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Potential for Eco-Industrial Park Development in Moncton, New Brunswick (Canada): A Comparative Analysis

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Abstract: Eco-industrial development projects are increasingly popular because of their ability to transform the traditional model of industrial parks into more sustainable forms of economic development. Still, few industrial parks worldwide have achieved the high degree of eco-transformation that characterizes eco-industrial parks (EIPs). Assessing the potential for eco-industrial development at the park or regional scale is an important step towards this goal. This study aimed to assess the potential for ecological development of a growing industrial park (Caledonia Industrial Estates (CIE), province of New Brunswick, Canada) following the principles of industrial ecology. A baseline survey of CIE businesses was conducted. The results were compared to results from similar assessments in three other industrial parks across Canada, located in Nova Scotia, Ontario and Saskatchewan. The main categories used for comparison were business variety and size, public transportation, green spaces, energy and material use, and environmental management organization. While showing that CIE has EIP potential, the results revealed similarities and differences between the industrial parks studied, some of which were related to barriers limiting the efficient use and sharing of resources. One way that was identified that could help CIE incorporate eco-industrial activities into their operations would be the appointment of an environmental management organization or a shared environmental manager. Strategies to foster EIP development, in general, are also identified. These findings, based on actual business experiences, can help determine which actions and activities are suitable for CIE and other business communities that consider eco-industrial development as their next phase. They are particularly relevant to industrial parks in a development or redevelopment phase.

Keywords: eco-industrial development; eco-transformation; industrial ecology; eco-industrial parks; baseline survey; barriers and opportunities

1. Introduction

Industrial ecology has emerged as a promising multi-disciplinary science for working towards achieving sustainable development of industrial systems [1]. In 1989, Frosch and Gallopoulos published a seminal work in this field, encouraging a transition from traditional industrial activities to a more integrated model of industrial activities—an industrial ecosystem. They described an industrial

ecosystem as a system in which "the consumption of energy and material is optimized, waste generation is minimized and the effluents of one process (...) serve as the raw material for another process" [2]. Industrial parks have since been identified as models of industrial ecosystems. In these eco-industrial parks (EIPs), businesses are encouraged to interact with each other and form networks of relationships in an attempt to mimic natural ecosystems and their sustainable functioning. Material and energy flows in EIPs should be (re)organized and integrated in such a way that they coincide with the material and energy flows of natural ecosystems [3,4].

Kalundborg, Denmark, is a well-known example of an industrial ecosystem [5]. It is often mentioned as a model of industrial symbiosis (IS), a term used in industrial ecology to describe traditionally separate industries that engage in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products [6], as well as knowledge sharing and long-term cultural change [7]. Kalundborg IS is considered unique because plant owners and managers live in the municipality, were not competitors and were all members of the local sport and social clubs, such that they were able to discuss their business operations in complete transparency. Consequently, this regional IS developed without being planned for at the outset [8]. Thus, one of the main conditions identified as being essential for development of similar projects elsewhere is cooperation and open information exchange between different plant managers. Analyses of Kalundborg's successful IS emphasized the importance of short "mental distances" (in analogy with the relatively short geographical distances also involved), trust, openness, and communication among company managers [9,10]. The size and diversity of the companies involved is also important [11,12]. In the case of Kalundborg, it is not located in a formal industrial park or estate, which is why some scholars do not call it an EIP, but rather an IS or "eco-industrial network" (the various terms used in the literature to refer to industrial developments focused around environmental management were summarized by Massard *et al.* [13] and Tudor *et al*. [14]). Still, it is often cited as the original inspiration for EIP development.

While there is no generally accepted definition of an EIP, there is general agreement that a broad systems definition, such as those given by the U.S. President's Council on Sustainable Development [15] and Lowe [16], should be used [17]. These definitions are in contrast to more constrained definitions [18] that adopt a narrow focus on company by-product exchanges (or "eco-chains") as the primary purpose of creating EIPs. Lowe [17] emphasized that the "eco" in EIP stands for economic as well as ecological benefits; he argued that a full systemic definition of an EIP is preferable because it offers more strategies to support the realization of a circular economy, also called "closed-loop" economy. As a recent shift in economic thinking, drawing in part on industrial ecology principles, circular economy has gained momentum and support in several countries, especially China, Germany and Japan [19–21]. The role that EIPs can play in achieving a circular economy has attracted renewed interest since China made circular economy its national development goal and promoted EIPs as one of the main drivers for achieving this goal [22–24]. EIPs and IS have also risen on the agenda of global institutions such as UNEP and the World Bank [25]. In 2010, the OECD cited IS as a form of "systemic innovation vital for future green growth" [26].

Local governments also play important roles in eco-industrial development, a process also known as "eco-restructuring" or "eco-transformation". Traditionally, economic developers are interested in job creation and bringing in new investments to their community. Alternative economic development is a tool they can use as a catalyst for change. This type of development addresses other issues such as environmental quality, health benefits, local impacts and job creation that provide better wages, increased productivity and greater economic multiplier effects [27]. Although local governments tend to be more interested in new industrial parks or sites than in older ones, their commitment to the redevelopment and revitalization of older sites is equally important for sustainability [28].

Despite numerous examples of EIP and IS initiatives either operating, planned or in development in various countries [13,29–31], few have garnered the success of Kalundborg [6,32,33]. In Canada, there has been little policy leadership or financial support by the federal and provincial governments

with regard to EIPs, even though they have espoused sustainable development and Burnside Industrial Park in Dartmouth, Nova Scotia, was the home of the world's first investigation into industrial parks as ecosystems. The leadership in Canada has come largely from municipalities which are responsible for the development and operation of most of the country's business and industrial parks. The spurs for many of these initiatives have often been academics and consultants, as is the case in the present study. However, at this time, no fully functional EIPs have been established in Canada, although a number of initiatives have been taken in the provinces of Alberta, British Colombia, Quebec, Ontario, New Brunswick and Nova Scotia. This contrasts with the situation in at least some countries where the national government has taken a leadership role. For example, in the early days of EIPs, it was the U.S. President's Council on Sustainable Development which promoted the concept endorsing several demonstration projects. Since then, the leadership has come from state and local organizations. Elsewhere, national governments in China, Thailand and South Korea have actively supported EIPs. In other countries, the champions have come from academia, municipal governments and provincial or state governments.

According to the attempts made to identify EIP and similar eco-industrial initiatives [6,29], only a small fraction of industrial parks in operation meet the definition and criteria of EIP or IS. For example, improved environmental performance of a business site, although a good start, does not warrant EIP status. Minimum requirements for EIP consideration [28,29,34], and criteria for examining the success of eco-industrial initiatives [23,35] have been proposed, but there are as yet no generally accepted performance standards nor indicators to monitor EIP development. Success and limiting factors have been identified [13,32]. However, since there are so many variables to take into consideration when designing and implementing EIPs and since there is insufficient experience at present to offer practical solutions for the obstacles facing EIP development [32], attracting businesses that will want to work together and develop potential for EIPs or IS is not a simple task [14,36,37]. At the various levels involved, including the individual firm level, the inter-firm level and the regional and governmental level [38], planners and decision-makers are eager to know what actions can be taken to promote the development of EIP in their specific settings and context. Likewise, it is important that the evolving status and potential of existing industrial parks in regards to eco-industrial development be better known.

This paper explores the eco-industrial development possibilities of a growing industrial park, the Caledonia Industrial Estates (CIE), located in Moncton (population 138,000 for Greater Moncton), the second largest city in the province of New Brunswick, on the East Coast of Canada. Comprised of a total of 670 ha, CIE is considered one of the hubs of economic development in the region, with important potential for further development [39]. Like most other industrial parks in Canada, there is no previous research on CIE's potential for EIP development. The objective of this study was to conduct a baseline analysis of businesses in CIE and compare these results with similar analyses done in three other industrial parks in Canada that had baseline information collected as part of eco-industrial initiatives.

2. Methods

2.1. CIE Data Collection

All businesses in CIE were invited to participate in a survey and initially contacted by phone to ask if they were available for an onsite interview. Of the 88 businesses contacted, 45 agreed to participate, representing 51% of total businesses in CIE. Once businesses agreed to participate, a meeting was scheduled with a knowledgeable employee (e.g., owner or manager) in order to administer the questionnaire, which took approximately 30 min. The questionnaire (twenty five questions) was divided into four sections, namely operations, currents practices, infrastructures and future initiatives. Employees were asked to identify quantities and sources of inputs (materials and energy) and outputs (products and wastes) of their respective businesses [40]. They were asked about their corporate

attitude in regards to environmental issues and to list the activities that would encourage their business to participate in eco-industrial initiatives. In addition, questions were asked about the number of employees as well as methods of transportation used by employees to get to their place of employment.

The survey sample contained a relatively wide variety of business categories (ten in total), with distribution and sales and service being the most common. Businesses that agreed to participate in the survey employed a total of 1923 full-time and 255 part-time employees. Amongst those interviewed, 9 businesses had less than 10 employees (micro), 24 had between 10 and 49 employees (small) and 12 had 50 or more employees (medium). None of the businesses interviewed had more than 500 employees. For some questions that used a Likert scale ranging from 1 to 5, the t-test was used to compare the scores [41].

2.2. Comparative Analysis

Using its baseline information, CIE was compared to three other industrial parks in Canada, based on business variety and size, green spaces, energy and material use and public transportation. These industrial parks are not currently considered as EIPs but they have been the focus of some eco-industrial development activities: Burnside Industrial Park, Dartmouth, Nova Scotia (NS) [42]; Pearson Eco-Business Zone (PEBZ), Toronto, Ontario (ON) [43]; and Ross Industrial Park, Regina, Saskatchewan (SK) [44], hereafter referred to as Burnside, PEBZ and Ross, respectively. Comparison was made on how the scope, composition and setup of an industrial park may influence its eco-industrial development according to the conceptual framework of industrial ecology for EIP development [10,45].

3. Results and Discussion

3.1. Results for Caledonia Industrial Estates (CIE)

Results for CIE showed that 67% of the businesses surveyed own their buildings, while 33% are leasing, which means that the majority of businesses have easier opportunities to renovate, upgrade or change the design of their building. Natural gas is available throughout CIE and 53% of businesses surveyed use it for space heating. A further 33% of businesses use electric heat, 9% use heating oil, 3% use propane and 2% use wood. In addition, 76% of businesses use electric energy to heat domestic water or for manufacturing processes, followed by natural gas at 15%, oil at 6% and propane at 3%.

Businesses were asked to identify barriers that limit their capacity to improve their energy efficiency (Table 1). Accordingly, 24 respondents (47%) claimed that there are no barriers that limit their capacity to improve their energy efficiency, contrary to a number of studies that identified financial and technical barriers to improve energy efficiency [46]. Drawing from the discussions during interviews, it appears these businesses are satisfied with their status quo with regards to energy efficiency. Raising awareness and giving out information on ways that businesses in CIE can improve their energy usage might help these businesses identify barriers and present solutions to overcome them. For the respondents that did identify barriers that limited their capacity to improve energy efficiency, cost was the most common. Results suggest that businesses are hesitant to invest in energy efficiency renovations or upgrades because they feel there are too many risks involved. Respondents explained that if they would have access to tools (e.g., energy audits) that would help them calculate payback periods on their investments, and to information regarding government grants and financing, they may be more willing to undertake energy efficiency projects.

Businesses were also surveyed on inventory inputs (materials and energy) and outputs (products and waste). While most of the businesses did not systematically quantify volumes of all inputs and outputs, it was noted that some businesses were better than others at tracking their material consumption. The general observation was that the larger businesses (medium-sized businesses in our case) were better at tracking the use of resources and materials. This has been noted in other surveys involving small and medium enterprises (SMEs) [42,47]. Notably, one particular business in the manufacturing

category was able to explain how waste product was being shipped for recycling through specific pathways (often for a profit) and provide the exact percentage of waste going to landfill, as well as pointing out areas worth considering to further reduce the percentage of landfill waste in the future.

Table 1. Barriers limiting the capacity of businesses in CIE to improve energy efficiency.

Barrier	Number of Times Mentioned	% of Times Mentioned
No barrier	24	47
Cost	17	33
Lease building	4	8
Not enough knowledge	2	4
Building design	2	4
Corporate headquarters	1	2
Time	1	2
Total	51	100

Businesses were supportive of initiatives that would make use of their waste for a productive and environmentally acceptable activity. On a scale of 1 ("never")–5 ("always"), the average was 4.7. A few of the respondents identified some interesting opportunities that might already exist in the park. Most of these opportunities related to their own operations, while others could be applied to the park as a whole:

- Retrieving heat from machinery
- Making better use of railroad transportation
- Retrieving hot water for heat transfer
- Recycling their own products instead of shipping them away
- Ensuring trucks coming back from deliveries are filled
- Composting waste products
- Finding uses and buyers for waste products
- Finding a use for used pallets.

CIE businesses were also asked to identify barriers regarding the level of support they would give to initiatives that aim to maximize waste usage through productive and environmentally acceptable activities (Table 2). Cost and time were the most frequently mentioned barriers that would influence whether businesses would participate in waste reduction initiatives. However, 16 businesses (29%) said that they would have no barriers for the support of waste reduction initiatives, which suggests they are open and willing to find ways of reducing the amount of waste generated in CIE.

Table 2. Barriers identified by businesses in CIE that limit their capacity to support opportunities to make use of their waste for a productive and environmentally acceptable activities.

Barrier	Number of Times Mentioned	% of Times Mentioned
Cost	19	35
No barrier	16	29
Time	10	18
Must have low impact on business operations	5	9
Corporate approval	4	7
Participation from all CIE businesses	1	2
Total	55	100

The most common mode of transportation used by CIE employees to get to work is a personal vehicle. Of the 2178 employees in the 45 businesses interviewed, about 1688 use their personal vehicle. Interestingly, carpooling is the second most popular mode of transportation to get to work, with 189 employees involved in carpooling. Bus transportation was the 5th most important mode of transportation, with 56 employees. Another factor that influences employees chosen modes of

transportation is parking space. For the 2178 employees, there are roughly 2588 parking spots in CIE. In other words, there are 19% more parking spots than there are employees in CIE.

The survey indicated that businesses are aware of the links between the environment and the economy. When asked if they thought it was important for industry to consider its impact on the environment, on a scale of 1 ("not at all")–5 ("very strongly"), the average response was 4.8. However, businesses appeared to distinguish between the environment as a general issue and climate change as a more specific issue. When asked if climate change is an important issue for their enterprise, the average was 3.7. This average is still high, but when compared to the environment in general, the difference is significant ($t(44) = 5.56$, $p < 0.001$). It is also noteworthy that many interviewees thought that climate change was an important issue personally, but downplayed their business's responsibility towards climate change.

3.2. Comparative Analysis of the Eco-Industrial Potential of the Four Industrial Parks

The results of the CIE survey were compared to the results of similar assessments conducted at Burnside, PEBZ and Ross. Burnside's industrial ecosystem project was initiated in 1992 when this park was targeted as a test site for the application of industrial ecology principles. At that time, researchers gathered their baseline data from a survey sample of 278 of 1200 businesses in the park of approximately 3000 ha. The purpose of the survey was to "gather information on the nature of the raw materials used and wastes generated; the types of facilities; attitudes toward and opportunities for pollutions prevention; and perceptions of the most important factors which would influence business people to change current practices" [42]. In 1996, Burnside was profiled with the objective of creating an EIP [6,15]. PEBZ includes an estimated 12,500 businesses over 12,000 ha of industrial and commercial land. It is a zone that brings together 23 business parks in an attempt at eco-industrial development [43]. The first phase of the Ross project was completed in 2006 by Eco-Industrial Solutions Ltd. [44], which presented a report on an overall summary of the resource baseline of more than 400 businesses in an area of almost 800 ha.

Several factors influencing the development of EIPs [13,14] are considered in comparing CIE, Burnside, PEBZ and Ross at baseline, as discussed below. A subsequent comparison, established between CIE and PEBZ, focuses on the barriers to eco-industrial development that were identified by businesses.

3.2.1. Categories of Businesses

When comparing the most common categories of businesses from all four industrial parks, CIE was found to be similar to the other three industrial parks (Table 3). However, when developing eco-industrial projects, developers must keep in mind that business categories must be diversified to ensure that materials and energy can cycle through efficiently. The involvement of a diverse range of firms with complementary material needs was found to be one of the measures that enhance the success of EIPs [14]. Geng and Côté [48] emphasized the importance of encouraging a large and diverse array of producers, consumers, scavengers and decomposers which take on roles that promote the cycling of materials. In an industrial system, metaphoric "scavengers" [49] are businesses that recover and separate materials and by-products while decomposers transform these products into useable resources. They mimic natural ecosystems with regards to cycling of materials [50]. When the study was conducted, three (6%) businesses could have been considered scavengers and decomposers in CIE. Burnside had 69 (5%) and PEBZ was estimated to have about 400 (3%). Even though CIE appears to have a similar proportion of these types of businesses compared to Burnside and PEBZ, a good strategy would be to try to attract more businesses of this type. Our results show that many materials are currently shipped outside the area or even outside the province for recycling or disposal.

Table 3. Main business categories present in each of the industrial parks considered [a].

Rank	CIE (NB)	Burnside (NS)	PEBZ (ON)	Ross [b] (SK)
1	Distributors	Contractors	Services	Trucking
2	Sales and service	Distributors	Manufacturing	Transportation
3	Manufacturing	Manufacturing	Retail	Logistics
4	Transportation	Printers	Wholesalers	

[a] For each industrial park, main categories represent more than 70% of respondents; [b] For Ross Industrial Park, the information in this table is from Transport Canada [51].

3.2.2. Size of Businesses

In comparison to the other industrial parks in the sample, CIE is smaller in terms of number of businesses (Table 4). Similar to the three other industrial parks, it is predominantly made up of micro and small businesses, albeit with a smaller ratio of micro businesses. Further, businesses in CIE with 1–49 employees represented 73% of total park businesses, compared to 93% and 92% in Burnside and Ross, respectively. PEBZ had 78% of businesses with 1–19 employees. Inversely, 27% of CIE businesses had 50 employees or more, while Burnside had 7% and Ross had 8%. This may reflect the age of the park, the nature of the development process or specificities of the region.

Table 4. Size of businesses in each industrial park, by number of employees.

Business Size	CIE (NB)	Burnside (NS)	PEBZ (ON)	Ross (SK)
Micro: 1–10 Small: 11–49 50 or more	9 (20%) 24 (53%) 12 (27%)	148 (53%) 111 (40%) 19 (7%)	1–19 employees = ~9725 (78%) 20–500 employees = ~2600 (21%)	83 (60%) 44 (32%) 11 (8%)
501 or more	-	-	500–999 employees = ~170 (1%)	2 (1%)
1000 or more	-	-	1000 or more = 5 (<1%)	-
Total [a]	45 (100%)	278 (100%)	12,500 (100%)	138 (100%)

[a] Total numbers for CIE, Burnside and Ross represent the number of businesses in their respective survey samples, while the total number for PEBZ corresponds to the total number of businesses in the Eco-Business Zone.

3.2.3. Public Transportation

Public transportation appeared to be a challenge for CIE, Burnside and Ross. CIE has one bus route (one bus stop) servicing 88 businesses, Burnside has 7 routes (10 bus stops) servicing 1500 businesses, and Ross has one route (3 bus stops) servicing more than 500 businesses. This might explain why 81% of CIE employees take a personal vehicle to work and at least 95% of Ross workers drive to work (data not available for Burnside). All three industrial parks have been designed to accommodate people driving in, complete with parking spots to spare. For the majority of businesses in Burnside, parking was not a limiting factor (there appears to be no correlation between the amount of parking spaces needed and those that are available) [42]. For Ross, there are almost 4700 parking spots for close to 6600 employees. CIE had by far the lowest employee/parking spot ratio, with 19% more parking spots than there are employees, which can be seen as counterproductive to promoting more environmentally sound modes of transportation. However, despite the available parking, it is estimated that 9% of employees carpool to work. This may be because the park is located at the outer limit of the city or because people tend to know each other due to the relatively small size of the Moncton community.

Also, the design of these industrial parks can discourage walking or biking to work, because there are little or no sidewalks or bicycle lanes. Given the fact that CIE is somewhat distant from residential neighborhoods, the best scenario might be to encourage carpooling, especially since park employees seemed to already be open to this idea. As for PEBZ, it benefits from the Smart Commute Program which offers services to member businesses to help promote commuting options such as

carpooling [43]. Although this is perhaps more suitable to urban regions with larger businesses that have the resources to coordinate such a program, one could potentially be tailored and developed to fit the needs of CIE.

3.2.4. Green Space

Besides affecting the aesthetics of a location, large parking lots influence the ecological integrity of industrial parks, since water runs off into the sewer systems rather than percolating to the soil. To increase the ecological integrity of industrial parks, as well as their attractiveness, the spatial perspective provided by landscape ecology is considered important in conceptualizing and planning EIPs [14]. Imitating the plush lawns and the manicured groupings of trees, bushes and flowerbeds typically introduced in suburbia would not be ideal for industrial parks either. Rather, their vegetation and landscape should imitate, or even better, blend into the indigenous diversity found in natural ecosystems [52].

Burnside has several lakes and wetlands remaining, including an engineered wetland which enhances the treatment of leachate from a former landfill and stormwater runoff from current industrial developments. Wetlands play an important function in site drainage and provide habitat and food for a variety of wildlife [53]. This industrial park is estimated to have more than 8% of total surface as scrub vegetation and trees [42]. PEBZ is also quite deprived of green spaces and those that remain are isolated from one another, which further fragments any remaining habitat. The park is estimated to have approximately 1000 ha (8%) of natural cover remaining, with the possibility of expanding to 1230 ha. Ross has only 5.6% of green space, with an estimated 4.7% of it being landscaped. The few green spaces remaining are weedy uplands areas, a "semi-natural" wetland and a few grass species that were introduced after development [44].

CIE boasts the Humphrey's Brook Trail which runs for 1.7 km along Humphrey's Brook, which is part of a larger network of trails. Because CIE is still in its early stages of development, it still has many green spaces that remain intact. Park management should be proactive and make the best ecologically-sound use of these precious green spaces when planning further industrial development, notably to preserve their environmental benefits [53].

3.2.5. Energy

The parks studied are located in similar climates with relatively long winters. Ross and PEBZ did have qualitative data on electricity and natural gas consumption. With these data, it was possible to estimate the percentage of businesses using electricity, natural gas or other sources. As shown in Table 5, CIE appeared to be on par with the other industrial parks in terms of the ratio between electricity and natural gas usage. This is despite the fact that the fuel sources for electricity generation vary among the four provinces, with the dominant sources of energy for electricity generation across the four provinces being large greenhouse gas emitters and generators of nuclear waste [54,55].

Table 5. Estimated proportions of businesses, in each industrial park, using different types of energy.

Business Energy Usage (% Businesses/Industrial Park) [a]			
Type of Energy	**CIE (NB)**	**PEBZ (ON)**	**Ross [b] (SK)**
Electricity	33	38	33
Natural Gas	53	52	67
Other	14	10	Unknown
Total	100	100	100

[a] Data not available for Burnside; [b] Total for only those businesses for which SaskPower provided electricity consumption data.

Other sources of energy were used by CIE businesses, such as oil, propane and wood. Wood is classified as biomass in New Brunswick and considered a form of renewable energy [56], but only 2%

of CIE businesses use wood as their heating source. Oil and propane, used by 12% of CIE businesses, are known to produce larger amounts of greenhouse gases than natural gas. One micro business in particular used propane to heat its repair shop, which is very costly. The owner explained that most of the heat was escaping through the roof or out the bay doors of the repair shop. These are all businesses that would benefit from energy efficiency tools or support programs, such as energy audits or eco-efficiency workshops. With the help of these tools, businesses could lower their energy consumption, save on heating costs and decrease their greenhouse gas emissions.

3.2.6. Materials

Globally, generating and managing waste has long been an expensive environmental and social issue. Materials that businesses have paid for but have not been able to extract value from are often referred to as "waste". Fortunately, the definition of waste is slowly changing. It is increasingly realized that there is value in waste and that it can be considered a resource [6,49,57]. EIPs have been shown to be most efficient when there is an agglomeration or clustering of organizations to utilize waste as a resource. This proximity generates externality savings, economies of scale (by reducing operation costs) and encourages innovation (through the development of new industries) [14,58]. This contributes to the realization of a more circular economy, *i.e.*, one that maximizes resource efficiency and minimizes waste production [59].

All four industrial parks in this study had one thing in common with regards to "waste": they generate large amounts. Data were not available for the most commonly wasted materials at Ross and PEBZ. However, Ross did provide a thorough list of manufacturing inputs and outputs, as well as materials flowing through warehouses and distribution centers. Even though this list cannot be used to compare with material usage in other parks, it serves to illustrate the variety of materials that circulate in industrial parks, in agreement with the observations made by others [48,57].

Concerning Burnside and CIE, Table 6 lists their most frequently wasted materials. Since both industrial parks each have distributors and manufacturers in the top four most common categories of businesses (Table 3), it is conceivable that they generate similar types of waste. Considering the 17-year separation period in the baseline data for Burnside and CIE, and the fact that the same results were found for most frequently wasted materials in CIE, our observation suggests that not much has changed in material use. Cardboard, paper, plastic and wood are most commonly found in packaging materials or pallets, which flow through almost any category of businesses, whether they are distribution or manufacturing businesses.

Table 6. Most frequently wasted materials in CIE and Burnside.

CIE (NB)	Burnside (NS)
Cardboard	Paper
Plastic	Cardboard
Paper	Wood
Wood	Oil (heating) [a]
Petroleum hydrocarbons/fluids	Electric (heating) [a]
Metal	Steel

[a] Heat wasted from the burning of oil or the use of electricity in machinery or processes.

One common problem faced by businesses in CIE in particular, regarding packaging materials, is that these are often made of more than one material or with a combination of components (e.g., glue, ink), making the materials notoriously difficult to recycle. On one hand, businesses do not like to see their employees spending too much time separating packaging materials to send to recycling. On the other hand, some packaging materials simply cannot be recycled at the present time because there are no local facilities equipped to handle them. Furthermore, some distribution practices make it impossible to recycle packaging materials. In one particular instance, an employee explained that

they use Styrofoam coolers to ship their product. Canada's Food and Drugs Act and Regulations prohibit the reuse or recycling of these Styrofoam coolers because of the nature of the product being shipped. Nonetheless, some businesses in CIE managed to reuse some of their packaging materials (e.g., cardboard) and recycle others (e.g., cardboard, paper, plastic). With further research or materials efficiency audits, opportunities could be found to further reduce the amount of currently wasted materials.

3.2.7. Environmental Management Organization

In contrast to other industrial parks in the study, CIE does not have an environmental management organization or a shared environmental manager. Between 1998 and 2012, Burnside received some assistance from the Eco-Efficiency Centre, a non-profit, non-government environmental management support center for small and medium-sized enterprises [6,60]. Ross receives assistance from the Regina Eco-Industrial Network Association (REINA), a membership-based, non-profit corporation working to improve the economic and environmental performance of Regina businesses, with a particular emphasis on Ross. The PEBZ project is managed by Partners in Project Green, an organization of the Toronto and Region Conservation Authority, where research projects and assistance programs are undertaken by three staff members [61]. For the success of EIPs, it has been argued that the existing management means of businesses in the park should be used as much as possible [28]. Other measures found to enhance the success of EIPs (e.g., the existence of a widespread support system; strategies to ensure full integration of environmental, ecological and spatial concepts; regular monitoring to ensure ecological goals) [14] benefit from adequate management. As noted by Kolpron Consultants, cited by Pellenbarg [28], an important challenge for the management of eco-industrial sites is to achieve gains both in ecological and economical terms. They introduced the term "Park Management" as a general strategy to attain this goal. This is consistent with recent findings showing that, for successful development and operation of eco-innovation parks, the success factor with the highest occurrence is related to the organizational and institutional setup of the parks and more specifically to the presence of an effective coordination body [13], also referred to as a management body [62]. A study of EIPs in Italy found that the main activities carried out by EIP management bodies were managing the environmental services for the companies and managing the development and promotion of the EIP through communication and dissemination initiatives [62]. One of the main roles of the management body was found to be the consultation with local stakeholders [62]. In practice though, EIP development with a comprehensive environmental management system at the park level is a relatively new concept [32].

3.3. Comparisons of Barriers Encountered at PEBZ and CIE

In 2008, a report published by the Toronto and Region Conservation Authority (TRCA) presented the strategy of Partners in Project Green: A Pearson Eco-Business Zone (PEBZ) [43]. This report had the most complete set of data that could be used to compare the results and the information that were obtained from the research with CIE businesses. The PEBZ project's vision is to work with local businesses in transforming the lands surrounding Toronto Pearson Airport into an internationally recognized eco-business zone. To get an idea of how businesses and local municipalities felt about introducing eco-industrial activities into their area, workshops were organized during which participants were encouraged to identify and discuss the potential challenges or issues associated with eco-industrial activities. Businesses in PEBZ came up with five main types of barriers associated with eco-industrial activities. As shown in Table 7, a comparison was made between the barriers identified by businesses from PEBZ in 2008 and the barriers that were most commonly mentioned by CIE businesses in our survey. Despite the differences in size and location of the businesses, similarities were found in the barriers, while differences noted may help to understand the challenges businesses face when asked to take an active role in eco-industrial initiatives.

Table 7. Comparison between five main types of barriers associated with eco-industrial activities in CIE and PEBZ.

Main Types of Barriers [a]	CIE (NB)	PEBZ (ON)
Costs	Costs of upgrading or renovating to improve waste and energy efficiency.	Costs of "going green"—business perceptions of how much it will cost to adopt green practices. Need for business cases that are related to local conditions.
	A better understanding and knowledge of financial benefits would encourage businesses to conduct energy or material efficiency audits.	
	Cost of supporting initiatives that would make use of waste for productive and environmentally acceptable activities.	
Roles and responsibilities	Some businesses mentioned grants, financing or low-interest loans to help with energy efficiency (e.g., role of government).	Businesses do not need to rely on public sector handouts, but do need guidance.
		"Disconnect" between staff and senior management.
	Some businesses would need to get approval from corporate headquarters to participate in eco-industrial activities.	How to convince senior management and where to get guidance?
Risks		Perceived liability issues.
		Difficulty in getting businesses to share information to overcome the 'business as usual' around directly sharing information with competitors.
Knowledge	Lack of time to learn about how to improve their environmental performance.	Lack of time and incentives for businesses to learn about what is involved, what is required of them, what are the potential benefits.
	Lack of knowledge about programs and information already available.	
	Get to know neighboring businesses and share useful information that would promote eco-industrial activities.	
Regulations	Some confusion between environmental regulations and non-environmental regulations (health and safety, food and drugs, *etc.*).	Outdated regulations do not support innovative business practices.
	Significant influence from customers, society and the economy instead of regulations.	
	Many businesses interviewed surpassed regulations.	

[a] Barriers are listed in no specific order.

3.3.1. Costs Barrier

The costs barrier was similar for both PEBZ and CIE. Businesses seemed hesitant to invest in "green" technologies, whether it be for upgrades, renovations, more efficient processes or changes in business practice. In both locations, businesses need to be convinced that they will get a reasonable payback or return on investment when adopting greener practices. For example, in CIE, businesses reported that they would be reluctant to spend money to improve their energy efficiency, especially during a period of economic downturn and uncertainty. Furthermore, results indicated that the biggest incentive CIE businesses would need to complete an energy audit would be to have a better understanding and better knowledge of the cost reduction that could result from audits. The same was reported for a material efficiency audit.

3.3.2. Roles and Responsibilities

There are both similarities and differences between PEBZ and CIE in terms of barriers relating to business roles and responsibilities. Businesses in the PEBZ tend to seek guidance while only few CIE businesses sought financial assistance. This difference may be explained by the fact that PEBZ has a greater number of larger businesses than CIE, which are generally better positioned to meet the resource and financial requirements of eco-industrial activities. Business size may also affect the way employees and senior management communicate. PEBZ businesses mentioned a "disconnect" between staff and senior management. There was no mention of this in CIE. In fact, most of the business managers at CIE were proud to speak of the involvement and participation of their employees in environmental initiatives (e.g., recycling, green committees). One challenge mentioned by some CIE businesses is that when they are a branch of a national or international corporation, managers must obtain permission from corporate headquarters to participate in eco-industrial activities.

3.3.3. Risks Barrier

Businesses in PEBZ seemed hesitant to participate openly in eco-industrial activities because of the risks associated with sharing information with potential competitors. A few businesses in CIE, especially the large ones, expressed similar concerns. However, smaller businesses in CIE would like to see more communication and sharing of information among businesses in the industrial park. One respondent mentioned that its business would like to get to know its neighbors and felt that this would create a sense of community in the park, which in turn would help identify potential business opportunities. This highlights the advantages and disadvantages of trying to integrate eco-industrial activities into industrial parks of different sizes and locations. A smaller park like CIE is comprised mostly of micro, and small and medium businesses that feel they can greatly benefit from working together with neighboring businesses. They feel they can trust their business community and improve their operations by collaborating together. In contrast, industrial regions such as PEBZ are so large that getting to know neighbors and developing a sense of community might be challenging. Hansen [63] argued that large industrial projects can be intimidating to neighboring business communities and that they often have difficulty forming linkages with the regional milieu. This difficulty may exist in large eco-industrial projects as well.

3.3.4. Knowledge Barrier

Both PEBZ and CIE seemed to experience similar knowledge barriers when facing the potential arrival of eco-industrial activities. Businesses at both locations did not want to spend too much time and effort on these initiatives. To be given serious consideration, eco-industrial activities would have to impact minimally on the daily operations of businesses and not negatively affect the economic bottom line. These findings echo those of a survey of sustainable business sites in development in the Netherlands, which found that the most frequently reported activities (called "sustainable actions") initiated or under consideration in the parks surveyed were the most easy to realize and corresponded to the lower ambition level [28].

Both PEBZ and CIE businesses seemed to lack awareness of the potential benefits associated with eco-industrial activities. While reporting they would be open to participate, they seemed to lack understanding of the potential offered by energy and resource savings. Eco-industrial management organizations, therefore, need to raise the awareness of businesses on the economic, social and environmental benefits associated with eco-industrial activities. Using case studies and examples that show how such programs can be run successfully could be an efficient approach in communicating with businesses in industrial parks [60].

All businesses in CIE were micro to medium businesses and over 80% of businesses in PEBZ were micro to medium businesses. The situation was similar in Burnside with a large proportion of SMEs. This should be given close consideration because there may be a difference in how to deal with

SMEs compared to larger businesses when trying to convince them to do more for the environment. In a report published by the Canadian Federation of Independent Business (CFIB) in 2007 [64], the main factors preventing SMEs from across the country from doing more for the environment were identified as: "not enough information" (34%), "too expensive" (26%) and "too complicated" (5%). What was even more interesting was that when barriers were compared by province, New Brunswick businesses (48%) were more likely to ask for information to understand what can be done at their business. This was higher than the national average (34%), and even more so than SMEs in the province of Ontario (31%). Our survey also found that relevant information was a serious barrier, as did the study conducted at Burnside [42]. Information gathering on a number of issues was part of the measures identified by Tudor *et al.* [14] that enhance the success of EIPs. Another measure was that businesses not be in direct competition with each other. This mitigates the risk identified in our study concerning the sharing of information with competitors.

3.3.5. Regulatory Barrier

PEBZ businesses expressed the concern that regulations tend not to support innovative business practices. This is consistent with other research findings [18,64,65]. When CIE businesses were asked if their operations were greatly influenced by environmental laws, regulations or bylaws, they gave an average answer of 3.4 on a scale of 5, reported in Table 8 as a function of the size of the enterprises surveyed. Micro businesses seemed to be more influenced by regulations than SMEs, which is consistent with the results published in 2007 by the CFIB [64], which stated that "(. . .) environmental requirements are often designed for large firms, or are very prescriptive in their approach, making it virtually impossible for smaller firms to understand the regulations, much less fully comply with them".

Table 8. Influence of environmental laws on business operations at CIE.

	Number of Businesses Participating in Study	**Average Influence (1: Never; 5: Always)**
Micro: <10 employees	9	4.00
Small: 10 to 49 employees	24	3.25
Medium: >50 employees	12	3.25
	Total: 45	Average: 3.4

Some of the environmental regulations mentioned were the New Brunswick environmental laws (e.g., Tire Stewardship Board), municipal bylaws (e.g., recycling) and LEED certification for construction companies. Many non-environmental regulations were also mentioned, which might explain why only an average of 3.4 was obtained. The most common non-environmental regulations were federal regulations (e.g., Canadian Food Inspection Agency, Health Canada) and provincial regulations (e.g., New Brunswick Department of Transportation, Health and Safety regulations). Interestingly in this context, some respondents in our survey mentioned that society, customers, the economy and personal motivation combined could have more influence on CIE business operations than provincial or municipal laws, regulations or bylaws. This might explain why a number of businesses interviewed (mostly larger ones) seemed relatively good at keeping up with regulations and were in fact surpassing them. These findings speak to the importance of policy and regulatory factors, as well as social and institutional factors, in relation to eco-industrial development.

4. Conclusions and Practical Implications

This study is the first to assess CIE's potential for eco-industrial development. The use of data from baseline assessments is noteworthy. Indeed, the insights that can be obtained from these data are not widely shared nor published, despite their value for understanding the potential for EIP development and for identifying opportunities in specific contexts. While the results presented might not necessarily

be generalized, they are valuable for future monitoring and evaluation of the industrial parks considered in relation to eco-industrial development, as well as for other industrial parks, businesses and stakeholders which can learn from sharing experiences and knowledge. This is important in order to garner the attention of the industry and global community and to foster eco-transformation in varied locations and contexts. Our results suggest that the following strategies are especially important to foster EIP development not only at the sites studied but also at other locations:

- Symbiosis
- Resource efficiency and waste materials management
- Support for scavenger and decomposer businesses
- Energy efficiency
- Public transportation
- Green space
- Environmental management and governance
- Financial incentives
- Knowledge and information dissemination.

CIE is the most recent and most promising industrial park for its growth potential in Atlantic Canada and, as such, receives considerable support from regional governments in the interest of attracting new investments. The public sector developer of CIE is open to learning about alternative methods of development that would increase the overall environmental performance of the industrial park and of its businesses. Our comparative analysis of CIE and three eco-industrial projects underway in different Canadian provinces provides valuable insights that can help establish short-term and long-term goals as well as determine what actions and eco-industrial activities could have positive impacts on CIE. This empirical research, based on actual businesses experiences, shows that there is considerable scope for action, especially for enabling greater inter-firm cooperation in managing environmental and resources issues at the park scale and in the region.

Although CIE is smaller in comparison to the other three parks studied, there are a number of opportunities as well as certain issues that need to be addressed. Based on the results of the present work, and building on best practices for EIP development, it appears that an important forward step for CIE should be to establish an environmental management organization or identify a shared environmental manager. The majority of park businesses do not have the time or resources to search for information on what they can do and how they can improve their environmental performance, let alone coordinate activities with other park businesses. An environmental management organization or a shared environmental manager would be responsible for coordinating eco-industrial activities and would become the information hub on eco-efficiency for CIE businesses. Such an information center seems critical if CIE wants to promote eco-industrial activities with park businesses, build a stronger sense of community and promote sustainability. To reduce material use through material exchanges and by-product synergies, businesses need to be able to advertise their material flows with the help of a central system, a system that allows other businesses to search for materials they need. A similar system could work for employees interested in carpooling. Additionally, information should be distributed to inform businesses on available government programs, loans and grants targeted to micro, small and medium businesses, particularly with regards to energy efficiency. Fact sheets could promote green business practices, ranging from more efficient production methods to greener landscaping methods, while information packages could advertise businesses in the area that reuse, recycle or re-manufacture products.

There is also a need for education and increased awareness on environmental issues and eco-industrial development. An environmental management organization or a shared environmental manager would be responsible for coordinating workshops, hosting training sessions and initiating consultation sessions with various stakeholders. These are great opportunities for businesses to meet, share information and learn about what neighboring businesses are doing to "green" their business

and minimize costs. One such tool that has produced positive results at the Eco-Efficiency Centre in Burnside Industrial Park is a free energy and environmental review. This tool helps businesses gain an understanding of how eco-efficiency and pollution prevention can benefit their triple bottom line [66]. A number of success stories have been identified and several companies are recognized at an annual "Environmental Excellence in Business" event. These eco-efficient companies are profiled in other business publications and promoted as models. Furthermore, in the interest of sustainable community development, eco-industrial activities could also be applied outside the boundaries of CIE. Given that CIE, as well as the Greater Moncton region, are relatively small in comparison to the other parks and regions that were studied, CIE could benefit from networks and relationships that could be established with stakeholders outside the boundaries of the park and with the community. This would increase diversity and establish common grounds for sustainable economic development in the region. Future studies could expand on the present findings by analyzing the interrelationships between economic players and with local stakeholders, in relation to eco-industrial development in the region.

Compared to other industrial parks across Canada, CIE appears to be well-positioned to initiate eco-industrial activities with park businesses. Indeed, the challenges faced by CIE businesses are similar to other industrial parks and businesses appear to be in favor of a move towards eco-efficient operations, provided that they are given the tools and the information that will foster viable eco-industrial development. Findings are also relevant to other industrial parks, notably those in a development or redevelopment phase that consider eco-industrial development as their next phase. Further research is needed to assess the potential for EIP development across Canada, monitor eco-industrial accomplishments and understand the factors influencing eco-transformation in the Canadian context, including regulatory and policy factors. Research aimed at developing indicators and a monitoring standard to measure and report progress in EIP development would also be valuable.

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