Creating value with wastes: a model and typology of sustainability within firms

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Abstract

The objective of this paper is to construct a model and propose a typology of residual material reclamation practices in manufacturing facilities. The qualitative study based on in-depth interviews with 60 managers demonstrated that residual material reclamation can be characterized by six key dimensions associated with the recovery and transformation of residuals: reclaiming goals, reclaiming scope, awareness of activities, manufacturing processes, environmental management and variety of materials used. The analysis of each dimension from a managerial point of view suggests five types of residual material reclamation: craft, broad consolidated, narrow consolidated, broad leverage and narrow leverage. The model and typology expand our understanding of residual material reclamation activities within organizations actively involved in sustainable initiatives. This study contributes to proposing an analytical framework aimed at understanding how practices concerning residual material reclamation are managed. Implications for organizational research and management are also discussed.

Keywords: sustainability; residual material reclamation; industrial ecology; analytical framework; dimensions

Introduction

The study of residual material reclamation represents one of the more interesting and challenging AREAS of industrial ecology and sustainability research for policymakers and managers (Ferrer and Whybark, 2001; Guide and Van Wassenhove, 2002; Nidumolu et al., 2009; Lubin and Esty, 2010). Indeed, residual material reclamation is one application of closed-loop manufacturing systems making it possible to reduce ecological impact on processes and develop products made from reused parts and materials from consumer and industrial sectors. As an application of industrial ecology, residual material reclamation enables manufacturing facilities to take advantage of the cyclic patterns of used material flows found in industrial and consumption systems. Thus, residual material reclamation within firms is consistent with a business model intended to create value with wastes through recovery, conversion and commercialization of environmentally friendly products, which is more likely to improve firms’ financial and operational efficiency, and environmental sustainability (Kabongo, 2010).
Within the literature on industrial ecology, a stream of research has focused on eco-efficiency at the firm level. This eco-efficiency is often linked to residual material reclamation practices and can be reinforced by various factors, especially the introduction of new technologies and the continuous rise in cost of raw materials (Weizsäcker et al., 1997; Lovins et al., 1999; Boiral and Kabongo, 2004; Loorbach et al., 2010). In fact, according to a recent international survey among international managers, the rising cost of raw materials has become the main concern of organizations (Grant Thornton, 2007).

In this perspective, use of residual materials instead of certain raw materials can represent a substantial source of savings for organizations. Nevertheless, these savings are most often analyzed from a theoretical, general and regional/global standpoint whereby residual material reclamation practices tend to appear as a monolithic process subordinate to the general principles of industrial ecology. Thus, the diversity of these practices, their organizational impact and their specific economic benefits are generally overlooked. Given the extent to which an increasing number of industrial facilities have promoted residual material reclamation practices, researchers need to better understand the circumstances and requirements of such ecological activities and how firms can perform them efficiently.

The purpose of this paper is to construct a model and to propose a typology of residual material reclamation practices through a qualitative study based on in-depth interviews with 60 managers who have designed and implemented innovative residual material reclamation practices. The overall view of the present research is guided by the principle that industrial ecology and residual material reclamation are not only technical issues, but also social and organizational phenomena (Cohen-Rosenthal, 2000; Edwards, 2005; Blackburn, 2007). The researchers argue that analyzing descriptions given by managers engaged in residual material reclamation yields new insight into its core characteristics. First, the paper will review studies on types of industrial ecology proposed in previous research by presenting their main characteristics and limits to the understanding of residual material reclamation practices at the firm level. Then, it will describe data collection methods and justify the choice of an interpretative approach. Finally, the paper will present and discuss the findings.

Characterization of Industrial Ecology Practices: a Literature Review

Industrial ecology and residual material reclamation literature on types of activity aimed at applying sustainable principles is not extensive (see for instance Preuss, 2005). Some descriptive works on conceptualizing underlying assumptions of industrial ecology on the issue of sustainability (Jelinski et al., 1992; Frosch, 1992; Huber, 2000) are based on implicit theory development derived from a philosophically focused approach of understanding nature as a model for industrial development (Isenmann, 2003). Others focus on the primary attributes of industrial ecology compared with pollution prevention (Oldenburg and Geiser, 1997). The few studies on types of industrial ecology practice (Boons and Baas, 1997; Chertow, 2000; Andersen, 2003; Wells and Seitz, 2005) focus mainly on technical or macro-economic aspects and do not shed light on managerial issues underlying these practices.

Residual material reclamation practices involve a variety of managerial issues, including business strategies intended to reinvent organizations in order to adopt and implement
In discussing the merits of the concept of industrial ecology, which has received increasing attention in the environmental policy community, Boons and Baas (1997) distinguished four industrial ecology types: product life cycle, material life cycle and geographic and sectoral areas. In the product life cycle area, industrial ecology draws from both producers and consumers and focuses on analysis of the impacts on the environment of a given product – such as an automobile, battery and tires – during its life cycle. Similarly, the material life cycle area of industrial ecology looks at the impacts on the environment of certain materials during their life cycle. Examples are steel, plastic, aluminum etc. The geographic type takes into account the coordination of the activities of industrial ecology among different actors located in a region. The coordination of activities of industrial ecology among organizations operating in an industrial sector is the focus of the sectoral type. The typology proposed by Boons and Baas (1997) focused on the organizational implications of the industrial ecology perspective. These types, drawn from organizational sociological concepts, emerge as organizations responsible for the integrated environmental activities of industrial processes that coordinate their own practices. However, managerial experiences of these integrated activities are not included in the study.

Chertow (2000) reviewed the literature on small industrial symbiosis and early efforts to develop eco-industrial parks focusing on the flow of materials and energy through local and regional economies. The study proposed a taxonomy of five types of material exchange, based upon a multidimensional approach previously proposed by Lowe et al. (1997). The taxonomy includes residual exchange activities in general; exchange within a facility, firm, or organization; exchange among firms collocated in a defined eco-industrial park; exchange among firms that are not collocated; and exchange among firms organized virtually across a broader region.

In elucidating interpretations of the concept of industrial ecology by analyzing the ‘most important contributions’ to industrial ecology, Andersen (2003) established a typology. This concept of mapping industrial ecology theoretical development based upon the levels of analysis and application differentiated five types of industrial ecology: product design, resource analysis, environmental management system, eco-industrial parks and factor X, which means that sustainable levels of material flows will not be reached unless and until the material intensity of the industrialized country is reduced by a factor of ten (Andersen, 2003, p. 40). This typology, drawn from various conceptualizations of industrial ecology, presents distinct views of the same phenomenon according to different specialists, rather than a unified corpus of characteristics of the practices of industrial ecology at the firm level. In their theoretical research drawing on the specific context of the automobile industry, Wells and Seitz (2005) proposed four categories of sustainable practices (Lubin and Esty, 2010), choice of management tools to better implement residual material reclamation (Epstein et al., 2010), transition from current production methods to more ecological ones (Bryson and Lombardi, 2009), demand for sustainable products and services that satisfy internal and external expectations of business leaders (Albino et al., 2009), calls for business leaders to embrace the principles of sustainability (Baumgartner, 2009), recognition of businesses’ power and role in transforming current patterns of consumption (Unruh and Ettenson, 2010), challenges faced by managers involved in residual material reclamation (Kabongo, 2010), and examples of successful and operational models of sustainable practices within firms (see Hamschmidt, 2007).
closed-loop supply chains for value-added businesses: internal, post-business, post-consumer and post-society.

Nevertheless, only a few of these studies have taken into account explanations offered by managers for industrial ecology practices applied at the organizational level. Indeed, as noted by Opoku (2004), the study of industrial ecology in terms of material and energy flow analyses, residual minimization and transformation technologies at regional/global levels tends to focus more on analytical framework and policy principles in order to meet industrial ecology objectives. However, this emphasis might limit the understanding of the adoption of sustainable action in organizations. The analysis of the functioning and the dynamics of residual material reclamation at individual firms is an experimental claim of the flow of residual materials transformed in production processes.

As noted earlier, and contrary to an analytical claim largely addressed by a huge body of research, this experimental claim highlights the fact that industrial ecology is not only a field of study, but also a field of practice (Boons and Roome, 2001). To further investigate the characteristics and practical applications of residual material reclamation, a qualitative study in manufacturing facilities was designed and conducted.

**Methodology**

*Interpretative Approach*

Analyzing the mechanisms of residual material reclamation based upon managerial discourse makes it possible to integrate various perspectives and experiences in line with a firm’s management issues. Thus, the researchers chose to ground the study in managerial discourse and connotations from an interpretative approach aimed at understanding how reality is constructed and interpreted by individuals from their specific experience (Berger and Luckmann, 1967; Burrell and Morgan, 1979; Crotty, 1998; Gephart, 2004).

The methodological approach of the study was based on a qualitative approach, well suited to analyzing and systematically structuring respondent discourse and interpretation collected during semi-directive interviews (McCracken, 1988; Yin, 1989; Creswell, 2003). This interpretative approach was inductive in the sense that it relied on the building of concepts and categories from appropriate insight provided by participants telling their stories and experiences throughout the study (Silverman, 1993).

*Data Collection and Sampling*

The study reported here was designed to identify key dimensions of residual material reclamation practices. In all, 56 managers from 12 selected industrial facilities implementing these practices participated in the study. In addition, three managers from three distinct companies that provided residual support services to the selected facilities and a government official responsible for the development of sustainable activities were also interviewed. Each participant described and discussed the structure and function of residual material reclamation practices.
practices implemented within their facilities over the previous five years. The official discussed the government view regarding the implementation of these practices and the application of different environmental laws and regulations.

The researchers selected 12 Canadian facilities representing seven distinct industrial sectors: scrap tires, mineral residue, cement kiln, acid-lead recycling, animal waste processing, pulp and paper, and industrial chemicals. The selection of these facilities was based on four criteria: residual material reclamation practices, accessibility of the facility, availability of firm managers and geographical proximity.

Since upper level managers play key roles in creating and implementing broad and comprehensive changes that affect the entire organization (Robbins, 2006), the participation of those who had planned and made decisions relating to residual material reclamation was essential. Interviews were conducted with upper and middle level managers in the facilities selected, including CEOs and senior vice-presidents. Given the fact that the case method in this type of research does not obey the logic of population sampling and representativeness (Yin, 1989), the number of participants varied between two and eight per facility. Table 1 summarizes the information on cases analyzed.

<table>
<thead>
<tr>
<th>Industrial sector</th>
<th>Case</th>
<th>Residual material reclamation streams</th>
<th>Number of employees</th>
<th>Number of interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scrap tires</td>
<td>1</td>
<td>Manufacturing of end user products from scrap truck tires</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Manufacturing of value-added products made with recycled rubber from scrap tires</td>
<td>117</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Production from scrap tires of liquid bitumen used in asphalt blends for road paving, as well as by the roofing industry</td>
<td>115</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Production of rubber crumbs from scrap truck tires</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>Stainless-steel and mineral waste</td>
<td>5</td>
<td>Recovery and processing of stainless steel as co-products from slag</td>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td>Cement</td>
<td>6</td>
<td>Production of magnesium from serpentine tailings</td>
<td>360</td>
<td>8</td>
</tr>
<tr>
<td>Lead-acid batteries</td>
<td>7</td>
<td>Reuse of 30 types of residue for fuel and alternative raw materials</td>
<td>388</td>
<td>6</td>
</tr>
<tr>
<td>Animal waste processing</td>
<td>8</td>
<td>Reuse of 80 types for fuel and alternative raw materials</td>
<td>200</td>
<td>4</td>
</tr>
<tr>
<td>Pulp and paper</td>
<td>9</td>
<td>Recycling of lead-acid batteries and other hazardous by-products</td>
<td>140</td>
<td>7</td>
</tr>
<tr>
<td>Industrial chemicals</td>
<td>10</td>
<td>Recycling of frying oils, grease, bones and fat Manufacturing of biodiesel</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Recovery of slag from the de-inking process</td>
<td>1000</td>
<td>6</td>
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<tr>
<td></td>
<td>12</td>
<td>Recovery of sulfuric acid (H_2SO_4) and recovery of liquid CO_2 from the manufacturing process of titanium dioxide pigment (TiO_2)</td>
<td>388</td>
<td>4</td>
</tr>
</tbody>
</table>

*Table 1. Cases analyzed

Data Analysis

The analysis of data followed the guidelines of the grounded theory approach of Strauss and Corbin (1990). This approach comprises two stages: an internal analysis of each case followed by a cross-sectional analysis of all the cases. The first stage involved three levels of analysis: condensation, organization and interpretation. The second stage involved a constant process of
comparison, deconstruction and grouping of collected data. The verbatim transcripts were broken down to determine categories aligned with pre-established concepts, and then according to evolving concepts as the categories were compared to each other. These categories, representing paradigmatic views of inquiry for residual material reclamation practices within organizations, were developed on the basis of an extensive review of academic and business literature (Maykut and Morehouse, 1994). Categories developed to organize data for this project included the following: goals of residual material reclamation, scope of activities, awareness of activities, design of manufacturing processes, environmental management and residual materials reclaimed. As noted earlier, the interpretative approach deals with understanding the actual production of meaning and concepts used by social actors (Gephart, 2004). Only when a particular meaning in a category became shared and dominant among respondents was it then used by researchers as a unit of meaning. The units of meaning thus were coded in terms of the indicators of the model of residual material reclamation or of the emerging themes. QRS N-Vivo software was used to analyze and codify data. This qualitative software facilitated the process of developing and organizing categories reflecting the main results of the study. Figure 1 shows the development of the categories of the study.

Results and Discussion

Participant Demographics

Table 2 reports participant demographics. In terms of level of responsibility in the company, the majority of participants reported upper level positions (76.6%) followed by middle (20%) and lower managerial positions (3.3%). Only one-fourth (25%) of the respondents held jobs related to environmental activities in their respective firms. Positions related to environmental activities indicated the extent to which residual reclamation practices were integrated in manufacturing processes. Respondents also reported the number of years they had been with the company. The majority (68.3%) indicated tenures of more than five years. The remaining respondents had been with their respective companies for three to five years (25%) or for less than three years (6.6%). The age of the respondents averaged 45 years. The majority of the respondents were male (93.3%). These results regarding the level of positions held and tenures of participants with their respective firms were consistent with the objectives of the study. As mentioned earlier, the level of positions held by respondents was consistent with the objective and design of the study. Upper level managers play key roles in creating and implementing broad and comprehensive changes that affect the entire organization (Robbins, 2006), and the participation of those who had planned and made decisions relating to residual material reclamation was essential.

Company Demographics

Table 3 reports company demographics and residual material reclamation practices. In terms of the type of organization, the cases selected represented a variety of organizations, with 16.6% in business-to-business and 25% in business-to-consumer; 58.3% of organizations operated in both markets. These 12 companies (100%) operated in a variety of industry sectors offering only physical goods. In terms of the number of years in business, the majority (83.3%) of organizations were established more than 18 years ago. The number of years in residual material
reclamation ranged from less than 10 years (16.6%) to 10 years or more but less than 30 years (75%). Only one organization (8.3%) has been practicing residual material reclamation for more than 30 years. Six of the 12 facilities analyzed (50%) started directly as residual material reclamation companies. The remaining cases (50%) added reclamation as a secondary activity later on. In terms of organizational structure, six organizations (50%) were single/independent firms. The remaining organizations were plants (25%) or subsidiaries (25%) of larger corporations. The organizational structure had an effect on the development of residual material reclamation activities. Single/independent firms were more likely to concentrate their activities on residual material reclamation than subsidiaries of larger corporations. The number of employees ranged from less than 50 employees (25%) to 50 employees or more, but less than 250 employees (41.6%). The remaining organizations employed between 250 and 1000 people (25%) and more than 1000 people (8.3%). The size of the firm did not seem to have an effect on the development of residual material reclamation activities. Finally, in 41.6% of the organizations, an environmental department dealt with social, environmental and ethical issues of residual material reclamation. The remaining organizations (58.3%) did not possess an environmental department.

Figure 1. Development of categories
Data analysis made it possible to characterize the key dimensions of a model of residual material reclamation associated with recovery and transformation of residuals. This characterization encompassed specific dimensions for analyzing and comparing the cases. The following sections discuss the proposed model of residual material reclamation. Figure 2 shows the development of one of the dimensions of the model: variety of materials used. This visualization includes development of the category based on the literature, the narratives from the respondents identifying the concept as a dimension of residual material reclamation, the interpretation of the narratives by the researchers and the development of new concepts as indicators of the dimension.

**A Model of Residual Material Reclamation**

The proposed model suggests that residual material reclamation can be analyzed in terms of six key dimensions: goals, scope, processes, materials reclaimed, environmental management and awareness. Each dimension is composed of indicators demonstrating how facility managers studied, designed and implemented distinct types of residual material reclamation adapted to their organizational environments. Figure 3 shows the dimensions of the model residual material reclamation and the 11 associated indicators. The arrows represent the interrelationships between these indicators.
Table 3. Company demographics

Underlying Goal

The underlying goal of the activities is the first dimension of the model of residual material reclamation. It describes the essence of reclamation activities. In general, practices observed in facilities analyzed included the following activities: transformation of waste; use of discarded, finished or semi-finished products as alternative raw materials; use of residue in a stage of the manufacturing process; waste material and consumption minimization by process optimization and addition of residue to finished products. All these practices pursuing residual material reclamation showed two distinct indicators: final product and internal manufacturing.
**Figure 2.** Development of concepts
The final product indicates that the primary goal of residual material reclamation is the transformation of residual materials into products sold to end-users (cases 1, 2, 4, 5, 6, 9, 10, 11 and 12). The studied firms are using these environmentally sound products to compete in emerging markets of environmentally friendly products. Finished products are introduced into these markets by matching supply and demand through effective market segmentation and product positioning, which explains the facilities’ strategic actions behind the manufacturing of a wide range of products from recycled materials. One manager stated:

*We manufacture a wide variety of end user products from scrap vehicles and truck tires. So far, we have been very successful with our products in the market. Perhaps the fact that they are environmentally sound helps us. 85% of our customers are in the agricultural sector. We have found a type of mat that meets the needs of our customers: ¾", 4 × 6 measurements and 100 lb weight. Our distribution networks work quite well and we have just entered an agreement with a new customer located in Japan (CEO, case 1).*

The internal manufacturing indicates that the underlying goal of residual material reclamation is the alteration, modification and improvement of the manufacturing process with the re-use of residual materials (cases 3, 7, 8, 11 and 12). This explains the use, after appropriate modification, of recycled rubber in the composition of bitumen (case 3) and the replacement of non-fuel raw materials (calcium oxide, silica, aluminum oxide and iron oxide) and fuel raw materials (diesel and natural gas) with a wide range of residual materials in cement kilns (cases 7 and 8).

**Scope of Activities**

The scope of activities is the second dimension of residual material reclamation. It reflects the extent of these activities in relation to the raison d’être and expertise of facilities studied. Two indicators are associated with scope of activities: integrality and fractionality. Integrality
indicates the situation in which a firm recovers and transforms residual materials at the level of its entire manufacturing processes. Integrality coincides with the métier and mission of the organization. The definition of a firm’s mission and purpose focuses on recovering and transforming residual materials. These activities are the raison d’être that guide and motivate firm managers to seek superior performance in transforming wastes. Seven (of 12) cases in the sample demonstrated integrality of residual reclamation (1, 2, 4, 5, 6, 9 and 10). A CEO describing the core business of his firm and the nature of wastes used in the discarded tires reclamation industry sector said

We take back discarded truck tires of a specific kind. For example, we do not process truck tires with nylon cap plies. We send them to secondary recycling companies. We make different sizes of rubber granule based upon the needs of our customers. For instance, when a customer wants something similar to virgin rubber, we produce fluff sized to minus \( \frac{1}{4} \)" mesh. When the customer wants something bigger, production can range from 10" to 200" mesh size (case 4).

Discussing the specific niche and expertise his firm has developed over the years in the lead-acid battery recycling sector, a senior vice-president of operations stated:

Our company is specialized in the processing, recycling and recovery of leaded materials. Its main inputs are automobile lead–acid batteries, any sort or kind of battery, waste from manufacturing plants and all sorts of materials that contain lead (case 9).

Fractionality refers to a situation in which residual material reclamation is limited to certain operations within the firm, captures only a portion of the firm’s activities and does not constitute the firm’s core business. Fractionality involves the adaptation of residual reclamation activities to the operations of one or two specific divisions. Moreover, respondents described it as an intended secondary activity of the firm. Five cases in the sample (3, 7, 8, 11 and 12) demonstrated fractionality of residual material reclamation. The following quote from a director of recycling energy operations in a cement plant describes the fractionality of residual material reclamation:

Our core business involves three areas of building materials: the manufacture of cement, aggregates and concrete, and gypsum. As a secondary activity, we reclaim a number of used materials at our facility (case 7).

Awareness of Residual Material Reclamation

Awareness of activities is the third dimension of the proposed model of residual material reclamation. This dimension focuses on predominant motivating factors of which firm managers are aware while designing and implementing reclaiming activities. Managers described these motivations or sensitivity of reclamation activities in terms of concerns for competitiveness, accessibility to alternative materials, environmental and ethical responsibility to society, solutions to specific operational challenges, and environmental regulations and laws in place. Interpretations showed that, with regard to residual material reclamation activities, managers were more sensitive to two indicators: market sensibility and stakeholder demands.

Market sensitivity refers to the extent of which managers sought primarily to maximize economic opportunities with the recovery and transformation of a variety of waste products.
Market preferences were, and still are, the main driving force. Additionally, a high level of material added value and existing functional recovery infrastructure contributed to motivating managers to adopt reclaiming strategies. In terms of economics, reclaiming activities go beyond the intuitive environmentally sound nature of industrial ecology initiatives. Eight cases in the sample demonstrated a market-oriented type of residual material reclamation (1, 2, 3, 4, 5, 6, 9 and 10). The following are examples of the market orientation as described by the respondents.

Economics is the driving force of our activities. I am proud that we participate in cleaning up the environment. But, we could not have done it if it was not profitable for the company (CEO, case 1).

The above excerpt shows that, for managers dealing primarily with market awareness, economic pressures are quite high. Discussing economic awareness, a senior vice-president, stated

When it comes to maximizing our profitability, we have never done so to the detriment of the environment. But an ecological action is first and foremost economically driven (case 9).

For firms with market awareness, the ecological function of residual material reclamation is primarily an economic function. Managers are more likely to implement residual material reclamation initiatives if they are economically profitable (Boiral and Kabongo, 2004).

Stakeholder awareness indicates the extent to which firm managers promote residual material reclamation activities to meet the environmental demands of multiple stakeholders, including top managers, shareholders, pressure groups and government at all levels. Descriptions of the activities at facilities with stakeholder awareness (cases 7, 8, 11 and 12) revealed that economic pressures to be profitable with scrap products were quite low. Coincidentally, residual material reclamation does not represent a core business of these facilities. Residual re-use and transformation is a viable alternative to conventional raw materials and to reducing the cost of landfill. An environment coordinator describing when the company began to reclaim residual materials in the paper and pulp plant said

Pressures came from our parent company to do something with the waste generated. It was also a time when paper and pulp mills had a bad reputation for polluting the environment. Residual material reclamation helped us change this image and also save money on landfill (case 11).

As a process engineer said, concerns for environmental regulations played a key role in the orientation of activities to reclaim sulfuric acid (H\(_2\)SO\(_4\)) and recover liquid CO\(_2\) from the manufacturing process of titanium dioxide pigment (TiO\(_2\)):

We were looking to minimize the use of used diluted acid that we were sending into the river at the time. We built a secondary plant to manufacture gypsum for that main reason. Research showed that we could bring this used diluted acid under control by re-using it in the production of gypsum. First of all, we wanted to comply with environmental regulations (case 11).

If cases 11 and 12 were sensitive to top management concerns and environmental regulations, cases 7 and 8 showed that residual material reclamation practices were initiated to improve the image of the cement industry as demanded by groups of shareholders. In fact, as stated by Van
Oss and Pandovani (2002), cement manufacturing is one of the very largest industrial emitters of CO$_2$, an important greenhouse gas.

Manufacturing Processes

Manufacturing processes is the fourth dimension of residual material reclamation. This dimension focuses on the way in which residual materials tasks are accomplished through use of technical and appropriate processes. An analysis of respondent discourses on this issue showed the relevance of two indicators: standardization and non-standardization. Standardized residual reclamation was based on formalized technical processes. Eleven cases in the sample demonstrated standardization of manufacturing processes used: cases 1, 2, 3, 5, 6, 7, 8, 9, 10, 11 and 12. For the most part, industrial ecology practices rely on experimentation and implementation of innovative technological processes (Boiral and Kabongo, 2004). Although the residual manufacturing process can be standardized, the technology developed is often unique and requires a great deal of investment and technology transfer, as stated by a manager:

*In cooperation with researchers at a local college, we developed a process that has not been used anywhere else in the world and we have already produced 5000 tons. We use a toxic product residual to make two products with commercial value* (production manager, case 9).

Non-standardized residual reclamation (case 4) was based on the trial-and-error type of technical processes that have not been validated theoretically and operationally. Non-standardized technical processes do not mean unsuccessful industrial ecology practices. Rather, a high level of experimentation, testing and learning by trying characterize a non-standardized type of residual material reclaiming:

*When we started, our equipment consisted of machines purchased from other industries, particularly mining, forestry and recycling. Therefore, we did not have any benchmark. Then, it was a question of reorganizing all our operations by developing equipment better adapted to our processes* (CEO, case 4).

Environmental Management

Environmental management—the fifth dimension of the model—focuses on firms’ efforts to reduce the environmental impacts of the reclaiming activities. As previously indicated, residual material reclamation is one application of closed-loop manufacturing systems making it possible to reduce ecological impacts on processes and develop products made from reused parts and materials from consumer and industrial sectors. A rigorous environmental management system often leads to the adoption of corporate environmental policies, the adoption and implementation of standards for environmental management system, and the development of environmental performance metrics (Schmidheiny, 1992; Smart, 1992; Shrivastava, 1996; Darnall et al., 2008; Lucas, 2010). Respondents’ discourses on this issue were used to identify two indicators: compliance and proactivity. Compliance (case 4) indicated a situation in which the facility analyzed was conforming to environmental laws, standards, regulations and other requirements related to residual material reclamation. Proactivity (all cases except 4) indicated the situation in which facilities went beyond compliance by heavily investing in and voluntarily taking measures to make protection of the environment at their facilities a first-class priority, as evidenced several
of their policies. Commenting on the efforts of environmental management system implemented, one environment coordinator stated

*The plant can generate an important quantity of dust. In all processes, dust collectors assure the quality of the air and the control of atmospheric emissions (case 7).*

**Material Variety**

The material variety is the last dimension of residual material reclamation. It reflects the variety of residual materials used and transformed. This represents the opportunity to reclaim residual materials, which is the process of creating a new firm or the implementation of waste materials reuse and transformation within an existing firm. Two indicators of residual material reclamation based on the variety of materials were identified: narrow line and broad line of materials reclaimed. With a narrow line, reclamation activities were geared toward the recovery and the transformation of one single type of waste. Managers invested and built capabilities to strengthen their competitive position in one kind of waste transformation. Five cases in the sample demonstrated a narrow product line of residual material reclamation (1, 2, 3, 4 and 6). A CEO talking about the founder of the company and the opportunity to recover and transform one type of waste said

*The company was founded 20 years ago by a man with entrepreneurial spirit. Ever on the lookout for opportunities, he saw tremendous potential in the generation and stockpiling of millions of discarded tires at the time. His greatest challenge was to find equipment to manufacture mat. With the help of a long-time friend, they built their first press and processed their first scrap tires (case 1).*

Similarly to case 1, case 6 developed capabilities to produce magnesium from serpentine tailings. Commenting on the choice of magnesium, the coordinator of environment described it as an opportunity to combine other contingent factors such as recycling infrastructure, resource recovery technology and supply network, stating

*The magnesium market had the potential to increase at the time the project was initiated. The owners located enormous reserves of serpentine tailings from which high quality magnesium could be produced. We bought reserves for about 200 years of operation and we are located right off the site! The company also noted the increased use of magnesium in the automobile and related industries. We had capabilities for all of that (case 6).*

With a broad product line, residual material reclamation was geared toward the recovery and transformation of a wide range of wastes. Whether a firm reclaimed a narrow or a broad line of residuals, residual material reclamation corresponded to the recognition of opportunities to expand activities into new processing operations to transform new kinds of residual material. As a CEO in the stainless-steel and mineral residue sector said,

*The company operates two distinct schemas of residual material reclamation. First, we recover and process stainless steel slag of two types: 300 and 400. We also process sterile iron ore composed basically of construction aggregates (case 5).*
Cement plants analyzed (cases 7 and 8) provided examples of a broad line of residuals reclaimed. The production of hydraulic cement and concretes allows the cement industry to use and consume a wide variety of waste as raw materials and fuel in the application of industrial ecology principles (Van Oss and Pandovani, 2002). As a director of energy and environment in the cement industry said,

*Talking about residual material reclamation at our plant, we utilize used oils, discarded tires, processed and contaminated wood and solid granulars as combustibles. We also take used catalysts from the oil industry in substitution of aluminum oxide, one of our main raw materials. We reuse 80 types of wastes. Our objective is to increase the number of combustibles and alternative fluent and raw materials (case 7).*

**The Typology of Residual Material Reclamation**

A typology is derived from the combination of several elements that are considered simultaneously in order to arrive at a given type of classification. The typology proposed takes into account the degree of involvement from each of the key components of the six dimensions of the model of residual material reclamation. Five types of residual material reclamation were identified: craft, narrow consolidated, broad consolidated, narrow leverage and broad leverage. Figure 4 depicts the typology of residual material reclamation.

- **Craft (case 4)** is a residual material reclamation that combines final product, integrality, market, non-standardization, compliance and a narrow line of materials reclaimed.
- **Broad consolidated (cases 1, 2, 4, 5, 6, 9 and 10)** is a residual material reclamation using final product, integrality, market, standardization, proactivity and a broad line of materials reclaimed.
- **Narrow consolidated (case 6)** is a light version of broad consolidation using final product, integrality, market, standardization, proactivity and a narrow line of materials reclaimed.
- **Broad leverage (cases 7, 8, 11 and 12)** is a residual material reclamation combining internal manufacturing, fractionality, market, standardization, proactivity and a broad line of materials reclaimed.
- **Narrow leverage (case 3)** a light version of broad consolidation using final product, integrality, market, standardization, proactivity and a narrow line of materials reclaimed.
Conclusion

When competing with companies that manufacture from conventional raw materials, facilities analyzed are more likely to adopt craft and consolidated—narrow and broad—types of residual material reclamation. This is observed in the transformation of discarded tires, stainless-steel, mineral residue, lead-acid used batteries and animal processing by-products into a variety of finished goods. When addressing issues related to material replacement in manufacturing processes, facilities analyzed are more likely to adopt leverage—narrow and broad—types of residual material reclamation.

Whatever the reasons for facility managers adopting typical residual material reclamation activities, these types are not mutually exclusive. One type tended to dominate the overall residual practices of each facility, but there was evidence, from descriptions by participants, of changes in the orientation of reclaiming activities over time. This is the case, for instance, of a facility that moves from reclaiming a narrow line of products to a broad line of products or from non-standardization to the standardization of processes. However, in both cases, such moves rely on investments in terms of research and development and technology transfer, as well as the development of internal core competencies in residual material reclamation (Boiral and Kabongo, 2004).

The typology presented in this paper depicts a general picture of residual material reclamation activities in the cases analyzed. First, the typology helps to distinguish the dimensions of residual material reclamation and the descriptions associated with them. Next, the typology provides an analytical framework in which public policies and business practices regarding residual material reclamation can be better studied and explained. Thus, public policies on incentives to recover, transform and use waste products can now be examined through the prism of types of residual material reclamation and the interests of organizational actors. These public policies are intended
to encourage the adoption of better waste management practices. Finally, the typology offers another conceptual framework in which organizations can design their product and manufacturing processes in relation to industrial ecology activities. It is worth noting that the proposed model and typology do not tell us about practices in terms of who performs them and how production processes are organized within a particular facility or process. This constitutes a drawback of the proposed model and typology.

The limitations of this study are twofold. First, given the fact that different dimensions explored during the interviews addressed the issue of efficiency of practices implemented, managers and strategists tend to be sensitive to questions regarding activities they have planned themselves and are responsible for. This sensitivity might play a role in favorable or critical answers concerning the function of these practices. As many scholars argue, managers are more likely to define and perceive organizational effectiveness in light of their own values, expectations or programs of action (Quinn and Rohrbaugh, 1983; Weick and Daft, 1983; Zammuto, 1984). Second, the researchers did not interview non-managerial employees. This would have undoubtedly brought a mitigated view of the whole phenomenon studied. Because of the exploratory character of the interviews conducted and the reduced sampling, the external validity of the present study is restricted. Therefore, conclusions remain preliminary. However, the methodology used points to an acceptable internal validity (Yin, 1989).

The results of the present study have implications for research in two areas. First, future research should consider a more enlarged and balanced sample that could include more diversified levels of management, and interviews with operators and also employees in non-managerial positions. Second, the ‘theory’ of industrial ecology at the firm level needs to be rethought. Empirical and theoretical research can be pursued to explore how practices of residual material reclamation can significantly contribute to the improvement of natural ecosystems while being profitable for individual firms. Another interesting topic is to analyze the changing customer needs and demands for environmentally friendly products, especially for those companies that manufacture end-user products from residuals. Analysis of the development of markets of environmentally friendly products and the kinds of pressure these markets put on the companies and their eco-efficiency also are promising topics for future research.

Managers can draw preliminary conclusions from the present study. As in any productive and commercial activity, the coherence and dynamism of practices ensure the economic success of residual material reclamation initiatives. Interviews analyzed showed the relevance of effective planning in the choice of materials to be re-used, and initiatives of recovery and technological innovation. As Graedel and Allenby argue (1995, pp. 183–189), managers of the firms engaged in industrial ecology practices are called upon to make strategic decisions regarding technology, equipment, product and process design. In other words, residual material reclamation practices take place in contexts of turbulence and perpetual change (Cameron et al., 1987). Turbulence leads to modifications of the firm environment and will have an impact on organizational structure. The interviews conducted showed structures suitable for stable environments. Based upon the singularity of residual material reclamation, managers should explore more flexible organizational structures. This might speed up the process of collective learning and the development of competencies related to several industrial ecology projects.
Understanding industrial ecology practices determines the potential of this concept for research, analysis and application. At an organizational level, understanding different types of residual material reclamation implies consideration of environmental, economic and societal dimensions associated with sustainability. The present research revealed themes relating to sustainable practices in organizations on which further research should focus.

References


