The Application of Life-Cycle Assessment within a Public Policy Framework – Theory and Reality

by

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Abstract

Public policy plays a major role in defining societal programs and frameworks, including issues related to environmental protection. Life-Cycle Assessment (LCA) offers a tool to provide comprehensive environmental impact information that can be applied within the public policy development process. However, direct application of LCA results within the public policy arena has been limited, as a result of process and technical barriers.

Despite the potential challenges and barriers, LCA could theoretically improve the decision-making process, and ultimately lead to better environmental outcomes.
To facilitate this process, this thesis develops and presents recommendations to encourage consistent approaches to incorporating LCA into public policy decision making, in order improve the informed consideration of environmental factors within public policy development.

In developing this thesis, information from existing literature provided a background of the use of LCA in public policy development and research into associated barriers. Literature was supplemented through interviews with subject matter experts, as well as practical LCA application through involvement with case studies with public policy elements. The current ISO LCA standards were also reviewed through a lens of public policy application. Research results were summarily integrated to develop a proposed framework for incorporating an improved LCA methodology into public policy development.

Research showed that barriers that limit the application of LCA within the public policy development process range from lack of technical knowledge and LCA understanding on the part of policy makers, to a lack of trust in LCA process and results. Many of the

identified barriers suggest that the failure of LCAs to contribute positively to public policy development is due to the process within which the LCA is being incorporated, rather than technical problems in the LCA itself. This led to the conclusion that a more open and inclusive process, with a focus on communication and understanding, may provide a better alternate framework for the development of public policy.

This approach suggests that effectively incorporating LCA within the overall public policy decision-making process requires a more normative multi-disciplinary approach that includes a range of stakeholders and public policy decision-makers in a collaborative process at all stages of the assessment. Involving decision-makers and a full range of stakeholders actively, wholly and genuinely throughout a transparent and robust LCA process would serve to build an effective public policy development framework that would facilitate increased integration of LCA. A set of recommendations for implementing this type of process represents a significant contribution of this thesis.

Additional recommendations suggest expanding the ISO LCA standards to embrace subjective and process elements, making them more robust, and encouraging the use of LCA in applications such as public policy.

An overall conclusion is that one of the most important aspects of incorporating LCA into public policy decisions is to encourage life-cycle thinking among policy makers. Considering the life-cycle implications will result in more informed and thoughtful decisions, even when a full LCA is not undertaken.

Preface

This thesis is an original work by Christina Seidel. Portions of this thesis have been compiled and are pending publication as a paper titled The Application of Life Cycle Assessment to Public Policy Development in the International Journal of Life Cycle Assessment.

Acknowledgements

I owe a great deal to my long-suffering supervisors, Dr. Michael Lipsett, and Dr. David Checkel. They have seen me through this process despite delays and setbacks, always encouraging me to soldier on. It is entirely due to their perseverance and inspiration that this thesis has materialized.

I would also like to acknowledge the many outside experts who contributed their knowledge and insight, adding much to the depth of research and conclusions. In particular, the individuals at CalRecycle, who led me through the California Used Oil LCA process were always very supportive and helpful in building my understanding of that monumental undertaking.

The staff and Board members of the Alberta Recycling Management Authority also deserve a special thank you for allowing me to use their Scrap Tire LCA as a guinea pig for this thesis. Following that process through in its entirety provided much of the hands-on research for this project.

Table of Contents

List of Tables

List of Figures

Glossary

ADP – Abiotic Depletion Potential

ARMA – Alberta Recycling Management Authority

CalRecycle – California Department of Resources Recycling and Recovery

CIELAP – Canadian Institute for Environmental Law and Policy

Decision Analysis – discipline comprising the philosophy, theory, methodology, and professional practice necessary to address important decisions in a formal manner.

EPA – Environmental Protection Agency

EU – European Union

EUROPEN – The European Organization for Packaging and the Environment

GHG – Greenhouse gas

ISO – International Organization for Standardization

LCIA – Life Cycle Impact Assessment

Life-Cycle Assessment – the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO, 2006)

MEBCalc – Measuring the Environmental Benefits Calculator – Sound Resource Management's proprietary software for computing the environmental footprint of a community's municipal solid waste (MSW) management system (Sound Resource Management, 2015)

PAH – Polycyclic aromatic hydrocarbon

PM – Particulate matter

Public policy – actions and decisions taken by governmental entities that affect other governmental entities, nongovernmental entities, the public, and private interests (Allen et al., 1995)

SETAC – Society of Environmental Toxicology and Chemistry

TRACI – Tool for the Reduction and Assessment of Chemical and other Environmental Impacts, a stand-alone computer program developed by the U.S. Environmental Protection Agency (Earth Shift, 2015)

UNEP – United Nations Environment Programme

VOC – Volatile organic compound

The Application of Life-Cycle Assessment within a Public Policy Framework – Theory and Reality

1 Introduction

Public policy is defined as “actions, decisions, statements, mandates, orders, or guidance taken by governmental entities that affect other governmental entities, nongovernmental entities, the public, and private interests” (Allen et al., 1995. p.15). Public policy plays a major role in defining societal programs and frameworks, including issues related to environmental protection. Public policy reflects assumptions of policy makers, based on their knowledge and experience, regarding the best resolution to a particular issue or problem (Michigan State University, 2005). Public policy development is the result of many factors that influence decision making (John, 2013) and multiple stakeholders with different values, perceptions and preferences, thereby resulting in a complex and unpredictable process (Cairney, 2013).

Accounting for this complex process, the development of good public environmental policy that delivers the desired results requires the consideration of relevant information, including environmental impacts, as well as impacts on stakeholders. Life-Cycle Assessment (LCA) offers a tool to provide comprehensive environmental impact information that can be applied within the public policy development process.

Life-Cycle Assessment is defined as “the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO, 2006, p.2). LCA is a “cradle-to-grave” approach for assessing industrial systems (EPA, 2006). Life-Cycle Assessment offers the ability to assess the environmental impacts of products through their entire life cycle, rather than only at specific phases. This incorporates stages such as raw material extraction, manufacture, use or consumption, and recycling or disposal. This life cycle system approach is also commonly referred to as cradle-to-grave. “Cradle-to-grave” begins with the gathering of raw materials from the earth and ends at the point when all materials are returned to the earth (EPA, 2006). By including environmental impacts throughout the life cycle, LCA provides a “comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection” (EPA, 2006, p.1).

According to the Society of Environmental Toxicology and Chemistry (SETAC), "the goal of applying life-cycle concepts to public policy is to identify public policy opportunities for reducing environmental burdens associated with design, manufacture, use, and ultimate disposal of products, processes, or activities over the entire life cycle" (Allen et al., 1995, p.77). ISO 14040 asserts that LCA can assist in informing decision-makers in industry, government or non-government organizations (e.g., for the purpose of strategic planning, priority setting, product or process design or redesign) (ISO 2006).

Life-Cycle Assessment (LCA) has been used by decision-makers across the European Union, Japan, Australia, and many other countries to inform public policy (CIELAP, 2009). In the U.S., LCA was applied federally to the Energy Independence and Security Act of 2007 to determine if the threshold standards for emissions reductions were being met, the first and only time federal regulatory policy mandated the use of LCA on a product or system. At the same time, there are numerous examples of the use of LCA at the U.S. state level, including California's evaluation of alternative hazardous waste management systems and comprehensive LCA of used lubricating and industrial oil management process; and Oregon's LCA of mail-order packaging, LCA-based approach to preventing construction and demolition waste, and life-cycle thinking in the development of recommendations for reducing greenhouse gases related to waste management. In Canada, LCA has been used to inform waste management strategies in Metro Vancouver, organics management methods and scrap tire management options at the provincial level in Alberta. However, little evidence exists to show direct influence of these LCA initiatives on public policy development.

In general, LCA has not been used within public policy development as much as it has been applied to other applications such as product design (Allen et al., 1995). Limited evidence of successful integration of LCA into public policy development also suggests that direct application of LCA results within the public policy arena has been limited, despite the official incorporation of LCA within the process in some cases. Reasons for this disconnect include both process and technical barriers. A review of these barriers and assessment of potential approaches to mitigate them is a primary research objective of this dissertation.

Despite the potential challenges and barriers, LCA offers a potentially valuable tool for assessing the full environmental impacts of public policy options involving product or process choices. When deciding between multiple alternatives, LCA can help decision-makers compare all major environmental impacts caused by products, processes, or services, helping to select the choice that results in the least impact to the environment (EPA, 2006). Facilitating its increased application in the public policy arena could theoretically improve the decision-making process, and ultimately lead to better environmental outcomes.

In order to encourage integration of LCA into public policy development, the main goal of this dissertation is to develop and present recommendations that encourage consistent approaches to incorporating LCA into public policy decision making, ultimately assisting in improving the informed consideration of environmental factors within public policy development.

In summary, the thesis developed is that barriers exist to the full and successful integration of LCA into the public policy development process, and that these barriers can be mitigated through effective process design. This thesis is developed through information from existing literature on the use of LCA in public policy development and associated barriers, interviews with subject matter experts, and case studies with public policy elements, to develop a proposed framework for incorporating an improved LCA methodology into public policy development.

2 Methodology

The project methodology was designed to address the primary research questions associated with the thesis:

1) What barriers exist to integration of LCA into the public policy development process?

2) How can these barriers be addressed to encourage increased incorporation of LCA within public policy decision-making?

The nature of the topic and types of research options available led to research methods focusing primarily on qualitative approaches including literature review, key informant interviews, group discussions, and case study analysis. To increase the robustness of these approaches, and validate conclusions resulting from the research, corroborating evidence from multiple approaches and sources was utilized where possible.

To provide context to the research, and to assess the potential for integrating LCA into public policy, an extensive literature review was conducted to identify previous research into this area, as well as provide further background of relevant public policy and LCA aspects. Because of the relatively long period of time and geographic range of the research topic, literature formed a primary source of information, particularly regarding LCA applications and barriers. Significant attention was given in the 1990s to the application of LCA within public policy development, both in Europe and the United States, as evidenced by a SETAC workshop on the topic in 1995. However, focus shifted to technical LCA standards after the turn of the century, leaving a strong foundation of literature from the earlier period, but a decreasing availability of LCA experts with experience in public policy applications. This led to the reliance on documentation from previous research in providing the foundation to the thesis.

The literature review was conducted using standard broad internet research, supplemented by a review of academic databases and journals accessed through the University of Alberta library. This literature review provided a strong foundation to subsequent research phases, including identifying potential key informants and case studies that could provide supplemental and supporting information to the foundational information in the literature.

Identified individuals who potentially have key knowledge into the application of LCA to public policy were contacted and interviewed to gain additional insight into the field. These key informant interviews were focused on North America for practical reasons, as well as to keep the context as relevant as possible. Individuals were chosen based on their experience with LCA and public policy, as identified in relevant literature research, as well as referrals from other contacts. As previously indicated, because of the time lapse since focused LCA public policy work in the 1990s, some potential key contacts could not be located, and may have even left the field. However, the ongoing work of the U.S. Environmental Protection Agency (EPA) on LCA led to a select number of key contacts who became key informants for the research, representing management positions in Pollution Prevention and Toxics, Resource Conservation and Recycling, and the former Manager for the EPA Research Program into Life Cycle Assessment. Similarly, individuals involved in reviewed case studies were primary informants based on their direct experience in application of LCA to public policy. A list of key contacts is included in Appendix B: Key Informant Contacts.

Key informant interviews followed a semi-structured, or focused, format, where respondents were engaged through a formal appointment, and a general guide outlining a list of topics and questions was developed to guide the interview. This semi-structured format provides some continuity between interviews, while at the same time allowing the interviewer to deviate from the pre-determined questions as appropriate to expand upon notable comments and explore additional topics that informants feel are relevant (Robert Wood Johnson Foundation, 2015). This format offered the best interview option for this research, allowing the interviewer to develop a rapport with the respondent, while also having the flexibility to deal with complex issues and questions (Sociology Central, 2015). This was particularly appropriate in this research to allow for the depth of LCA knowledge and experience represented by the key informants.

Interviews were initiated with an introduction that provided background and context to the research being conducted. This built on previous background that was provided in the invitation email, allowing respondents to gain familiarity with the research and objectives. This interview preamble was followed by a semi-structured interview that was conducted on an open-ended basis, with interviewees encouraged to share experience and perspective that they felt would be valuable to the research. A series of guiding questions provided structure to the interview, and ensured that primary topics were explored. An outline of the interview questions / format, as well as key message outcomes, is included in Appendix A. These questions varied between public policy informants and case study informants. However, as encouraged in a focused, semi-structured interview, the discussions evolved iteratively based on answers and input from the respondent (Sociology Central, 2015).

A review of case studies with a direct application of LCA to public policy was considered to be a key element to the research, as it offers the opportunity to inform the primary research questions in a direct way, providing observable evidence that can substantiate conclusions from less direct, and sometimes speculative, sources. The choice of case studies was based on application and opportunity, with an attempt to choose case studies that represent actual LCA application to public policy, rather than just information peripheral to the process, as well as an opportunity for direct involvement to provide for direct observation of the process.

The focal case study example involved direct experience through participation (as project manager) within a public policy-oriented LCA project case study – the Alberta Scrap Tire Recycling LCA. This direct case study involvement allowed for testing and validation of external research assumptions and conclusions, while experiencing the process of applying LCA to a public policy application. This level of direct participation, offered by the location of the project in Alberta, provided the researcher with the unique opportunity to interact with various levels of stakeholders and experts on an ongoing basis to assess issues and results throughout the entire length of the project. Specifically, the expert review panel, comprised of international LCA experts, provided a strong level of insight and expertise that informed the research, particularly on a technical level. At the same time, the stakeholders, including Alberta Recycling Management Authority (ARMA) staff and Board members from various sectors related to scrap tire management, provided insight into process involvement and expectations that played a strong role in informing the barriers associated with integrating LCA into public policy. To utilize the learnings of this process over the project's length, a project log book and meeting minutes were recorded and integrated into the project research.

To supplement this primary direct case study, an additional current case study – the CalRecycle Used Oil LCA – was identified during research, and investigated through interviews and literature reviews, as well as direct involvement of the researcher as a reviewer in the implementation phase. This case study was chosen based on its intent for LCA to directly influence used oil public policy in California, as well as its high standard of stakeholder involvement.

The integration of two separate case studies provided concrete practical examples of efforts to utilize LCA in a public policy context. Case study experience also offered opportunities to assess proposed process recommendations, either directly through experience, or indirectly through discussions with key informants.

As expected from literature on case study research, research practices included a variety of means, including literature review, interviews, group discussions, and observation to provide a detailed analysis of the particular scenario or situation (Q, 2015). The case studies are documented in a narrative format with descriptions of key aspects and results, providing for their extensive insights into the topic. Case study research was an appropriate and useful element of this dissertation, as it lends itself to in-depth analysis using multiple sources of information (Hancock and Algozzine, 2006).

Specifically, during this research process, barriers to successful incorporation of LCA into the public policy decision-making process were identified, and potential mitigating strategies to address these barriers were developed. In this way, the combination of literature review, key informant interviews, and case study analysis provided a firm foundation for developing process recommendations that would encourage successful incorporation of LCA into the public policy development process.

3 Public Policy Development Process

There is no single unifying theory in public policy, as the policy development process is complex and may appear unpredictable (Cairney, 2012). Instead, policy change and variation in the results of policy development are a result of the many various factors influencing decision-making (John, 2013). In addition, theory has shifted from the idea of central policymaking to more diverse policy input from multiple stakeholders, resulting in a process that potentially involves many participants with different values, perceptions and preferences (Cairney, 2013). Overall there have been relatively few innovations in the theory of public policy since 1998 (John, 2013).

The study of public policy and its complexities and unpredictability have led to many different theories and frameworks that were intended to improve the reliance and legitimacy of the process. Relatively current examples include (John, 2013):

- Policy Advocacy Coalition Framework – regards policy-making as a continual process with no strict beginning and end. In this framework, a coalition is an alliance of stakeholders with similar interests. Coalitions may take opposing sides in the policy debate, and include a broad range of stakeholders and interested parties.
- Policy Streams and Windows Approach – assumes continual policy change, as elements to the policy-making process shift and change on an ongoing basis. This approach also considers that ideas come from the sharing of agendas between decision makers.
- Punctuated Equilibrium Model – this model recognizes the presence of both change and stability in policy making, and strives to explain how decision-making is about the interaction of a range of factors, including institutions, socio-economic factors, and individual interests.

It is increasingly recognized that policymaking does not operate in discrete stages, as previous theory proposed; however, stages can be used to organize the process into a series of stages to encourage policy success (Cairney, 2013):

- identify goals
- identify policies to achieve goals
- select a policy measure
- ensure that the selection is legitimized by stakeholders
- identify the necessary resources
- implement the policy
- evaluate the results

The common aim of defining the public policy process is to highlight the conditions that have to be met to ensure ‘perfect’ implementation success (Cairney, 2013):

1. The policy’s objectives are clear, consistent and well communicated and understood.
2. The policy will work as intended.
3. The required resources are committed to implement the policy.
4. Policy is implemented by skilled and competent individuals.
5. Dependency relationships are minimal.
6. Stakeholder support is maintained throughout the process.
7. Outlying or unpredictable conditions do not significantly undermine the process or its results.

This list of conditions places a significant focus on stages outside focused policy formulation, showing that all stages of the process are critical to the ultimate success of public policy development. This is important to the recommendations to increase the incorporation of LCA into the public policy process that are developed in Chapter 8.

Examples of public policy instruments that can be applied to influence environmental outcomes include the following (Allen et al., 1995):

- Regulations
- Economic policy (e.g., incentives, taxes)
- Technology research and development
- Education, communications (e.g., product labeling)

The development of these policy instruments is conducted within a public policy development paradigm, which serves to develop the process within which policy is developed. Despite the lack of an overall unifying theory, it has been argued that there are two primary public policy paradigms – discourse theory and rational theory (Bras-Klapwijk, 1998). These theories provide the context to how the policy development process takes place, fundamentally affecting factors such as process elements and relative stakeholder roles.

1) Discourse Theory – stresses the need for an open and communicative discussion in which stakeholders learn about each other's perceptions on the issues. This theory emphasizes the importance of policy networks, argument and framing.

   Argument is central to the policy-making process in the discourse theory (Bras-Klapwijk, 1998), recognizing the crucial role that language and discourse play in framing both policy questions and discussions around policy alternatives (Fischer, 2003). This requires an open and inclusive process, with a focus on communication and understanding.

   The public policy making process has been characterized as a "continuous discursive struggle" (Bras-Klapwijk,1998, p.333), implying the importance of open dialogue and communication to the process. Public policy is understood to be developed through socially-interpreted understandings, with normative context and presumptions operating at a background level in forming policy definitions and understanding. Based on this influence, different discourses, definitions, and questions lead to different policy outcomes (Fischer, 2003).

This builds on the techniques of participatory policy analysis that emphasize interactions between citizens, analysts, and decision-makers, with the goal to encourage understanding and empower stakeholders through full transparency, and to promote serious public discussions (Fischer, 2003).

Within a discourse framework, the key function of an LCA is to support and stimulate sound discussion, with life-cycle research helping to create a full and open communication process between stakeholders with differing interests and perspectives (Bras-Klapwijk, 1999). Discourse theory therefore focusses on the process and participants, with technical information informing the process, rather than leading it.

2) Rational Theory – quantification and objectivity is emphasized, with technical information becoming the primary focus of the process

The rational theory is related to the utilitarian concept of comprehensive rationality that assumes policy-makers translate their values into policy in a clear and logical way through a process that incorporates a series of stages designed to maximize the benefits to society (Cairney, 2012). Under the rational paradigm, researchers provide the policy-maker with neutral, objective, applicable information that will directly assist in formulating the most effective policy (Bras-Klapwijk, 1999). LCA can thereby improve the public policy process by providing decision-makers with relevant information in a comprehensive way (Allen et al., 1995).

Rational decision-making can be seen to follow steps that closely parallel the methods of scientific research (Fischer, 2003):

1. Problem identification
2. Define goals and objectives
3. Determine consequences and probabilities of alternative solutions
4. Quantify costs and benefits of alternatives
5. Assess quantified predicted outcomes to select the most beneficial alternative

Similarly, rational (technocratic) policy analysis involves applying empirically-based technical methodologies, such as cost-benefit analysis and risk assessment, to policy issues (Fischer, 2003). However, negative impacts of rational studies on the argument process have been identified in the policy science literature, even to the point of suggesting that rational research may be a threat to open and communicative policy-making processes, and that methodologies that emphasize quantification and the use of formal methods are not beneficial to the development of sound public policy (Bras-Klapwijk, 1998). This suggests that the adoption of a rational paradigm within the decision-making process may not be the best approach to encourage inclusion of stakeholders within the process. Instead, adopting a paradigm, such as the discourse theory, that focusses on dialogue, communication and understanding may result in more effective participation from a wider range of stakeholders.

Bras-Klapwijk (1999) asserts that the rational paradigm of policymaking and analysis, in which the value of objective, simple indicators is emphasized, is dominant in the LCA scientific community, and that the LCA methodology has been primarily developed within this rational theory. Hofstetter (1998) supported this assertion, saying that LCAs have historically been dominated by the inventory analysis. As such, LCAs are traditionally conducted by experts, with little ongoing involvement of stakeholders, aside from initial contact during the goal and scoping stage, as well as at the conclusion of the project to report outcomes.

To fit within the rational paradigm, LCA results need to be conclusive, as well as objective, so they can help to identify the best public policy that will provide the most efficient means of achieving environmental goals (Bras-Klapwijk, 1999). However, it is well recognized that LCA results may not always offer conclusive results, and that there are many areas of evolving scientific knowledge in terms of impacts. There is also increased skepticism regarding the government's ability to solve problems through objective scientific analysis (Cairney, 2013).

One of the issues with rationally-based approaches is that they may deceptively offer an appearance of truth (Fischer, 2003), which goes beyond the concept of facts to imply a right or conclusive answer. This occurs through the process of quantifying decision-making criteria, resulting in what can be perceived as definitive answers to normative questions. This is driven by a desire to remain impartial and neutral, translating challenging social or political questions into scientific and technical answers. (Fischer, 2003)

Current policy analyst scholars instead are calling for the use of interpretive and discursive approaches to demonstrate that public policy is grounded in subjective factors, emphasizing the role of values and assumptions in influencing what are generally considered to be strictly empirical factors (Fischer, 2003).

Decision Analysis suggests that, in the light of uncertainty, it would be presumptuous to define a single optimum choice. Rather, it is preferred to develop a strategy, within which specific choices may evolve over time based on the current situation. (Neufville, 1990)

It is argued by some public policy scholars that traditional hierarchical and rule-bound forms of decision-making are no longer appropriate or sustainable, and current society requires the involvement of a wider range of stakeholders in the decision-making process (Atkinson et al., 2011). Bras-Klapwijk (1999) goes further to conclude that the rational paradigm is not valid for public environmental policies, and that the discourse paradigm provides a better alternate framework. This assertion is developed within the proposed public policy development framework in Section 8.

4 The Basics of Life-Cycle Assessment

Life-Cycle Assessment (LCA) is defined as “the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO, 2006, p.1). LCA is a “cradle-to-grave” approach for assessing industrial systems. “Cradle-to-grave” begins with raw material extraction and ends at the point when all materials are returned to the earth through disposal or destruction. LCA evaluates all product life stages through a perspective of all stages being connected to and dependent upon preceding and subsequent stages. LCA enables the calculation and estimation of the cumulative environmental impacts from all stages in the life cycle, and may include impacts, such as raw material extraction, transportation and disposal, not considered in other environmental impact models. By including a wider range of impacts throughout the life cycle, LCA provides a more comprehensive outlook on the environmental influence of the product or process and a more complete picture of the environmental trade-offs in product and process selection (EPA, 2006).

Specifically, LCA is a technique to assess the potential environmental impacts associated with a product, process, or service, by:

- Compiling an inventory of relevant energy and material inputs and environmental outputs
- Evaluating the potential environmental impacts associated with identified inputs and outputs
- Interpreting the results to help decision-makers make a more informed decision (EPA, 2006).

LCA consists of a series of stages (ISO, 1997):

1. Goal and scope definition
2. Inventory analysis
3. Life-cycle impact assessment
4. Interpretation

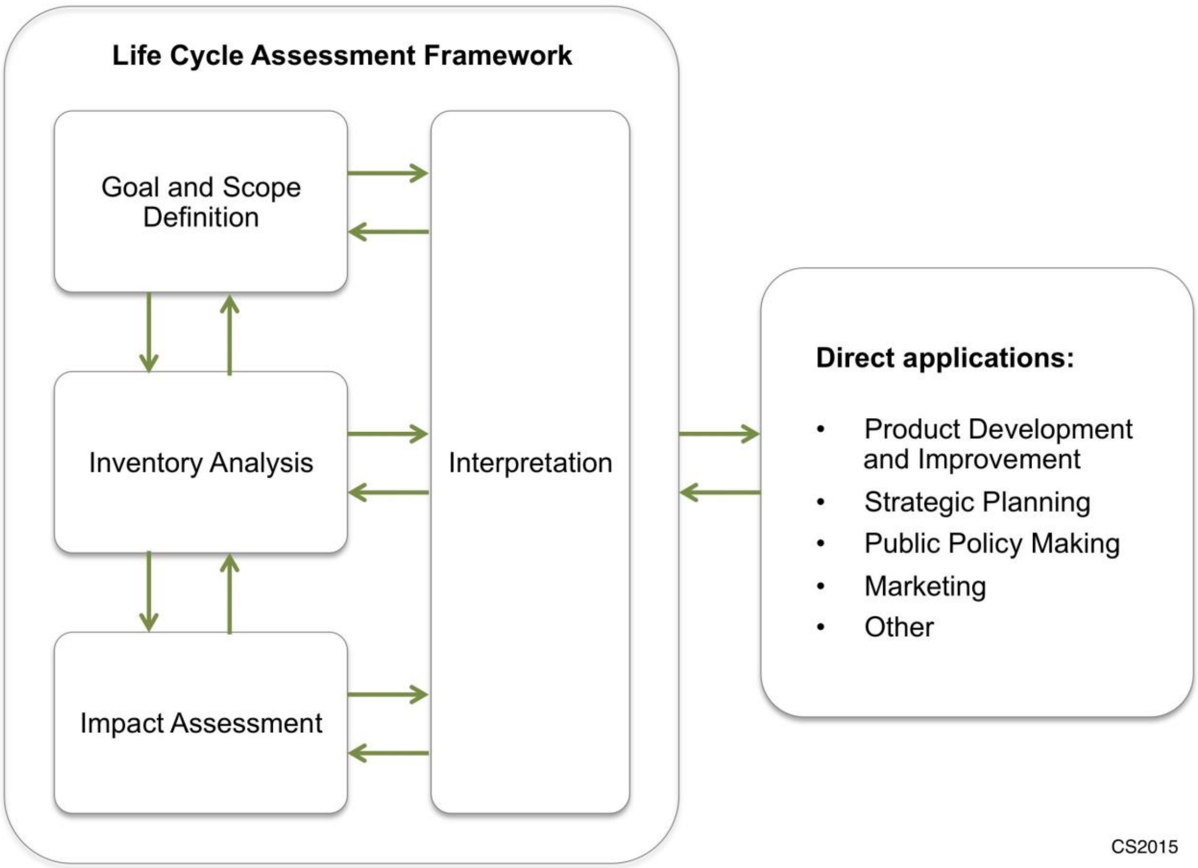


Figure 1: Stages of an LCA (ISO, 2006)

4.1 Goal and Scope Definition

This first stage of an LCA defines and describes the product, process or activity, establishing the context in which the assessment is to be made and identifying the boundaries and environmental impacts to be reviewed (EPA, 2006). Goal and scope definition is of fundamental importance, as LCA results are only relevant as they relate to the specific purpose of the study (Baumann and Tillman, 2004). The goal and scope definition can be compared to the Vision and Mission of an organization – guiding principles that provide a compass for the activities being undertaken, and that should be revisited regularly to ensure the project is on course. In terms of public policy, LCAs should be framed and boundaries established appropriately to reflect policy goals and audience (Allen et al., 1995).

Goal definition includes "stating the intended application of the study, the reason for carrying it out and to whom the results are intended to be communicated" (Baumann and Tillman, 2004; p.24). This phase also includes a number of decisions, including boundaries and environmental impacts that will be included (Baumann and Tillman, 2004). The Society of Environmental Toxicology and Chemistry (SETAC) presented a generic framework for applying life-cycle concepts to public policy, which had as a first step to identify the purpose of the public policy application, and what decisions are to be informed (Allen et al., 1995). This step corresponds with goal definition within the LCA process (identifying purpose), as well as scoping decisions that could likely result from the analysis.

The scope of the study includes a number of definitions: options to model, functional unit, impact categories, impact assessment method, system boundaries, principles for allocation, and data quality requirements (Baumann and Tillman, 2004). The scope should be sufficiently well defined to ensure that the breadth, depth and detail of the study are compatible and sufficient to address the stated goal (ISO, 2006).

According to ISO, the scope clearly specifies the functions of the system through a functional unit that provides a point of reference for comparisons between systems (ISO, 2006a). The functional unit quantifies the performance of a system in a way that allows for a consistent equivalent basis of comparison (EPA, 2006).The scoping exercise also allows the work to focus on the parts of the system that will be most affected by the considered decisions, thereby limiting the required effort and associated cost (Ekvall et al., 2007). Considering that cost can be a limiting factor to the increased adoption of LCA, this is an important aspect. For example, not all organizations can undertake the level of investment required for a comprehensive LCA process such as that undertaken by CalRecycle on Used Oil Management disposition options, which saw an investment of $2.5 million for this public LCA process (described in detail inCase Studies Chapter 10).

At this stage, the impacts to be included in the analysis must also be determined. The original SETAC Code of Practice from 1993 stated that an LCA should assess impacts on ecological health, human health and resource depletion. The ISO standard subsequently added man-made environment to the list. However, it is often recommended that consideration be given to all relevant environmental impacts. (Baumann and Tillman, 2004)

Ideally, if the goal and scope definition phase lays out the necessary framework, most of the value choices are imbedded in this phase, defining the requirements of the modeling phase to the extent that few subsequent value choices need to be made. However, in reality, LCA is necessarily an iterative process, as it is impossible to predict all the choices that will ultimately arise. (Baumann and Tillman, 2004)

An important aspect to the goal and scope definition stage is for the commissioner of the study to work with the practitioner to accurately define the ultimate objectives of the research and the most effective approach to achieve those objectives (Baumann and Tillman, 2004). One of the concerns is that the stated goal of the LCA may be too vague on which to build a modeling plan. The goal may need to be further interpreted in terms of a more specific purpose that provides the level of detail required by the practitioner to develop modeling details. This process requires concentrated time between the commissioner and practitioner to develop a goal or purpose with the required level of detail and specificity. (Baumann and Tillman, 2004) In the case of public policy, the commissioner is the public decision-maker, and potentially a broader group of interested stakeholders.

According to ISO, the goal should also state whether the results are intended to be used in comparative assertions intended to be disclosed to the public (ISO, 2006). ISO standard 14040 requires that if the study is intended to support a comparative assertion to be disclosed to the public, a critical review shall be conducted by interested parties. These reviews are usually conducted by a panel of experts, but may also include interested parties that may be affected by the conclusions. However, in reality, this stakeholder involvement is usually provided separately through a steering committee or similar advisory group (Baumann and Tillman, 2004).

The original SETAC Code of Practice recommended that critical reviews be conducted in parallel with the LCA process, rather than at the end. This would engage reviewers initially during the goal and scope definition, and again when there are initial results, and lastly when the final report is being prepared. (Baumann and Tillman, 2004) This approach was adopted during the Tire Recycling LCA in Alberta (reviewed under Case Study Review, Chapter 10) with positive results.

The following six basic decisions should be made at this initial stage to make the process more effective and efficient (EPA, 2006):

1. Define the Goal(s) of the Project
2. Determine What Type of Information Is Needed and Pertinent to Inform the Decision-Makers
3. Determine How Specific the Information Needs to be to Provide Value
4. Determine Format and System to Organize Data and the Display Results
5. Define the Scope of the Study
6. Determine the Ground Rules for Performing the Work

SETAC also included identification of stakeholders and soliciting their involvement at this preliminary stage when applying LCA to public policy, suggesting that it is important to establish an early dialogue with stakeholders and reach agreement on scope, boundary and limitations (Allen et al., 1995). Incorporating LCA into the decision making process, requires the participation of stakeholders, and especially decision makers, in the design stages. However, it is important to recognize that there is a risk that stakeholders with vested interests may attempt to use this opportunity to make political gains, potentially impacting the perceived legitimacy of the process (Lazarevic et al., 2012) if conclusions from the study appear to benefit certain stakeholders. Initiating the process with an initial chartering session that would define the rules of participation and put everyone involved on the same fundamental process foundation is one process option that could help to mitigate stakeholders attempting to take advantage of their involvement.

4.2 Inventory Analysis

"Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system" as defined by ISO (ISO, 2006, p.13). The inventory analysis is iterative, since as information is compiled, the need for additional data required to meet the goals of the study may become apparent. Similarly, limitations may be found that prevent the original approach from being successfully completed, and changes to the goal or scope may even be identified (ISO, 2006). This reality reinforces the concept that policy decision-makers should be part of the study team from the outset to be able to deal with these issues and decisions.

The EPA established a framework for performing an inventory analysis and assessing the quality of the resulting data, comprised of the following four steps (EPA, 2006):

1) Develop a flow diagram of the processes being evaluated

   Flow diagrams provide a visual overview of the inputs and outputs to a process or system, and are used to model all alternatives under consideration within the LCA (EPA, 2006). Figure 2 and Figure 3 show examples of flow diagrams that were developed for tire recycling options within the Alberta Tire Recycling LCA as part of the Case Study Review in Chapter 10 in this thesis. Similar diagrams were developed for all options considered within the LCA.

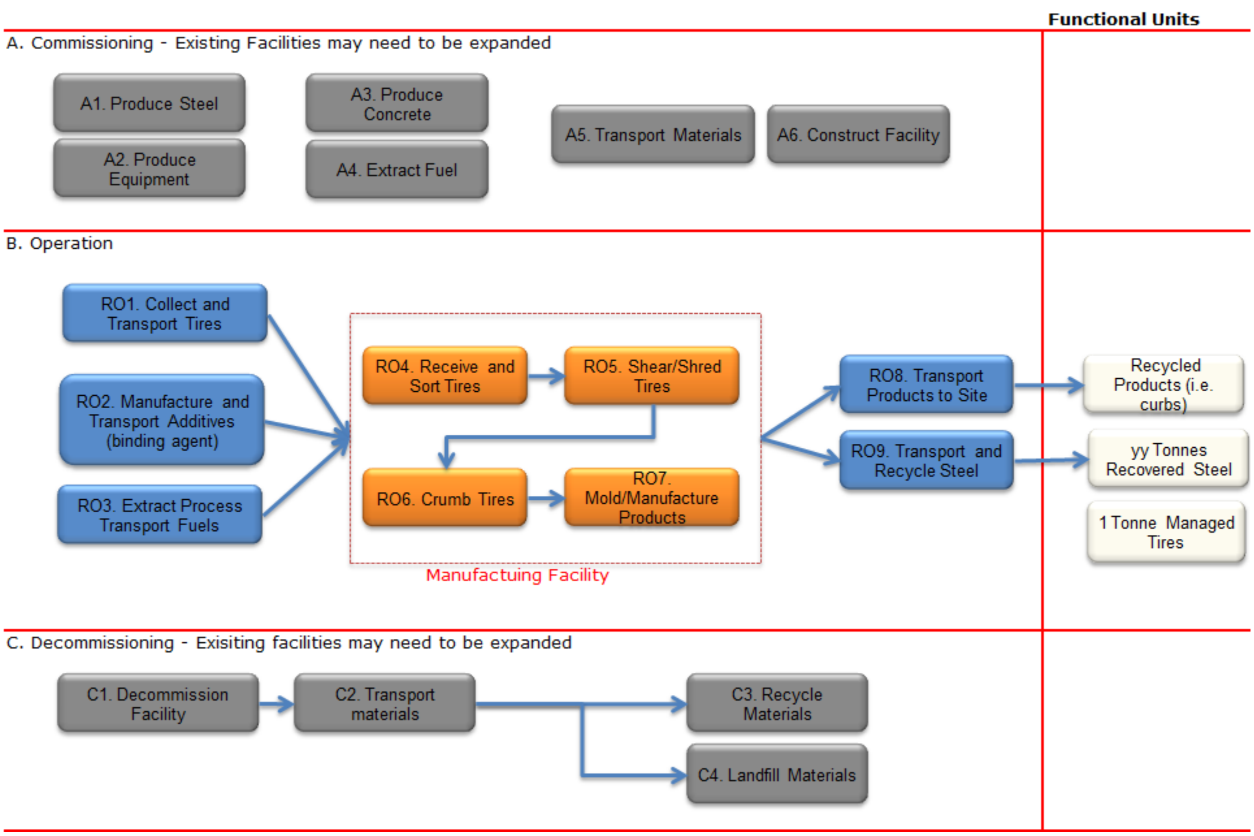


Figure 2: Flow diagram of Recycling Tires into Rubber Curbs (Pembina, 2010)

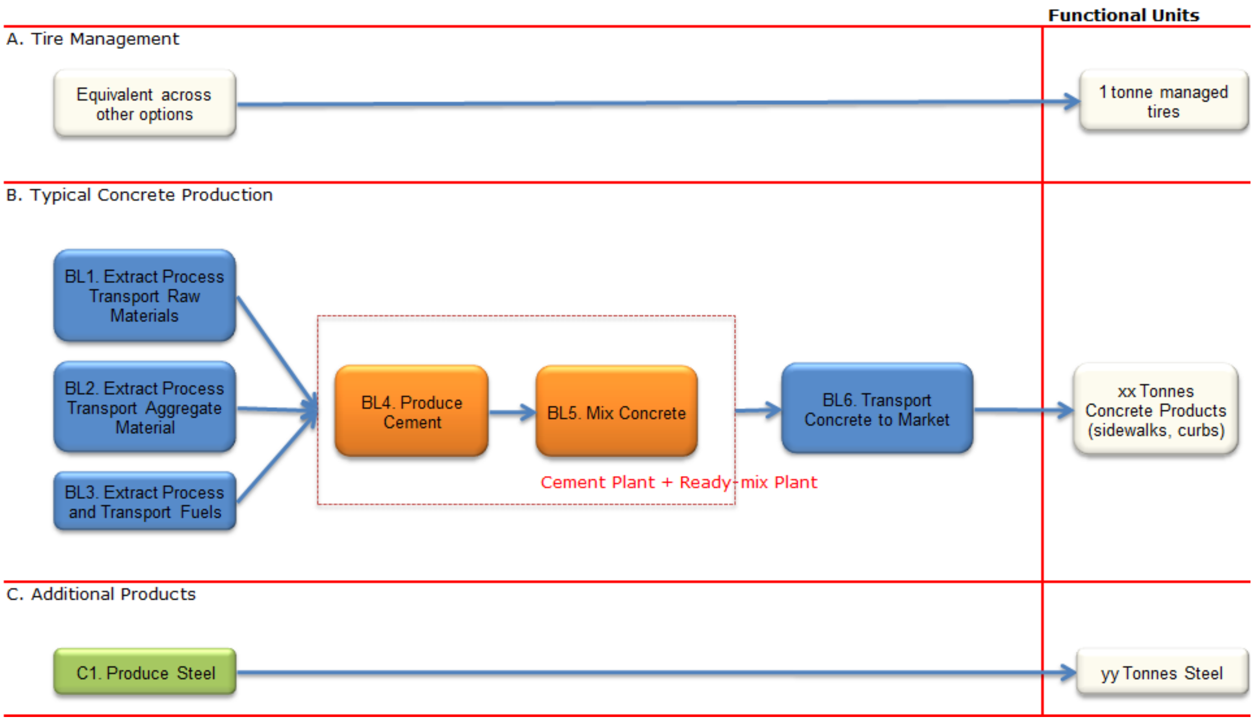


Figure 3: Flow diagram of Offset Activity – Producing Concrete Curbs (Pembina, 2010)

The flow diagrams show the comparison between inputs/ outputs associated with curbs made from recycled tires and standard concrete curbs. In this case, the production of concrete curbs is considered an offset activity, since the inputs and outputs associated with concrete curb production are reduced based on corresponding production of recycled rubber curbs, based on equivalent utility as defined by the functional unit (1 tonne managed tires).

2) Develop a data collection plan

A Life Cycle Inventory (LCI) data collection plan ensures that the quality and accuracy of data are maintained and meet the expectations of the decision-makers. Key elements of a data collection plan include (EPA, 2006):

- Defining data quality goals and identifying data quality indicators
- Identifying data sources and defining types of data
- Developing a data recording system (e.g., spreadsheet, checklist)

3) Collect data

Using the data collection plan, data is gathered for material and energy inputs, and environmental releases are quantified by type of pollutant (EPA, 2006). Data is collected for each unit process within the system boundary, including categories such as energy and raw material inputs, products produced, process waste, emissions to air, water and soil, and other environmental impacts that have been identified for inclusion during the scoping phase (ISO, 2006). Data should also include a quality indicator (e.g., accuracy, precision, representativeness, completeness). A description of how the data was generated can also be useful in judging quality, and of course contributes to transparency of the study. (EPA, 2006)

Data collection can involve research, site-visits and expert consultation, and can generate large quantities of data. Because of the effort required to directly obtain required data, commercially available LCA software packages are often utilized by practitioners (EPA, 2006).

In addition, a thorough inventory may require data that is considered proprietary, which can present challenges in terms of sufficient documentation for adequate transparency and an effective external review. Similarly the use of commercial software can produce transparency issues, since the source and methodology of data generation may not be overtly presented. (EPA, 2006)

4) Evaluate and report results

Once data is collected, inventory results are calculated for system unit processes and the functional unit that was defined during scoping. When systems include multiple outputs, allocation of data needs to occur. (ISO, 2006)

Results of the life-cycle inventory should include a full description of the methodology used in the analysis, including a definition of the systems analyzed, boundaries, and assumptions made in performing the inventory.

Results should be presented in a format that increases comprehension of the findings without oversimplifying them, and is consistent with the purpose of the study. (EPA, 2006)

The inventory analysis comprises the bulk of the technical data collection associated with the process, and as such is a very critical component related to providing the information required for the desired outcomes of the project.

Some LCA processes may end with the results of the inventory analysis. However, although much can be learned about a process by considering the life cycle inventory data, an impact assessment, as outlined next, provides a more meaningful basis to make comparisons (EPA, 2006).

4.3 Impact Assessment

The impact assessment stage assesses the potential human and ecological effects of inputs and outputs identified in the inventory analysis (EPA, 2006). The impact assessment translates environmental loads from the inventory results into environmental impacts (Baumann and Tillman, 2004).General categories of environmental impacts to be considered in an LCA include resource use, human health and ecological consequences (Baumann and Tillman, 2004).

Mandatory elements of a Life Cycle Impact Assessment (formerly ISO 14042) include impact category definition, classification and characterization. This results in an LCIA profile based on category indicator results. Optional subsequent elements include normalization, grouping, weighting and data quality analysis. (Baumann and Tillman, 2004)

Inventory results are classified according to type of environmental impact, and characterized by relative sizes of impacts using equivalency factors to aggregate results into a limited number of impact categories. The level of aggregation to include is critical, as too little leaves the information at a level of complexity that may be overwhelming and difficult to interpret, while too much aggregation can reduce transparency and add uncertainty (Baumann and Tillman, 2004).

Assessment can also include a process of valuation, or weighting, which attempts to weight impacts across categories (Finnveden, 1999). Whereas classification and characterization are required components of an LCA according to ISO, weighting is optional (Baumann and Tillman, 2004). This process attempts to provide a common unit of comparison between various impacts, in order to ease presentation and interpretation of the results, which can obviously be an advantage in presenting results to public policy officials. Valuation also makes the values involved in the weighting process more explicit (Johansson, 1999). At the same time, ISO states that there is no scientific basis for reducing LCA results to a single overall score or number (ISO, 1997). In addition, aggregating results within categories reduces the ability to accurately model actual environmental impacts (Ekvall et al., 2007).

There are a number of valuation methods that have been developed. These methods can be categorized in a number of ways, including the following (Finnveden, 1999):

1) Quantitative – total potential environmental impact (EI) can be calculated using $EI = V_i I_i$, where V is the valuation weighting factor and I is the impact for category i. Quantitative valuation methods can be:
    a. Case independent, or
    b. Case specific
2) Qualitative

Examples of valuation methods include (Sangle, 2002):

- Sustainability Levels – evaluate environmental issues in terms of sustainability
- Modeling of Eventual Effects – evaluate environmental issues in terms of impacts
- Societal Approach – presents environmental issues as stakeholder preferences
- Monetary Methods – translate environmental impacts in monetary terms using approaches such as the market price method, contingent valuation method, contingent choice method, and damage cost avoided method (“Ecosystem Valuation”, 2015).

  A current example of an LCA tool that incorporates the monetary valuation method is the Measuring the Environmental Benefits Calculator (MEBCalc™) proprietary software developed by Sound Resource Management for computing the environmental footprint of a community’s municipal solid waste management system. MEBCalc™ computes environmental costs and benefits of waste diversion and disposal methods over the full life cycle of each product and packaging material, from resource extraction through manufacturing to end-of-life (Sound Resource Management, 2015).

Since valuation methods are inherently subjective to some degree, the challenge is to determine which method to use in each circumstance. The choice of valuation method depends on two primary factors – who will be the ultimate user of the LCA, and the type of decision being informed (product, market, investment, or strategic) (Sangle, 2002).

Weighting inherently involves value decisions, and therefore it is to be expected that there will not be a consensus on these choices. ISO 14042 previously dealt with this issue by recommending that several different weighting factors and processes be used, and that a sensitivity analysis be conducted to assess their differences. ISO also requires transparency regarding all weighting processes (Baumann and Tillman, 2004).

It is important to note that weighting is very different from interpretation, since different valuation approaches can result in different results (Finnveden, 1999). This suggests that the process of weighting is critical to the subsequent interpretation, and as a result, the ultimate conclusions.

ISO does not allow for weighting to be used in comparative public LCAs, but instead requires comparisons to be made impact category by impact category (Baumann and Tillman, 2004).

Valuation inherently involves political, ideological and/or ethical values, which are influenced by perceptions and worldviews. Valuation weighting factors and methodology, and even the choice to use a valuation method, are all influenced by fundamental values. This can be avoided by not using a valuation method, however, this then requires comparisons to be made category by category, and not on an aggregated level (Finnveden, 1999). This can make it more challenging for the non-technical decision-maker to assess relative impacts.

It is important to be transparent about what values are incorporated into valuation methods (Johansson, 1999). This is one of the most important factors to integrate into the valuation process. Only if the process being used by the technical expert in weighing impacts across categories is presented in a clear, transparent way, can reviewers and users have any confidence in the validity and relative neutrality of the results.

Bras-Klapwijk (1999) argues that the use of simple quantitative ratings of alternatives (for example summary tables that indicate overall ratings of options) is in fact not helpful, since it does not provide transparency of the underlying assumptions. Rather, quantitative indicators should only be utilized as part of the overall verbal argument.

An example of this approach to oversimplify LCA results occurred in the Tire Recycling LCA Case Study (see Chapter 10), where management options were ranked (and also summarily rated by colour, with red being poor, yellow average, and green best) as follows:

Table 1: Alberta Tire Recycling LCA Option Rankings

Management option	# of good ratings	# of neutral ratings	# of poor ratings	Overall Ranking
TDA Leachate		8		0
Crumb	1	6	1	0
Manufactured products:				0
Rig mats	1	5	2	-1
Curbs	6	0	2	4
Shingles	5	3	0	5
Waste-to-energy:				0
Coal plant	2	3	3	-1
Cement kiln	3	0	5	-2
Incineration	2	3	3	-1

This approach was taken in an attempt to summarize and simplify the LCA results to make them easier for stakeholders (specifically Board members) to understand. However, as asserted by Bras-Klapwijk, this approach was not effective, as it was not seen as transparent.

Although the valuation stage is an obvious part of the process where value judgments are inherently applied, it can be argued that values can influence methodological choices for the other stages as well, such as the inventory analysis (Finnveden, 1999).

The valuation challenge is well summarized by the following quote:

> "The difficulty… is to combine objective scientific findings with subjective value judgements… to derive criteria whose application ensures that the weighing of different environmental aspects takes place in a transparent and reproducible manner" (Schmitz and Paulini, 1999, p. 8).

4.4 Interpretation

According to ISO 14040, life cycle interpretation is the "phase in which the findings from the inventory analysis and the impact assessment are considered together… to deliver results that are consistent with the defined goal and scope and which reach conclusions, explain limitations and provide recommendations (ISO, 2006, p.16). The interpretation stage is intended to evaluate the results of the inventory analysis and impact assessment with the ultimate goal of making an informed choice regarding the preferred product, process or service (EPA, 2006).

Results need to be presented in a format suitable for the intended audience (Baumann and Tillman, 2004). SETAC included a specific component within its framework for applying life-cycle concepts to public policy: present results, communicate, and motivate. This stage includes discussion of the results with stakeholders, and developing a communication strategy to share the subsequent public policy direction with a broader audience (Allen et al., 1995).

As an inherently qualitative element, interpretation is a phase where involvement of stakeholders in a collaborative process can be critical to the successful use of the results within the public policy development process.

5 Application of LCA to Public Policy Development

Perhaps the most comprehensive inspection of the public policy applications of LCA was conducted by Remke M. Bras-Klapwijk in her doctoral dissertation in 1999, where she focused on the use of LCAs in the development of public policy instruments such as eco taxes and eco-labeling. This followed publication of the proceedings from a Workshop on Application of Life-Cycle Assessment to Public Policy, delivered by the SETAC in 1995, suggesting the recognition of the value of LCA to public policy early in the tool's development. This thesis draws heavily upon the conclusions and suggestions of Dr. Bras-Klapwijk, SETAC contributors, as well as other policy-oriented LCA experts.

LCA has many potential applications within public policy development because of the common desire for policy to reduce environmental impacts, and the resulting need to identify opportunities for environmental improvement and assess environmental trade-offs between potential options (Allen et al., 1995). Within public policy development, LCAs are often conducted with the intention to provide additional quantitative information on which to base decisions regarding policy details. The European Union has concluded that "Life Cycle Assessments provide the best framework for assessing the potential environmental impacts of products currently available" (EU, 2011, p.1), and this could be extrapolated to assume that this would apply to processes, as well. Assuming that environmental impacts are an important consideration within public policy decisions, this suggests that LCA can provide valuable information on which to base policy decisions. The Canadian Institute for Environmental Law and Policy (CIELAP) adds that LCA can provide a valuable contribution as it "allows decision-makers to consider and address potential unintended environmental consequences that may undermine the potential for a decision to make an overall environmental improvement" (CIELAP, 2009, p.1).

Public policy decisions vary greatly, from narrow mandates to broad policies, and involve a wide range of institutions, from local municipal departments to federal agencies (Allen et al., 1995). Reed (2012) asserts that LCA could play an important role in the legislative policy process through contributions to problem identification, policy implementation, and policy evaluation stages. Specifically, in terms of problem identification, LCA can sometimes provide unforeseen information. LCA can also help in establishing implementation procedures and educating about the outcomes the policy decision will produce. And, finally, during policy evaluation, LCA can provide a comparative tool to measure policy effectiveness.

SETAC further suggests that the "use of life-cycle concepts and tools can link scientific, technological, and policy-making communities in an overall effort to find an appropriate balance between economic, environmental and energy considerations", by moving fragmented end-of-life approaches towards more holistic decision-making (Allen et al., 1995, p.1). The European Organization for Packaging and the Environment (EUROPEN) asserts that LCA is most useful in improving the environmental performance of individual systems, rather than comparing relative options (EUROPEN, 1999). However, life-cycle can also provide a framework to combine information from other tools such as risk assessment and environmental planning, which are often considered separately (Allen et al., 1995). LCA also has a broader scope than most other tools, and therefore can potentially provide long-term vision that can identify opportunities for the largest improvements (Allen et al., 1995).

The extensive use of LCA both within industry and public institutions further validates the perceived value that this tool offers the decision-making process. As a specific example of the opportunity for LCA to contribute to public policy, EUROPEN suggests that the role of LCA within waste management policy is as a "continuous benchmarking tool to maximize efficiency of resource use through a case-by-case approach" (EUROPEN, 1999, p.3).

Globally, the United Nations Environment Programme (UNEP) and SETAC launched an International Life Cycle Partnership, known as the Life-Cycle Initiative (LCI), to enable users around the world to put life cycle thinking (incorporating the basic concept of LCA without undertaking a detailed assessment (Lazarevic et al., 2012)) into effective practice. The LCI uses a long-term (2002 – 2016) initiative that was developed in three phases to "facilitate the generation and uptake of science-based life cycle approaches and information… by business, government, and civil society practice worldwide as a basis for sustainable consumption and production" (LCI, 2014, p.1).

The European Commission (EC) also identified the need for a public platform to share information on LCA, and to increase the availability of quality life-cycle data. The EC subsequently established the European Platform on Life Cycle Assessment (EPLCA) to support business and government needs for life cycle data and studies (EU, 2014).

Life Cycle Thinking has been applied to a number of policies and instruments in the European Union, including Integrated Product Policy, the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan, Green Public Procurement, EU Ecolabel, EU Eco-Management and Audit Scheme, Ecodesign, and Retail Forum. Life Cycle Thinking is also used in the Waste Framework Directive to help determine the benefits of different waste management options, as well as the Thematic Strategy on the prevention and recycling of waste, and the Thematic Strategy on the sustainable use of natural resources. It also plays a role in Eco-innovation and the EU Environmental Technologies Action Plan (ETAP) (EU, 2010).

The United States (and by association, Canada) has been relatively slow to integrate LCA into public policy, particularly as compared to Europe, where life-cycle thinking is widely encouraged, implemented and even mandated through policy (Reed, 2012). However, life-cycle information is beginning to play a larger role inside American governmental policy. Federally, LCA was applied to the Energy Independence and Security Act of 2007 (EISA) to determine if the threshold standards for emissions reductions were being met. EISA established eligibility requirements for renewable fuels, using the EPA's lifecycle GHG emissions analysis, to determine whether fuels meet GHG thresholds for different categories of renewable fuel. This requires a comprehensive evaluation of renewable fuels, as well as of gasoline and diesel, on the basis of their lifecycle greenhouse gas emissions. Under the EISA definition, the full fuel lifecycle includes "all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel by the ultimate consumer" (EPA, 2010, p.1). EISA established specific lifecycle GHG emission thresholds for renewable fuels, requiring a specified improvement compared to lifecycle GHG emissions for displaced fuel (gasoline or diesel, whichever is being replaced by the renewable fuel) (EPA, 2010). Although applying an LCA approach in terms of life cycle, it is important to note that EISA focuses on greenhouse gas impacts.

This is the first and only time federal regulatory policy mandated the use of LCA on a product or system (Reed, 2013 and Leith, personal communication, December 11, 2014). However, the Environmental Protection Agency (EPA) has been instrumental in the development of standards and methodologies, including the LCA software Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI). The EPA also uses life-cycle approaches in some of its initiatives, such as the Design for the Environment partnership program (Reed, 2012). The use of LCA in policy development at the federal level got a boost with the identification by the National Research Council of LCA as one of the most appropriate tools that can be applied in the proposed EPA Sustainability Assessment and Management process developed to better incorporate sustainability into decision making at the agency (NRC 2011). However, discussions with internal staff at the EPA suggest that this has not in fact led to much increase in incorporation of LCA within the agency to date.

There are numerous examples of the use of LCA at the U.S. state level, particularly California and Oregon. California Environmental Protection Agency's Department of Toxic Substances Control's Green Chemistry Initiative, introduced in 2007 to provide a framework for understanding and reducing the impacts of products containing toxic chemicals in the state, proposes a life-cycle perspective to evaluate products, processes, and decisions that influence the use of chemicals in products to avoid regretful substitutions or unintended consequences (Horvath and Chester, 2011).

California Environmental Protection Agency's Air Resources Board's Low Carbon Fuel Standard (LCFS), issued in 2007 and readopted in 2015, calls for a reduction of at least 10 percent in the carbon intensity of California's transportation fuels by 2020, and determines carbon intensity through a life-cycle analysis including the extraction, production, transportation, and combustion of a fuel (CEPA, 2015 and Environmental Leader, 2015).In the standard, "Global warming intensity" is a measure of all of the mechanisms that affect global climate including not only greenhouse gases (GHGs) but also other processes (like land use changes that may result from biofuel production). However, the standard does not address other public health and environmental impacts, such as air and water quality, water use, loss of habitat, and soil erosion, or other related policy issues. (University of California, 2007)

California's Department of Resources Recycling and Recovery (CalRecycle) conducted a comprehensive LCA of California's used lubricating and industrial oil management process (Reed, 2012). This example offers considerable insight into the process of incorporating LCA into the public policy process, and it forms one of the Case Study Reviews discussed in Chapter 10.

Oregon's Department of Environmental Quality undertook an LCA of mail-order packaging, an LCA-based approach to preventing construction and demolition waste, as well as life-cycle thinking in the development of recommendations for reducing greenhouse gases related to waste management.

In Canada, BC applied the California Low Carbon Fuel Standard, with the notable difference that it does not incorporate indirect land use values into the lifecycle analysis, which is seen as favouring unconventional oil sources, such as the oil sands (Pacific Institute for Climate Solutions, 2010). This shows the potential political fallout from LCA decisions. LCA has also been used to inform waste management planning in Metro Vancouver in its *Environmental Life Cycle Assessment of Waste Management Strategies with a Zero Waste Objective*, and at the provincial level in Alberta through a *Review of LCAs on Organics Management Methods & Development of an Environmental Hierarchy* commissioned by Alberta Environment. In addition, an LCA on scrap tire management options was conducted by Alberta Recycling Management Authority (ARMA), and provided internal ongoing access to the LCA process, and as a result is included as the primary Case Study in Chapter 10.

6 Barriers to Applying LCA within the Public Policy Development Process

Despite its perceived potential value, research suggests that the positive impact of LCA on public policy to date is limited. Assuming the additional information LCAs contribute to the decision-making process offers a positive contribution, there must be barriers leading to its lack of greater influence. Identification of these barriers was a primary research question within this dissertation that will subsequently lead to potential strategies to mitigate the barriers, therefore encouraging increased incorporation of LCA within public policy process. Barrier identification was researched using a review of available literature, including Proceedings from the Workshop on Application of Life-Cycle Assessment to Public Policy (Allen et al., 1995), writings of Bras-Klapwijk (1998 and 1999), Daniel Reed's PhD dissertation. This literature review was combined with direct research of case studies outlined in Chapter 10, as well as interviews with life-cycle experts, to create the following list of potential barriers to incorporating LCA results into public policy decisions:

1) Decision-makers lack the background or technical literacy to interpret and incorporate the results of the LCA.

   This is a very tempting conclusion for the rationally-minded LCA professional to account for the failure of comprehensive LCA results to be incorporated into public policy decisions. Many key decision-makers may be in fact be unfamiliar with LCA (Allen et al., 1995), and therefore may be unclear on how LCA results fit within the policy development process. In addition, LCA tends to be filled with jargon and populated by experts, and can be confusing to those unfamiliar with LCA concepts (Reed 2012). Bras-Klapwijk (1999) observed that stakeholders were often not able to interpret LCA results even when the process methodology was described in detail.

   Literature research, including Bras-Klapwijk (1998), as well as observations in the Alberta Tire Recycling case study (see Chapter 10), suggest that non-technical people may indeed be uncomfortable with the concept of applying the technical information presented by an LCA to the decision-making process, and prefer that technical "experts" play that role. In this process, goal-setting is separate from analysis. Policy makers set goals, while scientists are tasked with the job of analyzing the alternatives to meeting these goals. This way, the scientific analysis is intended to remain both relevant and objective. (Bras-Klapwijk, 1998)

2) Technical results are not presented in a way that can be positively utilized by decision-makers.

   This barrier is related to the first one, in that decision-makers can only incorporate information that is understandable and fits within their decision paradigm. Regardless of how valuable the information may be, if it cannot be readily utilized, it will remain outside the decision-making process.

   A 200-page report filled with pages of tables and charts is not a user-friendly format for decision makers, particularly if not presented with terminology and language familiar to the user. For example, although business management decision making is impacted by life cycle issues as they relate to business risk, LCA may be too detailed and time consuming to be useful to business decision makers. Rather, it would provide value only if it could be presented in business terms with simplified outputs and references such as economic impacts, and could provide information in the short timeframes that are a reality in business. (Cooper et al., 2004)

   At the same time, as high level managers may require simplified outputs and aggregated metrics, designers and technical people want to have access to fully transparent process results in order to understand and verify the reliability of the outputs (Cooper et al., 2004). This suggests the need for a process that meets the needs of various levels of participants within the decision-making process.

   This challenge to present results in a simple yet transparent way is exacerbated by the reality that decision-makers tend to want LCA results to be presented in a simplified format that indicates an obvious “winner”, despite the fact that this is neither reasonable nor desirable (Reed, 2012). This desire for the results to show winners and losers was also observed in the Alberta Tire Recycling case study.

   The idea of definitive conclusions is very appealing, as it makes the task of decision-making easier (Bras-Klapwijk,1998). This was also shown in research by Lazarevic et al., where it was shown that decision makers may often be rooted in a ‘definitive’ frame when defining the aim of an LCA, as reflected in their desire for ‘clear-cut’ answers and recommendations (Lazarevic et al., 2012). However, Bras-Klapwijk proposes that the LCA process be modified to provide a robust discussion between differing points of view, rather than pursuing definitive research.

3) Decision-makers have a lack of trust of LCA results or the overall process.

   Lack of acceptance of LCA as a decision-making tool was identified by SETAC as a barrier to its incorporation into the process (Allen et al., 1995). Since LCA is an information tool, decision-makers must value the information in order for it to be considered in policy development (Reed, 2012).

   This lack of trust is very likely related to a lack of understanding. If the decision-maker is not familiar with LCA and its potential application, they will be likely to discount its value to the process. This suggests that increased involvement and familiarization on the part of the decision-maker within the process would serve to build trust.

   The lack of trust and understanding of the process and results was evidenced in the Alberta Tire Recycling case study, limiting the integration of the research results into policy discussions.

4) LCA results are not seen as neutral.

   Historically, LCA results have tended to support the interests of the study sponsor, which has not tended to improve confidence in the neutrality of the process (Bras-Klapwijk, 1999). Even with the progress in LCA standards, there is still variability in how LCA can be applied to different systems, leaving the potential perception that it can be tailored to produce information that supports a specific agenda (Reed 2012). This certainly does not help in building trust regarding LCA results among decision-makers.

   Decision analysis itself is arguably unbiased like any other neutral tool. However, people can attempt to use decision analysis for good or for their own interests. Those with vested interests can rationalize their decisions by manipulating the elements of the analysis: the alternatives, information, and preferences (Howard, 2007).

There is also a tendency for political players to use LCA results in a polarizing way. Studies with rational features are particularly vulnerable to polarized use as a result of their perceived “black and white” nature. “LCAs are easily misused due to their apparent objectivity, and the quantitative and black box nature of their results” (Bras-Klapwijk, 1998, p.333). The formal methods used in LCA, although arguably designed to ensure the results remain objective and transparent, remain black boxes to those not trained in the process. Therefore, ensuring a high level of transparency in LCA results is important to combatting the tendency to use them in a polarizing way.

5) Clear or consistent results may be lacking as outcomes of the LCA.

Despite attempts to be clear and objective, LCA results are not always conclusive, and this may present particular challenges when multiple stakeholders with competing interests are involved (Bras-Klapwijk, 1999). This seems intuitive, since any potential ambiguity in the results can be seized upon by opponents to a particular decision to assert why an alternate choice should be made.

In addition, varying or even conflicting results can also be produced by multiple LCAs based on differing underlying assumptions (Bras-Klapwijk 1999). This does not lend itself to confidence in the resulting outcomes.

This is exacerbated by one of the challenges facing LCAs, which is the lack of scientific methodologies to deal with uncertain effects, resulting in the exclusion of effects that cannot be proven or quantified (Bras-Klapwijk, 1998 and CIELAP, 2009). LCA methodologies tend to ignore impacts that cannot be quantified or are uncertain (Bras-Klapwijk, 1999). However, excluding uncertain impacts could be seen as whitewashing to concerned stakeholders, suggesting that incorporating recognition of uncertainty into the evaluation would serve to deliver a more complete and transparent process. Approaches to dealing with uncertain effects inherently involve normative decisions which can be diametrically opposed, for example the precautionary principle versus requiring a burden of scientific proof.

The issue of uncertainty is also compounded by the experience that the audience tends to focus on the technical results, and disregard the issue of uncertainty, even when the uncertainty associated with certain results is clearly stated (Ekvall et al., 2007).

6) Complete and accurate inventory data may be difficult to find.

   Lack of accurate inventory data is a challenge to advancing LCA in public policy, and life-cycle inventories may rely on survey data that is unverified or incomplete (Reed, 2012). Data availability, applicability and quality are generally issues that need to be resolved (Allen et al., 1995). This remains a significant barrier to using LCA in policy development (Leith, personal communication, December 11, 2014).

   Lack of accurate, quality data to complete the inventory analysis may require additional research to populate the specified environmental indicator categories, increasing the resources required to complete the study. This was experienced in the Alberta Tire Recycling case study, where field research and proxy measures were utilized as a result of a lack of available data for certain measures.

7) The LCA process focuses on quantitative results to the exclusion of qualitative factors.

   Hofstetter (1998) asserts that LCAs have historically been dominated by the inventory analysis. As such, LCAs are traditionally conducted by experts, with little ongoing involvement of stakeholders throughout the process. In addition, all technical research arguably includes normative choices, but the imbedded value choices involved in this research are generally not recognized, and therefore are not fully transparent and justified (Bras-Klapwijk, 1999).

   This focus on technical content allows little opportunity for normative input from stakeholders, which may be their primary contribution. A focus on quantitative results also leads to the danger of alienating key stakeholders, who may feel their input is not valued or important. This disenfranchisement may result in opposition that is based on lack of engagement, rather than specific measureable concerns.

   Hofstetter also suggests that the approach of modeling all the inputs and outputs of a system leads to an intensive effort focused on data gathering and calculations that may be greater than the resulting decision-support benefit.

A technical focus was also identified as a barrier in the Alberta Tire Recycling case study (Chapter 10), where technical rigour was achieved to the detriment of the process as a whole, ultimately limiting the application of the LCA results.

8) Governments lack a framework for integrating LCA information into the decision-making process.

Governments lack a framework and context for integrating LCA information with other factors, such as economics and social impacts that are considered in the decision-making process (Reed, 2012). This is further magnified by a reluctance to give up traditional decision-making tools and techniques (Cooper et al., 2004). This lack of framework likely applies to other decision-making organizations, as well.

Regulatory and policy development at the government level tends to be focused on selected life cycle stages as opposed to understanding implications at a systems level (Cooper et al., 2004). This is exacerbated by a tendency for government policy-making to be incremental in nature (Cohen, 2013).

The lack of a formalized process for integrating LCA can also explain the existence of LCA work at the government level, such as some of the examples outlined in Chapter 5, but limited evidence of LCA actually influencing policy. In some of these cases, LCA may be informing policy makers, but not necessarily influencing policy.

Without process guidelines to integrate LCA, it is unlikely that it will be properly recognized or certainly not fully embraced by decision-makers. This suggests the need for more guidelines on effectively integrating LCA into the policy development process.

9) Government agencies bring specific interests to the process, potentially limiting the scope based on internal focus and knowledge.

The various missions of government agencies can create a barrier to effective incorporation of LCA in public policy by limiting the assessment to a reduced range of indicators, thus narrowing the scope and potentially excluding important impacts outside this scope (Curran, personal Communication, March 18, 2014). This focus on a narrow range of impacts is often driven by specific priorities and funding limitations (Leith, personal communication, December 11, 2014).

This is acknowledged in the public policy field, where it is recognized that institutions are important because they hold a group of participants (such as bureaucrats) within the policy process, while also potentially excluding others. They may set the agenda, and define problems in a particular manner. In this way, institutions can seem to create a stable policy environment that may potentially benefit specific interests, but this is only likely to remain for relatively short periods of time, as emerging issues and changes to other influencing factors can deliver changes in short order (John, 2013).

Although limiting the scope of an LCA can have a positive influence in terms of focus and resources, defining the scope based on pre-determined biases and priorities can in fact undermine the quality and integrity of the results.

10) Comprehensive public LCAs require considerable time and resources to complete.

Performing an LCA can be resource and time intensive, gathering the data can be problematic, and the availability of data can greatly impact the accuracy of the final results (EPA, 2006).

Even though it is hoped that the compilation and expansion of life-cycle inventories will gradually drive down the significant resources required to complete an LCA (Reed, 2012), the higher standard of accountability and transparency associated with a public policy LCA is reflected in a substantially higher cost than a standard comprehensive LCA (Curran, 2014). This increased requirement for depth, transparency and third party review was demonstrated in the $2.5 million, 2 ½ year process undertaken by CalRecycle in its Used Oil LCA (Carlson, personal communication, July 15, 2014). This example is further discussed in the Case Study Review Chapter 10.

Ironically, incorporating the additional level of participation required for full participation and accountability within a public policy development process is likely to take additional time and resources. The perceived timeframe associated with LCA is also a barrier to its incorporation (Cooper et al., 2004).

A number of these barriers suggest that the failure of LCAs to contribute positively to public policy development is not due to any deficiency within the LCA itself, but rather the process within which the LCA is being incorporated. It can be argued that all of the identified barriers, with the exception of purely technical barriers like lack of inventory data and lack of resources, can be at least partially mitigated through process modifications. It is this potential for process-oriented enhancements that will receive additional attention in the next section.

7 Addressing Barriers to Incorporation of LCA in Public Policy Development

Based on the previous identification of barriers to the incorporation of LCA within public policy development, the mitigation of these barriers appears to lie fundamentally within modifications to the process used to apply LCA to public policy. This chapter looks at some of the primary process-oriented considerations that could help in developing a framework for successfully integrating LCA into the public policy development process.

An overall methodology that has been recommended to overcome many of the barriers to effective use of LCAs in public policy development suggests a shift towards the discourse theory, where a more open and qualitative approach is taken and rich and balanced arguments on normative and factual issues is central (Bras-Klapwijk, 1998). This move towards a more qualitative, inclusive and holistic process has the potential to mitigate many of the process-related barriers identified previously.

This type of approach is supported by the EU in its assertion that LCA should be used as a decision-supporting tool rather than a decision-making tool, because the LCA process does not fully take into account economic and social impacts or some local factors (EU, 2011). LCA's preference for technical factors is outlined in the ISO 14040 standard which states "Decisions within an LCA are preferably based on natural science. If this is not possible, other scientific approaches (e.g., from social and economic sciences) may be used or international conventions may be referred to" (ISO, 2006, p.7).

The concept of LCA as a decision-support tool suggests that the value of LCA lies in the effective integration of information it provides within a broader, more holistic process. Hofstetter (1998) supports this in his observation that LCA is a decision support tool that is an integral part of the decision-making process, and therefore cannot be isolated from this process. ISO further suggests that generally "the information developed in an LCA or LCI study can be used as part of a much more comprehensive decision process" (ISO, 2006, p.vi).

The incorporation of non-technical elements, such as economics and social sciences, into LCAs was demonstrated in the CalRecycle Used Oil LCA project (see Chapter 10) where stakeholders identified a need for a comprehensive economic assessment to inform the life cycle analysis and develop policy recommendations to the California

Legislature (CalRecycle, 2013b). This was an example of stakeholders (and ultimately decision-makers) requesting the incorporation of additional elements into the broader LCA process.

Any type of more normative approach recognizes that, while LCAs are seen by technical experts as objective, and their process strives to maintain this, LCAs contain an implicit normative framework that may not match special interests' perception of the kind of evidence that needs to be considered (Bras-Klapwijk 1998). This is much different than a lack of technical objectivity. Rather, it recognizes that a focus on technical rigour has the danger of reinforcing the paradigm that only scientifically verifiable information adds value to the process. If allowed to permeate the process, this attitude can disenfranchise stakeholders, who may have opinions and concerns that they cannot express in technical or quantifiable terms.

LCA results tend to be formulated to be objective, conclusive and simple (Bras-Klapwijk, 1998). This rational paradigm can further alienate stakeholders through an emphasis on quantifiable outcomes that can make the results appear, particularly to non-technical stakeholders, as facts that cannot be disputed or discussed within the decision-making process, with the result being that process participants feel disempowered (CIELAP, 2009). As a result, attempts to bring objectivity and clarity to the debate through LCA can have the unintended consequence of disenfranchising stakeholders that may have important input to the process.

In practice, LCA practitioners strive to be objective and avoid making normative choices, instead leaving that role to the policy makers. However, LCA results depend on methodological choices made during the process, which are influenced by the values and perspectives of the practitioner and commissioner of the study (Ekvall et al., 2007). This creates a conundrum, since interpretation and application of LCA results inherently involve value judgments that are within the purview of the policy decision-maker. The incorporation of LCA information within the overall public policy decision-making process certainly extends beyond the ideal role of the LCA practitioner. Instead, there may ideally be an opportunity for the decision-making process to incorporate a multi-disciplinary approach that includes LCA experts, as well as economic and social experts, together with public policy decision-makers and key stakeholders in a collaborative process.

It is also important to recognize that even apparent objective information is inherently value-laden. This is particularly true of environmental impacts, whose measurement incorporates elements of subjectivity based on the cultural perspective of the observer (Bras-Klapwijk, 1999). This puts into question the notion of the LCA practitioner delivering conclusive recommendations, or even providing summary rankings as part of the process. Bras-Klapwijk (1999) argues that objective studies are in practice not possible, since all research includes normative choices. This is not an inherent problem in a discourse framework, but can present challenges when the approach is rational, in that the imbedded value choices are not transparent and therefore properly justified, in an attempt to make a study appear objective, when it has subjective elements (Bras-Klapwijk, 1999).

Bras-Klapwijk (1999) asserts that LCA practitioners should not claim objectivity, since that can limit debate on divergent perceptions, but rather should openly acknowledge the normative nature of the analysis. This is important to acknowledge, since it is recognized that LCA is full of subjectivity and does not properly separate objective from subjective elements (Hofstetter,1998).

Bras-Klapwijk (1999) argues that practitioners need a normative starting point from which to develop a good technical analysis, and this should be done in a transparent way to support policy makers. Hofstetter (1998) further suggests abandoning any attempts at separating objective from subjective steps within the LCA process, and instead recognizing that the entire process is embedded within what he terms as the "valuesphere". This asserts that values do not just come into play when results are interpreted, but rather are imbedded throughout the process (Hofstetter 1998). It can be argued that value judgments are present in the life cycle inventory stage (choice of methodology and boundaries), the life cycle impact assessment stage (classification and characterization), as well as the weighting of results (Lazarevic et al. 2012).

The reality of subjectivity is embedded within the LCA name itself, with "life cycle assessment" trumping "life cycle analysis" early in the development of the methodology, as a result of the recognition that LCAs include subjective elements (Baumann and Tillman, 2004). It is also important to note that all tools that analyze environmental systems suffer to some extent from issues associated with embedded values, not just LCA (Ekvall et al., 2007). This reflects the reality that all aspects of the decision-making process are inherently influenced by value judgements, and the process needs to consider and embrace this reality, rather than try to avoid it.On the technical side, Bras-Klapwijk (1999) suggested addressing issues associated with the rational LCA paradigm by improving accuracy, comprehensiveness and objectivity of the LCA process, as well as enhancing scientific discussion of LCA results through transparency and sensitivity analyses. The ISO standards have arguably contributed greatly to standardizing the methodology used to conduct LCAs, and have also served to increase transparency and scientific quality. At the same time, moves to make LCA more accessible and transparent through projects offering open source software and data could have the potential to increase data quality and availability, while also building participation and trust in the LCA process (Leith, 2014).

These fundamental process concepts are further developed into process elements that form a framework for integrating LCA into the development of public policy.

8 A Public Policy Development Process Framework that Embraces LCA

Building on the identified barriers that limit the incorporation of LCA within public policy, as well as the previous discussion around a more normative approach that could mitigate these barriers and assist in integrating LCA into the public policy development process, learnings from the research and case studies were applied to develop a framework of process suggestions to encourage this integration.

SETAC proposed a list of priorities for effectively incorporating LCA within the public policy development process (Allen et al., 1995):

- Ensure stakeholder involvement occurs early and throughout the process
- Encourage strong partnerships among stakeholders
- Document and communicate successful LCA applications, and use case studies to identify barriers and issues
- Encourage organizations to apply LCA to decision-making processes
- Educate public policy decision-makers on the concept and use of life-cycle thinking and LCA

Despite the time that has lapsed since this list was developed, the fundamental conclusions remain legitimate, and were verified through subsequent research findings within this dissertation. Therefore, these priorities were used as a foundation, and elaborated upon to provide a list of specific process recommendations that have the potential to address the previously outlined barriers to effective inclusion of LCA information in the decision-making process:

1) Involve decision-makers and other stakeholders actively, wholly and genuinely throughout the LCA process.

    - Identify stakeholders up front and invite them to participate.
    - Bring decision makers into the LCA process early and educate them on how LCAs work, and their potential contribution to the decision-making process.

- Provide for adequate facilitation/ oversight to accommodate the complexity of a multi-stakeholder process and fully engage the range of stakeholders.

Hofstetter (1998) asserted that LCAs are traditionally conducted by experts, with little ongoing involvement of stakeholders, aside from initial contact during the goal and scoping stage, as well as at the conclusion of the project to report outcomes. On the other end of the spectrum is a participatory analysis process, where stakeholders are actively involved throughout the process (Bras-Klapwijk, 1999), with corresponding allowance for significant focus on normative input. This is the type of process being proposed here.

Bras-Klapwijk (1999) asserts several reasons for using a participatory process, including that stakeholders learn about the issue throughout the process, rather than only at the end, gaining a greater understanding of the results, and buying into the process. Stakeholders also gain insight into underlying normative issues and assumptions, and ongoing interaction of stakeholders can result in increased collaboration and consensus, as stakeholders gain understanding of the perceptions, values and interests of other stakeholders, ideally building mutual understanding and respect. Ultimately, stakeholder involvement is likely to improve the quality of the study, since stakeholders provide information and insight that can greatly benefit the process, and ongoing input from a range of stakeholders serves to focus the research to issues that are truly relevant, while not excluding potentially important questions (Bras-Klapwijk, 1999).

The Alberta Tire Recycling case study (see Chapter 10) demonstrated the importance of involving stakeholders (in this case Board members) in all phases of the project to encourage understanding and engagement. The failure to fully engage Board members throughout the process led to a lack of acceptance and support of the LCA outcomes, demonstrating that if key stakeholders are not fully engaged, the likelihood of buy-in for the results is reduced. The Tire Recycling case study process was summarized in a RACI matrix ("ITSMTransition", 2015; Value Based Management, 2015), which is modified below to represent a general suggestion for the level of involvement of various stakeholders in the LCA process.

Table 2: RACI Matrix for LCA Process

	Goal / Scope Definition	Inventory Analysis	Impact Assessment	Interpretation
Direct Stakeholders (Decision-Makers)	RA	C	C	A
General Stakeholders (Public)	C	I	I	C
Project Manager	A	A	A	RA
Technical Team (Peer Review)	C	C	C	C
LCA Practitioner	C	R	R	R

R – Responsible; A – Accountable; C – Consulted; I – Informed

As shown, stakeholders are involved throughout the process, with decision-makers assuming accountability for key stages including Goal and Scope Definition and Interpretation. Stakeholders with an interest in the process, but less directly affected, are consulted at these key phases, and kept informed at a minimum throughout the remainder of the process. The Technical Peer Reviewers are actively consulted throughout, and the LCA Practitioner assumes direct responsibility for delivering the technical analysis portions of the work.

This matrix is only a general guideline, as the appropriate level of responsibility for various process participants will vary based on the specific situation, but should adhere to the recommendations presented in this overall process framework.

Stakeholder engagement should be actively encouraged by identifying and inviting stakeholders who have a vested interest in the outcome of the process. It is useful to define a stakeholder in a decision as "someone who can affect or will be affected by the decision" (Howard, 2007). Stakeholders can vary widely from regulators to interest groups and the public. In the CalRecycle Used Oil LCA case study, this step was facilitated through issuing a public open invitation to anyone identified as a potential stakeholder. In the case of the Alberta Tire Recycling LCA, stakeholder identification was simplified through the existing Board that represents significant stakeholders, thereby already providing a mechanism for stakeholder engagement. This shows that stakeholder identification will vary between cases.

Participation should be encouraged by facilitating involvement through consideration of schedules and other potential limitations, including limited resources of some stakeholders. If funding support is not possible for stakeholders such as non-profits, other approaches such as remote participation through conference calls and webinars that limit the time and resources required to take part in the process should be considered and actively supported. The challenge of engaging important non-profit stakeholders was demonstrated in the CalRecycle Used Oil LCA case study, where only one of 50 stakeholders was an Environmental Non-Governmental Organization (ENGO).

Stakeholders should be invited to be part of as much of the process as is feasible to encourage full engagement, understanding and commitment. However, the desire for full engagement needs to be balanced with the time required by stakeholders, as large time commitments may result in stakeholder fatigue. This was evidenced in the CalRecycle Used Oil LCA case study where stakeholder attrition of more than 20% occurred over the length of the project (Carlson, personal communication, July 15, 2014). Regular updates and reports at key process junctures, where significant outcomes arise or decisions need to be made, is a potential approach to balancing this issue.

Key to effective involvement of stakeholders is to genuinely engage them in the process. This includes ensuring involvement at all key decision points, and serious consideration of all input received. Stakeholders will be more likely to be committed to the process outcomes if they feel they have been genuinely engaged throughout, rather than brought in in a more token way, particularly after key decisions have already been made. One example of this is the SETAC proposal of an interactive peer review process through a multi-stakeholder panel that provides review at several stages (Allen et al, 1995). Ultimately, through a participatory process, there is the potential of building group consensus on strategies for moving forward (Bras-Klapwijk, 1999).

It is important to identify interested stakeholders before the LCA is initiated, and bring them into the process early on. This allows them to fully engage in the early stages, where key decisions such as goals and scope are made, and also benefit from the full background of the process and issues at hand. Early involvement of stakeholders can also have the complementary benefit of facilitating the process of collecting data and other information required for the LCA (Allen et al., 1995).

Effective participation of stakeholders with divergent interests can be challenging, however, and strong facilitation is a key element to encouraging mutual trust and open communication (Bras-Klapwijk, 1999). This can shift the role of the technical LCA analyst to facilitator, as well as technical expert. However, a multi-stakeholder process is much more complex to manage than a purely technical study, and may be beyond the capability of many technical experts to handle. Therefore, consideration should be given to incorporating a professional facilitator with experience in managing technical multi-stakeholder projects.

An example of successful engagement of a professional facilitator was the CalRecycle Used Oil LCA outlined in the case study examples, where an expert facilitator was contracted to manage their complex process involving numerous stakeholders, including capturing the resulting input to incorporate into the process.

A related example is the Project Technical Team that was formed as part of the Alberta Recycling Tire LCA case study, bringing together an expanded group of LCA experts and associated knowledge beyond what would be incorporated utilizing only a single organization as the sole LCA practitioner. This approach provided the equivalent of an ongoing peer review element that vetted concerns and dealt with questions as they arose, rather than identifying issues after the fact.

Ultimately, if stakeholders are involved in the early development and framing of the study, and feel they have an influence on choices made throughout the process, there is a greater chance that the results of the LCA will be taken into consideration in the subsequent decision-making process (Baumann and Tillman 2004). At the end of the day, the logic to arrive at a course of action must be sound, and the decision maker must be committed both to the process and to the significance of the decision (Howard, 2007).

2) Initiate the LCA process with effective introductory session and goal definition / scoping exercise.

- Introduce stakeholders to the concept and use of LCA.
- Define goal and scope of project, including conceptual modeling and definition of research questions.
- As part of the scoping exercise, define how LCA results will used in the ultimate decision.

Including stakeholders with a diverse range of backgrounds and varying levels of technical knowledge within the process requires additional thought and preparation to be undertaken initially to provide the background and information that will allow stakeholders to participate in a meaningful and productive way. One potentially effective approach is to begin with a background introduction on LCA – what it is, history of its development, and its potential for contributing useful information to the issue at hand. Essentially, this would be an LCA 101 primer, building on the SETAC concept of educating public policy decision-makers on the concept and use of life-cycle thinking and LCA.

This approach was undertaken in both the Alberta Scrap Tire LCA and CalRecycle Used Oil LCA case studies. In the Alberta case, the LCA 101 primer was presented to the full Board of Directors to introduce them to the project and increase their knowledge of the process. In the CalRecycle case, an LCA 101 session was held to ensure all participants understood the basics of LCA, as well as the decisions that would be required as part of the process.

Kicking off the process with an LCA 101 workshop will encourage the basic understanding of LCA by all involved stakeholders. This will help to address the barrier of decision-makers lacking background knowledge about LCA, and set them up to embrace the integration of LCA into the overall process. This type of workshop can also be used as a platform to engage stakeholders in the process, and build into subsequent steps like goal and scope definition.

Suggestions for an LCA 101 workshop to kick off the process are outlined below:

LCA 101

- History of LCA
- LCA Process Summary
    - Definition, description
- Examples of application of LCA (preferably related to topic at hand)
- Discussion of application of LCA within current decision-making process
    - Group discussion and agreement of how LCA will be used
- Group commitment to engagement within the process

The workshop outline can be modified to meet specific group requirements, but the primary elements are encouraged to be included. It is also suggested that an LCA expert be utilized to present the workshop, thereby adding credibility to the process.

In moving into goal and scope definition, Hofstetter (1998) suggested starting with a set of questions that help to clarify the process:

1. What is the aim of the LCA?
2. If the aim is to reduce environmental impacts, what is the environment and what are the impacts that should be reduced?
3. What are the causes of the impacts targeted for reduction?

The idea of these questions is to help to narrow the inventory analysis to the relevant factors, providing for a more efficient process. But, posing this type of questions can also help to orient stakeholders and set up the goal and scope definition exercise.

Building on the concept of framing the project up front, Bras-Klapwijk (1999) proposed the addition of two stages to the LCA methodology:

1) Conceptual modeling – this would make conceptualizing the problem and possible solutions formally part of the process, preventing the premature exclusion of issues that are important to specific stakeholders. This stage

was proposed to be added after the initial goal definition, essentially making it part of the formal scoping exercise.

This additional stage is consistent with Decision Analysis, where the first step is to organize the problem, formally recognizing all the possible options and outcomes, so important aspects are not overlooked (Neufville, 1990). Decision analysis is a procedure that balances the factors that influence a decision through a modeling structure that incorporates uncertainties, values, and preferences. The approach typically includes technical, marketing, competitive, and environmental factors in a computer model that allows for computation and manipulation of the inputs (Howard, 2007).

Decision Analysis was developed on the premise that a decision can be seen as a choice among alternatives that will result in outcomes that are uncertain, even though we have preferences for which outcome we prefer. It was felt that there was a need for a decision analysis process to assist in making important decisions, since many decision errors may only be apparent upon reflection after the decision is made in an intuitive manner (Howard, 2007).

Decision Analysis' use of a decision tree, as shown below in Figure 4, to show the flow of the decision-making process may be a useful tool in implementing Bras-Klapwijk's proposed modeling. The use of a model such as a decision tree could help to flesh out the process and identify potential alternatives or outcomes.

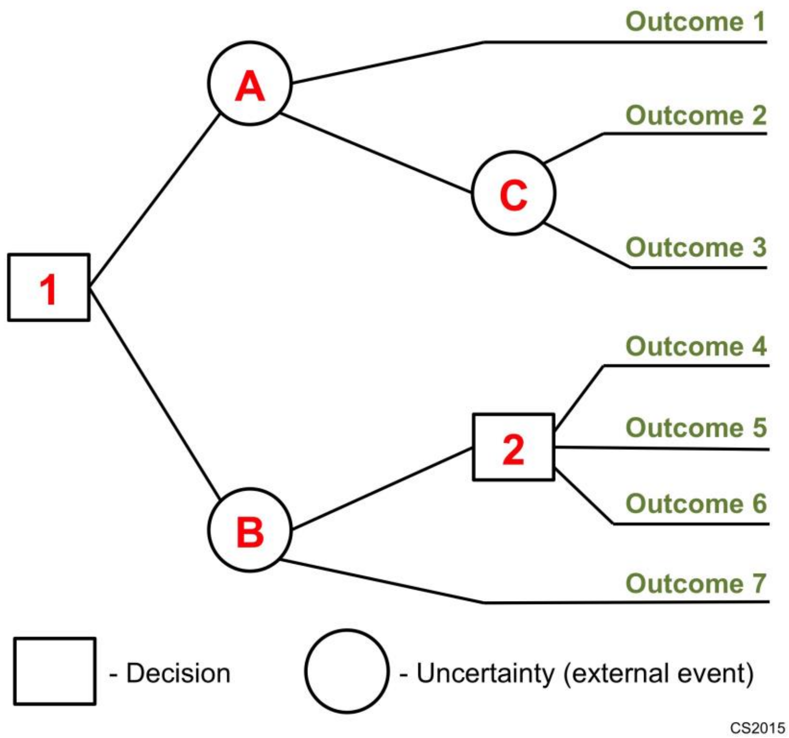


Figure 4: Decision Tree

(Source: adapted from http://www.time-management-guide.com/decision-tree.html)

As shown above, a decision tree includes both decision and chance nodes (Neufville, 1990).

There is a danger in using a decision tree model, however, as when people try to analyze decisions using a structure like a decision tree, they may be tempted to include every possible outcome or uncertainty they can think of, which results in an unanalyzable “bush”, rather than a more efficient “tree” with limited branches that can be more easily analyzed (Howard, 2007). Avoiding this by creating a focused analysis requires the elimination of factors that will not make a meaningful contribution to the decision.

An example of how the decision process can be simplified is by defining direct and indirect values: A direct value has value in and of itself, while an indirect value is a detail that relates to a direct value, but is not a direct value itself. For example, clean air has direct value, since most people feel it is important. Alternative energy technologies are an example of indirect value, as their value relates to the contribution they make to clean air, rather than any inherent value they have themselves. If decision-making can focus on direct values, avoiding the added complexity of indirect values, it can considerably simplify the decision-making process (Howard, 2007).

At the same time, recognizing options (alternatives that provide a new decision situation) and incorporating them as sequential decisions in the process is key to good decision analysis (Howard, 2007). In other words, good decision analysis should incorporate all options that are critical to the process, while avoiding unnecessary outcomes that are not important to the decision itself.

This type of approach could be integrated into the scoping stage, thereby providing focus on relevant factors, while ensuring that the process considers all aspects of importance to stakeholders.

2) Defining emergent research questions – this suggests the ability to adapt the research approach to the specific context of the study, ensuring that the questions being addressed are most relevant to the policy issue at hand. It also suggests an iterative approach, with the ability to add additional issues that may arise throughout the process, or similarly, to remove issues that are identified as irrelevant and not worthy of future research. The ultimate goal of this additional stage is to increase the relevance of the research to policy makers by focusing on key issues. Focusing the research may also have the added benefit of reducing the resources required to complete the research.

   Incorporating this approach will require the goal and scope to be revisited throughout the process to allow for adjustments as required to ensure research is targeted to key issues and outcomes identified by the project team.

It is important that the goal and scoping exercise include a clear definition of how the LCA results will ultimately be used in the decision-making process. This will assist with refining research questions, while also encouraging stakeholders to commit to duly consider LCA results in their decision through a formal recognition of that process. Formal adoption of this process will also provide an ongoing point of reference throughout the overall decision-making process.

3) Translate values and limitations of LCA concepts and methodologies into language decision-makers understand.

   Decision-makers involved in the LCA process from the start of a project will inherently gain LCA and process understanding though this involvement. However, descriptions and results delivered as part of any project reporting need to be presented in a simple yet comprehensive way, avoiding overly technical language and jargon that is readily understood only by those with intimate knowledge of the industry. This will encourage widespread use of the results, and incorporation by decision-makers who may have not been directly involved in the process.

   Decision analysis theory asserts that the process is more about clear thinking than about specific procedures, suggesting that language is very important. This is particularly important when discussing or sharing decisions, particularly with people outside the direct process. Defining specific language in the process can also help to focus the problem to its key elements. The ultimate goal is to use language in describing decisions that consists of the simplest, least confusing, most accurate terms for the concepts under discussion. (Howard, 2007)

   Examples of suggested terminology preferences are included in Table 3:

Table 3: Terminology Changes for Clarity and Simplicity (Howard, 2007)

Conventional Term	Preferred Term	Purpose of Change
dependence	relevance	emphasizes the informational rather than the causal nature of elements
outcome	prospect	emphasizes that decisions result in uncertain futures rather than a defined result
expected value	mean or average	recognizes that the expected value is seldom to be expected

In order to compile information for summary and presentation, inventory results are classified according to environmental indicator, and characterized using equivalency factors to aggregate results into a limited number of impact categories. For example, emissions of greenhouse gases (GHGs) such as carbon dioxide (CO_2) and methane, can be consolidated into a climate change impact category. This type of characterization is normally presented in terms of a representative indicator – in the case of GHGs, usually CO_2, represented as kg eCO_2, or kg of CO_2 equivalent. Common characterization measures are summarized in Table 4:

Table 4: Characterization Measures (compiled from Morris, 2011)

Indicator	Equivalency Unit	Equivalency Descriptor
Climate Change	kg eCO_2	kg of carbon dioxide equivalent
Eco-toxicity	kg e2,4-D	kg of 2,4-D equivalent
Acidification	kg eSO_2	kg of sulphur dioxide equivalent
Eutrophication	kg eN	kg of nitrogen equivalent
Human Toxicity	kg eToluene	kg of toluene equivalent
Human Carcinogenicity	kg eBenzene	kg of benzene equivalent

The level of aggregation is important – too little leaves too much complexity, which can potentially overwhelm and intimidate decision-makers. At the same time, too much aggregation, although producing a more simplified output, can produce levels of distrust based on lack of transparency. (Baumann and Tillman, 2004). Although attractive from a simplicity point of view, especially for non-technical decision-makers, oversimplification produced by weighting can also result in mistrust, as it can appear that assumptions led to foregone conclusions. To counter this skepticism, it is critical to be as transparent as possible in outlining the methods and assumptions being used. It is also critical to recognize the difference between impact measures and actual environmental outcomes. The LCA results indicate measures of outputs that have potential impacts. However, the actual outcomes of these impacts for a given situation would need to be assessed through a risk analysis. The proposed multi-stakeholder process can also help to validate any valuation or weighting methods that are incorporated into the study, as the involvement of stakeholders in this process can help outside observers and reviewers have confidence in the validity and relative neutrality of the results, particularly if the stakeholders involved include both experts who can add technical credibility and interested parties from various perspectives. This confidence in turn can encourage decision-makers to consider incorporating results into their decisions.

In an attempt to facilitate effective use of LCA within the decision-making process, a number of tools have been used to assist in presenting LCA results, including comparative matrices, relative ranking systems, and common unit (such as monetization) approaches. These tools, specifically common unit approaches, have been covered in more detail in the discussion of the Impact Assessment phase of an LCA (Chapter 4), where approaches to weighting impacts across categories are reviewed.

An example of how LCA results can be presented is shown in Table 5 below, where results are presented in a comparative matrix of impacts that also includes a composite indicator that has been developed using a common monetary unit.

Table 5: MEBCalc™ Evaluation of End-of-Life Methods for Leaf & Yard Waste (Morris, 2011)

		LCIA Results – Potential Impact Increase/(Decrease) Per Tonne Red Deer Leaf & Yard Waste						
EOL Management Method	**Composite Conceptual Environmental Cost/(Benefit)**	**Climate Change**	**Human Respiratory**	**Human Toxicity**	**Human Carcino-gencitiy**	**Eco-toxicity**	**Addifi-cation**	**Eutrophi-cation**
	($/tonne)	(kg eCO_2)	(kg $ePM_{2.5}$)	(kg eTuoluene)	(kg eBenzene)	(kg e2,4-D)	(kg eSO_2)	(kg eN)
Aerobic Composting	($3)	(190)	0.10	13	<0.005	0.45	0.83	0.11
LFGTE	$66	141	0.73	366	0.17	2.57	3.58	2.63
Mass Burn WTE	$71	455	0.39	268	0.24	4.72	2.82	2.61
	MEBCalc™ Default Conceptual Costs	$40/tonne eCO_2	$10,000/ tonne $ePM_{2.5}$	$118/tonne eToluene	$3,030/ tonne eBenzene	$3,280/ tonne e2,4-D	$410/ tonne eSO_2	$4/tonne eN

CS2015

This is an example of how a common unit of comparison, in this case $, is used to summarize impacts across categories. However, it is important to note that ISO states that there is no scientific basis for reducing LCA results to a single overall score or number (ISO, 1997).

Another approach to presenting complex results was undertaken in the Alberta Scrap Tire LCA case study (Chapter 10), where impacts were categorized on a scale of good, neutral and poor in a summary table to offer a simplified presentation of the overall results. However, this approach was not embraced by the process participants, suggesting a lack of direct engagement of stakeholders in the process of defining methods of presenting outcomes may have reduced the acceptance of this approach by undermining its legitimacy and transparency.

The function of these type of presentation tools is to present technical information in a format that is readily understood by lay individuals, allowing them to comfortably apply technical results within their decision-making role. As shown in the example above, these approaches can be very effective in presenting complex information in a summarized and understandable way. However, to be used effectively, these tools still require policy leaders to make decisions based on LCA results, combined with other information at hand, within their decision-making process. Acceptance of the results and process used to obtain these results is also a key element in effective incorporation.

4) Provide case studies of successful applications of LCA in public policy to give confidence to its use within the public policy arena.

Examples of successful use of LCA in public policy will inspire confidence and encourage decision makers, such as government officials, to incorporate LCA into the policy development process by developing frameworks for integration of LCA information. The first few public policy LCAs are bound to be initiated by leading public agencies, who are blazing the trail for subsequent public policy LCAs, ultimately allowing for evolution of the process to address barriers identified by these leaders, and for incorporation of this approach to become more the norm.

The CalRecycle Used Oil LCA project is likely to become a leading example of the application of LCA within public policy, and its initiation, ongoing support and promotion by California's Department of Resources Recycling and Recovery (CalRecycle) has been key to its success to date. The ability of the project to embrace multiple stakeholders and mitigate issues as they arise is a testament to the commitment of CalRecycle and the project team.

The ultimate application and results of the CalRecycle project will have a strong impact on the likelihood of other public agencies to undertake similar initiatives. However, the timeframe and cost associated with this project may prove a deterrent to others, despite the project manager's assertion that the acceptance of the study as a result was worth the investment.

There is also the question of who identifies these successful public policy applications of LCA and promotes awareness of their success. This would seem to be the role of international agencies or national governments, depending on jurisdiction, although that would require their interest and buy-in regarding the value and application of LCA at the public policy level. Alternately, neutral organizations and think tanks could play a role in information dissemination. However, coordination of the promotion of LCA within public policy will need to be conducted between multiple parties.

5) Integrate transparency into all elements of the process, including assumptions and uncertainties, and actively involve stakeholders in all discussions regarding these factors.

As part of the transparency of the technical components, the strengths and weaknesses of LCA should be outlined and understood by all stakeholders, along with a clear plan for integrating LCA results into the overall decision-making process. This should occur early in the process, well before an LCA is undertaken, in order to ensure the LCA will add value to the process, and receive due consideration. This can be incorporated into the initial LCA 101 orientation, where the importance of transparency can be reinforced.

Transparency is considered to be one of the strengths of a system like decision analysis, where the decision-making process is clearly presented, including the alternatives considered, the incorporated data and sources, and the preferences assumed (Howard, 2007). Outlining the process utilized in making a decision is certainly key to transparency.

A formal recognition of uncertain elements of the LCA will also enhance the transparency of the process, improving trust in the results by clearly defining areas where accuracy and confidence in the data may be lacking, and the corresponding uncertainty in the results. Giving decision-makers some sense around margins of error that may result from this uncertainty through tools like sensitivity analysis will serve to provide them with confidence around the variance that would result from unknown information, and whether that variance is significant.

There is the concern, however, that transparent recognition of uncertainty could make the results of LCA seem less credible, or highlight the unknown elements of the assessment. At the same time, the added complexity of addressing uncertainty elements and communicating them in a simple yet complete manner are also issues (Heijungsa, 2004). It is also important to recognize the difference between uncertainty, that can be addressed with better data, and variability that represents an inherent heterogeneity or diversity of data and therefore cannot be reduced (EPA, 2015).

Uncertainty information has been increasingly integrated into LCA methods, databases and software, as decision-makers increasingly recognize that uncertainties are important and should be made explicit (Heijungsa, 2004).

There are three primary type of uncertainty that should be recognized in LCA (Heijungsa, 2004):

- Unavailable data
- Inappropriate data
- Data with more than one identified value

These three types of uncertainty can also apply to relationships and choices, in addition to data.

Although it is important to recognize and address uncertainty within the process, at the same time, it is important to strive for clear, consistent results that can effectively be incorporated into decision-making. Uncertainty does not preclude making assumptions as required to develop conclusions. Rather, it only requires transparency in the process used to arrive at the assumptions.

Approaches to deal with uncertainty include efforts to minimize the uncertainty through additional research, consultation or statistical analysis; or approaches to explicitly identify and incorporate uncertainty into the process (Heijungsa, 2004). Examples of unavoidable uncertainty include lack of complete or verified inventory data for certain indicators. The means to deal with this uncertainty may involve additional research to generate additional data to provide more complete information, or finding proxies that are considered reasonable for the scenario.

Examples of this situation occurred in the Alberta Tire Recycling case study, where direct research was conducted into factors such as energy consumption at recycling facilities to allow for calculation of emissions associated with tire recycling operations. This was required because existing datasets did not include information for these facilities.

This case study also involved the use of a proxy in the case of the application of rubber crumb on sports fields. In order to provide an appropriate offset for displacement of alternative materials, consideration was given to the benefits provided by rubber crumb use, and polypropylene crumb was determined to be the closest proxy to provide the same benefits, and thus was utilized as the material used for displacement calculations.

The output model for the Alberta Tire Recycling LCA was presented in a standard Excel format that contained a high level of transparency regarding assumptions, data sources and calculations. This represents a good approach to open presentation of LCA process and results that can be reviewed and assessed easily.

The CalRecycle Used Oil online LCA model also integrates a number of descriptive features that are intended to enhance its transparency and usability.

The approach used to close uncertainty gaps needs to be discussed and approved by involved stakeholders, consistent with the stated goals of the study, and transparently outlined in the report. In cases such as this, the group process approved at the outset will need to be followed to encourage continued stakeholder support.

If the final LCA report is fully transparent, with methodology and assumptions openly reported, there is less need for a formal critical review, since arguably anyone can critically read the report (Baumann and Tillman 2004) since they have access to the details of the process, and stakeholders have been actively involved throughout the process. However, it is important to recognize that ISO 14040 requires a critical review in cases where LCA results are used to support comparative assertions (ISO 2006). A critical review can also provide an additional level of confidence, which may be important in a public project, such as the CalRecycle Used Oil LCA, which included engagement of a review team.

Incorporating a high level of transparency in LCA results can also serve to reduce the likelihood that they will be used in a polarizing way. This, combined with multi-stakeholder involvement, will serve to encourage a balanced and unbiased presentation of results. This is because potential biases of process participants will be balanced by other stakeholders as long as stakeholder representation is broad and includes individuals from a broad range of perspectives.

The move towards increased accessibility and transparency of LCA is an important step in improving trust in the process. Examples of this include the LCA Digital Commons project, driven by the U.S. Department of Agriculture, whose goal is to provide open access to LCA datasets and tools, making LCA data more openly accessible (USDA, 2014 and Leith, personal communication, December 11, 2014). Another example is Open LCA, conceived in 2006, providing the only widely available professional, full-scale Open Source LCA software (openLCA 2014).

To be open source, software needs to fulfil two main criteria, following the open source initiative (OSI) (openLCA, 2015):

- the source code of the software is available at no charge to everyone, and
- the license which accompanies every distributed software file recognizes the creator of the code, and provides a mechanism to further ensure the open source “nature” of the file.

This means openLCA is free to the user, and the software is fully transparent and can be freely shared. Models created in openLCA can also be shared, as limited by database licenses. However, users have no obligation to make data or models they create publicly accessible (openLCA, 2015).

This concept of opening both the software and data to public scrutiny, while also encouraging two-way data flow, is a step towards developing a public LCA system. This step can only serve to increase transparency, rigour and ultimately confidence in associated LCA outcomes. A more open LCA system also has the potential to reduce the resource burden associated with comprehensive LCAs.

6) Ensure the project team represents the full range of stakeholders affected by the policy, and vested interests are balanced.

Case study research conducted by SETAC suggested that public policy that incorporates life-cycle concepts requires acceptance by all interested stakeholders, and that their participation throughout the process is important (Allen et al., 1995). It is important to note that there are two groups of stakeholders who should be engaged: those who want to be part of the process, and those who are key to the success of the process. Those who want to be part of the process will generally respond to requests for involvement, while those who are key to the success may not necessarily desire to be engaged. An example of this is the CalRecycle Used Oil case study, where a large number of industry stakeholders voluntarily joined the process, while only one ENGO participated. Additional public interest stakeholders could have contributed positively to the process by bringing a broader perspective. In the case of the Alberta Tire Recycling LCA, lack of effective engagement of key stakeholders (the Alberta Recycling Management Association Board) negatively affected the incorporation of the LCA results.

SETAC suggested building a stakeholder partnership as part of the process to build trust and credibility, and encourage increased engagement in the process and its outcomes (Allen et al., 1995). This requires serious relationship building to be incorporated into the overall process, which may require additional time to be effectively implemented.

Incorporating stakeholders in the process from the outset can add time and complication to the process, as experienced in the CalRecycle Used Oil LCA case study. However, through a transparent, inclusive and collaborative process, the various stakeholders involved in decision-making will be more likely to embrace and fully utilize the opportunities presented by the LCA phase of the process. This is key, since LCA is an information tool, and decision-makers must value the information in order for it to be considered in policy development (Reed 2012).

It is critical that the decision-making process addresses the needs and particular constraints of all stakeholders and contributors. This needs to happen early in the decision-making process and recognize the role that various elements, including LCA, can and should play. By outlining this early, expectations of various process elements will be specific and realistic.

Engagement of a wide range of stakeholders will invariably shift the focus of the study from quantitative analysis to embrace qualitative factors, as many stakeholders will have normative input that will need to be considered in a participatory process. For example, non-technical stakeholders may have concerns such as quality of life impacts that may be hard to quantify, but are legitimate nonetheless. Attempts by technical experts to isolate or exclude qualitative input will need to be skillfully handled by process managers and facilitators.

Effective participation of stakeholders with divergent interests can be challenging, and strong facilitation is a key element to encouraging mutual trust and open communication (Bras-Klapwijk, 1999). This shifts the role of the analyst to facilitator, as well as technical expert. However, technical contributors may not have the skills required to play a facilitation role, in which case a qualified facilitator may be brought into the process to guide the ongoing input and involvement of multiple stakeholders.

Involving a professional facilitator offers a number of potential advantages:

- neutrality
- skill in handling potential conflict
- encouragement of full involvement of stakeholders

Possible negatives associated with involvement of a facilitator include:

- lack of understanding of overall process and background
- additional time and cost

The Cal Recycle Used Oil LCA case study outlines the use of a professional facilitator who was engaged to help mitigate the challenges posed by the large number of stakeholders involved. In this case, it was felt that effective facilitation was key to the project's success.

Involvement of stakeholders from the non-profit sector may require some form of funding support to offset costs associated with engagement. Non-profits may not have the resources to cover participation costs like travel that may be required to fully participate in the process. In addition, non-profit groups may have staffing limitations that could prevent them from dedicating the staff time required to engage in the process, particularly if it lasts for an extended period of time. Without this support, costs may be prohibitive to smaller non-profits who may have important insight to share.

In an effort to effectively incorporate LCA within the overall public policy decision-making process, the advisability of involving a wide range of stakeholders suggests that there may be an opportunity for the decision-making process to incorporate a multi-disciplinary approach that includes technical LCA experts, as well as economic and social experts, together with a range of stakeholders and public policy decision-makers in a collaborative process.

Baumann and Tillman (2004) support this concept by arguing that LCA models elements of natural, social and technical systems, and therefore needs to be multi-disciplinary in nature. They assert that inventory analysis primarily involves engineering skills because of its technical nature, while impact assessment requires expertise in natural science because of its requirement of knowledge regarding ecosystem function and impacts, and weighting incorporates social science elements based on the assessment of human values (Baumann and Tillman 2004).

Essentially, it is the development and implementation of a well-designed overall process that will facilitate acceptance and effective incorporation of specific phases, including the integration of technical LCA results. Conversely, a process that is seen as non-inclusive or leading to a predetermined outcome will be destined for failure, regardless of the rigour of the technical components it contains.

These process recommendations will be further discussed subsequently within a case study context that will review two primary public policy LCAs in U.S. and Canadian examples.

9 A Broader Process – Life Cycle Thinking

The use of LCA within a public policy framework is more complex than other technically-oriented applications, such as product evaluation and comparative analyses in that the decision-making process itself is more complex as a result of the multiple players involved, bringing diverse interests, viewpoints and backgrounds (Bras-Klapwijk 1999). As public policy decisions vary greatly, from narrow mandates to broad policies, and involve a wide range of institutions, from local municipal departments to federal agencies, the way LCA is applied within the public policy process can and should be different, based on its audience (Allen et al., 1995). The realities also may dictate the extent to which LCA is applied based on individual circumstances like scope and resources. However, limitations should not preclude the value that life-cycle considerations may offer, even if only on a limited basis.

The life-cycle approach can be presented on a continuum, from the qualitative (life-cycle thinking), to the quantitative (comprehensive life-cycle assessment) (Allen et al., 1995), as shown below:

Life-cycle thinking ⟷ Life-cycle assessment

Life-cycle thinking has been described as incorporating the basic concept of LCA without undertaking a detailed assessment of each process (Lazarevic et al., 2012).

Despite the recognized value that LCA can add to the decision-making process, it is important to recognize that LCA may not always be an appropriate addition to a public policy development process. In cases where resources, including both funding and time, are limited, LCA may simply not be a viable option. Therefore, it is important to weigh the availability of data, the time necessary to conduct the study, and the financial resources required against the projected benefits of the LCA (EPA, 2006).

The reality is that smaller organizations may not be able to utilize LCA, even when its potential contribution is recognized (Allen et al., 1995). However, in these cases, embracing life-cycle thinking can still add considerable value to the process, even in absence of a full technical LCA.

An example of how life cycle thinking has been incorporated into public policy is the development of Integrated Product Policy in the EU that attempts to bring together policies such as Extended Producer Responsibility and eco-labelling into a more holistic policy approach that seeks to minimize a products' environmental impacts by looking at all phases of its lifecycle and taking action where it is most effective (Baumann and Tillman, 2004 and EU, 2015). This approach also tries to avoid the shifting of environmental burdens from one part of the life cycle to another through an integrated approach.

Another EU example is The Waste Framework Directive, that has made the waste hierarchy legally binding for Member States, stating it "shall apply as a priority order in waste prevention and management legislation and policy". The Directive specifically calls for the departure of specific materials or streams from the waste hierarchy to be "justified by life cycle thinking on the overall impacts of the generation and management of such waste". (Lazarevic et al., 2012, p.200)

Perhaps one of the most important aspects of incorporating LCA into public policy decisions is to encourage life-cycle thinking among policy makers. Considering ramifications of decisions based on their full life cycle is good practice for all managers and politicians, and this approach can be adopted even without the need to undertake intensive life-cycle assessments. Considering the life-cycle implications will result in more informed and thoughtful decisions, even if a full LCA is not undertaken (Allen et al., 1995). It has also been suggested that the educational value of a conceptual application of LCA in helping to generally identify the results, key sensitivities and uncertainties cannot be understated (Lazarevic et al., 2012).

Therefore, it is important that public policy officials are encouraged to embrace life-cycle thinking in their decision-making process. This could initially be conceptual to introduce them to the approach, and evolve into more comprehensive LCAs in specific situations where warranted by the potential value LCA can offer.

10 Case Study Review

Case studies offer the opportunity to directly experience elements of research, as compared to more indirect options such as literature review and interviews. The following case studies present two examples of efforts to incorporate LCA into public policy development. As such, they are instructive in terms of demonstrating barriers to successful use of LCA in this application, as well as innovative approaches to addressing these barriers.

Potential case studies were identified through broader project research and personal references. The final case studies were chosen based on their direct application of LCA to public policy, as well as factors of opportunity such as location and contact availability. The Alberta Scrap Tire LCA, specifically, offered the opportunity for direct involvement (through hands-on participation as an active participant) and influence throughout the process, with the author playing the role of project manager. This allowed for an unparalleled amount of access to players and results that provided a level of insight beyond more remote interaction. Because of this direct involvement, conclusions from this case study were based primarily on observation and experience, combined with feedback and interviews with stakeholders and experts directly involved in the project. Specifically, the expert review panel, comprised of international LCA experts, provided a strong level of insight and expertise that informed the research, particularly on a technical level. At the same time, the stakeholders, including Board members from various sectors related to scrap tire management, provided insight into process involvement and expectations that played a strong role in informing the barriers associated with integrating LCA into public policy. This direct case study involvement allowed for testing and validation of external research assumptions and conclusions, while directly experiencing the process of applying LCA to a public policy application.

The CalRecycle Used Oil LCA was chosen as a supplemental case study based on its intent for LCA to directly influence used oil public policy in California, as well as its high standard of stakeholder involvement and accessibility and support of the key project manager. As the case study was largely complete, it was researched primarily through literature reviews and interviews with key LCA personnel, as well as direct involvement of the author as a reviewer in the implementation phase.

Case study results were used to validate conclusions from other research methods, specifically regarding barriers to integrating LCA into public policy and potential strategies to successfully mitigate these barriers and develop a successful framework for incorporating LCA into the public policy development process.

10.1 Alberta Scrap Tire Recycling Example

In late 2009, a project plan was developed by the Alberta Recycling Management Authority (ARMA) to complete a life-cycle assessment (LCA) process for reviewing scrap tire processing technologies that could be considered under Alberta's program. The project was developed subsequent to research being conducted and determining that life-cycle information for scrap tire options was predominantly limited to the European context, and was not quantitatively transferable to Canada, due to varying technologies and energy profiles (sonnevera, 2007).

The objectives of the project were to:

- Provide awareness of available leading tire waste management options from a life-cycle perspective
- Measure environmental benefits and risks of these options
- Inform the tire waste management decision-making processes
- Provide useful information to community members, policy makers and interested stakeholders

As manager of Alberta's scrap tire management program, ARMA makes decisions regarding acceptable options for handling tires that are part of the program, as well as relative funding levels provided for different dispositions. Therefore, the relative environmental outcomes associated with the different management options available are key elements for consideration within these decisions. It is the corresponding desire for greater understanding of the environmental impacts of various scrap tire management options that provided the impetus for this LCA project.

This project is an important case study, as it represents the application of LCA research to development of policy by a quasi-public body (ARMA is a Delegated Administrative Authority charged by the government of Alberta with oversight of a number of Alberta waste stewardship programs, including scrap tires). As such, ARMA is a reasonable proxy of a public policy development body. In addition, the ARMA Board of Directors is made up of a number of stakeholder representatives, thereby providing the added perspective of a multi-stakeholder group.

At the outset of the process, a project outline was developed that provided an overview of the project process to be incorporated to conduct a life-cycle assessment (LCA) to review scrap tire processing technologies that could be considered under Alberta's program. The outline included two phases:

- Development of an Alberta-specific LCA process for the review of scrap tire processing alternatives.
- Create ARMA Project Management Team
- Select Project Technical Team
- Selection of the processing options to be assessed
- Develop LCA process
- Assessment of selected technologies.

This process was vetted and approved by ARMA administration, through a series of meetings and technical submissions, prior to implementation. At this point, a Project Management Team was also created. This team was comprised of various administrative staff, but unfortunately, Board members chose to delegate this responsibility to administration, which in retrospect was not an ideal outcome, as it did not create direct engagement of Board members. The lesson learned from this experience would be to ensure that Board representatives, as primary stakeholders, are active participants in the Project Management Team, as well as other stages of the project. This would have more fully engaged these primary decision-makers, encouraging them to embrace the process and its results.

An initial LCA information session was held with the Board to provide background on LCA and introduce them to the concept of a comprehensive LCA process. The session was conducted at a special meeting of the Board, and was conducted by the project manager. It included a review of project goals, the scope of options that could be considered, as well as anticipated project outcomes. At this meeting, the make-up of the

Project Management and Technical teams were also introduced to the Board, along with their respective terms of reference. The session also included a primer on LCA, titled *What is Life-Cycle Assessment?*, conducted by an LCA expert from the University of Alberta. This primer included elements on the background of LCA, such as Figure 5:

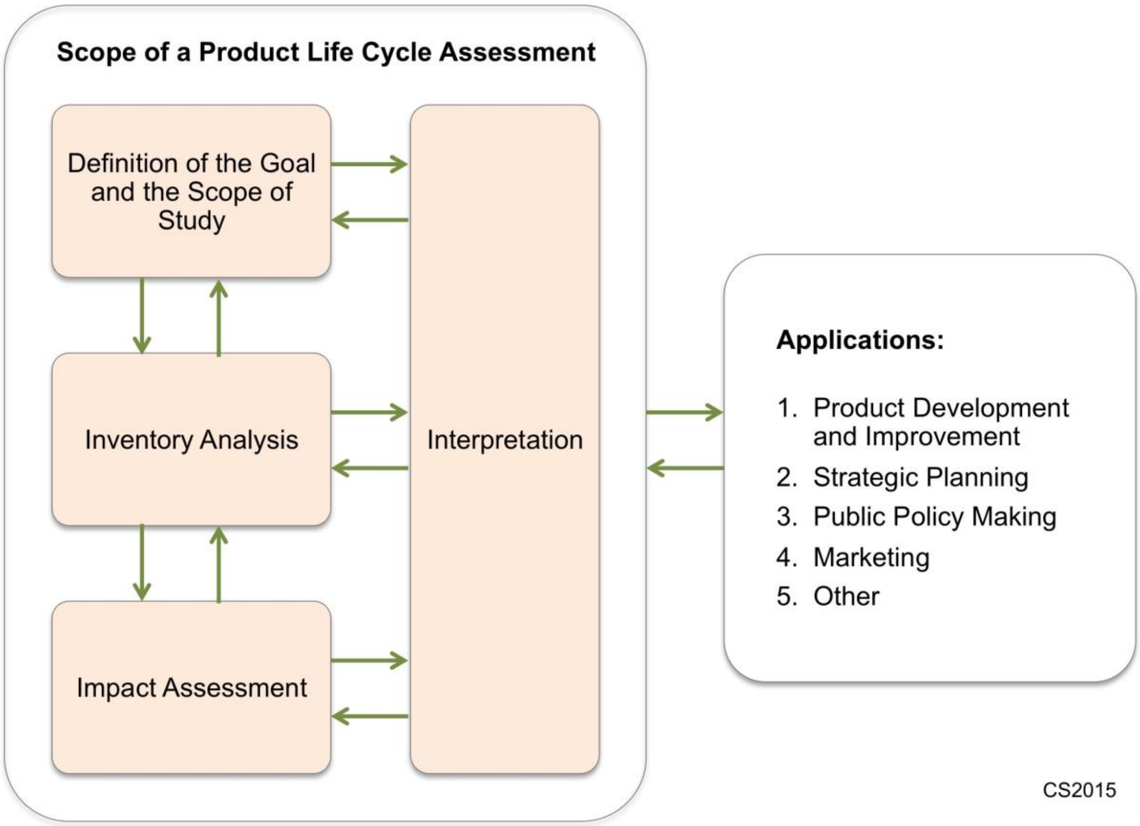


Figure 5: Life-Cycle Assessment Overview

It also included information on the process of applying LCA to tire recycling options, such as the process flow diagram shown in Figure 6:

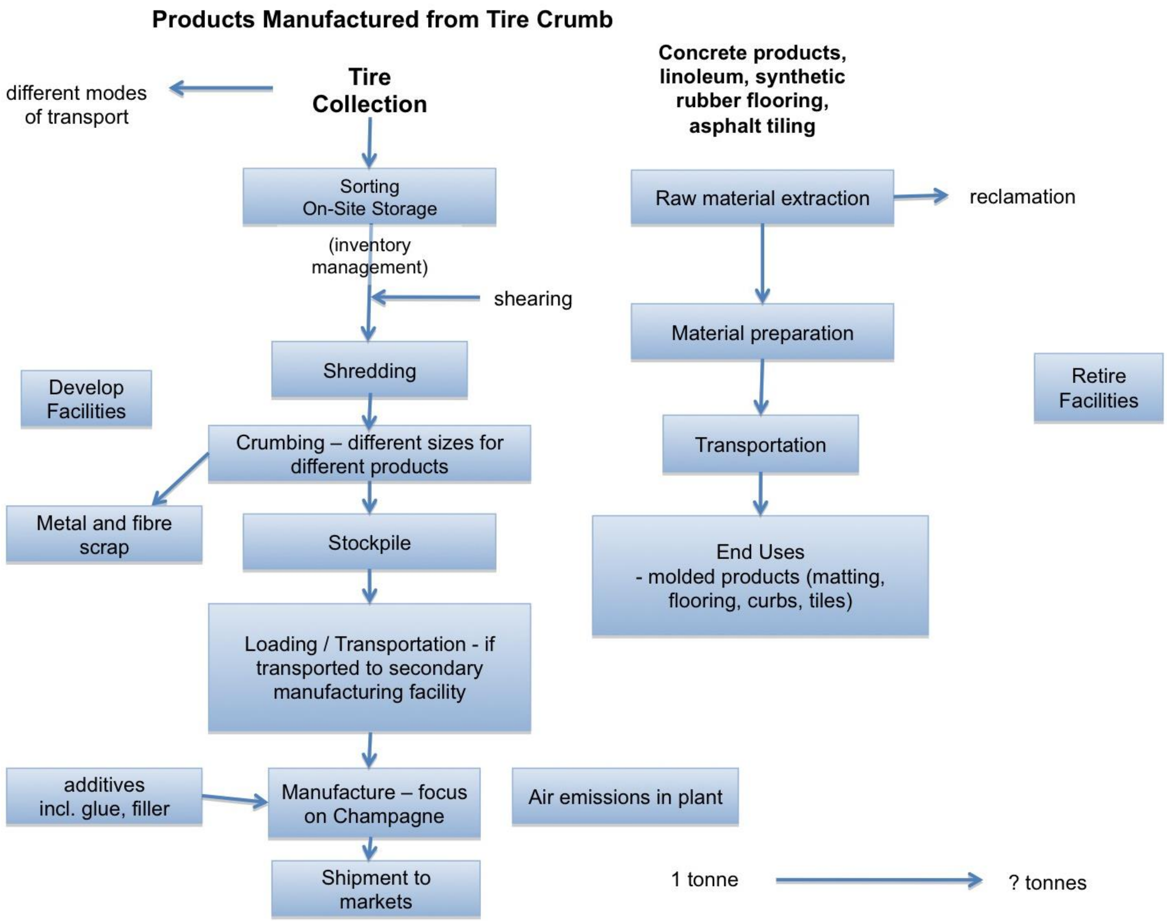


Figure 6: Process Flow Diagram for Manufactured Products

As suggested in the recommendations for LCA process previously outlined, this information session was intended to provide the background and information for stakeholders (in this case the ARMA Board and administration) to participate in a meaningful and productive way.

This is an example of involving decision-makers early in the LCA process, which is a prime element within the recommendations to address the barriers to effective inclusion of LCA in the decision-making process. However, the recommendations specify not only early engagement of stakeholders, but full and genuine involvement.

The ARMA experience suggests that the project should have been more comprehensively reviewed and approved by the ARMA Board of Directors at the outset, rather than assigning responsibility primarily to administrative staff. This would have served to engage the Board, or at least selected Board representatives, at a more detailed level, rather than simply providing high level approval. This would likely have resulted in a more genuine understanding of the LCA process by the Board, and consequently led to increased endorsement of the results by the ultimate decision-making body.

Because of the wide-ranging expertise and academic rigour required for the LCA research, it was suggested that a project technical team be individually selected and assembled to access the best available expertise in the field. This team would interact directly with an ARMA project management team to ensure the project developed in a way that was both technically sound and appropriate for the intended purpose. This approach provided for the recommendations laid out in the original proposed SETAC LCA standard that proposed an interactive peer review process for LCAs that are used to inform public policy processes, through a multi-stakeholder panel that provides review at several stages throughout the process (Allen et al., 1995).

Therefore, the first step was to create a project management team, consisting of ARMA management staff and Board members, to oversee the project and work with the project technical team throughout the development of the project. Unfortunately, this management team ended up being primarily administrative management, resulting in a less robust linkage to the ARMA Board of Directors, as previously mentioned.

The next step was to create a project technical team. Individuals were invited to serve on the team based on their expertise in the area of life-cycle assessment and/or tire processing technologies. It was anticipated that the technical team was likely to evolve throughout the project, as required to meet needs within specific components. The selection process consisted of initially appointing core committee members, who were invited to participate for the duration of the project, and assisted in subsequent invitations of additional team members as needs were identified.

The intention of the process was for the Project Management Team to provide oversight to the Project Technical Team throughout the duration of the project, considering high level issues such as adherence of the project to the defined objectives and process in the project plan, and reviewing key decisions that arose that could have implications to the overall project outcomes, budget or schedule.

The Project Technical Team worked with a consulting agency to develop an LCA process that considered the unique characteristics of Alberta's tire management program, building on existing LCA models, and utilizing available LCA knowledge to the fullest extent possible. This process of utilizing currently available information, while adapting existing models to the Alberta situation, was intended to provide for the best project outcome.

At the same time, the management team was intended to provide perspective on the level of comprehensiveness and types of outputs expected from the model. The expected outcome was a model with the capability of providing results that are quantitative, comprehensive, technically rigorous and relevant to the jurisdiction.

10.1.1 Process Results

The following RACI Matrix ("ITSMTransition", 2015; Value Based Management, 2015) represents the management process as it actually occurred in the Tire Recycling case study:

Table 6: Tire Recycling Case Study RACI Matrix

	Goal / Scope Definition	Inventory Analysis	Impact Assessment	Interpretation
ARMA Board	I	I	I	I
Management Team	RA	A	A	RA
Technical Team	R	RA	RA	RA
LCA Consultant	C	R	R	R

R – Responsible; A – Accountable; C – Consulted; I – Informed

The RACI Matrix below shows the management process as it would have occurred in an ideal situation:

	Goal / Scope Definition	Inventory Analysis	Impact Assessment	Interpretation
ARMA Board	RA	C	C	A
Management Team	A	A	A	RA
Technical Team	C	RA	RA	R
LCA Consultant	C	R	R	R

R – Responsible; A – Accountable; C – Consulted; I – Informed

As indicated, the ideal process would have involved and assigned more responsibility to the higher level stakeholders (the ARMA Board) throughout the process. Specifically, this proposed process would have seen the Board directly involved and accountable for the Goal and Scope Definition stage, and thoroughly consulted and updated throughout the Inventory Analysis and Impact Assessment stages. Ideally, the Board should also have been accountable for the Interpretation stage, encouraging their increased involvement during this critical part of the process in terms of applying results.

This would have implications on the other participants in the process, as well, with the Management Team sharing accountability with the Board for Goal and Scope Definition, and removing the Technical Team's accountability for the Interpretation phase. At the same time, the responsibility for Goal and Scope definition would be removed from the Technical Team, instead replaced with input through consultation. Similarly, the Technical Team would still be directly involved in the Interpretation phase, but would no longer be accountable for the results.

The incorporation of a Project Technical Team to oversee the completion of the LCA proved to be a successful approach, as the expertise provided by this team was able to readily deal with technical process questions as they arose, and provide an increased level of rigour and accountability to the LCA itself by involving an expanded group of LCA experts and associated knowledge beyond what would be incorporated utilizing only a single organization as the sole LCA practitioner. This approach provided the equivalent of an ongoing peer review element that vetted concerns and dealt with questions as they arose, rather than identifying issues after the fact. As a result of the complexity and rigour associated with LCAs, this approach is recommended to be adopted where feasible.

As much as the technical team approach was successful, the overall process could have been further improved. Upon reflection, it is likely that the strong focus on the technical process was achieved to the detriment of the process as a whole. As already cited in the literature, a strong technical focus can lead to disengagement of participants in the overall process. This certainly could have been the case with the Tire LCA process, as the desire to ensure technical rigour within the LCA led to a focus on this component that suggested its importance over other elements, detracting focus from the holistic process, while also potentially creating unrealistic expectations from higher level stakeholders. This conclusion was made as a result of discussions with the Board regarding their understanding and expectation of the process, once it became apparent that they did not fully embrace the results.

Ironically, the strong technical expertise offered by the technical team, while certainly providing the desired rigour to the LCA itself, may have discouraged the level of involvement from the management team and the ARMA Board that would have been preferred from an overall process view. This lack of involvement in turn led to unrealistic expectations of the project results.

The final LCA report delivered by the consulting firm was shared with the ARMA Board, and a summary presentation was delivered to outline the overall results. The presentation included project objectives, as well as an overview of the methodology incorporated. A review of the LCA process was also discussed to raise awareness of the technical component of the project, using descriptive graphics such as those below:

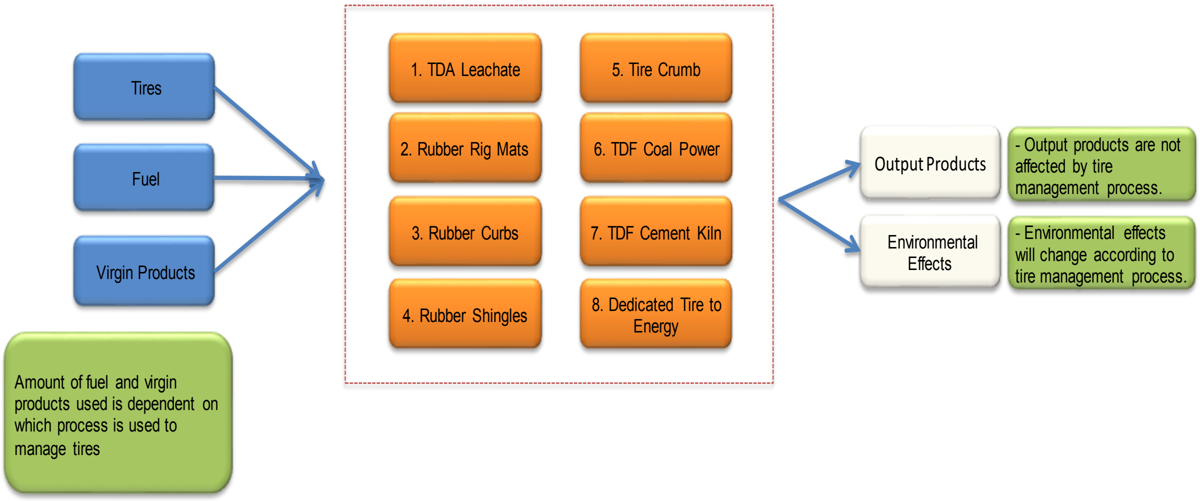


Figure 7: Process Map (Pembina, 2010)

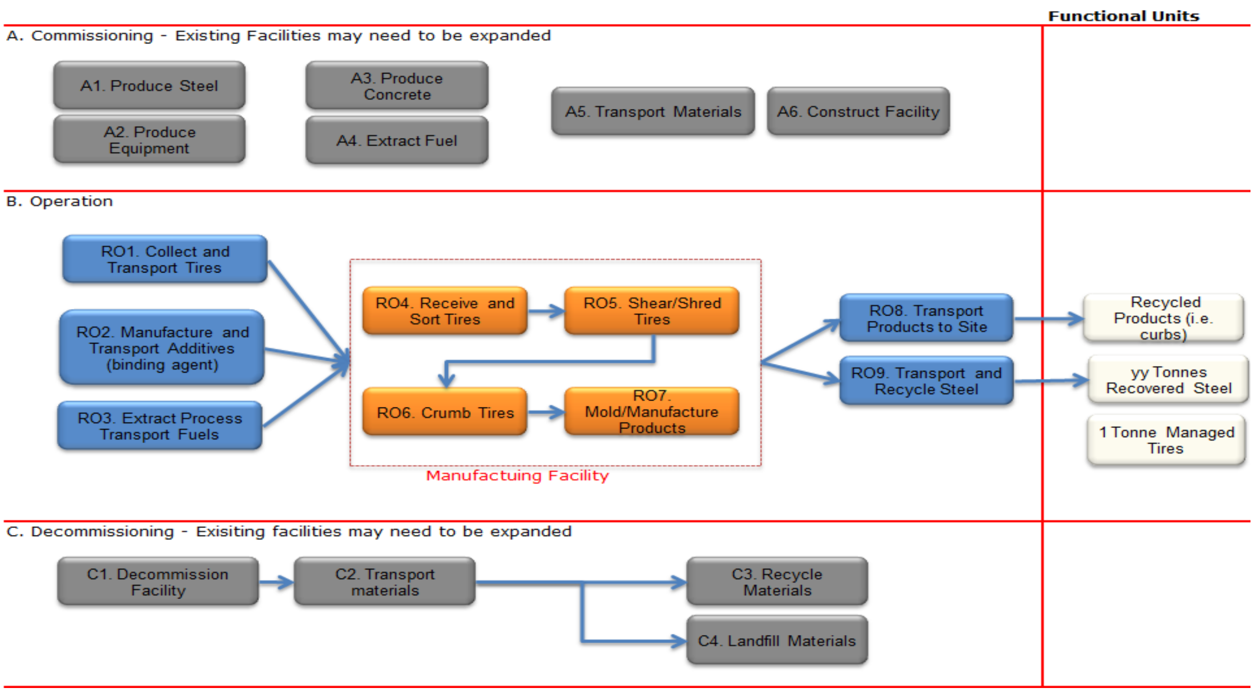


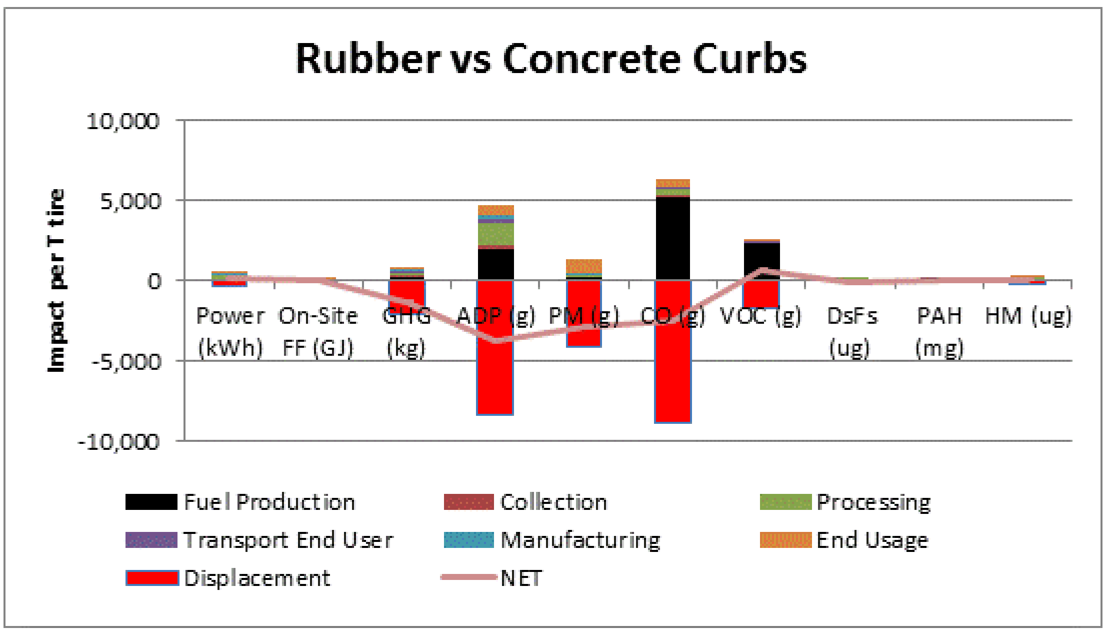
Figure 8: Tire LCA Process Diagram (Tires into Rubber Curbs) (Pembina, 2010)

The process diagrams map out the scrap tire management options (Figure 7) that were considered within the LCA, and the process elements and scope associated with the option of making curbs made from recycled tires (Figure 8).

All process diagrams can be found in Appendix D, where additional results from the full Alberta Tire Recycling LCA model are included.

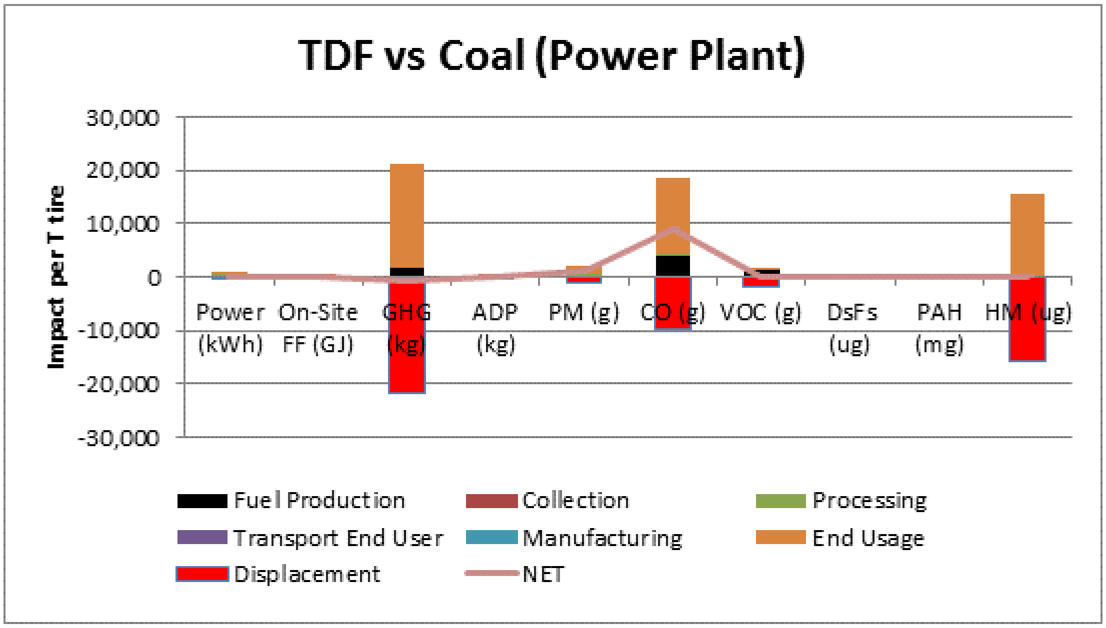
A discussion of the environmental parameters, as well as the management options assessed, and the process for their inclusion, were also presented, to provide an understanding of the process used for these key decisions. However, in retrospect, increased engagement of the Board during these key decisions would have resulted in a more robust process and likely increased endorsement of the results. This would have been consistent with the process recommendation to “initiate the process with effective introductory process and scoping exercise”. The scoping portion of this recommendation could have been more robust with increased involvement of the ARMA Board, rather than focus on the technical committee.

LCA results were presented individually by option, as well as comparatively by parameter, as shown in Figure 9 to Figure 12.



FF – Fossil Fuel, GHG – Greenhouse Gas, ADP – Acid Deposition, PM – Particulate Matter, CO – Carbon Monoxide, VOC – Volatile Organic Compounds, DsFs – Dioxins / Furans, PAH – Polycyclic Aromatic Hydrocarbons, HM – Heavy Metals

Figure 9: Sample LCA Option Results – Rubber Curbs (Pembina, 2010)

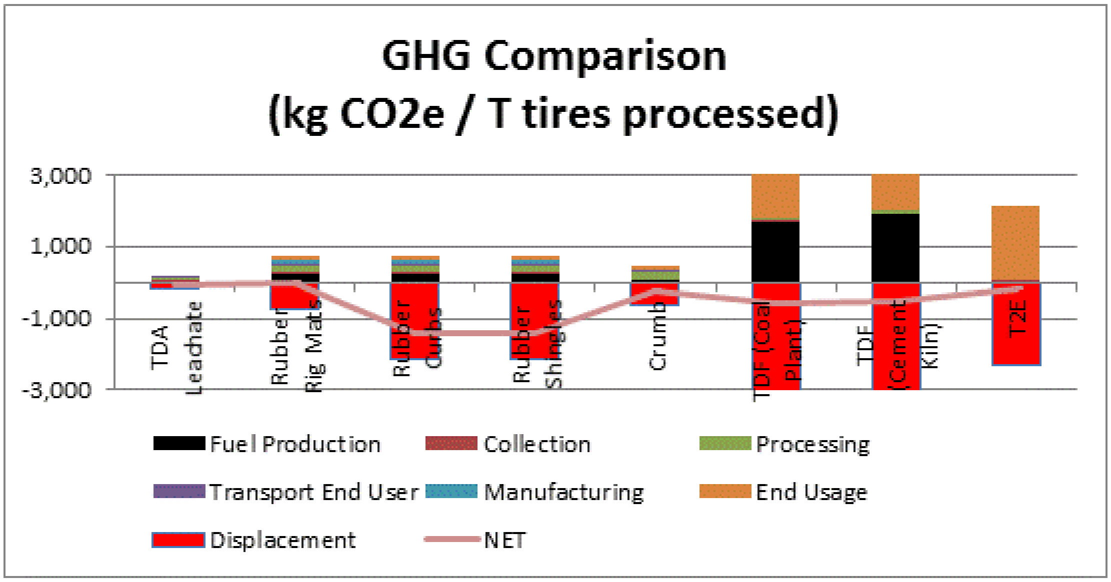


FF – Fossil Fuel, GHG – Greenhouse Gas, ADP – Acid Deposition, PM – Particulate Matter, CO – Carbon Monoxide, VOC – Volatile Organic Compounds, DsFs – Dioxins / Furans, PAH – Polycyclic Aromatic Hydrocarbons, HM – Heavy Metals

Figure 10: Sample LCA Option Results – Tire-Derived Fuel (Pembina, 2010)

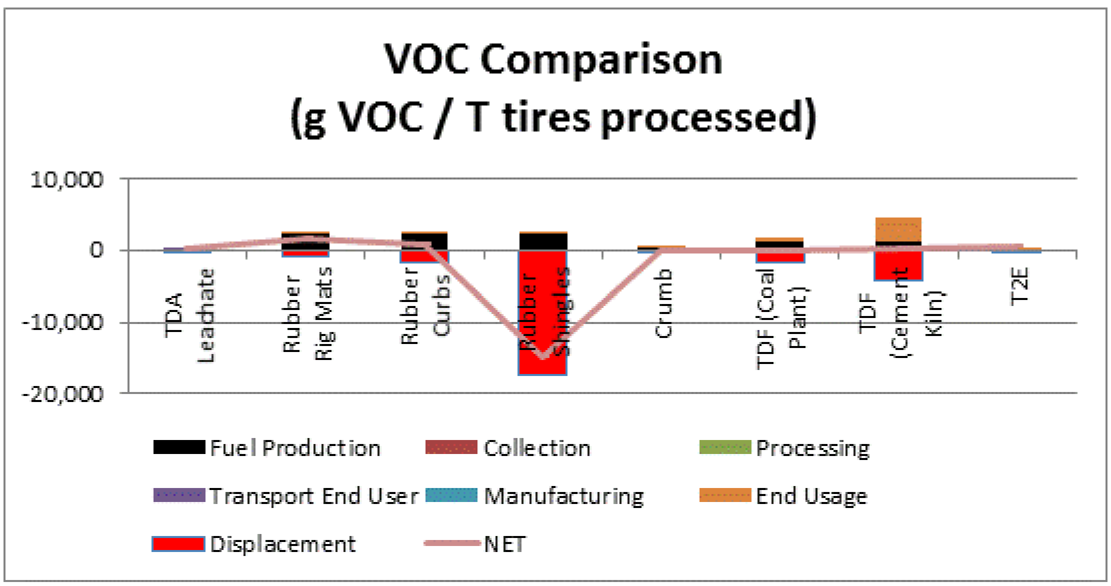
Figure 9 and Figure 10 are sample results of impacts associated with scrap tire recycling options compared to status quo options, indicated by the vertical bars broken into life-cycle stages, with the net impact shown by the horizontal line. For example, the net impact of using scrap tire for the manufacture of rubber curbs considers the displacement of concrete curbs that would have been used instead (represented by the red displacement portion of the impact bars), giving a net set of impacts as shown in Figure 9. In this case, the production of concrete curbs is considered an offset activity, since the inputs and outputs associated with concrete curb production are reduced based on corresponding production of recycled rubber curbs.

Similarly, Figure 10 shows the net impacts of tire-derived fuel, using coal as the displaced fuel.



FF – Fossil Fuel, GHG – Greenhouse Gas, ADP – Acid Deposition, PM – Particulate Matter, CO – Carbon Monoxide, VOC – Volatile Organic Compounds, DsFs – Dioxins / Furans, PAH – Polycyclic Aromatic Hydrocarbons, HM – Heavy Metals

Figure 11: Sample LCA Parameter Results – GHG (Pembina, 2010)



FF – Fossil Fuel, GHG – Greenhouse Gas, ADP – Acid Deposition, PM – Particulate Matter, CO – Carbon Monoxide, VOC – Volatile Organic Compounds, DsFs – Dioxins / Furans, PAH – Polycyclic Aromatic Hydrocarbons, HM – Heavy Metals

Figure 12: Sample LCA Parameter Results – VOC (Pembina, 2010)

Figure 11 and Figure 12 show the comparative results for all considered options, presented by environmental impact parameter, again considering all life-cycle stages, including displacement of status quo options. This provided for a visual of the relative impacts of all options by parameter.

Additional results can be found in Appendix D, or can be found in the full Alberta Tire Recycling LCA model, which is available from the Alberta Recycling Management Authority. A review of this model shows that the outputs and presentation of results include a high degree of transparency. This was one of the goals of the project team – to offer full access to the calculations and assumptions imbedded in the model. This is in accordance with the process recommendation to integrate transparency into all elements of the process. However, stakeholders (i.e., Board) should have been more actively involved throughout the entire process to fully meet the overall recommendation.

The technical results from the LCA were also presented in a summary format in Table 7:

Table 7: Scrap Tire LCA Impacts (per tonne of tires processed)

Management option	Power input (kWh)	On-site fossil fuel input (MJ)	GHG (kg CO2e)	ADP (g SO2e)	PM (g)	CO (g)	VOC (g)	Dioxins / Furans (ug)	PAHs (ug)	Heavy metals (ug)
TDA Leachate	39	-2473	-69	1106	201	529	132	0.001	-258	230
Crumb	106	-22338	-221	894	998	-2580	-124	-0.008	-230	71329
Manufactured products:										
Rig mats	103	19096	-11	-237	74	-6984	1554	0.014	-122	201967
Curbs	185	18115	-1438	-3720	-2862	-2533	682	-179.2	-1263	44828
Shingles	445	1927	-1408	-24978	-2418	2037	-14903	-0.024	193	-1403469
Waste-to-energy:										
Coal plant	144	-2089	-606	82062	1188	8890	-86	13.75	-1841	136534
Cement kiln	-220	-512	-499	81356	14187	8349	246	4932	-3147	-494209
Incineration	-30	-26086	-194	-5739	-77	1333	349	301	-1840	250461

Recognizing the data intensity of the information presented individually, as summarized in Table 7, even though the information was presented in person with extensive explanation and discussion, it was anticipated that the sheer volume of impact categories and numbers would overwhelm many of the stakeholders receiving the presentation. This in fact did occur, with the general response being one of "What does this all mean?"

Therefore, an attempt was made to summarize the information in a composite form that would assist in ranking and prioritizing options. This process involved rating the results for each impact category by good (green), neutral (yellow) or poor (red), as shown in Table 7. This provided a visual indication of the relative performance of the different management options within the chosen environmental indicators, without attempting to combine parameters through a weighting process.

In an attempt to further summarize the relative performance of various options, these rankings were then combined by subtracting the number of poor ratings from the number of good ratings to provide an overall ranking, as shown in Table 8. To emphasize the results, the options with the highest overall rankings were highlighted in green, while the lowest ranking options were highlighted in red.

Table 8: LCA Option Rankings

Management option	# of good ratings	# of neutral ratings	# of poor ratings	Overall Ranking
TDA Leachate		8		0
Crumb	1	6	1	0
Manufactured products:				0
Rig mats	1	5	2	-1
Curbs	6	0	2	4
Shingles	5	3	0	5
Waste-to-energy:				0
Coal plant	2	3	3	-1
Cement kiln	3	0	5	-2
Incineration	2	3	3	-1

It was hoped that this summary would provide an overall perspective of the relative performance of the different management options assessed in the LCA, reducing the requirement to interpret the data-intensive outputs. These representations address the process recommendation to translate LCA concepts and methodologies into language decision-makers understand. However, without direct engagement in the process of defining how outcomes would be presented, these attempts may have appeared to lack legitimacy and transparency, despite efforts to provide this detail through previously outlined results presented in multiple formats, as well as sharing of the full LCA model with Board members and offers to discuss content details.

This was demonstrated through questions and feedback from Board members that included skepticism of the results (primarily related to results that did not conform with preconceived assumptions), attachment to existing policies and practices (and associated desire to have results supporting them), and desire to have the process deliver a definitive answer (rather than just additional information). These conclusions regarding Board member responses were made based on group discussions with the Board as a whole, as well as feedback from individual Board members who participated in follow-up interviews.

This response suggested a lack of buy-in and acceptance of the results, in spite of these attempts to present and interpret the outcomes, as well as the obvious technical rigour associated with the LCA. This reality is consistent with the literature research in the conclusion that embracing LCA results is more about overall process than it is about technical validity.

Applying the proposed process recommendations to the project could have led to greater acceptance and incorporation of the results, in a number of ways. As previously mentioned, more active involvement of the ARMA Board of Directors from the outset would have resulted in more engagement on the part of these key stakeholders, improving their understanding of the LCA process, including technical decisions and limitations, very likely increasing buy-in of the project outcomes. More active updates and involvement of the Board throughout the project, particularly during key decision points such as scoping, would have served to keep them engaged throughout the process, rather than simply assigning oversight to administrative staff. Regular presentations from project managers at Board meetings, building on the initial LCA information session, would have assisted in keeping the Board engaged in the process.

Efforts to present results in a format understandable to the Board would also undoubtedly have been much more successful if the Board had been more intimately involved through the derivation of the results, as well as how results would be disseminated. Skepticism of the results was a reflection of a general lack of understanding of the process, in addition to a reaction to the results not validating preconceived assumptions, and potentially could have been mitigated through increased project engagement and buy-in. Attempts at transparency are contingent on a clear understanding of the issues being addressed, and the process incorporated throughout the LCA.

10.2 CalRecycle Used Oil LCA Project Example

As part of California Senate Bill (SB) 546 of 2009, introduced to make changes to the California Oil Recycling Enhancement Act (CalRecycle, 2014), California's Department of Resources Recycling and Recovery (CalRecycle) was directed to undertake the following identified steps related to an LCA for used oil management:

1. Contract with a third-party consultant with recognized expertise in life cycle assessments to coordinate a comprehensive life cycle analysis of the used lubricating and industrial oil management process, from generation through collection, transportation, and re-use alternatives;

2. Solicit input from representatives of all used oil stakeholders in defining the scope and design of the life cycle analysis, in conducting the life cycle analysis, and in issuing a draft report for public review and comment;

3. Evaluate the impacts of certain components of SB 546; and

4. Submit a report to the Legislature describing the findings of the life cycle analysis and “provide any recommendations for statutory changes that may be necessary to promote increased collection and responsible management of used oil (CalRecycle, 2013 and Leginfo, 2014).

The second directive prescribed a level of stakeholder involvement consistent with the process recommendations outlined previously. The stakeholder involvement process involved in this project made it possible to assess some of the benefits and challenges associated with this approach.

The inclusion of the LCA in the legislation was undertaken largely in response to industry opposition to some of the proposed measures in SB546, and therefore broad stakeholder involvement was integrated into the process from the outset (Carlson, personal communication, July 15, 2014). However, who stakeholders are and their level of involvement was not specifically defined in the directive. Therefore, these specifics needed to be determined by CalRecycle.

To meet this requirement, CalRecycle issued an open invitation to anyone identified as a potential stakeholder. The response to this call was strong, with close to 50 industry members initially signing up. Of this group, only one Environmental Non-Governmental Organization (ENGO) joined the project, Californians Against Waste, despite attempts on the part of CalRecycle to bring in other non-industry stakeholders (Carlson, personal communication, July 15, 2014). This imbalance in representation is certainly a concern in terms of stakeholder representation.

It may be difficult to obtain participation from non-profit organizations whose resources are already stretched. If funding is available, offering to offset participation costs for public non-profits may mitigate this barrier. In this case, CalRecycle was able to represent the public policy side, which helped to balance the heavy focus on industry stakeholders. However, increased outside non-profit representation would have been preferred to provide more complete and robust input.

The large number of stakeholders engaged in the process presented some management challenges. This was mitigated by contracting an expert facilitator (California State University at Sacramento) to manage the process and compile information (CalRecycle, 2013). However, it was recognized that if numbers had been smaller, the process would have been much simpler to manage (Carlson, personal communication, July 15, 2014). This points out a key consideration in increasing stakeholder engagement. In order to incorporate a broad range of stakeholders into the process, effective facilitation is key to encouraging engagement, as well as capturing the resulting input.

The difficulties associated with the large number of stakeholders was exacerbated by the process being technical in nature, requiring significant time investment on the part of participants, who were asked to participate in quarterly in-person meetings, additional conference calls and subcommittee work, as well as requests for review and feedback. This resulted in attrition in stakeholders, with less than 40 still involved at the end of the project (Carlson, personal communication, July 15, 2014). This speaks to the challenges associated with keeping stakeholders engaged in a complex and lengthy process. Final stakeholders included primary petroleum refiners (American Petroleum Institute, Western States Petroleum Association, Chevron, Exxon, BP, Lubrizol, etc), used oil re-refiners (Evergreen, Bango Oil, Heritage Crystal-Clean, Safety-Kleen, etc), Demenno Kerdoon / World Oil (used oil distiller), the National Oil Recycler's Association (NORA), Californians Against Waste, Independent Haulers, and others (CalRecycle, 2013a).

Despite the challenges associated with the extensive stakeholder involvement process incorporated by CalRecycle, the manager interviewed indicated he would do the same again. By opening it to a wide range of stakeholders, everyone felt they had a chance to participate and their voice was heard. As with most processes involving a wide range of stakeholders, there were still some dissenters who had issues with choices made in the LCA, but this situation was mitigated through efforts to be transparent in terms of outlining decisions that had to be made and clearly justifying resulting decisions (Carlson, personal communication, July 15, 2014).

To kick off the LCA process, and bring the stakeholders up to speed, an LCA 101 session was held with an LCA expert to ensure all participants understood the basics of LCA. The LCA contractor also outlined the decisions that would have to be required as part of the process. This type of introductory workshop provides a good foundation for stakeholders to gain a basic understanding of the process, and can also be used as a platform to engage participants. Following this initial orientation session, the group debated fundamental decisions such as goal, scope, boundaries and functional units for a number of months. This initial introductory process is consistent with the overall process recommendations previously outlined.

This intensive process is indicative of the approach taken throughout the LCA, resulting in the process requiring over 2 ½ years to complete, and costing approximately

$2.5 million, exclusive of CalRecycle staff time (including $1.5 million for an economic analysis). This contrasts to a normal LCA cost of $150,000 to $300,000 (Carlson, personal communication, July 15, 2014). The long timeframe required for the policy implications of this type of public LCA is also reflected in the fact that the final report to the Legislature was still undergoing the administrative review process as of late 2014, with no specified release date or information on final policy recommendations (Carlson, personal communication, November 20, 2014), and this remains the case at the end of 2015. This validates one of the previously mentioned barriers to successful integration of LCA into public policy development, confirming the significant resource requirements associated with these processes.

This large expenditure reflects the higher standard of accountability associated with a public policy LCA. CalRecycle indicated they felt that they could not afford to have the data challenged (and the potential associated loss of credibility), especially faced with a highly motivated group of stakeholders who were well funded, and with research abilities of their own. This meant there was little tolerance for doubt, and as a result, the LCA incorporated more depth and transparency, and a more intensive third-party review was undertaken. (Carlson, personal communication, July 15, 2014)

To provide a critical review of the LCA, CalRecycle assembled a review panel of experts in the life cycle assessment field with particular expertise in the life cycle analysis of energy systems, waste management, and used oil management (CalRecycle, 2013). This approach of assembling a group of experts to provide overall project review is similar to that taken for the ARMA tire LCA in Alberta, with the fundamental difference that the reviewers were brought in at the end of the LCA to provide a critical review, rather than providing oversight throughout the project. However, CalRecycle tried to create a balanced approach by involving the critical review panel chair throughout the process, while leaving the other panel members out of the process to ensure more independence and remove the possibility of bias. At the same time, some review panel members were invited to listen in on stakeholder meetings so they could gain understanding of the issues being discussed and the rationale behind decisions (Carlson, personal communication, November 20, 2014).

The aim of the Critical Review was to conclude whether:

- The methods used to carry out the study are consistent with ISO standards 14040 and 14044
- The methods used to carry out the study are scientifically and technically valid
- The data are appropriate and reasonable in relation to the goal of the study
- The interpretations reflect the limitations identified and the goal of the study
- The study is transparent and consistent (CalRecycle, 2013)

One of the conclusions of the reviewers was that more time should be spent on the conclusions and interpretation of results for a non-technical audience, to provide more information for policy makers (CalRecycle, 2013). This reinforces the importance of being able to present the results of an LCA in a format useable by policy makers. In this case, the LCA itself intentionally left out specific conclusions, as CalRecycle took on the task of delivering a separate report to the Legislature, potentially with policy recommendations. Therefore, the scope of the LCA was to provide technical results only and for CalRecycle to present preliminary findings to stakeholders prior to the public release of the report to the Legislature (Carlson, personal communication, July 15, 2014). However, this should probably have been made more clear in the LCA itself, so readers were not looking for policy recommendations in the technical report.

CalRecycle and the stakeholders involved in the LCA process also identified a need for a comprehensive economic assessment to inform the life cycle analysis and develop policy recommendations to the Legislature (CalRecycle, 2013b). This parallel research into economic impacts at the same time as environmental impacts shows the effect that stakeholders can have in the identification of factors that are important in policy development.

One of the additional developments of the CalRecycle LCA process was the development of a web application that would allow public access to the LCA model and also allow CalRecycle to easily update the model as required (Kuczenski, 2015). This web application underwent peer review testing for public release in the Fall of 2015 (Carlson, personal communication. May 22, 2015). The model was developed with extensive feedback and testing from interested stakeholders. This combined with the public access of the final model shows the commitment CalRecycle has to engagement and transparency within this process.

10.3 Key Case Study Lessons

Key lessons that were learned in the case studies, as reviewed in the case study narrative, were summarized as relevant to the thesis and incorporated into the summary of barriers and development of the process framework recommendations, as follows:

- Primary stakeholders should be active participants throughout all stages of the process. Lack of full engagement of key decision-makers can result in a lack of support for project outcomes.
- Initiating the process with an LCA 101 session that provides background and process information for stakeholders is an effective way to involve decision-makers early and provide a basic understanding of the process.
- Stakeholders should be involved in initial decisions such as goal and scope definition, and subsequently genuine involved in all major stages of the process, particularly any key decisions.
- A project technical team can be an effective approach to provide an ongoing peer review process throughout the project and deal with technical process questions as they arise. However, the technical aspect of this approach must not overshadow other process aspects, but rather fall within the broader holistic multi-stakeholder process.
- Technical rigour and transparency will not lead to stakeholder endorsement without effective engagement.
- Non-profit stakeholders are important to involve in the process, but may be challenged to participate due to issues like lack of time and resources.
- Expert facilitation can mitigate challenges associated with large numbers of stakeholders.
- Projects with a long and complex process may experience attrition in stakeholder involvement.
- Encouraging full stakeholder involvement can produce positive political feedback.

- LCAs conducted in the public realm can require significant time and resources as a result of the associated high level of accountability.
- LCA results need to be presented in a transparent format useable by decision-makers, and directly linked to stated goals of the LCA.

10.4 Case Studies Link to Proposed Public Policy Development Framework

As the case studies were key to informing the development of the proposed framework recommendations, it is valuable to review each proposed framework element from the perspective of the experience gained from the two case studies, as follows:

1) Involve decision-makers and other stakeholders actively, wholly and genuinely throughout the LCA process.

This key recommendation was embraced within both case studies, however, was more effectively met in the CalRecycle case study, with the noted exception that there was limited engagement of ENGOs, although this was not through any intentional exclusion, but rather likely a reality of the limited resources of ENGOs to be involved in the many competing issues they face.

Despite the intent of the Alberta Tire Recycling case study to meet this recommendation, enough focus was not placed on engagement of decision-makers, instead focusing on technical aspects, which resulted in the process falling short of this goal. In retrospect, more attention should been placed on insisting that Board members were more involved throughout all stages of the process, rather than delegating involvement to staff members and outside experts.

2) Initiate the LCA process with effective introductory session and goal definition/ scoping exercise.

Both case studies incorporated an LCA 101 session with stakeholders, although the CalRecycle case study more effectively carried the process forward into the goal and scoping stages, which likely solidified the successful ongoing engagement of stakeholders throughout the project.

The Alberta Tire Recycling LCA utilized an LCA introductory session for Board members, but did not further engage this broad group in goal and scope exercises. The Board instead chose to delegate this next stage to Management and Technical Committees.

3) Translate values and limitations of LCA concepts and methodologies into language decision-makers understand.

This recommendation was most directly attempted in the Alberta Tire Recycling case study, by presenting LCA results in multiple formats, including graphs and charts, by individual indicators as well as summary tables. This exercise demonstrated the conclusion that it is important for stakeholders to be involved in decisions regarding presentation of results, and that they are more likely to embrace results if they are directly involved in this process.

The CalRecycle case study inherently incorporated the recommendation within the stakeholder process, as stakeholders were intimately involved throughout the LCA. However, it remains to be seen how effectively results are communicated when the report is publicly released to the Legislature, as peer reviewers suggested more time be spent on presentation of results for a non-technical audience, to provide more information for policy makers.

4) Provide case studies of successful applications of LCA in public policy to give confidence to its use within the public policy arena.

This recommendation applies more to the application of the case study examples, rather than within the case studies themselves. The CalRecyle case study in particular appears to offer an opportunity to demonstrate how LCA can be incorporated into the public policy development process. However, this will be dependent upon the ultimate application of the results by the Legislature.

5) Integrate transparency into all elements of the process, including assumptions and uncertainties, and actively involve stakeholders in all discussions regarding these factors.

Both case studies attempted to achieve a high level of transparency in their reporting, as appropriate for public LCAs. Specifically, the Alberta Tire Recycling LCA model and report includes extensive information on assumptions, sources of data, and limitations related to uncertainty. However, the development of these outputs was largely undertaken by the technical committee, which limited the involvement of other stakeholders in these decisions.

The CalRecycle case study had a high level of transparency for stakeholders directly involved in the process. It also attempted to incorporate transparency into the resulting public online LCA model, including undertaking an expanded stakeholder review process of this model that included transparency elements. The degree to which transparency will be integrated into the final report to the Legislature remains to be seen.

6) Ensure the project team represents the full range of stakeholders affected by the policy, and vested interests are balanced.

Full involvement of stakeholders was embraced by both case study examples. This was inherent in the Alberta Tire Recycling case study through the involvement of the ARMA Board, that includes all tire recycling stakeholders within its governance structure. In the CalRecycle case study, soliciting input from all used oil stakeholders was mandated in the Senate Bill, and pursued through an open invitation to all identified stakeholders. This invitation received a strong response from industry stakeholders, but only one non-profit non-governmental organization (NGO). Although CalRecycle felt they could represent the public interest, involvement of additional NGOs would have provided increased stakeholder balance. To this end, increased efforts to engage a broader range of stakeholders, and address barriers to their involvement, would have been a positive enhancement to the process.

11 ISO Standards – Applications and Implications to Public Policy: A Critical Review

As the world-recognized standard for LCA, ISO standards 14040 and 14044 represent the model for conducting life-cycle projects. Therefore, it is useful to look at what the standards have to say about LCA elements that influence its application to public policy. This is particularly relevant in light of ISO's assertion that they "wish to make their portfolio of International Standards more visible to public policy makers and ensure that their standards address the needs and concerns of public policy makers", further suggesting that ISO standards can provide valuable support in the implementation of public policy (ISO/ IEC, 2015, p.3).

ISO further links good policy-making and good standardization practice through common characteristics, and asserts that it is important that stakeholders are involved in standards development efforts related to public policy. ISO standards are developed in a multi-stakeholder environment that provides for a wide range of technical views, including those relating to social and economic interests (ISO/ IEC, 2015). This suggests a holistic process that could potentially apply to the application of the standard itself.

ISO 14040 asserts that LCA can assist in "informing decision-makers in industry, government or non-government organizations (e.g., for the purpose of strategic planning, priority setting, product or process design or redesign)" (ISO 2006, p.v). This would apply to the public policy development process, suggesting the role LCA can play in providing information valuable to decision-makers who are part of the process. However, ISO does not further describe the informing process itself within the standard, instead choosing to focus on the technical aspects of LCA.

ISO further suggests that generally "the information developed in an LCA or LCI study can be used as part of a much more comprehensive decision process" (ISO, 2006, p.vi). This alludes to the fact that LCA is only one source of information being considered by decision-makers within the process.

ISO further asserts that LCA is "only one of several environmental management techniques (e.g., risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment) and might not be the most appropriate technique to use in all situations" (ISO, 2006, p.vi). This suggests that the value of the information an LCA will provide needs to be assessed for each situation, and that other techniques should be considered within the overall decision-making process.

ISO states within its standard: “The intended application of LCA or LCI results is considered during the goal and scope definition, but the application itself is outside the scope of this International Standard” (ISO, 2006, p.1). This is one hint given suggesting that the standard focuses on the delivery of the LCA itself, rather than the overall process within which the information will be applied. It also offers the potential that LCA application could be addressed within the standard to make it more robust, and ultimately, more broadly encourage its use.

One of the principles outlined in ISO 14040 states “Due to the inherent complexity in LCA, transparency is an important guiding principle in executing LCAs, in order to ensure a proper interpretation of the results” (ISO, 2006, p.7). This principle is intended to encourage good interpretation, however it also speaks to one of the key factors to successfully incorporating LCA into public policy. Transparency builds confidence in the process by clearly presenting assumptions and uncertainties for decision-makers to review, and is one of the primary factors recommended to be incorporated within the overall process to encourage increased adoption in the public policy arena.

11.1 Rational Approach

Another LCA Principle from ISO 14040 sums up the rational approach of this standard by outlining the Priority of a Scientific Approach:

> Decisions within an LCA are preferably based on natural science. If this is not possible, other scientific approaches (e.g., from social and economic sciences) may be used or international conventions may be referred to. If neither a scientific basis exists nor a justification based on other scientific approaches or international conventions is possible, then, as appropriate, decisions may be based on value choices. (ISO, 2006, p.7)

ISO 14044 reinforces this by stating that “value-choices and assumptions made during the selection of impact categories, category indicators and characterization models should be minimized” (ISO, 2006a, p.19).

This clearly shows the focus on technical analysis, with value choices and subjective input only given secondary consideration. This unfortunately undermines any potential role that non-technical elements can play in the process. This can also limit the ability to incorporate LCA effectively in the public policy process, since it can impact the input and engagement of certain stakeholders.

As discussed in previous sections, public policy is grounded in subjective factors, with values and assumptions playing key roles (Fischer, 2003). If the rational paradigm is not valid for public environmental policies, and the discourse paradigm provides a better alternate framework (Bras-Klapwijk, 1999), embracing non-rational elements of the LCA process within the ISO standard would encourage its use in public policy applications. This could be accomplished without taking away from the valuable technical rigour that is provided by the ISO standard by proposing a broader process framework that embraces non-technical elements.

11.2 Qualitative Elements

The Life-Cycle Impact Assessment (LCIA) portion of the ISO 14040 standard includes references to values and subjectivity, as follows:

> The impact assessment may include the iterative process of reviewing the goal and scope of the LCA study to determine if the objectives of the study have been met, or to modify the goal and scope if the assessment indicates that they cannot be achieved. (ISO, 2006, p.14)

This reaffirms the subjective element of goal and scope definition, which inherently requires value choices to be made, ideally by a range of affected stakeholders. The standard further indicates that

> Issues such as choice, modelling and evaluation of impact categories can introduce subjectivity into the LCIA phase. Therefore, transparency is critical to the impact assessment to ensure that assumptions are clearly described and reported. (ISO, 2006, p.14)

Again, the standard introduces transparency as a way to deal with issues resulting from value choices within the process. However, at the same time, it does not clearly outline or recommend a process that would address and embrace the subjective elements, and incorporate them into the overall approach.

Separation of the LCIA phase into different elements allows for "the use of values and subjectivity (hereafter referred to as value-choices), within each element, to be made transparent for critical review and reporting" (ISO, 2006, p.14). This suggestion within the standard reiterates the need for transparency when incorporating "value-choices" within an LCA.

ISO 14044 goes further into optional LCIA elements and their subjectivity, as follows:

> Ranking is based on value-choices. Different individuals, organizations and societies may have different preferences; therefore it is possible that different parties will reach different ranking results based on the same indicator results or normalized indicator results. (ISO, 2006a, p.21)
>
> Weighting steps are based on value-choices and are not scientifically based. Different individuals, organizations and societies may have different preferences; therefore it is possible that different parties will reach different weighting results based on the same indicator results or normalized indicator results. In an LCA it may be desirable to use several different weighting factors and weighting methods, and to conduct sensitivity analysis to assess the consequences on the LCIA results of different value-choices and weighting methods. (ISO, 2006a, p.22)

These are clear efforts on the part of ISO to indicate that LCIA inherently involves qualitative interpretive elements. This is summed up in the following statement from ISO 14044:

> An LCIA shall not provide the sole basis of comparative assertion intended to be disclosed to the public of overall environmental superiority or equivalence, as additional information will be necessary to overcome some of the inherent limitations in the LCIA. Value-choices, exclusion of spatial and temporal, threshold and dose-response information, relative approach, and the variation in precision among impact categories are examples of such limitations. (ISO, 2006a, p.23)

An attempt to limit the value-based assumptions made within LCIA is incorporated into the following procedural exclusion:

> “Weighting … shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public” (ISO, 2006a, p.23).

The fact that this applies only to studies that will be publicly released suggest that this is intended to encourage the public to consider a more robust set of indicators, and encourage more transparency in data presentation, rather than enabling the oversimplification of the range of impacts included in an LCA that could result in unwarranted assumptions and conclusions.

11.3 Life Cycle Interpretation

The ISO 14040 standard states that Life Cycle Interpretation “may take the form of conclusions and recommendations to decision-makers, consistent with the goal and scope of the study” (ISO, 2006, p.16). This recognizes the application of LCA within a decision-making context, which presumably could include public policy applications.

In identifying significant issues, ISO 14044 includes consideration of:

- “the value-choices used in the study as found in the goal and scope definition
- the role and responsibilities of the different interested parties as found in the goal and scope definition … and also the results from a concurrent critical review process, if conducted” (ISO, 2006a, p.25).

This requires consideration of non-technical elements of the LCA, as well as the potential roles to be played by interested parties, who may or may not have been directly involved in the LCA.

Part of the life cycle interpretation defined in ISO 14044 is to "draw conclusions, identify limitations and make recommendations for the intended audience of the LCA" *(*ISO, 2006a, p.27). One suggested element of this process is to:

> "draw preliminary conclusions and check that these are consistent with the requirements of the goal and scope of the study, including, in particular, data quality requirements, predefined assumptions and values, methodological and study limitations, and application-oriented requirements" (ISO, 2006a, p.27).

This requires the identification and outlining of value-based elements, in addition to technical components.

ISO also goes on to state "Whenever appropriate to the goal and scope of the study, specific recommendations to decision-makers should be explained" (ISO, 2006a, p.27). This clearly directs recommendations to decision-makers, who could encompass policy-makers.

11.4 Reporting

In referencing reporting of the results of an LCA, ISO 14040 instructs to "include reference and description of value choices used in the LCIA phase of the study in relation to characterization models, normalization, weighting, etc" (ISO, 2006, p.16). Further, in reference to reporting the interpretation phase, ISO 14044 "requires full transparency in terms of value choices, rationales and expert judgments" (ISO, 2006a, p.30). As previously, this recognizes the inherent use of value choices in this phase, and encourages transparency of their application.

The reporting requirements are more specific for third-party reports, with ISO 14044 specifying in this case:

> "descriptions of or reference to all value-choices used in relation to impact categories, characterization models, characterization factors, normalization, grouping, weighting and, elsewhere in the LCIA, a justification for their use and their influence on the results, conclusions and recommendations" (ISO, 2006a, p.29).

Similarly, for life-cycle interpretation:

> "full transparency in terms of value-choices, rationales and expert judgements" (ISO, 2006a, p.30).

In the case of comparative assertions intended to be disclosed to the public, if grouping is included in the LCA, reporting requirements become even more specific, including the following:

a) "the procedures and results used for grouping;

b) a statement that conclusions and recommendations derived from grouping are based on value-choices;

c) a justification of the criteria used for normalization and grouping (these can be personal, organizational or national value-choices);

d) the statement that "ISO 14044 does not specify any specific methodology or support the underlying value choices used to group the impact categories";

e) the statement that "The value-choices and judgements within the grouping procedures are the sole responsibilities of the commissioner of the study (e.g., government, community, organization, etc.)" (ISO, 2006a, p.31).

These reporting requirements show that the ISO standards deal with value choices primarily through full disclosure and transparency, the standard for which increases with the intent to publicly share the results. As with previous references, this shows the recognition that value choices are part of an LCA. However, while outlining recommendations and requirements around disclosing value elements, the standards are largely silent around effective approaches to incorporating normative elements within the LCA process.

11.4.1 Critical Review

The incorporation of a critical review within an LCA brings requirements within the ISO standards that embrace some of the key elements of incorporating LCA within a public policy process. ISO 14040 states that "a critical review may facilitate understanding and enhance the credibility of LCA, for example by involving interested parties" (ISO, 2006, p.17). This mention of interested parties offers the suggestion of an inclusionary process that may incorporate the multiple stakeholders that have an interest in public policy.

ISO 14040 goes on to explain that a critical review is required in cases where LCA results are used to support comparative assertions. This requirement is based on the premise that this LCA application is likely to affect “interested parties that are external to the LCA” (ISO, 2006, p.17). ISO 14044 further expands on this by suggesting that a critical review can “decrease the likelihood of misunderstandings or negative effects on external interested parties” (ISO, 2006a, p.31). However, as previously outlined, ISO notes the potential benefits of a critical review even if it is not required, specifically mentioning the involvement of interested parties that may not be directly involved in the LCA.

ISO further expands on the recommended critical review process, suggesting an independent expert chairing a review panel of at least three members. These panel members are to be selected based on their qualifications related to LCA. However, the standard also indicates: “This panel may also include other interested parties affected by the conclusions drawn from the LCA, such as government agencies, non-governmental groups, competitors and affected industries” (ISO, 2006, p.17). This confirms the acceptance within the critical review of a multi-stakeholder process that incorporates external stakeholders for reasons other than technical expertise.

If this concept were extended to the broad LCA process, by involving stakeholders at key stages of the process, such as Goal and Scope Definition, the incorporation of LCA into public policy development could be further facilitated.

11.4.2 Conclusions

In its efforts to remain technically focused, ISO does not encourage the incorporation of LCA into the public policy development process, instead potentially unintentionally discouraging it. It is recommended in the next review round that ISO directly addresses process questions around how LCA is used in decision-making processes, and embraces elements such as stakeholder involvement and incorporation of value decisions within the overall process.

12 Summary and Conclusions

LCA has many potential applications within public policy development because of the common desire for policy to reduce environmental impacts. LCA could play an important role through contributions to many stages of policy development, including problem identification, policy implementation, and policy evaluation.

This dissertation develops the thesis that barriers exist to the full and successful integration of LCA into the public policy development process, and that these barriers can be mitigated through effective process design. This thesis was developed through existing research as documented in the literature and personal communication with LCA experts, combined with experience through relevant case studies. The ability to correlate past research with direct case study experience provided a unique and compelling perspective on the topic, leading to new contributions regarding a recommended framework for integrating LCA into the public policy decision-making process.

A review of existing research concluded that LCA offers a valuable tool for assessment of the full environmental impacts of public policy options involving product or process choices, and that facilitating its increased application in the public policy arena could improve the decision-making process, and ultimately lead to better environmental outcomes.

However, LCA methodology has been primarily developed within the rational public policy theory, which requires results to be conclusive and objective. This contrasts with the discourse paradigm that requires an open and inclusive process, with a focus on communication and understanding. It is proposed that this more qualitative paradigm provides a better alternate framework for the development of public policy. This framework would provide for the technical rigour of LCA as provided in the ISO standard within a more holistic process that embraces the qualitative aspects that are key to incorporating LCA within public policy.

Unfortunately, results suggests that the positive impact of LCA on public policy to date is limited. Based on research and case study experience undertaken for this dissertation, a set of barriers to incorporation of LCA results into public policy decisions was compiled and verified using a combination of sources and methods to produce the following barrier list:

- Decision-makers lack the background or technical literacy to interpret and incorporate the results of the LCA
- Technical results are not presented in a way that can be positively utilized by decision-makers
- Decision-makers have a lack of trust of LCA results or the overall process
- LCA results are not seen as neutral
- Clear or consistent results may be lacking as outcomes of the LCA
- Complete and accurate inventory data may be difficult to find
- The LCA process focuses on quantitative results to the exclusion of qualitative factors
- Governments lack a framework for integrating LCA information into the decision-making process
- Government agencies bring specific interests to the process, potentially limiting the scope based on internal focus and knowledge
- Comprehensive public LCAs require considerable resources to complete

Upon review, a number of these barriers suggest that the failure of LCAs to contribute positively to public policy development is due largely to the process within which the LCA is being incorporated, rather than technical limitations of the LCA itself. Based on this assumption regarding the key role that process plays in the identified barriers, public policy development paradigms that provide the foundation for the public policy development process were reviewed within the context of existing research and case study experience to conclude that a shift towards the discourse theory, where a more open and qualitative approach is taken, has the potential to mitigate many of these process-related barriers.

Building on this premise, a review of the barriers to effective incorporation of LCA into public policy was combined with foundational process elements identified in the research and case study experience to provide a set of process recommendations that have the potential to encourage effective inclusion of LCA information in the decision-making process. These recommendations form a process framework that is the primary outcome of the thesis, and represents a unique contribution to the field of LCA within the context of public policy development:

- Involve decision-makers and other stakeholders actively, wholly and genuinely throughout the LCA process.
- Identify stakeholders up front and invite them to participate.
- Bring decision makers into the LCA process early and educate them on how LCAs work, and their potential contribution to the decision-making process.
- Provide for adequate facilitation/ oversight to accommodate the complexity of a multi-stakeholder process and fully engage the range of stakeholders.
- Initiate the LCA process with effective introductory session and scoping exercise.
- Introduce stakeholders to the concept and use of LCA through a primer session such as LCA 101.
- Define goal and scope of project, including conceptual modeling and definition of research questions.
- As part of the scoping exercise, define how LCA results will used in the ultimate decision.
- Translate values and limitations of LCA concepts and methodologies into language decision-makers understand.
- Provide case studies of successful applications of LCA in public policy to give confidence to its use within the public policy arena.
- Integrate transparency into all elements of the process, including assumptions and uncertainties, and actively involve stakeholders in all discussions regarding these factors.
- Ensure the project team represents the full range of stakeholders affected by the policy, and vested interests are balanced.

These recommendations are listed in no particular order of priority, but rather are all considered to be key elements to the success of integrating LCA into public policy decision-making. To ground these recommendations, it is also important that decision-makers commit to the overall process that includes how LCA results will be incorporated in their decision.

Application of these recommendations within cases of public policy decision-making would serve to help further develop an effective public policy development framework that would encourage and facilitate increased integration of LCA. As these principles are applied, it is further recommended that public policy organizations document their incorporation of these elements, and the resulting impact on the integration of LCA into their decision-making process, and publicly share the results so that other organizations can learn from their experience. This is suggested to be an iterative process, where the recommended process evolves through experience and public sharing.

It is also important to recognize that the extent to which LCA is applied will vary based on individual circumstances like scope and resources. However, limitations should not preclude the value that life-cycle considerations may offer. It is important that public policy officials are encouraged to embrace life-cycle thinking to the extent that is possible in their decision-making process, from conceptual to more comprehensive LCAs where warranted.

The role that standards play in the process should also be recognized. ISO standards 14040 and 14044 represent the globally-recognized model for conducting life-cycle projects, and have played a key role in establishing consistent approaches. However, while ISO recognizes the role LCA plays in the decision-making process, it focuses on the technical aspects of LCA, remaining largely silent on process and application issues. It also clearly defines value choices and subjective input as secondary considerations, focusing on quantitative analysis. Expanding the ISO LCA standards to embrace subjective and process elements would make them more robust, and ultimately, more broadly encourage the use of LCA in applications such as public policy.

Through the recognition and embracing of key conclusions and recommendations within this thesis, it is hoped that public policy development will continue to evolve towards increased inclusion of the valuable environmental information offered by Life-Cycle Assessment. Documentation of attempts to implement key aspects of the framework and additional research on the evolution of public policy towards integrating LCA will serve to continue to advance knowledge in this area.

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Appendix A: Key Informant Interview Guiding Questions

The following interview questions were developed to guide interviews with key informants. In keeping with the semi-structured interview format, questions only provided general guidance to the interviews, and informants were welcome to expand beyond the questions, adding perspective as they felt appropriate. This was important to provide latitude to allow for the range of experience and expertise of individuals interviewed.

LCA / Public Policy Experts

1) Are you aware of examples of LCA being successfully integrated into public policy development?
    a. If so, please provide details
        i. Level of government
        ii. Type of policy
        iii. Impetus for considering LCA
    b. Please reflect on how successfully the LCA was able to add value to the process.
2) What barriers do you feel there are that limit the use of LCA in public policy development?
3) Based on your experience, what opportunities exist for enhancing the use of LCA in public policy?
    a. What will it take to expand the application of LCA in public policy development?

Case Study Managers

1) What were the drivers behind using LCA as a decision-support tool?

2) What steps did you use to integrate LCA into your process?

3) How did you identify stakeholders to include?

    a. How many participated?

    b. How was their involvement facilitated?

    c. Did they add value to the process?

    d. Do you feel they bought into the process? Do you have suggestions for methods to increase engagement/ buy-in?

4) What would you change in the process to more effectively utilize LCA results?

5) Do you feel the LCA added value to your process?

Appendix B: Key Informant Contacts

Key informant contacts who provided insight into the research included the following individuals. Contact with these individuals included in-person or telephone interviews, email conversations and group discussions.

- Robert Carlson, Senior Environmental Scientist, Financial Assistance Division, California Department of Resource, Recycling and Recovery (CalRecycle)
- Dr. Mary Ann Curran – Editor-in-Chief, International Journal of Life Cycle Assessment; former manager for EPA Research Program into Life Cycle Assessment
- Graham Haines, Associate, Pembina Institute ((Tire Recycling LCA Consultant)
- Katherine Hart – Environmental Protection Specialist, Pollution Prevention/ Toxics; Project Lead, Design for Environment Program, EPA
- Roger Jackson, Executive Director, Alberta Used Oil Management Association
- Brandon Kuczenski. University of California, Santa Barbara (Used Oil LCA Practitioner)
- Angie Leith – Chief, Materials Conservation and Recycling Branch, Office of Resource Conservation and Recovery, EPA
- Matt McCulloch, Director, Pembina Institute (Tire Recycling LCA Technical Team)
- Ralph Torrie, ICF Consulting
- Keith Weitz, LCA Consultant, RTI International (Tire Recycling LCA Technical Team)
- Doug Wright, CEO, Alberta Recycling Management Authority

Appendix C: Interview Key Messages

The interviews with key informants resulted in a wide range of information regarding LCA and public policy. Key messages that informed this thesis have been compiled in the following summary:

- In 2010, National Research Council recommendations to EPA included adopting LCA as a tool
    - Not seeing much impact to date at EPA of the National Research Council's recommendation to use LCA
- Government budget cuts can limit progress
- Limited technical expertise on LCA
- Very limited application of LCA on public policy – renewable fuels only federal example
- Efforts to more open access to LCA databases – federal digital commons database
- Lack of data is barrier to application of LCA in policy
- May be limited to life cycle thinking
- LCA generally gaining traction
- Research has focused on technical issues – need to move on to education
- Some interests don't support full LCA – limited impacts driven by funding and priorities
- US government key LCA player
- Specific missions of government agencies can be a barrier, as each office interprets "life cycle" to match its mission, interests, and in-house capabilities
- Trend to "simplify" LCA by narrowing the scope can reduce the ability to identify unintended consequences
- Cost of doing a fully transparent LCA is a key barrier
- Transparency is more important and costly in the public domain

- Public policy LCAs:
    - more in-depth
    - more transparent
    - require increased third party review
- Fully involving stakeholders in the technical process requires a lot of time
    - Required investment can lead to attrition
    - Options like minimizing in-person meetings, conference calls and electronic participation options can help encourage participation
- Management of a large number of stakeholders can be difficult
    - Expert facilitation can play a role
    - Minimizing number of stakeholders would facilitate process
- Stakeholder involvement is worth the extra effort
    - Even when dissent remains, stakeholders at least feel their voice was heard
- LCA 101 presentation provides good foundation to start
- ENGOs may be inhibited from participating by time and $$

Appendix D: Alberta Scrap Tire LCA Model Results

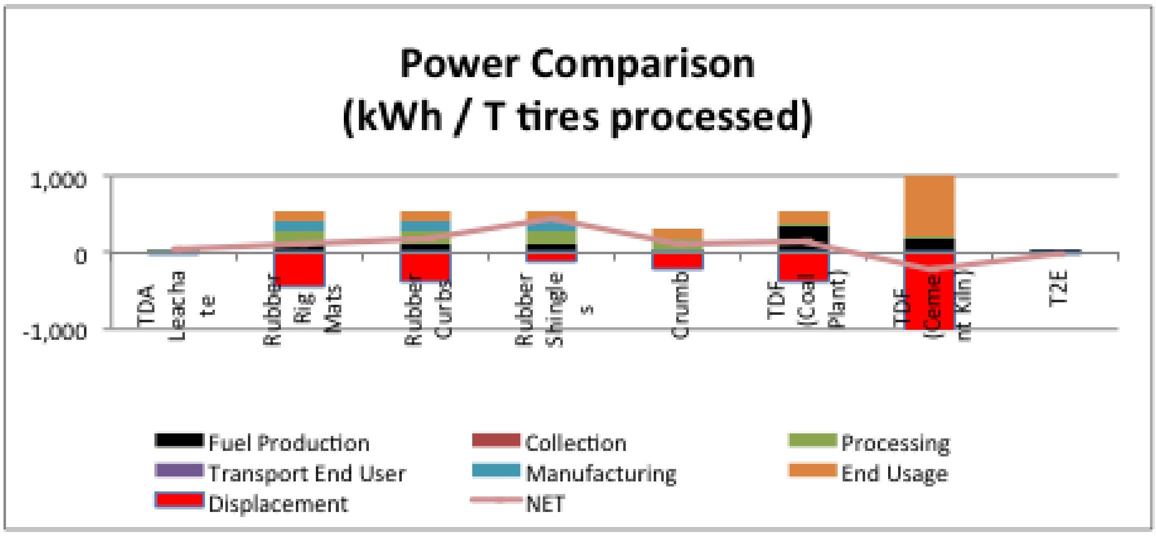

Figure D-1: Power Consumption by End Use (Pembina, 2010)

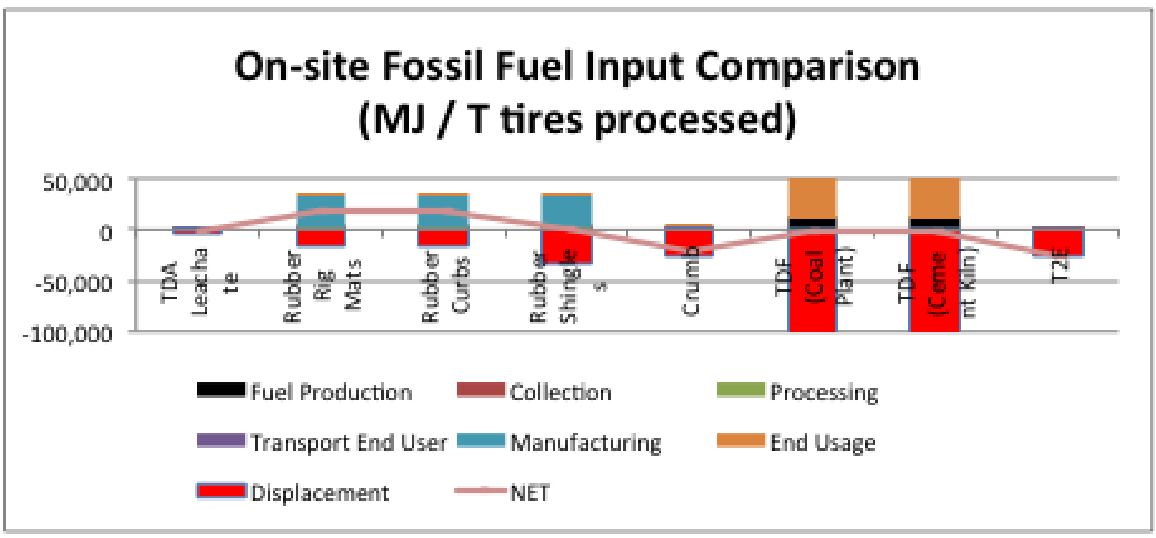

Figure D-2: Fossil Fuel Input by End Use (Pembina, 2010)

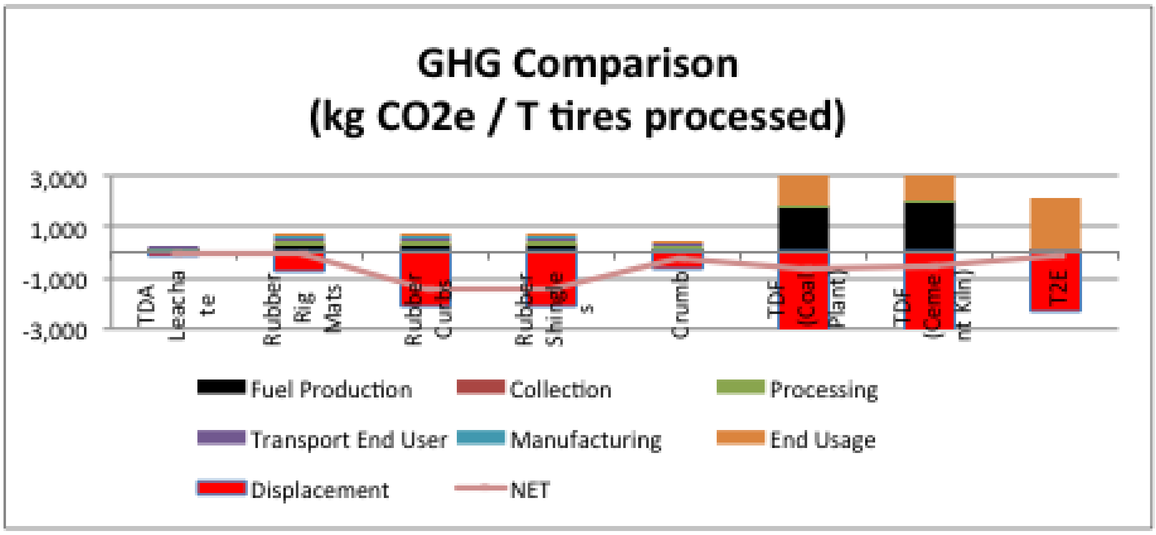

Figure D-3: GHG Impact by End Use (Pembina, 2010)

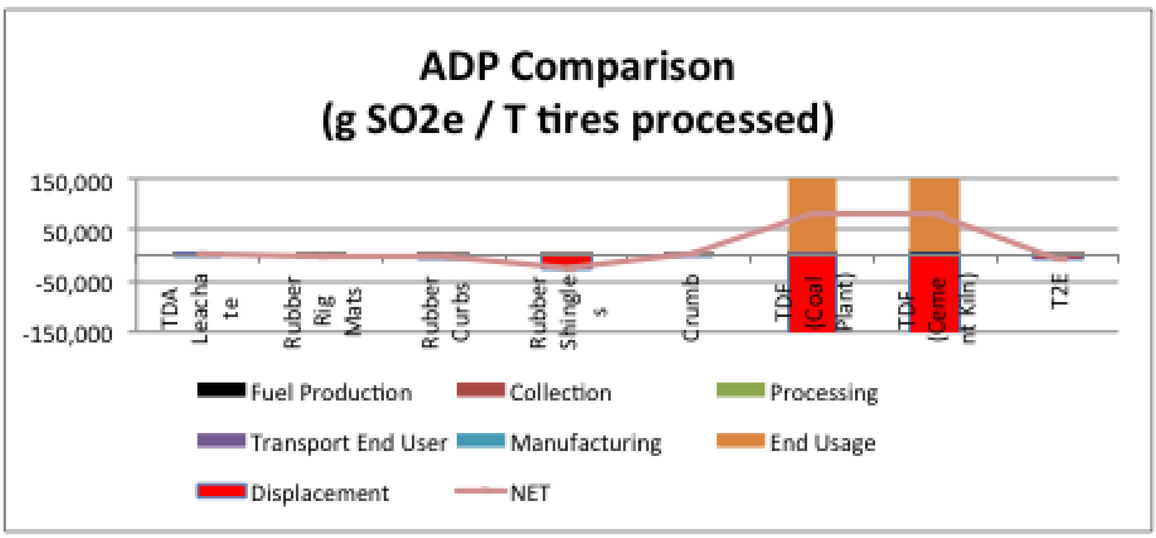

Figure D-4: Abiotic Depletion Potential by End Use (Pembina, 2010)

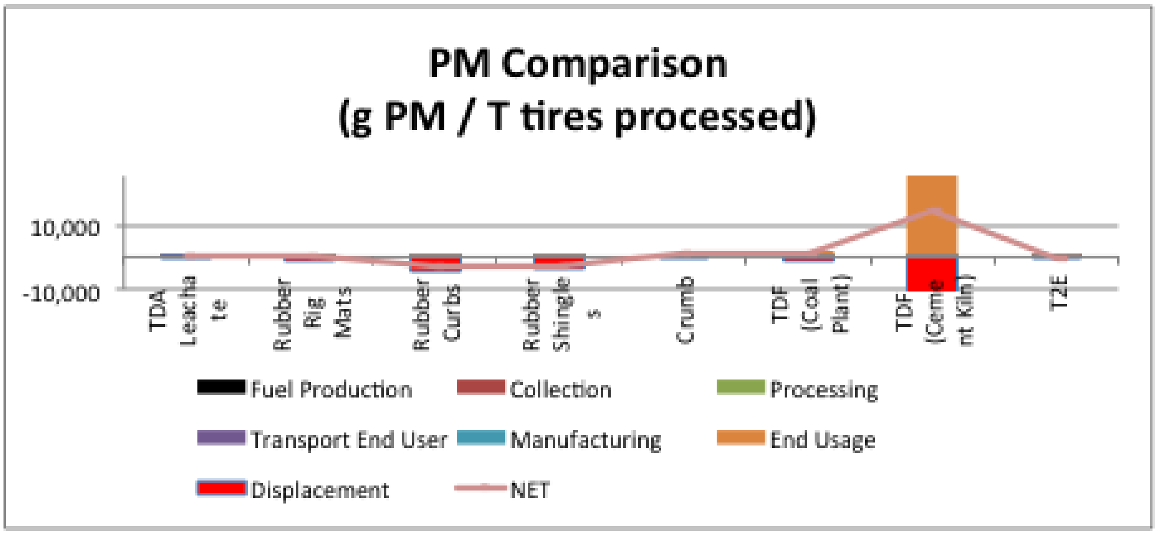

Figure D-5: Particulate Matter Emissions by End Use (Pembina, 2010)

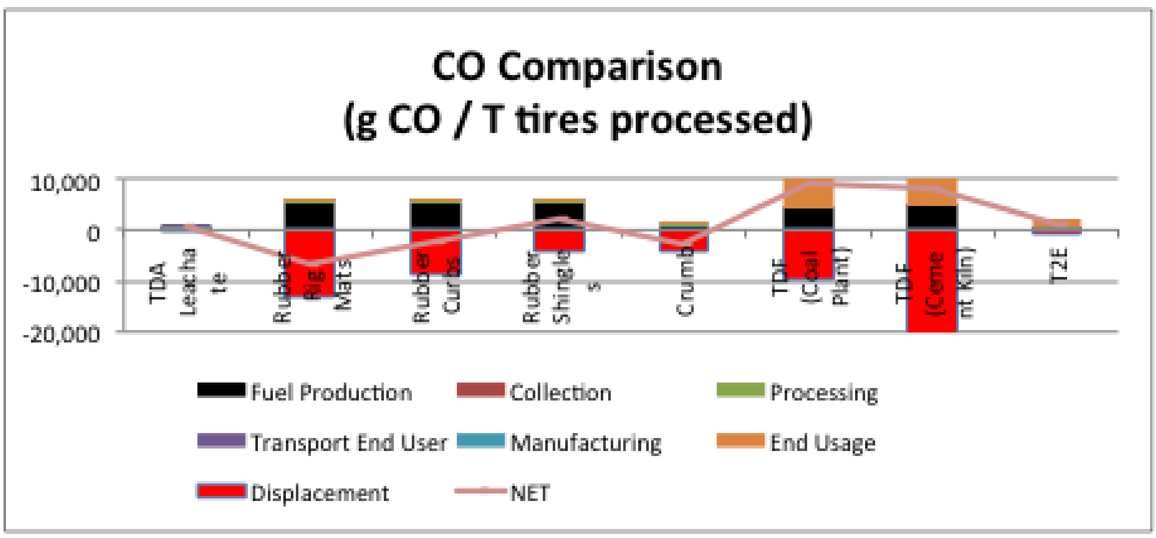

Figure D-6: Carbon Monoxide Emissions by End Use (Pembina, 2010)

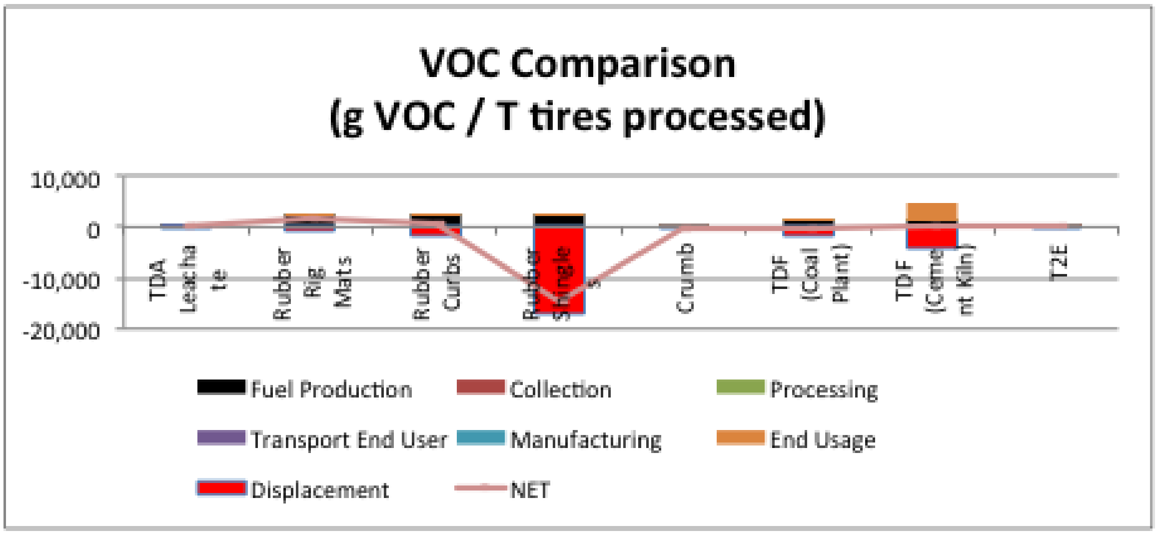

Figure D-7: Volatile Organic Compound Emissions by End Use (Pembina, 2010)

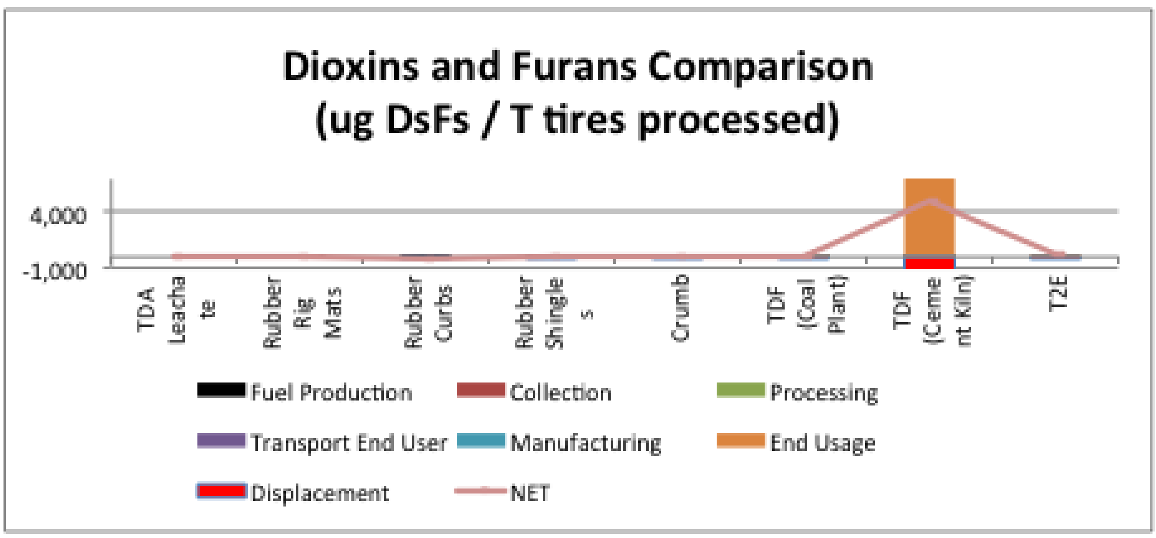

Figure D-8: Dioxin and Furan Emissions by End Use (Pembina, 2010)

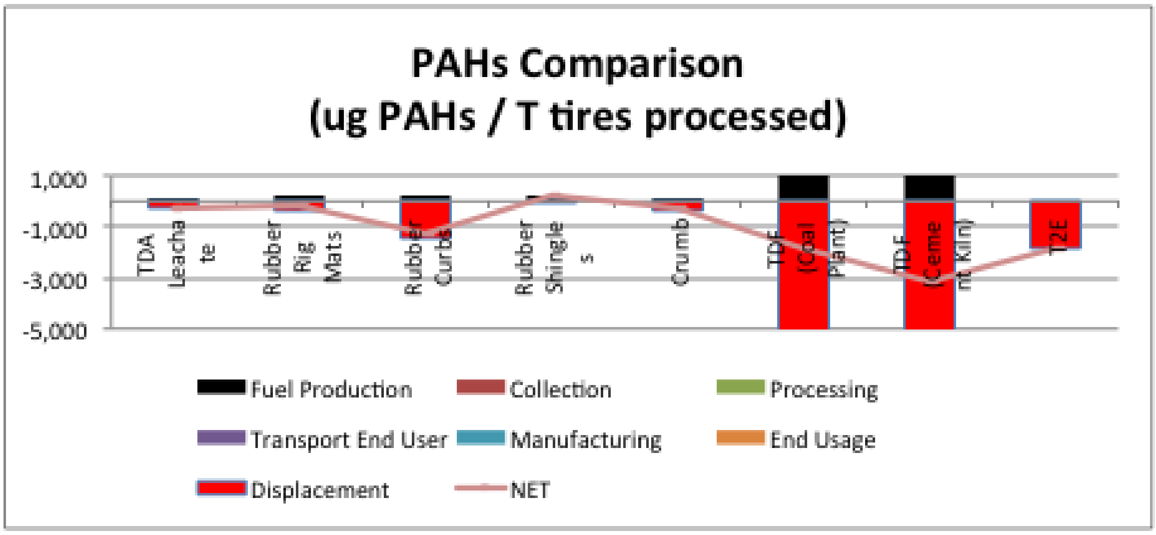

Figure D-9: Polycyclic Aromatic Hydrocarbon Emissions by End Use (Pembina, 2010)

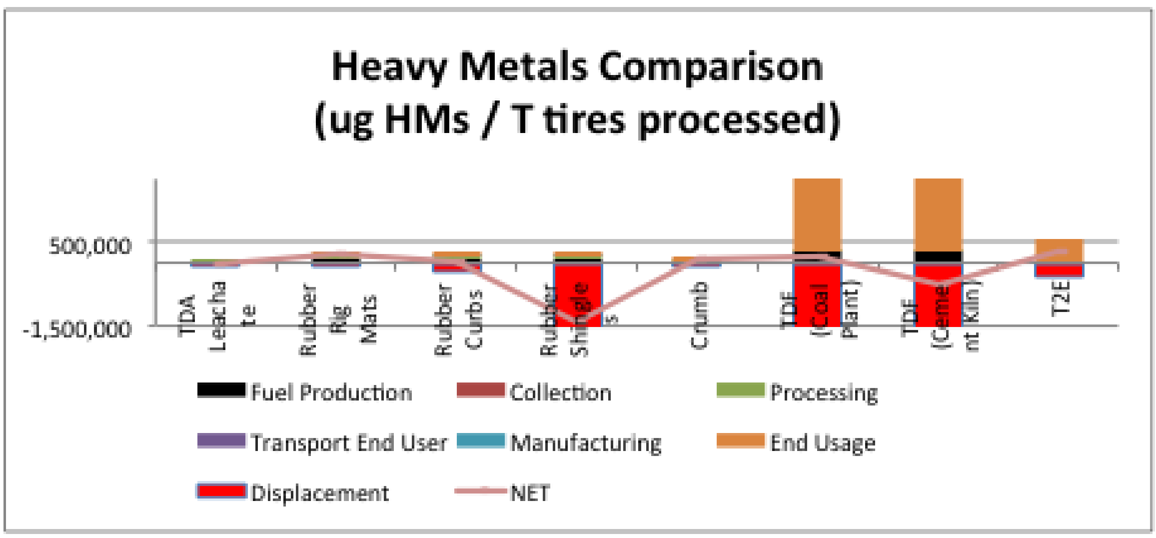

Figure D-10: Heavy Metals Emissions by End Use (Pembina, 2010)

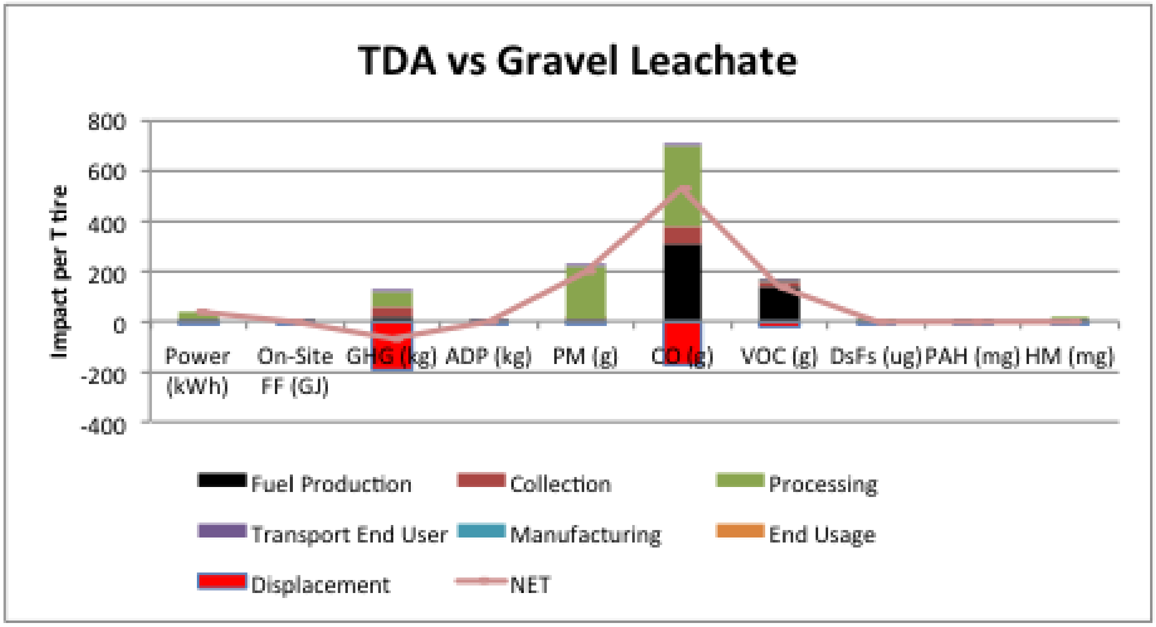

Figure D-11: Comparison of Impacts for Tire-Derived Aggregate Versus Gravel Leachate Collection Aggregate (Pembina, 2010)

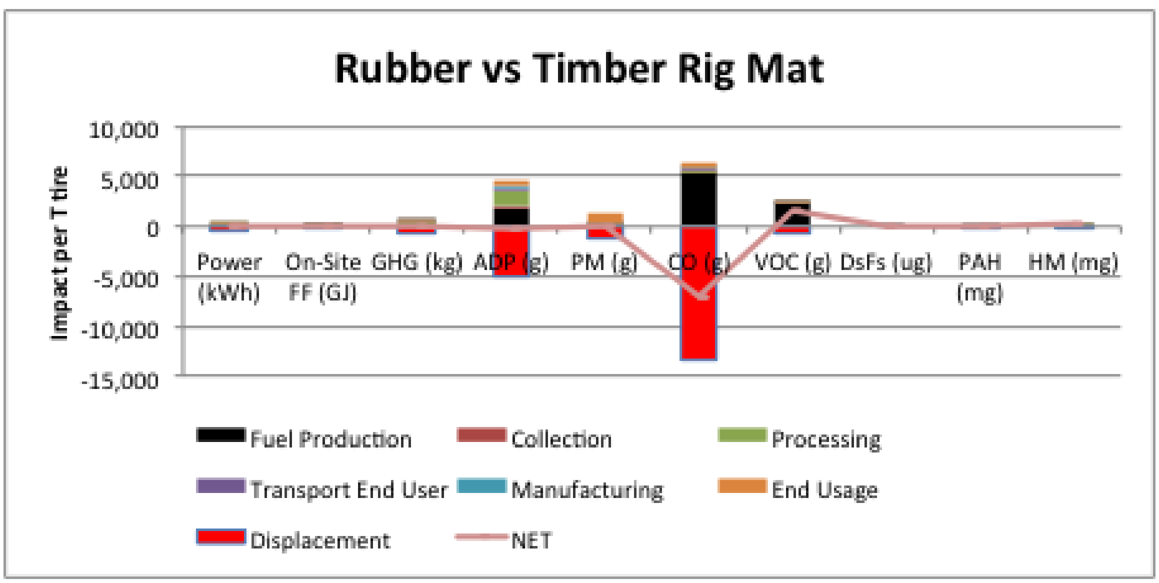

Figure D-12: Comparison of Impacts for Rubber Versus Wood Rig Mats (Pembina, 2010)

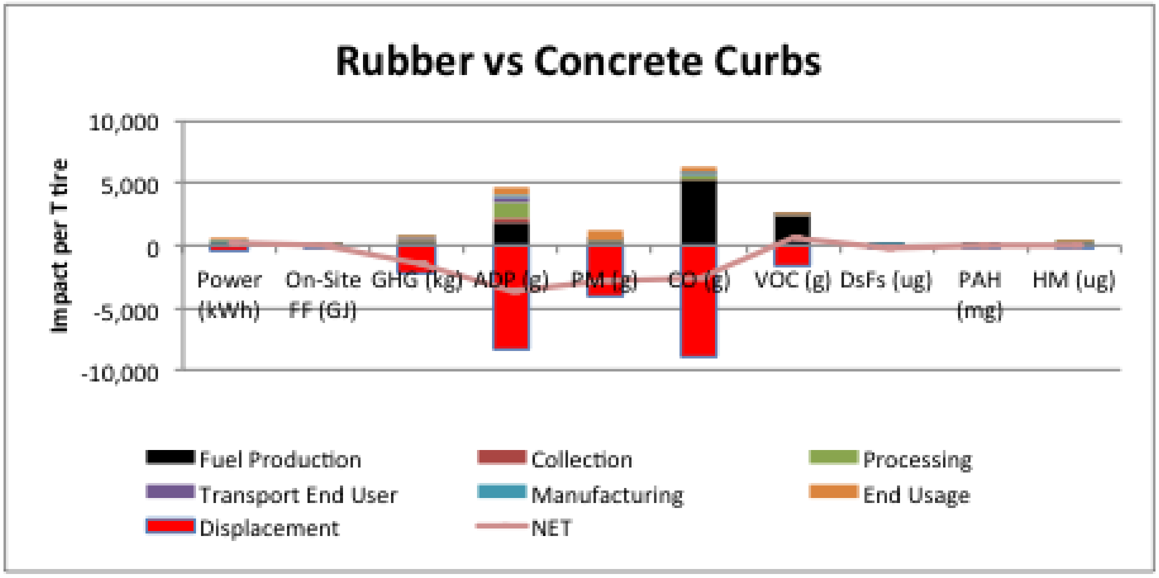

Figure D-13: Comparison of Impacts for Rubber Versus Concrete Curbs (Pembina, 2010)

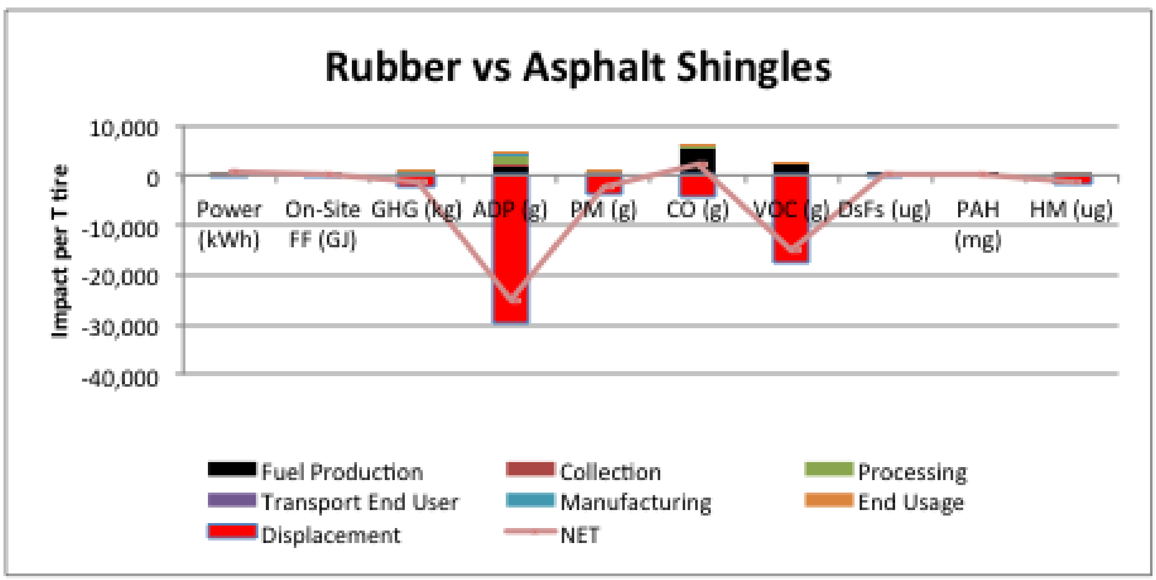

Figure D-14: Comparison of Impacts for Rubber Versus Asphalt Shingles (Pembina, 2010)

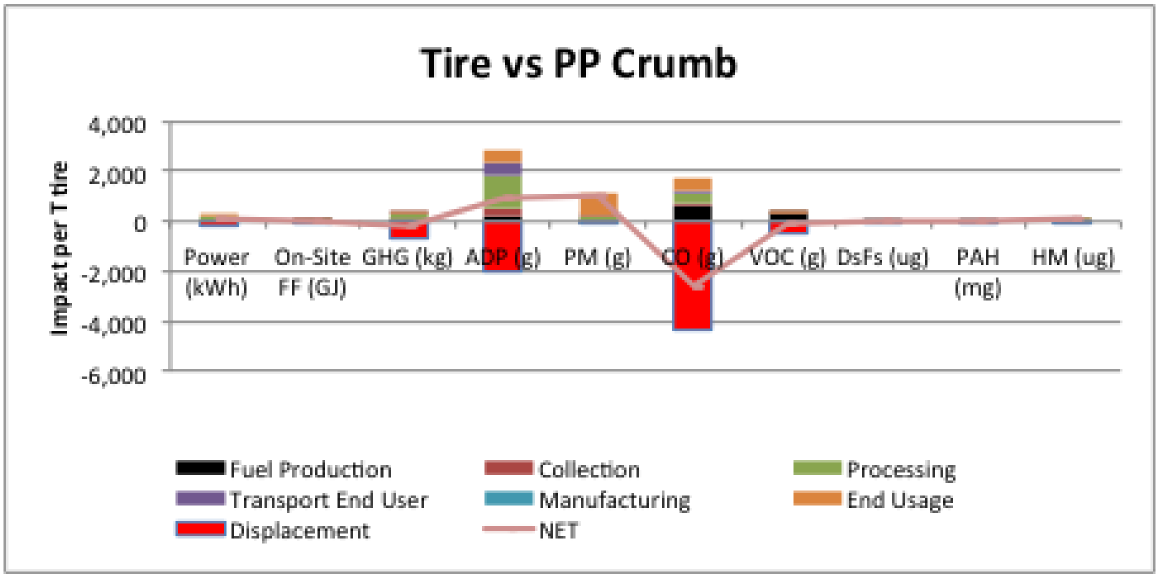

Figure D-15: Comparison of Impacts for Tire Crumb Versus Polypropylene (Pembina, 2010)

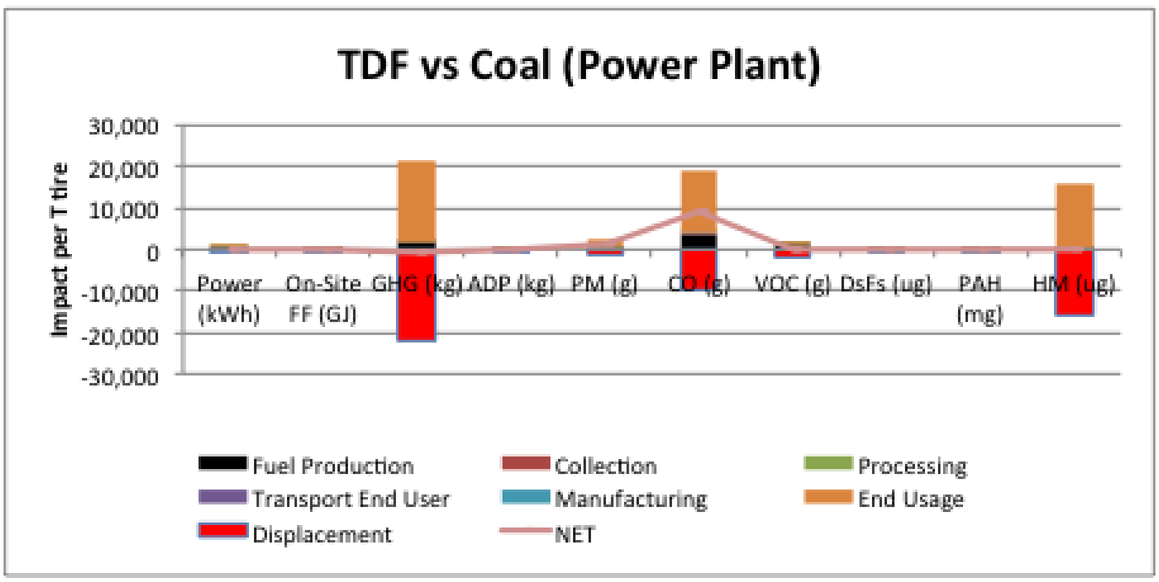

Figure D-16: Comparison of Impacts for Tire-Derived Fuel Versus Coal-Generated Power (Pembina, 2010)

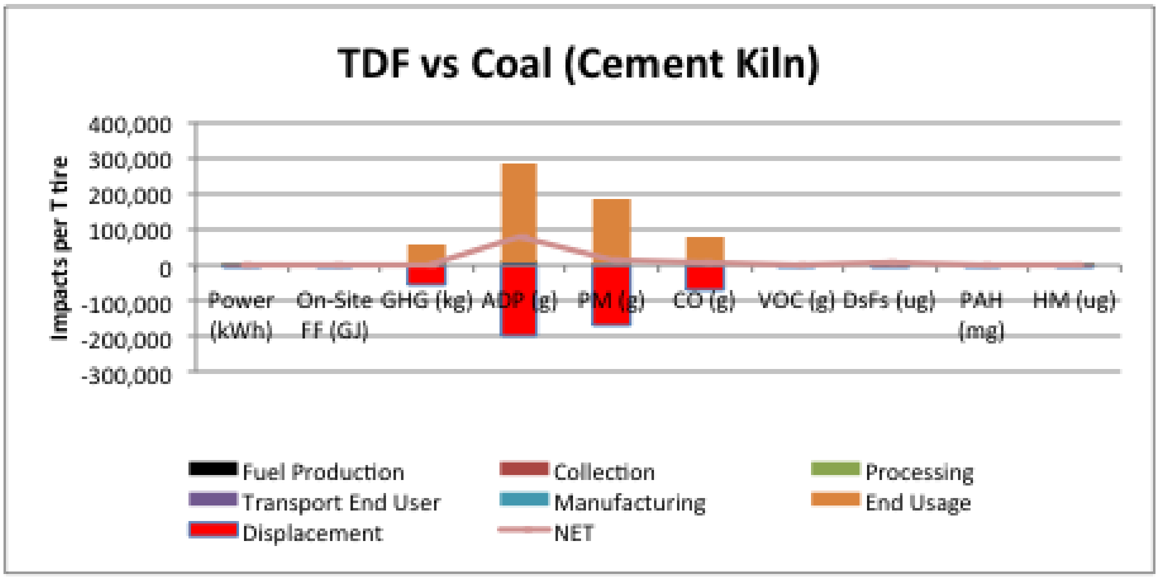

Figure D-17: Comparison of Impacts for Tire-Derived Fuel Versus Coal Fuel in a Cement Kiln (Pembina, 2010)

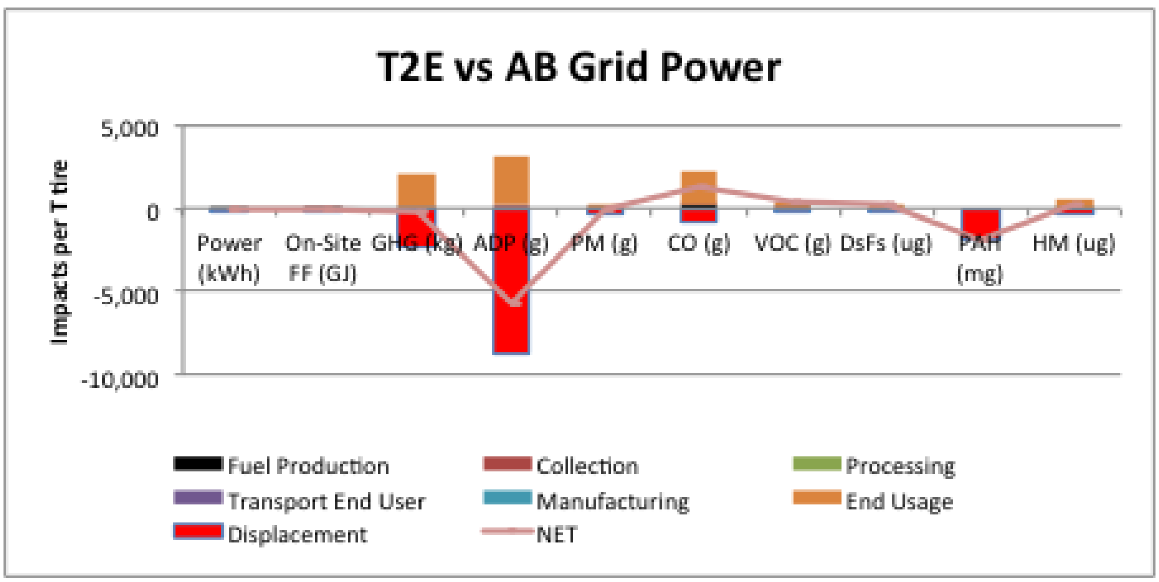

Figure D-18: Comparison of Impacts for Tire to Energy Versus Alberta Power Grid (Pembina, 2010)