Int J Life Cycle Assess (2016) 21:337–348
DOI 10.1007/s11367-015-1024-2

POLICIES AND SUPPORT IN RELATION TO LCA

The application of life cycle assessment to public policy development

Christina Seidel[1]

Received: 8 January 2015 / Accepted: 28 December 2015 / Published online: 15 January 2016

Abstract
Purpose Despite the potential value it offers, integration of life cycle assessment (LCA) into the development of environmental public policy has been limited. This paper researches potential barriers that may be limiting the use of LCA in public policy development, and considers process opportunities to increase this application.
Methods Research presented in this paper is primarily derived from reviews of existing literature and case studies, as well as interviews with key public policy officials with LCA experience. Direct experience of the author in LCA projects with public policy elements has also contributed to approaches and conclusions.
Results and discussion LCAs have historically been applied within a rational framework, with experts conducting the analysis and presenting results to decision-makers for application to public policy development. This segmented approach has resulted in limited incorporation of LCA results or even a broader approach of life cycle thinking within the public policy development process. 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. Overcoming the barriers to effective use of LCAs in public policy development will require a more normative approach to the LCA process that incorporates a broad group of stakeholders at all stages of the assessment. Specifically, a set of recommendations have been developed to produce a more inclusive and effective process.
Conclusions In an effort to effectively incorporate LCA within the overall public policy decision-making process, the decision-making process should incorporate a multidisciplinary approach that includes a range of stakeholders and public policy decision-makers in a collaborative process. 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 if a full LCA is not undertaken.

Keywords Decision-making process · Life cycle assessment · Life cycle thinking · Public policy

1 Introduction

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. Public policy-making is listed by ISO as one of the potential direct applications of LCA (ISO 2006).

ISO states that LCA can assist in decision-making in industry, governmental, or non-governmental organizations (ISO 2006), which would presume to include public policy development. According to the Society for Environmental

Responsible editor: Mary Ann Curran

✉ Christina Seidel
cseidel@sonnevera.com

[1] Sonnevera International Corp., Box 23, Bluffton, Alberta, Canada

Toxicology and Chemistry (SETAC), the goal of applying life cycle thinking to public policy is to identify opportunities for reducing environmental impacts associated with products or activities over the entire life cycle (Allen et al. 1995).

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). However, 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). This may be due to the inherent challenges associated with integrating LCA into the public policy process, as well as the relative strengths of LCA within certain applications such as product assessment.

Research also suggests that direct application of life cycle assessment results within the public policy arena has been limited, often despite the official incorporation of LCA within the process. There are a number of possible reasons for this disconnect. Decision-makers may not be completely comfortable with LCA and may be unclear on reasonable expectations for the process. In addition, incorporating life cycle assessment into the decision-making process can be fundamentally challenging, as the very nature of the results includes a variety of indicators that may not be directly comparable, and may not lead to clear conclusions.

Despite the potential challenges, LCA offers a valuable tool for assessment of the full environmental impacts of public policy options. Facilitating its increased application in the public policy arena could improve the decision-making process and ultimately lead to better environmental outcomes.

2 Policy development paradigms

There are two primary theories under which public policy is developed (Bras-Klapwijk 1998):

1. *Discourse theory* stresses the need for an open and inclusive process in which stakeholders learn about each other's perceptions on the issues, with a focus on communication and understanding.

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. Discourse theory therefore focuses on the process and participants, with the information being supportive.

2. *Rational theory* emphasizes quantification and objectivity, with technical information being the key factor in the process.

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). This rational approach is particularly relevant and useful in technically oriented public policy decisions such as infrastructure design or technology choices.

Bras-Klapwijk (1999) asserted that the rational paradigm of sound policy-making and analysis is dominant in the LCA scientific community and that the LCA methodology has been primarily developed within this rational theory. 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. 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. This leads to a level of uncertainly in LCA that must be acknowledged and considered by decision-makers.

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 (de Neufville 1990). This lends itself more to a discourse theory approach to public policy development.

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 premise is incorporated into proposed policy elements presented later in the paper.

3 Application of LCA to public policy development

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 concluded that LCA provides the best available framework for assessing the potential environmental impacts of products (EU 2011), 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 within this context.

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 policy 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.

ISO suggests that, generally, the information developed in an LCA study can be used as part of a much more comprehensive decision-making process (ISO 2006). 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 not be otherwise anticipated, and may undermine the potential for a decision to make an overall environmental improvement (CIELAP 2009). SETAC further suggests that the use of life cycle concepts and tools can link scientific and policy-making communities in an overall effort to find an appropriate balance between economic and environmental considerations, by moving fragmented end-of-life approaches toward more holistic decision-making through a framework that can 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).

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). The extensive use of LCA both within industry and public institutions further validates the perceived value that this tool offers the decision-making process.

At the global level, the United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (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 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 for business, government, and civil society practice worldwide as a basis for sustainable consumption and production* (LCI 2014).

Specifically, the USA 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 to determine if the threshold standards for emissions reductions were being met. This is the first and only time federal regulatory policy mandated the use of LCA on a product or system. 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 appeared to get 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 2014). 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.

At the same time, there are numerous examples of the use of LCA at the US state level, including the California Environmental Protection Agency's Department of Toxic Substances Control's evaluation of alternative hazardous waste management systems; Oregon Department of Environmental Quality's LCA of mail order packaging, 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; and California's Department of Resources Recycling and Recovery's (CalRecycle) comprehensive LCA of California's used lubricating and industrial oil management process (Reed 2012). This last example offers considerable insight into the process of incorporating LCA into the public policy process and will be discussed further as a case study.

4 Barriers to applying LCA to the public policy process

Despite its perceived potential value, literature 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 preventing its lack of greater influence, which may include one or more of the following:

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. This lack of familiarity may also create reluctance on the part of decision-makers who feel they lack the expertise needed to incorporate or interpret LCA within their 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).
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 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. This 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 or desirable (Reed 2012).

   However, decision-makers are no strangers to being faced with complex decisions and large amounts of information, so if they are convinced that LCA can assist in the process by presenting important information in a comprehensive yet focused manner, they are likely to embrace the addition.
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).
4. Clear or consistent results may be lacking as outcomes of the LCA.

   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.

   However, uncertainty is normal in many aspects of decision-making, including environmental assessments, and decision-makers should be encouraged to embrace the additional perspective that life cycle thinking can add to the decision process, rather than looking for key conclusive outcomes.
5. 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).
6. Governments lack a framework for integrating LCA information into the decision-making process.

   Governments lack a framework for integrating LCA information with other factors, such as economics and social impacts, that are considered in the decision-making process (Reed 2012). This suggests the need for more guidelines on effectively integrating LCA into the policy development process.

   This is exacerbated by the tendency for the policy-making process to be fragmented, making it more challenging to integrate a holistic approach like LCA. However, this recognition can ultimately lead to a more robust and integrated policy framework.
7. 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 2014). This focus on a narrow range of impacts is often driven by specific priorities and funding limitations (Leith 2014).

   Defining a framework and process for agencies to integrate LCA into public policy decisions will help to mitigate any tendency to prematurely narrow the scope.
8. Comprehensive public LCAs require considerable resources to complete.

   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 associated with a public policy LCA is reflected in a substantially higher cost than a standard comprehensive LCA. This was demonstrated in the $2.5 million, 2.5 year process undertaken by CalRecycle in its Used Oil LCA (Carlson 2014a). This example is further discussed as a

case study later.

The perceived additional time and cost associated with incorporating LCA can lead to hesitancy on the part of decision-makers who may prefer to expedite the process.

9. 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 2014).

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, but rather the process within which the LCA is being incorporated.

5 Addressing barriers to incorporation of LCA in policy development

An overall methodology that has been recommended to overcome the barriers to effective use of LCAs in public policy development suggests a shift toward 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 toward a more qualitative process has the potentially to mitigate many of the process-related barriers identified.

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). This 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.

This type of 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 rigor 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.

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).

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), and 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 imbedded values, not just LCA (Ekvall et al. 2007).

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 have the potential to increase data quality and availability, while also building participation and trust in the LCA process.

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.

These foundational process elements have been built upon and expanded 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. These recommendations are also consistent with the Core Values for the Practice of Public Participation set out by the International Association for Public Participation:

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

   - 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 to accommodate the complexity of a multi-stakeholder process and fully engage the range of stakeholders.

   Hofstetter (1998) asserted 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. On the other end of the spectrum is a participatory analysis process, where stakeholders are actively involved throughout the process (Bras-Klapwijk 1999).

   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. Ultimately, through a participatory process, there is the potential of building group consensus on strategies for moving forward.

   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).

   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).

2. 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 longevity of the results, and incorporation by decision-makers who may have not been directly involved in the process.

3. 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.

4. Present assumptions and uncertainties transparently within the process, 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.

   If the resulting 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), and stakeholders have been actively involved throughout the process.

   The move toward increased access 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 US Department of Agriculture, which goal is to provide open access to LCA datasets and tools, making LCA data more openly accessible (USDA 2014). Another example is Open LCA, conceived in 2006, providing the only widely available professional, full scale Open Source LCA software (openLCA 2014). This concept of opening both the software and data to public scrutiny, while also encouraging two-way data flow, is a step toward developing a public LCA system. This step can only serve to increase transparency, rigor, 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.

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

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.

In an effort to effectively incorporate LCA within the overall public policy decision-making process, 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, while impact assessment requires expertise in natural science, and weighting incorporates social science elements (Baumann and Tillman 2004).

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. 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.

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 shifts the role of the analyst to facilitator, as well as technical expert. Alternately, a qualified facilitator may be brought into the process to guide the ongoing input and involvement of multiple stakeholders.

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 rigor of the technical components it contains.

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). Ultimately, since LCA is an information tool, decision-makers must value the information in order for it to be considered in policy development (Reed 2012).

Process recommendations will be further discussed within a case study context in a subsequent paper that will review two primary public policy LCAs in US and Canadian examples.

6 A broader process—life cycle thinking

The use of LCA within a public policy framework is more complex than other applications 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). 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. As a result, the way LCA is applied within the public policy process can and should be different, based on its audience (Allen et al. 1995).

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):

Life cycle thinking↔Life cycle assessment

Considering the potential to utilize different levels of life cycle approach along this continuum offers a variety of options for different decision processes. This recognizes that, despite the value that LCA can add to the decision-making process, a full LCA (as represented on the quantitative end of the continuum) 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. 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.

Integrating life cycle thinking into existing policies or processes has the potential to increase their rigor and value. 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-labeling (Baumann and Tillman 2004). There is also the potential to incorporate an increased level of life cycle thinking into environmental review processes such as the Environmental Impact Statements (EIS) and Environmental Assessments (EA) federal agencies are required to prepare under the National Environmental Policy Act (NEPA), as well as other federal, state, and provincial environmental review practices.

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).

While encouraging life cycle thinking among decision-makers at the conceptual level, it is important to embrace the intent of the full range of potential environmental impacts throughout the life cycle, rather than a simplistic application of the concept to a small group of issues or narrow range of impacts. This will allow the concept to be embraced in a realistic, yet fulsome holistic way.

7 Case study review

The following case studies are 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.

7.1 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.

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). ARMA is made up of a number of stakeholder representatives, thereby providing a reasonable proxy of a public policy development body (Table 1).

At the outset of the process, a project outline was vetted and approved by ARMA, and an initial LCA information session was held with the Board to provide some background. This is an example of involving decision-makers early in the LCA process. However, the resulting 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 as a whole at a more detailed level, rather than simply providing high level approval.

Because of the wide-ranging expertise and academic rigor required for the LCA research, a Project Technical Team was individually selected and assembled, and interacted directly with an ARMA Project Management Team. 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.

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 Alberta-specific.

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 rigor and accountability to the LCA itself. 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.

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, 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 rigor within the LCA led to a focus on this component that suggested its importance over other elements,

Table 1 Scrap tire LCA impacts

Management option	Power input (kWh)	On-site fossil fuel input (MJ)	GHG (kg CO_2e)	ADP (g SO_2e)	PM (g)	CO (g)	VOC (g)	Dioxins/furans (μg)	PAHs (μg)	Heavy metals (μg)
TDA leachate	39	−2473	−69	1106	201	529	132	0.001	−258	230
Crumb	106	−22,338	−221	894	998	−2580	−124	−0.008	−230	71,329
Manufactured products:										
Rig mats	103	19,096	−11	−237	74	−6984	1554	0.014	−122	201,967
Curbs	185	18,115	−1438	−3720	−2862	−2533	682	−179.2	−1263	44,828
Shingles	445	1927	−1408	−24,978	−2418	2037	−14903	−0.024	193	−1403469
Waste-to-energy:										
Coal plant	144	−2089	−606	82,062	1188	8890	−86	13.75	−1841	136,534
Cement kiln	−220	−512	−499	81,356	14,187	8349	246	4932	−3147	−494,209
Incineration	−30	−26,086	−194	−5739	−77	1333	349	301	−1840	250,461

detracting focus from the holistic process, while also potentially creating unrealistic expectations from higher level stakeholders.

Ironically, the strong technical expertise offered by the technical team, while certainly providing the desired rigor 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.

LCA results were presented individually by option, as well as comparatively by parameter, and technical results from the LCA were also presented in a summary format, as shown in Figs. 1, 2, and 3 and Table 2. Recognizing the data intensity of the information presented individually, an attempt was also made to summarize the information in a composite form that would assist in ranking and prioritizing options.

Questions and feedback from Board members suggested a lack of buy-in and acceptance of the results, in spite of these attempts to present and interpret the results, as well as the obvious technical rigor 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. 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 and would have been mitigated through increased project buy-in. Attempts at transparency are contingent on a clear understanding of the issues being addressed, and the process incorporated throughout the LCA.

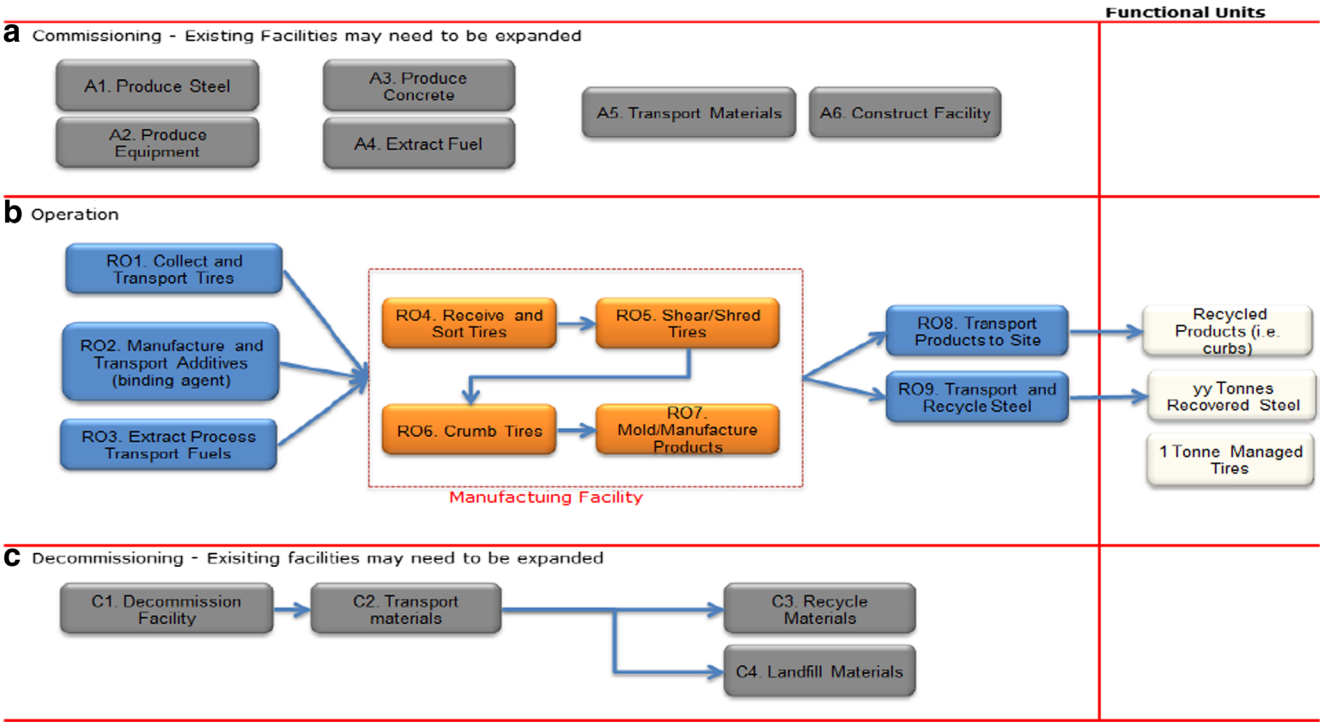

Fig. 1 Tire LCA process diagram

7.2 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 steps related to an LCA for used oil management:

1. Contract with a third-party consultant with recognized expertise in life cycle assessments
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
4. Submit a report to the Legislature describing the findings of the life cycle analysis and provide recommendations for statutory changes (CalRecycle 2014; 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.

Broad stakeholder involvement was integrated into the process from the outset; however, who stakeholders are and their

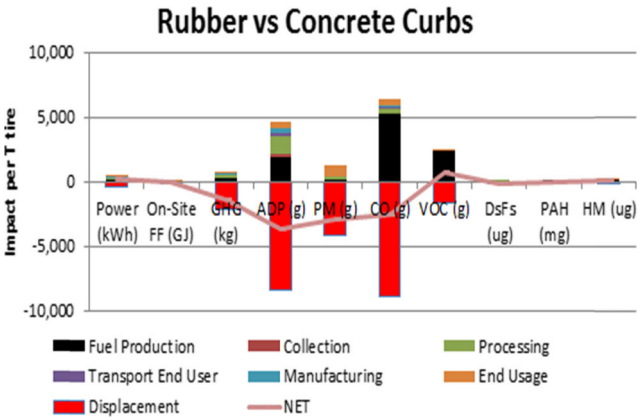

Fig. 2 Sample LCA option results

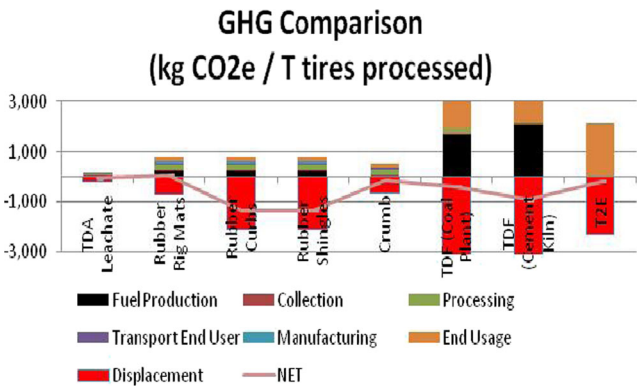

Fig. 3 Sample LCA parameter results

Table 2 LCA option rankings

Management option	No. of good ratings	No. of neutral ratings	No. of poor ratings	Overall ranking
TDA leachate		8		0
Crumb	1	6	1	0
Manufactured products:				
Rig mats	1	5	2	−1
Curbs	6	0	2	4
Singles	5	3	0	5
Waste-to-energy:				
Coal plant	2	3	3	−1
Cement kiln	3	0	5	−2
Incineration	2	3	3	−1

level of involvement was not specifically defined (Carlson 2014a, b). 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 2014a, b). This shows the difficulty in obtaining 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.

Managing the large number of stakeholders engaged in the process was handled by contracting an expert facilitator to manage the process and compile information. However, it was recognized that if numbers had been smaller, the process would have been much simpler to manage. The difficulties associated with the large number of stakeholders were exacerbated by the process being technical in nature, requiring significant time investment on the part of participants. This resulted in attrition in stakeholders, with less than 40 still involved at the end of the project (Carlson 2014a, b).

Despite the challenges associated with the extensive stakeholder involvement process, it was seen as a success, as a result of its openness and transparency (Carlson 2014a, b).

To kick off the LCA process, 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. Following this initial orientation session, the group debated fundamental decisions such as goal, scope, boundaries, and functional units for a number of months.

This intensive process is indicative of the approach taken throughout the LCA, resulting in the process requiring over 2.5 years to complete, and costing approximately $2.5 million, exclusive of staff time (including $1.5 million for an economic analysis). This contrasts to a normal LCA cost of $150,000 to $300,000 (Carlson 2014a, b). This confirms the significant resource requirements potentially 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, 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 2014a, b)

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 2014). 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 2014a, b).

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 2014). 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 2014a, b). However, this should probably have been made more clear in the LCA itself, so readers were not looking for policy recommendations.

8 Conclusions

LCA offers a valuable tool for assessment of the full environmental impacts of public policy options involving product or

process choices, and facilitating its increased application in the public policy arena could improve the decision-making process and ultimately lead to better environmental outcomes. The process within which LCA is being incorporated plays a significant role in the limited success of LCAs in contributing positively to public policy development. A shift toward a more open and qualitative approach has the potentially to mitigate process-related barriers. Increased stakeholder involvement throughout the LCA process and focus on communication and transparency are key elements to the success of integrating LCA into public policy decision-making.

Through a more inclusive process, it is hoped that public policy development will continue to evolve toward increased incorporation of the valuable environmental information offered by life cycle assessment.

References

Allen DT, Consoli FJ, Davis FJ, Davis GA, Fava JA, Warren JL (1995) Public Policy Applications of Life-Cycle Assessments – Proceedings from the Workshop on Application of Life-Cycle Assessment to Public Policy. In: David T. Allen, Frank J. Consoli, Gary A. Davis, James A. Fava and John L Warren (eds) SETAC Technical Publications Series. August, 1995. ISBN 1-880611-18-X assessment - Principles and framework. Second edition 2006-07-01

Baumann H, Tillman A-M (2004) The hitch Hiker's guide to LCA—an orientation in life cycle assessment methodology and application. Published by Studentlitteratur AB, Lund, Sweden, **ISBN 91-44-02364-2**

Bras-Klapwijk RM (1998) Are life cycle assessments a threat to sound public policy making? Delft University of Technology, Policy and Management, Department of Policy Analysis, The Netherlands. Int J Life Cycle Assess 3(6):333–342. doi:10.1007/BF02979344

Bras-Klapwijk RM (1999) Adjusting Life Cycle Assessment Methodology for Use in Public Policy Discourse. Doctoral dissertation - Delft University of Technology

CalRecycle (2014) Used oil recycling program statutes and regulations. Retrieved from http://www.calrecycle.ca.gov/usedoil/policylaw/default.htm. Accessed 12 November 2014

Carlson R (2014a) Financial Assistance Division, California Department of Resource, Recycling and Recovery (CalRecycle). Personal communication, July 15, 2014

Carlson R (2014b) Financial Assistance Division, California Department of Resource, Recycling and Recovery (CalRecycle). Personal communication, November 20, 2014

CIELAP (2009) CIELAP Brief on Life Cycle Assessment. Canadian Institute for Environmental Law and Policy. June 2009. Accessed at www.cielap.org on Feb. 19, 2011

Curran M (2014) Editor-in-chief - the international journal of life cycle assessment and former LCA research program manager at US EPA. Personal Communication

de Neufville R (1990) Applied Systems Analysis, Engineering Planning and Technology Management. McGraw-Hill, New York

Ekvall T, Assefa G, Bjorklund A, Eriksson O, Finnveden G (2007) What life-cycle assessment does and does not do in assessments of waste management. Science Direct – Waste Manage 27(2007):989–996

EU (2011) European Commission Environment. European Platform on Life Cycle Assessment. Accessed at http://ec.europa.eu/environment/ipp/lca.htm on Feb 21, 2011

EUROPEN (1999) Use of Life Cycle Asssessment (LCA) as a Policy Tool in the Field of Sustainable Packaging Waste Management. September, 1999

Hofstetter P (1998) Perspectives in Life Cycle Impact Assessment – A Structured Approach to Combine Models of the Technosphere, Ecosphere and Valusphere. Dissertation submitted to the Swiss Federal Institute of Technology. Zurich

ISO (2006) ISO 14040 International Standard. Environmental management - Life cycle

Lazarevic D, Buclet N, Brandt N (2012) The application of life cycle thinking in the context of European waste policy. J Clean Prod 29–30:199–207

LCI (2014) Life Cycle Initiative. Retrieved from http://www.lifecycleinitiative.org/about/about-lci/get-involved/be-a-part-of-a-work-area/. Accessed 7 June 2014

Leith A (2014) U.S. Environmental Protection Agency. Personal Communication

NRC (2014) Sustainability and the U.S. EPA, committee on incorporating sustainability in the U.S. environmental protection agency, science and technology for sustainability program, policy and global affairs division, national research council of the national academies. The National Academies Press. 2011

openLCA (2014) The openLCA project. Accessed at http://www.openlca.org/about-openlca. December 20, 2014

Reed D (2012) Life-cycle assessment in government policy in the United States. PhD diss., university of Tennessee, 2012. Retrieved from http://trace.tennessee.edu/utk_graddiss/1394

USDA (2014) LCA Commons – Data and Community for Life Cycle Assessment. United States Department of Agriculture. National Agricultural Library. Accessed at http://www.lcacommons.gov/. December 20, 2014