Urbanized Ecosystems:
Conceptualization to Application

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ABSTRACT

Urban areas are among the largest anthropogenic uses in terms of appropriation of land, energy, materials, and biological primary production, as well as in the alteration of the biogeochemical cycles of carbon, water, and nitrogen. Despite their significance in these respects, coherent descriptions and analyses of urban areas regarding the flux and cyclic processes of energy, materials, information and costs are relatively scarce. There exists an opportunity to investigate urban areas as analogous to ecosystems, thus allowing a complex, dynamical systems approach to be applied to the planning and management of built environments. Similar to how an ecologist studies natural environments within the hierarchal scale of an ecosystem, this novel approach is based on the investigation of urban areas as ecosystems onto themselves, or as urbanized ecosystems . Such an approach is scalable and transferable to neighborhoods, communities and regional applications.

The intent of this paper is to conceptualize urbanized ecosystems within a socio-ecological framework, so as to provide a basis for informed decision- and policymaking. Towards this end, this paper presents a methodology, Urbanized Ecosystems™ (UrbEcoSys™), developed as a proof of concept application for the Village of Oak Park, Illinois in 2009. This community was first conceptualized as a complex, dynamical ecosystem, based on scoping, inventorying, and assessing its critical variables and relationships as represented by the flux and cyclic processes of energy, materials, costs, and information. This conceptualization allowed a more formalized level of inquiry in the form of a system model. Findings in the form of baseline metrics were then used to develop alternative policy scenarios, which were then assessed relative to their alignment with the village's overall vision and policy. The outcomes from this assessment could then be used to support an informed decision- and policymaking process, prioritized within the municipal budget's allocation of finite resources.

CONFERENCE THEME: On Measurement: Quantifying sustainability, are we using the correct measures?

KEYWORDS: ecosystem model, system dynamics, sustainability metrics, urban ecology, resource allocation

1. INTRODUCTION

This paper is based on the research question; *'How can the planning and management of urban areas be conceptualized as urbanized ecosystems, so as to provide a basis for informed decision- and policymaking?'* This research question was derived from a socio-ecological theoretical framework developed by the National Science Foundation (NSF) for the Long-Term Ecological Research (LTER) program (LTER 2007). This framework provided a hierarchal structure of research questions nested within each other, from which the research question was explicated from a broadscope to narrowscope refinement process. Following this hierarchical progression, the intent of this paper is to conceptualize urbanized ecosystems within this socio-ecological theoretical framework, so as to provide a basis for informed planning and policymaking. From this conceptualization, the investigation focuses on how does one model an urbanized ecosystem in terms of its associated energy, material, information and economic cost fluxes and relative to various temporal and spatial scales, so as to provide a basis for informed decision- and policymaking?

The response to this question is formatted as follows in this paper. First, the *purpose* for the line of inquiry to investigate urban areas as analogous to ecosystems is provided, so as to establish the rationale for urbanized ecosystems. Second, an overview of *prior studies* pertaining to urbanized ecosystems is provided, from the disciplinary perspectives of urban planning, ecology and urban ecology. Third, the research *methods* are explained, including approach and expected findings. Finally, the paper concludes with a proof of concept application, with a summary of findings and outcomes.

2. PURPOSE

Urban systems are among the largest anthropogenic uses in terms of appropriation of land, energy, materials, and biological primary production, as well as in the alteration of the biogeochemical cycles of carbon, water, and nitrogen. For these reasons, it has been said that urban areas are the defining ecological phenomenon of the twenty-first century (Newman & Jennings 2008). Despite their significance in these respects, coherent descriptions and analyses of urban systems regarding an accounting of the fundamental flows of energy and materials and the efficiency of critical processes are relatively scarce.

There exists an opportunity to investigate urban areas as analogous to ecosystems, thus allowing a multi-scale, dynamical systems approach to be applied to the flux and cyclic processes of urban areas. Similar to how an ecologist studies natural environments, a systems approach would be based on the flow and relationships of energy, matter, information and costs. The hierarchal scale of micro-, meso, and macro ecosystems is equivalent to the multiple scales of urban areas, suggesting a scalable ecosystems approach as an appropriate method for assessing urban areas as integrated human-natural environments. This novel approach would be based on what is termed by this paper as an *urbanized ecosystem.*

An urbanized ecosystem model would serve as a basis for how energy, materials, information, and economic costs interact on a complex and dynamic urban scale. For example, how energy and material inputs are processed, the resultant output of anthropogenic greenhouse gas emissions, and the life-cycle costs of policy scenarios, can all be informed by a system model that links the multiple scales and relationships between informational, energy, material, and social networks that constitute the essential functioning of integrated human-natural environments.

The need for better understanding of urban ecosystems emerges from two trends (Pickett et al. 2008). One is the process of urbanization[2], a dominant demographic trend and an important component of land transformation. The expansion of urban areas is a significant cause of natural ecosystem conversion to varying rural-urban gradients of integrated human-natural environments. As human populations continue to increase in abundance and distribution, higher ratio of people have been attracted to urban areas leading to increased urban development. In 2000, 79 percent of the population of the United States resided within urbanized areas[3] or urban clusters[4] (U.S. Census Bureau 2000). On a global scale, population has experienced unprecedented urban growth in recent decades. In 2008, more than 50 percent of the world's population lived in urban areas, or about 3.1 billion, with 95 percent of the world's population concentrated on just 10 percent of the world's land (World Bank 2009).

The second trend is that urbanized lands have a disproportionate impact on local, regional and global systems. Anthropogenic impacts of urbanization have been attributed to; altered land cover and hydrology (Arnold and Gibbons 1996), an area of impervious land cover of 110,000 square kilometers in the United States (Elvidge et al. 2004), altered energy dynamics (Karl et al. 1988; Spronken-Smith and Oke 1998), and concentrated areas of greenhouse gas emissions (Satterthwaite 2009). All of these facts point to the need for conceptualization and better under¬standing of urban ecosystems, to explain and predict the system dynamics and impacts. While planning theory addresses some of the individual ecological impacts when they directly affect human populations and their built environments, further research is needed to develop a system dynamics approach as applied to the planning and management of urbanized areas.

Recent research by the Millennium Ecosystem Assessment[5] (MA) (2005) has identified significant gaps in socio-ecological research, the need for new theory, and the need for a better integration of conceptual and empirical research across a diverse set of approaches. MA advocates that new research must focus on understanding the long-term dynamic processes that are unique to socio-ecological systems versus purely social or purely biophysical systems. A new collaborative research framework is needed that integrates the internal and interactive dynamics of social and natural systems. According to MA, society is in need of fundamental research that transcends the ecological and social sciences, and demonstrates a commitment to the incorporation of social science into basic questions about ecosystem behavior, so as to transition to transdisciplinary[6] collaborations.

Studying the interactions of cumulative environmental effects related to rapid urbanization requires important changes in research methods. The fragmentation and specialization of much planning theory and research needs to be coupled by transdisciplinary research that studies the connection and coherence among seemingly disparate flux and cyclic processes of energy, materials, information and costs. It is the intent of this paper to participate in this effort by investigating urban areas as analogous to ecosystems, thus allowing a complex, multi-scale, systems approach to be applied to the planning and management of integrated human-natural environments. Such a systems approach is intended to provide a basis for informed decision- and policymaking, in response to V.O. Key's (1940, 1138) classic resource allocation question 70 years ago; "On what basis shall it be decided to allocate x dollars to activity A instead of activity B?"

3. PRIOR STUDIES IN URBAN PLANNING, ECOLOGY AND URBAN ECOLOGY

While the interactions of humans with the urban environment have traditionally been the province of urban planners, there have been only intermittent cases when it has been based on ecological functions, processes, or ecosystem services. In following the theoretical thread for a synthesis between urban planning and ecology, the trail leads upstream through Peter Calthorpe, Ian McHarg, Lewis Mumford, Raymond Unwin, Ebenezer Howard and eventually to the riverhead known as Patrick Geddes (1854 – 1932). As a botanist, sociologist, geographer and town planner, Patrick Geddes' planning concepts were derived from geographical and biological principles that were part of his knowledge base, which allowed Geddes a synthesis of aesthetic, social and biological understanding.

Other attempts to synthesize planning and ecology are intermittent through time. In his *Teoría General de la Urbanización (General Theory of Urbanization)* of 1867, Ildefonso Cerdà (1815 – 1876) viewed the city the same way that a functional biologist views biological processes; that is, in terms how something is constructed and operates (Soria y Puig and Cerdà 1999). In Cerdà's writings, he uses biological principles, such as homeostasis, in his analysis of urban functions (Choay 1997). Frederick Law Olmsted intuitively linked environmental properties to human well being in cities. In particular, in Anne Spirn's *The Language of Landscape* (as cited in Pickett et al 2001), Olmsted's design for the Boston Fens and Riverway shows ecological prescience in its sophisticated combination of wastewater management and recreational amenity. In *Design with Nature* (1969), Ian McHarg devised an Ecological Planning Model which was further advanced by Frederick Steiner in 2000 for landscapes (Ahern 2004), which provides somewhat of a framework for an ecological-based approach to urban ecosystems.

Of special note is Jay Forrester's work in the 1950s and 60s with system dynamics, which dealt with the simulation of interactions between flows, rates and feedback loops, which provided the essential conceptual foundation for urbanized ecosystems. Forrester's work, specifically with *Urban Dynamics* (1969), provided the structure to study urban areas as a high order, nonlinear and complex system with multiple feedback loops, rather than a first-order, linear sys¬tem with only negative feedback loops.

Urban ecology[7] has focused on designing the environmental amenities of cities for people, and on mitigating the environmental impacts of urban regions. This planning perspective is normative and claims ecological justification for specific planning approaches and goals (Sukopp 1998). As presented by Mary Cadenasso, Department of Plant Sciences / University of California at Davis at a 2006 *Urban Ecology* symposium at Chicago Botanic Garden[8], the study of urban ecology has historically developed in three phases. The first phase was represented by the Chicago School in the early 20th century (Park, Burgess, and McKenzie 1925) and focused on applying concepts of competition and niche partitioning from the ecological sciences to the sorting of groups in rapidly growing industrial cities. This approach was limited for its reliance in questionable ecological concepts and excluding individual behavioral decisions.

The second phase was based on the concepts of ecosystem metabolism and energetics that emerged in the 1950's by Eugene P. and H.T. Odum. This approach relied on the 'black box' approach, where inputs and outputs of the ecosystem are measured from which the functioning of the system could be measured. This approach was limited in that it failed to recognize the heterogeneity of systems, and considered humans only as biological organisms. The inclusion of human ecology within a defined ecosystem is necessary so as not to be restricted only to biological ecosystem models. Human ecosystems are driven largely by the interaction of biotic and abiotic components through the flow of information, and therefore integral to an ecosystem model (Stepp et al. 2003). In a similar vein,

The third and current phase of urban ecology is based on contemporary ecological concepts that include spatial heterogeneity, resilience, and the complexity of integrated human-natural environments. The National Science Foundation (NSF) has long since recognized the important role of ecological science in furthering the understanding of urbanized ecosystems, as evidenced by the Long-Term Ecological Research (LTER) program. In fact, NSF claims the need for research that integrates the ecological and social sciences has never been greater (LTER 2007). This third phase is exemplified by the three overarching core areas of study of the Baltimore Ecosystem Study (BES)[9], which is one the LTER programs funded by NSF. These core areas of study are as follows; 1) the structure of the system from biophysical, social, and built perspectives, 2) the fluxes of energy, matter, population, and capital, and 3) the feedback between eco¬logical information and environmental quality.

4. METHODS

The assessment methodology for the study of urbanized ecosystems is both descriptive and explanative. Descriptive in the sense that it answers the research question in terms of *what, where, when, and how*? Towards this end, a major portion of the methodology is based on observations, data acquisition and collection concerning the development of a baseline inventory of a boundaried urban area relative to the flux and cyclic processes of energy, materials, information, and costs.

Since it is not enough to describe the scope of urbanized ecosystems, it is also necessary to identify the *mechanism* that explains it. For this reason, causality is of primary importance. Therefore, since the research also examines the mechanism of *why*, the purpose of the research is also explanative. For example, quantifying the amount of stormwater runoff from various land cover is descriptive. Identifying the variable that explains why certain land covers have different amounts of stormwater runoff relative to other land covers is explanative. In order to determine how alternative planning interventions and policies influence an urbanized ecosystem structure and functions, a conceptual system model will be necessary in order to explain the likely outcomes and consequences in terms of energy, materials, information, and costs. Due the spatiotemporal uniqueness of each urban area, data acquisition and observations need to be place-specific to the urbanized ecosystem being assessed.

5. PROOF OF CONCEPT: VILLAGE OF OAK PARK

The above-described assessment methodology was further developed by the author as Urbanized Ecosystems™ (*UrbEcoSys*™), a proof of concept[10] application for the Village of Oak Park, IL, modelled as a dynamical complex ecosystem. This 2009 study conceptualized the Village of Oak Park as an urbanized ecosystem, so as to allow a more formalized level of inquiry. From this conceptualization, the scope, inventory, and assessment of Oak Park's energy, materials, information and economics costs was completed, relative to their alignment with the village's overall vision and policy. The intent was to support and enhance an informed decision- and policymaking process, which then could be prioritized within the municipal budget's allocation of finite resources. The Village of Oak Park is a mature, built-out, inner ring suburb adjacent to Chicago in west central Cook County, IL (Fig. 1), with a population of 53,103 (U.S. Census Bureau 2005-2009).

For the study, the village was modelled as an urbanized ecosystem (as diagrammed in Fig. 2). The input environment (IE) consists of energy, materials, information, and economic cost flows which are then processed by the system into resultant outputs. Energy inputs consist of any primary energy source directly associated with the functionality of the village, such as electricity, natural gas, vehicular motor fuel, and renewable energy (solar, wind, ground source); as well as indirectly associated, such as food production / distribution, and water supply / distribution. Material inputs consist of all goods produced by, and imported into, the system, as well as food, water (via water supply system or precipitation) and other abiotic and biotic components of relevant biogeochemical cycles.

Figure 1: Location map, Village of Oak Park, IL. Source: (Author 2011)

The output environment (OE) is comprised of processed energy, materials, information, and economic cost flows that are stored, consumed, converted, and/or degraded as outputs. For example, energy is represented as a one-way flow through the system that is converted to outputs consisting of heat, organic matter and organisms. Materials are represented as biogeochemical cycles of chemical compounds which are processed with some impact on subsequent utility (Odum 1997).

Information for both IE and OE is in the form of biological (genetic) or anthropogenic (formal and informal) knowledge bases and communication networks. Economic costs are defined as the monetary valuation of associated system inputs and outputs. Within each system there are processes (negative and positive feedback loops, energy circuits, heat sinks, etc.) which are governed by the laws of nature (photosynthesis, decomposition, etc.) and thermodynamics. While not a system variable itself, land use / land cover is a system determinant in the processing of energy and material inputs and subsequent outputs. Additional information is provided at *5.2. Phase 2 – Inventory.*

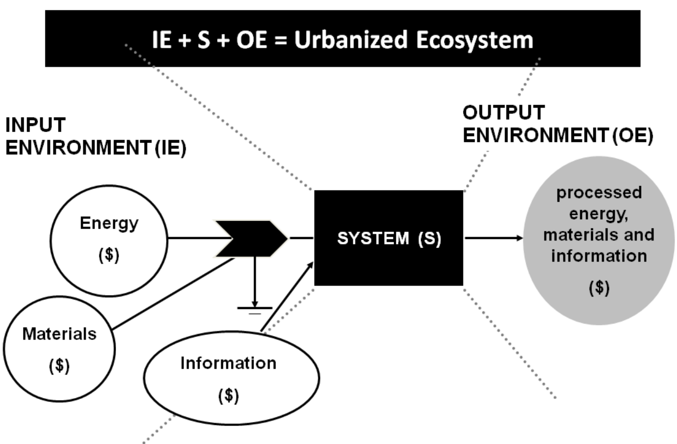

Figure 2: Diagram of ecosystem model. Source: (Author 2011)

Complex adaptive system models are based on equations reflecting known relationships between variables. Ideally, one would complete a comprehensive and detailed model of the Village of Oak Park which would include algorithms of all relevant energy, material and economic cost flows. If such a model existed, one might be able to predict with reasonable certainty where the village is headed in the future, foresee problems, and be guided to take action to avoid or mitigate adverse impacts. Unfortunately, no such model exists, and one will likely not be developed in the near-term future due to the overwhelming level of complexity inherent with the social systems of communities. For this reason, a narrative conceptual system model was used for the study of the Village of Oak Park.

Despite the inherent uncertainty of complex urban systems, it remains essential to inventory the essential components of an urbanized ecosystem, so as to establish baseline metrics and indicators that could provide accurate and reliable information about the viability, efficiency and costs of the system. This completion of an inventory is independent of any particular ideological view currently adopted by a community. Findings of the *UrbEcoSys*™ study were provided to the Village of Oak only as an assessment, rather than as planning and policy recommendations. How much value the village assigns to particular findings is a matter for public dialogue and policymaking, and should be derived from the village's overall vision and policy.

While the study left the assigning of values to the Village of Oak Park, it does rely upon a working concept of sustainability[11] to reference its assessment and findings. For the purpose of *UrbEcoSys*™, sustainability, at its core, is defined as an effort to create and maintain a dynamic regime of the Earth under which human population and its necessary material and energy consumption can be supported indefinitely by the biological system of the Earth. Sustainability, in fact, is not like a goal that can be reached, but rather like a corridor through time that must be followed (Cabezas et al. 2003).

In order to establish a reasonably detailed model of the Village of Oak Park, the following three separate phases were completed as part of *UrbEcoSys*™; scoping, inventory, and assessment.

5.1. PHASE 1 - SCOPING

Scoping defines the extent of analysis and the system boundaries. The boundaries for this project were defined as the geopolitical municipal boundaries of the Village of Oak Park; 1.5 mi. (2.4 km) by 3.0 mi. (4.8 km), or 4.5 mi^2 (11.7 km^2). As certain externalities (such as the political economy) and flows (such as air pollution) do not adhere to human-fabricated boundaries, the scale of the system boundaries is not only local, but regional, national, and even global as well.

That being said, it was not within the scope of the study to include cultural, social, and political concerns beyond the defined geopolitical boundaries of the Village Oak Park, although they were referenced as necessary. It should be also noted that *Phase I – Scoping* did not include the inventorying of energy, material, information, and cost flows related to overlapping government agencies other than the Village of Oak Park (such as school districts, park district, and township), although it may have included the spatial analysis of their land use / land cover in relationship to village- and privately-owned property.

5.2. PHASE 2 - INVENTORY

An inventory is required to provide all essential information about the viability of an urbanized ecosystem, and to serve as a benchmark for evaluating its future rate of change. It can also measure the system's performance relative to the village's overall vision and goals, as well as a basis for comparison with other communities. An important part of an inventory is identifying the essential networks and relationships within a system. This requires a process of aggregation and condensation of available information and data, and the directed search for missing information needed for a comprehensive description of the system.

The *Inventory Phase* consisted of the data compilation and documentation towards inventorying the current energy, material, information and cost flows to (inputs), through (throughputs), and from (outputs) the system boundaries of the village. This included a quantification of demographics (population, households, vehicles, etc.), infrastructure, energy inputs (solar radiation, wind profile,

Figure 3: Village of Oak Park. Source: (U.S. Census Bureau 2005-2009)

electricity, natural gas, motor fuel, etc.), energy outputs (pollution and greenhouse gas emissions), solid waste outputs (refuse, recyclables, yard waste, leaf litter), water inputs (precipitation, water supply, system leakage, etc.), and water outputs (stormwater, sewage, surface runoff, combined sewer overflow events, etc.). Energy and material flows are provided in terms of quantity (amount, costs, associated taxes, waste), type (residential, commercial, industrial, and municipal) and scale (individual, household, property, village-wide).

The *Inventory Phase* data sources were comprised of images, maps, digital orthophotos, and field measurements, primarily provided by the Oak Park Department of Public Works. Interviews with key division superintendents were completed to derive and compile specific data pertaining to public infrastructure, village fleet, capital improvements, operating and maintenance expenses, etc. Data was also made available from the local electric and natural gas utility companies concerning village-wide energy inputs and costs. The inventory also included GIS applications for representation and process modelling, based on the availability of GIS-related files from the Village of Oak Park. ESRI's ArcView 9.2 was used, along with such extensions as ArcGIS Spatial Analyst and Network Analyst.

5.3. PHASE 3 - ASSESSMENT

For most municipalities, the decision- and policymaking process relative to environmental-sustainability is somewhat fragmented and ad hoc. It is imperative that any assessment methodology be contextually relevant and place-specific, so as to capture the unique spatiotemporal attributes of an urbanized ecosystem. While a generic checklist of best practices are often referenced by planners as a guide for assessment methods, they often do not reflect the unique attributes unique to any specific place and time.

For an assessment methodology to be more than a checklist of best practices, a systems-based integrative approach is needed to seek interrelationships, patterns and synergies. The purpose of the *Assessment Phase* is to characterize and assess the viability and efficiency of the urbanized ecosystem *in situ*, as well as subsequent rate of change by using the baseline data and information obtained from the *Inventory Phase*. Towards this end, The *Assessment Phase* identifies 'synergies' and 'conflicts' between interrelated planning interventions. 'Synergies' are the interaction of two or more agents or forces so that their combined effect is greater than the sum of their individual effects 'Conflicts' include any interventions that adversely effect the performance or outcome of another strategy.

The *Assessment Phase* provides the 'logic' to assign prioritization relative to the potential effectiveness of planning interventions and policy, according to; 1) the level of difficulty in implementing the intervention in terms of expertise and technology (readily achievable, not readily achievable, not achievable); 2) the applicable time scale of implementation (immediate, near-term and long-term); and 3) the relative initial and life-cycle cost of implementing the intervention relative to a municipality's budget, external funding, and return on investment.

6. FINDINGS

The findings were provided as deliverable outcomes to the Village of Oak Park as a 108-page report (Oak Park 2009) on October 6, 2009, that included the baseline inventory, summary of assessment, and a review of critical next steps. While it was found that the Village of Oak Park had several exceptional attributes relative to peer communities, it still had the challenge of having an ecological footprint that far exceeded the carrying capacity at various local, regional, and global scales. While most of this excessive ecological footprint (Wackernagel and Rees 1996) is inherent for any community that is located within the infrastructure and standard of living of the United States, there were two primary issues that became apparent during the course of this study that are specific to Oak Park, as follows;

- The existing disconnect of accountability between those who derive the benefits of potential planning policy, and those who bear the costs. During the investigation, there appeared to be not only a lack of incentives to initiate potential planning interventions and policy, but often disincentives as well.
- The lost opportunity of not taking advantage of available renewable resources, while instead relying on an energy intensive, inefficient, and costly infrastructural system.

The following are but a few examples of these two issues.

6.1. ACCOUNTABILITY – WATER USAGE

Oak Park receives an annual rainfall of 35.8" (91.0 cm) / year (Illinois State Climatologist Office 2009), or 2.8 billion gallons. About 60 percent of this rainfall falls upon impervious land cover (streets, alleys, roads, parking lots, roof-tops, etc.); whereupon it is channeled to Oak Park's combined stormwater / sewer system. This system is connected 6 miles (9.7 km) downstream to the Stickney Waster Reclamation Plant of the Metropolitan Water Reclamation District (MWRD) of Greater Chicago.

The Village of Oak Park pays a wastewater treatment fee to MWRD which is based upon the amount of supply water provided to Oak Park from Lake Michigan via the City of Chicago. Property owners in Oak Park also pay an additional wastewater treatment fee to MWRD through their Cook County property tax bills, based on their property's estimated assessed value. Therefore, there is no economic incentive for the Village of Oak Park collectively, or property owners individually, to reduce their stormwater / sewer discharge, as there will be little, if any, cost savings benefit.

Based on the runoff coefficients (Ritter, Kochel, and Miller 2006) of the impervious land cover, approximately 1.7 billion gallons per year of stormwater output is discharged to MWRD. In 2008, the Village of Oak Park imported over 2 billion gallons per year of Lake Michigan supply water from the City of Chicago, at a cost to Oak Park resident end users of $8.8 million (Oak Park 2008c). As such, rainfall is being diverted to MWRD, the Village of Oak Park is paying the City of Chicago to pump, process, and deliver water from Lake Michigan for watering yards and gardens, washing cars, and other nonpotable water uses. Therefore, based on this accounting, while stormwater mitigation and/or treatment have no economic benefit to local residents, supply water use reduction has a double economic incentive.

6.2. RENEWABLE RESOURCES - ENERGY

Oak Park receives a vast amount of solar radiation within its 4.5 mi.^{2} (11.7 km^2) of land area. In terms of energy, Oak Park receives between 67M Btu/day during December, and 256M Btu/day during June (United States 1976). While this supply of solar energy is largely unused, in 2008 Oak Park residents imported 161M kWh of electricity from the local electric utility, Commonwealth Edison, at a cost of $21.9 million (Oak Park 2008a). In 2008, residents also imported over 26.4M therms per year from Nicor at a cost of $30.3 million (Nicor Gas 2008).

The resultant annual greenhouse gas emission in 2008 from this consumption of electricity included over 36.2M lbs. of carbon dioxide (CO2). Resultant air pollution emissions also included 375,000 lbs. of sulfur dioxide (SO2), and 599 lbs of high level nuclear waste (Commonwealth Edison 2009).

Despite this disconnect between available solar radiation with expensive, fossil-fuel or nuclear-based energy sources, it was found that the Village of Oak Park had a disincentive for reducing their imported energy use. The municipal util¬ity tax on Commonwealth Edison residential energy billings was nearly $1M per year, while the municipal utility tax on Nicor billings was $1.6M per year (Oak Park 2008b). Therefore, any reduction in electrical or natural gas usage would significantly reduce a primary revenue stream in the village operating budget's General Fund. A proposed policy to address this disconnect needed to be assessed from a multi-criteria, cost-benefit viewpoint. As such, three policy scenarios were completed (Table 1) for 10%, 20%, and 30%c energy use reductions relative to the 2008 baseline. Associated impacts were calculated for energy cost reduction for residents, municipal utility tax reduction, greenhouse gas (CO2) reduction, and high-level nuclear waste reduction.

6.3. ACCOUNTABILITY – WALKABILITY

Although Oak Park was originally planned and developed as a highly decentralized and walkable community, recent growth and development trends in the Chicago metropolitan area have exerted pressure on inner-ring suburbs, such as Oak Park, towards becoming a more centralized, auto-centric community. For example, in 1917, there were 2,372 autos registered in the Village of Oak Park (U.S. Works Progress Administration 1937). With a population at that time of 34,876 persons, that was

Annual Residential Electric Energy Use Reduction Policy Scenarios	2008 Baseline	Scenario A 10% Reduction	Scenario B 20% Reduction	Scenario C 30% Reduction
Usage (kWh) [usage reduction]	160,951,051 ---	144,855,946 [1,609,511]	128,760,841 [3,219,021]	122,665,736 [4,828,532]
Costs ($) [cost reduction]	$21,853,416 ---	$19,668,074 [$2,185,342]	$17,782,732 [$4,370,683]	$15,297,391 [$6,556,025]
Municipal Utility Tax ($) [tax revenue reduction]	$965,706 ---	$869,135 [$96,571]	$772,565 [$193,141]	$675,994 [$289,712]
CO_2 (lbs.) [CO_2 reduction]	36,217,335 ---	32,595,601 [3,621,734]	28,973,868 [7,243,467]	25,352,134 [10,865,200]
High-level nuclear waste (lbs.) [waste reduction]	599 ---	539 [60]	479 [120]	419 [180]

Table 1: Policy scenarios for electric energy use reduction in Oak Park, IL relative to 2008 baseline. Source: (Author 2011)

Figure 4: Urbanized Ecosystem v1.0 Source: (Author 2011)

one vehicle for every 15 residents. There are currently over 30,095 vehicles registered in Oak Park, with a population of 53,103 (U.S. Census Bureau 2005-2009), which is one vehicle for every 1.8 persons.

The net result is more Oak Park residents are being influenced to use their vehicles for local destinations, such as stores, parks, and schools, rather than walking or biking. To accommodate the increased vehicular traffic, the Village invests significant capital funding to construct, operate, maintain, and secure an infrastructure that is necessary for a more auto-centric community. Additional adverse impacts are also incurred from increased pollution emissions and resultant public health risks (such as asthma), decreased walking/exercise and resultant public health effects (such as obesity), and increased fossil fuel usage associated with global warming and security risks.

7. NEXT STEPS

The application of *Urbanized Ecosystems™ (UrbEcoSys™)* to the Village of Oak Park was a proof of concept. The next version is intended to build upon the lessons learned from *UrbEcoSys™v1.0*. The next step would be an Improvements Analysis, based on discussion and feedback from the village officials upon review of the finding resulting from the *Scoping, Inventory and Assessment Phases*. The amount of data and information gathered and compiled for this study has been comprehensive, and every effort has been made to compile, organize and integrate this information in a meaningful manner for various users. But the existing village data tended to be fragmented and decentralized, and a measurement, reporting and verification protocol is needed to ensure quality assurance of data.

While not included in the scope of this project, a recommended next step for the inventory phase would be to include relevant footprint analyses, such as a more comprehensive ecological footprint, greenhouse gas emissions footprint, and carbon footprint, completed both on individual household and village-wide scales.

Another next step would be to include the input of the inventoried data sets representing the energy, material, information, and economic cost flows within multiple and integrated Excel workbooks. This enhanced user-interface and functionality would allow causal relationships between data sets to be better realized for scenario building and projections, allowing village officials the capability of interactive decision- and policymaking that is necessary with regard to the complex adaptive system known as the Village of Oak Park.

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ENDNOTES

1. While the concept of *urbanized ecosystems* is derived from urban ecology, it remains distinct in its usage for this paper for an important reason. Urban ecology, as a subfield of ecology, focuses on the 'ecology *in* cities', while urbanized ecosystems focuses on the 'ecology *of* cities' (Grimm et al. 2000). The investigation of urban ecosystems requires a significant conceptual change in the way planning research frames questions about urban environments (Alberti 2009). Instead of asking, "How do humans affect ecological systems?" the question becomes, "How do humans interacting with their biophysical environment generate emergent collective behaviors (of humans, other species, and the systems themselves) in urbanizing landscapes?"

2. *Urbanization* is the increase in the proportion of a population that is urban as opposed to rural. It refers to the proportion of the total population concentrated in urban settlements, or else to a rise in this population. Since the total population is composed of the urban population and the rural, the proportion urban is a function of both (Davis, 1965).

3. *Urbanized area* is an area consisting of a central place(s) and adjacent territory with a general population density of at least 1,000 people per square mile of land area that together have a minimum residential population of at least 50,000 people.

4. *Urban cluster* is a densely settled territory that has at least 2,500 people but fewer than 50,000.

5. The *Millennium Ecosystem Assessment (MA)* was called for by the United Nations in 2000, and carried out between 2001 and 2005. The objective of the MA was to assess the consequences of ecosystem change for

human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MA was undertaken by an international network of scientists and other experts, with a process modelled on the Intergovernmental Panel on Climate Change (IPCC).

6. *Transdisciplinary* research is characterized by a process of collaboration between scientists and nonscientists on a specific real-world problem. This requires an epistemology, methodology and organization that go beyond disciplinary research. Knowledge and values from outside the realm of science are integrated into the research process. At the same time, the research process is opened up to the stakeholders, aiming at a mutual learning process (Walter et al. 2007).

7. *Urban ecology* is ecological research done in urban areas, which for the purpose of this paper, is a geographical term characterizing the land use of an area (Niemelä 1999). *Urban ecosystems* are those in which people live at high densities, or where the built infrastructure covers a large proportion of the land surface (Pickett et al. 2001). Beyond definitions, there are two distinct meanings of urban ecology in the literature (Sukopp 1998). One is a scientific definition, and the other emerges from urban planning. In ecology, the term urban ecology refers to studies of the distribution and abundance of organisms in and around cities, and on the biogeochemical budgets of urban areas. Urbanized ecosystems, the epicenter of human environmental impact, have traditionally not received adequate attention from ecologists (Kloor 1999). This may be because ecology has its roots in a worldview that stressed balance and equilibrium and regarded disturbance in general, and human intervention in particular, as a deflection from the more representative workings of ecological systems (Botkin 1992). Since these conditions were associated with more pristine conditions, as perceived in wilderness locations, this is where much of twentieth century ecology focused its attention. Urban ecology is now emerging from a long period of neglect and becoming an important disciplinary focus (Goode 1989).

8. Cadenasso, Mary L., "The Evolution of Urban Ecology in the United States: Application of Contemporary Ecological Concepts in Urban Systems" (keynote address presented at the Urban Ecology: Celebrating Ten Years of Chicago Wilderness symposium, Chicago Botanic Garden, October 20, 2006).The Baltimore Ecosystem Study (BES) conducts research on metropolitan Baltimore as an ecological system. The program integrates biological, physical, and social sciences. As a part of the National Science Foundation's Long-Term Ecological Research Network (LTER), BES seeks to understand how Baltimore's ecosystems change over time.

9. The Baltimore Ecosystem Study (BES) conducts research on metropolitan Baltimore as an ecological system. The program integrates biological, physical, and social sciences. As a part of the National Science Foundation's Long-Term Ecological Research Network (LTER), BES seeks to understand how Baltimore's ecosystems change over time.

10. *Proof of concept* is a short and/or incomplete realization of a certain idea to demonstrate its feasibility, or a demonstration in principle, whose purpose is to verify that some concept or theory is probably capable of exploitation in a useful manner.

11. While *sustainability* was listed as one of the frameworks from which to choose, terms relative to the specific application, such as *urban ecology*, are preferred. The use of the term sustainability is often arbitrary and ill-defined, which may result in confusion and misinterpretation. The term sustainability is a transitive verb which requires both a subject and object(s). Therefore the use of this term requires the inclusion of 'what is being sustained', and 'who is doing the sustaining'. Since the root word *sustain* is commonly defined as to 'keep in existence, maintaining', the term sustainability connotes something that will persist indefinitely. Since there is no natural or human-designed system that persists indefinitely, the use of the term sustainability needs to be within this conceptual framework