EXECUTIVE SUMMARY

Introduction and Objectives

Policy action on embodied carbon is growing quickly. Already, 2021–2023 has seen an unprecedented number of introduced and passed policies targeting embodied carbon reductions in the building and infrastructure sectors in the United States, Canada, and internationally. Policies aimed at reducing the embodied carbon of building and infrastructure projects and construction materials typically leverage life-cycle assessment (LCA) as a methodology to measure the impacts of a product or project and compare them against a percentage reduction target or embodied carbon performance standard (i.e., global warming potential (GWP) limit).

The effectiveness of policies in reducing embodied carbon relies on the health of the underlying **LCA ecosystem** – the standards, guidelines, data sources, tools, and actors/organizations that constitute the interdependent building blocks of LCA – to create consistent, reliable estimates of embodied carbon to report and benchmark products and projects.

In this report, the CLF lays out a vision for an ideal LCA ecosystem optimized for use as a tool for policy and private sector decarbonization action (focusing on the United States and Canada). This report aims to address existing obstacles to progress through three objectives:

1. **Demystify the standards, data sources, tools, and actors** that make up the current LCA ecosystem.
2. **Propose a roadmap** to maximize the potential of LCA of products and projects as a tool for effective policy.
3. **Highlight existing initiatives** to reduce redundancy and accelerate action.

Existing standards, data, and tools have enabled the growing action and knowledge on embodied carbon we see today, but the shift from voluntary best practice to incentives and regulations has increased the need for access, consistency, and transparency. For effective policy, federal and state government agencies, policymakers, and national/international nongovernmental organizations (NGOs) need to take on leadership to expand these efforts, create more standardization and coordination across siloed sectors, and ensure equitable representation and participation in standards development and programs.

An "ideal" LCA ecosystem optimized for policy would be:

- **open and transparent** through shifting the balance from proprietary data and models to open, high-quality data in public repositories and investing in open data infrastructure;
- **accessible** through expanded access to training, streamlined processes and tools for reporting, and financial support for those who really need it;
- **more comparable and reliable**, with differences in LCA results reflecting differences in the carbon footprints of products or projects, not differences in the data, tools, and methodologies used by practitioners;
- **globally harmonized** to streamline the use of LCA data and tools across borders and sectors;
- **able to keep pace with new materials, technologies, and processes** to better track and support decarbonization and to fill the gaps in current standards, data, and tools by exploring and measuring those new materials, technologies, and processes.

Exploring the Current LCA Ecosystem

The building blocks of the LCA ecosystem are (1) standards and modeling guidelines, (2) data sources, (3) tools, and (4) actors/organizations. The first section of the report provides an overview of each of the following four critical areas related to embodied carbon reductions in the built environment:

- **Foundational LCA:** foundational building blocks related to all scopes and scales of LCA;
- **Product LCA:** assessments of individual products, product types, and materials;
- **Building LCA:** assessments of buildings or parts of buildings (e.g. bays, wall assemblies, structures), also commonly referred to as whole-building LCA (WBLCA);
- **Roadway LCA:** assessments that include pavements and potentially other roadway infrastructure components such as bridges, tunnels, sidewalks, etc. This report considers the more commonly used term "pavement LCA" (FHWA, 2016) to be a subset of "roadway LCA." Roadway LCA is a subset of the larger category of infrastructure.

Key findings are summarized here by section:

Standards: International, consensus-based standards published by third-party standards organizations exist for foundational LCA, environmental product declarations (EPDs), building LCA, and roadway LCA. However, these standards vary in how much prescriptive or detailed guidance they provide to practitioners and are not globally harmonized. Effective LCA standards need to be both flexible – to be useful across different applications and over time – and prescriptive – to yield consistent methods, assumptions, and results across assessments. These two aspects are often in tension with each other. The less prescriptive a standard is, the more likely that the results of an LCA will vary due to differences in modeling practices, rather than differences associated with building materials or the building project. Product category rules (PCRs) are the most critical standards for guiding the consistent implementation and comparison of EPDs. More prescriptive and effective standards are still needed in the United States for building and roadway LCAs that can be referenced by policy and provide enough detailed guidance to result in comparable and reliable results.

Additionally, there is a need for updates to TRACI 2.1 (Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts), a life cycle impact assessment (LCIA) method published by the U.S. Environmental Protection Agency (EPA), and for development of a widely adopted methodology for calculating the benefits of carbon storage and land use and land-use change (LULUC) impacts.

Data Sources: LCAs rely on both primary "foreground" data and secondary "background" data. The terms "foreground" and "background" are relative: one study's foreground data can become another study's background data. For example, a cement supplier collects *foreground data* on its cement facility's operations to generate a cement product EPD. A concrete manufacturer that uses that particular cement product in its concrete mix may use the cement product EPD data as *background data* for the concrete mix EPD. Both the cement manufacturer and the concrete producer would rely on background data on fuels and electricity used at their facilities.

Background data sources that can be used *across* assessment types are critical to creating comparable and reliable results for policy and allowing, for example, EPDs to be used as a data source for building LCA or other product EPDs. Currently, background data sources come from a patchwork of proprietary and public datasets. Federal agencies play a critical role in providing public, transparent background data sources through the Federal LCA Commons and specific agency publications, but the management and updates to these datasets are currently underfunded and understaffed. Federal support in creating transparent, open life cycle inventory (LCI) data sources that can be prescribed by standards will be a critical step to more effective policy.

Foreground data collection is done by a wide variety of actors. Templates for collecting foreground data for products and projects will support consistency and comparability while reducing the time and effort required for project teams.

Tools: Existing tools already support the measurement of the embodied carbon of products, buildings, and pavements. Obtaining more comparable results from tools requires the adoption of national standards and harmonized background data through more up-to-date, comprehensive public background data sources that can be referenced *across* tools. The results from building and pavement/infrastructure LCA tools are not yet collected in a central database for benchmarking or reporting compliance in the United States or Canada.

Actors: A large number of stakeholders make up the LCA ecosystem, including policymakers, government agencies, standards organizations, voluntary programs, rating systems, NGOs and trade associations, academia, LCA practitioners, tool developers, owners / building developers, designers (architects, engineers), contractors, and manufacturers.

A Roadmap: Existing Challenges and Proposed Solutions

When synthesizing the solutions in this document, we found six themes across all areas, summarized in Figure 1: stronger standards, transparent data, increased practice, aligned tools, reporting databases, and better benchmarks. While these can be aligned into sequential steps, this process is iterative. For example, standards are used to produce data and to help align tools and benchmarks, which results in additional knowledge that will be used to improve the standards and further improve future data, tools, and benchmarks.

Each roadmap section of the report includes a summary of existing challenges followed by key steps to address these challenges for each LCA type.

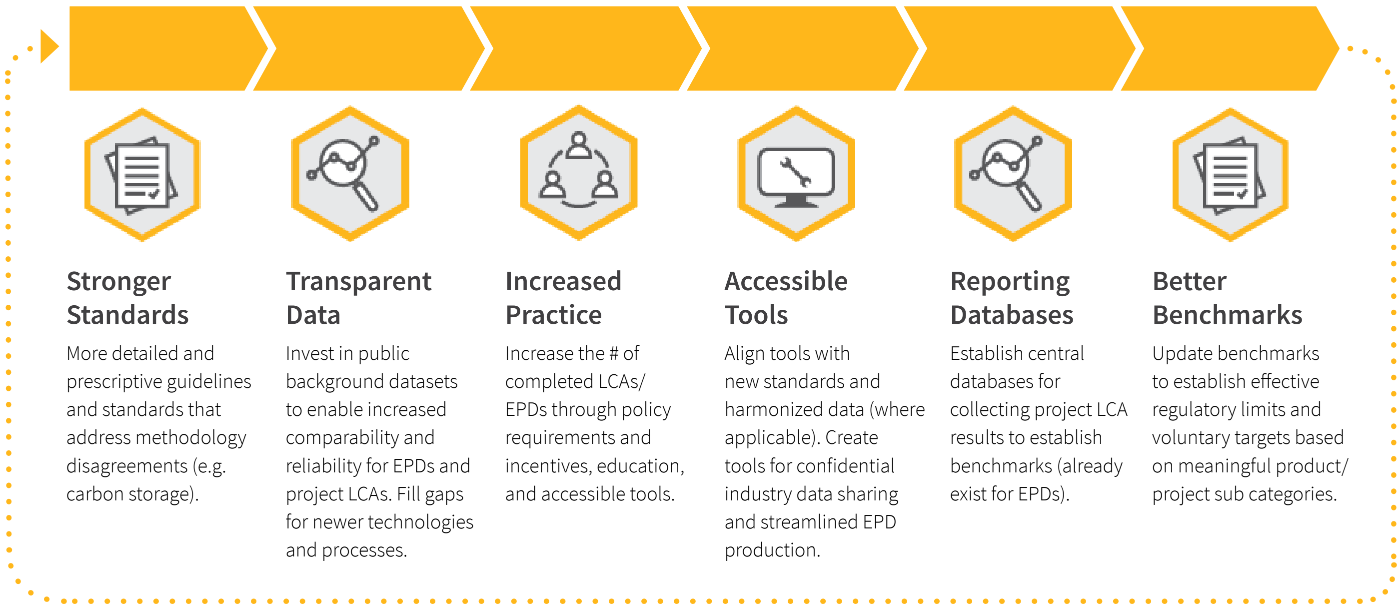

Figure 1. Themes across solutions for advancing the LCA ecosystem The roadmap for each of the four types of LCA addressed in the report differs, but six themes emerge across: stronger stsandards, transparent data, increased practice, accessible tools, reporting databases, and better benchmarks. These steps are sequential, the process is also iterative. For example, standards are used to produce data and help align tools and benchmarks; then we learn and go back and improve the standards which improves future data and tools and benchmarks.

Foundational LCA Ecosystem

Key challenges identified in the Foundational LCA section are the need for more reliable, transparent, and comparable LCA results, more access to LCA concepts, data, and tools, and more LCA education and training. Solutions laid out in this report for addressing these challenges are:

1. Increase access to high-quality, up-to-date, public LCA datasets and models as consistent sources for background data by improving staffing, funding, and planning for sustained updates to U.S. and Canadian federal LCI databases and public datasets.

2. Improve LCA standards to provide more detail and consistency by updating international standards to be more prescriptive on LCI data and LCA modeling protocols, updating the TRACI LCIA method, and developing a consensus standard for evaluating the GWP benefits of carbon storage.

3. Provide more LCA training and credential opportunities through university LCA programs to increase the number of LCA practitioners and support LCA community and practitioner consistency.

4. Fill gaps in available background data to increase the accuracy of LCA results by providing user-friendly tools for industry to report LCA data and LCA models confidentially to create more technology- and region-specific LCI data, filling gaps in public LCI repositories in relation to alternative materials and technologies, and strengthening service life and end-of-life (EOL) scenario data.

5. Improve the interoperability between LCI datasets and LCA datasets and tools through supporting international efforts to adopt a central nomenclature for elementary flows, increase LCI-LCIA interoperability, and move between datasets.

6. Explore opportunities to use LCA to address policy priorities beyond carbon through research and consensus-building on which impact factors outside of carbon are policy ready for addressing land, water, air, and environmental justice priorities.

Product LCA and EPDs Data Ecosystem

Key challenges identified in the Product LCA and EPDs section are the need for more access to EPDs and EPD data, current limitations on PCR development, inconsistency between North American and international EPD requirements, and the scarcity of representative, production-weighted data for establishing emissions thresholds. Solutions detailed in this report are:

1. **Continue to increase EPD availability and accessibility** by requiring EPDs in policy, providing government-funded assistance for EPD production and verification, increasing access to EPD generators, providing more widespread training, and adopting digital formats.

2. **Strengthen EPD standards (PCRs) and PCR development processes to increase EPD reliability and comparability** through supporting program operator funding and collaboration, diversifying stakeholder engagement on PCR committees, strengthening verification processes, and improving individual PCRs to be more detailed and prescriptive (background data prescriptions, standardized specificity requirements and definitions, uncertainty reporting, etc.).

3. **Create or adopt national and/or international PCR harmonization requirements** to support the use of EPDs as data sources for project or other product LCAs through voluntary adoption of requirements across program operators (e.g. UN Industrial Deep Decarbonization Initiative (IDDI), ACLCA Open PCR standard) or mandatory PCR harmonization requirements (federal standard, conformity assessment program, or similar).

4. **Increase access to public EPD generator tools** that allow for two-way integration with public datasets, are aligned with updated PCRs, and provide streamlined EPD development through simple data collection templates for manufacturers.

5. **Increase the availability of industry data for setting policy emissions thresholds** by requiring representativeness and statistical data measures in industry-wide EPDs (IW-EPDs), increasing participation in IW-EPD development, and leveraging industry input to determine appropriate product and region subcategories for emissions thresholds.

Building LCA Ecosystem

Key challenges identified in the Building LCA section are (1) the need for more reliable and consistent building LCA results, (2) the lack of building LCA benchmarks and targets, and (3) policy challenges. Solutions detailed in this report for addressing these challenges are:

1. **Create or adopt a national/North American building LCA standard** with prescriptive practitioner guidance for calculations and reporting, covering scope, modeling methods and assumptions, data requirements, uncertainty, and a common reporting framework.

2. **Fill gaps in data availability for materials and construction processes** through more guidance and training on primary data collection, filling gaps in available LCI data for new or otherwise missing products, providing geography- and/or technology-specific generic LCI data, improving EPDs' viability as data sources, and improving service life and EOL scenarios.

3. **Increase access to consistent and comparable building LCA tools** through working with tool developers to update tools to a national or North American building LCA standard and leveraging harmonized background datasets when possible.

4. **Increase building LCA use, accessibility, and trust** through requiring or incentivizing building LCA disclosure in codes and policies, providing practitioner training, providing general education for nonpractitioners, and building confidence in results through verification.

5. **Collect building LCA results and material quantities in a central database** that aligns with the reporting framework outlined by a North American building LCA standard, and connects to existing repositories and tools.

6. **Set effective and appropriate regulatory limits and voluntary targets for policy** by calculating national and/or regional baselines for limits and Paris-aligned building carbon budgets to inform voluntary targets and incentive programs.

7. **Identify prescriptive building embodied carbon reduction strategies and pathways** to complement GWP thresholds for use by policies and green building certifications that are updated over time as practices evolve and new materials/approaches become mainstream.

Infrastructure LCA Ecosystem

Infrastructure is a broad sector with many unique project types. Roadways are identified as the primary area for current focus related to LCA of infrastructure, with opportunity to expand to other types in the future. Key challenges identified in the roadway LCA section are (1) the need for more reliable and consistent infrastructure LCA results, (2) the limited scope of assessments and tools available, particularly beyond pavement, and (3) the lack of roadway LCA benchmarks and targets. Solutions detailed in this report for addressing these challenges are:

1. **Increase the number of roadway LCAs completed** through adjusting policy to require disclosure of LCA results for certain roadway projects, providing LCA training for transportation agency employees, and providing general education for others.

2. **Create North American infrastructure LCA standards**, beginning with pavement LCA, that prescribe scope, key background data, methods, reporting metrics, and LCIA method. Provide guidance for inventorying. Build on pavement LCAs to expand to roadways and other infrastructure.

3. **Build up public background datasets and fill gaps in data availability** through more guidance on training on primary data collection, filling gaps in available LCI data, providing geography- and/or technology-specific generic LCI data, and improving EPDs' viability as data sources.

4. **Increase access to infrastructure LCA tools** through updating existing pavement tools to align with the national standard, creating new LCA-CAD (computer-aided design) integrated tools, providing digital infrastructure for transportation agencies, and creating new tools beyond pavement.

5. **Collect roadway LCA results and material quantities in a central database** for analysis and benchmarking. Potentially leverage current tool providers or academic institutions to support transportation agencies.

6. **Set regulatory limits and voluntary benchmarks** by calculating national and/or regional baselines as well as Paris-aligned project carbon budgets to inform voluntary targets and incentive programs.

7. **Provide evidence-based prescriptive strategies as complementary pathways** to performance limits in policies and voluntary programs.