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Benchmarking eco-industrial park development: the case of Devens

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Abstract

Purpose – The purpose of this paper is to review and update Devens eco-industrial park sustainability indicators and benchmark progress made since 2000 in the seven key areas of its sustainability vision.

Design/methodology/approach – The authors examined publicly available data for Devens, Massachusetts, and obtained additional data from Devens Enterprise Commission and a survey of 29 local organizations.

Findings – Of the 43 indicators adopted by Devens eco-industrial park in 2012, 29 demonstrate progress, seven show lack of progress, six point to a potential progress, and for one no information was available in 2000 to evaluate progress. Most progress has been made in the areas of transportation, business and economic sustainability, governance and natural resources.

Research limitations/implications – For some proposed indicators no data were available to evaluate progress (e.g. waste generation, recycling, compositing, and landfill diversion) yet these are among the key measures for an eco-industrial park.

Practical implications – Proposed framework, indicators and lessons learned are of value for researchers and practitioners at other eco-industrial parks (EIPs) interested in benchmarking progress toward sustainable local development.

Social implications – The case provides insights on integrating sustainability in local economic development.

Originality/value – The study is paving the way toward development of a standardized set of sustainability indicators for EIPs in the USA.

Keywords Benchmarking, Sustainable development, Sustainability indicators, Framework,
Eco-industrial parks

Paper type Case study

Introduction

Within the broader field of industrial ecology, which examines the flow of physical resources through systems at different scales, the sub-field of industrial symbiosis (IS) focusses on these flows at the level of industrial clusters and industrial parks. The President's Council on Sustainable Development defined eco-industrial parks (EIPs) as "A community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy,

infrastructure and natural habitat), leading to economic gains, gains in environmental quality, and equitable enhancement of human resources for the business and local community" (President's Council on Sustainable Development, 1997).

In a world of constrained resources and growing population, EIPs are increasingly seen as a means for green growth and sustainable local and regional development. In 2010, Organization for Economic Cooperation and Development recognized IS "as a systemic innovation vital for green growth" (Lombardi and Laybourn, 2012). China became the first country to globally launch an eco-industrial park standard in 2006 and presently has at least 1,568 national and provincial-level industrial parks which are seen as critical for achieving a circular economy and national competitiveness (Shi *et al.*, 2012). Korea, Mexico, and most recently Brazil, have also actively supported development of EIPs through policy initiatives and guidance.

Despite the promise of such EIPs, their implementation in the USA remains problematic. Some of the main challenges identified include: attempts to plan EIPs around a narrow definition of waste, energy, and by-product exchange; focus predominantly on the technical analysis of IS while attention is needed on the role of social interactions, culture, and institutions; lack of commonly accepted criteria for EIPs in the USA; lack of agreed frameworks and methods for sustainability assessment; and lack of sufficient expertise in terms of researchers and practitioners working in the field of industrial ecology.

This paper presents the case of Devens, Massachusetts, and how this planned eco-industrial park and a former military site listed under the Comprehensive Environmental Response, Compensation, and Liability (CERCLA) Act, has managed to overcome some of the above challenges and advance sustainable local development. It focusses in particular on the role of sustainability indicators and institutional factors in this process. Created by the Massachusetts legislature in 1993, Devens had a sustainability vision from the very beginning and the goal to increase regional economic base by employing the principles of industrial ecology. Today, Devens is a regional enterprise zone which has attracted 95 organizations and contributed over $1.45 billion and 3,200 high-quality jobs to Massachusetts economy while cleaning up the local environment and advancing more sustainable infrastructure such as rail and green buildings (Veleva, 2012).

The authors aim to examine the following questions: what are the main factors for Devens success? Has it made progress in all seven areas of its sustainability vision? How can sustainability indicators be used to measure and communicate progress, promote transparency and accountability, and ultimately advance shared learning and cultural change associated with successful eco-industrial park development? What are the key lessons for other EIPs from Devens' two decades long redevelopment efforts? The paper begins with a section on EIPs as a means for sustainable local development. Devens eco-industrial park is introduced next, including its history, process for redevelopment and established sustainability vision and goals. The authors then present the novel sustainability indicators used by Devens to measure progress toward its social, environmental and economic goals, and the results from a comprehensive assessment of its progress. The paper concludes with a discussion of the role of indicators, factors for success, and lessons for other EIPs.

EIPs and sustainable local development: the measurement challenge

Industrial ecology (IE) was first defined by Frosch and Gallopoulos (1989) as an approach where "the use of energies and materials is optimized, wastes and pollution

are minimized, and there is an economically viable role for every product of a manufacturing process". IE is based on systems analysis and ecological principles, such as the fact that in nature there is no waste – the waste from one organism becomes food for another. While no agreed upon definition of IE exists yet, most definitions emphasize its multidisciplinary approach, the integration of industrial and ecological systems, minimization of negative environmental impacts, and the adoption of cyclical (closed-loop) manufacturing processes. With the growing environmental awareness and mandates, IE tools such as design for the environment and life cycle assessment have become increasingly popular in recent years to evaluate and minimize the environmental impacts of products and production processes.

The application of IE at a particular geographic location is referred to as eco-industrial park (EIP). EIP was initially defined as "collective approach to competitive advantage involving physical exchanges of materials, energy, water and by-products, enabled by geographical proximity of firms" (Chertow, 2000). Recent research from across the world has shown the actual economic and environmental benefits of IS in Europe (Baas and Boons, 2004; Sokka et al., 2011; Jacobsen, 2006), Asia (Shi et al., 2010; Tian et al., 2013), Australia (van Beers et al., 2007), and North America (Chertow and Lombardi, 2005). Developing physical exchanges, however, has remained problematic and Lombardi and Laybourn (2012) recently proposed redefining EIPs as a means to "engage diverse organizations in a network to foster eco-innovation and long-term culture change." Such definition promotes the idea that EIPs today are less about physical exchanges of materials and more about sharing of infrastructure and knowledge.

The main goal of IE and EIPs is to promote sustainable economic development at the global, regional and local levels. A number of researchers have identified EIPs as a tool for local and regional economic development (Deutz and Gibbs, 2008). The latter includes creating business clusters, promoting networking, and adopting supportive policies to enhance business competitiveness and job creation. More broadly, the literature on sustainability clusters has identified the importance of supporting infrastructure and other local factors in promoting productivity, innovation, and competitiveness (Maskell and Malmberg, 1995; Martin and Mayer, 2008; Porter and Kramer, 2011). Clusters do not include only the local businesses but also institutions such as schools, universities, trade associations, and non-profit organizations.

EIPs can be seen as supporting the resource-based view of the firm (Barney, 1991) where companies' resources can be a source of competitive advantage. Barney (1991) defines resources as "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness" (p. 101). Socially complex resources involving location, knowledge, inter-industry collaborations, and relationships, can be difficult for competitors to imitate and thus become a source of sustained competitive advantage. Wernerfelt (1984) has also demonstrated the role of non-financial (intangible) assets in creating competitive advantage.

In their recent work on creating shared value, Porter and Kramer (2011) emphasize the "profound effect" of a business location on a firm productivity and innovation, which still remains understudied by researchers. They argue that companies can create economic value by creating societal value. Local governments can play a particularly important role in promoting cluster development and local sustainable development by setting clear and measurable sustainability goals (e.g. around energy use, health and safety or infrastructure improvement). In this regard, sustainability indicators have

been used for more than 20 years by numerous communities worldwide to operationalize the concept of sustainable development, engage a wide group of stakeholders, and define and measure progress locally, regionally and nationally. While sustainability indicators alone cannot bring a change, they are critical for engaging various stakeholders, raising awareness and empowering communities and policy makers to advance progress toward sustainability vision and goals (Gahin *et al.*, 2003; Fraser *et al.*, 2006). They have been found to represent "an important new experiments in governance which "may be transformational not only to our identities as planners, politicians, or communities, but also to the relationships that are shaped between us" (Miller, 2005, p. 405). Indicators are also a key element of any performance management system and provide critical feedback for ensuring continuous improvement (Veleva *et al.*, 2001).

Traditional sustainability indicators for EIPs have been typically limited to measuring resources, by-product exchange, energy, water, and waste diversion. "Agreed frameworks and methods for sustainability assessment of IS are unfortunately still lacking," concludes van Berkel (2010). Studies have found that "the lack of indicators has impeded the movement of some parks toward eco-industrial development" (Geng *et al.*, 2008, p. 16). It also presents a major barrier to quantifying and communicating the benefits to companies and developers (van Berkel, 2010; Geng *et al.*, 2008; Lombardi and Laybourn, 2012). New, system-level indicators are needed to measure management and governance practices, social benefits, knowledge sharing, and collaborations that lead to greater resilience and competitiveness.

Study goals and methodology

The main goal of the study is to develop a comprehensive set of sustainability indicators to evaluate Devens' progress toward it sustainable redevelopment vision. The study also aims to demonstrate how EIPs can develop and use such indicators to measure and advance progress toward local sustainable development goals. It is expected that research findings will help advance the development of standardized sustainability indicators for EIPs which go beyond traditional environmental and economic indicators to incorporate measures of social sustainability, governance, and business engagement.

To evaluate progress by Devens eco-industrial park, the research team first assessed its sustainability vision, goals, and indicators to identify gaps, eliminate ineffective indicators and add new ones that better measure progress. Each new or existing indicator was evaluated using ten criteria for effective sustainability indicators (Swisher *et al.*, 2009: Sustainable Measures, 2010):

(1) the indicator reveals links between the economy, society, and the environment;

(2) the indicator addresses the carrying capacity of the community's natural resources and acknowledges ecological limits;

(3) the indicator provides a long-term view of the community, looking forward 25 or 50 years rather than 5 or 10;

(4) the indicator is sensitive and adaptable to changing circumstances and conditions such as the changing mix of businesses and other organizations in Devens;

(5) the indicator is clear, simple, and unambiguous;

(6) the indicator is reliable, providing accurate data and measuring what the community wants to measure;

(7) the indicator demonstrates how individuals and organizations contribute to the overall picture of sustainability;

(8) the indicator allows Devens to recognize how local sustainability is tied to and dependent on regional and global sustainability, and vice versa;

(9) the indicator is measurable, or based on accessible data which is either available or can be gathered; and

(10) the indicator is cost effective – obtaining the data are relatively easy and inexpensive.

While no indicator was expected to meet all ten criteria, the goal was to identify indicators that are less effective presently in evaluating Devens' progress toward sustainability and replace these with new indicators that better align with Devens seven sustainability issue areas (Veleva, 2012). Data for the proposed indicators were obtained by reviewing various Devens reports, and other documents, and with the assistance of the Devens Enterprise Commission (DEC), MassDevelopment, and the Devens Eco-Efficiency Center (DEEC). Additional data were obtained from interviews with a random sample of 29 local organizations in early 2013 (Devens Enterprise Commission (DEC), 2013; Veleva *et al.*, 2015).

Devens eco-industrial park – history, vision, and process for redevelopment
Devens is a regional enterprise zone created by the Massachusetts legislature in 1993 to aid the redevelopment of the former Fort Devens. First created in 1917 by the US Congress and the Department of the Army as a military base, Fort Devens consisted of predominantly rural lands from the adjacent Towns of Ayer, Shirley, Harvard, and Lancaster. When the closure of Fort Devens was announced in 1991, a local and regional movement toward base reuse planning was initiated. A Joint Boards of Selectmen from the four surrounding towns was formed to identify reuse opportunities and priorities. The Massachusetts legislature adopted Chapter 498 of the Acts of 1993, which created the DEC to take regulatory and permit-granting responsibilities for Devens. MassDevelopment, a quasi-state agency, retains the infrastructure, police, fire, and public works responsibilities of Devens (Devens Enterprise Commission (DEC), 2000).

The 1993 Fort Devens Charrette and the Devens Reuse Plan began the process of establishing the vision and goals for Devens redevelopment. The fundamental principles of Devens' redevelopment included sustainability and IE. Devens By-Laws, written in 1994, built upon sustainability goals and objectives established in the Reuse Plan through zoning, density, and groundwater resources, historic district, watercourse, and wetland protection. The result of this early planning was a vision for what sustainability means to Devens, its residents, users, and the involved public bodies: "the thoughtful and careful redevelopment of the base for the purpose of promoting economic development, social welfare, environmental protection, and natural resources" (DEC, 2000).

In 2000 after reviewing existing indicator sets and criteria, and incorporating public input and suggestions, a set of seven sustainability issues and 20 indicators for Devens were developed (DEC, 2000). The seven core sustainability issues are presented on Figure 1 and were supplemented by specific questions to guide indicator assessment over time.

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Figure 1.
Sustainable Devens:
framework and
seven key issues
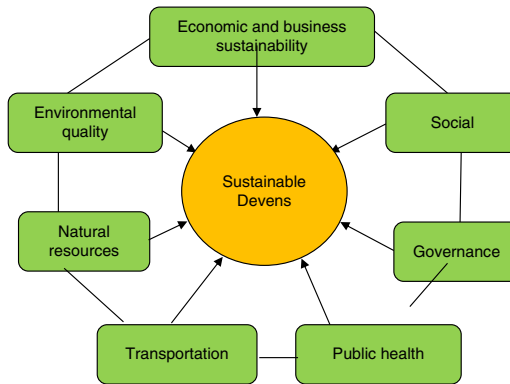
Source: Veleva (2012)

DEC

Redevelopment of Devens was focussed on attracting a diverse set of companies to provide a range of employment opportunities in order to provide "resilience from impacts associated with the loss of a single primary employer." Business development efforts were particularly focussed on attracting employers from the clusters that were seen as good fit for the community – e.g., military defense, life sciences, medical devices, plastics, and renewable energy technology (Hammer *et al.*, 2012).

In this process DEC and its Director Peter Lowitt have played a critical role in working toward achieving the Devens sustainability vision. As a Chair of the Eco-Industrial Development Council of North America and the key person behind the development of the Londonderry Ecological Industrial Park, Mr Lowitt focussed on three main aspects in redeveloping Devens as an internationally recognized EIP: promoting supportive local policies; establishing a separate entity to focus on providing education and building a network of collaborating firms; and implementing an open and inclusive process for measuring achievements and identifying gaps.

For instance, the initial Sustainable Indicator Report in 2000 identified two major issues that DEC worked to address over the past 12 years: lack of public transportation and alternatives to single occupancy passenger vehicles to commute to and from Devens, and lack of "green" buildings. To address the first issue, the Fitchburg Line Working Group was established with chair DEC Director Mr Lowitt. The group managed to secure $200 million investment to double track the rail between South Acton and Ayer and thus enable a viable reverse commute. To address the second issue, DEC adopted the Green Building Incentive Program and various regulatory changes to encourage the deployment of "green" buildings in Devens. DEC has also adopted policies for low-impact development and water resource protection. To build a network of collaborating companies and advance knowledge about the business benefits of environmental strategies, DEC established the Devens EcoStar Program and later, the DEEC. Regular communication with local businesses and residents through meetings, DEC website, and newsletter, have helped establish an inclusive and transparent process promoting greater trust and accountability.

DEEC

To engage local organizations and promote building linkages and advancing Devens development as an eco-industrial park, DEC Director Mr Lowitt brought in a

sustainability consultant in 2001 to develop the membership program EcoStar which was launched in 2005 as a voluntary branded program "to enable businesses and organizations in the Devens (MA) area to gain eco-efficiencies by pursuing strategies that improve environmental and economic performances" (EcoStar, 2012). In 2007 EcoStar transitioned to become the DEEC, a non-profit organization with the goal to assist local businesses and organizations in reducing operating costs and environmental impacts through efficiency, reuse, and recycling. The center offers workshops around more sustainable operational practices, environmental, health and safety (EHS) roundtable (a monthly open forum for EHS professionals to discuss experiences, trends and best practices as well as potential collaborations), energy efficiency assistance, recycling assistance, the Great Exchange (a forum for exchanging and repurposing waste), and educational tours among others. For example, Eglomise Designs saved more than $1,800 per year by implementing an employee engagement program to promote energy conservation. The Great Exchange helped repurpose 61 tons of materials in 2012, saving $24,000 to the 50 entities participating in it (see Box 1).

Devens sustainability indicators study

In summer 2012 DEC launched a project to update Devens sustainability indicators and measure progress made since 2000 in each of the seven core areas. As part of the process to solicit input into the draft indicators report and finalize proposed goals and indicators, DEC staff met with Devens businesses at the September 12, 2012 Devens Business Breakfast, and with the public as part of the October 11, 2012 annual MassDevelopment Board of Directors meeting (Veleva, 2012).

The indicator study revealed a lack of data for measuring some indicators (e.g. government responsiveness, percent of firms that collaborate, landfill diversion, employee health and wellness). To obtain such data as well as feedback from local organizations, the DEC partnered with the UMass Boston Center for Sustainable Enterprise and Regional Competitiveness to conduct a survey in the first quarter of 2013. In total, 29 Devens organizations participated in the survey which also included face-to-face interviews (31 percent participation rate) (DEC, 2013; Veleva *et al.*, 2015).

As result of the indicator review six indicators were dropped from the original list of 20 sustainability indicators and 29 new indicators were proposed to better measure progress in each of the seven sustainability issue areas. The indicators that were dropped included "productivity/company revenue per employee," "percent of mothers with adequate prenatal care," "total chronic diseases related deaths

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Box 1. The Great Exchange, Devens

The Great Exchange was launched in 2007 as a forum to divert unwanted items and materials from the landfill to reusable opportunities. Managed by Dona Neely, Executive Director of the DEEC, the program repurposed 61 tons of materials in 2012 saving $24,000 to the 50 participating 50 entities. Some of the main materials exchanged included foam packing sheets, bubble wrap, elastics, cloth bags, furniture, equipment, and small boxes. Waste, such as ten gallon pails, plastic jars, Styrofoam blocks, and fabric scrap are "turned into art" by local schools and museums. Since the first exchange took place in 2008, the program has partnered with over 100 global firms, small businesses, service providers, daycare facilities, nonprofits, and municipalities and repurposed 500 tons of materials helping participants avoid over $200,000 in purchase and disposal costs (Devens Eco-Efficiency Center, 2012 Annual Report, www.ecostardevens.com/2012%20annual%20report.pdf).

per 100,000 population," "road-conditions-level of service," "open space and recreation plan in place," and "total solid waste per capita" (Veleva, 2012). Table I presents the full list of sustainability indicators as well as related goals/targets and the progress made since 2000. Below are described the key indicators and findings for each of the seven sustainability areas.

Economic and business sustainability
Some of Devens' key redevelopment goals included attracting and retaining businesses and other organizations to Devens; promoting business sustainability; and creating employment opportunities and high-paying jobs. These are also goals for any community or region committed to sustainable development and long-term viability. Since 2000 Devens has made significant progress in these areas. Four new indicators were included to evaluate sustainable economic progress more accurately: "number of organizations in Devens," "number of jobs/employees," "annual mean wage compared to Massachusetts average," and "percent of Devens organizations participating in the Eco-Efficiency Center Events." The indicator "productivity/company revenue per employee," was dropped for two reasons: productivity varies significantly with the changing variety of local businesses and therefore is not a good measure to track progress; and increasing number of studies have demonstrated that productivity is a poor measure of sustainability and economic progress (Jackson, 2012).

While the local economy is closely linked to the US economy and experienced significant contraction during the great recession of 2007-2009 in terms of business bankruptcies, relocation, and reduced revenues, overall, progress has been made in all areas except unemployment rate. The economic expansion of Devens over the past ten years has been achieved without exceeding the Devens' carrying capacity, defined as the total build out area permitted as well as other threshold factors such as water consumption and traffic. A 2012 study found that in 2010 Devens contributed more than $1.45 billion to the Massachusetts economy (UMass Donahue Institute, 2012).

Two of the indicators in this section – "Percent of Devens organizations participating in the Eco-Efficiency Center events" and "Percent of firms that purchase together, share equipment or personnel" indirectly measure the business benefits of locating in an EIP as a source of competitive advantage. The latter is result of the unique access to resources such as knowledge, relationships, and value chain collaborations that advance firms' efficiency and effectiveness (Barney, 1991).

Social sustainability
Social sustainability relates to a community's social well-being and quality of life. While Devens is currently primarily a business community (in 2010 there were 1,840 people living in Devens and 3,208 people working there), a wealth of passive and active recreational open space and a residential population contributes to the region and the overall sustainability of Devens. It provides both an attractive place for business as well as a site for recreational events and housing at a variety of price points. Two new indicators in this area have been added to measure social goals more accurately: "the number of people participating in community events" and "the percent of affordable housing" (Veleva, 2012).

While limited in its ability to expand housing development and thus the number of people living locally (housing units are capped at 282 units by the Devens Reuse Plan and Bylaws), Devens has made progress in all but one indicator area. The decline in
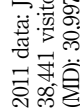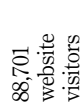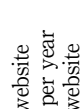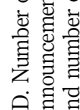
Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
Economic and business sustainability						
1. Is the economy healthy?	Attract and retain companies/ organizations to Devens within the carrying capacity	1A. Number of companies and non-profit organizations	60	95	YES	Source: Mark Sternman, 2012 Donahue Institute Study. Total of 95 includes 65 businesses, 19 nonprofits, and 11 government entities
	Maintain unemployment rate below the MA average	1B. Unemployment rate compared to MA average 1B.1 – average for 4 neighboring towns (Ayer, Harvard, Lancaster, Shirley) 1B.2 – average for 24 MA communities designated as impact region	1B.1 – 2.3% vs 4.6% in MA 1B.2 – 2.5% vs 4.6% in MA	1B.1 – 7.9% vs 7.4% in MA 1B.2 – 8.2% vs 7.4% in MA	NO	Source: Mark Sternman from MD; 2010 US Census, MA average: 7.4%; http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_10_5YR_S2301&prodType=table
	Increase the number of jobs in Devens	1C. Number of jobs/ employees	na	3,208	MIN	Source: Edmund Starzec, MassDev, 2012 Donahue Institute study (data for 2010)
	Increase the number of high-paying jobs	1D. Annual mean wage vs MA average	na	$68,794 vs MA average of $57,799	YES	Source: 2012 Donahue Study (2010 data); 2011 BLS www.bls.gov/oes/current/oes_ma.htm#00-0000
Are Devens organizations embracing sustainability?	Increase participation in the Devens Eco-Efficiency Center (DEEC) events	1E. Percent of Devens organizations participating in the Eco-Efficiency Center events	0	37%	YES	Source: Dona Neely, DEEC; 35 organizations out of 95 (note: DEEC has had interaction with 80% of Devens businesses)

Table I.
Devens
sustainability
indicators, June 2013

Table I.

Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
	Increase the % of firms that purchase together, share equipment, personnel	1F. Percent of firms that purchase together, share equipment or personnel	36%	86%	YES	Percentage of respondents that currently partner with other organizations in Devens and surrounding region. Source: 2013 Business Sustainability Practices and Indicators Survey
Social 2. Is the community healthy socially?	Increase number of arts, cultural events and performances at public sites	2A. Number of arts, cultural events, or performances at public sites	3	89+	YES	Source: Maura Peeler, 2011 salesdevens@truenorthhotels.com, and Social and Community Events Appendix
	Increase the number of recreational events available to public	2B. Number of public recreational events	75	34	NO	Source: 2011 data from MassDevelopment Public Works, Kate Walsh, KWalsh@Massdevelopment.com
	Increase participation in community events	2C. Number of people participating in community events	~120,000	~300,000	YES	Source: 2011 Annual Report Devens (brochure), Peter Lowitt
	Achieve at least 25% affordable housing	2D. Percent of affordable housing (households earning 80% or less of median income per HUD)	100% (20 units)	40% (50 units)	YES	Source: Peter Lowitt, in 2012 there were 50 affordable units out of 126 total housing units
Governance 3. Is the government responsive?	Maintain high-government	3A. Public perception of governmentt	na	66% rated very Responsive	TBD	Source: 2013 Business Sustainability Practices and Indicators Survey

(continued)

Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
	responsiveness to citizens and business	responsiveness via public survey				
	Offer expedited permitting process in less than 75 days	3B. Average time to obtain a permit	50 days	46 days	YES	Source: 2011 Devens Annual Report (brochure); Neil Angus
	Promote high level of transparency and engagement	3C. Number of annual meetings with citizens and businesses	na	25 meetings	MIN	Source: Neil Angus; 21 DEC public meetings, 4 meetings with residents' groups, 2011
	Improve communication with companies/citizens	3D. Number of website announcements per year and number of website visitors	na	88,701 website visitors	MIN	2011 data: J. Lee, N. Angus: DEC website: 38,441 visitors Devens website (MD): 30,997 EcoStar: 19,263
	Clean up all CERCLA sites, USTs and remove Devens from superfund list	3E. Percent of CERCLA sites which have been cleaned up ($investment in cleanup); USTs removed; Devens on superfund list	na	100%; still on superfund list	YES	Source: Ron Ostrowski Cleaned up all 324 CERCLA sites; pulled up all 200 known UST; Army spent $170 million
Public health 4. Are members of the community healthy?	Promote Devens as a walkable community	4A. Total linear feet of sidewalks and % of roads with sidewalks	40,673 linear feet (35%)	65,482 linear feet (57%) in 2012	YES	Source: Neil Angus
		4B. Total linear miles of trails	5.44 miles	12.46 miles	YES	Source: Neil Angus, 16 trails in 2011
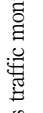
Table I.

Table I.

Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
	Promote intermodal accessibility and TDM benefits	4C. Total linear miles of bike lanes	0 miles	0 miles	NO	Source: Neil Angus
	Achieve a rate of workplace injuries below US average	4D. OSHA reported total case rate (TCR) of injuries and illnesses for Devens	na	TCR 2.6 (<national average of 3.8)	YES	2009/2010 data from OSHA – www.osha.gov/pls/odi/establishment_search.html
	Achieve total days away from work below US average	4E. OSHA reported days away from work (DAFWII) case rate	na	DAFWII: 1.97 (> national average of 1.9)	NO	2009/2010 data from OSHA – www.osha.gov/pls/odi/establishment_search.html
Transportation 5. Are adequate transportation facilities available?	Increase % of commuters using alternatives to driving (e.g. transit, biking, walking, working from home or carpooling)	5A. Percentage of commuters using transit, carpool, biking, walking, or working from home	4%	10%	YES	Source: 2010 Devens traffic monitoring report: 90% drive, 6% carpool, 2% bike, 1% transit, 1% walk; MA: 71.9% drive, 9.4% transit, 4.7% walk, 4.2% work from home, 8.2% carpool; year 2000 survey: 475 drive, 17 carpool, 4-other
	Increase rail available to local citizens and businesses	5B. Total linear feet of rail available to local businesses and residents	8,000 ft	14,300 ft	YES	Source: Neil Angus, 2012 data

Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
	Maintain total vehicle miles (VMT) below threshold of 59,625	5C. Vehicle miles traveled (VMT) total and per 1,000 ft^2 occupied space	About 13,000 total; 13.9 VMT per 1,000 ft^2	33,396 total or 9.1 VMT per 1,000 ft^2	YES	Source: 2010 Devens traffic monitoring report
Natural resources						
6. Are local natural resources in adequate supply to meet future needs?	Maintain water consumption below the max threshold of 4.8 mgd authorized by DEP	6A. Water consumption as percent of available supply	100%	16.7%	YES	Source: Jim Moore, MassDevelopment
7. Is biodiversity intact?		7A. Size, shape, and composition of wildlife habitat areas	Large, varied, unbroken, connected	Large, varied, unbroken, connected	YES	Source: Neil Angus, Green Infrastructure Map
	Maintain at least 30% of land as open space	7B. Percent of area permanently protected as open space	24% (1,073 acres)	25% (1,118 acres)	YES	Source: Neil Angus, 2012 data; additional 460 acres is pending permanent protection
	Reduce percent of impervious surface	7C. Percent of impervious surface	10.3% (454 acres)	10.1% (444 acres)	YES	Source: Neil Angus, see Appendix E

(*continued*)

Table I.

Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
	Adaptive reuse of existing buildings	7D. Total square feet of buildings reused and as % of all former buildings	271,237 ft^2 or 18.2%	760,347 ft^2 or 51%	YES	2000 and 2012 data by Neil Angus; total available former buildings: 1,490,430 ft^2
8. Is energy consumption excessive?	Reduce energy use per 1,000 ft^2 occupied space	8A. kWh of electricity consumed per 1,000 sq.ft. of occupied space	43,799 MWh total use; 46,672 kWh/ 1,000 ft^2	91,320 MWh total use; 23,028 kWh/1,000 ft^2	MIN	Source: Data for 2000 and 2008 provided by Jim Moore; Note: Poor indicator-industry specific
		8B. Therms of natural gas consumed per 1,000 sq.ft. of developed space	695	7,347	NO	Source: Jim Moore, Devens Utilities
		8C. Percentage use of renewable energy	0%	Less than 0.25%	YES	Source: 2011 data by Jim Moore, Devens Utilities; two small residential solar panels; proposed 3 MW solar farm to be built by EBZ Solar
	Reduce energy use in municipal buildings 20% by FY2012 and 35% by FY2020 (baseline FY2004)	8D. Municipal buildings electricity use (in kWh)	na	1,373,877 kWh	MIN	Source: Spreadsheet sent by P. Lowitt for 2008; Goal from MA Executive Order 484 (2007) – www.dsireusa.org/incentives/ incentive.cfm?Incentive_ Code = MA13R&re = 1&ee =
		8E. Municipal buildings natural gas use (in therms)	na	91,939 therms	MIN	Source: MDFA Usage Spreadsheet for 2008

(*continued*)

Table I.

Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
	Increase total square footage and percent of certifiable green buildings	8F. Green buildings square footage as % of total occupied space; % of residential and commercial buildings certifiable green	0%	14% (24% of residential and 8% of commercial buildings)	YES	Source: Neil Angus, in 2012 there was 513,672 ft^2 of green building; total occupied space in 2010: 3,662,758 ft^2
Environmental quality						
9. Is the local environment healthy?	Maintain 100% safe drinking water	9A. Drinking water quality	100% safe, zero violations	100% safe, zero violations	YES	Source: 2010 Report to Consumers on Water Quality
10. Is the regional environment healthy?	Maintain ranking 1 for watershed quality	10A. Watershed quality index	Ranking 1	Ranking 1	YES	Source: NH Volunteer River Assessment Program NRWA 2012 Field Data Sheet
	Reduce toxics release inventory (TRI) emissions per 1,000 ft^2 of occupied space	10B. Total TRI emissions and TRI emissions per 1,000 ft^2 occupied space	120 lb (0.13 lb per 1,000 ft^2 occupied space)	461,579 lb (126 lb per 1,000 ft^2 occupied space)	NO	Source: 2010 EPA data, http://iaspub.epa.gov/triexplorer/release_chem?p-view=ZPCH&trilib = TRIQ0&sort=_VIEW_&sort_fmt=1&state = &city=&spc =&zipcode=01434&zipsrch=yes& chemical=All+chemicals&industry=ALL &year = 2010&tab_ rpt = 1&fld = RELLBY&fld = TSFDSP
11. Are wastes reduced, reused, or recycled?	Increase the percent of waste that is recycled	11A. Percentage of solid waste recycled	0.03%	56% (year 2004)	YES	Source: Mass Dev; 3,023.7 tons recycled in 2010; 715.26 tons in 2011; DPW 2004 report

(continued)

Table I.

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Table I.

Issues	Goal or threshold	Indicators	2,000 data	Current data	Progress made?	Comments/source of information
	Increase amount of solid waste reused	11B. Tons of solid waste reused as result of the Eco-Efficiency Center work	0 tons	60 tons	YES	Source: 2011 data, Dona Neely, Devens Eco-efficiency Center
	Reduce total chemical use per 1,000 ft² occupied space	11C. Total chemical use (lb) and lb per 1,000 ft² occupied space	10,518 lb total chemical use; 11.2 lb per 1,000 ft² occupied space	6,445,719 lb (1,760 lb per 1,000 ft² occupied space)	NO	Source: 2000 and 2009 TURI data, http://turadata.turi.org/report.php?action=report_community_quantity_current_year&community=DEVENS; will vary by industry mix
	Increase landfill diversion	11D. Landfill diversion (tons diverted and diversion rate as % of all solid waste)	na	50%	YES	Source: 2013 Business Sustainability Practices and Indicators Survey
	Increase collection of hazardous household waste	11E. Number of days/year of HHW collection; total lbs of HHW collected	na	20 days	YES	Source: Eco-efficiency Center
	Increase composting	11F. Percent/number of organizations and households which are composting; total lb/tons composted per week/year	na	1 company; 900 lb/week	YES	Source: Dona Neely, Eco-efficiency Center; the only organization composting in June 2012 was Hilton's Great American Grill Restaurant

Notes: Devens total area: 4,400 acres; number of residents in 2000 – 1,017; in 2010 – 1,840 people (US census). Total ft² of commercial/industrial buildings in 2012: 6,200,413 ft². Total occupied space: in 2012 – about 4,000,000 ft², in 2010 – 3,662,758 ft², in 2008 – 3,965,578 ft², in 2000 – 938,439 ft²

public recreational events could be due to two things: the different methodology for tracking these in 2000 and 2012 (the data for 2000 could not be verified), and the opening of the Mass Youth Soccer Association fields in Lunenburg in the intervening time between reports. On the positive side, since 2000 Devens has become well-known as a center for softball, soccer, and lacrosse games and tournaments. An estimated 300,000 people participated in local recreational events in 2011 compared to 120,000 in 2000. In total, 40 percent of the housing units in 2011 (50 out of 126 units in total) were classified as affordable, significantly exceeding Devens' goal of having at least 25 percent of housing classified as affordable (Veleva, 2012).

Governance
Community governance is usually defined as "the processes for making all the decisions and plans that affect life in the community, whether made by public or private organizations or by citizens" (Results That Matter (RTM), 2012). Since DEC and MassDevelopment are the two organizations tasked with the responsibility to govern the redevelopment of Devens, this sustainability issue area aims to evaluate how well they are fulfilling this task. An effective community governance model includes three core aspects: engaging citizens, getting things done, and measuring results (RTM, 2012). Good governance indicators should measure each of these three core aspects. Results from the indicator analysis reveal that Devens is making good progress in this area, although no data were available from year 2000 for three of the five indicators – "public perception of government responsiveness," "number of annual meetings with citizens and businesses," and "number of website announcements per year and number of website visitors." A survey was used to measure public perceptions of government responsiveness, where results revealed that 66 percent of participating organizations rated local government as very responsive, and 25 percent – somewhat responsive.

Public health
Typical indicators measuring the health of a community population include prevalence of diabetes, heart disease, people with health insurance, and percent of mothers with adequate prenatal care (Center for Disease Control and Prevention, 2015). Two metrics were used in 2000 to track the health status of Devens' population – "percent of mothers with adequate prenatal care" and "total chronic disease-related deaths per 100,000." No public health data are, however, collected presently for Devens by the Massachusetts Department of Public Health (the MassCHIP database does not include Devens). In addition, with the adoption of universal health coverage in Massachusetts, the first indicator became less relevant. Therefore, these two indicators were dropped, and five new indicators are proposed with focus on residents and employees health promotion and prevention: "total linear feet of sidewalks and percent of roads with sidewalks," "total linear miles of trails," "total linear miles of bike lanes," "OSHA reported Total Case Rate of injuries and illnesses," and "OSHA reported Days Away from Work case rate." Additional data on the number of businesses offering walking clubs or other programs to promote employee health and wellness were collected through the survey and interviews in 2013 (DEC, 2013). Overall Devens has made progress in three of the five indicator areas (see Table I). Future work will focus on building bike lanes to promote resident and worker health, as well as safety education through DEEC roundtables to address worker health and safety.

Transportation

Providing adequate transportation facilities and alternatives to driving are critical to building a more sustainable community as these relate to air and water pollution, public health indicators, and the preservation of natural resources. Devens has made significant progress since 2000 in all three indicator areas. Some of its achievements include the deployment of double tracks from South Acton to Ayer; the change in commuter rail schedule in December 2009 to allow an early express train from Fitchburg to North Station; the expansion of parking spaces at the South Acton station along with a shuttle to commuter rail stops; the advancement of the Fitchburg Line Reverse Commute project, scheduled to be completed in early 2013; and the significant expansion of the total linear feet of rail available to local businesses. The percent of commuters using alternatives to driving has also increased from 4 to 10 percent. Total miles driven have remained below the threshold identified in the 2010 Devens traffic monitoring report (Veleva, 2012).

Natural resources

The availability of natural resources increasingly limits development and growth. In order to ensure sustainability, communities need to measure and manage carefully their use of resources like water, land, and energy. While all five indicators from 2000 were kept in the indicator set to evaluate progress, indicators "total annual MWh of electricity use" and "therms of natural gas consumed" are both poor measures of excessive energy consumption, which varies significantly with the changing mix of Devens businesses. A better measure would look at the electricity and natural gas used by municipal buildings where a state-wide goal exists to reduce use by 20 percent in FY2012 and by 35 percent in FY2020, compared to a FY2004 baseline. Six new indicators were proposed to evaluate progress in natural resources preservation: "percent of area permanently protected as open space," "percent of impervious surface," "total square feet of former military buildings reused," "municipal buildings electricity use," "municipal buildings natural gas use," and "green buildings square footage as percent of total occupied space." Overall Devens has made a good progress in this area, in particularly increasing the percent of permanently protected land, reducing the percent of impervious surfaces, reusing former military buildings and expanding the "green" buildings from zero in 2000 to 14 percent of all buildings in 2012.

Environmental quality

A key goal of the 1994 Devens Reuse Plan entailed redeveloping Devens while improving its environment and cleaning up sites contaminated by the US Army. The main areas measured in 2000 involved water quality and solid waste. The indicator "open space and recreation plan in place" was dropped because such a plan now exists (and the goal has been achieved), and a new indicator measuring open space was introduced (Veleva, 2012). Six new indicators were added to evaluate air quality (not measured in 2000) and better examine progress toward reuse, recycling, and composting: "total Toxic Release Inventory (TRI) emissions and TRI emissions per 1,000 ft^2 of occupied space," "tons of solid waste reused," "total chemical use and pounds per 1,000 ft^2 of occupied space," "landfill diversion," "number of days per year of HHW collection and total pounds collected," and "percent/number of organizations and households which are composting as well as total pounds/tons composted per week."

Including indicators to measure waste reduction at the source, reuse, recycling, and composting are critical for an eco-industrial park like Devens. Such indicators have gained

in importance as available landfill space declines, tipping fees go up, and new mandates require higher diversion rates. Yet, their measurement is challenging as most organizations do not track such data. Despite the significant achievements in the area of environmental quality, more work remains to be done in the area of waste and emissions reduction where the DEEC can continue to provide leadership by educating and assisting companies.

Discussion

The above analysis of the indicator results demonstrates that overall Devens has made significant progress in most areas over the past decade. Of the 43 indicators adopted in 2012, 29 demonstrate progress ("yes"), seven show lack of progress ("no"), six point to a potential progress ("maybe"), and for one no information was available in 2000 to evaluate progress (Veleva, 2012). Most progress has been made in the following areas:

- the number of organizations based in Devens increased from 60 to 95;

- since its launch in 2007, the DEEC has had some form of interaction with more than 80 percent of the establishments in Devens;

- the number of people participating in community events increased from 120,000 to 300,000;

- all 324 CERCLA sites have been cleaned up and all known USTs removed;

- the total linear feet of sidewalks has doubled from 40,673 to 65,482, representing 57 percent of the Devens roads in 2012;

- the total linear miles of trails has also more than doubled from 5.44 to 12.46 miles;

- percentage of commuters using alternatives to driving has increased from 4 percent to 10 percent;

- freight rail available to local businesses increased from 8,000 to 14,300 linear feet; and

- percent of sustainable/high performance ("green") buildings represented 14 percent of the total square footage of all occupied space in 2012 (no "green" buildings existed in 2000).

While a smaller set of indicators is easier and can be more cost effective to manage, limiting the indicators would not provide the necessary comprehensive feedback on all key sustainability goals pursued in Devens. Considering that updating the indicators is expected to take place every five years, it was decided to keep the number of indicators around 35-40.

Indicators are only tools and in order to be meaningful and actionable, they must be related to and measure-specific goals, targets, or thresholds. Some thresholds were included in the 2000 progress report, but it is critical to include specific goals, targets, or thresholds for each issue area and indicator to assess progress. In fact, developing effective indicator systems should always begin with identifying the main community goals and targets, and then formulating specific indicators to measure progress over time (Table I includes some specific goals and thresholds identified during the research; these were presented and finalized in a public hearing).

The research found that obtaining data on waste generation, recycling, composting, and overall landfill diversion is challenging. While these are key indicators to track by any eco-industrial park, they are challenging to measure since most companies do not have a system in place to track them. In the future DEC plans to hire a contractor to collect such data and further help companies reduce waste disposal.

Interviews with local organizations found that 45 percent of Devens establishments use other companies waste as a raw material but these exchanges included low-value items (e.g. packing sheets, bubble wrap, elastics, furniture, small boxes, and plastic jars). The fact that despite its two-decade long redevelopment Devens still does not have any major exchanges of materials or by-products confirms earlier studies that have identified a range of technical, legal, economic, and organizational barriers (Gibbs and Deutz, 2007). In addition, since most heavy manufacturing has moved abroad, there is less heavy material usage available for major by-product exchanges. In this sense Devens represents an eco-industrial model for light industrial parks, which is more relevant to the US industry presently (Lowitt, 2008). In the twenty-first century knowledge-based economy, Devens case provides empirical evidence in support of Lombardi and Laybourn's (2012) proposal to expand the definition of EIPs to include exchanges of knowledge, information, and expertise, which are sources of innovation and greater business and local competitiveness. A comprehensive set of sustainability indicators for EIPs should include indicators measuring such practices.

The study revealed that MassDevelopment and DEC's investment in redeveloping Devens infrastructure have worked well to attract businesses to Devens. The interviews with local organizations found that the top reason for firms to locate to Devens is the access to good infrastructure (roads, trains, and green buildings), identified by 67 percent of participants (other reasons included the lower cost of real estate at 59 percent, and tax benefits at 52 percent). Expedited permitting (37 percent) and ability to collaborate with other businesses (33 percent) were also important factors for locating to Devens (DEC, 2013). These are important insights for developers and policy makers interested in advancing eco-industrial park development.

Interviews with local organizations also confirmed that Devens' current initiatives were in line with the top sustainability needs of the majority of local organizations (61 percent of interviewees identified reducing the cost of energy and the cost of materials as their top challenges). Many organizations have benefited from the collaboration activities facilitated by DEEC and many more were open to the idea of collaboration. Interviews with local firms found that 86 percent of Devens organizations partnered with others locally (on average each interviewed organization collaborated with 2.5 other Devens firms) and 79 percent saw opportunities to benefit from partnerships with others in Devens (e.g. from shared space and contingency space use, joint purchasing, services and waste disposal, training, sharing contractors, and suppliers) (DEC, 2013). These are all important indicators to measure and report when evaluating progress at EIPs as they can be a source of sustained competitive advantage for participating firms (Barney, 1991).

The study of Devens EIP development provides empirical evidence of the role that institutional capacity plays in developing EIP networks. Such capacity has three dimensions – relational capacity, knowledge capacity, and mobilization capacity (Boons and Spekkink, 2012). Through the educational and other events offered for Devens companies, DEC and DEEC are helping local organizations develop "stronger personal and professional relationships and increased trust in each other, which increases the likelihood that the stakeholders will begin to share and jointly produce knowledge and negotiate potentially conflicting issues" (Boons and Spekkink, 2012).

With its workshops and roundtables as well as the Great Exchange, DEEC has played a critical role in promoting shared knowledge and learning, building trust and encouraging environmentally favorable behavior among firms located in Devens and neighboring communities. This confirms previous studies that have examined the role

of social factors, including champions, in advancing collaborations and cooperative approach to resource management (Ashton and Bain, 2012; Boons and Spekkink, 2012). By creating a separate entity focussed on promoting IE principles and greater collaborations among local firms, Devens has put in place the necessary institutional infrastructure to ensure activities will continue even in case of personnel changes and loss of key IE champions.

The case of Devens confirms that "developing EIPs is likely to be a long process where immediate results are unlikely to be forthcoming" (Gibbs and Deutz, 2007). Devens' two-decade long journey demonstrates that EIPs can serve as a means for advancing sustainable local development. In this process sustainability indicators can serve as a key tool for measuring and guiding progress toward established goals, promoting transparency and accountability, and educating local community and companies about sustainable local development. Such indicators, however, must move beyond the traditional measures of energy and materials efficiency, by-product exchange and landfill diversion, to include measures of social sustainability, firm sustainability and governance.

While each eco-industrial park will have its own sustainability vision for redevelopment, Devens' framework and most of its sustainability indicators can be adopted by other EIPs. Benchmarking progress is critical for identifying gaps and opportunities, raising awareness and engaging stakeholders to promote and advance a common sustainability vision. While indicators are only a tool and they cannot alone lead to change, Devens experience demonstrates the critical role of sustainability indicators and local champions in identifying and addressing key challenges by adopting a transparent and inclusive process, supportive policies, and providing technical assistance for local companies. Future research should aim to develop a set of common indicators for EIPs as well as guidance on developing supplemental, location-specific indicators to measure and report progress.

Conclusion

Key to Devens EIP success is its vision that serves community and business interests, a plan to achieve that vision, a collaborative structure to implement the plan and a viable process to measure progress, revisit goals, and refine plans and strategies as conditions change. The case of Devens demonstrates that successful development of EIPs is a slow process and requires establishing an organization focussed on identifying and facilitating networking activities and collaborations. In this process sustainability indicators have served as a valuable tool to raise awareness, promote transparency and accountability and guide local policies toward established goals and targets.

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