iCity: The Sustainable City

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Foreword

As societies become more affluent, the consumption of energy and materials grows inevitably, and such a trend is clearly unsustainable. Govind was passionate about increasing the awareness of our society's consumptive lifestyles, the anthropogenic causes of global warming, and how to deal with their consequences. He sought for us to design an idealized and nearly self-sustainable region by utilizing a systems engineering approach in which all significant entities and interactions could be considered and modeled accordingly.

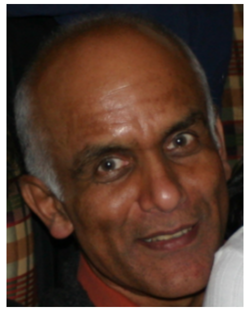
Having grown up on a small farm in India, Govind was well aware of the rapidly accelerating depletion of natural resources and of the deteriorating environment. By affectionately recalling stories of his Toyota Camry—which he had proudly driven for the last twenty years—and of the fact that he still purchased clothes from the same tailor in India, Govind taught us to recognize that all aspects of our lives that affect the sustainability of our planet. The increased consumption of goods and resources accompanying an improved standard of living has increased the demand of energy and raw materials that has exacerbated global warming.

Govind himself came to the Georgia Tech Honors Program with this seminar. In it, Govind was provided with an opportunity to create an interdisciplinary course on this special topic that he is especially passionate about. He revealed that to us that social and economic growth has caused a significant burden on the environment by a loss of biodiversity, contaminated air and groundwater, etc. and asked us to design and document a solution.

iCity is our solution. iCity was inspired and fostered by Govind.

We dedicate this paper to Govind and publicize it in his honor, with fond memories, heartfelt sorrow, and wishes inspired by this great man and carried forth by us, his students.

—T. Govindaraj's Fall 2007 ISyE 4833HP Class: Engineering manufacturing and service systems for sustainability.



T. Govindaraj
(1949 – 2007)

Admired professor
Celebrated colleague
Cherished friend

Introduction

The iCity project is the embodiment of the concept that a city can be ecologically, socially, financially, and temporally sustainable while maintaining the high quality of life afforded by modern technology. The city is engineered to passively change the unsustainable behaviors and practices of modern American culture and provide alternatives that can be sustained for generations to come without harm to the people or their environment. Its design aims to minimize the city's impact on its immediate environment and the city's global footprint by reducing the consumption of fossil fuels in favor of alternative energy sources, reducing carbon dioxide emissions, and using energy more effciently in every aspect of the city's life. The physical layout of the city and its entire infrastructure are geared to encourage citizens to live a more economical, practical, and sustainable lifestyle and to foster a strong sense of community and distinctive sense of place. Beyond being merely environmentally sustainable, the city must be socially, culturally, financially, and economically sustainable to be as nurturing a home as possible for the people who live there. The iCity is meant to be the prime example of an "ecocity" whose belief in sustainability, efficiency and human vitality (how to simultaneously sustain humanity and live as a person in a world where efficiency and environmental sustainability is essential) can be adapted to any geographic location, but it is also an example of how to take advantage of the unique resources of a particular place in innovative, ecologically sustainable ways. By calling attention to the successes of sustainable living already immersed in today's society, the iCity will be able to make the public aware of the destruction today's wasteful lifestyle is inflicting on the earth, thus promoting a movement toward greater economic and social sustainability in cities around the world.

iCity, USA, is located at latitude 36°25' north and longitude 88°15' west in the extreme northwestern corner of Tennessee. It lies just below the Kentucky border, about twenty miles north of the town of Huntingdon, TN, and ten miles west of Kentucky lake. There is a 40 foot variation in elevation in the area, between 120 and 160 feet above sea level. The climate of Tennessee is temperate: long, humid summers with peak July temperatures in the nineties (Fahrenheit) and cool winters (low January temperatures in the mid-twenties, with occasional snow). It has plentiful water resources, with annual average precipitation of about 50 inches. It sits on the shallow eastern edge of the MacNairy-Nacatoch groundwater aquifer, part of an aquifer system that provides 11 million gallons of water daily to the western half or Tennessee. We have chosen this fairly benign region as the location for the iCity because of its generality: because it lacks severe extremes of weather and geography, a city design that works here will meet the requirements of many temperate regions around the globe and will also be able to adapt to the specific needs of more severe climates at both ends of the spectrum and everywhere in between.

1 Urban Design

1.1 City Layout as Representation

Urban design and city planning have historically been physical representations of societal values as well as major influences on behavior and culture in general. The city of Versailles was conceived as a palace for King Louis XIV and stresses this fact through an axial arrangement [Allen, 2002]. That is, all major roads lead to the king's palace, placing him in the middle of all citizens' lives. Similarly, Thomas Jefferson created the University of Virginia on axial arrangement as well, except with the library as the main focus. The adjacent residence halls were created equal but unique, an idea he wanted to stress in his then fledgling country [Allen, 2002].

As a concept, it is important establish the layout of a sustainable city around the idea of preserving natural conditions alongside the emphasis on efficiency. This can be achieved by interspersing greenspace at frequent intervals and then providing them with priority. For example, a collection of homes could possess a communal garden that is set apart from the public and is completely uninterrupted by other thoroughfares or perhaps even cuts through them [Alexander, 1977]. On the other hand, several small multipurpose buildings could share a park space that is specifically set apart away from roads. Either way, it creates a level of concern for what already exists and sets up a precedent for preservation on a more macroscopic level because it orients the inhabitants toward nature.

To stress the idea of environment and individual contribution, the actual layout of the city can be decentralized and focused on a set of focus points or clusters. This nodular system, being on a smaller scale, allows for a more intimate interaction between city and citizen (much like that of a county to state) and allows closer and more real-time feedback between city goals and inhabitant participation. The center then could consist of a large, city-shared park or garden to rectify the importance of the concept the city is trying to establish. This type of nodular city has already been proposed and put into effect by Ebenezer Howard.

His “garden city” was composed of a decentralized layout stressing civic and social hubs surrounded by constant greenspace [Britannica, 2007].

1.2 The Living City

To establish a sustainable urban landscape iCity will have fewer sprawling lawns and more native meadows and woods [Verner, 1998]. The focus of greenspace in iCity will be maximum sustainability including reduced watering and a reduction of plant-causing allergies. Any lawns within the city will be mowed with non-motorized reel mowers less frequently and the clippings will remain on the lawn as mulch. When irrigation is necessary iCity will incorporate only high-efficiency irrigation.

There should be incentives for planting approved types of trees, shrubs, flowers, and grasses within iCity. The planting of any male trees or shrubs will be discouraged. Such plants are often sold as “seedless” or “fruitless” varieties but it simply means that they are males and that they will produce large amounts of allergenic pollen which iCity also seeks to avoid. Instead female trees and shrubs will be planted. Even though female plants may be messier than males, they produce no pollen, and they actually trap and remove pollen from the air. Very good all-female sod is available (for pollen-free lawns) and will be encouraged for the few lawns around iCity. In fact, these female lawns stay low and require less-frequent mowing. Leafy types of ground-cover will be utilized as much as possible, to avoid even more mowing [Bormann et al., 2001]. A major necessity when designing a sustainable iCity is to utilize as many plants as possible that are native to Tennessee around the site. Some of Tennessee’s native plants include American Beech trees, American Holly, Black Oak and Cherry Trees, Mountain Laurel, Virginia Bluebells, and Wild Columbine. Fun, fruit trees will be planted to attract birds which eat harmful insects.

Urban forests, wetlands, and stream-side vegetation buffer storm-water runoff, control pollution, help recharge natural groundwater reservoirs, and minimize flooding in urban areas. iCity will have fresh air, plenty of water, and minimal flooding. By buffering the harsh, urban experience urban forests, parks, and other greenspace provide invaluable recreation and relaxation [Programme et al., 2001]. Well-managed, urban green spaces can add to the health and education benefits already proven of urban ecosystems. iCity will utilize systematic tree-care programs and attention will be paid to effects of soil conditions, restrictions to root growth, droughts caused by the channeling off of rain, and the undergrowth among plantings will be plentiful [Programme et al., 2001]. The urban landscape of iCity will consist of diverse flower beds, wildflower meadows, and woodsy areas—possibly even an orchard or two. The green spaces will be extremely dynamic but very sustainable and pollen-free. By separating the nodes of iCity with woody forests and incorporating the same plants within each section of the city the effect will be mesmerizing. Our green, sustainable, ideal iCity will include all the positive aspects of rural areas including organic food production, breathtaking aesthetics of greenspace, and clean, fresh air.

1.3 Nodal Structure

The industrially oriented minor nodes should be closer to the canal ring, as discussed in section 4.1, for freight delivery purposes. Shopping and entertainment nodes should lie adjacent to other major nodes, so as to facilitate cross-overs. Social services nodes should lie in the center of the major node, much in the same adjacency fashion as the city itself, with its central area and its major nodes. This is to provide easy accessibility to all necessary civil services from any other minor node. Residential nodes are free to lie wherever, but should probably be cushioned and surrounded by other nodes, to buffer accesses from outside the major node, and yet provide easy access to other minor nodes. The overall structure should then resemble a smaller social services central node, partially (by 1/3) engulfed by a larger residential node, both forming a dual-center system, surrounded by the other nodes. Greenspace should be evenly dispersed throughout the minor nodes, especially along adjoining borders between them, so as to create common buffer zones system. Lastly, the central node will be connected to the overall city as the other ma jor nodes are: by monorail and selective roads.

The industrially oriented minor nodes should be closer to the canal ring, as mentioned in section 4.1, for freight delivery purposes. Shopping and entertainment nodes should lie adjacent to other major nodes, so as to facilitate cross-overs. Social services nodes should lie in the center of the major node, much in the same adjacency fashion as the city itself, with its central area and its major nodes. This is to provide easy accessibility to all necessary civil services from any other minor node. Residential nodes are free to lie wherever, but should probably be cushioned and surrounded by other nodes, to buffer accesses from outside the major node, and yet provide easy access to other minor nodes. The overall structure should then resemble a smaller social services central node, partially (by 1/3) engulfed by a larger residential node, both forming a dual-center system, surrounded by the other nodes. Greenspace should be evenly dispersed throughout the minor nodes, especially along adjoining borders between them, so as to create common buffer zones system. Urban forests, parks, wetlands, and stream-side vegetation buffer storm-water runoff, control pollution, help recharge natural groundwater reservoirs, and minimize flooding in urban areas. Thus, greenspaces will provide a buffer zone between minor nodes, maintain a healthy urban area, and present residents with freedom for outdoor recreation, revitalization, and relaxation. Lastly, the central node will be connected to the overall city as the other major nodes are: by monorail and selective roads.

1.4 A Pedestrian City

Additionally, the thoroughfares must be redesigned to put emphasis on the pedestrian and not the vehicle, which of course is a major source of pollutants. By making the street a place to live (rather than travel), it pulls people onto the sidewalk. This is easily implemented by simply increasing the width of pedestrian paths and creating incentives for them to access it (cafes, small plazas, etc.). A decrease in parking space area would similarly discourage vehicular travel, perhaps going lower that Christopher Alexander's proposed 9% of available land [Alexander, 1977]. This type of redevelopment coupled with a re-envisioned transport system could potentially cut back the vehicular congestion that is so apparent in today's cities.

As far as vehicular transportation is concerned, there are three major considerations, all geared towards emphasizing the focus of the public transportation system, the buses. First, public transportation must be made as efficient as possible. Take, for example, Curitiba, Brazil. Its bus system is astounding, working in a nodal structure with dedicated lanes and extreme efficiency. The model more resembles a train, however the costs are much lower and it ends up being far more efficient. In the iCity, this model will be used, however with a few modifications. Personal cars will still be discouraged, but City Cars (conceptualized by MIT) may instead be used for those who need more personalized travel (disabled persons, people with luggage, etc.). (Traditional taxis with a pick-up-along-the-way ideal may also be used instead.) The buses are intended primarily as transportation between minor nodes of the same major node, but there will be a few routes that cross the border into other major nodes. This system of buses is also planned to be supplemented by a monorail system (mostly for aesthetics) that links the major nodes of the iCity. Both types of public vehicles will be designed for high efficiency and powered by either electricity from the central grid or biogas, depending upon the production capacity of the city's composting facilities.

Second, public transportation must be aesthetic and luxurious. The current perception of buses (often rightly so) is that they are for those who cannot afford other means of transportation and that they reflect this feature in the conditions of travel, the condition of the vehicle, and the conditions of it occupants. Travel on the buses and railway in the iCity must be of the utmost comfort: a smooth ride, plenty of legroom (which can be achieved by having more buses and fewer passengers per bus). A wireless router should be located on the bus itself (connecting to passing buses and routers in a self-sustaining network along the way). The buses themselves should look very aesthetic, sleek, and appealing; their exteriors and interiors kept clean and attractive. Lastly, the bus should be encouraged for use by all classes of citizens, so as to represent a proper distribution of the population and so garner all sorts of clientèle, who's fears of the other passengers have been effectively dissuaded.

Thirdly, public transportation must not be seen as a sacrifice for the public good. It must rather be seen as an upgrade from previous times – A purely positive update from the previous state of cars and mixed transportation. This perception is important, because the people must have no disgruntled feelings about the public transportation system and must rather be Stockholm-syndromed into defending this system of transportation and truly liking it to their core. This is more an issue of propaganda and social tailoring, but it is important nonetheless.

Buses should come very frequently and at steady intervals and be easily boarded and disembarked. To facilitate the boarding and disembarking, RFID-enabled bus passes will be used, likely integrated into the citizen ID card (for citizens only, of course). Visitors can purchase temporary passes much like the MARTA rail system in Atlanta. The fee should be integrated into various offers by employers, so as to encourage citizens to use the system. The structure of the system should be easily understood and intuitive. Something along the lines of line A1, meaning major node A, minor node 1, denoting the highlight of that bus route's route. The costs associated with the bus system are, of course, extremely variable and unpredictable with many, many unknowns at the moment. A single bus, however, should cost between thousands to tens of thousands of dollars. The actual infrastructure of the transportation will be quite simple, consisting simply of asphalt roads. There will be a dedicated bus lane and a lane for cars. On the outside might possibly be a smaller lane, separated by some sort of physical divider, for bicycles. The layout of the roads will be that of a grid. Traffic will be monitored in real-time, and lights and various road signals will be adjusted accordingly. To aid in general transportation tracking, all buses, rail cars, barges, and trucks (more on those last two in a bit) will be fitted with a GPS transmitter.

Complimenting this system on a macroscopic level will be the monorail, which will be designed to be as aesthetic as possible and be elevated to a height of approximately two stories. It should serve to not only transport people, but also showcase the beauty of the city from above. It need not be able to support heavy traffic, as citizens will travel between major nodes rather infrequently. Besides connecting the major nodes in a circular fashion, it will also connect every major node to the central node, in much the same redundant fashion that the buses and roads do. Costs for the monorail system are uncertain, as they vary wildly depending upon the scope of the project and the manufacturer of the system. It is, however, relatively (and surprisingly) cheap to implement, with a wide variety of industrial packages offered by various companies. An intermediate monorail system's (the likes of which is the type the iCity would use) project, costs entirely from 5 to 30 million dollars per mile, with this one being approximately $9 million/mile. One advantage of the system, other than its cost, is that it pollutes very little, being quite efficient and using solely electrical power and in relative moderation (also keeping it quite quiet). Another keen advantage is that, being elevated, it shall have little impact upon the surrounding environment, thereby allowing greater flexibility with the planning of the city, such as cars being able to pass under it.

2 The Residential Sector

2.1 Combatting Sprawl

What else must be addressed then, alongside traffic, and localization? The defining condition of the contemporary urban landscape is sprawl [Crowley, 2002]. That is, suburban developments are pushing further and further away from cities in clusters that require long range highways and excessive parking lots. This encourages the use of cars and the inefficient use of land. The result is akin to a newly introduced species taking over the existing environment: uncontrolled growth. Urban landscapes today expand seemingly without bound, only contributing to congestion both on the road and in the metro-city area. Internal organization has the potential to be a major advantage for cities but often ends up more divisive which often leads to social stratification within the city [Ellin, 2007].

Sprawl is essentially generated when there is a clustering of similar socioeconomic statuses and it protrudes in a homogeneous mass, usually defined by a middle class constituency. Cities create grids (water, electric, etc.) only on which buildings can receive utilities. The problem becomes when a client wishes to build off the grid and then connect to it [Crowley, 2002]. This extension of the grid is financially very attractive but problems arise when the extensions do not stop and continue linearly outward where it may be more quite and spacious. This reintroduces long range, hi speed transit routes. This issue must be resolved internally, on the level of individual buildings.

Housing in iCity will not take the form of single-family units but rather that of mixed use buildings and developments, composite buildings that mix residential and retail or office spaces by story. For example, a mixed use building can have residential upper floors and a lower floor of retail space, or a mixed use development of a dozen or more buildings can contain retail spaces on the lower floors and office spaces on the upper floors. Mixed use developments prevent urban sprawl, which is a city planning problem that increases the reliance on automobiles; "[activate] urban areas during more hours of the day" [Miller, 2003], which also decreases the dependence on cars and "increases travel options" [Miller, 2003], including the option to walk; "[increase] housing options for diverse household types"; and "[create] a local sense of place" [Miller, 2003]. These high-density housing types create urban spaces that foster community growth and public health simultaneously.

2.2 Sustainable Construction

Two environmentally damaging problems that today's average house creates are energy-intensive and high waste-yielding processes and usage; these can occur in the construction, maintenance, and demolition phase. These problems can be curtailed by using materials that are less energy-intensive or low waste-yielding, such as steel and wood as opposed to concrete. For example, carbon dioxide emission resulting from construction is "850 [kg/m^2 for steel reinforced concrete], 250 [kg/m^2 for wooden single-family houses] and 400 [kg/m^2 for lightweight steel structure single-family houses]" [Suzuki et al., 1995]. Also, the transportation of these materials and parts to the construction site must be efficient in producing the least amount of carbon dioxide as possible. Thus, concrete is not favorable, since it is heavy and takes a very long time to transport, as opposed to lighter, better choices such as steel or wood. Also the entire process of manufacture, transportation, and construction must be modular so that the most efficient systems can be created to use the least amount of energy and to produce the least amount of waste and carbon dioxide possible. By creating a kit of parts, standard elements of a building (such as columns, beams, and girders) can be replicated economically, manufactured quickly, assembled easily, and adapted to create different forms. To limit the waste and energy expenditure in the demolition phase, housing must be designed with permanence in mind, with proper testing of interior ventilation systems and proper installation of window glazing. No building should be haphazardly slapped together, and buildings should only use materials that can be recycled or reused and constructed and demolished with expending as little energy as possible. For example, architect Shigeru Ban, world-renowned for his many "green" buildings, constructed many paper buildings are permanent structures that require very little to take down and construct [Kimmelman, 2007].

As for the maintenance stage of a house, the stage in which residents contribute to their homes' carbon dioxide output, energy is used in four broad ways: for electricity to run lights and appliances; for water heating; for climate control (heat and cooling); and for cooking. Most of this is currently provided by electricity and/or natural gas. The total energy consumed by a home in the United States comes to approximately 8900 kWh/yr. Our goal in designing iCity's housing is to minimize homes' consumption of energy as much as possible, as well as converting to renewable sources for the energy that is used.

2.3 Home Energy Use

As previously mentioned, the electricity used by homes will be provided by PV cells installed on the roof of the house, and excess energy collected during the day will be stored in Li+ batteries either per house or per neighborhood. It is important, therefore, to assess how many PV cells are needed to power a house and how much they cost. PV systems cost about $8000 per kW of generating capacity to install (home PV systems are usually about 1.5 kW), and a study by Mississippi State University reported that a 1 kW PV system (300 ft^2 of roof space) in central Mississippi, which receives comparable amounts of sunlight to Tennessee, can produce about 1250 kWh/yr of useable energy. Comparing this figure to the 1780 kWh/yr that can be achieved simply by eliminating the energy used for heat and realizing that the other efficiencies of the passivhaus will push the number even lower, it seems likely that PV cells could easily meet the energy needs of a home in iCity. The outlook is even more optimistic for apartment buildings, which have much more roof space and could even have PV sidings on some of the outer walls. Another important means of decreasing the amount of energy homes use is to use only energy-efficient home appliances. It is likely that iCity will have very strict product efficiency codes in place for home appliances assembled or sold in the city.

Finally, energy for cooking, which in most modern homes is supplied by electricity or natural gas, must be accounted for. If our goal is to keep electricity use down, gas stoves are preferable, but there we encounter the problem of using a nonrenewable resource, which we are trying as much as possible to avoid. To solve this dilemma, iCity's homes will be supplied with natural gas, specifically methane, produced by the composting of organic waste. Citywide composting facilities will exist as part of the city's emphasis on recycling and reuse, and they will provide homes with natural gas for cooking instead of releasing it into the atmosphere.

2.4 The Passivhaus Concept

To lower the expenditure of energy during the maintenance or living stage of a house, conventional coal-powered energy will be replaced by renewable energy (such as wind and solar energy or geothermal heating), and conventional homes will be replaced with passivhauses (also known as passive houses), "a building in which a comfortable interior climate can be maintained without active heating and cooling systems (Adamson 1987 and Feist 1988)" [Feist, 2007b]. The basic principal of the passivhaus is that a combination of improved ventilation and tight insulation eliminate the need for any active heating or cooling systems at all. The standards are strict: while a normal house uses more than 150 kWh/m^2-yr of energy, a passivhaus must keep its total energy consumption under 33 kWh/m^2-yr, while its energy use specifically for heating and cooling must be less than 15 kWh/m^2-yr. Since as much as 80% of a current home's energy input is heat, the virtual elimination of this energy drain means that we are now free to use renewable energy sources, even if they have a smaller generating capacity, because we can assume that we only need to provide 20% of the energy a current house uses, or about 1780 kWh/yr.

Because "39 percent of energy consumed in . . . homes is space heating and cooling"

[Australia, 2005], finding methods to reduce the need to use energy to heat and cool homes is essential to a sustainable design. Passivhauses utilize passive solar heating and a passive ventilation system to heat the home and circulate the air. Passive solar heating maximizes winter heat gain, minimizes winter heat loss, and heats areas when needed [Australia, 2005]. In this form of heating, “solar radiation is trapped by the greenhouse action of correctly oriented ([south] facing) windows exposed to full sun,” then the “Trapped heat is absorbed and stored by materials with high thermal mass (usually masonry) inside the house” [Australia, 2005]. This heat is then released at night or at other times when needed to “offset heat losses to lower outdoor temperatures” [Australia, 2005]. In passive ventilation, polluted or stale air (exhaust air) is constantly removed from the house, while fresh air supplied from the outdoors is constantly pumped to substitute the removed air [Feist, 2007c]. No air is recirculated, leading to a high level of indoor air quality. This ventilation system is mechanized and requires a heat recovery unit to balance any ventilation losses [Feist, 2007c]. To recover heat, a counterflow heat exchanger that takes uses warm extract air to heat the unpolluted fresh air, which can then heat the house (the extract air then leaves the house as exhaust air) [Feist, 2007c]. In order for the passive solar heating and ventilation system to work, the house must be as airtight as possible, windows must be properly glazed, and thermal mass and insulation must be correctly located inside and around the house. All in all, the energy used “for space heating is reduced by 90 percent compared to average houses of the building stock and by 75 percent compared to ordinary new construction” [Feist, 2007c]. Passivhauses only require “15 kilowatt-hours per square meter living space each year” for heating [Feist, 2007c], which is much less than in low energy houses and far less than in the average, conventional house in the US, which is on average 79.5 kWh/m^2 (Tester). Additionally, because of the superior ventilation system, air quality, and lighting, the comfort level of a Passivhaus is “significantly better” than that of a regular home [Feist, 2007c].

The structure and orientation of the house itself can be used to further reduce home energy use. Large windows oriented to face the sun can help heat the house and provide natural light, and they can also be placed in facing pairs to catch a cross-breeze when opened (though the passivhaus design allows for an electric air-exchange ventilation system). iCity will take advantage of these truly “passive” designs to make both private homes and apartment buildings as close to zero-energy as possible. For example, apartment buildings can be built so they are only one unit thick, allowing individual apartments access to cross-breeze ventilation, and windows can be shaded so they allow light into the building in the winter when the sun is low, but block it in the summer when the sun is hotter but higher.

The excellent interior home quality of the passivhaus, provided by the excellent indoor air quality and connection to nature, when coupled with communal areas such as sunrooms, gardens, free greenspace and other amenities produce a livelier, sustainable, healthier lifestyle for iCity's citizens that help promote the city's practices and encourage other cities around the world to adopt a sustainable lifestyle. Communal amenities such as an interior garden space in the middle of a housing complex promote a sense of a community, closeness to nature, better ventilation throughout the complex, and the affection that allows a building and its ideal to sustain into the future.

Sustainability does not depend solely on the materials used, the technology employed, or the source of energy; it also depends on the care taken to create a place and the feelings evoked by the place in return. As Shigeru Ban states, "A concrete-and-steel building can be temporary. It can be taken down or destroyed by an earthquake. But paper can last. It's a question of love. My paper church was still around after 10 years. If a building is loved, it becomes permanent" [Kimmelman, 2007]. Thus, these housing complexes must be mindful of not only the efficiency of energy used, but also the people who live in it, by providing communal greenspaces, by being aesthetically-pleasing, by using soft landscaping to shelter the complex from any harmful weather conditions and to beautify the surroundings, and by using other means necessary to allow the inhabitants to feel amazed and at home and ease with living sustainably.

2.5 Financial Sustainability of Passivhaus

Some argue against sustainable housing and passive solar heating and ventilation because they believe these systems are very expensive and not worth the energy saved; this is untrue and unsupported by facts. A study by the Passivhaus Institut in Germany proves that a passivhaus with initial additional investment of 15,000€ to the investment of a standard German house reaps an annual savings of 585€. The calculation used to determine these savings involves additional mortgage annuity (bank), reduced interest (1 year), heating energy savings of 11,000 kWh/a, heating energy cost saving with 65 Ct/Liter h-oil, and additional electricity cost for ventilation with 18 Ct/kWh. The calculation does not include any loan disbursements and reductions for ecological building, which in Germany amount to savings of approximately 880€ annually. Also, the equation used rounds the passivhaus initial costs up to 15,000€ from a calculated 14,000€ to ensure that underestimating of cost would not occur [Feist, 2007a]. The time required for a passivhaus to earn back its initial costs is approximately 26 years (stemming from the aforementioned calculations), which benefits a long-term commitment to sustainability. Additionally, the advantages of a passivhaus continue from economical to environmental considerations because passivhaus inhabitants and owners not only save money, but also help lower carbon dioxide emissions and make the environment healthier and cleaner for future generations. In addition, the energy consumption of a passivhaus is so little that inhabitants will no longer worry about paying bills. Plus, indoor air quality is far above that of a traditional house; the house will contain no moldy walls, drafts, or cold feet. And, of the 14,000€ discussed above, approximately 75% would go to local builders, while the remaining 25% goes to purchase materials from local retailers; this creates jobs, saves transportation costs, and avoids "the costs of international tensions. . . seen in the newspaper on any given day" [Feist, 2007a].

In sorting the most important elements of a city, sustainable housing emerges as an integral element needed to make all other aspects of a city sustainable. Housing is the type of building most needed and used in cities. In the United States, "buildings account for 39% of total energy use, 12% of total water consumption, 68% of total electricity consumption, [and] 38% of total carbon dioxide emissions" [Agency, 2004]. And, commercial buildings in 1995 encompassed only "32 percent of total residential floorspace (residential data from the 1993 Residential Energy Consumption Survey)" in 1993 [Agency, 2004]. The function of housing is primarily residential, but design solutions for residences can be widely applied to other types of buildings, such as commercial or office. Housing not only influences where, how, and how frequently citizens travel, but also the location of other buildings, of transportation, and of greenspace; social or political hierarchy; and the quality of life that compels a person to inhabit and appreciate their home. Aspects of iCity's housing that seek to solve the problems that unsustainable design that has dealt us include low waste-yielding processes, low-energy construction and materials, efficient use of energy, mixed use buildings, efficient location of housing, and an efficient form of housing that creates not only a great quality of life but also a sense of community and place.

3 The Commercial Sector

However, one should not only focus on sustainable housing, but also on sustainable commercialism, in its location, housing (physical accommodations), logistics, and transportation system. Design solutions for residential housing can be widely applied to commercial housing. For example, office and retail (such as clothing) housing can implement the passivhaus system, as the iCity's commercial housing combines with the residential housing to form larger mixed use developments. Most of the passivhaus systems will still function efficiently for these types of commercial uses. As for the energy sources for businesses, office buildings, government buildings, retails spaces, and so on, these buildings will of course strive to meet passivhaus energy standards, but because of the vastly different use of the buildings, this may not be possible, at least as far as heating and cooling are concerned. For example, most residents work in an office during the daytime and do not occupy their own home at this time. Thus, the majority of the energy for heating and cooling in the mixed-use developments should be expended on commercial housing.

Geothermal heat pumps (GHPs) are an efficient and renewable means of indoor climate control that could work equally well for homes and apartment buildings, if needed. A typical GHP costs about $2500 per ton of pipes, but they require very little maintenance and are typically guaranteed for between 25 and 50 years. The problem that arises with iCity's use of the GHP is the orientation of the pipes: they can be vertical or horizontal, and typically, the vertical orientation is preferred in situations when little space is available, as is the case in a city. However, the vertical boreholes can be as much as 250 ft deep, so it is unclear whether Tennessee's high water table would permit their use. Although horizontal loops only need to be buried 3 to 6 ft below the ground, they stretch between 400 and 600 ft laterally per ton of piping, and unfortunately, that much land is not likely to be available in an urban setting for other larger-scale public buildings, such as a concert hall or sports arena. But the following is a possible solution: since iCity is to be built from the ground up, we are free to install as much infrastructure underneath the buildings as we want, including plumbing, electrical wiring, and GHP pipes, without concerning ourselves with the difficulty of expensive excavation beneath extant buildings. If a network of GHP pipes were installed with regularly spaced access points above ground, public and commercial developments could grow over them and "plug in" to the system as they were built.

The GHP systems themselves rely on an electric motor for power, and of course commercial and public buildings require a substantial amount of energy for lighting and so forth, so they also need a source of electricity. Like apartment buildings, public and commercial buildings' size gives them the potential to make effective use of roof- and wall-installed PV arrays. However, some businesses—supermarkets, for example—use so much electricity that they would probably have to be connected to the citywide power grid (discussed later in the paper) that draws electricity from a conventional (probably coal-fired) power plant. Thus, a new design must be created for sustainable grocery stores. The food purchased and eaten in iCity will come mostly from local, organic farms, with supplementary community gardens and private residential gardens. The food being shipped from local farms will not be housed in a traditional, energy-feasting supermarket because the refrigerators and freezers in such facilities consume a significant amount of energy and contribute largely to the carbon dioxide output of supermarkets. Rather, fresh food will be sold in outdoor markets where everything is brought to the market in the morning, fresh and never frozen. Of course, pre-packaged food commodities, such as organic nuts and coffee beans, will still be available. These will be housed in the interior section of the market, inventoried into computers located around the store for customers to pick and select their items. However, iCity encourages consumers to order these products online via the iCity network to cut down on energy consumption. Once ordered, these items will be personally delivered to the residents via an efficient truck delivery system. A medium-size fleet of delivery trucks will ship the products (freight) to the resident's home straight from warehouses to reduce the space needed in stores and thus the energy consumed by these stores.

4 The Industrial Sector

4.1 Freight Transportation

iCity's unique "canal" is a very interesting system. It calls for the freight transportation for the city to be primarily transported on passive barges floating in a weak current of water in a canal that circles the center of the city. These barges need not be powered at all, and simply be passively carried by the water current and nudged in the right direction with the aid of a tugboat, which will probably be powered by carbon-cleaned coal or natural gas. Upon arrival at a docking area, a hydraulic lift can raise a large metal gate (with holes to allow the water to pass) to stop the barge and help secure it for loading or unloading. It is initially thought that four pumping stations should be placed equidistantly on the canal, so as to keep the first few meters of water in slow, barge-carrying motion. The water for the canal can easily be diverted from various nearby water sources, all stemming from the Kentucky lake. The most likely combination of candidates to glean water from would be the drainage canal for the Blood River and its forks and the Holly Fork Creek and its distributaries. There are several distinct advantages to using a canal-barge system:

It is cheap: construction costs are relatively and comparatively low, and maintenance costs are almost negligible. The cost of one standard $550,000 (as of 2005) and excavation of the canal costs about $8 per cubic yard, and the canal need not be lined, as the water flow is quite slow and the water is derived from preexisting waterways. The cost of a complete rail system (not just the rails) is about $250,000 per mile (in 1995). Given this cost, the cost for a train itself is stupid to consider, though in educational interest varies a good deal and is within the magnitude of hundred-thousand dollars for the train itself, not counting the freight cars.

It provides far more transportation power than other means; one 24-barge tow can move the same amount of cargo as 180 rail cars or 1440 trucks. It is very quiet. A rail system would disturb surrounding communities. It is very eco-friendly. Energy used is extremely minimal, only with the tugboats, pumping stations, and hydraulic gates will energy be used. It is highly aesthetically pleasing, and the slow water current and lack of lining will allow plants, algae, and animals to thrive as they would in the local river ecosystems. As will be discussed in more detail in section 5, the canal water will be kept clean and free of industrial waste by city ordinance.

Here is an overview of the entire freight transportation system. First, the freight enters the city via the main arteries of water, rail, or road (by truck), then the freight is unloaded temporarily into relatively small warehousing units that lay next to the docking station for the canal (along the periphery of the center of the city). The barges are steadily loaded with the freight as they come by, and ferry it to the appropriate major node docking station on the other side of the canal. Once there, the freight is unloaded again into a temporary, relatively small warehousing unit that serves the entire major node. (If it is for industrial purposes, it can be directly shipped to that industry on the waterside via its own private dock.) The aforementioned fleet of smaller (a little larger than delivery-size) trucks then steadily relay the freight to the appropriate stores, businesses, and homes, the first two which are responsible for their own very small-scale warehousing and stocking, thereby relieving centralized warehousing and instead making it more distributed.

4.2 Industrial Symbiosis

The canal system is the centerpiece of iCity's policy of encouraging symbiosis among its industries. Industrial symbiosis is a system in which the output of each plant, both finished products and byproducts, can be recycled into use in a neighboring plant (for example, the waste heat generated in one factory is piped to an adjacent factory to heat a boiler). A symbiotic industrial system is more efficient with its resources than a fragmented one, minimizing waste and coming closer to achieving self-sufficiency, an ideally sustainable condition. It is also flexible enough to absorb new industries, which can, if well-coordinated with the industries already present, provide new resources for the system and new "sinks" for waste outputs. The difficulty of organizing a symbiotic industrial system is in the logistics of materials flow among so many diverse industries, but the canal provides a simple, intuitive solution to the problem. The industries of each major node of the city will be located on the canal for convenient shipping, and the water in the canal flows continuously in one direction. Therefore, if plant A uses one of the products of plant B, then plant A will be physically located downstream from plant B, which will be located downstream from plant C, from which it receives some of its resources. Each industry will be located downstream from the ones from which it receives input materials, and since the canal loops around, circular chains of dependence are possible—A depends on B, which depends on C, which depends on A. Materials flow continually in one direction, but can still be sent anywhere in the city, at any time.

It should be noted that the initial example of industrial symbiosis (the recycling of waste heat from one industry to another), is not a likely scenario in iCity, because iCity will not be home to any of the heavy manufacturing industries that use and produce large amounts of heat. iCity's industrial sector will be composed of "light," industries, which require less capital, more labor (providing more jobs), and generally have less environmental impact than heavy industry. Light industries are concerned with the production of finished products, for example, textiles, clothing, shoes, furniture, and consumer electronics. Materials exchange between light industries will not be as intense as it would be in a city of heavy industries that produce intermediate products (i.e. refined steel) explicitly for processing by other industries, nor will it include such nonphysical resources as heat, which is needed to power boilers and furnaces that most light industry does not use.

4.3 Recycling and Composting for Energy

Two specific industries are important to the sustainable vision of iCity. First, iCity is going to have an aggressive and comprehensive recycling program, and the collection, sorting, and pre-processing of recyclable goods will form a respectable component of the industrial sector. One of the most important features of this recycling program is also a key piece of the transportation system and a picture of industrial symbiosis in action—a composting plant for the city's organic, which produces biofuel to run the public bus system, provide homes with heat for cooking, and, depending upon the plant's production capacity, provide some of the electricity used by iCity's other industries. Because iCity seems to be depending so much upon this composting plant, it is worth looking in more detail at the process of biogas production.

Industrial composting plants accept of all the same waste products that can be composted at home—plant waste from the kitchen and garden, livestock manure (from the surrounding agricultural land), leaves, wood chips, paper, and so forth—but also meat and dairy products, which cannot be composted at home because of the heat and speed needed to kill pathogens, as well as sewage and municipal waste. Industrial composting uses mainly anaerobic bacteria to decompose the organic matter, and their digestion process produces methane, the "natural gas" we use as fuel. Methane is a greenhouse gas, but industrial composting plants capture it, keeping it out of the atmosphere, and refine it so that it can be used in any of the ways natural gas is used. Composting also releases carbon dioxide, but unlike the carbon in coal that has been stored for millenia, this carbon would have been released anyway when the input materials decomposed naturally, so the composting process has no net effect on carbon output.

As an off-the-cuff estimate of how much biofuel a city's municipal waste can produce, consider that New York City's population of 8.1 million people produces about 25,000 tons of garbage per day. Assuming that 60% of this is biodegradable and that one ton of compost produces 115 m^3 of biogas (the equivalent of 18.5 gal. of gasoline), a city of iCity's maximum size of 700,000 people could theoretically produce the biogas equivalent of about 24,000 gallons of gasoline daily (8.76 million gal/yr). Assuming energy efficient hybrid-electric buses and trains, it does not seem unreasonable to expect this amount of biofuel to support the commuter transportation system and some of the industrial sector.

4.4 The Grid and Underground Coal Gasification

Biofuel cannot meet all the industrial sector's energy needs, however, so at least one more energy source must be found to provide power to the manufacturing plants and the tugboats in use in the canal. The scale of industrial energy demand and its stable, predictable rate of use make it the perfect client for a conventional power grid of the kind most cities use today. This grid, which can also supply electricity to the transportation sector, public energy consumers (street lights, etc.), and parts of the commercial sector as needed, will derive its energy, at least in the short term, from "gasified" coal that has been harvested without opencast mining, and which has had its carbon dioxide content captured and stored. The nearest coal resources are north of iCity in western Kentucky, within 200 miles and easily accessible. Once again, it is assumed that coal will only be used until renewable energy sources like wind and hydroelectric power become viable on an industrial scale—the processes of underground coal gasification (UCG) and carbon capture and storage (CCS) render coal use environmentally benign, but not indefinitely sustainable.

With regard to the cost of these relatively new (developed within the last thirty years) technologies, UCG is less expensive than traditional coal mining because it eliminates the need to buy or ship solid coal, does not require the purchase and maintenance of an aboveground boiler, and produces no ash that must be managed. Additionally, the requirements for UCG are compatible with those for CCS, meaning that an acceptable location for carbon storage (an unmineable coal seam or a saline aquifer) is likely to be found at or near the UCG site, so there will be no transport costs when disposing of the captured carbon. Furthermore, the cost of CCS itself is lowered when it is used in conjunction with UCG (it increases the cost of the UCG process by about 20%, as opposed to causing a 30-35% cost increase at a traditional coal-burning plant). The method of CCS a UCG would use, known as "pre-combustion" CCS, would take place in the seam, during the gasification process, where the depth of the seam and the resulting high pressure of gases there would lower the capture cost. The only problem with both UCG and CCS is that they must be very carefully monitored in order to prevent groundwater contamination. The most ideal sites for UCG/CCS have few good groundwater resources nearby, and both iCity and western Kentucky have useful aquifer systems. A UCG/CCS plant in this region would have to be very carefully controlled to protect the area's groundwater resources.

Two important points must be stressed here: first, note that coal—even cleanly obtained and cleanly burned coal—is a limited resource that iCity will only use as long as necessary. Once renewable energy sources become efficient enough to provide electricity on an industrial scale, coal-fired plants will no longer be necessary. Second, energy from coal is only an option in the short term if it has been obtained through UCG and CSS! Coal mining is so detrimental to the local environment, and traditional coal burning yields such high carbon emissions that the use of uncleaned, conventionally mined coal would undo all the good that iCity's other emissions-reducing efforts will achieve.

4.5 Legal Issues

The industrial sector of iCity will require substantial legal oversight to enable it run smoothly. A complex interlocking industrial system such as the symbiotic model must have a legal process in place for allocating resources and mediating partnerships between industries. The recycling industry will need to cooperate closely with municipal public services to collect recyclable products, as will the composting plant. iCity will also regulate some aspects of its industries' behavior as it affects the environment. Only businesses that agree to meet environmental health standards set by iCity (emissions caps and restrictions on industrial waste, especially with regard to carbon dioxide the quality of water in the canal) in addition to any industry-wide requirements already in place may build plants or factories in iCity. One of the most important considerations is what must be done with industrial wastewater, "black water" that is not fit for human contact. The industrial sector will in all likelihood draw much of its water from the canal, but obviously the effluent wastewater cannot be simply released back into circulation. In order to deal sustainably with the large amounts of both industrial and domestic black water that iCity will produce, a complex water management system including means of black and grey water reclamation must be in use.

5 Sustainable Water Use

5.1 Sources

The major problem with most modern water and sanitation systems stems from sewage systems that are expensive to operate, even more costly to maintain, and tremendously inefficient in terms of their disposal of black water. In iCity's proposed water scheme, the means for addressing this issue will be broken down into the implementation of a large scale living machine system, the implementation of a state-of the art treatment with separate grey water sanitation, and the use of solar energy for in-home water heating, all of which are compatible with the goal of a sustainable water system.

Water supply systems obtain water from a variety of locations, including groundwater, surface water, and conservation (desalination is not feasible here). Groundwater is the primary source where the water table is adequate as can be seen in the majority of countries such as Germany that retains 65% and France which retains around 62%; the rest is siphoned either by direct or indirect means from surface water (Water Supply and Public Water Supply). The water is typically then purified, disinfected through chlorination and sometimes fluoridated. Treated water then either flows by gravity or is pumped to reservoirs such as water towers. Typically, sewage treatment involves three stages, which consist of primary, secondary and tertiary treatment. First, the solids are separated from the wastewater stream. Then dissolved biological matter is progressively converted into a solid mass by using native, water-borne bacteria. Finally, the biological solids are neutralized then disposed of or re-used, and the treated water may be disinfected chemically or physically. If it is sufficiently clean, it can be used for groundwater recharge, which would be beneficial for source replenishment (Wastewater). Once the water is used, wastewater is typically discharged in a sewer system and treated in a wastewater treatment plant before being discharged into a river, lake or the sea. Alternatively, it could also be reused for landscaping, irrigation or industrial use.

5.2 Greywater Reclamation

As far as a sustainable system is concerned, the composite material of the pipe network, how it will address input and output, and generally how the system works are of utmost concern. Steel pipes installed more than 80 years ago have proven to be much more resilient to failure than pipes made of different materials installed more recently. Therefore, it is reasonable to utilize some oxide of steel for pipe construction; however, determining the exact composition is beyond the scope of this work (Sustainable). The central design for the proposed water system is to have three separate lines based on water content and allow intermittent stations to deal with their logistics modularly. By doing so, efficiency in the re-distribution of sanitary water, either reclaimed from the black water or grey water filtration, can readily be re-introduced to the system. The amount of nodes should not be predetermined, but taking a case study from Clearwater, Florida, where 108,000 people live, there are 3 sanitation centers and 78 pumps for all underground piping (EPA). The City of Atlanta operates 16 pump stations for wastewater and retains four water reclamation centers (Pump). Another necessary facet would be the insertion of a backflow prevention system which protects potable water from hazards, although potential stoppages would already be marginalized because of the internal independency of the system. Backflow devices are now required by law because there are over 10,000 reported cases of backflow contamination each year (EPA). The simplest and most effective way to provide backflow prevention is to provide an air gap, which is simply a space between any devices that opens to a plumbing system (like a valve or faucet) and any place where water can collect or pool (1). This would be the general layout of the system which would be flexible and yet maintain a rigid and effective framework.

5.3 The Living Machine

A hefty obstacle to sustainable water use is the overly obstructive treatment process for black water waste and sewage because a majority of water is used for this reason. Taking an example from France where in cities there are no public restrooms (therefore highly discouraging use), 59% percent of residential water use is still attributed to bath, shower and toilet use, all of which contributes, contemporarily, to black water pipelines (Water Supply). Clearly, to be most resourceful, a manner of recycling this to be used for some means is of utmost importance. Additionally, ensuring that water actually gets to its destination is important and it is measured by a ratio called the non-revenue water level which is a percent of total water which is lost before it reaches the customer. Engineering intense societies keep low NRW's, such as Germany's 7% and Japan's 10% (Non-Revenue Water).

Many processes in a wastewater treatment plant are designed to mimic the natural treatment processes that occur in the environment. If not overloaded, bacteria in the environment will consume organic contaminants, although this will reduce the levels of oxygen in the water and may significantly change the overall ecology of the receiving water. Native bacterial populations feed on the organic contaminants, and the numbers of disease-causing microorganisms are reduced by natural environmental conditions ("Wastewater Treatment"). A modern process that attempts to best mimic this natural ecologic practice is that of the Living Machine. Living Machines are a form of biological wastewater treatment designed to mimic the cleansing functions of wetlands. Aquatic and wetland plants, bacteria, algae, protozoa, plankton, snails, clams, fish and other organisms are used in the system to provide specific cleansing processes in the form of an artificial trophic food chain. The first advantage of this system is that conventional treatment has a narrow focus and often has sludge by-product, which in turn requires another cleansing system (Environmental). In addition, conventional treatment often uses harmful chemicals (primarily chlorine) to precipitate phosphorus and nitrogen out of the water to settle into the sludge. In fact, chemical cost was the single largest component cost for nine of the ten waste filtering processes conducted by Industrial Engineers for the EPA (Cost). Bio-processes simply bypass chemical inputs (Wolovitz). Traditional processes do not adequately seize heavy metals, and the sludge can also contain manmade organic compounds that are difficult to decompose. Living machines can sequester heavy metals by plant uptake; the plants can then be incinerated, and the metals isolated in ash for safe storage. These life-giving machines convert sludge into organic tissues such as fish, flowers and medicinal plants that have human uses (Environmental).

It's a worthwhile ideal, but is it feasible? Traditional facilities require larger capital investment, and demand more labor and energy cost than their ecological counterparts. However, the Living Machine has only been shown to remove about 50 percent of influent phosphorous (with influents in the range of 5-11 mg/L); this isn't very alarming but it could result in an algal boom, simply adding to maintenance cost (Water Quality). Additionally, the process requires a greenhouse for reliable operation in the cold weather of more temperate climates, adding to the system cost. The system is, however capable of treating wastewaters to BOD5, TSS, and Total Nitrogen < 10 mg/L, Nitrate < 5 mg/L, and Ammonia < 1 mg/L, all of which surpass the necessary quality levels set by the EPA. And, contradictory to intuition, a black water purification system, which retains many of the features as a Living Machine, was recently initialized in San Diego and " 'is as pure as distilled water' and about the same cost as buying water from wholesalers"(Archibold).

Process-wise, a typical Living Machine comprises six principal treatment components after influent screening. In progression order, these are an anaerobic reactor, an anoxic tank, a closed aerobic reactor, aerobic reactors, a clarifier, and "ecological fluidized beds" (EFBs). The routine operation and maintenance requirements include those of a conventional plant with the addition of cleaning the inlet/outlet structure, cleaning the screen and tank, removing and disposing sludge, and maintaining and repairing machinery. Scheduled harvesting to promote plant growth and removal of accumulated plant litter could also be included in addition to controlling things like fish and snail populations. It should also be noted that the temperature must be maintained in order sustain sufficient biological activity throughout the winter. In temperate climates, a greenhouse is used to keep water temperatures warm so that plants do not winterize. Living machines use screens, bio-filters, plumbing, large plastic tanks, reed beds, rocks, fans, pumps and other mechanical devices, and it is noteworthy that the EPA's analysis was compiled in 2001, so at present time it would be realistic to account for advances in design and/or technology. Some living machines are stand-alone greenhouses, while others are built into larger buildings, and for use in the proposed city, as can be seen from the data in Table 2, a nodular system catering to specific areas would be less susceptible to backups as well as financially more efficient. Finally we have the solution to the industrial water dilemma! Industries will be responsible locally for their own black water, as is suggested by the EPA's report, and industrial water will be deposited locally into groundwater or the canal only after it has been put through an on-site living machine.

Living machines in use for water sanitation can also be part of the public green space, especially machines in catering to residential areas. The open tanks that hold plants and fish could form a unique type of green space that would be at least visible to the public, even if they must still be kept slightly separate so the water purification process is not disturbed. But not only are the living systems themselves aesthetically pleasing, but the greenhouses in which they are located can be put to dual use for the cultivation of edible fruits and vegetables, as in a community garden, or even for sale in local organic markets. Other food sources will be similar to other American cities but only local, organic products will be shipped into the city. The construction of large supermarkets will be discouraged. The refrigerators and freezers in such facilities consume a significant amount of energy that iCity will try to avoid. Instead, large outdoor markets will be encouraged. These markets could even be housed in the living machine greenhouses during the winters. Healthy, fresh, local fruits, vegetables, grains and meats can all be sold at local markets without depending on commercial refrigerators and freezers.

5.4 Sustainable Home Water Heating

Hot water is simply an energetic disaster, but ironically a necessity for washing clothes, cooking and other tasks. The solution, may lie in modern photovoltaics. By using concentrated sunlight, Spectrolab demonstrated the ability of a photovoltaic cell to convert 40.7% of the sun's energy into electricity ("Boeing Spectrolab"). "The terrestrial cell we have developed uses the same technology base as our space-based cells. So, once qualified, they can be manufactured in very high volumes with minimal impact to production flow." The scalability is very important because the innovation is so extraordinary it seems unviable. The fluids that are circulated into the collectors are separated from the heated water that will be used in the home by a double-walled heat exchanger. A heat exchanger is used to transfer the heat from the fluids circulating through the collectors to the water used in the home. The fluids that are used in the collectors could be water, oil, an antifreeze solution, or a refrigerant (Solar). The heat exchangers should be double-walled to prevent contamination of the household water. A controller or in home computer would activate the pumps to the collectors and heat exchanger when design temperature differences are reached ("Green Living").

Is this a sufficient means of providing hot water? The Electric and Hydrogen Technology and Systems Center in May 2004 published a map indicating a potential sun collecting power for full tilt photovoltaic receptors given that they face South at approximately the same angle as their latitude and they have full sun for six hours a day for regions in the USA. As an example, an area in Tennessee near Memphis can get anywhere from 4.5-5.5 $kWh/m^2/day$ (3). Running with this and assuming each home could have two square meters, either allocated or on the house, of radioactive capturing potential (which is pessimistic), a single household would produce an average of approximately 10 kWh/day. Excess energy could potentially be redirected to a grid or household generator. To give a sense of perspective, a 50 J light bulb would use 500 watt hours if left on for ten hours, just 5% of the house's energy allotment on a normal day. Angular constraints could be considered if architectural perspective were taken into account, but since it isn't concrete I can assume my estimates are reasonable. People who are not using their residence during the day would be contributing to their own and others' well-being; if solar panels were to be more public, they could possibly attempt to integrate with the natural ecology (2).

In summary, the water system is actually quite complex, relying on a variety of up-to-date technologies. Traditionally, solar panels might be used for heating purposes, but since the passivhauses will be abundant, solar power could be used for home appliance, water and electrical network contribution. A network of Living Machines could treat waste through a system of anaerobic reactors, anoxic tanks, closed aerobic reactors, regular aerobic reactors, clarifiers and ecologically fluidized beds (Environmental). The water system could be above or below ground, including the Living Machines themselves, but what is vital is that a separate gray water line is added that can be used conveniently for watering plants, washing cars, etc. Through the utilization of this solid foundation in how to approach the problems surrounding water resources management, I believe that the goal of engineering a sustainable society will be more readily achieved.

6 Information Infrastructure

The multiple water systems, public and freight transportation systems, as well as various other systems will all need to be monitored and analyzed by a cohesive and ubiquitous networking system. A unified, high-bandwidth, redundant information infrastructure proves itself integral to the healthy and sustainable development of iCity's citizens. Through a cohesive composite of wired and wireless networking, citizens will gain permanent, uninterrupted access to the hybrid network from virtually any location within the city limits. What follows will serve as guidelines for distributing information throughout the city via a robust information infrastructure. This objective includes the personal communication of citizens and communications for the governmental and non-governmental entities that will be using the system, progressing into a delineation of the physical hardware required for the functioning of the system, with applications to the abstract services provided to citizens.

Content that will be transported on the network will be a unification of all current media types, including television, landline and cell phone service, and the Internet. The scope of this document will outline the network's role in distributing this media and not necessarily content generation, which would better fit into a marketing or governmental planning committee created to supplement the private producers of content such as television stations and web sites. The cases where a government entity would be responsible for distributing information will include public services such as interactive maps, public service billboards, and other information from governmental entities.

In order to meet these needs, iCity's core infrastructure will need to be extensive and capable, yet readily-expandable. As time progresses and more means of distributing information are made available, the network topology will undoubtedly change to incorporate future technologies within the network. Therefore, future expansion and present abilities are paramount. In addition, the network will need to be able to gracefully sustain mishaps, including loss of service to sectors of the city and the rapid renewal of service. Ideally, natural disasters, accidents, and unforeseen catastrophes such as terrorist attack would be unable to disrupt service. In order to alleviate these issues, an extensive distributed network will be implemented, including redundant connections in order to eliminate single points of failure from the network.

6.1 Wired Network

The physical network will be structured in tandem with the layout of iCity, which has been engineered as a distributed network of decentralized nodes. It should first be noted that connections to the world outside to iCity are of the utmost importance. Such a connection will be supplied via a partnership with a leading metropolitan fiber optic supplier. A bid with Lucent Technologies, for example, would allow the installation of a system known as the WaveStar TDM 10G—a synchronous optical network solution fed from an underground OC-192 fiber optic line switched through a primary network operations center (NOC) located near the center of the city [Wire, 2000]. Such a connection will provide iCity with a maximum bandwidth of 9953.28 Mbit/s (payload: 9621.504 Mbit/s; overhead: 331.776 Mbit/s), an extremely high bandwidth for a city of only 700,000 citizens [Kawamoto, 2007]. With a transmission rate of roughly 10Gbit/s, every one of our citizens will have access to a sustained 14Mbit/s throughput (via rudimentary division), more than adequate for any present and most near future applications. Signals will be filtered and routed from the central NOC to distributed switching stations within each of the outlying city nodes, thereby providing a relatively decentralized, tiered structure of bandwidth dissemination. NOCs will actively route traffic relative to congestion points and fluctuating levels of network load, in addition to retaining the ability to transmit government data (such as sensitive information and PSAs) natively through specifically designed protocols available exclusively to iCity administrators. In addition, NOCs will serve a dual purpose as a redundant data repository for applications of the network. From localized NOCs, flexible fiber optic cables will branch into office buildings and apartments (research institutions and corporations will be provided with additional bandwidth in accordance with estimated usage), granting all citizens access to high-speed wired communications [Dobbin, 2007].

Unifying services such as television, voice and data communications, with the Internet in one consistent medium provides several advantages. Laying and maintaining a single network of cables criss-crossing the streets of the city is much simpler than doing so in separate lines for individual services. Upgrades to the backbone of the network will have a larger effect on the entire population, and carrying multiples types of data on one network simplifies the distribution structure of that data. Seeing as the future is moving towards becoming this unified structure at present, there is no need to base a city on an outdated foundation of a network.

6.2 Wireless Network

In conjunction with a wired network, a robust, distributed wireless system proves imperative to a fully integrated, connected, and informed society. Considering the increasing prevalence of Wi-Fi networks, the city providing a wireless backbone for cell phones, PDAs, laptops, and other mobile devices, would prove beneficial. Although those using speed-critical applications will still prefer to be physically connected to the network due to decreased latency and higher throughput, the wireless option will be very appealing to the city as a whole. The future in wireless networking is the 4G standard, still drafting with input from major players in the field. Given the time required for construction in the city, it will not be unreasonable to wait for the standard to be fully finalized, instead of working to implement or create a different, inferior standard. With 4G's estimated download speeds of 1000kbit/s [Rouffet, 2005], the network will supply more than adequate bandwidth to serve all uses of the wireless access.

The wireless network will be structured to provide seamless 4G wireless access throughout iCity. Signal boosters will vary in both power and number according to estimated usage (e.g. outdoor green space vs. crowded office building). Furthermore, access points will be spaced and configured such that wireless devices remain continuously and uniformly connected whilst mobile throughout the city, even during inter-nodal transportation due to seamless handoffs. Wireless transmitters must aesthetically blend into surroundings, being primarily constructed unobtrusively on sides of buildings, rather than in stand-alone towers [Vanderbilt, 2002]. Localized NOCs will provide switching and routing services responsible for integration of wired and wireless protocols. 4G access will be structured upon one of the 802.XXx standards (e.g. 802.11b, 802.11n, 802.20), most likely the novel 802.20 standard fully integrated with iBurst (high capacity spatial division multiple access).

6.3 Network Applications

Having listed the guidelines for the physical infrastructure, one shall consider applications and usage of the network. Network access will be available to all iCity residents (through city ID numbers) in all residential areas, available free of charge in both wired and wireless forms. Citizens may opt to purchase higher levels of access and additional services through designated carriers holding government-mandated contracts. Optional RFID cards containing encrypted citizen ID numbers will allow for localized database queries to access, for example, previously saved locations from any public information kiosk (such as a map bulletin). Internet (data), television, and phone. will be collectively integrated within one unified, yet distributed network. Network congestion will be tracked by localized NOCs as well as the centralized NOC. Redundancy, combined with a distributed structure, ensures that outages and repairs will in no way hamper network performance, as data will be actively rerouted to avoid bottlenecks.

6.3.1 Traffic Routing

Similarly, physical road transportation/traffic will be electronically monitored and automatically redirected in accordance with the National Transportation Communications for Intelligent Transportation System Protocol (NTCIP). Throughout the city, non-intrusive, aesthetically-tailored maps and billboards will display pertinent information (be it traffic information, city wide events, emergency notifications, etc.). GPS tracking through the wireless network will allow the usage of interactive mapping within the city, one such implication being the optimization of travel distance and time, hence minimizing energy consumption and unnecessary congestion.

The transportation network will consist of a series of buses within major nodes, complemented by a rail system between major nodes and out to connect the city to the rest of the country. The greatest application for real-time traffic analysis would therefore be in regulating the traffic lights that control the buses and the few private vehicles, along with emergency response vehicles such as ambulances, police units, and fire trucks. It is feasible to create a system capable of routing traffic such that high priority emergency response vehicles encounter green lights from their origin to their destination, calculated based on some sort of geolocating mechanism determined by triangulation from various wireless access points. Another means of achieving the same end, priority traffic routing for emergency vehicles, is already being implemented through the usage of mobile infrared transmitters, or MIRTs, to slightly extend green lights in low-priority mode or rapidly change a light from red to green in high-priority mode, differentiated by frequency [Poulsen, 2005]. By feeding the data of which lights have been changed into a central database, a computational model could be used to predict the path of the emergency vehicle and then open lights ahead in ways that give other traffic more notice of the change. In one current implementation, lights can go from red to green in two seconds, which requires that perpendicular lanes of traffic would have their lights switched from green to red in the same amount of time, in all probability quite dangerous. Predictive modeling or a query from the traffic routing subsystem to the law enforcement section for the relevant information would increase safety of other vehicles and also ensure that emergency response vehicles reach their destination in a suitably rapid time frame.

6.3.2 Traffic Routing Updates

Another benefit of having an omni-connected transportation network is that the information of buses' and trains' locations can be used to present the information to citizens, as is being done currently in San Francisco, Denver, Dublin and multiple cities in Taiwan [Schweiger, 2003]. Also, the information can be placed on a publicly-accessible website as is being done in San Francisco, or also put into signs physically located at the bus stop, like in Rome, Portland, and London. The signs are not for show either, being quite accurate. According to research done by First World Congress on ITS for London Transportation over Route 18's annual 7.5 million boarders, "Accuracy of the information on the signs was within plus or minus one minute 50% of the time; within plus or minus two minutes 75% of the time and within plus or minus five minutes for 96% of the time." [Schweiger, 2003]. A reliable network for aggregating and storing the information would be within the realm of the city's information infrastructure.

Although the gains being made in these cities are quite impressive, iCity's are higher still: dynamically updated maps. Instead of having simply a board informing passengers of the nearest bus, a map will be able to direct the citizen in the optimal way to a destination of their choosing. But because inputting the same destination will lead to suboptimal usage of the technology, a method of storing and recalling common destinations on a per-user basis must be implemented.

6.4 ID Card

One possible method of automating the process of storing and retrieving personal information is the implementation of privately keyed universal ID cards. Enacted with an RFID transmitter or traditional bar-code or magnetic strip technology, the user could utilize a uniquely encrypted WPA2 key to access personal data storage for reading/writing of information to iCity's centralized citizen database.

Upon completion of citizenship application evaluation and testing procedures, citizens will be issued a unique 11-digit citizen ID number. This number will be recorded in the secure, centralized government database, as well as being given to the citizen for memorization, much as a social security number is today. The database location is at the NOCs, which are synced and backed up across the city. Subsequently, this unique ID number will be further processed through a one-way functional encryption method, thereby generating a potentially unlimited number of unique private hashes. One such hash will be selected, linked to opt-in centralized databases as the individual sees fit for his or her use. This number, in turn, will be stored on the ID card. The extra layer of abstraction allows a citizen, in the event of a compromised card, to minimize data loss by cancelling the specific hash and generating another one at a nearby office by providing their unique, uncompromised ID number, much as the process of cancelling a credit card today. Biometric technologies may be further implemented as seen fit for differing levels of secure access to sensitive data.

The uses of the card include storage of emergency contacts, locations, medical information, voter registration, criminal record, and others. The ID card could also serve as a driver's license, credit/debit card, and even be tied into gift cards of retail outlets. The goal is to unify the plethora of cards currently carried by citizens into a single card. Of course, the privacy implications of such a scheme are great. In order to mitigate potential loss of privacy, entities accessing the central database will be restricted to access only their section of data. The DMV may only access the driver's license section, doctors the medical information, financial institutions the credit/debit card, retailers the gift card. In order to prevent corrosion of privacy rights, there will need to be an entity strong enough to enforce these distinctions. While commercial firms should not be powerful enough to gain access to personal information extraneous to their needs, the government itself, mainly law enforcement agencies, would be most susceptible to ravaging the rights of citizens through unnecessary fishing of information from the database. Partnerships between consumers, retailers, and the government oversee the administration and access of this database. The exact nature of this regulation is best left to the analysis of the governmental functions of the city. If deemed unworkable, there is always the ability to keep the system as it remains currently, with all these uses authenticated and administered separately. The worst scenario of the ID card system is that those who feel it is beneficial will make use of it, while those who don't are able to continue using the long-tested system of the present.

As society moves into a new paradigm of global awareness, technology will serve a new role as both the product and engine of humankind's ever-increasing capabilities. Nevertheless, we have proven that the forces of sustainability and technological innovation are not mutually exclusive, yet, rather, if correctly tailored, function as a synergistic whole. The creation of a robust, high-speed, fully-integrated network affords iCity residents this prerequisite level of astounding interconnectivity. Current and near-future technologies allow a feasible means of providing citizens seamless and secure access to vital information, as well as entertainment, through a joint mesh of voice and data communications, wired and wireless. iCity, representing the pinnacle of a sustainable, well-informed society, will rest firmly upon the shoulders of its ubiquitous information infrastructure.

7 Government and Laws

Our city's government will make every effort possible to maintain the city's sustainable society and its resulting social equality. This is exemplified by the design and planning behind the city's citizen ID card, which combines progressive new technology and convenience with the legal aspects necessary to function in the United States. In order to create and maintain the sustainable way of life in the city, the government will have a noticeable role in regulating the city's industry and thus directing the city's economy [Janda et al., 2005]. To prevent the government from developing into a frightening totalitarianism and controlling all aspects of society, the citizens of the city will be able to check the extent of the government's power through their voting and elections [Janda et al., 2005]. By localizing the government, the city's citizens will have the opportunity to have a direct influence on the policy decisions concerning themselves and their city [Janda et al., 2005].

7.1 Government Structure

It has been resolved that the city will be governed by an elected city council, as a form of municipal government. In accordance, with the 1953 amendments to the Constitution, our city's municipal government will enact ordinances under the authority granted in the city charter, and also derive its legislative power from that source [Laska, 1977]. The city council will serve as the governing body of the city, with the power to pass ordinances, manage appropriations and the city budget, levy local taxes, appoint local officials, and maintain the policy aspects of the city in general. Since the citizens of the city will be fully connected and networked together, they will have the ability to vote on most issues through a public referendum of sorts and a public polling system. Public opinion polling involves interviewing a sample of citizens in order to estimate the public opinion as a whole [Janda et al., 2005]. Though this system of elections will not generate true political equality, it still emphasizes the concept of one vote per person, as advocated in the United States Constitution. Ideally, the all the citizens within the city will fare equitably in wealth, education and social status, thus reflecting social and political equality [Janda et al., 2005]. Citywide elections will be held in compliance with the national voting standards, and elections for local offices will be held annually, as well as every four years, coinciding with the presidential election. The vote from the general public will serve as more of a strong recommendation to the council, which will then vote in the manner of the federal government's Electoral College. Hopefully this system will prevent any citizens that may become more influential than others from exerting their influence on political decisions.

7.2 Public Policy

Distributive policies, regulation, and incentives will be designed to allocate government resources towards more companies and consumer goods that will be more sustainable in the long run. Government spending for public highways and roads, schools, and local green space will benefit all of the citizens in the city, as well as any visitors. One way to discourage people from commuting from nearby communities into the city would be by enacting a congestion tax upon non-city residents who travel into the city. This type of disincentive is justifiable since daily commuter traffic is a large source of undesirable pollution and carbon emissions. City visitors can still drive their own cars within the city; they would just have to pay the unfavorable tax. It would also counter the principle of relying heavily upon mass transit, instead of personal vehicles. The city's system of transportation relies on dedicated bus lanes, which then doesn't allow for many parking spaces. Large parking decks outside the city limits will be available for visitors and city residents to park their cars. This purposely decreases the efficiency and convenience of everyone driving themselves and creating avoidable congestion and release of pollutants into the atmosphere. If people still choose to maintain and use their own personal cars, the emissions standards will be raised significantly and the cars will be required to either use alternative fuel sources or conform to higher fuel efficiency standards.

All motor vehicles within the city limits will be expected to obey the transportation laws, as set forth by the state of Tennessee's Department of Motor Vehicles. These laws will be enforced jointly by the local and state police force, and violators will be prosecuted accordingly.

The government will protect the established order of the city by authorizing a police force to guard residents' safety, health, and welfare. The crime rate of the city is projected to be lower than most urban cities, although it clearly cannot be avoided. The city police force will patrol the city's jurisdiction on mostly foot and by bicycle, as well as being stationed upon the monorail and sporadically throughout the bus routes. There will be a small number off police cars and other public emergency vehicles, such as fire trucks and ambulances. Delivery trucks and mail trucks will also be on the roads, but the public service vehicles will be the only vehicles granted special priority over the public buses.

A sustainable city, however ideal, will not be without crime. The city capital will also include a local courthouse for minor infractions and misdemeanors, but trials and proceedings of any felonies or capital crimes will be relocated to the nearest state or federal courts. The city will have temporary holding cells at the police station, but any whom are indicted and sentenced to prison time will be exported to the nearest state or federal prison facility to serve their time.

The city's nodes will be divided up into numerous school districts, which will be responsible for administering elementary and secondary school programs. There will be a local public school system, spread around and through the main nodes of the city. Children of the appropriate age will be required to attend school, as set under state and federal laws. There will not be any city school buses, as schools will be conveniently located within a reasonable walking or bicycling distance. Residents of the city may petition to construct churches of different denominations to be built within the city limits, pending approval of the city council and by majority vote of the residents of the city. Any agriculture and farming within the city limits will be organic and most of the products will only be distributed locally.

Since the city is situated in northwestern Tennessee, it is assumed that the residents will be representative of typical American life expectancy, and not subject to third-world constraints of disease, poverty, famine, lack of sanitation, or exponential reproductive rates. The idea has been suggested that government incentives and redistributional policies may be used to control the population growth of the city, perhaps by taxing large families more so than smaller ones. However, our city may run into opposition in implementing such a policy, since larger families may be more financially stressed than smaller ones—on the simple assumption that more mouths to feed necessitates a larger income. Controlling the population of the city would also help maintain the status quo of the city, as influxes of people moving into the city could potentially change and affect different aspects and the mindsets of the residents within of the city.

Although some of the city's policies and ideals may be unconventional or even extreme, they are necessary for the city to maintain the desired sustainable lifestyle, minimizing energy consumption and toxic pollutants. Strong policies must be implemented and remain effective in order for the city to maintain itself and set a precedent for similar cities in the future.

8 Population and Demographics

The sustainability problems of interest relating to Population and Demographics can be divided into three areas: Population Growth Control, Distribution of Wealth, and Cultural Sustainability.

8.1 Population Growth Control

Here we build from the assumption that a city designed and implemented with a certain maximum carrying capacity will be more sustainable than one that grows without bounds. Therefore, the city, by design, has been planned around an optimal population of 700,000. Unlike Curitiba, which grew and continues to grow without a population limit [Schwartz, 2006], having a population of 1.8 million in 2003 [Gnatek, 2003], the city will have in place controls ensuring that city population does not exceed the optimum. Unlike the population taxes considered in section 7.2, these controls are based on direct market action by the city's government, rather than being based on indirect influence on population via tax incentification. The controls are simple:

1. Purchase all land three miles beyond any city development, forming a buffer around the city. This land will be owned by the city and will be kept in a natural state, with no development within it except necessary infrastructure such as power lines, water lines, and roads.

2. In the event that population exceeds the city optimum because of new development or increased living place density, the city government will buy housing within the city and either demolish it or convert it to non-residential use, such as parks or offices.

Taking these resolutions, from one perspective, there is no need to account for labor shortages or unmet housing demand, because the labor and housing economies would form themselves around the fact that city population has a ceiling of 700,000. For example, a person who wishes to move into the city may buy out someone who currently lives there, and a business which cannot find labor will go out of business or relocate, and its assets would be bought by another person or company. A company of a type that typically has low-skilled, low-wage labor, such as some service or food companies, but chooses to remain within the iCity, will be forced to raise its wages, making its workers better off. The company's customers, in turn, would pay higher prices for their goods or services, according to higher wages and market demand. Following this logic, essential services with typically low wages such as waste disposal or courier services would not be unavailable in the event of very high housing costs—they would simply cost more. People would pay the higher price, because essential services are just that—essential—and have an inherently inelastic demand curve. In this way, all essential services would still be offered within the city, but in the event that the iCity's founders decide that they want the iCity's income distribution to be more representative of the income distribution of the United States, the following alternative approach may be adopted.

An alternative to this unregulated approach to housing, while still avoiding incentification through taxes, is to, instead of having the government act directly in the city's housing market, control the market indirectly by imposing restrictions on buyers and sellers. This regulation-based approach is to segregate the housing market based on income, thus perhaps (for example) building an income distribution into our iCity which is representative of the population of the United States as a whole. As for structure of this regulation, an n-tier system, with n levels of resident income, could be constructed wherein in order to purchase or rent a given residence, an individual must prove that his income lies within the requirements of the income range associated with that residence. In this way, the housing market is still kept 'free' in many respects, with residents who have a given range of income being able to bid competitively for housing alongside other potential buyers within that same income range. While an element of the free market is kept, buyers are at the same time being protected from completely unaffordable housing prices. Therefore, with these income range controls in place, comparatively wealthy individuals will not be able to force individuals with lower incomes out of the city, as the wealthy individuals will not be permitted to purchase or rent housing space that has an income range classification below their own level of income. If this n-tier system is implemented, the tiers will have to be made sufficiently narrow that potential residents lacking financial resources are not driven out of the housing market by those lying within their income bracket but possessing considerably more income. Visually, if housing in the city is in very high demand, a noticeable clustering effect would occur in the housing market, where price will tend toward the high end of the affordability distribution of buyers within each bracket. Therefore, within a bracket, high and low income bounds should be kept within 10-15% of each other.

8.2 Distribution of Wealth

In the case that the iCity housing market is saturated, and prices become elevated due to high demand, the lower portion of the city's income distribution would be raised due to the higher mean income of the city's residents. Wages of other residents being held constant, the income distribution of the city would become more narrow. Even if a narrowing effect were not seen, the city's mean income would be raised, and stark noticeable differences in education level and standard of living—as seen more commonly between the lower and middle classes than between the middle and upper classes—would become less common, therefore decreasing visually *perceived* differences in income level. A relatively narrow income distribution (or more accurately perceived income distribution, since a person's perception is his or her model for reality) means less economic inequality and consequently less social unrest, unhappiness, class conflicts, and crime. The caveat with allowing this income elevation to take place, however, is that the income distribution of the people within the city would not be reflective of the income distribution of the United States overall, and thus the city would not seem accessible to some individuals with lower incomes.

Because a city does not have control of federal or state income taxes, the city will not have any control of effective income distribution through any taxes, except for the portion of sales tax which is distributed locally. Therefore, in order to further narrow the city's effective income distribution, establish the following resolution: Increase sales tax for luxury goods which are bought disproportionately more by wealthier individuals than is the average staple good.

8.3 Cultural Sustainability

Premise: a sustainable culture is peaceful, and on balance, its constituent members feel peace toward each other. To achieve a sustainable culture, the idea of "The Expanding Circle," popularized by Peter Singer and addressed by Steven Pinker [Pinker, 2007], must apply to our iCity. That is, city members must extend empathy and a sense of worth not only to family and friends, but also to other individuals within the city. More friendships and more positive feelings, on balance, mean happier people [Diener and Oishi, 2005]. Furthermore, optimism, a characteristically positive emotion, has been shown to directly improve operational performance in some occupations [Luthans et al., 2004], leading to the reasonable induction that optimism—which is associated with positive thinking—might very well have a positive impact on work and economic productivity overall. From these core ideas, and with the intent of increasing positive thinking and inter-resident cooperation within the city, establish the following resolutions:

1. Disperse artwork in the form of pictures, statues, and videos throughout the city which depict, as a theme, cooperation and goodwill among people.
2. Create the police department, and all departments which interact with the public, with a culture of compassion, understanding, and goodwill toward the citizens they serve.
3. Respond to criminals with empathy by allowing them to participate in positive rehabilitation programs during incarceration or parole.

Finally, it is a simple fact that no matter how technologically savvy or logistically efficient the design of a city may be, it cannot hope to fulfill dreams of sustainable living if the people who live there do not have a sustainable mindset. The public must be encouraged to remain not only aware of but actively involved in the pursuit of conservative living and efficiency simply by living in the city. iCity is designed in every way to achieve the goal of keeping the citizens' minds on sustainability, from the pleasant public green spaces and plazas that keep nature in the public eye to the bus system that makes clean, efficient transportation preferable and enjoyable.

Conclusion

As human society advances, we face the unending responsibility to make the best possible use of the resources our Earth provides us, and to live in harmony with our environment, not one destroying the other. The iCity strives to show that integrating a sustainable lifestyle with our modern technological society is not only possible but feasible, and that this woefully overdue fusion will create a higher quality of life to sustain our generation and the (hopefully) bountiful generations to come. It is the authors' hope that the iCity's living example would animate cities the world over to live sustainably so that future generations can live as we do, with comfort, ease, and happiness.

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