Lessons Learned in Developing an Environmental Product Declaration Program for the Asphalt Industry in North America

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ABSTRACT
The objective of this paper is to report the technical and organizational challenges involved in the development of the North American Environmental Product Declaration program for asphalt mixtures. Developing a Life Cycle Assessment (LCA) for asphalt mixtures presents the challenge of coordinating consistent assumptions across industries and stakeholders, and requiring a harmonized decision-making process that accounts for the impacts of materials across the supply and value chain. While, the methods of LCA are rational and well defined, the decisions defining the various assumptions are often arrived at through a negotiation process shaped by stakeholder relationships and priorities. There is much discussion in the literature regarding the technical challenges of conducting an LCA involving choice of system boundary, functional unit, and allocation procedures used for co-products and recycled products. However, the formulation process of these technical questions within the context of stakeholder biases and heuristics are seldom explicitly discussed, even though they play an important role in how the technical challenges are resolved. Hence, the paper explores how differences in stakeholder priorities and perspectives, in the pavement construction industry, directly shape the Product Category Rules (PCR) defining the program by drawing attention to specific LCA related technical questions and highlights how the solutions were negotiated. The primary challenge identified is how to ensure technical rigor of the underlying LCA, while recognizing the interests of the stakeholders and ensuring the delivery of a program that is effective. The paper discusses how technical issues regarding system boundary choice, data use and allocation presented challenges for the PCR Development Working Group accounting for different stakeholder interests. Within this context the paper will highlight the developed PCR and present relevant results from the underlying LCA.

KEYWORDS: Life Cycle Assessment, Sustainability, Environmental Product Declaration, Innovation Adoption, Change Management.

Introduction

The principles and framework for conducting an attributional Life Cycle Assessment (LCA) for products and processes are outlined in ISO standard 14040. An LCA accounts for cradle-to-grave environmental impacts of a product or process, including the impacts incurred during the mining, extraction, manufacturing and production phases of all the raw materials involved in the process; the distances travelled in transporting them through the supply chain, and the impacts involved in the use and eventual end-of-life disposal of the materials.

For a complex system such as a pavement system, developing an LCA poses the challenge of coordinating consistent assumptions across industries and stakeholders, requiring a harmonized decision-making process that accounts for the impacts of materials across the supply

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and value chain. While, the methods of LCA are rational and well defined, the decisions defining the various assumptions are often arrived at through a negotiation process defined by stakeholder relationships and priorities. There is evidence from decision science that human decision-making is influenced by individual biases and heuristics and is sensitive to formulation, context and procedure (Kahneman and Lovallo 1993; Kahneman and Tversky 2000). While there is much discussion in the literature regarding the technical challenges of conducting an LCA involving choice of system boundary, functional unit, and allocation procedures used for co-products and recycled products; the formulation process of the technical LCA questions within the context of stakeholder biases and heuristics are seldom explicitly discussed, even though they play an important role in how the technical challenges are resolved. In addition, an understanding of the collaborative and competitive forces shaping the stakeholder interactions and the incentive mechanisms in place can be crucial to this discussion.

Hence, the objective of this paper is to explore the extent to which technical decisions, involved in an LCA underlying the development of an Environmental Product Declaration (EPD) program, are shaped by negotiations between stakeholders with competing objectives. The development of North American EPD program for asphalt mixtures presented the opportunity to observe direct stakeholder involvement in shaping LCA questions within the context of the technical and organizational challenges in the pavement construction industry.

The paper starts with an introduction to the EPD program development process. Next it establishes the role played by stakeholders in the decision-making process given their affiliations and relationship to the asphalt materials industry. Finally, the paper discusses the technical and organizational challenges that were negotiated through the decision-making process and their impact on the LCA supporting the EPD program.

The Structure of EPD Programs

The EPD program was developed with the goal of standardizing industry specific LCA assumptions, allowing for credible and transparent reporting. The EPD is a Type III Environmental Label as defined in *ISO Standard ISO 14025:2006, Environmental Labels and Declarations – General principles* (International Orginization for Standardization 2006). It communicates the environmental impacts of a product or service using methods in Life Cycle Assessment (LCA). The process used to develop an EPD ensures consistent data collection, analysis and reporting requirements, supported by third party verification. This ensures the reliability of the information communicated through an EPD. Typically an EPD development process adheres to various international standards; chief among them is the ISO 14025 standard.

EPDs are developed on the basis of Product Category Rules (PCR) – a consensus document that defines the rules, requirements and guidelines for conducting the LCA that supports an EPD. Specifically, it provides guidelines for:

1. Defining the functional and declared units of comparison for a product.
2. Establishing the goal and scope, and defines the system boundaries for conducting the LCA that supports the EPD. It specifies the modules and processes in each of the life cycle stages and that would have to be considered in an LCA for developing an EPD.
3. Outlining data collection and specification when developing the life cycle inventory, requiring reporting across a twelve-month period, reflecting technology in current use and ensuring the use of geographically pertinent data.
4. Ensuring the quality of the data collected, (including tolerances) for conducting the underlying LCA.

5. Reporting the environmental impacts across relevant product impact categories using appropriate characterization factors. Example categories are: environmental impact indicators (such as Global Warming Potential), total primary energy consumption and material resource consumption.

Based on a given PCR, an EPD can be developed to convey information from Business-to-Business (B-to-B: cradle to gate) or from Business-to-Consumer (B-to-C: cradle to grave).

In order to maintain the accuracy, reliability, and the unbiased integrity of an EPD, multiple stakeholders are involved with the peer-review and third party verification in place. Typically three different types of organizations can play the role of program operator: professional organizations such as American Society for Testing and Materials (ASTM) International, environmental compliance consultants and industry trade associations. In the United States state agencies have not played the role of a program operator, but they are qualified to. Program operators develop industry specific PCR in compliance with ISO 14025. The PCR development process involves participation from various stakeholders including customers, producers and upstream manufacturers. In addition, an independent review panel provides a peer-review of the developed PCR. Using the PCR developed by the program operators, manufacturers and producers of the product can develop a specific EPD, based on an LCA conducted using input data, on materials and energy use, specific to their operations and processes. A third party (or the program operator) must certify the EPD as being compliant with the PCR. In the construction materials industry, currently, there is a growing demand for directly involving industries in developing PCR that are reflective of realities within the industry.

For this program, the operator is the National Asphalt Pavement Association (NAPA), an industry association with significant expertise in asphalt materials, rather than a central regulatory agency. Organizationally, this is akin to a bottom-up consensus driven effort that directly engages stakeholders with voluntary adoption, driven by market forces; as different from a top-down regulatory process.

An ISO compliant EPD program must go through multiple stakeholder review processes. The PCR must be prepared in consensus with a PCR Development Working Group (DWG) representing a consensus from various industry, agency and academic stakeholders. Before publication the PCR has to be available for public comment for a period of one month and in order to be ISO compliant the program operator must address all comments and an independent external committee of three reviewers representing expertise in the specific field and LCA methodology must verify the final document. This clearly presents a situation where multiple conflicting perspectives require attention, and the PCR becomes a document that is socially negotiated. The next section outlines the stakeholders who were part of the PCR DWG and their relationships to the asphalt industry.

Stakeholders on the PCR DWG

Within the context of the asphalt pavement industry, the stakeholders included customers, representatives from other industries that collaborate with, or are part of the upstream product supply chain, state agencies that may play a regulatory role and academic advisors. Non-profit associations that are usually funded by industry constituents (typically for-profit contractors and producers) represent industry interests by providing technical support and advocacy. Examples of such organizations are: National Asphalt Pavement Association (NAPA), the Asphalt Institute (AI) and the National Stone, Sand and Gravel Association (NSSGA), each representing the interests of their respective industries. State agencies that may play a regulatory role include

Departments of Transportation (DOT), Tollway Authorities, Cities and Metropolitan Planning Organizations (MPO) at the state level, and the US Department of Transportation, specifically, the Federal Highway Administration (FHWA). They serve as public owners directly responsible for planning and design decisions and contracting authority. Academic organizations and think tanks who contribute to furthering knowledge and practice in the field. The relationships between all the different stakeholders can be classified primarily as regulatory, collaborative, competitive, and advisory.

The relationship between the industries can vary from collaborative to cooperative, depending on their position in the product supply chain. For example, concrete and asphalt mixtures are products that can each be used to design and construct pavement sections of comparable functionality, thus making the respective industries competitors. As a result, agencies must intentionally keep pavement type selection fair so that neither industry is disadvantaged inadvertently due to practice guidelines. The stone crushing and aggregate industry on the other hand, tends to have a collaborative relationship with both the concrete and asphalt industries as they provide crushed stone, and coarse aggregate that is used in both asphalt and concrete mixtures. However, all industries tend to cooperate in their governmental advocacy for improved highway and infrastructure funding.

State Departments of Transportation (DOT) and municipal agencies at the federal, state and local level play the role of setting design and construction specifications. In addition, as the owner, DOTs can call for alternative bids based on life cycle costing methods when selecting between competing asphalt and concrete pavement designs. This ensures the most optimal use of taxpayer dollars, while selecting designs that promise the best long-term performance.

At the federal level, under the US DOT umbrella, of specific interest is FHWA's role in supporting state and local governments through financial and technical assistance. Notably, FHWA supports research and collaboration efforts and considers its mission to improve mobility through national leadership, innovation, and program delivery. Specifically, the emphasis on "innovation and program delivery" often positions FHWA to help further best practices and develop guidelines for adopting cutting edge technologies in addition to providing educational briefs. In addition, they have methods of incentivizing the adoption of practices by states through funding mechanisms.

Academic organizations including universities and think tanks are a part of this stakeholder ecosystem though their position is less participatory and more advisory. University faculty often led research into questions that shed light on best practice. Strictly speaking, such positions are considered neutral, with an emphasis on supporting best practices.

Interactions between the stakeholders have led to a combination of forces that have been crucial towards the development and adoption of EPD programs.

1. *Incentive:* Public agencies such as Illinois Tollway with their aggressive embrace of LCA in their overall decision-making process, as well as the implications of legislation in California requiring reduction of greenhouse gas emissions, have created incentives for industry to evolve towards low emission processes. The inclusion of EPDs within the International Green Construction Codes, various rating systems and consumer demand for greener infrastructure is creating demand and incentives for industry to evolve.
2. *Competitive:* Given that concrete and asphalt pavements compete in pavement selection decisions, there has been a movement towards developing "greener" mixtures that are also more durable and cost effective in the long run. This has fuelled the use of recycled materials in both concrete and asphalt pavements. Investments by both industries'

research concerning pavement-vehicle interactions have been spurred by competition to establish the relative benefits of each material type from a life cycle perspective, with an emphasis on vehicle fuel consumption performance during the use phase. In each case, the competitive forces have nudged the industry into accepting life cycle thinking.

3. *Collaborative:* The Sustainable Pavements Technology Working Group effort that has brought agency, industry, and academia to the table has been critical in furthering standards and consensus driven protocols that support the adoption of life cycle thinking in practice.

These three forces have created a greater demand for pavement related EPDs. Broadly, the forces motivating EPD programs are the promise of competitive advantage in the market place, fueled by incentive opportunities provided by regulatory agencies, and often as a collaborative necessity when it is necessary to synchronize best practice with partner organizations and allied industries. In acknowledgement of these forces, the PCR DWG was selected as follows: Asphalt plant owners/producers (three members), representative from Asphalt Institute, and the petroleum industry, both allied collaborative industry (one member each), pavement construction contractor (one member), public agency owners (one member from a state DOT, one from a city municipality), representative from a public regulatory agency (one member) and one asphalt industry expert from academia. The authors of this paper facilitated this committee of ten members.

Technical and Organizational Challenges in EPD Program Development

The process followed the EPD program development guidelines as per ISO 14025:2006. The discussion examines how technical issues regarding system boundary choice, data use and allocation presented challenges for the PCR Development Working Group accounting for different stakeholder interests**.**

System Boundary and Declared Units

The purpose of the PCR is to accommodate the use and implementation of EPDs that will provide the basis for comparing cradle-to-gate environmental impacts for the production of asphalt mixtures. As per the recommendations of ISO 14025:2006, the environmental impacts of all asphalt mixtures that have an EPD compliant with this program can be compared. Therefore, EPDs compliant with this PCR will only reflect differences in plant energy use, material use, and plant emissions, thus providing an effective approach to comparing the environmental impacts of the process used in producing asphalt mixtures. Some of the challenges encountered in defining the system boundaries were related to identifying justifications for cut-off exclusion criteria, as listed below:

1. As this EPD program functions at the B-to-B interface (or cradle-to-gate), a declared unit of 1 short ton of asphalt mixture is used. This is not the same as a functional unit, as the unit is not associated with a functionality of the asphalt mixture.
2. The impact of plant infrastructure is discounted as these impacts are similar across all plants and can be considered as a common overhead. This is justifiable because, differences in plant energy use due to age and/or maintenance requirements are already accounted for as part of the process energy calculations. Hence, capital goods are being omitted in this study, and being considered non-essential to the comparison and not relevant with regard to the decisions that will be supported by the EPDs.

3. No differentiation is being made between a hot asphalt mixture and a warm asphalt mixture, instead for each asphalt mixture the plant production temperature will be declared in the EPD. Reduced production temperature can reduce the energy requirements and thus lower the environmental impacts of asphalt production. Different plants achieve temperature reduction in different ways, however the use of Reclaimed Asphalt Pavement (RAP) and/or polymer-modified asphalts can place a limit to how far the temperature can be reduced. This creates significant variability in the actual temperatures at which so-called lower temperature asphalt mixtures are produced. Therefore, it is preferable if each mixture explicitly declares the production temperature, and the use of any pertinent warm mix technology that has been used to do so.
4. In case of insufficient input data or data gaps for a unit process, the cut-off criteria is being limited to 1% of renewable and non-renewable primary energy usage, and 1% of the total mass input of that unit process, unless a material has the potential of causing significant emissions into the air, water or soil, or is known to be resource intensive. The total sum of neglected input flows is limited and shall not exceed 5% of energy usage and mass.
5. Materials that are less than 1% of the total mass input, but are considered environmentally relevant are chemical additives and polymers.
6. Upstream impacts of extraction, production and manufacturing of any material that is not consumed in the production of the asphalt mixture, and is considered to be "part" of the plant infrastructure, is being excluded. Consumables such as conveyor belts and lubricants are being excluded, as the total consumption of these materials that can be ascribed to a mixture is negligible.

The system boundaries defined by the PCR are strictly cradle-to-gate for asphalt mixtures.

Accuracy, Availability and Use of Datasets

A common impulse among program reviewers is to look for "accuracy" in the data that is used or the outcomes that are measured using the indicators. As the word "accuracy" is best applied to measurements it applies to the reporting of primary data (i.e. the process specific data within the asphalt plant that is seeking an EPD including definite measurable quantities such as annual energy use, total quantities of materials used and observed stack emissions data). Primary data is reported directly at the plants and includes the following items reported over a 12 month period, in the last 5 years:

1. Total asphalt produced at the plant, reported in US short tons
2. Total electricity in kWh.
3. Generator energy - Diesel fuel in gallons or in liters.
4. Plant burner energy (primary and secondary) – used in one or more of the following:
   a. Natural gas use in MCF or MMBTu
   b. Propane used in gallons or in liters
   c. Diesel fuel in gallons or in liters
   d. Recycle fuel oil in gallons or in liters
   e. Biofuels in gallons or in liters
5. Hot-oil heater energy
6. Mobile equipment energy - Diesel fuel use in gallons or in liters
7. Aggregate used in production in US short tons
8. Asphalt binder used in production in US short tons

9. One-way distances travelled to plant for asphalt binder and aggregate (both virgin and recycled), expressed in US short ton-miles.
10. Water used in gallons or in liters.
11. Stack emissions from plant in Lbs. or in Kg.

Pre-determined scenarios: For the parameters that may be difficult to estimate or collect primary data for, the following has been used.

1. Default energy requirements for processing of RAP/RAS is 0.1 gal/short ton or 0.4 kWh/short ton.
2. Distance travelled by RAP/RAS to plant is 50 miles.

The following principles have supported the primary data collection design and process for this LCA study.

1. <u>Ease of Collection:</u> Ensure that the primary data collection process is practical and can be conducted by plant managers. This will reduce the data collection burden in the long run thus improving the possibility of adoption of the EPD program.
2. <u>Data Aggregation:</u> The total annual (12 month period) use of primary energy and material use data will be collected. Daily average data for consumption is also being collected, to provide a validity check for the annual reported data. This allows assessment of differentials in impact categories due to (i) energy use (electricity, natural gas etc.), (ii) the mixture design, and (iii) the distances travelled by the raw materials to the plant.
3. <u>Primary Data Analysis:</u> An analysis of the primary data is provided to examine trends in energy use and their relative sensitivity to moisture and aggregate type in different regions. The results from this analysis can help plants identify ways of improving plant operating efficiencies while also providing a method to identify possible errors in data reporting.
4. <u>Data Quality Assurance:</u> As plant managers are directly reporting all data, it is very important to create checks and balances to insure data quality, and identify possible errors or anomalies in reporting. Hence the following criteria have to be met:
    a. Time period: All data reported must be reflective of plant production over a period of 12 uninterrupted months, within the last 5 years, or the most recent data available.
    b. Documents on file: Primary data reported should be based on utility and energy bills, sales records and other similar documents all of which should be on file and easily accessible.
    c. Correctness Check: Data reported by plants that do not fall within the error margins based on these trends should be checked for reporting errors.
    d. Geography: All data reported for a plant must be specific to that plant. Company averages should not be used.
5. <u>Data Gaps:</u> Efforts should be made to ensure gaps in primary data collection are limited to only those items for which a predetermined scenario has been provided

When the assessment involves data from upstream processes the notion of accuracy becomes difficult to enforce, as the data is derived from estimated upstream life cycle inventories. For example, the upstream impacts due to the extraction and refining of crude oil. These data sets are referred to as secondary data (i.e. data from processes that are within the system boundary but not immediate to the process being studied). Currently life cycle inventories for upstream processes are based on industry wide estimates. Some upstream datasets that come from other chemical industries, such as chemical additives in warm mix asphalt or anti-strip agents, can be difficult to acquire.

Some of these datasets are publicly available while others are proprietary. The publicly available datasets, while most accessible are often presented with limited guarantee or review. The proprietary datasets are available for a fee, but their guarantee of quality is often based on professional reputation and internal review processes that are not always transparent to stakeholders.

The interests of the asphalt industry producers and contractors are to develop the EPD program using free and public datasets. This choice is motivated by two reasons: (i) public datasets are transparent and verifiable, and (ii) being free they reduce the cost of the EPD program. Transparency is important to the industry as it helps establish credibility. This is particularly important as most customers in the asphalt pavement industry are public. Keeping the cost low is also very important as a high price point will deter industry members from getting their mixtures certified through the EPD program. The challenge here is to choose between the following choices along with the accompanying trade-offs:

1. *Use proprietary data:* The risk of data quality is no longer owned by the program, but rather transferred to data providers like EcoInvent or Gabi (Thinkstep, Inc). The trade-off: the cost of obtaining an EPD will go up as the significant cost of the proprietary data will get transferred to the producers and contractors. This may prove to be a deterrent for the adoption of EPD programs in the industry.
2. *Use public data:* In this case the data sets being used in the EPD are verifiable and transparent. This works well when the data sets are from specific public agencies, such as the eGRID electricity production datasets, or the data maintained by the US Department of Energy. However, the US life cycle inventories provided by National Renewable Energy Laboratory, explicitly come without review or guarantee. Therefore, this leaves the EPD program open to criticism. The cost of the EPD remains low and the transparency is attractive.

In addressing the above trade-off, the following principles have supported the secondary data selection process.

1. <u>Uniformity in Use of Life Cycle Inventories:</u> The scope of the PCR supported by this LCA requires asphalt mixtures with EPD from this program be comparable. Therefore, it is critical *all* LCA supporting EPD certified by this program use recommended upstream inventories. Previous work has shown that even with the same primary data a choice of different upstream inventories can create significant differences in the final LCA results. Therefore, it is of critical importance, that upstream inventories specified by the program operator be used in any LCA conducted to support an EPD certified by this program. If this uniformity is not maintained, EPDs provided by this program will not be comparable, thus defeating its goal.
2. <u>Transparency of Life Cycle Inventories:</u> This EPD program intends to respect the spirit of transparency in environmental performance reporting. Therefore, it is of critical importance to this program all upstream data sources be available *publicly* and *economically* to anybody who wishes to reproduce the results of the impact assessment. The program intends to remove barriers to providing third parties access to the process and calculations supporting the underlying LCA.

3. Geography and Regionalization: This effort discussed use of upstream data specific to the United States. US average data is used for electricity. However, for LCA supporting EPDs, it is critical regional energy mixes from eGRID be used to reflect regional differences. Similarly, at this time, the inventory and allocation for asphalt binder is based on the US average, however EPDs for specific mixes should reflect regional allocation factors based on their Petroleum Administration for Defense Districts (PADD) region.
4. Data Gaps: Given the emphasis on transparency and uniform use of the same upstream inventories, a trade-off is public datasets are not easily available for all mixture components – particularly chemical additives and polymers. While these chemical additives are usually less than 1% by mass of the mixture, they cannot be ignored, as they tend to have a disproportionately large environmental impact. Excluding them reduces the scope of the EPD, even though it comes with the recognition that this is a first step towards expansion of scope in future, as and when the data for the chemicals become available. Therefore, the PCR suggested the use of similar chemicals to reasonably approximate the impacts. This also may compromise the EPD, as the choice of an approximate chemical can be subjective and prone to error and potential over estimation of impacts.
5. Dependence on LCI Data from Allied Industries: The life cycle inventory of asphalt mixtures is dependent on upstream data from various other industries, most importantly the petroleum refining industry. At this time reasonable placeholder data is being used for the binder. NAPA is in conversation with Asphalt Institute and as they develop a detailed LCI for the asphalt binder, it will be harmonized as an input to this EPD. Therefore, it is important to recognize this is currently not a data gap, but rather work in progress that will ensure harmony between asphalt mixtures and various critical upstream products.

The above values were arrived at in discussion with the stakeholders in the PCR DWG, and were driven by a desire to balance two goals: (i) develop an EPD program that is accessible and easily adoptable by the industry, and (ii) ensure that the technical rigor of the EPD program is maintained within the limitations of cost and available data. Both are laudable goals, while the latter is a technical challenge requiring a careful LCA, the former is a question of easing adoption of tools such as EPDs that further life cycle thinking.

A trade-off point may prove to be based in a gradual introduction of the program, with each version expanding the scope of mixtures that can be certified while ensuring that the burden of adopting the program is low. However, that is based on two assumptions: (i) the quality and completeness of public datasets will improve over time, and (ii) in future datasets from other industries (like additives) will become available. Both these issues remain outside the control of the stakeholders.

Allocation Factors

The question of allocation in LCA provides an opportunity to examine the role of social collaboration within and across industries. Allocation refers to the process involved in dividing the environmental impacts of a multifunction process between each of the co-products that are produced from it. For example, the crude oil refining process produces multiple products that are used by many different downstream industries. Another situation where the issue of allocation becomes pertinent is when a product serves multiple industrial processes, some of which may be disparate, through the course of its life cycle, i.e. it gets recycled after its first use in one process to be used in a different process one or more times thereafter. The question revolves around how the life cycle environmental impacts of the product are to be assigned across the different processes that utilize the product.

A consistent allocation procedure is necessary to account for the impacts in each of these cases, so that the same impacts are not accounted for twice, and/or that no impacts have been excluded from the accounting process. This procedure is not simply a technical question, as each stakeholder is motivated to be held accountable for as little of the burden for a co-product or recycled product. Hence, ISO 14041 recommends that when it comes to co-products, allocation should be avoided whenever possible, in favor of system boundary expansion (International Orginization for Standardization 1998). System boundary expansion allows for the system boundary of the multifunction process to be expanded to include processes that benefit from one or more of the co-products. This is particularly useful when one of the co-products is replacing a virgin material, allowing the producer of the multifunction process to argue that the co-product produced by them is helping avoid the burden of producing the virgin material it is replacing.

While this technique attempts to view the question of allocation purely as one of mass and energy balance, it is difficult to apply in all cases. The social negotiation of allocation is difficult to avoid. The different perspectives can be examined as follows:

1. *The producer of a multifunction process:* The producer's priorities are shaped by the economic value of each co-product. The fate of a co-product that is not the primary source of economic value is dictated by its demand in other markets. The producer has an interest in profiting from it by selling it or stockpiling it for future use.
2. *The downstream user of a co-product originating in a multi-function process:* The user will want to inherit only the portion of the environmental burden that is associated with the co-product that they are using. The allocation of the impacts can be done either based on the relative economic value of the co-product or based on its relative mass/volume fraction.
3. *The recycler:* The recycler expects to gain credit for creating a re-use opportunity for a waste material from their process, rather than landfilling it. This credit is reflected in the incentives provided to customers for recycling glass and paper.
4. *The producer who utilizes a recycled product:* When the use of recycled or post use material can be used to reduce the use of virgin material, the producer expects credit for reducing the impacts associated with use of virgin material.

The above perspectives present a potential for inconsistent allocation, based in how a material is valued differently by a producer and user. These issues become apparent within the asphalt pavement materials industry as each of the four perspectives are represented.

Asphalt binder is a fractional distillation column bottom product, a co-product of the petroleum refining - a multi-function process. It is a critical component of the asphalt mixture that is produced in an asphalt plant and used as a pavement material. Further, after its first application, the asphalt pavement can be milled and crush and converted into Reclaimed Asphalt Pavement (RAP). RAP can be used to replace virgin aggregate (a quarry product of stone crushing), and also a small, but not negligible portion, of asphalt binder to the new mixture. The following questions of allocation arise:

1. How should the impacts of crude oil extraction, transportation to refinery and refining be allocated appropriately to the asphalt binder?
2. How should the upstream impacts of allocation of recycled material such as RAP be allocated to the mixture?

The response to the first question requires a negotiation between the asphalt mixture production industry and the petroleum refining industry with the objective of arriving at a consistent allocation procedure across all co-products. The challenges framing such a discussion are as follows:

1. A mass based allocation is not entirely fair because, as a heavy fraction, the density for asphalt places it at a disadvantage compared to the lighter fractions that are the primary consumers of energy during distillation. Conversely, it could be argued that as the asphalt does not use any energy during distillation, the energy consumed should be allocated only to the distillates. Both these situations are difficult to defend as they, respectively, either over estimate or underestimate the impacts associated with the binder.
2. An economic allocation based on the relative economic values of each of the co-products can be considered, but this comes with accompanying challenges. All refineries do not produce liquid asphalt binder. Sometimes the heaviest fraction is further refined into lighter fractions. Depending on the demand for asphalt binder, refineries can, from time to time, selectively choose to sell or further refine the asphalt binder. The process energy in refining the binder is significantly higher.

Currently a combination of mass based and economic allocation are applied on a case by case basis while the asphalt industry and the petroleum industry are negotiating the best path forward.

When it comes to the use of RAP, the question of allocation is based on who takes on the credits associated with the use of the reclaimed pavement. An agency may seek to gain credit for using RAP – indeed, green-rating systems such as FHWA INVEST or Greenroads, credit the use of RAP in projects. Even though this is not a closed loop recycling process (i.e., the product is not being recycled into the same pavement), it is within the same industry and hence the cut-off allocation method is used. In this method, the stakeholder recycling the pavement does not get any credit, but gets to avoid the end-of-life impacts (including landfill), while the stakeholder using the RAP to substitute virgin aggregate takes on the burden of preparing the RAP for reuse (fractionating) receives getting credit for the reduced impacts associated with the reduced use of virgin aggregate. As RAP could be generated multiple times, from the same material, this approach ensures that the impacts for each use are allocated appropriately.

The allocation of recycled material becomes more complicated when the industry creating the recycled product is directly in competition with the industry that is using the recycled product. For example, recycled concrete aggregate (RCA) could be used in both asphalt and concrete pavements, although given the competition between the industries; the price of the recycled product varies. The possibility exists where the downstream industry and the upstream industry inappropriately avoid the burdens of first production and manufacturing, each expecting the other to account for it. This will require harmonization between competing industries in future.

Asphalt Mixture Families

The objective of defining mix design families is to illustrate the sensitivity of LCA indicators to marginal changes in asphalt mixture designs. It is likely to serve the following purposes:

1. As an asphalt mixture design support tool to meet LCA targets (e.g., equivalent CO2 emissions in global warming potential), while considering alternative designs.
2. As a method to cluster mixtures that have minor variations in design and environmental impacts.

The asphalt binder has the highest relative impact of all the constituent materials in the mixture. The asphalt binder content in the mixture is a combination of the virgin asphalt binder content and the contributions from recycled materials used such as RAP and recycled asphalt shingles (RAS). As the RAP and RAS contents of a mixture increase, the percentage of virgin asphalt binder replaced also increases. Hence, as a mixture design varies starting with a virgin asphalt mix (with no RAP or RAS), the impacts are varied as follows: there is a reduction in use of virgin asphalt binder and virgin aggregate, there is an added impact due the processing and transport of the RAP and RAS from their respective sources. Over all, they present a reduction in the estimated impacts compared to the baseline impacts for a virgin mix. Of course, the baseline is specific to the primary data inputs for a particular plant, and may vary by region and plant energy use trends.

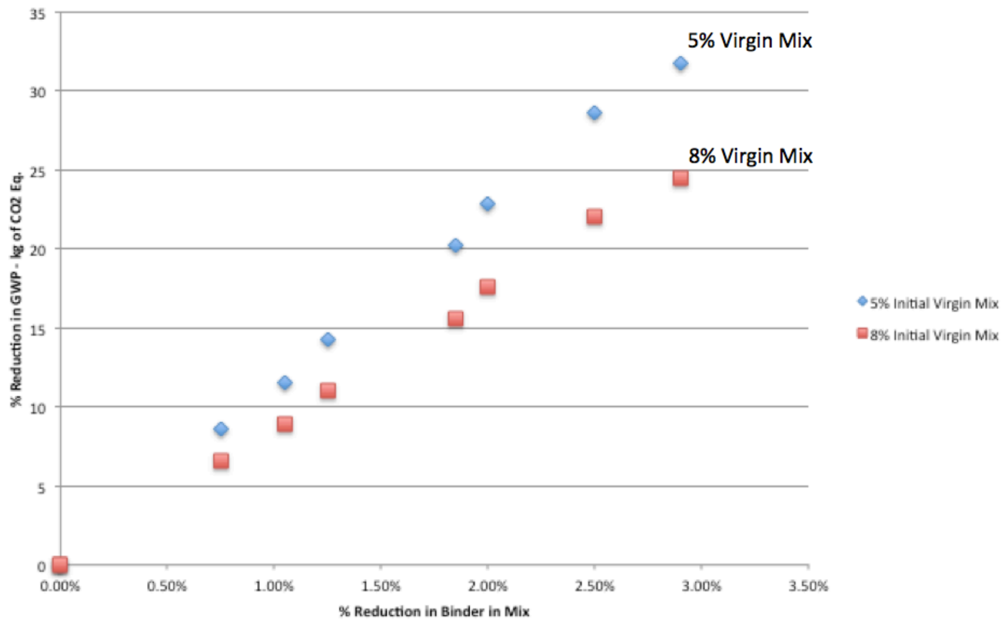

Figure 1: Percentage change in GWP as asphalt binder is reduced[3]

Therefore, a reasonable way to cluster asphalt mixes by environmental impacts is to rank them by reduction in virgin asphalt binder content, with respect to a baseline virgin mixture. For example, starting with a mixture that has 5% virgin asphalt binder, considering a family of mixes (specific to the plant) that can be designed by introducing RAP and/or RAS till the asphalt binder has been replaced by 50%, i.e. the mixture has a 2.5% virgin asphalt binder. Needless to say, the members of such a family can vary in design for different percentages of RAP and RAS. A range for the GWP for the family can be established, allowing mix designers to understand how the GWP changes as they vary their mix designs. Figure 1, illustrates the sensitivity of GWP to the change in mixture through asphalt binder replacement by adding RAP and RAS, starting from two base mixes one with 5% virgin binder and the other with 8% virgin binder for primary data specific to a plant. It is worth reiterating that the trends across a family are dependent on a baseline mix design and plant specific energy use data.

[3] This plot is plant specific and based on working data that has not been finalized yet as this work is in progress. The intention of this diagram is to highlight the trend.

Conclusion

This paper presents the challenges that were addressed by asphalt industry stakeholders who participated in the PCR development process for the NAPA EPD program. The paper discusses the ongoing technical and organizational challenges in addressing the following specific LCA related technical issues: (i) challenges in defining system boundaries, (ii) challenges in identifying sources of transparent and high quality inventory data, (iii) challenges in estimating missing inventory data, (iv) challenges in harmonization with allied upstream material supplier industries; namely the petroleum refining industry, (iv) challenges in allocating impacts to co-products and recycled materials such as asphalt binder, and reclaimed asphalt pavements among others. Each of these factors is discussed, both from the perspective of the technical requirements of the program as well as the stakeholder concerns regarding product economics and production viability.

While these issues are yet to be resolved through accepted long term industry based protocols; at their heart is the tension between implementing rigorously verified, transparent programs that make accurate estimates of environmental and process improvements versus, easing the adoption of life cycle based approaches through a step-by-step approach based in incremental improvement in the estimation process. The LCA process is critical to quantifying environmental impacts of products and processes. However, a lack of standardized LCA rules has been a stumbling block in its adoption in the decision-making process. While the FHWA SPTWG is in the process of identifying pavement industry LCA standards, through a collaborative process, the negotiations of that process closely reflect the industry forces discussed in this paper. As such efforts are likely to have direct impacts on stakeholder economic bottom lines, implementation must be carefully negotiated without compromising the underlying rigor, or deterring long-term adoption.

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