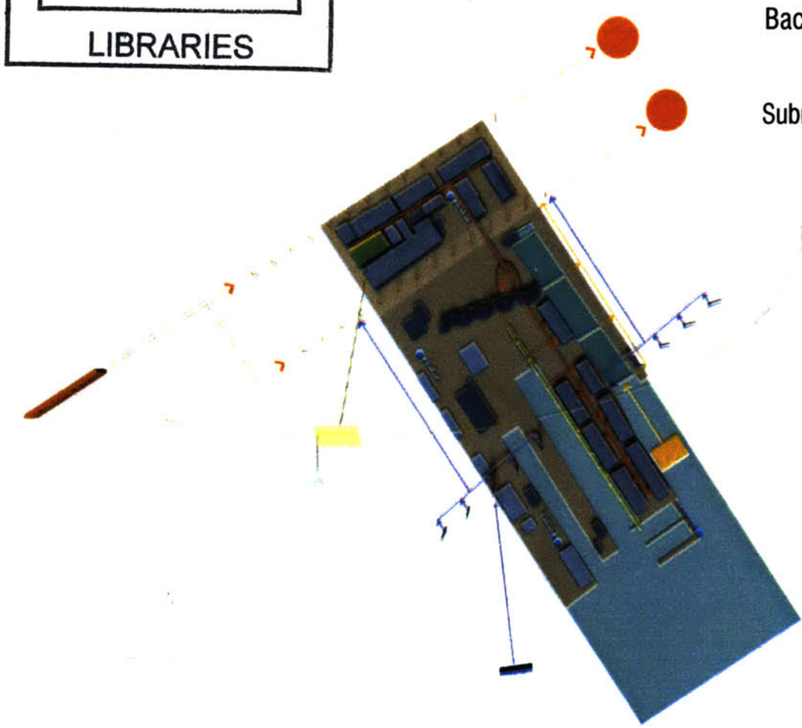
A RE-CONNECTION

Modeling Built Works After Natural Systems



Laurie Anne Griffith
Bachelor of Environmental Design, May 1996, Miami University of Ohio.

Submitted to the Department of Architecture in partial fulfillment of the requirements for the Degree of

Master of Architecture
at the Massachusetts Institute of Technology
February 2001

signature of author: ______________________
Laurie A. Griffith — Department of Architecture MIT
19 December 2001

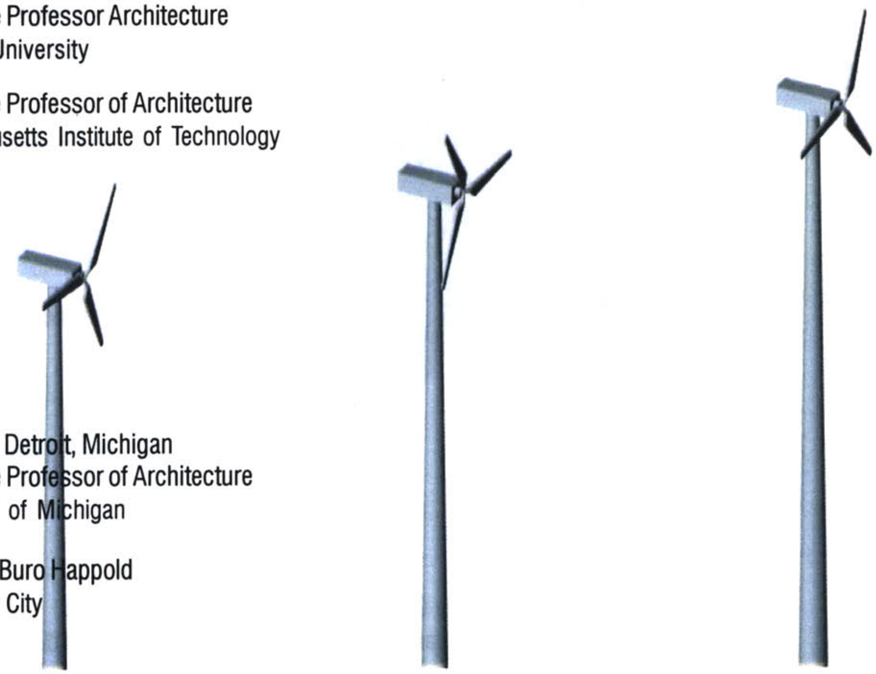
certified by: ______________________
John E. Fernandez — Assistant Professor Building Technologies
Thesis Advisor

accepted by: ______________________
Roy Strickland — Principal Research Scientist in Architecture
Chairman Departmental Committee on Graduate Students

Readers:

Michelle Addington — Associate Professor Architecture
Harvard University

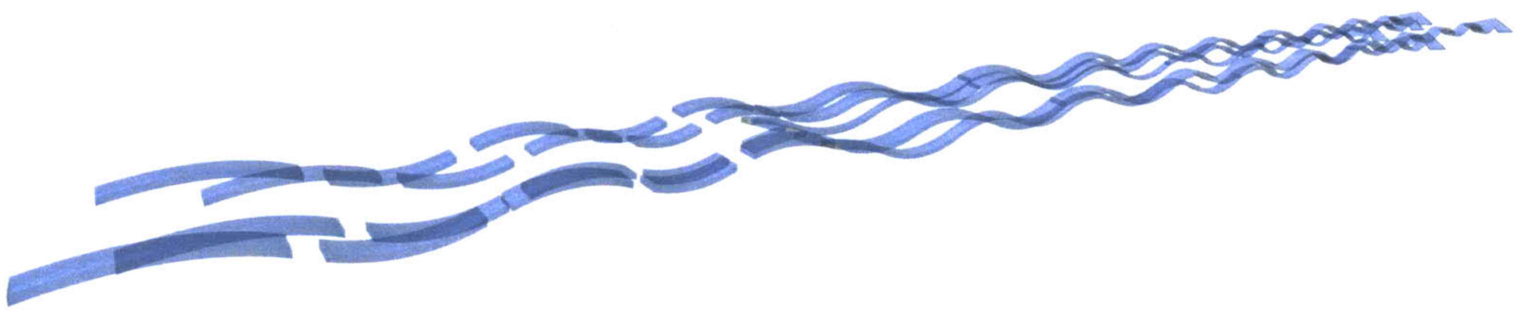
Andrew Scott — Associate Professor of Architecture
Massachusetts Institute of Technology



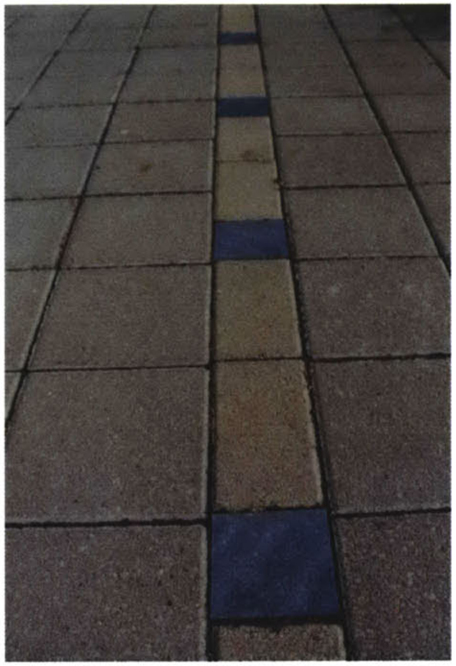
Members of final review:

Annette LeCuyer — Architect, Detroit, Michigan
Associate Professor of Architecture
University of Michigan

Tony McLaughlin — Engineer, Buro Happold
New York City



much appreciation goes to... rob z, mom & dad g, mark j, john f, sergio s, michelle a, andrew s, mrs. marvin e. goody



CHAPTERS

6

A RE-CONNECTION
Modeling Built Works After Natural Systems

by Laurie Anne Griffith

Submitted on 19 January 2001 to the Department of Architecture in partial fulfillment of the requirements for the Degree of Master of Architecture from the Massachusetts Institute of Technology.

ABSTRACT

The constructed world is full of built works that consume energy and emit unusable waste. This is fostered by the act of 'masking' the true situation and the lack of imbedded feedback, associated with the destructive operations of centralized, unintelligent systems. This inefficient organization encourages the destructive processes of production and consumption to remain unaccountable, broadening the disparity between the built environment and the natural ecosystem. Similarly, there is an increasing social disconnection between people and the natural environment, signified by less time spent outdoors and particular advancements in building technology.

In order to counter this trend, this thesis takes the position that it is imperative to become more ecologically and socially interconnected. To accomplish this, it is necessary to draw from the efficiency and interdependency of the natural environment; therefore, built systems must model themselves after natural systems. In response to this need, I have proposed built works as net *producers* of energy, inherently giving to the livelihood of the whole, and participating in an expressed, dynamic built world *eco-system/place*.

This intention was initially addressed by establishing criteria to re-define the relationships between existing built works and energy production, motivated by the notions of a whole-systems methodology <3.1>, renewable energy production and recycling <3.2>, and social involvement and influence <3.3>. The design intention was then executed by focusing on both energy flows and available renewable energy sources, coupled with a process of un-masking and re-connecting in order to heighten awareness, respect, and delight in the context of the built environment. As the set of criteria was conceived, a 'typical' urban site was chosen on which to integrate and test these intentions. The following design exploration addresses the means employed to *transform the existing site into an energy producing system of entities, and an ecologically and socially interconnected built place.*

Thesis advisor: John E. Fernandez   Assistant Professor Building Technologies

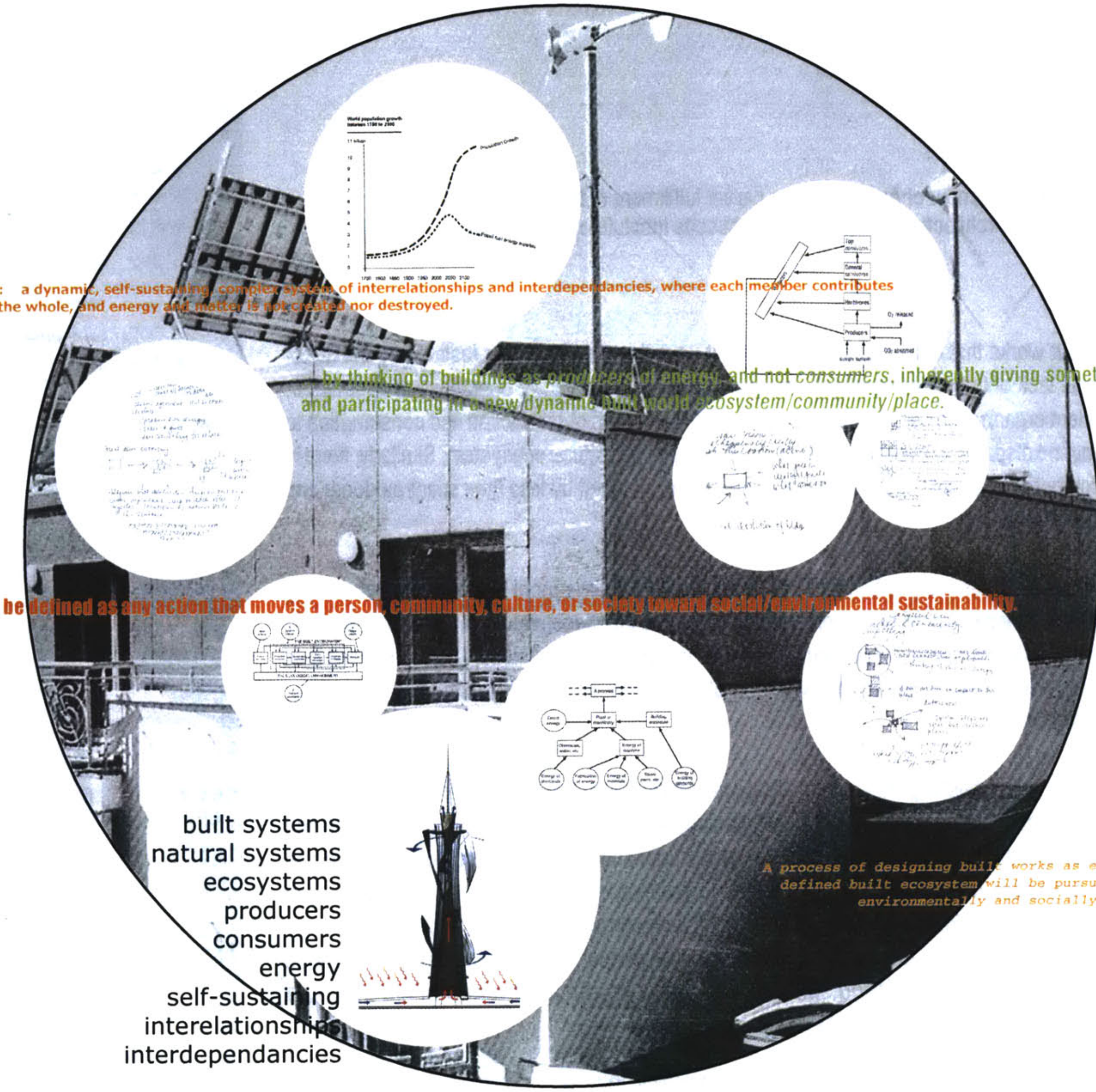
built works: *any construct that is designed and built by humans, specifically that has mechanized parts that require some form of energy to operate. Examples in the context of this thesis include buildings and infrastructure.*

system: *an assemblage of a number of parts adjusted and related as a connected whole in a manner to create a chain of mutual dependencies.*

1.0

ecosystem: a dynamic, self-sustaining, complex system of interrelationships and interdependancies, where each member contributes in some way to the whole, and energy and matter is not created nor destroyed.

by thinking of buildings as *producers* of energy, and not *consumers*, inherently giving something to the good of the whole, and participating in a new dynamic built world *ecosystem/community/place.*



Progress could be defined as any action that moves a person, community, culture, or society toward social/environmental sustainability.

built systems
natural systems
ecosystems
producers
consumers
energy
self-sustaining
interelationships
interdependancies

A process of designing built works as energy producers within a defined built ecosystem will be pursued in order to make an environmentally and socially sound place.

INTRODUCTION

How to begin

We have lived by the assumption that what was good for us would be good for the world.

We have been wrong.

We must change our lives, so that it will be possible to live by the contrary assumption that what is good for the world will be good for us.
And that requires that we make the effort to know that world and learn what is good for it.

We must learn to cooperate in its processes, and to yield to its limits.
But even more important, we must learn to acknowledge that the creation is full of mystery; we will never clearly understand it.

We must abandon arrogance and stand in awe.
We must recover the sense of the majesty of the creation, and the ability to be worshipful in its presence.

For it is only on the condition of humility and reverence before the world that our species will be able to remain in it.

Wendell Berry, *Recollected Essays*

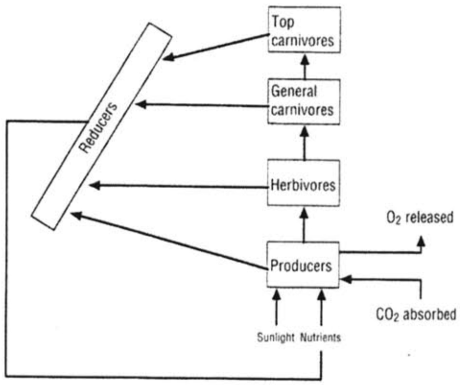


diagram of ecosystem

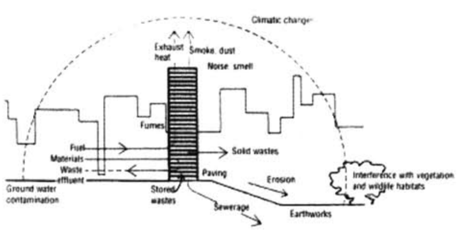


diagram of built system

why

It is my belief, that in society's current way of thinking and practice, the natural environment and the built environment share little in common. The natural environment operates within the context of the ecosystem, defined by Kenneth Yeang as a dynamic, self-sustaining, complex set of inter-relationships and interdependencies, where each member contributes in some capacity to the whole, and energy and matter is neither created nor destroyed.[1] Simply stated, the natural environment achieves a total energy loop. Conversely, the 'mindset' of the built environment chooses to be dominant over and claim independence from the natural environment.[2] It seeks to create its own artificial systems, neglects to be an equal participant of the ecosystem, and does not concern itself with contributing to the livelihood of a whole. Therefore, the built environment is a discontinuous input/waste loop.

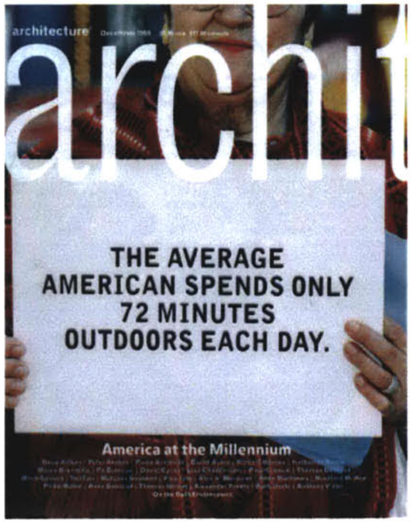
The built environment, in its attempt to 'survive' and 'progress', continues to be more destructive than sustainable towards the natural environment. Non-renewable natural resources by definition have a finite end due to the imbalance in the rate at which they are consumed, compared to the rate they are naturally formed. The waste that is produced from one part of the built environment is typically not useful to any other part, and therefore creates residues that degrade the integrity of the natural environment. It is this linear and autonomous approach that continues to be a detriment rather than an asset to the built environment, forming a 'gap' between it and the natural environment.

This disparity that exists between the natural and built environments has been greatly accelerated and exacerbated through the advent of industrialization. The Industrial Revolution gave rise to modern capitalism and expanded the possibilities for material development and progress.[3] Rapid industrialization continues to drive forward centralized production. As a result, it has become increasingly difficult for people to fathom the repercussions of their actions in relation to the natural environment. This lack of awareness is caused by such factors as the inability of people to visually perceive the ramifications of their actions, and the practice of concealing, or 'masking', that alters the true perception of a situation due to artificial and autonomous systems.

Through advances in technology, the production of goods continues to become evermore centralized, coupled with the abilities to control systems and communicate easily across longer distances. Conglomerates found in all facets of the built environment, from farming - to banking - to manufacturing, continue to absorb more and more distributed parts, thereby growing ever larger. This trend removes the processes and connections of these systems from the foreground of the everyday, to the background of the remote. While becoming increasingly centralized is beneficial in some respects, in terms of energy production, energy use, and the dynamic, unpredictable nature of any particular locality, centralized production is inflexible. Currently, most energy is produced from a highly centralized system comprised of a few power plants providing for numerous, widely dispersed buildings and industries. This organization renders the entire system rigid in a very complex, fluctuating environment.

The complexity and centralization of industrial processes foster the inability of people to witness the dynamics and variables of the built world, and therefore these remain masked. Most energy and industrial flows are invisible or only partly visible, and therefore these processes are taken for granted.[4] For example, the raw materials used for energy production do not originate from a 'local' source for most locations. Due to this lack of 'visual presence', there exists no reason for a person to question the negative effects that result from production. It is also difficult for people to perceive visible repercussions to the environment because the effects typically span longer than a single human generation. This obscures the ability to witness the consequences within a lifetime, and fosters the epidemic of not considering and planning for the future. There currently exist few provisions of feedback to question the consequences for the built world, the natural world, and future generations.

This division further persists because capitalism neglects to place value on the natural resources that it employs.[5] This neglect again vindicates the actual situation to be disguised, and therefore conceals any negative impacts that an action may have in relation to the environment. An example of this includes the lack of monetary value assessed for damage to the ecosystem when extracting non-renewable materials. By not quantifying the economic worth of natural destruction, most raw materials appear to be abundant and economical. Government subsidies, globalization of trade, and imbalances in market power also obscure the true economic cost of environmental destruction or the use of non-renewable energy.[6] This masking currently 'appears' to take care of the situation; however, it is only a temporary fix, meanwhile leaving the process of natural destruction and its toll mysterious to the great majority of people.



In tandem with the gap that exists between built and natural systems, there endures a social disconnection between people and the natural environment. This has become apparent as the ties between people and the their surrounds become increasingly tenuous. This is caused by the lack of direct connection with the natural environment due to the loss of greenspace in developed areas, a result of low-density development; and a lack of appreciation for open, fallow land. There is also a decrease in the amount of time that people spend outdoors. In the United States, those who are employed (and presumably becoming more productive) find that they are working one hundred to two hundred hours more per year than people did twenty years ago.[7] Finally, the introduction of artificial mechanical systems into the built environment fosters a barrier between natural systems and the buildings that people inhabit. The goal of mechanical heating and cooling systems is to "achieve a thermal 'steady-state' across time and a thermal equilibrium across space."[8] This type of uniformity is very unnatural, requiring a great deal of effort and energy to sustain. Lisa Heschong claims that "when thermal comfort is a constant condition, constant in both space and time, it becomes so abstract that it loses the potential to focus affection,"[9] and therefore any connection with the outdoor environment.

Built systems relentlessly progress and advance with little acknowledgement or awareness of the needs of their surroundings, the needs of the fellow parts within their locale, or the abundance or exploitation of the natural resources on which they are so dependant. Conversely, it can be observed that natural systems everywhere constantly operate, advance, and coordinate in a complex, dynamic global cycle. Natural systems operate on free, clean energy received from the sun. This energy is transferred from food into waste by one part of the system, which becomes food again for another, rendering the parts interdependent. The inherent goal is to evolve and transform as conditions change with time, and, as such, the system as a whole continues to evolve, prosper and survive. It is the ultimate example of a set of relationships that achieves a continuous input-waste loop, despite millions of parts. This phenomenon has sustained for thousands of years, and is proof that it is possible to exist on Earth without destroying the integrity of natural resources or the survival of the parts of the system. This thesis asks the question: *why is this not a model for the built environment?*

What

Progress, Deregulation, and Renewable Energy Sources

At a time when there exists a disconnection between people, built works, and the environment, the need for a goal and a purpose firmly grounded in social and ecological ideas is imperative. Currently, the built environment is driven by material progress, which valorizes human defiance of the ecosystem, as we consume huge amounts of non-renewable energy and produce vast amounts of useless waste. A new definition of social and economic progress should be *any action that moves a person, community, culture, or society toward social and environmental sustainability*. For a society to progress, it should choose to recognize and respect the requirements and rights of future generations, as well as the requirements and intrinsic value of all species. Implicit in this new definition of progress is a continuous input/waste cycle, the concept of giving to the livelihood of the whole, and an interconnection and interdependency among the parts of a system.

A recent change within the power industry begins to set the stage for the potential to work towards this new concept of progress in relation to energy production. Energy companies across the United States are currently experiencing a monumental shift in the way the industry is organized. While a centralized organization of energy production has been the historical trend, a recent change is beginning to emerge, potentially encouraging new possibilities and directions both in the act of energy production and the system design. This shift is primarily due to 'deregulation', defined as the establishment of freedom of both private and corporate entities to choose from which power company they wish to purchase their energy, as well as the type of energy, be it renewable or non-renewable. This was mandated originally in order to encourage a competitive market. However, other effects have resulted, such as the increased freedom within the individual's production and consumption of power use and the potential for renewable energy production. This shift is in its infancy, and it is unclear what trajectory these changes will take. Therefore, there exists the opportunity to propose an expanded role for clean energy production in the context of a new built 'eco-system' and to address the need for reconnection. <2.0>

The choice to focus on energy use and production for this thesis comes from the basic notion that energy serves as the 'food' for built works. The main source of our energy comes from non-renewable resources of a finite amount, as previously noted. Kenneth Yeang states that 28% of the total energy currently produced in the world goes into the operation of buildings.[10] Both the harvesting and use of energy are destructive processes to the natural environment. By acknowledging the fact that we are destroying and depleting the finite natural resources, it becomes necessary to reconsider the source of our energy. With this in mind, a challenge emerges to discover the means to produce and use clean energy from such sources as the sun, wind, and water. The potential for this is clearly demonstrated everywhere, as this is the energy that powers the natural environment. This renewable energy is both plentiful and free, and when used in an appropriate manner, does not cause destruction nor deplete the environment. <3.2>

Whole-Systems Methodology - Synthesis of progress, deregulation and renewable energy

As noted above, centralized energy production does not allow flexibility in relation to particular needs of individual localities or smaller parts within the system. Centralized production also lacks a sense of progressing for the good and welfare of the whole, being a hierarchical organization that traditionally takes from the natural resources and returns only residues and unusable wastes. The recent transformations in the production of energy within a deregulated market opens up new opportunities in regards to the concept and organization of the system. This is marked by the potential for a more dispersed, locally founded organization of many smaller, equal parts. As well, due to recent advancements in technology, all of the distributed parts can be connected and communicate, thereby forming a whole-system organization with an overall common set of goals.

A whole-systems approach applied to the built environment requires a shift in mentality from the way in which built works are currently designed and operated. Inherent to a system is a continuous loop that holds all parts responsible and accountable for the wastes that are created, as well as instilling a sense of 'what is good for the whole, is good for the individual'. This follows the rule in the natural ecosystem of waste=food, and engenders contributing to the livelihood of the whole. Therefore, in order for the system to survive and prosper, all parts must not only take from natural resources, but they must give an equal or greater useful amount. Also intrinsic to a systems approach is a more equally distributed series of parts throughout the system, rather than a few central nodes. This allows for processes to be controlled on a more localized level. The parts in a certain area are able to react and respond to unique changes or situations in their immediate surrounds, changes which may not affect other similar parts elsewhere in the entire system.

By looking to the organization of a systems approach, it is now possible to structure choices, decisions, and actions based on a logic that is implicit to the system. The logic of this structure is to work together for the good of the whole, for the good of each of the parts, and towards prosperity for all, within a constantly changing environment. While this may seem an impossible task, it is the same organization and design of the natural ecosystem which has existed, prospered, and evolved for many hundreds of years. Therefore, in order to operate more efficiently, to conserve the environment, and to conceive of energy production and consumption in a more holistic sense, this thesis advocates the need to model built systems after a 'whole-systems'/ natural systems methodology. <3.1>

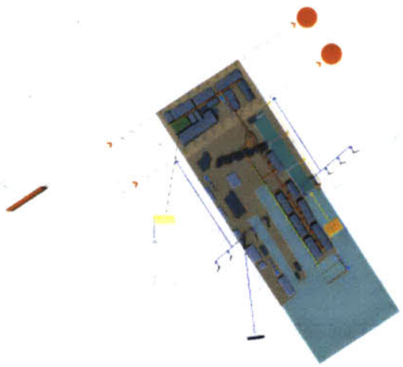
How

Method

The concepts of built works as energy producers and a whole-system mentality are notions contrary to the way in which the built environment is currently conceived, designed, and operated. In order to establish a set of rules and goals that would differ from what is currently practiced and thought, it was necessary to establish a set of criteria. This set of criteria resulted from variables and dynamics that allowed a new understanding and organization of built works in relation to the design proposal. The criteria were established through two means: firstly, in order to quantify and characterize the 'tangible' criteria, research of both the concepts underlying whole-systems mentality and renewable energy technologies was employed, and secondly, in order to realize and depict the 'intangible' criteria, firsthand experience of relevant projects was employed. The criteria were developed relating to both the potential and process of producing clean energy in an urban block, and the physical relationship/presence and social role of such a system to the people who would use, inhabit, and experience the chosen site.

The criteria were broken down into the three areas of whole-systems approach, or performance criteria; renewable energy technologies, or physical criteria; and social involvement and interaction, or social criteria. The performance criteria involve concepts from a systems mentality and the characteristics underlying the dynamics of the eco-system. <3.1> The physical criteria involve notions of climate, site, context, potential renewable energy sources and localized production. <3.2> The social criteria involve notions of the reconnection of people with the natural environment through the encouragement to learn, sense and experience in the built environment. <3.3> Research for the social criteria was drawn from both past projects of my own that have addressed this topic, and conducted through visiting related projects in order to experience firsthand the sense of integration of a whole-systems approach, renewable energy technologies into the built environment, and the impact and/or changes that these create within the social sense of the people affiliated who used the project. <4.0> Once the criteria were established, a design process emerged out of the new set of rules and characteristics. The criteria served as a reference for making decisions for the design project that followed.

Design Project



An industrial site within the context of Portland, Maine was chosen based on the criteria, the program of the existing buildings, and the need for a 'typical site'. The site consists of a typical urban block extending out to docks/ coastal frontage. The existing building uses on the site are industrial/ manufacturing, residential, and commercial/ retail. The intention of the project was to speculate on the role of decentralized renewable energy production introduced to an existing urban site. The site was to operate as a testing ground for ideas prompted by this intention. An existing urban site was chosen simply to force the project to deal with the most problematic of areas in relation to waste and residues. In order to serve as a testbed, the site needed to be 'typical' in nature in terms of the renewable energy sources available. Therefore, the ideas and concepts that emerged could be translated to other coastal sites (prototypical).

The first step was to formulate a design process. This was derived from a series of force mapping exercises drawn from climate data and the existing site analysis/ dynamics. The results from the mappings served as a logic to make spatial design decisions. <5.0> The force mappings were followed by a series of exercises moving through macro- and micro-scales, motivated by the nature of working with a systems approach. The investigation focused on the site as a WHOLE, the site in relation to surrounding context as WHOLE +, and on individual MOMENTS within the SYSTEM found on the site. The design proposal took on the role of an expressed renewable energy producing infrastructure, creating an interconnectedness among the parts of the system, as well as an implied connection to the larger system of the city, the region, etc.

Throughout this process, the design project investigated the role and relationship of the energy infrastructure with the people who would use, inhabit, and experience the proposed design. The various systems were deliberately placed in the foreground in order to exhibit a presence. This provided strong design implications on the physical presence of the infrastructure in relation to the architecture of the site, as well as the potential for it to be understood as a learning tool for those who would experience it. In order to realistically ground the proposal, the design was tested in terms of calculated energy produced by the proposed infrastructure against calculated energy demand by the existing buildings on the site <6.0>

Assumptions

Being a design proposal that is projected ahead 20 to 30 years, this thesis asks to accept and assume the following points:

- *Renewable energy is either equal in cost or cheaper than traditional fossil fuel energy production, and the technology is as efficient. Therefore it is now sensible to use renewable sources as a viable energysource to power the built environment.*

- *The choice to focus and analyze a system based only on energy flows admittedly frames and limits the ideas of a 'whole-system' mentality which involves all aspects, dynamics, and variables, as well as the interconnectedness and interdependency that they encumber. The choice to frame the analysis was done in order to assure the ability to explore the ideas sufficiently within the amount of time.*

- *The site chosen represents private, public, and jurisdictional boundaries that are created with complete ignorance to the boundaries of natural processes. Therefore, while there is a specific and bounded site chosen, at times throughout the design project, connections were made that transcend the boundary established at the outset, thinking of it as a permeable, evolving boundary. As well, it was assumed that all land and building surfaces were fair game to build upon and work with, despite issues of public and private domain. A discussion of this comes later in order to address actual causes of action that might make such a decision a reality.*

While this project is a proposal for the future, due to the current imbalance in renewable and non-renewable energy costs, there are historic precedents that tie this decentralized concept to the past. The next chapter recounts the history of energy production in the United States as it shifted from decentralized to centralized, and tracks the events that led finally to deregulation.

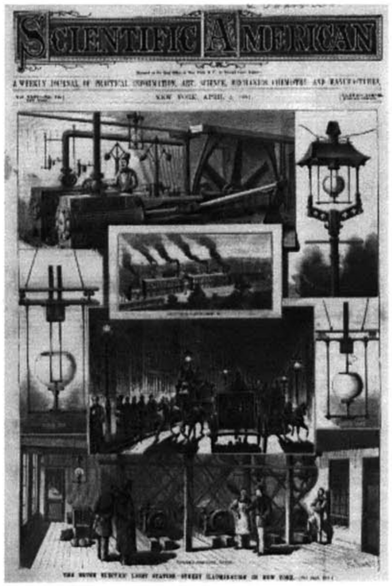
ENERGY INFRASTRUCTURE AND DE-REGULATION

The Evolution of Energy Production and the Living Grid

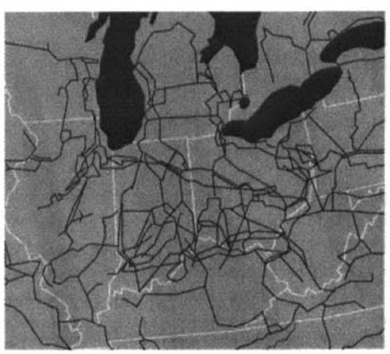
BACKGROUND

In the 1880's and up through the 1930's, a drive through the rural Midwest of America would have revealed the steadfast and determined will of farmers and their desire to be a part of the country's growing standard of living, brought about through the development of electrical generation. Due to the dispersed nature of development in rural parts of the country, power companies did not make it a priority to construct power lines to connect farmers to the grid that was forming across the nation. Therefore, on each farm, one could find 'jimmy-rigged' versions of windmills, known at the time as windchargers, small generators, and mechanisms for solar-heated water. Each farm became its own autonomous power plant, and a network of power lines was nowhere to be seen. It was the ultimate in a decentralized structure of power generation.

In 1882, Thomas Edison designed and built an electric network prototype in the financial district of New York City. Wires connecting steam engines, generators, and electric lights were strung together in order to illuminate nearby restaurants and shops. His network could not span more than a mile away from his shop, due to the fact that he was producing power via direct current (DC). Having accomplished this feat, the 'Wizard of Menlo Park' "imagined a host of isolated power plants spaced regularly throughout [an entire city], supplemented by small generation stations housed in factories, hotels, and other large businesses that used his equipment."[1] Edison's concept for supplying power was localized and small scale, obviously posing little threat to those who were becoming concerned for the dissident effects of concentrated corporate enterprises like the railroad companies at the time.



electricity-related inventions by Edison


power grids across the Midwest

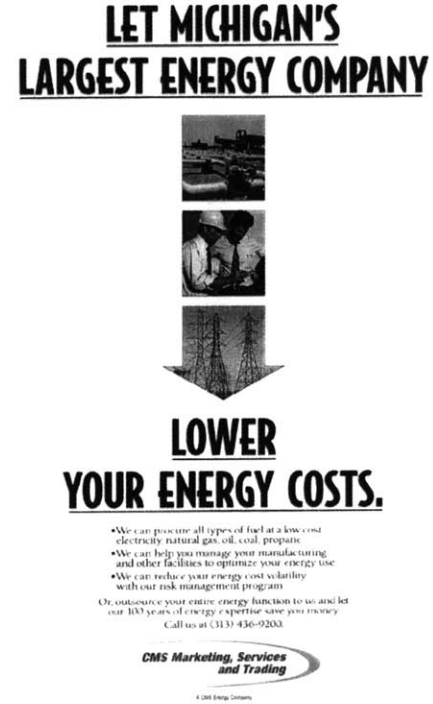
With the advent of alternating current (AC) shortly after Edison's invention, there existed the technology to transfer current long distances through wired networks. Prior to this, localized production and transmission was to be the structure of power generation, as forecasted by Edison. Now, this technological advancement would radically alter the structure from being highly dispersed, to highly centralized production. From this point on, DC electric systems were abandoned, and AC utilities would grow into giant, centralized electric power conglomerates, paralleled with railroad companies as both public necessities and public villains.[2]

In the beginning of the age of electrification, companies that produced and transmitted power to customers were privately owned entities, competing with one another often by duplicating wiring systems in an attempt to gain the same customers. It became clear very quickly, that with the growing demand for power, and the huge amount of capital that was needed to develop and extend the transmission system, redundancies would not bring generating costs down. Therefore, in 1907, the managers and owners of the large power companies worked together with the government to form a *utility consensus*; investor-owned power companies with the designation as natural monopolies, giving them the right to sell electricity in a noncompetitive market.[3] At this time, it was generally believed that huge corporations could provide essential services and products in ways not possible by smaller competing firms, and that 'bigness' did not necessarily imply exploitation or wrongdoing.[4] State regulatory commissions were established in order to ensure reasonably priced energy and good service, such that society benefitted from the operations of the now non-competitive companies. This structure lasted for seven decades, creating a power grid system that connected the whole nation. Then a series of actions and laws were put into place that unintentionally would again drastically change the structure of the production of electrical power.[5]

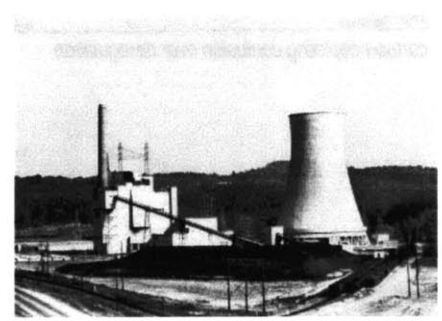
Within the established non-competitive system, it was intended that the utility consensus would form a long-lasting and stable structure for the expansion of the electric system. For seventy years, managers used improvements in generation, transmission, and distribution technologies to lower the cost of electricity substantially in the name of improving Americans' material standard of living.[6] At the same time, through public relations campaigns, utility managers attained great power and support from financiers, manufacturers, academics, and the regulatory groups, earning approbation and little objection for creating the best functioning electric utility in the world. With this accumulated power and authority, the leaders of the utility systems strove to decrease outside influences so that they could acquire greater control over variables that might have destabilized their rule. This was orchestrated through encouraging the creation of conservative, but steadily improving inventions originating within the system, meanwhile, discouraging radical, more efficient inventions emerging from outside the system.[7] It was this kind of control that, in the long run, would ironically strip the accumulated power away from the electric utilities.

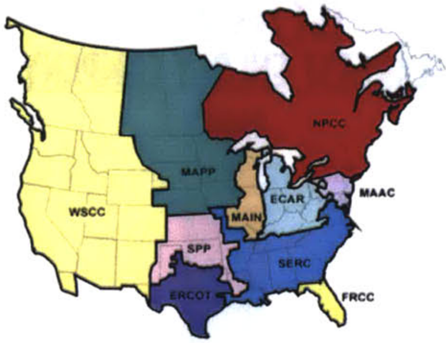
This structure held fast until the 1970's, when unexpected events began to raise questions by outsiders of the now ominous, centralized, seemingly regulated system of the utility companies. Shifting views in the nature of how people felt about government intervention and recent technological advancements prompted new federal laws that were put into place. These laws allowed non-regulated power producers to generate electricity by whatever means, then forced utilities to purchase this power. Additionally, government provisions and incentives were put into place to research and develop as well as encourage the use of power from renewable means via wind, solar, water, and biomass.[8] It was discovered in time that the competitive, non-regulated companies were able to produce power, both renewable and non-renewable, just as economically as the monstrous, regulated companies. Questions about the regulated centralized system continued to arise.

As stated earlier, utility managers previously strove to uproot radical technologies; now the new laws encouraged such innovations. This reduced the control of the utilities, and established a wide-open playing field for energy production. Ironically enough, the impact of these new technologies originated from analyzing cost-effectiveness and small-scale production, two criteria that were not always of importance in the centralized system. By working with small-scale energy producing stations, the ability to produce power locally to certain nodes was more flexible and quicker to respond to changing needs. Additionally, localized generators minimized the transmission and distribution costs, whereas the traditionally centralized system would send electricity across hundreds of miles.[9] The new laws also created opportunity for energy producers to employ the by-products of power generation for industrial processes, such as excess heat or steam that could be tapped into by a local factory or manufacturer. Industrial and residential self-generation was also possible, where companies and homeowners that produced excess power could sell it back to the grid for profit. An entirely new environment had emerged, establishing unique possibilities, and charging a once stagnant system with innovative

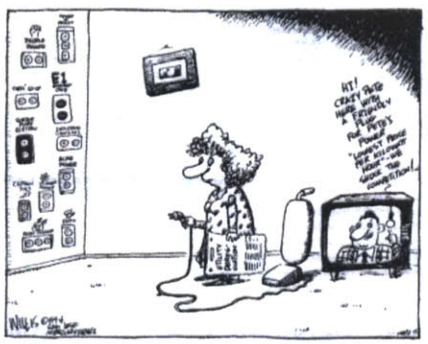


advertisement for power utility


centralized power production



regional organizations of power utilities



cartoon depicting confusion over deregulation

emerging potentials. This environment brought into question whether a different competitive structure was necessary to continue to encourage such beneficial change. And in response, the centralized structure began tumbling down.

DEREGULATION

Deregulation of the electric power structure was established with the passing of the Energy Policy Act of 1992. It is a top-down federal and state effort to lower energy prices by creating competition in the market among companies generating electricity. Deregulation allows for customers to choose from which company they wish to purchase their electricity, be it based on what is most economical or a personal interest in renewable generation. Traditionally, power utilities acted mutually in the three areas of generation (power plants), transmission (main national power lines), and distribution (local and regional power lines).[10] Deregulation currently affects only the generation of power, and therefore the existing utility in a given area continues to oversee the transmission and distribution of electricity.[11]

Through the joint efforts of the utility consensus, prior to deregulation, the large network infrastructure of power lines was built, piece by piece over the course of the seventy year reign. This grid covers the entire country, and interconnects the transmission and distribution wires, operating as several smaller, regional grids. This interconnection allowed utilities to engage in economic power transactions with one another and enhanced reliability by providing additional capability and back-up power paths for emergency situations.[12] Currently, nearly all power plants and customers are connected to this grid.[13] Due to the nature of electricity, coordination and communication among utilities is imperative. Electricity cannot be moved from one point to another; rather, electricity always travels through the path of least resistance. Also, large amounts of electricity cannot be stored and therefore must be produced and delivered at the time of demand. Deregulation and greater competition has led to expanded use of the grid, with the number of transactions and the number of energy generators continually increasing. The transmission system is being transformed and upgraded to meet these changes.[14] With technological advancements in the 1980's and 90's in microelectronics, these transformations are possible. The new advancements allow for information regarding prices, buyers and sellers as well as the electricity to be transmitted and tracked easily. Also, smart control measuring systems used for monitoring are now highly adept, allowing for complex systems to be built and regulated by computers, with a high level of accuracy.[15]

Deregulation has not only encouraged greater competition, it has also opened the door for the addition of many smaller power generators, from small power plants down to the individual residential producer. Advancements in small scale technologies have paved the road for further decentralization of the system, to the point of individual homeowners producing their own power with fuel cells, micro-turbines, photovoltaic cells, and energy storage systems, in order to sell it back to the grid. Typically, the production of power from renewable energy sources is served best if produced close to where it is consumed, lessening the need for extensive transmission lines. Therefore, the relationships implied are local or regional relationships. This could go as far as homes detaching themselves from the grid and running independently, or connecting with neighbors and other businesses to create similar alliances that utilities obtained by interconnecting their transmission systems.[16] Ironically, the overall world economy is becoming increasingly centralized, with fewer but ever larger participants. Conversely, the electric grid system already achieved centralization, and is now potentially returning full circle, with smaller businesses in greater numbers producing energy in an increasingly localized, even individualized scale.

While many of the changes that come with deregulation of the electrical system appear to be beneficial, there may be changes that are detrimental for advancements made previously through utility and government incentives. When power utilities worked together as a consensus, they were able to speak with one voice, and to address such issues and campaigns as acid rain and energy efficiency programs in unison. Now that the companies are in competition with one another, the industry has become divided. In order for the power utilities to compete in this new market with smaller, low-cost companies, many cut back costly 'social' programs such as energy conservation initiatives.[17] Also, some activists claim that deregulation will encourage pressure on the production of the cheapest priced electricity, and therefore renewable generation could lose out due to money not being designated for research and development. It is their belief that in order for renewable energy to continue as a source, government incentives must be put in place within the deregulated market.[18] Therefore, deregulation does not necessarily mean a shift towards increased use of renewable sources and production; use of renewable energy technologies continues to be an effort driven by those who are concerned with the current state of affairs in regards to the environment.

individual residence integration of PV's

just flip the switch

power lines as network

THE POTENTIAL OPPORTUNITIES

While the law creating deregulation was passed in 1992, it has been a slow process for the market to move into free competition. Each state must decide how it wants to incorporate this new organization, and therefore new laws and regulation must be drafted. This shift in the system is at its earliest stages, and it is unclear the trajectory this phenomenon will take. This situation provides an opportunity to propose the role of energy production, especially clean enegry production, in the coming years.

The shift through history in the electric power generation structure from decentralized to centralized and now potentially decentralized again is unique. The structure of the system at the outset began as decentralized simply because the technology limited it to such applications. Whether it was 'home grown' or generated through Thomas Edison's innovations, there was an inherent limit to the area the system could serve and the number of users that could participate. Shortly after Edison's creation, AC power was discovered, opening up the ability to transmit electricity longer distances, as well as other advancements that followed which allowed for greater complexity in a network. Once these technological hurdles were overcome, the financial barrier had to be addressed. It was quickly understood that by forming a consensus and pooling knowledge, technology, labor, and capital, affordable electricity could be produced for the benefit of society. This began the first shift into a centralized structure, where companies expanded in order to have enough capital and clout. It was this shift that removed the presence of manageable power production from society and put it into what became the elite power managers' hands. While this produced certain problems, it was through these efforts that the lofty goal of building and designing an interconnected grid across the nation was possible.

Now, the grid is in place, and a third shift is just beginning to lead back to what is speculated to be again a decentralized organization. Why is this process now coming full circle, and why is this of potential interest to the benefit of society? There are logical, interrelated reasons for such a shift, motivated by <1> technological advancements in relation to systems, leading to and providing for <2> economic feasibility of renewable energy production, and as a result sparking <3> social changes in attitude towards human impact on the environment.

[1] The first reason begins with the notion the more decentralized a system is, the greater the potential to be more adept at being aware and able to react to local dynamics. As stated previously, the more flexible the system can be to changing conditions, the more efficiently it will operate. This heightened ability to react and respond is possible with technological advancements in feedback systems. Decentralized also means bringing the systems into the foreground, thereby unmasking the processes so they are no longer mysterious. Visual feedback and presence helps to encourage people to be aware of the systems and the processes in their surroundings. There currently exist few provisions of feedback for why a person would feel compelled to question the ramifications he or she may be creating for the built world, the natural world, and future generations. Therefore, decentralized organization and feedback systems can encourage responsibility. <3.1>

[2] Technological advancements have also made it increasingly economically feasible to produce energy from renewable sources such as solar, wind, and water. With the cost of production for renewable sources beginning to rival that of traditional generation sources, renewable power becomes a viable issue. This is beneficial to the environment in terms of reducing degradation to the eco-system. <3.2>

[3] The potential for viable renewable energy sources has raised social concerns regarding the destruction people are causing to the environment and in turn to themselves by harvesting and consuming non-renewable resources. Attitudes are beginning to change to reflect such concerns, as organizations, businesses, and individual homeowners begin to implement novel approaches of producing their own clean energy. This could potentially become a way to reconnect the gap that exists between the natural environment, the built environment, and people. <3.3>

It is amusing and possibly difficult to imagine a return to a time when individuals produced their own power and windmills were dotted across the rural landscape. Likewise, the image of "a host of isolated power plants spaced regularly throughout [an entire city], supplemented by small generation stations housed in factories, hotels, and other large businesses that used his equipment" may seem inconceivable. However, it is possible that this is the direction that the effects of deregulation and continuing technological advancements may lead, coupled with arising dissatisfaction with the 'business-as-usual' of depleting fossil fuels for consumption. These unknowns ask for speculation, and this is precisely where the design investigation begins. The opportunity to propose the role of energy production in the future is both exciting and necessary, given the many variables (criteria) to be discussed in the following three sections.

3.1 PERFORMANCE CRITERIA
Systems Appoach to Built Works

Systems approach
Interconnectedness
Interdependency
Linkages

Feedback systems
System of checks & balances
Simple & straightforward design
Self-critical to learn & adjust

Total energy loop
Logic of energy flows
Waste is food
Contribute positively

De-centralized/ distributed
Adapt/ respond to changing conditions
Update/ upgrade
Flexible

CONSTRUCTION OF CRITERIA

Modeling Built Works After Natural Systems

This compiled list reflects the criteria derived from the following three sections of PERFORMANCE, PHYSICAL, and SOCIAL criteria. In order to conceive of the design of energy producing built works differently from the way buildings are currently designed, it was necessary to compile a new set of criteria. These criteria were used to inform and structure the following design proposal as a set of 'guidelines'. These guidelines were referred to over the course of the investigation. The following three sections elaborate on the formulation of the criteria related to the intentions of the project.

3.2 PHYSICAL CRITERIA

Renewable Energy Technologies

Locally produced
Diverse sources
Construction for upgrading/ flexible

South facing
Unobstructed by shadows
Space for movement & rotation
Able to position at appropriate angle
Provision for excess produced energy/ material

30' above any obstruction w/i 300' radius
Sufficient space for swept area
Noise and sight consideration
Vibration consideration

Means to hold back & release
Provide storage space for excess
Provide catchment system

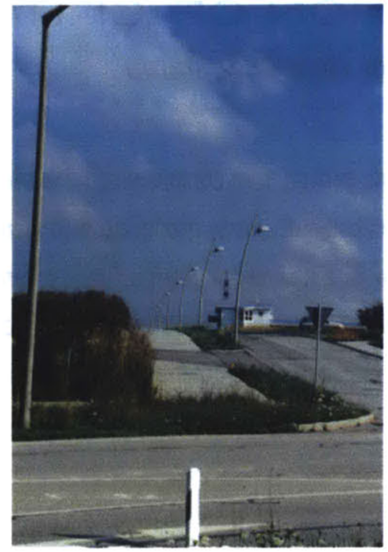
3.3 SOCIAL CRITERIA

Translucent Telephones, Prismacolor Pinwheels, and Wind Walls

Show what is not normally seen
Create a sense of curiosity
Express how it works

A learning tool
Feedback systems
Control systems

Encourage participation
Encourage a sense of ownership



28

SYSTEMS APPROACH TO BUILT WORKS

Modeling Built Works After Natural Systems

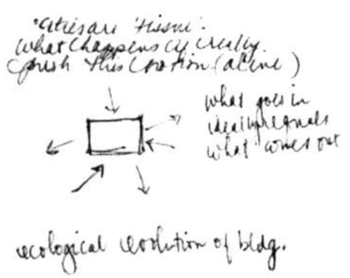
PERFORMANCE CRITERIA

In order to model built works after natural systems, it is necessary to isolate the logic and understand the inherent dynamics and characteristics of a closed-loop system. This section sought this logic in order to provide objectives the design project would incorporate while designing renewable energy structures for the existing site. This thesis takes the position that built works currently operate as autonomous, consuming entities that do not consider the effects and repercussions caused to the natural environment by their actions. Therefore, by taking the fundamental qualities of a closed-loop system, and integrating them into the design criteria of built works, the potential for the built environment to begin to work in tandem with the natural environment can exist.

SYSTEMS STRUCTURE

A system describes an overall organization and agreement of a multitude of parts working together, each contributing in its own equally important role in the livelihood of the whole. A system does not concern itself with notions of hierarchy or different degrees of power; rather, it is accepted that any part is equally important as all other parts of the system. The general structure of a system is comprised of four main components: the individual *members*, the *links* that form the network, the *whole* system, and the surrounding *environment*.

In order to illustrate the characteristics of a system, imagine a group of marbles on a slightly uneven tabletop. Now, with one continuous piece of string, imagine tying loops tightly around each marble, leaving extra string suspended between each marble. The marbles have become *members* of a system. The system is denoted by the string that is the *link* between each



member, forming an overall network through the single piece of string. This network, connecting the members and their interactions, forms the *whole* of the system. Prior to being a member of a system, an independent marble could easily roll and fall off the table. Additionally, one marble could knock another marble off the tabletop due to the lack of organization; therefore, working independently subjugated the marbles to vulnerability. However, by agreeing to work together, under a prescribed set of mutual goals, both the individual members and the system as a whole become more stable, effective, and efficient. It is necessary to recognize that while a system can have a multitude of variables by definition, in order to make the system effective and efficient, it is a matter of choosing the right variables to incorporate; superfluous variables do not aid in the overseeing of the complexity of a system.[1] Likewise, a system that becomes increasingly simple and less diverse can also become increasingly fragile and vulnerable.[2]

The marbles are now linked; if a marble begins to roll, it has the support of the remaining members to hold it back. The network 'informs' the system one member is rolling by becoming taut, and pulling at the corresponding adjacent marbles. Constraints exist that expect the parts of the system to uphold their end of the agreement for the survival of the whole. For the sake of the exercise, we will assume that the system has a vested interest in staying on the table. This goal is achieved by each member accepting the responsibility of both give and take. If a few marbles begin to roll away from the group, then other members must exert energy in order to keep the whole system of marbles on the table.

The links and mutual agreements within a system speak of an implied *interconnectedness* and *interdependency* that are inherent to natural systems. All of the members are both connected to the other members of the system, and dependent on each other in order to uphold both the integrity of the whole and the individual. Therefore, all systems, cycles, and functions must interact and make decisions by considering the effects on others.[3] External conditions are constantly in flux, as tabletops frequently are bumped into. It is therefore vital to be able to react and evolve through connectivity to such changes.[4] If one member in a system must alter its individual process in order to react to such a change, this effect in turn may permeate to all other members of the system. By choosing not to consider the system as a whole, it leaves the system's integrity in jeopardy, and with that, you might lose your marbles.

WASTE IS FOOD

In a closed-loop system, all of the energy and mass that the system begins with is all that the system will ever have. It is a matter of the system converting the energy and mass into different forms and uses, depending on the process and requirements of any one part in its duty to the whole. At various points in a system, a member may perform a process that produces what that particular member considers to be waste, or a byproduct that has no use to the member any longer. For a closed-loop system to survive, what is waste for one member must also be energy or food for a different member. This waste is then absorbed back into the system, making the use of material and energy in the system efficient. In order to continue the longevity of the system, nothing is wasted, and there are no residuals created to degrade the integrity of the system or the surrounding environment. The interconnected nature of a system demands that the various members contribute in some positive way to the good of the whole; if a member takes from the system, it also gives back.

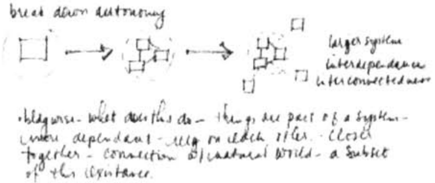
SYSTEMS ORGANIZATION

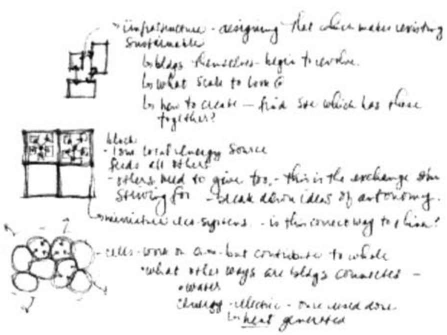
A natural system is not a hierarchical organization, but rather a group of equally powerful, mutually interconnected parts. It naturally takes the organization of decentralized, distributed members, whose placement is determined by both the needs of the system, and the proximity to resources necessary for the individual members to function. Being a closed-loop system, a natural environment does not have extraneous energy in order to transport material to another member simply because that member wishes to be in a remote and impractical location. By expending wasteful, unusable energy, the overall system and its environment begins to degrade as the amount of useful resources depletes and cannot be replenished.

A system organized in a distributed fashion has the ability to locally respond and react to changing conditions occurring in its immediate surrounds, or in a particular area of the system, fostering flexibility. Flexibility is imperative when attempting to be highly efficient. Operating on a local level allows the system to update and upgrade as necessary when conditions in the external environment change. The ease of upgrading with enhancements, improvements or replacements is necessary for the system to remain efficient in an ever-changing environment.[5]

SYSTEM OF CHECKS AND BALANCES

The correspondence of an interconnected system is maintained through the network, which plays the all-important role of knowing how and when to facilitate the needs of the members. When changes occur to the exterior environment in which the system operates, it is necessary for the system to have the capacity to be aware of these changes in order to react and respond. Therefore, systems must have built-in feedback loops, to make the system 'smart'. Feedback loops operate in a similar fashion as a system of check and balances, where the system is always monitored by the network, and alerted when a change is necessary in a certain area. A feedback loop supervises the efficiency of the system, in order to make sure that one member or area is not wasting more energy than it is giving back. These checks not only ensure that balance on a steady basis occurs, but





also throughout the entire lifespan of the system, whatever long-term changes may occur in the surrounding environment.[6]

In this sense, the system has a built-in intelligence; it not only becomes aware of the need for change, it decides how to make the necessary changes, and finally, it learns from such changes. The system accepts that its responsibility exists over the course of its lifetime, and chooses to be self-critical, agreeing that it must evolve just as the surrounding environment evolves.

In terms of built systems, the efficiency and flexibility that is afforded through the technological advancements of control and feedback systems provides for the opportunity to produce less waste. This feedback is achieved through controls, which provide accurate information regarding the state of the system. By analyzing the results, the system can adjust to the particular situation and location. The system can additionally have goals implemented, not only cutting back on waste, but always striving to become more efficient and, therefore, more responsible. Continuing advancements in technology will also aid in this endeavor, as ubiquitous microchips already alallow simple controls of 'neural networks' that can learn using fuzzy logic, allowing the system to make decisions.[7] There also exists 'distributed intelligence,' a control system that uses many decentralized decision-makers of comparable rank, interpreting events under shared rules, learning and interacting with one another, and controlling their collective behavior through the interaction of their diverse local decisions. The logic of such a system has been modeled after the dynamics of the natural ecosystem.[8] This type of system can help to synthesize the overall system of electrical generation if it is to continue to use the grid as a shared infrastructure.

Amory Lovins talks about his concept known as the 'soft path,' where "rather than depend on large-scale technology, such as nuclear power plants, the soft path relied on diverse, small-scale generation devices, most notable those that produce electricity from renewable energy sources, such as the wind and sun. Flexible in meeting the needs of users, these technologies could be easily understood and controlled by common people, unlike the vast and complicated energy networks managed by technocrats in large corporate or government organizations."[9] While a decentralized approach is better, it is also imperative to always consider the overall system as a whole, and how changes on a local level can affect the overall integrity of the system. This is more easily achieved from the bottom-up than from the top-down, as individuals at their various locations know what they need, and can also be aware of the overall dynamics of the system. In contrast, one main body in control of all smaller parts is never capable of being aware of the intricacies of the individual parts. Therefore, inefficiency is built into such a centralized system by default.

NATURAL SYSTEMS AND BUILT SYSTEMS

Natural systems are not subjugated to political or jurisdictional boundaries that humans impose on the ground the way in which built systems often are. The boundaries of natural systems are constantly rearranging, in order to adjust to the changes in the environment.[10] This must be considered when setting out to place a built system, in that the confines of the perimeter of the site are most likely not the confines of all of the sources of energy and materials. Therefore, it is conceivable that built systems may begin to reach out to form connections and links that permeate such 'physical' boundaries in order to be more efficient. It must be accepted that a built system can never replace the immense complexities and abilities of natural systems.[11] It is understood that all built systems will generate some degree of unusable waste or residue. Consideration must be given as to whether or not the surrounding natural system is able to absorb and recycle the wastes and residues that are unavoidably created.[12] Just as the parts within a system are subjected to scrutiny over producing usable waste for other parts in the system, built systems should also be subjected to such scrutiny in relation to the natural environment. Built systems should not only practice efficiency and conservation of the energy and resources that are employed to operate, they should also consider a reparative role in relation to the eco-system.[13] Considerable damage has been caused to the natural environment due to the way in which built systems are considered, designed, and operate. By providing a surplus of benefits back to the natural system, we can begin to bring all systems, built and natural, back to an equilibrium.

Many existing projects implementing renewable energy technologies have done so either at an individual, autonomous scale or a large, utility scale. The concept of a systems approach played a significant role in the conception of the design investigation as a local scale system of energy producing infrastructure. The proposed system of entities were to operate like a suture, being stitched into the existing site, attempting to reconnect built works with natural systems through the process of energy production. The concept of technological feedback monitors and controls was not specifically dealt with in the design project; a different type of feedback was pursued. This was visual and experiencial feedback to allow people who come in contact with the systems to see and understand the processes before them. This is discussed further in section <3.3>. The next section introduces renewable energy technologies.

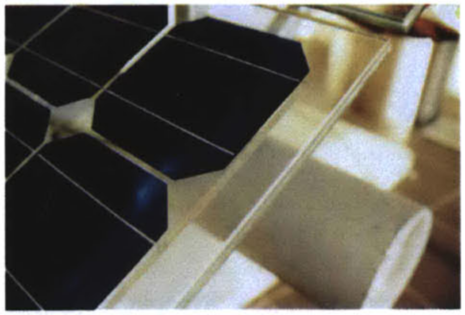
RENEWABLE ENERGY TECHNOLOGIES

Constraints, Opportunities and Necessities of the Tools of the Trade

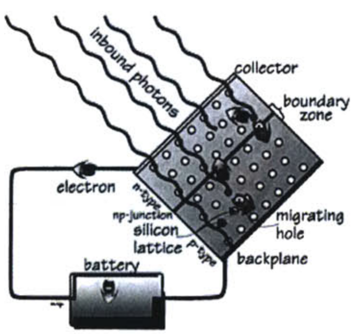
PHYSICAL CRITERIA

The following information summarizes the current and projected state of three sources of renewable energies that this thesis will look to employ and consider in new and innovative ways; these three sources are *solar power* with photovoltaics and thermal generation, *wind power* generated by wind turbines, and *water power* from tidal barrages and water re-use with water collection systems. Each description of the renewable energy source begins by stating a brief history of the source, followed by an explanation of the technologies and their current state of development. This information is intended to establish the concrete set of criteria that includes both the logic and the physical tools that this thesis will refer to in formulating the design process. The thesis then possesses a reference guide to designing renewable energy production within the built environment.

As a rule, clean energy generation works best if produced adjacent to where the power will be consumed. For instance, it was found in California that it was cheaper to wire alley lights to solar cells than to connect them to the closest existing wires.[1] In relation to economics, making a change on a small scale is much less disruptive and costly than it is on a very large scale. Current and up-and-coming technologies in relation to renewable energy have been found to work best in smaller, decentralized applications. This is based on the idea of properly scaling a system, determined by the rate and the location of customer demand. A study found that approximately seventy-five uncounted effects of scale on economics typically make decentralized power sources, including renewable resources, about tenfold more valuable than traditionally supposed.[2] Additionally, by being in close proximity to customers, the possibility for employing the by-products of energy production to nearby industrial processes exists.[3]



photovoltaic array (monocrystalline)



PV cell generating electricity

SOLAR POWER

Photovoltaics

Photovoltaics (PV) are semi-conductor devices that convert light in the form of photons directly into electricity as a power source. Photovoltaics were discovered in the early 1950's when working with transistor radio technology. These devices remained a laboratory curiosity until the 1960's and the advent of space flight. While grossly expensive to produce at the time, they provided a remote, efficient, long-life energy source. Since a need existed, research ensued into the technology, resulting in a steady decrease in cost from over $40,000 per watt to current prices of about $6 per watt and falling.[4]

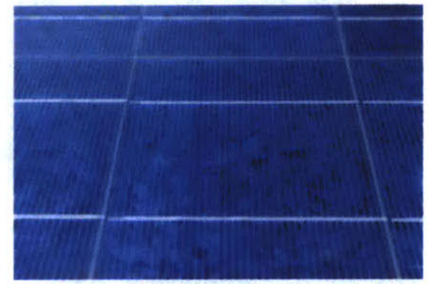
Photovoltaic cells are primarily composed of silicon, a waste product from electronic manufacturing. The silicon is in a solid-state composition that is 'doped', or coated, on each side with dissimilar positive and negative semiconducting materials. When photons from solar radiation fall onto the surface, a flow of electrons from the top side to the back side ensues, caused by the excess energy imparted from the stream of photons absorbed by the cell. This flow creates the electrical potential output.[5] As these electrons flow through an external circuit, they distribute their embodied energy as work for such processes as turning motors. The electrons then return to the solar cell, forming a cycle, and repeat the process provided photons from the sun continue to be absorbed by the surface. This process is completely self-contained and solid-state, therefore no materials are consumed or emitted into the environment, nor are there any moving parts.[6]

There are three types of photovoltaic cells that have evolved over the years of research, each one varying slightly from the other in terms of manufacturing cost and efficiency. All three types are currently being used in industry as different applications warrant different needs. Single crystal, or monocrystalline is the oldest and most expensive technique to produce solar cells; however, it continues to be the most efficient. Large cylindrical or hexagonal loaves of single-crystal silicon are grown in an oven, then sliced into wafers, doped with the appropriate semiconducting material, and assembled into a module typically under a protective layer of glass or plastic. It is a process that is very well developed and clean.[7] There are two variations of monocrystalline cells, these being a high-efficiency cell, dark blue in color and efficiency of 17%, and a screen-printed cell, dark gray in color and efficiency of 14%.[8]

Screen printed multicrystalline or polycrystalline is the second type of photovoltaic material. It is made by the same process as the single crystal method, but from a different type of silicon. Square loaves are formed from a type of silicon with multiple crystals having boundaries that impede the flow of electrons.[9] Due to the inconsistency of the material and the reduced ability of the electrons to flow, there is a lower conversion efficiency when compared to single-crystal silicon. These modules have an efficiency rating of 13%.[10] These cells are also sliced into wafers and doped, then assembled into a photovoltaic module. While this type of photovoltaic cell is less efficient, the cost to produce the cells is cheaper than mono-crystalline due to the less exacting process of manufacturing. It is also possible to place the cells in denser configurations due to the fact that they are square in section as opposed to the round or hexagonal section of the monocrystalline cells. The multicrystal patterns are apparent in the module, and are a varying dark blue color.

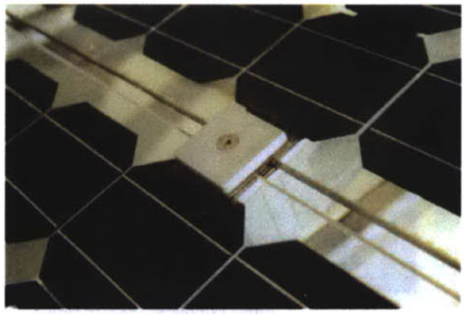
Amorphous thin-film is the final type of photovoltaic cell, and is the most recent advancement. In this process, the silicon is vaporized and deposited on glass or stainless steel, in large areas if desired.[11] The manufacturing process and the lower amount of silicon used per cell in thin film PV's costs less than either mono- or poly-crystal silicon; however, it is currently the least efficient of all three methods. Amorphous photovoltaics can be deposited on glass with varying transmission levels, and are only two-thousandths of a millimeter in thickness. The translucency levels range from black with no light transmission, to gray with 5% light transmission, and finally to gray with 10% light transmission. Once the amorphous silicon is deposited on the glass, spaces are laser-cut to create separate cells which can then be wired together.[12] A design or pattern can be implemented for appearance as well as to increase translucency.[13] Thin-film cells currently experience power 'fading' from 10% to 15%; however, this loss is being reduced as the technology advances. Thin-film cells deposited on stainless steel have the possibility of being somewhat flexible, based on the thickness of the backing material, and thin-films placed on glass can provide shading and generate power simultaneously.[14]

All three types of photovoltaics are used in many applications, from private to commerical, and a variety of scales from an individual building to utility energy farms. The main determining factor for which type of silicon one would choose is typically the appropriate balance between cost and efficiency for the particular application. Prior to choosing the type of cell, the climate and the amount of sunlight an area receives must be reviewed as they are the next two most important factors

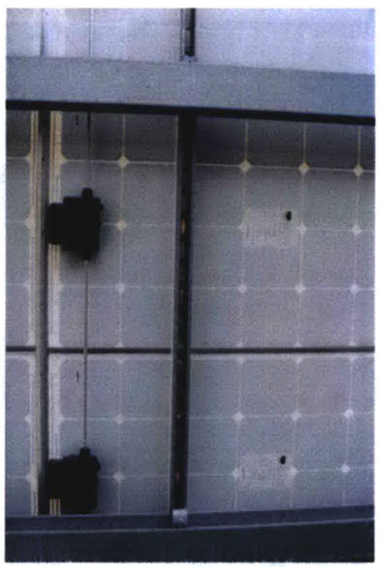


multicrystalline photovoltaics

patterns and shading



PV module



PV array

when considering the possibility of effectively producing solar energy. Photovoltaic performance increases with a higher percentage of sunny days, and a cooler climate. As solar cells generate energy, they also produce heat on the back side of the cell. With additional ambient heat from the surrounding air, the capabilities of the cell are reduced and power output lowers. Photovoltaics perform less well when temperatures rise above 80 °F.[15] A rise in temperature can be minimized by allowing the back of the cells to be well ventilated. If the cells are placed on the roof or wall of a building, the opportunity exists to recover and re-use the excess heat generated by the cells to heat the indoor space and increase overall system efficiency.[16] Photovoltaics perform less efficiently when it is overcast or cloudy; however, they still generate some energy. A flat plate solar module can generate 50-70% of the rated output under a bright overcast sky and 5-10% under a dark overcast sky.[17] Shadows cast onto the array have the same effect as clouds covering the sun. Therefore, precautions must be taken to avoid any shadow casting.

A single solar cell has been designed to be a modular component that can be combined into larger and gradually expanding systems in order to custom fit a specific need. *Solar cells* wired together form a *PV laminate*, which is then mounted in a frame to form a *solar module*. Modules can either be wired in *parallel* to increase current, or in *series* to increase voltage. The industry standard is 36 cells in series to compose a module. Modules are typically sandwiched between a front sheet of tempered glass and an aluminum frame sealed for weatherproofing.[18] A junction box is placed on the back of the module for the electrical connections to other modules. Connecting modules together for a larger system forms a *PV string* when wired in series or a *PV array* when wired in parallel. Different combinations of these configurations can achieve a custom output.[19] The inherent modular design of both cells and modules allows the overall system to be very flexible, with the ability to evolve and change easily over time as needs and technologies change. Industry standards allow modules from different manufacturers to be wired together, provided each module has the same rated voltage within one volt of the other.[20]

The placement of PV modules is dependant on the latitude of the site and the provisions to support the modules, whether it be static or dynamic, horizontal or vertical. Static PV modules must be positioned in order to maximize their exposure to the sun during the entire day and all throughout the year. If it is possible to have the module tilted at an angle, the ideal position is the same angle as the latitude of the site and facing due south. If the module is capable of seasonal adjustment, it is preferable to be oriented horizontally in summer, and vertically in winter in relation to varying sun angles throughout the year. Photovoltaics are lightweight, and therefore provide opportunity to rotate the module on a tracking system in order to remain perpendicular to the sun's rays throughout the day and year, achieving the maximum energy output.[21] Typically, the use of a solar tracker significantly increases the cost of the system, so it must be determined if the extra energy gained by following the sun offsets the cost of the tracking device. Solar trackers can either be passive, operating by the movement of a low viscosity liquid that heats up and flows in order to tilt the module to remain roughly perpendicular to the sun; or active, where a sensor sends information to a motor which mechanically orients the module to remain perpendicular to the sun.

The energy that is produced from a photovoltaic array is direct current (DC), and can be used in this state if the consumption is local. If the electricity needs to travel long distances or the local system is connected to the grid via an intertie system, an inverter is necessary in the system in order to transform the energy to alternating current. If excess energy is produced and not needed for consumption, it can be sold back to the grid for profit, or stored in a battery for later use.[22] Batteries have been standardized at a nominal 12 volts for charging; therefore, modules typically produce somewhere between 14 and 18 volts, as the source of voltage must be higher for effective battery charging.[23]

THERMAL SOLAR COLLECTION

The energy from the sun cannot only be transferred into usable electricity for power, but it can also be absorbed for thermal heat. This is a very old, low-tech method for producing hot water from solar radiation. The types of thermal heat collector systems are window collector panels, solar absorber mats, flat plate collectors, evacuated flat collectors, evacuated tube collectors, and high efficiency collector systems.[24] The most common type are the flat-plate collectors, which can use either air or water as the absorbing material. Water is more common, as it has a higher capacity to absorb heat than air. The absorbing material is circulated through the collectors and then returns to where the heat is extracted. The four main components of a flat-plate collector are the transparent cover plate, a black absorber plate, an enclosed insulated box, and flow pipes and passages to permit and control the flow of the fluid and the process of heat extraction. Similar to pho-

flat-plate solar thermal collectors

evacuated tube collectors

tovoltaic modules, collectors are most efficient when oriented due south, and positioned at the latitude angle of the site. Solar thermal systems are primarily used to collect heat for hot water use indoors.[25]

If freezing is a possibility in the given climate, the solution in the system will contain an anti-freeze fluid. In this case, the heat must be transferred from the fluid in the system to the water inside by conduction, a less efficient method. If freezing is not a problem, the water that is heated in the collector is taken down into the storage hot water tank indoors for eventual use. The pump is the principle mechanical part of the system in order to make the water flow through the tubes. The pump can be powered by a solar cell, thereby only circulating water for heating when there is enough solar radiation from the sun.[26]

old and new wind technology

WIND POWER

Wind Turbines

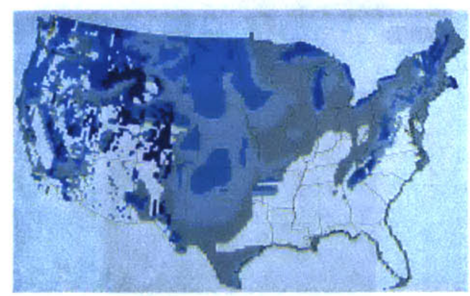
Wind is another 'free' and inexhaustible energy source that people have historically tapped into for thousands of years. Wind is generated by heat from the sun. Different proximities to the sun create temperature differentials on the earth's surface between the equator and the poles, as well as between the earth's ground and the atmosphere.[27] Due to these differentials, the wind begins to blow, as the air attempts to 'even out' these differentials. Wind patterns are distorted by the earth's rotation, topography, and localized pressure and temperature differentials.[28] Wind as a source of motive power is probably only second to muscle power, being used to drive ships for exploration and international trade. Windmills have a long history back to the Sumerians and the Chinese that were used primarily for pumping water for irrigation and milling. Wind energy had its big start in the United States when it powered windchargers for use by farmers in the rural Midwest to pump water and for electricity generation. Windchargers lost their popularity and fell into a state of disrepair in the 1940's and early 1950's when the New Deal and the Rural Electrification Administration were put into place, and the grid was brought out to rural parts of the country.

Wind energy came back into interest in the U.S. with the energy crisis of the 1970s, when the government began to fund research into the viability of large scale energy producing wind turbines, a windmill that is used only for electricity generation. The research most significantly revealed that simply scaling up wind turbines in order to produce more energy was highly problematic, and brought into question the appropriate magnitude of such technologies. It was the smaller, private 'garage' manufacturers that found the means to produce energy with off-the-shelf parts for less money, renewing wind generation as a competitive and potentially viable energy source.[29] The large scale turbine research did; however, provide the foundation for the engineering of the blades and motors for advanced turbines of today.[30]

The requirements for wind power generation for a site are often more particular than those for solar energy production. The main deciding factor is the average, or mean, speed of the wind for a particular site. Speed is very important because of the cubic power law associated with wind, stating the energy available in a wind stream is proportional to the cube of its speed. By doubling the wind speed, the amount of energy produced increases by eight times, and therefore siting the wind turbine is more important than improving it's efficiency by one or two percent.[31] The ideal site is one that is near the crest of a high, smoothly rising ridge on the downwind side of a large flat plain. The next most important characteristic includes being free from obstructions in all directions in order to avoid sheltering and turbulence to the blades. The placement of multiple turbines must be considered such that if the wind changes direction, some of the turbines do not become downstream from others too often.

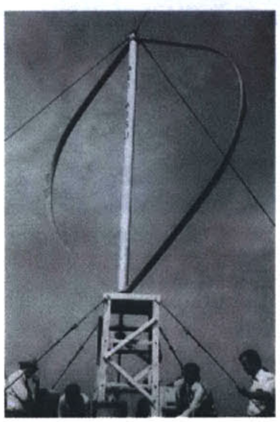
The power available from the wind is a function of the air density, the area of the rotors intercepting the wind, and the instantaneous wind velocity. An increase in any of these factors will increase the amount of generated power. Air density varies with temperature and elevation. Cold air is denser than warm air. Therefore, a wind turbine in a cold climate will produce more energy than one in a warm climate at the same elevation. Additionally, a wind turbine near sea level will produce more energy than one on top of a mountain peak at the same temperature.[32] Classes of wind have been determined for different areas in the country, which serve as a beginning point for determining if the wind speeds are viable for efficient energy generation. Typically, a minimal average annual wind speed of 5 m/s or 11 mph, which is power class 3 or higher, is necessary for grid-connected situations. Minimal annual wind speeds of 3 - 4 m/s or 7-9 mph, which is power class 1 or higher, are adequate for stand-alone applications or remote areas. The minimal average annual wind speed is a speed that is equaled or exceeded for more than 50 percent of the time. Wind-power density is measured in watts per square meter and indicates how much energy is available

mini turbine free from obstructions



wind power class map for the US


HAWTs


VAWT

at a site for conversion by a wind turbine, and is associated with the power class of an area.[33]

Wind turbines currently are most effective in remote areas which the electrical grid does not reach. In situations such as this, it typically is cheaper to utilize wind energy rather than to bring a powerline out to the area. Wind energy used in an area where the grid already exists is, for now, restricted to areas with higher wind speeds in order to compete with the cost of nonrenewable energy sources.[34]

There are two types of turbines, one which is oriented horizontally to the wind stream and one which is oriented vertically to the wind stream. A horizontal-axis machine, or HAWT, has the axis of rotation oriented horizontally in relation to the ground and parallel to the wind stream. These resemble the typical fan design, and consist of a one, two, or three blade rotor with an aerofoil cross section placed upwind of the tower. This is the original type of wind turbine, and has been perfected in terms of energy efficiency and generation close to its theoretical maximum of 59.3 percent.[35,36] Power output can be controlled in high wind speeds by using spoilers or restricting the rotation speed. This type of wind turbine must have the means to track the direction of the wind either through a mechanical sensing system or a tail fin.

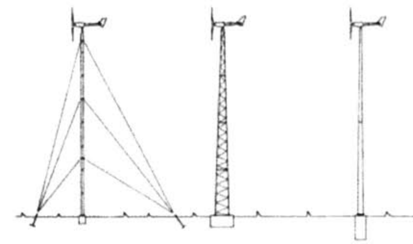
The second type of wind turbine is a vertical-axis machine, or VAWT, in which the axis of rotation is vertical to the ground and perpendicular to the wind stream. Vertical axis wind turbines are a more recent discovery, and have the advantage of being able to receive wind from all directions due to the nature of their geometry. VAWTs always have the mechanical parts of the machine near the ground; therefore, are easier and safer to repair. These machines have a wider variety of uses, being found on top of buildings for ventilation, and on signs for advertising. Vertical axis turbines have a lower efficiency than the HAWT because of the negative returning-power contribution, working against the wind. However, modern designs claim to be approaching 50 percent efficiency.[37] Due to their relative newness, VAWTs are still making advances in design and efficiency. As stated earlier, the power generated by a wind turbine is a function of the effective swept area and the efficiency of the machine. A HAWT sweeps a circular area, and the VAWT sweeps a rectangular area. VAW's have the ability to sweep a much larger area than a HAWT, and therefore can potentially make up the difference in efficiency in this way.

Wind turbines are primarily fastened to one of three types of towers: freestanding metal lattice structures, freestanding tubular towers, or guyed masts. Tubular towers are either tapered or straight-walled, and guyed masts either use lattice tower sections or tubing. These towers are typically connected into the ground for support, but it is possible to fasten them to the side of a building. If fastened to a building, it is recommended that the building not be inhabited due to the noise and vibration that the wind turbines can potentially generate.[38] A rule of thumb is to design the turbine so that it is 30 feet above any obstruction within 300 feet of the tower. In some cases, with micro turbines, it is possible to place them on a tower only 20 feet above the ground; however, the potential of energy output is possibly sacrificed to an extent, as well as the increased amount of turbulence that the turbine will endure due to the potential proximity to obstructions.[39]

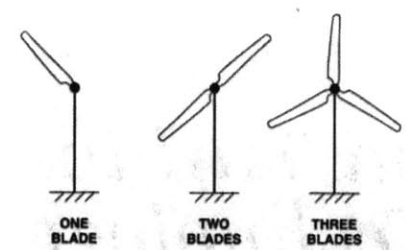
There are different scales of wind turbines, depending on the amount of energy to be produced, the nature of the site, and the nature of the wind at a site. The scale is related to both the diameter of the rotors, and the height of the tower. The potential of a wind turbine is best expressed by the rotor diameter, defining the 'swept area.' A turbine with a larger swept area will generate more power than one with a smaller swept area.[40] The concept of 'the taller the tower the greater the power' holds true most of the time. Therefore, the higher the wind turbine can be on a site, the more wind power potential.[41] Micro turbines typically are connected to towers of 20-50 feet in height, with rotor diameters of two to four feet. A single micro turbine can be used for such applications as recreational vehicles, sailing, and fence charging. Mini turbines are connected to towers of 100 feet or taller, depending on the terrain and surrounding obstructions, with diameters of four to nine feet. A single mini turbine can be used in such applications as remote vacation cabins. Macro turbines are connected to towers 100 feet or more, with diameters of nine to twenty-three feet. A single macro turbine can be used for powering homes, farms, ranches, small businesses, and telecommunications.[42]

Choosing a larger generator and wind turbine may seem to be the obvious solution for producing more power, but it is typically not economical. It is a careful balance between capital cost, electricity demand and wind regime for a given site.[43] It has been additionally proven that multiple smaller wind turbines used in conjunction are far more cost efficient and produce more energy on average than a single large turbine. This is due to the lower capital cost and the reduced amount of down time when one breaks down.

The potential site impacts of wind turbines are due primarily to appearance and noise. Visual impact of wind turbines is a subjective issue. Some feel that wind farms are

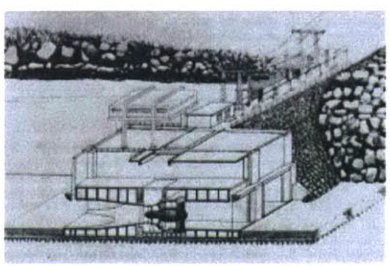


guyed mast, lattice, freestanding tubular



44

ocean tide



tidal barrage with water turbine

an amazing sight, while others feel they are a visual nuisance. Noise from turbines is generated by the gearbox and the wind moving across the blades. The actual levels of sound on a site with rated wind speed levels are the same with or without a wind turbine; the difference is the nature of the sound. The noise that is generated from wind only is constantly changing, and is considered by most as acceptable background noise. The noise from a wind turbine is regular and rhythmic, making it detectable and distracting for some. The noise can be lessened both through the siting of the wind turbine and the mechanics of the machine. The larger the turbine, the higher the wind speed, the greater the degree of noise.[44] A degree of noise to some has been considered a reminder that the wind is generating power; to others, it is bothersome. Wind turbines can generate power without displacing people or throughways, as is often the case with a conventional power station. Walkways can coexist underneath and around wind turbines without any problem or threat.[45]

WATER POWER AND COLLECTION

Tidal Barrages

Water can contribute to renewable power generation through the flowing of water downward such as in a stream or river, as well as with tidal flows in the ocean. Since the project site is adjacent to the ocean shore, opportunities exist for obtaining energy from the tide. Tides are caused by the rotation of the earth and the gravitational pull from the moon and the sun. As the earth rotates, the surface is alternately pulled by the moon or the sun, causing the oceans to bulge, and therefore creating the rhythmic rise and fall of the tide, usually twice daily. The sun's gravitational pull is less than that of the moon; therefore, one tide is often not as dramatic as the other.[46]

Not all coastal sites are suitable for tidal energy generation, as the change in the level of water from low tide to high tide may not be significant enough. The further one travels away from the equator, the opportunities rise. Tides in Florida average two feet, and in Maine they average more than eighteen feet of vertical rise.[47] Also, inlet areas can be too sheltered and therefore decrease the dramatic rise and fall that occurs on the actual coastline.

The mechanism to harness tidal energy is known as a tidal barrage. A barrage is built across an inlet area, acting like a dam and generating power not unlike the method for low-head hydroelectric power. At points along the barrage, gates and turbines are placed to facilitate the flow of water and to capture the energy. If the tide is falling, the gates are closed in order to store the water between the shore and the barrage until the low tide is met. Once the difference in water level on either side of the barrage is at its greatest, the gates are opened to allow the water to flow through. This difference in height creates *hydrostatic head*, causing the water to flow through the turbines, turning the electric generators which produce electricity. The barrage can also generate electricity as the tide is rising, by closing the gates and holding the water outside of the controlled area until the high tide is reached, then opening the gates and allowing the water to rush back in.[48]

The electricity that is generated from tidal flows is not constant; however, it is highly predictable and reliable compared to the wind and the sun. Power that is generated by tidal flows may not come at an ideal time, and therefore provisions may need to be made to store the energy temporarily. This is described in the renewable energy systems section. The turbines that generate the energy can also be used as pumps to pump additional water behind the barrage during times of low electrical demand. The water can then be released at times of high electrical demand and increase the value of the power produced.[49]

WATER COLLECTION

While harvesting rainwater does not generate additional renewable energy, it does save energy by use of a free material that is otherwise bought by most people from their municipality.

Rainwater can easily be collected from the roof of a building through a simple system of downspouts. The roof is the most common means of collecting rainwater; however, water can also be harvested from driveways or swales in yards, which is then directed into a pipe or a storage container. The best roof material for collection is metal, as it is the most impervious to water and is also the smoothest material, allowing the maximum amount of the water to easily reach the collection system.[50] Collected rainwater to be used for outdoor applications such as watering or gardening can be stored outdoors as long as there is not a problem with freezing. It can either be stored above or below the ground, a decision typically

swales to collect rainwater

influenced by cost. Storing below ground will keep the water at a cooler temperature for most of the year. For collected water that is to be used indoors, it would be diverted inside to be filtered and stored. The system should be below the height at which the water is collected in order to take advantage of gravity flow and to avoid the need for a pump. Once this water is filtered, it can be used for such purposes as the washing machine and the toilet.[51]

RENEWABLE ENERGY SYSTEMS

The various systems of PV, thermal collection, turbines, and barrages that work with the aforementioned renewable energy technologies can either be employed individually, or can be paired or grouped together to create a more diversified energy system. Multiple systems are potentially more efficient and can help to generate energy throughout the majority of the year. Hybrid wind and photovoltaic systems work very well together, since in most climates, the times of the day and year when photovoltaics do not generate energy (night and winter) are typically the times when the wind is strongest. Wind has a higher power density than does solar, so a wind turbine will contribute positively to the overall energy generated, even at a low wind site. Putting these two sources together additively covers a greater part of the day and the year that renewable energy can be generated, thereby lessening the reliance on a backup system or series of batteries.[52] In general, diversification of sources is advantageous for utilization of renewable energy rather than relying on one source.

There are two ways an energy system can be designed when using locally produced renewable power. The first is to run independent of the grid, where all energy available is energy that is produced on site. Any excess energy is either diverted to other uses or stored in batteries. For systems that are off the grid and operate self-sufficiently, back-up batteries are a necessity for times when the amount of produced power cannot match the demand. This is only suitable for very small systems, due to the cost, size, and weight of batteries. The second system design is to have an intertie system, where the site is connected to the grid, but locally produces renewable energy for itself. Any excess energy that is produced can be sold back to the utility grid or to a neighboring site. If there is not enough energy produced by the site via renewable means, the site can still receive energy from the grid or from neighboring sites.

As stated earlier, the technology that is being applied to the electrical utility grid today is such that it can handle complicated numbers and types of transactions between individuals and the utility companies. Therefore, if an intertie system is not producing enough of its own electricity via the renewable sources that it has employed, then electricity from the grid will seamlessly be delivered to the site for consumption. Likewise, if the site is producing more power than it needs, and any battery storage system is fully charged, then the excess power is seamlessly placed on the grid, and becomes a credit from the energy utility.[53]

The flexibility of the grid makes renewable energy production on a localized level very feasible. Therefore, another possibility would be for the excess to be sold to a neighbor. The producer and consumer would negotiate a rate, and the utility would credit the consumer's bill with the excess energy that was supplied to the grid by the producer. The utility would assess a fee to the producer for using the utility's lines.[54]

The final option in a system with excess power is to create an artificial load. This is often possible only if the site has a need for certain factors. If a site has a need for a large amount of hot water and large capacity storage, then the excess electricity can be diverted to heat the water. Likewise, the excess energy can be used to keep water in storage cooler if necessary. Water could also be pumped uphill and stored, then released to drive a water turbine for energy at peak time.[55]

This section provided background information based on the current technologies in the aforementioned sources of renewable energy. The physical requirements of the systems were referred to when implementing them into the design.

A List

show what is not normally seen
create a sense of curiosity
express how it works

a learning tool
feedback systems
control systems

encourage participation
encourage a sense of ownership
provide a sense of contributing to the whole

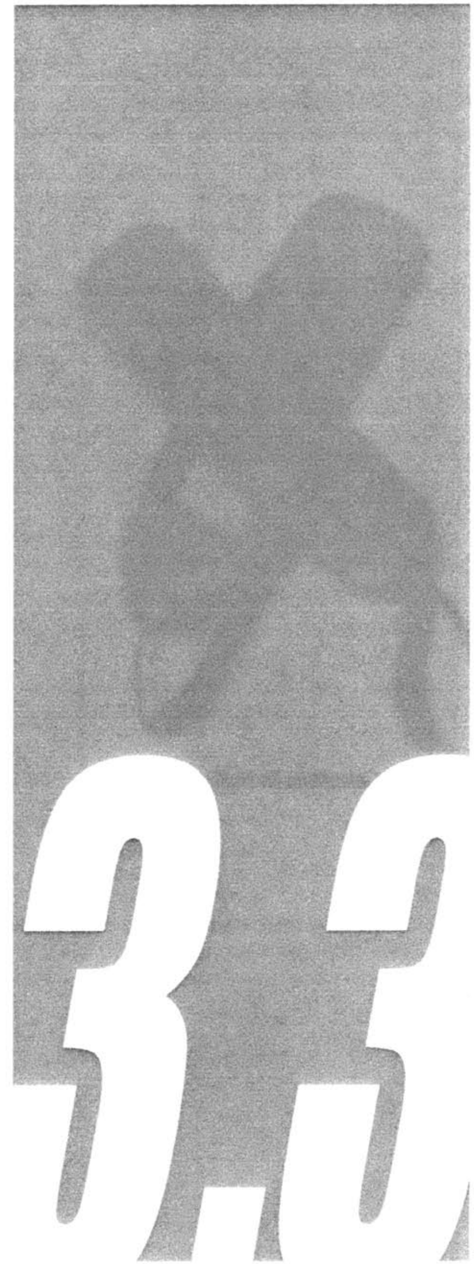
TRANSLUCENT TELEPHONES, PRISMACOLOR PINWHEELS, AND WIND WALLS

The 'touchy-feely' Part

SOCIAL CRITERIA

The intentions of the criteria thus far have presented ideas relating to the fundamental logic of natural systems and a systems approach, as well as illustrated the types and uses of renewable energy producing materials and objects. These two areas represent the performance-based and physical requirements, respectively, that are inherent when working with the concepts of natural systems and renewable energy technologies. The final area of criteria is derived from social ideas that are not concrete or tangible as the previous listed criteria, nor are they able to be proven through a performance test on paper. This criterion confronts what it means to experience a place, to be engaged with and to learn from one's surroundings, to feel responsible and aware of the repercussions for one's actions, and to be a positive contributing part of a greater whole. This type of criteria is often not considered in the design of infrastructure, nor specifically with the newly expanding area of renewable energies in the built context. It is my belief that for a technology that is dependant on responsibility, a change in lifestyle, and a shift in consideration of only the individual to consideration of the whole, it is imperative to consider how this renewable energy technology is introduced into built works and our lives. This section discusses personal observations and concepts dealt with in past projects that outline a set of criteria to frame the social aspirations of the design project, to be combined with the discoveries and observations from visits to existing projects as described in <4.0>

This section begins by stating a list of criteria, then continues by elaborating on each of the three groups of points in the context of an example. These examples, an everyday object and two personal projects, are meant to illustrate the intent of the specific criteria, as well as serve as benchmarks to signal the degree of understanding that was brought to the outset of the investigation. These ideas, grouped with the performance criteria and the physical criteria, are to be explored, challenged, and developed during the design aspect of this project. It was intended that a new dimension and a deeper understanding would be attained during the course of the design project, as well as a strengthening of the design by working with and providing for the following experiential opportunities.



WHY SUCH A LIST

Translucent Telephones

translucent telephone (in blueberry)

show what is not normally seen
create a sense of curiosity
express how it works

I cannot remember precisely how old I was when I first saw one, but I can still picture the catalogue page in my mind. I was that age when distractions like music, clothes, and hairstyles became apparent, and I was now in the market for my own phone. This was not to be any telephone, rather a phone that was translucent, one I could actually see the innards of the magical talking machine. The one that I had witnessed in the catalogue even came in different translucent colors, and all the phone's glory was right there, in the flesh.

To this day, I have never owned a translucent telephone. It was many years before I could have any phone, let alone a translucent one, with my parental upbringing as it were. Interestingly enough, when I see a translucent telephone, or most anything with its parts exposed through the housing, I am instantly caught up in its workings, and I have never overcome nor forgotten this fact. At the time, I could not have imagined the importance of this attraction, or that such a discovery would become one of the main intentions of such a graduate thesis. However, there is something very intriguing, very magical about seeing the working parts of an object, no matter how banal or how high tech the object may be. It begins to allow a person to understand on some primitive level what is happening inside the object. It reveals that there are small working pieces, little colored wires, chipboards, or maybe the only discernable thing is a little flashing light. Whatever the case may be, it expresses that there is more to an object than its outward appearance, and all too often today, we are denied experiencing such wonderment.

I keep finding that the older that I get, the more I want to see and understand; the more that I understand, the stronger my desire grows to learn more. The pace at which technology is advancing makes this very difficult. At times the reaction is to give up, as it feels hopeless that a person could ever understand what really happens inside a computer, or under the hood of a car, or even how electricity comes out of the electrical socket any time you need it. Many parts are now 'computerized', and therefore completely mystifying to the user, as the parts that make up the system do not physically express the role they have within the system. When a user is left feeling it is pointless to try to understand the mechanics of an object, this renders the user out of control of the object or system. With the complexity and speed of technology ever increasing, the degree of losing control does the same. This potentially is related to the feeling people express today of not having control of their lives. This seems appropriate when so many objects or systems that people come in contact with throughout an entire day are seemingly beyond their capacity to understand. Why should people think and learn anymore from their objects? The computer chips can do many things for them.

As I look around me, I realize that a few others have come upon this similar realization, and it has won a lot of attention from the public. iMac computers by Apple are now becoming one of the more popular models on the market, when not so long ago, they were rumored to be going under. The computer that has put them on top again did not do so in the power and capacity of the machine, but rather by enticing people's senses and curiosity. It comes in wonderful bright colors of translucent plastic, so one can see all the parts of the machine inside. Never has a computer granted the user the opportunity to look inside one of these 'black boxes', unless the owner was daring enough to open one up. iMac computers sit on one's desk like a giant piece of hard candy. I have never worked with a computer I felt enough affection for that it warranted being eaten. There must be something to this.

Being given the opportunity to witness on a simplified level the way a thing works potentially entices someone to be interested. When the human-made world is displayed in a gray galvanized box, there is not much interesting there to look at, nor begin to contemplate and understand. Many systems in the world are mysterious and invisible, such as oil drilling, energy production, or trash collecting, as the majority of people never witness any or all of the steps that are taken to complete any one task. As stated earlier, with centralized production, all steps become so removed from the foreground, all that they know is the final product is available to them, be it gasoline or electricity. No one ever bothers to consider where it may have come from, nor the steps involved with processing of the end product. If a person never witnesses the results or the repercussions of a task, then why would she be expected to consider their actions and responsibilities?

Translucent telephones are just a metaphor to illustrate a few simple ideas. Putting everything in a gray galvanized box, which is comparable to processes becoming increasingly centralized, encourages the idea of 'masking'. It removes any opportunity or ability for the people who come in contact with the box, or who use the product, to ever know anything about it or its origins.

iMac computer

It is uninteresting and boring. If the ideas or the steps embodied in a process, or the mechanics of a system, could be revealed in some capacity to those who come in contact or use the product, there is the potential for some degree of engagement. For some, it might cause a little curiosity, and simply be considered for a moment. For others, they may begin to see how the system works, and how it changes based on different variables, and this becomes something they continue to watch in order to 'break the code'.

Additionally, it is my belief that people will feel more in control and more aware of their surroundings if the mechanisms involved in their lives are simply expressed and demystified for them. In this way, by being able to see the working parts, or the motion, or reaction as something acts upon or changes in the system, it can spark a sense of curiosity. People are attracted to change, become 'numb' to constant, or unchanging conditions. As Amory Lovins states, "People are not simple, uniform entities that thrive in a box. They are, rather, complex living organisms that evolved in and still function best in a dynamic and diverse environment."[1] If one can visually sense how something works, then s/he can begin to understand what it is doing and what its purpose is. If this can be tied to something that s/he connects with in his/her daily life, something that s/he is a part of, then this is an even stronger association.

Prismacolor Pinwheels

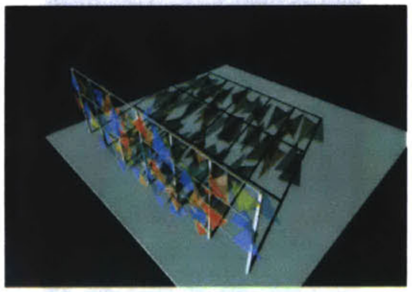
a learning tool
feedback systems
control systems

A graduate seminar project serves as the next example, which taught and revealed to me the power and influence a designer can have on the designs she creates. During this semester, I became aware that people in general were losing a connection with the natural outdoor world, due to such things as spending less time outdoors and spending more time in buildings that seal them off from the ever changing environment. In response to this, I chose to make a project which was functional and energy efficient, while at the same time would express and create awareness of the continual change in our surroundings. The intention was to make a memorable experience, by forming a connection with the natural time cycles that occur in the environment all around. Additionally, I became interested in the notions of buildings working passively and actively in response to the environment, and how this could be expressed for the people using or passing through the space. Spending the semester teaching myself how to build circuit boards and to generate energy from solar radiation, I combined the technical know-how I attained with the desire to express a building's response to the changing environment.

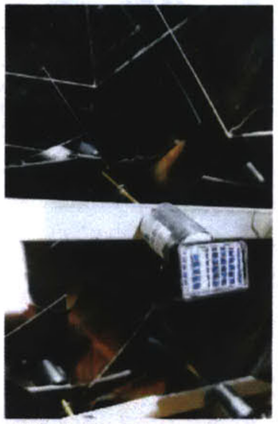
The premise of the design was to install a 'fan wall' on the south facade of a building. The fans, or pinwheels, were meant to block the transmission of solar radiation into the interior of the building and flush out any collected heat in the wall. This was done in order to control heat gain, as well as to allow the wall to present itself as an ever-changing facade. The design is full of motion and light, directly responding to the varying levels of sunlight throughout any given day. The pinwheels are operated by photovoltaic cells, which directly transfer solar radiation into electrical current. The energy produced by the PV cells is used to power motors that rotate the pinwheels. Each pinwheel-motor combination is powered by its own PV cell, so the various pinwheels rotate relative to the amount of solar radiation the solar cell is receiving. The phenomenon of a cloud blocking the sunlight on a portion of the wall is translated by that area of the wall slowing down. The pinwheels themselves are made out of polarizing material - a rigid, translucent plastic film, which possesses the ability to block the transfer of light. The amount of transmission is affected by the way two layers of the polarizing film are overlapped and rotated relative to each other. When the fans rotate, this process occurs, thereby reducing the amount of solar radiation that passes into the space. Therefore, the source of the problem becomes the power behind the solution; as well, the system

wall section prototype

pattern, color, shadow



facade concept model


PV cell and motor


motion/ change/ feedback

only operates when it is necessary and at the pace which is necessary. It is a very efficient, 'intelligent' facade.

The system as a whole becomes a time-marker and intends to enhance people's awareness of the cyclical changes outdoors. Throughout the course of the year, the amount of time the pinwheels operate increases during warmer months, and decreases during colder months. Likewise, the system reacts accordingly to sunny days and overcast days. It is even sensitive to a person walking by outside, casting his or her shadow on the surface and causing the pinwheels to slow down. By being simple and explicit in its function and mechanics, the wall exhibits a design that translates the changes in the environment outside into visual feedback in order for the viewer to observe and learn. When a system provides feedback, it is only then that the viewer or operator can learn from the system. The feedback reveals what the system responds to, as well as what makes the system run more or less efficiently. It is from feedback that conclusions can be made as to how to improve the system.

In general, many industrial processes do not incorporate feedback systems to keep them in check and in line. As Amory Lovins states, "Living systems are regulated by such limiting factors as seasons, weather, sun, soil and temperature, all of which are governed by feedback loops. Feedback in nature is continual."[2] Lovins also claims that systems without any form of feedback are 'stupid', whereas systems with even the most rudimentary of feedback systems can gain 'intelligence' very quickly.[3] As well, the people who participate or come in contact with such a system with feedback, also become more intelligent, and possibly feel more in control.

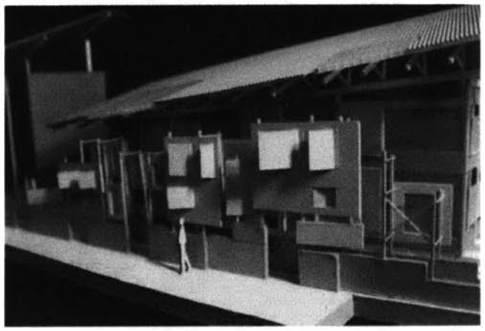
In addition to feedback systems, control systems are also necessary to oversee complex variables and reactions. Control systems patterned after biological systems can take vast amounts of information and variables and make decisions based on fuzzy logic that people are not able to do in comparable time and with as much accuracy. With the advanced technology available now, 'distributed intelligence' control systems can orchestrate many decentralized decision makers, all of equal deciding power. This is done by talking to one another, by interpreting events, as well as interacting and learning from each other in order to control their collective behavior, similar to the way an ecosystem operates.[4] When control systems are coupled with feedback systems, people can observe and learn from the system, they can trace the changes in the system, and they can see what they can do to make the system work better for themselves and all those involved.

Wind Walls

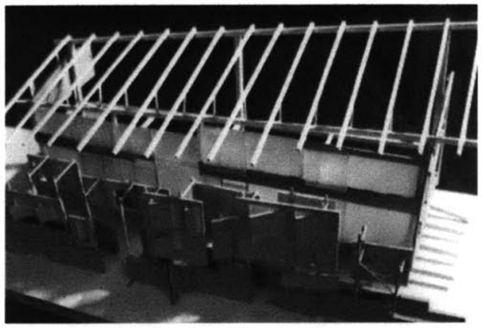
encourage participation
encourage a sense of ownership
sense of contributing to the whole

A second project that I have chosen is from a graduate studio and illustrates the final area of social criteria . This investigation addressed the idea of a 'wind wall', which passively and actively controlled the flow of wind, as well as became a screen onto which the daily changes and interaction of life were presented. The project took place on a site along the eastern coast of Japan known for the natural dry wind that comes off of the ocean in the summer months which helps to cool the residents from the often hot, humid air found slightly inland. The initial response was to create a means of directing and controlling the wind particular to this area in order to allow the residents to deflect the breeze into their homes as they choose. The wall finds its place exteriorly between the residences, thereby each side being shared by either a family or couple. Through the course of the semester, I became intrigued by the opportunities that the shared piece of infrastructure lent itself and pursued the notion of the wall being more than simply the means to deflect the wind, but to additionally serve as a 'backdrop' on which the activities of the day, the varying breeze, and the social interactions were conveyed. The wall was changeable and maneuverable, with areas the residents could claim as their own, and participate with the moving and adjusting of the wall to suit their needs, be it to create more privacy, create more outdoor space, or to facilitate the flow of the wind through their home when it became hot and humid. The wall changed its appearance and function similar to a living thing evolving and reacting to environmental changes.

Differing from the previous project, I chose to explore the idea of allowing the people who came in contact with the wall to not only be able to visually experience it, but also to be able to control the functioning of the wall. I felt that this took the idea of learning and observing feedback a step further, as the changes that they physically made would be conveyed directly on the wall, and would affect those who also used the wall (learning by doing). These effects could be as simple as moving a panel in order to channel the wind into their home, or more complex by closing a series of panels in order to gain more social privacy from the people across the way, depending on what they wished to affect or convey. The idea of encouraged participation became intriguing in that the participant became a part of the system, and his/her actions contributed either positively or negatively to the greater whole.



movement of panels to deflect wind for comfort



environmental infrastructure element

wind wall between two residences

human interaction with components of wall

It was my belief that by being directly involved in a system, people will be more aware of their actions, and therefore will act more responsibly, as they will be held accountable for their actions. When working with the ideas behind a systems approach explained in <3.1> (cyclical thinking, continuous loop, interdependency and interconnectedness), it is not only imperative to express and reveal in some manner the way in which the system works and the way the system reacts, but additionally to allow people to be contributors to the system. It is only in this way that people will feel responsible for their actions, thereby shifting the concept of each person out for his/her own, to the notion that everyone contributes to the good of the whole. The responsibility one upholds becomes tangible and necessary; it creates a sense of community, and, in turn, it will ideally permeate other aspects of his/her life, as he/she begins to make connections based on his/her actions in relation to those around them, as well as those who come after him/her, and on down the line.

It is also imperative that the people who live and work in an area, and whose lives come in contact with such systems, also feel a degree of ownership. Whether they claim a piece of the system, as in the case with the shared sides of the wind walls, or they are affected by the efficiency of the system, such as the cost of their energy bills, there should be some aspect of the system that inherently causes people to want to participate in a way that is responsible and helps the welfare of the whole. This becomes fulfilling for the well-being of the system, as well as the well-being of the now interconnected and interdependent place, which is working together to make the system better for all.

CONCLUSION

The social criteria establishes expectations that the design embraced throughout the investigation. While the system criteria and the physical criteria can be tested and proven if necessary, the social expectations are not so easily demonstrated without actually creating and building such a scenario, and observing how people interact with each other and with the system of the built works. It is therefore intended that the social criteria act as a guide that influences the design and layout of the proposal in a positive and humanistic fashion. It is my feeling that not only must changes in our way of designing and constructing built systems occur, but changes must also occur in order to express and reveal that changes need to be made in attitude and way of life in order to harmonize our behavior with that of the ecosystem. Therefore, these social criteria are meant to reveal and teach people in a positive, educative, and exciting way in order to spark interest, curiosity, and fascination, and ideally, make them think.

CASE STUDIES - PROJECTS VISITED

Observations of Renewable Technologies in the Built Environment

THE RENEWING ODYSSEY

The performance <3.1> and physical <3.2> criteria for renewable energy technologies previously discussed can be researched and tested through quantifiable and qualifiable means. Conversely, the social criteria <3.3> embody ideas that must be experienced or observed, and are not easily tested until built. Therefore, in order to understand the social implications of integrating renewable technologies into the built environment, I deemed it necessary to visit projects exemplifying these notions. Experiencing the projects firsthand would allow me to synthesize my beliefs regarding the connection that I feel needs to exist between people, their community, and their built environment, with the findings that I would make while visiting the projects. There were three main categories of observations that I sought: [1] to see the construction, the physical constraints, and the opportunities that renewable technologies present; [2] to observe how the designs of buildings react and respond to the integration of the renewable technologies as well as innovations that emerge; [3] finally, to experience how people come in contact with the energy producing technologies and the buildings they share, and whether or not people should and could actively engage with these technologies in a positive way. The projects that I visited were found in the countries of Germany and Netherlands. These two countries were chosen because their governments currently enforce the strictest energy codes, promoting clean energy and minimizing fossil-fuel based production. Progressive government incentives have been put into place to encourage renewable technologies to be implemented into the built environment; therefore, a concentrated number of significant projects have emerged.

While there were many different types of projects visited over the course of the journey, I began to categorize the projects into four groups. The first two groups relate to the degree to which the renewable technology was incorporated into the design, that being whether it was simply applied or integrated. The second two groups relate to the location of the technology, whether it was located remotely or locally. The following are descriptive narratives of my observations of these projects transcribed from traveling notes. The experiences served as an invaluable source of intangible information that I found myself referring back to time and again while embarking on the thesis design project.

4.0

Applied Technologies

'...the term 'applied' refers to much of what I am finding on these projects. Applied technologies represent the first generation of attempts at integrating renewable energy technologies into the built environment. In some cases, the relationship is the building simply lends the technology a south-facing surface material on either a wall or roof. In others, it is more of a parasitic relationship, where the technology is unscrupulously attached and feeding off of the building more than the building benefits from the technology.' '...viewing roofs and south-facing facades of buildings simply as surfaces that an energy-producing material or panel can be attached to is limited and singular; the opportunity exists to do and to be more. As well, the technologies found in these instances appear foreign and odd... panels often being forced into compromising positions or locations, minimizing the efficiency and causing redundant construction.', '...Applied technologies do make sense when they are being introduced onto an already existing building or construct; however, it is not rigorous enough in new construction if the building does not acknowledge or respond to the introduction of the technology. The projects often miss opportunities in that sometimes the energy producing material is not even detectable, and therefore has little engagement with the user of the building.'

Integrated Technologies

'Projects that fit into this category are those in which the building and the renewable technology are responding and reacting to each other in some manner and the technology serves more than a single purpose... Integrated examples are the second or third generation of projects, learning from the 'applied' group. In these projects, the design of the building itself takes on a different character from the 'standard' residence or commercial building, becoming clever and inventive with the introduction of the renewable energy technologies.' '...projects using PV's to generate energy as well as for shading (dual purpose)... projects that create an intermediate buffer zone, working with patterns and translucent material characteristics to encourage the dramatic play of light and shadow... whole projects actually rotating in order to track the path of the sun...' 'The construction is no longer so redundant, attempting to merge technologies into wall/façade systems; discovering opportunities that simultaneously collect energy, block direct sun, and capitalize on indirect light and ventilation. The energy producing capabilities of the projects are much more palpable than the projects that simply applied the technologies; often the projects are oriented entirely to the south, as well as implementing strong gestures of angled roofs and sloped walls. The projects are much more in touch with the outdoors, providing expansive views and natural light. They are more alive and open, putting the people inside in tune with light changes throughout the day.'

Remote Technologies

'...the larger scale technologies are often located remotely away from any city or town. These projects always come across as 'oddities,' yet exciting discoveries that people seek out... Wind turbines make sense in such an arrangement due to their large scale and their ability to produce energy that is simply thrown onto the grid. Occuring in remote areas, the turbines are located in a place that is more strongly connected with the natural forces and more exposed. Observing them, one can experience the direct relationship between the speed and direction of the wind and the reactions that the turbines make in order to capture the maximum amount of energy as possible.' '...being away from developed areas allows these large scale technologies to act independently; they can take on unusual forms (angles, slopes) and incorporate movement in order to harness as much energy as possible... the turbines create a recognizable landmark or point in the landscape, point of destination; large scale – better to view from a distance - I now understand that there is a need to have a graduated language of technologies in more open, less dense areas all the way through the integration of technologies in more dense urban areas.'

Local Technologies

'These projects have implemented renewable energy technologies on a local scale. The production of energy became an underlying theme, or thread, serving as a way in which the community is tied together, demarcating different areas associated with certain energy producing technologies. In one residential community planned project, producing clean energy was a part of the 'everyday surrounds', as wind turbines were in the distance, solar thermal panels were placed onto roofs in an area of the housing, and photovoltaic panels were found on many of the housing units. The solar thermal panels produced hot water on a local scale, storing it in a large underground tank for the consumption of people in the community... the integration of the technologies into a neighborhood provided open space for people to use as publicly shared space.' '...project reveals the inner workings of a small scale co-generation plant that produced energy for a neighborhood. The plant was situated adjacent to the neighborhood that it served, displaying the process to produce the energy in an aesthetic way. It became a recognizable 'node' to the community, a point from which people obtained their power.'

LESSONS LEARNED

Visiting these projects firsthand provided a type of information that could not have been obtained otherwise. It allowed me to experience the sense that these projects provids for those who come in contact with them, and helped me to develop my ideas and beliefs regarding the importance and responsibility of introducing these technologies into the built environment. The projects demonstrated various ideas, concepts, opportunities and mistakes, as well as the need to integrate these renewable energy technologies in an innovative, creative and sensitive manner. Glimpses of the ideas presented here can be detected in the following design project, the ideas evolving over the course of the semester, emerging finally into a unified language. One of the most important lessons and concepts that was learned was that it is, in fact, possible for people in an area to be aware of the role of renewable energy. The concept of renewable energy being produced on a regional scale, serving as a system or network that could be one way to tie a community together, was observed in the project in Kronsburg, Germany. The system was the giver of energy; it provided open space for people to gather (where rain water was collected and held in retention ponds) and hills for children to play on (hot water storage tank). The hot water system became an underground network that served many people, connecting them. The strong sense of community in this neighborhood was not completely the effect of the renewable energy technologies and policies in this place, but it was a positive result.

66

PORTLAND, MAINE

PROJECT SITE

SITE ANALYSIS AND FORMULATION OF DESIGN PROCESS

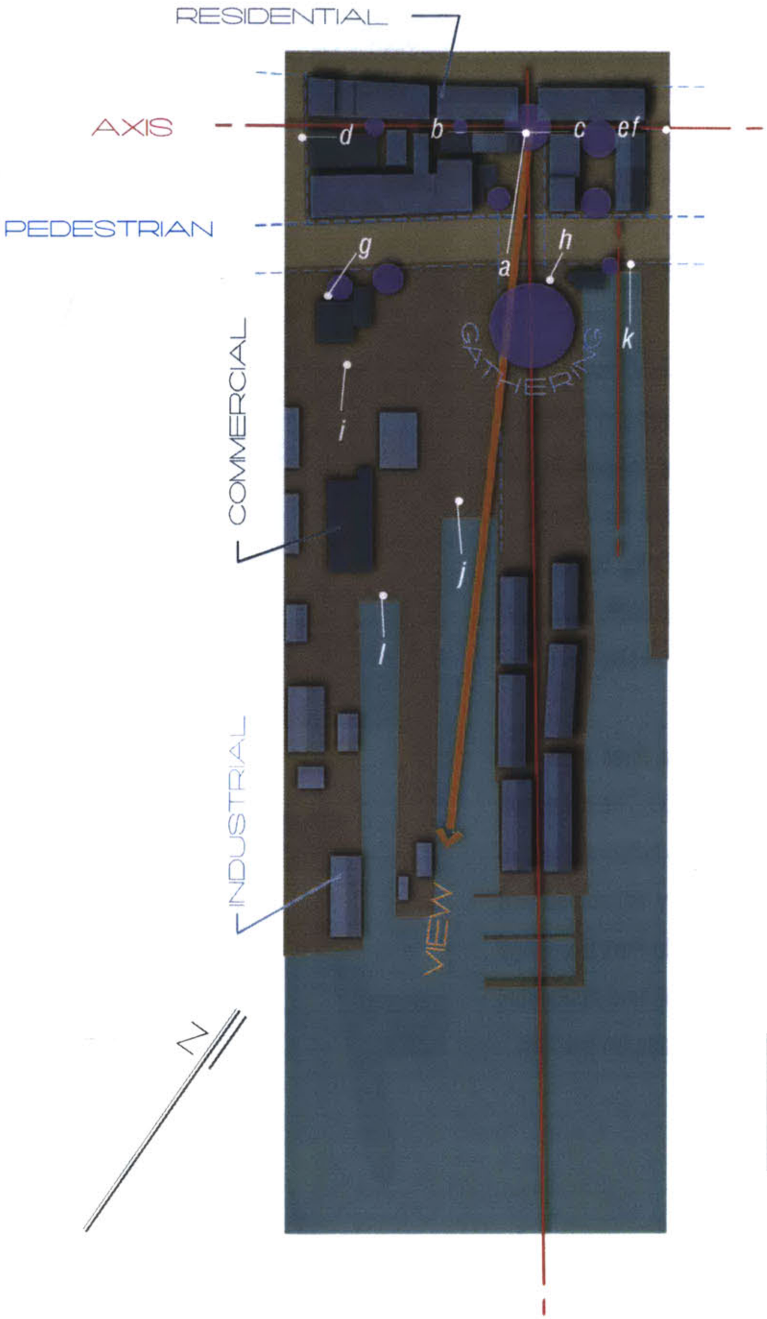
Role of the Site and Natural Force Mapping

'TYPICAL SITE' – PORTLAND, MAINE

The site for this project was chosen initially based on personal familiarity with the area, and more specifically, based on its ability to operate as a 'typical site'. The intention of the design investigation was to generate prototypical ideas and concepts resulting from the introduction and integration of renewable energy technologies into an existing urban site. In order for the investigation to operate as proto-typical, the site was to have neither extremely favorable nor unfavorable conditions in relation to the harnessing of natural forces for the production of clean energy. Rather, an average site in relation to potential energy was sought, thereby allowing the ideas and concepts to be translated or replicated to other comparable 'average' sites. The site acted as a test-bed for ideas; it was not integral to react specifically to the 'placeness' of the site.

The project site is located in Portland, Maine, on the East coast of the United States. Portland lies on a three mile long peninsula extending into the ocean, roughly rectangular in shape, with a population of approximately 64,000. The peninsula is saddle-shaped lengthways in section, with a hill on either end. The city center occupies a ridge that runs between the two hills, a place very exposed to the natural elements. Historically, Portland has been a harbor city, largely influenced and sustained by the fishing industry. The site is located on the southeastern side of the peninsula, in the Old Port Exchange district. This site was specifically chosen due to the existing composition of commercial/retail, industrial, and residential building uses as well as the varying conditions on the site of denser urban fabric and open, industrial-scape on the bay.

5.0




a


b


c


d


e


f


g


h


i


j

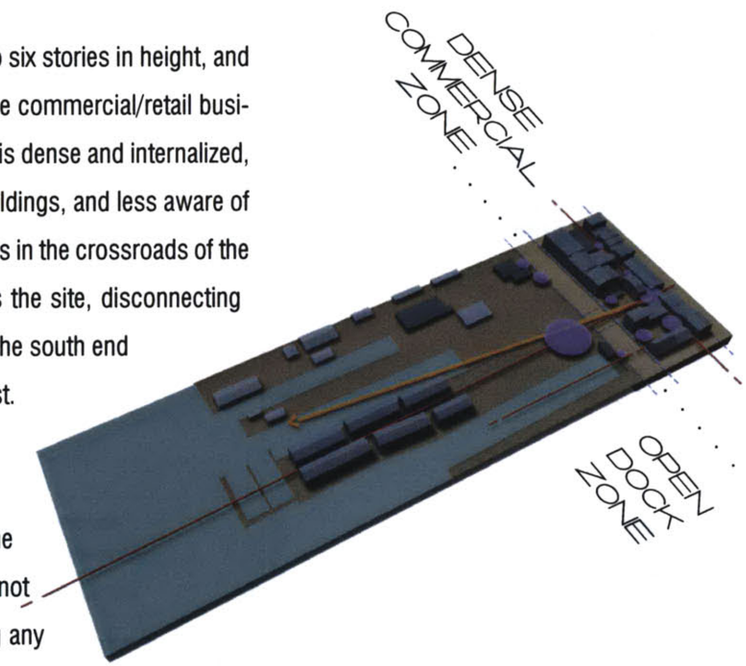

k


l

SITE ANALYSIS

The project site is roughly 600 feet wide by 1,900 feet in length, oriented 33 degrees off of north. The specific site boundaries were determined by framing an area that allowed the project to accomplish the aims in the given time, and to facilitate the choice to work at a variety of scales. It is critical to note, in terms of working and designing with natural forces and natural systems, the depicted boundary is very artificial. Over the course of the investigation, the project zoomed both in and out in order to reconcile with the nature of natural forces and to draw from the interconnected essence of a systems approach. The bounded site shown here became known as the 'WHOLE'.

The northernmost part of the site is comprised of 19th century brick and granite buildings, four to six stories in height, and closely spaced such that the alleys are only pedestrian accessible. These buildings typically have commercial/retail business on the street level, with residential or office space on the upper levels. The sense in the area is dense and internalized, where one is more aware of the happenings immediately around him/her in the alleys and the buildings, and less aware of the larger, natural conditions of the sky, ocean and climate. An open central gathering space occurs in the crossroads of the alleys, where a strong visual connection is made out to the harbor. A main street cuts across the site, disconnecting access and awareness of the densely inhabited area from the docks and ocean. The majority of the south end of the site is existing industrial infill, with remnants of boats and docks from a fishing industry past. Newer residential townhouses exist on one half of the dock area of the site, and metal industrial buildings and warehouses are on the other. Crossing the street immediately removes one from the very internalized zone of the commercial area and opens one up to the elements. This area of the site is highly unorganized and lacking definition in what it is attempting to be or do. People cannot easily reach the docks or the inlets, as the space is taken up by haphazard parking. It is lacking any place to gather or movement paths specifically for pedestrians. One now enters the very exposed part of the site, and bigness of water and sky becomes apparent. Moving further out towards the ocean, the awareness of the natural forces becomes increasingly apparent.



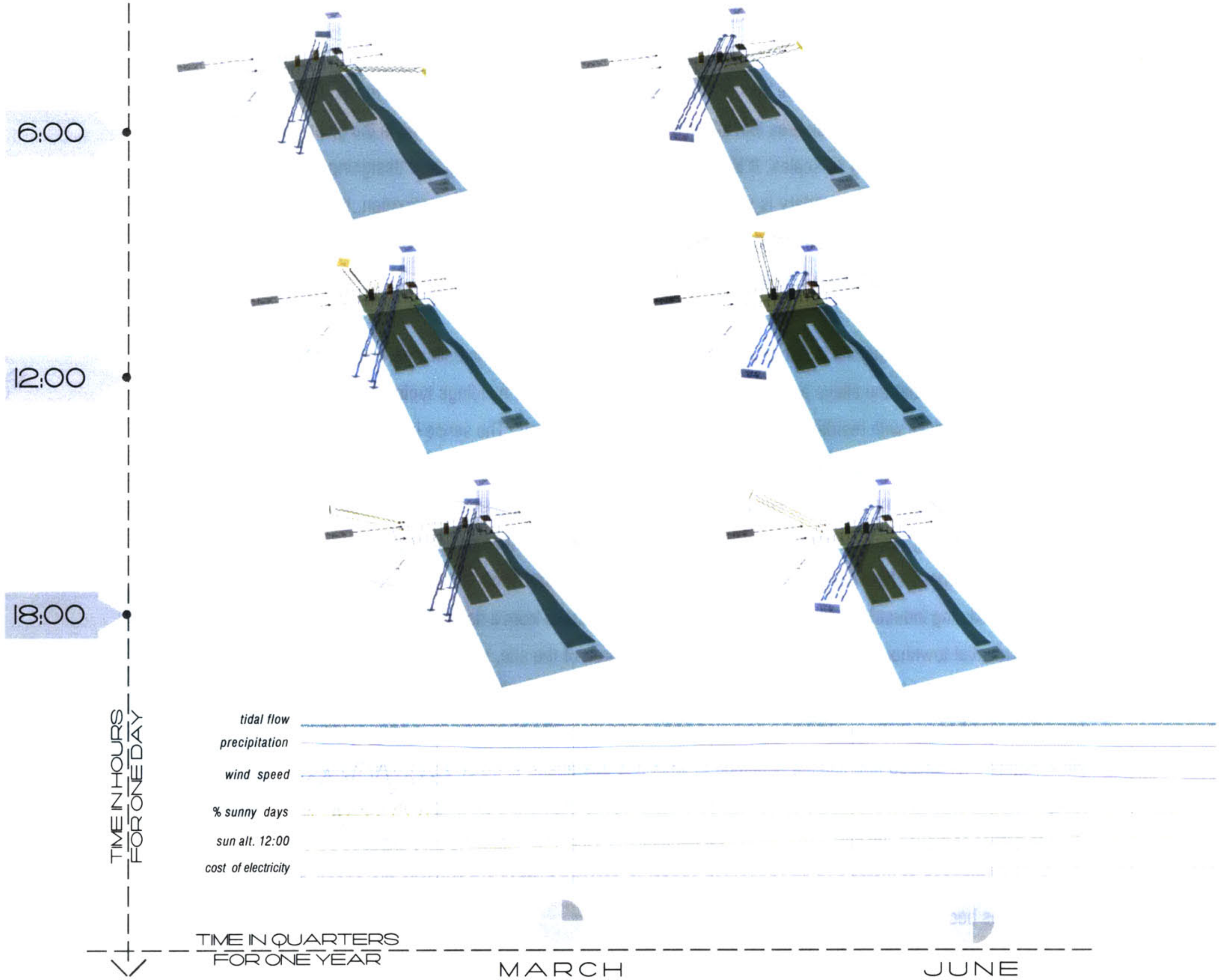
represents cost of electricity produced away from the site as it varies during day and year

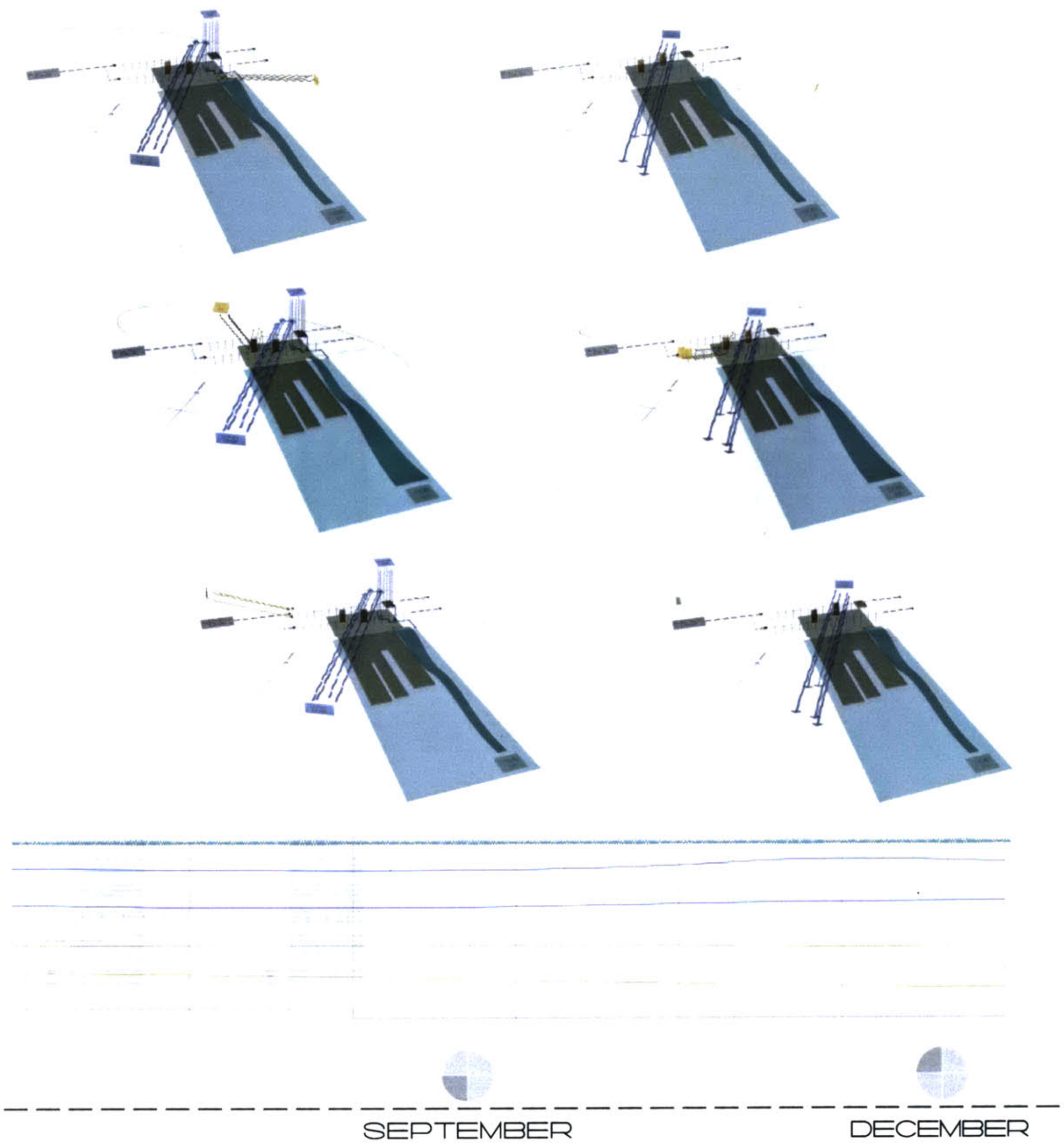
represents azmuth and altitude of sun during the day and the year; average percentage of sunny days during the particular month

represents the direction and the average speed of the wind during the particular month

represents the average amount of precipitation for the particular month

represents the rise and fall of the tide particular to the time of day; height in feet relative to sea level



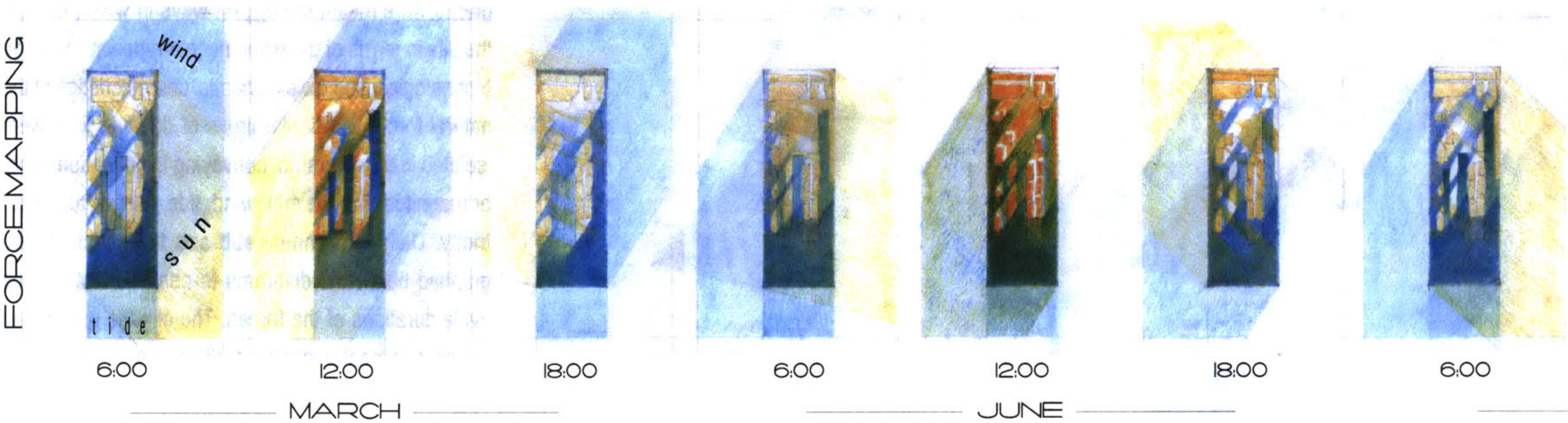


CLIMATE AND DESIGN PROCESS

Natural force diagrams

The initial step of the design process was to take the factual information of the climate data for the site and transpose it into a visual diagram format. These diagrams were meant to suggest ways in which to view the site in terms of the placement of renewable energy technologies, and the experiential characteristics of the natural forces. Particular times of day and year were isolated in the diagrams, conveying the directions and/or magnitudes of the sun, wind, tide, rainfall, and electricity. Daily and annual ebb and flow cycles were graphed below the diagrams to compare the various cycle durations of the forces. The climate in Portland is one of a cooler, northern climate, somewhat tempered by the presence of the ocean. The average annual temperature is a high of 54.9 °F and a low of 35.8 °F, and wind speeds average 8.7 m.p.h. The tide rises and falls roughly 10 feet twice a day, and sunshine possible averages 57% of the year. Portland receives between 3" to 4" of rain per month. This exercise suggested to me that there were spatial qualities in relation to the way in which we comprehend and experience natural forces, as well as an emerging logic that began to locate the various technologies to be implemented on the site. This step became a catalyst in suggesting a process of mapping the natural forces as seen in the following two steps, becoming a significant informer to the design process.

FORCE MAPPING



INITIAL SPATIAL STUDIES

_idea of layering and intensity - these become signifiers

CLIMATE AND DESIGN PROCESS

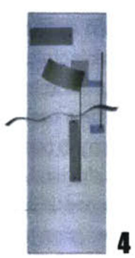
Natural force mapping **1**

Once the 'factual' information had been transposed from the previous exercise, it was necessary to further decode the visual information into a more useful form. The next step was to map the natural forces of the sun, wind, and tide, in terms of direction/orientation and magnitude. The three forces were depicted through the use of color, the force directions are a function of the brush strokes, and the intensity of the color signifies the magnitude of the force. The same times of day and year were employed from the previous step. This resulted in natural force mappings which I believed depicts the climate data more in the way a person experiences the forces on the site. A spatial organization, or code, emerged. To test and analyze the spatial qualities, four three-dimensional abstract models were overlaid on the mappings and constructed. These four abstractions represent the first attempt at a 3-D representation and layout of the various renewable technologies on the site in response to the diagrams and the mappings done up to this point.

OVERLAPPING
DIRECTIONAL

12:00 18:00 6:00 12:00 18:00

SEPTEMBER — DECEMBER



4

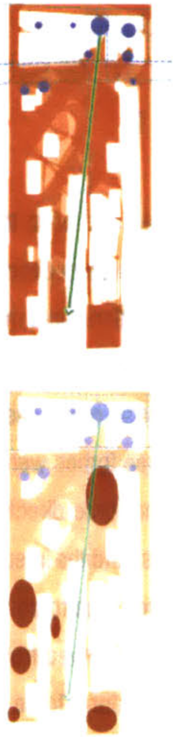
SPATIAL

ORIENTATION

INTENSITIES

*layering + intensity - opportunities_*

EXPOSURE / SHELTER ANNUAL AND SEASONAL

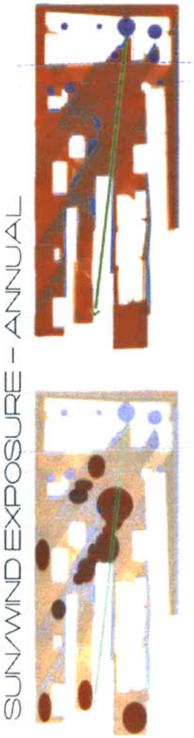


SUN EXPOSURE - ANNUAL

- most exposed areas occur as a result of openness or a place that is extended out towards south/ocean
- more informative as to where to place PV arrays and solar thermal panels
- in general, attitude towards sun is positive for majority of the year, exposure is advantageous for people to keep warm

WIND EXPOSURE - ANNUAL

- most exposed areas where a lack of building density; in similar form to the areas of maximum sun exposure - relationship
- suggests places for wind catchment, locates places not advantageous for movement or especially destination points during cold months
- if sheltering is desired, proper geometry as suggested by existing conditions is necessary

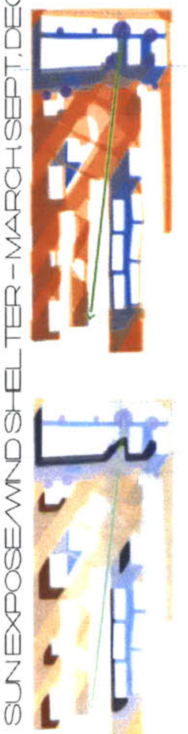


SUN/WIND EXPOSURE - ANNUAL

- relationship to natural forces in terms of location on site and awareness level - stratification
- ideas of various degrees of exposure that can be controlled based on the need (ie: block wind, partially shade sun; expose wind, shade from sun)
- overlapping of forces
- suggests provision of shelter for movement/ gathering points, as well as shielding for buildings against forces

WIND SHELTER - MARCH, SEPT, DEC

- geometries of buildings in relation to wind direction observed, as well as proximity of buildings to one another to form sheltered space
- two main areas of shelter from wind, suggests need for some means of connection



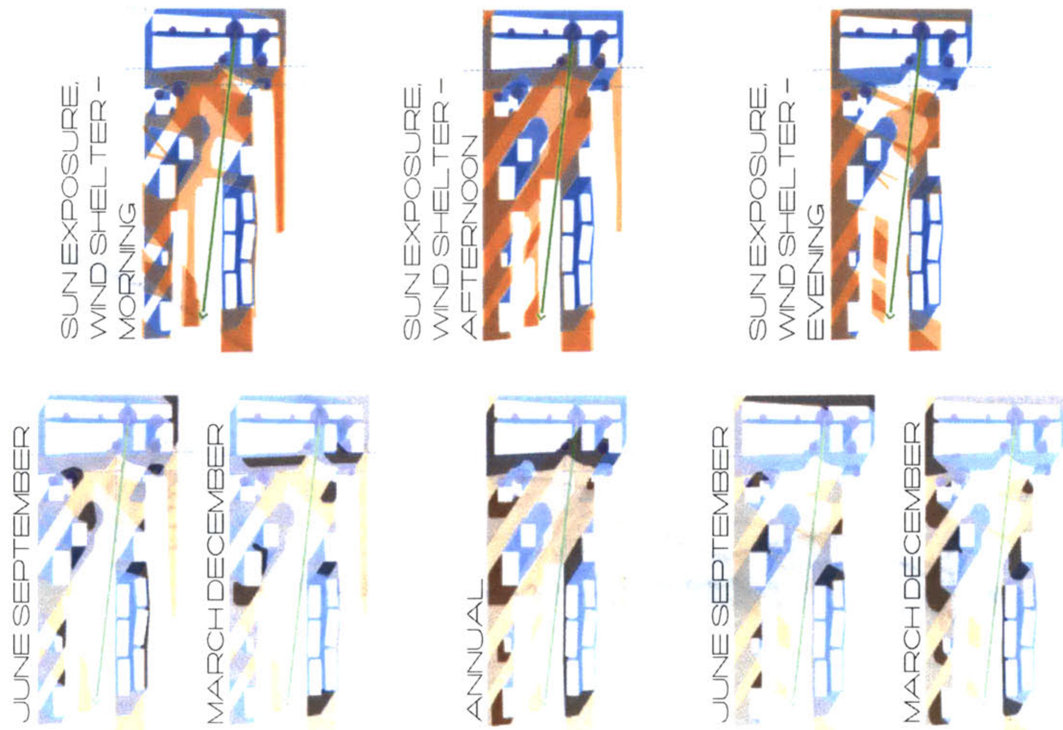
SUN EXPOSE/WIND SHELTER - MARCH, SEPT, DEC

- ideal for colder seasons - providing shelter from wind, and exposed to sun
- exist. conditions result from geometries, can be copied for places of movement and gathering
- various degrees of shelter - small scale - position body in comfortable place (recline); large scale - move into comfortable location (walking)
- small degree of shelter - movement; high degree of shelter - gathering

SUN SHELTER, WIND EXPOSURE - JUNE, NOON

- warmer times of year warrant need for degree of shelter from sun, exposure to breeze
- speaks of mediation places, ie: 'edge conditions', where a person adjusts one's position as necessary to create comfort in terms of sun and wind exposure
- suggests ideas pertaining to shadows (shade) moving as sun moves over course of day, and therefore sheltered space moves also - personal tracking

EXPOSURE/ SHELTER TIMES OF DAY

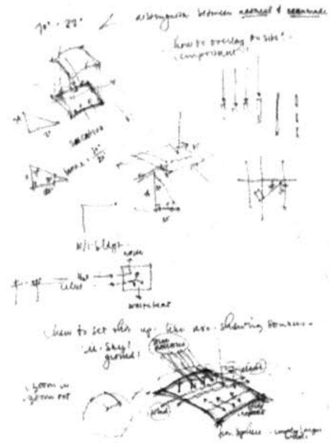


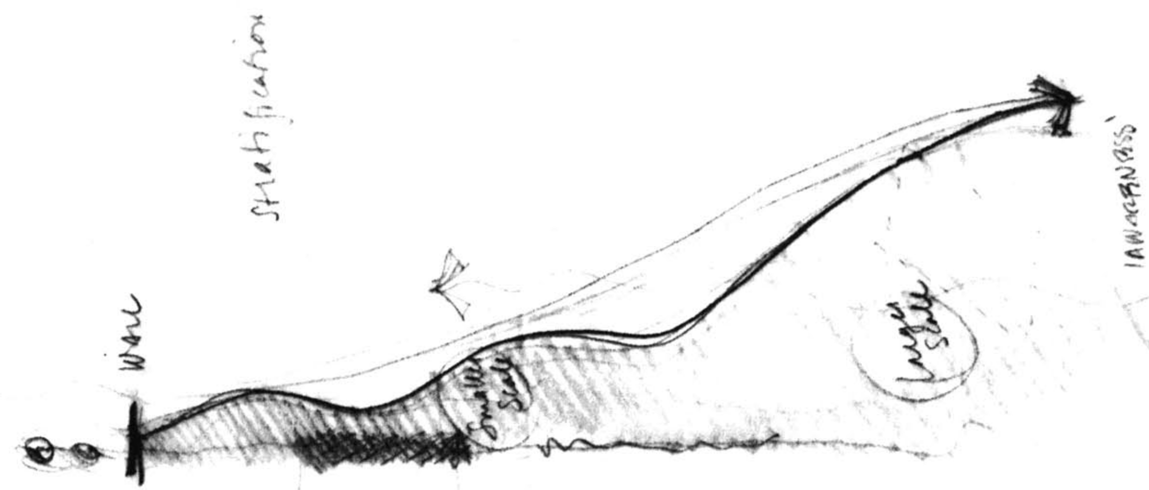
- *existing conditions that are advantageous for movement/ gathering during morning hours*
- *existing conditions that are advantageous for movement/ gathering during afternoon hours*
- *existing conditions that are advantageous for movement/ gathering during late afternoon/ evening hours*

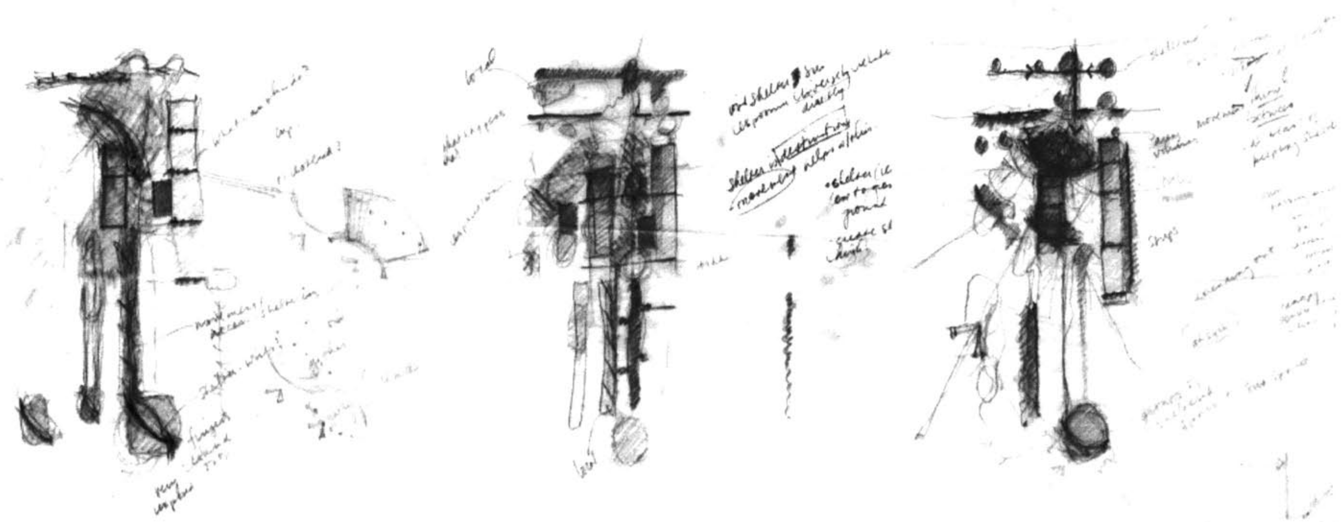
CLIMATE AND DESIGN PROCESS

Natural force mapping **2**

It was necessary for the force mapping to go through a second iteration, after sensing the pertinent information had not been fully realized from the previous step. It was at this point that I began to think of the site in terms of SHELTER and EXPOSURE in relation to places of MOVEMENT and GATHERING. These ideas arose out of revisiting the issues of the exposed exterior areas in this climate in relation to the need for comfort and shelter during different seasons of the year. The connection was made between the need of the renewable technologies to be exposed to the natural forces, which simultaneously could provide shelter to people underneath, against, or within the structure. Taking the previous mappings, the information was transposed by layering combinations of areas exposed and sheltered from the sun and wind. The resultant mappings released geometries/ spatial relationships that established a logic by which to design and place the technologies, as well as provided a secondary role for the technologies as potential movement and gathering spaces. Most importantly, the simple logic of inversely using the renewable technologies to both produce energy and shelter provides people inhabiting the space the potential for reconnections.



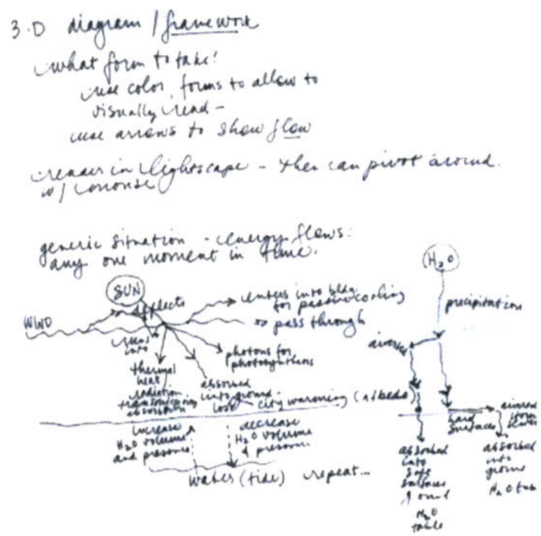

Stratification
wall
awareness
smaller scale
larger scale

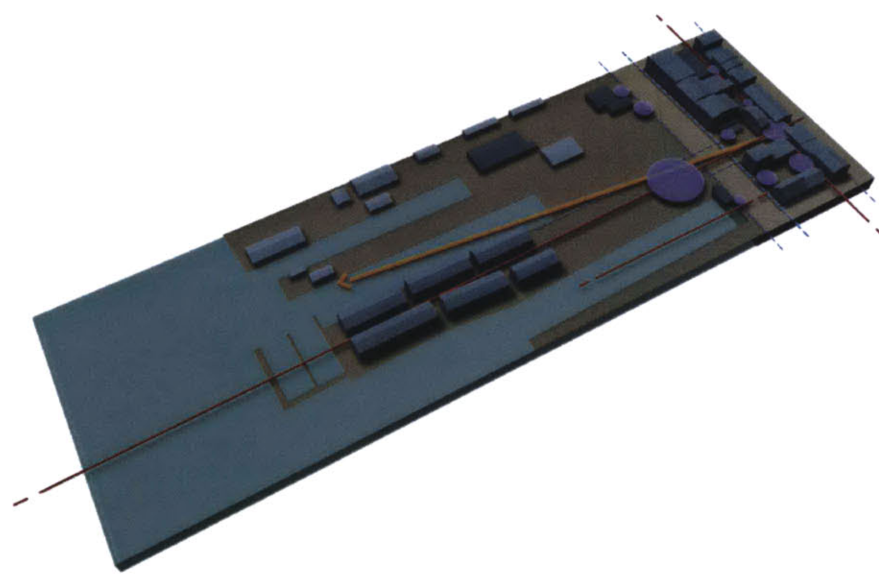


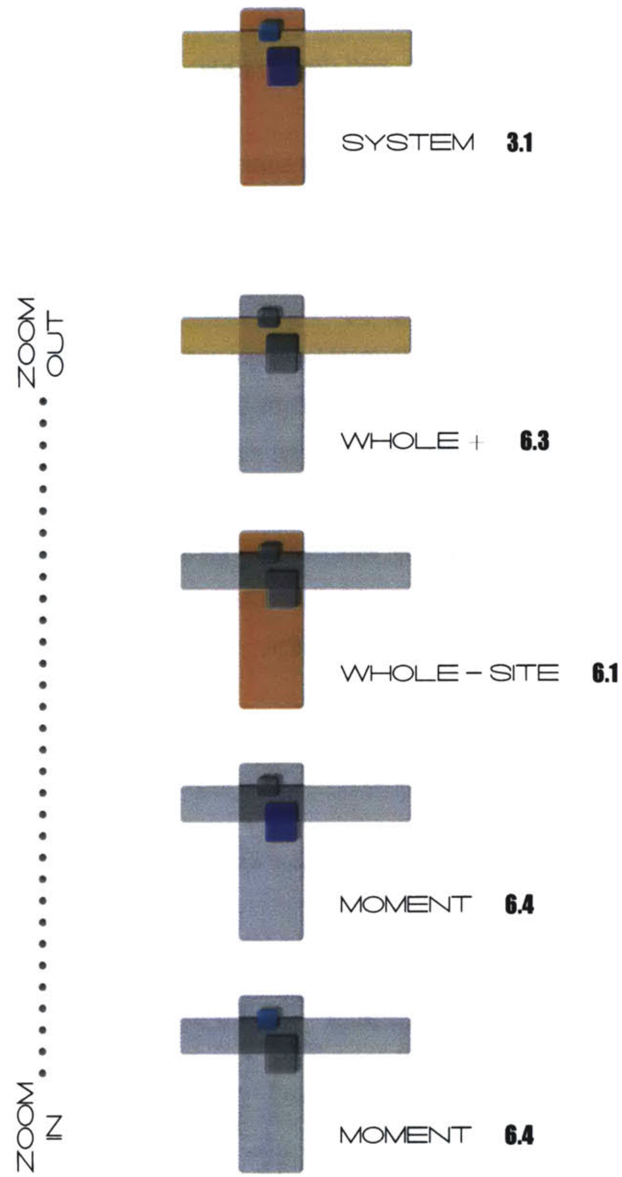
CONCLUSIONS

Natural forces, energy generation, and design logic

The choice was made to view the natural forces of solar radiation, wind, tide, and rainfall available on this site as energy generators, as well as informers of a design process that reconnects people with the forces. The means to do this were not known or understood at the outset of this process. The steps that were taken formed an exploration where each step informed the next, and resulted in a design logic that melded together a decision-making process in terms of locating the renewable technologies, as well as an informant for where people would inhabit the site in terms of movement and gathering. This way of abstracting data/ information into three-dimensional visual forms was very influential in the formulation of the design process. Rather than dealing only with the magnitudes of forces, the mapping represented the information as something with mass or volume, that took up space, and could be physically experienced by people. Making the vital connection between shelter and exposure, inhabitation of the site, and the relationship to the natural forces was critical in bridging the problematic social/ environmental gaps. These notions are further discussed and developed, as well as the design logic, in the steps described in section <6.0>.






SYSTEM 3.1
ZOOM OUT
WHOLE + 6.3
WHOLE – SITE 6.1
MOMENT 6.4
MOMENT 6.4
ZOOM IN

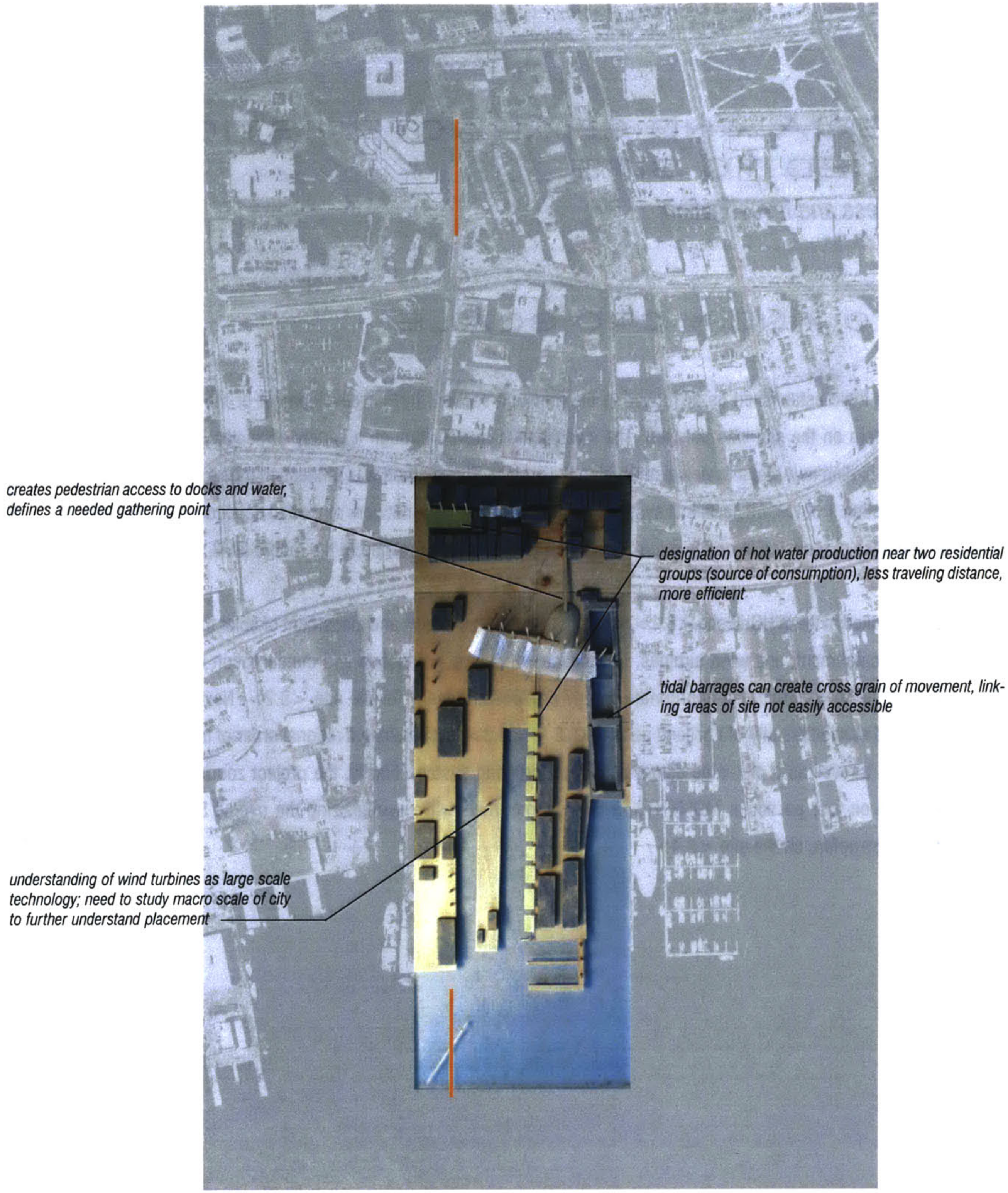
CRITERIA AND CHARACTERISTICS APPLIED TO SITE

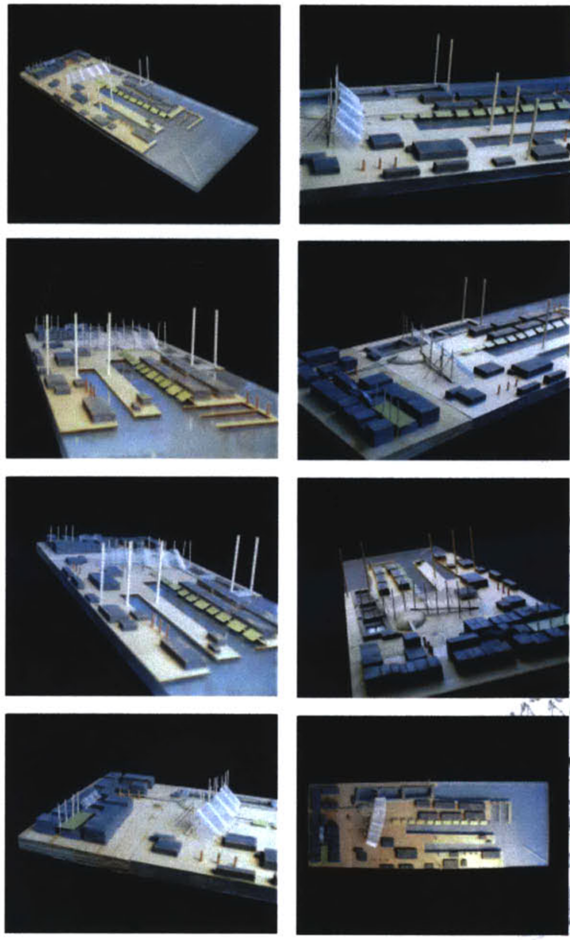
Design Process and Investigation

MACRO AND MICRO SCALE

With the design logic established as described in the previous section, further development of the renewable energy technology system on the site was pursued. The investigation moved through a variety of scales in order to bracket different zones, finding new ways to view and develop the project. This method was influenced by the systems approach described in section <3.1>. All parts in a system are interconnected by a network of mutual dependencies. Because of this interrelationship, focusing in on the micro level helps to inform ideas related to the macro level, and vice versa.

The first step looked at the WHOLE site <6.1>, working through an ordering and placement of solar thermal, PV's, water storage, water catchment, and wind turbines. Calculations of energy production and consumption were introduced at this point in order to determine an appropriate energy production density for the site <6.2>. Next, the investigation zoomed out and studied the city of Portland as a WHOLE + <6.3>, establishing a rational order of large scale technology placement, as well as a city-wide datum and larger ordering system. Finally, the project zoomed in to the micro scale, focusing on four particular MOMENTS in the scheme, meanwhile synthesizing the overall SYSTEM of energy producing infrastructure on the site <6.4>.

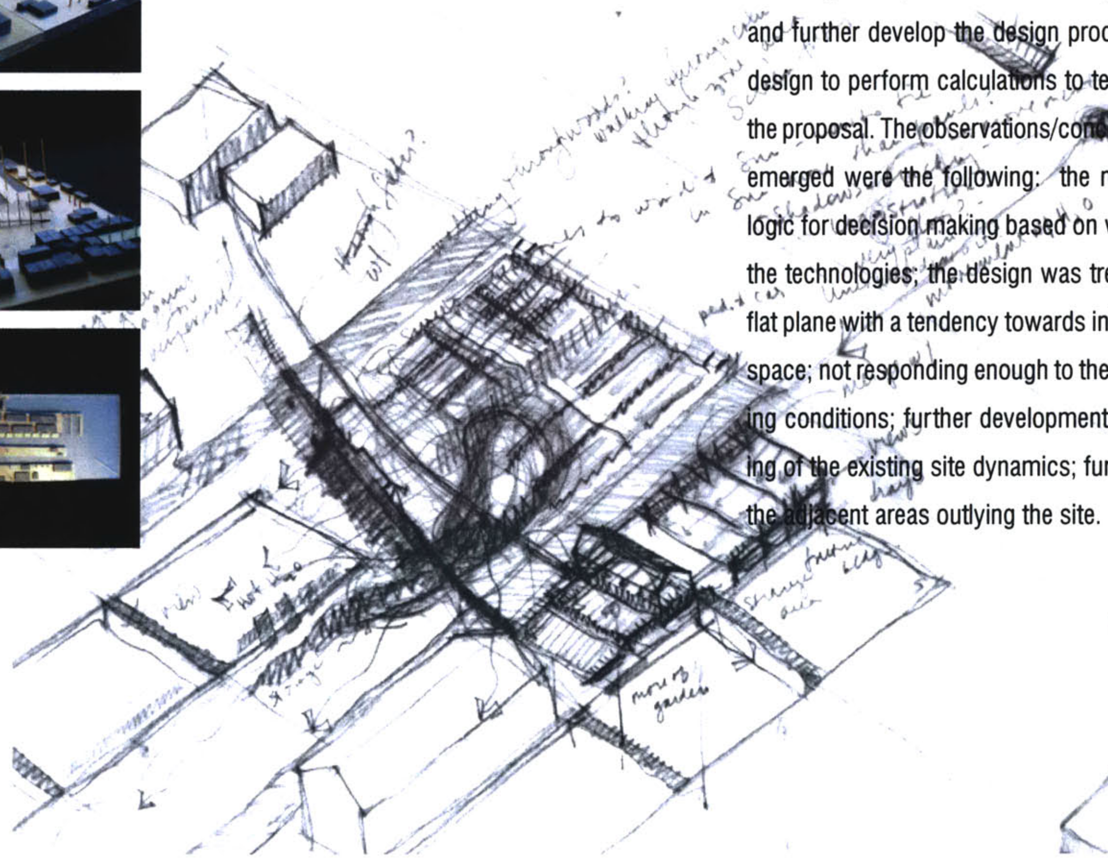

creates pedestrian access to docks and water, defines a needed gathering point
designation of hot water production near two residential groups (source of consumption), less traveling distance, more efficient
tidal barrages can create cross grain of movement, linking areas of site not easily accessible
understanding of wind turbines as large scale technology; need to study macro scale of city to further understand placement

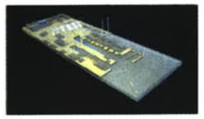


6.1 WHOLE

Initial system layout

This stage represents the first attempt at placing the various technologies on the site, struggling with each system as to placement on the site in terms of the outlined criteria. The purpose of this step was twofold: to move the design to a point in order to analyze, study, critique, and further develop the design process; to freeze the design to perform calculations to test the efficiency of the proposal. The observations/concerns/criticisms that emerged were the following: the need to establish a logic for decision making based on what order to place the technologies; the design was treating the site as a flat plane with a tendency towards inhabiting the vacant space; not responding enough to the surrounding existing conditions; further development of an understanding of the existing site dynamics; further recognition of the adjacent areas outlying the site.

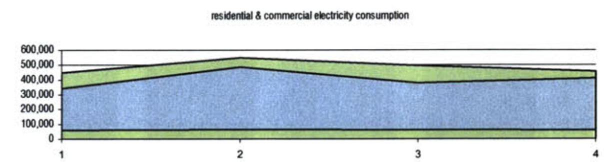




Renewable Energy Production Calculations

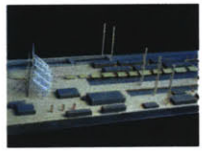
Set 1.0

Existing Buildings on Site - Electricity Consumption



Building type:	*Sq. Footage*		Consumption factor	*Spring*	*Summer*	*Fall*	*Winter*	*Total electricity demand kWh*
			Commercial electricity consumption factors : [3]	23.00%	28.20%	25.40%	23.40%	
COMMERCIAL	206,703.00		9.40 kWh/ sq.ft./ yr.[1]	446,891.89	547,928.31	493,524.08	454,663.92	1,943,008.20
			Residential electricity consumption factors : [3]	21.10%	30.10%	23.40%	25.40%	
RESIDENTIAL	296,550.00	210 housing units	7,675.00 kWh/ housing unit/ yr.[2]	340,079.25	485,136.75	377,149.50	409,384.50	1,611,750.00
			Industrial electricity consumption factors : [3]	24.60%	26.10%	25.20%	24.10%	
INDUSTRIAL	26,340.00		9.40 kWh/ sq.ft./ yr.[1]	60,908.62	64,622.56	62,394.19	59,670.64	247,596.00
			SEASONAL TOTALS:	847,879.75	1,097,687.62	933,067.77	923,719.05	

TOTAL CONSUMPTION -3,802,354.20 kWh annually



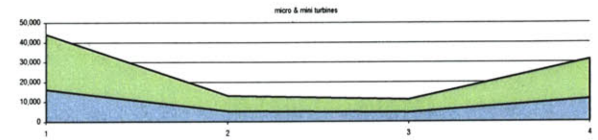
Initial Proposal - Wind Energy Production

Micro turbine swept area:	50.26	ft^2	(8 ft. diam.)
Mini turbine swept area:	153.93	ft^2	(14 ft. diam.)

Wind speeds (mph)[4]	100 ft.	200 ft.
spring	15.0	17.8
summer	10.4	11.6
fall	9.9	11.0
winter	13.4	16.0

air density at sea level 0.005088

cube factor 1.9
turbine efficiency factor[5] 30%



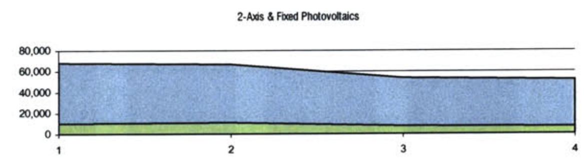
		Spring	Summer	Fall	Winter	Total - annual kWh
Micro turbine (8' dia.)	1	1,086.22	362.04	308.89	757.55	2,514.70
proposed micro turbines:	15	16,293.28	5,430.61	4,633.34	11,363.26	37,720.50
Mini turbine (14' dia.)	1	5,559.14	1,538.58	1,297.70	3,993.54	12,388.97
proposed mini turbines:	5	27,795.72	7,692.89	6,488.52	19967.69	61,944.83
SEASONAL TOTALS:		44,089.01	13,123.50	11,121.87	31,330.95	

TOTAL PRODUCTION 99,665.32 kWh annually

3%

Initial Proposal - Solar Energy Production

Latitude: N43.65 degrees
Longitude: W 70.32 degrees



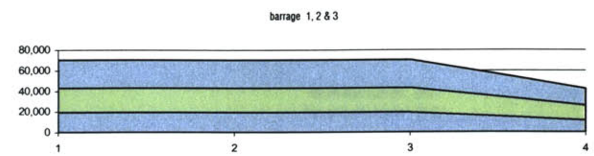
				Spring	Summer	Fall	Winter	Total - annual kWh
altitude na azimuth na	*2-Axis tracking*[6]							
	1 module (9.33 ft^2)			47.44	51.04	35.10	33.03	166.61
	bank of 18 modules (167.94 ft^2)			853.92	918.72	631.80	594.54	2,998.98
	proposed bank of 18 modules	12		10,247.04	11,024.64	7,581.60	7,134.48	35,987.76
altitude 43.7 degrees azimuth 180 (south)	*Fixed*[6]							
	1 module (9.33 ft^2)			35.35	34.59	27.77	26.87	124.58
	bank of 4 modules (37.32 ft^2)			141.40	138.36	111.08	107.48	498.32
	ft^2 modules proposed	18,000	1,928 factor	68,154.80	66,689.52	53,540.56	51,805.36	240,190.24
	SEASONAL TOTALS:			78,401.84	77,714.16	61,122.16	58,939.84	

TOTAL PRODUCTION 276,178.00 kWh annually

7%

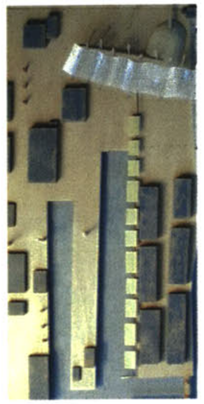
Initial Proposal - Tidal Energy Production

tide height range[7]	11.7 ft.	3.57 m
efficiency factor	0.34	



	area in sq. ft.	area in km²		Spring	Summer	Fall	Winter	Total - annual kWh
tidal barrage area 1:	35,250	####	*Tidal barrage #1*	70,447.32	70,447.32	70,447.32	42,268.39	253,610.35
tidal barrage area 2:	21,750	####	*Tidal barrage #2*	43,369.86	43,369.86	43,369.86	26,021.92	156,131.50
tidal barrage area 3:	9,750	####	*Tidal barrage #3*	19,319.56	19,319.56	19,319.56	11,591.74	69,550.43
			SEASONAL TOTALS:	133,136.74	133,136.74	133,136.74	79,882.05	
			SEASONAL BALANCE:	-592,252.16	-873,713.22	-727,687.00	-753,566.21	

TOTAL PRODUCTION	479,292.28	kWh annually	13%
BALANCE	*-2,947,218.59*	kWh annually	22%



Existing Buildings on Site - Hot Water Consumption

RESIDENTIAL					
	210 housing units on site				
	2.66 people / housing unit[8]				
	558.6 total people	30	gallons hot water/ day[9]	16,758.00	total residential
COMMERCIAL					
	9,046 total commerical businesses				
	113,078 employees				
	12.5 employees/ commercial space				
	70 businesses				
	875.00 total employees	0.5	gallons hot water/ day[9]	437.50	total commercial

TOTAL DEMAND -17,195.50 gallons per day

Initial Proposal - Solar Thermal Hot Water Production

THERMAL COLLECTORS				
flat plate collectors	14,900	sq. ft. total proposed	0.75	sq. ft./ gallon water[9]
STORAGE	11,175.00	gallons to be stored for daily demand		

TOTAL PRODUCTION 11,175.00 gallons per day

65%

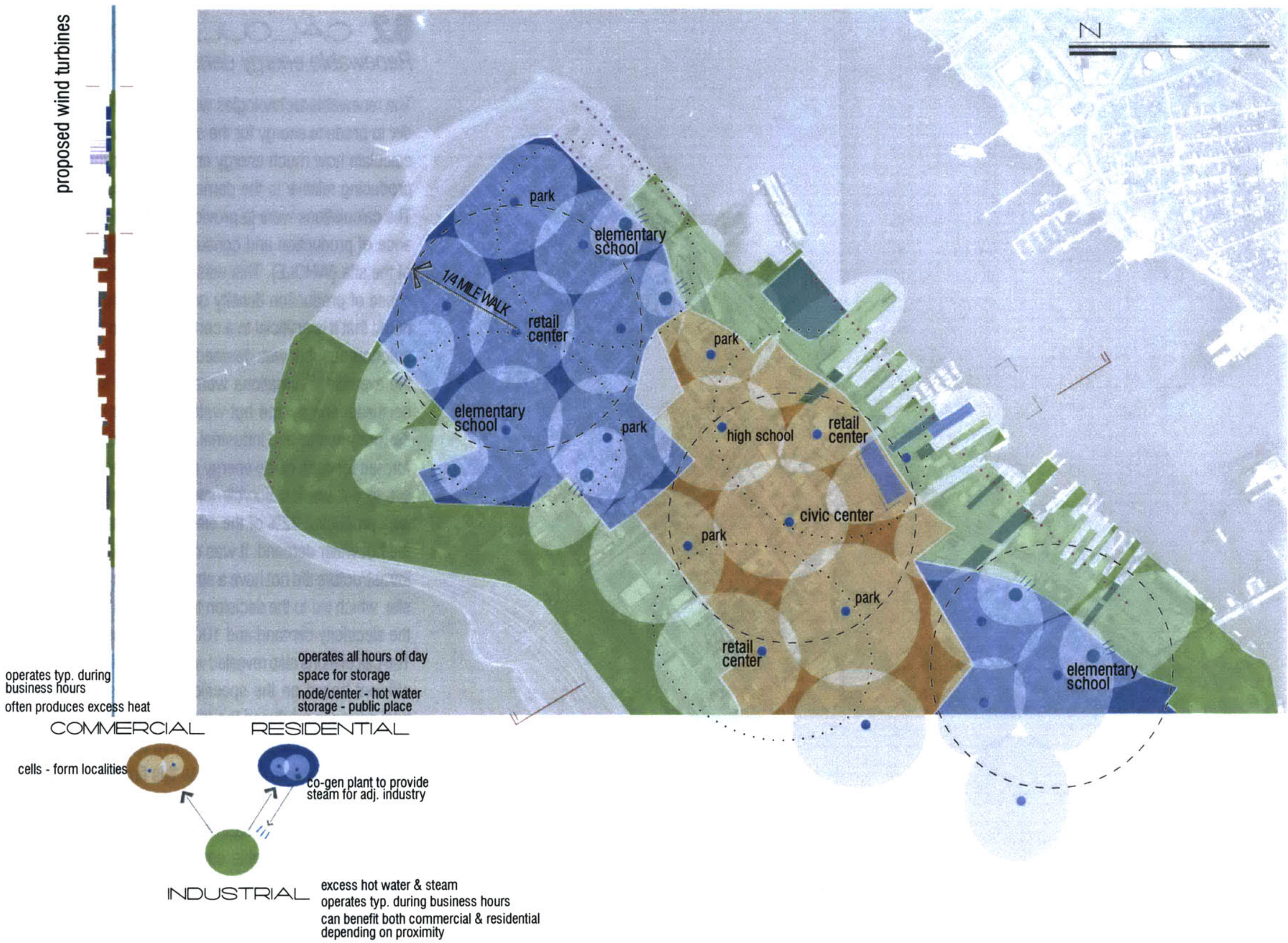
BALANCE *-6,020.50* gallons per day

6.2 CALCULATIONS

Renewable energy density for site

The renewable technologies were being implemented in order to produce energy for the site; thus it was necessary to calculate how much energy and hot water the design was producing relative to the demand of the existing buildings. The calculations were to provide ballpark figures of the balance of production and consumption within the boundary of the site (WHOLE). This was done in order to establish a sense of production density on such a site. It needs to be noted that it is artificial to a certain extent to treat the site as autonomous, but was deemed acceptable for the nature of the exercise. Estimations were calculated from figures on northeast energy and hot water consumption for residential, commercial and industrial. Calculations were then performed for each of the energy producing technologies relative to the site location/climate. It was found that the site was producing 22% of the electricity demand and 65% of the hot water demand. It was my sense that the renewable infrastructure did not have a strong enough presence on the site, which led to the decision to attempt to produce 50% of the electricity demand and 100% of the hot water demand. The calculations also revealed which technologies were most efficient based on the specific characteristics of the site; tidal barrages produced the most energy, followed by photovoltaics. The density of these two technologies was increased hereafter in response to this finding.

This step was very critical in terms of validating the potential of introducing renewable energy systems to such a site. The calculations further diversified the investigation by focusing on the efficiency and ability of the technologies, as well as on the aesthetic and experiential offerings.



proposed wind turbines
N
park
elementary school
1/4 MILE WALK
retail center
elementary school
park
park
high school
retail center
civic center
park
park
retail center
elementary school
operates typ. during business hours
often produces excess heat
COMMERCIAL
operates all hours of day
space for storage
node/center - hot water storage - public place
RESIDENTIAL
cells - form localities
co-gen plant to provide steam for adj. industry
INDUSTRIAL
excess hot water & steam
operates typ. during business hours
can benefit both commercial & residential depending on proximity

WIND TURBINES:

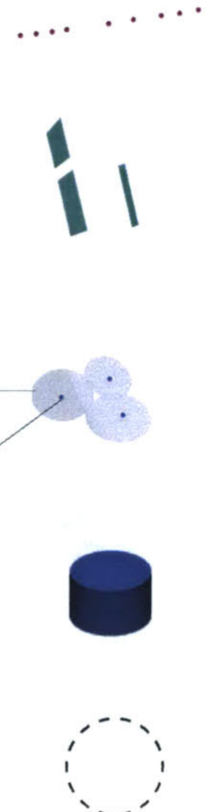
- large scale technology
- form single screen, filter
- create datum across jagged coastal edge
- reiterate scale of buildings at city center

TIDAL BARRAGES:

- secondary scale technology
- form rhythm of interventions along coast
- bring tide motion closer to inhabitated space

CELLS/NODES:

- cells form 'localities' that are sensed through an established language/system of nodes
- cell size based on abilities of hot water system:
  diameter of cell ~1,300' (~1/4 mile)
  number of households ~ 260
- within cells hot water storage becomes center/node
- size of hot water storage tank & berm:
  hot water consumption/household/day~ 65 gallons
  total volume of storage capabilities ~16,900 gallons
  dimensions of cylinder ~ 20' high, 33' diameter
- secondary network established that forms larger ordering principle of various types of nodes
  school facilities (elementary, junior high, high school)
  commercial/retail shopping centers
  public open spaces/ parks

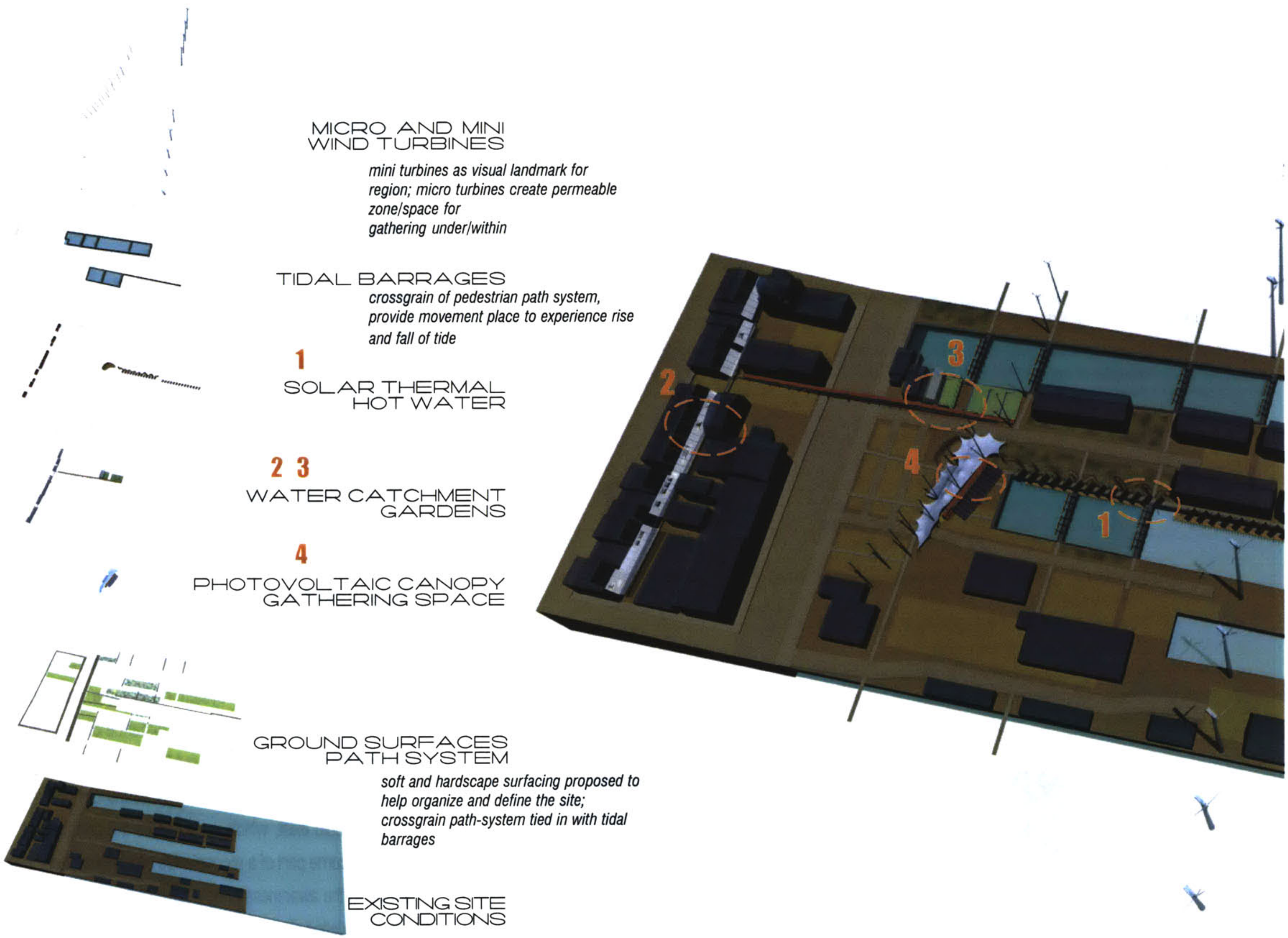


6.3 WHOLE +

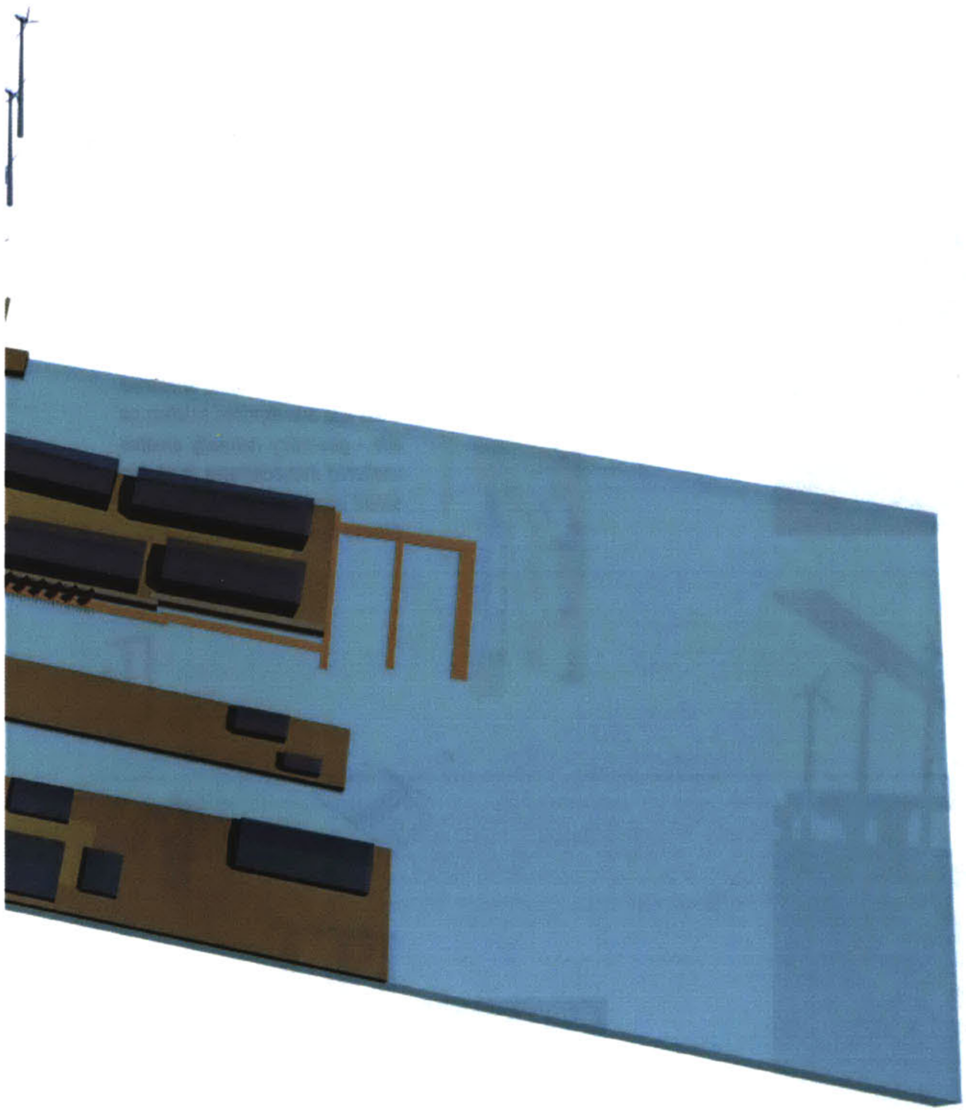
Site, larger context & ordering system

This stage looked at the system of renewable energy production at the macro scale. Three main discoveries resulted from this step. The first established a system of placement ordering of the different technologies on the site, namely the large scale technologies of wind turbines and tidal barrages. Next, ideas were developed regarding different building uses and the potential to exchange and recycle excess energy (heat or steam) to other buildings in close proximity. The conclusion was made that a variety of building uses was better suited in a locality than the typical zoning for only one; again, the idea of diversity. Finally, and most significant was the discovery made relating to solar thermal technology. Being the only technology working with energy in the form of heat, it is highly dependant on the need to be located adjacent to its consumption point. Decisions were made based on information from a comparable case study project in Germany. A language of hot water storage mounds was placed across the city, where zones had been demarcated based on the area the local solar thermal system could serve. Also factored in was the widely accepted walking distance of a quarter mile as being the maximum distance public nodes should be located from where people live. In the center of the cell, the storage mound would exist, which would serve the community, and would become part of a recognizable ordering system. This is similar to the awareness people have of the intangible boundaries that define elementary school districts in a town.

criteria and characteristics applied to site



MICRO AND MINI
WIND TURBINES
mini turbines as visual landmark for region; micro turbines create permeable zone/space for gathering under/within
TIDAL BARRAGES
crossgrain of pedestrian path system, provide movement place to experience rise and fall of tide
1
SOLAR THERMAL
HOT WATER
2 3
WATER CATCHMENT
GARDENS
4
PHOTOVOLTAIC CANOPY
GATHERING SPACE
GROUND SURFACES
PATH SYSTEM
soft and hardscape surfacing proposed to help organize and define the site; crossgrain path-system tied in with tidal barrages
EXISTING SITE
CONDITIONS
2
3
4
1



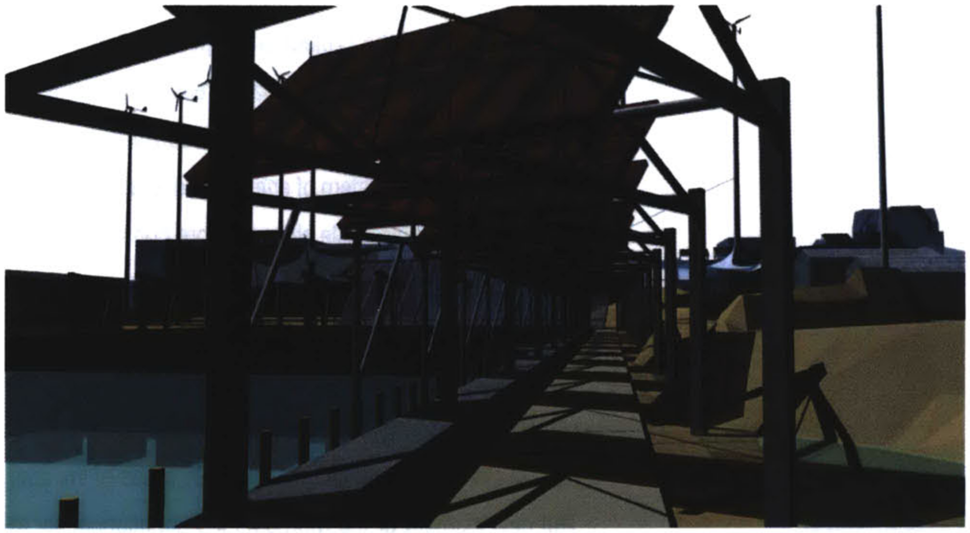
6.4 SYSTEM

Development and synthesis

The remainder of the project was spent working at the micro scale, developing four main areas, or MOMENTS, on the site. These moments represent subsystems in relation to the overall system of energy producing infrastructure. Working in this scale allowed more consideration in terms of how one would come in contact and experience the technologies. Thought was given to additional roles the energy producing technologies could serve, such as places for gathering that would provide a degree of shelter and movement in the highly exposed areas of the site. The development of the moments led simultaneously to the general synthesis of the system depicted here; this represents the final proposal. The investigation focused more on the subsystems and their development, and less so on the overall synthesis of the system. Three main concepts resulted from the introduction of renewable systems to the site. These concepts were in terms of: [1] spatial construction as prototypical design, [2] new types of space, [3] and finally, qualities of space.

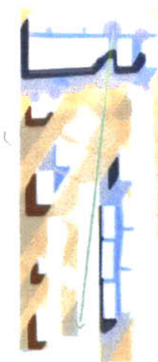
criteria and characteristics applied to site

1 SOLAR THERMAL / STORAGE MOUNDS

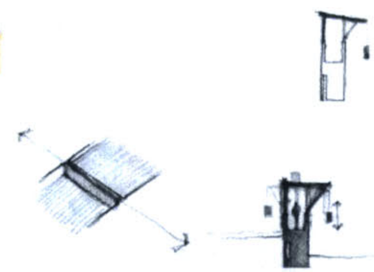


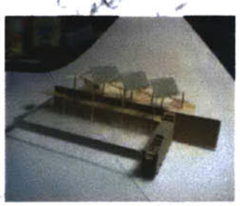
[1] PROTOTYPICAL CONCEPTS

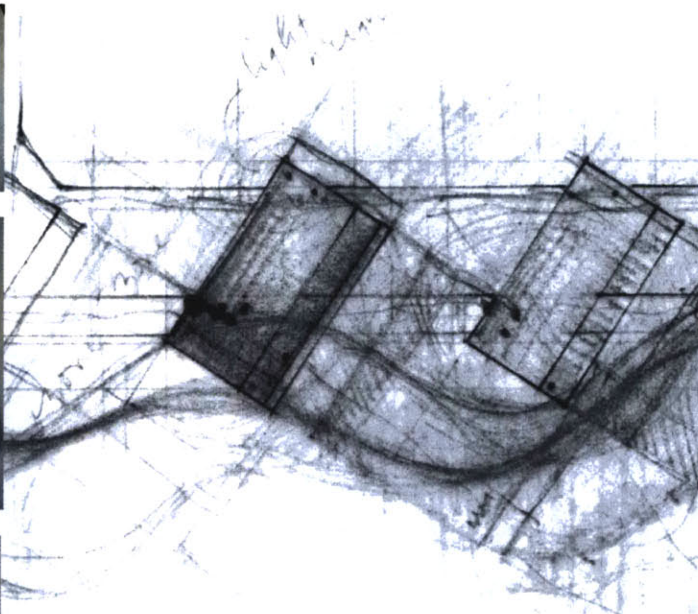
The solar thermal structure/earth mound combination is one of the examples that is easily translated or replicated to another site. The main requirements of the system are close proximity to hot water consumption and storage points, and orientation to the sun/wind.

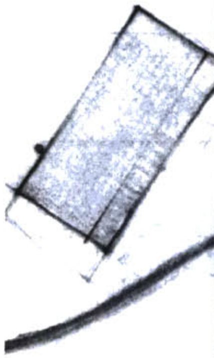


mapping of winter wind sheltered areas and sun exposed existing on site - geometry naturally creates sheltered microclimates in winter; shield people from cold wind and expose to warm sun for comfort





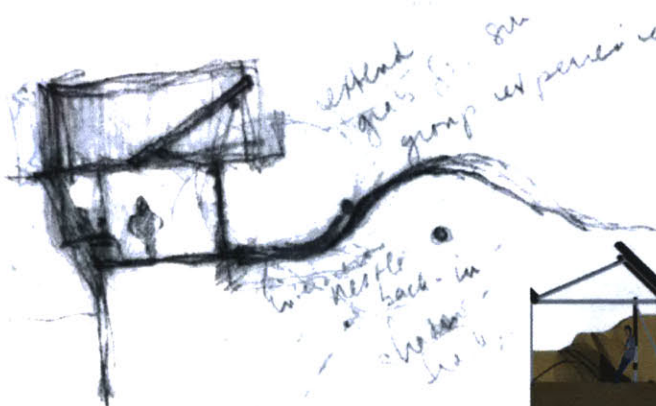


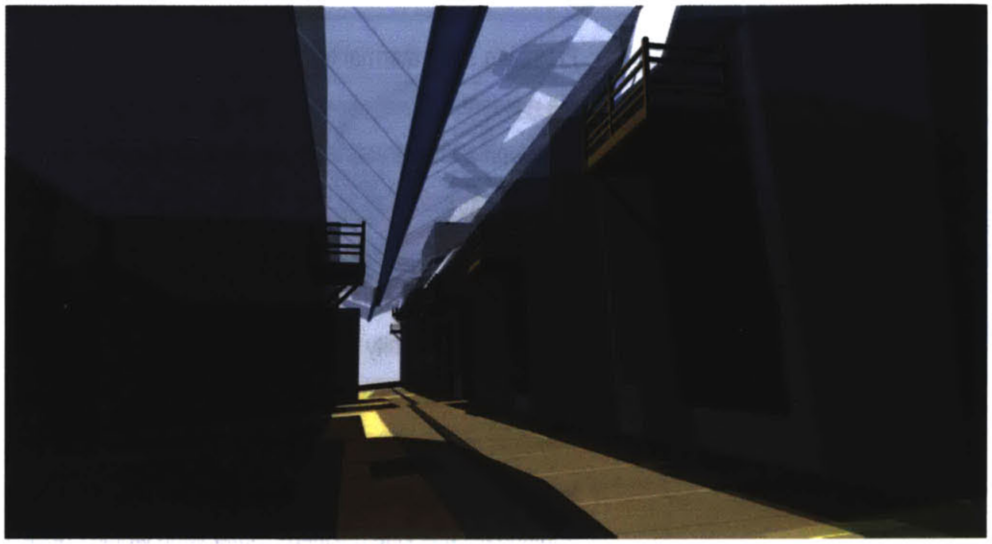


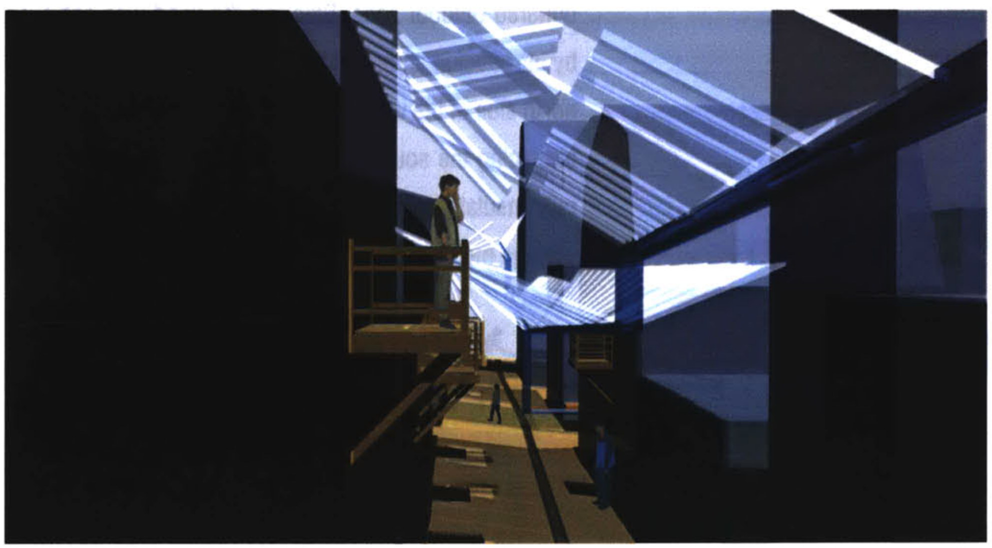
6.41 MOMENT

Solar thermal & storage mounds

Providing solar thermal hot water production adjacent to the residential townhouses on the site led to the design of prototypical infrastructure for a pedestrian movement path. The structure needed to support the panels at the necessary angle and axis, as well as span a long distance in order to provide for the necessary number of panels. This led to an opportunity to define a linear movement space that provided shade from the high angled sun in the summer time and exposure to low angled sun in the winter for warmth. The force mapping exercises < 5.3 > found that additionally blocking northern winter wind would create a buffered outdoor zone. Blocking the wind was achieved by introducing an undulating earth mound/wall along the north side of the walkway, forming small gathering pockets facing the south. The earth mound provided a naturally insulated place for the water to travel to the large storage mound, as well as a place to rest and sit.



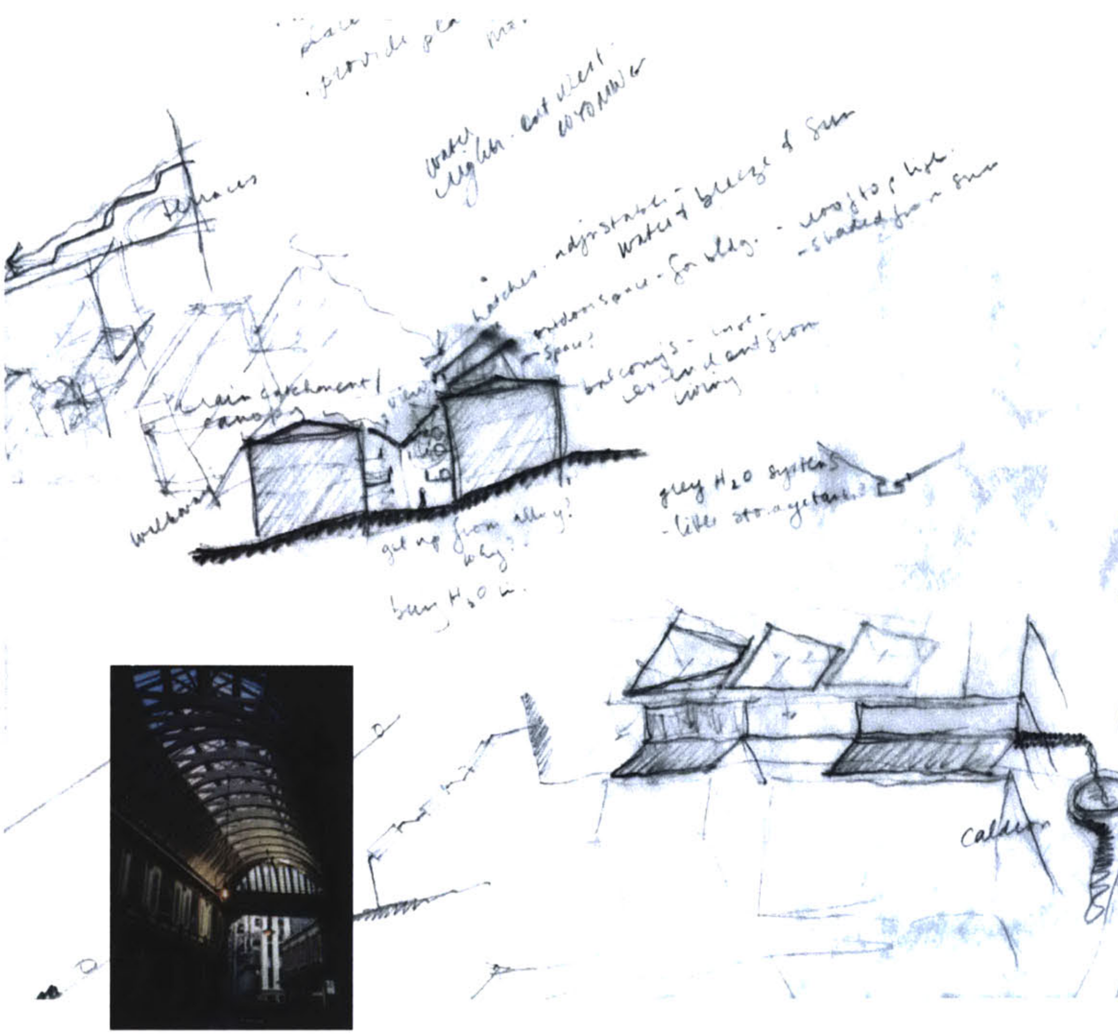




[1] PROTOTYPICAL CONCEPTS

The combination of solar thermal and water collection system could be replicated or translated to other similar urban sites/ conditions depending on the particular situation.

mapping of wind sheltered areas existing on site (lateral environmental forces); therefore, not protected from rain or snow (from above); potential to collect rain water also presents the opportunity to shelter the main retail/commercial pedestrian artery on the site

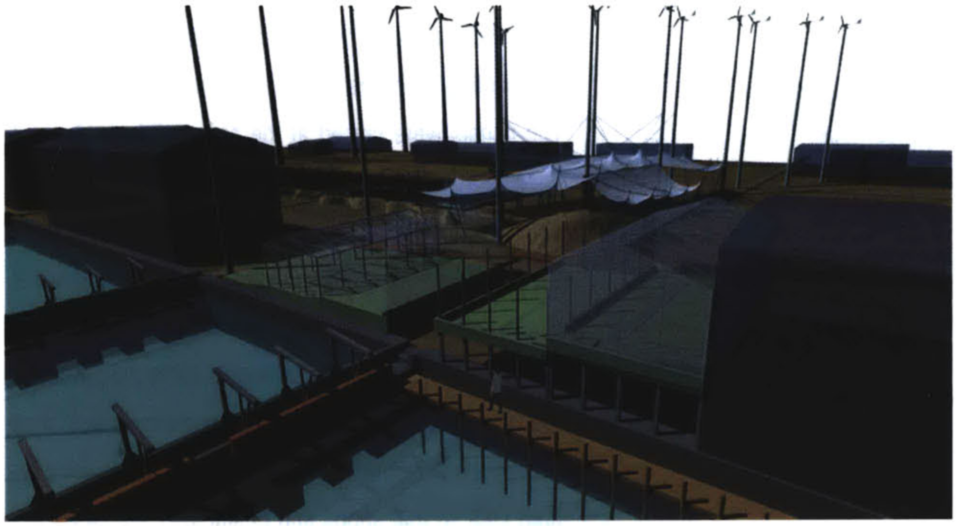


6.42 MOMENT

Solar thermal & rainwater collection

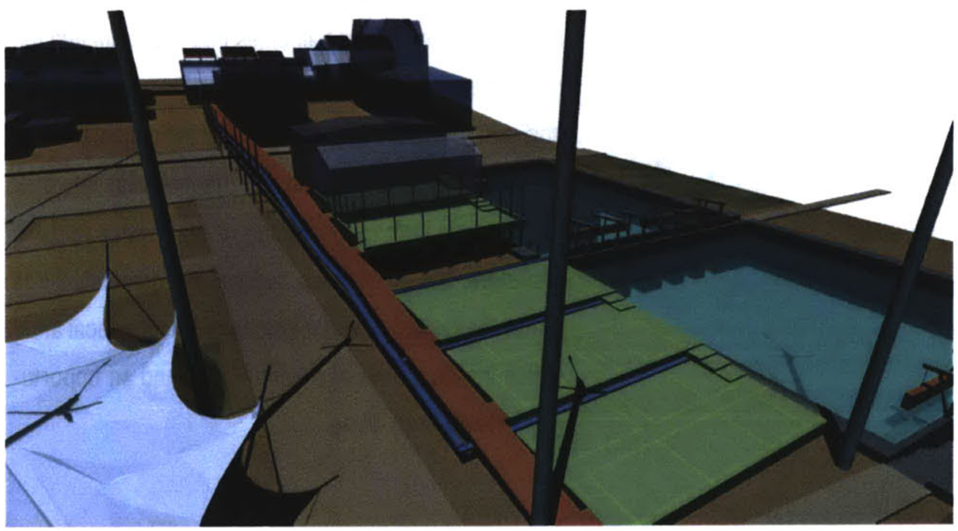
Solar thermal panels were implemented on the roofs of the existing buildings in the northern area of the site. The panels were placed at the appropriate angle, and became a surface suitable for collecting rainwater. Glass panels in the form of a 'V' section were introduced over the alleyway. Rainwater would fall off the solar thermal panels, onto the glass panels, then be carried away in the water channel. The glass panels serve the purposes to both collect and channel the rainwater; as well, they provide shelter from both rain and snow below the covered area so that shops and businesses are easily accessed when the weather otherwise prevents this. The buildings have existing balconies that reach out into the public alleyway. Glass panels above a balcony are movable such that individuals can control the amount of ventilation they receive or to actively channel water into their own storage tank for gardening or gray water system. Therefore, the individual's actions are connected into the larger system of water catchment for the local area, which instills a level of responsibility, and an opportunity to learn from doing.

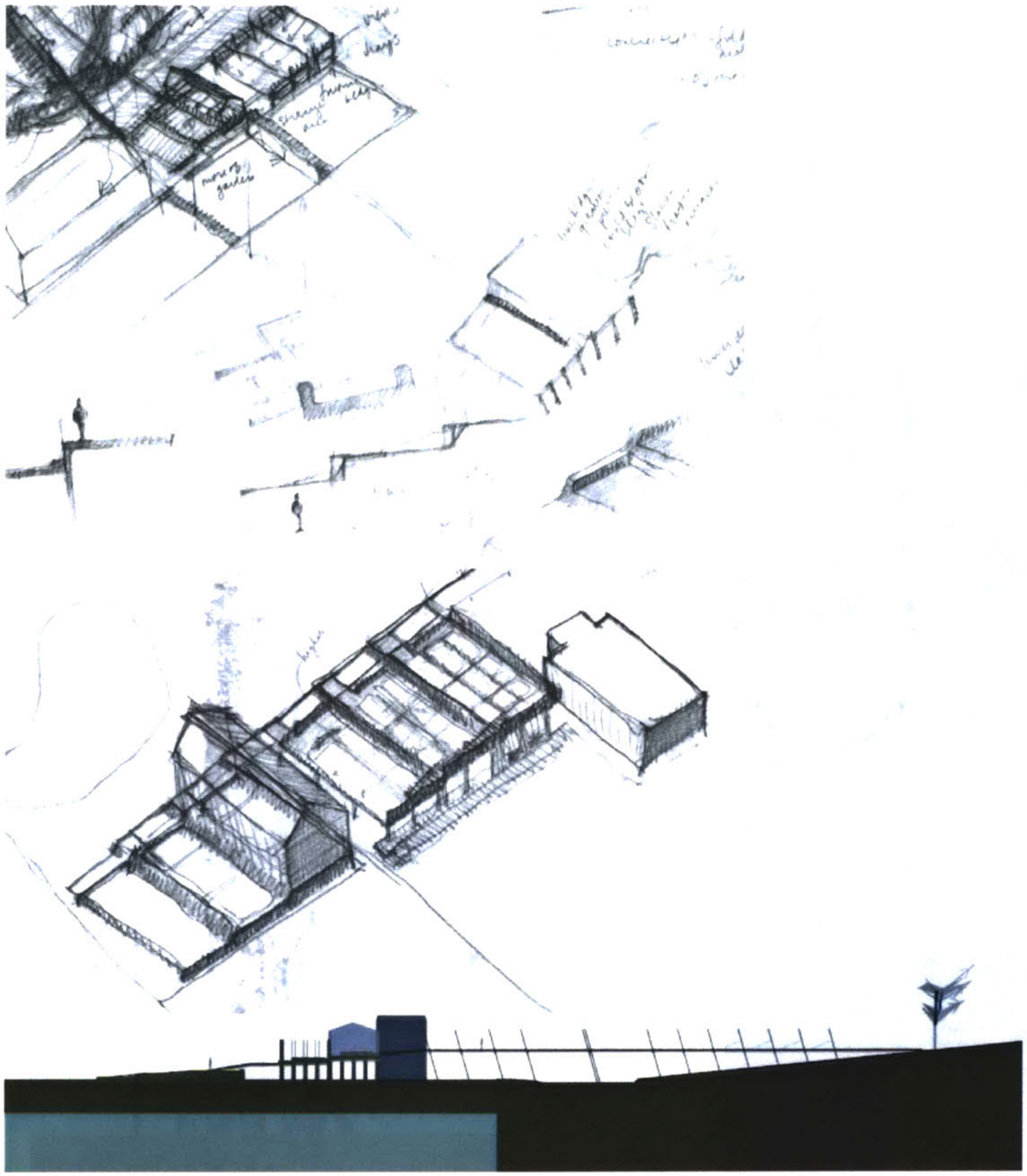
RAINWATER CATCHMENT SYSTEM / PUBLIC GREENSPACE



[2] NEW TYPES OF SPACE

Greenspace in the city is necessary; a neighborhood scale rainwater catchment system reinforces the ability for urban greenspace. Establishing the combination of water catchment and greenspace could be replicated and inserted all over the city. The greenspace can take on a new role, be it integrated into a building or as outdoor gardens. The greenspace and rainwater catchment system connects people to the cycles of precipitation and the need of water for living things.





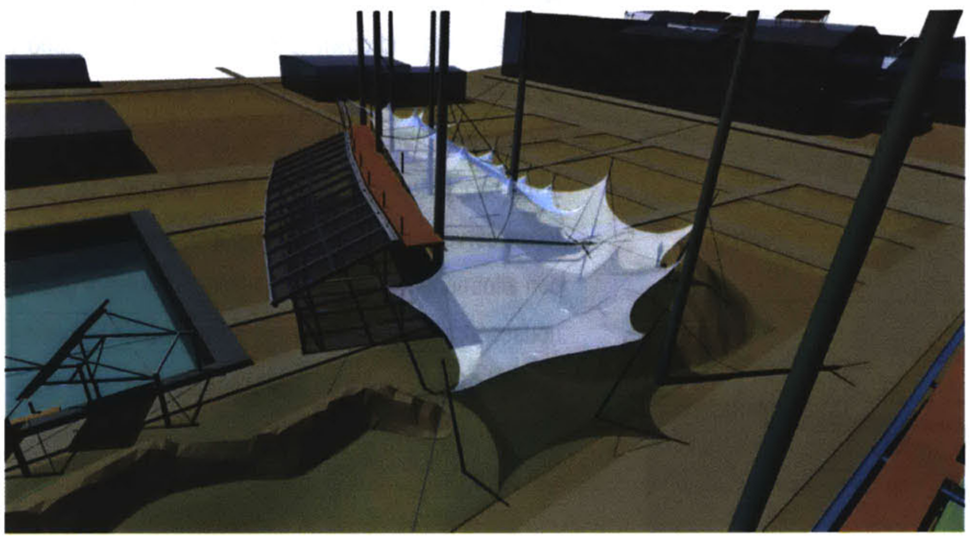
6.43 MOMENT

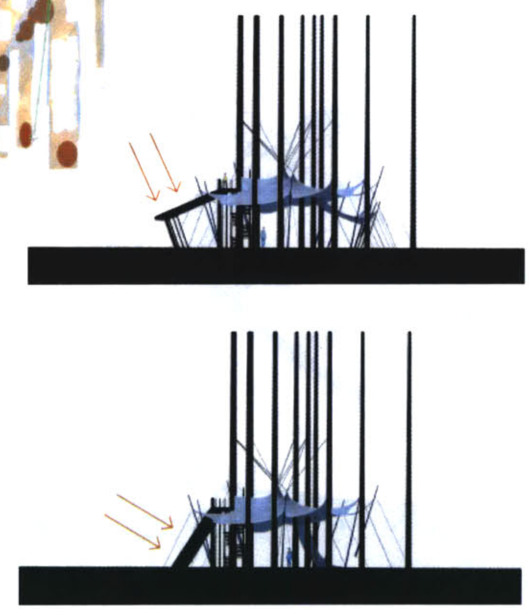
Rainwater collection & public greenspace

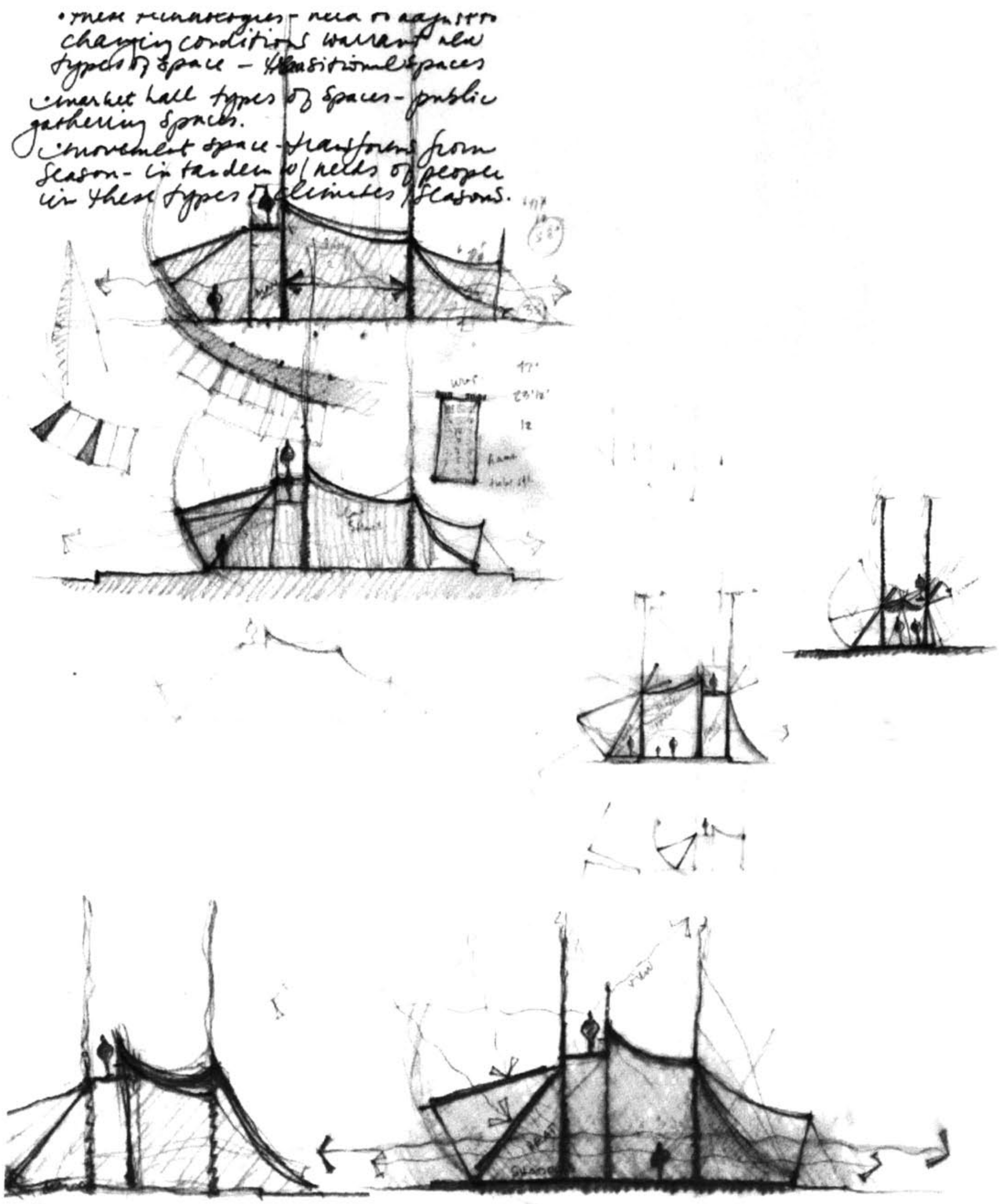
The rainwater collected by the glass panel arcade system described in <6.42> is stored underground until needed. Garden platforms are introduced on the dock side of the street, forming terraces stepping down to the ground level. The platforms are constructed through a simple steel structure, providing space underneath the platforms for parking, storage, or building by the water's edge. The structure continues up through the platforms providing a framework for assembling greenhouse panels in wintertime. When water is needed to nourish the gardens, it is released from the storage tanks and travels by gravity feed in a gently sloping channel across the main road and down to the platforms. The support for the channel additionally allows for a pedestrian walkway to more safely traverse the busy road, as well as allow people to travel with the flow of water. The platforms serve multiple uses, from public greenspace, garden allotments for residents to lease, or interior greenhouses/atrium spaces that could be absorbed by commercial or civic buildings to provide a better work environment.

[3] QUALITIES OF SPACE

In working with renewable energy technologies, and drawing influence from natural forces as design informers, a particular quality of space emerged, a transforming/ transitional space that can react and respond to the changing environmental conditions. The lightweight, flexible, intermediate space that the canopy/tent structure creates resulted from integrating the needs of the technologies implemented, as well as providing a sheltered gathering space for people on the most exposed area of the site.







6.44 MOMENT

Wind turbines & PV canopy space

The need for a defined gathering space on the dockside of the site has been previously discussed. The siting of the large hot water storage mound began the locating of this node, as well as the association with the group of micro turbines. The bases of the turbines form a space, bounded by the grounded earth mound. The concept of providing a large public space that was in between indoor and outdoor emerged as a transitional space that changes by opening/extending in summer and closing/receding in winter. This resulted from the need and ability to adjust the angle of photovoltaics between high summer and low winter sun angles. The space would adjust itself to benefit both the technology it employed for producing energy efficiently, as well as provide comfort for the people inhabiting it. In warm months, the two sides would extend up to create a highly permeable zone covered only by the tensile canopy covered with PV cells, thus providing shade from the summer sun, and allowing breeze, ventilation and people to pass through. In winter, the sides would shut down, enclosing the space to block out cold winter wind and to hold in solar heat gain. This created a transitional space for public events, such as farmers markets and symphonies.

CONCLUSION

Last remarks and next steps...

The main function of the project investigation was to ask questions and provoke thought in the context of renewable energy production in the built environment. The intentions of this project from the outset were largely utopian and idealistic; it was clear that such aims would not thoroughly be solved and investigated in the course of one semester. Therefore, the investigation was conceived as a 'first pass' to bring out various issues, concepts, and questions in order to outline a life-long agenda. While it is noted that the investigation only scratched the surface of this large topic, the design did, however, reach a certain level of resolve, demonstrating the viability of the project, as well as to bring up relevant questions and issues. These unanswered questions validate the need for ongoing exploration, research, design, and thought into this important and provocative area, and serve as an opportunity to propose future investigations.

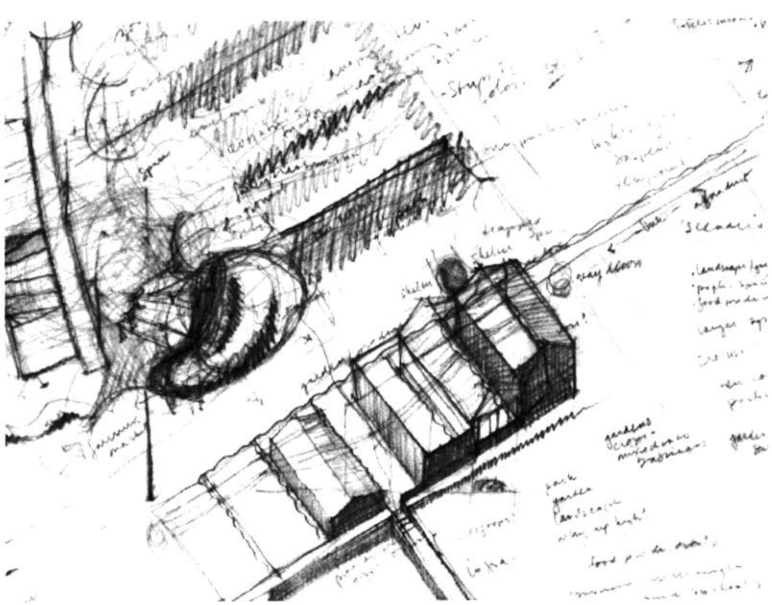
At the conclusion of this first pass, it is clear to me that the intentions of this project remain necessary and pertinent issues worthy of consideration. I continue to believe strongly in the need to pursue the production of clean energy, to model built systems after natural systems, to contribute positively to the community and ecosystem, and especially to treat people as intelligent beings with something positive to offer others and capable of creative learning. This thesis more broadly advocates a collective shift in attitude regarding what is important and valuable in our lives; a collective shift is central to the potential for this concept of re-connection. This project has proposed ways in which a re-connection could be facilitated, but needs to go further. However, having gone through the investigation, some inspiring, instructive conclusions have emerged.

When drafting the proposal for this project slightly less than one year ago, I had projected that the design would be radical in its aims and pursuits, assuming that a drastic solution was the only means to counter the difficult problems described in the introduction <1.0>. Ironically, at the completion of this first pass, what actually came out of the investigation was, in some respects, the exact opposite. The outlined criteria was deliberately referenced to structure decisions and launched the design investigation into a new direction, coupled with the new design methodology that emerged out of the force mapping exercises. From this process, I assumed a radical result would come about; instead the design inadvertently transformed very traditional

7.0

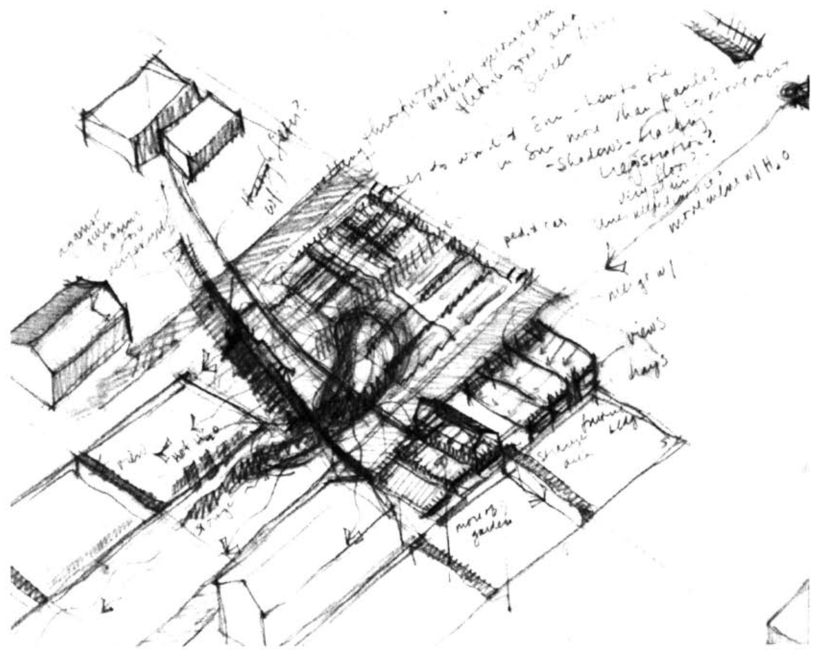
notions of public gathering, movement and recreational spaces (arcades, esplanades), to additionally serve the role of producing clean energy. This was one of the more exciting and unforeseeable findings that the project came upon, and speaks highly of the fact that there is still reason to draw from the past, while at the same time to continue to evolve and respond to the changing technologies. This finding reaffirmed my convictions that it was, in fact, possible to make this re-connection, presuming we once knew a stronger connection with natural systems and community in the past.

Another area of resolve was the force mapping method formulated out of the direct relationship of the harvesting of energy and the performance criteria and experiential qualities of natural forces. This process proved invaluable to the aims of the project, that being to reconnect both built systems and people back with natural systems. At the outset of this investigation, I understood the design process to be an important aspect to the development of the project; I did not realize until further along the critical and influential role this process would play. By starting with factual data, and transposing it into a visual format, the project discovered new ways to make decisions that directly related to the aims of the renewable energy production and integration. Additionally, it made the critical inverse relationship between the technologies and the natural forces, and the technologies and the people sheltered in their midst. This significant finding made it clear that it was possible to make the connection in a simple, intuitive, and aesthetic manner.



There were certain conclusions I wanted to reach at the outset of the project, but was unclear how these would play out by the end. The conclusions that came out of this project were much more in the realm of unpredictable but pleasant surprises, and speak of the many faces of the project still left to disclose. The remaining unanswered questions continue to be similar to those at the beginning, and speak more of the limited time spent thus far on the project. The following discussion serves the purpose to outline and project where future work in this area should go as informed by the process and findings of this thesis, in order to focus on and deal with the remaining questions.

One question that was briefly addressed during the investigation in section<6.3> is the role and degree of importance of building uses in relation to energy recycling in a local area. Zoning practices in the United States advocate grouping of like-use buildings in defined areas of a city. In some respects, this is arguably a beneficial way of planning in terms of assuring a certain quality of work and life atmosphere. However, when one thinks in terms of highly efficient energy production, there are opportunities being missed with this type of layout. As briefly discussed in section <6.3>, the different building uses of commercial, residential and industrial have different times of operation and different energy needs. Residential occupation typically is opposite the time of day commercial and industrial uses operate. Additionally, commercial and residential typically only consume energy, while some industrial processes produce energy by-products in the form of heat and steam. For the most part, these energy by-products are lost into the atmosphere, resulting in a highly wasteful and inefficient system, as well as creating and supporting redundancies as a result of this planning mentality.

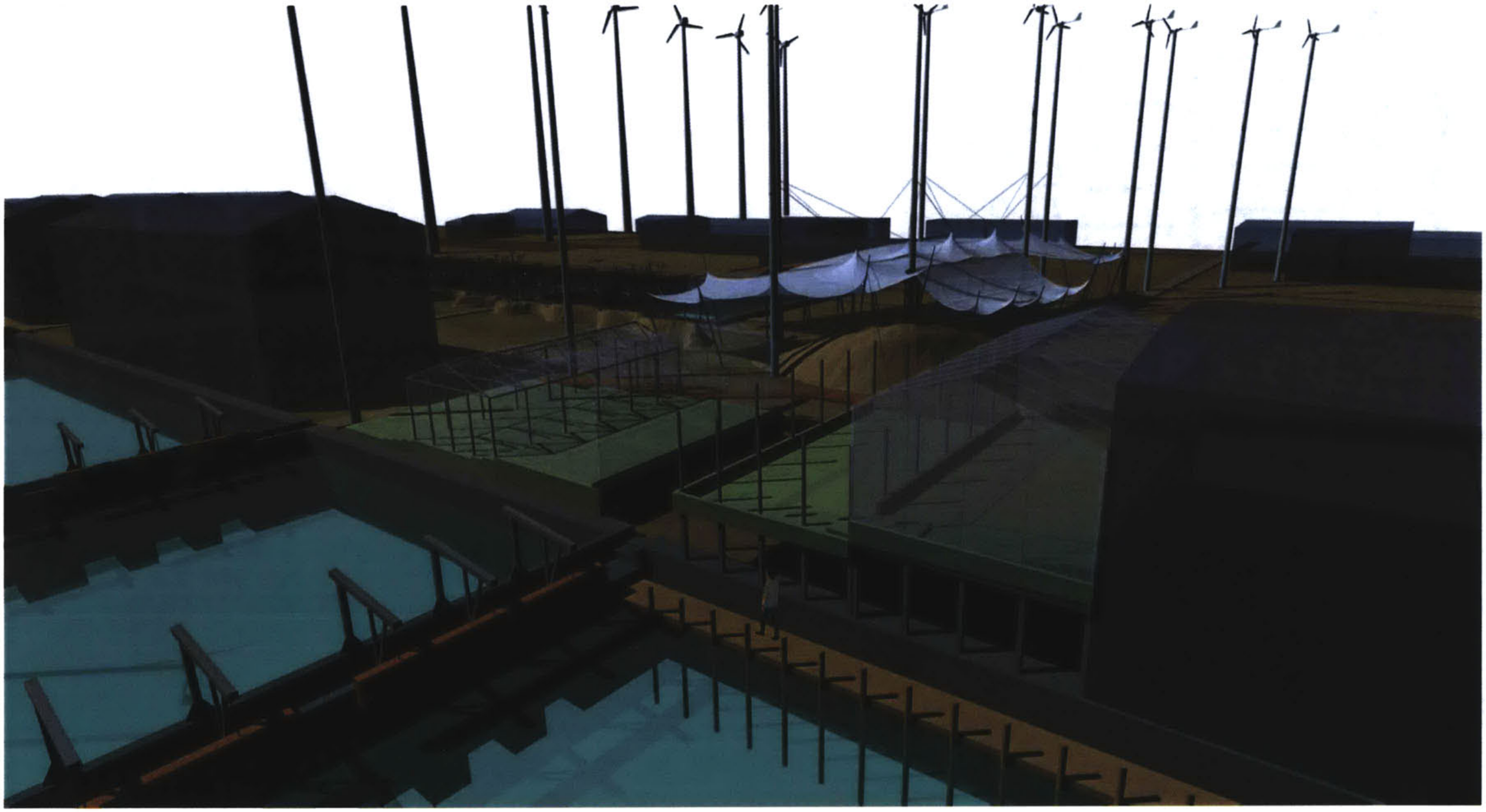


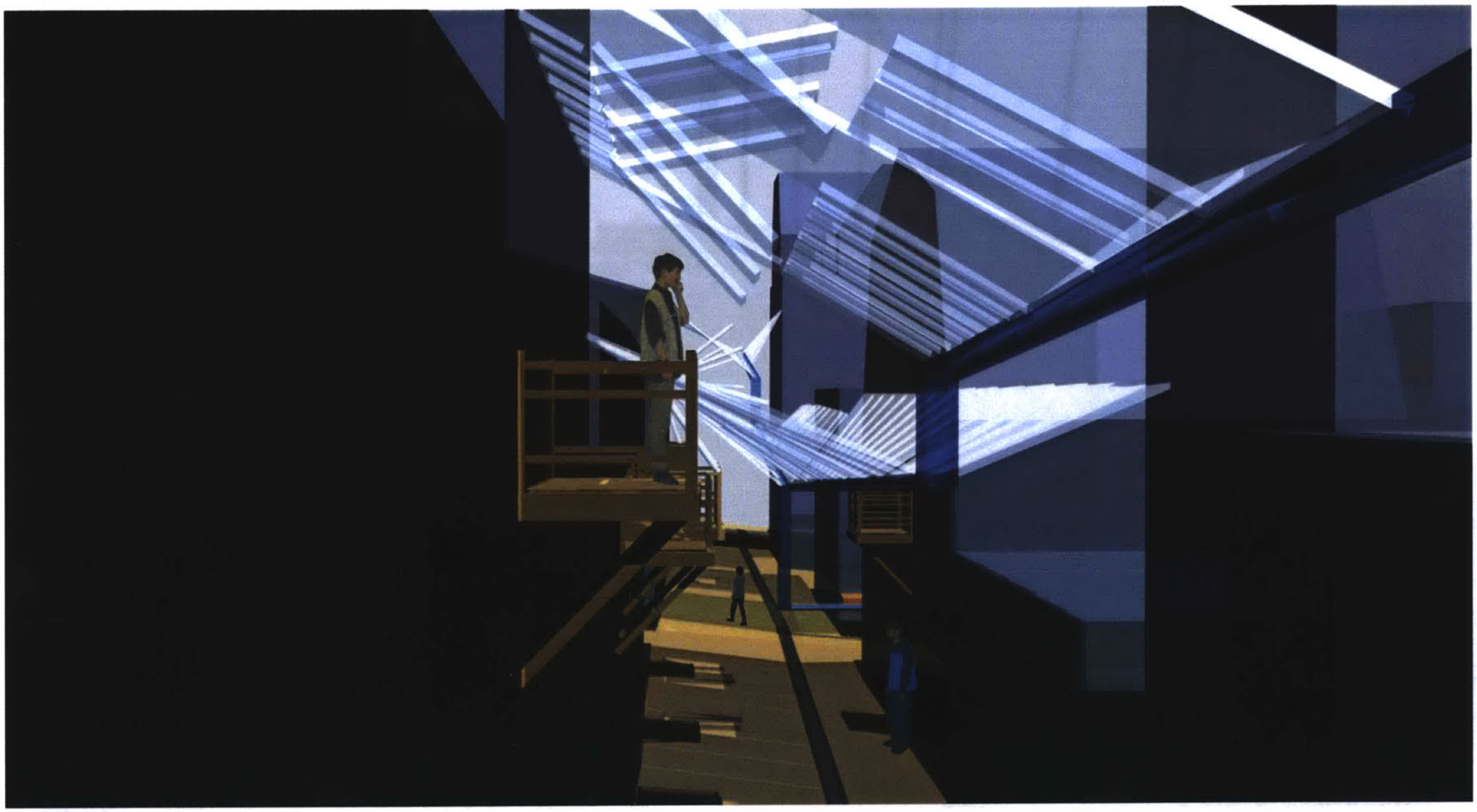
There are however other ways of viewing city planning in terms of energy efficiency. By taking advantage of the opposite times of day that commercial and residential operate, excess heat that is produced in a commercial office building from running all day could be channeled to residential buildings in the evenings, where people have gone home from work. As well, industrial processes that produce excess heat or steam could be placed adjacent to commercial and residential buildings; delivering the excess heat or steam to the commercial business during the day and the residences during the night. Industrial buildings could be distributed across the city in relation to locations of neighborhood co-generation power plants, working together mutually to produce the products (energy or manufacturing) and share the excess energy such that the system on the neighborhood scale becomes increasingly efficient. These notions bring up interesting new relationships and ways to consider the planning and zoning practices for the built environment. As stated in section <3.1>, the ecosystem does not support individual parts locating themselves based on individual convenience or desire, as this is highly inefficient; therefore, nor should the built environment.

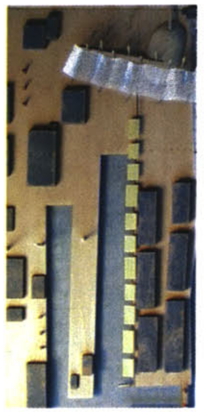
A possible investigation that could focus on this issue would be to look further into existing projects that operate on the neighborhood/ local level of energy generation and the recycling of energy, and to analyze the successes and shortcomings. Also, it would be useful to determine what specific types of industry are best suited adjacent to neighborhood co-generation plants, and how this could affect a residential neighborhood both positively and negatively. Compiling examples of commercial and residential buildings passing heat energy between them, and the technologies that exist to facilitate this would be useful. Finally, and most significant, would be to consider and speculate how these ideas alter the way we currently consider the built environment and determine what design strategies could be introduced that might come out of this new organization.

A second question yet to be addressed is the role of eminent domain, local law policy, and the network of community social structures in terms of introducing and integrating such technologies into the built environment. American's enjoy overseeing their personal property, and do not wish to be overwhelmed with laws and mandates regarding their belongings. However, operating as individual, autonomous, inefficient buildings will not result in a more holistic, communal, efficient situation. This is the same attitude that continues to enforce built systems to be in complete denial of the natural ecosystem and the wasting away of natural resources. Therefore, it is interesting to consider how such a project would actually come to be. That is, would it be proposed and overseen by the government of the city; would it be the result of a community wishing to create more meaningful places; or is it an 'energy park' that tourists come to visit and learn about the new technologies and how they can be integrated into their lives? Perhaps even more fundamental, does it result out of necessity or by choice? While questions such as these are not so easily answered specifically through research, finding comparable projects that have undertaken similar initiatives would begin to frame a proposal such as this in a more realistic sense. Codes in relation to infrastructure should also be studied in order to reveal more about the potential implementation of such a project.

The final question to be tested is how well the ideas, concept prototypes, and design methods from this first pass translate to another site. This would reveal the success of the proposal in terms of the aims. This would be initially tested by choosing another comparable coastal site and translate the ideas. A more challenging and informative project would be to introduce the ideas and prototypes to a very different type of site, with similar natural resources. An example of this might be a smaller town or a residential area. This would force the concepts to come to terms with the specific dynamics and built environment of the chosen place, and inevitably reveal more depth to the design method, and prototypical concepts.







Existing Buildings on Site - Hot Water Consumption

RESIDENTIAL						
	210	housing units on site				
	2.66	people / housing unit				
	558.6	total people	30	gallons hot water/ day	total residential	
COMMERCIAL						
	9,046	total commercial businesses				
	113,078	employees				
	12.5	employees/ commercial space				
	70	businesses				
	875.00	total employees	0.5	gallons hot water/ day	total commercial	
					gallons per day	

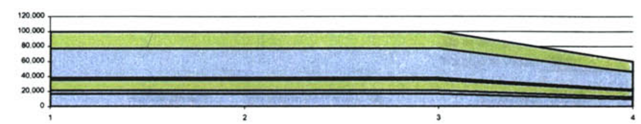
Initial Proposal - Solar Thermal Hot Water Production

THERMAL COLLECTORS						
flat plate collectors	11,500	sq. ft. total proposed	0.75	sq. ft./ gallon water	gallons per day	50%
STORAGE	8,625.00	gallons to be stored for daily demand				
				BALANCE	gallons per day	

These calculations represent the energy producing capacity of the site at the completion of the design project. The first set of calculations in section <6.2> established the need for a higher energy production 'density' on the site. The goal was made to produce 50% of the electricity and 100% of the hot water demand on the site. While these goals influenced the design and integration of the energy producing infrastructure, other dimensions of the project were also being addressed simultaneously; dimensions such as consideration for human interaction and inhabitation of the technologies. The opposition of these two intentions began having significant impacts on particular areas of the proposed design in terms of scale and the need to strike an acceptable balance. Therefore, the established goal for hot water production was not achieved due to the decision to preference human scale over monstrous solar thermal panels. Further investigation of this project would be useful in terms of finding the proper balance between these two dynamics; the limits of this iteration simply suggest that there exists a need to establish such a balance.

Initial Proposal - Tidal Energy Production

tide height range[7]	11.7 ft.	3.57 m
efficiency factor	0.34	



	area in sq. ft.	area in km²		Spring	Summer	Fall	Winter	Total - annual kWh
tidal barrage area 1:	8,370	7.83E-04	*Tidal barrage #1*	16,701.62	16,701.62	16,701.62	10,020.97	70,146.81
tidal barrage area 2:	17,645	1.65E-03	*Tidal barrage #2*	35,209.09	35,209.09	35,209.09	21,125.46	147,878.20
tidal barrage area 3:	10,835	1.01E-03	*Tidal barrage #3*	21,620.32	21,620.32	21,620.32	12,972.19	90,805.34
tidal barrage area 4:	19,123	1.79E-03	*Tidal barrage #4*	38,158.32	38,158.32	38,158.32	22,894.99	160,264.93
tidal barrage area 5:	38,831	3.63E-03	*Tidal barrage #5*	77,483.95	77,483.95	77,483.95	46,490.37	325,432.60
tidal barrage area 6:	49,948	4.67E-03	*Tidal barrage #6*	99,666.98	99,666.98	99,666.98	59,800.19	418,601.32
			SEASONAL TOTALS:	288,840.29	288,840.29	288,840.29	173,304.17	
			SEASONAL BALANCE:	-234,429.99	-697,085.46	-545,716.85	-517,134.44	

TOTAL PRODUCTION	1,213,129.21	kWh annually	32%
BALANCE	*-1,588,091.60*	kWh annually	58%

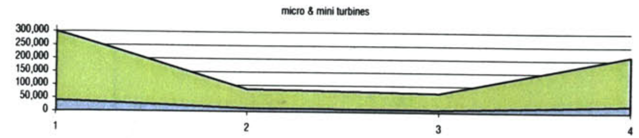
Initial Proposal - Wind Energy Production

Micro turbine swept area:	132.73 ft²	(13'-6" ft. diam.)
Mini turbine swept area:	1809.56 ft²	(48 ft. diam.)

Wind speeds (mph)[4]	100 ft.	200 ft.
spring	15.0	17.8
summer	10.4	11.6
fall	9.9	11.0
winter	13.4	16.0

air density at sea level 0.005088

cube factor 1.9
turbine efficiency factor[5] 30%

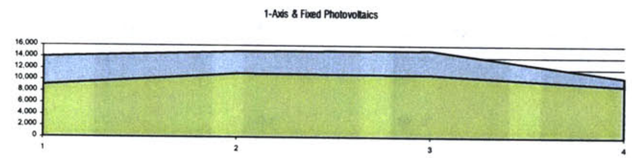


		Spring	Summer	Fall	Winter	Total - annual kWh
Micro turbine (8' dia.)	1	2,868.56	956.10	815.74	2,000.59	6,640.99
proposed micro turbines:	14	40,159.84	13,385.42	11,420.31	28,008.28	120,982.13
Mini turbine (14' dia.)	1	65,351.82	18,087.11	15,255.47	46,431.06	145,641.37
proposed mini turbines:	4	261,407.30	72,348.43	61,021.89	185,724.26	768,289.73
SEASONAL TOTALS:		301,567.14	85,733.85	72,442.19	213,732.54	

TOTAL PRODUCTION 889,271.87 kWh annually **23%**

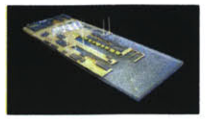
Initial Proposal - Solar Energy Production

Latitude: N43.65 degrees
Longitude: W 70.32 degrees



			Spring	Summer	Fall	Winter	Total - annual kWh
altitude na / azimuth na	*One-Axis*[6]						
	1 module (9.33 ft²)		39.00	47.68	47.06	39.00	162.52
	bank of 18 modules (167.94 ft²)		702.00	858.24	847.08	702.00	2,925.36
	proposed bank of 18 modules	12.9	9,055.80	11,071.30	10,927.33	9,055.80	46,792.94
altitude 43.7 degrees / azimuth 180 (south)	*Fixed Canopy*[6]						
	1 module (9.33 ft²)		31.86	34.07	34.49	23.90	124.32
	bank of 4 modules (37.32 ft²)		127.44	136.28	137.96	95.60	497.28
	ft² modules proposed	4,092 (439 factor)	13,986.54	14,956.73	15,141.11	10,492.10	65,068.58
	SEASONAL TOTALS:		23,042.34	26,028.03	26,068.44	19,547.90	

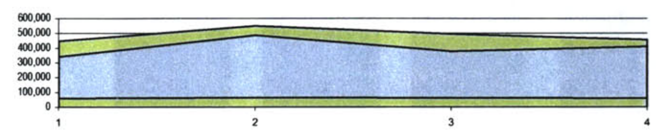
TOTAL PRODUCTION 111,861.52 kWh annually **3%**



Renewable Energy Production Calculations - *final*

Set 2.0

Existing Buildings on Site - Electricity Consumption



Building type:	*Sq. Footage*		Consumption factor		*Spring*	*Summer*	*Fall*	*Winter*	*Total electricity demand kWh*
			Commercial electricity consumption factors :[3]		23.00%	28.20%	25.40%	23.40%	
COMMERCIAL	206,703.00		9.40	kWh/ sq.ft./ yr.[1]	446,891.89	547,928.31	493,524.08	454,663.92	1,943,008.20
			Residential electricity consumption factors :[3]		21.10%	30.10%	23.40%	25.40%	
RESIDENTIAL	296,550.00	210 housing units	7,675.00	kWh/ housing unit/ yr.[2]	340,079.25	485,136.75	377,149.50	409,384.50	1,611,750.00
			Industrial electricity consumption factors :[3]		24.60%	26.10%	25.20%	24.10%	
INDUSTRIAL	26,340.00		9.40	kWh/ sq.ft./ yr.[1]	60,908.62	64,622.56	62,394.19	59,670.64	247,596.00
				SEASONAL TOTALS:	847,879.75	1,097,687.62	933,067.77	923,719.05	

TOTAL CONSUMPTION -3,802,354.20 kWh annually

ENDNOTES

1.0 INTRODUTION AND INTENTIONS

[1] Kenneth Yeang, *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings*, pg. 12.
[2] Ibid. pg. 31.
[3] Amory Lovins, L. Hunter Lovins, Paul Hawken, *Natural Capitalism*, pg. 2.
[4] Ibid. pg. 48.
[5] Ibid. pg. 5.
[6] Ibid. pg. 2-3.
[7] Ibid. pg. 56.
[8] James Masrton Fitch, *American Building: The Environmental Forces That Shape It*, pg. 46.
[9] Lisa Herschong, *Thermal Delight in Architecture*, pg. 51.
[10] Kenneth Yeang, *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings*, pg. 72.

2.0 ENERGY INFRASTRUCTURE AND DE-REGULATION

[1] Richard H. Hirsh, *Power Loss*, pg. 12.
[2] Ibid, pg. 13.
[3] Ibid, pg. 1.
[4] Ibid, pg. 23.
[5] Ibid, pg. 3.
[6] Ibid, pg. 1.
[7] Ibid, pg. 3.
[8] Ibid, pg. 114.
[9] Ibid, pg. 116.
[10] "Electric Deregulation Q & A (September 17, 1999)," at wysiwyg://148/http://www.enn.com/enn-features-archive/1999/091799/deregulation_4812.asp
[11] "Electricity Deregulation," at http://www.greenmountain.com/electricity/choices/dereg.asp
[12] "Competition/Regulation: The Living Grid," at http://www.eei.org/issues/comp_reg/power5.htm
[13] "How Does Electricity Get to Your Home," at http://www.greenmountain.com/electricity/choices/grid.asp
[14] "Competition/Regulation: The Living Grid," at http://www.eei.org/issues/comp_reg/power5.htm
[15] Richard H. Hirsh, *Power Loss*, pg. 269.
[16] "Powering a Generation: Understanding Deregulation #1," at http://www.americanhistory.si.edu/csr/powering/dereg1.htm
[17] "Powering a Generation: Understanding Deregulation #1," at http://www.americanhistory.si.edu/csr/powering/dereg1.htm
[18] "Activists Warn of Deregulation Shortcoming news source on the environment," at wysiwyg://151/http://www.enn.com/enn-features-archive/1999/09/090399/incentive_5446.asp

3.1 SYSTEMS APPROACH TO BUILT WORKS

[1] Kenneth Yeang, *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings*, pg. 60.
[2] Ibid. pg. 36.
[3] Ibid. pg. 49.
[4] Ibid. pg. 38.
[5] Ibid. pg. 35.
[6] Ibid. pg. 36.
[7] Amory Lovins, L. Hunter Lovins, Paul Hawken, *Natural Capitalism*, pg. 67.
[8] Ibid, pg. 67.
[9] Ibid. pg. 143.
[10] Ibid. pg. 49.
[11] Ibid. pg. 39.
[12] Ibid. pg. 50.
[13] Ibid. pg. 59.

3.2 RENEWABLE TECHNOLOGIES

[1] Amory Lovins, L. Hunter Lovins, Paul Hawken, *Natural Capitalism*, pg. 248.
[2] Ibid, pg. 131.
[3] Richard H. Hirsh, *Power Loss*, pg. 116.
[4] "Real Goods - Learn Everything About Renewable Energy" at http://www.solareco.com/articles/article.cfm?id=26
[5] Peter Smith & Adrian Pitts, *Concepts in Practice: Energy*, pg. 41.
[6] "About Solar Power>FAQ>Technical Questions" at http://www.bpsolarex.com/3rd-FAQ_technical_questions.html
[7] "Building Power for the Future", pdf file found at: http://www.bpsolar.com
[8] Ibid.
[9] "About Solar Power>Silicon" at: http://www.bpsolarex.com/3rd-Silicon.html
[10] Peter Smith and Adrian Pitts, *Concepts in Practice: Energy*, pg. 42.
[11] "Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=28
[12] "About Solar Power>Silicon" at: http://www.bpsolarex.com/3rd-Silicon.html
[13] Sophia Behling, *Sol Power*, pg. 218.
[14] "Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=28
[15] Brian Edwards, *Sustainable Architecture*, pg. 104.
[16] "Building Power for the Future", pdf. file found at: http://www.bpsolar.com
[17] "About Solar Power> FAQ> General Questions" at http://www.bpsolar.com/3rd-FAQ_general_questions.html

[18] "Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=27
[19] "Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=29
[20] Ibid.
[21] Brian Edwards, *Sustainable Architecture*, pg. 103.
[22] Peter Smith & Adrian Pitts, *Concepts in Practice: Energy, pg. 42.*
[23] "Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=29
[24] Klaus Daniels, *Low-Tech Light-Tech High-Tech: Building in the Information Age*, pg. 58.
[25] Peter Smith & Adrian Pitts, *Concepts in Practice: Energy*, pg. 26.
[26] "Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=96
[27] Brian Edwards, *Sustainable Architecture*, pg. 108.
[28] "How Solar Energy Works" at http://www.ucsusa.org/energy/brief.solar.html
[29] Richard F. Hirsch, *Power Loss*, pg. 108.
[30] "How Wind Energy Works" at http://www.ucsusa.org/energy/brief.wind.html
[31] "Basic Principles of Wind Resource Evaluation" at http://www.awea.org/faq/basicwr.html
[32] Paul Gipe, *Wind Energy Basics: A Guide to Small and Micro Wind Systems*, pg. 7.
[33] "Basic Principles of Wind Resource Evaluation" at http://www.awea.org/faq/basicwr.html
[34] "How Wind Energy Works" at http://www.ucsusa.org/energy/brief.wind.html
[35] "Basic Wind Turbine Configurations" at http://www.awea.org/faq/basiccf.html
[36] Brian Edwards, *Sustainable Architecture* pg. 109.
[37] Brian Edwards, *Sustainable Architecture*, pg. 110.
[38] Paul Gipe, *Wind Energy Basics: A Guide to Small and Micro Wind Systems*, pg. 40.
[39] Ibid. pg. 73.
[40] Ibid. pg. 9.
[41] "How Wind Energy Works" at http://www.ucsusa.org/energy/brief.wind.html
[42] Paul Gipe, *Wind Energy Basics: A Guide to Small and Micro Wind Systems*, pg. 13.
[43] Brian Edwards, *Sustainable Architecture*, pg. 110
[44] Paul Gipe, *Wind Energy Basics: A Guide to Small and Micro Wind Systems*, pg. 75.
[45] Brian Edwards, *Sustainable Architecture*, pg. 112.
[46] "Energy Facts: Tidal Energy" at http://www.iclei.org/efacts/tidal.htm
[47] "Energy From the Oceans" at http://zebu.uoregon.edu/1998/ph162/115.html
[48] "Energy Facts: Tidal Energy" at http://www.iclei.org/efacts/tidal.htm
[49] "Energy From the Oceans" at http://zebu.uoregon.edu/1998/ph162/115.html
[50] "Texas Guide to Rainwater Harvesting" at http://www.twdb.state.tx.us/assistance/conservation/ici.htm
[51] Brian Edwards, *Sustainable Energy*, pg. 127.
[52] Paul Gipe, *Wind Energy Basics: A Guide to Small and Macro Wind Systems*, pgs. 44-45.

3.2 RENEWABLE TECHNOLOGIES *con't.*

[53] "Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=31
[54] Brian Edwards, *Sustainable Energy*, pg. 111.
[55] Ibid. pg. 111.

3.3 TRANSLUCENT TELEPHONES, PRISMACOLOR PINWHEELS AND WIND WALLS

[1] Amory Lovins, L. Hunter Lovins, Paul Hawken, *Natural Capitalism*, pg. 88.
[2] Ibid. pgs. 48-49.
[3] Ibid. pg. 283.
[4] Ibid. pg. 67.

ILLUSTRATIONS

0.0 CHAPTER OUTLINE

pg. 4. Personal image from Gelsenkirchen, Germany, 2000.

1.0 INTRODUTION AND INTENTIONS

pg. 6. DOE/NREL at: http://www.nrel.gov/data/pix/
pg. 8. non-hand drawn diagrams from Yeang, Ken. *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings*; images from Melet, Ed. *Sustainable Architecture: Towards a Diverse Built Environment*; Edwards, Brian. *Sustainable Architecture: European Directives and Building Design.*
pg. 10. Yeang, Ken. *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings.*
Ibid.
pg. 12. *Architecture Magazine*, December 1999.

2.0 ENERGY INFRASTRUCTURE AND DE-REGULATION

pg. 18. US Department of Agriculture and DOE/NREL at: http://www.nrel.gov/data/pix/
pg. 20. Smithsonian Institute at: http://americanhistory.si.edu/csr/powering/quiklist.htm/
Smil, Vaclav. *Energies: An Illustrated Guide to the Bioshpere and Civilization.*
pg. 21. Smithsonian Institute at: http://americanhistory.si.edu/csr/powering/quiklist.htm/
CMS Energy at: http://americanhistory.si.edu/csr/powering/quiklist.htm/
pg. 22. North American Electric Reliability Council at: http://www.nerc.com/regional/
by Scott Willis from Hirsch, Richard, *Power Loss*.
pg. 23. Personal image from Freiburg, Germany, 2000.
pg. 24. DOE/NREL at: http://www.nrel.gov/data/pix/
Personal image from Portland, Maine, 2000.

3.1 SYSTEMS APPROACH TO BUILT WORKS

pg. 26. Personal image from NYC, 2000.
pg. 28. Personal image from Black Forest region, Germany, 2000.

3.2 RENEWABLE TECHNOLOGIES

pg. 34. Personal image from Freiburg, Germany, 2000.
pg. 36. Personal image from Gelsenkirchen, Germany, 2000.
By Micheal Potts from *The Independent Home.*
pg. 37. Personal image from Chichester, New Hampshire, 2000.
Personal image from Herne-Sodigen, Germany, 2000.
pg. 38. Personal image from Freiburg, Germany, 2000.
Personal image from Freiburg, Germany, 2000.
pg. 39. Personal image from Freiburg, Germany, 2000.
Personal image from Freiburg, Germany, 2000.
pg. 40. DOE/NREL at: http://www.nrel.gov/data/pix/
pg. 41. Personal image from Black Forest region, Germany, 2000.
at: http://www.awea.org/faq/usresource.html
pg. 42. Personal image from Black Forest Region, Germany, 2000.
Gipe, Paul. *Wind Energy Basics: A Guide to Small and Micro Wind Systems.*
pg. 43. Ibid.
Ibid.
pg. 44. DOE/NREL at: http://www.nrel.gov/data/pix/
Baker, A.C. *Tidal Power*.
pg. 45. Personal image from Kronsburg, Hannover, Germany, 2000.

3.3 TRANSLUCENT TELEPHONES, PRISMACOLOR PINWHEELS AND WIND WALLS

pg. 48. Personal image from NYC, 2000.
pg. 50. By John Gurzonski at: http://www.lvrj.com/lvrj_home/2000/Jul-13-Thu-2000/photos/phone.jpg
pg. 51. Ibid.
pg. 53. Personal images from graduate seminar course (3), 1999.
pg. 54. Ibid. (5).
pg. 55. Personal images from graduate studio course (2), 2000.
pg. 56. Ibid. (2).
pg. 58. Personal image from Gelsenkirchen, Germany, 2000.

4.0 CASE STUDIES – PROJECTS VISITED

pg. 60. Personal images from various projects in Germany and Netherlands, 2000.
pg. 61. Black and white image from Daniels, Klaus. *Low Tech, Light-Tech , High Tech*: *Building in the Information Age.*
Personal images from various projects in Germany and Netherlands, 2000.
pg. 62. Ibid.
pg. 63. Ibid.
pg. 64. Ibid.

6.0 MOMENTS AND SYSTEM – DEVELOPMENT AND SYNTHESIS

pg. 85. Personal image from NYC, 2000.
pg. 95. Personal image from London, England, 1994.

7.0 CONCLUSION

pg. 100. Personal image from EXPO 2000, Hannover, Germany, 2000.

BIBLIOGRAPHY

logic of ecosystems and energy flows

Daniels, Klaus. *The Technology of Ecological Building*: Birkhouser, Basle, 1995.
Yeang, Kenneth. *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings.* Prestel: London, 1999.

energy companies and deregulation

"Activists Warn of DeregulationShortcoming news source on the environment," at wysiwyg://151/http://www.enn.com/enn-features-archive/1999/09/090399/incentive_5446.asp
"Competition/Regulation: The Living Grid," at http://www.eei.org/issues/comp_reg/power5.htm
"Electric Deregulation Q & A (September 17, 1999)," at wysiwyg://148/http://www.enn.com/enn-features-archive/1999/091799/deregulation_4812.asp
"Electricity Deregulation," at http://www.greenmountain.com/electricity/choices/dereg.asp
Hirsh, Richard F. *Power Loss: The Origins of Deregulation and Restructuring in the American Electric Utility System.* MIT Press: Cambridge, Massachusetts, 1999.
"How Does Electricity Get to Your Home," at http://www.greenmountain.com/electricity/choices/grid.asp
"Powering a Generation: Understanding Deregulation #1," at http://www.americanhistory.si.edu/csr/powering/dereg1.htm

sustainable buildings - energy producers

Anink, David. *Handbook of Sustainable Building: An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment.* James and James: London, 1996.
Banham, Reyner. *The Architecture of the Well-Tempered Environment*, University of Chicago Press: Chicago, 1969.
Behling, Sophia. *Sol Power: The Evolution of Solar Architecture*. Prestel: Munich, 1996.
Crowther, Richard L. *Ecologic Architecture*. Butterworth Architecture: Boston, 1992.
Daniels, Klaus. *Low Tech, Light-Tech , High Tech: Building in the Information Age*: Birkhouser, Basle,1998.
Edwards, Brian. *Sustainable Architecture: European Directives and Building Design.* Architectural Press: Oxford, 1996.
Herzog, T. *Solar Energy in Architecture amd Urban Planning*: Munich, 1996.
Melet, Ed. *Sustainable Architecture, Towards a Diverse Built Environment,* NAI Publishers: Rotterdam, 1999.
Slessor, Catherine. *Eco-Tech : Sustainable Architecture and High Technology*. Thames and Hudson: New York, 1997.

social and economic issues and the natural environment

Hawken, Paul; Lovins, Amory & L. Hunter. *Natural Capitalism: Creating the Next Industrial Revolution*. Little, Brown & Company: New York, 1999.
Maser, Chris. *Sustainable Community Development: Principles and Concepts.* St. Lucie Press: Delray, Florida, 1997.
Tenner, Edward. *Why Things Bite Back*, Vintage Books: New York, 1996.

renewable energy technologies

solar

"About Solar Power> FAQ> General Questions" at http://www.bpsolar.com/3rd-FAQ_general_questions.html
"About Solar Power>FAQ>Technical Questions" at http://www.bpsolarex.com/3rd-FAQ_technical_questions.html
"About Solar Power>Silicon" at: http://www.bpsolarex.com/3rd-Silicon.html
"Building Power for the Future", pdf file found at: http://www.bpsolar.com
"How Solar Energy Works" at http://www.ucsusa.org/energy/brief.solar.html
"Real Goods - Learn Everything About Renewable Energy" at http://www.solareco.com/articles/article.cfm?id=26
"Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=27
"Real Goods - Learn Everything About Renewable Energy" at http://www.solareco.com/articles/article.cfm?id=28
"Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=29
"Real Goods - learn everything about renewable energy" at http://www.solareco.com/articles/article.cfm?id=96

wind

"Basics: Energy Output of Wind Turbines" at http://www.awea.org/faq/basicen.html
"Basic Principles of Wind Resource Evaluation" at http://www.awea.org/faq/basicwr.html
"Basic Wind Turbine Configurations" at http://www.awea.org/faq/basiccf.html
Gipe, Paul. *Wind Energy Basics: A Guide to Small and Micro Wind Systems*. Chelsea Green Publishing Company: White River Junction, Vermont, 1999.
"How Wind Energy Works" at http://www.ucsusa.org/energy/brief.wind.html

water

"Energy Facts: Tidal Energy" at http://www.iclei.org/efacts/tidal.htm
"Energy From the Oceans" at http://zebu.uoregon.edu/1998/ph162/115.html
"Energy Facts: Tidal Energy" at http://www.iclei.org/efacts/tidal.htm
"Real Goods - Learn Evergything About Renewable Energy" at http://www.solareco.com/articles/article.cfm?id=34
"Real Goods - Learn Everything About Renewable Energy" at http://www.solareco.com/articles/article.cfm?id=31
"Texas Guide to Rainwater Harvesting" at http://www.twdb.state.tx.us/assistance/conservation/ici.htm
Baker, A.C. *Tidal Power*. Peter Perebrinus Ltd: London, England, 1991.

technical information & data sources

energy consumption/ production sources

"Daily Climate Data - Portland" at: http://www.nws.noaa.gov/cgi-bin/box/showcl.pl
"Energy Consumption and Expenditures", at: ftp://ftp.eia.doe.gov/pub/consumption/commercial/ce95tb4.pdf.
"Energy Consumption and Expenditures", at: http://www.eia.doe.gov/emeu/recs/recs97_ce/t1_9c.html.
"FEMP - Solar Water Heating" at: http://www.eren.doe.gov/femp/prodtech/sw_water.html
Gaquin, Deirdre A., Littman, Mark S., U.S. Census 1999 County and City Extra: Annual Metro, City, and County Data Book, Eighth Edition. Bernan Press: Washington, D.C. 1999.
"PVWATTS: AC Energy and Cost Savings" at: http://rredc.nrel.gov/solar/codes_algs/PVWATTS/code/pvwatts.cgi.
"Tide Predictions for Portland, Maine" at: http://co-ops.nos.noaa.gov/tides/nynePORT.html
"U.S. Electric Utility Retail Sales of Electricity by Sector, 1990 Through June 2000 - Northeast" at: http:www.eia.doe.gov/cneaf/electricity/epm/epmt44.txt.