3. LEATHER INDUSTRIAL ECOLOGY FOR SUSTAINABLE DEVELOPMENT

3.1 Preamble

The investment made by industries would always aim at profitable outcomes. When the waste produced in leather industries is more than the actual product, it highlights the necessity to transform the leather solid waste into a usable and beneficial product. Converting the leather solid waste generated into fertilizers not only provides economical benefits but it adds to the ecological benefits that is the need of the hour.

The leather industries could definitely have a LSWM department with experts who could manage the waste effectively by improving system such that they bring about an ecological and economical balance. Thus, enhance the contribution of the industrial sector towards environmental upgradation and environmental friendly atmosphere in these spheres.

3.2 Leather Industrial Ecology

Leather industrial activities are increasingly in confrontation with ecological systems. Continued leather waste resource exploitation and environmental impacts of resource use and pollution are cause for concern around the study area. One broad approach emerging in response to these concerns is called Leather Industrial Ecology (LIE). According to Frosch and Gallopolos (1989), two of the earliest U.S. proponents of IE explain that "the traditional model of industrial activity - in which individual manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of - should be transformed into a more integrated
model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process...serve as the raw material for another process." For Frosch and Gallopoulos (1992:290), IE serves as "a better system for the coordination of technology, industrial processes, and consumer behavior."

Graedel and Allenby (1995:9) in the first textbook on IE assert that, "Industrial Ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital."

IE is described as an information driven field in which the advances of the "information revolution" can be harnessed for improving the environmental performance of industry.

Frosch and Uenohara (1994:2) explain that "Industrial ecology provides an integrated systems approach to managing the environmental effects of using energy, materials, and capital in industrial ecosystems. To optimize resource use (and to minimize waste flows back to the environment), managers need a better understanding of the metabolism (use and transformation) of materials and energy in industrial ecosystems, better information about potential waste sources and uses, and improved mechanisms (markets, incentives, and regulatory structures) that encourage systems optimization of materials and energy use."
Using ambiguous terms to define IE, Allenby (1992) writes that "industrial ecology may be defined as the means by which a state of sustainable development is approached and maintained. It consists of a systems view of human economic activity and its interrelationship with fundamental biological, chemical, and physical systems with the goal of establishing and maintaining the human species at levels that can be sustained indefinitely - given continued economic, cultural, and technological evolution." Lowe (1993) similarly argues that "Industrial Ecology is a foundation for creating sustainable industry in a sustainable society," employing a "whole systems approach to design and management of the industrial system in the context of local ecosystems and the global biosphere."

Socolow argues that "Industrial ecology is a metaphor for looking at our civilization," which provides perspectives on long-term habitability, global scope, the overwhelming of natural systems, vulnerability, mass-flow analysis, and centrality of the firm and the farm (Socolow1994:3). For Socolow, as for many other proponents of IE, the perspectives of IE "add up to new thinking".

Tibbs (1992) and Ehrenfeld (1994) have laid out what they consider the basic components of IE, which we will discuss in more detail below. Ehrenfeld's list (based on Tibbs 1992) of the seven components of IE (Ehrenfeld 1994:16) is useful as a base for discussing which concepts different authors accept or consider critical to IE. This list includes: (1) improving metabolic pathways for materials use and industrial processes; (2) creating loop-closing industrial practices; (3) dematerializing industrial output; (4) systematizing patterns of energy use; (5) balancing industrial input and output to natural ecosystem capacity; (6) aligning policy to conform with long-term industrial system evolution; and, (7) creating new action-coordinating structures, communicative linkages, and information.
Therefore, leather industrial ecology is just not about waste management but it aims at resolving waste-management issues economically. The leather solid waste produced could be utilized in an effective way where the industrialists to benefit productively and to identify and implement strategies that integrate environmental concerns into economic activities.

3.2.1 The Concept of Sustainable Industrialization

The newfound emphasis on sustainable development within the Leather business community signals an emerging synthesis between traditional business values and the concepts of environmental and social responsibility. Practically, speaking, as global environmental and economic pressures intensify, the need for sustainability awareness will become a business imperative.

Sustainable industrialization is a derivative of the concept of sustainable development. Sustainable development has been described in terms of three dimensions, domains or pillars. In the three-dimension model, these are seen as "economic, environmental and social" or "ecology, economy and equity".

According to ecological economist, Malte Faber, ecological economics is defined by its focus on nature, justice, and time. Issues of intergenerational equity, irreversibility of environmental change, uncertainty of long-term outcomes, and sustainable development guide ecological economic analysis and valuation. According to John Baden “the improvement of environment quality depends on the market economy and the existence of legitimate and protected property rights.” They enable the effective practice of personal responsibility and the development of mechanisms to protect the environment. The State can in this context “create conditions which encourage the people to save the environment.”
One of the most significant barriers to sustainable development is the broad scope and complexity of the issues that need to be addressed, ranging from the minimization of ecological impacts associated with leather industrial waste streams to enhancement of quality of life in the study area. It is difficult for decision making teams to anticipate the multitude of cause and effect chains that drive the ultimate beneficial or adverse impacts of their proposed investments or technical innovations.

### 3.2.2 Role of Leather Companies

Leather business plays a special role in industrial ecology in two respects. Because of the potential for environmental improvement that is seen to lie largely with technological innovation, businesses as a locus of technological expertise are an important agent for accomplishing environmental goals. Further, some in the industrial ecology community view command-and-control regulation as importantly inefficient and, at times, as counterproductive.

Perhaps more significantly, and in keeping with the systems focus of the field, industrial ecology is seen by many as a means to escape from the reductionist basis of historic command-and-control schemes (Ehrenfeld 2000a). Regardless of the premise, a heightened role for business is an active topic of investigation in industrial ecology and a necessary component of a shift to a less antagonistic, more cooperative and, what is hoped, a more effective approach to environmental policy (Schmidheiny 1992).

### 3.3 Leather Industrial Ecology and Cleaner Production:

Clean (or cleaner) leather production is an approach to environmental management which aims to encourage new processes, products and services which are
cleaner and more resource efficient. It emphasizes a preventive approach to environmental management taking into account impacts over the whole life cycle of leather products and services.

There are clear conceptual resonances between industrial ecology and cleaner leather production. Both are motivated by concerns about the increasing environmental impacts of industrial economic systems. They emerged at more or less the same time (the late 1980s to mid-1990s) in the evolution of environmental management. Both have spawned their own journals and their own literature. A brief survey of this literature reveals strong intellectual overlaps between the two models. For example, the Journal of Cleaner Production (published by Elsevier Science) advertises its scope as including the following concepts:

- Pollution prevention,
- Source reduction,
- Industrial ecology,
- Life cycle assessment,
- Waste minimization,
- Sustainable development.

Thus cleaner production claims to include industrial ecology within its remit, and has on one occasion devoted a special issue of the journal to industrial ecology (Ashford and Cote 1997). At the same time, the Journal of Industrial Ecology (published by The MIT Press) ‘focuses on the potential role of industry in reducing environmental burdens throughout the product life cycle from the extraction of raw materials, to the production of goods, to the use of those goods, to the management of
the resulting wastes’. Without explicitly using the term, the journal’s list of topics includes much of the ground covered by cleaner production.

In spite of these similarities and overlaps, the two concepts emerged in slightly different ways from slightly different places, and there are, at least on some interpretations, discernible differences in approach which flow from these historical idiosyncrasies. This chapter sketches briefly the history of the concept of cleaner production and its integration into a network of activities coordinated by the United Nations Environment Programme (UNEP). It next sets out some of the underlying principles of cleaner production and describes how these are translated into operational strategies. Finally, it discusses key similarities and differences between cleaner production and industrial ecology.

Jackson (1993) identified these guiding principles as precaution, prevention and integration. First of all, the lessons of the precautionary principle (Raffensberger and Tickner 1999; Sand 2000) are clearly relevant in structuring a new approach to environmental protection. This principle emerged as an important factor in environmental policy at around the same time as cleaner production emerged as a new environmental management paradigm. The earliest formulation of the principle can be traced back to the first international Conference on the Protection of the North Sea in 1984 (Dethlefsen et al. 1993). The second conference, in 1987, formalized acceptance of the principle by agreeing to ‘reduce polluting emissions’ of particular kinds of substances ‘especially where there is reason to assume that certain damage or harmful effects . . . are likely to be caused by such substances’ (North Sea Ministers 1987). The fundamental import of the principle is to take action to mitigate potential causes of environmental pollution in advance of conclusive scientific evidence about actual effects. Though originally formulated in terms of a specific class of substances –
namely those that are persistent, toxic and bioaccumulable – subsequent applications of and attempts to explicate the principle have stressed that the domain of precaution could potentially be applied to all anthropogenic emissions. As such, the principle enshrines a call to reduce the material outputs from all industrial systems: in effect therefore to engage in cleaner production.

The principle of prevention provides perhaps the most fundamental distinction between the concept of cleaner production and earlier environmental protection strategies (Hirschhorn and Oldenburg 1991; Hirschhorn et al. 1993). Preventive environmental management also requires actions to be taken upstream, before environmental impacts occur. This is in contrast to more traditional environmental management strategies which by focusing on environmental endpoints tend to clean up pollution, as it were, after the fact. Such clean-up strategies can sometimes ‘prevent’ environmental emissions from affecting human health, and for this reason remain important within environmental management. But they are expensive ways of dealing with anthropogenic impacts on the environment, and generally fail to address the root causes of pollution. Preventive environmental management also distinguishes itself from end-of pipe environmental management which attempts to ‘prevent’ the emission of specific pollutants into a particular environmental medium by placing some kind of filter or treatment between the emission and the environment. Again, the logic of prevention is to seek intervention at an earlier stage of the process in such a way that the polluting emission does not arise in the first place.

There is a sense in which the prevention is thus a directional strategy: it looks as far as possible upstream in a network of causes and effects; it attempts to identify those elements within the causal network which lead to a particular problem; and it then takes action at the source to avoid the problem. The preventive approach
recognizes the demand for products and services as the prime mover in the impact of anthropogenic systems on the environment. In particular, therefore, the preventive nature of clean leather production entails the need to ‘reconsider leather product design, consumer demand for leather products, patterns of material consumption, and indeed the entire basis of economic activity’.

Finally, cleaner leather production attempts to formulate an integrated approach to environmental protection. Traditional end-of-pipe approaches have tended to concentrate on specific environmental medium: air, water or land. One of the failures of earlier management approaches was to reduce specific environmental emissions at the expense of emissions into different medium. Cleaner leather production attempts to avoid this problem by concentrating on all material flows, rather than selected ones. Furthermore, as the definitions point out, cleaner leather production demands that attention be paid to emissions over the whole life cycle of the product or service from raw material extraction, through conversion and production, distribution, utilization or consumption, re-use or recycling, and to ultimate disposal. There are ‘fifteen steps to clean leather production’ as follows:

- consume consciously and consume less,
- conserve resources and use only renewable,
- establish community decision making,
- require public access to information,
- ensure leather waste cleaning worker protection,
- convert to chemical-free leathers,
- mandate clean leather production audits,
- eliminate toxic emissions and discharges,
- stop toxic leather waste disposal,
- Phase out toxic chemical production,
- ban hazardous technology and waste trade,
- prohibit toxic leather waste recycling,
- prosecute corporate criminals,
- be active in your community,
- support Greenpeace.

3.4 Leather Industrial Ecosystems

Leather Industrial ecosystems, designed ‘from scratch’ to imitate nature by utilizing the waste products of each component firm as raw materials for another, are an attractive theoretical idea, but as yet mostly at the proposal stage. It is important to stress that process changes to take advantage of returns to closing the materials cycle are very definitely not another version of ‘end-of-pipe’ treatment of wastes.

The key feature of most industrial ecosystems that have been proposed is what might be termed ‘economies of integration’. To be sure, large scale is also required, in most cases. But beyond that, both vertical and horizontal integration are required. Leather industrial ecosystem essentially depends on converting (former) leather waste streams into useful products. This means that some producers must be induced to accept unfamiliar inputs (that is, converted wastes) rather than traditional raw materials. In some cases they will have to invest large sums of money to create new processing facilities, based on unproven – or semi proven – concepts.

To summarize, leather industrial ecosystems are very appealing in concept. Properly organized and structured, they exemplify a built-in incentive to minimize
wastes and losses of intermediates. But much research is needed to clarify the optimum organizational and financial structure of such an entity.

3.5 Leather Material Flow Analysis

Leather Material Flow Analysis has become a fast-growing field of research with increasing policy relevance. Leather material flow analysis (LMFA) refers to the analysis of the throughput of process chains comprising extraction, chemical transformation, manufacturing, consumption, recycling and disposal of waste materials. It is based on accounts in physical units (usually in terms of tons) quantifying the inputs and outputs of those processes. The subjects of the accounting are chemically defined substances on the one hand and natural or technical compounds or ‘bulk’ materials on the other hand. LMFA has often been used as a synonym for leather material flow accounting; in a strict sense the accounting represents only one of several steps of the analysis, and has a clear linkage to economic accounting.

In general LMFA provides a system-analytical view of various interlinked processes and flows to support the strategic and priority-oriented design of management measures. In line with environmental protection policy as it has evolved since the 1970s, LMFA have been applied to control the flow of leather waste hazardous substances. The results contributed to public policy in different ways:

The analyses assisted in finding a consensus on the data which is an important prerequisite for policy measures.

- LMFA has led to new insights and to changes in environmental policy
- The analyses discovered new problems
They also contributed to finding new solutions. The use and policy relevance of type II analyses have been increased in recent years in the following ways (Bringezu 2000b):

- Support for policy debate on goals and targets, especially with regard to the resource and eco-efficiency debate and the integration of environmental and economic policies,
- Number of companies providing firm and product accounts,
- Provision of economy-wide material flow accounts for regular use in official statistical compilations,
- Derivation of indicators for progress towards sustainability.

3.6 Leather Material Flow Analysis and Economic Modeling

A standard LMFA gives an overview of the current, or even historical, leather waste material status in a country (or economy). But in order to approach issues like sustainable development, there is also a need to analyze possible future developments of leather waste material flows. This is especially true when analyzing how different policies (environmental and others) may affect the leather waste material flows in the study area.

The flows of leather waste materials are to a large degree determined by the broad interplay between different agents (the consumers and producers) that characterizes economies today. There is, for instance, a large volume of deliveries inside and between the different leather production centres. Changes in the end consumption of leather product will have repercussions through most sectors in the economy, since it is not only the producer of the product that must change the production but also producers of intermediate goods and raw materials. When
studying the use of leather waste materials it is important to consider this complexity. Economic models do attempt to handle this interaction between economic agents and can therefore be considered as suitable tools for predicting and analyzing the consumption of leather materials.

When doing a forecast of leather waste material flows one has to choose a model that describes the society, or economy, that the forecast will cover. This model may be rather simple. The model may also be more complicated and take into account interactions between different (economic) sectors and activities. For this type of forecast one often uses macroeconomic models, and preferably so-called ‘computable general equilibrium’ (CGE) models. This will consider some examples of forecasting and policy analysis based on the second alternative, in the form of economic models, to see how they could be used together with information about leather waste material flows in order to forecast these flows.

When using models to do a forecast it is important to keep in mind that it will only give a picture of a possible development; it can never be looked upon as a definite answer. A forecast is most useful when comparing different possible developments, and especially in seeing how different policy measures might affect the development. One often starts with a business-as-usual path; that is, what is thought to be the most likely development given actual trends and today’s policy. Then, by using the model, one constructs one or more new paths where the measure to be analyzed is implemented. Comparing these various paths gives a picture of how effective the measure might be.

It is also important to keep in mind that a model is necessarily a description of a limited aspect of a society. A model builder must always make a choice between
simplicity and realism; the simpler (and maybe more user-friendly) the model, the less realistic. A model that is very detailed and hence more realistic runs the risk of being difficult to manage (although modern computer science has largely eliminated computational problems) and, worse, opaque. The more complicated the model is the more difficult it will be to interpret the results, and to determine how different effects interrelate. This is a crucial point, because it explains why most economic models up to now have neglected leather waste material/energy flows.

3.6 Economic Modeling

Economic models can be viewed as paper laboratories economists can use to conduct *gedanken* experiments, since it is impossible to perform these experiments in real life. There exist several types of models that can be used for different types of analyses of economic character, including macroeconomic, input–output and general equilibrium models. The models all have different virtues and drawbacks that cannot be further examined here. For long-term forecasts of the allocation of resources, that is labor, and all kind of physical materials, capital and consumption goods, one often uses general equilibrium models. Therefore we will focus mainly on this type of model.

The idea of general equilibrium is a fundamental pillar in economic theory, and basically it assumes that all the markets that make up an economy either are in or tends towards a state of equilibrium. This means that for each market the supply of each good or service will equal the demand for that good or service. Adam Smith’s notion about the invisible hand coordinating market clearance can be viewed as the starting point of the theory of general equilibrium (Smith 1993 [1776]), but the first to formally describe general equilibrium was Walras (1995 [1874]). The idea was
developed over the years and can be said to have reached maturity in the work by Arrow and Debreu (1954). It is therefore often referred to as the Arrow–Debreu economy. Introduction to the formal theory of general equilibrium can be found in numerous economic textbooks; see, for example, Hildenbrand and Kirman (1988), Ellickson (1993) and Myles (1995).

By the development of computable (that is, numerical multisectoral) general equilibrium models (CGE models), the theory of general equilibrium became an operational tool in empirically oriented economic analysis. CGE models with realistic empirical representation of one or more countries are often called applied general equilibrium (AGE) models. The models consist of a set of aggregated economic agents, who demand or supply aggregated goods (consumption goods, services and production factors). The agents are supposed to be rational in the economic sense, meaning that consumers maximize their utility and producers maximize profit. The model endogenously determines quantities and relative prices, at a point in time, and thereby the resource allocation in the economy, such that all markets clear.

It is commonly agreed that CGE modeling began with the work of Johansen (1960), which was the starting point for the MSG (multisectoral growth) model, a model still being developed and refined at Statistics Norway and used by the Norwegian authorities. The two latest versions, MSG-5 and MSG-6, are documented in Holmoy (1992) and Holmoy and Hoegeland (1997). The CGE model ORANI, developed for Australia, can be looked upon as an elaboration of the MSG model, see Dixon et al. (1982). Introduction to and surveys of the methods and theories developed in AGE and CGE modeling can be found in Fullerton et al. (1984), Shoven and Whalley (1984, 1992), Bovenberg (1985), Bergman (1990) and Dixon et al. (1992).
Of course there exists a lot of criticism of general equilibrium models, basically referring to the (lack of) realism in describing the functions of a society. The criticism ranges from the need to extend and further develop GE models, as in Walker (1997), to a more fundamental critique of the underlying theory, especially the lack of an endogenous theory of technological progress and the implausibility of growth in a state of static equilibrium. See, for example, Black (1995) and Ayres (2000).

3.6.1 Models Integrating Material Flows and Economic Concerns

The main purpose is to describe models that can be used to estimate possible trends in the development of total consumption of leather materials. So far there are not many documented studies in this field: the models used for economic and environmental forecasts most often have dealt with the costs of emissions to air, and are expressed in monetary instead of physical units. To forecast physical material flows, including emissions, one has to integrate an economic model that predicts future extraction, production and consumption with a model that estimates some physical measurements of materials and natural resources, preferably the weight in tons or the embodied energy content of wastes (a measure of its potential to initiate a chemical reaction with the environment).

An early contribution by Ayres and Kneese (1969) points to the need to integrate a material balance perspective in economic modeling. This need is based on the fact that residuals (waste) are an inherent and normal part of production and consumption. Further, the quantities of these residuals increases with increases in population and/or level of output, and they cannot be properly dealt with by considering different environmental medias in isolation. Ayres and Kneese construct a formal theoretical extension of a general equilibrium model (the so-called ‘Walras–
Cassel’ model), that includes the mass balance condition by introducing an (unpriced) environmental sector and using physical units for production and consumption. In order to become an analytical tool this model has to be fed with enormous amounts of data, and the computation, at least at that time, would have been extremely difficult. The theoretical model is still useful, however, as it shows that partial analysis of isolated environmental problems can lead to serious errors.

There were hardly any applications of the idea propagated by Ayres and Kneese (1969) until 1994, when a work was published describing a dynamic macroeconomic model with a material balance perspective (van den Bergh and Nijkamp 1994). The authors’ aim was to construct a model suitable for studies of the long-term relationship between an economy and its natural environment. The model was designed to capture two main elements. The first was the two-way interaction between population growth, investments, technology and productivity, on one side, and declining environmental quality and resource extraction on the other. The second element was a more realistic representation of the interdependence between various environmental effects achieved by using the material balance perspective. The model integrates economic growth theory and material balance accounting by combining complex interactions between the economy and the environment. It is not analytically soluble, but is more suitable for simulation. It was calibrated to fulfill certain conditions in a base case scenario, in which logical, realistic or plausible values were chosen for different variables. Then 10 different scenarios were constructed, changing initial stocks of capital, natural resources, pollution and/or nonrenewable resources, including or not including ethical concerns and feedback from environment to investment. Van den Bergh and Nijkamp concluded that cautious behavior regarding
the environment in the long run does not necessarily lead to (strongly) declining economic performance.

Another effort to connect a material balance module to the MSG model is documented in Ibenholt (1998). The main purpose of that study was to analyze the generation of waste in production processes, on the basis of the physical law of conservation of mass. The difference between the physical input (raw materials and intermediate goods) and the produced physical output (intermediate or final goods) is the residual consisting of emissions to air, land and water. The MSG-EE model, an energy and environmental version of MSG (Alfsen et al. 1996), was used to predict the economic variables needed for the analysis, namely production and use of different physical inputs, all measured in monetary units. The factors converting monetary to physical units were assumed to be constant during the forecasting period (1993–2010), meaning that each monetary unit of a physical input or product in each production sector has a constant weight. This is of course a simplification, but it may be fairly realistic, considering the aggregation level (between 30 and 40 physical input and output goods). The method does not consider changes in the material intensity of each physical input or output, but it does incorporate changes in the amount of total material input per produced unit.

The study predicts a growth in the residuals from manufacturing industries of 74 per cent from 1993 to 2010. The growth is partly explained by an anticipated growth in material intensity along the economic development path. Increasing material intensity is partly caused by the strong substitution possibilities between labor and material input in the MSG model, and it might very well be overestimated. The study did not include any alternative scenarios, such as different policies towards the material consumption, since the main purpose was to compare the mass balance
perspective on waste generation with the method used in Bruvoll and Ibenholt (1997), where the generation of waste was explained by the development either in physical input or in production.

Another approach is described in Dellink and Kandelaars (2000). They combined the Dutch AGE model Taxinc with the material flow model Flux, which is an input–output type of database that describes the physical flows of materials in the Netherlands in 1990. The integration is incomplete since there is no endogenous feedback between the two models. The purpose of the study is to analyze material policies with the aim of reducing the use of specific materials (zinc and lead). The following policies were simulated: a regulatory levy on the primary use of zinc, on the throughput of zinc, on products that contain zinc, on the primary use of lead, and on the primary use of both zinc and lead. The tax revenue from the material levy was redistributed by reducing the employer’s contribution to social security. First the material flow model is used to determine the use of zinc and lead in different production sectors, which determines the magnitude of the tax for each sector. The levy is then imposed in the Taxinc model and a new equilibrium is calculated. The result from the Taxinc model is imported to the Flux model to calculate the effect in physical units. The conclusion that can be drawn from the study is that the macroeconomic impact of the tested tax policies achieved reductions in material use of 5 to 10 per cent while total production decreased by less than 0.2 per cent. The material-intensive production sectors would, however, suffer rather severe effects. Since the model does not allow for substitution between different materials, the results should be interpreted with great care.

Two related studies are Bruvoll (1998) and Bruvoll and Ibenholt (1998). Bruvoll (1998) uses the MSG model to simulate a green tax reform where a tax is
levied on plastic, wood pulp, cardboard and virgin paper materials, while the payroll tax is decreased (employers’ contribution to social security). The tax rate in different production sectors is calculated on the basis of data from the national accounting system. The effects from this tax reform are similar to the ones in Dellink and Kandelaars (2000), namely that a rather substantial reduction in material use is possible at a rather low macroeconomic cost. Bruvoll and Ibenholt (1998) levy a general tax on all materials used in production, and show a clear, positive environmental effect in the form of reduced emissions to air and waste quantities. However, the welfare effect is uncertain owing to reductions in production and material consumption.

Other studies that forecast waste generated are Nagelhout et al. (1990), Bruvoll and Ibenholt (1997, 1999) and Andersen et al. (1999). All these studies use fixed coefficients to explain the generation of waste, but they differ in the choice of explanatory variables. Nagelhout et al. (1990) and Andersen et al. (1999) use production and consumption forecasts by an economic model as explanatory variables, whereas Bruvoll and Ibenholt (1997, 1999) link waste generated in production sectors to the use of intermediates. A weakness of the method of fixed coefficients is the inability to capture changes in the material intensity that ought to lead to changing waste amounts.

In summary, there are few economic models integrating a material perspective and none of them can be regarded as anything more than a step towards a comprehensive and analytical model. Nevertheless, these models can yield valuable insights.
3.6.2 Converting Between Economical and Physical Data

Since an economic model uses monetary units, whereas a material flow analysis uses physical units, some link between these different units is needed. The increasing effort to construct physical materials accounts and to incorporate these in the monetary national accounts will most certainly be of valuable help in this conversion.

A common simplification in most models mentioned above is the assumption of constant conversion factors between physical and monetary units. The models disregard the fact that product development and/or changes in the composition of aggregated commodities can cause the mass of these commodities to change. Constructing exogenously variable conversion factors would probably not be technically difficult, but the problem lies in determining how these factors should develop over time. Endogenously variable conversion factors would be a far more difficult task, and certainly beyond current capabilities. If material accounts, or other forms of physical statistics, become more common and are constructed on a regular basis it would be possible, at least in theory, to construct time series of conversion factors. This could ultimately prove useful when determining how conversion factors develop over time, and what might affect them.

A major weakness with general equilibrium models is the way they handle technological development. The most common way to specify technological progress in these models is to use so-called ‘Hicks-neutral’ progress within each sector; that is, annual efficiency gain is assumed equal for all factor inputs in the same sector. Thus it does not directly influence the relationship between the various factor inputs within a sector. However, it affects relative factor prices and thereby, indirectly, changes the
composition of the factor inputs in a sector. This approach assumes that technological progress is exogenous. In addition, it is likely that most CGE models can only anticipate marginal changes in technological progress, since substantial changes might make the model (which assumes growth in perpetual equilibrium) collapse.

If one uses an input–output model for forecasts, instead of an AGE model, it is easier to apply larger shifts in the technological progress rate. A global input–output model for forecasts of global emissions of greenhouse gases for the years 2010 and 2020 is the World Model (Duchin and Lange 1996). Also several efforts have been made to endogenize technological development in economic models. This branch of economic thought is called the ‘new’ theory of endogenous growth; see, for instance, Romer (1986, 1987, 1990), Lucas (1988) and Grossman and Helpman (1994). For discussion of methods of endogenous technological progress and environmental issues, see Victor et al. (1994), Goulder and Schneider (1999) and Parry et al. (2000).

Despite the imperfect handling of technological development in AGE models, they offer valuable insight into one effect such development can have on the use of material. In the literature on energy use there has long been a discussion about the so-called ‘rebound effect’, meaning that more efficient energy equipment could increase total energy use. See Energy Policy (2000) for an overview and summary of this discussion.

In some cases, at least, increased efficiency in the utilization of resources in production may result in a fall in real prices of the commodities/resources that experience the strongest efficiency increases. This will make us richer (income effect) and at the same time physical resources and products become cheaper (price effect).
Being richer we can consume more. Since physical goods become relatively cheaper we can increase the demand for them. Through these mechanisms increased resource efficiency might actually increase the total use of the resource. This is the case in the study by Ibenholt (1998), where rebound is one of the main causes of the strong growth in residuals. See also Chapter 18 for a discussion of rematerialization that might be due to this rebound effect.

Commodities are essentially (transformed) natural resources with a rent attached. From a welfare perspective it is optimal to tax this rent, even though the tax base could be rather difficult to define in practice. Another argument for taxation of material consumption is the environmental problems this consumption causes. According to economic theory a cost-effective way to deal with such problems is through different forms of taxation. See, for instance, Pearce and Turner (1990), Repetto et al. (1992) and Lesser et al. (1997). The studies by Bruvoll (1998), Bruvoll and Ibenholt (1998) and Dellink and Kandelaars (2000) are all based on the idea of pricing materials in accordance with the environmental problems they incur, and they all show that this might be a rather cost-effective way to reduce environmental pressure.

The price mechanism is an important tool for steering technological development. Increased prices on natural resources and materials will most certainly spur technological development towards less material-intensive products and production processes, while at the same time dampening the rebound effects of this development. Keeping real prices of the physical resources constant, or even letting them rise, would modify the demand increasing (rebound) effect of technological progress. As mentioned above, ordinary AGE models do not fully capture the effect
the price mechanism would have on technological development. This, in context, must be considered a severe weakness.

3.7 Leather Industrial Ecology and Green Design

There is a growing body of knowledge in the form of design heuristics and tools for green design. With its focus of system-wide resource flows, leather industrial ecology is a major source of such approaches. However, economic and engineering issues predominate in green design. Moreover, many methods used for environmental analysis are not appropriate for design decision making. Ecological inventories and conventional leather product life cycle assessment operate with data needs and time requirements that make them difficult to incorporate into the design process, especially during the important conceptual design stage. Even conventional tools such as stochastic modeling and decision analysis can inhibit the conceptual design phase or vastly lengthen the time taken to consider each alternative. Ideally, green design tools would be ‘invisible’ to the designer save as additional attributes to consider in evaluating a design. We must select the places to intervene carefully so as to reduce complexity and be certain that the new tools and environmentally conscious objectives are appropriate and useful. In particular, designers need useful environmental standards representations, access to the latest technology opportunities, easily applied rating systems for design impact on the environment, and tools to help assess life cycle implications, including accounting systems to reflect the full environmental costs of new designs.

Decision making during the design process is critical for the achievement of environmental goals. It has been estimated that 70 per cent or more of the life cycle cost of a typical product is determined during design (USNRC 1991). Much of the
production process and operational impacts of leather product are determined through
decisions such as material choices or component power consumption. A traditional
means of achieving environmental requirements is to add ‘end-of-pipe’ control
processes for waste treatment. While a large proportion of environmental engineering
still focuses on waste treatment processes, it has become increasingly clear that
pollution prevention and waste reduction through design can be much more effective
(Bishop 2000; Fiksel 1996; Reijnders 1996; USOTA 1992).

How can we effectively influence design decisions to achieve environmental
goals? Design is a complicated and rather messy process, with numerous competing
requirements and a premium on rapid decision making. Designers tend to be
overloaded with conflicting criteria and information. Aids for green design must be
easily and rapidly applied to be effective. Assessing environmental impacts requires
analysis of downstream effects during production, operation and disposal. We
especially wish to identify design changes that have low cost but considerable
downstream benefits. For example, we may wish to include features such as ‘snap
fits’ that have little or no extra initial cost but make disassembly and thus re-use easier
(Kirby and Wadehra 1993). Effectively incorporating environmental concerns in
decision making requires extension or modification of synthesis methods to consider a
wider range of alternatives and requirements. Different strategies for information
dissemination, incentive structures and design aids may be required along these
different dimensions, but there should be a core concern for environmental objectives
related to toxic leather waste materials discharges, energy use and waste material use.

Green design often relies on practical knowledge (Burall 1991; Fiksel 1996;
Reijnders 1996). Green design methods typically take the form of design heuristics,
technology examples (such as solvent substitutions) and waste re-use examples (for
example, waste heat productively sold). Few automated design aids are available, while many design processes rely on computer aids for geometric representation, tolerance and synthesis.

Defining appropriate objectives for green design is a contentious issue in its own right (Lave et al. 1994). Maximizing leather waste recycling is not appropriate since the recycling may occur at inordinate cost or incidental environmental harm. Similarly, eliminating all toxic materials in leather products is not appropriate since the toxic materials may be useful and their discharge into the environment prevented during and after use. Following leather industrial ecology perspective, we will focus upon toxic leather waste material discharges to the environment, energy use, and material use and re-use in what follows.

What has been driving design decisions towards more environmentally conscious leather products and processes? Without being comprehensive, some important incentives can be noted. Direct regulation of technology and emissions has had an undeniable impact, but has also resulted in expensive adversarial relationships. Recognition of eventual liabilities for product and facility disposal has occurred, although the extent to which such remediation liabilities are abstracted to the design stage is questionable in many cases. Opportunities to gain by marketing ‘green products’ (or restricting sales of competing, non-green products) also exist, especially for leasing or taking back products and then handling recycling in a closed loop. Technological changes also create opportunities, as in CFC substitutes or new energy-efficient very large-scale integrated (VLSI) chips. Proactive changes such as reductions in toxic releases are also apparent in many companies. Reporting programs have focused more attention on environmental performance by managers, the public and investors. Finally, voluntary standards such as the ISO 14000 Environmental
Performance Standards have induced change in participating organizations (Cascio 1996; ISO 1998).

3.8 **Leather Industrial Ecology and Risk Analysis**

Risk analysis in industrial contexts consists of four integrated processes: (a) identifying underlying sources of risk; (b) determining the pathways by which such risks can materialize; (c) estimating the potential consequences of these risks under various scenarios; and (d) providing the means for mitigating and coping with these consequences. Specific risks, once identified, are usually characterized by the probability of their occurrence and the magnitude of their consequences, but many other attributes of risks may be of interest to individuals affected by these risks. Risks can have both positive and negative outcomes and can occur in any domain of a company’s operations, from engineering to finance.

A great deal of work in corporate finance and insurance has gone into the design of efficient risk management instruments for risks that can be monetized (for example, Doherty 2000) and, to the extent that the consequences of these risks are borne by the owners of an enterprise, there are strong incentives for managers to make efficient choices in balancing risks and returns. This is not usually true for industrial risks having safety, health or environmental (SHE) impacts, since these impacts are often borne by the ecosystem and by uninvolved third parties, including future generations. Thus, for SHE risks, market forces are not usually sufficient to motivate a profit-oriented company to operate efficiently.

Achieving efficient trade-offs here requires instead that industrial practice be tempered by regulation and public participation. Exactly how this should occur for various types of SHE risks has been a major area of development in the literature of
industrial ecology and will be the focus of this chapter. It first considers the central drivers of risk analysis in industrial contexts, since this has motivated much of the research in this area. Thereafter, the chapter briefly reviews key elements of current approaches to industrial ecology (IE) for SHE risks.

In the industrial ecology framework, each company has a special role as a steward of the environment and ecosystem within which it operates. Naturally, this role of product stewardship and environmental waste and risk management encompasses suppliers and customers just as ‘extended value-chain analysis’ encompassed suppliers and customers in the traditional supply chain improvement process. Indeed, it is useful to review the factors underlying the focus and need for industrial risk analysis in parallel with the extended supply chain.

Integrating the supply chain to identify, mitigate and manage risks requires integration with key business processes, measurement of results and commitment from top management. A number of managerial concepts, tools and systems exist that promote these steps towards sustainable risk practices. Essentially, all the tools of industrial ecology noted throughout this handbook have important implications in promoting reduction of SHE risks. For example, life cycle analysis, gated DfX screens (where Design for X includes X factors such as Environment, Safety, Disassembly and Recycling) and reverse logistics all promote more sustainable products and supply chains and can have significant effects on the overall SHE risks of these supply chains by reducing their P, B and T content.

Of the new management systems to promote SHE risk reduction and sustainable industrial practices, the best known is certainly the Environmental Management System (EMS) under the international standards ISO 14000 (Carter
1999) and related systems such as those promulgated by the European Union under the Eco- Management Audit Scheme (EMAS). ISO 14000 began development in 1991, after the Industrial ecology and risk analysis 469 successful deployment of ISO 9000 standards, and the aspirations underlying ISO 14000 were motivated by the experience with ISO 9000. Recent empirical research shows that process mapping, as embodied in good IE practice and in the ISO 9000 quality standard, can be a significant aid to discovering process defects and fixing them (Angel 2000). By extension, this same logic of process excellence appears to apply to risks and ecological effects, and industrial practice is increasingly reflecting this belief (CCPS 1989; Bern 1998; Friedman 1997). Systems such as ISO 14000, EMAS and related process safety standards have become essential vehicles across the globe in codifying a company’s SHE practices, in promoting auditing standards for these, and in providing the public and regulators with information about company SHE performance (Lofstedt et al. 2000; Kunreuther et al. 2000).

A prime mover for implementing IE is government regulation and economists have been concerned since the beginning of environmental regulation to provide the logical underpinnings for such regulation. In the context of the management of risk, economic models focus on the incentives a firm faces to engage in efficient risk mitigation. Theoretical and empirical results from this literature show that, if the firm does not internalize all the consequences of its decisions regarding risk, it will tend to under invest in risk mitigation. This in turn awakens the call for regulation of such risks. A number of models have been developed to investigate the consequences of various forms of regulation that attempt to rectify the noted underinvestment problem (for example, Shavell 1984; Gruenspecht and Lave 1989; Watabe 1999).
An alternative approach to risk regulation has been suggested by Kleindorfer and Orts (1998), and this approach is increasingly evident in North America and the European Union. The approach is called ‘informational regulation’ (IR) of risks and is based on the original ideas of Ronald Coase (Coase 1960). The IR approach requires firms to share information on their risk management programs and their performance with the public. The idea is to make it easy for NGOs, local community groups and affected citizens to identify the risks they face and, by providing thereby leverage for such groups, to put pressure on firms to improve their risk performance. Under IR, the locus of risk regulation moves away from government bureaucracy to local bargaining between affected communities, armed with legitimate information on the risks they face, and the companies giving rise to such risks. This approach is especially compelling when the risks involved are largely local and borne by an identified group of stakeholders, such as a community hosting an industrial facility.

General procedures and a host of tools and industrial applications of risk analysis have been developed over the past half-century. A good survey of these is available in Haines (1998) and further research progress is reported in the primary journal in the field, Risk Analysis. The accepted conceptual structure for managing SHE risks includes the following activities (see Friedman 1997):

- hazard identification: listing materials, processes and products of potential concern and qualitatively prioritizing these by their relative hazard;
- risk assessment: determining the credible releases, exposure pathways and events that might result from various events and scenarios and calculating the median and worst-case hazard zones associated with these;
risk analysis: considering all safety systems, redundancies and mitigation possibilities, calculating detailed probability distributions for the hazards identified and considering damage reduction possibilities;

risk management: specifying risk acceptance and risk reduction guidelines, specifying process hazards management procedures, including emergency response procedures, structuring financial and insurance provisions and establishing communication procedures with affected employees and the public.

For each of the above steps, companies can rely on a variety of tools and methodologies to assist them (Haimes 1998). In the hazard identification phase, data and procedures from industry sources help to determine levels of hazard of various leather processes, materials and products. The tools of industrial ecology in mapping material and energy flows (for example, Ayres 1997b; Ayres and Ayres 1997) are essential diagnostic tools to indicate likely sources and magnitudes of emissions and leather solid wastes in key processes. In risk assessment, a variety of decision support systems are available for computing for various chemicals dispersion dynamics and their consequences. Risk analysis is supported by general tools, such as process simulation, decision analysis and event and fault tree methods, as well as by customization of these tools for use in leather industrial units. The literature on risk and insurance is well developed in the area of SHE risks (Freeman and Kunreuther 1997), as are approaches to emergency response. Finally, survey methods and other empirical approaches to measuring the perceptions of community members of the industrial risks they face are now widely developed (motivated by the work of Slovic 1987) to assist decision makers in determining what various stakeholders are concerned about and how best to communicate with them about risk reduction possibilities.
When these processes and tools are applied to a setting, the results achieved can be remarkable. In line with the findings of the effects of quality management programs, these results are in two key areas. The first is the structuring of a strong management system for companies that links their strategy process and their operations to a legitimate, science based framework to identify, assess and manage their SHE risks. The second is an organic structure of shared knowledge that allows all stakeholders in a company’s operations to understand the potential effects of these operations on the company’s ecosystem. This systemic knowledge, and the purposeful activity triggered by it to achieve a sustainable fit between a company and its environment, is the most important characteristic of the industrial ecology approach to SHE risks.

3.9 Leather Industrial Ecology and Extended Producer Responsibility

Green design or design for environment (DFE) and cleaner leather production can address an extensive list of environmental issues throughout leather products life cycle. Nevertheless, some impacts are currently beyond their control, especially those associated with discarded leather solid waste products. The bottleneck is often disposal, and it cannot be overemphasized that DFE features in leather product can only facilitate – and not ensure – recycling.

A relatively new direction in government policy is now being adopted by most OECD (Organization of Economic Cooperation and Development) countries. It encourages leather manufacturers, in particular, to accept greater responsibility for their products when they reach end-of-life (EOL) and are discarded. Extended producer responsibility (EPR) represents a more systematic approach with the potential to revolutionize the way products are conceived, used, recovered and
ultimately re-used, recycled or disposed of. The OECD has provided a definition of extended producer responsibility:

“EPR is defined, for the purposes of the OECD project, as the extension of the responsibilities of producers to the post-consumer stage of products’ life cycles. EPR strategies suggest that the use and post-consumer phases of a product’s life cycle are important aspects of the ‘pollution’ for which responsibility must be assumed under the Polluter Pays Principle. (OECD 1996b, pp.15–16)”

A key objective of EPR, given the OECD definition, is ‘to transfer the costs of leather waste management from authorities to those actors [i.e. the producers] most able to influence the characteristics of products which can become problematic at the postconsumer stage: waste volume, toxicity, and recyclability’ (ibid., p.16). By transferring these costs, governments hope to provide powerful incentives for producers to prevent leather solid waste generation, reduce the use of potentially toxic inputs, design products that are easily recyclable and internalize the costs.

EPR is a logical extension of the ‘polluter pays’ principle. It rests on an argument that the environmental impacts of resource depletion, waste and pollution are a function of the system of production and consumption of goods and services. Those impacts are substantially determined at the point of production, where key choices are made – on materials, processing and finishing technology, product function and durability, systems of distribution, marketing and so on. If that system is to evolve in a way that reduces environmental impacts, there is a need for policies that create appropriate feedback mechanisms for producers that will direct their investment towards continuous environmental improvement. In brief, EPR can be considered as an effective policy mechanism to promote the integration of the life cycle
environmental costs associated with products into the market price for the product. The transferred of waste management costs is seen as a critical driver or incentive for industry to internalize the complete range of costs associated with managing end-of-life waste.

The other critical factor is the extent of interaction required between and among environmental management approaches. To talk of EPR in isolation from DFE, remanufacturing, supply chain management or LCA is to fail to recognize the interconnections between product design, environmental assessment and EOL processing methods, all of which are increasingly vital tools in maximizing the commercial viability of EPR schemes. This further reinforces the need for such tools and methods to work in harmony in pursuit of sustainability. Furthermore, it also highlights the relevance of industrial ecology as a way of meshing approaches in a more holistic manner by which resources can be used in a hyper efficient way.

Finally, while EPR is often discussed in terms of government regulations, the essence of such policy objectives relates to the way sustainable leather production and consumption might be realized through increased levels of leather solid waste avoidance and resource recovery. This highlights that many of the real challenges rest with industry and its ability to be just as innovative in ‘unmaking’ products as it is in ‘making’ them. Similarly, consumers will need to consider their role and obligations in ‘de-purchasing’ their end-of-life products.
3.10 Summary

To be able to design and adopt the most appropriate leather solid waste management system, a proper theoretical background has to be established. It can be asserted that when one is looking for a scientific systematization, and ultimately aiming at establishing an explanatory and predictive order among the domain problems of leather solid waste management, a theory is required.

It was argued that Leather Waste Management Theory is to be built under the paradigm of Leather Industrial Ecology, and their side-by-side advancement can greatly contribute to the development of a sustainable agenda of waste management. The Theory of Waste Management is based on the considerations that leather solid waste management is to prevent waste causing harm to human health and the environment, and application of waste management leads to conservation of resources. However, Leather Industrial Ecology successfully combines leather solid waste minimization and resources use optimization measures, and ensure that resources are effectively circulated within ecosystems. Research continues to evolve the Theory of Waste Management, which will assist in incorporating environmental concerns into leather industrial process and leather product design.