivity or resolution of the system (NDT).
    - **Contact transducers** are used for direct contact inspections, and are generally hand manipulated. They have elements protected in a rugged casing to withstand sliding contact with a variety of materials.
    - **Immersion transducers** do not contact the component. These transducers are designed to operate in a liquid environment and all connections are watertight. Immersion transducers usually have an impedance matching layer that helps to get more sound energy into the water and, into the component being inspected.
    - **Dual element transducers** contain two independently operated elements in a single housing. On of the elements transmits and the other receives the ultrasonic signal. Dual element transducers are especially where reflectors well suited for making measurements in applications where reflectors are very near the transducer.
    - **Delay line transducer** provides versatility with a variety of replaceable options. They are design for use in applications such as high precision thickness gauging of thin materials and delamination check in composite

materials. They are also useful in high temperature measurement applications since the delay line provides some insulation to the piezoelectric element from the heat.

  - **Angle beam transducers** are used to introduce a refracted shear wave into the test material. The angle sound path allows the sound beam to be reflected from the back wall to improve detect ability of flaws in and around welded areas. They are also used to generate surface waves for use in detecting defects on the surface of a component.

- **Actuators** are mechanisms for activating process control equipment by use of pneumatic, hydraulic, or electronic signals. It controls the output into an action to the signal controlling element.
  - **Manual actuators** employ levers, gears, or wheels to facilitate movement while an automatic actuator has an external power source to provide the force and motion to operate a valve remotely or automatically.
  - **Electromechanical** exploits the mutual attraction of soft ferrous materials in a magnetic field. The device has one coil which provides the field energy and the energy to be transformed. The attractive force is unidirectional so a return device of some type is needed; often a spring, relays or solenoids based on this principle are widely used in cars to switch a range of electrical equipment with a current demand of more than about 10 amps.
  - **Hydraulic and pneumatic actuators** are fluid quarter-turn actuators, often simple devices with a minimum of mechanical parts, used on linear or quarter-turn valves. Sufficient air pressure acts on a piston to provide in a linear motion for gate or globe valves.
  - **Electric actuators** have a motor drive that provides to operate. It can be multi-turn actuators and quarter-turn actuators.

9. RESPONSIVE SKINS

9.1 Building envelope

Building skins are partitions walls that defines interior from exterior environments. Fluctuations in weather conditions affect the overall indoor environments depending on how the building skins are design. Building skins should adjust to weather conditions, changes in people needs and to the natural environment. Smart skins are the result of integration of external conditions as stimulus to the skin envelope that senses fluctuation of the outdoor environment through smart sensors and delivers the message through the actuators in which modifies the indoor environments. But how we came about to such innovation on smart environments?

9.2 History

Man has built shelters from sun, rain, wind and heat. The first building skins were orienting towards fulfilling specific functions depending on geographical location. Later on, partitions were built in different types of construction methods and construction materials. Some of them were pure esthetic and some of them served specific purposes. Openings through the skins were small as possible to prevent energy loss and to maximize protection. Rooms were dark and had no ventilation to the indoor environment so the necessity of introduce more ventilation and lighting but keeping the necessary protection from the sun and heat as well as from intruders became more challenging. Except houses and structures remain with small openings for a very long time until the industrial revolution came about.

The introduction of better construction materials revolutionized the way we used to perceive our built environment.

Iron and glass opened up new opportunities in the construction field. Massive and decorative walls cease to exist because of these new metal structures carrying same or more loads than stones. Designers started to manipulate lighting into the buildings as a connection to the exterior environment.

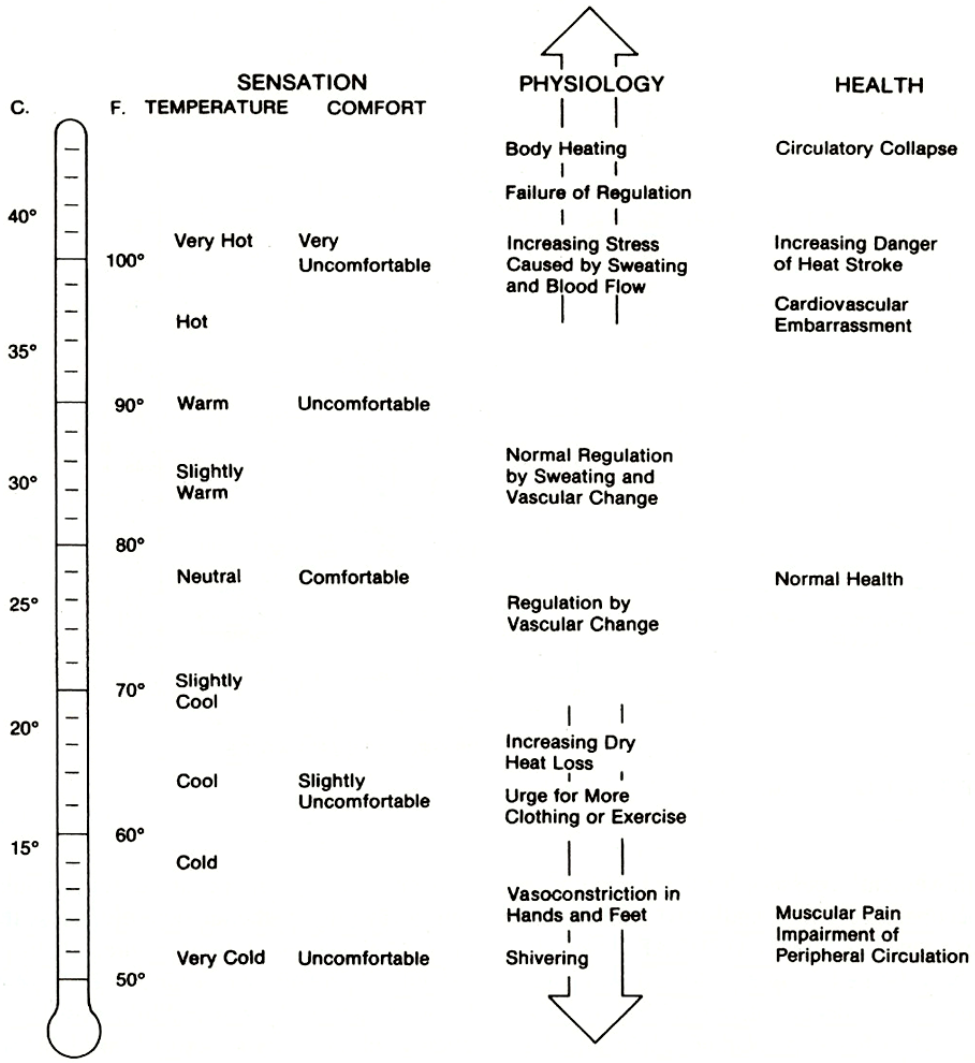
The growing independence of the building skin from its structural function leads of necessity to its complete separation from the load-bearing structure (Schittich). The first skins that are fully freed from the load bearing structure were called curtain walls. Glassing facades in high-rise buildings began to appear but new problems started to rise. These new problems like thermal control, water tight, air tight, moisture control were the new challenges that architects needed to address base on the joints of different materials and other factors. So let's look at the most common problems now on days.

9.3 Thermal control

Thermal and atmospheric conditions in buildings are usually controlled in order to provide health and comfort to occupants through HVAC systems. The feeling of comfort is entirely based on the sense of organs like eyes, ears, nose, tactile up to the brain. Thermal comfort I is achieved when all our sensors agree to such. The comfort mode is affected by two types of heat, Sensible heat is when temperature is added or subtracted and latent heat is the heat changed from solid to liquid or liquid to gas. There is a heat balance that we all seek for. There are some major factors that affect maintaining a thermal equilibrium.

- Air temperature
- Humidity
- Mean radiant temperature
- Clothing and variations of all

The following is a comfort chart that helps us understand at what temperature level our body feels comfort and discomfort.



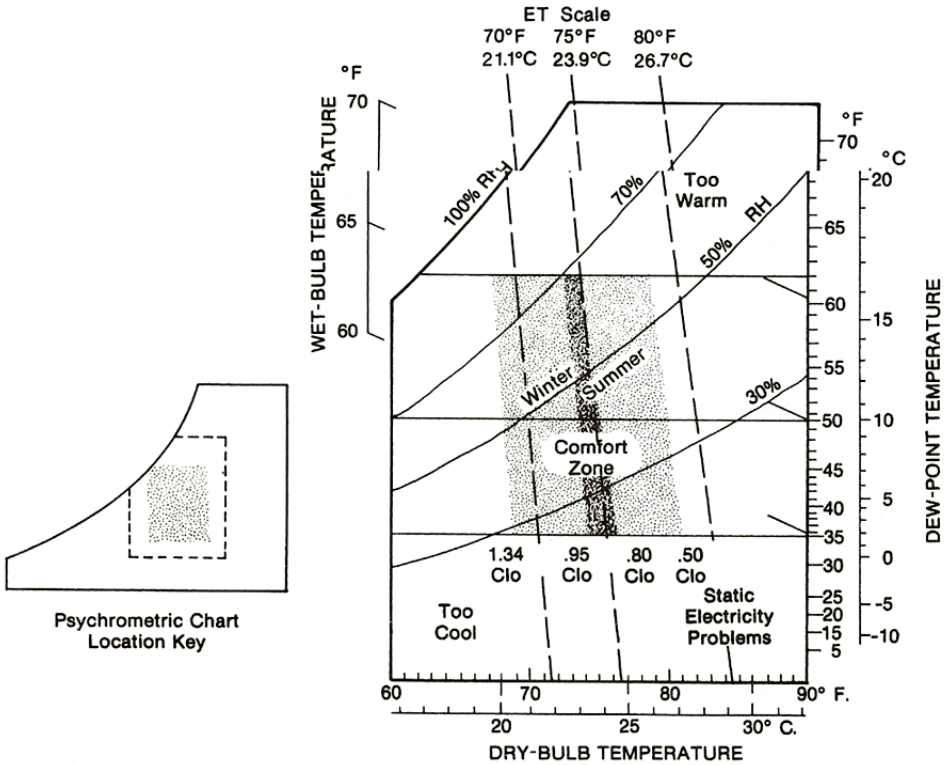
Source: The Building Environment 3rd edition Pg 23

The ET scale correlated to physiological reactions, comfort, and health.

The comfort chart is useful for determining design condition to be met by a building envelope and its heating, ventilation, and air conditioning equipment. But there are variables to be look at that affects the thermo comfort individually. For example, men generally feel warmer than women on initial exposure to a given temperature but later feel cooler approaching women's thermal sensations after 1 to 2 hours in the environment (Schittich 27). Comfort conditions seem independent of the time of the day or night. Different countries may have different comfort standards as a result of particular climate extremes. Clothing customs may affect thermal comfort. At the end there is no one set of conditions that will satisfy all occupants but the designer has to provide a range of comfort standard conditions to begin with.

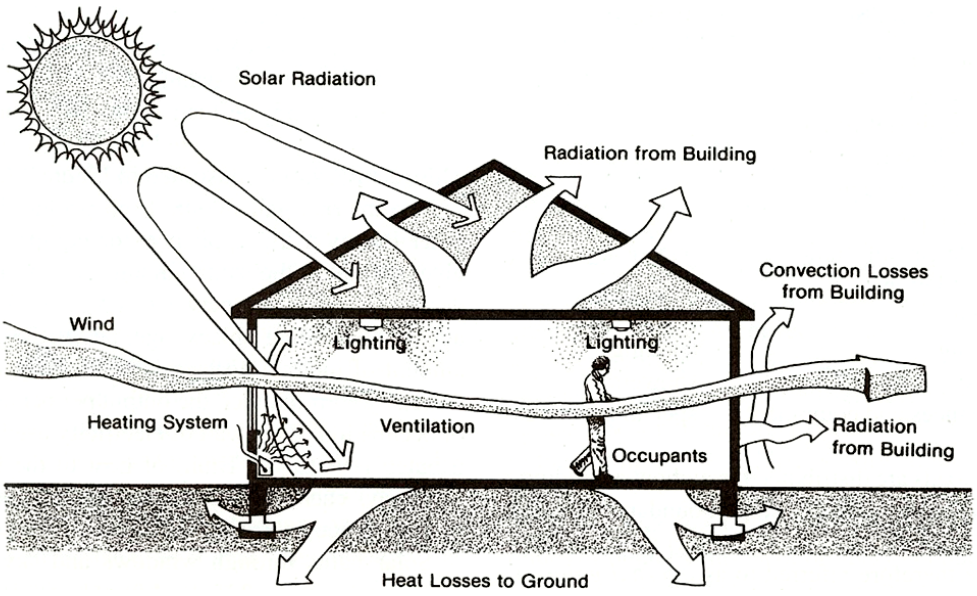
The principles of thermodynamic help us understand the science of thermal transfer. But it is easy to understand that heat transfer from higher temperature to lower temperature. Heat is absorbed by or transmitted through a building envelope by radiation, convection, and conduction. Construction materials have different R values that distinguished them from others, the higher the value the better the insulation of heat.

Architects use graphic and visual models to analyze the transfer of heat into a building. But it also tells them how fast heat is entering or living the building. These should be utilized as much as possible to passively maintain an acceptable interior climate with minimum additional energy use.



Source: The Building Environment 3rd edition Pg 24

The comfort chart.



Source: The Building Environment 3rd edition Pg 64

Heat gains and losses in buildings

9.4 Water tight

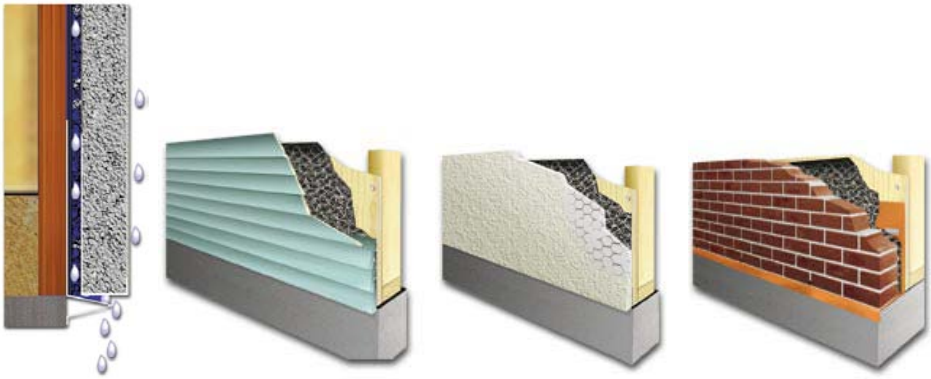
One major factor that affects the interior environment is how building materials repel or absorbed water. Water alters some materials causing them to swell or expand, another can transport pollutants or create mold which will affect directly the indoor air quality. Water can enter walls from many sources like rainy days, snow, even sprinklers from landscape irrigations.

We have learned a lot from previous technologies and construction methods to better of the intrusion of water into buildings. The increase of technology has allowed us to introduce additional components to building enclosures and manage water properly. According to Linda Brock and her book “Designing the exterior wall” there are four basic systems to manage water filtration.

- **Face-sealed barrier walls** are meant to stop water right from the cladding or exterior finishes. One true barrier against water penetration is concrete.
- **Internal drainage plane walls** are secondary defense to stop water that passes through the cladding and drain any condensed vapor. This method is more effective than face-sealed barrier wall.

- **Drainage cavity walls** work between the cladding face and the drainage plane. This method works on stone veneers or other cladding method on exterior walls.
- **Pressure equalized rain screen wall** is a drainage cavity wall designed so that the air pressure of the cavity behind the cladding is similar to the exterior air pressure.

Source: www.deltadry.com

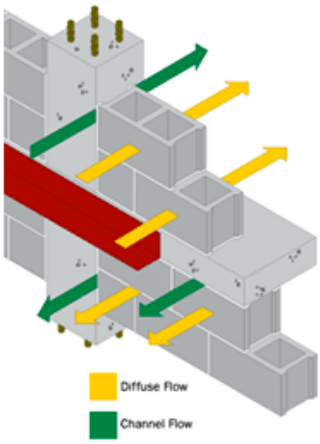


Source: www.stucoflex.com

9.5 Air Tight

Air movement in buildings produces positive pressures on the windward side and negative infiltration of the leeward side. According to Linda Brock the natural phenomenon caused by warm air rising in a building is called the chimney or stack effect. Generally, negative pressure is desired in heating climates and positive pressure in

cooling climates. Controlling the flow of air to a point of zero air movement into the building is desired because it reduces leakage of conditioned air meaning mechanical systems need to operate longer, meaning higher energy consumption. Controlling the flow of air into buildings also prevents airborne pollutants, decrease in humidification needs, condensation problems, and prevent mold and bad indoor quality air. Henry Company is a manufactured company that provides building systems to improve superior building performance. According to henry.com website uncontrolled air movement in a building causes differential air flow caused by the stack effect.

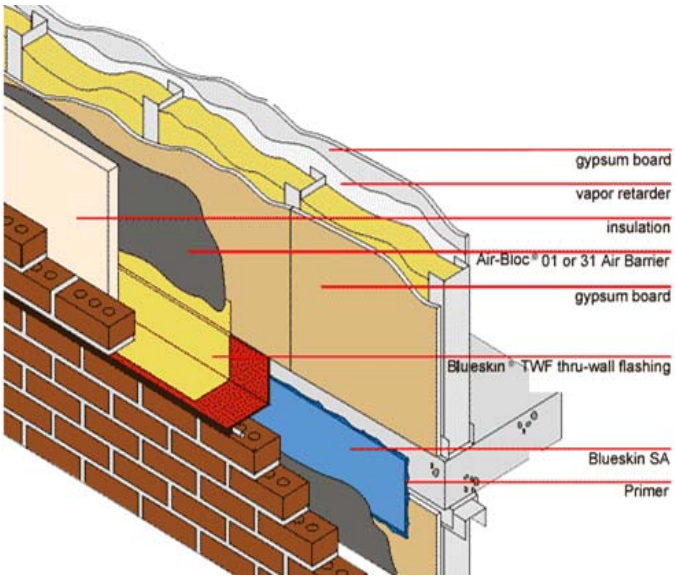


Source: www.henry.com

Henry categorized air barrier membranes in two types:

1. **Vapor permeable Air Barrier** in which resist air leakage and rain penetration through the building envelope. The fact that this is vapor permeable they allow the diffusion of moisture in the form of vapor making it non vapor barrier.
2. **Non-permeable Air Barrier** resists air leakage and rain penetration and vapor diffusion which makes it air/vapor barrier.

The following is atypical application of some of Henry's products to control air flow into buildings on cladding walls.



Source: stucoflex.com

According to the Journal of Building Enclosure Design Winter 07 issue, incorporating air barrier membrane system will depend on a number of factors:

- Seasonal weather conditions from exterior to interior spaces.
- Wall construction types including connections, deflection and building movement.
- Cladding (rain screen) system, location of secondary rain barrier.
- Cladding anchors and/or brick ties, wall openings and other penetrations.
- Location and placement of thermal insulation

The article focuses on two basic type of air barrier:

- **Fluid-applied air barrier membrane system** provides a complete monolithic uniform coating over the intended substrates. They are applied to a specific wet film thickness specified by the manufacturer, which serves a number of issues including; long term durability, elongation/recovery, crack bridging, water resistance, gasket effect (self healing), and the ability to effectively seal rough surfaces.
- **Self-adhered sheet air barrier** is an alternative to fluid-applied membranes. These barriers are categorized as permeable and non-permeable.

Air barrier systems need to be design as a system and considering whether the building has to be permeable or non-permeable depending on the climate.

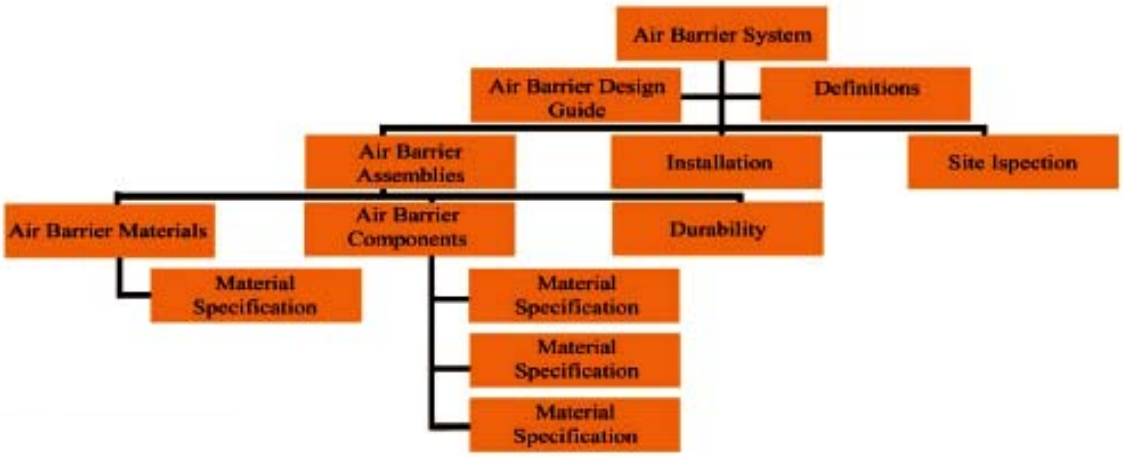
For instance, on hot humid climates the system will include the followings:

1. Exterior cladding
2. air space
3. non-permeable air/vapor barrier over the back up wall
4. and the necessary insulation to the interior

For cold climates the system needs to include the followings:

1. permeable air barrier on sheathing board over steel studs with insulation in the stud cavity
2. an interior vapor retarder and gypsum wall board.

Buildings need to be analyzed as individual projects from the majority in order to understand the aesthetic, performance requirements, climatic conditions and expected design life of the building, selection of materials and the geographical location of the building. The system can be analyzed though mock up to evaluate its performance.
The best way to start developing the best system for the building depending on location is to develop a family tree for air barrier as shown on the following chart as standards for the building enclosure (JBED).



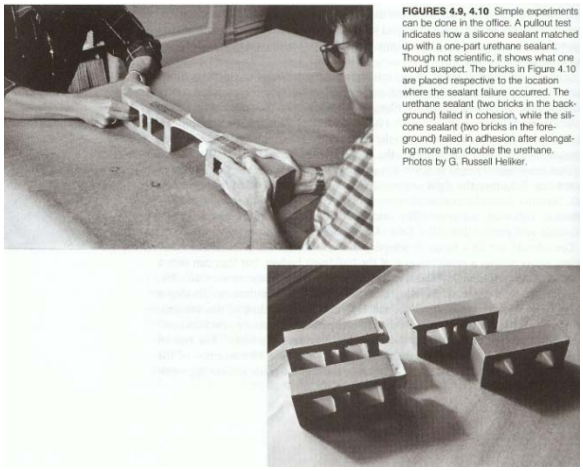
Source: Journal of Building Enclosure Design Winter 07

9.6 Sealing Joints

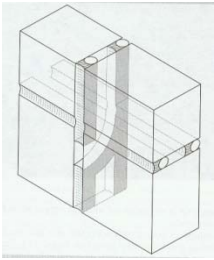
Some of the common problems in cladding walls are that designers don't pay much attention to lateral forces. Cladding or siding materials attached directly to the frame can withstand positive win pressure but when negative pressure is apply to the sidings they fly like paper.

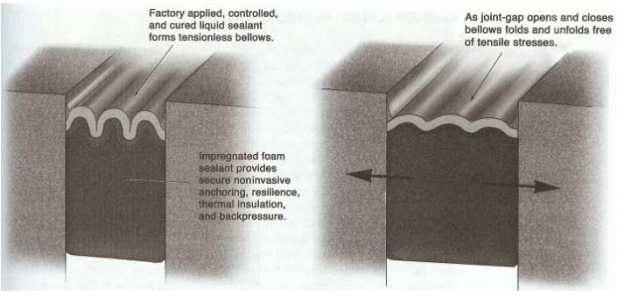
Other common problems when brick veneer or stone is apply are the expansion and contraction of the materials from weather conditions in which affects the joints. These fluctuations cause elastic deformation and creep making the wall vulnerable to water, air, and heat filtrations.

To star addressing this problem the architect needs to identify the locations where there is a change of plane, material change, in which an expansion joint is needed.
Joints have to be sized and properly located as well as choosing proper sealants that allows some elasticity, puncture and vandalism, ultraviolet resistance, and chemical abrasion resistance.



FIGURES 4.9, 4.10 Simple experiments can be done in the office. A pullout test indicates how a silicone sealant matched up with a one-part urethane sealant. Though not scientific, it shows what one would suspect. The bricks in Figure 4.10 are placed respective to the location where the sealant failure occurred. The urethane sealant (two bricks in the background) failed in cohesion, while the silicone sealant (two bricks in the foreground) failed in adhesion after elongating more than double the urethane. Photos by G. Russell Heliker.





Source: Designing The Exterior Wall by Linda Brock

Construction materials need to be chosen carefully because each material has different tolerances when selected for cladding purposes. The architect needs to design lateral support of lightweight cladding for negative and positive pressure (Brock).

9.7 Double Skin

The term of double skin façade varies from country to country. They can be called Active façade, passive façade, double envelope, dynamic façade, ventilated façade, environmental façade, intelligent glass façade, supply air window and more and so its definition. Double skin façade, is constructed of two layers of walls separated by a space for ventilation purposes, preventing radiation getting into the building and much more. The science behind double facades benefit the building in many ways here are some benefits:

- Acoustic insulation
- Thermal insulation during winter and summer
- Night time ventilation
- Energy savings and reduced environmental impacts
- Better protection of the shading or lighting devices
- Reduction of wind pressure effects
- Transparency

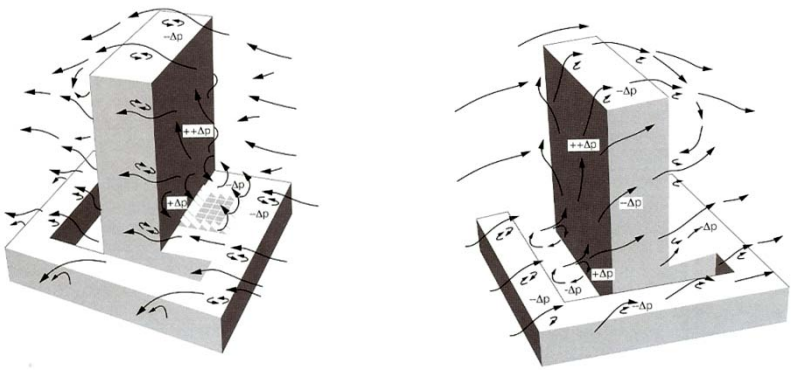
Some disadvantages can be as follow:

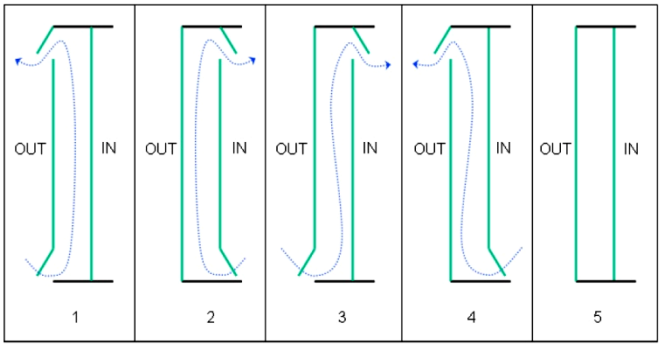
- Higher construction cost
- Reduction of rental office space
- Additional maintenance and operational costs
- Overheating problems
- Increase weight of the structure

According to Harris Poirazis and his article Double Skin Facades a literature review, double skin façade is a system consisting of two wall planes facing each other allowing air flow in between. This ventilation can be natural or mechanically operated. The glass skins can be single or double glazing. Solar properties are the

same as single skin façade. However, because of the double layer a thermal buffer zone is formed which reduces the heat losses and enables passive solar gains. Ventilation in buildings can be achieved by three different methods (Loncour).

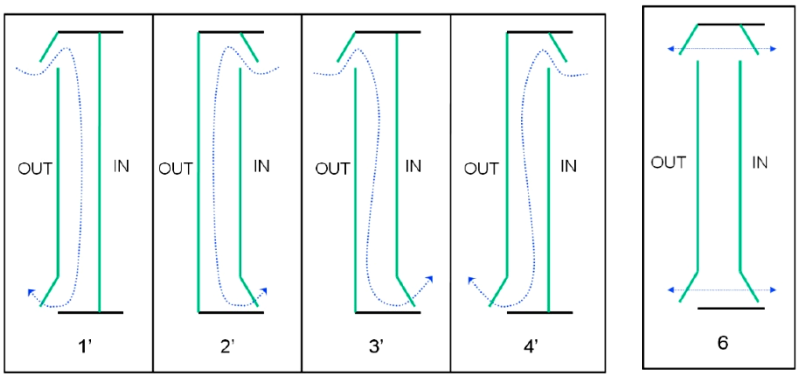
Type of ventilation	Type of facade
Natural	Passive façade
Mechanical	Active façade
Hybrid	Interactive facade



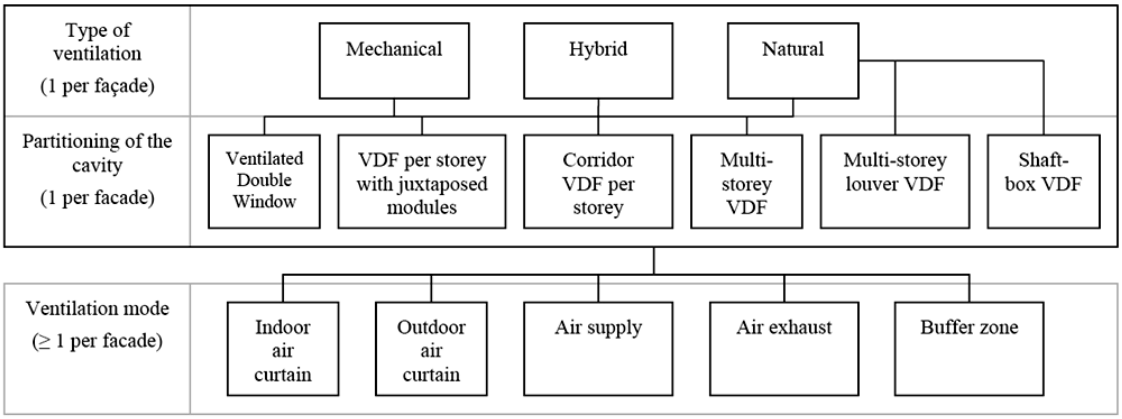


Five main ventilation modes

Source: Ventilated Double Facades pdf online



Variants to the main ventilation modes
Source: Ventilated Double Facades pdf online.



Various concepts of ventilated double facades imaginable by combining the three classificatory criteria
Source: Ventilated Double Façade pdf online.

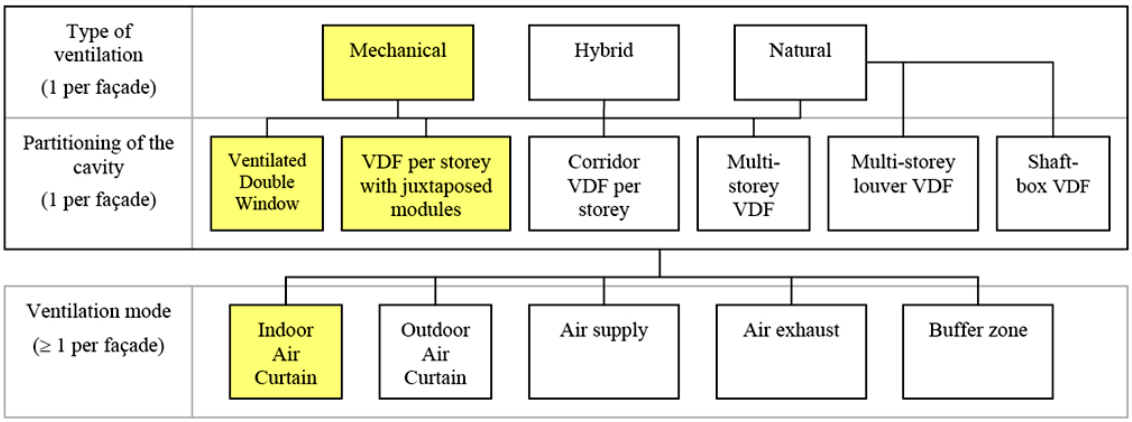


Illustration of the main characteristics of the mechanically ventilated double facades
Source: Ventilated Double Facades pdf online

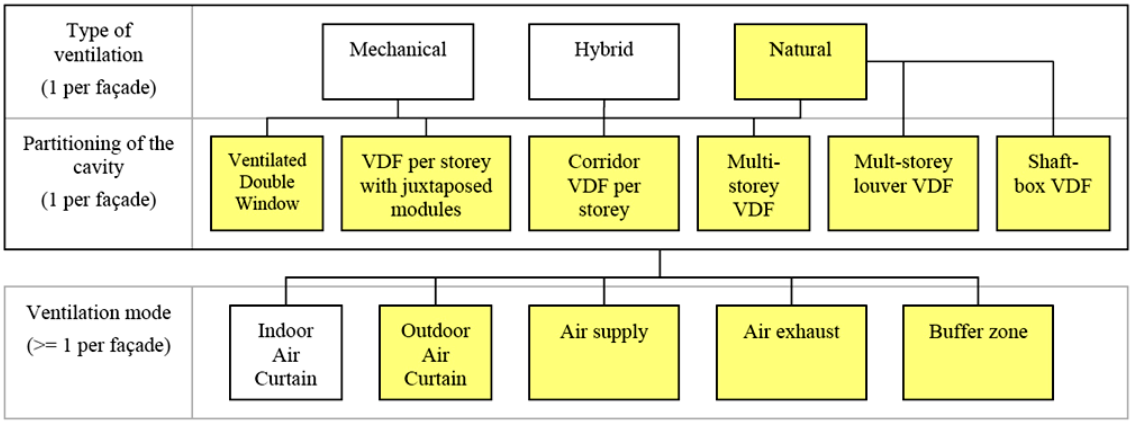
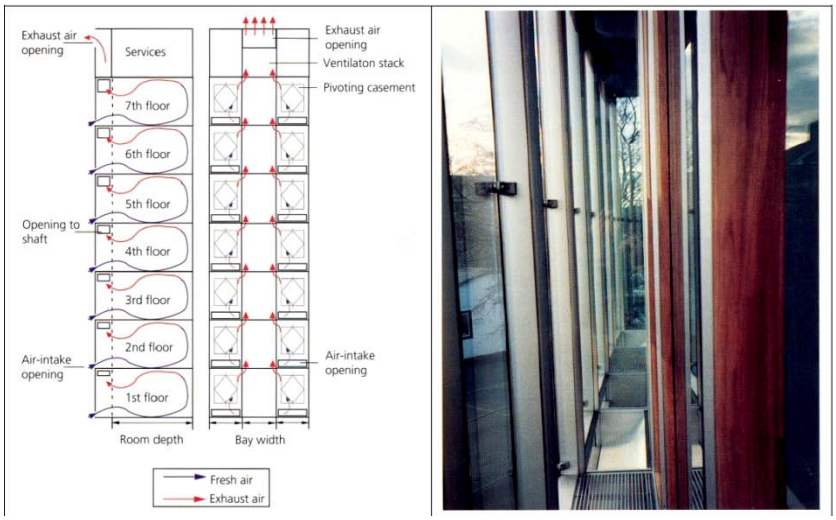


Illustration of the main characteristics of naturally ventilated double facades
Source: Ventilated Double Facades pdf online



Ventilation concept at the level of the façade

View of the façade and vertical ventilation ducts-alternation of the façade elements partition by story with juxtaposed module

Source: Ventilated Double Façade pdf online

9.8 Curtain Walls

A curtain wall is the skin envelope of a building in which does not carry any dead load from the building except its own weight. This type of walls are design to resist air and water filtration alone with the forces acting on the building like wind with positive and negative forces, seismic by the inertia of the curtain wall, its own dead weight load, thermal load by understanding the coefficient of thermal expansion and contractions, and/or blast loads especially now on days with security systems.

Selecting the proper materials for the design of curtain walls takes place during or after the schematic design. The process is to start developing the structural support for analysis. One form of conducting analyses of curtain walls are to build mock ups for study purposes and to make sure to deliver the intent purpose. Once the design has developed more, full mock ups are built to offer insight into cost implications, adjusting materials and fabrication techniques, review shop drawings, to better achieve the esthetic, function, cost and intent purpose.

According to Michael J. Crosbie and his book Curtain Walls: curtain wall consultants work closely with the design firm during the schematic design all the way to the end of construction phase. The main objective for the curtain wall consultants is to work as early as possible to serve as a mediator between the design firm and the manufactures during the construction phase.

One of the most important topics that need to be evaluated as many times as possible are the methods of constructing the systems, choosing the right materials, evaluate the energy performance intent, lighting, moisture, thermal penetrations to the building and others.

In general skin envelopes are usually made of three basic materials glass, metal, and stone. From these basic materials the owner, architect and consultants can choose other innovated materials depending on the design intent to be delivered.

Here are some examples of glass, metal, and stone curtain walls:

Glass

Cheung Kong Center

Hong Kong

Concept: Highly transparent expressive during day and night and to establish its presence through its simplicity and elegance between the Hong Kong and Shanghai Bank.

Curtain wall: Reflective glass curtain wall with a grid of stainless steel lines. The steel plays an important role by reflecting natural and artificial light complementing the reflective glass. During the day the floodlights mounted onto the stainless steel curtain wall column covers give some visual texture on the facades. At night the floodlights melts with the reflecting light and a secondary fiber-optic lighting into the curtain wall skin at the intersection of the panels allows to change character as the lights change in color and design during times of festivals.

Source: Intelligent Glass Facades by Andrea Compagno 2002

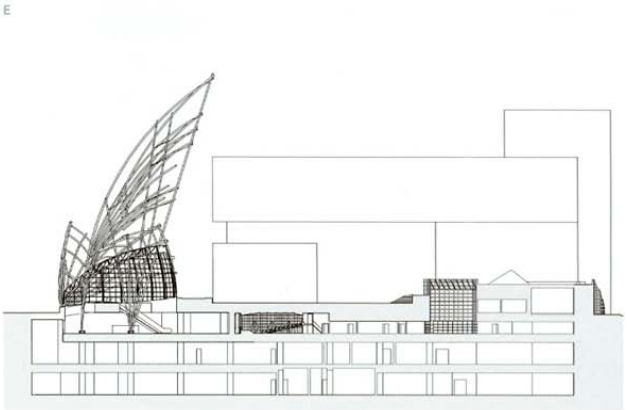
Metal

National Museum of art

Osaka

Concept: Gateway to the Osaka Cultural Center. The Natural Museum of Art contrast with the surrounding buildings heavy weighting down to the ground with the appearance of bamboo planted in the ground moving with the slight breeze of the wind.

Curtain Wall: Tubular stainless steel structure that serves as the main structural system to support the delicate transparent glass attached to aluminum mullions. The glass sits beneath the structural framing making it transparent the eye.



Source: Intelligent Glass Facades by
Andrea Compagno 2002

Stone

Forest Residential Tower

Tokyo

Concept: To establish a cultural tie to the modern city of Tokyo by implementing Japanese ceramic tile prevalent in the culture. The tiles are precast to concrete panels anchored to the building's steel structure.

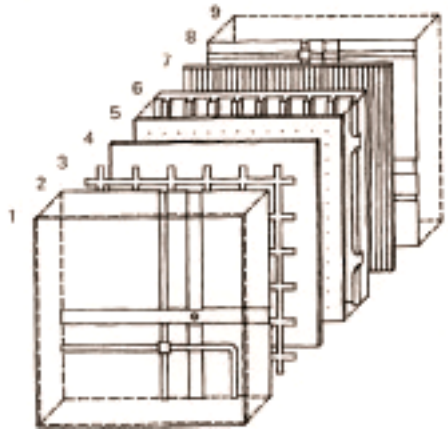
Source: Intelligent Glass Facades by Andrea Compagno 2002

9.9 Innovated Skins

Building envelopes have become more complex and smart in function thanks to new technologies now available. Building skins are not just partitions from the exterior to the interior environment. Now on days building skins needs to serve many purposes in which conventional partitions could not accomplish. The main objective is to reduce energy consumption to a minimum or in some cases to be fully energy sufficient. The following are some innovated strategies from designers, engineers, and architects for the development of smart skins.

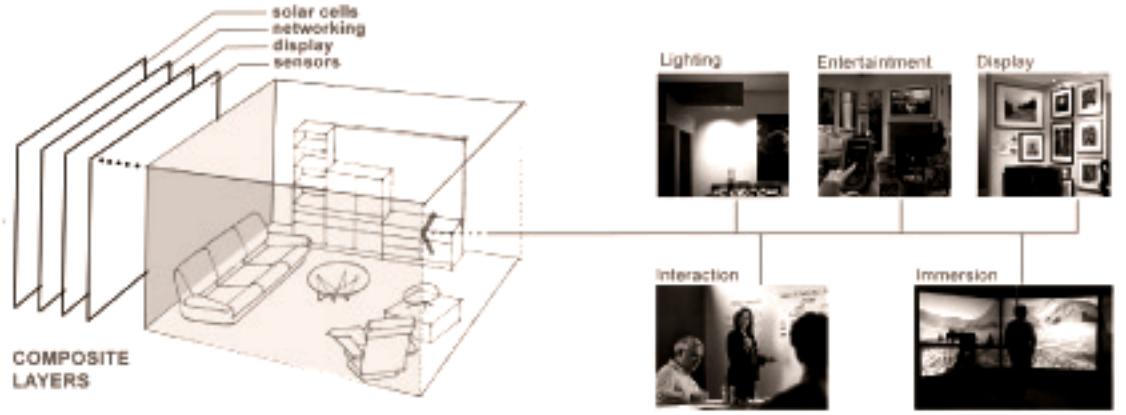
Osman Ataman and John Rogers and their article "**Toward New Wall Systems: Lighter, Stronger, Versatile**" quote: "As a principle element of architecture, technology has allowed for the wall to become an increasingly dynamic component of the built environment. The traditional connotations and objectives related to the wall are being

redefined: static becomes fluid, opaque becomes transparent, barrier becomes filter and boundary becomes borderless. Combining smart materials, intelligent systems, engineering, and art can create a component that does not just support and define but significantly enhances the architectural space."



Proposal of Mike Davies in 1981 for the "polyvalent wall":

1. silica weather skin
2. sensor and control logic
3. photoelectric grid
4. thermal sheet radiator
5. elektro-reflective deposition
6. Micro-pore gas flow layers
7. electro-reflective deposition
8. sensor and control logic
9. silica deposition substrate

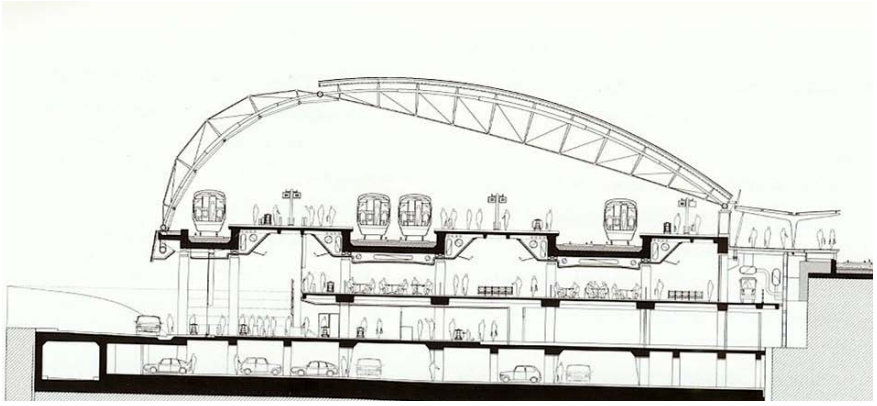


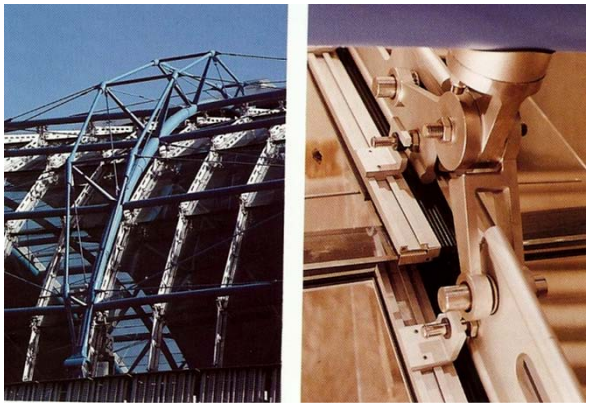
"Smart Wall" is designed to respond to multi-modal design demands by simple property changes to the material with control systems

Source: Towards New Wall Systems

http://cumincades.scix.net/data/works/att/sigradi2006_e131c.content.pdf

Waterloo International Station, London 1994 by Nicholas Grimshaw und Partner is a single glazed hall in the London terminus of the Channel Tunnel Rail link. The roof spans decrease from 50 to 35 meters. The roof is very asymmetric and responds to climate conditions by letting natural ventilation into the station in some sections of the roof as shown below.

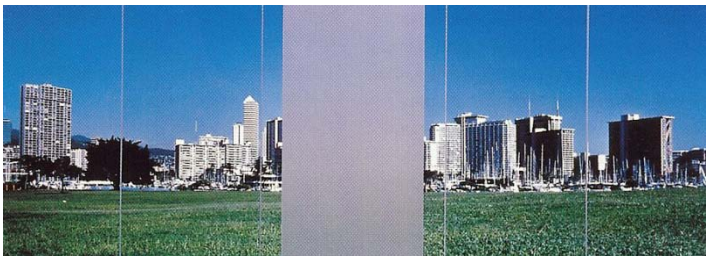




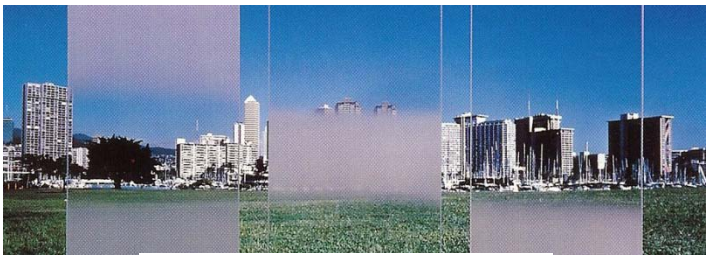
Source: Intelligent Glass Facades by Andrea Compagno 2002

Angle-selective views

The use of glass has been promising new developments from esthetic, structural, functional, and visual strategies. Functional layers in glass like angle-selective layers scatter incident light from a particular angle and thus become non-transparent. It contains thick polymer films by a process of photopolymerisation, done by ultraviolet light during the manufacture process.



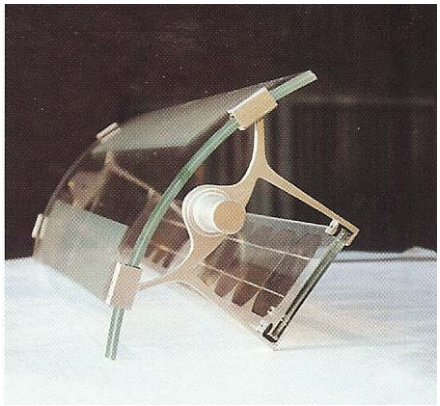
Source: Intelligent Glass Facades by Andrea Compagno 2002



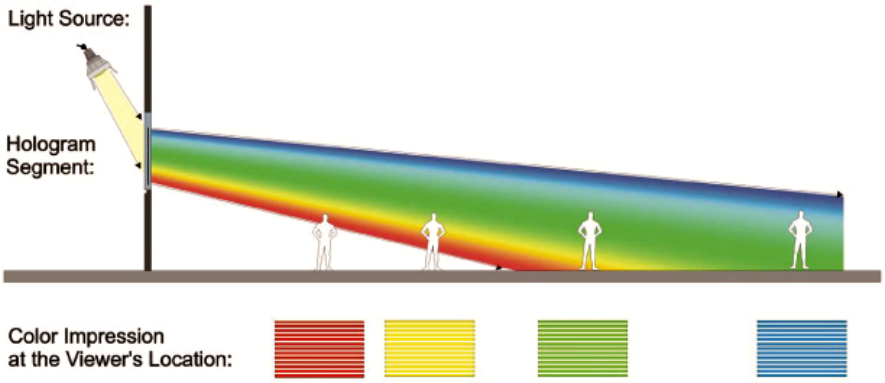
Source: Intelligent Glass Facades by
Andrea Compagno 2002

Holographic glass louvers

Holographic louvers were developed to produce rotating solar shading elements which enable the use of standard sized solar cells. These solar shading elements rotate on their axis to track the sun.



Source: Intelligent Glass Facades by
Andrea Compagno 2002



Color image of holographic display is changing by movement of spectator

Source: Intelligent Glass Facades by
Andrea Compagno 2002

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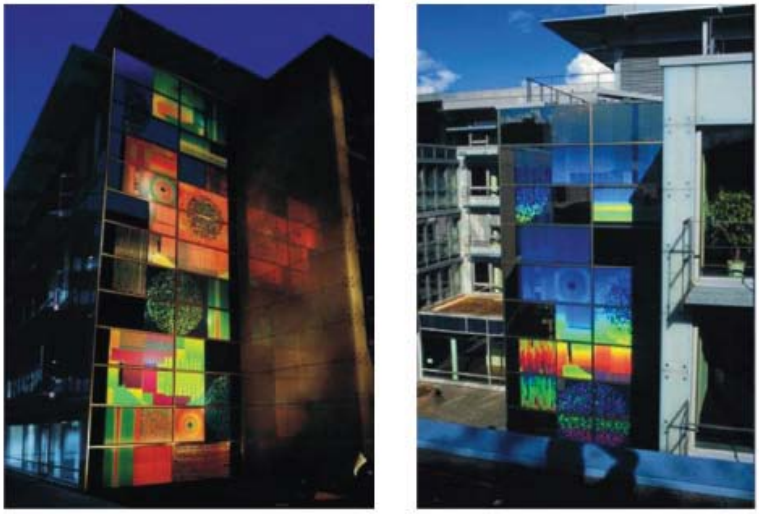
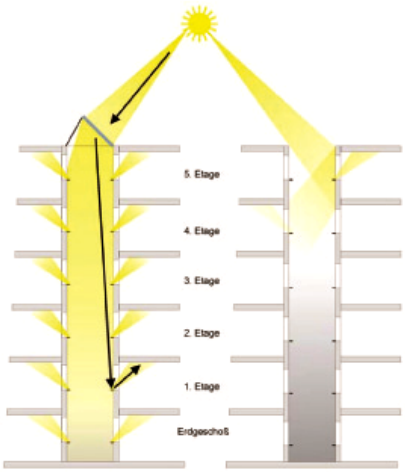


Reflective glass cladding with holographic displays in DFG Building in Bonn

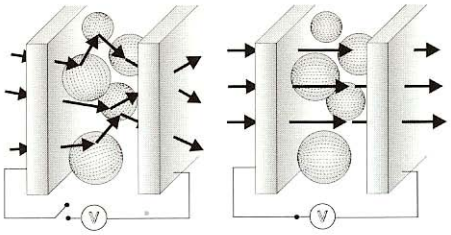


Redirection of sunlight by holographic roof glazing for improved daylighting of high an narrow courtyards and atria

Source: Intelligent Glass Facades by
Andrea Compagno 2002

Electro-optic layers

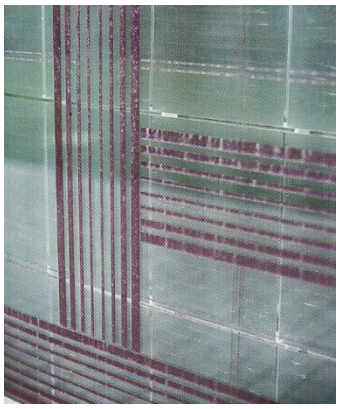
Smart materials that need a voltage to activate the liquid crystal between the layers. When a voltage is applied, the molecules align themselves along the lines of the electrical field in this state the system is then able to transmit light as long as the electric field is maintained.

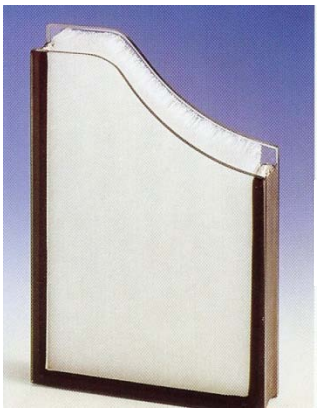


Source: Intelligent Glass Facades by Andrea Compagno 2002

Glass filled with insulated properties

Granular aerogel is used to fill between two layers of glass encapsulated for insulation purposes.

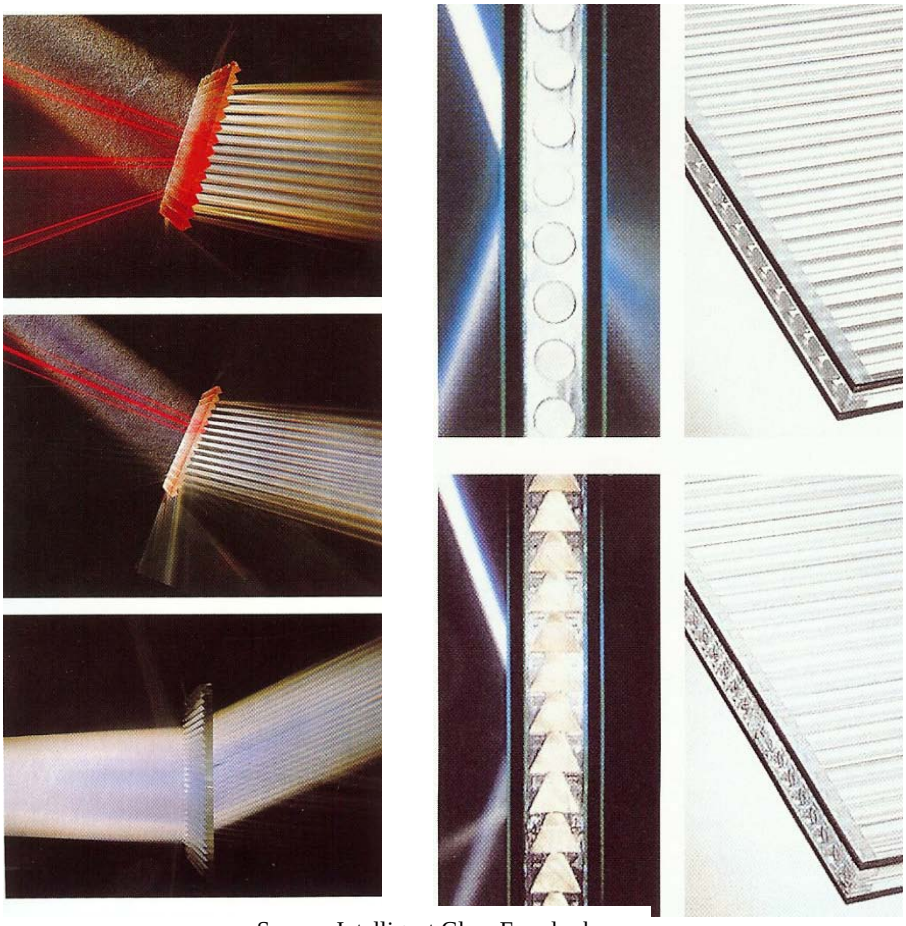




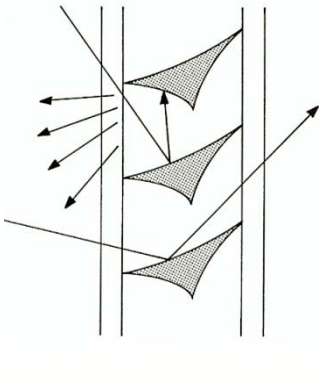
Source: Intelligent Glass Facades by Andrea Compagno 2002

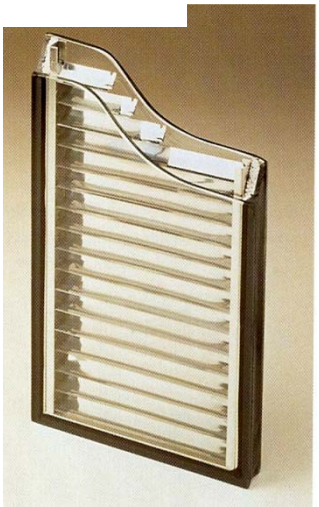
Fillings with Light Redirecting Properties

This method of light deflection is different than other solar protections. These exploit optical principles such as reflection, transmission or refraction in order to block direct sunlight on the one hand, and on the other to admit diffuse light into the interior or to deflect it into the back of the room.



Source: Intelligent Glass Facades by Andrea Compagno 2002

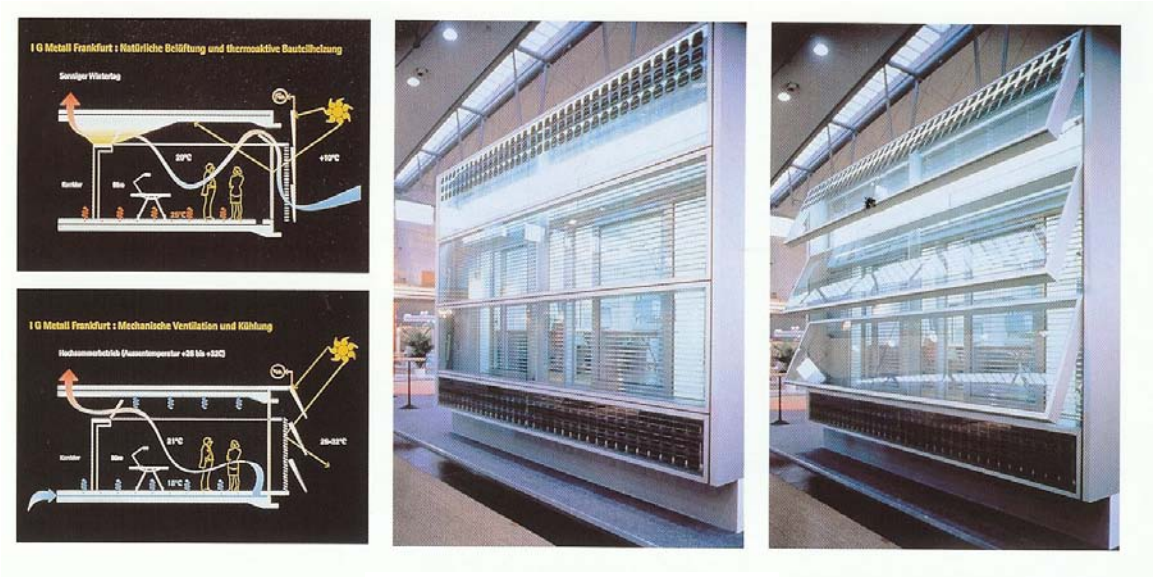




Source: Intelligent Glass Facades by Andrea Compagno 2002

Active double skin façade

Foster and Partners did not win a competition for the headquarters of IG Metal in Frankfurt am Main in 1996 nevertheless they built this prototype façade for exhibition purposes.



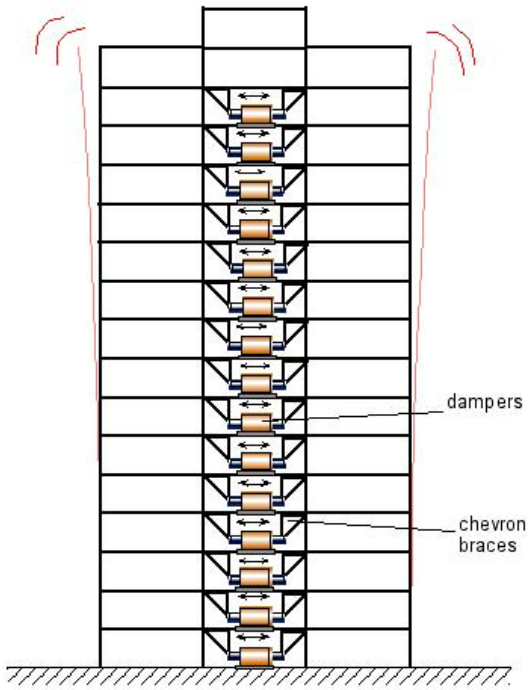
Source: Intelligent Glass Facades by
Andrea Compagno 2002

10. RESPONSIVE STRUCTURES

10.1 Smart Structures

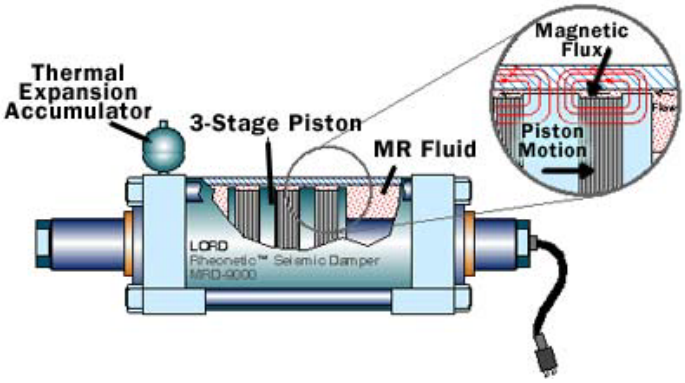
Smart structures are an integration of sensors, actuators, and a control system. Apart from the use of better functional materials as sensors and actuators, an important part of a “smarter” structure is to develop an optimized control algorithm that could guide the actuators to perform required functions after sensing changes.

Active damping is one of the most studied areas using smart structures.
According to Kevin Bonsor and his article How smart structures will work describes how smart dampers work on a building. The smart damper contains this smart material called Magnetorheological fluid (MR fluid), to stabilize buildings during earthquakes. MR fluid is a liquid in which changes to a solid form when is exposed to a magnetic force, and then back to a liquid once the magnetic force is removed. The sensors that trigger the magnetic field are called tremors.



Source: How stuff works “How smart structures will work” by Kevin Bonsor

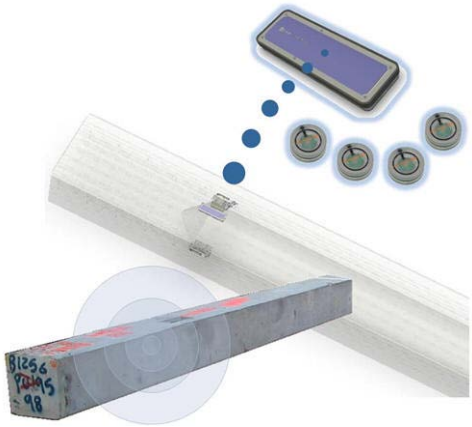
Bonsor describes that buildings and bridges are susceptible to resonance due to high winds and seismic activity. Dampers absorb the vibration forces.



Source: How stuff works “How smart structures will work” by Kevin Bonsor

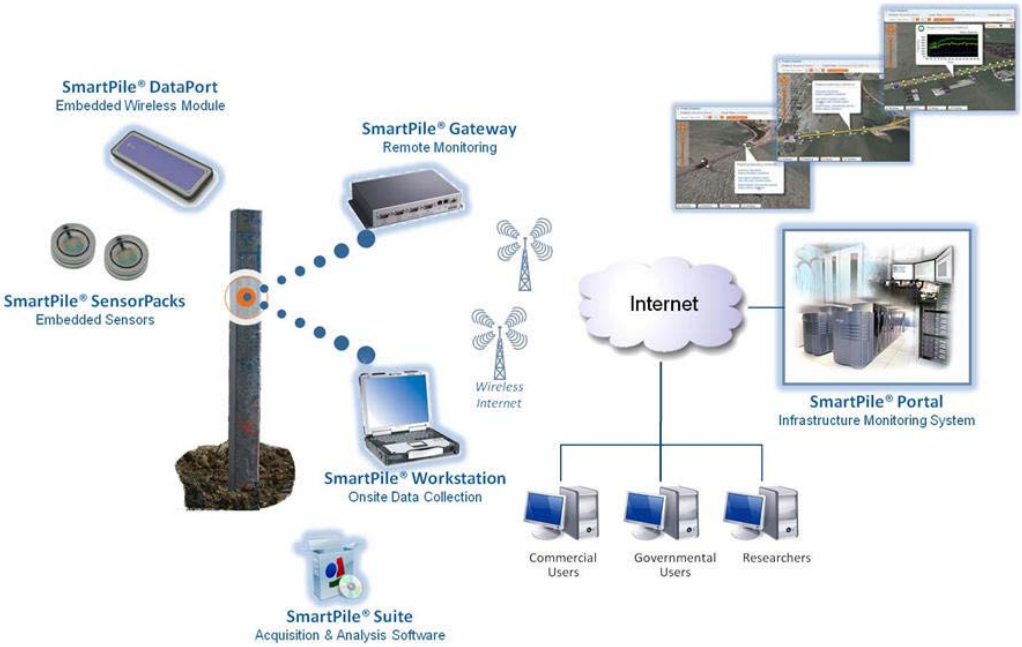
MR damper could be one meter long and weight 250 kilograms and exert 20 tons of vibration force on a building.

Smart structures inc online offers services to large structures by monitoring large structures like bridges. The process is strait forward it starts in making concrete smart by embedded wireless sensor device for data collection, and it is called SmartPile device. These devices consist of data port, which is a small battery powered electronic unit that is embedded into a concrete which will transmit wireless signal.



Smart Concrete

Source: www.smart-structures-inc.com

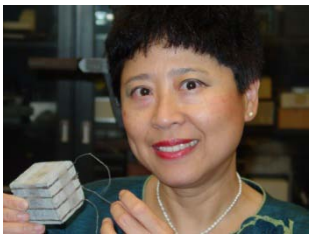


Smart Infrastructure

Source: www.smart-structures-inc.com

10.2 Smart Concrete

The technology was innovated and patented by Deborah Chung at the State University of New York according to University at Buffalo News center. The technology is simple by adding short carbon fibers to the conventional concrete. This new mixture makes the concrete able to detect stress and tiny deformations within in it. The probe that detects this stress can be placed outside the structures. The same principle can be applied to detect underground stress that builds prior to an earthquake, to monitor buildings occupancy for intruders or for stragglers during an evacuation and more. This change of electrical resistivity with strain is a phenomenon known as piezoresistivity (Purdue).



UB Scientist Deborah Chung Professor and Niagara
Mohawk Chair of Materials Research, Department

10.3 Smart Bricks

According to News Bureau University of Illinois at Urbana Champaign Jim Kloeppel, Physical Sciences Editor, Professor Chang Liu an electrical and computer engineer led the team that developed a smart brick. Smart Brick

Kloeppel explains on his article that the prototype has a thermistor, two-axis accelerometer, multiplexer, transmitter, antenna and battery hidden inside a brick. Once is built into a wall the brick could monitor a building's temperature, vibration and movement. The information can be processed accordingly.

Professor Chang Liu

Source: news bureau University of Illinois at Urbana-Champaign

11. PERFORMANCE ARQUITECTURE

11.1 Definition

Smart buildings is the integration of disciplines working side by side in which materials, structures, and systems respond and adapt to weather conditions and to human presence making responsible environments. Integrated smart systems connected to the skeleton, walls, ceilings and floors which respond to a moment in time.

Building systems target the followings

- **Envelope systems** in forms of structural, thermal, solar, luminous, aerodynamic, acoustical, and hydrological forms.
- **Services** HVAC, electrical, plumbing, vertical transportation, and life safety systems.
- **Structural** elements providing static equilibrium against gravity and dynamic loads
- **Interior** partitions, finishes, lighting, acoustics, furniture, and more.
- **Site** landscape systems, parking, drainage, vegetation, utilities,

11.2 Advance Building Systems

11.2.1 Heating

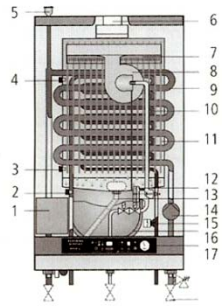
According to Klaus Daniels and his book “Advanced Building Systems” Heat can be generated by various methods:

- **District Heat** is produce by heat exchanger through steam, hot water, warm water
- **Solid fuels** produce by boilers from wood, coal, peat, waste, biomass
- **Liquid cells** produce from boiler installation, conversion boilers by heating oil benzene, bio-oils
- **Gaseous fuels** from boiler installations, through natural gas, liquid gas, methane, and biogas.
- **Electrical energy**
- **Geothermal energy** ground water, bore holes.
- **Environmental energy** air, surface water, waste water.

- **Solar energy** solar radiation

Condensing gas heater (wall-mounted) for heating and warm water generation,
output range
6.5 – 18 kW for heating,
6.5 – 22.1 kW for warm water
(Product image: Brötje)

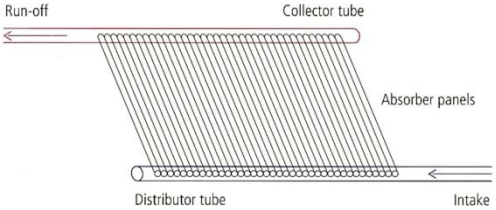
1 Electronic control
2 Warm water NTC
3 Return NTC
4 Feed NTC
5 Quick-action ventilating valve
6 Connection to flue gas system
7 Modulating, premixing metal-mesh burner
8 Speed-controlled fan
9 Heat exchanger coil for heating
10 Heat exchanger coil for warm water
11 Al-Si heat exchanger
12 Modulating gas valve



13 Condensation water pipe
14 Heating cycle pump
15 Flow switch warm water
16 Expansion tank 12 l
17 Control panel
18 Maintenance valves

Gas heater

Source: Advanced Building systems by Klaus Daniels2003

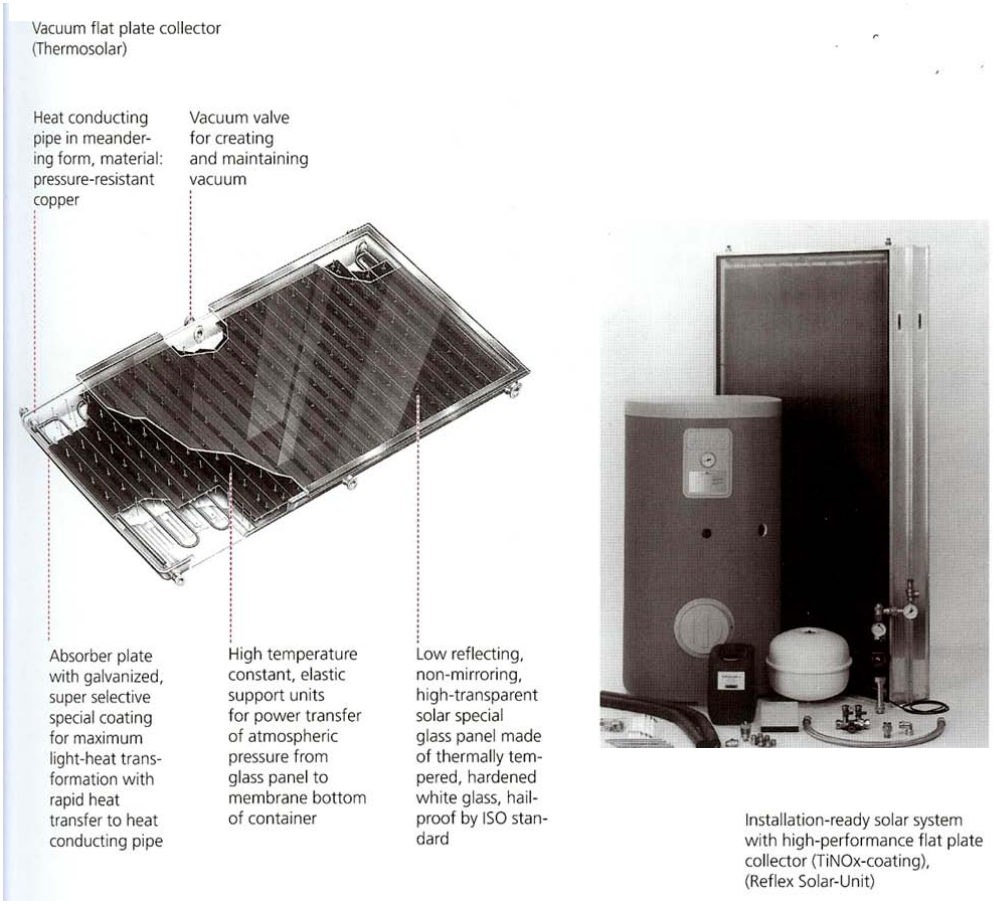


Structure of solar absorber

Solar absorber for swimming pool
300 m² absorber surface

Solar collectors

Solar collectors



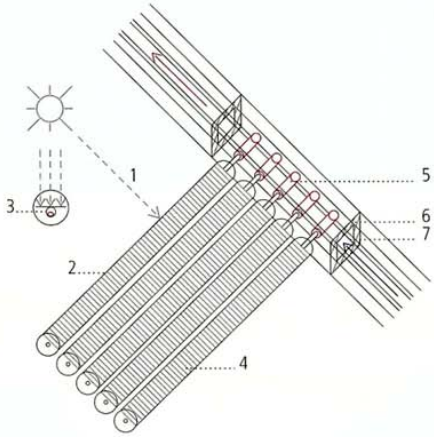
Source: Advanced Building systems by Klaus Daniels2003

Evacuated heat collectors transform incident solar energy into heat. The solar radiation permeates the evacuated glass tube and falls onto the absorber surfaces inside the tube, where is transformed into heat. One down side that needs to be study is that the cost-benefit depending on the heat gained in summer can be raised to temperature levels that are sufficiently high to supply energy to absorption chillers.

Evacuated tube collectors

Source: Advanced Building systems by Klaus Daniels2003

Evacuated tube collectors
(Image: Viessmann)



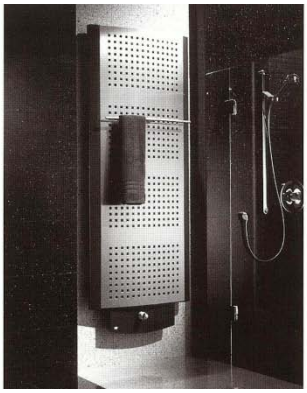
Evacuated tube collectors

Source: Advanced Building systems by Klaus Daniels2003

Principle of evacuated tube collector

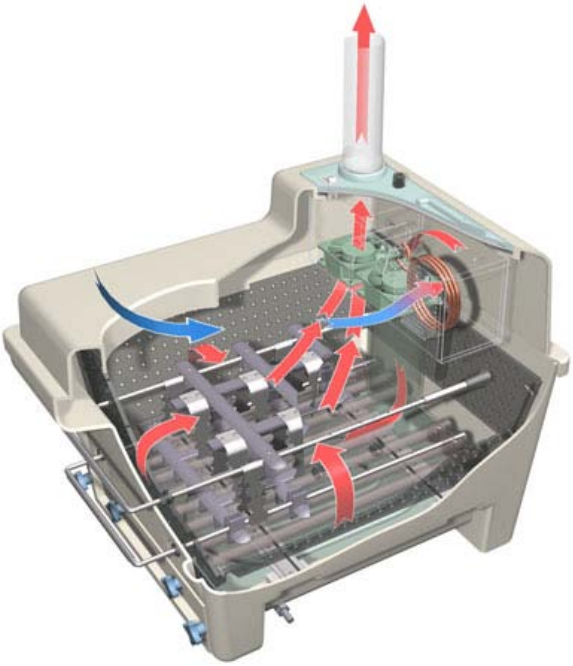
1 Heat radiation
2 Glass tube
3 Conducting tube with filling
4 Absorber, selectively coated
5 Condenser
6 Heat insulation
7 Heat exchanger tube

The following are electric heaters for localize areas

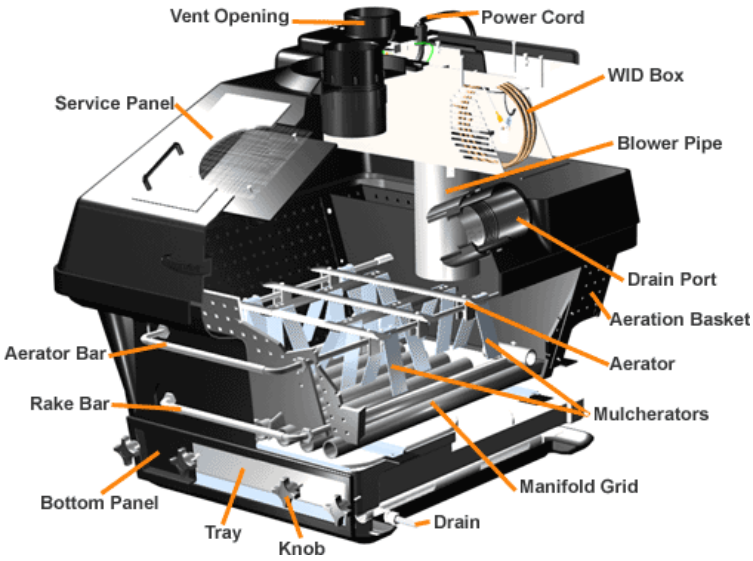


Source: Advanced Building systems by Klaus Daniels2003

11.2.2 Sanitation



Source: www.envirolet.com



Source: www.envirolet.com

Composting toilet systems are designed with six-way Aeration and evaporation process. The composting toilet is clean, sanitary and odor free.

11.2.3 Fire protection

Fireproof composites can be designed as structural and load bearing products according to Goodrich a manufactured specialized on innovated materials. FireRoc is a composite material that has the following characteristics:

- Non-Combustible
- Thermally Stable
- Hydrolytically stable
- Low thermal conductivity
- Mid-range Flexural Strength

This smart material is capable to withstand heat reaching 2000 degrees F and remain its mechanical properties.



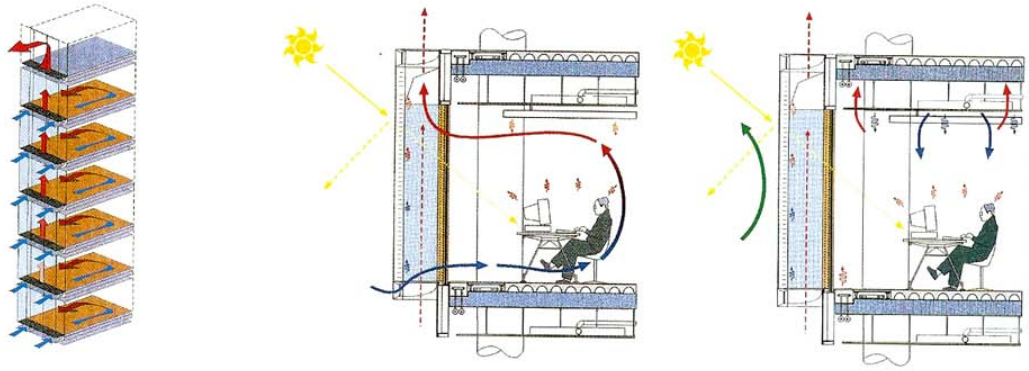




Source: www.epp.goodrich.com

11.2.4 Ventilation

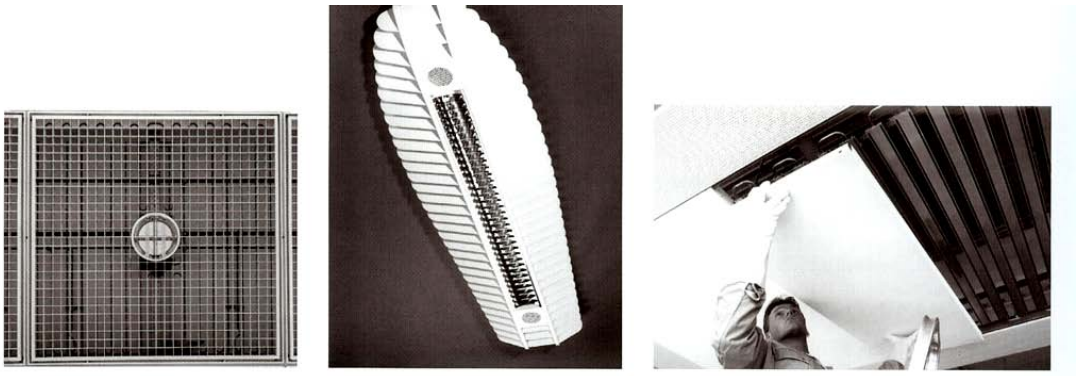
Natural ventilation can be achieved by passive design through various methods. Smart structures help us achieve natural ventilation with automated windows or louvers when buildings are exposed to extreme weather conditions.



Source: Intelligent Glass Façade by Andrea Compagno 2002

11.2.5 Lighting

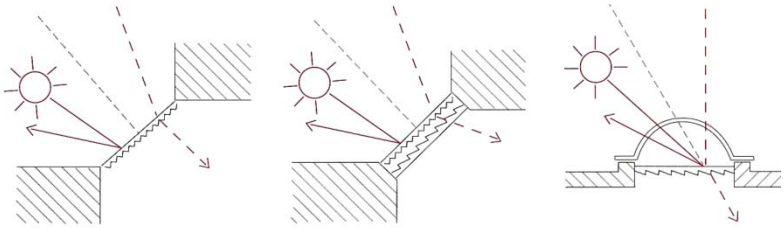
Example of LED and OLED lighting features

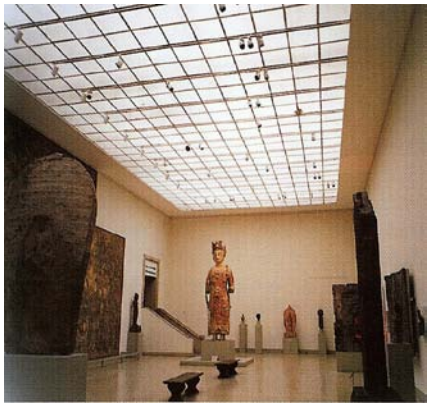


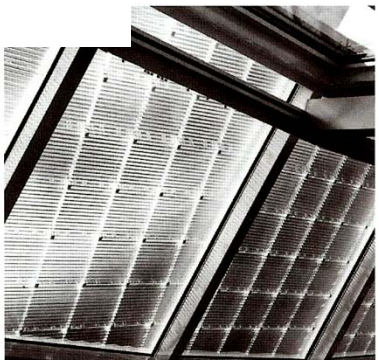
Source: Advance Building Systems by Klaus Daniels 2003

11.2.6 Daylighting

Examples of holographic features for daylighting purposes.

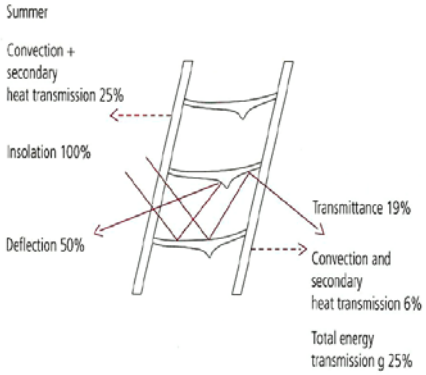






Source: Intelligent Glass Facades by Andrea Compagno 2002

Source: Advance Building Systems by Klaus Daniels 2003



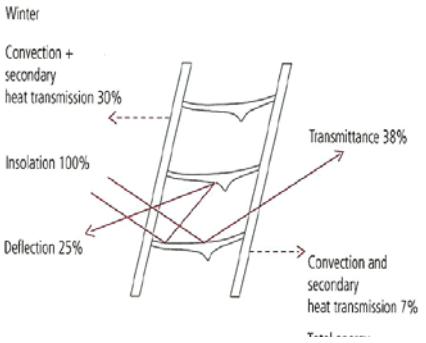
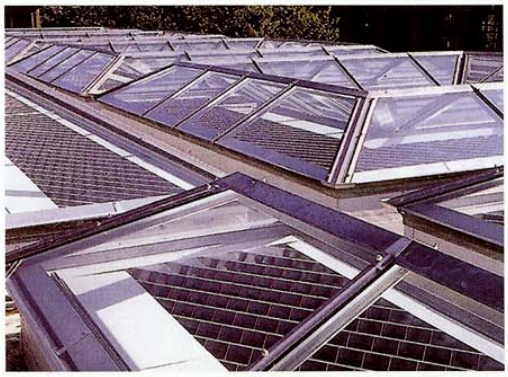
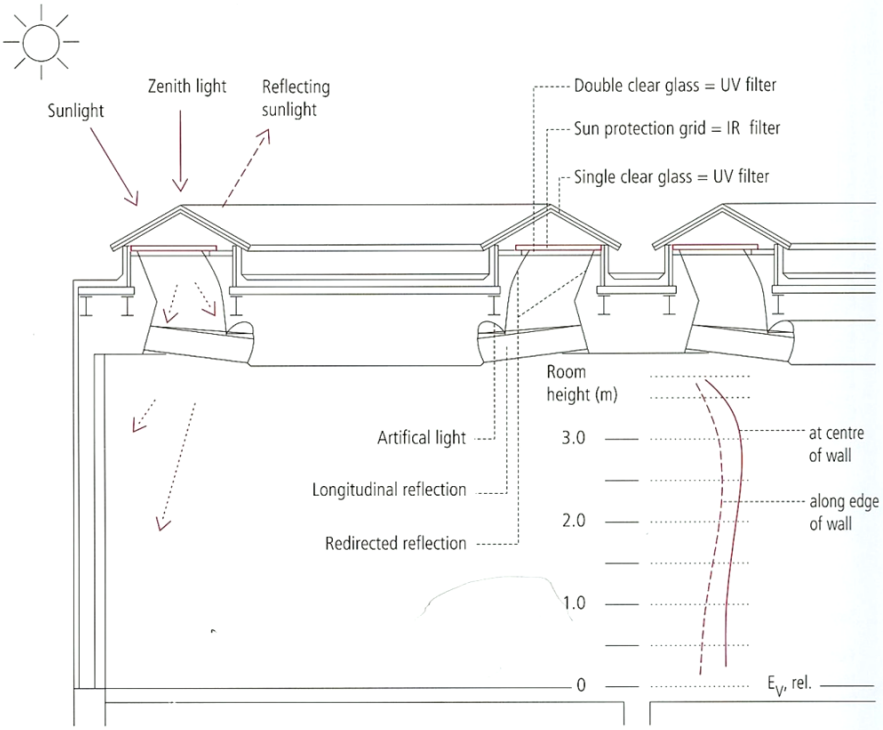


Figure 10.20
Aluminium skylight,
Museum of Natural History,
Stuttgart

Source: Intelligent Glass Facades by Andrea Compagno 2002



Source: Intelligent Glass Facades by Andrea Compagno 2002



Source: Intelligent Glass Facades by Andrea Compagno 2002

11.2.7 Indoor Environmental Quality

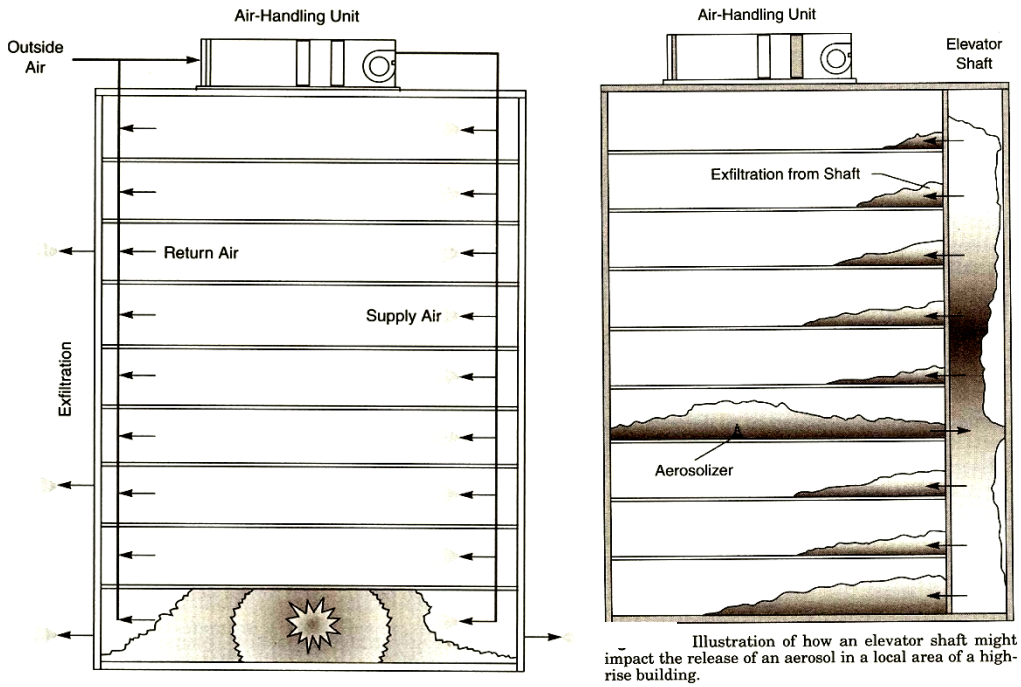
Indoor environment starts with the choice of materials. Selecting the right indoor materials is necessary in order to achieve the maximum indoor air quality.

The green building movement has succeeded integrating indoor environmental issues that helps building become high performance in providing indoor air quality. The USGBC's LEED addresses this issue by providing points to buildings that achieve higher indoor quality.

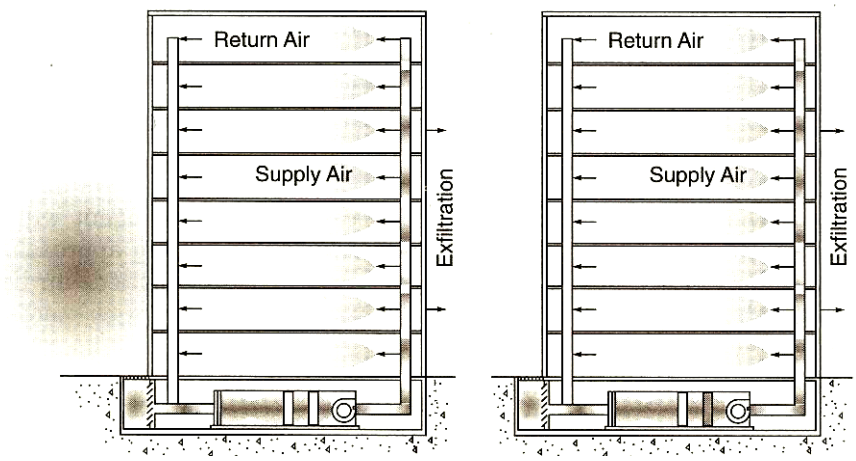
In my intent to deliver an air tight envelope I have to take the approach of immune the building from the polluted environment especially from the S02 level at the Kilauea Volcano National Park. The best approach is to learn from biological chemical weapons systems to understand how to purify air when such pathogens surround a building.

Wladyslaw Jan Kowalski an his book "Immune Building Systems Technology" identifies how pathogens can be spread, treat and immune a building in case of a biochemical attack.

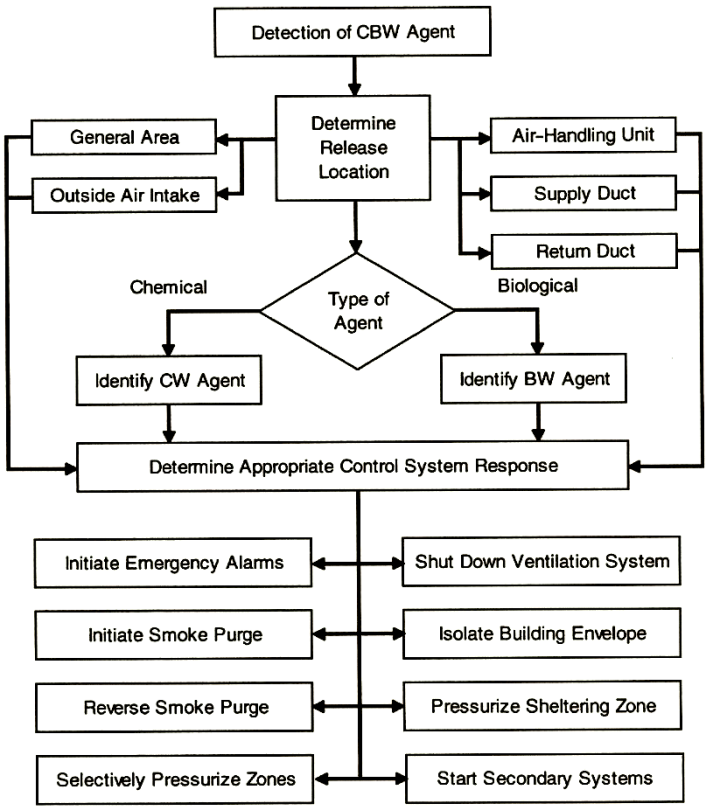
The following are biochemical attack scenarios which show how pathogens can spread into the building through the conventional HVAC system and elevators.



Source: Immune Building Systems Technology by Wladyslaw Jan Kowalski



Source: Immune Building Systems Technology by Wladyslaw Jan Kowalski



Control logic flow diagram for identification and response to a CBW attack in a high rise building

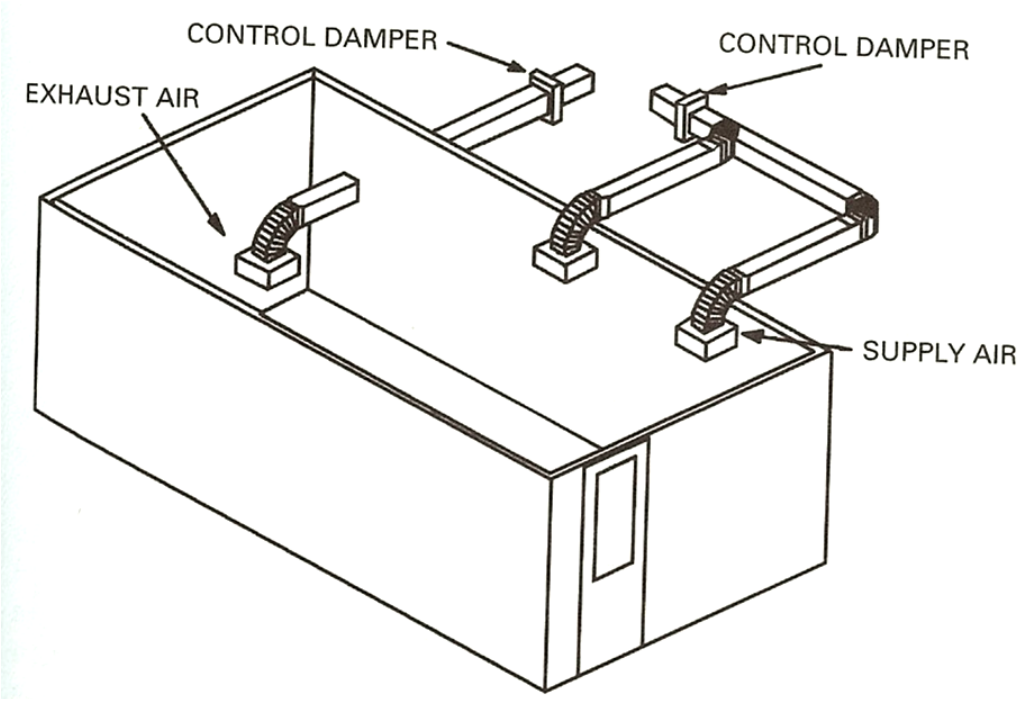
Source: Immune Building Systems Technology by Wladyslaw Jan Kowalski

Immune Building Systems Technology by Wladyslaw Jan Kowalski

Technology	Applications	Advantages	Disadvantages
Thermal disinfection	Sewage air treatment	Simple and effective	Costly
Cryogenic freezing	Food disinfection	Simple	Costly, preserves some microbes
Desiccation	Air cleaning	Cost-free by-product of desiccant or dehumidification systems	Not cost-effective as a stand-alone air disinfection technology
Passive solar exposure	Air and surface disinfection	Free	Slow, not always practical
Vegetation air cleaning	Air quality	Simple	Only partly effective, soil can breed fungi
Antimicrobial coatings	May enhance filters, protects surfaces	Prevents microbial growth, may facilitate remediation	Removal performance unknown, concerns about dislodging of coatings
Electrostatic filters	Air cleaning	Enhances filtration, removes dust	Increased energy consumption, susceptible to humidity
Negative ionization	Dust removal	Simple, not costly	Only partly effective
Ultrasonication	Water treatment	May enhance other technologies	Expensive, may not be practical in air
Photocatalytic oxidation (PCO)	Air cleaning	Removes biological and chemical agents	Performance largely unknown, may be comparatively expensive
Ozone air disinfection	Air cleaning, disinfection	Simple, effective, low cost	Possible leakage of ozone
Microwave irradiation	Air cleaning, disinfection	Simple, possibly cost-effective	Slow, performance unknown
Pulsed white light	Air cleaning	Rapid disinfection, well understood	Costly for air disinfection
Pulsed filtered light	Air cleaning, operating rooms, skin decontamination	Rapid disinfection, not harmful with UV removed	Costly for air disinfection
Pulsed electric fields	Air cleaning, food disinfection	Rapid disinfection, well understood	Costly for air disinfection
Gamma irradiation	Air cleaning, disinfection	Effective against BW agents	Hazardous, expensive, subject to regulatory control
Electron beams	Air cleaning, disinfection	Effective against BW agents	Costly

Alternative Immune Building Technologies

Source Immune building systems Technology by Wladyslaw Jan Kowalski



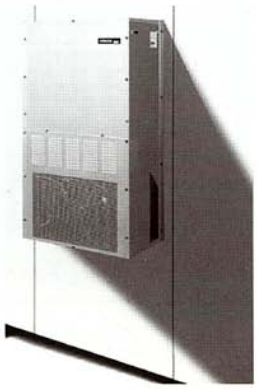
Isolation room or sheltering zone using control dampers to pressurize an area

Source Immune building systems Technology by Wladyslaw Jan Kowalski

The following are room air conditioner units as an alternative cooling system.

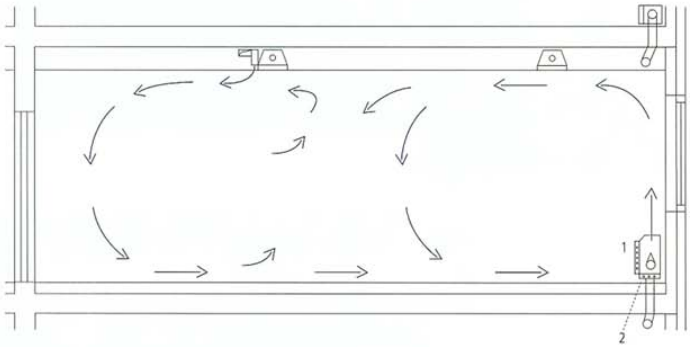
Air-conditioning room unit with built-in heat pump

Fan-coil unit as underfloor unit (Image: Trox)



Precision air-conditioning unit in container construction, e.g. for mobile radio container

Source: Advanced Building Systems by Klaus Daniels 2003

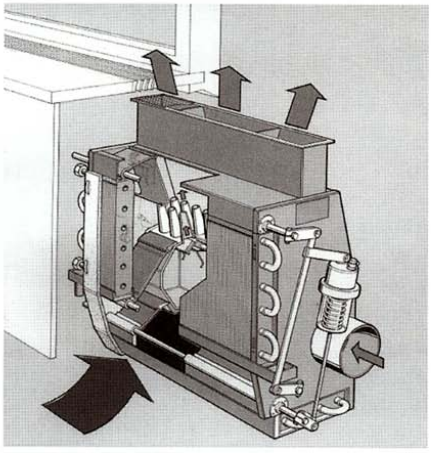


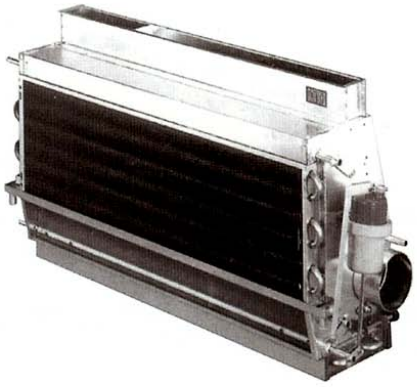
1 Cooling component
2 Heating component

Injection technology for optimum room air movement for induction systems and fan-coil systems

1 Cooling component
2 Heating component

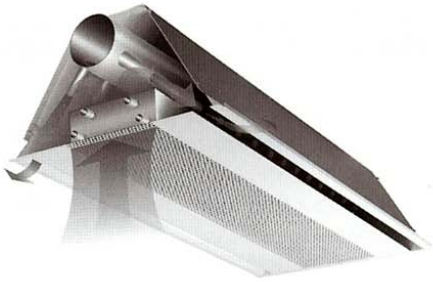
Source: Advanced Building Systems by Klaus Daniels 2003





Four-conductor induction unit for variable volume flow systems, (Type HFW, LTG)

Source: Advanced Building Systems by Klaus Daniels 2003



Ceiling induction outlet (Series DID, TROX)

Source: Advanced Building Systems by Klaus Daniels 2003

12. RESPONSIVE BUILDINGS

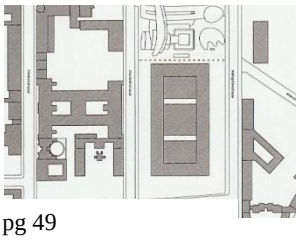
12.1 Case Studies

12.1.1 GSW Headquarters

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 49

Building data	
Contract value	DM160m
Area	47,873m^2
Typical floorplate	800m
Number of storeys	21
Price per m^2	DM3340/m^2
Annual energy use	n/a
Typical energy use for building type	n/a
Annual CO_2 output	n/a
Number of sensors	>1000
Visited by authors	✘
Monitored by others	✔

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg49



GSW Headquarters is one of the largest housing in Berlin. Originally it comprised of 17 storey office building, with a three storey low block surrounded by a three storey drum. The building was completed in September 1999, which idea came from a design competition won by Sauerbruch Hutton (Wigginton 49).

The intelligence factor

Intelligent features	
Building management system	■
Learning facility	
Weather data	■
Responsive lights	■
Sun tracking facility	■
Occupant override	■
Self-generation – CHP/PV/wind	
Night cooling	■
Solar water heating	

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 49

The comfort and energy efficiency in the building had been provided by two intelligent factors. The building ventilation mostly thought out the year is induced by the thermal flue. The other intelligent factor is the occupant control (50).

It provides an additional space to be linked to the original building. After the competition, the economy indicates that most of the parts of the tower should be rented out, which required some revisions of the design concept and needed greater layout flexibility (50).

Accommodation

The building has a curving arc plan, the floor-to-floor height is low for a modern office building or any building for daylighting. Its location is being sheltered by prevailing wind and mitigates environmental problems. A new lift and service core connects the new tower with the existing tower (50).

Energy Strategy

The double wall is the main component on the west side which provides protection from heat loss. During calm weather, the thermal flue induced ventilation. The central constituent is with natural ventilation and low energy strategy as the center aspect of concept (50).

Daylighting

The daylighting should be in accordance with the German regulations with the environmental objectives of the Client and the design team. The narrow floor plan was selected because of the low floor to floor height. The good daylighting that's provided to the office floors from both sides is due to the fully glazed wall. Because good daylighting is available from at least one side, the need of artificial lighting is reduced. The bright environment is also attained from the perforations of the vertical louvers of the thermal flue which also provides and amazing views across Berlin (52).

Artificial lighting

The European Intrabus System is the lighting control adopted because of its flexibility and enable room layouts to be changed without rewiring. Linear fluorescent fittings with 60 degree cut-off louvers provide lighting to the offices. The row of light fittings are switched off by photocells, the rest is manually switched in groups. Occupants can override the automated daylight linked switching (52).

Solar Control

The west glazing is protected by perforated vertically pivoting and sliding panels and the east glazing is the integral blinds (53).

Controls

The key elements of the environmental system are the building management system. (BMS). It controls airflow in the thermal and recommends to users to use either the mechanical or natural ventilation. If daylight is sensed a separate light control system switches off the perimeter lighting.

Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection		■	■
Glare control – blinds/louvres/fixed		■	■
Responsive artificial lighting control		■	■
Heating control		■	■
Heat recovery – warmth/cooling	■	■	■
Cooling control	■	■	■
Ventilation control		■	■
Fabric control – windows/dampers/doors	■	■	■
Insulation – night/solar			

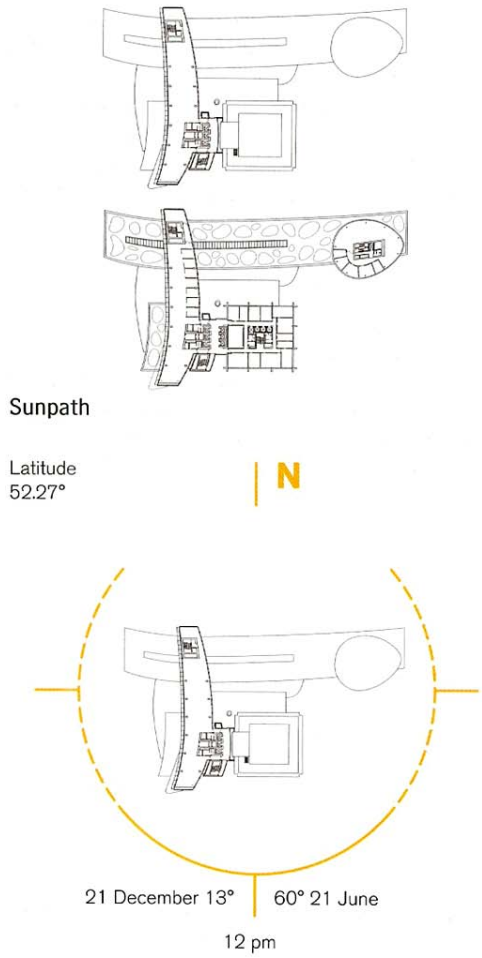
Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 53

The systems can be overridden by the occupants. The key feature of the building is the user control. It incorporates both to override and to give advice. Override is provided to the ventilation control and that during occupied hours it enables occupants to affect airflow to the building. The occupants can override the BMS for either mechanical or natural mode of ventilation with the wall mounted zone controllers (53).

Operating Modes

The modes can be switched by zone between BMS and occupier control. The BMS systems were not commissioned because the building was only occupied for one year (54).

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 52, 53



Façade transparency	
North	65%
East	58%
West	65%
South	45%
U-values	
Walls	0.3W/m^{2}K
Roof	0.25W/m^{2}K
West façade glazing (total)	1.2W/m^{2}K

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 50

12.1.2 The Environmental Building

Façade transparency	
North	45%
East	5%
South	45%
West	5%
Roof	10%
U-values	
Walls	0.32W/m^{2}K
Slab	0.33W/m^{2}K
Roof	0.24W/m^{2}K
Windows	2.00W/m^{2}K

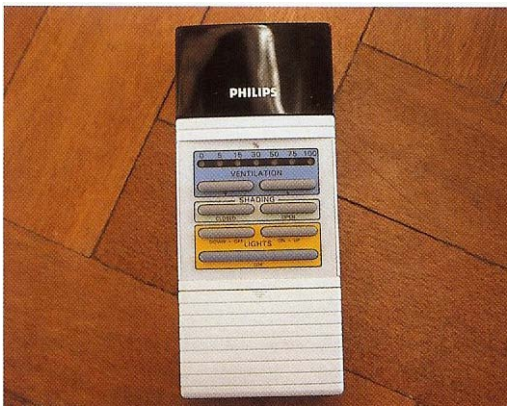
Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 75

The building was based on the new performance specification, Energy Efficient Office of the future, devised by BRECSU and was also decided to adopt a new method of procurement, in the form of the New Engineering Contract (75).

Intelligence factor

Naturally ventilated with automatic controlled windows at high level. Users use remote controls to determine ventilation levels (windows), shading (glass louvers) and lighting. Daylight sensors automatically regulate the lighting according to daylight levels. Cooled down by buildings concrete structure. The BMS controls the heating, ventilation and cooling systems for optimum comfort (75).

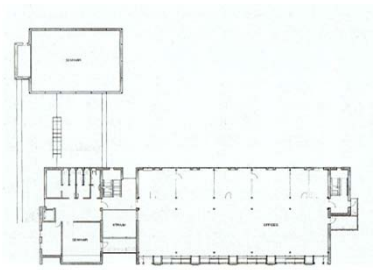
Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection		■	■
Glare control – blinds/louvres/fixed	■	■	■
Responsive artificial lighting control		■	■
Heating control		■	■
Heat recovery – warmth/cooling	■		
Cooling control			■
Ventilation control		■	■
Fabric control – windows/dampers/doors			■
Insulation – night/solar	■		



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 80

Accommodation

The building is an L-shaped plan with a three-storey office wing and has been designed to accommodate 100 staff, and offers seminar facilities for up to 140 people (76).



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 76

Energy strategy

The building is heated by a low-pressure hot water system supplying an under floor heating circuit and perimeter radiators for summertime active cooling. It is naturally ventilated using the slab to absorb heat during day and cooled by ventilation at night (76).

Site and climate

The BRE campus is located on the outskirts of Watford in southern England.

Glazing

The building has main windows with softwood frames and white powder-coated aluminum outside, and double glazing coating of argon gas. Windows can be opened manual or by BMS on high level (77).

Heating

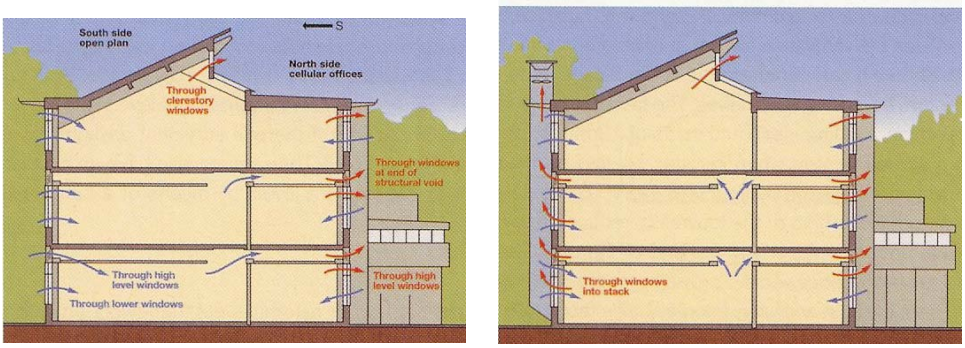
Two low-NO_x natural gas-fired boilers feed a low-pressure hot water heating loop and pipes for underfloor heating run in bands in the floor screed. Fresh air inlet is preheated before admitted through offices. Hot water is supplied from a central calorifier in the first floor plant room and electric water heaters are used in office kitchens (77).

Cooling

Natural ventilation is used in summertime. Windows are opened manually and exposed slab soffit is the main exposed thermal mass. At the top floor the clerestory windows are automatically controlled to promote cross ventilation. The upper windows can be opened by the BMS at night to induce cooling of the thermal mass. Cool water is pumped in the plant room maintaining all-year temperatures of 10 and 12 degrees Celsius (77).

Ventilation

Cross ventilation is the predominant mode of air transfer, with single-sided ventilation for the cellular offices. It is controlled on temperature sensors in main offices. Toilets are ventilated with windows by a mechanical system. Ventilation stacks in first floor are openable in the south façade with etched glass blocks. Second floor has a split-pitch roof with automatically controlled north-facing clerestory windows. In the main seminar space, air is drawn through a heatin/coolin battery in an undercroft below the stage, and then through ducts within the raised seating (78).



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 80

Electricity generation

The south facing wall of the seminar rooms is clad with a 47 m2 array of photovoltaic cells. Electricity is generated as DC current, and fed directly into the main electrical switch room (78).

Daylighting

Daylight is maximized with large areas of glazing on the north and south facades, giving daylight factors of over 2% across the 13.5m floor plate. The ceilings are painted white to penetrate the light. The main windows, etched-glass hoppers to the rear of the glass block ventilation stack provide some additional daylight (78).

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 79

Artificial lighting

Highly efficient fluorescent tubes have been installed that automatically compensates for daylight levels and occupancy. Users use hand-held controls to allow light levels (79).

Solar control

The motorized louvers are adjusted by the BMS every 15 minutes. Occupants can override the automatic setting of the louvers to reduce glare if they wish. Internally, blue fabric roller blind are provided for additional occupant-controlled glare reduction (79).

Controls

The BMS was developed jointly by Trend and Phillips to control ventilation systems, heating window shading and lights. All controls for BMS go to a common network by a LON network. The computer controls the degree and period of window opening and relies on the sensing of internal temperature. The system is linked to Max Fordham's offices for fine tuning during first year (80).

User control

Users have a controller to control lights, windows and louvers, local ventilation and lower roller blinds for additional glare, and local thermostat offering temperature control (80).

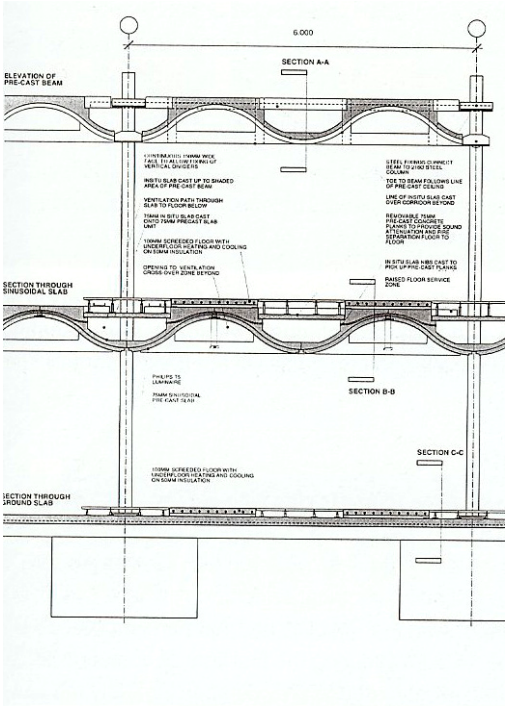
Operating modes

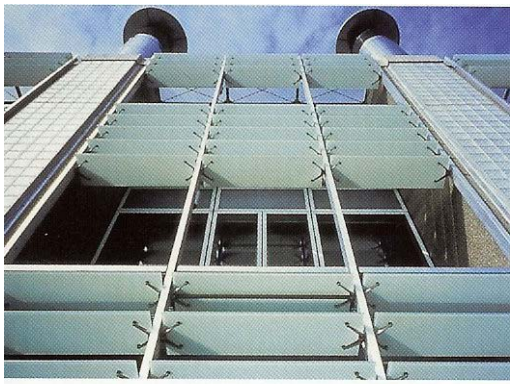
Winter day- Windows into the ventilation ducts are opened to provide minimum fresh air, radiator s and under floor heating maintain minimum temperatures.

Winter night- provide no ventilation to the building and only heat to prevent frost within the building.

Summer day- provide minimum ventilation unless above summer temperature.

Summer night (81).





Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 79, 81

12.1.3 The Brundtland Centre

Intelligent features	
Building management system	■
Learning facility	
Weather data	
Responsive lights	■
Sun tracking facility	
Occupant override	■
Self-generation – CHP/PV/wind	
Night cooling	■
Solar water heating	

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 103

Intelligence Factor

Windows are automatically controlled to prevent glare, heat (ventilation), and fans turn on by movement, which are generated by photovoltaic's. The building was built for energy saving and positioned as a compass with rooms according to its pints to gain useful heating contribution (103).

Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection		■	■
Glare control – blinds/louvres/fixed		■	■
Responsive artificial lighting control		■	■
Heating control			■
Heat recovery – warmth/cooling			■
Cooling control			■
Ventilation control		■	■
Fabric control – windows/dampers/doors			■
Insulation – night/solar			■

Energy

Natural ventilation, solar energy, active cooling is avoided, and the deal is to reduce half of energy than other normal buildings.

Construction

Concrete, clay brick, with insulation, yellow brick, wood floors, and concrete ceiling. Glazed roof to allow daylight and glare free north light.

Heat/Cooling

Heat is reduced by passive solar gain strategy, auto fans in office rooms, and temperature is controlled by radiators. Cooling is avoided from Danish code; it is reduced by building thermo mass and semi-passive night ventilation system (104).

Ventilation

Incoming air enters building which is preheated into individual rooms. Fans are minimized in use; some fans are controlled by detectors (105).

Electricity Generation

Roof incorporates photovoltaic cells to allow 20% daylight. Electricity production by sun is used by photovoltaic's, which meet electrical requirements in summer and only 20% in winter (106).

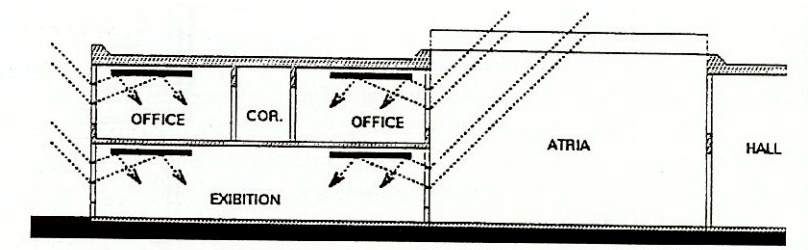
Daylighting

Has 3 part façade with innovative control strategies for daylight and artificial lighting. Venetian blind systems- redirect diffuse daylight onto the ceiling. An upper daylight window allows sunlight but prevents outside view. Central uses inverted venetian blinds that are adjustable. Bottom level uses normal windows that are manual venetian blinds. Fluorescent tubes in upper and central levels are used for artificial lightings. It uses switches to lower or increase light b the BMS, building management system (107).

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 106

Controls/User Control

BMS is a standard system monitoring energy, blinds in angles, and controls level of artificial lights. User control is by lighting levels operated by individuals (107).



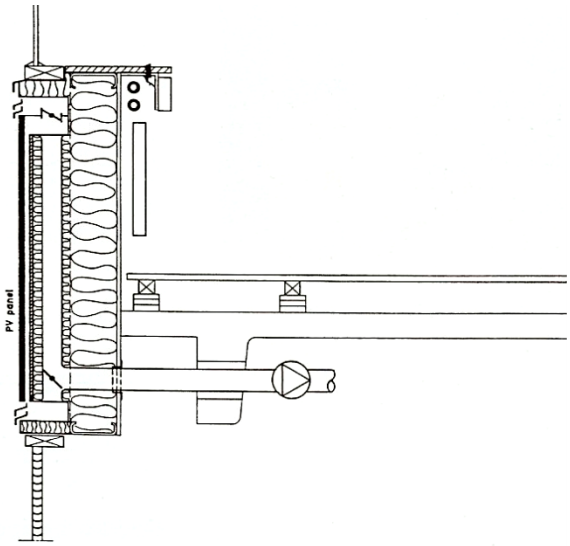
Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 106

Performance

Decision makers, consultants, architects go through comprehensive monitoring. Delivered energy consumption is consumed of 38 kWh/m2 per year in heat, light, and ventilation. Reduction of 72% in total energy consumption compared by Danish building (106).

Façade transparency	
North	40%
East	0%
South	80%
West	40%
Roof	20%
U-values	
Walls	0.30W/m^{2}K
Slab	n/a
Roof	0.20W/m^{2}K
Atrium roof glazing	1.60W/m^{2}K
Daylight windows	0.90–1.80W/m^{2}K
Vision windows	1.10–1.80W/m^{2}K
Atrium glazing (SW)	1.40W/m^{2}K

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 105,106



Building data	
Contract value	16.78m DKK
Area	1878m^2
Typical floorplate	12m
Number of storeys	2
Price per m^2	~£860/m^2
Annual energy use	38 kWh/m^{2*}
Typical energy use for building type	n/a
Annual CO_2 output	n/a
Number of sensors	n/a
Visited by authors	✗
Monitored by others	✔

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 105,106

12.1.4The Green Building

The green building is a European urban prototype building with a sophisticate energy philosophy.

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 109

Intelligence Factor

The courtyard inside the building is automatically ventilated with roof lights and natural ventilation. Hot and cold water is fed by micro bore pipes embedded in the structure. Electricity is generated by wind turbines and photovoltaic. The building structure imitates the human circulatory system. The control software receives data by the Met Office (109).

Intelligent features	
Building management system	■
Learning facility	
Weather data	■
Responsive lights	
Sun tracking facility	
Occupant override	
Self-generation – CHP/PV/wind	■
Night cooling	■
Solar water heating	■

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 106

Accommodation/Energy strategy

The building is a European apartment divided into different sized bedroom units. The building has a basement, office, and three upper levels. It was designed to build a full courtyard in the centre. Building is constructed on a 6 storey central courtyard oriented southwards having natural ventilation and light. Thermo mass is an energy strategy for climate moderator. Electricity generated by photovoltaic cells and wind turbines on roof with solar collectors for hot water (109).

Site/Construction/Glaze

Located on Temple Bar and has an air poll

recycled brick, external Rockwood insulation, colored render on outside fence, and concrete roof and frame. The internal is constructed by linoleum, natural jute carpets,

recycled wood and tiles, and exposed concrete. The windows are softwood with double glaze that has argon gas (110).

Heat/Cooling/Ventilation

Thermo mass and an electric heat pump system are used for heat. The courtyard has a concentric heat for plants. A cooling circulation of borehole water goes through pipe work system that is used for heating. Street level air and evening air cools basement from open courtyard. For ventilation the windows are manually opened, it has fan assistance when CO2 exceed the limit. The courtyard provides natural ventilation. External and internal windows are opened for individuals. Mechanical ventilation, plants, and electric fans are for ventilation throughout the building (111).

Electricity generation

Photovoltaic cells and wind generators on the roof produces electricity, as well as 3 wind turbines meets 100% of light needs (112).

Daylighting/Artificial lighting

The courtyard provides a narrow light to basement from the roof. Glazing is increased on lower floors and the bay windows are maximized for natural light. Artificial light is manually controlled using fluorescent lights (112).

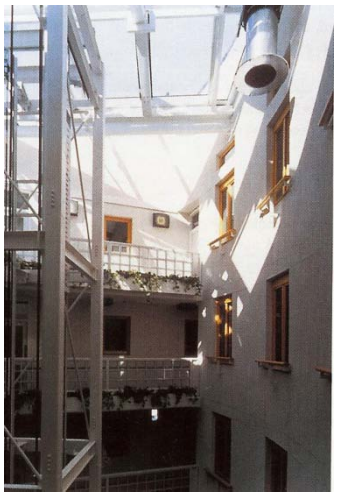
Solar control/Controls/User Control

There are 2 street facades facing east and west for solar control. The BMS is responsible for the heat pump and the controls receive data from Met Office. In each apartment there are switch controls over windows and lighting and same goes for retail and office areas (112).

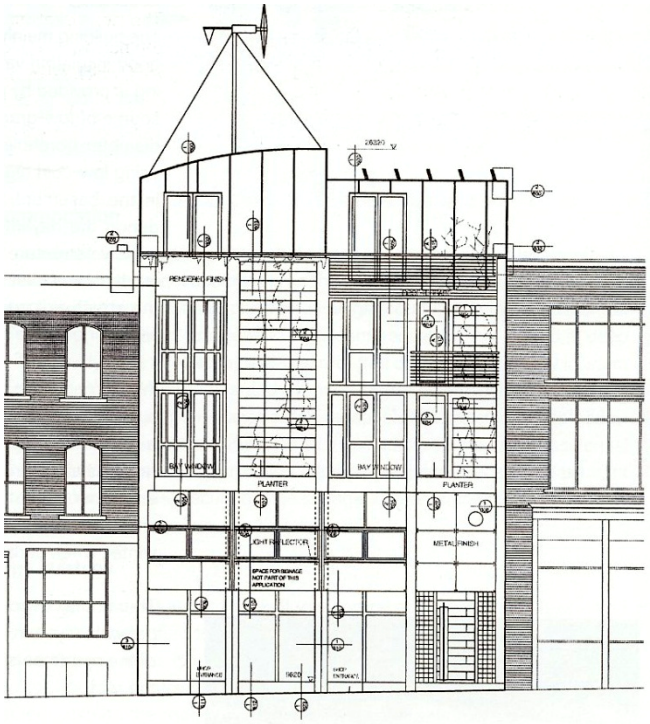
Operating modes

Operating modes for winter is to mix fresh and recirculated air at closed roof level that is then passed in canvas duct in courtyard to basement. The heat is then pumped and raised throughout the building, at night the heat is stored and distributed in pipes. During

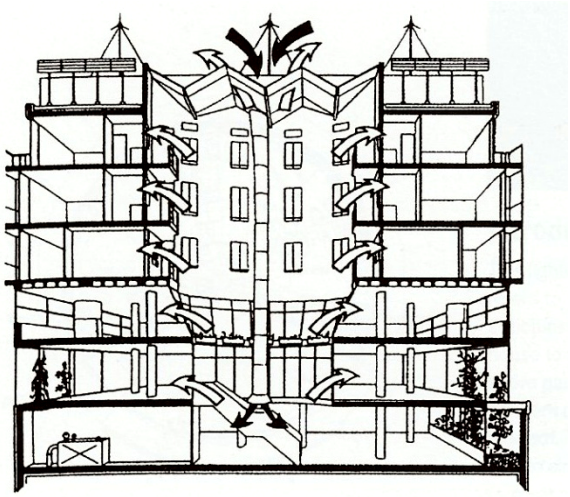
summer air is drawn to basement from above pavement level then passes dense planting, and finally to the central courtyard (113).



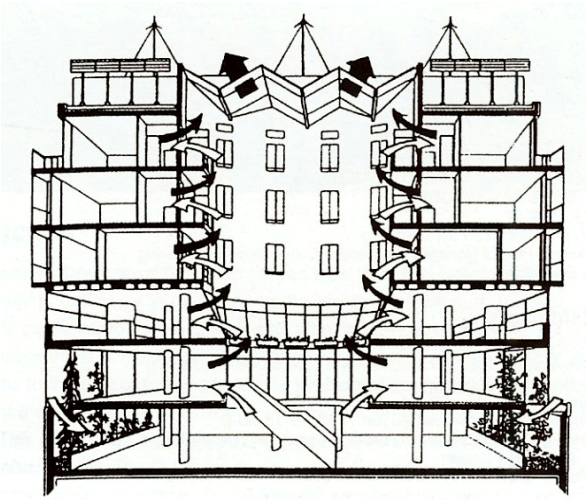
Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 112,113



Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection	■		
Glare control – blinds/louvres/fixed	■		
Responsive artificial lighting control		■	
Heating control			■
Heat recovery – warmth/cooling			■
Cooling control			■
Ventilation control		■	■
Fabric control – windows/dampers/doors			■
Insulation – night/solar			



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 113,114



Building data	
Contract value	IRL£1.5m
Area	~1500m^2
Typical floorplate	5–6m
Number of storeys	5 + B
Price per m^2	~£1000/m^2
Annual energy use	28kWh/m^2*
Typical energy use for building type	96kWh/m^2
Annual CO_2 output	n/a
Number of sensors	100
Visited by authors	✗
Monitored by others	✔

12.1.4 Heliotrop

It is a light weight tree house which cantilevered from a central stair shaft that revolves the house to track the sun. A tracking photovoltaic array is mounted on the roof independent from the main house.

Intelligence factor

The occupancy switch tells the BMS that room is in used and controls the ventilation and heating input to rooms. It varies its orientation in response to sun's position.

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 115

Energy Strategy

The building is programmed to follow the sun in which aim is provide all the energy to the house from the sun (116).

Site and Climate

It is situated at the hottest place in Germany- (at the upper Rhine Valley and on the edge of Black Forest (116).

Glazing

Triple glazing is predominantly used which is krypton-filled cavities, low-e coatings and insulating blinds (116).

Heating

It is only required between November and February. Hot water and part of energy demand is provided from installed evacuated tube collectors on the balustrade of the

perimeter balcony. An electric heating system is the back-up for water heating system. Fresh air supplied mechanically to the space can be warmed in winter by the earth heat exchanger (117).

Cooling

Ventilation air can be pre-cooled by passing it through the heat exchanger. The glazed side of the building can be turned away from the sun. To prevent unwanted solar it is then programmed to offset its revolution (117).

Ventilation

The earth heat exchanger maintains year round temperature. The air is pre-cooled or pre-heated depending on the season. Keeping windows open can be used especially during summer (117).

Electricity generation

A photovoltaic array on the roof which operates independently of the house is programmed to follow the sun on two axis tracking system. It is always positioned for maximum sun exposure (118).

Daylighting

Windows provide natural light and views to all perimeter rooms. Rooms on the south side have full-height glazing (118).

Solar control

Metal balconies around the perimeter of the tower can double as external sunshades other than as maintenance access and fire escape. Aluminized fabric blinds can be raised from floor level to reduce unwanted solar gain internally (118).

Controls

Temperature sensor and occupancy switch are fitted in each room which help the computer determine heat and air inputs.

User control

The building rotation can be manually overridden

Operating modes

The house can be turned away from the sun during the summer to prevent overheating.

Performance

Continuous measurements of the house began in the late 1995. During this test period, there was no ventilation or subterranean heat exchange. There is no delayed tracking of the house to minimize solar gain.

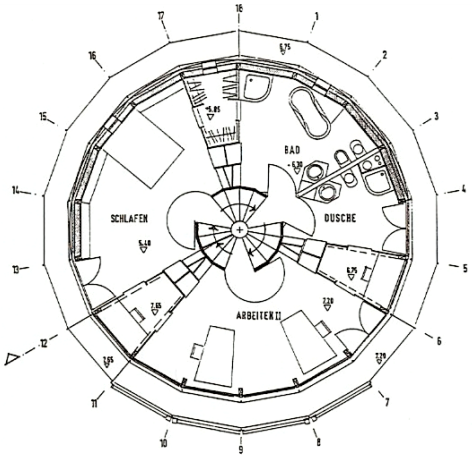
Delivered energy consumption

Actual heating demand lies close to the predicted heating energy demand.

Design process

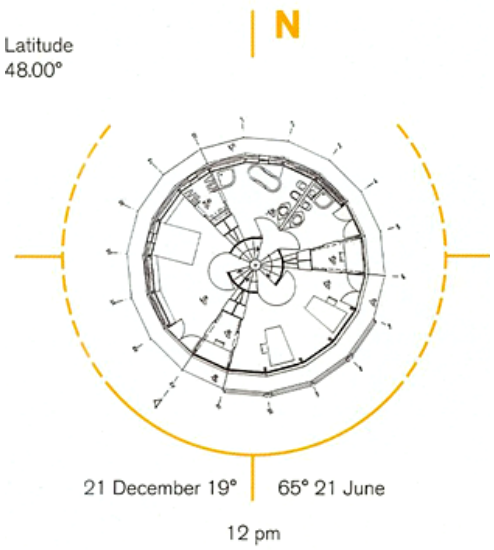
Energy lost is calculated by heat loss and infiltration. Heat gain is from internal sources and the sun.

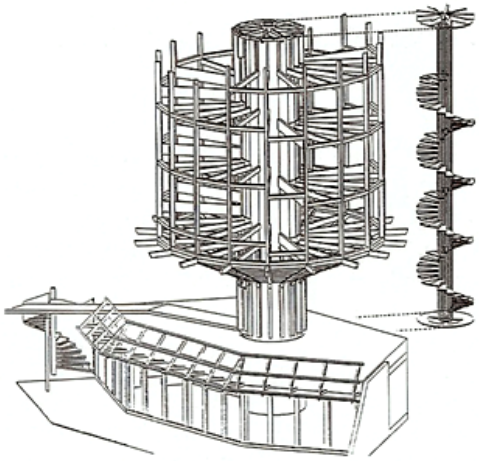
Intelligent features	
Building management system	■
Learning facility	
Weather data	■
Responsive lights	
Sun tracking facility	■
Occupant override	■
Self-generation – CHP/PV/wind	■
Night cooling	■
Solar water heating	■



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 115

Sunpath





Façade transparency	
North	20%
South	100%
Roof	0%
U-values	
Walls	0.13W/m²K
Slab	0.20W/m²K
Roof	0.13W/m²K
Windows	0.50W/m²K

Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection	■		
Glare control – blinds/louvres/fixed		■	
Responsive artificial lighting control		■	
Heating control			■
Heat recovery – warmth/cooling			■
Cooling control			
Ventilation control			■
Fabric control – windows/dampers/doors			
Insulation – night/solar		■	

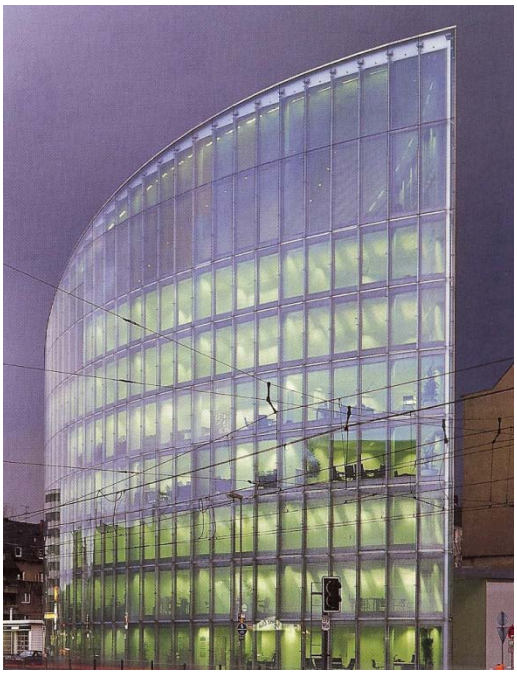
Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 116,118

Building data	
Contract value	DM3.2m
Area	285m^2
Typical floorplate	4.2m
Number of storeys	3 + B
Price per m^2	~£3800/m^2
Annual energy use	25.3kWh/m^2
Typical energy use for building type	200kWh/m^2
Annual CO_2 output	Negative (PVs)
Number of sensors	100
Visited by authors	✔
Monitored by others	✔

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 119, 120

12.1.6 Business Promotion Centre

Europe building to provide office space and galleries to be rented to companies which are pioneering the city's post-industrial revival. To create an energy-saving building that was electronically controlled but not artificially serviced.



Intelligence factor

Double skin contains computer-controlled blinds, which automatically tilt according to information received from heat and light sensors in each room. A gas fired co generation plant feeds an absorption chiller, providing both hot and cold water as well as electricity. Control system includes sophisticated software that analyses current and anticipated weather conditions. And uses data to calculate heating, lighting, and shading levels for the building a day or two advanced (125).

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 125

Energy strategy

Innovative heating and air conditioning system is used as well as the entire building is glazed with a dual skin envelope with a 200mm air gap (126).

Glazing

The glazed skin is suspended from a steel ring beam. The inner skin f the double wall consists of side-hung windows with thermally insulated double-glazing glass with hard low-e coating. Inner windows are opened for maintenance only and outer skin is made up of planar glazing panels (126).

Heating

An under-floor heating system is set into the floor. Hot water is provided to the system by a gas fired co-generation plant, which produces hot water as a by-product in the generation of electricity (126).

Cooling

Chilled ceiling panels are used in a system of modified heat exchangers attached to suspended ceiling panels. The chilled water is produced in a cooling machine, is then circulated at about 13 degrees Celsius, and absorbs excess heat by radiation exchange (127).

Ventilation

Windows are not opened from busy main road along building and only opened for maintenance. Fresh air is ducted through the suspended ceiling of the floor below, and fed into a 30mm cavity formed by PVC vacuum-formed egg crate shell used as permanent shuttering, then spills into empty spaces into floor against the façade giving a fresh air in rooms (127).

Electricity generation

Electricity is generated by a gas-fired combined heat and power unit.

Daylighting

The high provision of glazing and the relatively shallow floor plan provide good levels of natural lighting, which can be controlled by the motorized blinds.

Artificial lighting

Low energy light fittings for VDUs are fitted throughout.

Solar Control

Facades are linked to light and temperature sensors. Each of the 50,000 silver-coated slates is microprocessor controlled to tilt according to the command from the central BMS. Blinds provide a view when closed and opened for cleaning (127).

Controls

The building management system (BMS) was designed to control the building's distribution and consumption of energy micro-electronically. The building's brain is a powerful PC calculating heating, lighting and shading levels for the building in advance.

The data is directed to Meteorological Office from a rooftop weather station measuring solar radiation, temperature, and wind speed (127).

Building data	
Contract value	~£5m
Area	4000m^2
Typical floorplate	6m
Number of storeys	8 + B
Price per m^2	~£1250/m^2
Annual energy use	n/a
Typical energy use for building type	n/a
Annual CO_2 output	n/a
Number of sensors	n/a
Visited by authors	✔
Monitored by others	✔

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 76

User control

Over 200 control panels replacing light switch that connects to the BMS allowing individuals adjusting temperature, humidity, light and shading. Blinds can be done manually.

Operating modes

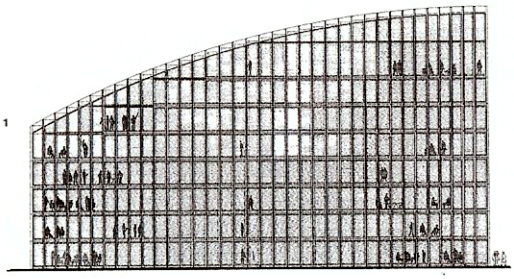
Winter day- pre-heated fresh air by an underfloor heating system and other occupant gains. Heating effect is achieved through passive solar gain and the blinds is optimized by the BMS for maximum daylighting.

Summer day- Fresh air is supplied dehumidified at a temperature below ambient. Radiant cooling is provided by chilled ceiling panels, and polluted air is extracted and replaced by clean air. The blinds tilt to adjust unwanted solar gain and limit glare discomfort.

Performance

Is being closely monitored by a research project at Duisburg's Gerhard Mercator University. Electricity consumption will be self-generated.

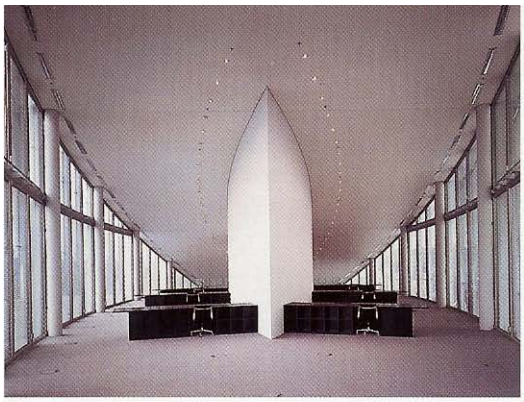
Intelligent features	
Building management system	■
Learning facility	
Weather data	■
Responsive lights	
Sun tracking facility	
Occupant override	■
Self-generation – CHP/PV/wind	■
Night cooling	
Solar water heating	

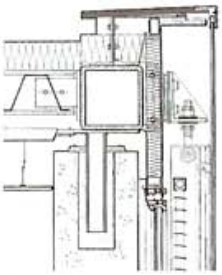


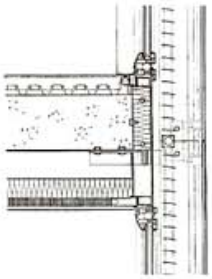
Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 76

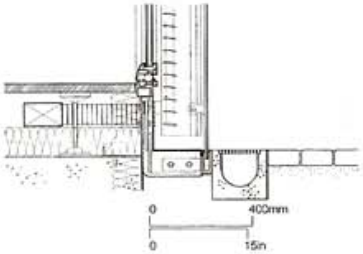
Façade transparency	
East	100%
West	100%
Roof	0%

U-values	
Double skin	1.40W/m²K
Slab	n/a
Roof	n/a

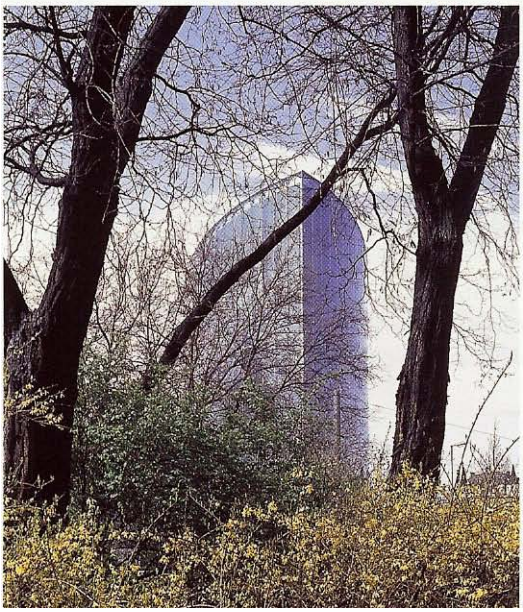








Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection		■	■
Glare control – blinds/louvres/fixed		■	■
Responsive artificial lighting control		■	
Heating control		■	■
Heat recovery – warmth/cooling			
Cooling control		■	■
Ventilation control			■
Fabric control – windows/dampers/doors			
Insulation – night/solar			



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 76

12.1.7 SUVA Insurance Company

The building is a district agency for SUVA. The original 6 storey building was built in 1950. The architects were commissioned to overclad the original building and improve the thermal lighting performance (137).

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 76

Brief

Its main objective is to avoid contradiction of blocking the sun with the external blinds. Artificial lighting supplements the low light levels on sunny days. It is also an energy conservation strategy (137).

Glazing

The new inner windows are of high performance timber with aluminum facing. The new glazed façade is divided into three horizontal bands of motorized top=hinged windows and each lever is automatically controlled with different function (138).

Heating

The lower band of glazing functions as the solar gain. Mechanical ventilation provides ventilation. Radiators provides additional heating. A district heating system supplies heat in form of steam (138).

Cooling

It relies both on mechanical and natural air transfers. Night cooling is promoted when lower panel is open to dissipate daytime heat from stone façade (139).

Ventilation

It is mechanically provided through floor inlets waste air extracted at ceiling level. Natural ventilation is attained by opening the inner windows manually (139).

Electricity generation

The photovoltaic cells at the roof of the building generates electricity to charge batteries for uninterrupted power supply and for emergency lighting system (139).

Daylighting

The upper band of glazing inhibit the direct view of the sky and refracting the direct rays of the sun (139).

Artificial lighting

The lighting system is computer controlled with sensors which determines the need of lights or not in the offices (140).

Solar control

The adjustable prismatic panel provides internal glare control. It obscure the direct view of the sky vault and refract the sun's ray into the depth of the plan. External fabric blinds provide additional solar protection (140).

Controls

The central building management system controls the window operating motors, the lighting, security and plant operation. The control unit consists of a PC, graphical screen output and a maintenance log printer. Wall switches are used to control over the immediate environment such as for external vision glazing panel, operable windows and local temperature control (140).

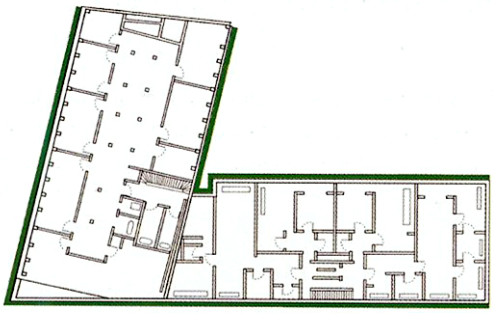
Operating modes

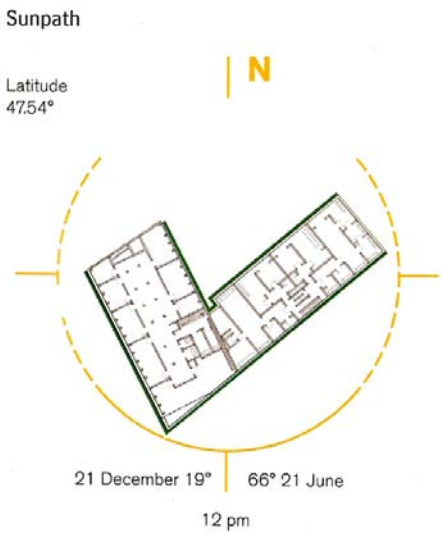
The closed external panels save heating energy during the winter. During summer, the panels are fully opened to obtain the opposite effect.

Design process

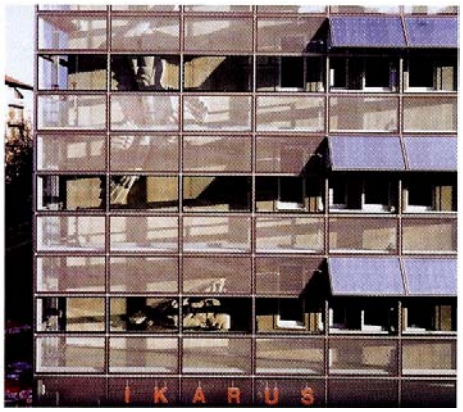
Before the design was completed, a prototype was created and fitted with complete data collection system. The client agreed to the project after the success of the endurance test.

Intelligent features	
Building management system	■
Learning facility	
Weather data	■
Responsive lights	■
Sun tracking facility	
Occupant override	■
Self-generation – CHP/PV/wind	■
Night cooling	■
Solar water heating	■





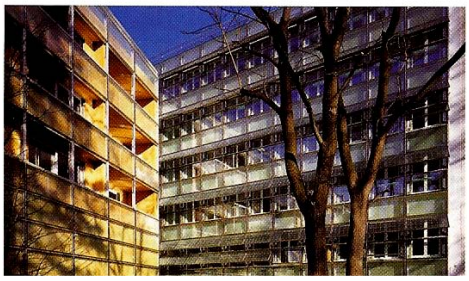
Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 137, 138

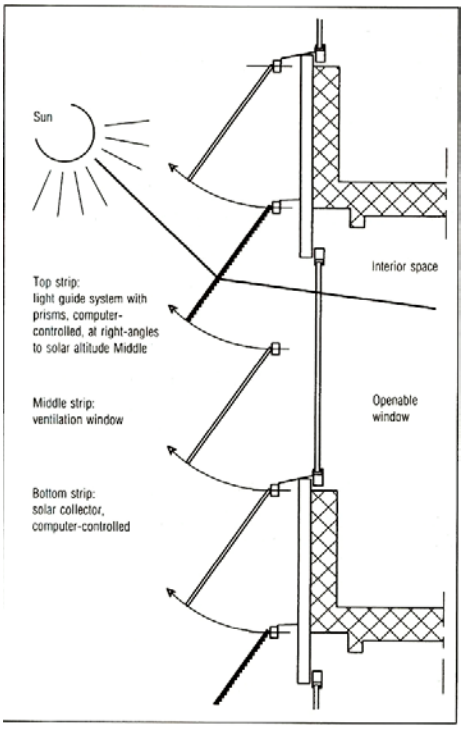


Façade transparency	
North	45%
East	5%
South	45%
West	5%
Roof	10%

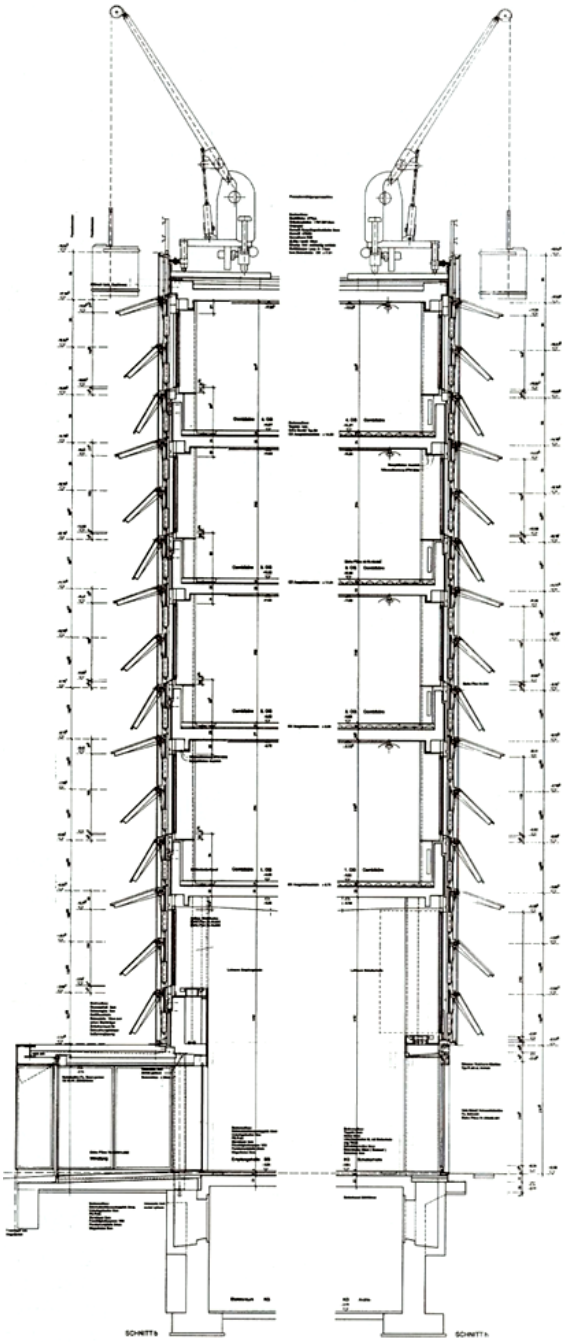
U-values	
Walls	0.32 W/m²K
Slab	0.33 W/m²K
Roof	0.24 W/m²K
Windows	2.00 W/m²K

Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection			■
Glare control – blinds/louvres/fixed			■
Responsive artificial lighting control		■	
Heating control		■	■
Heat recovery – warmth/cooling			
Cooling control			■
Ventilation control		■	■
Fabric control – windows/dampers/doors			■
Insulation – night/solar			■

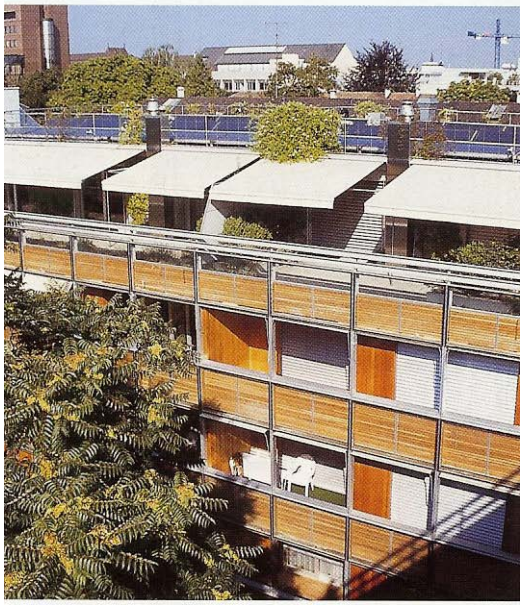




Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 138, 139,140

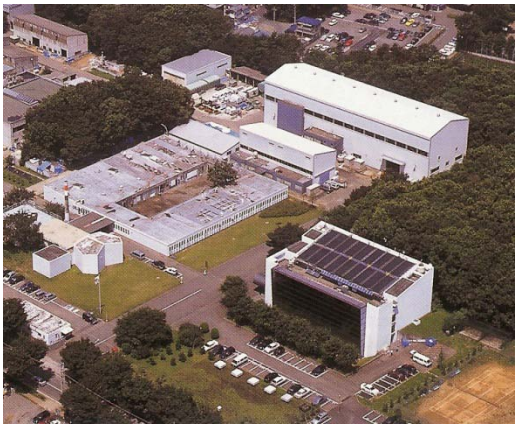


Building data	
Contract value	n/a
Area	n/a
Typical floorplate	n/a
Number of storeys	6 ex/5+3B new
Price per m^2	n/a
Annual energy use	n/a
Typical energy use for building type	n/a
Annual CO_2 output	n/a
Number of sensors	n/a
Visited by authors	✔
Monitored by others	✗



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 141

12.1.8 Super Energy Conservation Building



A Japanese Ohbayashi Corporation building. It has about 98 energy conserving technologies used for research. IT was considered as the most energy-efficient building in the world at the time.

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 159

Intelligence factor

The lighting inside the building is under photocell control that depends on daylight. Inside the building there are auto vents at the top and bottom levels for cooling. During night the auto insulation blinds are raised towards the south for cooling. For pre-cooling in the building is computer controlled for use in the next day. Photocell control provides the main lighting . Automatically insulated blinds can be raised at night which form the element of the double skin. The building is pre-cooled at night in time for the next day with a computer controlled purge facility (159).

Intelligent features	
Building management system	■
Learning facility	
Weather data	
Responsive lights	■
Sun tracking facility	
Occupant override	
Self-generation – CHP/PV/wind	■
Night cooling	■
Solar water heating	■

Accommodation

Windowless areas are to protect interior from sun. Accommodate research institutes administration and scientists.

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 159

Energy strategy/Glaze/Construction

The double skin is used to preheat incoming air. In summer, vents open for natural ventilation. The glazed double skin façade is to preheat air coming in and are also used to

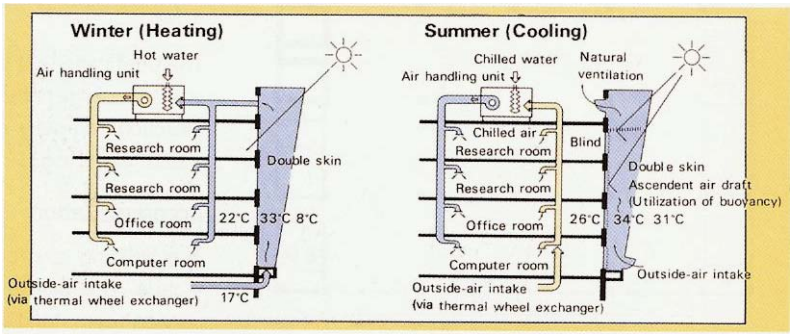
ventilate throughout building. The construction materials used were pre pressed concrete slabs (160).

Heating and cooling

For heating the building has a hot water storage tank that stores water. It uses coiled plastic pipes that store surplus energy that provide energy for heat pumps. A computer control is used for air intake to preheat then goes through the building by fans and ducts. Auto insulation blinds descent at night to reduce heat loss. Domestic hot water is provided by 126 evacuated tube solar collectors on the roof. Another water storage tank is used for cooling the building and by opening vents for ventilation (160).

Ventilation/Electricity generation

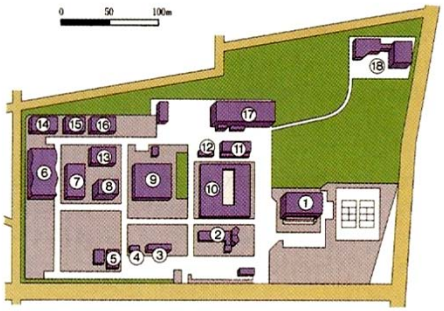
The building is fully air conditioned for ventilation. Open vents and fresh air inlets on north side are other ventilation styles. To provide electricity is by the photovoltaic array on roof for heating (160).

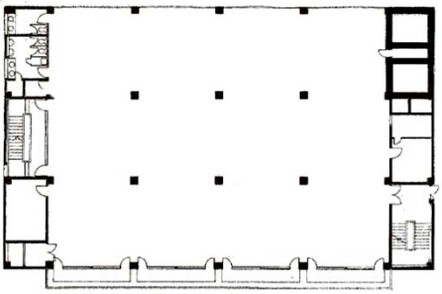


Intelligent control	Passive	Manual	Automatic
Daylight adjustment – reflection/protection			
Glare control – blinds/louvres/fixed			■
Responsive artificial lighting control			■
Heating control			■
Heat recovery – warmth/cooling			■
Cooling control			■
Ventilation control			■

Building data	
Contract value	n/a
Area m^2	3776m^2
Typical floorplate	n/a
Number of storeys	3 + B
Price per m^2	n/a
Annual energy use	112kWh/m^2
Typical energy use for building type	441kWh/m^2
Annual CO_2 output	n/a
Number of sensors	300
Visited by authors	x

Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 160, 162



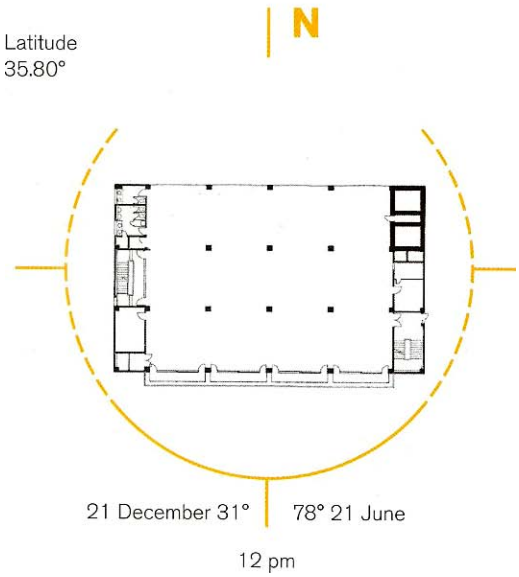


Daylighting/ Artificial Lighting

For day light the windows provide a view than daylight. Some areas inside the building are limited in daylight. Artificial lighting is low powered ambient lighting and task lighting, which are controlled by photocell (162).

Façade transparency	
North	35%
East	5%
South	65%
West	5%
Roof	0%

Sunpath



Source: Intelligent Skins by Michael Wigginton and Jude Harris 2002 pg 160

Controls/Performance/Energy consumption

Computer controls the restroom and stairs lights. In conference rooms a “key” for the lights is provided to turn it on and to turn off you take the key out; floodlights illuminate the ceiling. The solar controls the direct sun by louvered blinds on the outside office windows. Switches are controlled by the BMS, computer, and sensors. During the winter and summer there is an operating mode for heat and cooling. The Obayashi Corporation modifies CO2 level to take in fresh air. Energy consumption consumes of 86.7Mcal/m2 to 95.9Mcal/m2 energy than a conventional Japanese building of 378 Mcal/m2.

13. INTERACTIVE ARCHITECTURE

13.1 Definition

Responsiveness implies to sensitivity. Traditionally sensitivity and exposure was thought as disruptive input that interferes with traditional working methods but is a myth far gone when interactive architecture expose oneself to a whole of new sensations within the architectural umbrella.

Designing smart or responsive architecture is a collaboration of disciplines to create responsive environments. Science and technology are the primary tools for the creation of one. So we can say that it runs wherever we hear opposing terms use to describe complex situations: Subject/object, self/other, form/function, organic/inorganic, static/dynamic, observer/observed.

This interactive world to the environment makes us aware of our own evolutionary transformation as the key to evolution itself.

13.2Public Buildings

Public buildings should get a head start in this environmental revolution because of the publicity and the perfect opportunity that public spaces offer to introduce these new responsive environments. Building should interact to other buildings in such a way that we can participate in such interactions.

Memory wall
Architect: Kathryn Findlay
Hotel Puerta America, Madrid, Spain 2005

Source: Responsive Environments Architecture art and Design by Lucy Bullivant 2006

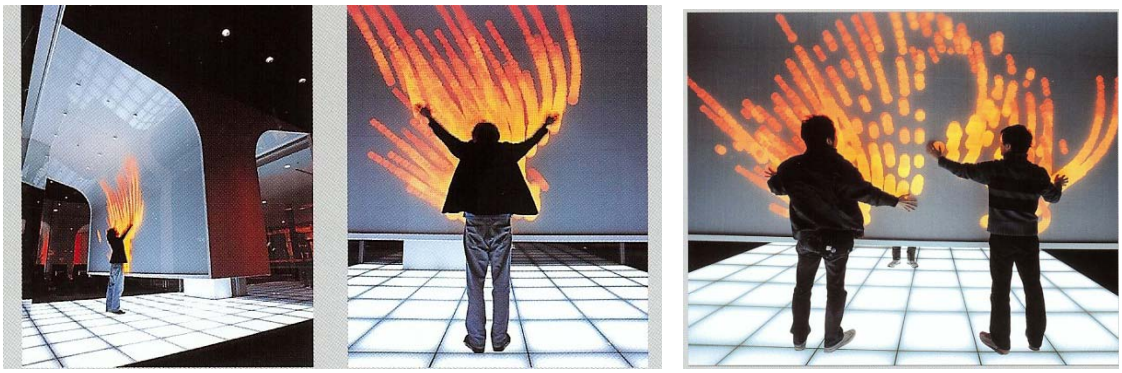
"If intelligent spaces were truly intelligent, we might not like them, because we want them to be intelligent but acquiescent" Lucy Bullivant

Allianz Arena, Munich Germany 2005

The stadium has a rubber clamping system that allows them to expand and flex. The LEDs are fixed around the edge of each cushion, which is printed with a pattern of white dots so that the light sources are diffused (Bullivant).

Source: Responsive Environments Architecture art and Design by Lucy Bullivant 2006

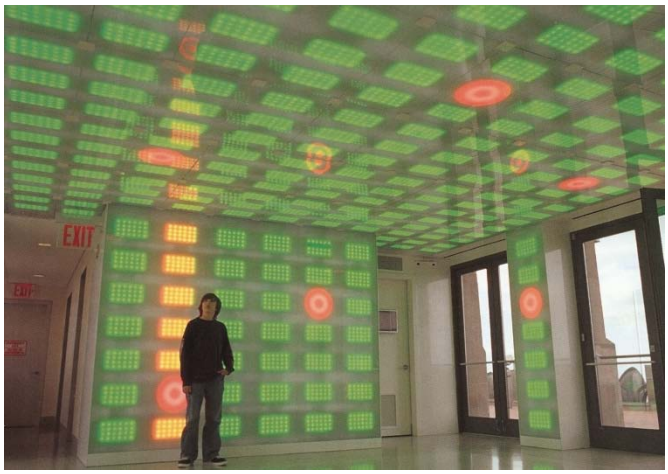
Klein Dytham and Toshio Iwai designed in a public area an interactive playful screen sensitive to the touch. It is an earthquake proof that communicates when a seismic is occurring. Infrared sensors detect an approach visitor and starts interacting but when it is touched it begins to play with the visitor.



Source: 4dspace interactive Architecture by Lucy Bullivan 2005

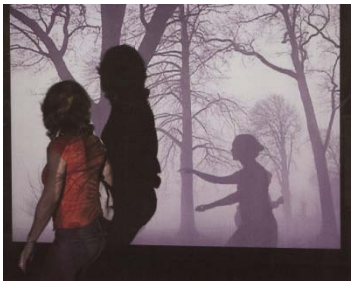
Electroland, Ta

LED lights track and follow the visitor and engage with a mood display around the walls and ceiling.

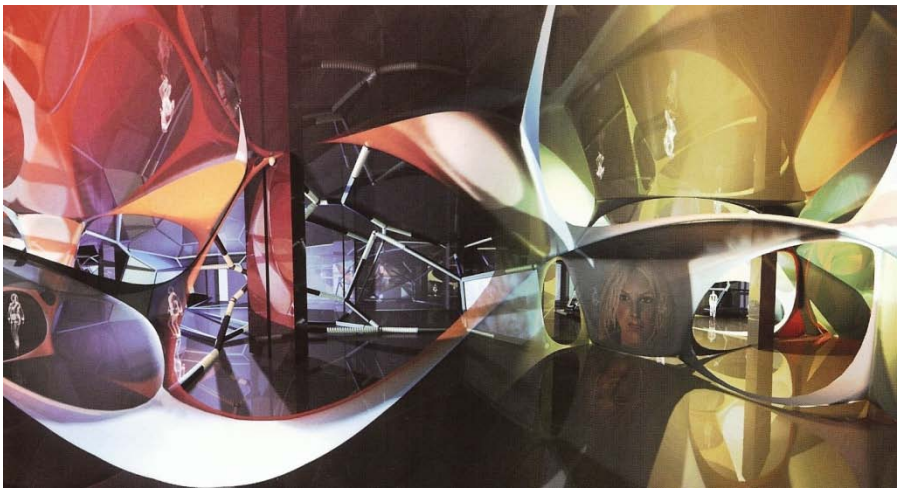


Source: 4dsocial interactive design environments by Lucy Bullivan 2007

My works reward viewers with an immediate, visceral sense of presence, while simultaneously inducing them to understand the conceptual motivation and deeper meaning behind the work.
Scott Snibbe



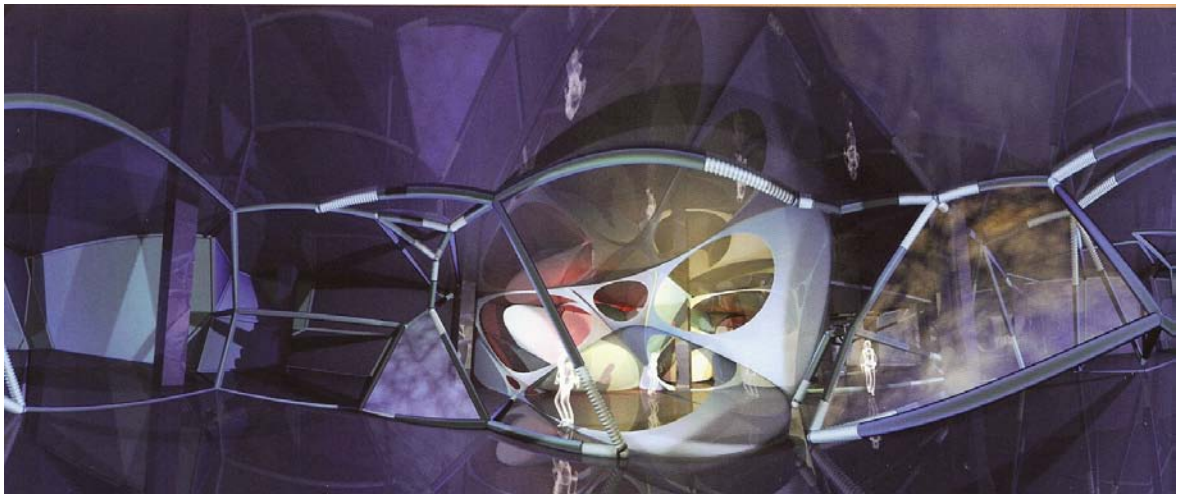
Digital Pavilion Korea, Sampang-dong, Seoul, South Korea, 2006



Second floor is surrounded with multimedia displayed against the dynamic walls creating a cellular structure within the building.

Source: 4dsocial Interactive Design Environments by Lucy Bullivan 2007

The cellular walls are controlled and kinetically manipulated using actuators in the beams of the structural system. The cell system breaks up into smaller, more dynamic and flexible components and organic spaces.



It’s important to be aware that space changes, and is not a void but full of things, wavelengths, for instance, so our relationship with space is not superficial.
Philippe Rahm

14. SMART ENVIRONEMNTS

14.1Definition

Is the intelligent solution to the physical environment in which sensors, transducers, actuators, are connected to each other controlled by a building management system BMS, to allow a physical change appropriate and pleasant to the occupants where conventional buildings methods cannot provide it.

This technology is flexible and adaptable which transforms dead spaces into a pleasant experience. Smart environments replace the known physical labor and sometimes the hazardous work with smart systems integrated within the building.

14.2 Purpose of smart environments:

As technology increases, the need for intelligent buildings rise because multipurpose uses require multiple indoor environment needs. The main objective is to provide comfort and quality life to all occupants. We can say that climate change has forces us to redefine our traditional building methods in which buildings are no longer inanimate and colorless rather they are becoming living objects in which environments adapt to radical climate changes and more.

14.3 What makes a building off the grid?

Buildings are considered off the grid when they are no longer connected to public services like sewer, electricity, water main, and others.

14.4 What do we need to make this prototype off the Grid?

-By self generate electricity,

-By harvest water for consumption.

-And by provide alternatives for sewer system and more.

THE DESIGN

PART II

THE RESEARCH PROTOTYPE

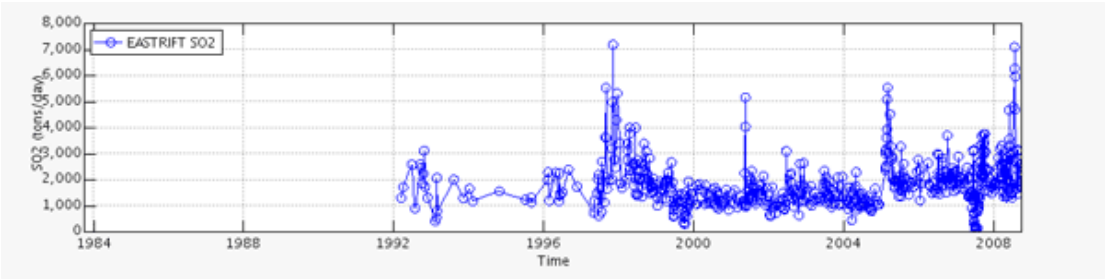
15. PLANNING AND PHYLOSOPHY OF DESIGN

15.1 Site Analysis

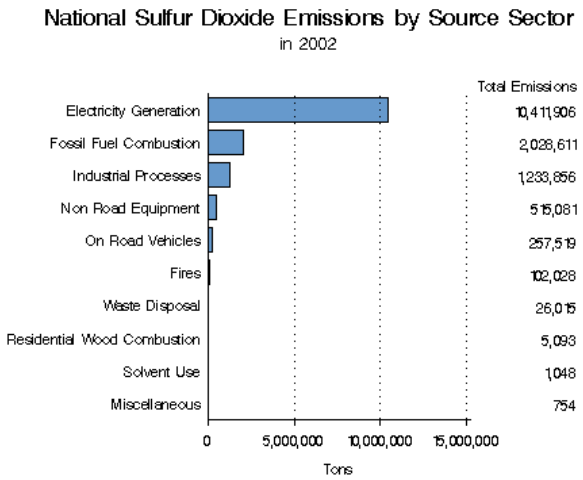
The site is located on the Big Island of Hawaii right at the Volcano National Park. The prototype will be situated at one of the most unpredictable weather conditions and prone to high winds, earthquakes, lava flows, air pollution, acid rain, and extreme weather conditions due to the location at the Kau desert southwest from the Kilauea Caldera. The site is not accessible by vehicle; to get there one has to hike for about a mile from the main highway. There is no much vegetation around due to previous volcanic activities. It is situated at an altitude of 3,000 feet above sea level with Mauna Loa view to the west and the ocean to the south.

One of the biggest concerns to get to the site is that the recent VOG containing SO2 levels can be hazardous to people, animals, and vegetation.
Scientist at the Hawaiian volcano monitor the sulfur dioxide gas levels which the Kilauea and Pu'u 'O'o craters produce daily.

According to nps.gov recent SO2 records the Kilauea volcano emits around 4 to 5 thousand tons of sulfur dioxide each day, including CO2 and vapor water comparing to a yearly national sulfur dioxide by sector.



Source: http://hvo.wr.usgs.gov/hazards/FAQ_SO2-Vog-Ash/P1.html

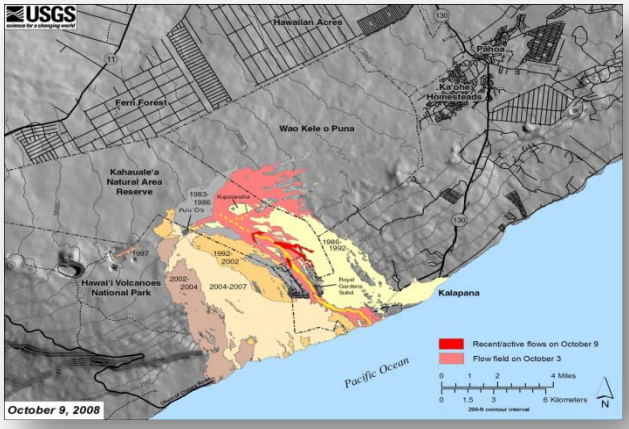


Source: http://www.epa.gov/air/emissions/so2.htm

Source: http://www.hawaii-guide.com/images/large_downloadables/hawaiian_islands_map_1280x960.jpg

Location of site

Source: nps.gov

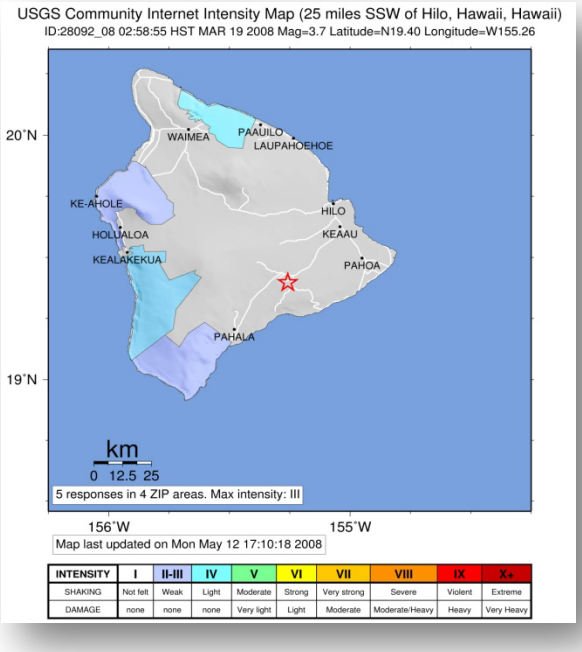


USGS record of volcanic activity by the Kilauea Volcano

Source: nps.gov

Kilauea's gas (VOG) emitting more than 4 thousand tons of SO2 daily in recent records 2008

Source: nps.gov



Recent earthquakes located near by the site.

Source: nps.gov

Unpredictable lava flows by the Kilauea and Pu'uO'o craters, clearing everything on its path.

Source: nps.gov

The Flyspec, pictured here strapped to an HVO vehicle, has replaced the larger, heavier, and more expensive optical correlation spectrometer (COSPEC), which was used to measure SO2 emissions at Kīlauea for over two decades. A scientific comparison of Flyspec and COSPEC showed no loss in accuracy or precision of data collected with the mini-spectrometer.

Scientist monitoring SO2 levels on accessible roads

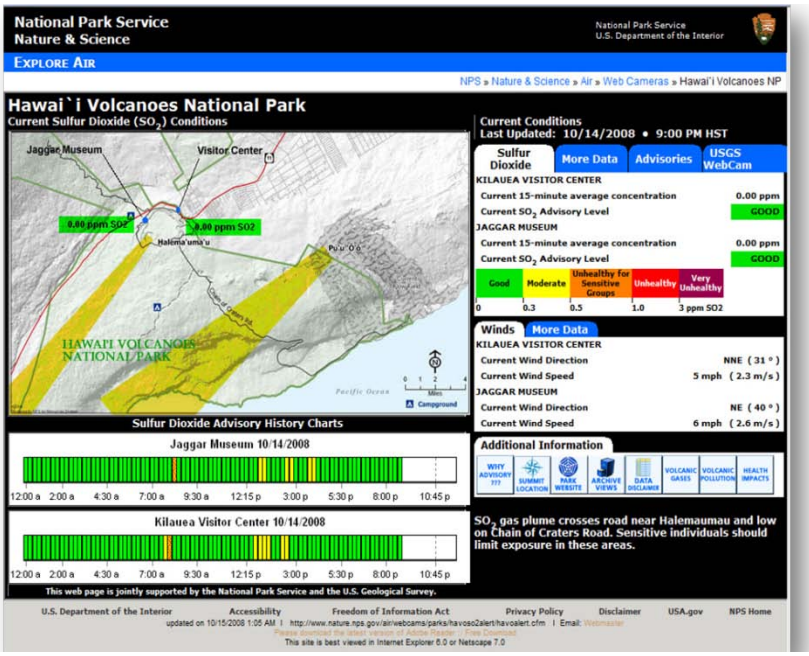
Source: nps.gov

Scientist conducting field samples.

Source: nps.gov

Actual shelters are no more than 8’ x 10’ enough space to store little equipment.

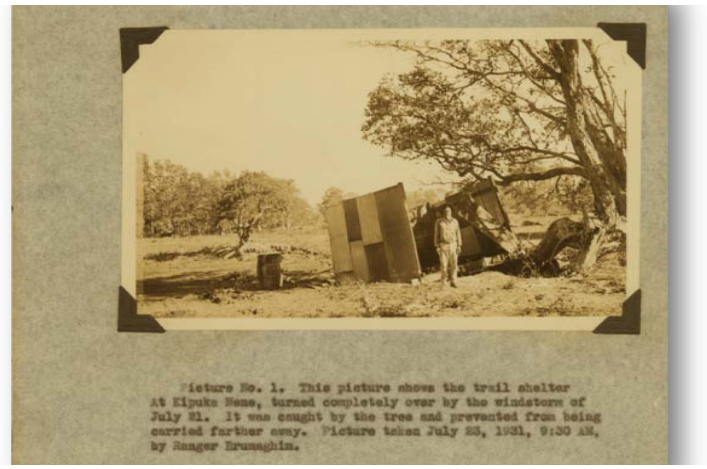
Source: http://hvo.wr.usgs.gov/hazards/FAQ_SO2-Vog-Ash/P1.html



Scientist at the Volcano National Park monitors the SO2 levels every 15 minutes. They provide a website to inform the public of major SO2 hazards in the area. From Good, moderate, unhealthy for sensitive groups, unhealthy and very unhealthy are the level conditions.

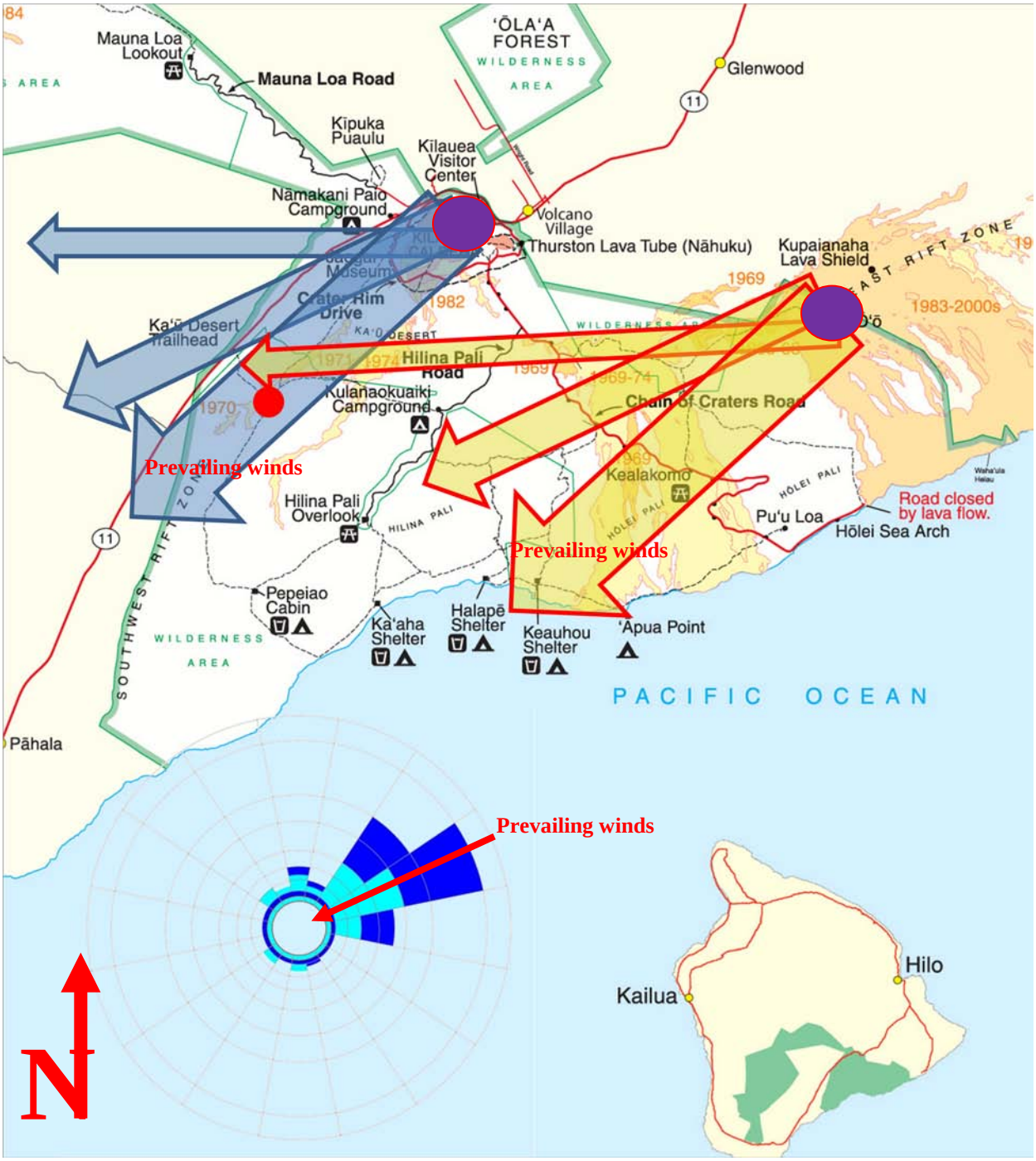
Source: http://www.nature.nps.gov/air/webcams/parks/havoso2alert/havoalert.cfm

The Volcano National park Archive has records of many cabins destroyed by strong winds during hurricane seasons.



Source: scanned photos from the NPS Archive files

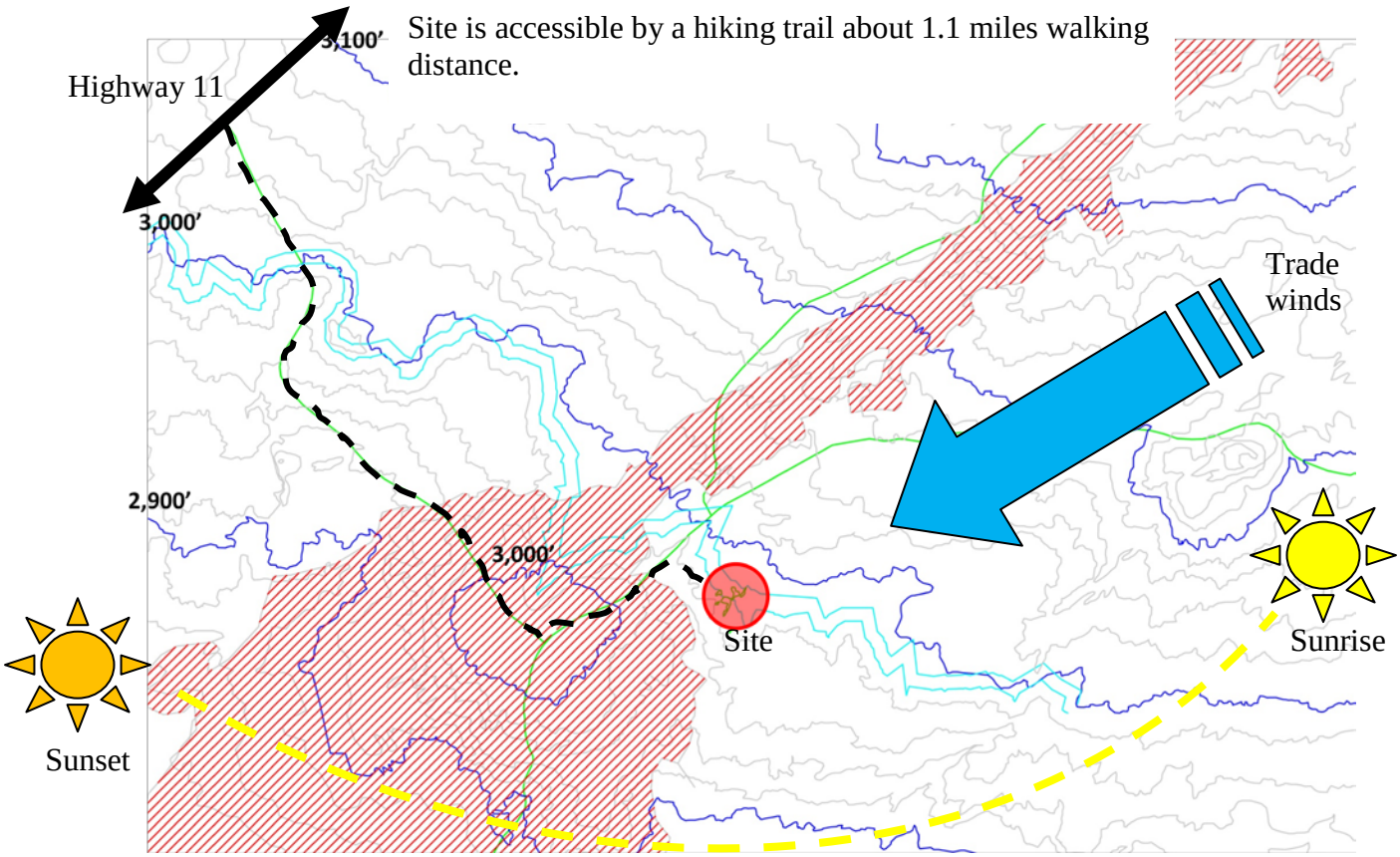
The following map shows the two craters that produce S02 and the three most common wind patterns directions. It also shows the contamination path in which the site gets affected.



Map Source: nps.gov and adjusted with wind pattern direction by my person to represent which areas of the Volcano National Park gets affected by the S02 including the site.

Nearest vehicle transportation is Highway 11.

Site is accessible by a hiking trail about 1.1 miles walking distance.



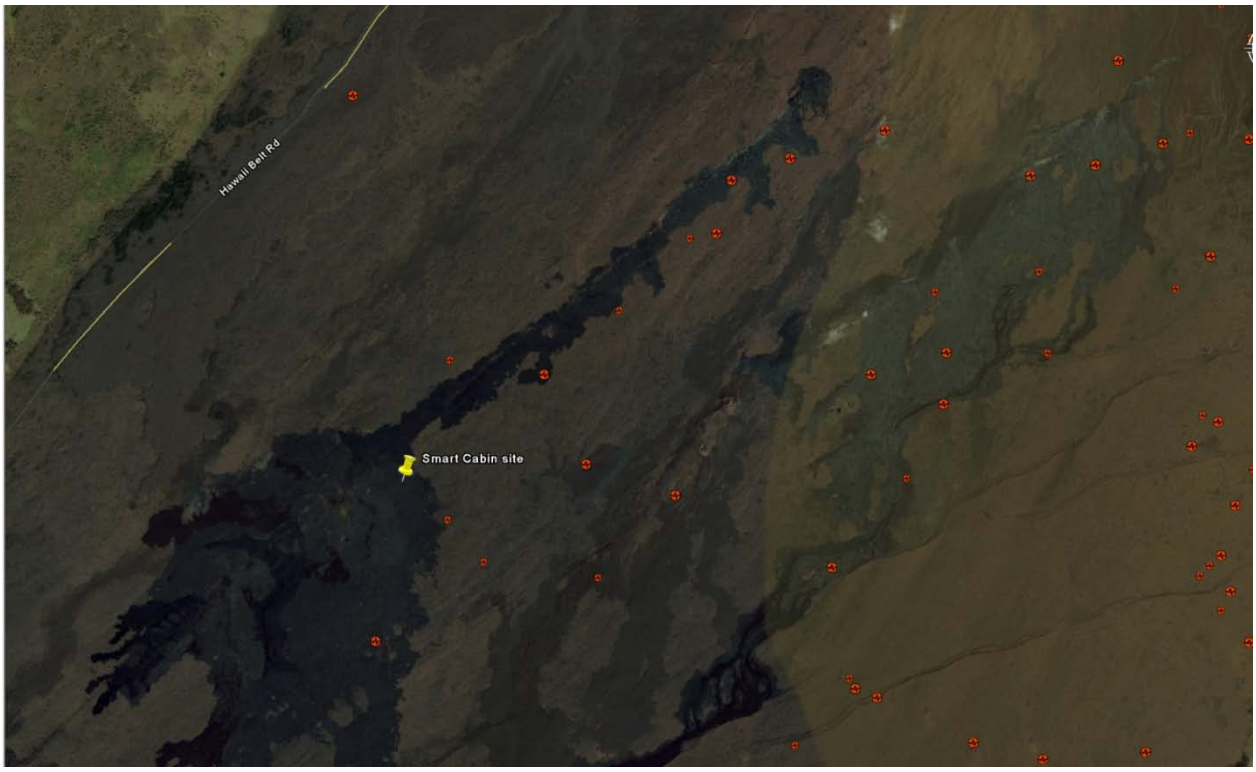
Site Plan
Source by Author

The hiking trails are surrounded by Ahus pile of rocks which helps to orient hikers in the area.

Pictures taken by author during Summer school field trip at the site when unexpected SO2 gas (VOG) surround us making our hike impossible to continue.

Picture source: By author during summer school 08 in which VOG made trip impossible.

Epicenter for Earthquakes Source: Google maps



15.2 The Analogy

We need to take the approach of nature overall from science and engineering in order to understand the inner structure systems of smart buildings. For example we can learn from the variety of skin in nature and the response and adaptation to the natural environment and its biological composition.

- **The outer bark of a tree** in which it is protected from the outside world. It is continually renewed from within, and it helps keep out moisture in the rain, and prevents the tree from losing moisture when the air is dry. It insulates against cold and heat and wards off insect enemies (arborday.org).

- **The biological shelter of mollusks** these are seashells to protect the fleshy bodies of clams, oysters, snails, and others in order to survive. The early mollusks that happened to develop hard shells managed to survive more than 500 million years between themselves and their predators (The shape of Life, www.pbs.org/kcet/shapeoflife/.)

- **Birds skin** is a thin delicate which produces specialized structures called feathers. These feathers usually cover exposed areas of skin. Birds are found all around the world and in many different habitats, from deserts and savannas to aquatic and marine, from tropical jungles to Antarctic ice fields. Feathers have evolved a variety of forms that allow birds to exist in specific environments (Davidson).

- **Fish skin** according to Tara Law from the University of British Columbia, the skin of fishes may play a substantial role in swimming mechanics.

- **Polar Bear Skin** and the hypothesis of absorption of UV through the hairs to warm up the bear skin (Rozell).

- **The Human Skin** with many functions for protection, sensation, heat regulation, control evaporation, aesthetic and communication, excretion, absorption, and water resistance (Parker)

Nature has a lot to show us specially the way skin is integrated in which can adapt to almost all weather conditions but at the same time is fragile, sensitive, and prone to

diseases. So let's observe closely how an intelligent system adjusts to create an adequate internal environment to protect other systems within it.

This way we can view buildings as a series of integrated biological systems in which each system has different functions.

The smooth running of these systems allows an unlimited use of the building as Klaus Daniels appointed on his book Advanced Building Systems. Building systems can account from 25% to 50% of the entire construction cost. Therefore they play an overall factor of the project development. One question we can ask ourselves is, does complex building systems apply to large and complex projects only or it can be integrated into small scale projects? How feasible is to implement this smart mechanical system into small scale project? If not what are those variables?

Building performance is attributed to a level of thermal, hygienic, acoustic, and visual comfort but not limited to electromagnetic, security, vertical circulation, even with the sick building syndrome as Klaus defines on his book.

The connection and flexibility to adapt from interior to the exterior environment or vice versa and/or to the human presence play an important role when smart environments respond to such ecological and biological cycles. This flexibility applies when all building systems are actually integrated as a whole as in comparison with the human body perfectly connected with the skeletal, muscular, nervous, respiratory, digestive, cardiovascular, endocrine, skin hair systems and others. For the human body, it will be impossible to be detached from one of these systems because they depend of each other to coexist even when the body responds to basic voluntary or involuntary movements.

The next generation of buildings should be looked at as artificial biological systems, which are integrated and connected to each other with a computerized artificial intelligence to monitor the outcome of such systems for superior performance and maintenance of such built organs within the building. The next generation of buildings

will no longer be inanimate objects but metaphorically speaking as living bodies which serve basic and more complex commands to serve complex human needs.

15.3 Project Intent

Smart environments are the result of a flexible and adaptable technology such as building enclosure systems in which respond to a certain stimuli. The science of such response will be analyzed and study for performance and practicability.

The natural environment should interact with the built environment. The impact that we do to the environment will have a direct effect to the overall human comfort conditions, so we need to strive for zero energy consumption within the next decade or so for the ultimate performance. Buildings need to be flexible, adaptable, and sensitive even to the point that buildings can be energy generators that maintains itself, be able to respond to human comfort, visually appropriate to any culture, and be part of an intelligent system that enforces the revolution of the green approach.

The built of smart environments should be a recollection of technologies working closely with science to strive for the ultimate performance utilizing new or redefining traditional construction materials with the help of appliances or biological systems that respond to basic needs and to more complex ones for the comfort to human beings.

15.4 Methodology

This project is intended to serve as a review of the current best practice in the relatively new field on intelligence in buildings. There is a misconception of where to apply the terminology of smart buildings on these days, mainly because not all modern mechanically operated buildings are considered artificially intelligent. My intent is to utilize a methodology and identify such intelligent buildings constructed now on days that fulfill an intelligent purpose and create smart environments with the utilization of intelligent building systems that makes it responsible to the environment and to coexist side by side with people for the ultimate performance in architecture.

We had look at study cases on different types of buildings such as airports, laboratories, hospitals, and other multipurpose buildings in which architects, designers and engineers had incorporated into building enclosure systems in order to adjust indoor climate conditions and respond to other variables to provide security, healthy and responsible environments. These systems shall be operated automatically in respond to functions but not limited to the following:

- Smart structural system
- Develop an immune system building
- Enhancement of daylight with shelves/ reflectors
- Protection from the sun with louvers/blinds
- Insulation like night time shutters
- Ventilations like automated dampers
- Collection of heat with the use of solar collectors
- The decrease of sound with acoustic dampers
- Exploitation of pressure differentials with the use of ventilation chimneys

15.5 Outcomes

The project will consist basically of two parts. The first part, (Arch 546) was dedicated to the research as seen on part one of this paper and establish a design methodology, in order to understand and identify building enclosure systems in which to create smart environments. This methodology could be prescriptive to large and small scale projects depending on how adaptable, interactive, and transformable the building needs to be in any type of buildings. In my second semester the continuation of my

Research-Design Project in smart environments, I will design a prototype independent from public utilities to serve as a refuge from the extreme natural conditions at the Ka'u Desert, Hawaii Volcanoes National Park in the island of Hawaii. There will be several possible sites to incorporate this smart cabin prototype subject to radical natural forces within the Kilauea and the Pu'u O'o Craters.

The program is intended to respond to many challenges like:

- High levels of SO2
- Earthquakes
- Fire brush
- Lava flow
- Zero utility services

I will use a methodology to create a smart environment within the cabin that can be used as a temporary shelter for hikers to have a break from the natural changing environment conditions and to scientists that may need to conduct scientific studies within the nearby areas for the recollection of data and further analysis.

Some of the requirements are the utilization of responsible construction materials to the environment and other enclosure systems to deliver a responsive architecture in a remote area with unstable weather conditions and other natural forces and be cultural accepted.

15.6 Objectives and Goals

1. Buildings should sustain extreme weather conditions and respond to:
   - Earthquakes

- Strong winds
- Fire hazards
- High levels of air pollutants
- Acid rain

2. Use of renewable energy consumption
   - Wind
   - PV
3. Building skin shall be prefabricated and the use of green products and smart material to achieve smart systems.
4. Provide excellent indoor air quality by means of Active-Passive design.
5. Minimize carbon footprint and redefine our traditional methodology and visualization of the use of traditional and ecological materials.
6. Intelligent building performance should reflect in
   - Building skin
   - Services:
   - Sanitation, Fire protection, heating, ventilation, lighting, day lighting, indoor environment quality, solar control, water efficiency.
7. Create an smart environment by means of intelligent materials, systems and structures if possible.
8. Building organization should be straight forward, minimalist and functional.
9. Building should have the same language throughout the entire site.
10. Construction methods:
    - Foundations systems should have minimum impact to the site
    - Structural system should be universal and assemble on site
    - building enclosures and interior partitions should be prefabricated

15.7 Approaching the problem:

The solutions of two of the problems are: air pollution requires a combination of technologies for radical approaches such as: Bioterrorism and their solution to isolate chemical warfare disperse in a building and to control them. Some smart materials are

place to detect biological or chemical agents and others are for intelligent uses in which they play an important role in smart environments.

Another problem is that the site gets affected by constant earthquakes, to reinforce the main structure it is recommended to utilize a combination of smart structural systems like dampers, actuators, and hybrid systems which help stabilized the main structure depending of the seismic intensities.

15.8 Main objective of placing a building on this site:

To probe that conventional building method cannot control the extreme conditions of the area in which the only solution for such radical environment conditions and to make a building livable are the combination of multidiscipline, technologies, and especially the utilization of intelligent systems which creates smart environments. Climate change is real and it will bring radical and extreme weather conditions close as this one in the near future so we need to start giving smart solutions for impossible tasks.

15.9 How to understand smart systems strategies? The role of the architect.

It is important that the problem is defined before to start giving solutions. Planning is important and setting up the goals earlier will help to start defining smart environments. The Architect needs to understand emerging technologies and how smart system and materials can be utilize to accomplish such goals. The very first steps are to find sustainable solutions and if the building is off the grid, real passive and sustainable solutions are to be given.

16. DESIGN, PROGRAM, PLAN AND ORGANIZATION

The smart cabin and information center serves four distinct purposes:

1. The cabins are a rest place for hikers and visitors to stay in the Kau Desert for a night or two the maximum. The cabin will accommodate eight visitors at the time in which it will provide shelter from the exterior environment. The cabin provides the followings: resting area, gaming entertainment, cooking area, dining, showers, restrooms, and sleeping rooms. Visitors can enjoy the views from their sleeping quarters to the Mauna Kea Volcano and go outdoors when the environment management will allow it because of unpredictable outdoor air pollutants.
2. The information Center will inform visitors with the newest technologies about the building and the National Park activities. This information center will have a maximum occupancy capacity of 25 people at the same time. There will be booths with security alone the trail to the site allowing visitors hike the trail of 1.8 mile hike in a flat terrain accordingly. Interactive information booths will be the primary information displays within the visitor center.
3. A field observatory will provide work station to 8 scientists allowing them to work and conduct their studies and observations as a substation from the main Kilauea Observatory. The field observatory will provide 8 workstations, computer room, 2 meeting rooms, workshop area, lockers, and storage area mainly for the observatory personnel.
4. A greenhouse shelter is the heart of the immune air system for the entire facility. This shelter will be the primary source of storing rain water gather from the buildings roofs and process the water according to the needs and purify it for dinking purposes. It also accommodates two main air handling units with their own filtration system to purify and provide quality indoor air to all the buildings in the facility. The greenhouse will have selected plants that helps purified common air pollutants as well as to help propagate the surroundings with indigenous plants.

The following charts are the goals to achieved smart environments by defining the smart system, method and materials.

Smart cabin systems	Method	Smart Material
Control of solar radiation transmitting through the building envelope	Spectral Absorptivity/transmission of envelope materials Relative position of envelope.	Suspended particle panels Liquid crystal panels Photochromics Electrochromics Lover or panel systems Exterior and exterior radiation (light) sensors photovoltaic's, photoelectric Controls/actuators shape memory alloys, electro- and magnetorestrictive

Smart cabin systems	Method	Smart Material
Control of conductive heat transfer through the building envelope	Thermal conductivity of envelope materials Heat capacity of interior material	Thermotropic, phase-change materials Phase change materials

Source by Author

Smart cabin systems	Method	Smart Material
Energy delivery	Conversion of ambient energy to electrical energy Daylight sensing illuminance measurements Occupancy sensing	Photovoltaic's and wind power Photoelectric pyroelectrics

Source by Author

Smart cabin systems	Method	Smart Material
Optimization of HVAC systems	Temperature sensing humidity sensing Occupancy sensing CO2 sensing SO2 sensing HO2 sensing Heat sensing And others	Thermoelectric, pyroelectrics, biosensors, chemical sensors, optical MEMS Thermoelectric, phase-change materials, heat pipes

Source by Author

Smart cabin systems	Method	Smart Material
Control of structural systems	Stress and deformation monitoring, crack monitoring, vibration monitoring.	Fiber optics, piezoelectric, electrorheologicals (ERs), Magnetorheological, shape memory alloys.

Source by Author

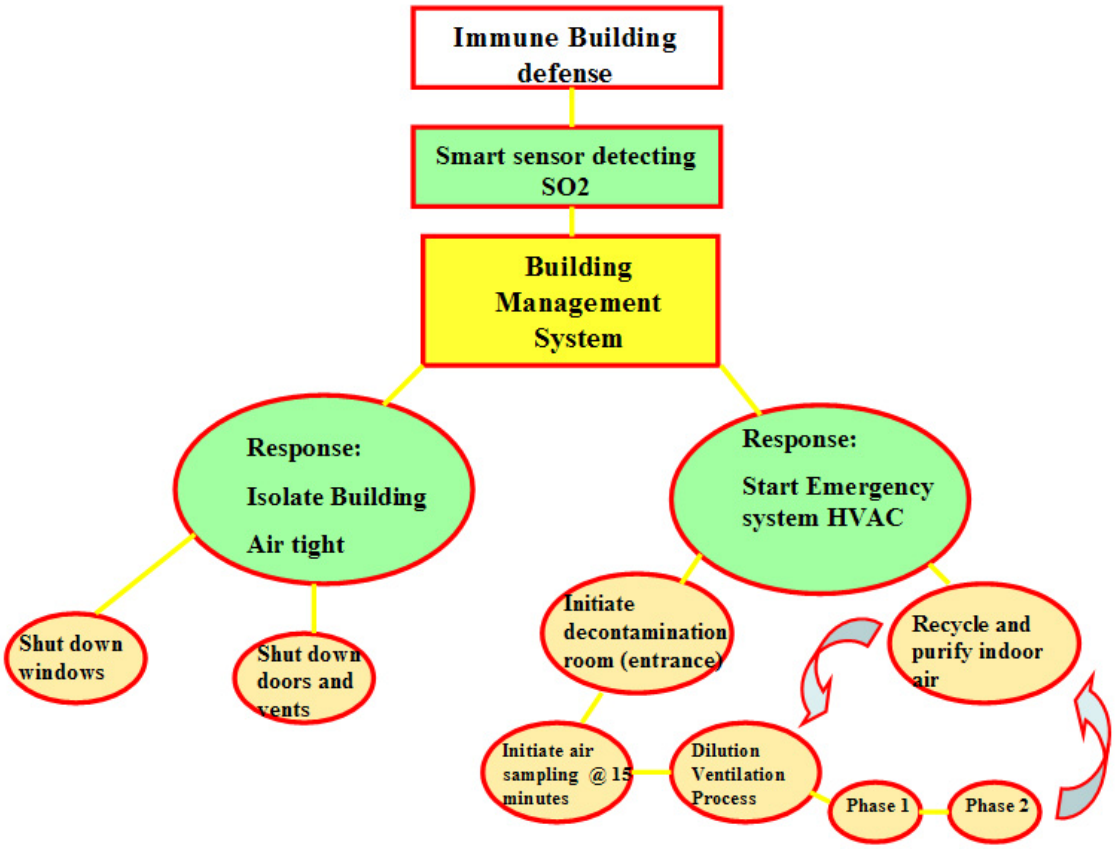
The following chart by Michelle helps understand the concept behind smart environments. The Building Management System needs the necessary data to observe and monitor the implemented smart systems for ultimate performance, accuracy, and life span of such as follow:

Environments		Cognition		Implementation	
Types	Behaviors	Approach	Levels	Model	Strategy
Surrounding Environments Air Thermal Lighting Sound Structural Other Use of environment Resting Workshop Kitchen Bathroom	Behaviors Parameters Single Multiple All relevant Increasing behaviors addressed	None Information rich Systems Expert system Artificial intelligence Metaphor models	Direct responses Use of info Guided responses Reasoning evaluation Reflection Increasing cognition	Direct mechatronic Enhanced mechatronic Constitutive models Metaphor models	Discrete component and system control Real persuasive, effective, Human voice, gesture, body tracking, other Intrinsic responses

Source: Smart Materials and Technologies by Michelle Addington and Daniel Schodek

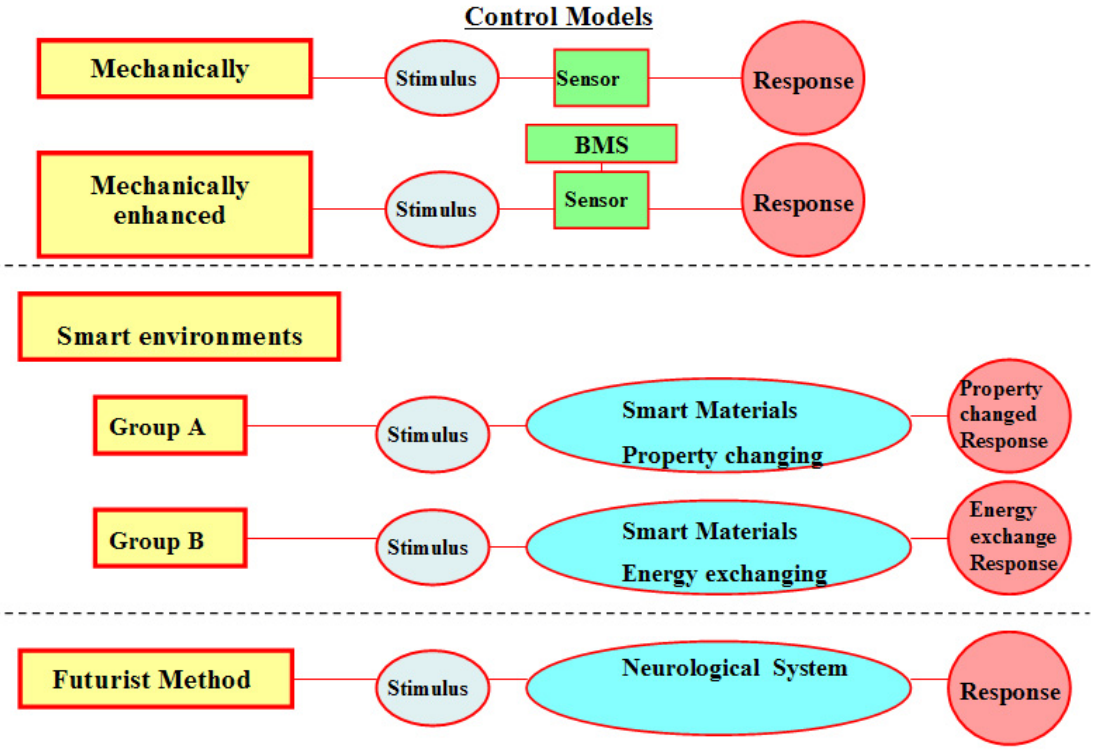
The following chart helps define the problem of air pollutants in which the buildings will be expose to. From here my approach to the problem is to develop an immune system defense as if the entire site was affected by biological chemical weapon. Such technology was developed soon after 9/11 attacks when some federal buildings were threatened with biological weapons as Anthrax and others. The site is affected specially with unpredictable high levels of S02 from the nearest craters Kilauea and Pu'u 'O'o.
As we mentioned Wladyslaw and his book "Immune Building Systems Technology" identifies how pathogens can be spread, treat and immune a building in case of such biochemical attacks.

My approach to the solution is unique in a way because the outdoor air is the contaminated one instead of coming from indoors. Wladyslaw's approach is the most appropriate to isolate the entire building but instead of providing fresh air from outdoors the fresh air will come from the greenhouse. It is necessary to filter properly the remaining air because of contaminants residuals, this process will be explain later on.



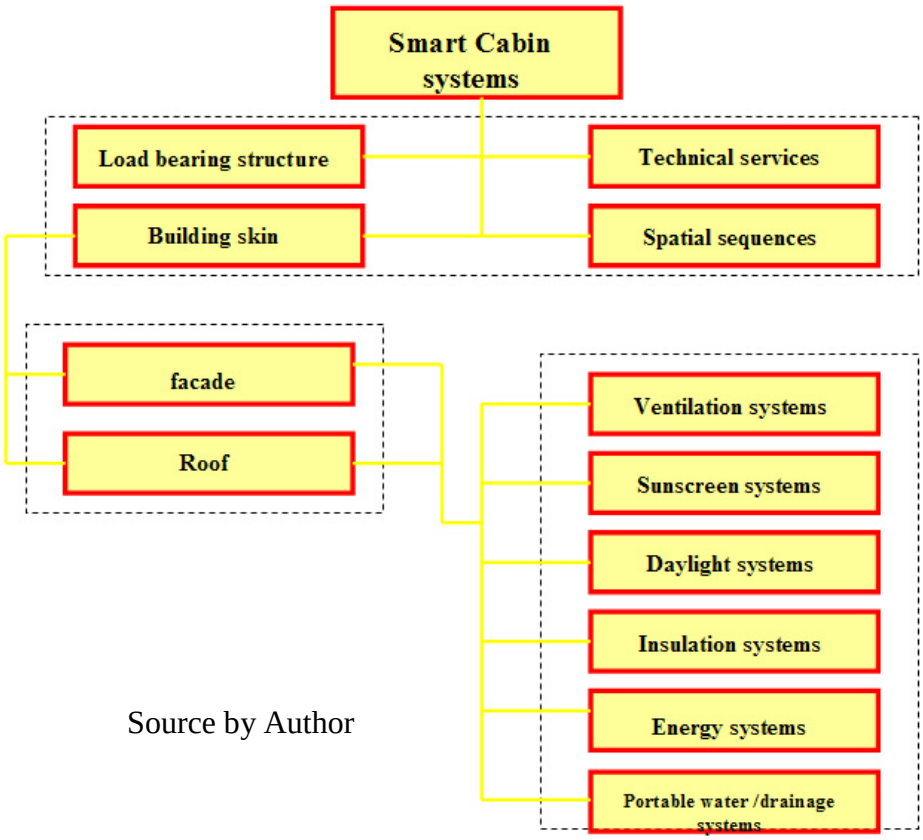
Source by Author

Smart systems can be operated with or without a Building Manager System the only difference is that the BMS analyze data and can be programmed to learn from patterns and to better respond to such stimulus that triggers the change. BMS can report malfunctions from sensors, actuators and mechanical failures and it is easy to identify the problem and give the proper solution accurately.



Source by Author

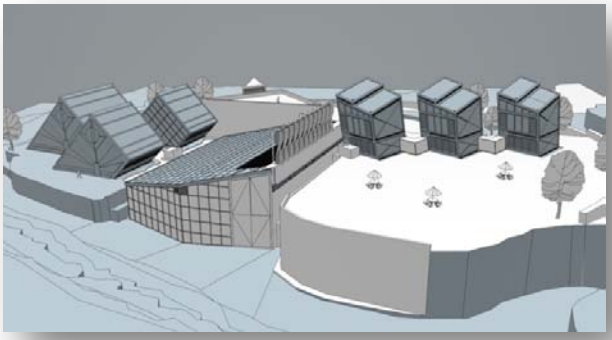
Smart environments can be achieved by smart materials that have property changing or energy exchanging. Systems with property changing automatically respond to the stimulus and the energy exchanging one has to trigger physically to activate it. In my approach to smart environments within the property both approaches are suggested.



Source by Author

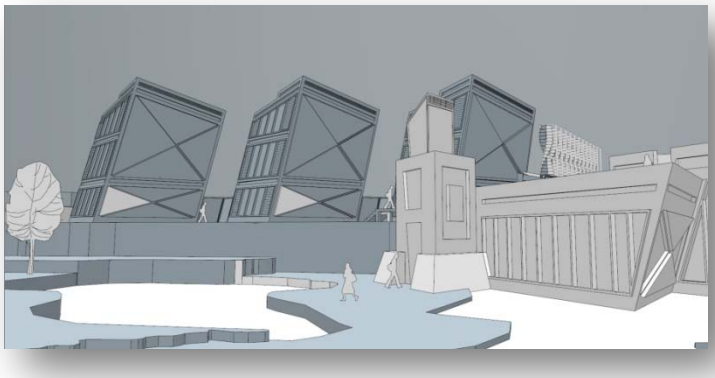
16.1 Design concept

The project sits right on unstable ground due to volcano activities and more, from this fact the design approach mimics instability such as: odd shapes, crystallizations, sudden turn, and from the inner core spits fresh and quality air instead of toxic gases a reverse approach to maintain a perfect building indoor balance.



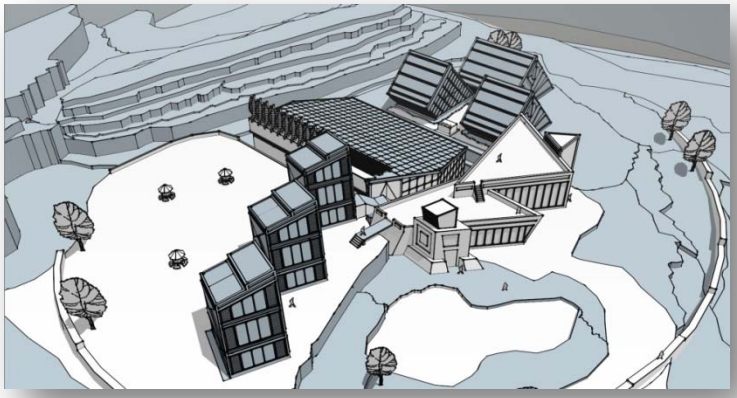
Source by Author

Source: nps.gov



Source by Author

Source: nps.gov

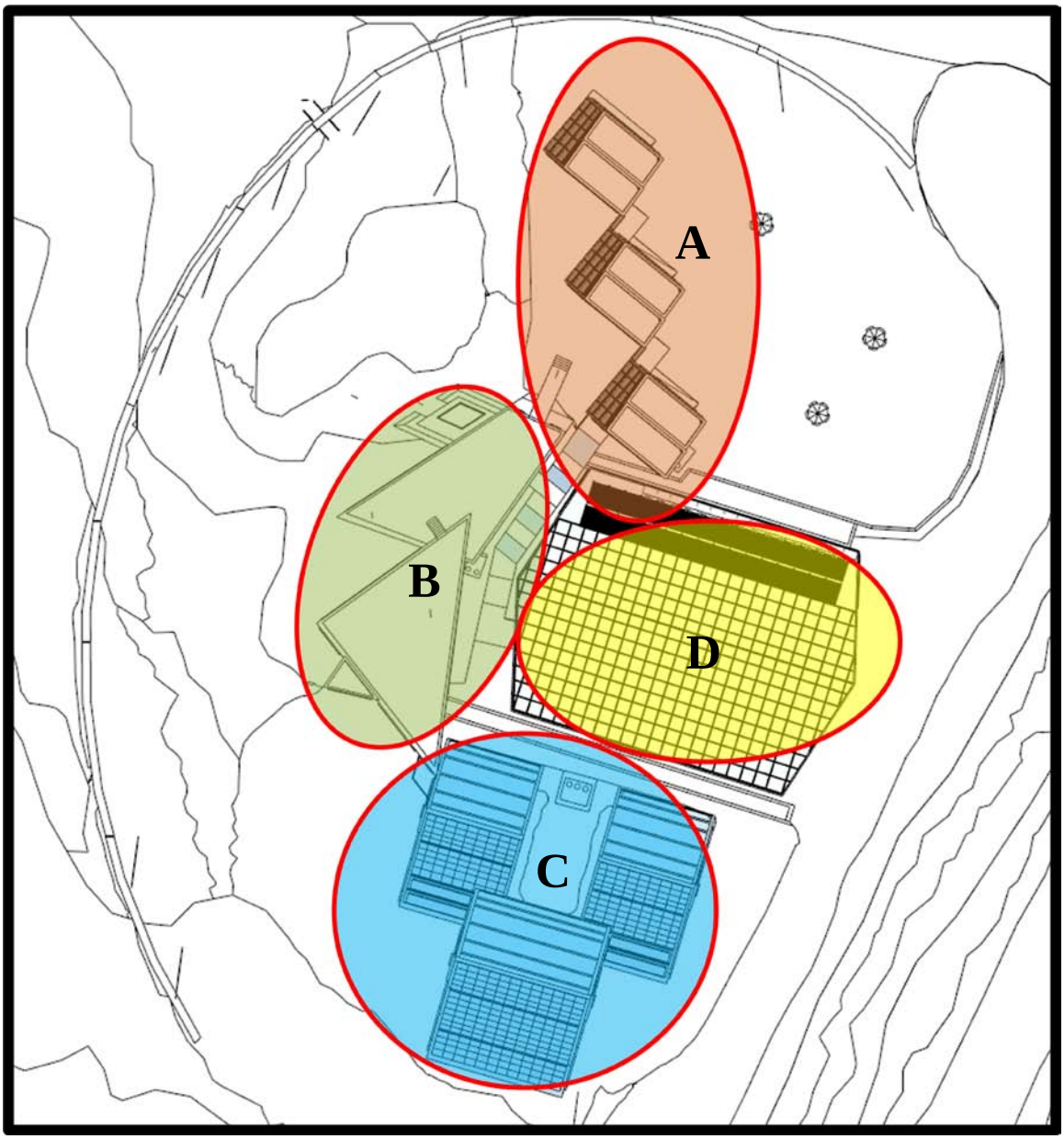


Source by Author

Source: nps.gov

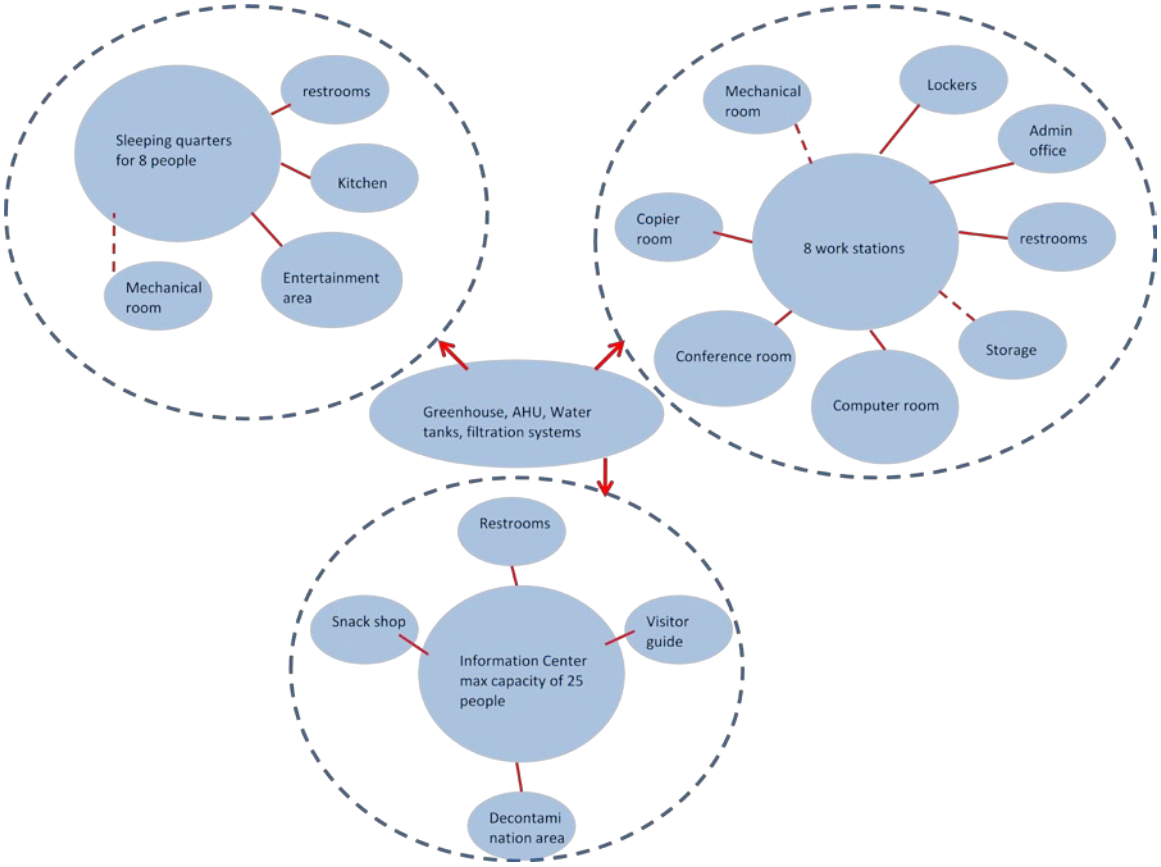
The facility was divided into four main sections: A, B, C, and D. Every section has its own control system but they all report to the BMS located in Section C for security purposes.

The immune building system has its main components in building D which distributes the purified air to Sections A, B, and C.



Source by Author

As part of the program to help the design process I developed a bubble diagram which helped me organize sector by sector with its own requirements and functions.



Source by Author

16.2 Sustainable Design Guidelines

- Avoid environmental impact from the location of the building to the site.
- Protect green fields, preserve habitat and natural resources.
- No vehicle uses on site therefore zero development impact from automobile use.
- Eliminate water pollution and sources of contaminations.
- Reduce heat island effect by selecting less thermal gradient differences between the cabin and natural habitat.

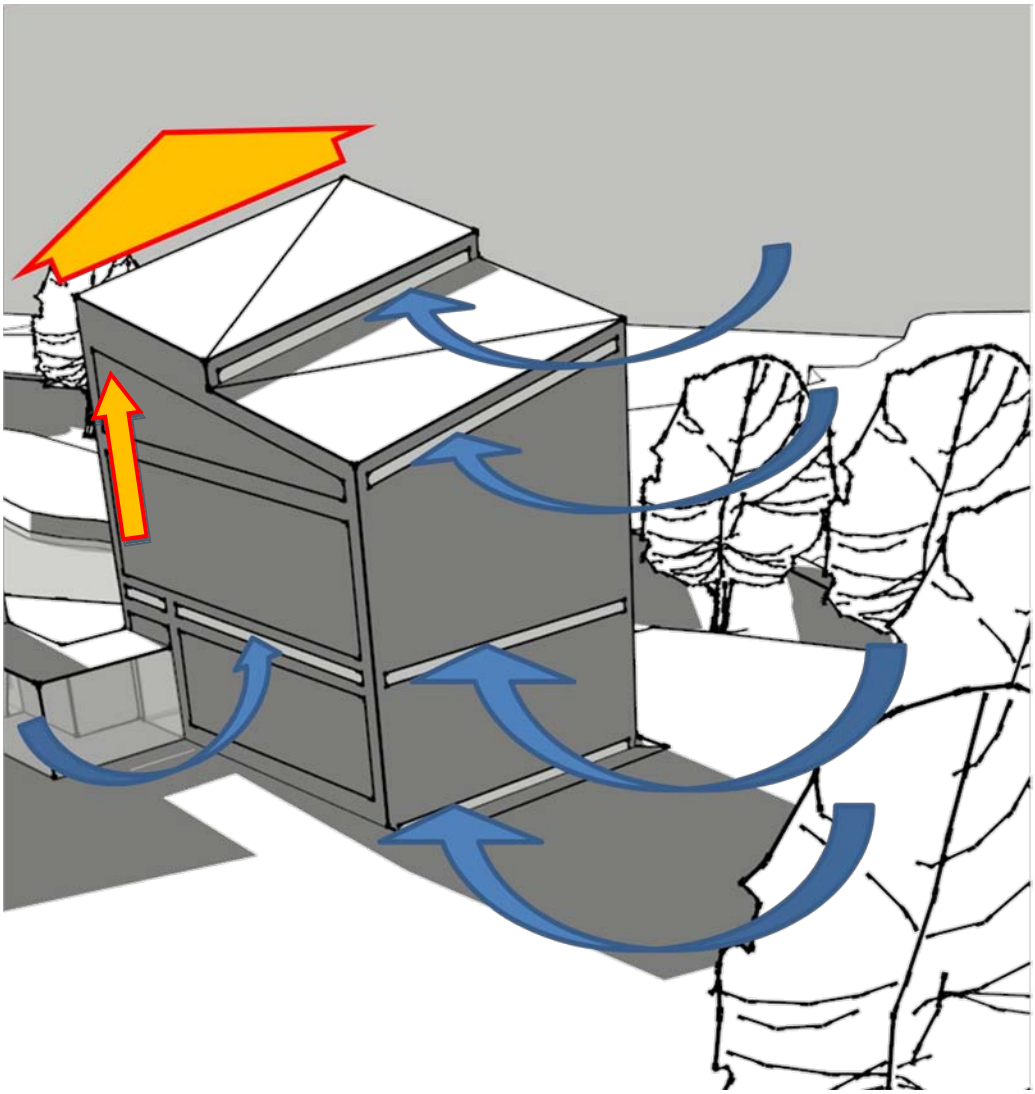
- Minimize light trespass from the cabin and site, skyglow, improve nighttime visibility through glare reduction and reduce development impact on nocturnal environment.
- Minimize excavation on site.
- Cabin should have waste management control based on building occupancy of 8 by providing recycle containers.
- Used of prefab materials and delivery method of modular spaces by aircraft to the site, therefore minimize carbon footprint.
- The utilization of environmental friendly materials and expand the life span of smart materials and systems through carefully selection of materials.

16.3 Passive control systems

As part of the program all building at the site need to have passive air ventilation methods without interfering when active methods kicks in to reduce the gain of heat into the buildings. The following diagram is one of the three buildings for the Sector A or appointed to be as sleeping quarters which shows the natural air flow in and out of the building walls. The building has 5 openings between floors, and ceiling systems that keep a constant air flow into the cavity walls minimizing the heat gain. This constant air flow does not required mechanical systems and it is classified as Passive heat control.

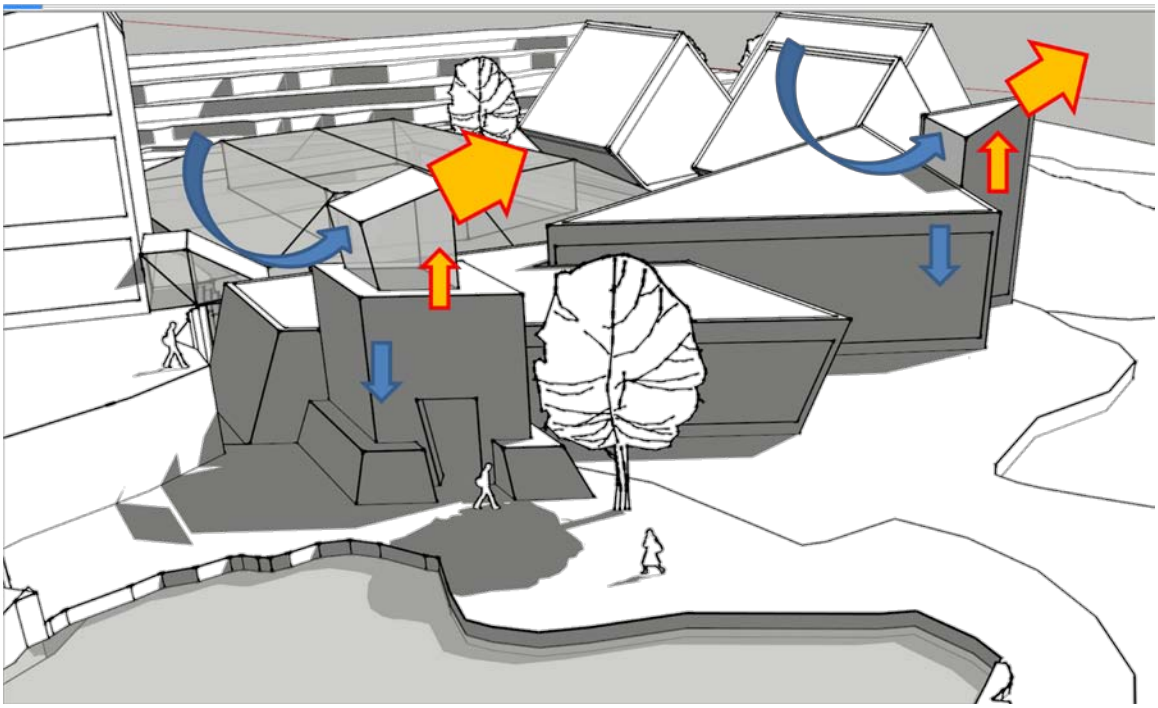
16.4 Standardizations

- ANSI/ASTM-E779-03 Standard test method for determine air leakage rate by fan-pressurizations. This test method covers a standardized technique for measuring air leakage rates through a building envelope under controlled pressurization and de-pressurization. This test method is intended to produce a method of airtieghtness of a building envelope.



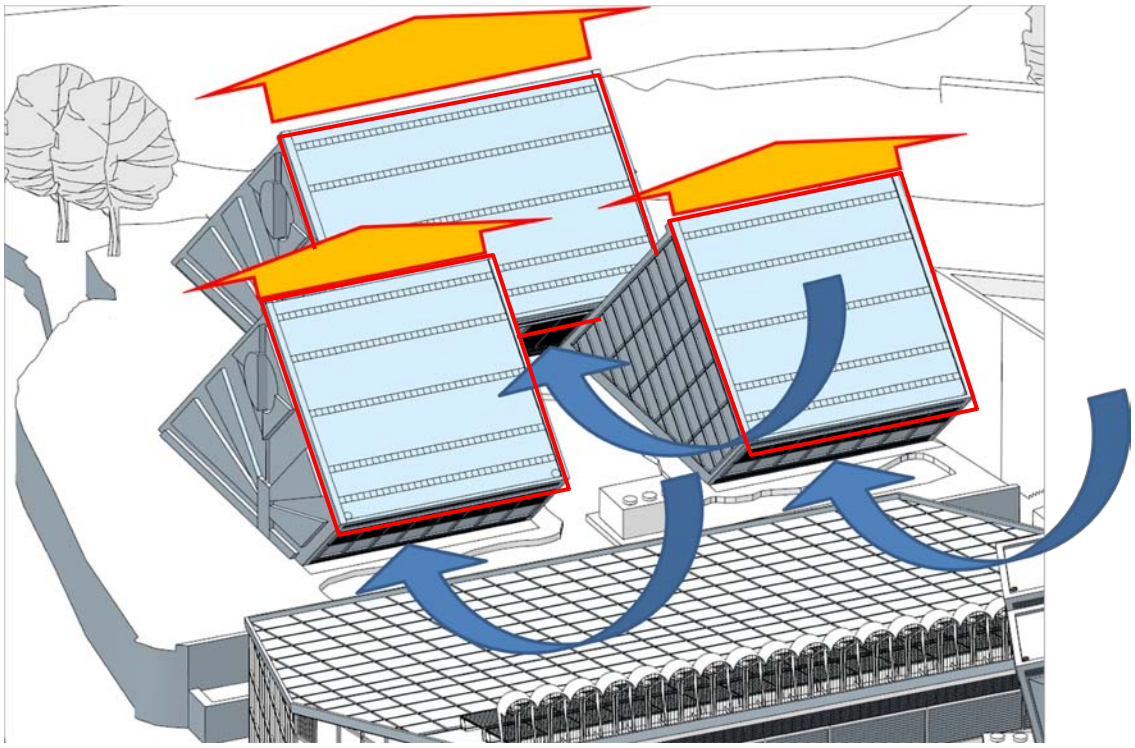
Source by Author

In sector B known as the information center, has a traditional method of passive cooling by cooling towers. This method has integrated sensors that trigger off and on the mechanism to open the tower vent as needed when there is no outdoor contamination by S02 volcanic gases. The graphic shows the incoming trade winds caught by the towers forcing cool air down into the buildings. The towers also have a separate exhaust vent to release indoor warm air out the same towers.



Source by Author

The next diagram classified as sector C or office buildings shows how the building traps and forces the outdoor air into the buildings primary to keep a constant air flow into the wall cavities to minimize the heat gain especially the walls facing south. The roof, marked with a red line does not gain heat because it is positioned at more than 40 degrees angle therefore heat gain is at a very minimum. There will be times during the year especially during summer when the sun position will be almost 90 degrees above some heat can be gain but at the same time due to a high wind patterns at the site, it keeps the roof well ventilated especially in the roof cavity getting rid of the heat before it reaches the other roof layer. The process will be explained in detail later on.



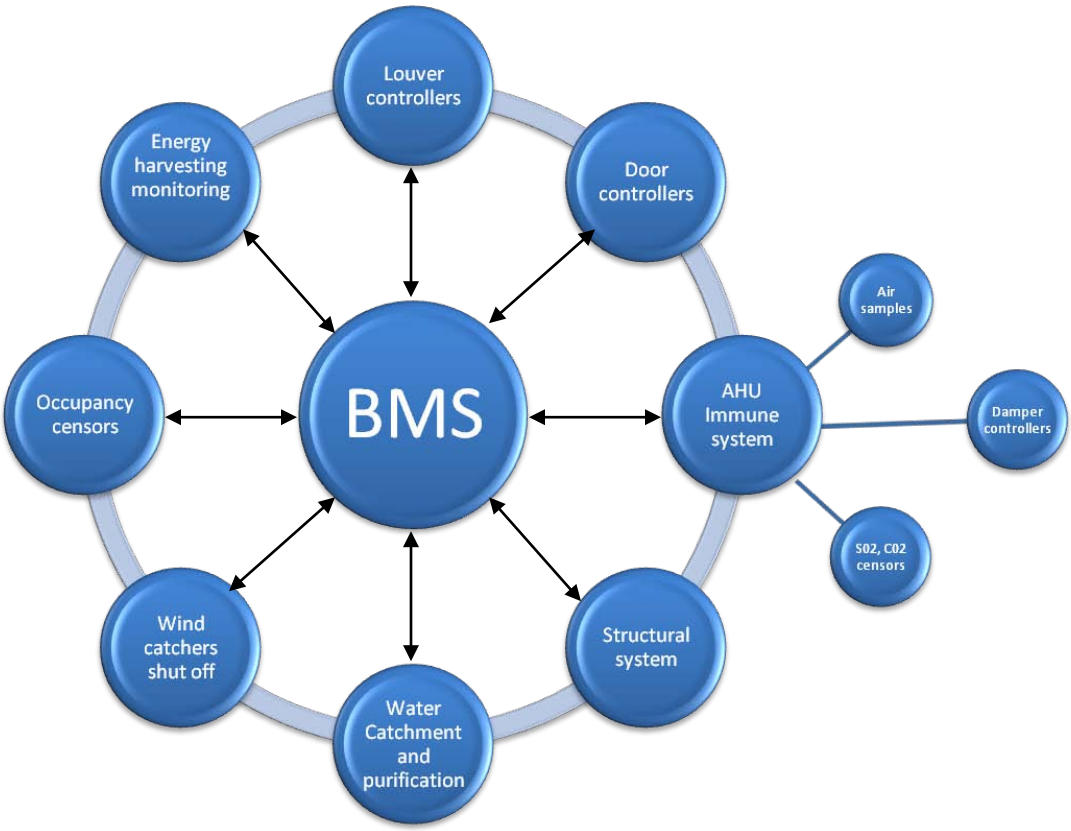
Source by Author

We have seen passive heat control approaches but this does not make a building smart, as part of the program some of the smart systems or active controls that will be integrated in the building will be working side by side with passive methods. These passive/active controls it is needed because of unpredictable air pollution in which the facility will be expose to. From this concept to explain graphically how the intelligent systems will be working together, the next graph will explain how the Building Manager System takes control of the active mechanisms allowing this mechanical change.

16.5 Use of Smart windows

The types of system to be integrated on the smart cabin are:

- Thermochromic –visual reduction - radiation reduction - activated by heat
- Thermotropic –visual reduction – reduction in radiation and conductivity- activated by heat
- Electrochromic – total visual block – proportional reduction – activated by voltage

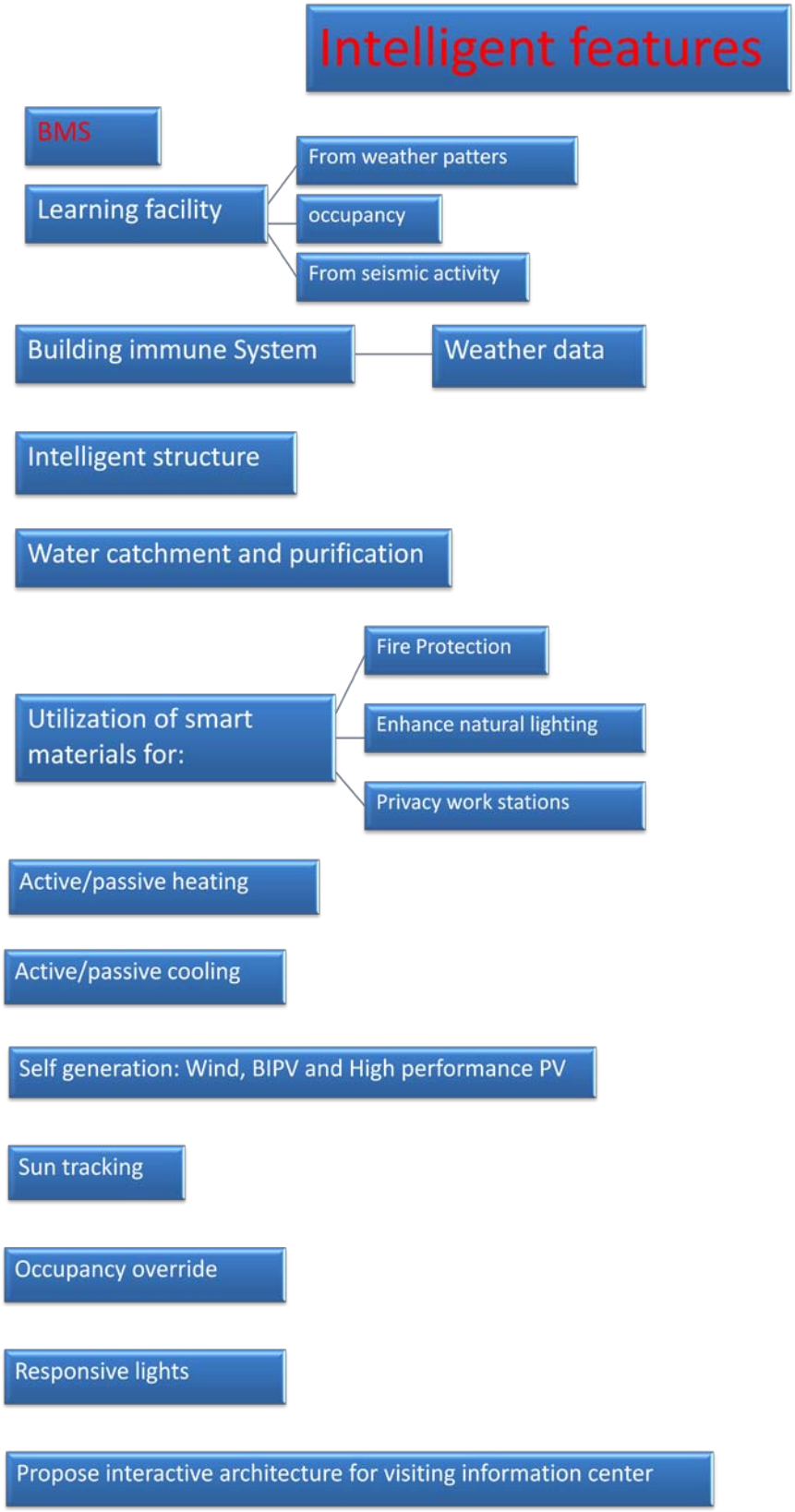


Source by Author

It is important to understand on this particular project that without a BMS it will be hard to manage and to determine if a controller is working properly. The BMS will call upon maintenance if there is a need to do repairs or simple to remember maintain all mechanical systems properly by simple tuning them up.

It is known that by keeping a constant maintenance regularly the life span of all mechanical systems will increase. Some of the purposes of integrating a learning facility to the BMS is to study analytically the data obtain and intelligently predict weather patterns to increase accuracy when such mechanical systems needs to take action and minimize errors when activating the building immune system, or to control movements within the main structural system when the buildings are expose to certain seismic intensity because such smart structures need to operate according to intensity.

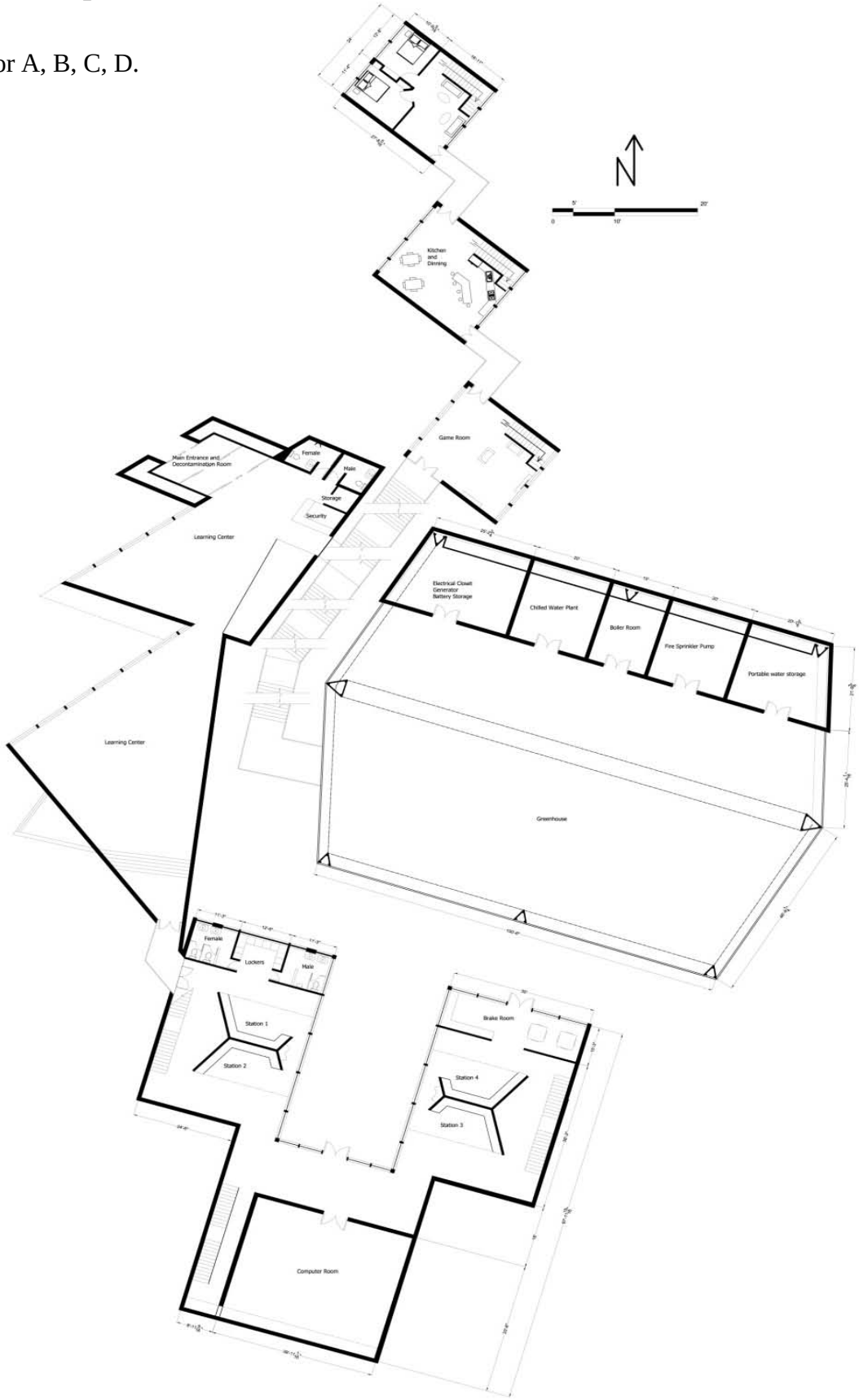
16.6 Intelligent Features



Source by Author

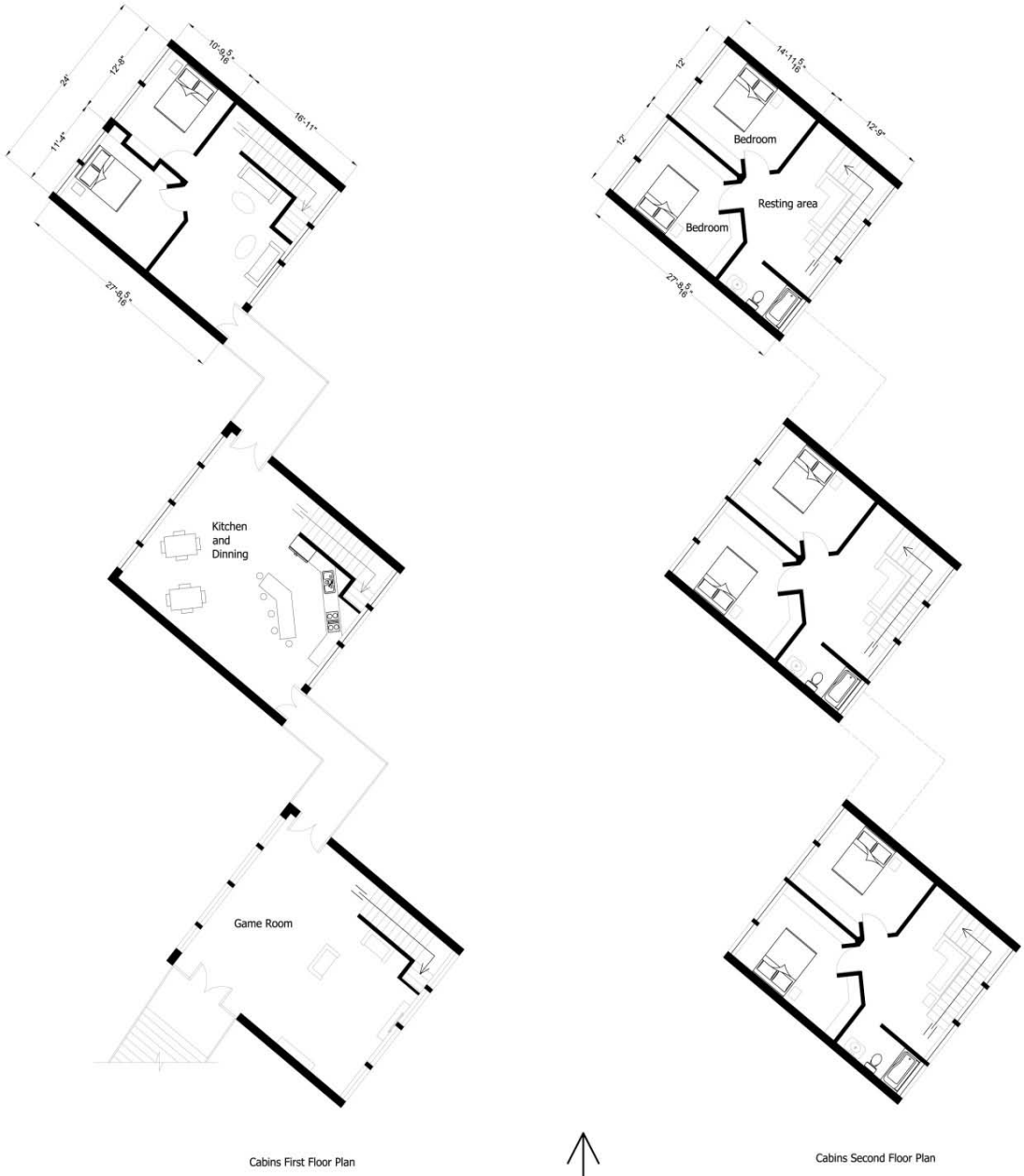
16.7 Floor plans

Sector A, B, C, D.

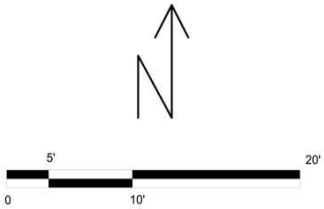


Source by Author

Sector A (Cabins) Floor plans



First two bottom floors are public services like game room and resting area, kitchen and dining room.



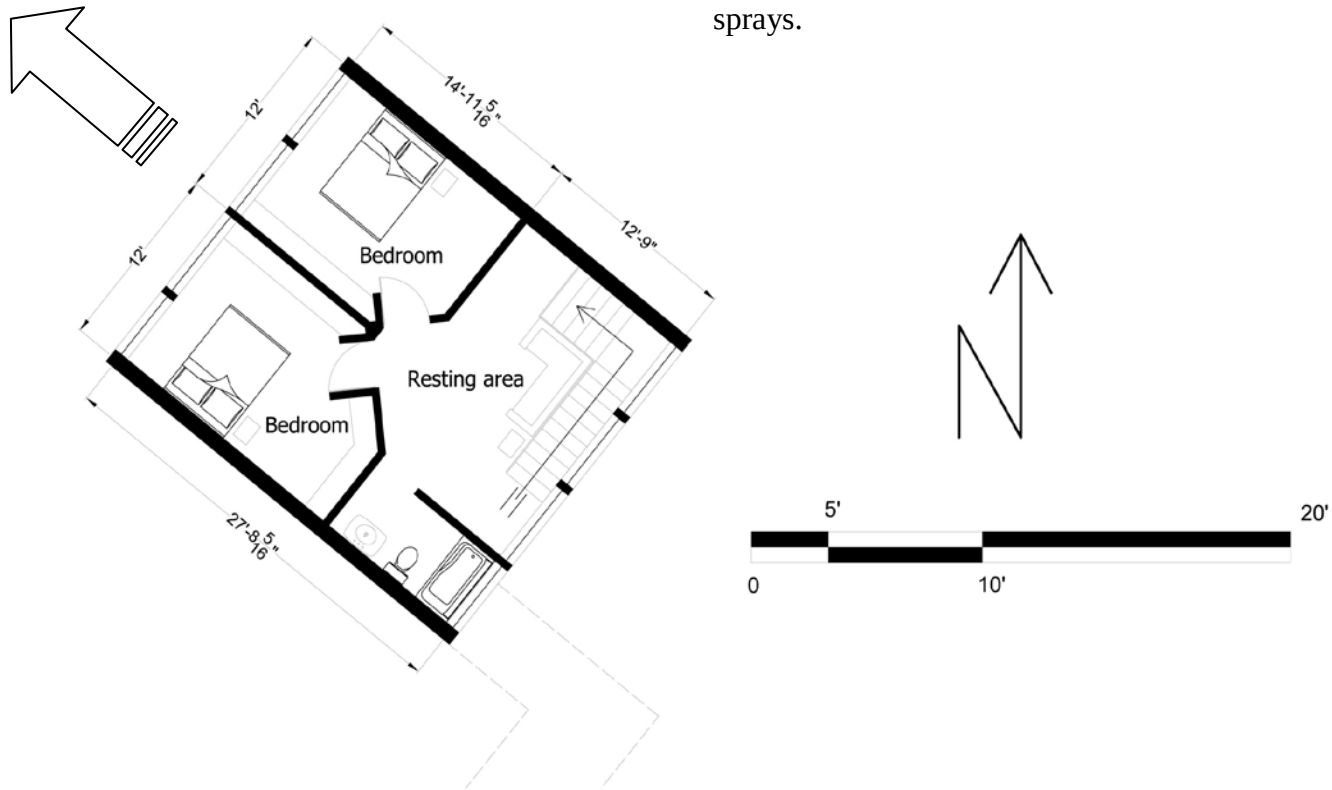
Second floors are dedicated to provide sleeping quarters to visitors.

Source by Author

Closer view to second floor cabin

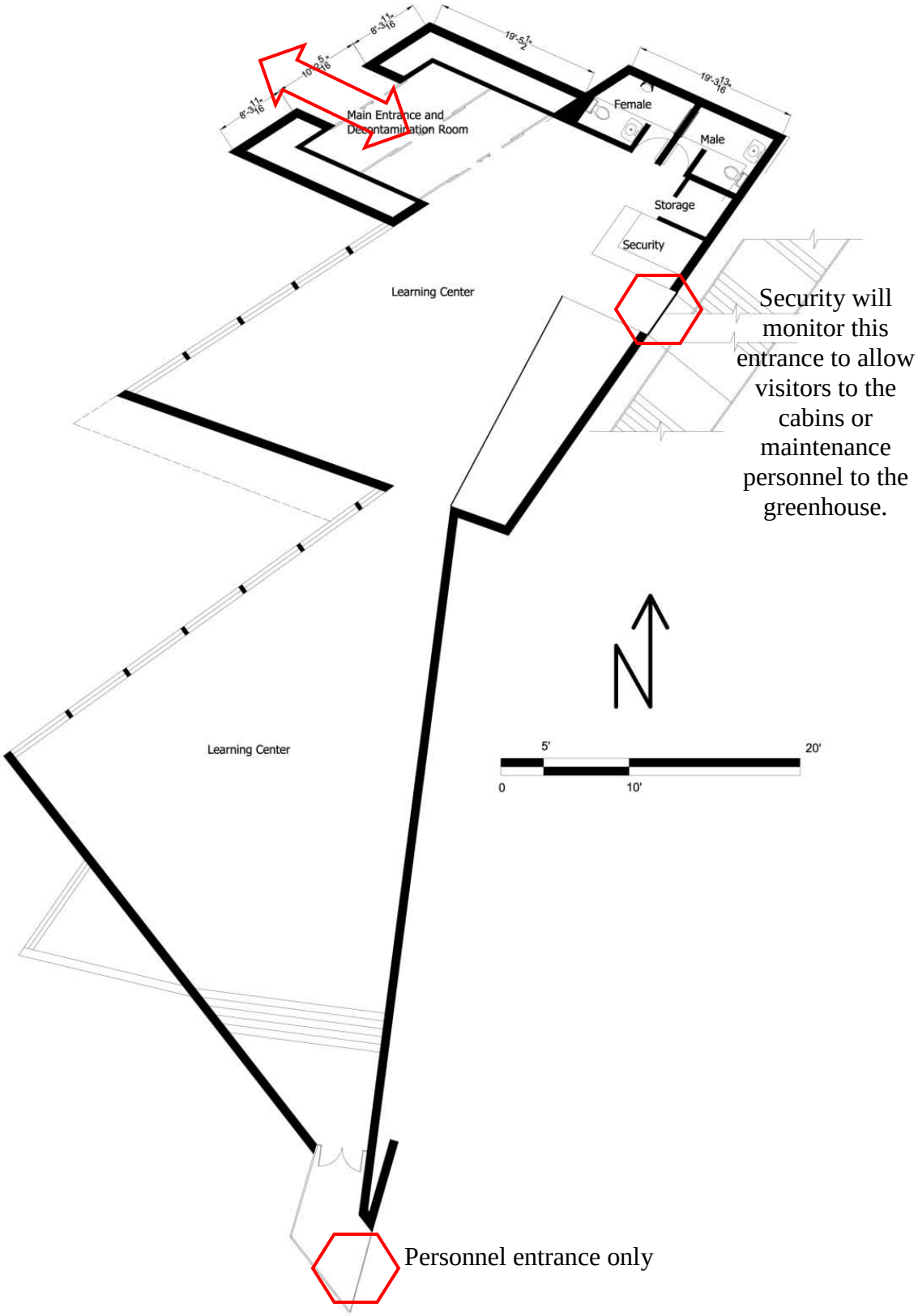
Views to Mauna Loa

Note that all restrooms will have composting toilets, efficient water closets and shower sprays.



Source by Author

The entire facility will shut off if the sensors detect S02 levels surrounding the property. When this happens, the only entrance to the entire facility will be by the information center. The information center has a main entrance which will serve as a decontamination area with positive pressure that will help decontaminate the air enclose within this space. The contamination area is divided into two spaces by a glass seal doors allowing occupants go through it by decompression chambers filtering the remaining S02 gases within each chamber at the time. Once the visitor crosses through these chambers by an allowable time sequence, the BMS will allow the visitor to enter the learning center in which fresh and purified air will welcome the visitor.

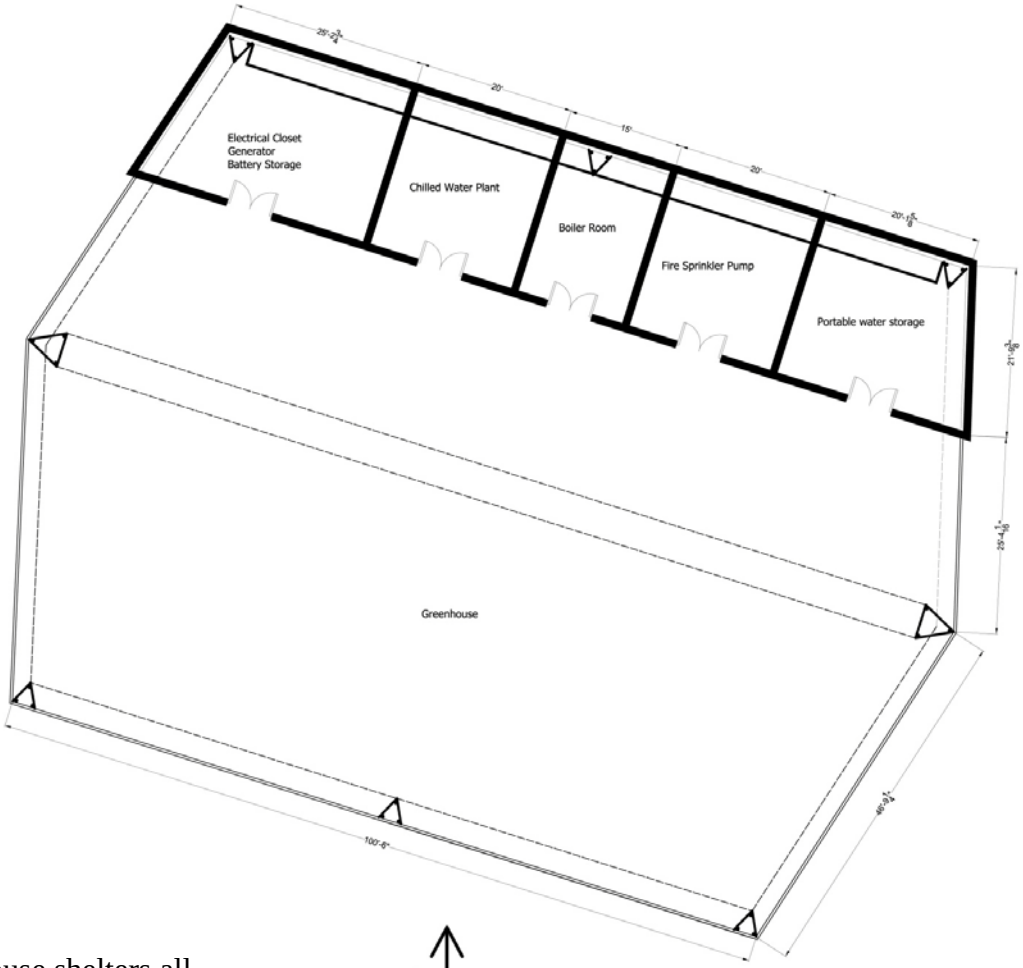


Source by Author

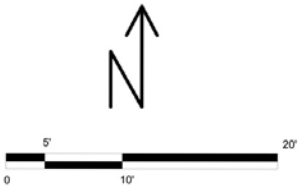
The only public visiting areas are sector A and sector B. Sector C and D is off limits for visitors. Sector C or the office spaces provides 8 working stations, a computer room located in the first floor and a conference room right above it.

Source by Author

The office spaces will be occupied only during office hours.



Green House shelters all mechanical systems and nurture specified plants as a passive method of air purification system that will distribute fresh air to the entire facility when it is needed.



These mechanical rooms are:

- Electrical closet
- Chilled Water Plant
- Boiler Rom
- Fire Sprinkler Pump
- Portable water storage

Source by Author

17. INTEGRATED SYSTEMS

17.1 Energy: Self-generation, Wind, BIPV, HPPV.

In order to find out if the project is fissile and to see if it can sustain itself we need to estimate the energy consumption. Let's start by approximating the sensible cooling air tons per building sector.

17.2 Sensible cooling tons per buildings

Cabins sq/f:

Total floor plan sq/f = 4,266 divided by an approximation rule of thumb sq/f per ton 425=1ton of cooling air. We can exert that we need 10 tons of sensible air for the cabins.

Learning Center sq/f:

The building sq/f has 4,100sq/f divided by the rule of thumb in this case 400 we need 10 tons of sensible air with a maximum occupancy of 25.

Office buildings sq/f:

Total of 12,076 sq/f divided by the rule of thumb 400sq/f per ton= 30 tons because of the high volume of spaces.

Computer room sq/f:

Rule of thumb=

1 watt = 3.41 Btus

12,00 Btus = 1 Ton

The computer room in sector C needs to have its own tons of sensible air because computer rooms can generate a lot of heat due to hours of operation in this case it will be running 24 hours 7 days a week. Bill Mann a mechanical engineer has a graph online to help calculating computer room and servers sensible tons of cooling air as follow:

1 watt = 3.41 BTUs
12,000 BTUs = 1 Ton of Sensible Air

THE MAGIC GRAPH

WATTS/ SQ.FT.	BTUs PER WATT	BTUs PER SQ.FT.	DIVIDE 12,000 BY BTUs PER SQ.FT.	SQ.FT. PER TON OF AIR	SENSIBLE TONS OF AIR PER 1,000 SQ.FT.
40	3.41	136.4	87.98	87.98	11.37
45	3.41	153.45	78.20	78.20	12.79
50	3.41	170.5	70.38	70.38	14.21
55	3.41	187.55	63.98	63.98	15.63
60	3.41	204.6	58.65	58.65	17.05
65	3.41	221.65	54.14	54.14	18.47
70	3.41	238.7	50.27	50.27	19.89

Note that as watts/sq.ft. and sensible tons of air go up, the square feet per ton of air goes down. This means more space for environmental systems and less available for business equipment.

TYPICAL WATTS PER SQUARE FOOT

	Watts Per Sq. Ft.	Comments
1. Legacy Data Centers (i.e. Large IBM, Unisys, etc.)	35-45	
2. Mixed Legacy and Servers (6-8 Servers Per Rack)	45-50	
3. Server Rooms with 6-8 Servers Per Rack (12-30 Racks)	45-50	1.8 kW - 2.5 kW per Rack
4. Server Rooms with 8-12 Servers Per Rack (20-35 Racks	50-60	2.5 kW - 3.0 kW per Rack
5. Server Rooms with 12-18 Servers Per Rack (40-80 Racks)	55-70	3.0 kW - 4.0 kW per Rack
6. Server Rooms with 20-40 Servers Per Rack (Over 60 Racks)	70-100	Over 4.0 kW per Rack

The following table is provided for you to make your own high-level power per square foot and HVAC calculations. Fill in values for questions 1 and 2 below and then click on "Calculate" below. A new section will appear with full calculations.

1. How many watts per square foot are estimated?	45
2. How many square feet in your computer room?	1000

Total Watts	45,000
Total BTUs	153,450
Total Sensible Tons of Air	12.79

OTHER USEFUL CALCULATIONS

Total BTUs Per Square Foot	153.45
Total Square Feet Pet Ton of Air	78.20

Source: http://www.abrconsulting.com/Custom_Code_Pages/calc4.php

17.3 Energy consumption per building

A- Cabins

Stove 1,500w x 3h=

Dishwasher 1000w x 1h=

Refrigerator 200w x 24h=

Microwave large 2000w x 1h=

Dishwashing machine 500w 1h=

42” TV plasma 250w x 4h=

Stereo 200w x 4h=

Alarm clock 20w x 24h=

Hair dryer 1000w x 1h= 59,000watts/h =60 Kw/h

B-Learning center

8 computers as reference for interactive architecture 320w x 8 x 8h= 20,480watts 20.48 Kw/h

C -Office Building:

2 computers x 320 watts per computer x 8 stations=

1 small printer x 180 watts per unit x 8 stations= 2,420 watts = 2.42 kw/h

C -Conference room and brake room:

Large printer = 1,400 w x 4 hours daily= Coffee maker= 200w x 8h=

Microwave large= 2000w x 5h= Refrigerator= 200w x 24h=

TV 42” Plasma 250w x 4h= 6 fans= 150w x 6 fans= 900w x 4h=

Sound stereo= 200w x 4h= 27,400 watts/h = 27.4 Kw/h

D-Greenhouse

15 industrial fans= 130 w x 15 x 12h per day= 23,400 watts = 23.4Kw/h

As part of the planning buildings B and C will only operate 8.5 hours a day 7 days a week because of that the need of Sensible cooling varies as follow, with the exception of the computer room that will have a separate 24 hours AC system.

17.4 Building B and C energy consumption during the day

Sensible cooling needed	**Appliances and lighting**
Building B= 30 tons	Building B= 32 Kw/day
Building C= 10 tons	Building C= 22.5 Kw day

Total of 40 tons x 3.5 by the rule of thumb per kw/h x 8.5 hours of service during the day + daily consumption of electricity by appliances and lighting = 1,314.5 Kwh /day

This means I need PV that generates 140KW/h
I have 7,695 sq/f of High performance PV which generates 17.9 watts per sq/f generates exactly 140 Kw/h which it balance without the need of battery backup.

17.5 Building A, C (computer room) and building D attempted to provide power 24h/7

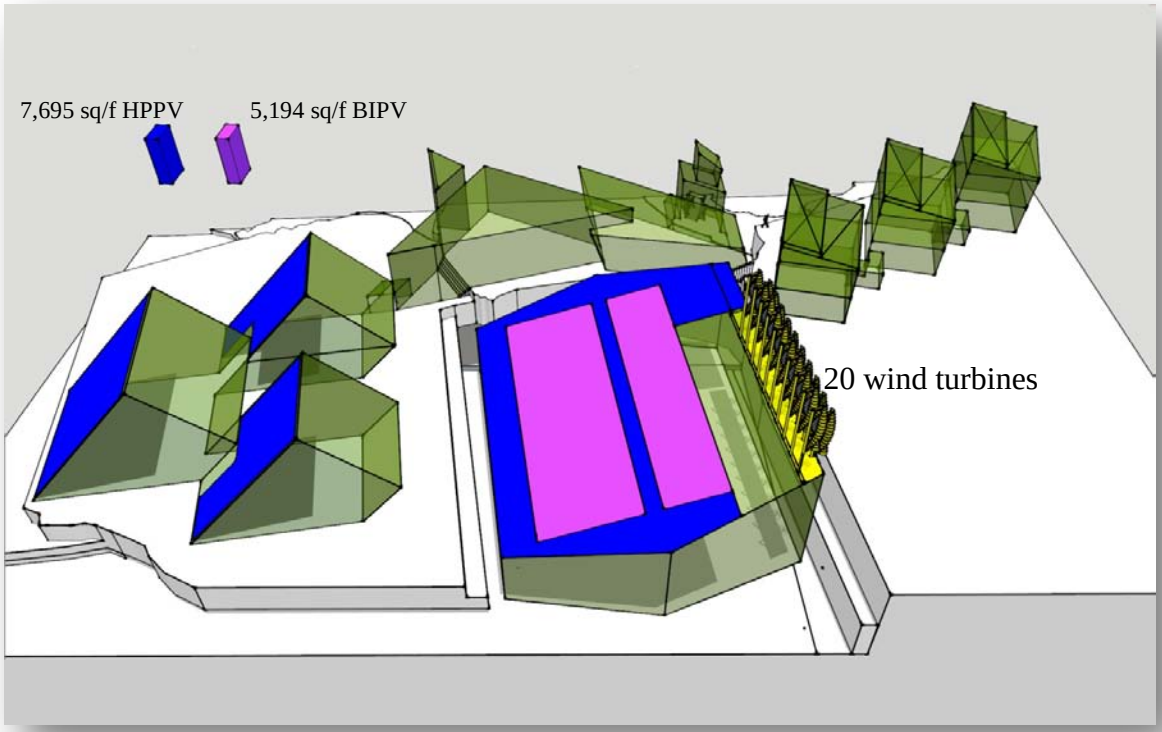
Sensible cooling needed	**Appliances and lighting**
Building A= 10 tons	Building A= 60 Kw/day
Computer Room C= 13 tons	Building D= 23.4 Kw day

Total of 23 tons x 3.5 by the rule of thumb per kw/h x 24 hours of service + daily consumption of electricity by appliances and lighting = 84 kw/h

This means BIPV and Wind has to generate 84KW per hour

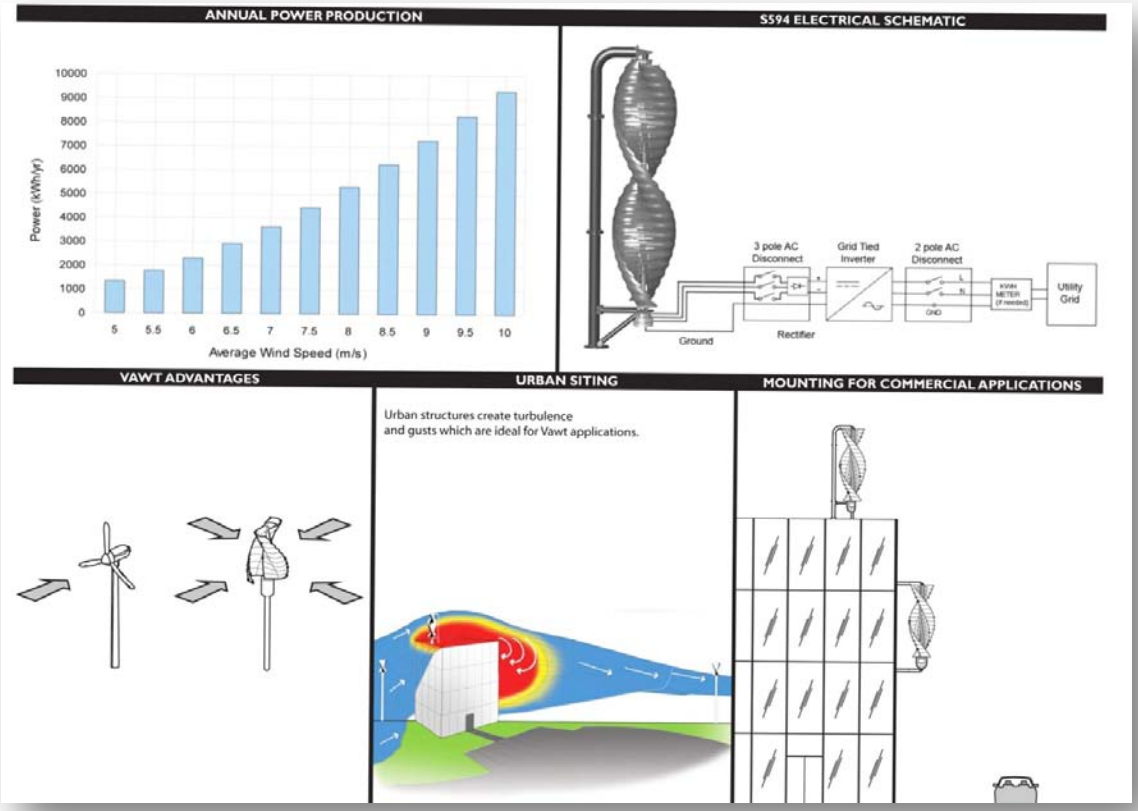
I have 5,194 sqf of BIPV which will generate 58Kw/h I need 26 kw/h from the wind harvesting.

Each wind turbine generates about 1.3 Kw/h so I need about 20 wind turbines to break it even without the use of battery backup. The entire facility will have a generator back up as an alternative if some malfunctioning from the wind and solar panels.



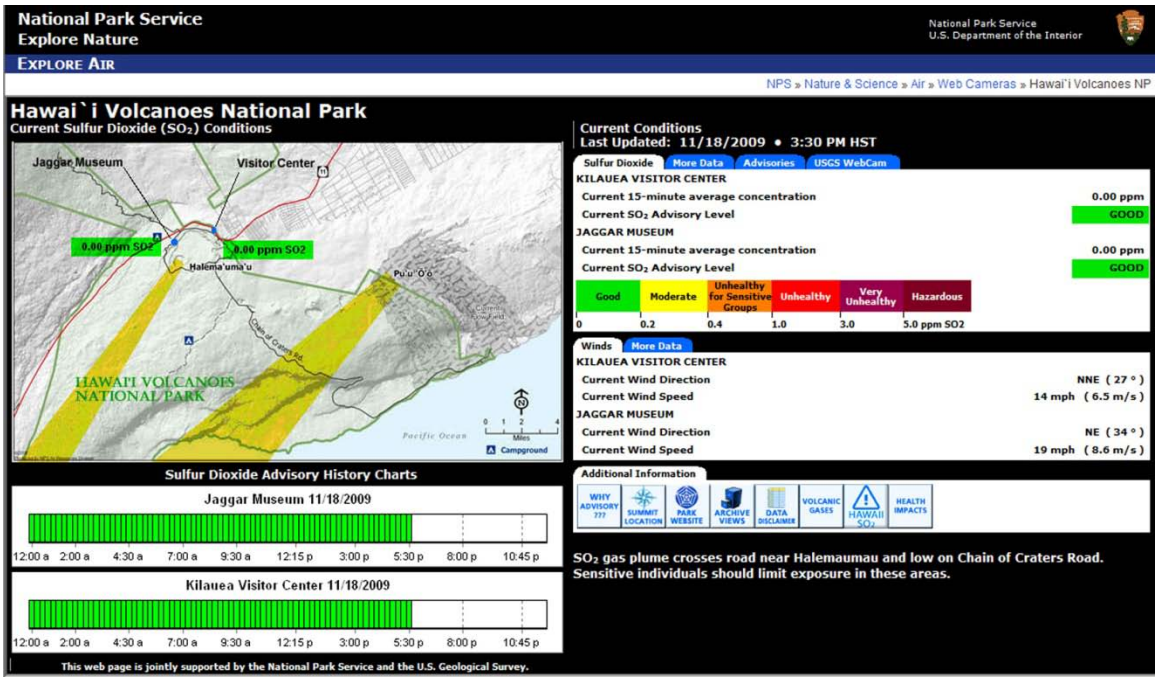
Source by Author

Source: http://www.helixwind.com/en/S594.php



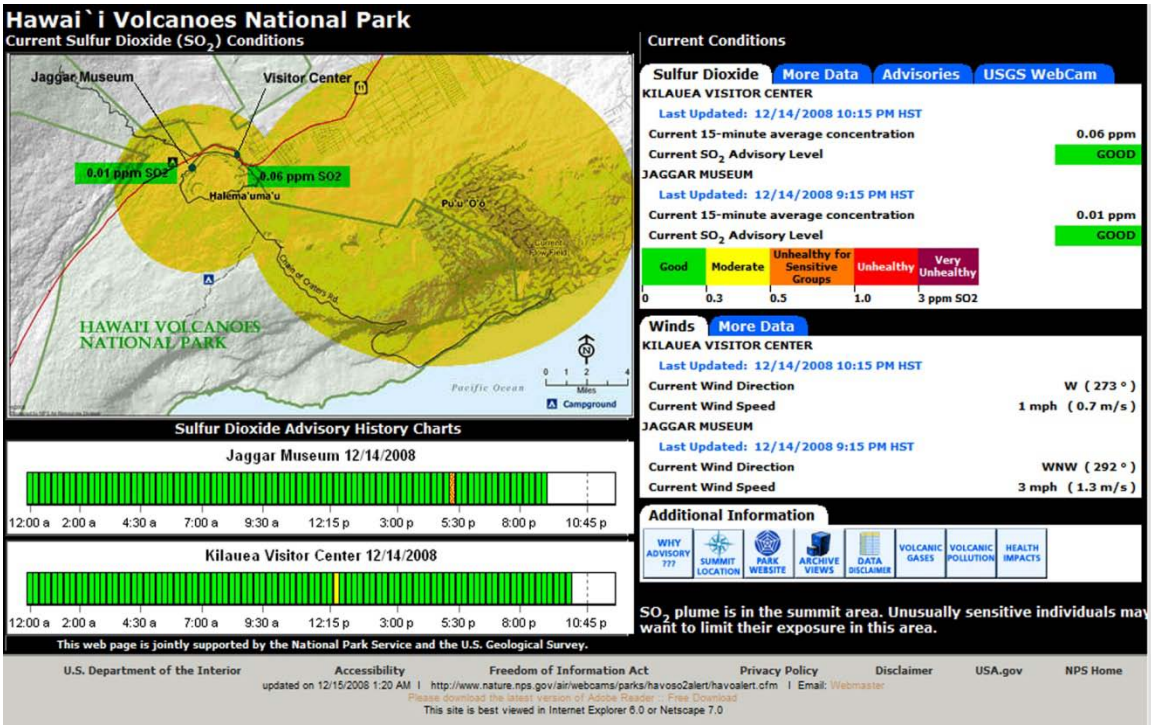
Source: http://www.helixwind.com/en/S594.php

Although there is enough wind turbines alone with the HPPV and BIPV panels to generate enough energy for the entire facility to run the systems 24 hours a day for 7 days a week, the immune system will not be running unless the system senses levels of S02 around the outdoor perimeters. There are times that the crater does not emit as much S02 into the air therefore it is not considered hazardous to human as shown below:



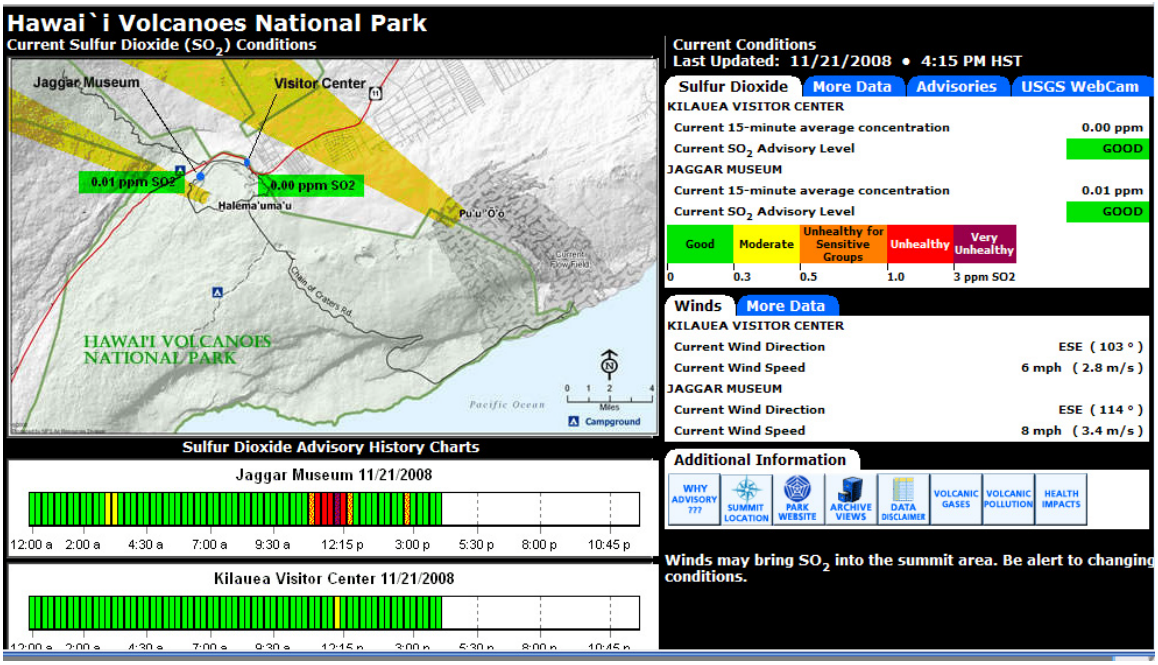
Source: http://www.nature.nps.gov/air/webcams/parks/havoso2alert/havoalert.cfm

There are moments that the winds stay still as long as 45 minutes at times in which S02 gases will remain in the area shown in the next nps report.



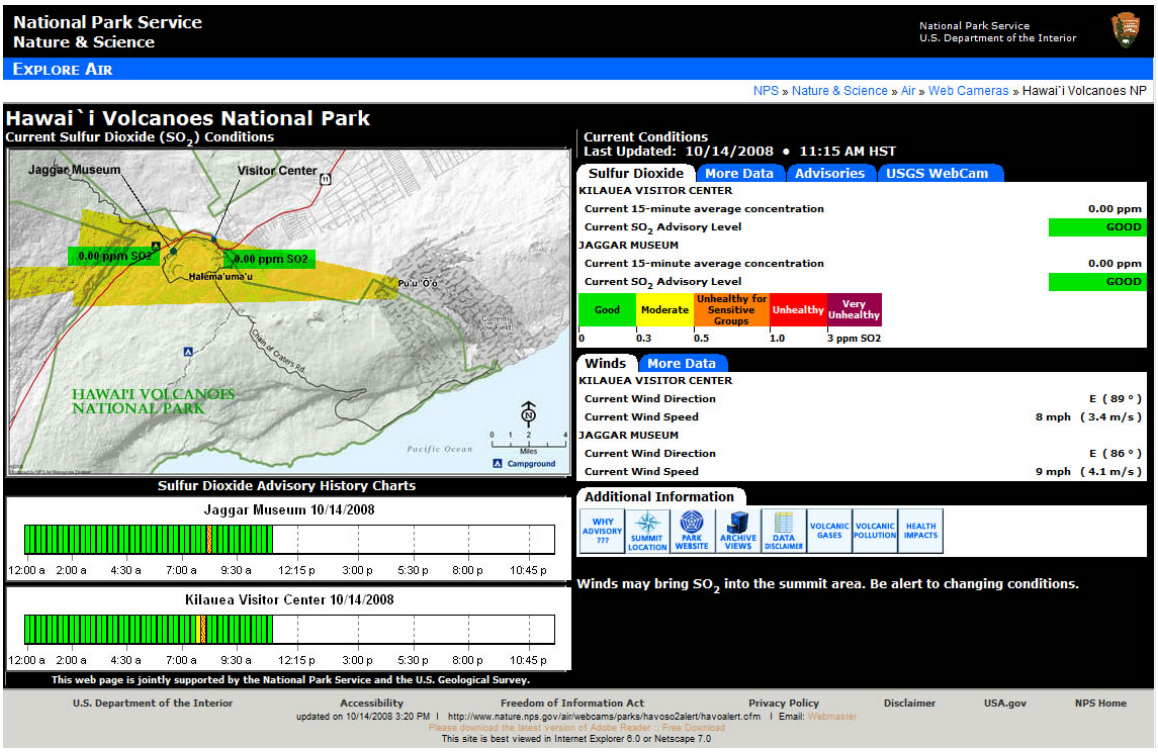
Source: http://www.nature.nps.gov/air/webcams/parks/havoso2alert/havoalert.cfm

Another example of wind changing patterns are when we have Kona winds which sometimes it is not healthy for nearby populations as shown below, when this happens the site does not get affected by the VOG.

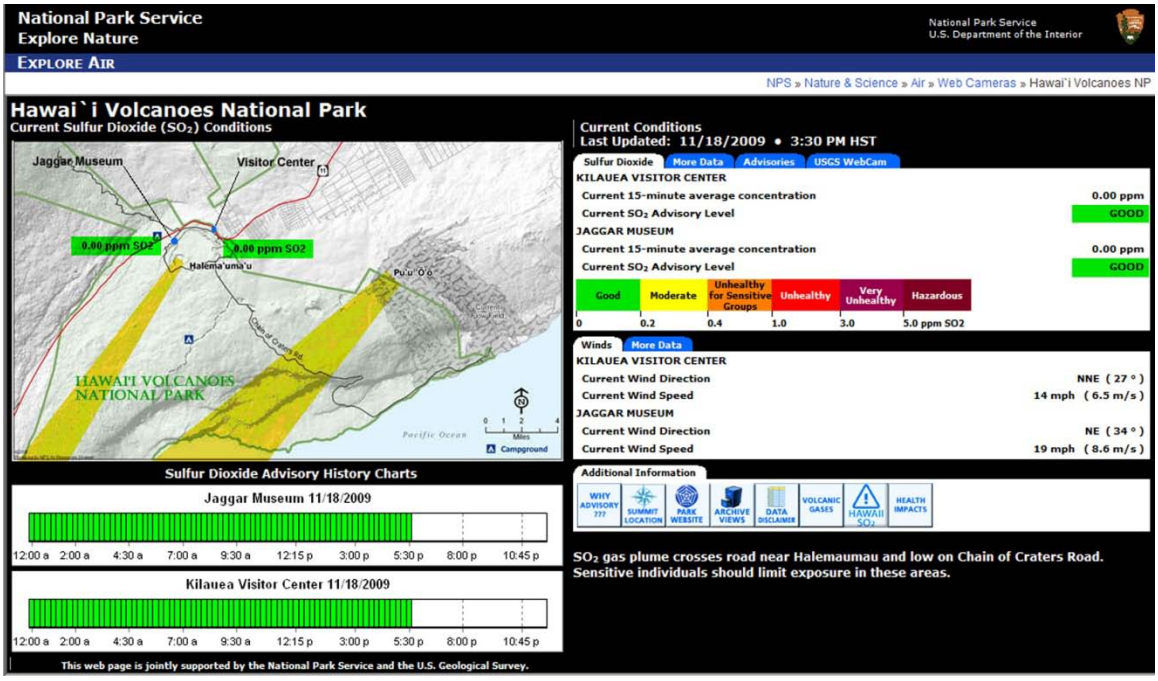


Source: http://www.nature.nps.gov/air/webcams/parks/havoso2alert/havoalert.cfm

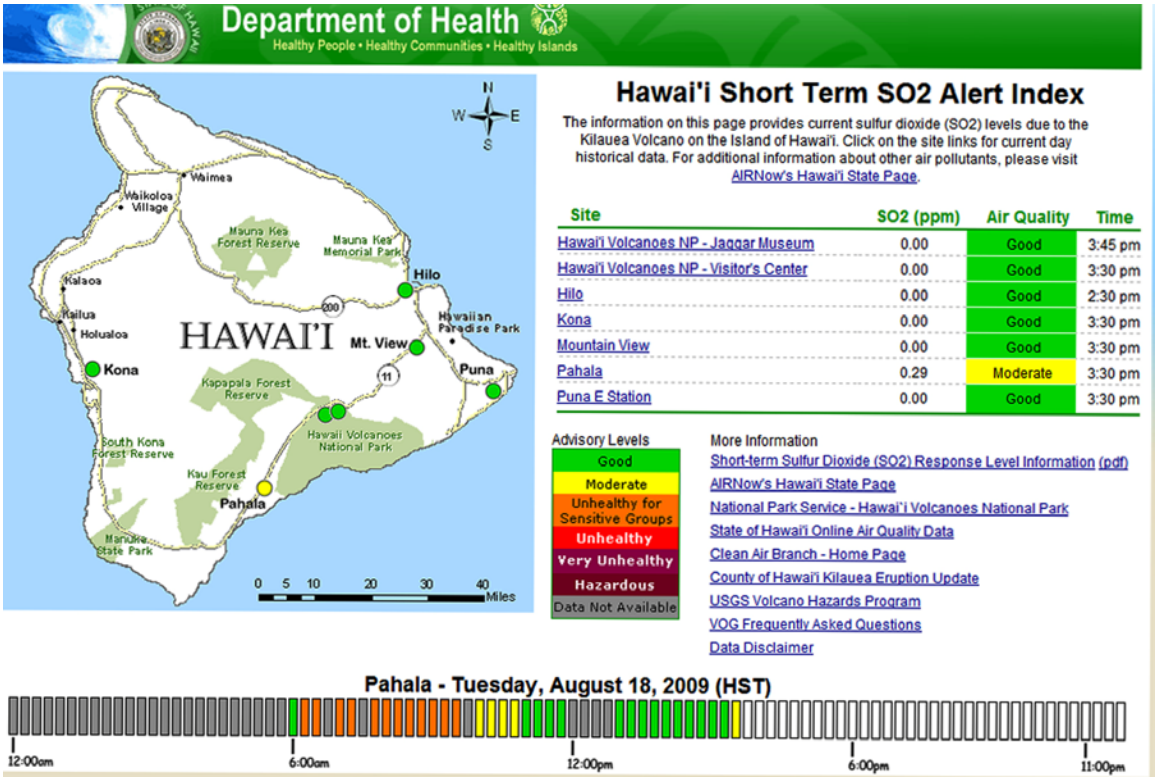
Below are examples of normal wind patterns that affects the site momentarily.



Source: http://www.nature.nps.gov/air/webcams/parks/havoso2alert/havoalert.cfm



Source: http://www.nature.nps.gov/air/webcams/parks/havoso2alert/havoalert.cfm



17.6 Water efficiency

- Provide water catchment systems and the use of recycling water for landscape purposes.
- Provide smart filtering system in the cabin.
- Recycle gray water.
- Reduce portable water usage.
- Use of Waterless self contained toilet.
- Calculate water usage per occupant.
- Recycle from sink and shower filtering the gray water for irrigation or other purposes.

17.7 Water catchment: From harvesting to purification and application.

Water catchment roof SQ/F

Cabins = 2,016 sq/f

Learning Center = 4,080 sq/f

Offices = 10,786 sq/f

Greenhouse = 10,413 sq/f

Total sq/f 27,295 x .625 gallons of water per inch of rain = 17,059.375 gallons/sq/f

Monthly catchment = 120,837.2 g/sq/f

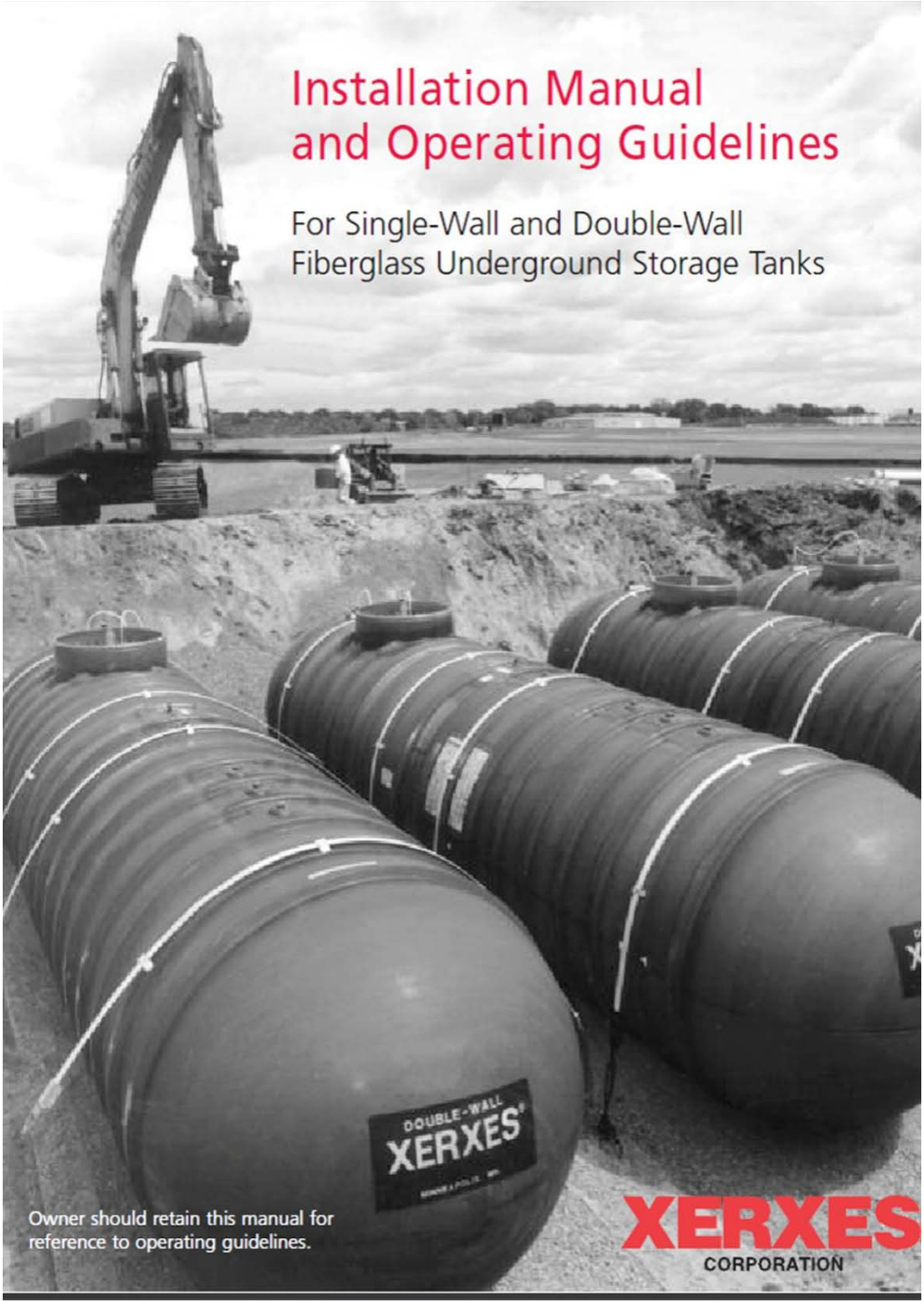
Annually = 1,450,046.875 g/sq/f

The Greenhouse will have 3 underground fiberglass storage tanks with 48,389 gallons actual capacity per tank. Total of 145,167 gallons, dedicated to none-portable water usage but needs to be filtered from the acidic stage. In addition there will be a 14, 781 gallons capacity above ground fiberglass storage tank that will be purifying water for drinking purposes.

Total of water storage of 159,948 gallons

In addition to the water tanks sheltered underground in the greenhouse, there is a pond sit on a natural ditch outdoors by the main entrance with a depth of about 5 feet that can storage about 19,000 gallons of water which can be utilize as an alternative storage especially for the driest month of January and February.

This natural pond keeps the main entrance somewhat cool because of the evaporation process.



Source: http://www.xerxes.com/storage-tanks/water-waste-tanks/potable-water-tanks.html

XERXES® CORPORATION

Tank Handling Data

Single-Wall (SW) and Double-Wall (DW) Tanks

(See the Xerxes Multicompartment Tank brochure for multicompartment tank data.)

Nominal Tank Diameter (Ft.) (SW & DW)	Nominal Tank Capacity (Gal.) (SW & DW)	Actual Tank Capacity * (Gal.)		Actual Tank Diameter ** (Ft./In.)		Actual Tank Length (Ft./In.)		Nominal Tank Weight *** (Lb.)		
		SW	DW	SW	DW	SW	DW	SW	DW	DW W/ Monitoring Fluid
4	600	602	602	4'-1 1/2"	4'-1"	6'-11 7/8"	7'-3 1/2"	500	800	1,000
	1,000	1,009	1,009	4'-1 1/2"	4'-1"	11'-3 7/8"	11'-7 1/2"	700	1,100	1,400
6	2,000	2,376	—	6'-3 1/2"	—	13'-5 3/4"	—	1,000	—	—
	2,500	—	2,319	—	6'-3 1/2"	—	13'-5 3/4"	—	1,800	2,400
	3,000	2,973	2,904	6'-3 1/2"	6'-3 1/2"	16'-4 1/4"	16'-4 1/4"	1,200	2,100	2,800
	4,000	4,131	3,782	6'-3 1/2"	6'-3 1/2"	21'-11 1/8"	20'-8"	1,600	2,500	3,500
	5,000	5,064	4,952	6'-3 1/2"	6'-3 1/2"	26'-5"	26'-5"	1,900	3,100	4,300
	6,000	5,960	5,829	6'-3 1/2"	6'-3 1/2"	30'-8 3/4"	30'-8 3/4"	2,200	3,600	4,900
8	2,000	2,189	—	8'-0"	—	9'-1/2"	—	900	—	—
	3,000	3,271	—	8'-0"	—	12'-3"	—	1,200	—	—
	4,000	4,218	4,156	8'-0"	8'-0"	15'-1/2"	15'-1/2"	1,400	2,200	3,100
	5,000	5,165	5,049	8'-0"	8'-0"	17'-8 1/2"	17'-8 1/2"	1,700	2,600	3,700
	6,000	6,084	5,998	8'-0"	8'-0"	20'-6 1/2"	20'-6 1/2"	2,000	2,900	4,300
	8,000	7,950	7,841	8'-0"	8'-0"	26'-1/2"	26'-1/2"	2,500	3,600	5,400
	10,000	9,816	9,684	8'-0"	8'-0"	31'-6 1/2"	31'-6 1/2"	3,000	4,300	6,600
	12,000	11,682	11,527	8'-0"	8'-0"	37'-1/2"	37'-1/2"	3,500	5,000	7,700
	15,000	14,975	14,781	8'-0"	8'-0"	46'-9"	46'-9"	4,500	6,400	9,800
10	10,000	10,563	10,369	10'-4"	10'-4"	21'-5 1/4"	21'-5 1/4"	3,200	4,500	6,200
	12,000	12,068	11,849	10'-4"	10'-4"	24'-1/4"	24'-1/4"	3,600	5,000	7,000
	15,000	15,248	14,976	10'-4"	10'-4"	29'-5 3/4"	29'-5 3/4"	4,500	6,100	8,600
	20,000	20,055	19,703	10'-4"	10'-4"	37'-8 3/4"	37'-8 3/4"	5,700	7,700	11,000
	25,000	25,783	25,336	10'-4"	10'-4"	47'-6 3/4"	47'-6 3/4"	7,900	10,000	14,300
	30,000	30,590	30,063	10'-4"	10'-4"	55'-9 3/4"	55'-9 3/4"	9,400	11,900	17,000
	35,000	35,397	34,790	10'-4"	10'-4"	64'-3/4"	64'-3/4"	10,500	13,600	19,600
	40,000	41,004	40,304	10'-4"	10'-4"	73'-8 1/4"	73'-8 1/4"	12,100	16,000	23,000
12	20,000	20,781	—	11'-11"	—	29'-4"	—	9,200	—	—
	25,000	25,541	—	11'-11"	—	35'-7"	—	10,600	—	—
	30,000	31,253	—	11'-11"	—	43'-1"	—	12,500	—	—
	35,000	36,013	—	11'-11"	—	49'-4"	—	13,900	—	—
	40,000	39,821	—	11'-11"	—	54'-4"	—	15,000	—	—
	48,000	48,389	—	11'-11"	—	65'-7"	—	17,700	—	—
	50,000	50,293	—	11'-11"	—	68'-1"	—	18,300	—	—

* If an overfill-protection device, such as a ball-float or flapper valve, is installed in the tank, the actual tank capacity will be reduced.

** Actual height of the tank may be greater than actual tank diameter due to fittings and accessories. Load height during shipping may vary due to tank placement on shipping trailer.

*** Adding accessories to the tank may increase the tank weight.

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ximc11/07pp

Source: http://www.xerxes.com/storage-tanks/water-waste-tanks/potable-water-tanks.html

17.8 Portable water to be consumed

3 cabins 8 visitors per day.

A person consumes about 24 gallons of water a day for drinking, cooking, shower and hygiene a month is 672 gallons x 8 occupants= 5,376 gallons per month.

Washing machine and dishwasher consumes about 50 gallons + x 8 people = 400 gallons every 2 days a month is 6,000 gallons of water which can be recycle for later used.

Learning Center

This Room will only consume water when visitors use the restrooms.

The maximum occupancy for the learning center is 75. Restroom will have waterless urinals, and composite toilets. Lavatories will be the only water usage if a person will use 1.5 gallons max per lavatory and the facility will operate 8 hours a day the maximum water usage per month will be= 9,000 gallons per month if each occupant uses the lavatory 5 times a day 6 days a week.

Offices

The water consumption is as follow:

Restrooms will utilize waterless urinal, composite toilets, and water efficient lavatories.

Lavatories consumption will be: 8 people washing hands 6 times a day per 1 gallon per use=72 gallons a day x 6 days a week per month will be=1,728 gallons.

Greenhouse (None-portable water)

Irrigation will be done to plants by drip irrigation (Micro irrigation) with organic fertilizer directly into the irrigation system. This method will cut down on evaporation and water usage will be saved. This method will increase yields and it will apply directly to the plant's root zone. Taller plants will have hygrometer to measure the water content in the pot depending of the height, and if the plants are indigenous it will consume less water but normally we can generalize that a mid size tree needs 4 gallons a day.

The greenhouse will shelter proximally 500 plants meaning 2,200 gallons per day = 61,600 per month which is rounded because the greenhouse have spray nuzzles overhead which will be turn on periodically alone with the fans to create a natural cool habitat.

17.9 Total water to be consumed

Cabins= 11,376 gallons/month

Learning Center= 9,000 gallons/month

Offices= 1,728 gallons/month

Greenhouse= 61,600 gallons/month

Total water to be harvest= 83,704 rounded to 85,000 gallons/month. Per year = 1,020,000 gallons per year

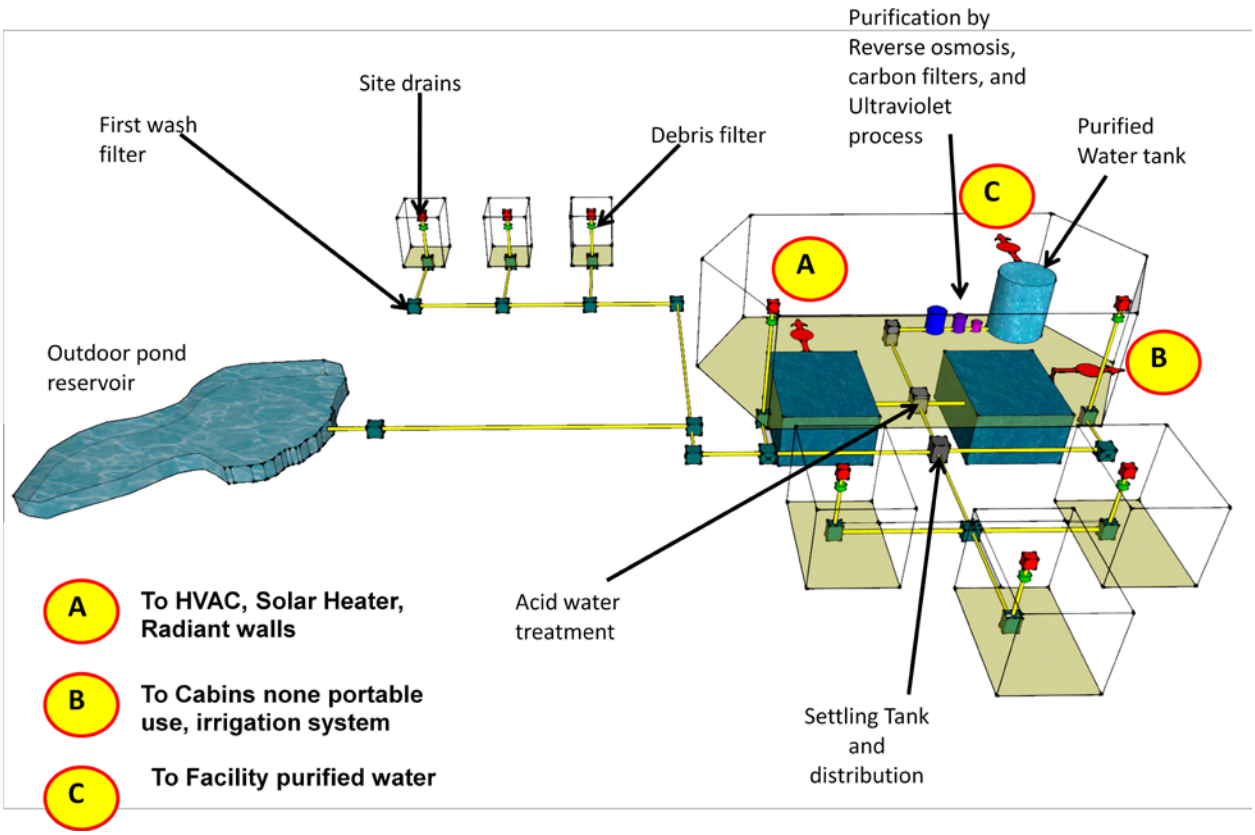
Monthly rainfall (inches) during 1998 at selected locations on the island of Hawai'i

STATION	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	YEAR
Hwn. Bchs.	1.43	1.07	5.26	9.82	13.36	11.14	6.28	8.77	8.69	14.20	11.42	10.35	101.79
HI Volcanoes Natl. Pk.	0.63	1.31	5.20	13.90	12.90	7.08	1.69	4.91	4.21	7.59	12.19	12.41	84.02
Hawi	2.86	3.30	6.69	8.42	8.48	9.86	4.20	3.78	5.10	4.14	5.36	5.51	67.7
Hilo Airport	0.13	2.40	3.67	8.86	15.65	11.27	6.09	8.48	10.76	16.01	15.57	9.89	108.78

Source: http://www.ctahr.hawaii.edu/oc/freepubs/pdf/RM-12.pdf

Average rain water captured including the outdoor pond per month is: 88,760 gallons/sq/f, annually is about 1,065,120 gallons/sq/f.

Total storage area monthly is 120,837.2 minus average water consume by entire facility is 85,000 = 35,837.2 gallons difference as a backup for drier season and extra evaporation periods**.**



Source: By Author

Ph level of drinking water ranges from 6.5 to 8.5, 7 is neutral higher than 7 is consider alkaline and lower than 7 is consider acidic.

Water tested at the Kau desert is 4.0 and it is consider very acidic because of the volcanic activity.

Some tips to contra rest the acidic level of the water at the Kau area is to store it in concrete tanks or by adding bicarbonate of soda to the tank alone with other types of filtration processes.

There will be three methods of purification process especially for the smaller tank to purify the water before distribute it into the entire facility.

These purification processes are:

- Carbon filters (Microfiltration with the use of nanotechnology)
- Reverse osmosis
- Ultraviolet sterilization

The system will have an intelligent water testing method to control the purification process levels.

Some benefits of underground water storage are:

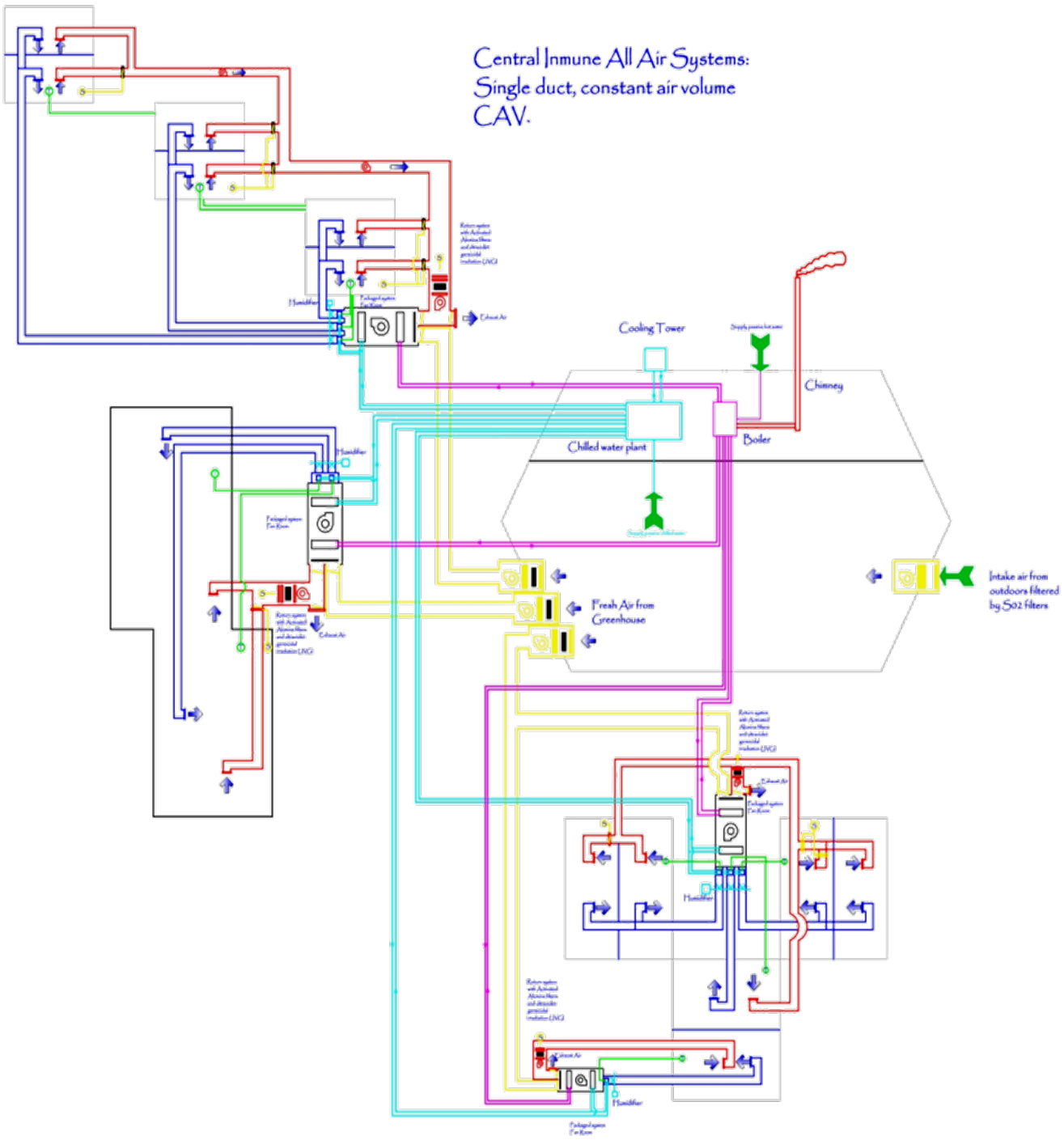
- Underground storage keeps water chilled
- Limits exposure to sunlight

17.10 The Immune system approach.

Central all air System: single duct, constant air volume CAV

Advantages:

1. Relatively small space requirement
2. Excellent temperature and humidity control over a wide range of zone loads
3. Proper ventilation and air quality in each zone is maintained as the supply air around is kept constant under all conditions.
4. Great potential for energy conservations by:
   a. Use of natural cold air from the greenhouse
   b. Chilled water stored underground
   c. Vacuum tube solar collectors and insulated heat exchanger.
5. Building pressurization can be achieved easily.
6. The complete air conditioning plant including the supply air return, air fans can be located away from the conditioned space. Due to this it is possible to use a wide variety of air filters for the purpose of purifying the contaminated air with S02 and other pollutants as well as avoid noise in the conditioned space.
7. Applications: this type of air system are commonly used by office buildings, classrooms, labs, hospitals, hotels Ships and computer rooms, etc where a quality and constant air volume is require.

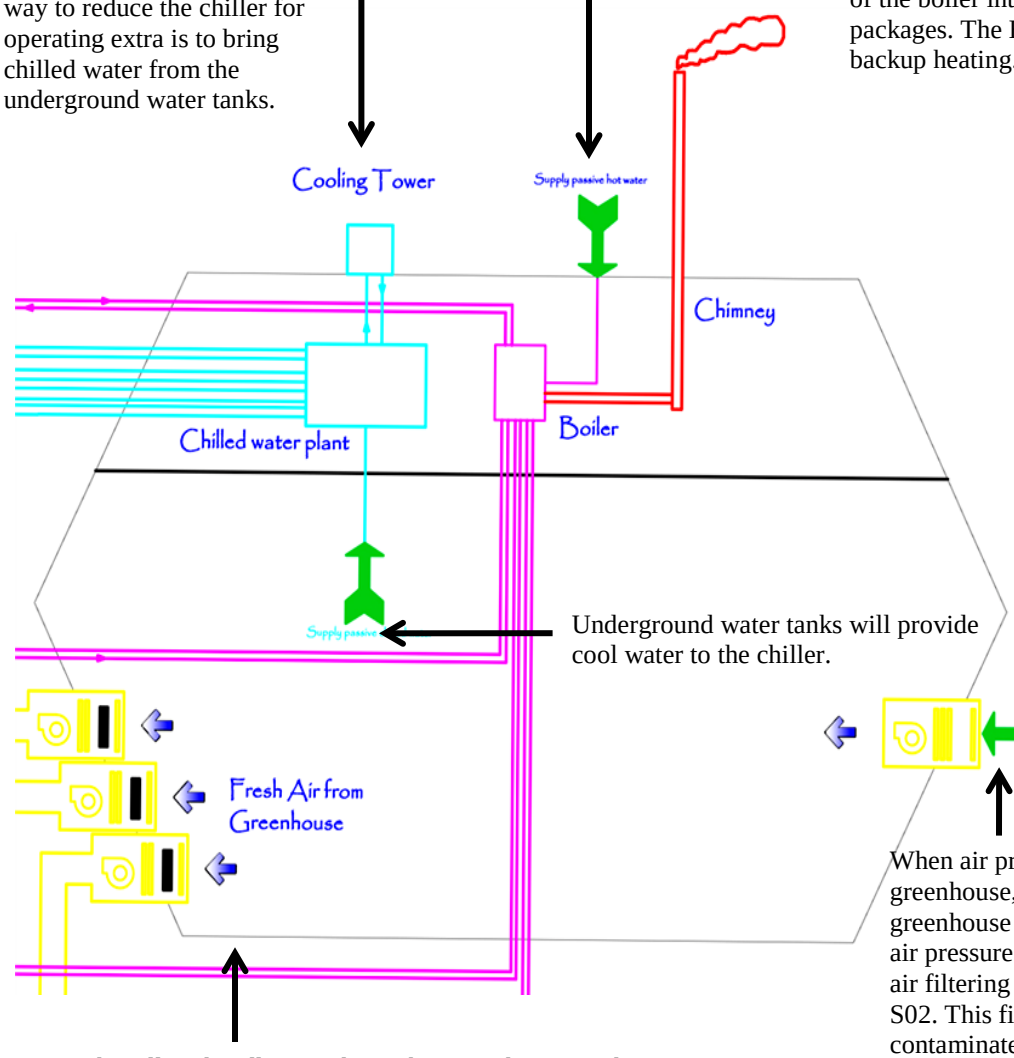


Schematic Immune System Design

Source: By Author

There is a sustainable method to reduce energy consumption especially when providing sensible air into the sectors. The purpose of the chiller plant is to provide chilled water to the air handling packages. One way to reduce the chiller for operating extra is to bring chilled water from the underground water tanks.

Another sustainable method to minimize energy consumption is to provide a passive heating method explained in detail later on. This method will provide hot water instead of the boiler into the air handling packages. The Boiler will be there as a backup heating.



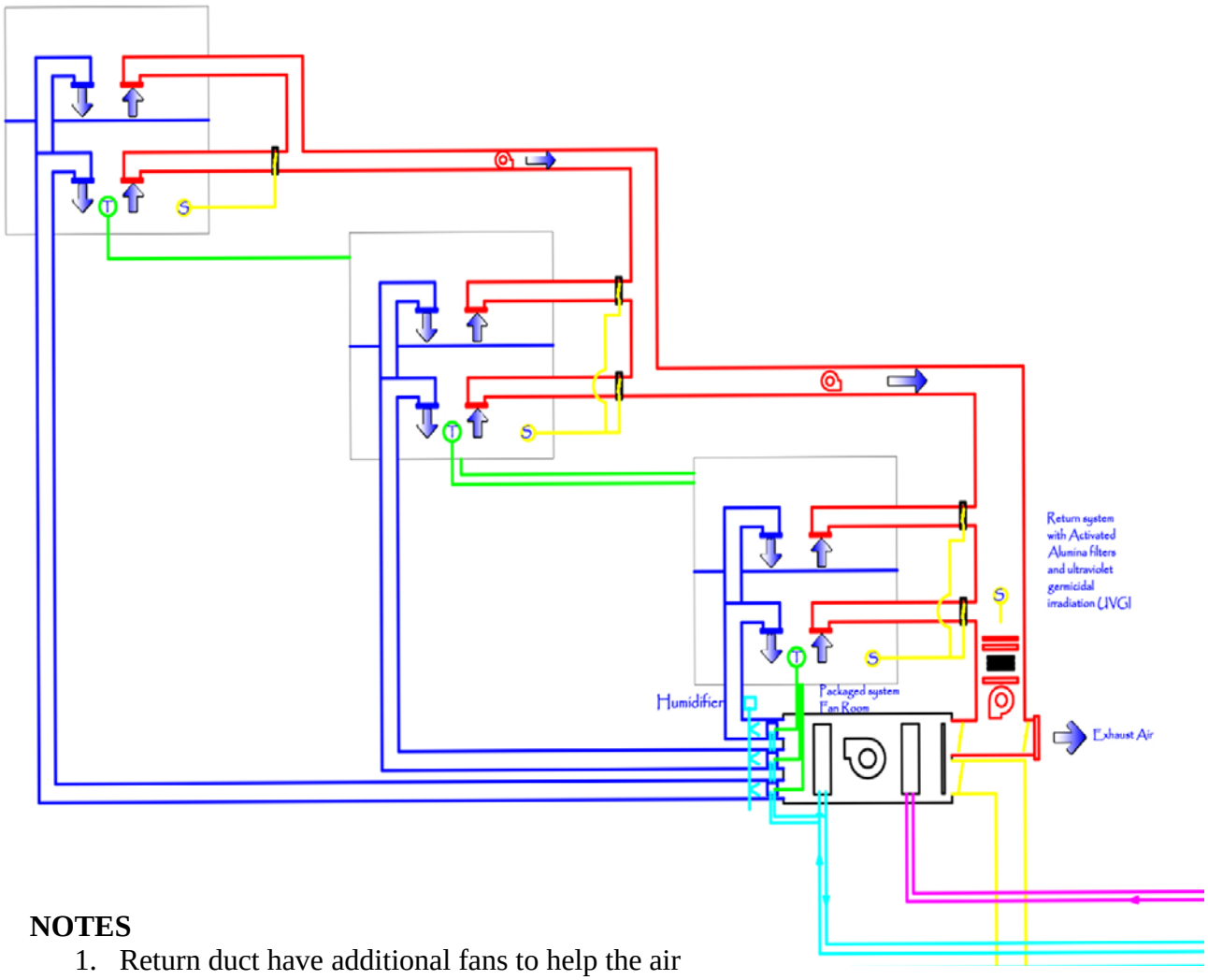
Underground water tanks will provide cool water to the chiller.

When air pressure drops in the greenhouse, the air intake into the greenhouse will operate to level the air pressure. This air intake has an air filtering the first step to filter S02. This filter does not get rid of all contaminated volcanic gases; instead it reduces the amount of S02 and other chemical gases into the greenhouse. The remaining gases that get into the greenhouse will be controlled before it reaches the air packages through passive control and more filtering process.

Note that all air handling packages have intake air, in this project because of the contaminated air from outdoors there is need to have extra insulated air duct with a higher R value, recommended R6 with metalized polyester vapor barrier which will help keep the air intake cool when travels through the duct. Also note that all greenhouses have a higher C02 content because of photosynthesis process. Plants emits C02 during the night to solve the problem of bringing C02 into our air handling packages we have to filter the fresh air from the greenhouse from C02. One benefit of having high levels of C02 in the greenhouse is that increases the yield growth of plants. This air intake from the greenhouse will have sensors to monitor C02 levels traveling the duct into the air handling package unit.

Schematic Immune System Design (Greenhouse)

Source: By Author

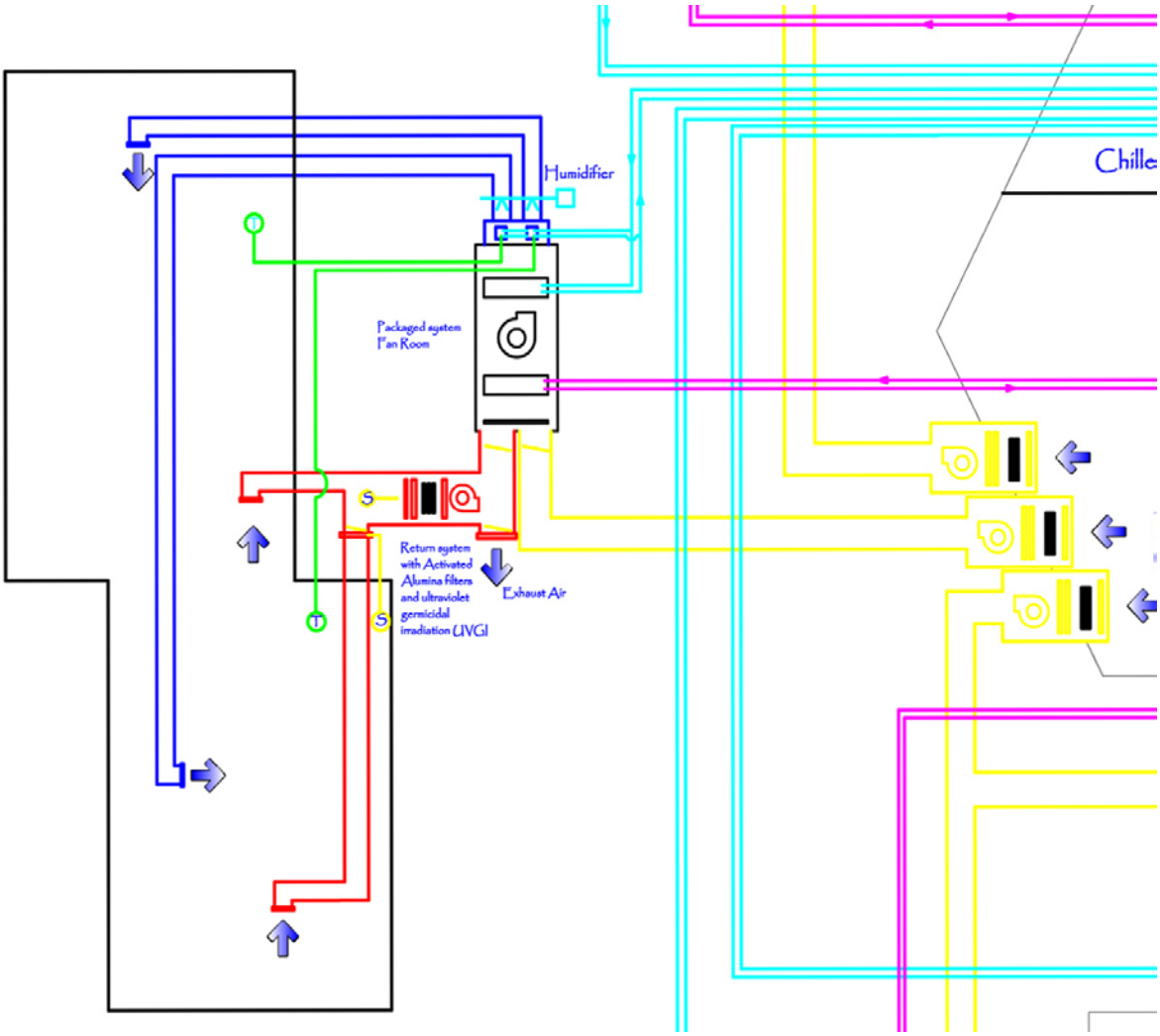


NOTES

1. Return duct have additional fans to help the air return to the air package
2. At the end of the return duct there is a filtration process in which filters the S02 and other gases remaining in the interior air before it goes back into the units.
3. All rooms have a thermostat to control the sensible air temperatures.
4. All returns have sensors to evaluate the contaminated air to better control the filtration process.

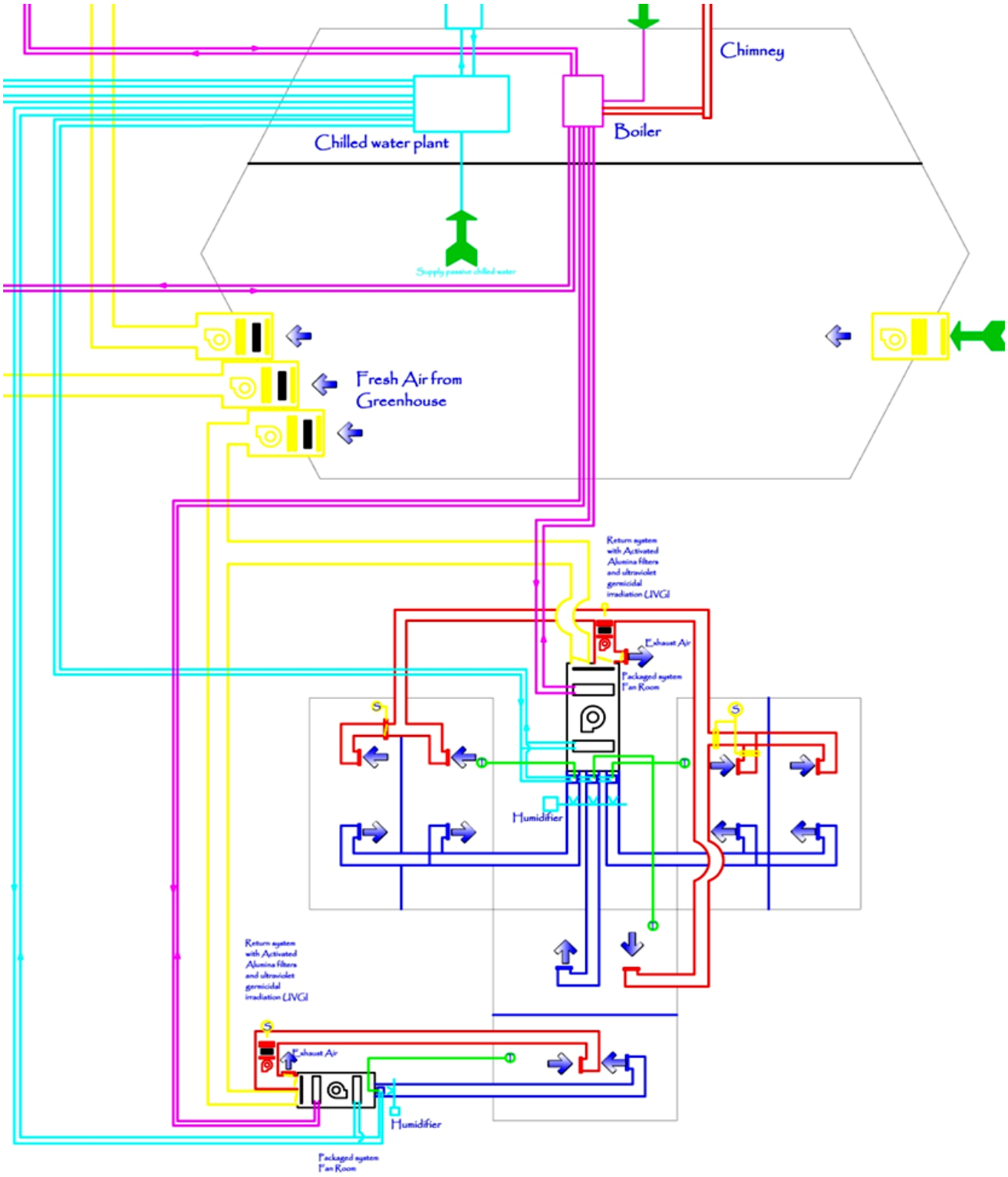
Schematic Immune System Design (Sector A)

Source: By Author



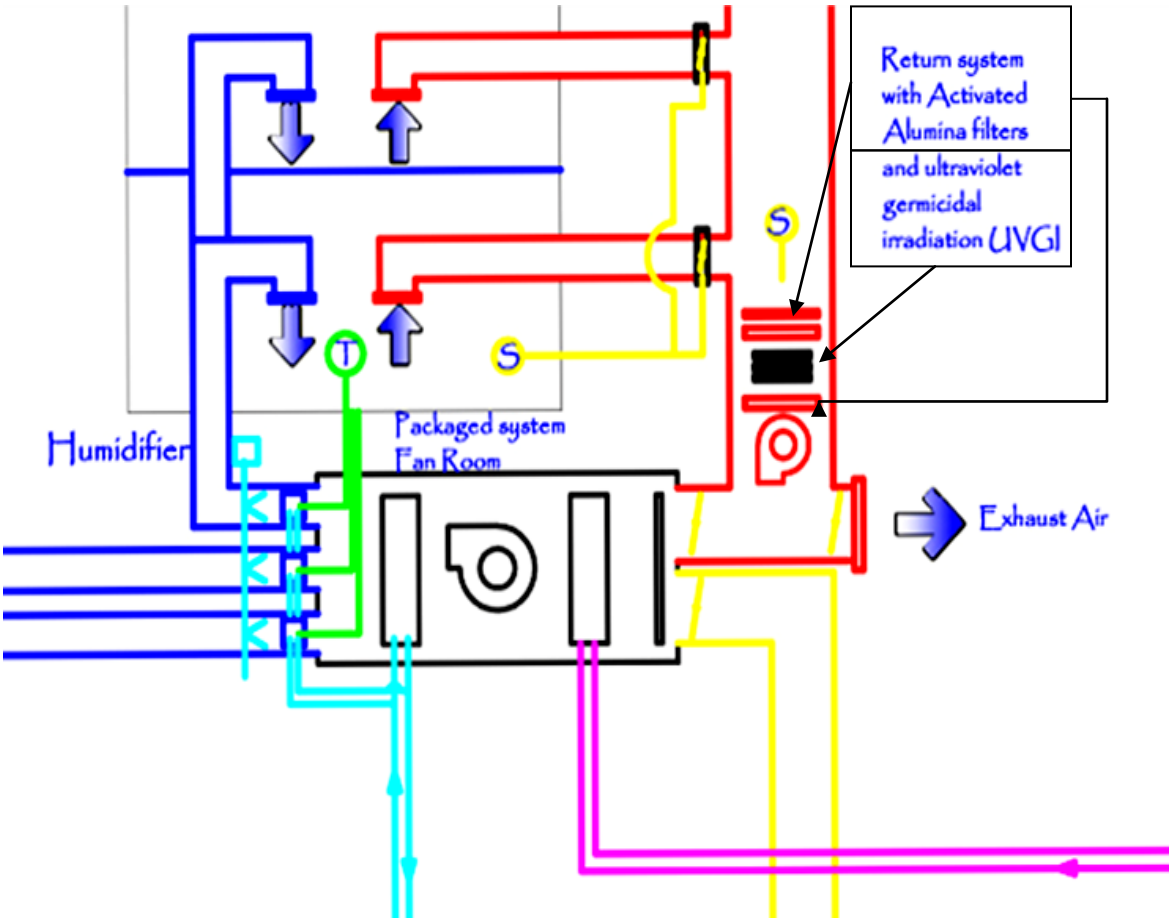
Schematic Immune System Design (Sector B)

Source: By Author



Schematic Immune System Design (Sector C and Computer Room)

Source: By Author



Schematic Immune System Design Close-up Sector A

Source: By Author

18.BUILDING ENVELOPE

18.1 Materiality and Construction Details

As part of the program in order to minimize working man hours at the site it is needed to introduce prefabricated structures because of the following benefits:

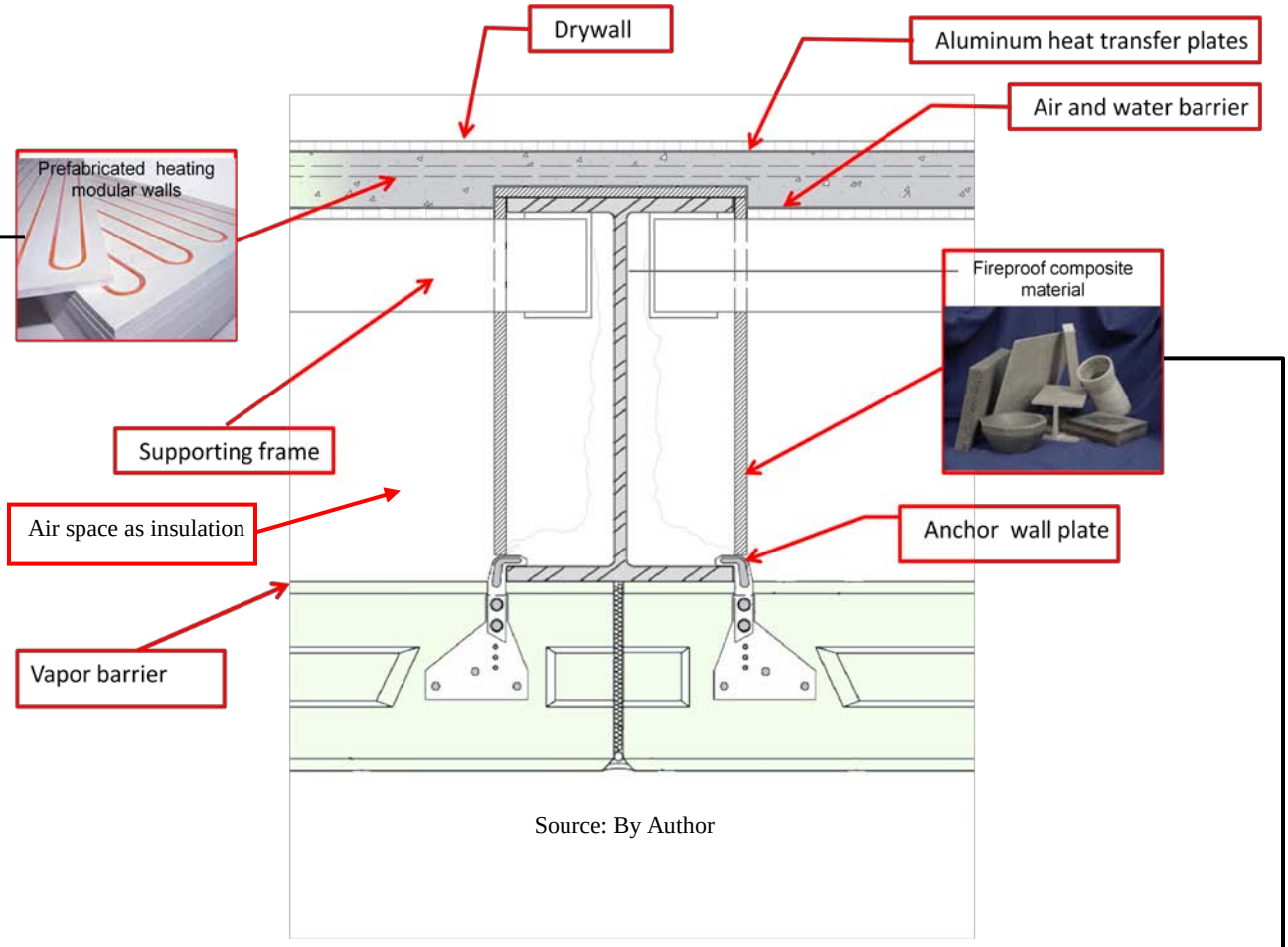
- Architectural design freedom is grand including choices of color, texture, and details.
- Fits schedule demands and budget
- Largest panels minimize the number of joints therefore reduces the chance for water penetration especially this buildings needs to be water and air tight.
- Building process of panels can start as early as half way into schematic design
- Easy transportation to the site and assembly
- Supports green design and it is environmentally friendly
- Can be put on site without worrying about weather conditions
- Depends of the thickness, panels are excellent in fire proofing the building
- Minimizes the use of multiple materials
- Creates shear walls

The overall design approaches in all buildings are as follow:

- Main steel structural framing
- Use of precast concrete panels as the main design
- Use of double wall and ceiling systems
- Aluminum window framing
- Use of double glaze windows and some exterior glass windows can be fire proof
- Use of smart windows
- All buildings are to be air and water tight and have good acoustic interior materials
- Cabins are to introduce prefabricated interior heating modular walls
- Main steel structure needs to be fire proof

The following are construction details in which new systems are introduce:

The following detail pertains to the cabins because all interior walls have prefabricated heating modular panels. Each panel is connected to a main hot water system which will provide radiant heat to all cabins (Sector A). Temperatures at the Kau desert especially during winter time can be as low as 20 to 30 degrees F. and extremely high during the day reaching over 105 in some areas in the desert. Structural steel columns are to be protected with fireproof composite material which will provide greater fire protection to expose steel. This fireproof composite can handle 2000 f degrees of continuous flame.

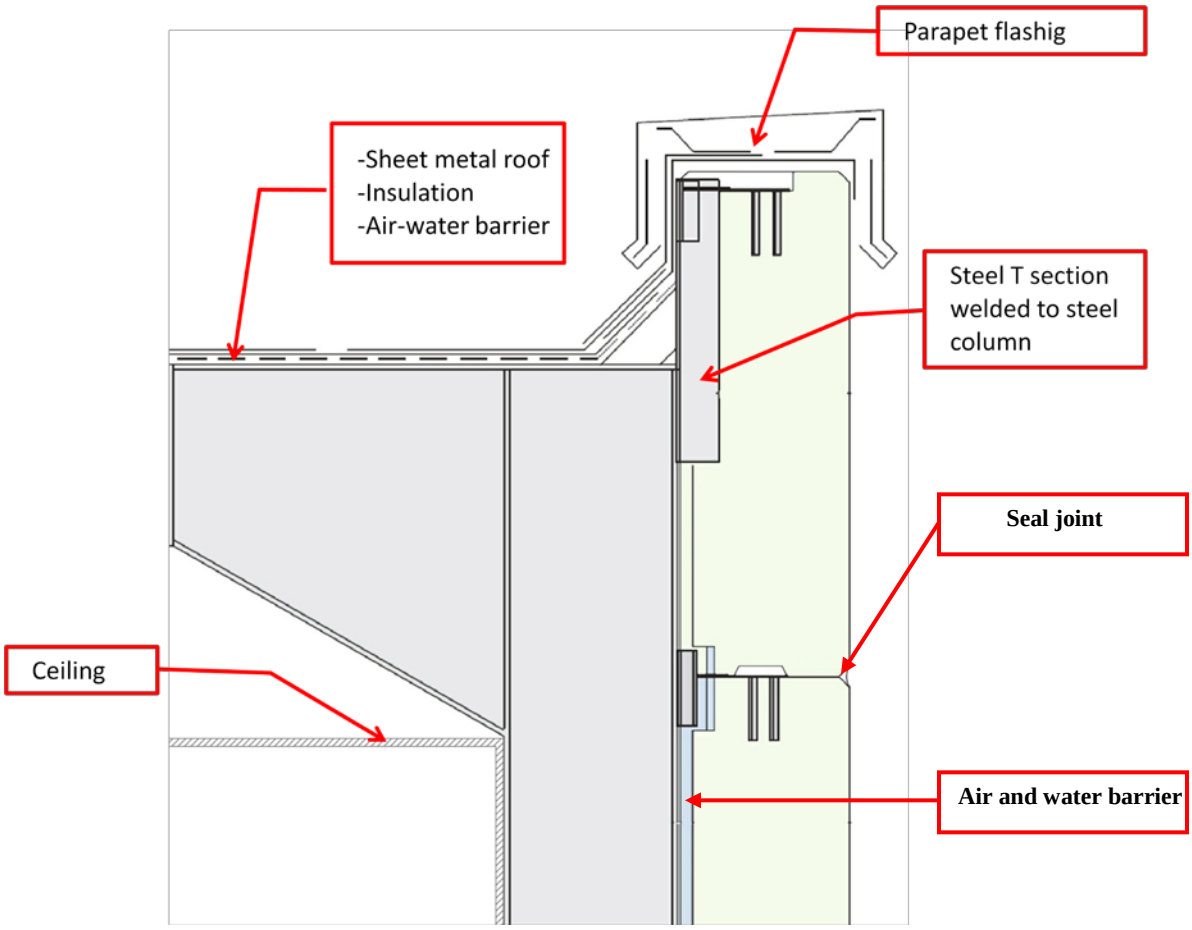


Source: By Author

Source: http://www.constructionresources.com/products/pdfs/services/Variotherm_Modular_Wall_Heating.pdf

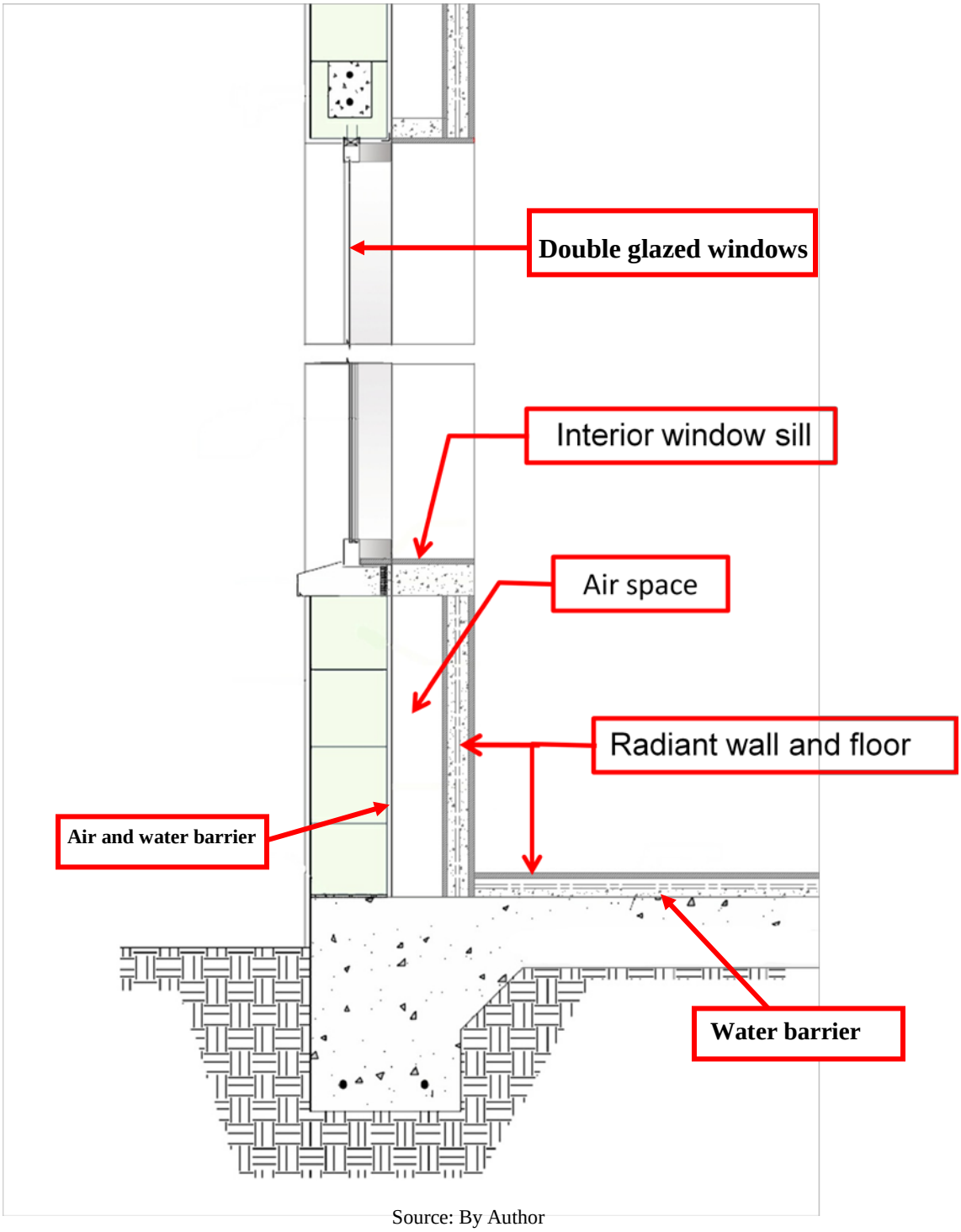
Source: www.epp.goodrich.com

The following detail pertains to Sector A, to all cabins roof detail and the attachment of precast concrete panels to the steel framing.



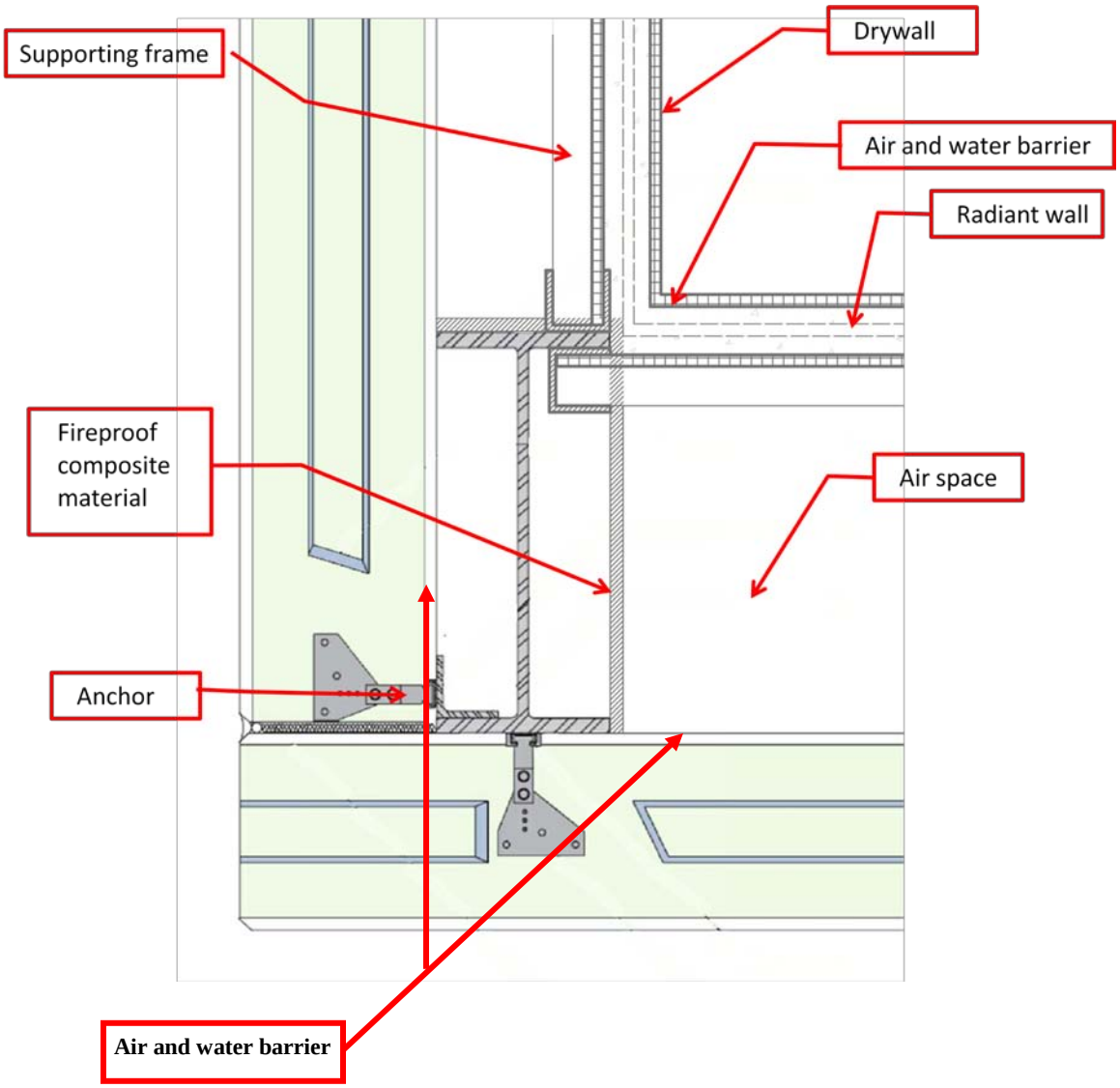
Source: By Author

Cabins wall section and the main components of the double wall system:



Source: By Author

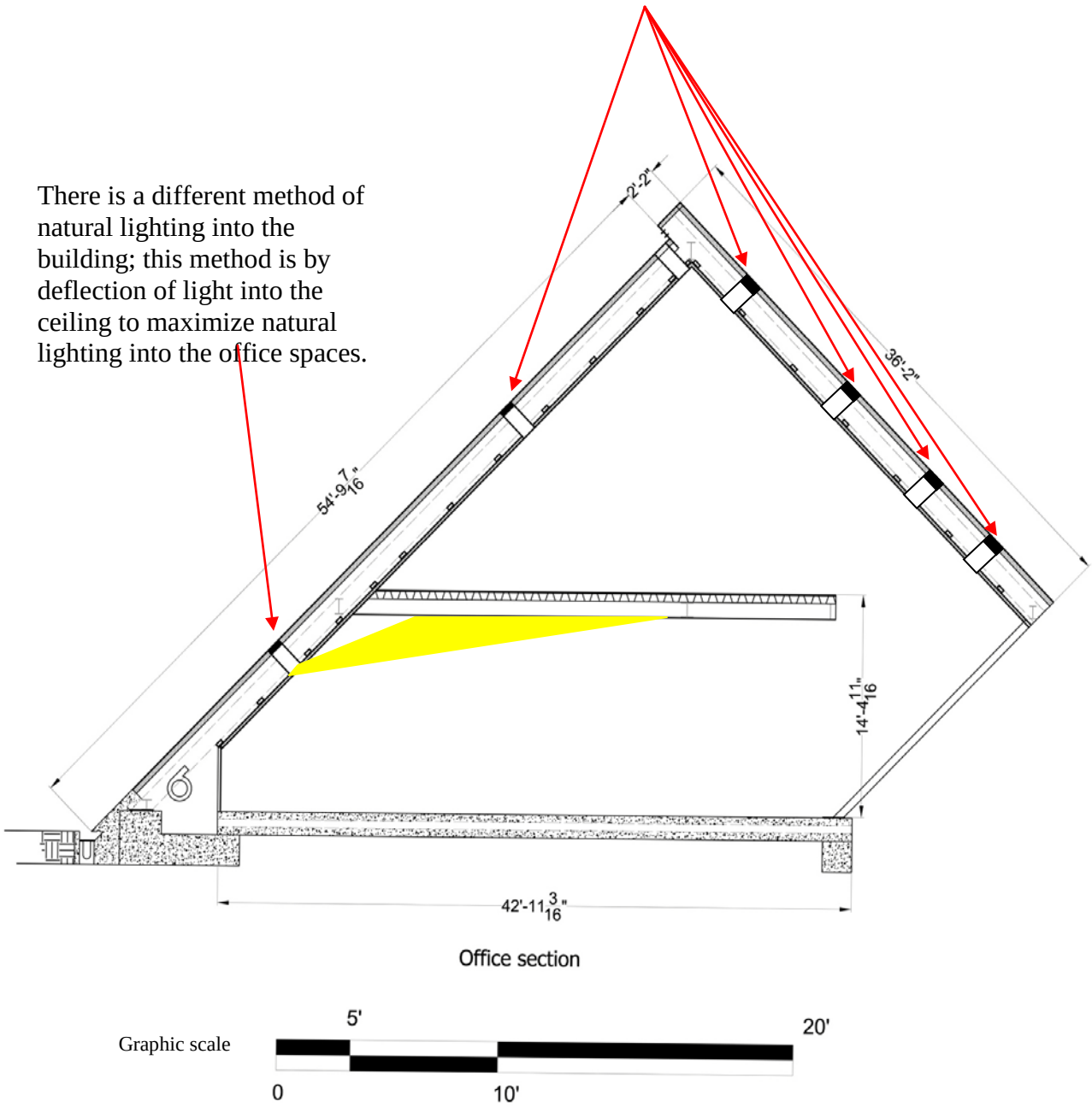
Another typical corner detail and its main components



Source: By Author

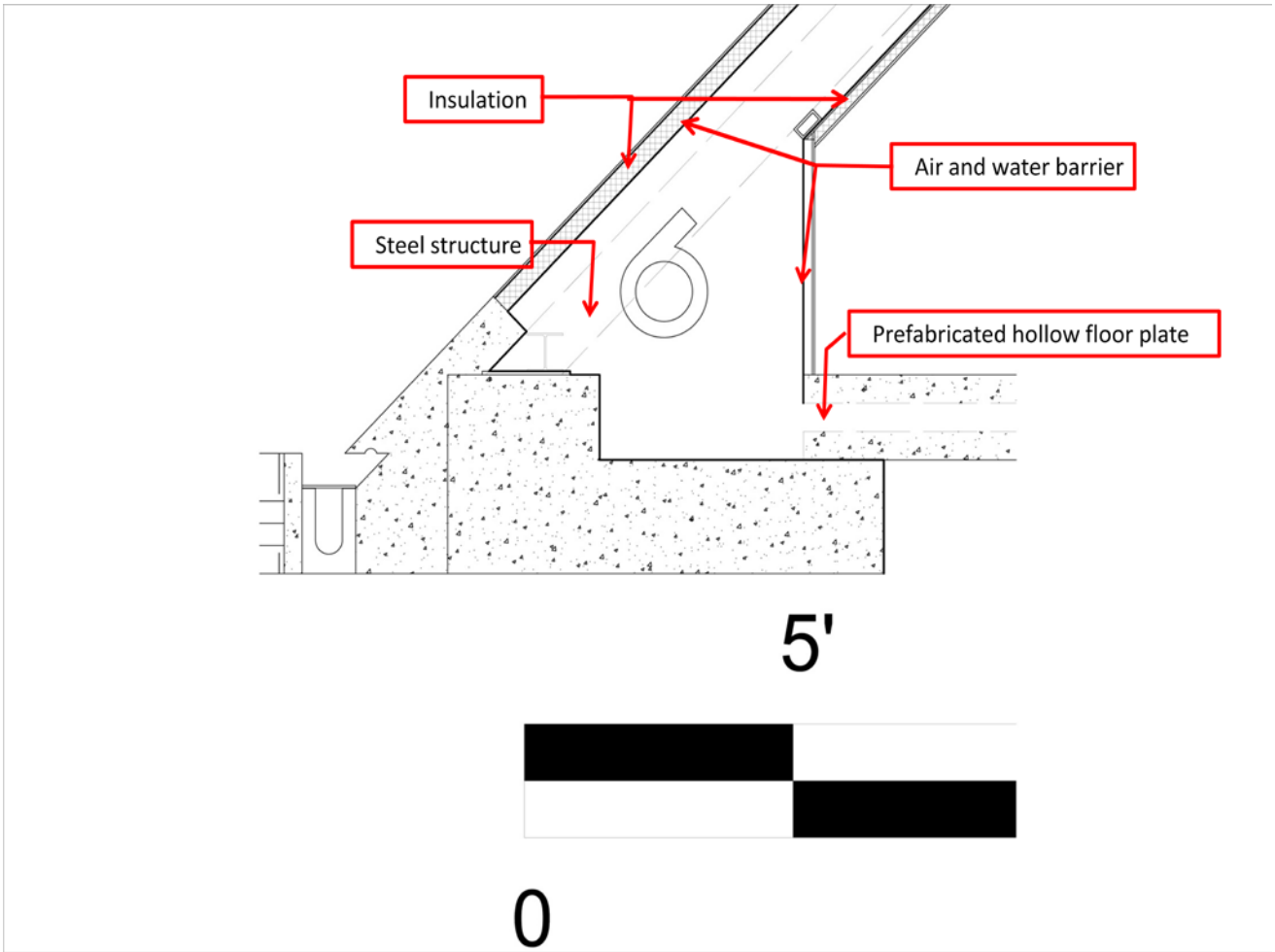
The office buildings have integrated Aerogel skylights into the South wall and the roof which allows light to enter the building and keeps the heat out as a passive natural lighting.

There is a different method of natural lighting into the building; this method is by deflection of light into the ceiling to maximize natural lighting into the office spaces.



Sector C cross section

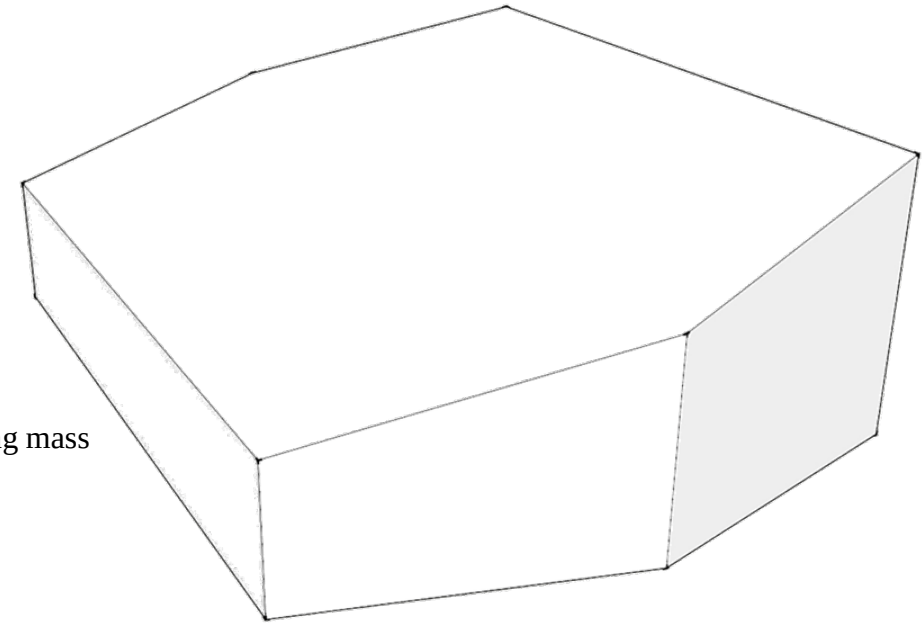
Source: By Author



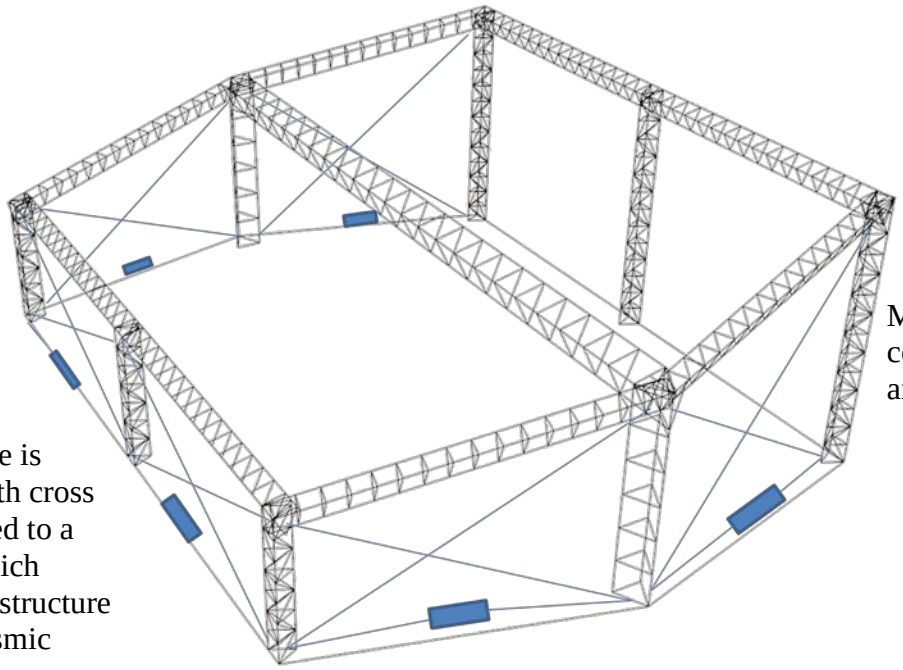
Sector C Corner detail cross section

Source: By Author

The greenhouse has a different design approach in materiality, a hexagon in shape with a roof that faces the sun throughout the day. The greenhouse main structure has triangulated 3D columns and trusses which resembles complexity in appearance but delicate in function. The greenhouse connects all buildings by providing them with the most vital elements in life Air and water.



Overall building mass

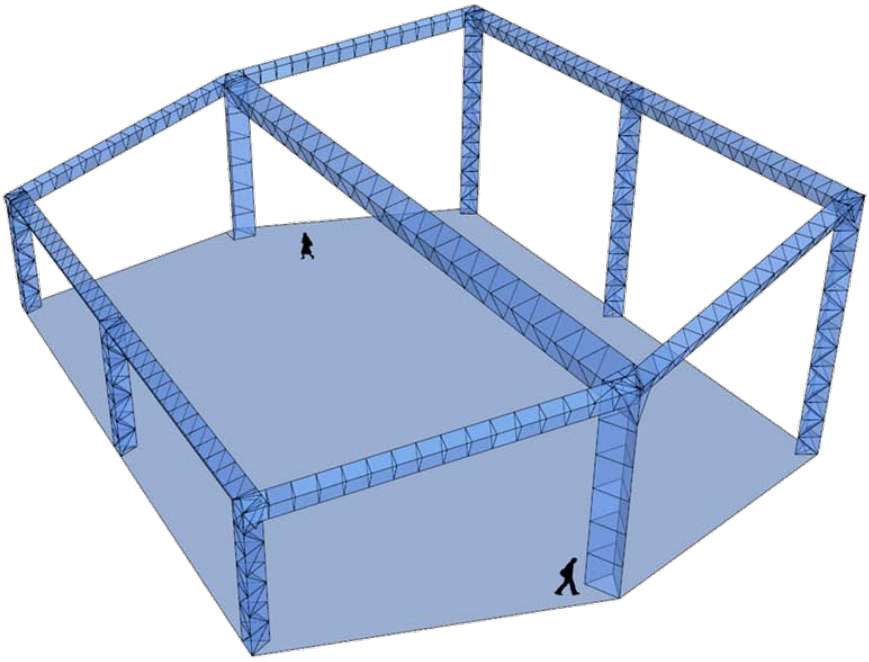


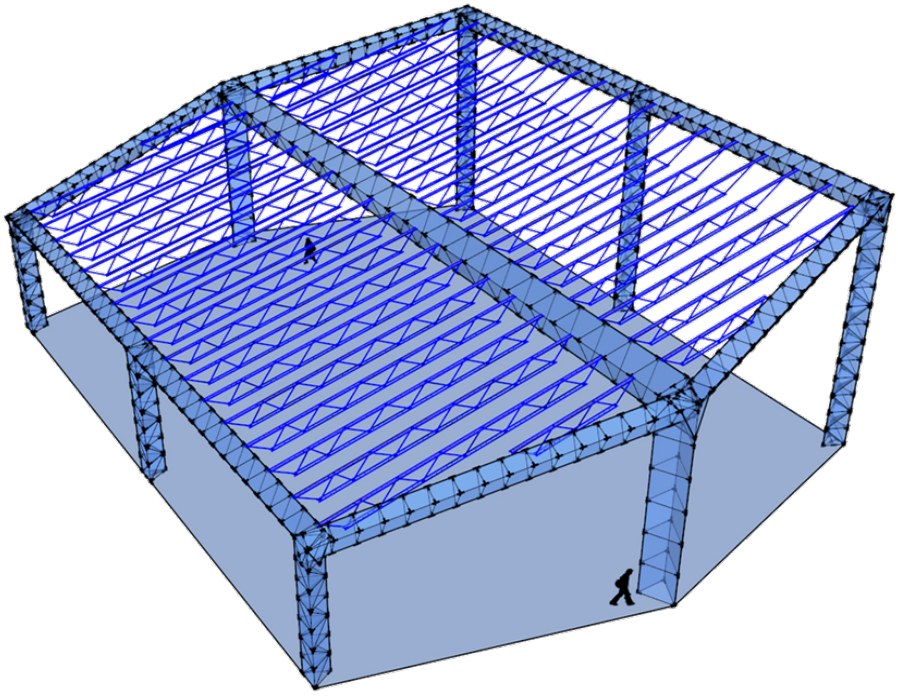
Main structural system consists in 3D columns and trusses.

Main structure is reinforced with cross cables attached to a damper in which stabilizes the structure in case of seismic activities.

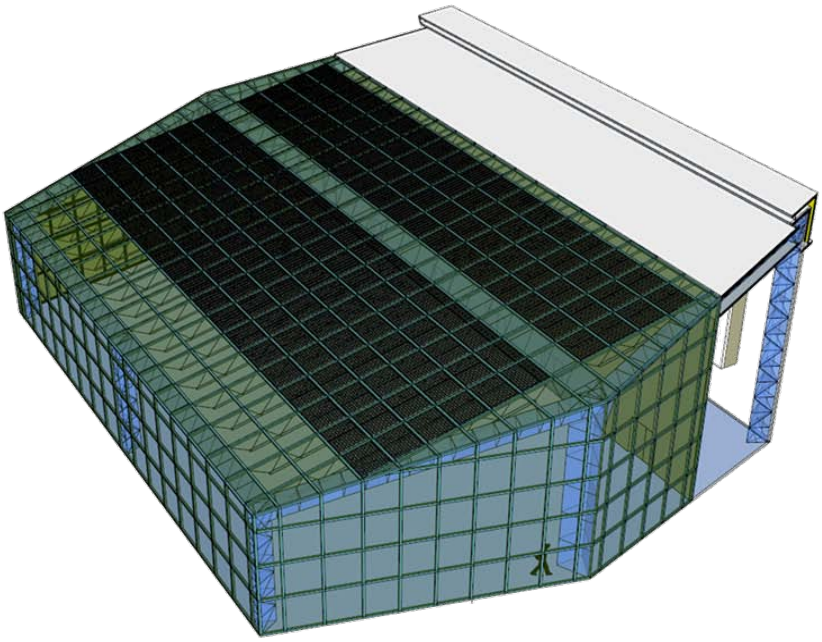
Source: By Author

Greenhouse building process methods

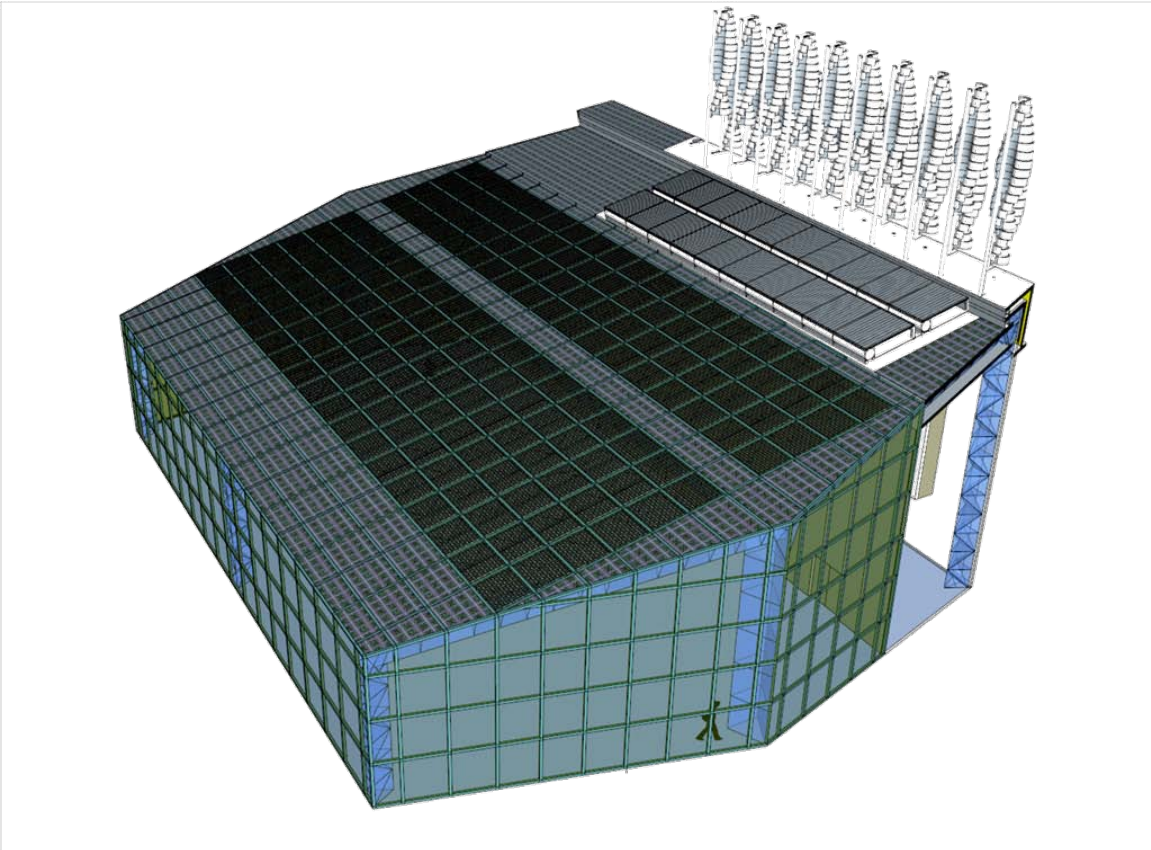


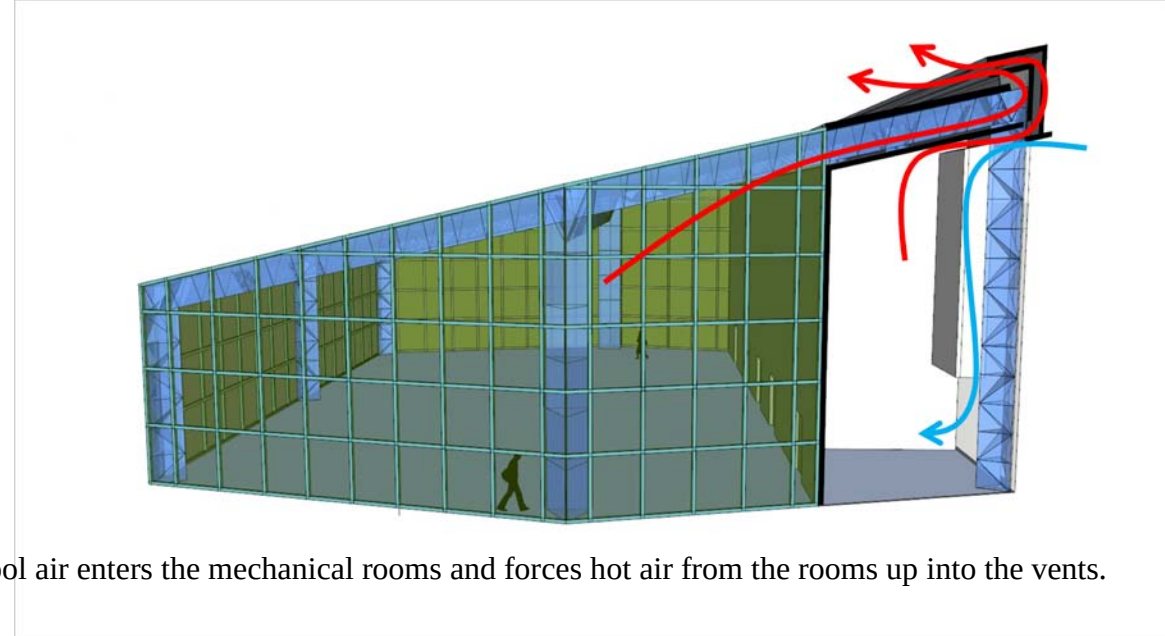


Source: By Author



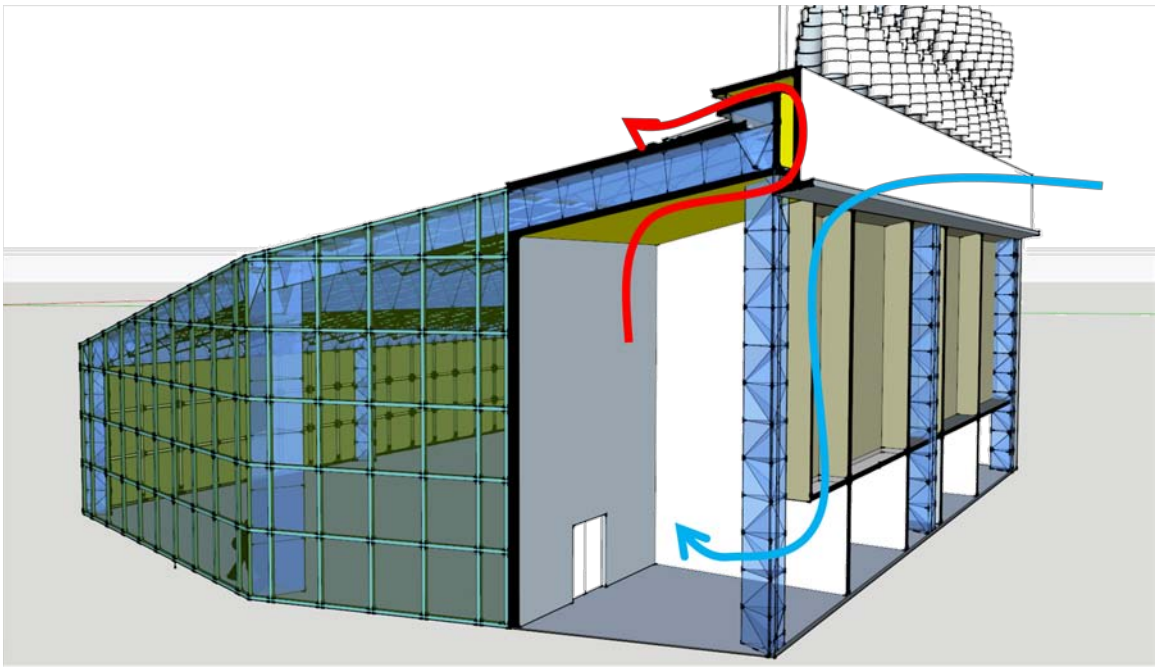
Source: By Author



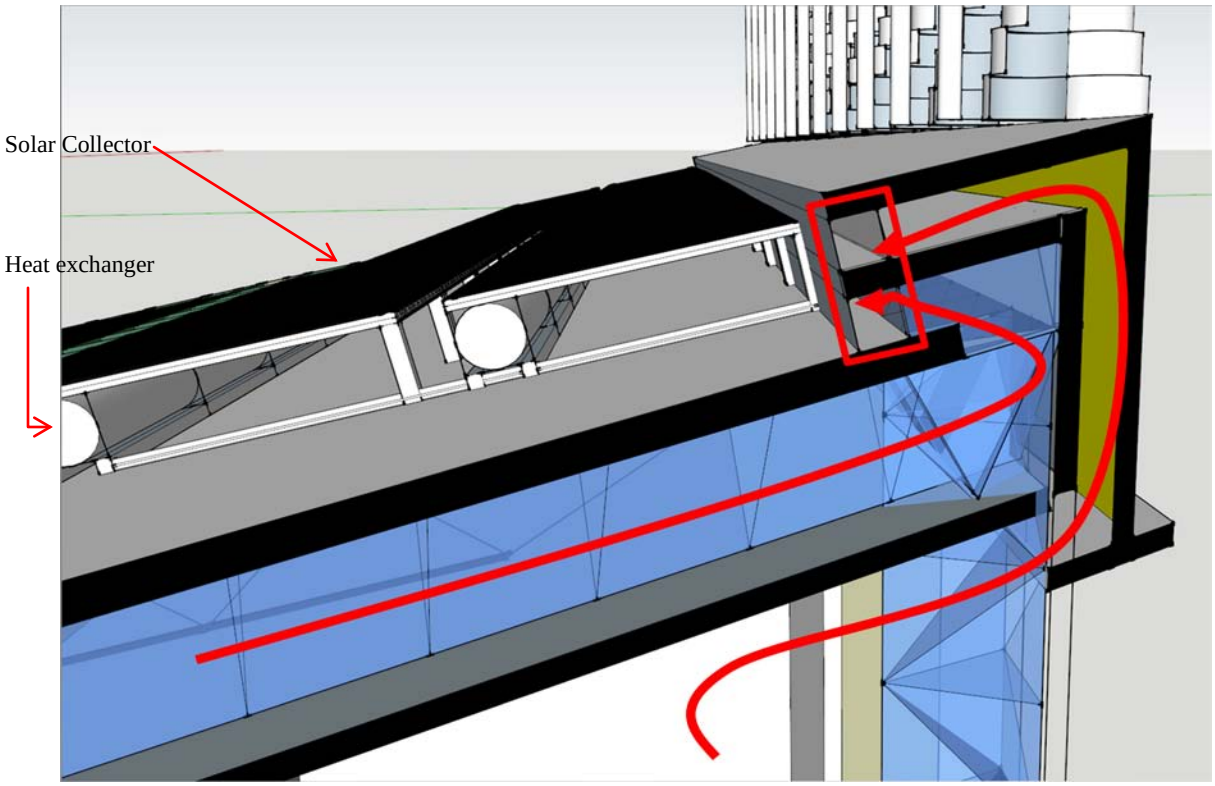


Cool air enters the mechanical rooms and forces hot air from the rooms up into the vents.

Source: By Author

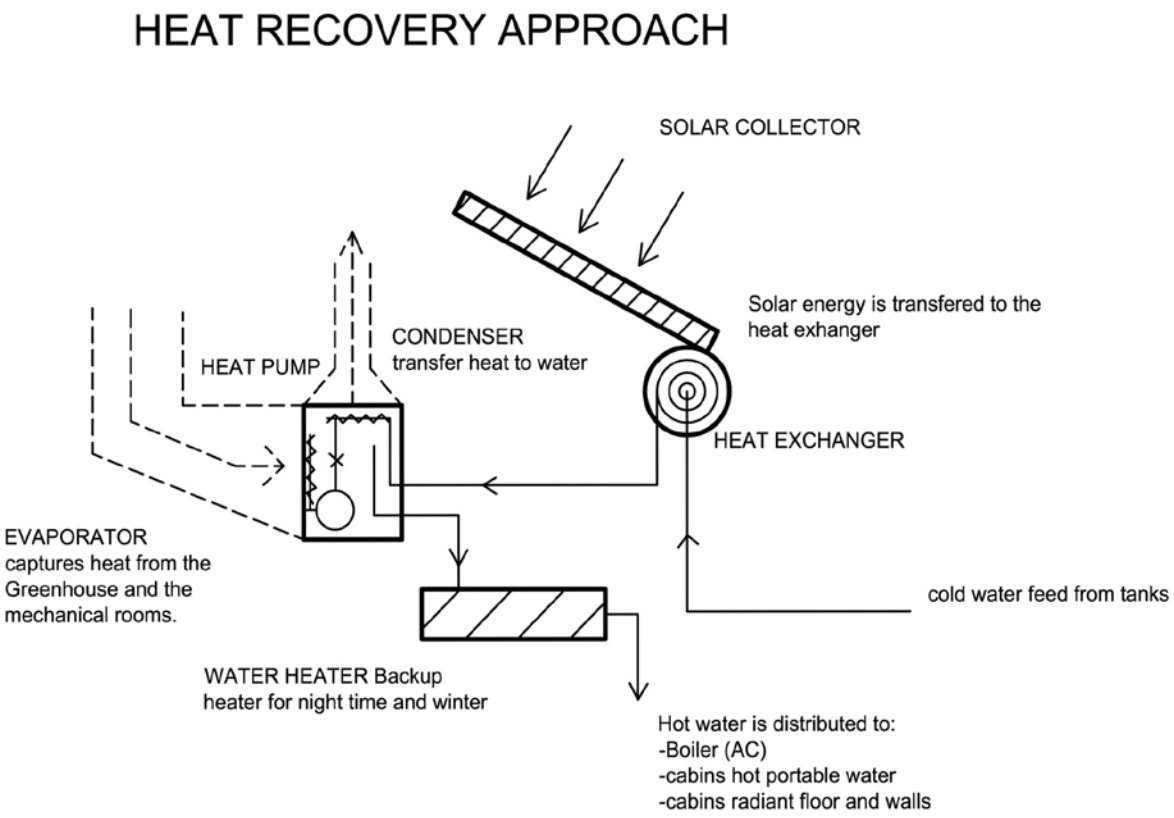


Source: By Author

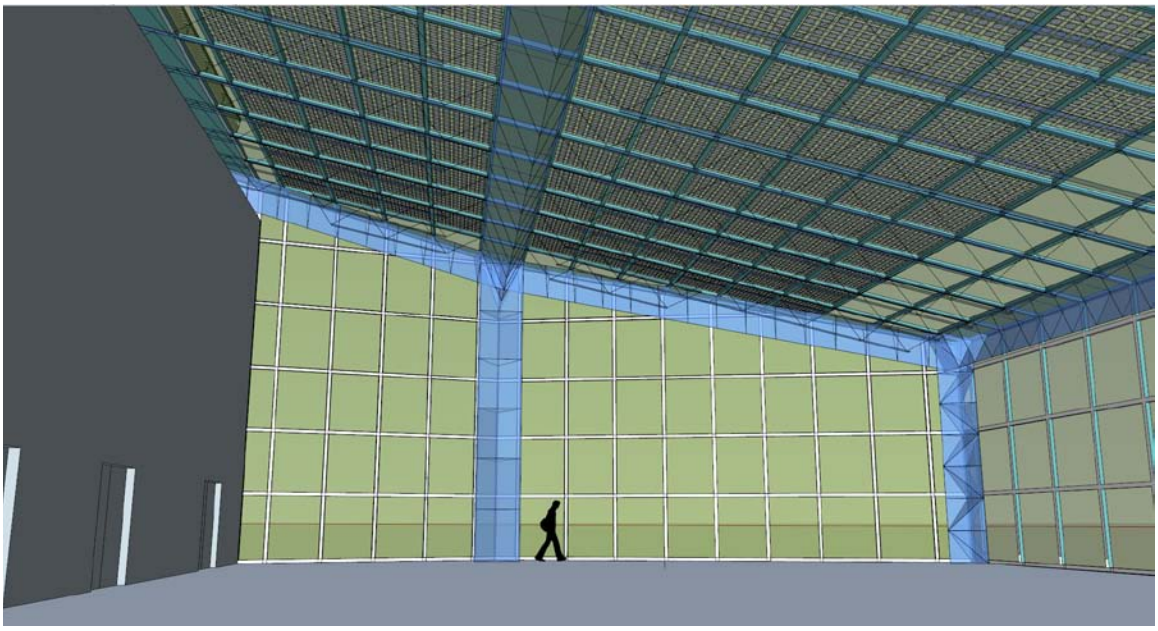


Hot air from the mechanical rooms and the greenhouse is recycled with the use of an evaporator as a secondary heat process to the hot water.

Source: By Author



Source: Being Sustainable by Denis Fukai page 71



Source: By Author

When there is a lot of water condensation and plant transpiration in the greenhouse due to high indoor temperatures, the nozzle sprays just below the 3D trusses turns on periodically providing an intermittent breeze throughout the greenhouse. Fans will be running during high temperatures above 90F degrees just below the spray line creating a constant airflow movement which cools down the interior temperatures as if it was a natural air conditioner thanks to evapotranspiration. The space between the roof and the fans is dedicated to let the extra heat travel alone the roof which is recycled down the line.

The roof has incorporated BIPV for dual purposes; to generate necessary energy for consumption and to reduce the amount of sun into the greenhouse therefore high temperature are reduce dramatically.

Note that all air handling packages have air intake from the greenhouse located about 5 to 6' off the ground because of the fact that cold air stays at lower levels. Also to reduce heat gain at the floor level and to prevent water accumulation from the nuzzle sprays, it is recommended to have a 3" top layer of round pebbles on top of a sand layer which helps drain the water without accumulating, therefore, preventing the growth of mold.
The greenhouse plants are strategically chosen to increase indoor air quality and purification purposes from pollutants. The most common indoor pollutants are:

- formaldehyde
- Benzene
- Trichloroethylene

These indoor pollutants can be taken care of the use of impregnated carbon filters.

- Volatile Organic Compounds
- Radon
- Carbon monoxide

These indoor pollutants can be taken care by design and best practices.

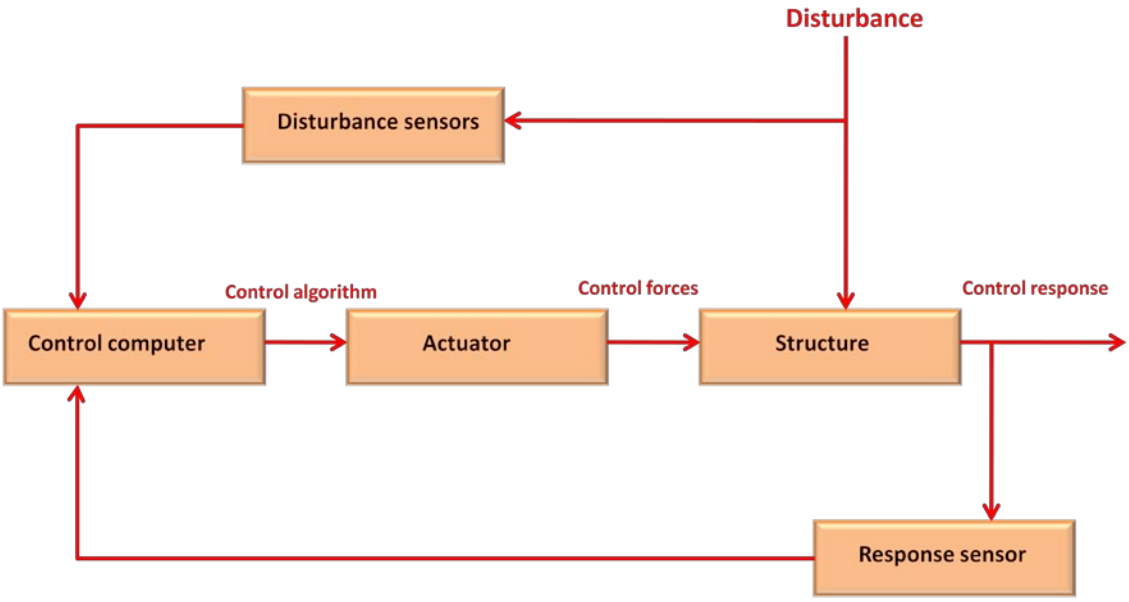
- And others

Also passive solar exposure and vegetation reduce the bacterial biofiltration load of indoor air. Some recommended plants for the greenhouse are: Bamboo palm (Chamaedoren Seifritzi), Chinese evergreen (Aglaonema).

Source: By Author

18.2 Main components of smart structures

As a designer one has to know the components of smart structures and how it works to better understand its uses and to incorporate this intelligent system on qualified projects. Smart structures helps stabilize the main structure and minimize damage to walls, ceilings and the most important to prevent damage directly to the main structure. The architect has to work alone with the structural engineer to choose the most appropriate system for accuracy. Franklin and his book Smart Structures helps understand the steps and what it needs for smart dampers to respond to disturbances in the next chart.

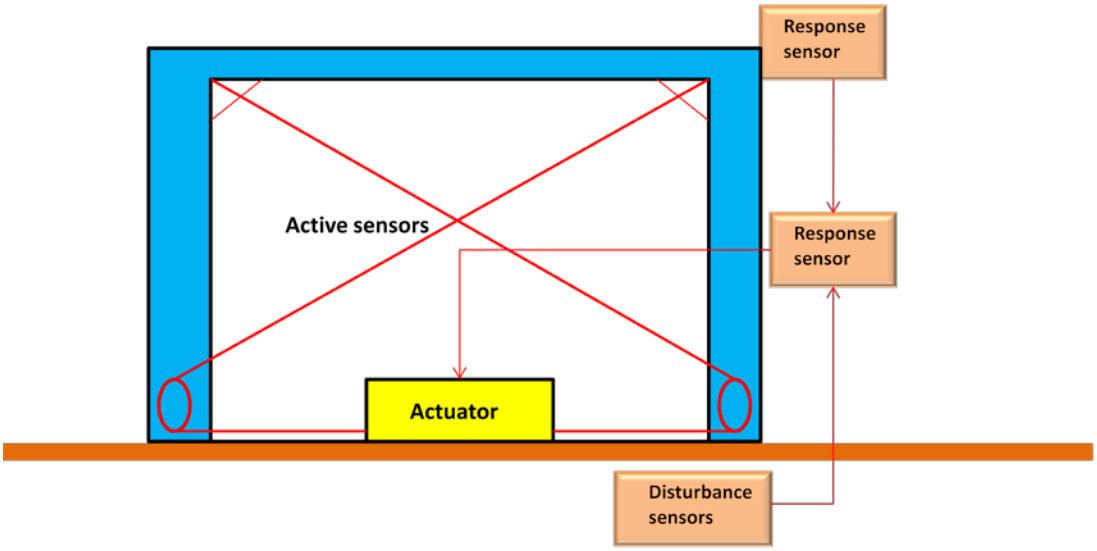


According to Franklin Y. Cheng the former senior investigator, Intelligent Systems Center on his book Smart Structures page 172 Figure 4.9

Open-closed-loop disturbance-compensated control system

Source: Smart Structures by Franklin Y. Cheng page 172

The next diagram is one of the smart systems utilize in the greenhouse which shows the process when it is activated.

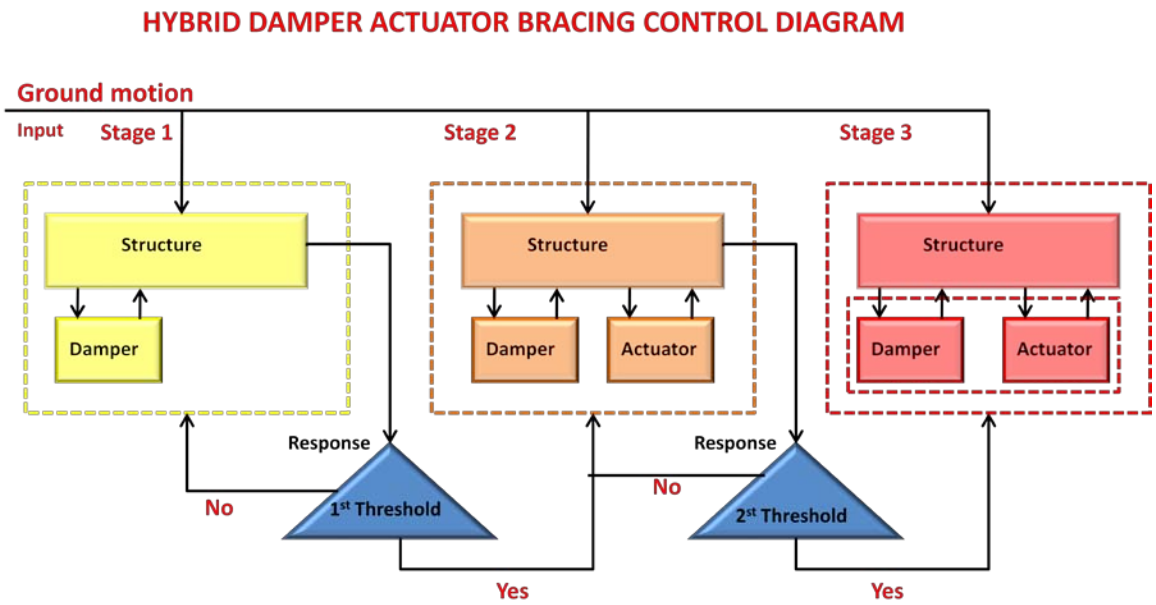


According to Franklin Y. Cheng the former senior investigator, Intelligent Systems Center on his book Smart Structures page 172 Figure 4.10

Open-closed-loop disturbance-compensated control system

Source: Smart Structures by Franklin Y. Cheng page 172

The site chosen at the Kau desert has records of a lot of seismic activities due to unstable platonic plates and volcano activities. The intensity level varies from 3.0 to 6.0 degrees at a Richter scale. Cheng developed a hybrid damper actuator bracing control system which I will utilize in all the buildings because the system adjusts in response to the intensity of the seismic as he explains in the next diagram.



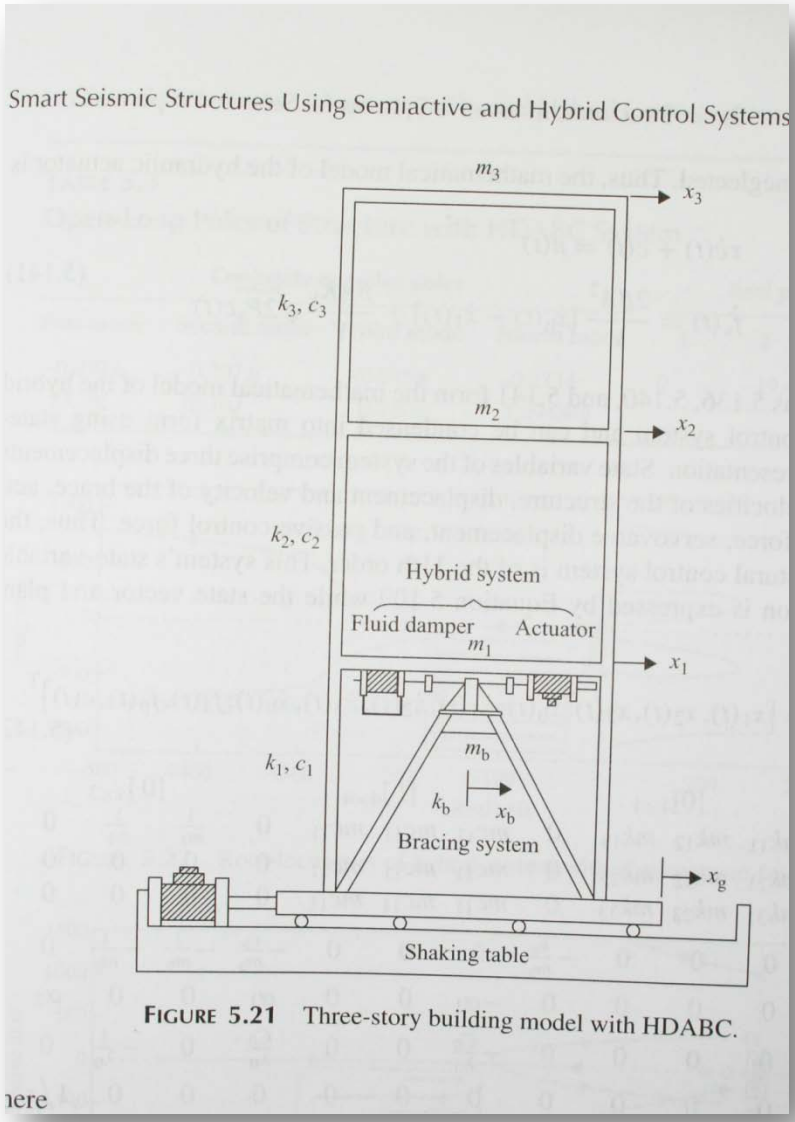
Source: Smart Structures by Franklin Y. Cheng

According to Franklin Y. Cheng the former senior investigator, Intelligent Systems Center on his book Smart Structures page 283 Figure 5.15 a Flowchart of the three-stage intelligent hybrid system

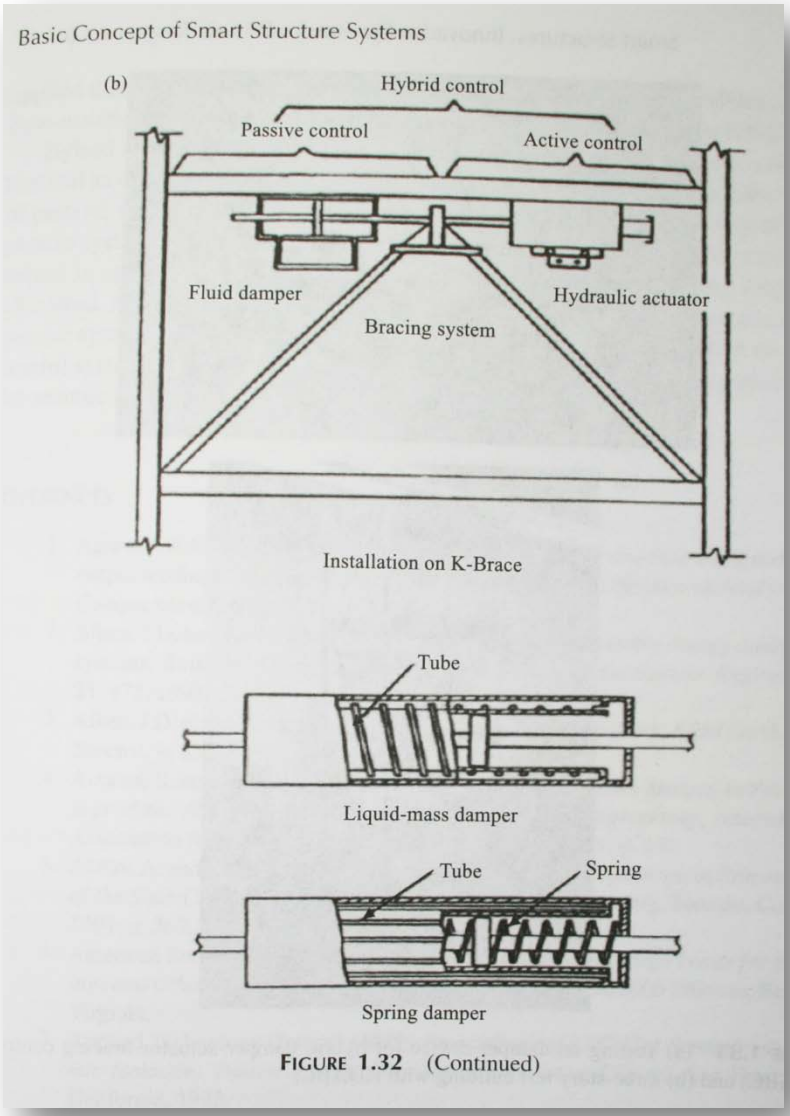
1. The most critical structural response is determined and two threshold values are set for it.
2. The system works within stage 1 for small earthquake excitations that yield structural response lower than the first threshold.
3. The actuator starts working and the system moves into stage 2 whenever the response exceeds the first threshold value.

4. When the response exceeds the second threshold value, the feedback gain is adjusted to generate larger control force. The system functions in stage 3.

The following diagram is an example of a K bracing with Hybrid Control System which can be applied to small building such as the one at Sector A (cabins).



Source: Smart Structures by Franklin Y. Cheng



Source: Smart Structures by Franklin Y. Cheng

The following examples are extracted from Cheng's book "Smart Structures" some are passive methods and some are smart dampers at a small scale and can be applied to small structures.

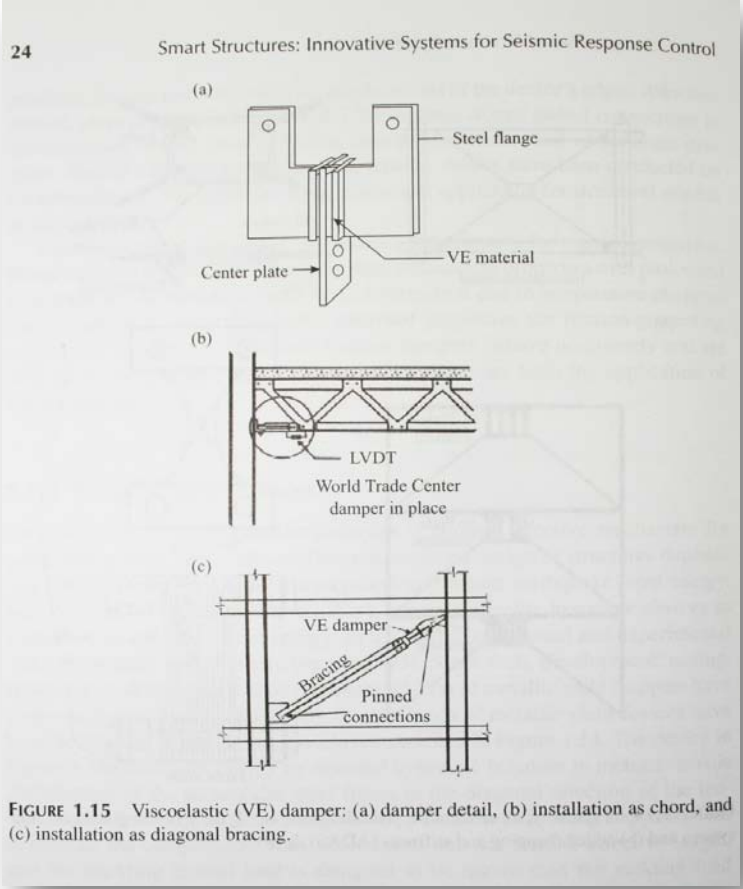


FIGURE 1.15 Viscoelastic (VE) damper: (a) damper detail, (b) installation as chord, and (c) installation as diagonal bracing.

Source: Smart Structures by Franklin Y. Cheng

9.2.2 Hybrid Controlled Single-Story Building with SSI

The soil influence of the inertia interaction is dominant for the shallow foundation [18,19], for which the reaction is expressed by a series of stiffness-damper units between the foundation and the soil with their values provided in the impedance function [1,16]. Figure 9.3 shows the SSI consideration for the hybrid controlled single story building resting on the soil. The impedance function is given in

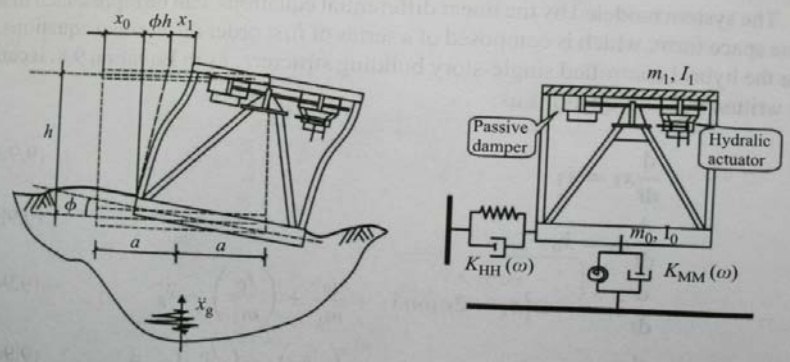
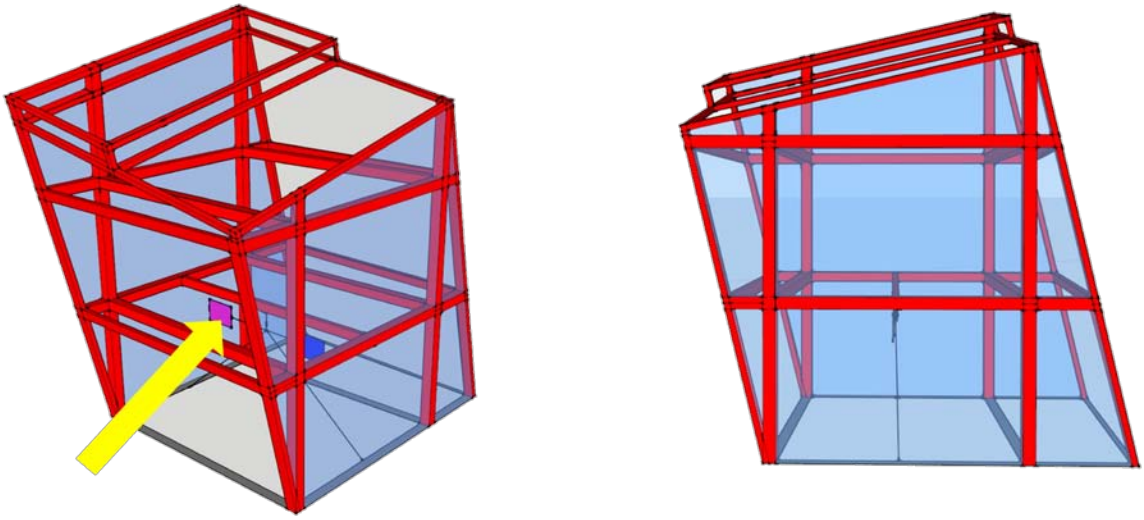


FIGURE 9.3 HDABC system on soil.

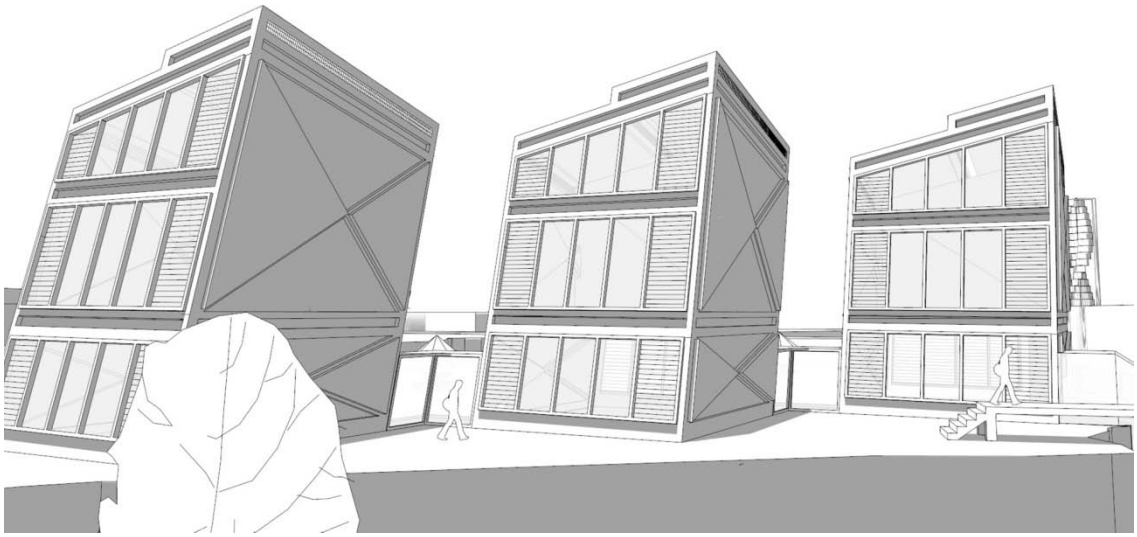
Source: Smart Structures by Franklin Y. Cheng

The exterior building appearance in Sector A (Cabins), are as if where going to fall because it has an slanted appearance but the main structure that supports the buildings is quiet simple by steel columns and beams and cantilever floors.

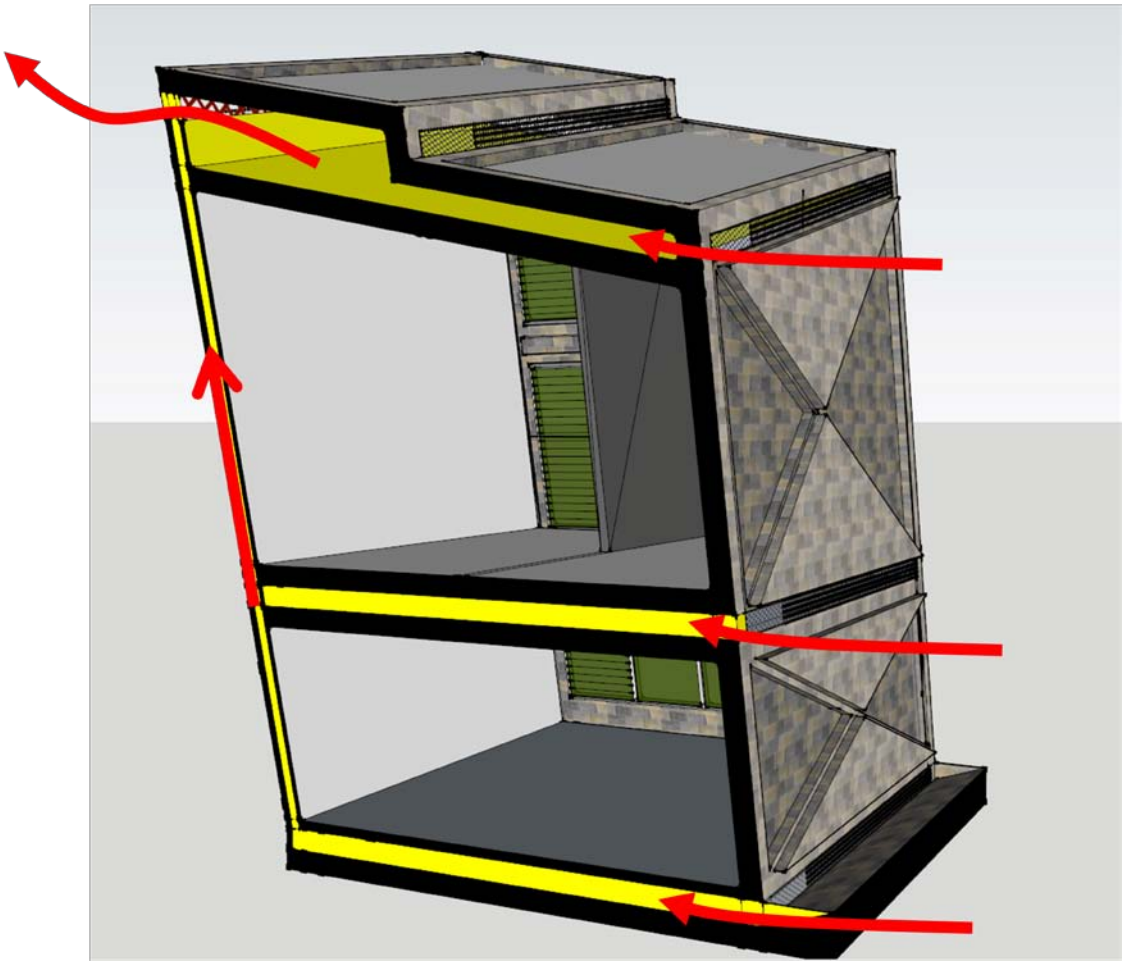
Note that the main structure has incorporated a hybrid system damper and actuator on the first floors.



Source: By Author



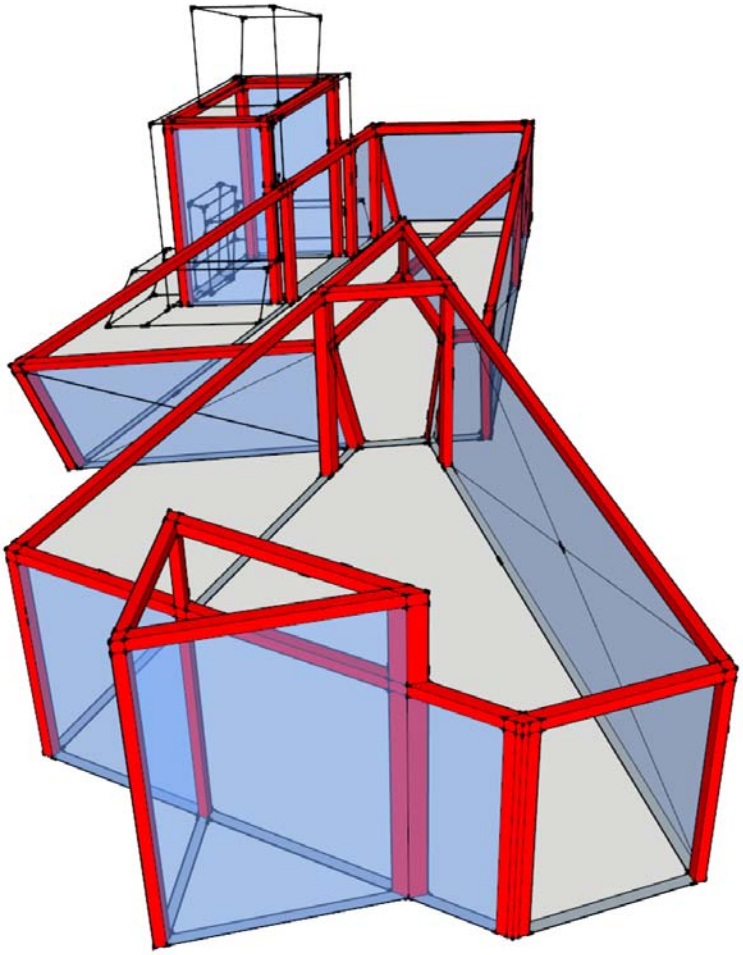
The following diagram represents the passive heat control into the buildings and how a constant air flows into the cavities walls, floor and ceiling.



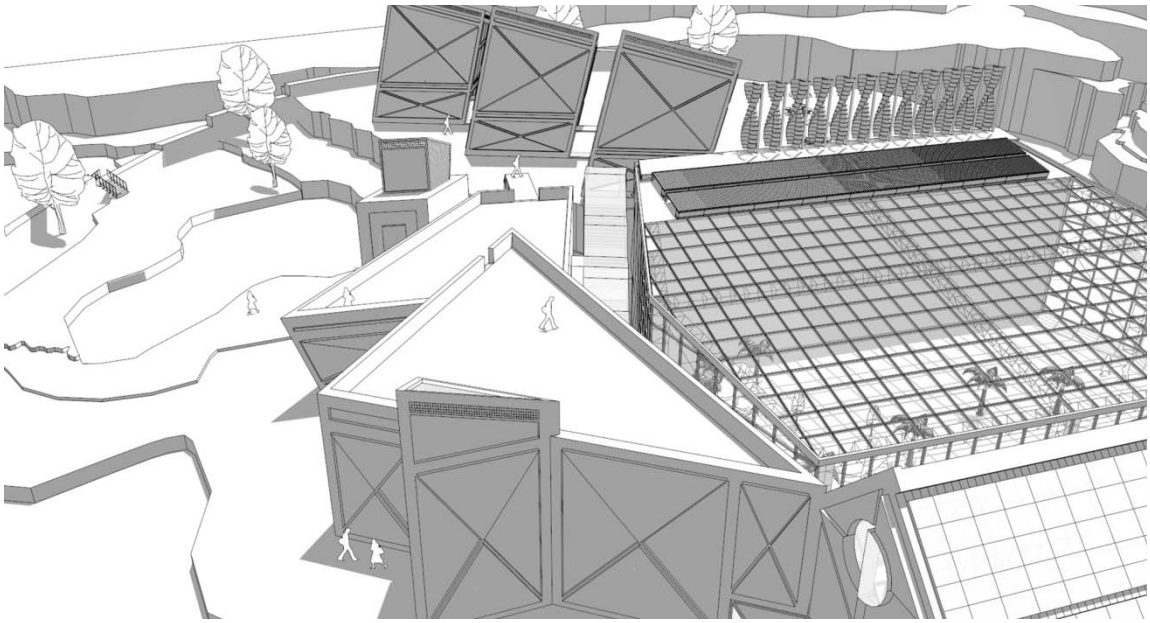
Source: By Author

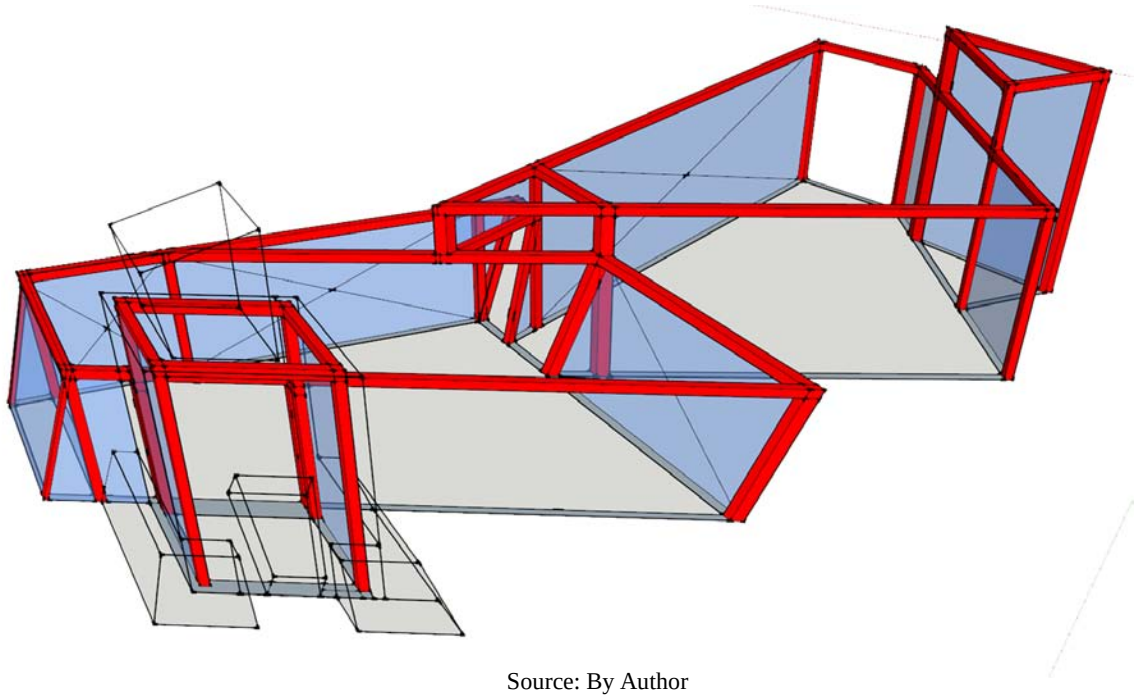
The following schematic diagram shows the main structural framing in Sector B (Learning Center) and how the slanted wall support is achieved. Note also that all exterior walls that have prefabricated concrete panels act as shear walls reinforced with tension cables attached to smart dampers that will help resist seismic activities.

Sector B Main structural support framing



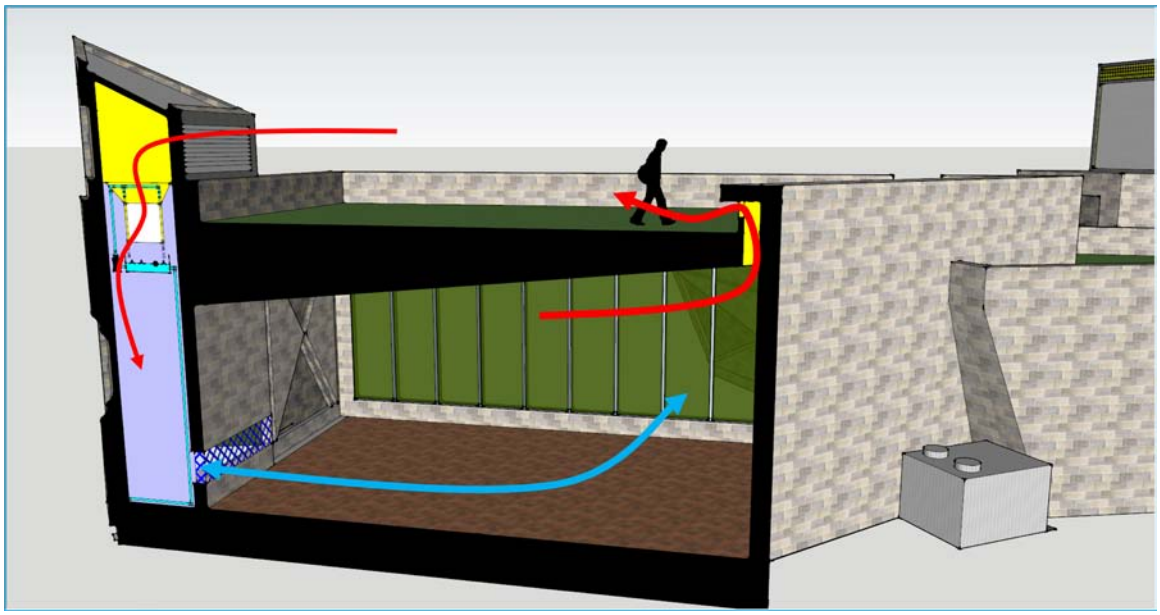
Source: By Author





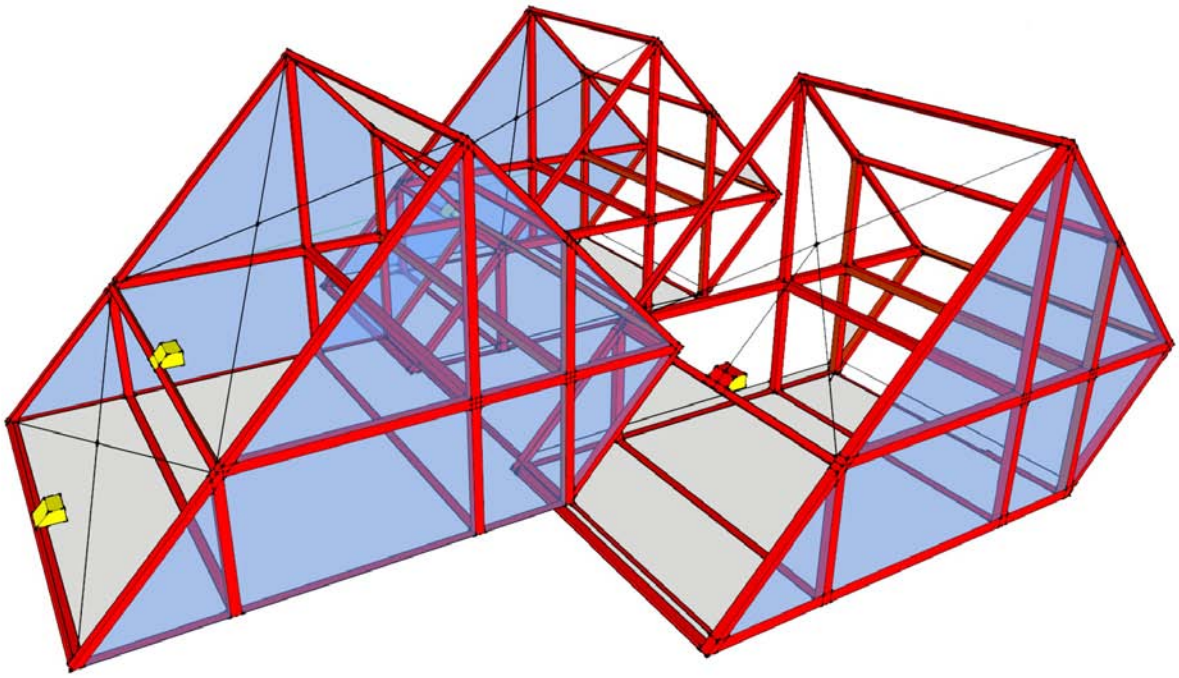
Source: By Author

The following schematic diagrams shows how the wind towers is activated when there is no outdoor pollutants to provide passive cooling into the learning center using a wet damper into the wind towers to help cool down more the outdoor air.

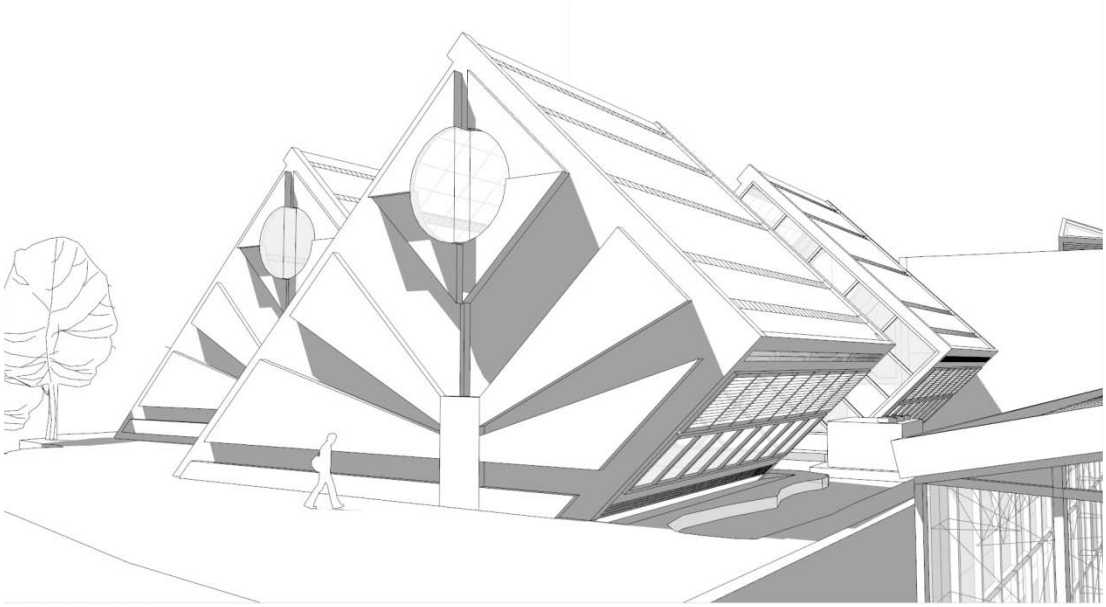


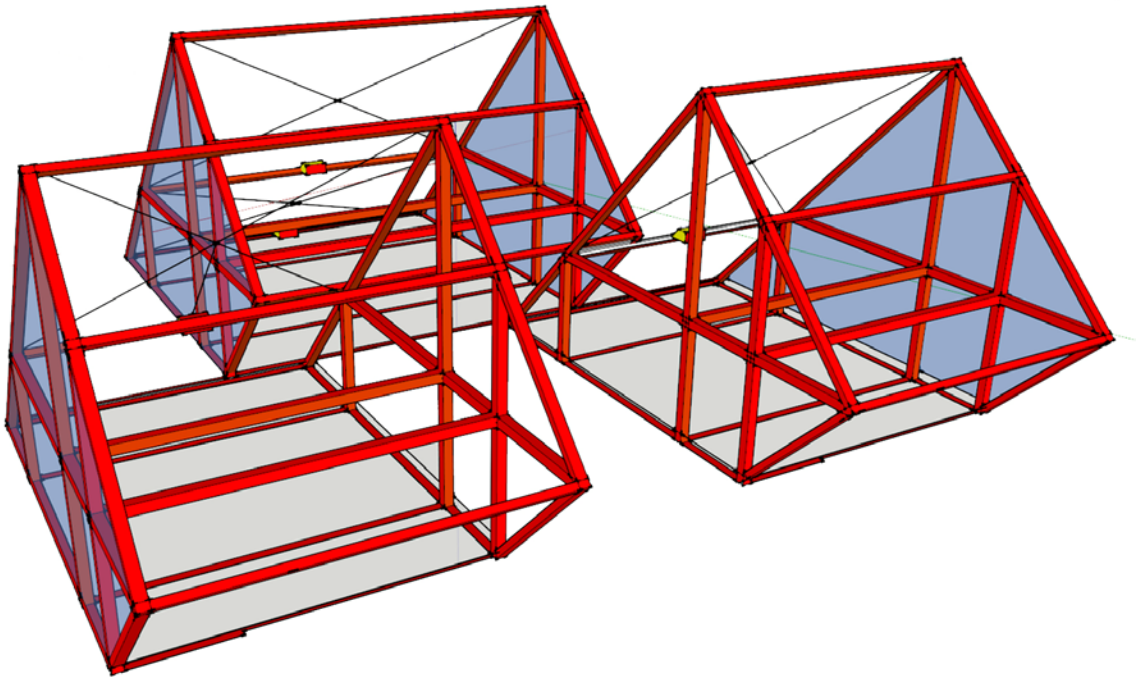
Source: By Author

The next two schematic diagrams shows how Sector C (Office buildings) are put together by simple steel column and beam system as well as the use of cantilever floor to have a visual exterior effect that these buildings are falling down. The South wall is reinforced with smart system device damper and crossover tension cables to stabilize the main structure in case of seismic activities.

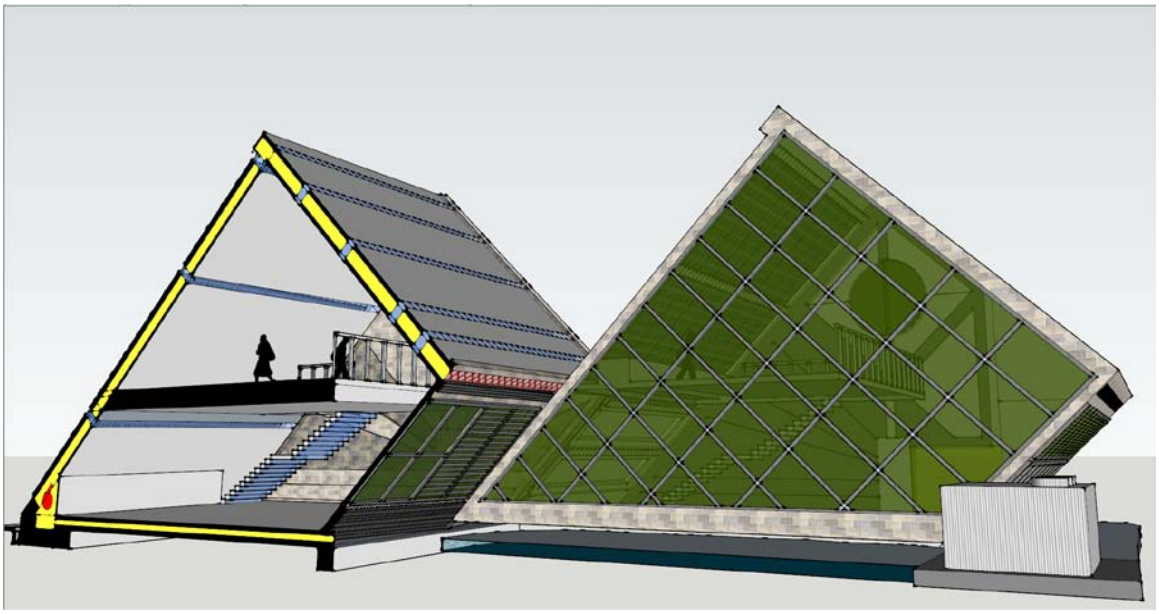


Source: By Author



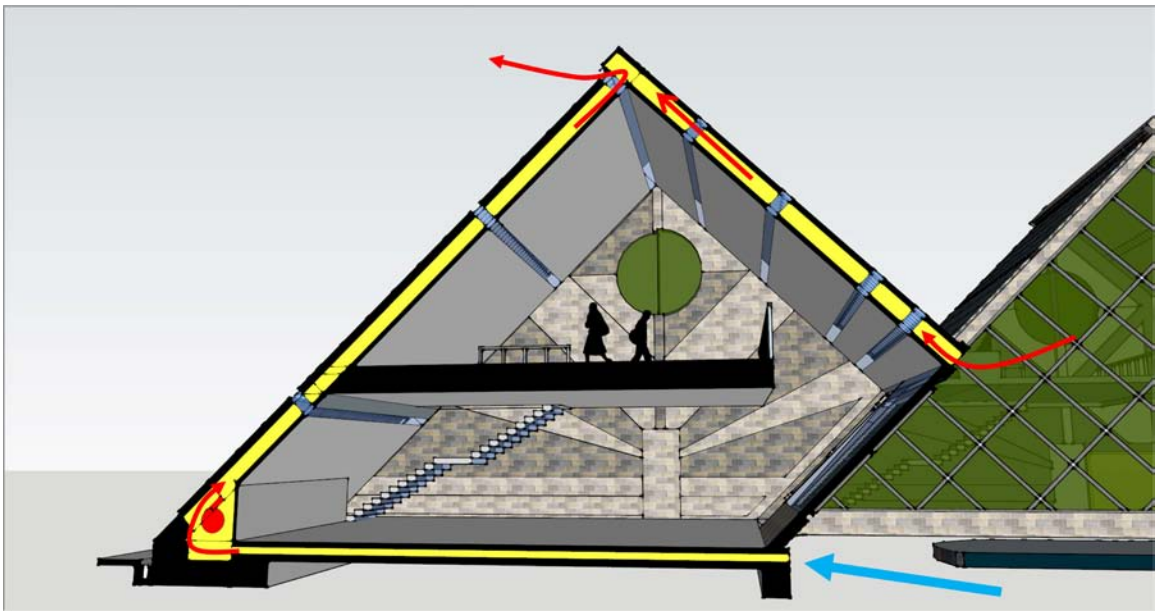


Source: By Author



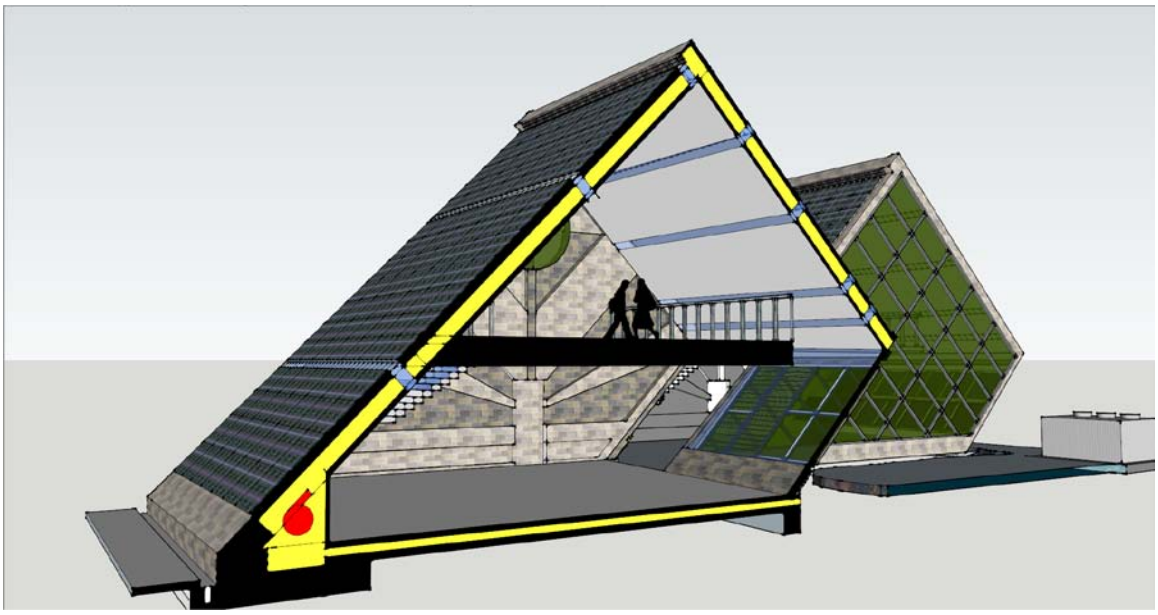
Source: By Author

The next schematic diagram in Sector C (Office buildings) shows how passive heat control helps air out the floor, wall and roof. If you look carefully on the left corner I implemented a fan that will turn on when it needs to especially when winds drop or change in direction as the Kona winds that does not last much. The fan will run also when it senses that there is a lot of humidity, intensive heats, and change of wind patterns.



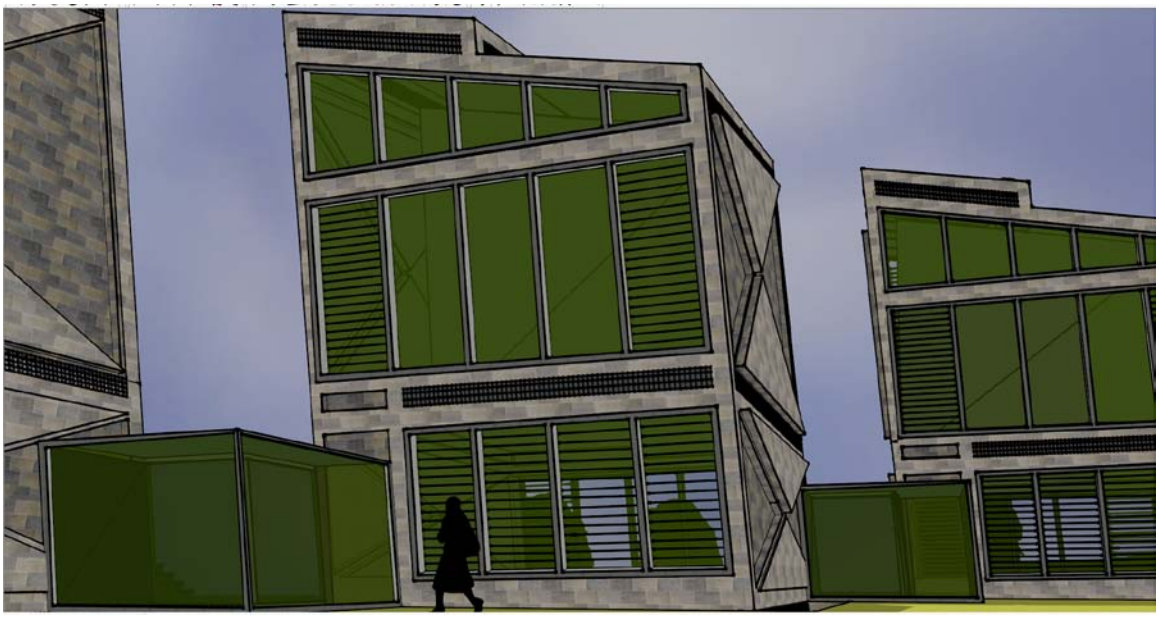
Source: By Author

The south wall will face the suns path mainly to have a good angle for the HPPV throughout the day. The High Performance Photovoltaic panels (HPPV) will be set just above the south wall in these buildings for two purposes: one is to help air out the PV panels, two is that PV help reduce the gain of heat into the building because it reflects back into the atmosphere the extra heat carry by the sunrays.

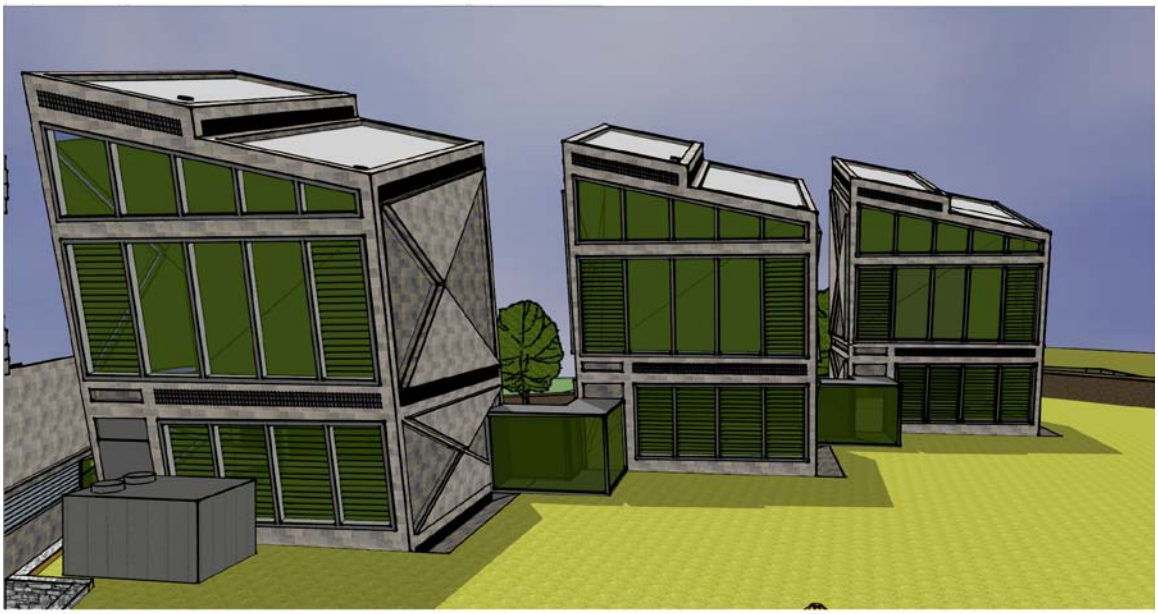


Source: By Author

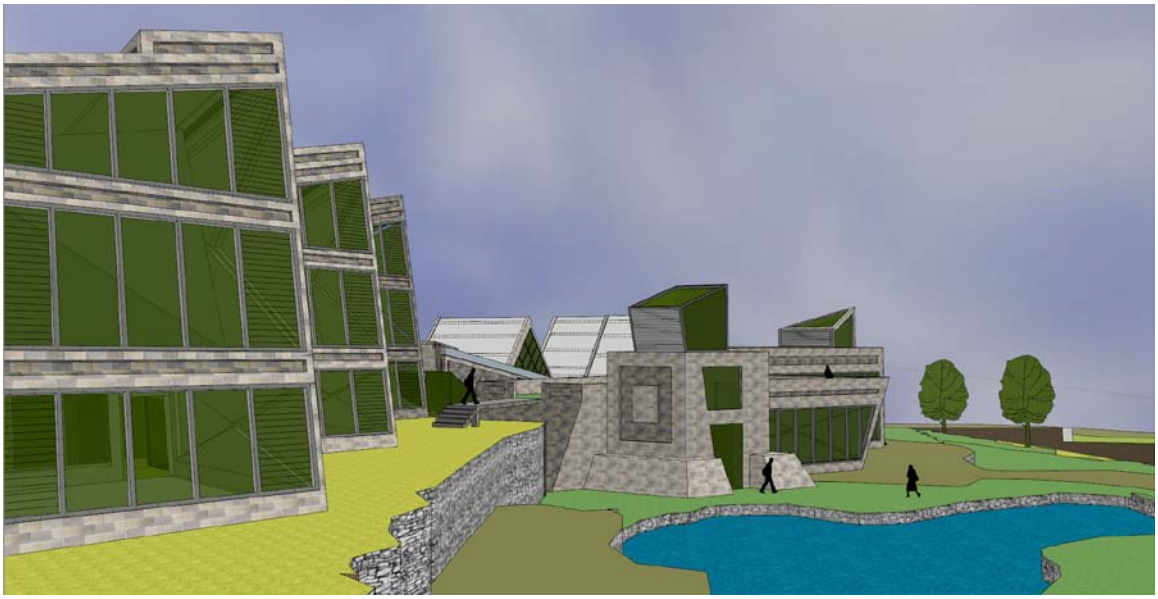
The followings are schematic renderings to show some exterior textures, visual expressions and building orientations.



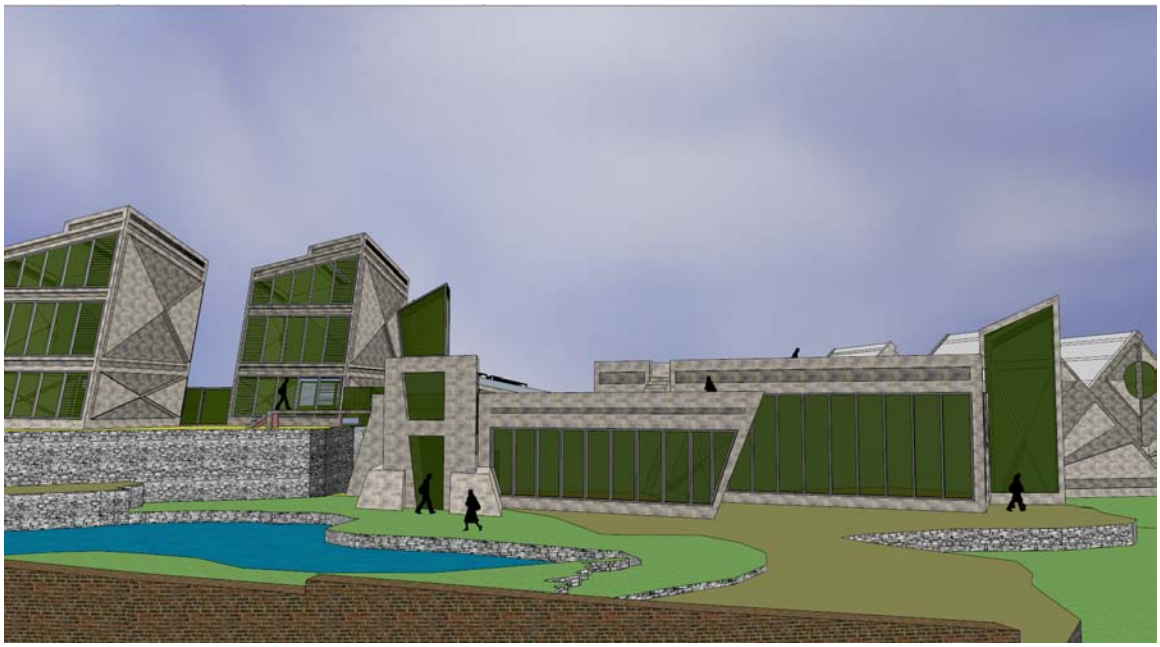
Sector A or Cabins west view
Source: By Author



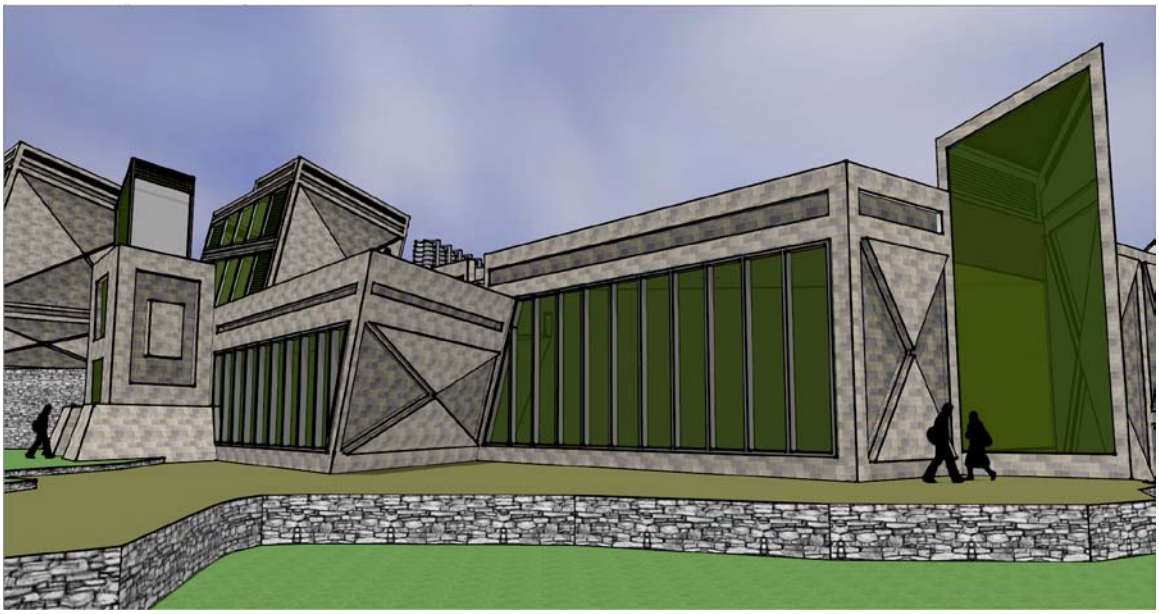
Sector A or Cabins
Source: By Author



Sector A and B Southeast view
Source: By Author



Sector A and B East view
Source: By Author

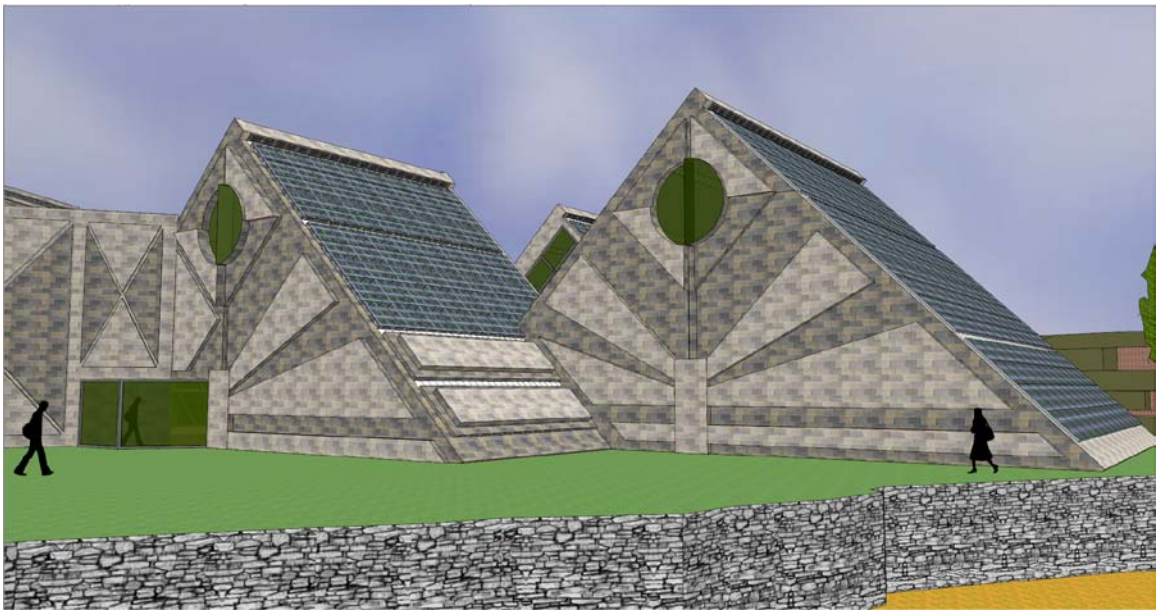


Sector B Northeast view
Source: By Author

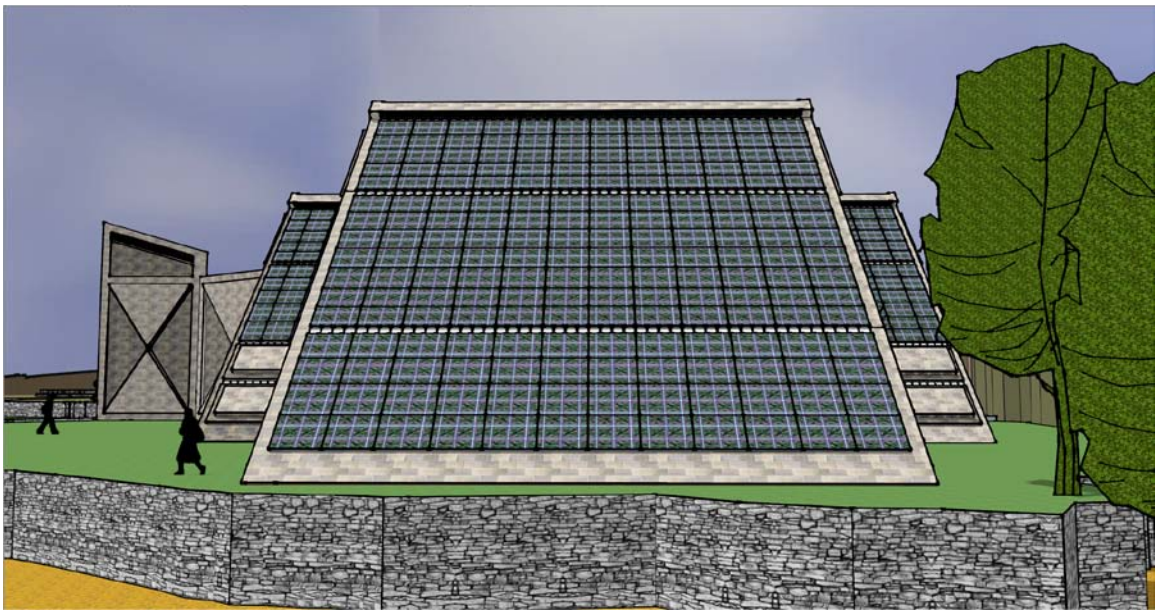
Sector A and B North view
Source: By Author

Sector B Rooftop Southeast view
Source: By Author

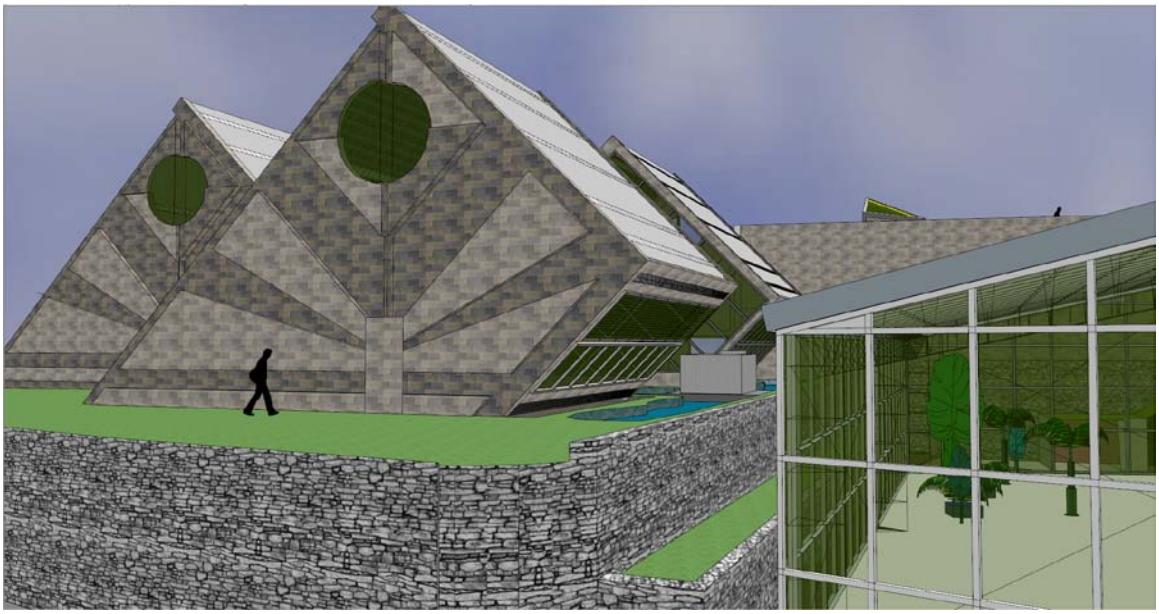
Sector B Ground level North view
Source: By Author



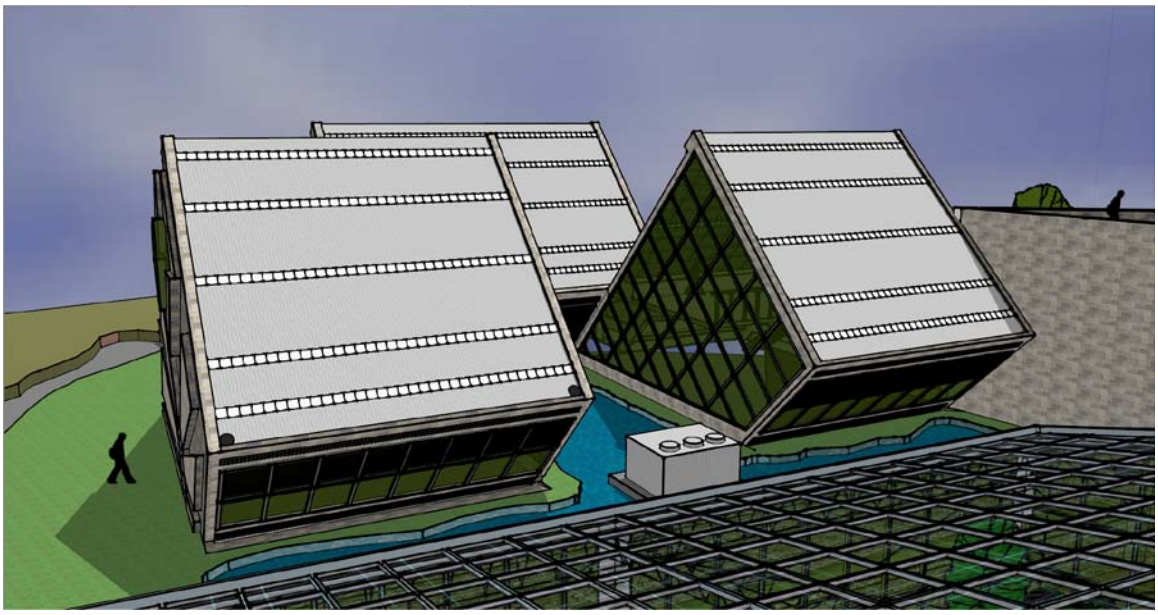
Sector C Ground level East view
Source: By Author



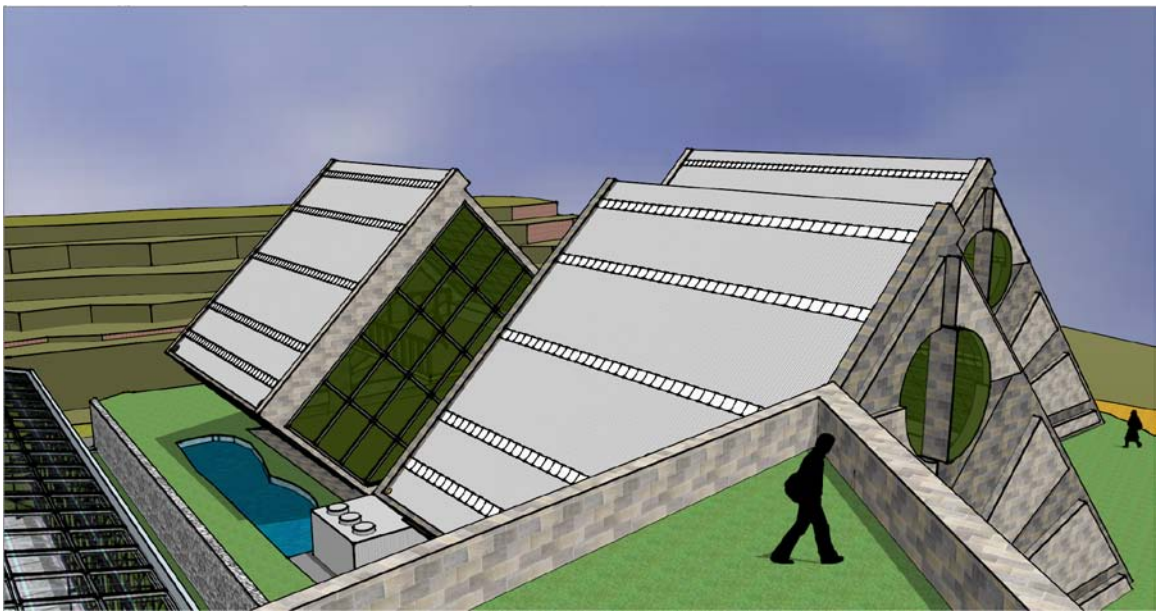
Sector C Ground level North view
Source: By Author



Sector C Ground level Southwest view
Source: By Author



Sector C South bird view
Source: By Author



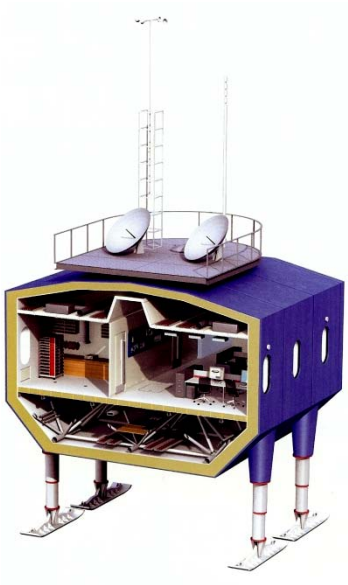
Sector C from rooftop on sector B Southeast view
Source: By Author

18.3 Aesthetic approach

The Research prototype at the Kau's desert by Kilauea volcano sits right in the middle of a desert surrounded by nature alone. But let's ask ourselves a question how big structures are perceived if they are the only foreign object in the area?

Halley VI Antarctic Research Station

Source: http://www.hbarchitects.co.uk/pdf/Halley%20VI%20detail%20description.pdf



Halley VI Antarctica Base, Project 2005 by Hugh Broughton Architects and Faber Maunsell Ltd a winner competition in 2005. Their design is based on a series of separate buildings modules, founded on skis to allow easy relocation and rearrangement of the facility if user requirements change. The largest module is centrally located and contains operations, communications, eating and recreation and double height. It has low environmental impact. According to Robert Kronenburg a bio-digester will be used to create clean waste water and dry solids

Source: http://www.hbarchitects.co.uk/pdf/Halley%20VI%20detail%20description.pdf

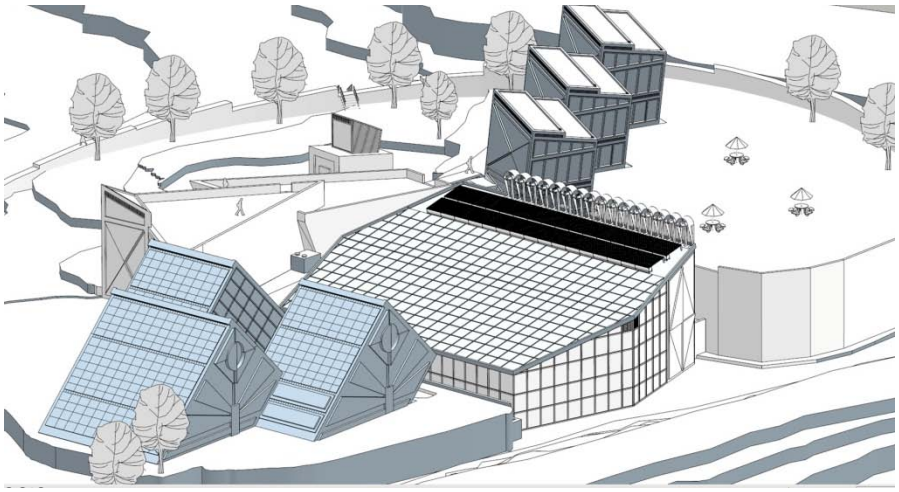
18.4 How are these permanent structures observed?

Haleakala Observatory Maui, Hawaii the only foreign permanent construction at Haleakala Volcano, Maui, HI

Source: Haleakala observatory online

Mauna Loa observatory The big Island of Hawaii, Hilo

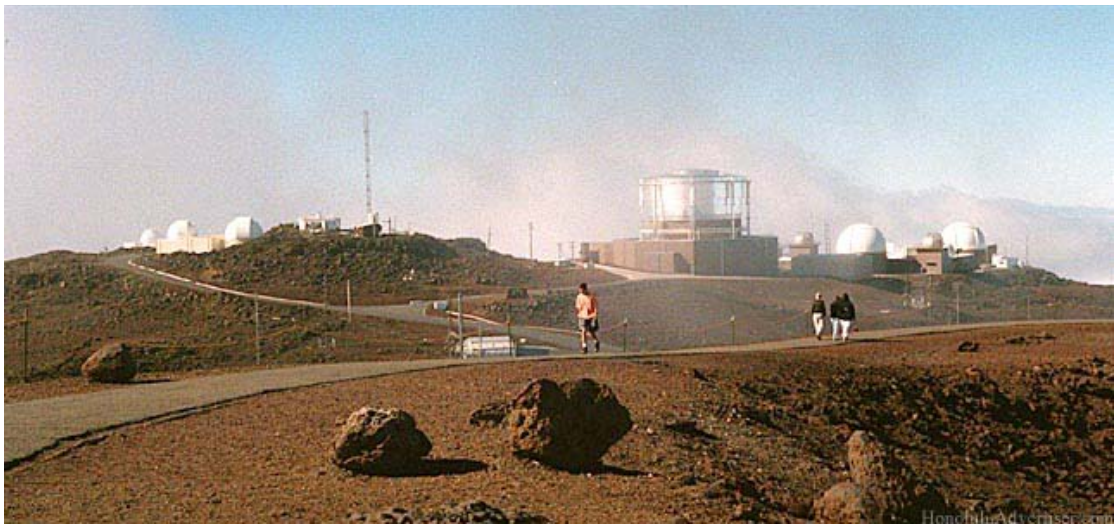
Source: web.hao.ucar.edu



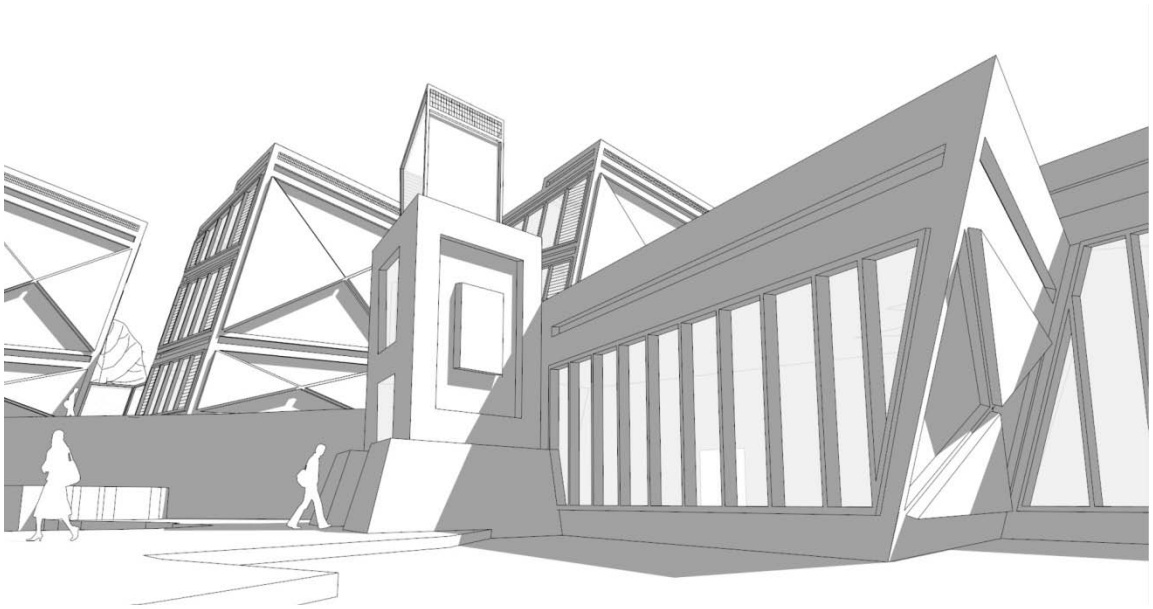
Desert Kau's Research Prototype. The big island of Hawaii, Kilauea Volcano, Hawaii

Source: By Author

Do they create an environmental impact because of their permanent structures?



Source: Haleakala observatory online



Source: By Author

19. CONCLUTION

Smart environments take a lot of planning especially in early stages of design. It is hard to visualize smart environment especially when we need to put it into graphics. It is something that you actually perceive when you enter a building and sometimes it can't be perceive at all because the intelligence behind the scenes runs smoothly which is invisible to the eye, all you can perceive is comfort, excitement, and a sense of peace at times.

Social needs had change radically with the rise of new technologies. The twenty one century technologies focuses primarily in providing comfort, innovation, and much more by been responsible towards our environment in which we live in especially when climate change takes effect. Smart solutions in architecture are one of the answers to this rising problems of global warming.

This paper is dedicated to new emerging technologies in architecture one cannot say how smart a building can be by dumping a bunch of smart systems into a building but to look at endless possibilities with the integration of disciplines working side by side in which we unified our goals to introduce new approaches. These new approaches creates new technologies, new technologies creates endless opportunities of employment and solutions to radical problems.

This project thesis approach is a passive/active solution to such extreme conditions at the Kau desert near the Kilauea caldera. It is all about seeking solutions for the ultimate performance in architecture to introduce new technologies, intelligent building systems and to build what we call now Smart buildings with smart environments.

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