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APPLES TO ORANGES:
Comparing Building Materials Data

Liane Hancock, Louisiana Tech University, *lianeh@latech.edu*

ABSTRACT
Why does no digital platform attempt to present all performance and sustainability characteristics for building materials in a way that side by side comparison is possible? Is the breadth of data too difficult to model? If the data could be visualized, what would it reveal? This article describes a digital platform with criteria that represents: look and feel; performance criteria; sustainability metrics; ecolabels and LEED points; access to materials safety data sheets, health product declarations, and environmental product declarations. With more than two hundred criteria, this populated model produces information at the scale of big data. Visual analysis of an initial input of data is most surprising in the area of sustainability, revealing significant voids in data and emerging patterns of disclosure.

KEYWORDS: materials, big data, sustainability, performance

1.0 INTRODUCTION

The building industry relies on the materials sector, which consists of a highly distributed network of companies that are loosely affiliated. Unlike the airline industry, the building materials sector cannot depend upon big manufacturers for standardization in publication of data. Ranging in size from boutique companies to architectural divisions within large multi-national conglomerates, each manufacturer approaches their communications differently and comparison between products is nearly impossible.

This article begins by investigating the specific issues that make the comparisons of sustainability and performance metrics problematic. It discusses the isolation of industries with regards to report of data and the range of terminology that results. This article then asks two questions. Could a single model map all the sustainability criteria being used within the building materials sector? What would visualization of the data reveal about the sector? To assemble the model, we analyzed a range of materials sustainability standards, isolating and listing their criteria. Analysis of individual materials allowed for the real time input of additional criteria, producing a model that dynamically adjusts to changes in the sector. We populated the database with an initial set of seventy building materials to show the quantities of data published publicly by manufacturers. Selected across industries, this data represents both interior and exterior materials in an effort to mirror the sector. Visualizing this data reveals a landscape of big data fraught with substantial voids in information, interlaced with portions of the sector embracing publication of data and harmonization.

2.0 DATA DIALECTS

The data that manufacturers present on their materials is tailored specifically to their individual industry, such as the carpet or glass industry. The terminology and distribution of information isolates these industries from users and from each other. Each industry speaks its own dialect, and there is no infrastructure that gathers and presents these varying terms in a single platform.
While this article emphasizes sustainability criteria, the database also includes performance attributes. A discussion of these attributes provides a good illustration of this variation in terminology. The terms used to describe performance attributes are highly specific, but the

words themselves are barely distinguishable. Color fast, fade resistant, lightfastness, and UV resistance relate to degradation of materials by the sun. The carpet industry and the upholstery industry differentiate the terms because of the specific effects upon their products, but, this vocabulary is nearly homogenous to anyone else. The healthcare industry distinguishes between antibacterial, bacteria resistant, and bacteriostatic; necessary differentiation, but confusing to the uninitiated. For fire resistance, materials bear the label Class 1, 2 or Class A, B, C depending on level of flame spread. The numeric system applies to materials like gypsum board, plywood, and carpet while the alphabetical system applies to roofs, ceiling tiles, some countertops, and wallcovering. Figure 1 provides a list of all performance attributes cataloged during this study.

PERFORMANCE ATTRIBUTES

PERFORMANCE		
Moisture	Absorbent Porous Wicking Treated/Sealed Water Resistant	Waterproof Impervious Moisture Resistant
Acoustic	Sound Reflecting Sound Diffusing Sound Absorbing Sound Deadening	
Fire	Fireproof Fire Retardant Fire Resistant Flame Retardant Flame Resistant Heat Resistant	Smoke Resistant Self Extinguishing Fire Suppression Class A, Class B, Class C Class 1, Class 2
UV (SUN)	UV Resistant Fade Resistant Color Fast Lightfastness	
Durability & Resistance	SURFACE RESISTANCE Bulletproof Puncture Resistant Impact Resistant Scratch Resistant Sag Resistant Wear Resistant Stain Resistant Soil Resistant ANTISTATIC Anti-Static Static Control FRICTION Skip Resistant Skid Resistant Slip Resistant	CHEMICAL Anti-Corrosive Chemical Resistant Bleach Resistant Acid Resistant BACTERIA Antibacterial Bacteria Resistant Bacteriostatic Bactericidal Non-Porous Mildew/Mold Resistant Antimicrobial Anti-Allergenic

Figure 1: Performance criteria cataloged during this study.

2.1 Categorizing Sustainability Attributes

Sustainability attributes describe a wide, yet precise range of criteria. Because the language that describes these attributes is similar, it is difficult to distinguish each attribute from the others. To organize the attributes, we categorized and differentiated them based upon: environmental impacts adopted by existing standards and databases; attributes across life cycle phases; and a method for representing different levels of implementation, from qualitative statements to quantitative metrics.

Across existing materials sustainability standards and materials databases, environmental impacts typically divide into six categories: resource use, energy use, human health and toxicity, emissions, water use, and social accountability. We adopted this logic of categorization for the model. Each environmental impact divides into subcategories. The terminology within these subcategories is particular; but it is also similar enough that it becomes difficult for the layman to distinguish unless seen side by side. For example, materials may present data on resource impacts such as recycled content and reclaimed content, or, in another example, biologically based content and rapidly renewable content. The differences between these attributes are significant, but the language is similar enough to cause confusion. The model also considers environmental impacts across stages of lifecycle: acquisition, manufacturing and construction, use and maintenance, and end of life. All stages pertain to some categories, while other categories limit their application to only certain stages. For instance, energy use generates criteria across all stages, whereas resource use primarily produces criteria across acquisition and disposal.

Different industries and their products use widely different resources, and at different stages. Some require large amounts of raw materials, others are energy intensive, and still others significantly impact water resources. Criteria that do not impact an industry are retained in this model, not deleted. Recording the lack of impact is significant in creating a complete picture for each industry, and providing the opportunity for comparison across industries.

The model also characterizes criteria based upon measurability: disclosure such as published audits and materials formulation; qualitative attributes such as policy or goal based criteria; relative metrics such as reduction in terms of numeric percentage, for instance reduction in energy use over a stated period of time; and quantitative metrics such as specific numeric limits or bans.

With regard to toxicity and human health, and emissions impacts, this method translates industry recognized benchmarks into the following levels[1]: disclosure, reduction, and ban across red lists, chemical families, and specific chemicals. Existing lists include Living Building Challenge, EPA, LEED, and Perkins+Will Precautionary List. Individual chemicals and chemical families are currently listed in the model as building materials are input. At a later date, the expectation is that a list of chemicals will be input into the database. Crowd sourced research projects, such as Tox21 by the National Institutes of Health and Environmental Protection Agency, seek to test the toxicology of chemicals used in manufacturing processes. Eighteen hundred reports were released in 2014[2]. The goal is to release data on ten thousand chemicals, a number easily accommodated by the database discussed in this article.

Figure 2 provides a list of all sustainability attributes included in the model.

SUSTAINABILITY ATTRIBUTES

SUSTAINABILITY ATTRIBUTES	Resource Use	Recycled Content: Post Industrial, Post Consumer Reclaimed/Reused Content Biologically Based Content Rapidly Renewable Content Wood Sourcing Verification Biodegradability/Compostability	Designed for Disassembly Dematerialization Recovery Program: Material, Product, Waste LCI Reductions Raw Material Extraction Impact Study Publicly Disclosed Material Inventory
	Energy	Energy Use: Reduction, Limits Embodied Energy Renewable Energy Offsets Energy Recovery	LCI Reductions: Energy Efficiency Publicly Disclosed Strategy Energy Use Publicly Disclosed Energy Audit
	Toxicity Human Health	Public Disclosure of Toxins, Reduction of Toxins, Ban of Toxins: Through Red Lists, Chemical Families, Specific Chemicals	LCI Reductions Publicly Disclosed Material Formula Third Party Toxicology Assessment
	Toxicity Media Pollutants	Public Disclosure of Emissions, Reduction of Emissions, Ban of Emissions: Through Red Lists, Chemical Families, Specific Chemicals	Embodied Carbon LCI Reductions: Climate Change Emissions
	Water Use	Water Consumption: Public Disclosure, Reductions, Limits Net-Zero Water Waterfootprint Water Recycling	Waste Water Quality Body of Water Protection LCI Reduction: Eutrophication LCI Reduction: Water Use Reduction
	Social Accountability	ISO Compliant Environmental Management System ISO Compliant Quality Management System Employee Training for Ethics	US Labor Practices Adopted at All Global Facilities Supplier Assessment and Verifications Public Statement of on Non-Discrimination Labor Force Metrics Reported
CERTIFICATIONS	ABNT Ecolabel Austrian Ecolabel Blue Angel China Environmental Label Cradle 2 Cradle Eco Logo EU Ecolabel GECA German TUV Green Circle Green Seal Green Squared Green Tag Certified Greener Product Certification Seal GSA Advantage Environmental Products ICC-ES Save Level Natureplus New Zealand Environmental Choice Nordic Swan	NSF 140, 332, 336 SCS Environmentally Preferable Product SMaRT ULE Sustainable Product UN Global Compact EnerGuide Energy Star Energy Guide BASTA eco-INSTITUT Eurofins Indoor Air Comfort FloorScore Green Label Greenguard Air Quality Hazardous Substance Free Mark Indoor Advantage Sustainable Choice AUB-Zertifikat BRE Certified Environmental Profile Ecomark India, Japan	Green Tick NSF Environmental Claims Verification USDA Biobased Product USDA Biopreferred Carbon Free Certified Carbon Reduction Label Cleaner and Green Certification Climate Cool Climatop BPI Compostable OK Compost Smart Watermark WaterSense WaterWise American Tree Farm System CSA Sustainable Forest Management FSC Chain of Custody Certification PEFC Sustainable Forestry Initiative
USGBC LEED	Sustainable Sites Water Efficiency Materials and Resources Indoor Air Quality Innovation in Design Regional Priority		
DOCUMENTATION	Health Product Declaration Environmental Product Declaration Life Cycle Assessment Material Safety Data Sheet		

Figure 2: Sustainability criteria included in the model.

2.2 Standards and Certifications

To create value for a manufacturer's environmentally sustainable efforts, many companies seek certification for their products. There are dozens of standards organizations that issue certifications: Cradle2Cradle, GreenGuard, Nordic Swan, EU Ecolabel, and FSC are just a few. The number and variety of certifications creates confusion. In addition, the standards organizations and their certifications have non-descriptive and indistinguishable names, insignia, and seals, and often these names and graphics are tangentially related to what is being evaluated. With the exception of Energy Star and FSC, standards organizations and their certifications bear little name recognition, except within their specific sector. In 2014, UL Environment published the white article "Claiming Green", which asserts "Not all certifications marks are created equal. Some are actually difficult to decipher, either because the name doesn't explicitly convey the meaning or because they don't include qualifying language that specifies the exact environmental benefit they measure"[3].

Standards organizations certify only a small percentage of market-share across products. Evaluating SMaRT, and Cradle2Cradle, both multi-attribute standards that certify a wide variety of materials, and NSF 140, a multi-attribute standard pertaining to the carpet industry, as of 2015: SMaRT had 65 certified products (29 pertaining to furniture, 31 manufacturers, and last updated November, 2012)[4]; Cradle2Cradle had more than 2000 certified products, of which 130 were building materials and supplies, and 120 were interior design materials and furniture, making a total of 250 materials related to the building industry[5]; and NSF140 had 28 carpet product platforms[6].

Manufacturers choose which criteria they fulfill to achieve the threshold of certification, and then both certifiers and manufacturers do not reveal this information publicly. Many standards award certification at levels, silver, gold, platinum, but these levels of evaluation do not transfer across certifications, adding to opaqueness. Unlike certifications that focus only on a building product, BREEAM and USGBC LEED are different: they certify an entire building. For example, LEED criteria emphasize how materials, products, and systems behave in a building once they are installed, with a small number of criteria focusing upon the sourcing of building materials. Across the 110 criteria Material & Resources environmental product declaration, sourcing of raw materials, and material ingredients, and Indoor Environmental Quality Credit low emitting materials are the main credits that pertain to materials[7]. This is like trying to define manufacturers' efforts on sustainability through a language of nine words.

2.3 Differentiating this Platform from Other Building Material Databases

Materials databases such as MaterialConnexxion, materia.nl, and the UT Austin materials lab provide data on material look, feel, and performance, but are largely silent on sustainability. EcoScorecard offers a database of more than 30,000 materials, but limits sustainability information to LEED points. BEES and Pharos go into great detail evaluating the toxicity of materials, but are silent on other environmental impact categories. Databases that link to building information modeling provide life cycle assessment data that is numeric, calculable, and intended for comparison. However, such tools do not represent qualitative attributes including manufacturer led goal-based initiatives or percentage reductions in environmental impacts over time; nor do they provide data across all environmental impacts. Paula Melton states, "What's typically referred to as a 'whole-building LCA' is in fact nothing of the kind; the term is used loosely to describe a variety of assembly- and building-level analyses that may or may not include typical LCA impact categories… and may in fact only look at the construction phase of the building"[8].

Our model is not a standard; it is a database. Each entry presents information published by manufacturers on sustainability attributes for a building material. The format organizes the data for a material on a single page; it also allows for comparison between materials. Users can evaluate the sustainability of different materials for the same product application. For instance, it can simultaneously provide data for a perforated metal panel system, a wood louver system, and a terracotta rain screen. The platform can also be used to investigate the sustainable attributes of different industries that have similar processes. For example, a user can compare reported data on energy usage during the manufacturing process for ceramic and glass products.

3.0 RESEARCH METHODS

In order to fully describe the range of building materials attributes, it was necessary to design a model for the data that presented: look and feel; performance attributes; sustainability metrics; ecolabels and LEED points; and access to material safety data sheets, health product declarations, and environmental product declarations.

3.1 Creating a Dynamic Environment and Listing Criteria

To design the database, the team at Louisiana Tech University developed a traditional, static, hierarchical taxonomy for attributes such as material makeup, translucency, texture, and finish. When describing performance and sustainability criteria, however, a heuristic method became necessary. While a selection of specifications and standards provided the bulk of the criteria, no one source of information provided all the possible terms. Plus, additional terms became apparent with the individual entry of materials. If the database was implemented as a static tool, the attributes would be limited to what existed at the time that the database was initially modeled. Instead, the model is a dynamic environment. Attributes can be added in real time, and made available to all materials already existing in the database.

To build the sustainability portion of the database, we aggregated sustainability criteria from eight materials sustainability standards: Cradle2Cradle, SMaRT, EU Flower, Good Environmental Choice Australia, Nordic Swan, NSF/ANSI 140, BIFMA, and NSF/ANSI 336. This selection of standards was based on a study completed at Washington University in St. Louis, in 2011, in which the author was a participant. These certifications broadly represented the material sustainability certification landscape, and criteria focused upon the stages of resource extraction, manufacturing, and end of life phases. These standards were analyzed, isolating the criteria required to achieve certification. Each criterion for the standard was listed, establishing sub-categories within the six environmental impacts categories. The model also included: ecolabel and certification; LEED criteria; and criteria emphasizing sustainability during the use and maintenance stage of lifecycle assessment.

3.2 Design of Data Management

The innovation in the design of the database is that the platform accommodates so many types of information. The team recognized that each sustainable attribute can be described with the same four characteristics: a unique name for each attribute, which is common across all building material entries; whether the attribute is measureable; if it is measureable, one or more data entries; and a list of unit(s) associated with the attribute, so that the user can select the appropriate unit of measure for the specific data entry. In addition, each attribute is categorized as an ecolabel/certification, environmental impact based on life cycle stage, or LEED criterion.

Depending upon the type of attribute, the database provides different subsets from the master unit list. For Post-Consumer Recycled Content, a percentage as unit is appropriate. For Dematerialization, a percentage (of decrease in material) and numeric entry of start date to end date, in years, is appropriate. For Embodied Energy, the unit is energy unit/product unit, so for example btu/ft^2. In the case of this example units include: energy unit/linear dimension, energy unit/area, and energy unit/volume such as btu/linear foot, btu/ft^2, btu/ga; including both Imperial and Metric units. By providing an array of units tailored to the specific attribute, data entry is greatly simplified. In addition, a user may select a specific unit type and the database can automatically recalculate and display within that system (Imperial to Metric and Metric to Imperial), facilitating comparison between materials (Figure 3). Exceptions from this structure are toxicity and emissions. In such cases each named attribute requires selection from a drop down menu of emissions terms, redlist(s), chemical family (or families), or individual chemical(s), with each subsequent selection allowing further numeric entry and choice of corresponding unit (Figure 4).

3.3 Design Selection and Populating the Database

The initial dataset of 70 building materials represents both interior and exterior applications. Application, such as exterior cladding or glazing serves as a way to group materials with a range of manufacturers representing each application. The initial dataset included at most one material per manufacturer. Only the data represented on the manufacturer's website in conjunction with environmental product declaration, life cycle analysis, health product declaration, and material safety data sheet furnished information for the model. No assumptions about data were made. For instance, even though silica is locally sourced by the glass industry, glass manufacturers' websites do not mention regional priority; therefore that data was not included. In an effort to represent the range of data that manufacturers publish on sustainability, our selection incorporated a preponderance of manufacturers considered leaders in sustainability. Approximately 17 percent of the 70 materials entered carry a health product declaration, environmental product declaration, and/or life cycle assessment.

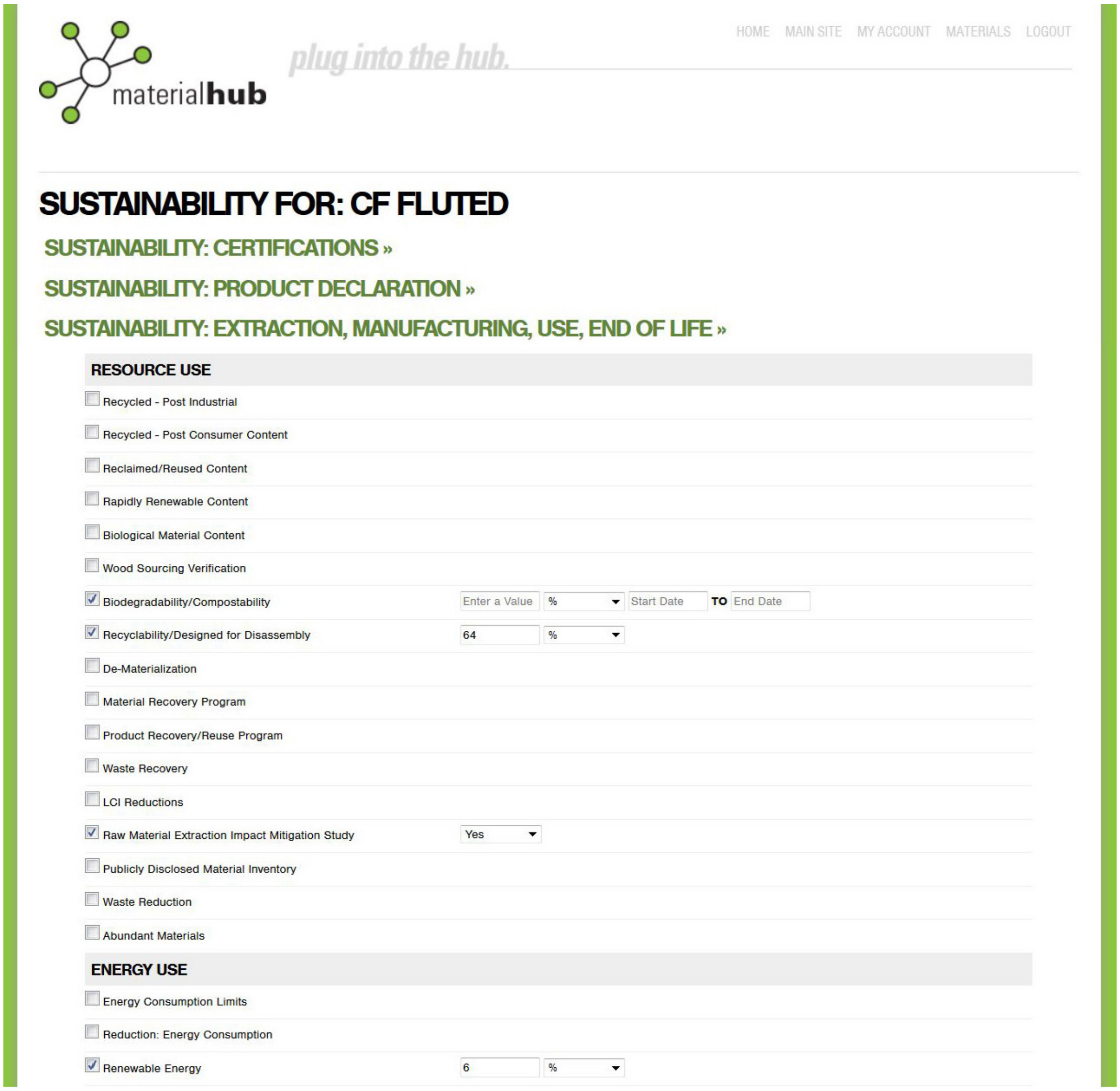


Figure 3: Data entry screen for Resource Use Impact Category. Data is for specific insulated metal panels.

Figure 4: Data entry screen for Toxicity Media Pollutants. Data is for specific insulated metal panels.

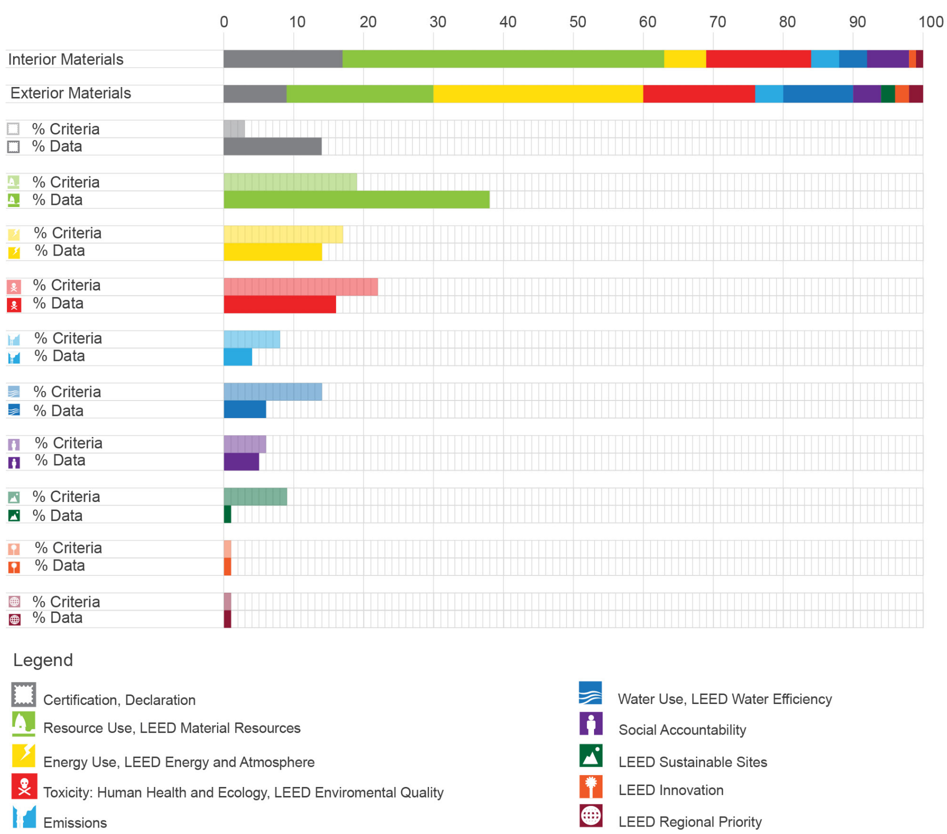
4.0 BIG DATA AND THE GREAT VOID

With more than 150 criteria focusing upon sustainability, the database represents the breadth of sustainability criteria that exist in the sector today (Figure 2). With so many possibilities, the model produces information at the scale of big data. Visualization of the initial dataset of 70 materials in tables demonstrates where manufacturers are reporting data across the sector, allowing comparison. This visualization reveals significant voids in information and emerging patterns of disclosure. For example, even though the initial dataset includes a range of manufacturers who are considered leaders in sustainability, no individual material presents data on more than 22 sustainability criteria, equivalent to 14 percent of possible criteria. That material is a specific type of insulating metal panels.

While manufacturers release data in efforts to increase transparency, there is still great hesitancy to reveal information on material makeup and processing. Under the shield of trade secrets, companies shroud toxic materials and processes that they are uninterested in revealing, leaving a void within the human health and toxicity impact category. Additional concerns now revolve around where liability resides with manufacturers' choices to disclose chemical makeup.

Looking across the data, it also seems that manufacturers predominantly focus upon what data their direct competitors reveal, and lack a broader understanding of the range of metrics that might be studied. For example, the production of glass is an energy intensive process, and so it is understandable that companies do not publish information on their energy usage. However, they are also silent on water use, social accountability, energy recovery, and regional priority for their resources.

Table 1: Distribution of both criteria and initial input data in percentages.



4.1 Environmental Impact Categories

The largest disclosure of data is in the resource use impact category for interior finishes. This is consistent with the fact that the public is most likely to be involved in material selection. They have the greatest awareness of this impact category; and are therefore most likely to ask for a manufacturer's metrics in this area and to respond to marketing on the subject. This impact category is also one of two places that LEED awards points for the selection of building materials (Table 1).

Most companies whose products have a biologically-based makeup focus their sustainability efforts in the resource use impact category; conversely, materials with significant petroleum-based content downplay that content by presenting a broader range of data across impact categories. This seems true of the plastics industry and may partially explain the breadth of data that the carpet industry publishes.

With regard to exterior materials, the greatest focus is upon sustainability through energy performance.

Human Health and Toxicity presents some of the oldest metrics, many of which are established through legislation. Taking Human Health and Toxicity together with LEED Environmental Quality, 22 percent of the criteria are dedicated to this environmental impact category – the greatest percentage among environmental impact categories. It is interesting to note Certifications, and Resource Use each hold a smaller percentage of criteria, but our analysis shows a larger percent of data falling within those criteria in comparison to Human Health and Toxicity. This is testament to their popularity.

Water is one of the most recently implemented impact categories, and has relatively few criteria. Across the initial dataset, the ceramic tile industry and the carpet industry provide the most data reporting on water. Social Accountability holds a relatively small percentage of criteria and data with most of the criteria being rooted in application of US legislation abroad (Table 1).

4.2 Visualization of the Initial Dataset and Disclosure

In Tables 2 and 3, visualization of the data for the seventy materials shows every sustainability attribute for each material and whether the criterion's value is null (blank) or whether data has been entered (colored block). Colored blocks organize according to: certification/ecolabel/declaration; environmental impact category across Life Cycle stages; and LEED categories.

Analysis of the initial dataset indicates significant differences in disclosure across individual industries. For example, the carpet industry shows consistency, reporting data across nearly all impact categories. In contrast, wallcovering and upholstery companies deliver almost no information on sustainability initiatives. One would expect that since both industries employ woven goods, they should publish similar data. This difference may be based on widely different supply chain management.

With regard to size, it seems that large manufacturers have the financial resources to test for a broad range of criteria, producing data across all sustainable impact categories. On the opposite end of the scale, a number of small companies embrace collecting data on sustainability as a way to differentiate themselves from larger firms. In a few cases the data reveals direct competition between firms that have nearly indistinguishable products.

Table 2: Visualization of input data for 26 exterior materials.

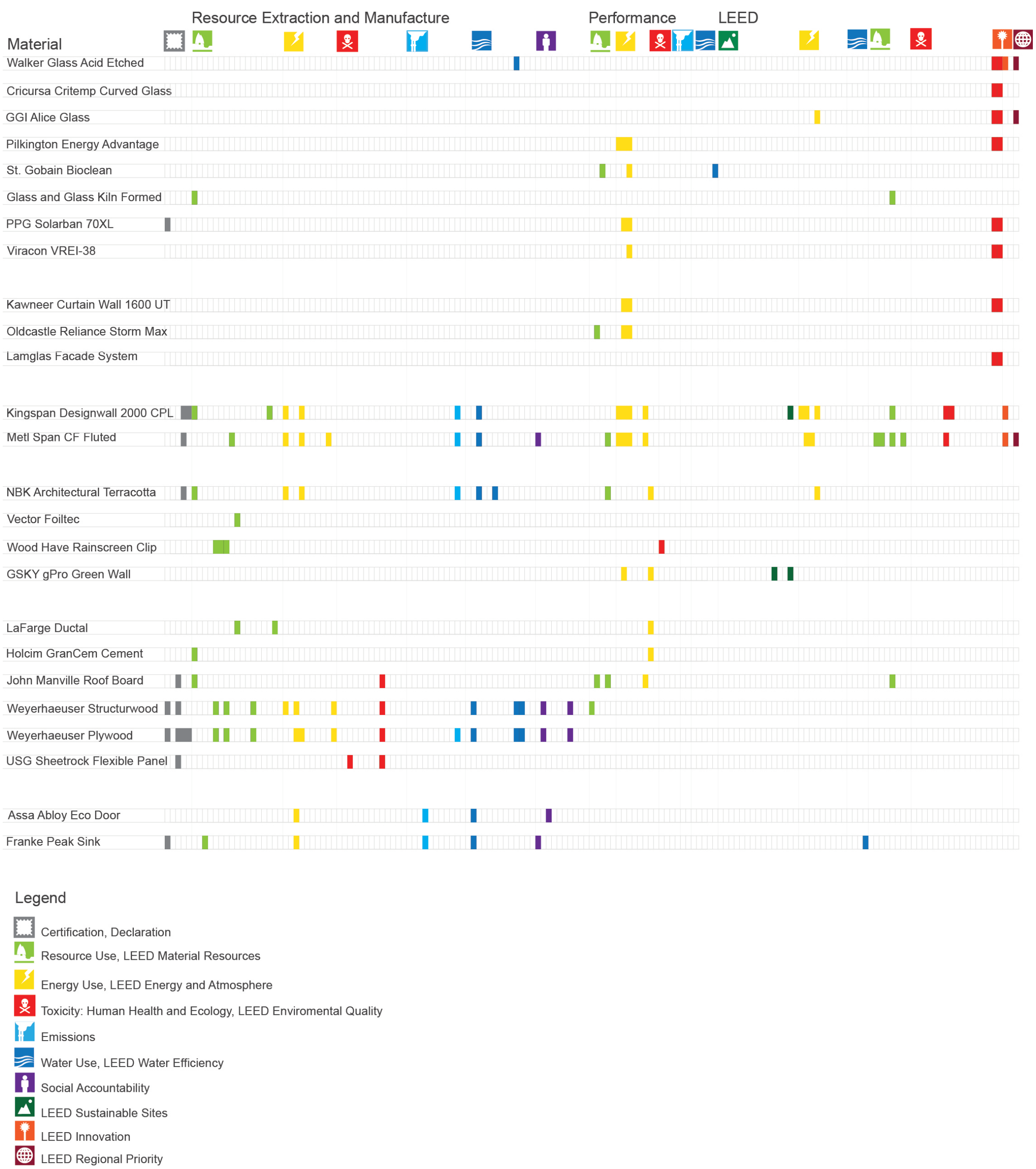
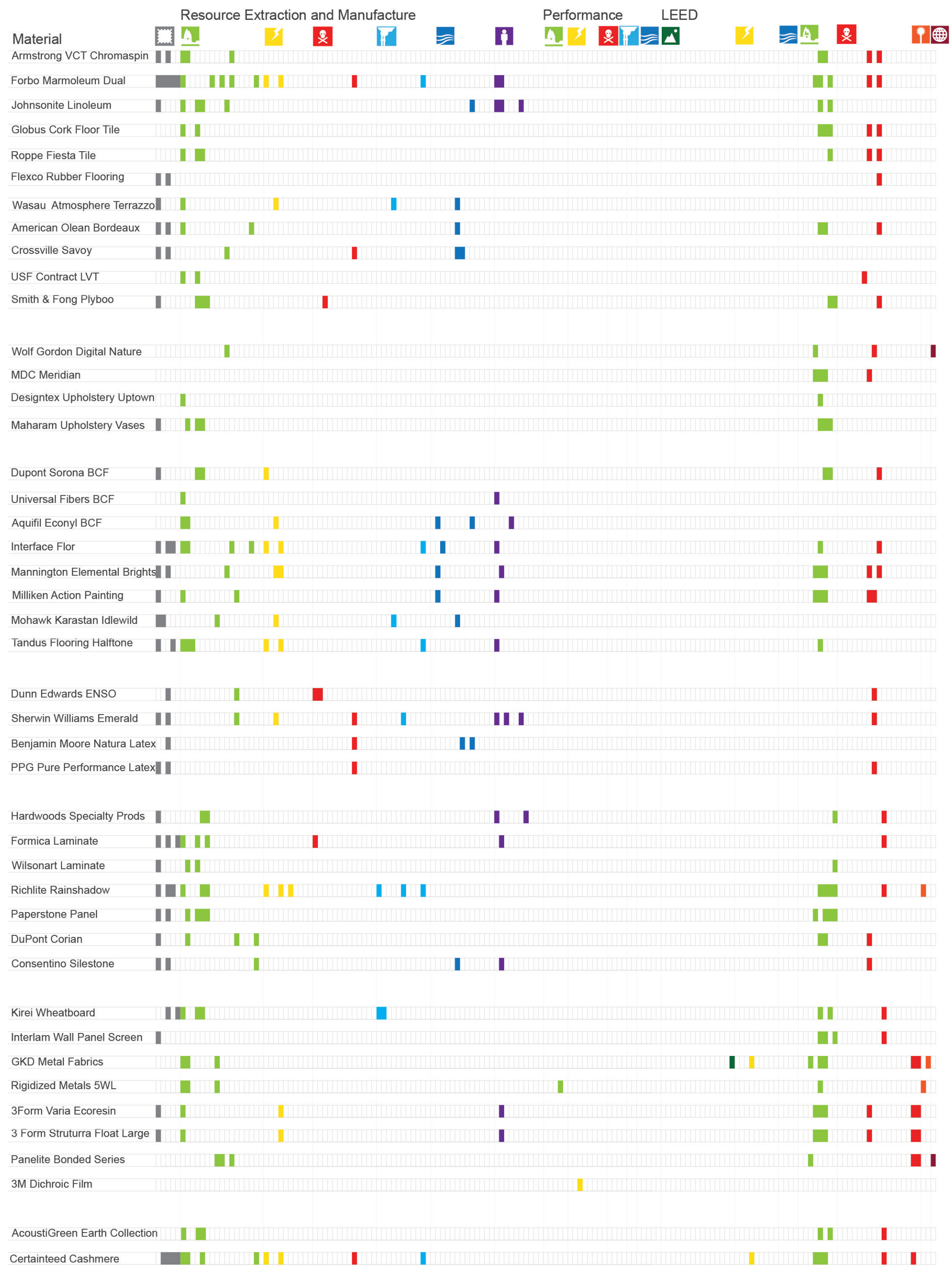


Table 3: Visualization of input data for 44 exterior materials.



5.0 CONCLUSION

This study establishes a database that includes the breadth of sustainability criteria across the building materials sector. Instead of simplifying information, we have created a dynamic network of data that provides a snapshot of the current landscape of sustainability criteria for building materials. To accomplish this, the team designed a simple data structure that accommodates the range of criteria used by manufacturers and material sustainability standards, from qualitative attributes to numerical metrics. Additionally, the design of the data structure enables categorization of these attributes across environmental impacts and lifecycle stages.

An initial attempt to compare materials across industries appears to reveal industries that are too specific; where variation in data reporting is too large; and that attempts to compare products across industries will be apples to oranges. Additionally, with so many sustainability attributes to evaluate, simultaneous consideration seems certain to result in confusion.

However, when we widen the frame and visualize the data across all the attributes, the voids become as important as the data itself. Industries are not disclosing different data, instead the data is episodic across the range of possible attributes, and the individual disclosures do not align. Once the voids become part of the data, then it is possible to compare products across industries. The simultaneous consideration of all the sustainability attributes does not cause confusion because the populated database results in hardly any information. Analysis reveals disclosure of data at several scales, and through discrete strategies: across individual environmental impacts; within specific industries; and at the scale of direct competition between corporations. As a result, visualization of the populated database accurately exhibits the atomized approach by which the sector discloses data across sustainability attributes today.

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