2009

Incorporating solar technology to design in humid subtropical climates

Andres Mamontoff
University of South Florida

Incorporating Solar Technology to Design

in Humid Subtropical Climates

by

Andres Mamontoff

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: Steven Cooke, M.A.R.C.
Stanley Russell, M.A.R.C
Elias Stefanakos, Ph.D.

Date of Approval:
November 10, 2009

Keywords: Photovoltaic, form, function, alternate, energy

Table of Contents

List of Figures

Incorporating Solar Technology to Design in Humid Subtropical Climates

Andres Mamontoff

ABSTRACT

This research will strive to establish a design methodology to achieve an ideal balance or ratio between solar energy available at a given site and the electrical energy requirement of a residence in a humid subtropical climate. Solar technology should be considered as an important element of the design and not a mere energy source added after the design has been completed. The introduction of this technology should be established at the conceptual stage and evolve through the whole design process of the project.

Solar energy is without doubt the best choice as an alternate to fossil fuels in Florida's humid subtropical climate, however harnessing this readily available energy source requires careful planning. Adding solar energy components during the final design stage will impact negatively on the aesthetics of the design and most likely will not provide the energy necessary to achieve sustainability. Each climate and latitude requires different strategies to maximize available solar energy, thus the design has to adapt to the energy source of the given site.

Florida's original vernacular design concepts dealt with solar energy issues in a passive way, by providing shelter from the sun and creating air circulation for

evaporative cooling. Today's photovoltaic technology can activate vernacular principles and create new sustainable typologies. Unlike tropical climates, the humid subtropical deals with high relative humidity in the summer months, thus demanding the use of mechanical cooling in order to reach the required comfort zone within the building's envelope. Fortunately solar energy is readily available in Florida during the critical summer season when the largest electrical loads are required by mechanical cooling.

An "off the grid" sustainable design could be achieved if electrical energy use is minimized to the essentials, wind technology is used to complement the photovoltaic system and alternate energy sources as gas, alcohol and alike are used for other household energy demands that do not need to be of electrical type. This design criteria will allow Florida residents to experience a more fulfilling existence by interacting with nature in a more dynamic, efficient and intimate way.

Chapter 1 - Introduction

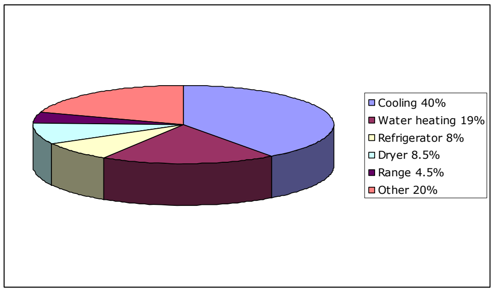
The intent of this thesis is to establish a set of sustainable design principles in order to assist the designer to achieve a high degree of sustainability by the use of solar energy and other design strategies that fit the requirements of the humid subtropical climate. The research will center on residential housing in a suburban context with the primary goal of establishing the most convenient grid alignment to maximize the solar energy available at the site and at the same time provide optimum pedestrian circulation.

The growing demand for fossil fuels and the negative impact created by their use is placing an unprecedented stress on our environment and society. Established western nations with well established economies are becoming vulnerable to the rising fuel prices due to the high demand created by emerging nations like China and India that have a large population bases and a strong appetite for fossil fuels. The solution to this growing demand for fossil fuels lays in reducing energy consumption and the use of alternate fuels, if both strategies are applied properly a sustainable alternative to conventional land development and home building can be achieved.

Developers have emphasized on generic low cost approaches to the housing issues, only looking to the short range financial benefits and thus providing basic pleasing aesthetics but low efficiency. This generic approach of building cooled or heated boxes have discarded the importance of climate, high technology and vernacular principles. For example, most homes recently built in Florida are constantly cooled or heated because the designs are based on only mechanical means to achieve comfort. A large amount of energy could be saved if the homes were designed on the principle of climate. Florida offers six months of the year of comfortable weather which requires minimal use of cooling or heating. Architecture has the responsibility to achieve an acceptable balance of good design and clean energy use. A successful design should not be just an aesthetically pleasing building but a combination of aesthetics and efficiency for a particular climate.

The humid subtropical environment is one of the most difficult climates to master as far as electrical energy consumption, mainly due to the need of mechanical cooling during the hot summer months. Mechanical cooling is required not only for human comfort but also to prevent mildew and other inconveniences brought about by humidity. Fortunately the latitude of humid subtropical climates offers many days of effective insolation during the summer, providing a large amount of free and clean energy when is needed the most. The design effort should seriously concentrate on climate and sources of alternate energy at the conceptual level, thus becoming a partial design generator.

In the state of Florida the energy required for cooling the interior of a home and water heating represents almost sixty percent of all the energy used by the residence. The goal of the architect should be to try to offset this percentage of energy consumption as much as possible utilizing solar energy. If planning is done properly this goal could be easily achieved or perhaps exceeded.



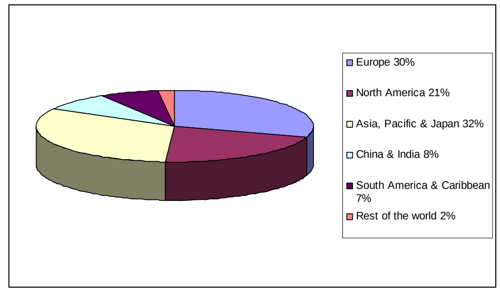


Fig.1-2 Average electrical consumption per household in Florida and world use of photovoltaic energy.

In Europe the use of PV energy is higher than in North America by seven percent even though they have little access to low latitudes where PV energy is more efficient. The following chapters will elaborate in detail various strategies to capture solar energy efficiently and methodologies to diminish energy consumption in a humid subtropical environment.

Chapter 2 – Climate

Understanding climate is the key to a successful sustainable design. The effect of weather on a structure varies greatly from climate to climate. Materials perform differently and therefore the techniques to achieve human comfort within a building vary by climate.

Humid Subtropical Climate

The humid subtropical climate does not encompass a large percentage of our world's land mass, and perhaps for this reason it has not received the attention that it deserves. Unlike the tropical environment the humid subtropics have to deal with a higher relative humidity, the main cause of discomfort to humans during the summer months.

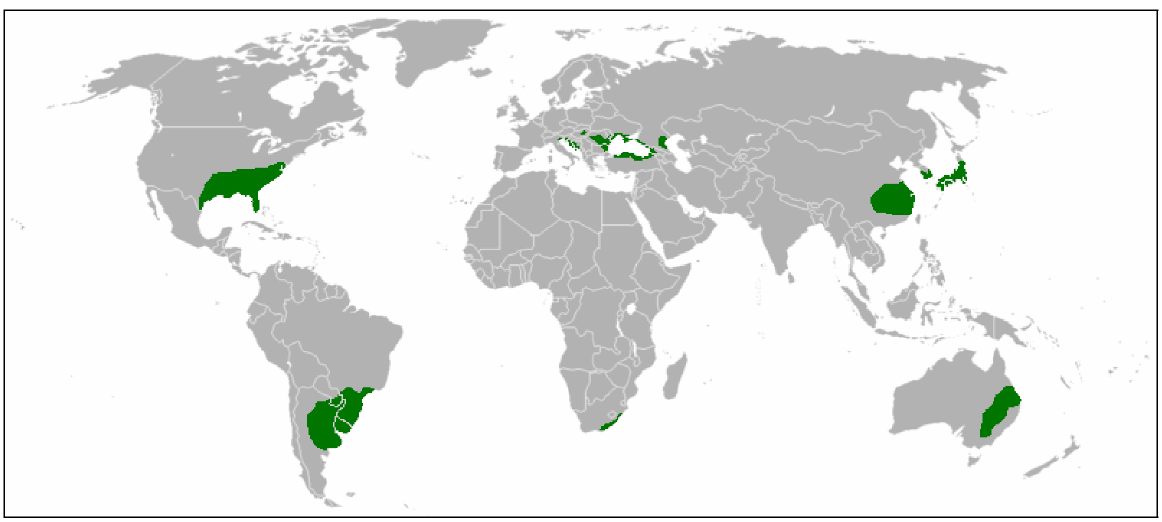


Fig.3 Humid subtropical climate

Within the humid subtropical areas shown above there are variations or micro climatic environments that must be considered thoroughly before the beginning of the design process. These variations are mainly related to altitude, two degrees Celsius are lost in every thousand feet of altitude, as well as exposure to large bodies of water which usually cause beneficial air movement like sea breezes. The research will be conducted at a site in the state of Florida therefore the analysis data will be limited to this state only.

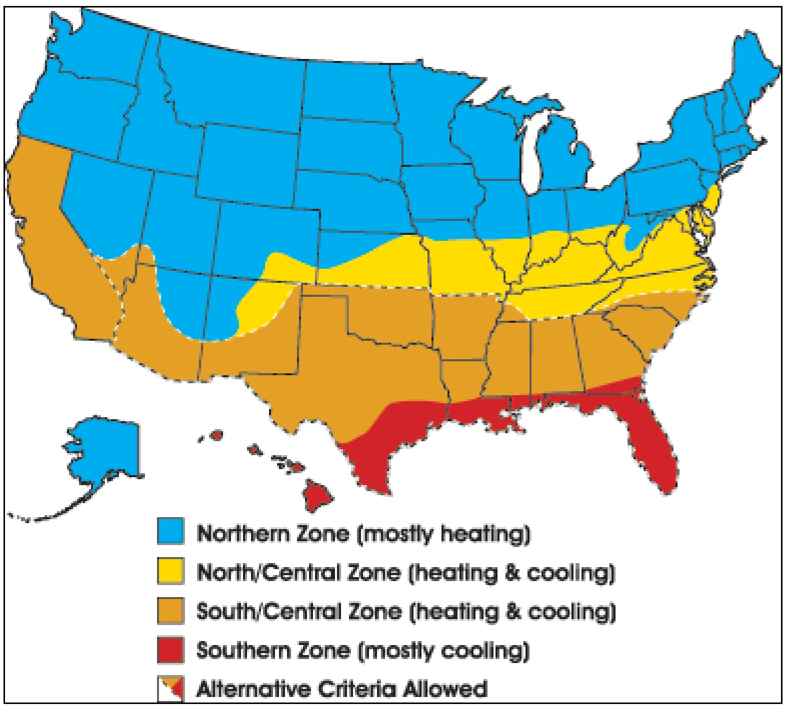


Fig.4 The humid subtropical climate is depicted as the southern zone

Controlling Climate to Achieve Human Comfort

Each climate requires a specific type of attention in order to achieve human comfort. The main task for a designer in humid subtropical climate is to control relative humidity within the buildings envelope. This issue has been effectively controlled with the use of mechanical cooling, which greatly reduces the amount of moisture in the air. This a very efficient way to control humidity but it also represents forty percent of the energy consumed by a Florida household. The methodology of cooling a home has become so generic and simplistic that most homes use air conditioning throughout the whole year, even when it is not required because relative humidity levels and temperatures during half of the year are within the human comfort zone.

Psychrometric Chart

This chart establishes the ranges of comfort for a particular climate and shows which levels of relative humidity and temperature are acceptable for human comfort in a given climate.

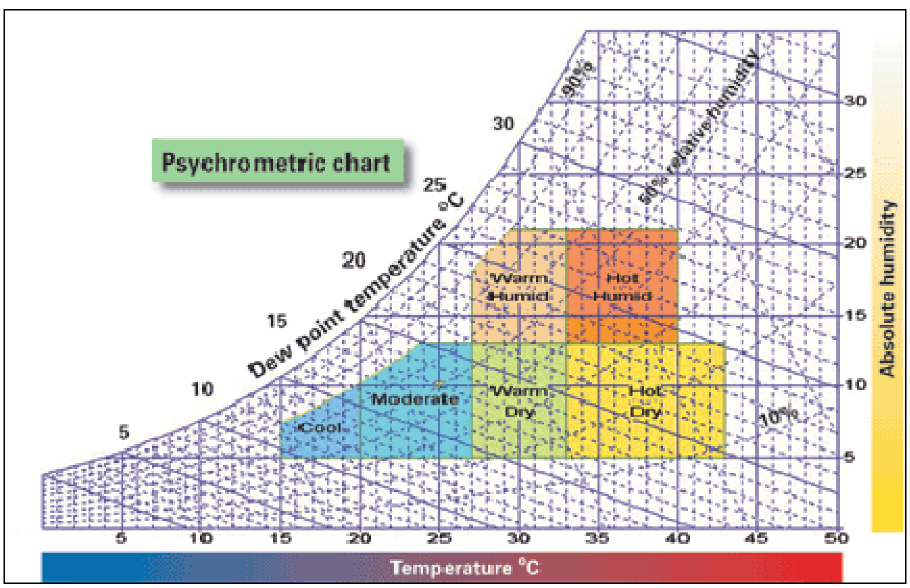


Fig.5 Psychrometric chart

Unlike a tropical environment the humid subtropical climate can not depend only on evaporative cooling caused by natural air flow through a home during the summer months. The average relative humidity chart shown in the next page clearly shows the contrast in relative humidity from Key West, located on the border line between a tropical and subtropical environment and Gainesville which is located in the center of Florida. Key West's afternoon relative humidity average remains within the comfort zone in the summer, thus allowing evaporative cooling by air movement without the necessity of mechanical cooling.

Average Relative Humidity

The relative humidity in Key West is lower than in Gainesville even though is surrounded by sea water. The cause of this condition is the lower air temperature caused by air movement like sea breezes.

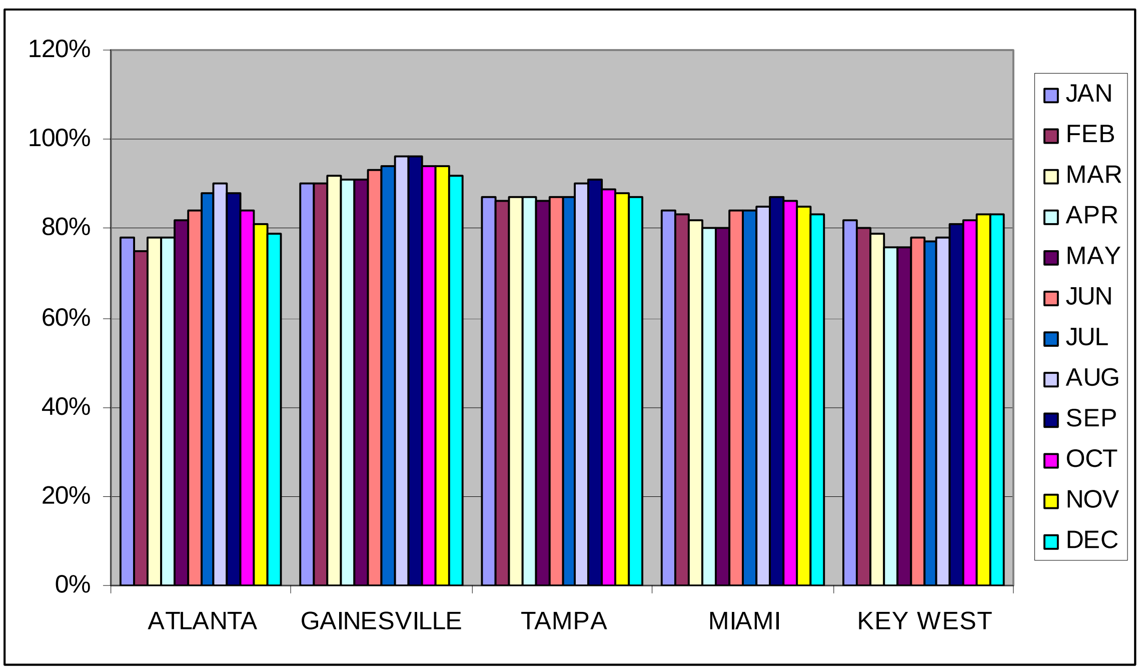


Fig.6 Relative humidity averages

Natural Air Circulation

Most homes in Florida are not designed to take advantage of the comfortable temperatures offered by spring and fall. During these two season windows should be open and natural air circulation should take the place of mechanical cooling. This could represent an important savings in energy consumption and more importantly take advantage of engaging Florida's beautiful weather.

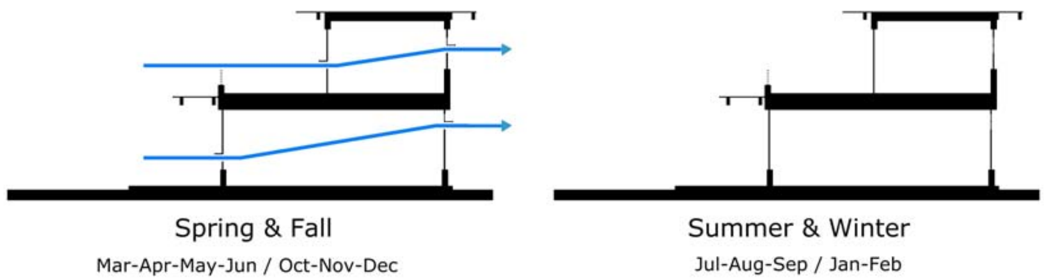


Fig.7 Natural passive cooling and heating can be achieved in the spring and fall months.

Chapter 3 – Solar Energy

The long term financial and environmental benefits from the use of solar energy are well documented, yet most designers are very timid in introducing this energy source to their designs. The two main uses of solar energy are to generate electrical energy and the heating of water. The solar array is not limited to energy production only and it can be used to provide shading when used outside the roof envelope, like porches or louver systems

Understanding Photovoltaic Technology

This research is not about photovoltaic modules but how to apply this technology to residential design, thus a brief explanation on this technology will be given at this time.

Solar cells are composed of various semi conducting materials. Semiconductors are materials, which become electrically conductive when supplied with light or heat, but which operate as insulators at low temperatures.

Over 95% of all the solar cells produced worldwide are composed of the semiconductor material Silicon (Si). As the second most abundant element in earth's crust, silicon has the advantage, of being available in sufficient quantities, and additionally processing the material does not burden the environment.(Web design Heindl Internet AG)

The solar array has become a very efficient way to generate electricity in particular climates. In the case of Florida and the humid subtropical climate the solar array reaches the highest efficiency rate due to the particular effect of diffuse radiation, common to this particular climate. This allows for the modules to generate electrical current even when the sun's radiation is not perpendicular to the modules surface.

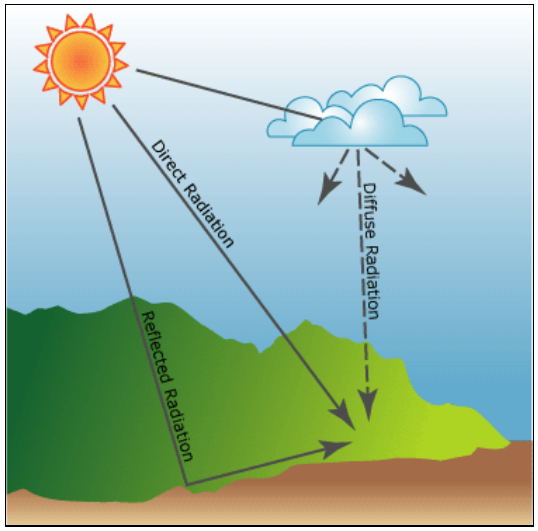


Fig.8 Diffuse radiation

Sizing The Photovoltaic Array System

In order to incorporate solar technology to design it has to be clear that the size of the solar array is directly proportional to the expected energy consumption of the home. In many cases the allocated area of the PV arrays does not provide enough energy to meet the electrical load of the residence, for this reason the array's area should be determined before the conceptual or schematic process of the design is initiated. Once the program is known the electric load should be determined and thus a minimum array area will be easily calculated.

There are many available resources to the designer on this subject, thus this chapter will only provide a sample form for a basic understanding of how the electric load is determined. Energy management is essential to achieve an off the grid condition, electrical use should be limited to components that can not use alternate energy sources but electric energy.

The shown example for a residence were gas appliances will be used in combination with a standard electric system fro lighting and cooling.

PHOTOVALTIC ARRAY SIZE

Name: Prototype AC electric & gas **Date: _10_/_20_/_2009___**
Address: Odessa, FL 33556
SF: 2520 SF LA **Phone:( ) -**

Appliance	Watts	Hours / day	Watt-hour / day	Notes
Lights 1st floor	350	3	1050	5 @ 70
Lights 2nd floor	350	3	1050	5 @ 70
Exterior Lights	120	10	1200	2 @ 60
Refrigerator	600	6	3600	
Washing machine	150	1	150	
Clothes Dryer	0	1	0	Gas
Dishwasher	0	1	0	Gas
Air conditioning 1 (3T)	3920	12	47040	LG
Air conditioning 2 (3T)	0	12	0	
Ceiling fans	240	24	5760	4 ea @ 30
Water heater	0	1	0	Bosch AE125 @ 2hrs/day
Computer / printer	200	8	1600	
TV/DVD	200	6	1200	
Coffee maker	800	1	800	
Range / Oven	0	1	0	Gas
Microvawe	1000	0.5	500	
Stereo	30	2	60	
Vacum cleaner	200	0.1	20	
Hair dryer	1000	0.1	100	
Freezer	0	6	0	
Iron	1200	0.5	600	
Well	2300	4	9200	
Softner	200	2	400	
Lift station	1300	1	1300	
Pool pump	2000	1	2000	
Total watt-hour / day			77630	
KWH/day		1000	77630	**77.63**
Watt-hour / day			77630	**Cell type:**
Adjusted load *	1.5		116445	
Solar energy available**	5			
Peak watts required WP			23289	
Cell type Watt / ft sq ***		17.4		
Array size ft sq			**1338.4**	

* Average system losses. ** From NREL map. *** Specified by manufacturer

Fig.9 PV array sizing form for electric and gas system.

Traditional PV Use

The common place for a solar array in a residential application is on the roof and for obvious reasons. The function of the roof is evolving and its shape is starting to change in order to accommodate to its new function which is not only to provide shelter but an important source of energy.

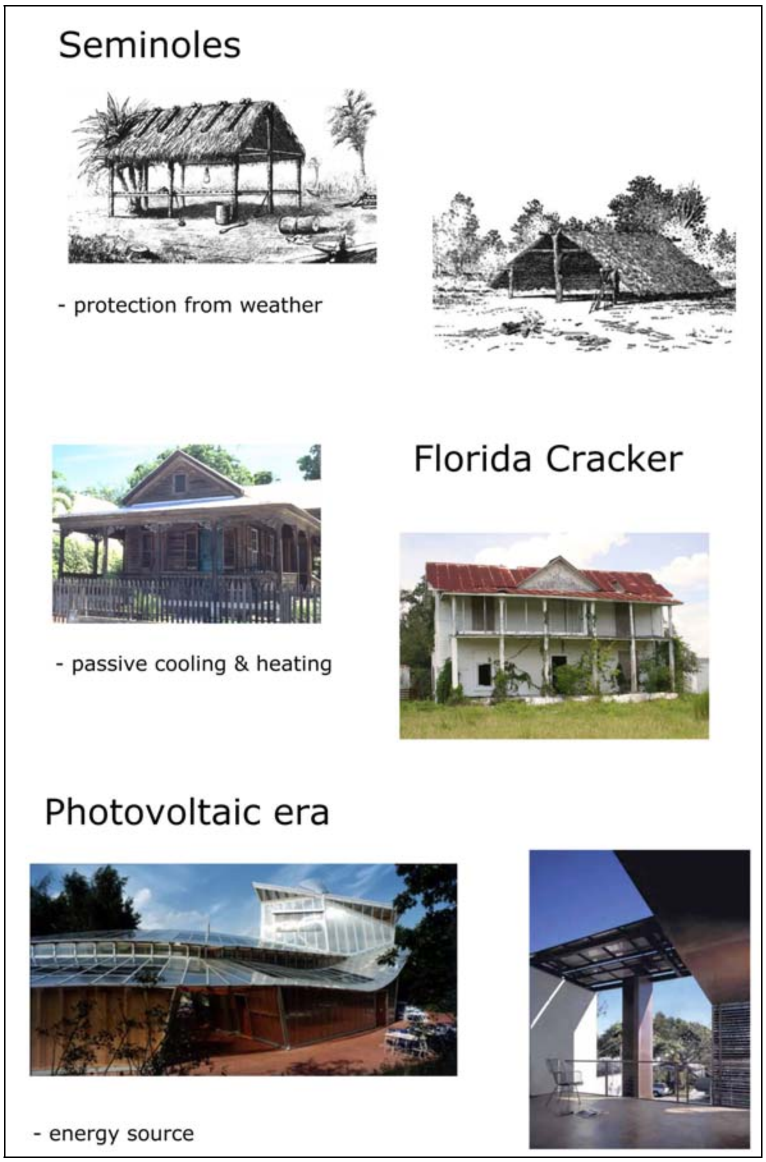


Fig.10 The evolution of the roof

Photovoltaic Roof Models

In a subtropical climate the most efficient alignment for a photovoltaic roofing system is facing the southern and south western exposures. The projected shadows of the following conceptual massing models show a summer mid afternoon condition.

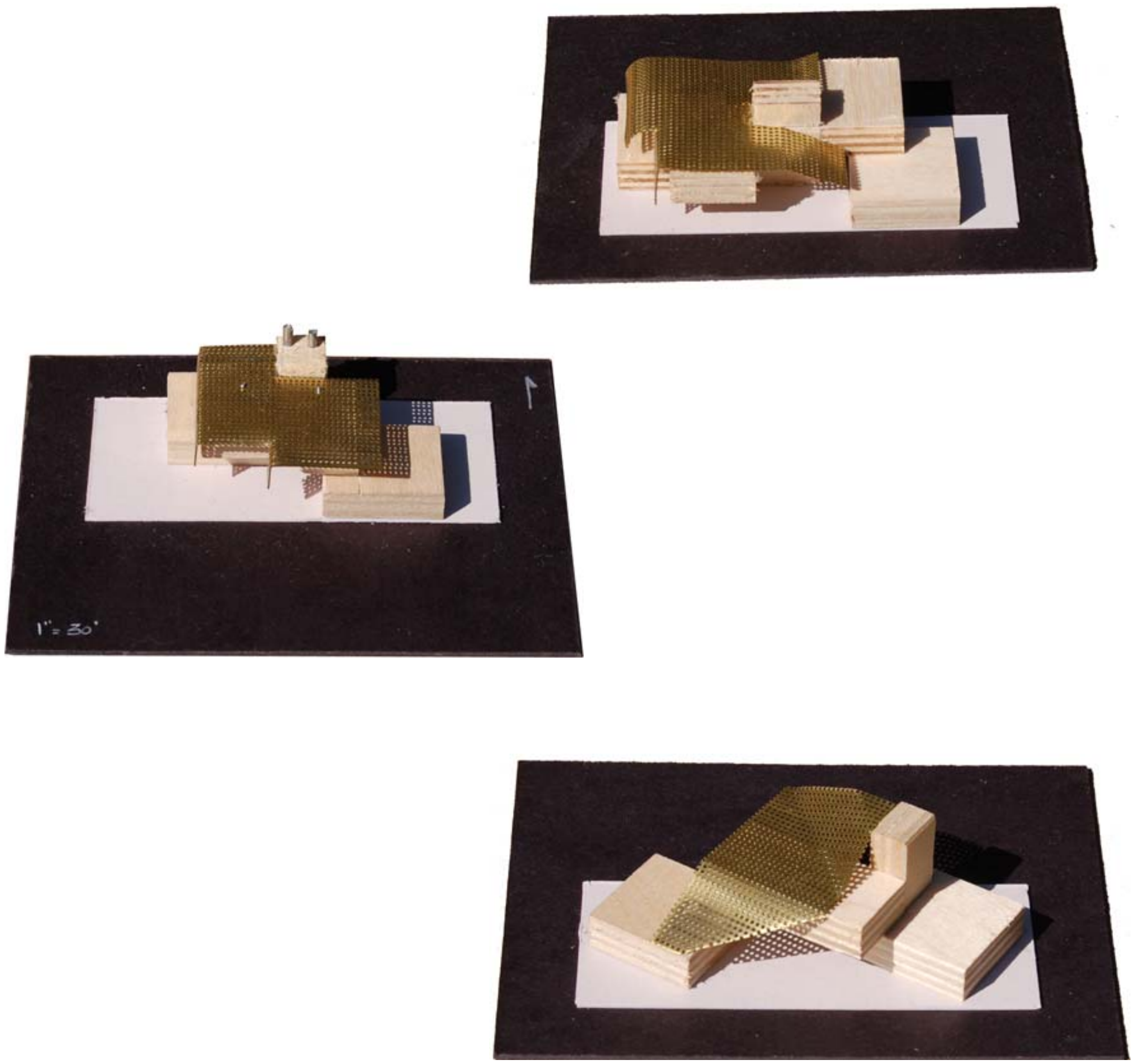


Fig.11 Massing models of various photovoltaic roof concepts in a summer afternoon condition.

Alternate Use of PV Arrays

A successful design must consider all aspects of the site's environmental conditions, then harness them through the building's envelope. The various components of the structure have evolved through the use of technology, their functions have become more sophisticated thus their forms should be dictated by their functions. Photovoltaic arrays can now also be considered a major component of a structure, with more functions than just generating energy.

The architect has an unlimited opportunity to manipulate a solar array and find secondary functions for it. The following concepts are just a few examples of the alternate benefits of solar modules.

Fig.12 A set of solar modules slide over the roof's overhang to provide additional shading to a southern exposure

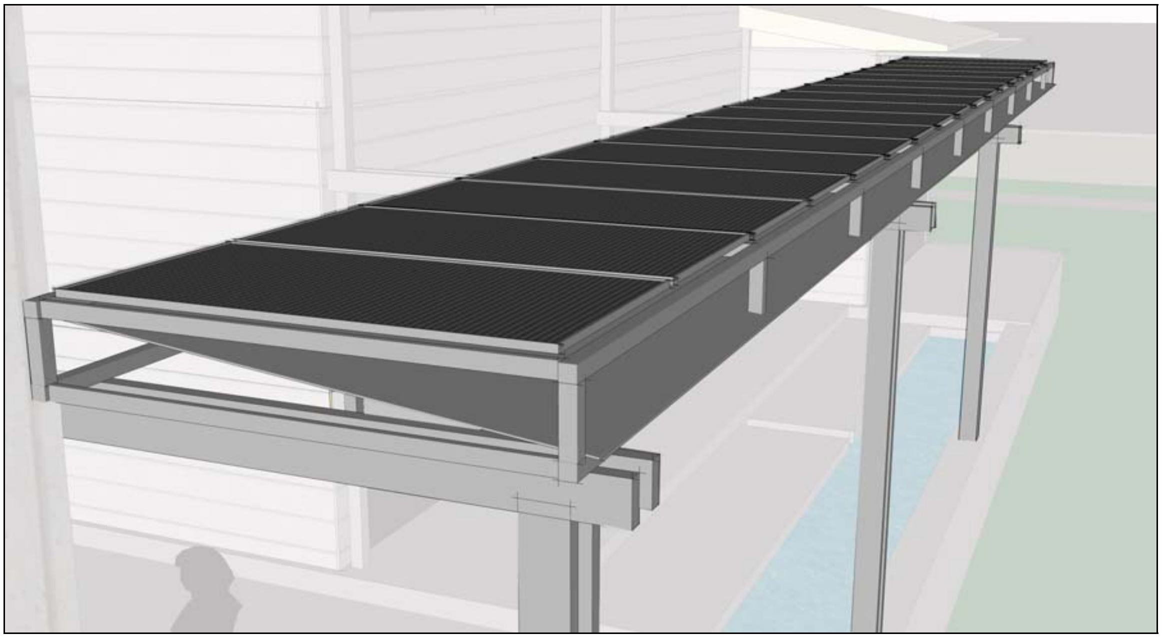


Fig.13 Solar array provides shade, rain water passing through between modules is diverted with a light metal roof system.

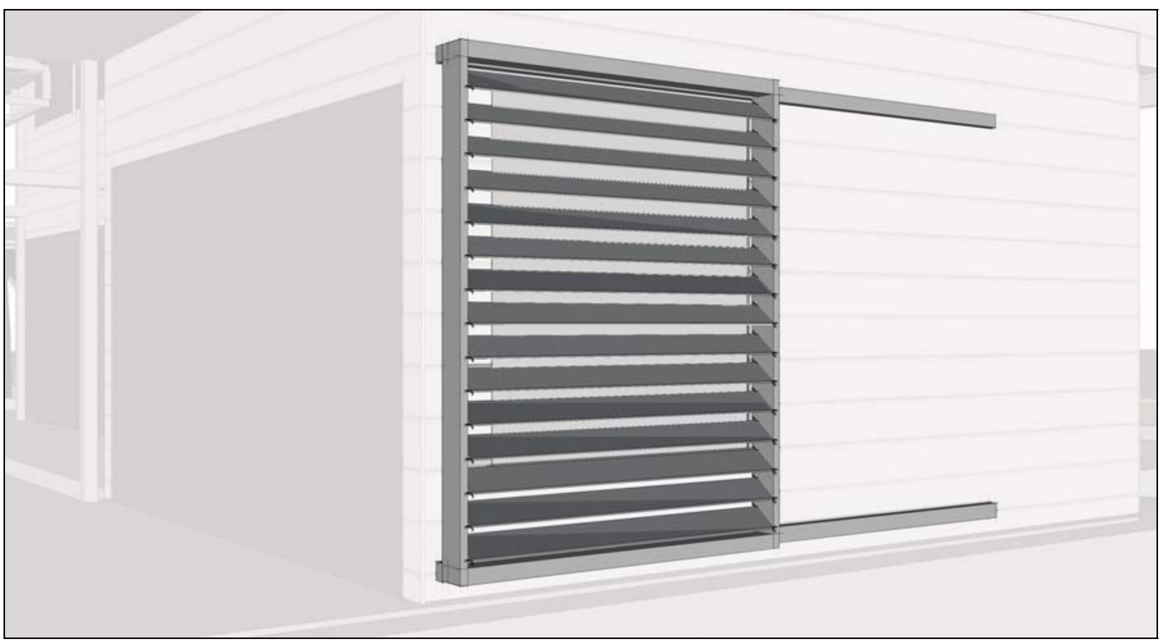


Fig.14 Solar adjustable louver system, it can also be moved to the side of the window opening if sun light is desired inside the building.

Solar Water Heating

Water heating accounts for almost twenty percent of the electric energy required by an average home (Fig.1), the solution to reduce this high electric energy use is by placing the water heating system on the roof. The technology has dramatically improved over the years and the systems can be easily concealed, minimizing the impact on aesthetics. This method for water heating will be covered in the schematic design chapter.

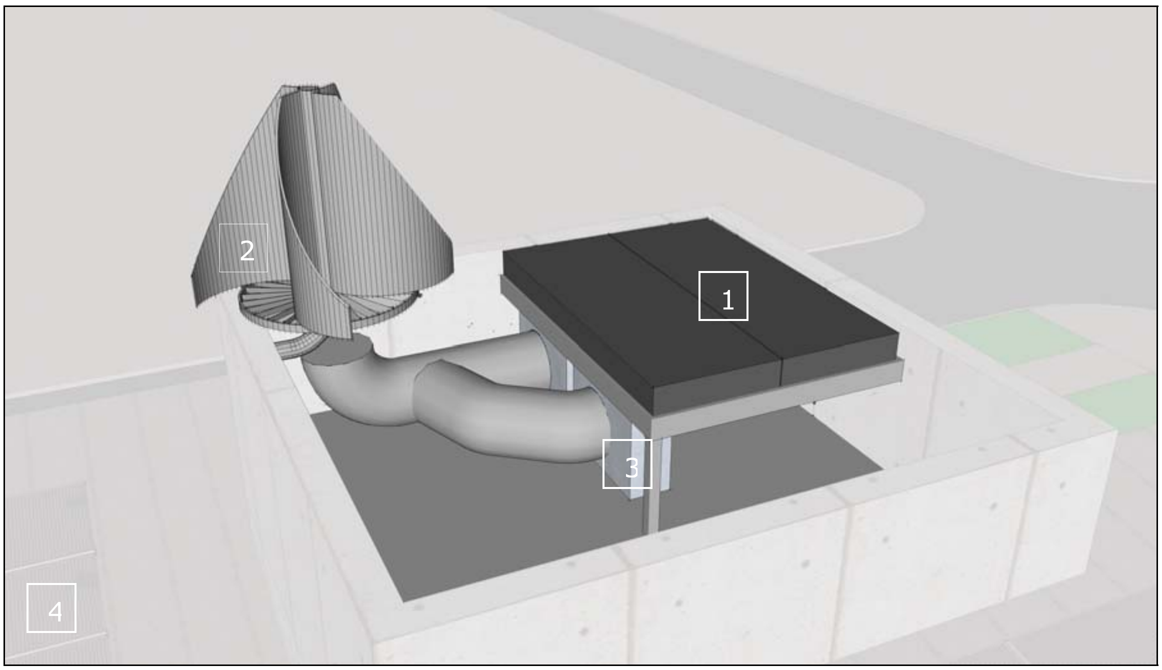


Fig.15 Location of water heating 1, wind turbine 2, air conditioning 3, solar arrays 4.

Wind Technology

This energy resource has also made important technological improvements and it can provide an important complimentary energy resource for PV arrays. In a battery operated array system wind generators can provide battery charging capabilities during the night as well as during poor weather conditions. Florida's weather patterns during the summer (when the electrical loads are critical) do not provide constant winds, however frequent thunderstorms could power wind turbines when sun light is not present. Another possible strategy was discovered during this research that could prove this technology very useful by routing the air circulation caused by the air conditioning compressors to the turbine blades.

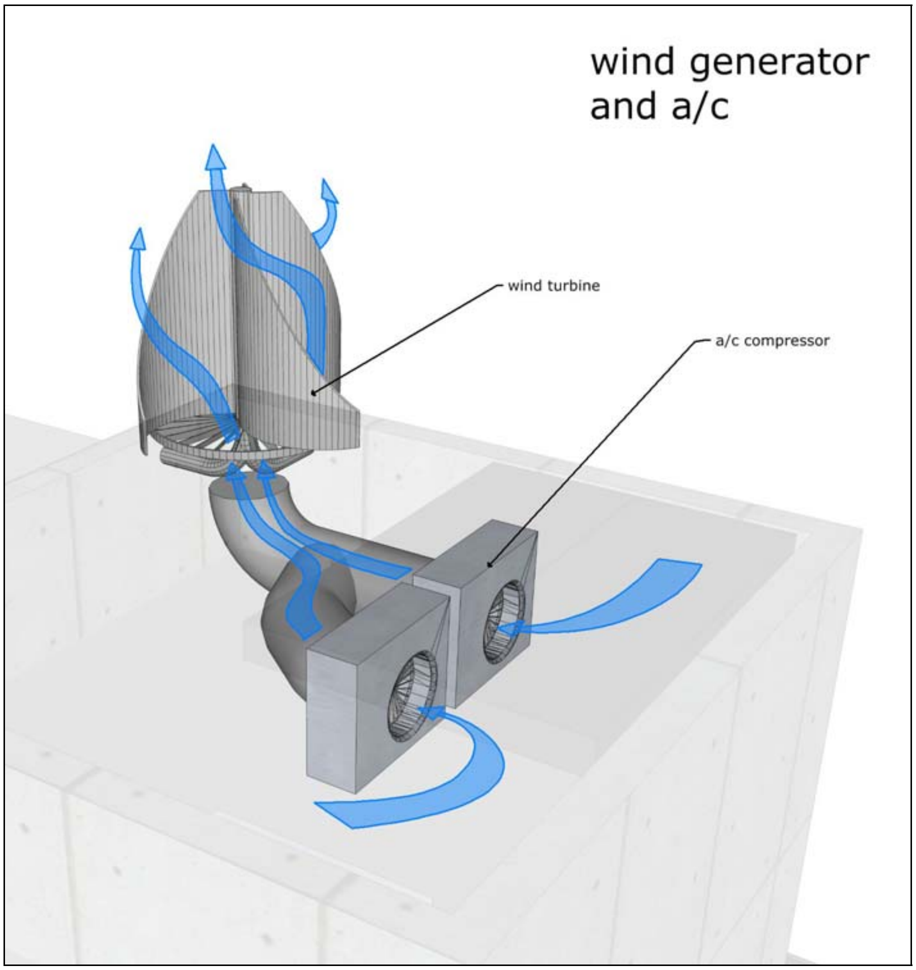


Fig.16 Wind turbine activated by a/c compressors.

Chapter 4 – Case Studies Photovoltaic Technologies

A strong effort was made to locate case studies based on incorporating solar technology to design in humid subtropical climates, unfortunately the four case studies selected are located in different climatic settings. Nevertheless is the design strategy that has the most value, thus this research will adapt the case study concepts to the humid subtropical climate.

Solar Umbrella Residence – Pugh + Scarpa Architecture

Project Location: Venice, CA
Project Size: 1,800 SF
Project Date: 2005

Inspired by Paul Rudolph's umbrella house of 1953. Passive and active solar design strategies render the residence 100% energy neutral. The design allows for easy natural air circulation thus minimizing the use of mechanical cooling.

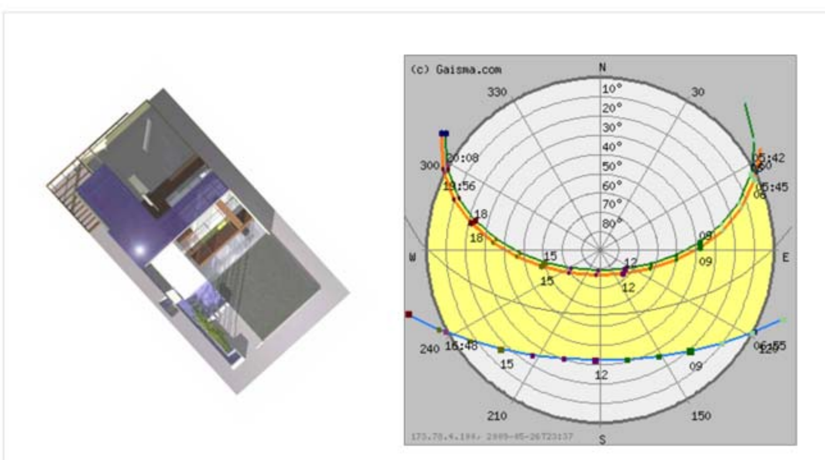


Fig.17 Insolation chart for Los Angeles WWW.Gaisma.com

The solar arrays are not attached to the roof but actually are placed above it, acting as a shading membrane that instead of reflecting the solar radiation it maximizes it for electric energy. By shading the structure the solar array diminishes the thermal conductivity of the structure, thus creating a cooler environment within the building envelope.

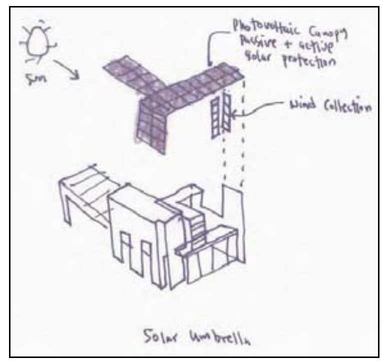


Fig.18–19 Solar arrays are located over the low slope roof area and also along the western wall.

Fig.20-21 Multiple functions of solar arrays.

Solar Decathlon 2007 – Technishe Universitat Darmstadt, Germany

Project Location: Washington DC competition
Project Size: 800 SF
Project Date: 2007

The Solar Decathlon is an international competition sponsored by the U.S. Department of Energy. Originally conceived in 1999 and currently taking place every two years in Washington DC. The 2007 winner was a team from Germany that provided great ingenuity and practicality in applying solar panels to both walls and roof areas.

The structure was built in Germany, then disassembled and brought to Washington DC for the competition. For this reason the alignment of the structure has no bearing and the design proves it, since the structure is rectangular in shape and provides the louver concept on any if its sides.

Fig.22-23 PV louver system in opened and closed positions

The louver system has three functions, providing shade to protect the actual walls from heat gain when the angle of the sun is low, to generate energy and to provide air circulation when the sun reaches its zenith.

Fig.24 PV louvers

Fig.25 Louvers are closed to provide shade and protect actual walls and glazing from heat gain.

Fig.26 Winter conditions when the sun provides heat to the home through direct sun light.

The last two photographs show the roof's solar modules in a water shedding function but not as shading device, creating a perfect solarium for cold climates. In a hot humid subtropical climate a translucent array would be replaced by a solid type to provide the necessary shade.

Steinhude Sea Recreation Facility - Randall Stout Architects, Inc.

Project Location: Steinhude, Germany
Project type: Recreation facility
Project size: 3190 SF
Project completion: June 2000

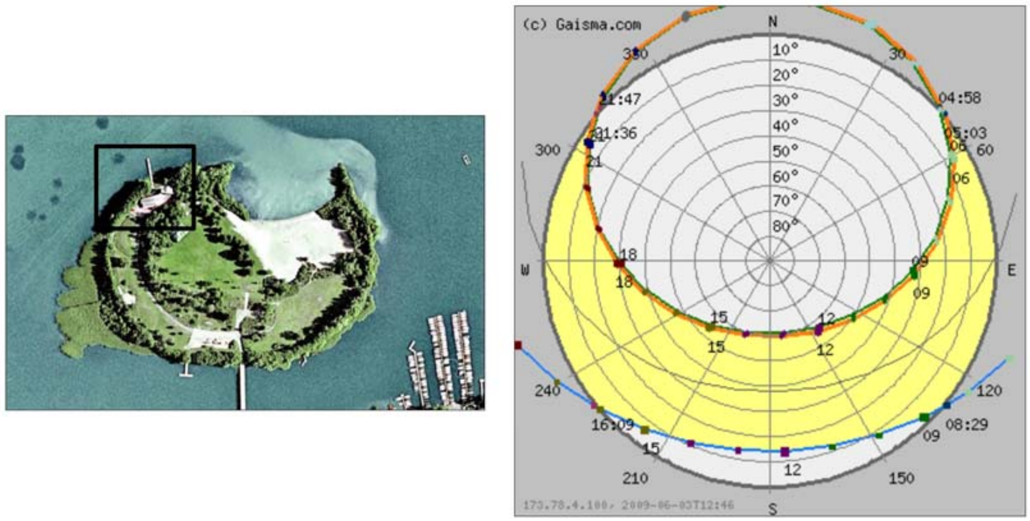


Fig.27 Steinhude insolation chart

A recreation facility is located on a small island at Steinhude Sea, Germany. Photovoltaic panels play an important role in achieving sustainability, however due to the climatic conditions other means of heating are needed and the use of a seed-oil fueled cogeneration micro turbine is required. Unlike the previous case studies the photovoltaic system has been integrated into the roofing system, which also incorporates many translucent panels to create a solarium effect. This concept is not applicable in a hot humid environment but the strategy in how to incorporate solar panels and water heating systems into the roof is very creative.

Fig.28 Southern access to Steinhud Recreation facility. Photo credit: Peter Hubbe

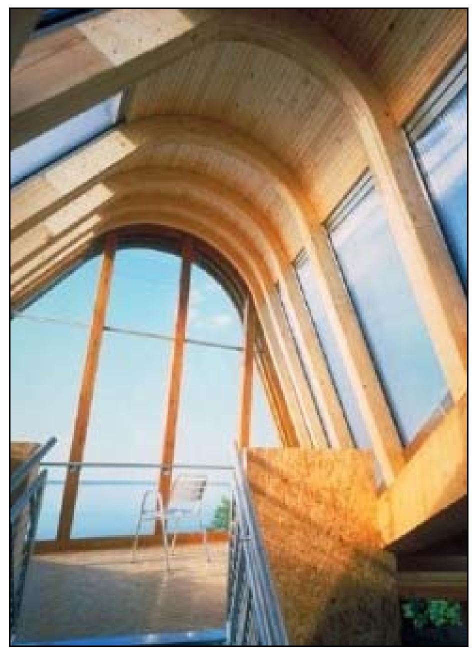


Fig.29-30 Lake access to Steinhud (left) and lookout over a solarium (right). Photo credit: Peter Hubbe

The above photographs show the lookout area which faces north, which is accessed through the solarium's stairs below it, large operable skylights offer good heat gain the winter and efficient air circulation in the summer months.

Chapter 5 – Evolution of Suburbia

In order to implement a new design methodology which incorporates solar technology as the main energy resource important considerations should be made during the land development process. This thesis will concentrate mainly on the suburban option because it is the one development process that causes the most damage to Florida's environment.

America's infatuation with the automobile has created an uncontrolled land development strategy based on roads that lead nowhere and urban type densities within the suburban context. This chapter will analyze the evolution of suburbia and how it can be modified to diminish the impact on our fragile ecosystem, reduce the dependence on the automobile and maximize solar technology. The suburban density concept evolved from being a place where land was plotted in large parcels around the outskirts of an urban center to what it is today, small parcels at a driving distance from an urban center.

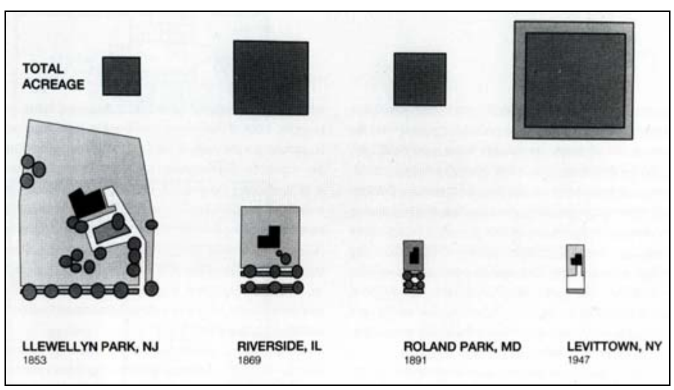


Fig.31 Density ratio evolution of a suburban setting. (Avi Freedman 1952)

Basically suburbia has evolved to a low density urban setting. For this reason it should be considered to treat new development on the same principles as urban environments. The idea that curvy roads means suburbia and a grid system means urban does not apply anymore. Suburbia should be defined through density ratios and even then the road alignment should follow design principles based on efficiency and in this thesis case, solar alignment.

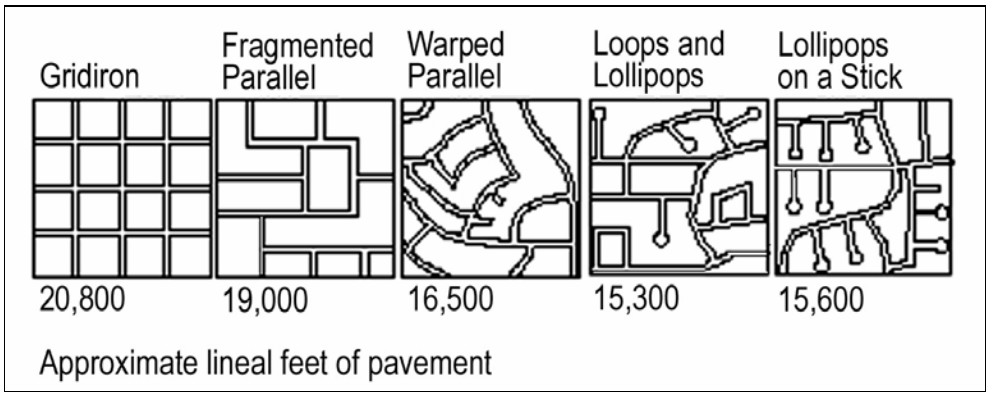


Fig.32 Economics of land development

By observing the above chart it becomes evident that economic forces have shaped the evolution of suburbia. The initial cost of development has been the driving factor of the forms of suburban developments, the lollipops and sticks are the norm today. However, the economics for the actual dwellers of these new suburbs become more expensive, in order to get from one side of a typical subdivision to the entrance point takes a lot more driving than in a grid system. In conclusion the grid typology is by far more effective from the dwellers economic perspective.

Urban Form Determinates

Through history most adopted forms of settlements evolved by determinants that can be categorized as follows.

Natural

- Topography
- Climate
- Construction materials and technology

Man made

- Economic
- Political
- Religious
- Pre urban cadastre
- Defense
- Aggrandizement
- The gridiron

In today's environment urban and suburban settings are determined mainly by man made economic and political determinants that sometimes follow pre urban cadastres or the natural determinants like topography and climate.

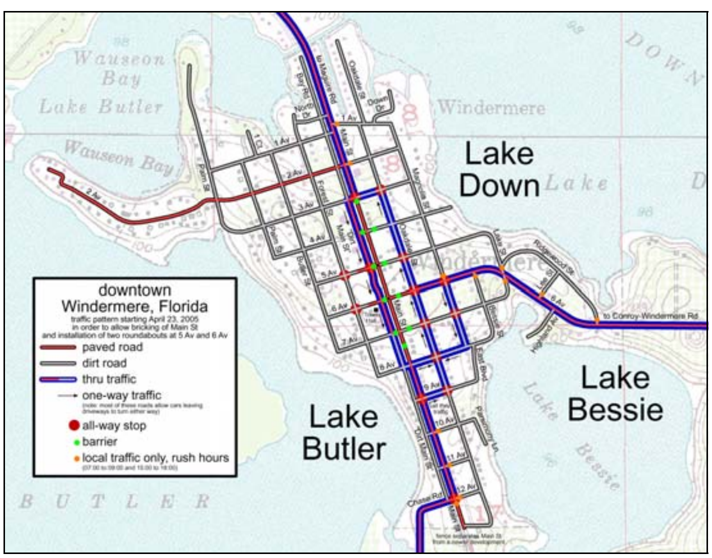


Fig.33 The a man made gridiron determinant following a topography determinant.

Typologies of Pattern

Stephen Marshall has developed the ABCD typology that is very helpful to understand the evolution of street and road patterns.

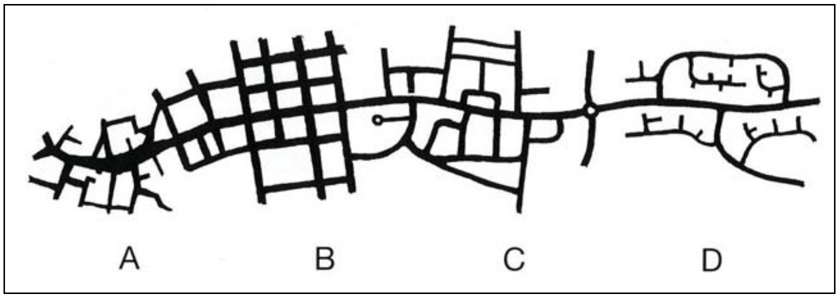


Fig.34 Urban evolution. (Stephen Marshall 1967)

Type	Example pattern	Typical location	Frontages	Transport era
A-type *Altstadt*		Historic core	Built frontages	Era of pedestrian and horseback
B-type Bilateral		Gridiron (central, or extension, or citywide)	Built frontages	Era of horse and carriage
C-type Characteristic/ Conjoint		Anywhere; including individual villages or suburban extensions: often astride arterial routes	Built frontages or buildings set back in space ('pavilions')	Any Era of public transport; car
D-type Distributory		Peripheral development: off-line pods or superblock infill	Buildings set back in space, access only to minor roads	Era of the car

Fig.35 Typologies of pattern evolutions. (Stephen Marshall 1967)

Alignment

The concept of alignment was studied extensively and many well know architects like Le Corbusier have written about the importance of alignment in building design and urban planning. Today's energy demands are proving that alignment is now more important than in the recent past and solar technology is making it more evident. Proper alignment today means access to energy resources that where not available when the gridiron concept was established.

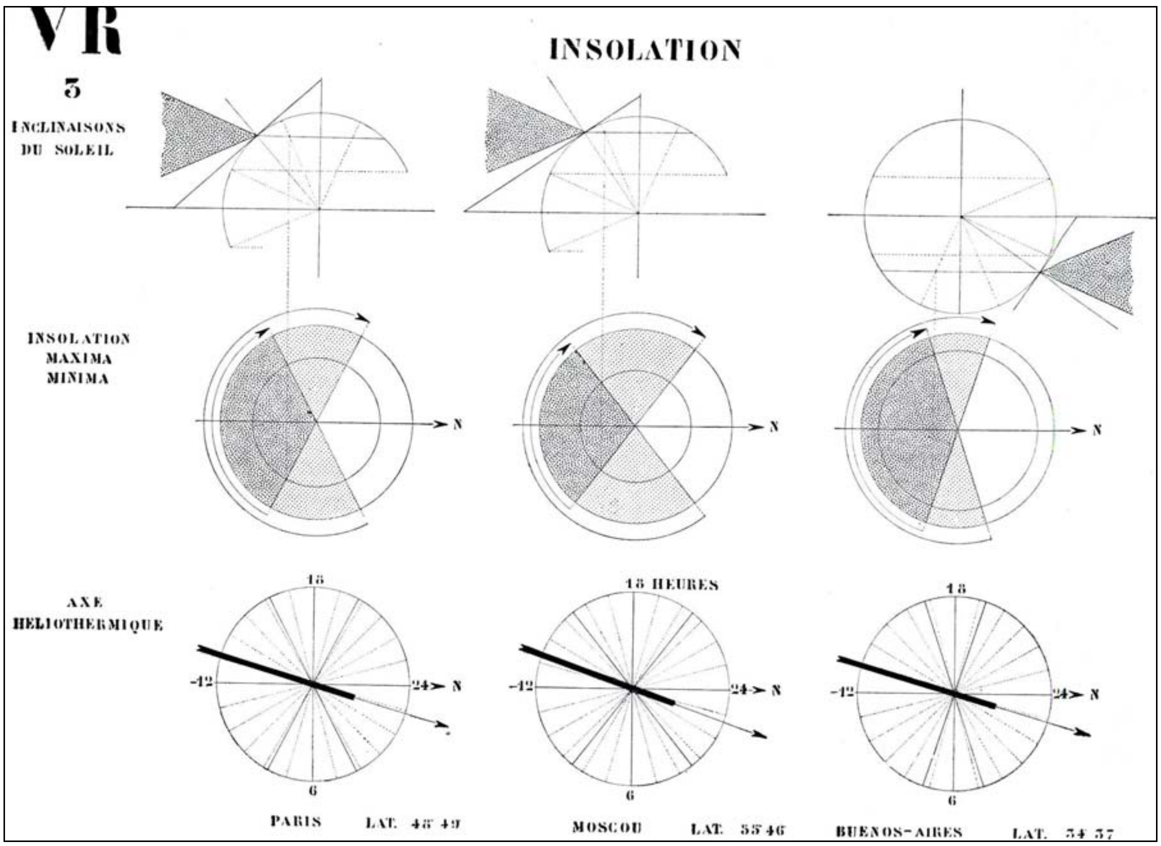


Fig.36 Insolation concept and the importance of alignment. (Le Corbusier 1933)

In the book The Radiant City, Le Corbusier wrote that the heliothermic axis should determine all city ground plans.

Chapter 6 – Program and Site Selection

The selected site is located in the north west corner of Hillsborough County, an area known as Keystone. This area is well known for its abundant lakes and country style living.

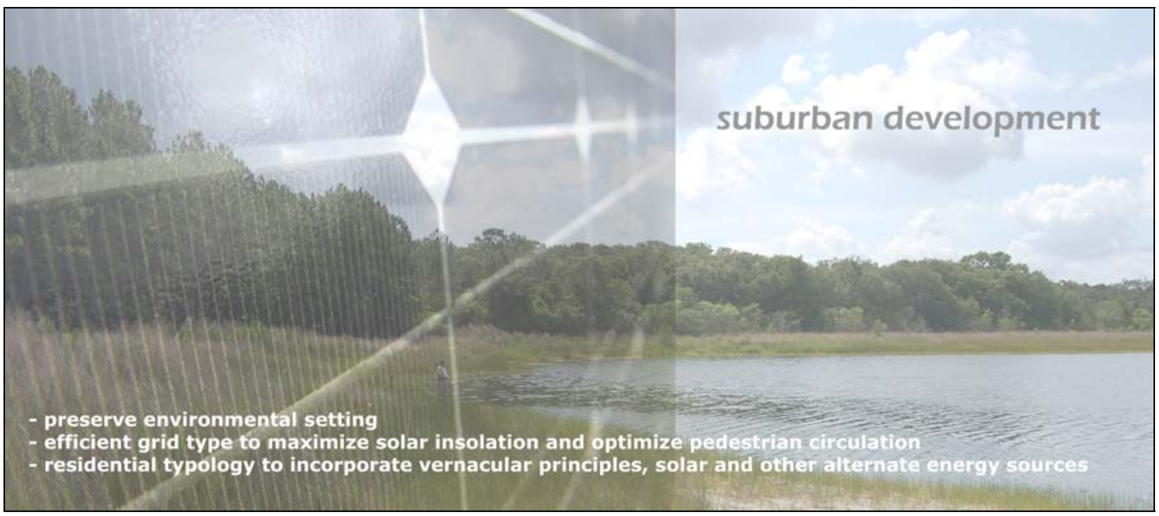


Fig.37 Program

Over the last couple of decades the Keystone community has been battling developers over the density and typologies of land development in this area. For this reason the site was considered to be a good example of how to develop a country environment with the least amount of damage to its traditions and minimizing environmental impact. The site is located in a designated rural service area where the zoning allows for a maximum of one home per acre.

The property in question is owned by the city of Saint Petersburg and is being used as a pumping station of fresh water for the exclusive use of Pinellas county. The owner the property has an agreement with Hillsborough county which allows the exploitation of the property as a public park in exchange which in return levies the real estate tax from the owner. In return Hillsborough county has the first right of refusal in case the property goes on the market. The intention of this research is to develop a program for this property that would make it of interest for Hillsborough county to purchase the land if it becomes available and allow it to be developed within the scope of this research.

Site Analysis

Major connecting roads divide the property into four sections, which would allow for diverse suburban typologies.

Fig.38 Location and land use map.

The current suburban forms that surround the area set a precedent as to the type of land use and which density should be considered for a sustainable development of the property. The development strategy is based on maintaining the public park and allowing only a partial development of the property. The intention of this project is to minimize the environmental impact and not to alter the current life style of the community. The surrounding area has been developed into two main typologies and densities. The proposed strategy is to maintain the same densities but develop a better the typology to better integrate the development to the existing park and areas adjacent to the site.

Because of the strategic location of the property a public transport hub is proposed. This is a concept that is pointed out but not part of this research which is about solar technology. The public transport hub is not only a good concept for the movement of people but as a large roof area that could provide large energy resources for the park, the transportation hub as well as a possible charging station for electric vehicles.

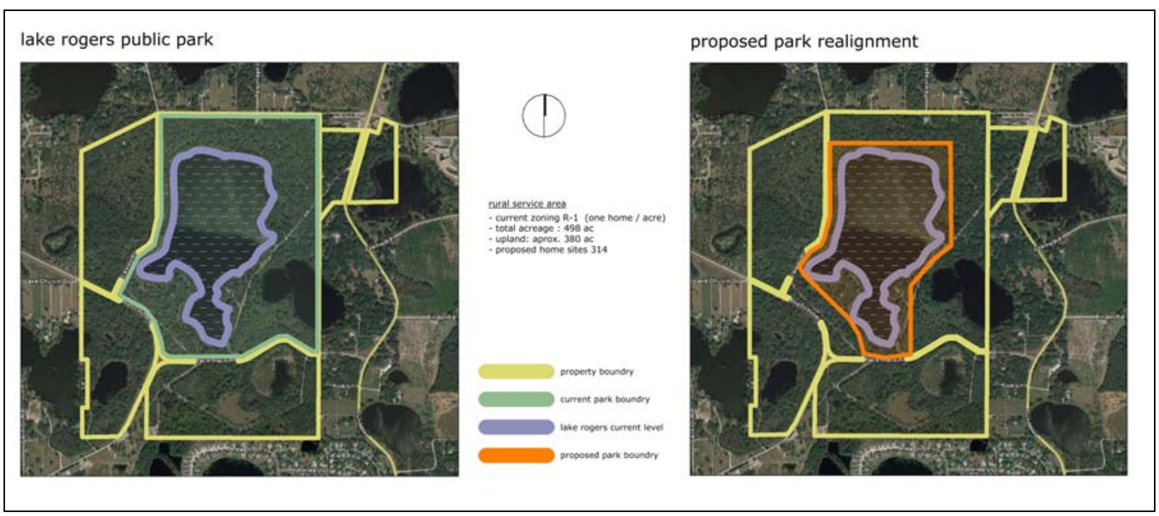


Fig.39 Existing property use and proposed future use.

The historic determinants started with a topography – rectilinear that determined residential development and road forms. More recent economic – curvilinear determinants influenced the residential development pattern, increasing density and changing the community's identity.

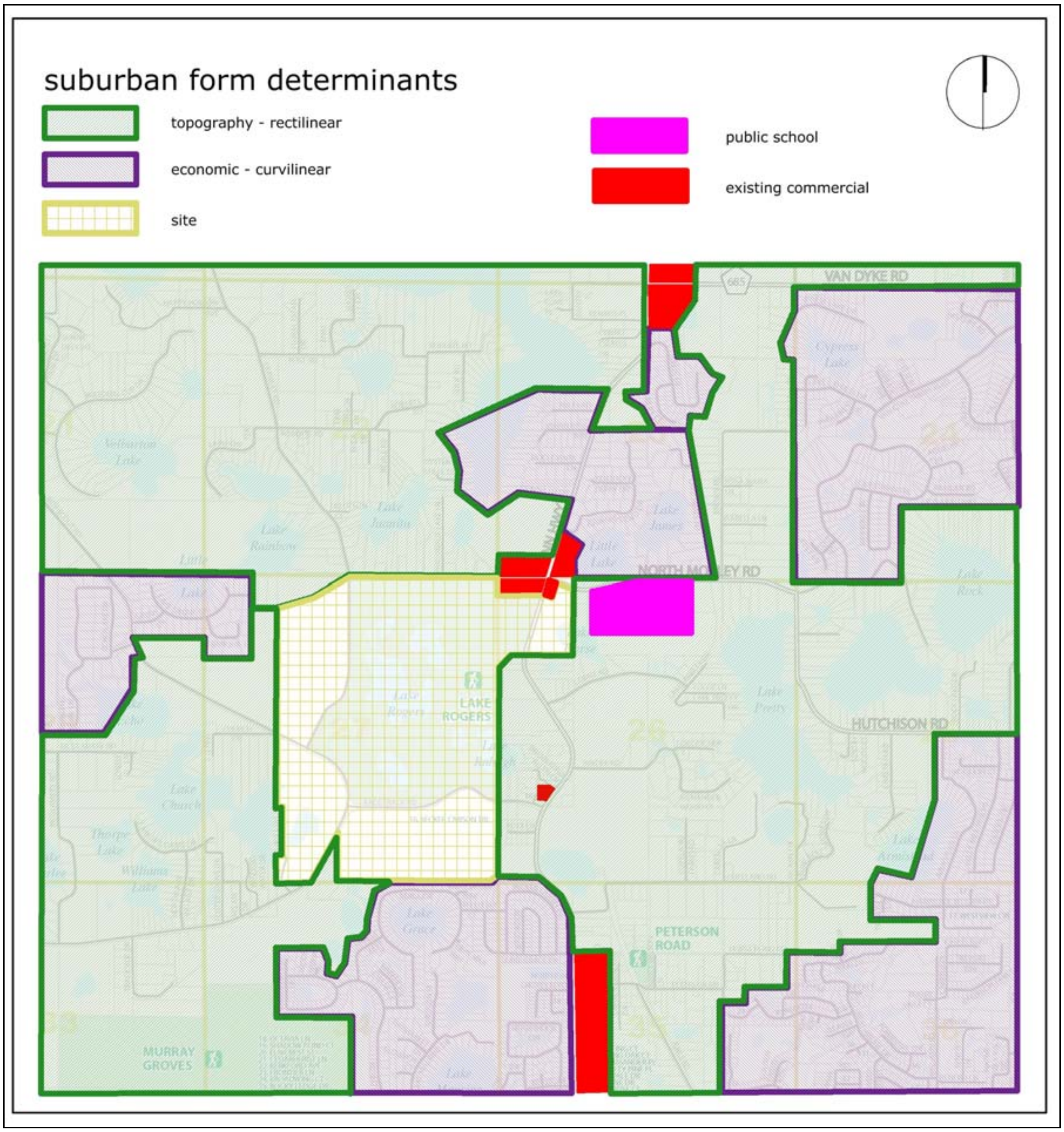


Fig.40 Area context

The existing road system around the site provides excellent connectivity on all axis. As the area grew in density this ideal connectivity has become a major traffic issue that is now affecting the community's fiber.

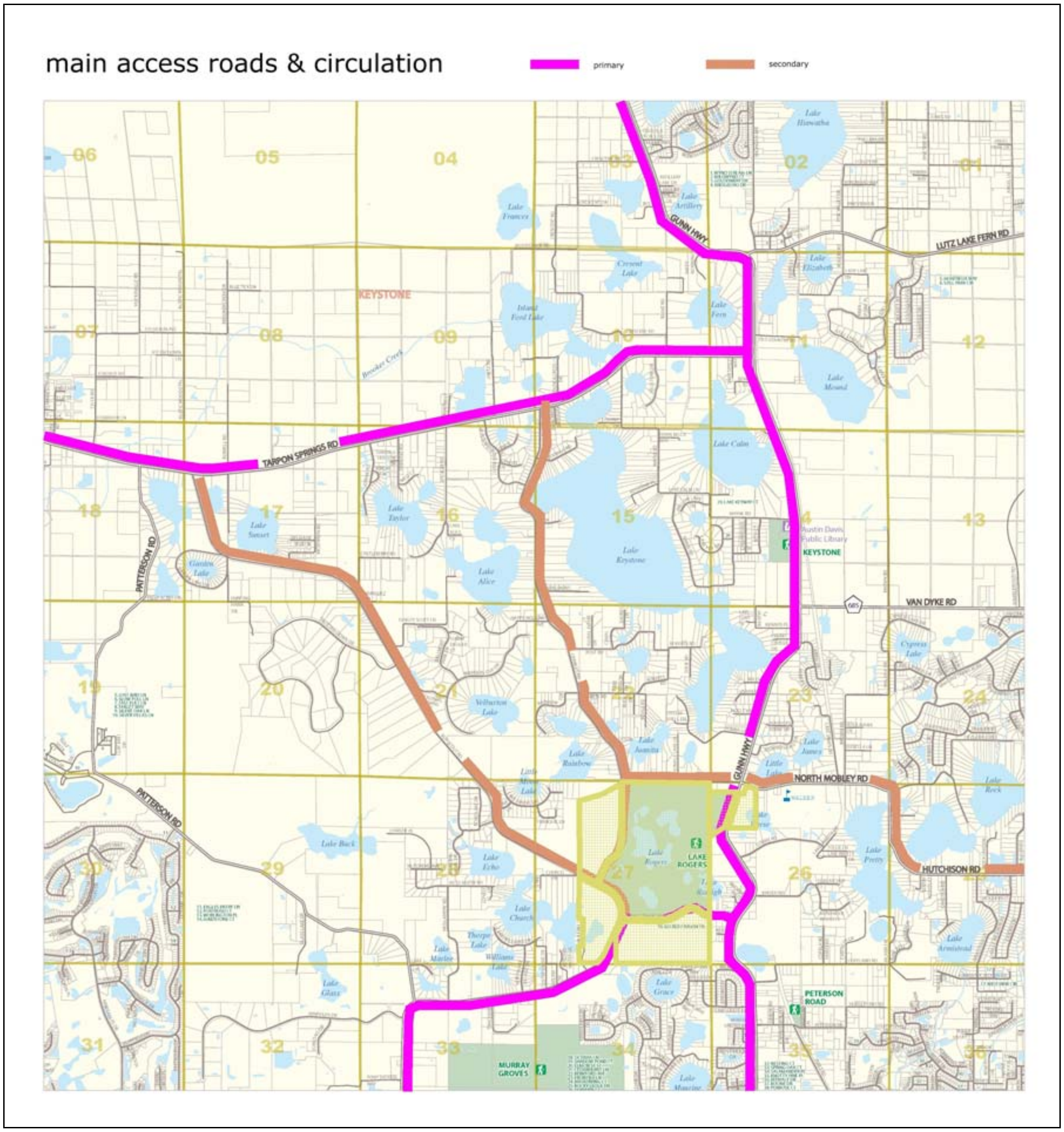


Fig.41 Main access roads

The site is strategically located, providing excellent connectivity through existing roads, making it ideal for a public transportation hub. This could reduce the traffic problems that are currently affecting these country roads.

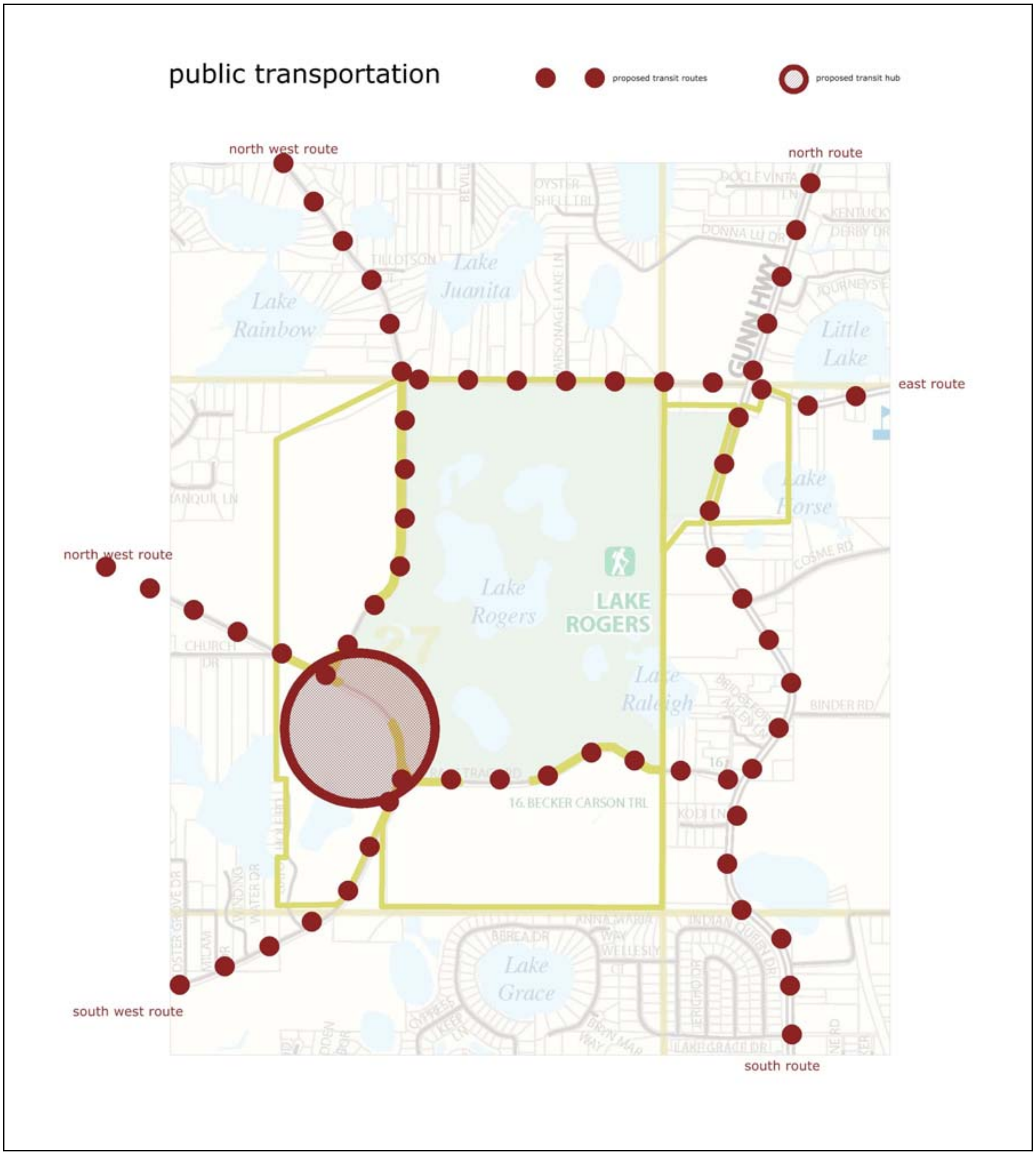


Fig.42 Proposed public transport hub

The public park could be complemented with extensions to designated water retention areas. Also important is the connectivity between the park and the public transportation hub.

Fig.43 Public realm of proposed development

The topographic rectilinear section is selected for areas with a large percentage of wetlands. It will not require ground work and it will fall under the unimproved subdivision category, limiting development to connecting roads only.

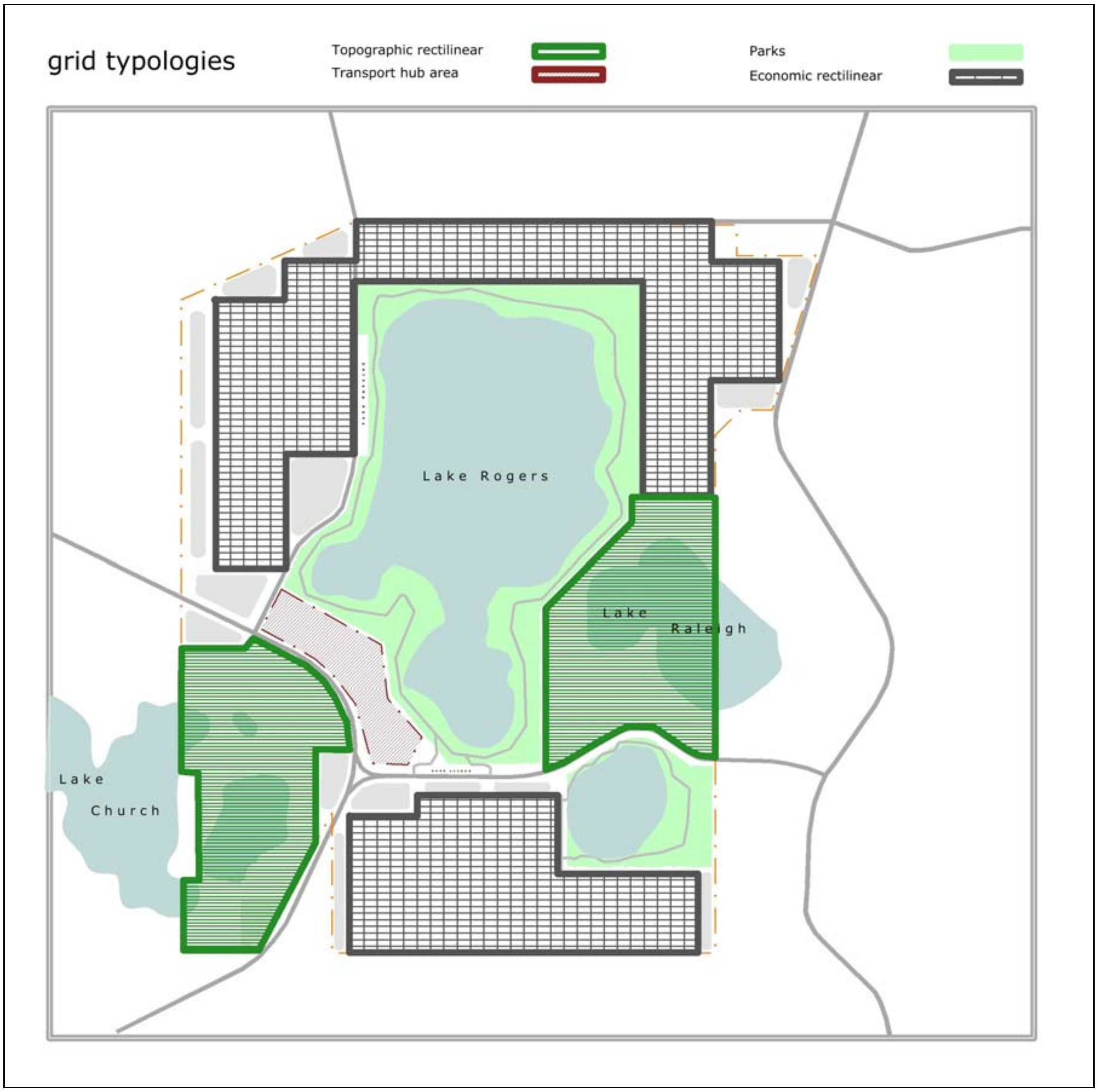


Fig.44 Proposed grid typologies

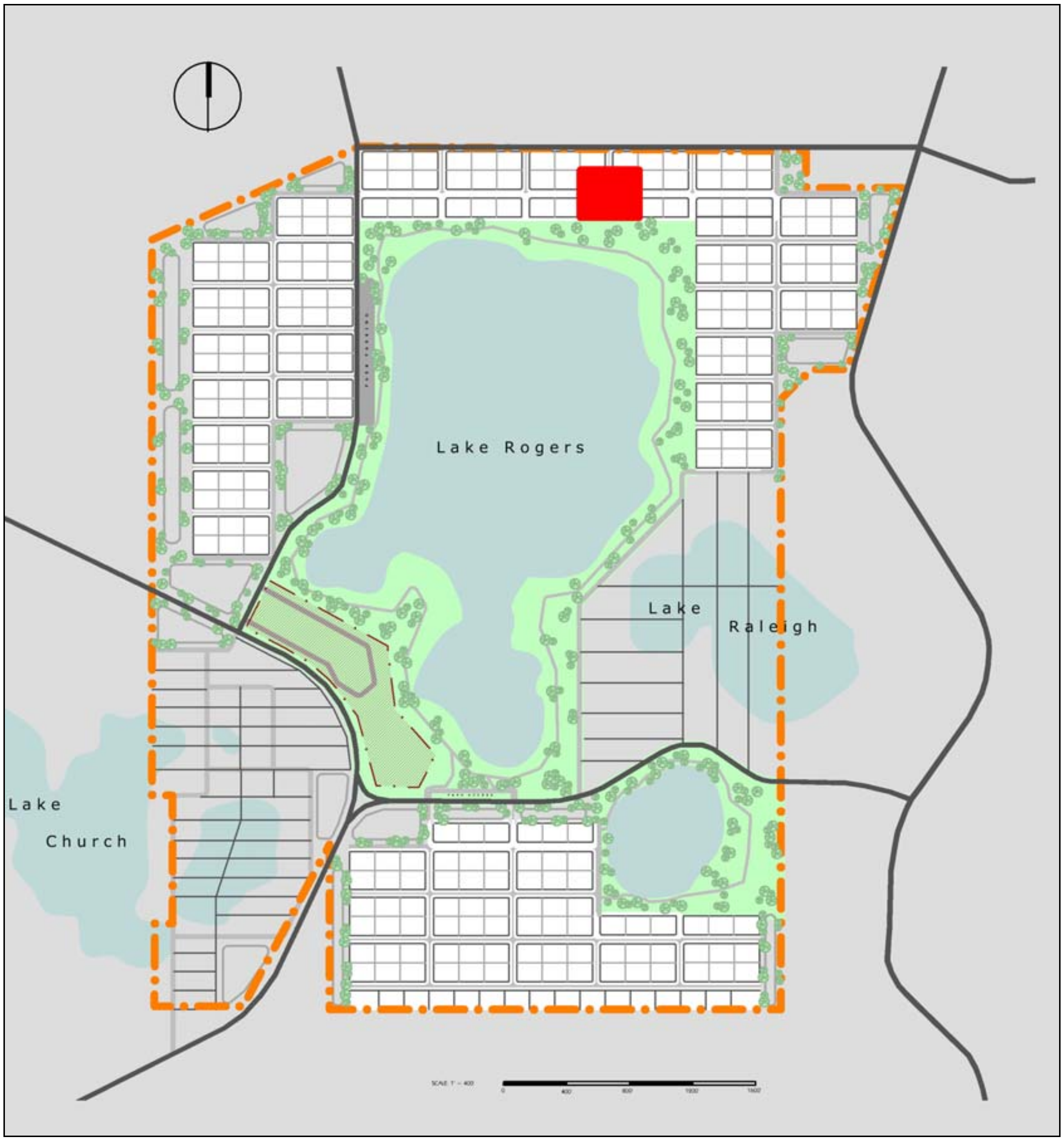


Fig.45 Master plan.

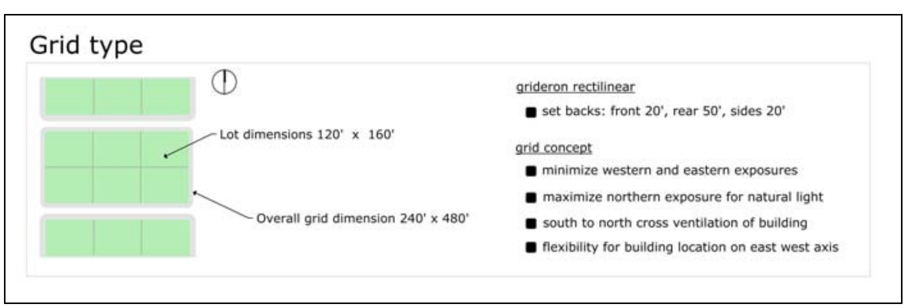


Fig.46 Proposed grid and setbacks

The proposed grid type was developed to provide the best alignment possible for the use of photovoltaic technology as the main source of energy for the community. The grid also provides a strong interaction with the public park and allows pedestrian connectivity through the park to the transport hub. Minimizing environmental impact is very important, the plan below shows the dark grid lines where vegetation will be removed to make way for roads but not disturbing the areas within the grid's blocks.

Fig.47 Environmental plan.

Chapter 7 – Prototype Residence Design Concept

The residential design concept is based on sun exposure and air circulation in order to minimize energy consumption and achieve a sustainable design. The east west alignment of the grid and lots allows a longer daily exposure to the sun and thus gaining more insolation on the photovoltaic arrays. This alignment also provides the opportunity to minimize western and eastern walls and thus glazing exposures and reducing heat gain during the summer. The larger northern exposure provides for free natural light throughout the year and the wide southern exposure provides for the winter heat gain when necessary.

Vernacular Concept

The dog trot vernacular typology was selected mainly because of its strong engagement with outside spaces and good air circulation.

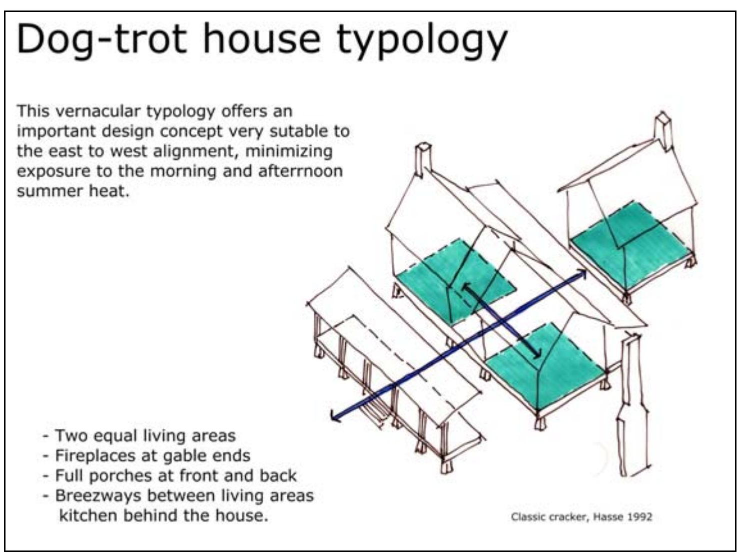


Fig.48 Dog-trot typology.

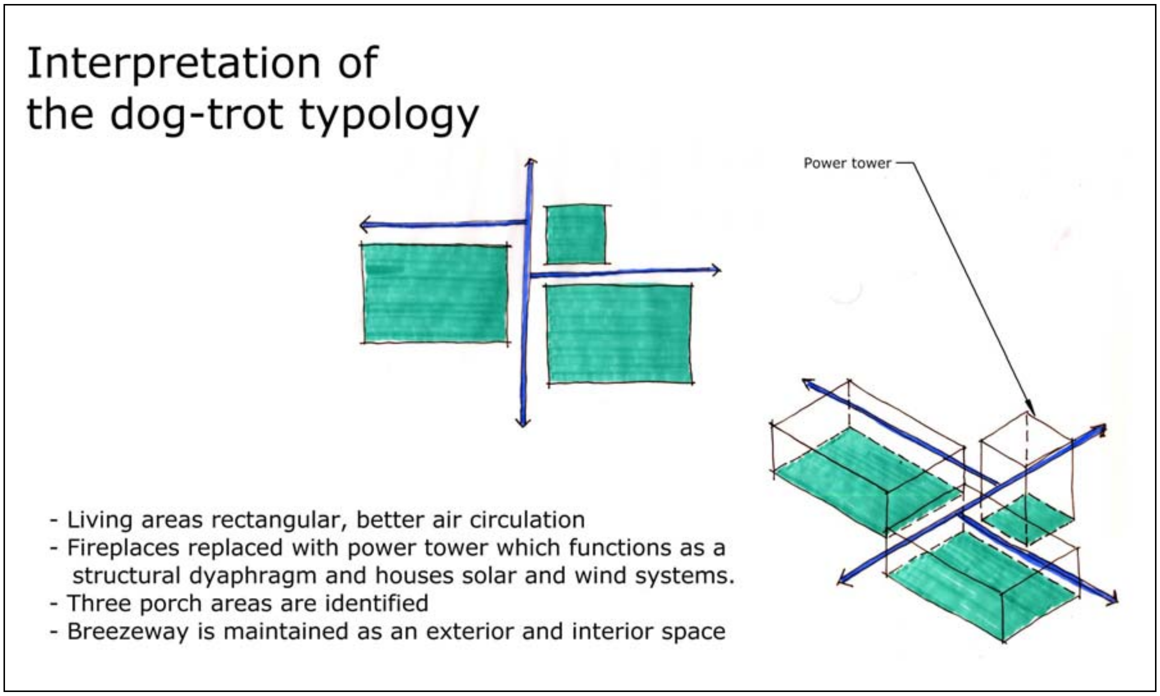
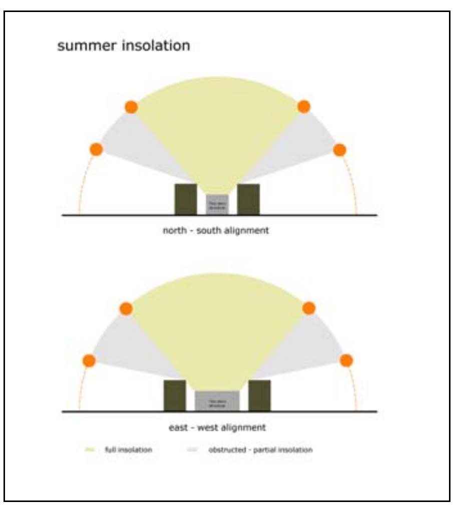


Fig.49 Interpretation of typology.

Insolation Concept

If the site provides the opportunity for an east west alignment solar exposure will be maximized resulting in a more efficient design.



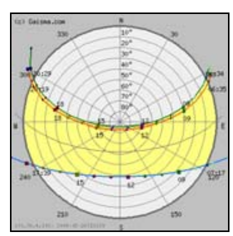


Fig.50 Odessa insolation.

Fig.51 Alignment comparison.

Conceptual Sketch Model

This sketch model shows one of the alternatives for the integration of stationary and adjustable photovoltaic elements.

Fig.52 Sketch model North East perspective.

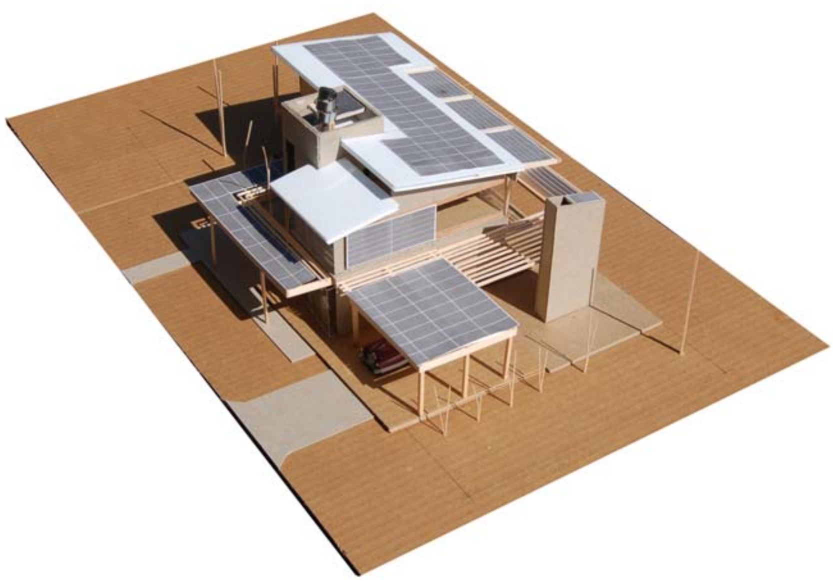


Fig.53 Sketch model North West perspective.

Corner Condition and Site

A corner condition shows how a the same residential typology performs aesthetically because of alignment. Each corner shows a different facade of the building since the residence is not built on the concept of a front or rear but for solar alignment. The ideal condition is to have different architectural concepts for each corner lot, nevertheless efficiency can show variety from a street perspective when a grid system is used.

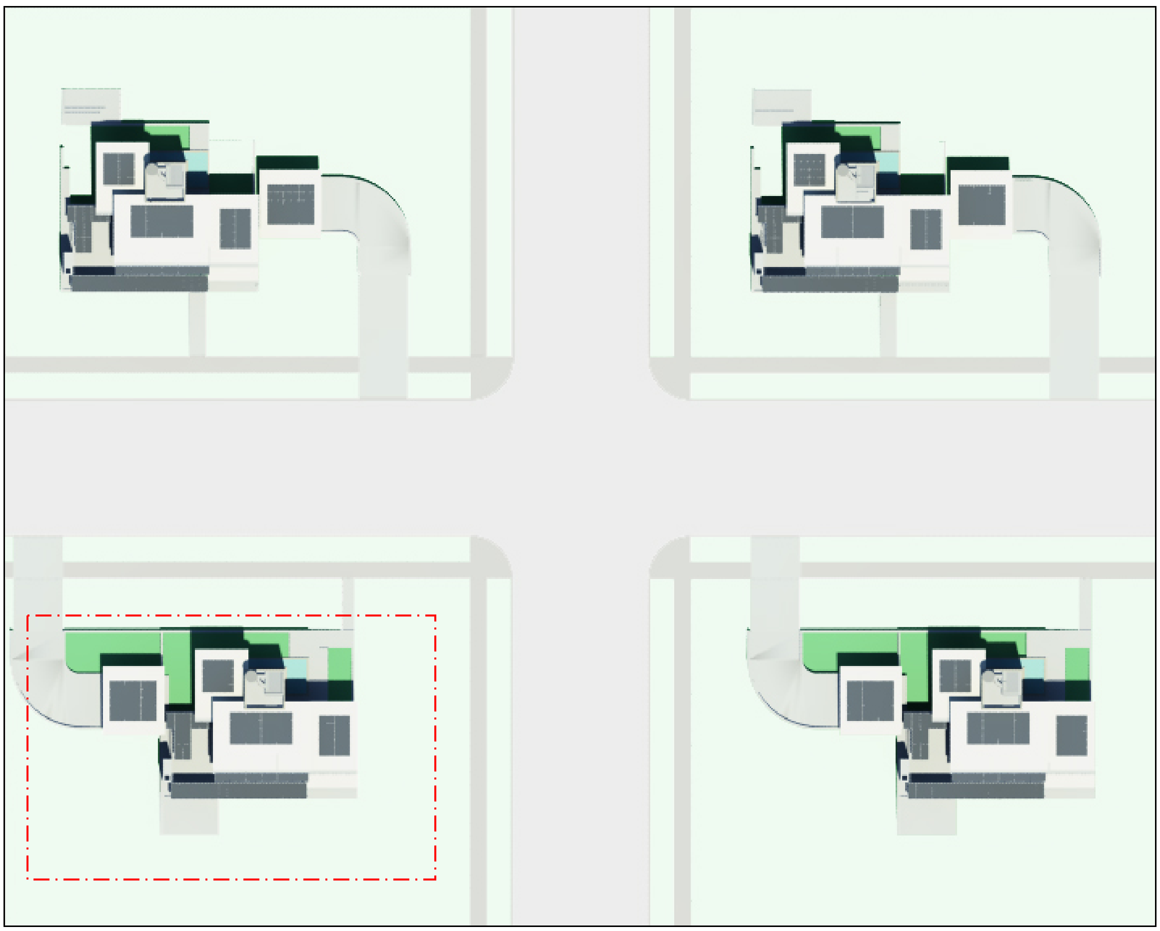


Fig.54 Corner condition with minor changes in home layouts. Red outline shows prototype site.

Site and Floor Plans

The floor plan design is not the major priority of this study, in general the floor plans are site specific. In this case the site is just a rectangular lot developed from a grid study and alignment concepts. In a real condition the floor plan lay out will accommodate to the real natural setting of the site. Nevertheless the floor plans intent is to maximize natural lighting from the northern exposure, allow for natural ventilation and provide views to a lake located to the south side of the lot.

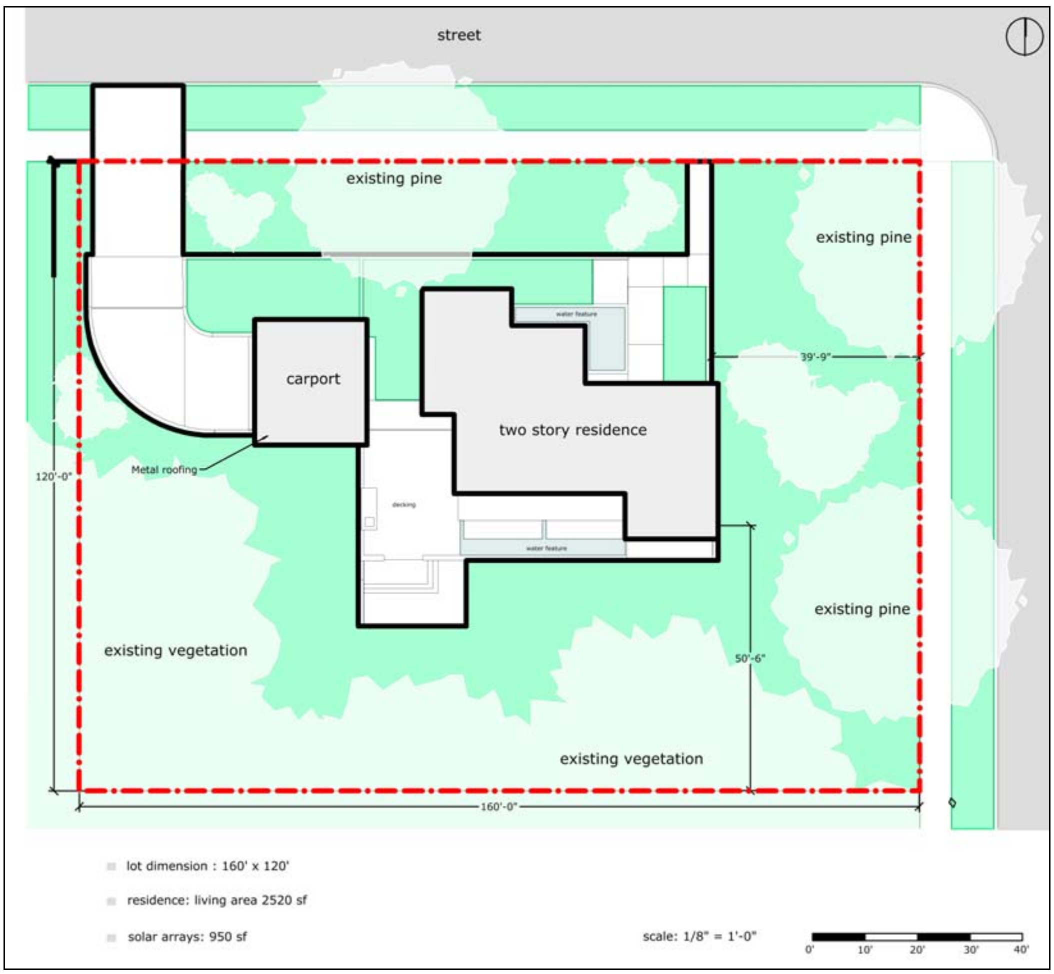


Fig.55 Site Plan

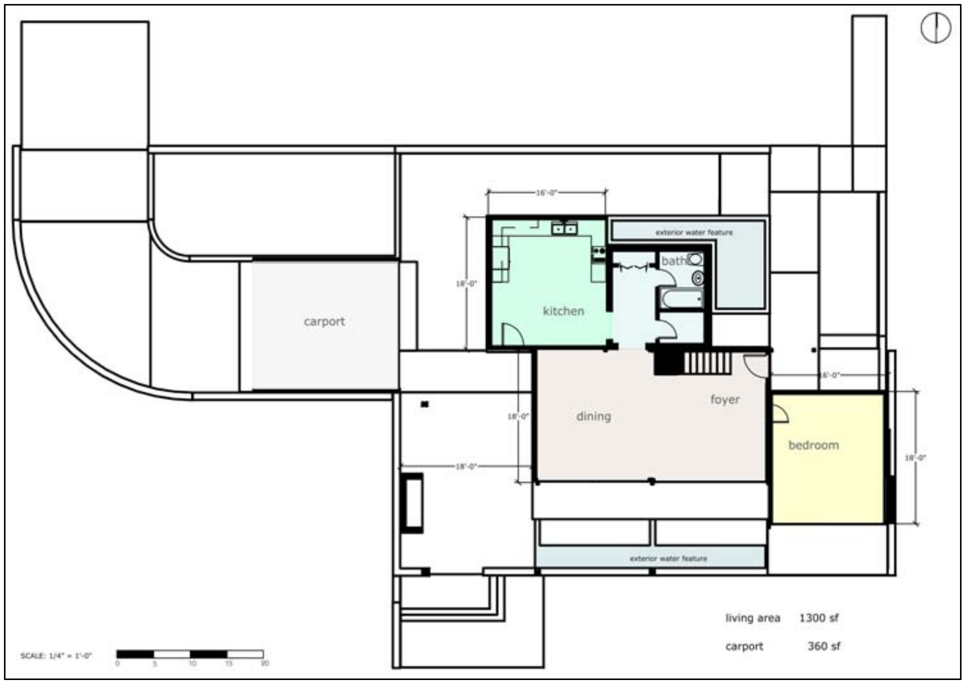


Fig.56 First floor.

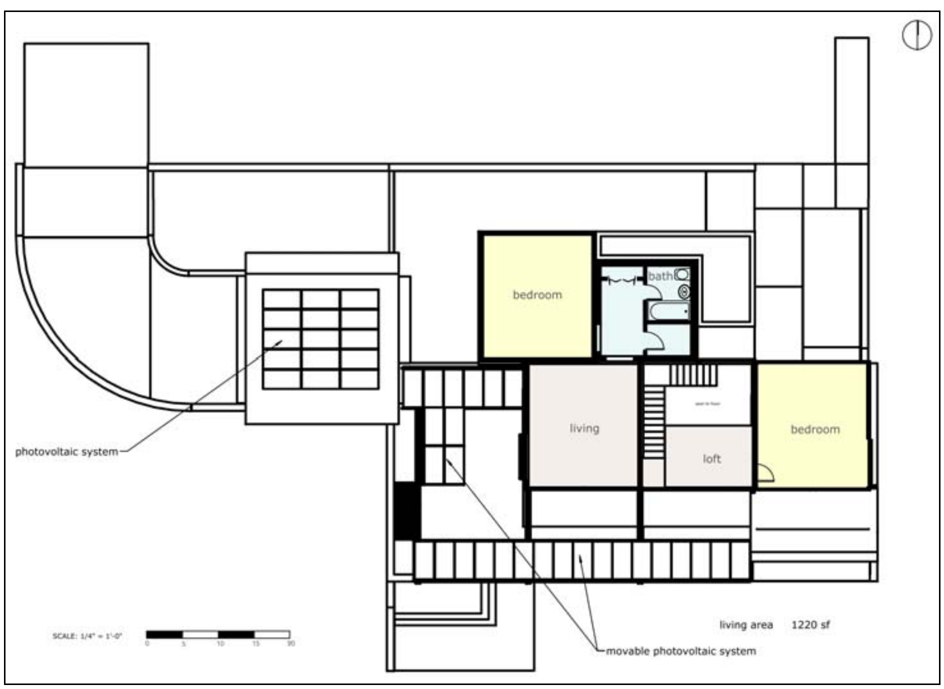


Fig.57 Second floor.

Sections

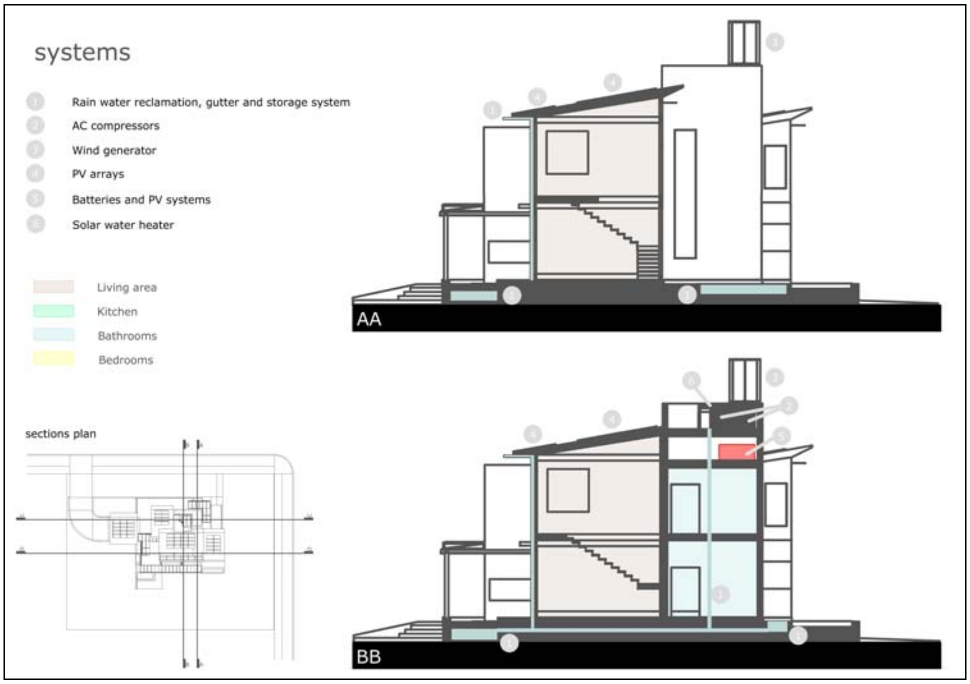


Fig.58 Sections AA – BB

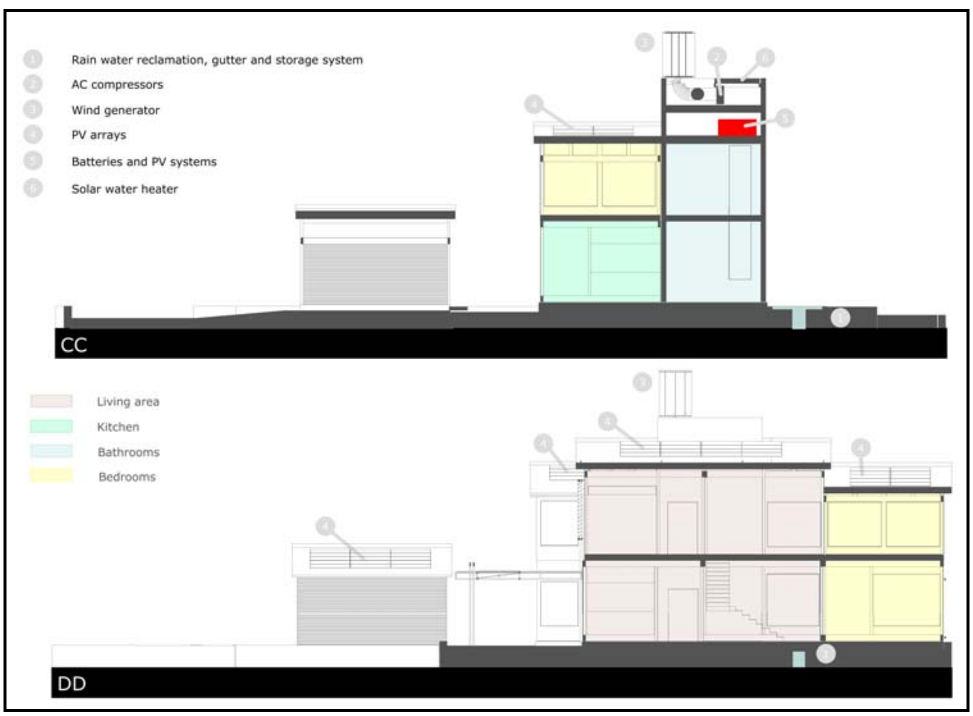


Fig.59 Sections CC - DD

Systems

Even though this research is based on integrating solar technology to design other considerations have to be taken during the design process to conserve energy and to minimize the impact on the environment.

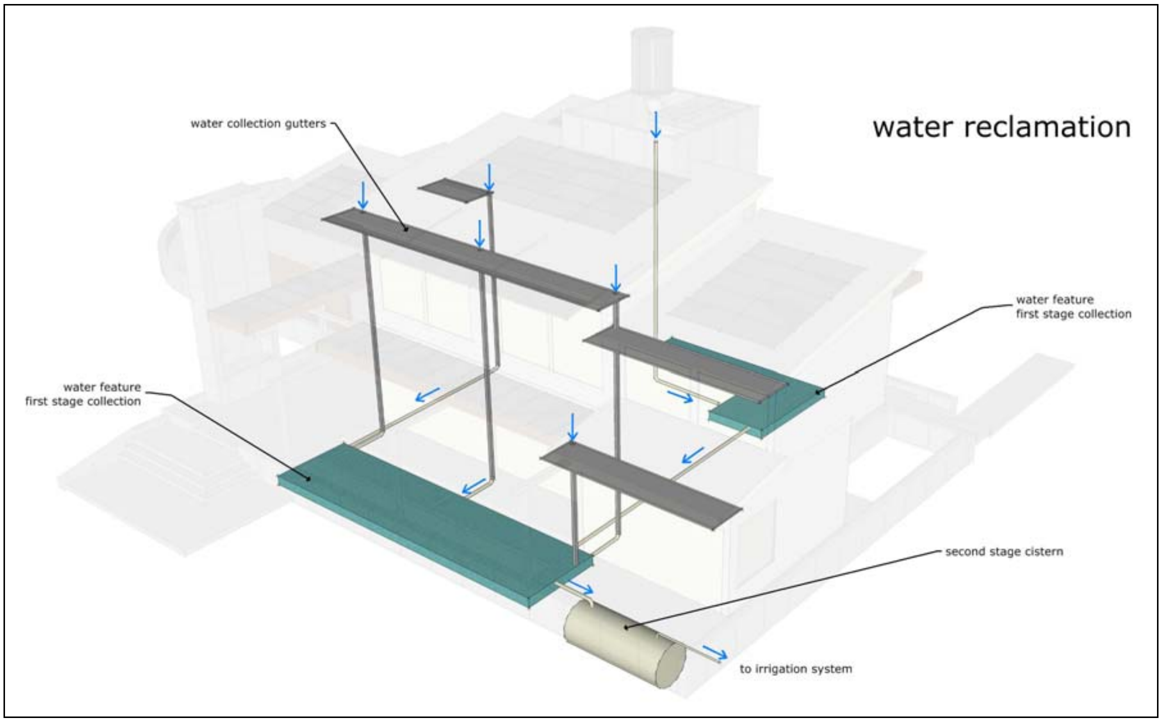


Fig.60 Water reclamation, to minimize retention areas for water runoff.

Instead of elevating the grade to meet code requirements at the entire site foundation walls will elevate the home site only thus minimizing deforestation and leaving the natural grade level around the homes. Also roof run off from rain water will be captured and stored for irrigation thus minimizing erosion and flooding downstream.

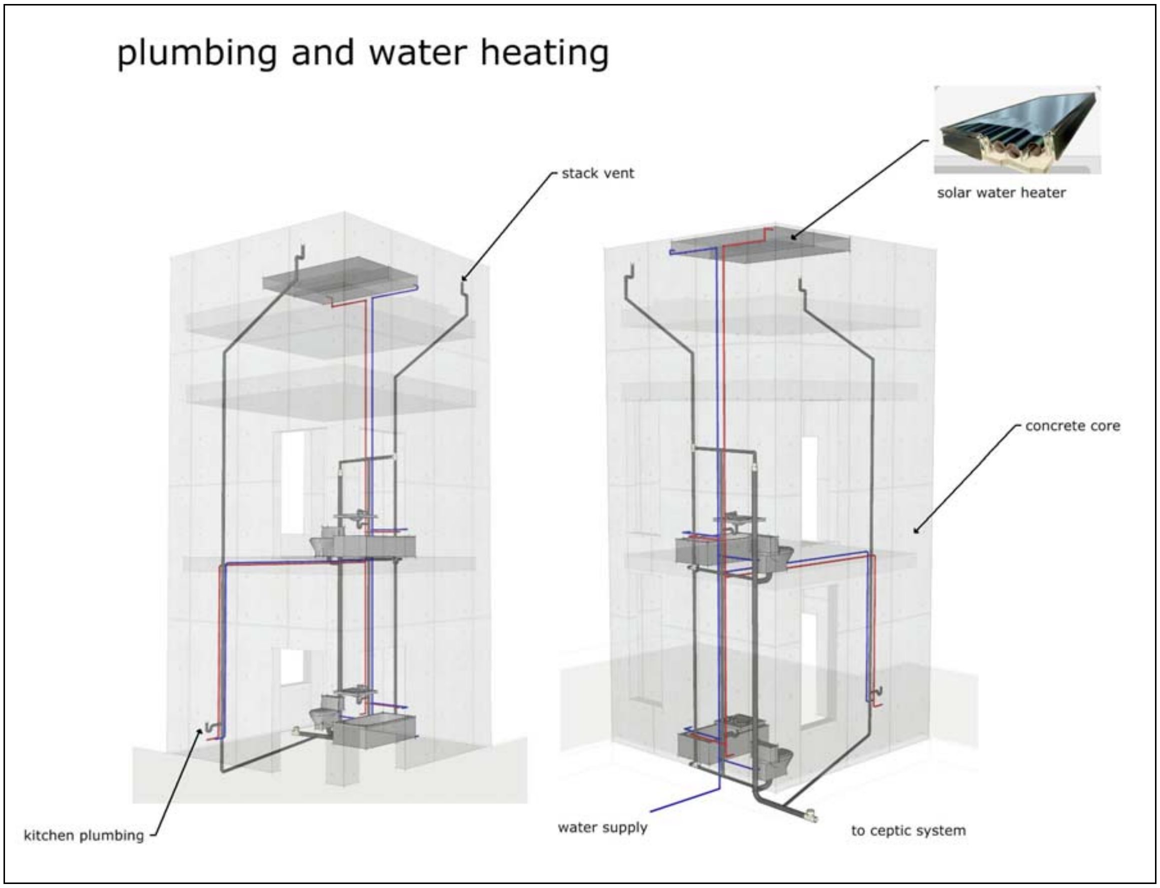


Fig.61 The plumbing is aligned vertically.

The plumbing system is integrated into the central concrete tower to minimize cost and to conceal the solar water heaters behind the parapet walls. The bathrooms are also located within the tower thus minimizing waste of hot water. The core tower fulfills two main roles a structural one to control shear forces for the whole home and as storage area for the photovoltaic system, air conditioning compressors and the solar water heaters.

The solar arrays are separated into two categories, stationary modules on the roof and adjustable modules over porches and windows. The details on adjustable modules were covered earlier, this chapter will cover the locations of the modules and how they interact with the residence depending on the seasons.

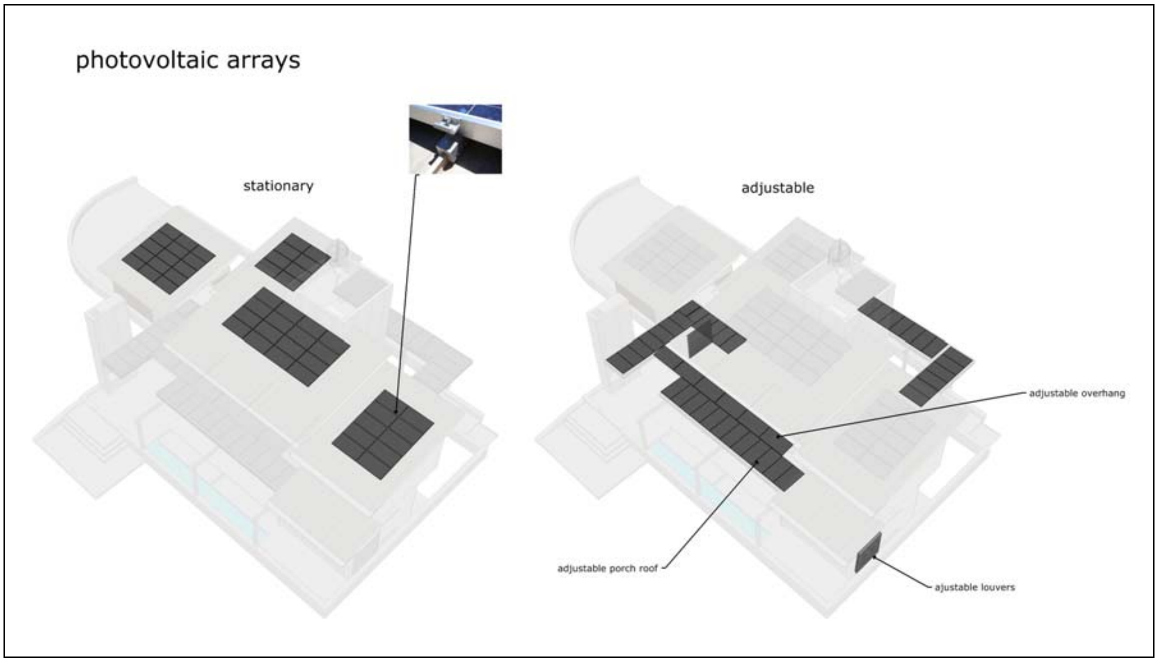


Fig.62 Location of stationary and adjustable solar arrays.

Integrating Passive Design Concepts with PV Systems

The following graphic representations show an example of how passive cooling and heating concepts can be integrated with photovoltaic technology. These adjustable components can provide more efficiency and simultaneously create changing exterior spaces for different seasons, thus engaging the outdoors.

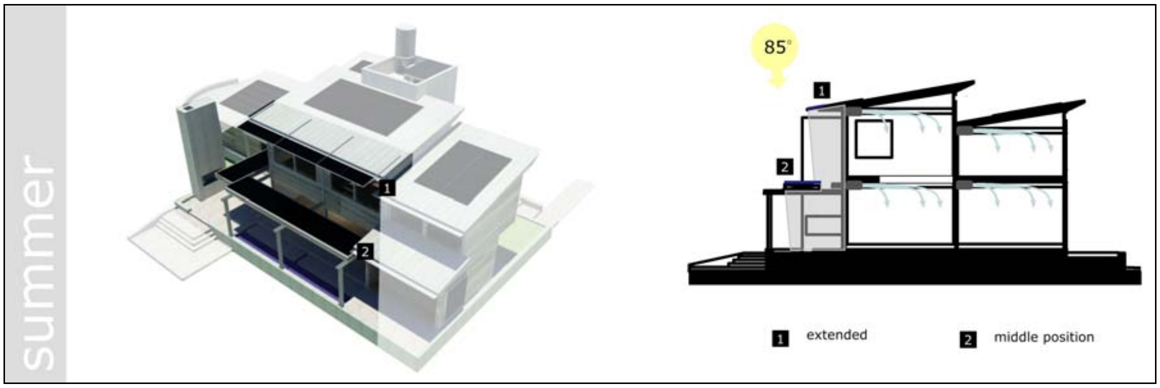


Fig.63 Summer setting of adjustable arrays. Solar azimuth at 85 degrees.

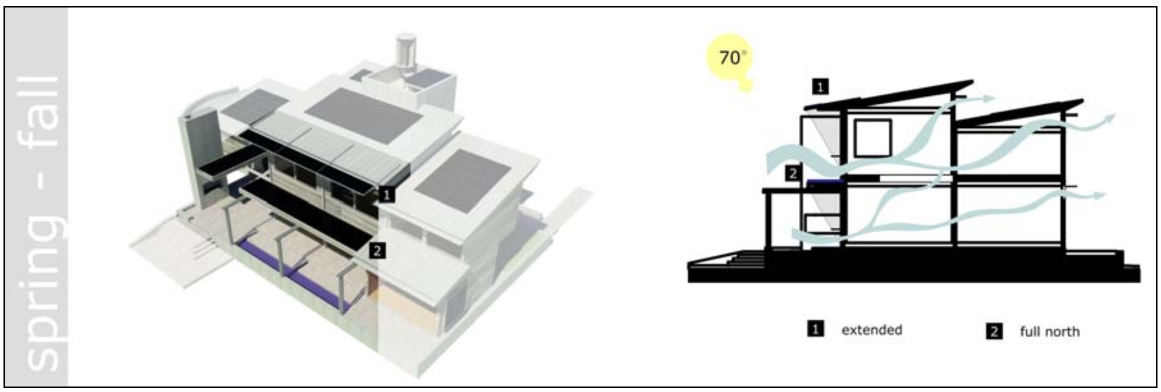


Fig.64 Spring and fall setting of adjustable arrays. Solar azimuth at 70 degrees.

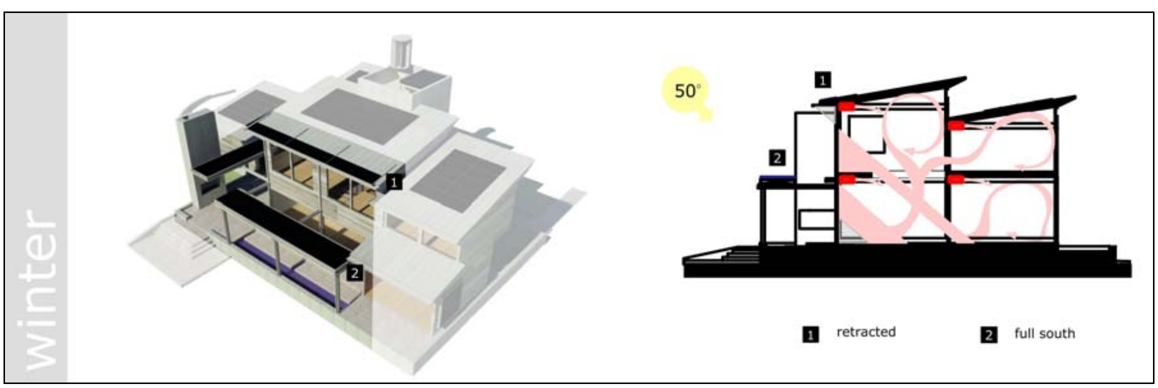


Fig.65 Winter setting of adjustable arrays. Solar azimuth at 50 degrees.

Chapter 8 – Structural Concept and Elevations

Tower Concept

The concrete tower provides the strength to counteract the shear forces present in a subtropical environment during hurricane season. Prefabricated metal modular components are then attached to the tower. This allows for fast and practical assembly.

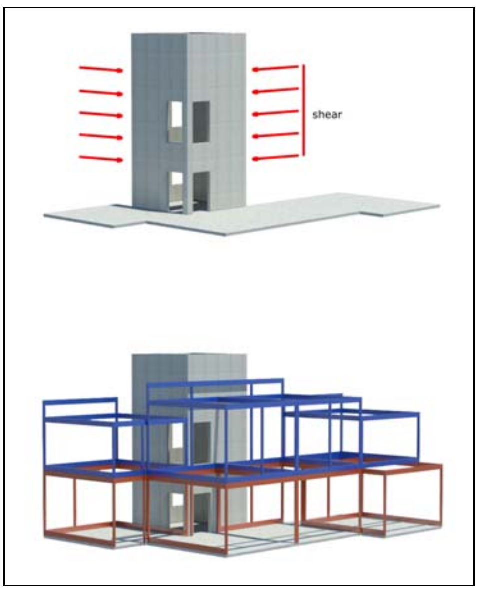


Fig.66-67 Structural concept and construction process.

The tower is not strictly a structural component but it also houses the main components of a solar residence. Systems for mechanical cooling, batteries and converters for the photovoltaic array system, solar water heaters, plumbing and wind turbines.

Final Model

Model making is a key component of a good design, the following photographs depict the final model at various stages of construction, concrete elements are represented in dark wood.

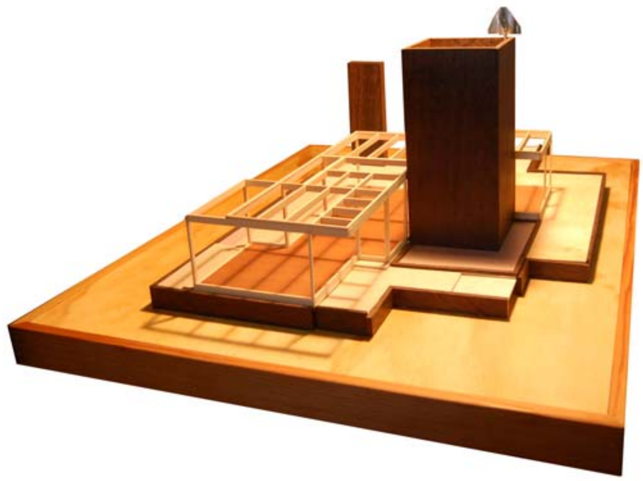


Fig.68 Model east perspective.

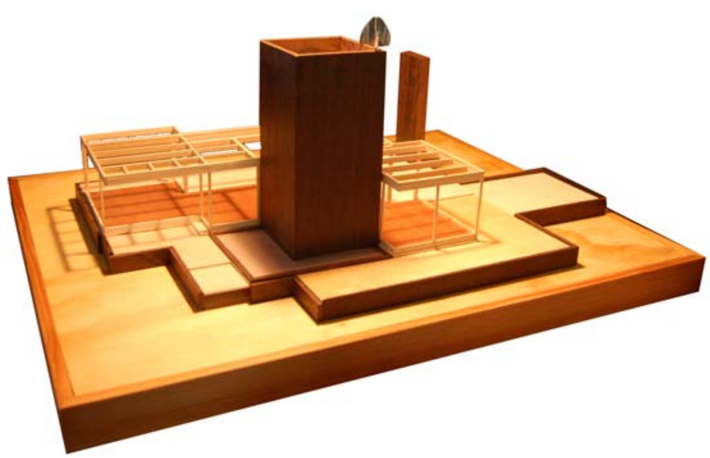


Fig.69 Model north perspective.

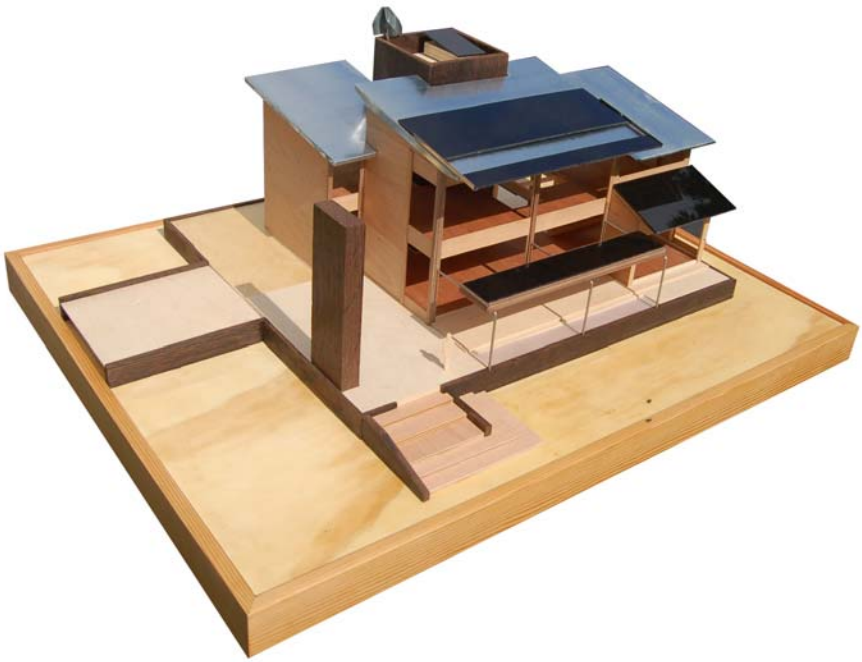


Fig.70 Model south west perspective in winter mode.

Fig.71 Model south west perspective summer mode.

Elevations

In order to maintain the natural grade and vegetation around the home this prototype residence was elevated to meet the required slab elevation by the use exposed foundation walls. Glazing to the east is minimized to reduce heat gain and also is protected with a cantilever at the entrance and with photovoltaic louvers.

Fig.72 East elevation.

Most glazing is on the northern exposure to minimize heat gain and allow for plenty of natural light to minimize on artificial light during the day. Top windows allow for excellent ventilation during fall and spring months.

Fig.73 North elevation.

To maximize the view to the lake and park located to the south a large amount of glazing is provided on the southern exposure. This also allows very good natural ventilation conditions for the fall and spring seasons.

Fig.74 South elevation.

Glazing to the west is kept to a minimum and adjustable photovoltaic louvers are used to protect the opening. The large BBQ tower also acts a shelter from the hot western sun during the summer months.

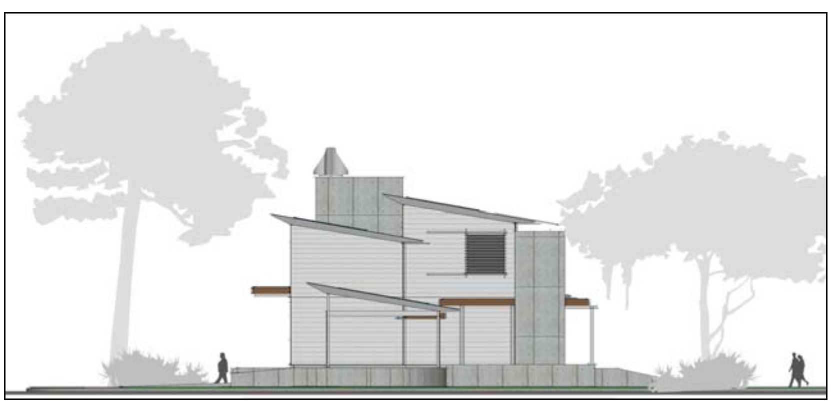


Fig.75 West elevation.

Perspectives

An important design strategy is to minimizing the exposure of solar panels from the street level. This rendering also shows the permeability to air circulation of the residence on its south to north axis.

Fig.76 South west perspective. Adjustable arrays set for winter allowing heat gain to interior.

Fig.77 View to west from south side of home. Adjustable array set for winter conditions.

Fig.78 View to south. Engaging the outdoors. Array settings to winter conditions.

Conclusion

This research has observed that solar technology has reached a level of efficiency through which sustainable residential development is achievable. Solar energy is an enviable asset that humid subtropical climates enjoy but unfortunately do not use enough. Creative designers have been capable to achieve sustainability by incorporating solar energy as a main component of their designs, even in climates where solar energy is not readily available as in Florida and other subtropical areas.

Combining solar energy and vernacular design strategies allows the architect to engage the local climate and use it as a design generator. Our climate must be engaged and thoroughly enjoyed and not just looked at through a tightly sealed window. Solar energy has an overwhelming role in Florida's climate and it should be without doubt a major determinant during the design process.

Attaching photovoltaic components to the skin of a structure is a very simple task in today's highly technological environment, it is just a matter of applying a methodology to our designs and incorporate this readily available energy source early in the design process. This research developed few components that combine energy sources into actual structural elements that engage a design by complimenting exterior and interior spaces.

The prototype developed in this research has proven that basic vernacular concepts will provide an excellent guideline for conservation and minimization of energy use. The goal is to reach the perfect balance of conservation and maximum use of available solar energy at the site. A good integration of natural light, air circulation and mechanical cooling will reduce the size of the photovoltaic system.

Solar alignment is without doubt the key to a successful design, and this research has elaborated on the principles of alignment through history. Technological evolution is forcing the basic alignment concepts to evolve as well. A thorough site analysis must be conducted before a street alignment is laid out in order to assure maximum insolation to most home sites.

Design strategies for an efficient integration of solar technology to residential designs are unlimited. It is the architect's responsibility to recognize the benefits of the sun's energy in a given climate and then integrate these benefits into the inner fiber of his design.

References

Archer, John. 2005. *Architecture and suburbia : From english villa to american dream house, 1690-2000*. Minneapolis: University of Minnesota Press.

Asimakopoulos, D., D. N. Asimakopoulos, M. Santamouris, and M. Santamouris. 1996. *Passive cooling of buildings*. London: James & James.

Baird, George. 2001. *The architectural expression of environmental control systems*. London ; New York: Spon Press.

Bankston, Charles A. and Jeffrey Cook. 1989. *Passive cooling*. Solar heat technologies ; 8. Cambridge, Mass.: MIT Press.

Bansal, N. K., Gerd Hauser, and Gernot Minke. 1994. *Passive building design : A handbook of natural climatic control*. Amsterdam ; New York: Elsevier Science B.V.

Bay, Joo Hwa and Boon Lay Ong. 2006. *Tropical sustainable architecture : Social and environmental dimensions*. Oxford ; Burlington, MA: Architectural Press.

Brown, Robert D. and Terry J. Gillespie. 1995. *Microclimatic landscape design : Creating thermal comfort and energy efficiency*. New York: John Wiley & Sons.

Castagnoli, F. 1971. *Orthogonal town planning in antiquity. [translated from the italian*Cambridge, Mass., MIT Press.

Chiras, Daniel D. 2002. *The solar house : Passive solar heating and cooling*. White River Junction, VT: Chelsea Green Pub.

Cowan, Henry J. 1991. *Handbook of architectural technology*. New York: Van Nostrand Reinhold.

Crosbie, Mike. 1994. *Green architecture : A guide to sustainable design*. Rockport, Mass; Washington, D.C.: Rockport Publishers; distributed by the American Institute of Architects Press.

Domin, Christopher and Joseph King. 2002. *Paul rudolph : The florida houses*. 1st ed. New York: Princeton Architectural Press.

Fathy, Hassan, Walter Shearer, and Abd al Raḥmān Sulṭān. 1986. *Natural energy and vernacular architecture : Principles and examples with reference to hot arid climates*. Chicago: Published for the United Nations University by the University of Chicago Press.

Friedman, Avi. 2002. *Planning the new suburbia : Flexibility by design*. Vancouver: UBC Press.

Fry, Maxwell, Jane Drew, and Jane Drew. 1982. *Tropical architecture in the dry and humid zones*. 2d ed. Malabar, Fla.: R.E. Krieger Pub. Co.

Galloway, Terry. 2004. *Solar house : A guide for the solar designer*. Oxford ; Burlington, MA: Architectural Press.

Garg, Vijay K. 1998. *Applied computational fluid dynamics*. Mechanical engineering (marcel dekker, inc.) ; 116. New York: Marcel Dekker.

Givoni, Baruch. 1994. *Passive and low energy cooling of buildings*. New York: Van Nostrand Reinhold.

Goad, Philip and Anoma Pieris. 2005. *New directions in tropical asian architecture*. Singapore; North Clarendon, VT: Periplus; Tuttle distributor.

Haase, Ronald W. 1992. *Classic cracker : Florida's wood-frame vernacular architecture*. 1st ed. Sarasota, Fla.: Pineapple Press.

Hausladen, Gerhard, Petra Liedl, John O'Toole, and Michael de Saldanha. 2008. *Climateskin : Building-skin concepts that can do more with less energy*. Basel ; Boston: Birkhäuser.

International Energy Agency Solar Heating and Cooling Programme and United States Dept. of Energy. 1989. *Passive and hybrid solar low energy buildings microform : Design context*. Design information booklet ; no. 2. Paris, France; Washington, D.C.?: International Energy Agency, Solar Heating and Cooling Program; U.S. Dept. of Energy; Supt. of Docs., U.S. G.P.O., distributor.

Jencks, Charles and Karl Kropf. 1997. *Theories and manifestoes of contemporary architecture*. Chichester, West Sussex: Academy Editions.

Koch Nielsen, Holger. 2002. *Stay cool : A design guide for the built environment in hot climates*. London, UK: James & James.

Kok, Hans, Michael J. Holtz, International Energy Agency Solar Heating and Cooling Programme, and United States Dept. of Energy. 1990. *Passive and hybrid solar low energy buildings microform : Passive solar homes, case studies*. Design information booklet ; no. 6. Paris; Washington, D.C.: International Energy Agency; Supt. of Docs., U.S. G.P.O., distributor.

Le Corbusier. 1967. *The radiant city; elements of a doctrine of urbanism to be used as the basis of our machine-age civilization*. New York: Orion Press.

Lechner, Norbert. 1991. *Heating, cooling, lighting : Design methods for architects*. New York: Wiley.

Lefaivre, Liane, Bruno Stagno, and Alexander Tzonis. 2001. *Tropical architecture : Critical regionalism in the age of globalization*. Chichester ; New York; The Netherlands: Wiley-Academic; C. Fonds.

Maguire, Robert A. 1974. *Gogol from the twentieth century; eleven essays. selected, edited, translated, and introduced*. Princeton, N.J.: Princeton University Press.

Marshall, Stephen. 2005. *Streets & patterns*. 1st ed. New York: Spon.

McHarg, Ian L. 1992. *Design with nature*. 25 anniversary ed. New York: J. Wiley.

Merrilees, Doug, Evelyn V. Loveday, and Ralph Wolfe. 1980. *Low-cost pole building construction*. Charlotte, Vt.: Garden Way Pub.

Morris, A. E. J. 1979. *History of urban form : Before the industrial revolutions*. 2d ed. New York: Wiley.

National Solar Heating and Cooling Information Center, Franklin Institute Laboratories for Research and Development, David Haviland, David S. Haviland, Walter Kroner, WalterM Kroner, National Solar Heating and Cooling Information Center, et al. 1977. *Passive design ideas for the energy conscious architect*. Rockville, Md.: Dept. of Housing and Urban Development.

National Solar Heating and Cooling Information Center, Franklin Institute Laboratories for Research and Development, David Haviland, David S. Haviland, Walter Kroner, New York State Energy Research and Development Authority, Rensselaer Polytechnic Institute, United States Dept. of Energy, and United States Dept. of Housing and Urban Development. 1977. *Passive design ideas for the energy conscious builder*. Rockville, Md.: Dept. of Housing and Urban Development.

Nesbitt, Kate. 1996. *Theorizing a new agenda for architecture : An anthology of architectural theory 1965-1995*. 1st ed. New York: Princeton Architectural Press.

Pope, Albert. 1996. *Ladders*. Architecture at rice university ; 34. Houston, Tex.; New York: Rice School of Architecture; Princeton Architectural Press.

Reps, John William. 1969. *Town planning in frontier america*. Princeton, N.J: Princeton University Press.

Steele, James. 2005. *Ecological architecture : A critical history*. London: Thames & Hudson.

Stitt, Fred A. 1999. *Ecological design handbook : Sustainable strategies for architecture, landscape architecture, interior design, and planning*. McGraw-hill handbooks. London ; New York: McGraw-Hill.

United States Conservation and Renewable Energy Inquiry and Referral Service. 1986. *Passive cooling*. FS (united states. conservation and renewable energy inquiry and referral service) ; 186. [2 ., Dec. 1985] ed. Silver Spring, MD: U.S. Dept. of Energy, Conservation and Renewable Energy Inquiry and Referral Service.

United States Dept. of Energy Heating & Cooling Research & Development Branch. 1979. *Interim report : National program plan for passive and hybrid solar heating and cooling*. Washington; Dept. of Energy, Assistant Secretary for Conservation and Solar Applications, Heating & Cooling Research & Development Branch; for sale by the Supt. of Docs., U.S: Govt. Print. Off.

Vale, Brenda and Robert James Dennis Vale. 2000. *The new autonomous house : Design and planning for sustainability*. New York, N.Y.: Thames & Hudson.

Van der Ryn, Sim and Stuart Cowan. 1996. *Ecological design*. Washington, D.C.: Island Press.

Wolfe, Ralph, Peter Clegg, and Peter Clegg. 1979. *Home energy for the eighties*. Charlotte, Vt.: Garden Way Pub.

Yudelson, Jerry. 2008. *The green building revolution*. Washington: Island Press.