# ESTABLISHING METHODS OF MEASUREMENT FOR REGENERATIVE DEVELOPMENT AT AN URBAN DENSITY

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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To my wife, Danielle, for her love, support, and inspiration

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As the popularity of sustainable development has progressed as a means of moderating and reducing environmental impact, the concept of regenerating the environment has emerged as a more recent attempt to redirect the movement towards increasing the ecological productivity of the environment as opposed to improved degradation. Increasing trends toward urban living prompts the need to focus on the urban environment and regenerative development at that scale.

The objective of this thesis is to establish variables and methods of measuring regenerative development in an urban context. The process of determining these issues consisted of a literature review, collection of urban consumption data, analysis of existing regenerative evaluation methods, and recommendations for an urban regenerative development measurement method.

This study concluded that in order for a measurement tool to address the urban density, it must address transportation and displaced energy impacts, as well as the method's ease of use and measure of ecosystems services. Furthermore, the interests and values of the user play a significant role in determining the type of measurement selected.

# CHAPTER 1
# INTRODUCTION

Though movements for environmentally sensitive development have existed for centuries at various scales, recent awareness regarding climate change, resource depletion, and overall environmental degradation has brought about a much stronger emphasis on creating long-term solutions to these issues.

As the popularity of sustainable development has progressed as a means of moderating and reducing environmental impact, the concept of regenerating the environment has emerged as a more recent attempt to redirect the movement towards increasing the ecological productivity of the environment as opposed to slowing the rate of degradation. Proponents of the regenerative approach argue that limiting environmental impact alone is not sufficient in respect to the amount of damage that has and continues to occur.

## Regeneration at the Urban Density

Regenerative development remains primitive in its development and has predominately pertained to individual, small scale sites. The application of this concept to an urban density is both pertinent and problematic, as an expected 60 percent of the population is predicted to be living in urban environments by the year 2030 (Girardet 2004).

As displayed by Figure 1-1, the consistent increase in urban populations provides strong confirmation of the need to address the sustainability of these types of development. Though many cities currently operate with enormous levels of resources and energy use, the high ratio of land to people in urban areas provides a significant opportunity for the shared consumption and generation of energy. The high consumption levels coupled with the large demand for living in urban environments creates a significant need for establishing regenerative urban settings.

## Problem Statement

Because developments with urban density have such high potential for improving resource use and generation, the application of regenerative techniques may prove to be extremely effective. However, difficulties in the collection of data and fragmentation of relevant professional fields have significantly hindered the development of regenerative studies. The application of existing research in regenerative capabilities to an urban context is essential to address the growing urban environments across the globe.

While existing efforts have been made to measure regenerative development, they have lacked key elements for the application at an urban density. Determining the necessary variables for developing a framework for measuring urban regenerative development is necessary to maintain progress in the field as well as foster increased collection of consumption and regeneration data.

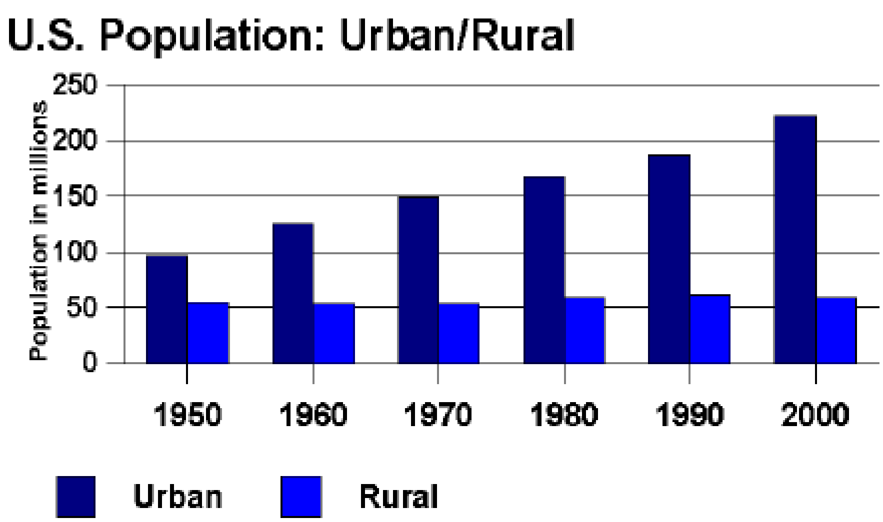


Figure 1-1. Population Change from 1950-2000 (Source: rtc.ruralinstitute.umt.edu/RuDis/RuDemography.htm. Last accessed June, 2009).

## Study Objectives

The primary objective of this thesis is to develop an appropriate framework for measuring regenerative development within an urban context through the through the study of existing regenerative evaluation methods and determination of relevant variable at the urban density of regenerative development.

# CHAPTER 2
# LITERATURE REVIEW

Various movements within the ‘sustainable development’ concept have emerged over the last several decades in attempts to create a more sustainable environment relative to contemporary development. While countless research exists under the umbrella of sustainability, ‘regenerative design,’ has developed as a promising approach, though the considerable amount of data required to determine a regenerative status may be hindering the topic’s development. However, the study of related movements, such as ‘positive development’, ‘permaculture’, and ‘urban sustainability’ may prove to be beneficial in the application of regenerative development to an urban setting.

## Regenerative Design

Ian McHarg’s “Design with Nature” is often considered a central source of ecological design. While natural building techniques have a lengthy history, this became one of the first form and comprehensive studies of ecological design. In it, McHarg attempts to bring environmental consciousness to the developed world by applying environmental theories to actual environments and determining ideal urban settlements (1969). Several key individuals began developing upon this concept of ecological design in the 1980s: John and Nancy Todd from the biology field, and John Lyle, a landscape architecture professional. Addressing the scientific issues in ecological design, “Bioshelters, Ocean Arks, City Farming: Ecology as the Basis of Design” offers techniques and concepts relevant to the built environment (Todd 1984). As part of this contribution, Todd provided nine precepts for biological design:

1. The living world is the matrix for all design
2. Design should follow, not oppose, the laws of life
3. Biological equity must determine design
4. Design must reflect bioregionality
5. Projects should be based on renewable energy sources
6. Design should be sustainable through the integration of living systems
7. Design should be co-evolutionary with the natural world
8. Building and design should help to heal the planet
9. Design should follow a sacred ecology

(1984)

Elaborating upon these precepts, Todd provides valuable examples of ecological and regenerative strategies for urban settings, including solar sewage walls, garden parks, city lakes, bioshelter parks, aquaculture, and rooftop farms (1984). In “Design for Human Ecosystems,” John Lyle offered the “principles, methods, and techniques for shaping landscape, land use, and natural resources in ways that can make human ecosystems function in the sustainable ways of natural ecosystems (1985, p.v). Using a basis for energy flows developed by Howard Odum, Lyle perceived this systems approach as relevant to ecological design. According to Lyle, Odum’s technique would be a useful tool for designing man-made ecosystems and describing the flow of materials and energy (1985, p.233). With the structure of all activities broken down into a common form of energy, the inputs and outputs are able to be more closely and more comprehensively managed. The application of these concepts to the built environment allows stakeholders to recognize that the development of the environment requires an unbelievable amount of energy to construct and operate.

Elaborating upon the theories of ecological design, ‘regenerative design’ was later developed by Lyle and based on the concepts of ecological design and systems ecology. “Regenerative Design for Sustainable Development” later provided a standard for the theory of designing the built environment in such a way that attempts to increase the ecological productivity of development. Using energy as a metric for regeneration, Lyle uses case studies to assess energy consumption and offers the possibility of using strategies such as renewable energy as a method for creating a regenerative site (1994). By locally increasing the productivity of a site through renewable energy and ecosystem services, the resulting system is meant to maintain the vitality of the environment. While consumption information was collected in detail for case studies such as the Center for Regenerative Studies, little to no energy data was established regarding the generation of energy. Though details are not provided, Lyle offered that "the keys to sustainability lie in the urban landscape" (1994, p.286). Since Lyle's contribution in 1994, little progress has been made in the field of regenerative design, with the exception of the contributions of Bill Reed, current President of the Integrative Design Collaborative. Recognizing the shifts that have occurred toward a more sustainable building atmosphere, Reed developed a diagram (Figure 2-1) which defines the progression of environmentally based development and "clearly lays out a road map that informs us about where we are today in the process of shifting design paradigms and what the evolutionary trajectory may look like" (Kibert 2008 p. 124).

Though the topic has generally developed separately from regenerative development, ecosystems services became a relevant metric for integrating true ecosystem based design into regenerative development through the efforts of individuals such as Robert Costanza and Victor Olgyay. Costanza et al. provided a cohesive list of ecosystems services and offering the importance of measuring their value with "The value of the world's ecosystem services and natural capital" in 1997. According to this work, "ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997, p.253). The estimated value of seventeen major ecosystem goods and services categories was established. Building upon Costanza's work in 2004, Victor Olgyay and Julee Herdt developed "The application of ecosystems services criteria for green building assessment," which developed an ecologically derived baseline to determine the negative or positive output of buildings. Likely the most advanced regenerative measurement tool to date, the criteria was established with the use of the 'index of building sustainability' (IBS) and the 'index of efficiency in sustainability' (IES) metrics. "The IBS is the fraction of the annual carrying capacity of the project's land that is consumed by a building," and "the IES is the quantity of land required to meet a sustainability index of 1" (Olgyay and Herdt 2004, p.391). These metrics were developed based on the notion that "an ecologically derived baseline can be used to measure negative impacts as well as positive impacts of buildings and will be referred to as the ecosystems services method. The measurement also allows vastly different project types and sizes to be used and compared on an equal basis" (Olgyay and Herdt 2004, p. 389).

Using very similar language to that of regenerative design, Janis Birkeland's 'Positive Development' approach suggests that urban development should be built in such a way to "add both ecological and social value beyond conditions that existed prior to development," and that "genuine sustainability would require that urban development provide net positive social and ecological gains to compensate for previous lost natural capital and carrying capacity" (2008, p.1). Acknowledging the input/output method of measurement, the positive development theory opposes the metric of energy as the measure of positive net energy, posing that "units of energy (or money) cannot capture the essence of space, time and ecological waste in the built environment" (Birkeland 2008, p.2). Birkeland also offers several strategies for achieving positive development status at a city scale, including living machines, which can “create a virtuous cycle where waste, in effect, cleans the air and water and builds soil” (2008, p.3).

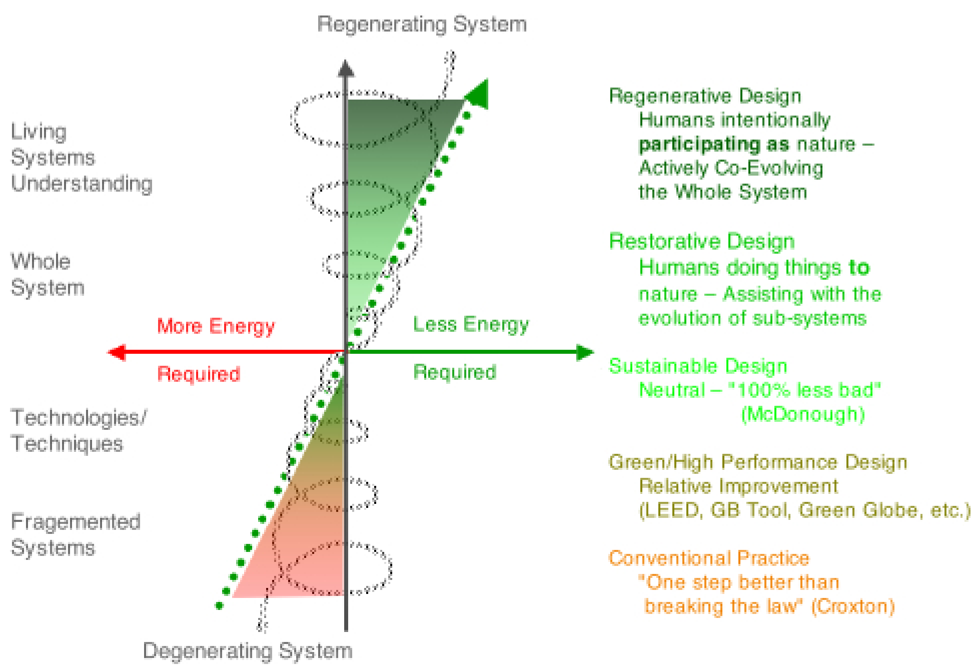


Figure 2-1. Bill Reed’s Regenerating System Diagram from the Integrative Design Collaborative and Regenesis, 2004

## Urban Context

Though few studies have been developed to address urban regenerative development, many urban sustainability efforts have been developed which could offer insights into large scale regenerative studies. Due to the rising demand of urban living, determining vital elements of its consumption and conservation measures is beneficial to determining its regenerative development potential. Urban areas offer unique complications to regenerative development efforts, including high pollution rates and many other activities which have a negative effect on plant populations, animal survival, and ecological processes (Kendle and Forbes 1997). Urban climates offer increased difficulties in reducing energy due to higher heat energy produced from human processes (Kendle and Forbes 1997). Despite significant disruption to the natural ecosystem, however, urban environments still offer unique potential for ecological processes which can offer a higher disturbance tolerance, higher adaptation rates, and broader food ranges (Kendle and Forbes 1997).

Ratings such as the “Green Metro Index” developed by the World Resources Institute (1993) and the “Environmental Sustainability Index” later developed by Dan Esty (2001) have offered great insight into measuring urban sustainability, but these ratings were generally qualitative evaluations and could not be used to measure regenerative development (Portney 2003). Many cities to date have developed sustainability initiatives which reflect similar qualities to that of regenerative development. San Francisco’s initiative, for example, suggested focus on factors such as biodiversity, food and agriculture, and transportation (Portney 2003). Though these are key variables for determining regenerative development, however, these initiatives do not capture quantitative data for measurement. Adding to the difficulties of measurement, many cities operate on resources developed outside the city boundaries, consuming undetermined amounts of additional energy. Dating back many years, urbanization of cities such as Athens, Greece was “made possible by the bio-productivity of forests and farmland outside the city” (Girardet 2004, p.37). Tokyo, for example, “imports 78% of its energy, 60% of its food, and 82% of its timber from other countries” (Girardet 2004, p.91). For this reason, many researchers put emphasis on self-sustaining cities. Environmentalist Aromar Revi, for example, has developed the notion of RUrbanism, which aims to adapt cities to their local ecosystems and their potential to supply resources on a sustainable basis (Girardet 2004). Movements toward self reliant city systems such as this would make measurement and evaluation of energy consumption much more practical. Until such systems exist, however, external displacements of energy are a key element of a city’s comprehensive consumption.

# CHAPTER 3
# METHODOLOGY

## Scope

Though the definition of an urban setting varies between disciplines and organizations, a standardized value was required for uniformity within this study. Because cities often have similar characteristics at comparable densities, population density was used as the determination of an urban area. As the most objective source, the United States Census Bureau's classification of an urban density was used. According to Census 2000, the Census Bureau classified urban areas as those which consisted of "core census block groups or blocks that have a population density of at least 1,000 people per square mile, and surrounding census blocks that have an overall density of at least 500 people per square mile" (U.S. Census Bureau 2000). These values were established as a minimum classification. To keep the data as accurate as possible, data was only collected for cities which had population densities of a minimum of 1000 people per square mile and a maximum of 10,000 people per square mile in order to keep the collected data relevant to average urban densities.

Although the factors affecting the environmental impacts of cities encompass a large spectrum of issues, this study intended to limit these issues to those directly involved in the planning, development, and/or building processes. Therefore, factors such as commercial product consumption were excluded from this study.

## Limitations

While the generalized strategies for achieving regenerative design have been established, very little has been developed in practice to verify the feasibility of creating sites that truly generate more energy than was put into their development. Because there has been no standardization of regenerative development characteristics, confirmation and analysis of these practices has been difficult to accomplish. Many claims of ‘regenerative design’ developments utilize regenerative techniques; however, there is often no data to back up these assertions. While the limited nature of established case studies makes determining specific data it more difficult for measurement analysis, the ability to determine variables and methods of measurement is still possible.

Also, fragmentation between relevant fields of study has brought about difficulties in the progression of regenerative development. Professionals in design, construction, planning, ecology, and agriculture all provide essential information to the regenerative development; however, interaction between these disciplines is very inadequate. More communication and sharing of knowledge between these areas would provide a more streamlined process for the success of regenerative development.

## Methodology

The methodology used for this thesis consisted of a literature review, collection of urban consumption data, analysis of existing regenerative evaluation methods, and recommendations for an urban regenerative development measurement method.

A detailed literature review on regenerative development, urban planning, and developmental impacts was first developed to assess the current state of regenerative and urban development.

A sample set of data was then collected to represent an urban area attempting to be regenerative. The characteristics of this potential city reflected the potential embodied energy of urban development processes, including construction, utilities, food production and consumption, transportation, and the initial impact of producing photovoltaic energy systems (PV Embodied Energy), as well as the energy from materials and processes which are developed outside the boundary of the city (Displaced Energy). Energy which could potentially be generated from urban processes was also listed, including food production and renewable energy production. Additionally, prospective ecosystem services within an urban setting were listed, including gas and water regulation, pollination, habitat, culture, and recreation. The construction impact values represent estimates of the embodied energy of the extraction, production, and construction of the building materials and processes. Operational energy values are estimated from city utility consumption data. The values derived for food production and consumption reflect estimates of the energy required to grow food in urban environments as well as the amount of energy representing the actual amount of food produced and consumed. Although many of the values reflected accurate averages and information, the actual variables for this input were only intended to be estimated for the evaluation of measurement methods.

The sample data reflected a moderate to high level of urban density at 10,000 people per square mile with a 50 square mile area. This level of density is reflective of cities such as Philadelphia, PA and Washington, D.C. When development becomes this concentrated, cities tend to share resources to a higher degree. While public transportation is often integrated when cities reach the minimum level of urban density (1000 people/square mile), the number and frequency of routes are generally much higher and comprehensive in terms of their efficiency when density starts to reach tens of thousands. Furthermore, structures generally become much higher and have multiple uses.

Figure 3-1. Philadelphia, PA (Source: http://phillyskyline.com/bldgs/comcast/comcast_uc784.jpg.Last accessed June, 2009).

Figure 3-2. Street in Washington, D.C. (Source: http://www.grandboulevard.net/tod/pedestriansTOD%20PIC%201.jpg. Last accessed June, 2009).

Once sufficient data was collected, Olgyay's ecosystems services method and a standard input/output method were assessed as possible frameworks for determining urban regeneration. Estimated simulations were used for data entry into the evaluation methods.

The simulation of generalized urban characteristics was then applied to the ecosystems services method, as well as a standard input/output evaluation, in order to determine the applicability of the criteria at such an increase in scale. Because it can be translated to all three metrics, Gigajoules per hectare per year was used uniformly for all values.

In order to operate on a standard baseline of site capacity, Olgyay used a global average ecosystem productivity value established by Wackernagel and Rees which was also used for this evaluation. This value, set at 100 GJ/ha/yr, is the quantity of land required to absorb the $CO^2$ emissions produced from the materials and energy used and consumed during the development process (Olgyay 2004).

For existing urban development, determining construction impacts can be extremely difficult. The embodied energy invested in such large levels of development is rarely researched and recorded, especially in cases where the urban environment has existed for decades. Furthermore, the generally fragmented and privatized nature of development makes a unified measurement nearly impossible during development. Considering the scale of development and substantial level of inefficient development, the ability to surpass the total impacts of construction would likely never occur. Because urban centers progress, transform, and adapt, estimations and values of construction impacts at an active status may more effectively be used as a metric for establishing goals. The impacts of construction for a city were calculated as follows:

Material (quantity) x (embodied energy)/(ecosystem productivity in GJ/ha/yr) = ecosystem services consumed (ha/yr)

Operational impacts were then calculated in a similar manner using data from city utility consumption.

An input/output measurement method was then evaluated similarly to the first simulation. The same estimated data was used to deduct the total energy consumption from the total energy generation to produce a straightforward observation of known energy activity without incorporating the relativity of land area and average ecosystem productivity. Joules were used as a standard variable in order to maintain the same metric throughout the evaluation to obtain accurate results.

Once the simulation of measurement methods took place, the methods were evaluated for use at an urban density. The benefits and problems were then addressed, with recommendations made for future development. Based on these recommendations, a third method of measurement was formed as a possible urban regenerative development tool, and recommendations were offered for the development of the topic.

## CHAPTER 4
## DATA ANALYSIS AND RESULTS

The urban data which was collected for use in measurement applications was summarized, and the sample data was then simulated and summarized in the Ecosystem Services and Input/Output Measurement Methods.

**Sample Data**

| **Urban Sample Data** | |
|---|---|
| *Size* 50 square miles | |
| *Density* 10000 ppl/sq. mi. | |
| **Characteristics** | |
| | |
| *Energy Consumption* | *GJ/yr* |
| Construction | 310000000 |
| Utility | 211000000 |
| PV Embodied Energy (initial) | 1100000 |
| Food (Production + Consumption) | 42000 |
| Transportation | 80000000 |
| Displaced Energy | 15000000 |
| | |
| *Energy Generation* | *GJ/yr* |
| Food Production | 550 |
| Example: 25 story vertical farm with 100,000 sf footprint, 10000 sf community gardens | |
| Local PV Energy | 60000 |
| Example: 10 MW photovoltaic system | |
| | |
| *Example Ecosystem Services* | |
| Gas Regulation | |
| Water Regulation | |
| Pollination | |
| Culture | |
| Habitat | |
| Recreation | |

Figure 4-1. Sample Urban Regenerative Development Data

## Ecosystems Services Method

Table 4-1. Olgyay Construction Impacts Evaluation (per year) using Sample Data

| Construction Impacts | | | | |
|---|---|---|---|---|
| *Description* | *GJ/yr* | *GJ/ha/yr* | *Hectares (ha)* | *Acres* |
| Urban Sample | 310000000 | 100 | 3100000 | 7660267 |

Table 4-2. Olgyay Operational Impacts Evaluation (per year) using Sample Data

| Operational Impacts | | | | |
|---|---|---|---|---|
| *Description* | *GJ/yr* | *GJ/ha/yr* | *Hectares (ha)* | *Acres* |
| Urban Sample | 211000000 | 100 | 2110000 | 5213924 |

Table 4-3. Olgyay IBS and IES Summary Results

| Summary of IBS and IES Results | | | | |
|---|---|---|---|---|
| *Description* | *Construction Impacts* | | *Operational Impacts* | |
| | IBS | IES | IBS | IES |
| Urban Sample | 239.38 | 7660267 | 162.94 | 5213924 |

## Input/Output Method

Table 4-4. Input/Output Evaluation using Sample Data

| Input/Output | |
|---|---|
| *Consumption* | *GJ/yr* |
| Construction Impacts | 310000000 |
| Operational Impacts | 211000000 |
| Transportation Impacts | 80000000 |
| Renewable Embodied Energy | 1100000 |
| Food Production Impacts | 42000 |
| Displaced Impacts | 15000000 |
| Total | *617142000* |
| *Generation* | *GJ/yr* |
| Renewable Energy | 60000 |
| Food Production | 550 |
| Total | 60550 |
| *Energy Consumed* | *617135450* |

## Findings

The analysis of existing methods of measurement as a benchmark for assessing regeneration at an urban density resulted in several issues which needed to be addressed:

- Transportation Impacts
- Displacement of Energy
- Ease of Use
- Measurement of Ecosystem Services

Olgyay's recently developed criteria for determining the level of regenerative development may be effective for individual, small scale development such as the farm house it uses as a case study, many factors cause his evaluation to lack essential factors that contribute to a regenerative development at an urban density. A standard input/output measurement gives an opportunity to input any necessary factors, but it lacks structure and requires extensive data, research, and knowledge.

While both techniques offer valid elements, neither is ideal for use at an urban density. Olgyay's method offers an easy structure for the measurement of regenerative capacity. The method, however, was developed with basic elements consistent with use in the context of small scale or individual projects. When constructing a small scale structure, the measurement of embodied energy for that process is generally much simpler than for a dense organization of structures representing multiple structures. While the construction and operational impact analyses may be measured in a similar fashion, they represent a much more complex network of measurements. Factors of transportation energy and the transfer/displacement of energy between projects are significant elements at the city scale which are not reflected with this evaluation.

### Transportation

When measuring the consumption of an urban city, the time and effort spend traveling to points within the city is extensive and is a significant contribution to overall energy consumption. Individual vehicle use between sites and public transportation are adjustable factors in the development of a city. If planned correctly, urban environments can significantly limit and possibly eliminate the need for consumptive transportation methods. Because transportation is a crucial part of urban energy waste and can be regulated, it must be addressed in the measurement of regenerative development. While this requires additional calculation not addressed in the established methods, this can easily be added to the evaluation within the operational impacts.

**Displacement of Energy**

Though it may be partially true for all scales of development, the displacement of energy plays a significant role in the embodied energy of an entire urban system. While specific projects within a city may be developed to be regenerative, much of the energy that may have been used at that site may be redirected outside city boundaries or to another portion of the city. For example, increasing the ecological productivity of non-productive sites (i.e. parking lot to community garden) creates a positive energy flow for that particular site, but it may lead to increases in energy for other variables (i.e. increase in transportation due to more limited parking.

**Measuring Ecosystem Services**

Olgyay's method for addressing ecosystem services focuses on an ecosystem's capacity to absorb waste as the most appropriate metric relative to the development industry (Olgyay 2004). While waste absorption is a key ecological factor for construction, it also limits the ability to address established urban regenerative techniques that have an effect on the overall productivity of a given land area.

Olgyay's criteria use a baseline global ecological productivity in order to measure with a standardized land area. The 100 GJ/ha/yr figure derives from an assumed energy-to-land ratio, which is the amount of energy that can be produced per hectare of ecologically productive land (Wackernagel and Rees 1996). In a traditional urban environment, the verticality creates issues where multiple levels of a structure may be ecologically productive (i.e. vertical farming). Additionally, the typical development of urban environments represents a type of land whose productivity is likely to be below the global average. This variation could create skewed results.

Because the evaluation assesses regenerative development based on a standardized ecological carrying capacity of land, many established regenerative design techniques go unrecognized through this evaluation. If properly initiated, practices such as roof gardens and living machines may create positive net energy flows which would never be established through Olgyay's measurement.

The input/output evaluation provides a framework which is both accurate and adaptive. The ability to specify any factors to be measured allows the user to include as many variables that can be measured using the same metric. This means primary regenerative techniques such as food production and renewable energy generation are easily factored as part of attempts at a positive energy flow.

**Ease of Use**

There are two main issues with the use of an input/output system in urban regenerative development. Although the system has the ability to be very precise, the amount of data required to achieve such accuracy is tremendous. If all variables are not measured and/or are unable to be measured, the result becomes an inaccurate representation of energy flow. Also, the open interface requires significant knowledge in every factor applied. This becomes very difficult to practically use this evaluation, unless experts from several fields are readily available during evaluation. While the ecosystems services method is more generic, it provides an interface that is much easier to use.

## Urban Regeneration Method

In order to address the previously mentioned concerns, a new measurement evaluation was developed which combined the structures of the ecosystems services evaluation and input/output method. The net energy value in Joules of all consumptions and generations (construction and operational impacts, transportation, displacement, food production, etc.) which can be measured in the same metric (Joules) was first calculated. This single value was then compared to an ecological carrying capacity of land area much like the method used by Olgyay, determining a single IBS and IES value, as opposed to separate values for construction and operation impacts. The construction and operation impacts were combined to address the evolving nature of urban environments. Because construction is traditionally a constant factor in urban development, incorporating its value on an annual basis may be more accurate. This also provides a straightforward measurement process while allowing the user to address the urban impacts as a whole system. These resulting values are able to incorporate the use of regenerative development strategies and all valid consumption and generation values while maintaining a standard metric that is proportional to land area.

**Sample Evaluation**

| *Consumption Inputs* | *GJ/yr* |
|---|---:|
| Construction Impacts | 310000000 |
| Operational Impacts | 211000000 |
| Transportation Impacts | 80000000 |
| Renewable Embodied Energy | 1100000 |
| Food Production Impacts | 42000 |
| Displaced Impacts | 15000000 |
| | |
| **Total Impacts** | **617142000** |
| | |
| ***Generation Inputs*** | ***GJ/yr*** |
| Renewable Energy | 60000 |
| Food Production | 550 |
| | |
| **Total Production** | **60550** |

| Total GJ | GJ/ha/yr | Hectares (ha) | Acres |
|---|---:|---:|---:|
| 617135450 | 100 | 6171354 | 15201363 |

| IBS | IES |
|---|---|
| 475.04 | 15201363 |

Figure 4-2. Urban Regeneration Measurement Method

# CHAPTER 5
# CONCLUSIONS AND RECOMMENDATIONS

Using existing regenerative development measurement methods and extensive research of regenerative design techniques, urban planning, and ecosystem services, a set of variables were determined to be of essential value for the evaluation of regeneration at the urban density, including transportation impacts, displacement of energy, ease of use, and measurement of ecosystem services. The actual nature of urban regenerative development measurements, however, will be dependant upon the intentions and values of its users.

Because there appears to be a dichotomy between designers of regenerative development who desire a focus on returning ecosystem services and those who wish to create a positive net energy in development, different evaluations must exist in order to respectively address these discrepancies. Those wishing to generate ecosystem services will have difficulty in finding standard metrics for many services which may be considered vital to urban environments, such as recreation and culture. In cases such as this, many assumptions would have to be made, and the use of measurement may not be the appropriate type of evaluation. However, several services that are directly related to urban development will likely be predominantly used, including waste assimilation and food production. As these metrics can be more easily defined, they could be integrated into a structure very similar to Olgyay's measurement and evaluated against construction, operation, transportation, and displacement impacts. In instances where factors are known, specific, and measurable, a standard input/output evaluation would be more useful in making direct comparisons. If future research stems more information regarding the measurement of ecosystems services, any development in urban regenerative development evaluation must adjust accordingly.

Until more progress in ecosystems services measurement is made, a combination of input/output and ecosystems services evaluation may be most beneficial in obtaining to most accurate results. The ability to integrate regenerative development techniques as part of the net energy before applying to carrying capacity can create a more comprehensive reflection of an urban system.

As the sustainability movement becomes more commonplace, regenerative development will ideally become a new goal to strive for in creating long-term environmental solutions. If systems for its evaluation are already in place by the time this occurs, the transition may be much smoother. Because the concept of regenerative development is relatively new, existing measurement of the embodied energy during and after development has yet to be established as common practice and creates strong difficulties in determining regenerative status. Multi-disciplinary cooperation during the urban planning process is crucial to develop cities in an ecologically sustainable and regenerative manner. While the data required for determining the feasibility of a regenerative urban environment may not be currently available, the basis for understanding how to measure its status and what factors are applicable to its measurement is well within reach.

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# BIOGRAPHICAL SKETCH

Joe M. Hart, Jr. was born and raised in Daytona Beach, Florida. After graduating with honors from Atlantic High School, he was accepted into the Architecture program at the University of Florida in 2003. Upon graduating with a Bachelor of Design in Architecture with a minor in environmental studies, Joe immediately began graduate studies at the University of Florida's M.E. Rinker, Sr. School of Building Construction in hopes to obtain a comprehensive knowledge of the development process through the completion of a Master of Science in Building Construction. With a strong interest in sustainable development which was established as an undergraduate student, Joe continued his environmental studies with the Certificate of Sustainable Construction program, which culminated with his attainment of a LEED Accredited Professional Certification in April 2009. Joe married his girlfriend of 11 years in February of 2009. Upon completion of his graduate studies, Joe plans on utilizing his knowledge to continue contributions to the field of sustainable development.