Architectural Symbiosis

Tim Kimball

University of South Florida

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Architectural Symbiosis

by

Tim Kimball

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Architecture
School of Architecture and Community Design
College of The Arts
University of South Florida

Major Professor:  Steve Cooke, M. Arch.
Ryan Minney, M. Arch.
Sean Williams, M. Arch.

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I want to dedicate this to my mother who pushed me to go back to school after I became paralyzed in 1991. I would also like to thank Karen Wilkinson of Vocational Rehabilitation. Also, I would like to thank Steve Cooke, Trent Greene, Jodi Solito, Mary Hayward and Dan Powers. Without their support and encouragement I don’t think any of this would have been possible.
I would like to acknowledge Hillsborough Area Regional Transit, A.K.A. Hartline. Because of your ongoing efforts to comply with the ADA, I was able to get to campus when I had no other transportation.
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The world is facing two fundamental problems. The first problem is a rapidly increasing demand for energy. The second problem is increasing greenhouse gas emissions that are directly resulting from our energy consumption. The primary greenhouse gas in question here is carbon dioxide produced from the burning of fossil fuels. It has been demonstrated through scientific articles and studies that carbon dioxide is directly linked to rising atmospheric temperatures. Buildings represent a significant percentage of this CO2 production.

Many architectural theses and treatises have been written advocating architecture that is more energy efficient and which uses sustainable materials and processes as necessary steps towards solving the global warming crisis.

With the threat of global warming looming, everyday architecture must go through a transformation. Sustainable buildings should not be limited to rarefied architectural gems. Instead, sustainable architecture should become a commonplace condition in the built environment. In order to achieve this, we need sustainable architecture that not only addresses the environmental issues but also pays for itself and pays the building owner for taking on such a task.

To answer this need, I intend to design a mixed-use multifamily building that exists in the environment as a living system. As all living things, it must function utilizing the resources available in that environment. It must have a practical and economically viable onsite energy production and storage methodology that is
environmentally benign and takes advantage of freely available natural resources. It must react to changes in the environment to better manage its resources and it must be able to store resources for later use. Lastly, it should foster sustainable living practices of its occupants.

By building in this way, architecture can take on a new role as symbiatus rather than parasite in the environment, producing its own pollution free energy and clean water. Each building acts as a life support system for its inhabitants but is also part of a macroscale biosphere. If resources are managed carefully, an exportable energy surplus can be generated representing an economic benefit to the owner. This provides an economic directive to adopt sustainable practices.
[A designer is] an emerging synthesis of artist, inventor, mechanic, objective economist and evolutionary strategist.

- Buckminster Fuller
It is absolutely imperative we understand that human beings do not exist in a vacuum. We are, like every other living organism on this planet, completely dependent on the quality of the environment that we inhabit. It is incumbent upon us to respect and maintain the cradle of humanity since we now wield considerable power to alter the landscape. We can wield that power recklessly, without regard to our neighbors and without any regard to future generations, or we can wield that power responsibly and effectively while still providing for our immediate needs. Some believe that there is a choice that must be made between human needs and protecting the environment. This is a false choice. We really can do both. Architects are routinely asked to reconcile disparate and conflicting directives. The solutions to these conflicting directives are often surprising and yield unexpected benefits.

The evidence is very clear that human activity is having an effect on the overall health of our ecosystem.

![Carbon Emissions from Fossil Fuel Burning by Sector, 2002](img)

*Figure 01 - Kyoto Carbon percentages*

*Source: John Browne, “Beyond Kyoto,” Foreign Affairs, 1 July 2004.*
400 Thousand Years of Atmospheric Carbon Dioxide Concentration and Temperature Change

Figure 02 - CO2 & Temperature Chart


Graphic: Michael Ernst, The Woods Hole Research Center
Since buildings are responsible for at least 25% of this problem (fig. 1), architects are in a unique position to offer some possible solutions. We could try to build new architecture that does less damage to the environment. We could try to upgrade all of the existing buildings to be more sustainable. But, that pays modest dividends and upgrading everything is nearly impossible. (Not to mention, expensive.) So, what can be done?

What if people started building structures that can offset some of the damage that’s currently being done to the natural system? What if architecture could take on a new role as symbiant rather than parasite in the environment, producing its own pollution free energy and clean water, wherein each building acts as a life support system for its inhabitants but is also part of a macro scale biosphere? And furthermore, what if you had a building type that came with a viable business model designed to sustain operations indefinitely with the potential to reap some profit as well?

It is important to recognize that every building has an economic life. Our clients usually have economic motivations for the buildings that they ask us to design on their behalf. Architects must consider these economic realities and have an understanding of the economic environment during the earliest design phases. Only then can you begin to deliver solutions for your client that are holistically designed and economically viable.

My approach is to examine the underlying forces that drive our current unsustainable behaviors,
which are primarily economic, and ask if it might be possible to use those same forces to achieve a new set of objectives. Students of Aiki Jujutsu, a traditional Japanese martial art, understand that when dealing with overwhelming force, it’s best to avoid direct opposition. The basic tenet of Aiki Jujutsu is to never oppose force with force but to redirect and utilize the power of the attack to overthrow the enemy with their own strength.

With this in mind, the designer has a strategy for promoting sustainable architecture and living practices. The designer can harness economic forces to further the cause of sustainability. But how do we do this? We have to exploit the resources available to us locally and produce a marketable product. We must design our architecture to support and enhance that effort.

In Florida we are fortunate to have a very potent natural resource available to us. That resource is solar energy. Traditionally, Floridians expend substantial amounts of energy attempting to combat the effects of the intense solar radiation that we experience here. But, we could be taking advantage of this resource instead. Each new building that is built could add to its program the function of micro utility, meaning that they could have enough solar energy output to provide some carbon free power to its neighbors and receive an economic benefit for doing so. If we do this, we can begin the shift from a carbon producing paradigm to the new carbon neutral paradigm. (fig. 3)
## Paradigm shift

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I have always believed that if you truly care about the environment then you should live in the city. Urban spaces make the maximum use of the land that we occupy as a species. This allows more of the environment to remain wild and support animal and plant life, which in turn supports human life. The density of the urban environment allows for minimized travel distances, which translates into lower energy usage as people conduct their daily lives.

The building typology that typifies urban development is the mixed-use building. The mixed-use building typology, with its inherent efficiencies, has the added benefit of contributing to the critical mass necessary to create urban communities that are vibrant, exciting and draw people into the urban core. In light of these facts, and in attempt to live up to the ideals I have outlined, I am proposing a mixed-use residential structure with a few modifications. Instead of the traditional components of residential space, retail and/or office space, there will be a new mix of uses:

- Cultivation
- Habitation
- Micro-Utility

This new mixed-use typology can go into existing suburban neighborhoods surrounding an urban center on an infill basis. Over time, these structures can begin
to create a cellular network of independent nodes producing carbon-free energy and providing some of that energy to the neighboring ‘legacy’ buildings while producing various marketable agricultural products that are grown on site as well.

Problem Statement

The design challenge that I have set forth in this thesis project is to develop a residential mixed-use building that lives off of the land. The interplay and overlapping of different building functions will be explored as they influence and mold the architectural form. The local climate presents special problems and opportunities in relation to the creation of spaces that allow for maximum personal comfort while using minimal resources. Water use and treatment will also present unique challenges.

Figure 04 - Cellular Diagram
Project Goals

- Evaluate and compare alternative energy sources and develop comprehensive strategies for maximizing cultivation of those energy sources
- Identify and implement appropriate passive design strategies specific to the site and local climate.
- Support and encourage sustainable living practices
- Create spaces that foster a sense of community thereby encouraging urban life
- Environmental remediation, to leave the air and water cleaner than when it entered the site.
- Provide opportunities for urban agriculture and aquaculture
“Design is a learning experience. So my agenda is to figure out what I want to learn next.”

- Ayse Birsel, Industrial Designer and President, Olive1:1
Case Study 1: Earthship Biotecture

This architectural movement was started by architect Michael Reynolds. The primary aim of the Earthship design is to be a self-sustaining capsule like a sailing vessel. The Earthship operates utilizing freely available natural resources that exist in the environment. Built almost entirely out of recycled materials, including discarded tires, bottles, cans and other reclaimed building materials, the Earthship conserves natural resources by extending the useful life of materials that would otherwise be discarded. The tires are used as forms for the rammed earth structure which is a hallmark of the Earthship movement. The massive nature of the rammed earth walls serves as a thermal mass that helps

Figure 05 - Section, rainwater storage

Figure 06 - Section, passive design features
to regulate internal temperatures within the structure.

Water use in an Earthship is highly efficient. Earthships harvest rainwater and store it on site. Potable water is never used for things like flushing toilets or irrigation. Instead, a sophisticated system of graywater which employs constructed wetlands ensures that water is used no less than four times before it exits the structure.

The constructed wetlands serve a dual purpose. They filter gray water, removing organic compounds and particulate matter before use in non-potable applications and they provide a planting area that can be utilized for the cultivation of food for use by the occupants.
Lessons Learned

The Earthship design is successful in the climate that it was originally designed for, which was a dry desert climate. However, thermal massing is not appropriate for a humid subtropical climate because unlike the desert climate, daytime and nighttime temperatures do not vary widely and because the ever-present humidity serves as an insulator which prevents proper thermal transfer. The geothermal constant could be utilized to aid in temperature regulation through other techniques such as ground source heat pumps in place of traditional HVAC.

- Rainwater can be harvested and utilized more efficiently than traditional plumbing systems and use patterns allow.
- By implementing passive strategies that are appropriate for the climate, a significant reduction in energy usage can be realized.
- Alternative energy sources, such as wind and solar, become feasible when energy demands are reduced through passive strategies.
- An environmental benefit can be realized by on-site cultivation of some percentage of food resources required by the buildings occupants.
Figure 09 - Interior view, biocell

Figure 10 - Exterior perspective, Earthship

Figure 11 - Section, biocell

Figure 12 - Rainwater catchment, Earthship
Case Study 2: Mountain Dwellings

- Architects: Bjarke Ingels Group
- Location: Drestad, DK
- Program: Multi-family residential
- Completion year: 2008
- Constructed Area: 33,000 m²

Mountain Dwellings consists of two thirds parking and one third living space. Uses are layered with living space supported by the parking. The structure of the parking is arranged to create an artificial hill. The artificial hill provides opportunities for the living space to be exposed to sunlight, views and ventilation. Multi-tiered rooftop green space provides occupants
with some access to nature in an urban setting.

Unfortunately, no attempt was made to take advantage of opportunities for alternative energy cultivation.

Lessons Learned

- Combining uses and layering them in a creative fashion can create opportunities for green space in an urban environment.
- Utilitarian elements can be screened with more aesthetically pleasing components creating a more harmonious design.
- Opportunities for community can be realized through creative spatial arrangements.

*Figure 15 - Diagram, Massing Evolution*
Figure 16 - Arial perspective

Figure 17 - Perspective from terrace

Figure 18 - Section

Figure 19 - Perspective showing terraces
Case Study 3: Big Dig House

- Architects: Single Speed Design
- Location: Lexington, MA, USA
- Program: Private House
- Completion year: 2008
- Constructed Area: 353 m²

The Big Dig House is an artfully designed single-family residence constructed from salvaged components left over from Boston’s Big Dig project. The steel and concrete components are designed with much higher carrying capacity than standard residential construction. This additional carrying capacity allows for substantial rooftop gardens. Because this building was constructed
Figure 22 - Interior Perspective, Big Dig House

Figure 23 - Interior Perspective, Big Dig House

Figure 24 - Raw Materials
using standardized industrial components, the architects planned the building as if it were a pre-fab system.

Using repurposed steel structural members and roadway panels, the structural framing was completed in only 12 hours instead of an estimated two weeks for standard framing. This undoubtably represented a substantial savings in construction costs.

The idea of using standardized ‘erector set’ components leads to the possibility of designing structures with what the architects call on their website “Strategic front end planning” wherein the components of a structure are designed for the eventual possibility that it may be dismantled and those elements reused in another construction project. This conserves resources along with the embodied energy within the materials.
Lessons Learned

- Standardized components can be arranged to create aesthetically pleasing spaces.
- Modular, prefabricated components can save time and money in construction.
- Reused components save resources and energy.
- Structures can be designed to be easily dismantled or reconfigured.
Figure 28 - Section, Big Dig House
“All architecture is shelter, all great architecture is the design of space that contains, cuddles, exalts, or stimulates the persons in that space.”

- Philip Johnson
This project will be done in Tampa, Florida because it has extensive suburban areas surrounding its urban core that could benefit from an intervention such as I am proposing. Also, Tampa’s climate offers significant amounts of rain water and sunlight which can be harvested. Tampa has an extended growing season which will also be an advantage for this project as well.

For many projects, site specific selection can be of paramount importance. It can make the difference between a project that is merely “good” and a project that is spectacular. But in this particular case, site selection isn’t as critical because this project will be designed as an example infill construction within an existing neighborhood context. I want this to be something that can be repeated somewhere else, so my selection criteria will be driven by principles of sustainability and by suitability for the particular building type, which in this case is residential.

Primary characteristics under consideration:

**Proximity to the urban core** - As stated before, it is preferable to have a site that is close to the downtown area. This minimizes travel distances for the occupants when accessing workplaces or the amenities that the city has to offer. Public transportation becomes a more viable option when travel distances are short. All of these things translate into lower energy use as people conduct their daily lives.
**Access to sunlight** - Unblocked southern exposure is required because solar radiation will be collected as a primary energy source. There will also be some light agriculture being done on site, which will require sunlight as well.

**Non-virgin land** - Urban sprawl is responsible for a reduction in natural habitat for many plant and animal species that we rely upon to maintain a healthy ecosystem. Therefore, it is preferable to “recycle” land that has already been transformed for human use.

**General Site Information**

- **Tampa, Florida**
- **Latitude**: +27.94722 (27°56’49.992”N)
- **Longitude**: -82.45861 (82°27’30.996”W)
- **Time zone**: UTC -5 hours
- **Country**: United States
- **Continent**: Americas
- **Sub-region**: Northern America
- **Altitude**: ~10 ft

Topography is generally flat. [1]
Figure 29 - Map of U.S. / Florida
Local Climate

The Tampa Bay area has a humid subtropical climate, with warm temperatures and the threat of thunderstorms during the summer and the winter frost about every 2-3 years. Tampa itself experiences a summer wet season, where nearly two-thirds of the annual precipitation falls in the months of June through September. The area is listed by the United States Department of Agriculture (USDA) as being in hardiness zone 10, which is about the northern limit of where coconut palms and royal palms can be grown. Highs usually range between 65 and 95 °F (18 and 35 °C) year round. Tampa's official high has never reached 100
°F (38 °C) – the all-time record high temperature is 99 °F (37 °C), recorded on June 5, 1985.[2]

In the winter, average temperatures range from the low to mid 70s during the day to the low to mid 50s at night. However, sustained colder air from Canada does push into the area on several occasions every winter, dropping the highs and lows to 15 degrees below the average or even colder. The temperature falls below freezing an average of 2 to 3 times per year, though this does not occur every season. [4] Since the Tampa area is home to a diverse range of freeze-sensitive agriculture and aquaculture, major freezes, although very infrequent, are a major concern. The lowest temperature ever recorded in Tampa was 18 °F (−8 °C) on December 13, 1962. [2]
Because of frequent summer thunderstorms, Tampa has a pronounced wet season, receiving an average of about 28 inches (710 mm) of rain from June and September but only about 18 inches (460 mm) during the remaining eight months of the year. The historical averages during the late summer, especially September, are augmented by tropical cyclones, which can easily deposit many inches of rain in one day. Outside of the summer rainy season, most of the area's precipitation is delivered by the occasional passage of a weather front. [2]

The previous section labeled ‘Local Climate’ contains excerpts from Wikipedia. (http://en.wikipedia.org/wiki/Tampa,_Florida#Climate) Individual internal references are listed in the ‘References’ section.
Figure 36 - Average Temperature Range

Figure 37 - Average wind direction and speed

Figure 38 - Local Solar Angles

Figure 39 - A, Winter Solstice  B, Equinox  C, Summer Solstice
Site Selection

The site that I have chosen lies between 7th Avenue and Oak Avenue on Morgan Street. This site is in an old Tampa neighborhood called Tampa Heights. 7th Avenue is one of old Tampa's characteristic brick lined streets and it leads straight into the heart of Ybor city which lies about 10 blocks to the east. Tampa's central business District lies to the south about 10 blocks. In much of the neighborhood, mature oak trees line the streets and provide much-needed shade which creates a very walkable neighborhood. There are two major developments planned nearby. (fig. 37) Encore lies to the southeast of our site, which is
a redevelopment of the Central Park neighborhood. Riverfront lies to the west of the site. Since Tampa’s central business district is surrounded by water on the eastern, western and southern edges, future growth will tend to be towards the north. Ybor city’s growth has been primarily to the south but space is limited in that direction so future growth will probably be to the west along Palm and 7th Avenue. The selection of this particular site is designed to take advantage of the eventual merging of Tampa’s central business district and Ybor city as well as Tampa Heights eventual redevelopment. The approximate dimensions of the site are 222’ x 295’ with an area of approximately 65,490 s.f. and consists of 6 RS-50 lots, each approximately 50’ x 100’.

Selling Points:

- Close to transit
- Close to CBD / Ybor City
- Easy access to interstate
- Non-Virgin land

*Figure 42 - Site lines showing lots*
Design—in terms of thinking and process—is the champion of the future, envisaging and interpreting insights and ideas through strategy, ideas, products, spaces and communications.

- Peter Haythornthwaite, Principal, creativelab
The focus of my research is to identify and evaluate various technologies that may be used to achieve the aforementioned goals of:

- Generating an excess of carbon-free power
- Zero discharge sewage
- Passive climate control (where possible)
- On-site food cultivation

In nature, nothing goes to waste. The refuse of one organism becomes the fuel for another organism. A sort of Yin-Yang relationship is often formed wherein one organism cannot exist without the other. We call this symbiosis. As mentioned in the previous section, we want to look for possibilities for achieving symbiosis between the systems that we will be using, thereby enhancing function and creating efficiencies within the overall system. We also want to evaluate each technology in terms of high tech or low-tech solutions with a bias towards low-tech solutions because they tend to be more simply constructed and easier to maintain. Flexibility will be another consideration. Throughout a buildings lifecycle, it may be asked to serve a variety of functions. New technologies may arise as well. So, it is preferable to provide options and opportunities for people to take advantage of new technologies and adapting to new uses without locking us in to any particular function. With this in mind, I will be seeking to put together a suite of technologies that is best suited to this climate and building typology, while being upgradable wherever possible.
Technologies under Consideration:

- Photovoltaics
- Concentrated Solar Thermal
- Algae Derived Biodiesel
- Small-Scale Aquaculture
- Solid-State Lighting
- Ground source heat pump
- Hydrogen Electrolysis

Photovoltaics

There are now two classes of photovoltaics: traditional silicon-based solar cells and a new class called dye sensitized cells. Silicon-based solar panels have been around for some time and are more or less a known entity to most architects. A typical solar cell converts sunlight into electricity at about 14%, which is not very high. They are prone to impact damage and come with a significant upfront costs. However, once installed, they require very little maintenance (aside from cleaning) and there are almost no associated operating costs. Solar panel installations can be relatively compact and in some cases are even integrated into building components such as roofing tiles or wall panels.

Dye sensitized solar cells (DSC) are designed to mimic photosynthesis. A description of the technology from Dyesol: “In basic realisation a dye solar cell comprises a layer of nano-particulate titania (Titanium Dioxide) formed on a transparent electrically conducting substrate and photosensitised by a monolayer of dye. An electrolyte, based on an Iodide-Tri-iodide redox system is placed between the layer of photosensitised...
titania and a second electrically conducting catalytic substrate." [16] The DSC has several advantages: The dyes and electrolytes can be deposited on nearly any substrate in a printing process that dramatically increases the speed of manufacturing as well as dropping the price to produce them. Unlike traditional silicon-based solar technology, the DSC is flexible and can be printed on cloth, plastic, glass etc. The savings in cost and flexibility in application opens up a whole new set of possibilities for the designer, with the potential to have the entire building envelope capable of producing carbon free power. However, while this technology shows enormous potential for the future, I decided against using it in this particular project because I was unable to obtain data regarding the
Concentrated Solar

Concentrated solar power uses mirrors or lenses to focus sunlight from a large area to a relatively small target area. Typically some type of solar tracking device is employed to keep sunlight focused on the target area. There are two types of concentrated solar power: Concentrated photovoltaic (CPV) and concentrated solar thermal (CST). The CPV concept is basically a way of supercharging the electrical output of traditional photovoltaic cells by concentrating more sunlight on the cells. Typical concentrations are between 2 and 100 suns with a theoretical efficiency near 50%.[18] CST
concentrates sunlight to create high temperatures. This thermal energy can be used for a variety of functions such as creating steam for power generation, process heat, domestic hot water, or space heating. [19] While this technology has relatively low construction costs, they are moderately complex machines that require maintenance and are prone to mechanical failure from time to time. Another downside to solar concentrating technology is that equipment has a relatively high profile and will be affected by high winds. This technology would work well in a parking lot or on top of a large flat building such as a mall or warehouse, but it is inappropriate for this project because of the previously mentioned issues of susceptibility to high winds and maintenance and operational costs.

Figure 48 - Parabolic Solar Concentrator
Algae Derived Biodiesel

Algae grown in bioreactors can grow at exponential rates while consuming carbon dioxide and organic material suspended in the water. The algae that is produced can be pressed produce oil which can be converted to biodiesel. [20] Algae cultivation can be paired with aquaculture or be used to remove organic solids in wastewater treatment system. This type of pairing achieves our desired goal of symbiosis. However, these systems can be somewhat complex to operate and are prone to malfunction or contamination making them an appropriate for a residential application.

Figure 49 - Algae Photo-bioreactor diagram

Figure 50 - Biofence Algae Photo-bioreactor
Hydrogen Electrolysis

Any excess electrical power that is produced can be used to produce hydrogen and oxygen by passing a current through water. Hydrogen gas can be used in any application where natural gas could be used such as cooking, production of domestic hot water, or space heating. Hydrogen can also be used in a fuel cell to produce electricity when other sources are not available or it could be used as a fuel for vehicular transportation. Equipment capable of producing large amounts of hydrogen can be expensive to install and maintain but given the versatility of hydrogen as a potential storage medium and fuel that cost could be justified, possibly as a communal asset.

*Figure 51 - Electrolysis Diagram*
Small-Scale Aquaculture

There is a growing movement of people who have discovered that fish can be raised in relatively small spaces with rather low-tech equipment. In some cases, the material used to create such a system consists of little more than a few plastic 55 gallon drums, a little bit of plumbing, and some air or water pumps. When paired with hydroponic agriculture, a symbiotic relationship can be achieved that enhances the function of both systems.[12] These systems can realize a respectable return on investment. According to Jonathan Woods: “For each dollar that you spend in food, maintenance and utilities, you can expect to harvest $1.75 to $2.00 worth of fish. If you also are

Figure 52 - Diagram, Aquaculture cell with biofilter

Figure 53 - Diagram, Hydroponic Planting Bed
Figure 54 - Photo, Aquaculture Cell 1

Figure 56 - Hydroponic growing beds as biofilter

Figure 55 - Photo, Aquaculture in greenhouse

Figure 57 - Photo, Aquaculture Cell 2
growing vegetables in the aquaponic system, then you will harvest $1.25 worth of vegetables as well. The total return per dollar is close to three dollars for the aquaponic system and two dollars for the simple recirculating system.” [21] Florida’s climate is perfectly suited to such an endeavor with its warm temperatures and extended growing season.

Solid-State Lighting

Solid-state lighting, also known as LED lighting, offers several advantages over traditional incandescent and compact fluorescent lighting. This form of lighting can use as little as 10% of the energy required to power a comparable incandescent bulb while producing the

Figure 58 - Electrical Diagram, Light Emitting Diode

Figure 59 - LED Replacement Bulb
same amount of light. LEDs also offer a superior usable lifespan, lasting between 35,000 and 50,000 hours. By comparison, compact fluorescents are typically rated between 10,000 and 15,000 hours and incandecents are known to have a useful life between 1,000 and 2,000 hours. [22] Unlike fluorescent lamps, LEDs contain no toxic materials. LEDs also produce very little heat, which reduces cooling loads and associated energy costs. The major disadvantages of LEDs are: Voltage sensitivity, Light quality, temperature sensitivity, and a relatively high upfront cost. Light quality continues to improve as the technology matures and proper engineering can mitigate the issues of voltage and temperature. Lastly, the high upfront cost is more than offset by the lifespan of LEDs.

Ground Source Heat Pump

This uses the same refrigeration cycle as traditional heat pumps but instead of exchanging heat with the ambient air, ground source heat pumps utilize the constant temperature underground to increase efficiency by exchanging heat with the ground, which tends to vary significantly less than the ambient air temperature and offers a more favorable temperature differential. This translates into less energy required to transfer heat into or out of the building. There are two types of ground source heat pumps: Closed Loop And Open Loop. Closed loop ground source heat pumps use two wells, one well draws water up to be circulated over the coils and the other well serves as a discharge.
Closed loop ground source heat pumps circulate some kind of heat transfer fluid through a series of buried pipes (fig 60) that are designed to transfer heat to the surrounding soil. In some cases, a series of closed loop wells are utilized instead as a heat transfer device. [23]

Figure 60 - Horizontal Closed Loop Heat Exchanger
### Formulas & Calculations

Average rainfall 46” (3.83’) Per yr.

Collection area 1200 s.F.
Collection area 2000 s.F.

1200 * 3.83 = 4596 Cubic feet
2000 * 3.83 = 7660 Cubic feet

4596 * 7.4 = 34,010 Gal
7660 * 7.4 = 56,684 Gal

34,010 / 365 = 93 Gal per day
56,684 / 365 = 155 Gal per day

Conventional use: 63.9 Gal per day
Target: 40 gal

3X tank 4,775 gal - 8’6 dia. 11’3” H
14,375 Gal tot

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<tr>
<td>Baths (50 gal/bath * .14 Bath/capita day)</td>
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<tr>
<td>Faucets (est.)</td>
<td>9</td>
</tr>
<tr>
<td>Dish washer (13 gal/load * .17 Load/capita day)</td>
<td>2.2</td>
</tr>
<tr>
<td>Washing machine (50 gal/load * .30 Load/capita day)</td>
<td>15</td>
</tr>
<tr>
<td>Water softener</td>
<td>5</td>
</tr>
<tr>
<td><strong>Tot</strong></td>
<td><strong>63.9</strong></td>
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<table>
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<th>Activity</th>
<th>Usage</th>
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<td>Toilet leakage (use greywater - 0 freshwater used)</td>
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<td>Faucets (est.)</td>
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<tr>
<td>Dish washer (13 gal/load * .17 Load/capita day)</td>
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</tr>
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Design is a form of competitive advantage. People tend to think of design as good art, good visual language, which it absolutely has to be. But it’s also about the ability to do systems thinking.

- James P. Hackett, President and CEO, Steelase
Programming concepts

- Generate an excess of green power
- Zero discharge sewage
- Systems in symbiosis
- Passive climate control
- On-site food cultivation

Building Materials

- Concrete structural skeleton
- Thermally isolated steel skin

Minimum Performance Characteristics

- Typical energy usage per-unit should be less than 2.5 kWh per day
- Primary energy source should exceed 5 kWh per day output

Systems

- Photovoltaic solar power

- Ground source heat pump
- Hydrogen electrolysis as energy storage medium
- Radiant panel heating/cooling
- Rainwater harvesting
- Gray water recirculation System / constructed wetlands
- Small-scale aquaculture

Architectural Elements

- Windows – clerestory, north light
- Overhangs should be designed to do admit light from November to mid April and provide shade all other months.
- Raised living platform
- Multi-cell Cistern
- Thermal chimney or stack effect
Design, in the end, is about creating better things for people. Along the way, it can generate better profits as well.

- Bruce Nussbaum, Editorial Page Editor, Business Week
After reviewing the various technologies available and selecting those that best suit my purposes, I
set out to determine the basic massing. I wanted to respect the local building codes wherever possible and respond to the conditions that were present within the neighborhood context. Figure 42 shows just the most basic massing at scale along with the required parking. This is an attempt to get a feel for how things might fit on the site within the established setbacks. Figure 43 shows a variation with parking underneath the structure and proposed rooftop tensile structures designed to provide some shade for users of the proposed rooftop garden. Figure 44 shows a distributed plan with each unit oriented in the ideal position with the long sides facing north and south. This scheme is problematic...
because the unit in the center of the eastern column would have access problems. Figure 45 shows a less than ideal orientation for the units, but it solves the access issues of the previous layout. This scheme also offers the advantage of a large central area that could be used as a communal cultivation area and central pond for the collection of rainwater. The close proximity of the neighboring units provides some shade for the eastern and western exposures. Well-designed overhangs and/or a bris de soliel could mitigate the Eastern or Western exposures as well.
Figure 65 - Systems, Kit of Parts
Figure 66 - Systems diagram, Water
Figure 67 - Systems diagram, Power
After establishing the orientation and distribution of the units, I created a couple of systems models in order to have a visual representation of the various linkages between the systems (figs 48-50). Figure 48 shows a basic kit of parts and it contains 3-D graphic representations of the technologies that I intend to incorporate into this project. Figure 49 shows a diagram of all the systems in the project that use water and how they are interconnected. It is important to note that there are separations within the system. Potable water has never used for things that do not require it. Instead, gray water is used for flushing toilets and irrigation of non-agricultural planting beds. Also, there is a separation between agricultural and non-agricultural uses such that water carrying human waste is never used for edible crops. This eliminates the possibility of introducing pathogens into the agricultural systems. Figure 50 shows the energy gathering and storage systems. The solar panels in that diagram are arranged in the form of a solar tree. However, that configuration was determined to be impractical for Florida given the high winds that might be potentially seen in the case of a hurricane. A wind turbine is included in the mix despite the fact that Florida is not known for a particularly productive wind energy resources because it is relatively inexpensive and is a good complement to solar power. Also included in the mix, there is hydrogen electrolysis equipment and a fuel cell to provide some energy storage capabilities as well as potential to provide hydrogen fuel for vehicles. The fuel cell also
provides potential for co-generation. Since fuel cells
tended generate large amounts of heat, that heat could
be used to provide hot water or space heating during the
winter. My intention is to design the overall system such
that one could build everything at once, or implement
the main features of the system and add some of the
secondary functions at a later date as capital becomes
available.

Having established the massing and orientation
as well as the systems, I did a series of sketch models
based loosely on traditional tropical architecture. (figs
51-54) These designs employ a raised living platform to
take advantage of cross breezes and light construction
to minimize the effects of thermal saturation within the
construction materials. I eventually settled on sketch
number one as the prototype form, but any of these variations could be employed to suit varying spatial or functional requirements.

Figures 55 through 58 show further development of the prototype, including possible window configurations as well as railings and staircases. Figure 55 shows a proposed underground cistern for rainwater storage.
SITE WORK

In figure 76 we have an early proposal showing a central stepped rain catchment pond with 4’ outer retaining wall. This pond would be used to store excess rainwater and service secondary function of being the final stage of a water treatment system called a constructed wetland. Water that is drawn from this pond can be used to serve some of the users water needs with a little further treatment. Figure 77 shows proposed drain field configuration with two communal septic tanks. The approximate dimensions for the drain fields are 2’ x 25’, which is calculated to be the optimal size and shape for a 2000 ft.² building. I intentionally designed in some extra capacity so that the constructed wetland can not
be overwhelmed. I then tried thinking of the pond in terms of land-based aquaculture ponds and I created a more organically formed series of berms to make the sides. (fig 78) The green block mass on the west end of the pond represents a proposed pumphouse and remote mechanical space for the entire development or possibly, a caretakers workspace. Figure 79 shows a deck spanning the pond to allow passage from one side of the property to the other as well as providing access for the aquacultural operations, such as feeding or harvesting. Landscaping around the pond will include plants chosen to aid in the water treatment process and maintain the health of the pond.
I then decided that it might be better to separate the aquaculture function from the ponds function of sewage treatment and rainwater runoff storage. This avoids the possibility of pathogens from human waste contaminating food crops. Shown in figure 80 and 64, aquaculture can be performed in a series of small containers approximately 8 feet across and 4 feet deep. Around the perimeter of the wall, there are hybrid hydroponic planting beds which act as a filtration system for the aquaculture cells. However, this configuration places severe limitations on the amount of production that can be achieved in both the agricultural and the aquacultural endeavors. So a new configuration was necessary that allows for the achieved separations while providing more space for fish and food production.
The final configuration took the form of a greenhouse or conservatory with a long central trough for aquaculture that is ringed by concentric bands of walkway space and multitiered hydroponic growing beds. (figs 83, 84) Construction would be precast concrete forms tilted up and tied together with a series of longitudinal beams running the length of the structure. The side walls and roof could be enclosed with either glazing or polycarbonate panels. Figure 84 shows a removable canvas shade cloth that can be stretched over the structure to control solar heat gain and help control the interior conditions. Septic drain fields were then relocated to the landscaping planters between the residential units and a large communal cistern for rainwater storage can go under the greenhouse.
Design is an integrative process that seeks resolution (not compromise) through cross-disciplinary teamwork. Design is intentional. Success by design simply means prospering on purpose.

- Michael Smythe, Partner, Creationz Consultants
Figure 85 - Longitudinal Section
Figure 86 - Example Floor Plan

Figure 87 - Hardscape Plan

Figure 88 - Site Plan
Figure 89 - Western Elevation

Figure 90 - Southern Elevation
Figure 91 - Perspective, 7th & Morgan
Figure 94 - Perspective, 7th & Morgan
Figure 95 - Perspective, Private Outdoor Living Space
Figure 96 - Interior Perspective, Kitchen
CONCLUSION

“Good design helps build and sustain competitive advantage.”

Peak power output for the micro-utility portion is 180,000 Watts or 180 KW. With peak hours of sunlight varying between 4 to 7 per day, the system has a theoretical peak output range of 630 KWh and 1260 KWh. Of course, output varies as conditions change.

Power usage for the buildings’ operations are estimated to be:

- 52KW Hydrogen Generator (2x)
- 30KW (6 units x 5KW)
- 10KW Aquaponics operations
- 5KW Exterior lighting

83KW Excess output available for export back to the grid at peak production and usage.

Hydrogen output is rated at 20 kg 99.99% purity per day @ up 2,500 psi. Capable of fueling small fleet of 12 - 16 vehicles. Additional capacity can be added by adding additional units. Excess production can be stored in tanks underground. Stored hydrogen can be used in a fuel cell during times of no solar output.

A variety of fish types and stages of growth, including shellfish, shrimp or crayfish, can be cultivated in the greenhouse in the long central aquaculture trough by dividing it into segments. Approximately 3000 ft.² of hydroponic growing beds are available for cultivation of fruits and vegetables with an upper-level crop cultivated overhead such as orchids for additional production possibilities.
Individual units’ rainwater storage capacity is approximately $40' \times 45' \times 10' = 18,000$ cubic feet.

Storm water retention capability:
$150' \times 40'' \times 10' = 60,000$ cubic feet

Design Development Notes

- Add vertical axis turbines
- Add solar domestic hot water panels
- Explore composting possibilities to reduce solid waste
- Explore possibilities for using solar still to create potable water from non-potable sources. (Possibly on the roof of the greenhouse) [24]

*Figure 97 - Solar Still, Sectional Diagram*
REFERENCES


REFERENCES


REFERENCES


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“Good design doesn’t cost, but it pays.”

- Richard H. Driehaus, Chicago Money Manager and Philanthropist, Richard H. Driehaus Foundation
Appendix A - CO2 Emissions Scenarios

Figure 1

Figure 2