Packaging Life Cycle Inventory Data Review

Prepared for:

The Sustainability Consortium Packaging Working Group

Prepared by:

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and the

Sustainable Packaging Coalition

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This report has been prepared by Quantis, a team of world-leading experts in the field of environmental life cycle assessment. Quantis works with companies, governments, and other decision makers to identify and implement the right actions for minimizing the environmental footprint of products and services. Founded in 2009, the firm maintains its global headquarters in Lausanne, Switzerland with branches in Boston, Montréal, and Paris. Quantis provides the highest level of proficiency in delivering state-of-the-art analysis and solutions for organizations striving to be leaders in the global sustainability effort. This report has been prepared by the United States office of Quantis. Please direct all questions regarding this report to Quantis USA.

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The Sustainable Packaging Coalition® (SPC) is an industry working group dedicated to a more robust environmental vision for packaging. Through strong member support, an informed and science-based approach, supply chain collaborations and continuous outreach, we endeavor to build packaging systems that encourage economic prosperity and a sustainable flow of materials. The SPC is a project of GreenBlue®, a nonprofit that equips business with the science and resources to make products more sustainable.

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EXECUTIVE SUMMARY	Packaging Life Cycle Inventory Data Review

Context

The Sustainability Consortium (TSC) is working to create, analyze, and communicate comparable and standardized information about the life cycle of consumer products through the development of Sustainability Measurement and Reporting Systems (SMRSs) under various sector-based working groups. A primary need of the SMRS effort is life cycle inventory (LCI) data on packaging and other materials to enable sustainability measurements and reporting based on life cycle assessment (LCA). In order to leverage existing data, a review has been performed of available life cycle inventory (LCI) data for materials, manufacturing, and end-of-life steps related to packaging. The overall objective of this work is to provide informational support to the Packaging Working group in developing the Sustainability Measurement and Reporting System (SMRS).

This data review is global in scope and covers data related to packaging. All available databases and literature were reviewed, including, for example, the databases Ecoinvent, GaBi, Plastics Europe, US LCI, and the Korean LCI database. In all, the review looked at over 100 pieces of literature, 65 databases and software modules, and thousands of individual datasets. Bibliographic information and availability was recorded for databases and literature. In addition to data availability, the review includes information about the datasets to evaluate data quality: geography; time period; transparency; data completeness; and descriptions of technological relevance and data sources. The amount of data for each material and geography was then compared with global production of packaging materials.

Results

The main findings cover material representativeness; data consistency, transparency, and documentation; end-of-life processes; geographic representativeness; and data access and format.

Material representativeness: While many datasets exist for the basic packaging materials (e.g. aluminum, steel, polyethylene, and PET), there are significant gaps in the existence of any data for many other materials used in packaging, including: bio-based materials such as biopolymers and natural fibers; highly packaging-specific materials and processing steps like composites and composite-making processes; and ancillary materials such as adhesives, inks, coatings, and additives.

Data consistency, transparency, and documentation: To be used within the SMRS framework, aspects of data such as system boundaries and allocation methodology must be consistent across a product category, and data must be transparent and well-documented. This review demonstrates that there is some diversity among the various data sources. To improve and validate the consistency within this data will require a large effort. Taking advantage of those databases that have rather broad and consistent coverage already, such as GaBi and Ecoinvent, is one important strategy to mitigate this issue.

End-of-life processes: The end-of-life disposal of packaging may have important implications for and opportunities to improve its sustainability performance. In general, there is a lack of adequate information on end-of-life, and particularly recycling for geographies other than Europe. The variation in disposal may be greater across geographies than the variation in production, yet there is a narrower geographic coverage for disposal.

Geographic representativeness: The majority of data is available for production in Europe, with some in Asia and North America. However, data for regions outside of those areas is scarce. While data sets can be adapted to different geographies (such as by modifying sources of electricity, etc.), this is not a full solution and risks giving a false sense of geographic completeness.

Data access and format: Not all data is freely available, and issues related to licensing for multiple SMRS users will need to be taken into account. In addition, while there are efforts to establish a common data format, it should be noted that use of data from many data sources will require significant and ongoing effort to maintain updated data in a uniform format.

Recommendations

A rather comprehensive and controlled system is needed for providing default data to be used within the SMRS and for governing the conditions under which participants can deviate from this prescribed path. The first element needed is a plan for improving the overall availability and quality of LCI data for packaging. A second element needed is a mapping of the pre-existing and newly developed data to the possible range of conditions under which production may occur in an SMRS user's product system. Further effort is needed to ensure consistency in the format and availability of data for users. Finally, clear guidance and perhaps an assurance process are needed to support users who would make an exception to the prescribed data.

The creation of the data system described may require a multimillion dollar investment. While TSC may not currently have the resources available to directly build the data structure needed, it may be in the position to stimulate development of data to fill important gaps, and to assemble and curate the existing data into a cohesive structure. It will take a significant amount of time to put this structure in place and so efforts in this direction are needed to further inform the vision of the SMRS framework.

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1 Motivation

The Sustainability Consortium (TSC) is working to create, analyze, and communicate comparable and standardized information about the life cycle of consumer products through the development of Sustainability Measurement and Reporting Systems (SMRSs) under various sector-based working groups. Because packaging is a topic that intersects all categories of consumer goods, TSC has formed a Packaging Working Group (PWG) as a cross-cutting effort to apply a consistent approach to the handling of packaging within the SMRS development process.

A primary need of the SMRS effort is life cycle inventory (LCI) data on packaging and other materials to enable sustainability measurements and reporting based on life cycle assessment (LCA). Containers and packaging materials are environmentally significant and important to include in life cycle assessments. Although usually a lesser contributor to environmental impact than the products it protects, in 2010 containers and packaging comprised the largest portion of municipal solid waste generated in the United States – 75.6 million tons or 30% by weight.[1] In many cases, packaging can directly contribute to the environmental impact of consumer products and in many other cases, it can indirectly effect a product's impact by influencing product damage rates or consumer use of the product.

A recently finalized effort under the Consumer Goods Forum (CGF), the Global Protocol on Packaging Sustainability 2.0 (GPPS 2.0), brought together a broad group of leading retailers, consumer goods manufacturers, and packaging converters to collaboratively produce a set of metrics for supply chain packaging sustainability. This effort built on prior work to define metrics for sustainability in packaging undertaken by the Sustainable Packaging Coalition (SPC). The GPPS 2.0 includes a significant focus on LCA-based metrics, providing a general taxonomy of the areas of environmental impact that might be considered and guidance on interpreting the currently available measures for each. While the GPPS 2.0 report provides guidance on definition and interpretation of LCA-based information, it intentionally stops short of prescribing a given set of metrics to be applied in all cases or of recommending a certain set of LCI data for a packaging system. This limitation is due in part to a lack of consensus on these matters and to a rapid evolution of both LCI data and life cycle impact assessment (LCIA) methodologies. In the case of LCI data, the limitation is also due to a lack of a clear and complete view of what LCI data exists, how these data vary by region, and how suitable various data sources are for use in such efforts.

It is useful at the outset of this data review to consider the specific requirements of TSC's SMRS. While the GPPS 2.0 was intended to help assist in specific discussions about the supply chains for individual packaging systems, the intention of TSC's SMRS is much broader: to report consistent measures on all consumer goods within a given category. The ultimate intention is two-fold: (1) to provide a useful tool for product manufacturers to use internally for improvement of their product's environmental

[1] United States Environmental Protection Agency, Office of Solid Waste. (2011). *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Tables and Figures for 2010.* Table 9. [http://www.epa.gov/epawaste/nonhaz/municipal/pubs/2010_MSW_Tables_and_Figures_508.pdf]

performance, and (2) to provide retailers, consumers, and others with a useful tool to make performance comparisons within a product category. Typically, LCA results produced from independent sources are not viewed as inherently comparable due to an expectation that variation in the data sources and in the scope and methodologies chosen make it difficult to distinguish a true difference from one caused by the differing techniques. ISO 14044 presents a framework for making inter-product comparisons. This framework relies heavily on external expert review to validate that the comparison is based on reasonably consistent data and methods and that the scope and methodology of the study is chosen in a way to adequately achieve a true comparison of environmental performance. In the case of TSC's SMRS, this role of assuring consistency and relevance of data and methods is attempting to be taken on directly through much more stringent guidelines on how the calculations are done and perhaps even by internalizing much of the calculation within standardized computer models. The result will surely be much higher comparability between results than exists today for any two LCA results taken at random from companies competing in a given product category. The key question is will they be good enough to foster decision makers' confidence that meaningful differences are shown. To consider the question from a more useful angle: *what are the necessary characteristics of TSC's SMRS that would enable such confidence?*

The present evaluation considers only the question of data requirements and does so only within the context of packaging. It does not directly address concerns around standardization of scope and methodology within SMRS and it does not speak directly to non-packaging related materials or processes. The lack of adequate LCI data, the variability in quality of LCI data, and especially the lack of a reasonable understanding of the state of existing LCI data are potentially serious barrier in the SMRS - endeavor. The main considerations are first to evaluate what LCI data exists with regard to packaging, what are its characteristics, and then to consider how these compare with the necessary requirements to support TSC's SMRS.

In order to begin to fill this gap and to leverage relevant existing LCI efforts toward the goals of the SMRS project, this study surveys existing LCI datasets related to packaging materials and processes. Although the use of the information provided here as part of the SMRS effort is not fully determined, these datasets may be adopted into an approved LCI database to benefit member organizations and to promote sustainable packaging across all consumer goods sectors. This study also identifies major gaps in LCI datasets and prioritizes research for developing a more complete system of data resources for including packaging in lifecycle assessments of consumer goods. It is a first effort under TSC to understand the state of LCI data and may also serve as a paradigm for similar efforts to understand the status quo of LCI data within other sectors.

2 Goals

The overall objective is to provide information support for the development of a strategic direction for the Packaging Working Group. This includes:

- Determining the current availability of process-based life cycle inventory (LCI) data on packaging materials, processing, and end-of-life;
- Describing these data in terms of geographic and temporal coverage, as well as quality-related information about the data such as transparency and others;
- Evaluating critical elements missing from within the available LCI data;
- Prioritizing future research so that the most critical data gaps are filled first.

3 Study scope

This review is global in scope. The survey of data availability and quality focused on the materials and packaging formats listed in Table 1 and on the processes and end-of-life treatments found in Table 2. These lists originated with the TSC PWG and were expanded through consultation with the SPC and during investigation of available datasets. This list includes major packaging materials and processing steps, with asterisks for high-profile materials.

Table 1: Materials included in survey

Materials		
Aluminum*	Label	Polyethylene (PE)
Bamboo	Low Density Polyethylene (LDPE)*	Polyethylene Terephthalate (PET, PETE)*
Biaxially Oriented Polypropylene (BOPP)	Limited Use Pallet (One-Way, odd-size, etc)	Polyhydroxyallkanoate (PHA)
Biopolymer	Liquid Packaging Board	Polylactic Acid (PLA)*
Blended plant based bio-polymers (e.g., PET with PE from sugar cane molasses)	Linear Low Density Polyethylene (LLDPE)*	Plastic, unspecified
Boxboard with wet strength additive	Medium Density Polyethylene (MDPE)	Plastic ledge
Celluose film	Medium Density Fiberboard	Plastic pallet
Chipboard	Metallized Oriented Polypropylene (OPP with a very thin layer of aluminum)	Plywood
Coated Freesheet (e.g., high-end magazine)	Metallized Polyethylene Terephthalate (PET with a very thin layer of aluminum)	Polyurethane (flexible) foam
Coated Groundwood (e.g., standard magazine)	Modified Starch - Mater-bi	Polyurethane (rigid) foam
Corrugated board, unspecified*	Multi-layer film – majority nylon	Polyurethane (PU)
Corrugated: Bleached	Multi-layer film – majority polyester	Polypropylene (PP)*
Corrugated: Mini Flute	Multi-layer film – majority polyethylene	Polystyrene (PS)*
Corrugated: Moisture Resistant - Wax Alternative	Multi-layer film – majority polyethylene terephthalate	Polyvinyl Chloride (PVC)*
Corrugated: Moisture Resistant - Waxed	Multi-layer film – majority polypropylene	Pulp
Corrugated: Pre-Printed	Multi-layer film – majority styrenic resins	Recycled Folding Boxboard
Corrugated: Semi-bleached	Nylon*	rHDPE (High Density Polyethylene – recycled)
Corrugated: Unbleached	Oriented Polypropylene (OPP)	rPET (Polyethylene Terethalate - recycled)
Cotton	Paper, unspecified	Slip-sheet – paper based
Dimensional Lumber	Paper Laminate (Paper/Poly/Foil/Poly)	Slip-sheet – polymer - LDPE
Expanded Polystyrene (EPS)	Polymer Laminate (Polymer/Foil)	Solid Bleached Sulfate (SBS) Board
Ethylene Vinyl Acetate (EVA)*	Paperboard, unspecified*	Solid Unbleached Sulfate (SUS) Board -- Cardboard*
Plastic film	Paperboard: Coated Recycled	Starch
Glass*	Paperboard: Coated Bleached	Steel*
High Density Polyethylene (HDPE)*	Paperboard: Coated Unbleached Kraft (CUK)	Styrene Acrylonitrile copolymer (SAN)
High Impact Polystyrene (HIPS)	Paperboard: Solid Bleached Sulfate (SBS)	Supercalendered (e.g., newspaper inserts)
Hemp	Paperboard: Uncoated Bleached Kraft	Testliner
Kraft Paper	Paperboard: Uncoated Recycled (URB)	Uncoated Freesheet (e.g., copy paper)
Kraft Paper, Bleached	Paperboard: Uncoated Unbleached Kraft	Uncoated Groundwood (e.g., newsprint)
Kraft Paper, Unbleached	Polycarbonate (PC)	Wood*

Packaging Formats	
Aseptic Packaging - Paperboard Based (TetraPak)*	Moulded Cellulosic Fibres (e.g. bagasse, palm, reeds, rice hull plant based polymer)
Aseptic Packaging – Resin Based	RPC (Reusable Plastic Container) HDPE
Composite Cans (fiber, metal, and/or plastic components)	Slip-sheet – polymer - HDPE
Molded Pulp Packaging	Wood pallet

* denotes high-profile materials

Table 2: Processes and End-of-Life treatments included in survey

Processes	
Can Making - Aluminum	Injection Molding
Can Making - Steel	Injection Stretch Blow Molding
Conversion of carton	Laminating Cardboard-Aluminum
Conversion of corrugated boxes	Laminating foil (dry)
Conversion of paper bags	Laminating Paper-Aluminum
Conversion of shrink wrap	Laminating Paper-Aluminum-PE
Conversion of stretch wrap	Laminating Paper-PP
Corrugating/Lamination	Laminating solvent free
Die Cutting	Metal Sheet Rolling
Blow molding	Molding pulp (electric and/or steam)
Extrusion Blow Molding	Palletizing
Extrusion, plastic film	Printing
Film Blowing	Printing, Flexographic
Foaming, expanding	Printing, Gravure
Glass Making	Stretch blow molding
Heat adhesion	Thermoforming
Injection Blow molding	Tube extrusion
End-of-Life	
Combustion, unspecified	Mechanical Recycling
Combustion with energy recovery (WtE)	Landfill, unspecified
Combustion without energy recovery (incineration)	Traditional Landfill Disposal with Methane Recovery
Compost (industrial)	Traditional Landfill Disposal without Methane Recovery

All available databases and literature were reviewed. This includes: proprietary databases maintained by consultants and research institutes like Ecoinvent and GaBi; industry databases such as Plastics Europe; and national databases such as US LCI, Korean LCI, and the Chinese Life Cycle Reference Database (CLCD). Economic input-output databases were not included in the review, as the information they contain is, by design, generic and aggregated for whole classes of materials and services. The data from input-output databases has too low of a resolution for the purposes of the SMRS program. The complete list of databases is found in the attached spreadsheet.

4 Approach

The approach of this survey occurred in three distinct phases. Phase 1 was a discovery phase, which focused on locating available datasets and literature. During Phase 2 the datasets and literature were evaluated, and in Phase 3 a gap assessment was performed.

Phase 1: Discovery

Discovery of literature included searching Internet and journal publications. Discovery of databases and datasets included extensive investigation of existing lists of databases and LCA software. These lists include the European Commission's Joint Research Centre LCA Resources Directory,[2] the United Nations Environment Program (UNEP) Database registry,[3] the U.S. Environmental Protection Agency's LCA Resources list,[4] and the resources list in life-cycle.org.[5] The databases and software found in these lists were investigated online. To supplement this research, Quantis individually contacted the managers and developers of these tools with questionnaires. In all, the review looked at over 100 pieces of literature, 65 databases and software modules, and thousands of individual datasets. Bibliographic information and availability was recorded for both databases and literature.

Phase 2: Review

To complete the review phase, Quantis developed evaluation templates for databases, datasets, and literature. This evaluation template captures indications of the reliability and accuracy of the data as well as information appropriate for a pedigree matrix.[6]

Measures of pollutant releases or resource uses are rarely performed specifically for an LCA study. Most or all data used in an LCA therefore reflect measurements made of events that are judged to be similar or **representative of those being modeled. Indicators of data representativeness include the degree to which the time frame, geography, and technology mix of the data matches the system being studied. When performing an LCA study, a pedigree matrix is used to evaluate data quality of datasets used, using indicators of the reliability of the data and the representativeness of the data. The pedigree matrix for rating inventory data appears in Table 3, and a complete discussion of this topic can be found in Frischknecht, et al (2007).[7]**

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[2] European Commission – Joint Research Centre. LCA Tools, Services and Data. LCA Tools [http://lca.jrc.ec.europa.eu/lcainfohub/toolList.vm] and LCA Databases [http://lca.jrc.ec.europa.eu/lcainfohub/databaseList.vm] were investigated.
[3] Found online at [http://lca-data.org:8080/web/guest]
[4] Found online at [http://www.epa.gov/nrmrl/lcaccess/resources.html]
[5] LCA Links! Links to LCA topics found on the web. LCA Resources [http://www.life-cycle.org/?page_id=24]
[6] A "pedigree matrix" is a commonly used tool for evaluation of the quality of LCI data. It provides a standardized approach for relating qualitative evaluations of the LCI data to quantitative estimates of the uncertainty of the data.
[7] Frischknecht R., et al (2007). Overview and Methodology. ecoinvent-report No.1. Swiss Center for Life Cycle Inventories, 2007. P43-47

Table 3: Pedigree matrix used to assess the quality of data sources, derived from Weidema & Wesnaes (1996) [8]

Indicator score	1	2	3	4	5
Reliability	Verified data based on measurements	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on assumptions	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate
Completeness	Representative data from a sufficient sample of sites over an adequate period to even out normal fluctuations	Representative data from a smaller number of sites but for adequate periods	Representative data from an adequate number of sites but from shorter periods	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Representativeness unknown or incomplete data from a smaller number of sites and/or from shorter periods
Temporal correlation	Less than 3 years of difference to year of study	Less than 6 years difference	Less than 10 years difference	Less than 15 years difference	Age of data unknown or more than 15 years of difference
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown area or area with very different production conditions
Further technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials but same technology	Data on related processes or materials but different technology

It should be noted that many aspects relating to the quality of LCI data are context-dependent. While some aspects of quality are inherent in the data (e.g., the accuracy of the original underlying measurements), other aspects of data quality depend on how well the data represent the case in question. Data that are of high quality when used in one study may be low quality for another study. These aspects cannot be evaluated absent the relevant context and so this effort has attempted to provide the necessary information to judge a dataset's applicability for use in a future LCA study's context (e.g., specifying geographic coverage). This effort does not indicate whether the geography represented by the data is "good" or "bad", as that evaluation can only be made in application of the data.

The dataset, database, and literature evaluation templates developed for this work were reviewed by the Packaging Working Group and shared to benefit similar efforts in other sectors of The Sustainability Consortium.

[8] Weidema, B.P., Wesnaes, M.S., 1996. Data quality management for life cycle inventories - an example of using data quality indicators. *Journal of Cleaner Production.* 4, 167-174. Retrieved from http://www.nims.go.jp/ecomaterial/LCA/discussion/bow/jcpdqi.htm

The review proceeded by examining a database or software module for its appropriateness for inclusion in this review, and then cataloging and evaluating datasets within appropriate databases or software. Databases and software modules deemed inappropriate for inclusion are those that are either no longer available, that aggregate or use existing external datasets, that are input-output databases, or that do not carry packaging-relevant data (*i.e.*, only construction materials). The attached spreadsheet ('Databases' tab) includes all databases examined.

A total of 16 databases were deemed appropriate to the study, and, from them, approximately 1300 datasets are included in the review. The attached spreadsheet ('datasets' tabs) includes this complete list. When deciding if a dataset is applicable to a packaging material or process and should be included in the review, the decision was made to include most datasets. The list was later refined, and a conservative removal of duplicate datasets (those included in multiple databases) was performed. The conservative approach to duplicate removal avoided undue removal of datasets, but may have allowed some duplicates to remain. Complete metadata descriptions were not available for all databases and datasets, but as much information as possible was recorded.

While extensive, this review cannot be considered absolutely thorough. Interest in life cycle assessment and in sustainable packaging is expanding rapidly, with data being collected and generated by a variety of entities. However, the depth of research performed for this review is expected to be the most thorough of its type currently available. It has uncovered a significant amount of usable data and should accurately inform future work to fill gaps.

Phase 3: Gap Assessment

The gap assessment looked specifically at materials used in large volumes in packaging. Each dataset or literature piece was 'tagged' with one or more of the material names found in Table 1, the processes or end-of-life options found in Table 2, or, as applicable, a combination of those tags. Using these tags, Quantis recorded the number and geographic specificity of datasets available for the highest volume materials, as well as datasets available for the materials and processes listed by TSC. These are compared with the volume of each material produced by region.

While specific to the United States, the US Environmental Protection Agency's studies of municipal solid waste were used to identify high-volume materials. This is based on an assumption that the relative proportions of use of various packaging materials experienced in the United States is reasonably representative of the proportions globally. Global data are not available to test this hypothesis, but the study authors believe it to be a sound way of identifying a class of most important materials.

The mass of packaging materials sent to landfills in the U.S. in 2010 is found in Table 4, and is part of a table which appears in the 2011 US EPA report *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Tables and Figures for 2010.* For high volume materials, the gap assessment examined rates of production in different geographical regions to compare to geographical data availability.

Table 4: Packaging Generated* in the Municipal Waste Stream, 2010[9]

Containers and Packaging	Thousands of Tons, 2009	Percentage of Total Containers & Packaging
Glass Packaging		
Beer and Soft Drink Bottles**	5,670	7%
Wine and Liquor Bottles	1,700	2%
Other Bottles & Jars	1,990	3%
Total Glass Packaging	***9,360***	***12%***
Steel Packaging		
Beer and Soft Drink Cans	Neg.	
Cans	2,300	3%
Other Steel Packaging	440	1%
Total Steel Packaging	**2,740**	**4%**
Aluminum Packaging		
Beer and Soft Drink Cans	1,370	2%
Other Cans Neg.	70	0%
Foil and Closures	460	1%
Total Aluminum Packaging	***1,900***	***3%***
Paper & Paperboard Packaging		
Corrugated Boxes	29,050	38%
Gable Top/Aseptic Cartons‡	540	1%
Folding Cartons	5,470	7%
Other Paperboard Packaging	90	0%
Bags and Sacks	1,040	1%
Wrapping Papers	Neg.	
Other Paper Packaging	1,490	2%
Total Paper & Board Pkg	***37,680***	***50%***
Plastics Packaging		
PET Bottles and Jars	2,670	4%
HDPE Natural Bottles	800	1%
Other Containers	1,830	2%
Bags and Sacks	770	1%
Wraps	3,160	4%
Subtotal Bags, Sacks, and Wraps	3,930	5%
Other Plastics Packaging	4,450	6%
Total Plastics Packaging	***13,680***	***18%***
Wood Packaging	**9,940**	**13%**
Other Misc. Packaging	**340**	**0%**
Total Containers & Packaging	***75,640***	

* Generation before materials recovery or combustion.
** Includes carbonated drinks and non-carbonated water, teas, flavored drinks, and ready-to-drink alcoholic coolers and cocktails.
‡ Includes milk, juice, and other products packaged in gable top cartons and liquid food aseptic cartons.
Details may not add to totals due to rounding.
Neg. = Less than 5,000 tons or 0.05 percent.
Source: Franklin Associates, A Division of ERG

[9] United States Environmental Protection Agency, Office of Solid Waste. (2011). *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Tables and Figures for 2010.* Table 18. [http://www.epa.gov/epawaste/nonhaz/municipal/pubs/2010_MSW_Tables_and_Figures_508.pdf]

5 Results & Discussion

The main body of results is found in the attached Excel document, which contains the literature and data review.

In general, Ecoinvent and GaBi are the databases with the highest number of datasets. Additional databases of note include ELCD, GEMIS, ProBas, SPINE@CPM, and, for geographically-specific data, the Canadian Raw Materials Database, Korea LCI database, Life Cycle Assessment Society of Japan database (JLCA), Chinese Life Cycle Database (CLCD), and USLCI.

Constraints in access to datasets prevented a thorough assessment of the quality of every dataset and database, or the completeness of the inventories included in each dataset. Not all of the databases are open to the public without a fee. For example, while KCL Ecodata has multiple datasets about paper and paperboard manufacturing, these datasets are only available in rolled-up form and only to clients of Oy Keskuslaboratorio-Centrallaboratorium Ab (KCL), Finland. In addition, as discussed above, data quality and appropriateness is specific to its application. As such, the review focused on transparency and ease of judging data appropriateness.

Geography

The large majority of datasets available represent materials and processes from Europe, either for individual countries or a European average. Asia, specifically South Korea, is the continent with the next highest number of datasets. The breakdown by continent appears in Figure 1. The representation by country for Asia appears in Figure 2, and representation by country for Europe in Figure 3.

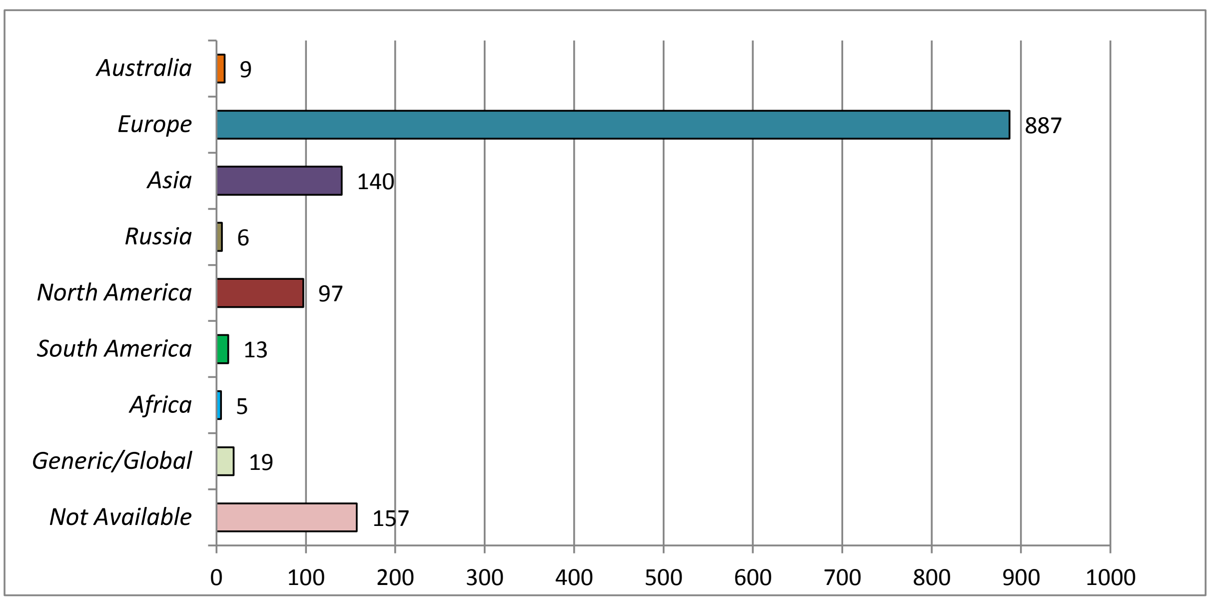

Figure 1: Geographic Breakdown: Total Dataset Number by continent

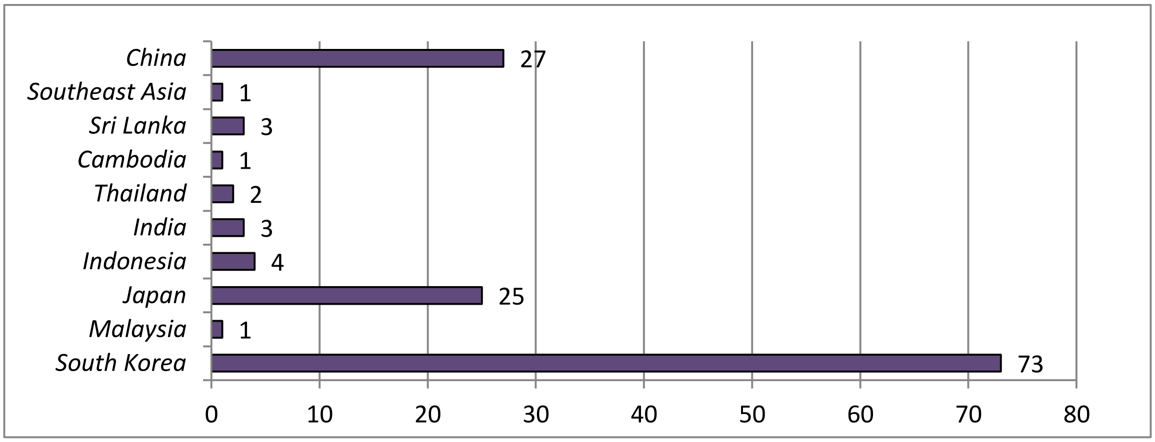

Figure 2: Geographic Breakdown: Total Dataset Number by country in Asia

The Korea LCI database has over 70 datasets for production of packaging materials within South Korea. The Japanese JCLA database holds 23 packaging-related datasets for Japan, covering aluminum products, cartons, and several polymers. The Chinese Life Cycle Resource Database (CLCD), ProBas, GEMIS, and Ecoinvent carry datasets for production in China.

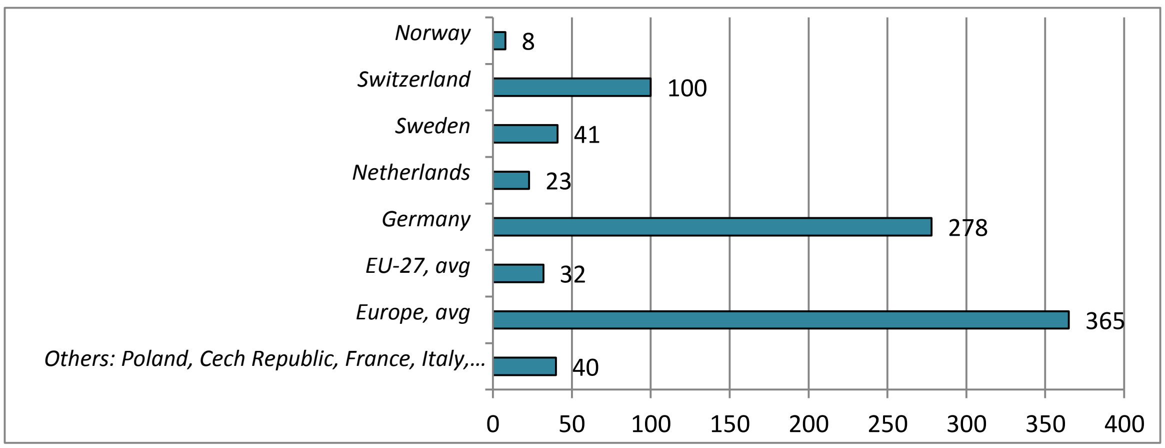

Figure 3: Geographic Breakdown: Total Dataset Number by country in Europe

Datasets from developing areas such as Brazil, India, Southeast Asia (Indonesia, Malaysia, Sri Lanka), and the African continent cover extraction and some processing of natural materials—jute; cotton; wood; soy; sugarcane; and palm and coconut oils—but have very sparse manufacturing data. Aside from agricultural products and timber, little data are available for Brazil, and next to no data is available for other South American countries. Also, very little data is available for Australia or Africa, though, with the possible exception of Australian aluminum, their contribution to the worldwide production and consumption of the major packaging materials is likely smaller than other continents. The Australian AUSLCI database, which is currently under development, promises a small number of datasets for Australia, and the GEMIS database includes aluminum from Australia. Finally, the Ecoinvent database is currently engaged in efforts to expand LCI data coverage in Brazil, India, and South Africa.

The geographic context of a dataset may be important if production methods and end of life treatments differ across geographies or regulations of emissions are more or less stringent.

Materials

A comparison of packaging material production to data availability is performed by material group: plastics; wood and paper; aluminum; and steel, with data availability compared to geographic production of each material.

Plastics

Figure 4 shows the worldwide plastics production by region, as reported by the PlasticsEurope Market Research Group.

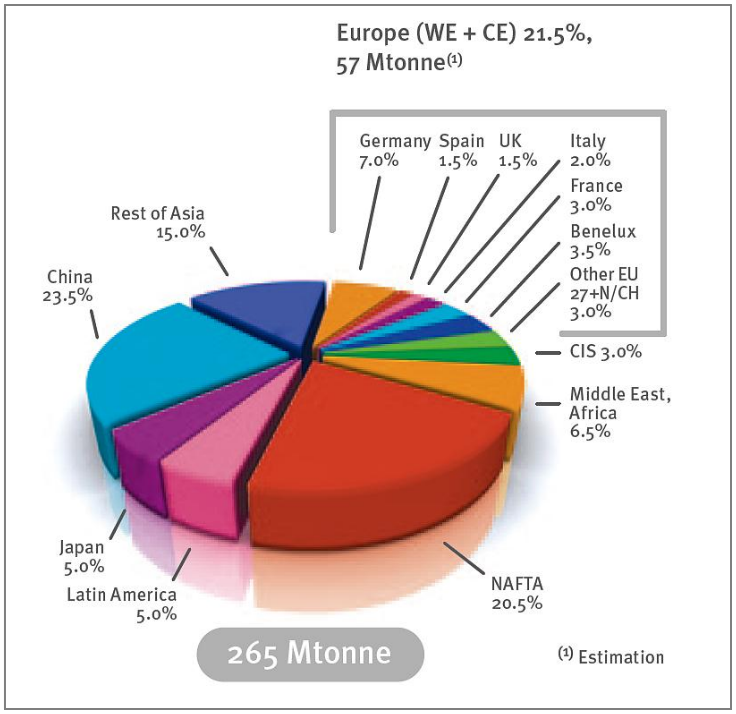

Figure 4: World Plastics Production 2010[10]
Source: Figure taken from PlasticsEurope Market Research Group (PEMRG)

Europe is responsible for 21.5% of global plastics production; Canada, US, and Mexico (NAFTA) 20.5%; China 23.5%; and the rest of Asia 20%. Latin America, Russia and other former Soviet states (CIS), and the Middle East and Africa also contribute to the global production.[11] In contrast, Figure 5 displays the availability of data for plastics by country. This data includes production as well as material-specific processing and end-of-life.

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[10] PlasticsEurope. *Plastics – The Facts 2011: An analysis of European plastics production, demand, and recovery for 2010.* Page 6.
[11] PlasticsEurope. *Plastics – The Facts 2011: An analysis of European plastics production, demand, and recovery for 2010.* Page 6.

No datasets are available for plastics production in Latin America, CIS countries, the Middle East, or Africa, though datasets are available for China, Japan, South Korea, the United States, Canada, and European nations. The largest gaps in data compared to production are Asia, the Middle East and Africa, and Latin America. No datasets exist for Mexico, but Mexico's contribution to the NAFTA production may be small. Packaging-specific plastics production is not available by geographic region, but for purposes of this gap assessment, it is assumed that the relative contribution of each geographic region to plastics packaging production is similar.

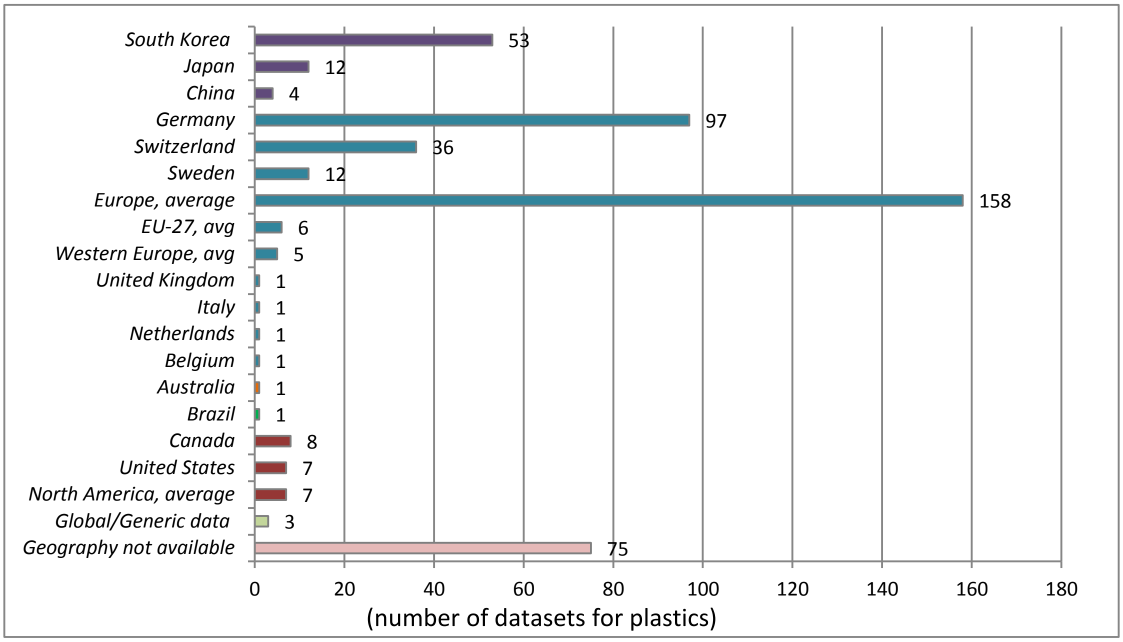

Figure 5: Number of plastics datasets including material production, processing, and end-of-life

Figure 6 shows the demand for plastics in Europe (EU and Switzerland) by market segment. Overall, packaging comprised 39.0% of the European demand for plastics in 2010, with LDPE, LLDPE, HDPE, PP, PET, and PS being the major contributors by weight.[12] Multiple LCI datasets and literature data sources are available for all of these materials, as seen in Figure 7.

[12] PlasticsEurope. *Plastics – The Facts 2011: An analysis of European plastics production, demand, and recovery for 2010.* Page 7.

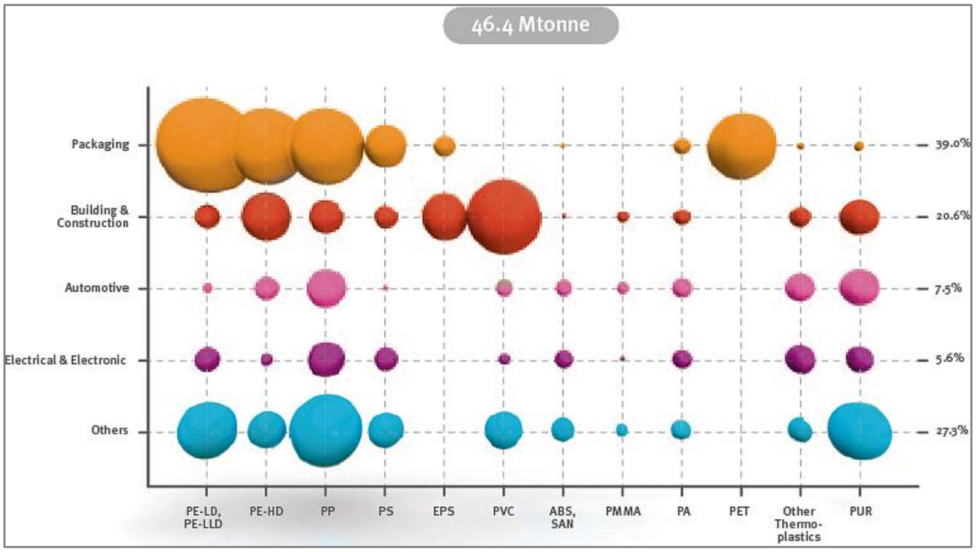

Figure 6: European demand for plastics by market segment
Source: Figure taken from PlasticsEurope Market Research Group (PEMRG)

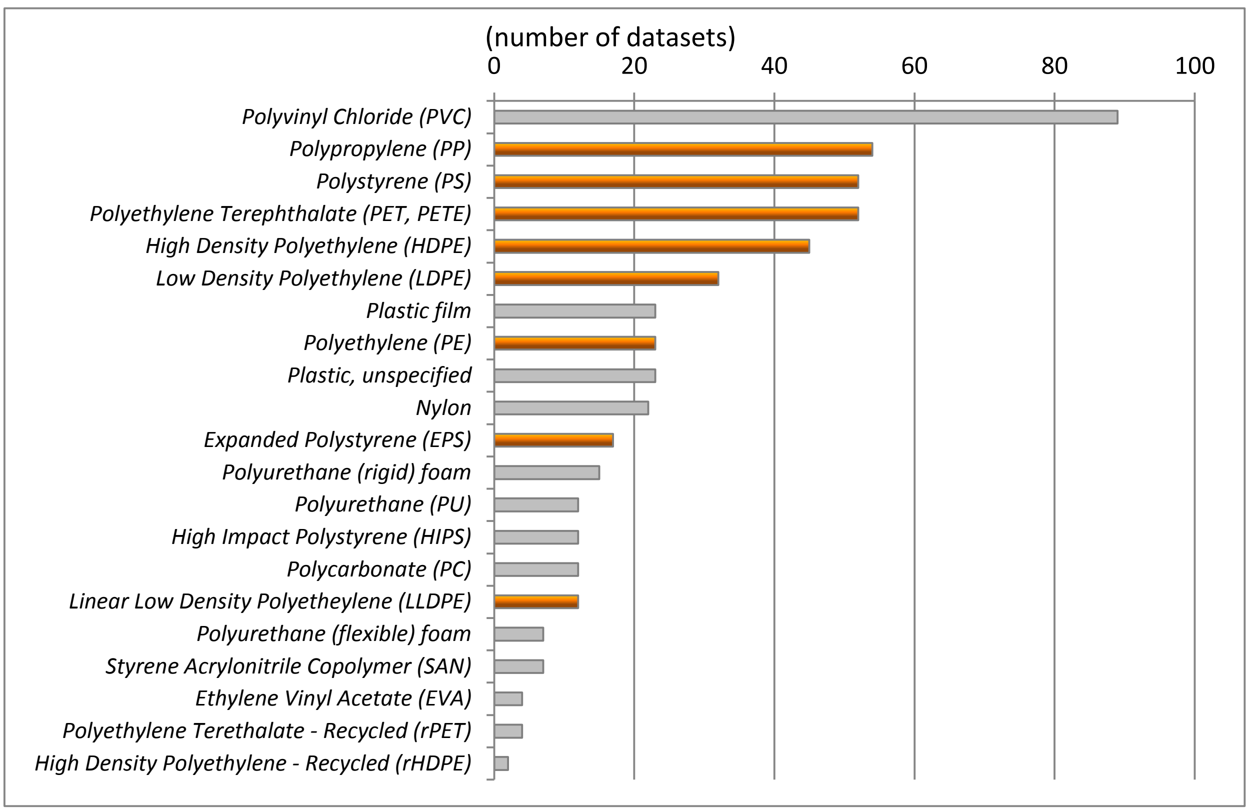

Figure 7: Plastics datasets and literature data sources, by material, Includes material-specific processing and end-of-life. Those resins contributing most of the production volume are highlighted orange.

Wood and Paper Products

Figure 8 shows the total (overall) availability of datasets by material within the wood and paper sector.

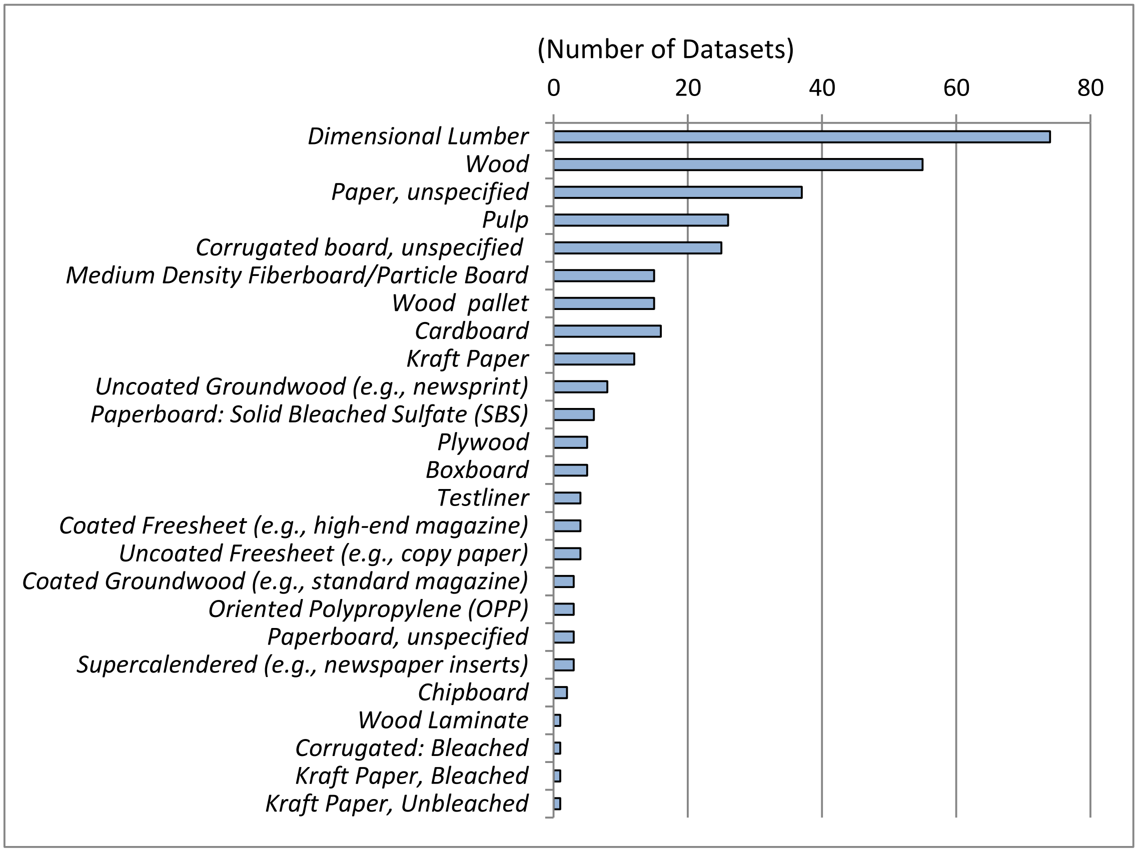

Figure 8: Number of wood and paper datasets and literature data sources, by material. Includes material-specific processing and end-of-life

Figure 9 shows the production and consumption of paper and other wood products worldwide in 2004.[13] Clearly, Europe and the United States are the largest producers and consumers of paper and paper board and other wood products.

[13] Production Imports and Exports of Selected Forest Products. (2009). In *UNEP/GRID-Arendal Maps and Graphics Library*. Retrieved 00:52, October 11, 2011 from [http://maps.grida.no/go/graphic/production-imports-and-exports-of-selected-forest-products].

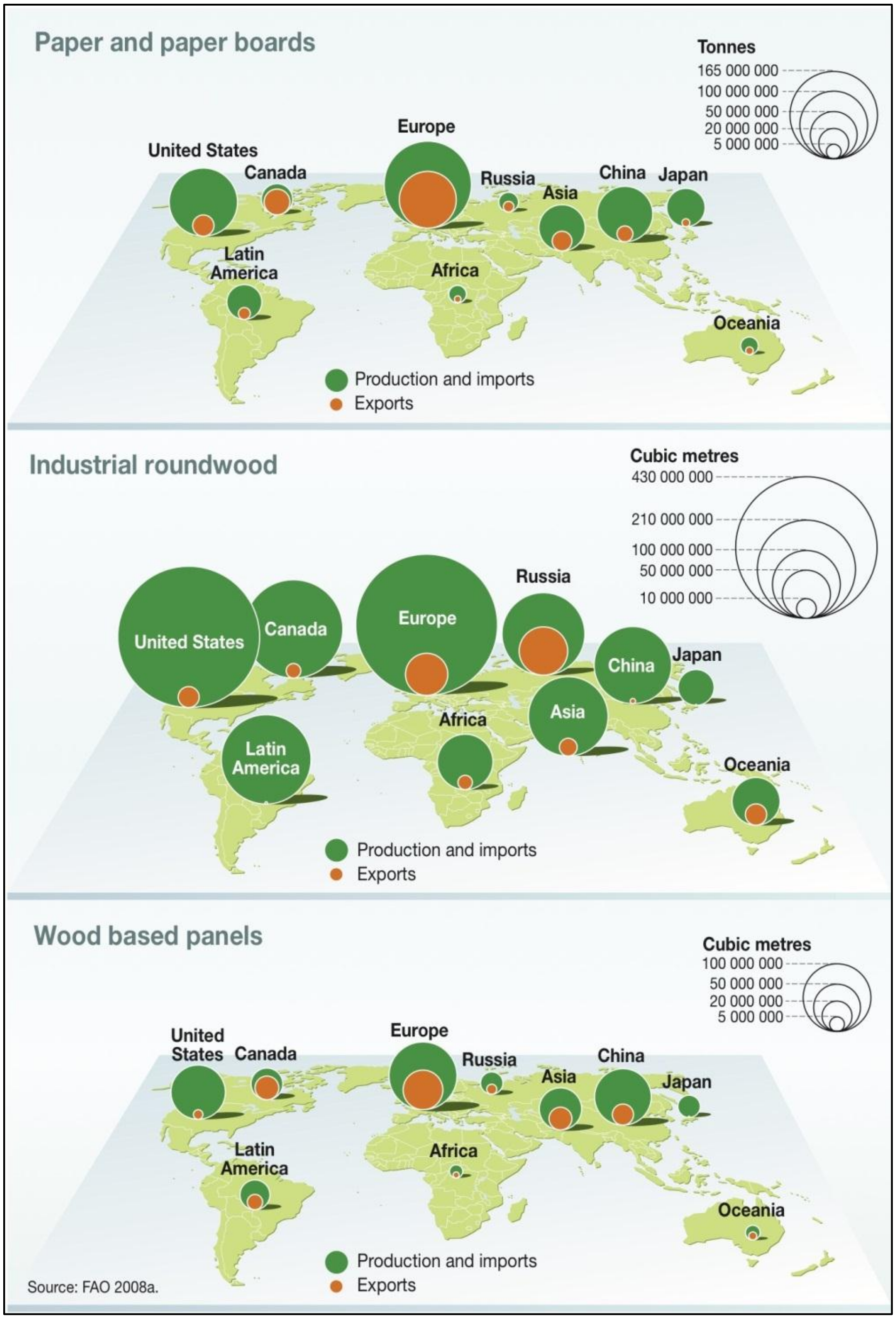

Figure 9: Production Imports and Exports of Selected Forest Products

Figure 10 compares the 2010 production of sawnwood by country with the availability of datasets for wood materials. (Source of data on production: FAO STAT.[14]) Countries responsible for less than 0.5% of the total sawnwood production are not listed, though the continent totals reflect their contributions. Continent totals of datasets also include datasets that are representative of an average for that continent. While the production data is for *production* of sawnwood, the count of datasets includes data for material production, processing, and end of life steps.

Similarly, Figure 11 compares the 2010 production of wrapping and packaging paper and board by country with the geographic availability of datasets for pulp and paper materials. (Source of production data: FAO STAT.[15]) Countries responsible for less than 0.2% of the total sawnwood production are not listed, though the continent totals reflect their contributions. As with Figure 10, continent totals of datasets also include datasets that are representative of an average for that continent. And, while the production data is for *production* of wrapping and packaging paper and board, the count of datasets includes data for material production, processing, and end of life treatments.

There are multiple datasets in Europe and in the United States for dimensional lumber and pulp production. Canada, China, Japan, other regions of Asia, and South America also produce substantial amounts of these materials but do not have relating life cycle inventory data.

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[14] FAO Statistics Division 2012 | 07 May 2012 ForesSTAT: http://faostat.fao.org/site/626/default.aspx#ancor (Sawnwood (Total))

[15] FAO Statistics Division 2012 | 07 May 2012 ForesSTAT: http://faostat.fao.org/site/626/default.aspx#ancor (Wrapg+Packg Paper+Board)

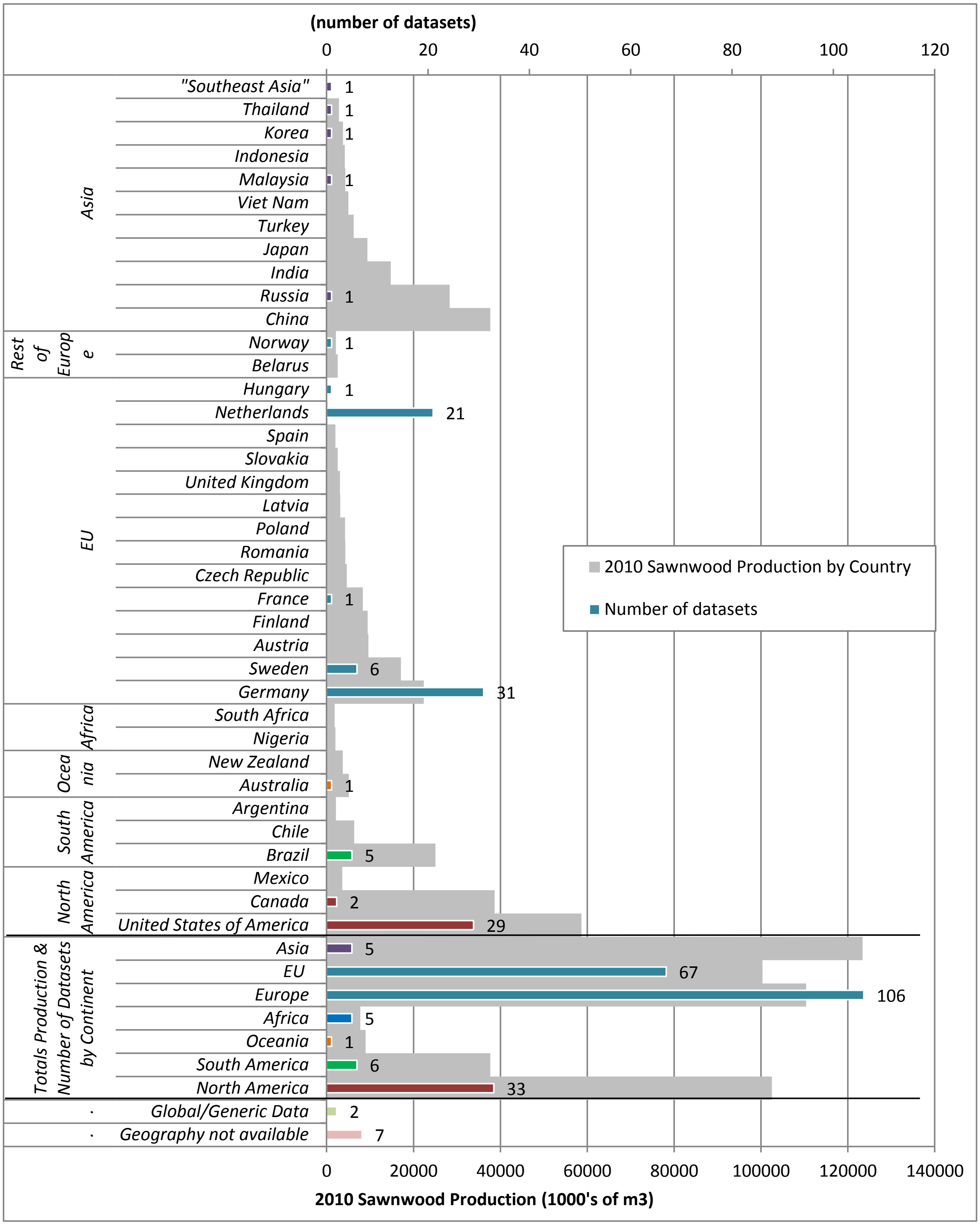

Figure 10: Worldwide production of sawnwood (1000 m3) in 2010, overlaid with number of datasets for wood and wood products. ***Note:*** *Number of datasets includes data for materials, processing / milling steps, and end-of-life in addition to sawnwood production.* For definition of sawnwood see: http://faostat.fao.org/portals/_faostat/documents/forestproductsdefinitions.htm

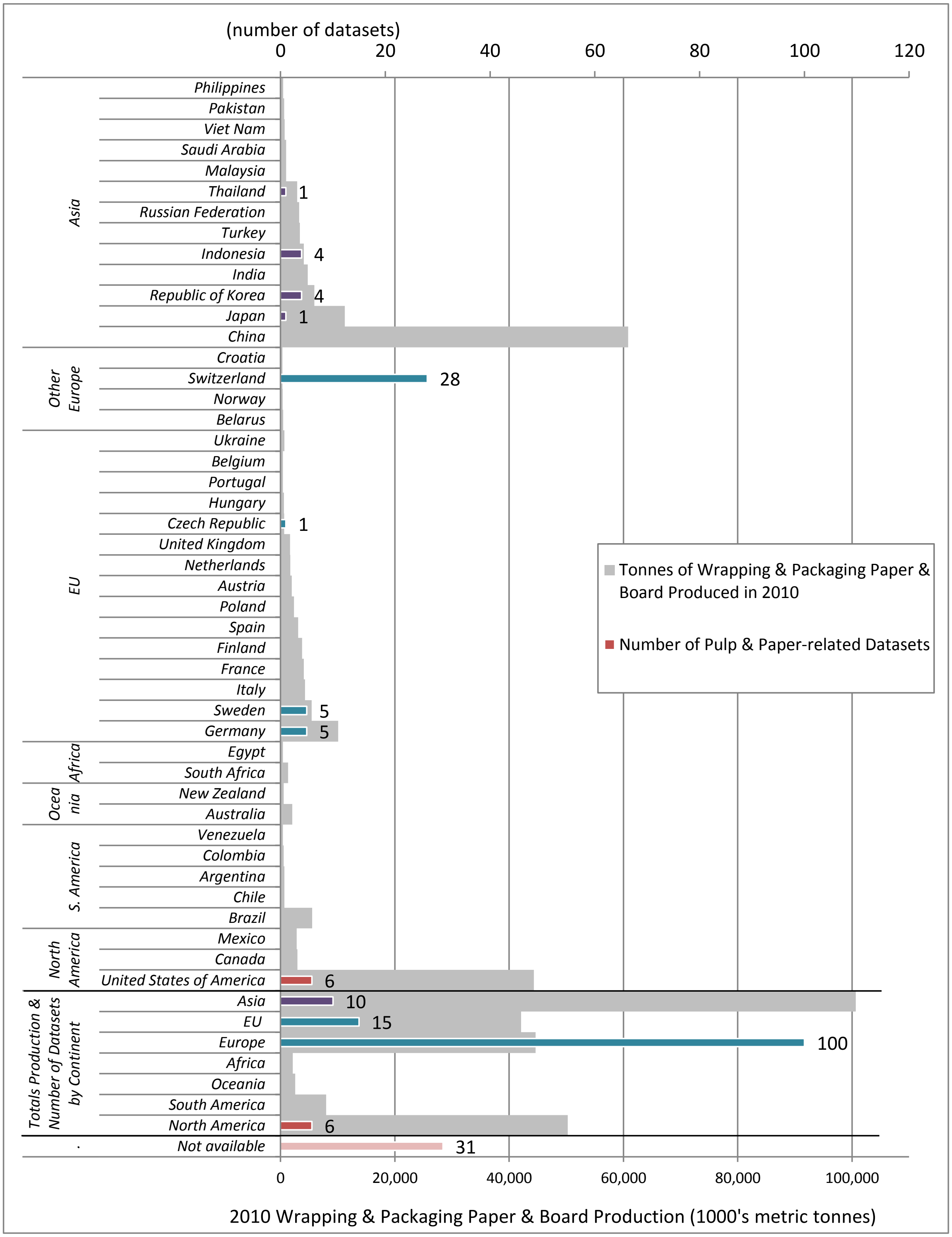

Figure 11: Worldwide production of wrapping & packaging paper & board (1000 metric tonnes) in 2010, overlaid with number of datasets for pulp & paper. ***Note:*** *Number of datasets includes data for materials, processing / milling steps, and end-of-life in addition to production.* For definition of packaging paper see: http://faostat.fao.org/portals/_faostat/documents/forestproductsdefinitions.htm

Aluminum

Figure 12 compares primary aluminum production by country in 2009 (shown in gray) with the total number of datasets available for aluminum by country.

Continent totals of datasets include datasets that are representative of an average for that continent. While the production data is for *production* of primary aluminum, the count of datasets includes data for material production, processing, and end of life. While the comparison between primary aluminum production and data availability for all aluminum life cycle stages is not exact, this comparison still serves to identify regions of the world for which aluminum data may be lacking.

There are datasets for aluminum production and processing in Australia, Japan, Russia, South Korea, North America (Canada, United States, and North America combined), as well as many countries within Europe and datasets for European averages. In terms of data gaps, India, South America, Africa and the Gulf Region are all producers of primary aluminum but have no aluminum datasets.

<u>Footnotes for Primary Aluminum Production Data in Figure 12:</u>

(e) Estimated
(1) World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
(2) Primary aluminum is defined as: “The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well that of any metal produced from either returned scrap of remelted material.- International reporting practices vary from country to country, some-nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given- specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through March 29, 2010.
(3) Reported figure.
(4) Primary ingot plus secondary ingot.
(5) Ingot and rolling billet production.
(6) Primary ingot.
(7) Excludes high purity aluminum containing 99.995% or more as follows, in metric tons: 2005-45,413; 2006-49,667; 2007-50,777 (revised); 2008-51,000 (revised); and 2009-52,000 (estimated).
(8) Primary unalloyed ingot plus secondary unalloyed ingot.
(9) Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.
Source of Production Data (and footnotes): USGS Minerals Yearbook [16]

[16] Production data from USGS 2010 Minerals Yearbook, Table 13. [Available at http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/myb1-2010-alumi.pdf]

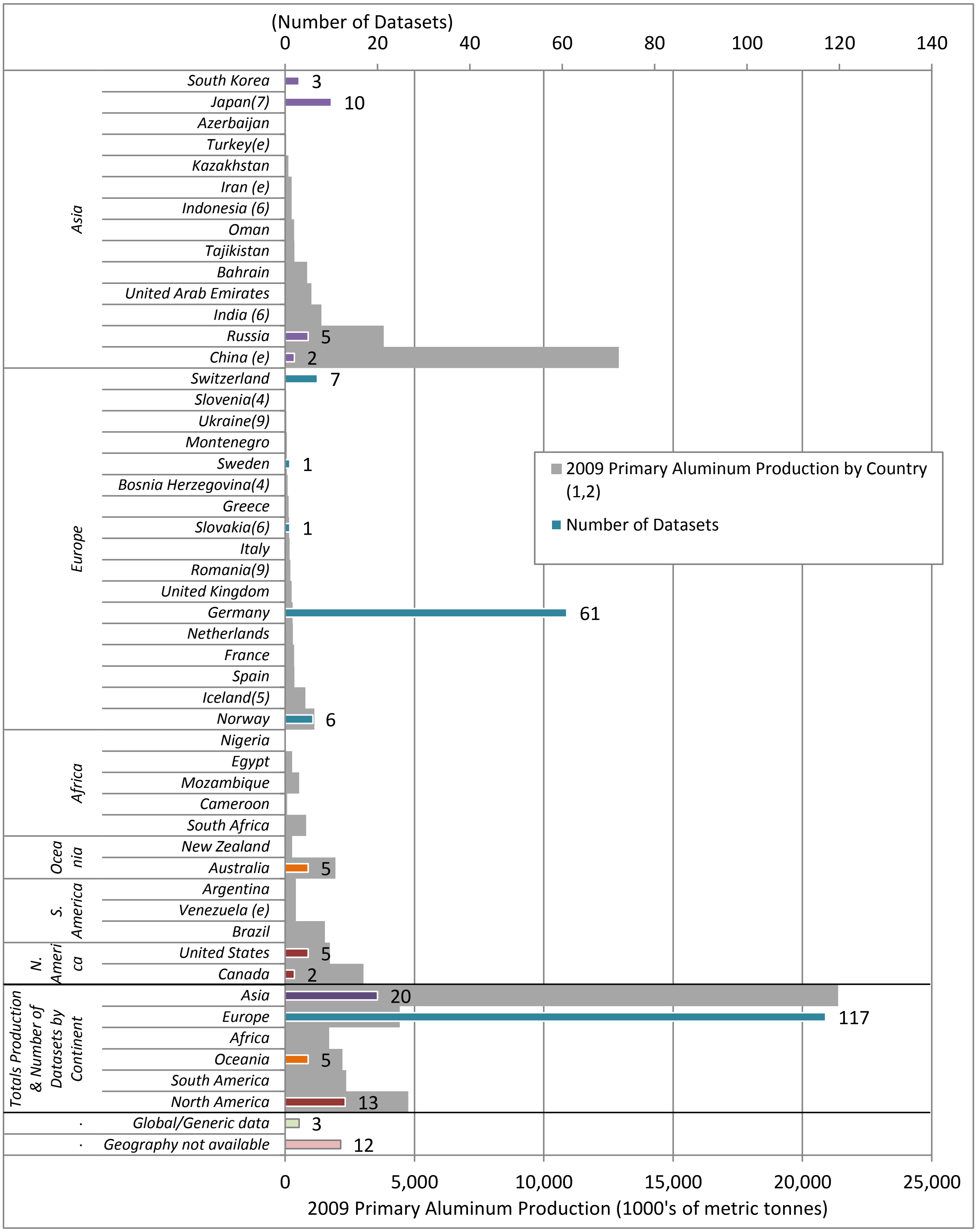

Figure 12: Worldwide Primary Aluminum Production by Weight, 2009, overlaid with number of datasets for Aluminum. ***Note:*** *Number of datasets includes data for materials, processing / milling steps, and end-of-life in addition to primary aluminum production.*

Steel

Figure 13 shows the global crude steel production in gray, coupled with the number of available datasets for each country. While the production data is for *production* of primary aluminum, the count of datasets includes data for material production, processing, and end of life. Continent totals of datasets include datasets that are representative of an average for that continent.

Asia is the largest-producing continent, and within Asia, China and Japan are the largest producers.[17] The available data over-represents Europe and under-represents Asia. There are many datasets for steel production and processing throughout Europe with less in Australia, China, Japan, India (1 set), Russia, and North America. Further granularity may be obtained by comparing specific steel products by geography (ingot, liquid steel, cold rolled, and crude steel production by process).

<u>Footnotes for Raw Steel Production Data in Figure 13:</u>

(e) Estimated

(1) World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

(2) Steel formed in solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

(3) Table includes data available through September 8, 2011.

(4) In addition to the countries listed, Mozambique is known to have steelmaking plants, but available information is inadequate to make reliable estimates of output levels.

(5) Data for year ending June 30 of that stated.

(6) Reported figure.

(7) Excludes castings.

(8) Figures reported by the State Statistical Bureau that the Government of China considers as official statistical data.

Source of Production Data (and footnotes): USGS Minerals Yearbook [18]

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[17] Production data from USGS 2010 Minerals Yearbook, Table 10. [Available at http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/myb1-2010-feste.pdf]

[18] Production data from USGS 2010 Minerals Yearbook, Table 10. [Available at http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/myb1-2010-feste.pdf]

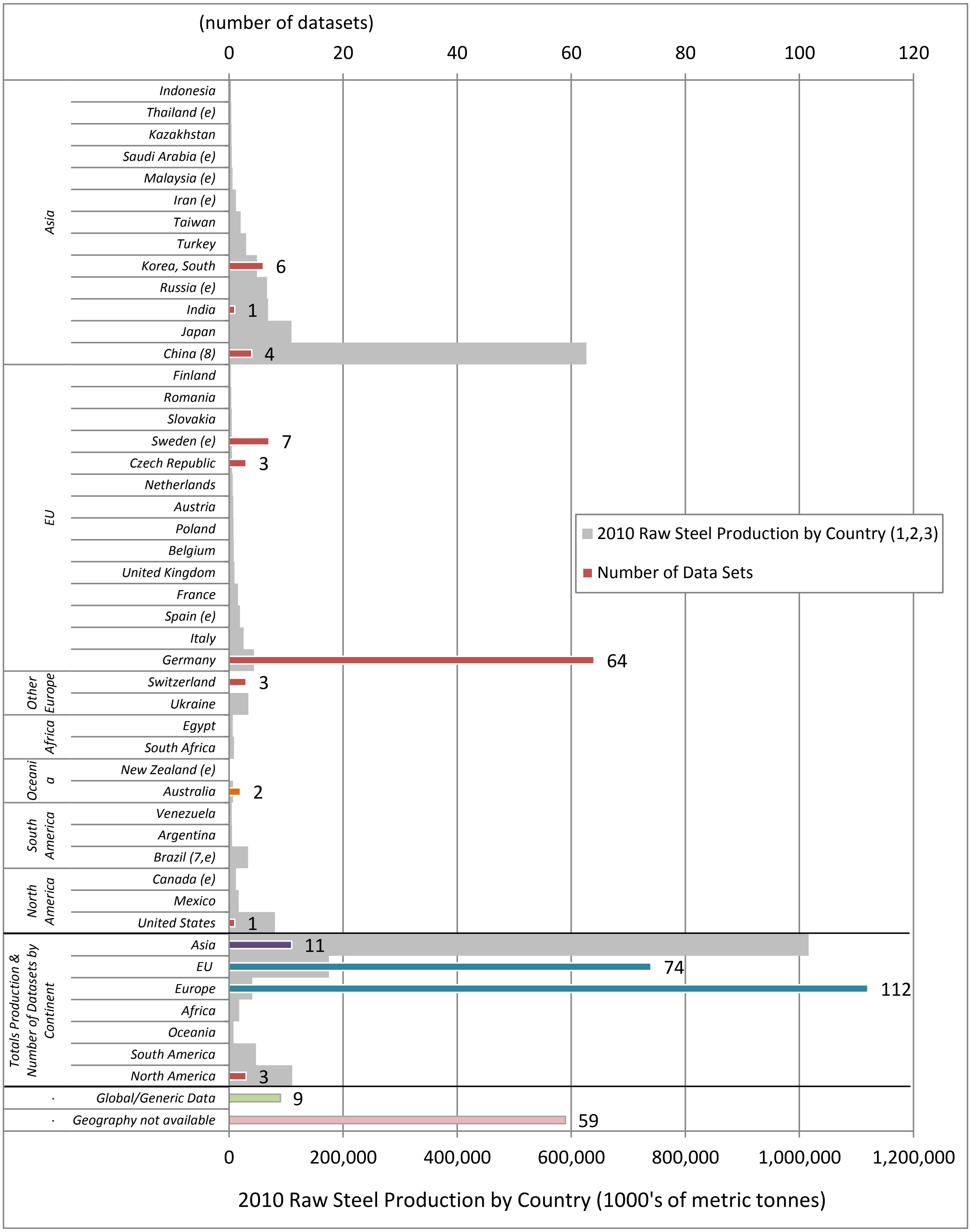

Figure 13: Worldwide Raw Steel Production by Weight, 2010, overlaid with the number steel datasets, available for each country. ***Note:*** *Number of datasets includes data for materials, processing / milling steps, and end-of-life in addition to raw steel production.*

Gaps for Other Materials

While steel, aluminum, plastics, wood and paper products lack data for certain regions, they do have a fair number of datasets.

Data falls short for entire classes of materials including biomaterials, additives, and laminates and other compounds. The number of available datasets and literature data sources for these materials is show in Figure 14.

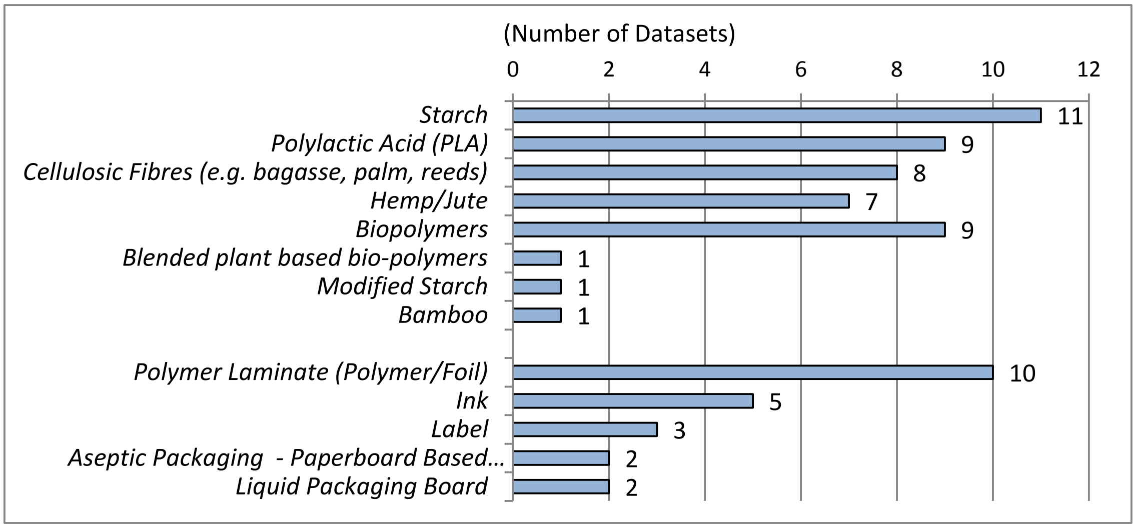

Figure 14: Biomaterial and ancillary material datasets and literature data sources by material

Some datasets are available for polylactide (PLA), jute, fibers, starch, and a handful of bioplastics. There are many datasets for farming and/or collection and processing of raw materials and other precursors to biomaterials. These include corn/maize, sugarcane, soybeans, oil palm, and coconut oil. However, these are not complete datasets for biologically-based packaging materials. Only one piece of literature was found for bamboo.

Only a few datasets exist for laminated or compound materials (e.g. polymer/foil laminates.). These materials, as well as specific types of paper and paperboard may be too specialized for many databases to tackle at this point in the development of life cycle inventory data.

Finally, few datasets exist for additives to plastics and other materials. These include plasticizers, dyes, adhesives, coatings, and inks, and the datasets for other materials rarely reference the addition of such chemical additives.

Processes

Transformation processes are not always specified in datasets. Some datasets give very generic descriptions of the process being modeled, making it difficult to match to the list of processes of interest.

There are many datasets for different steel and aluminum processing steps included in the review. Because of the diverse nature of packaging materials and applications, the appropriateness of each process for a potential packaging LCA is difficult to assess.

As with production of plastics material, Europe and North America have the largest number of plastics processing datasets, with some representation from South Korea. The processing steps that are best represented by available life cycle data include extrusion, blow molding, injection molding, thermoforming, and metal sheet rolling. In general, laminating processes and highly packaging-specific processes such as can-making and production of stretch-and shrink-wrap are not available for many geographies.

End-of-Life

The vast majority of end-of-life data are available only for European contexts. Exceptions include: Japan (incineration); South Korea (recycling corrugated cardboard, recycling HDPE, recycling wood, and incineration and landfill of several materials); and the United States (waste-to-energy, recycled HDPE and PET [rHDPE and rPET], and recycling of general materials). There are no data outside of Europe for compost.

A few datasets explicitly indicate that they are for products or materials that include recycled content: aluminum, steel, paper and corrugated boxes, expanded polystyrene, and cotton – almost all in European countries -- and rHDPE and rPET in the United States. However, all datasets that deal with recycling must also be considered as datasets for feedstock materials or end-of-life. In building a system model, a life cycle practitioner will choose whether to allocate recycling to end-of-life or to a recycled-content feedstock, or use it in a different allocation method. In general, data for recycling processes and recycled materials are not widely available. Outside of Europe, only the US and South Korea have developed datasets related to recycling. The breakdown by material and country appears in Figure 15.

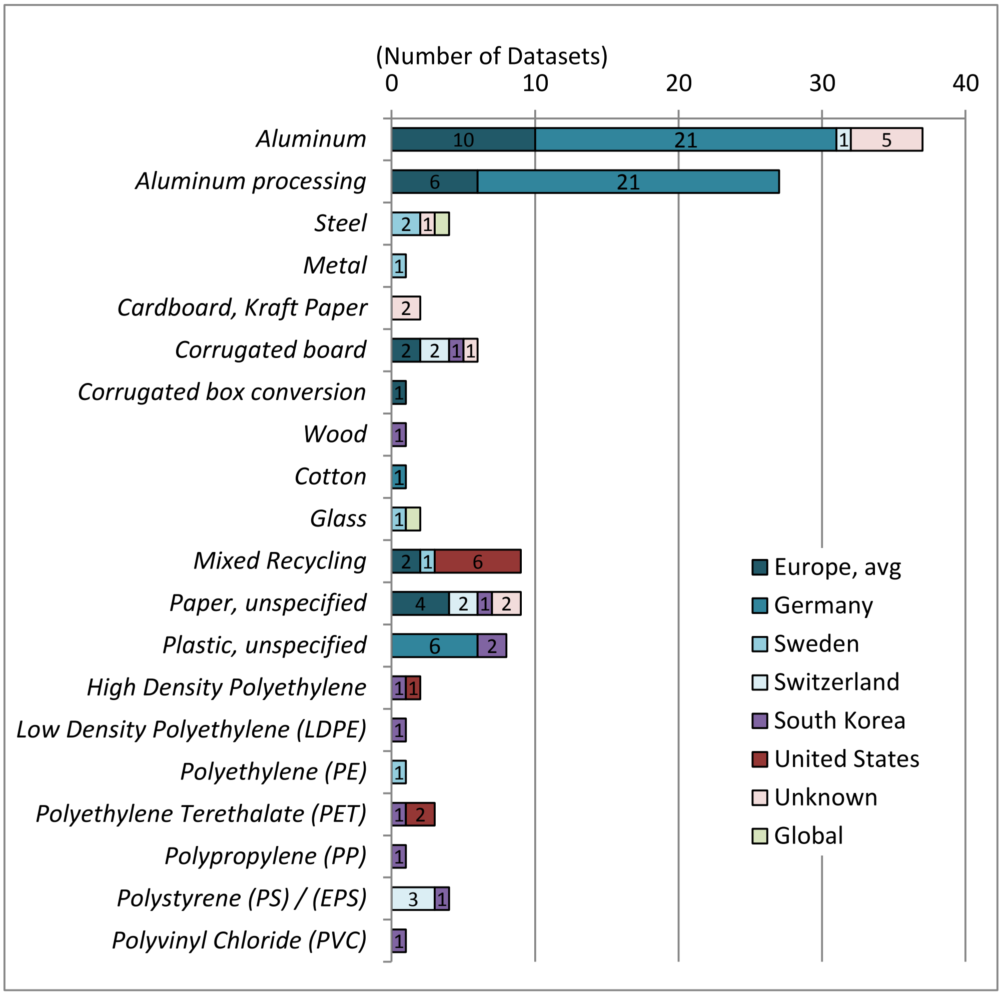

Figure 15: Datasets for recycling processes and recycled materials, by material and geography

In the United States a significant percentage of packaging materials are recovered for recycling. In 2010, 48.5% of containers and packaging generated in MSW were recovered for recycling. This included 71.3% of all paper and paperboard containers and packaging (mostly corrugated), 33.4% of all glass containers, 23.1% of wood packaging, about 13.5% of plastic containers and packaging (mostly bottles and jars), and 55.4% of all metal containers and packaging.[19] Given the large amounts of packaging waste produced in the U.S. and increasing efforts to recover it, additional datasets for recycling in the United States would be appropriate. The same conclusion applies to recycling data for other countries outside of Europe.

[19] United States Environmental Protection Agency, Office of Solid Waste. (2011). *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Tables and Figures for 2010.* Table 21. [http://www.epa.gov/epawaste/nonhaz/municipal/pubs/2010_MSW_Tables_and_Figures_508.pdf]

6 Strategic Findings

While many datasets exist for the basic raw materials that are used in packaging, there remain very significant data needs to support packaging models for the goals of TSC's SMRS program. This section presents the main challenges identified for the SMRS program based on the current status of packaging LCI data availability.

Material representativeness

The most basic need for the SMRS project is to ensure some level of data completeness across materials. After data completeness for materials has been addressed, factors such as geographic and temporal relevance and other aspects of quality can be considered. While most traditional packaging materials have data available—and in some cases have wide geographic coverage with reasonable data quality—several major packaging materials and a large number of minor packaging materials have very little or no data available. Without data on a material, it is impossible to characterize the environmental performance of packaging made from it or to compare its performance with other materials.

This lack of LCI data is most prevalent among materials that are produced and used in relatively low volumes in comparison to the most prominent packaging options. Emerging materials that apply feedstock substitution or other technological enhancement to improve their environmental profile fall into this category and are underrepresented in the LCI data, making it difficult to assess their environmental performance as compared to traditional alternatives. Nevertheless, an operational SMRS that can address a large percentage of packaging used within today's marketplace must fill these gaps. There are also data availability problems for composite materials – both data gaps for base materials (e.g., board and film) and inadequate information about the conversion steps of base materials into composites. One option for filling data gaps may include the development of datasets for a material or product, followed by verification of those datasets by the manufacturers of those materials or products. This approach would add to the body of data without a manufacturer having to supply confidential information. However, the resulting datasets may not completely represent the material or product and may suffer from a lack of confidence or buy-in to the efforts by the manufacturers asked to participate.

Finally, there are data gaps for a range of "emerging" materials that have traditionally been infrequently used. Some of these materials are poised to grow rapidly in market-share, partly due to a *presumed* high level of sustainability performance even though little or no LCI data actually exists to make such an evaluation. Bio-derived materials and compostable/biodegradable materials, especially plastics, are perhaps the most common example of such materials. The number of different materials and production routes in these categories that are entering the market, or still in research stage, is growing quickly, and the availability of data to measure their performance is quite low. A possible partial solution is for TSC to require that manufacturers of such materials provide credible LCI data to the SMRS program if that manufacturer intends to see its material's sustainability performance reflected in the system. This approach might provide additional coverage of some materials but might not be sufficient to see all gaps filled with regard to less common materials and in particular might result in those materials for which the measured performance is low not participating or being represented in the system.

Data consistency, transparency, and documentation

Even if data exists, it may not be useful within the SMRS framework if it cannot be demonstrated to be a part of a consistent and valid assessment across a given product category. This requires that the data included within the SMRS is prepared in a reasonably consistent manner. Inconsistencies in such aspects as the system boundary description, the approach to allocation between co-products, the inclusion and categorization of inventory flows, and the units of measure can make it difficult or impossible to use one set of data alongside another. While this assessment has focused primarily on the issue of data availability, the review also provides a first view of the diversity of information sources and some of the characteristics of each of these sources. To improve and validate the consistency within a body of data that the SMRS might draw on will require a large and concentrated effort. Taking advantage of databases that have rather broad and consistent coverage already, such as GaBi and Ecoinvent, is one important strategy to mitigate this issue. In addition, other global sources of data can be encouraged to follow the guidelines and practices set out by these leading databases and/or other global guidance, such as the recent work of the UNEP-SETAC Life Cycle Initiative.[20]

Equally important are the joined issues of data documentation and transparency. To achieve the high level of credibility required by the SMRS program, a thorough explanation of the origin of the information being used must be available to those who might review it. Not all sources of data inventoried by this review appear to provide a high level of documentation, although some may provide a greater amount with the purchase of a database license. This will be an important issue to consider when choosing among those data that might be included within the SMRS program.

Indiscriminant use of datasets from different databases will likely lead to significant discrepancies in the boundary and scope of the data used. However, it may be appropriate to select one database and use that database as background data. In this approach, foreground data from a variety of databases could be used, or it could be freshly developed for the material or product of interest. Foreground data is, for example, the amount of electricity used by a process while background data would be the inventory associated with production and delivery of that electricity. The US LCI data sets are an example of this type of system; they frequently list specific unit process inputs, though the database does not have a full inventory dataset developed for each of those unit processes. These unit processes could be filled by their respective background data sets in GaBi or Ecoinvent. This approach largely maintains consistency in scope and transparency, so long as the foreground data are well-understood, consistent, and documented.

[20] http://www.estis.net/sites/lcinit/default.asp?site=lcinit&page_id=ABD68212-F8D8-48A6-83A0-9D82DE7ED61A

End of life treatment processes and other phases of the life cycle

When considering the environmental sustainability performance of any product or material, it is of course important to consider not only the impact of its production, but of its whole life cycle, including use and disposal. While packaging rarely has significant impacts during its use phase, the end-of-life disposal may have important implications for its sustainability performance and may offer opportunities to improve that performance. Although data regarding the end-of-life impact of major materials is available within select geographies, it is clear that the information on this section of the packaging life cycle is in general inadequate to fully support the SMRS program. Many materials have little or no data regarding end-of-life processes. Also, while the specifics of these processes may vary more substantially among geographies than production processes, the overall geographic coverage of the data is worse. Even for some major materials, such as many plastics, data on important end of life routes like recycling is not available.

Because the impact of materials containing recycled content may be affected by the impact of recycling processes, depending on whether a portion of those processes is allocated to these materials, these data gaps are also relevant for improving data regarding recycled materials. The approach for allocation of impacts across multiple lifetimes within recycling loops is a unique issue that should be considered carefully as the SMRS is further developed.

It should be noted that packaging materials are also transported prior to filling and then transported to the marketplace with the product. LCI data regarding transport is therefore also a necessity, though not addressed here, to enable a full consideration of the impact of packaging within an SMRS. There may be other examples of activities happening during the life of certain packages that will require LCI data on additional industrial activities.

Geographic representativeness

As documented above, many countries and regions of the world have little LCI data for relevant packaging material production and conversion processes. Because such processes may differ significantly among various markets, it is important to understand these differences and either collect or model data to fill gaps or provide adequate justification for extrapolation across regions. In many cases, the “background” processes, such as energy and transportation, may be updated for those geographies, while foreground information on material flows and environmental emissions may be extrapolated from the data available elsewhere. While potentially a step in the right direction, this is not a full solution to the problem and risks giving some users of the information a false sense of completeness because the data appears to have a geographic specificity that does not fully exist. There is therefore an urgent need to better understand and fill data gaps regarding differentiation in production conditions across geographies.

Secondary Materials

Secondary materials in packaging include additives to plastic resins such as plasticizers and dyes, adhesives, coatings, and inks.

Especially in the case of plastic resins, various chemical additives are often added in small to moderate amounts to impart such qualities as color, flexibility, rigidity, flame retardance, or other desirable properties. However, representation in LCA often omits the inclusion of such chemicals, either as an oversight or as an intentional exclusion justified by their small mass contribution. However, in total, such additives may be an important part of the sustainability story for some materials. There is generally a lack of specificity within LCI data of what additives might be included in which amounts to create a modified resin, as well as on the environmental impact of these additives. A further potential concern may be the eventual fate of those additives in such cases where they themselves may cause some degree of environmental concern, such as in the case of some flame retarding chemicals.

Various adhesion chemicals used in packaging application also fall within the category of data gap where the materials may hold significant implications in terms of environmental burdens and process economics. Finally, some datasets exist for ink materials for different types of printing. However, given the specialization of ink materials and the potential for significant environmental profiles of ink production, this also constitutes a materials data gap. The development of datasets for the additives, adhesives, coatings, and inks may present some difficulty; due to their formulated chemistries, their composition may be seen as proprietary.

Data access and format

The review made here presents the data and information for which the authors could find some evidence, but in some cases data were not available for the author's evaluation or for TSC's use in the SMRS program. In some instances, a purchased license is necessary to view or use the data. Because of the disjointed nature of the various LCI programs throughout the globe, the process for obtaining licenses for all relevant data to allow their use by the wide range of groups that might participate in the SMRS program will need to be taken into consideration. In addition, although some commonalities and emerging standards exist regarding the formatting of such data, there is not a clear single choice for the delivery of such data and therefore the use of data from many data sources requires significant additional efforts to convert formats. This challenge is made more difficult as the managers of data sources each make more frequent updates and require data to be reconverted to the format used. A more global standard regarding data format and nomenclature would help solve this issue.

7 Considerations for Next Steps

The existing body of LCI data does not sufficiently provide high quality data across various materials and processes when considering variations in technology and geography. This lack of data availability creates an important risk for the SMRS program: even if producers are able to specify with high detail the locations, processes, and technologies with which their products are produced, the body of existing LCI data to which this data could be mapped is unlikely to adequately reflect potentially important differences in the environmental flows within various supply chains.

This creates both a risk that differences that are shown within the SMRS system are not true differences, as well as a risk that true differences that exist between products are not reflected within the SMRS. While such risks can never be fully eliminated, they could be greatly reduced through improvements in the LCI data supporting the system. In order to minimize these risks, it is necessary to focus on both the quality of the data available to the system and on the consistency with which data is selected to represent a given condition.

Ensuring that data of sufficient quality is available to those using TSC's SMRS requires the existence or creation of data that meets requirements of geographic, temporal, and technological specificity and that has adequate attributes of accuracy, completeness, and consistency. Where data meeting these requirements does not exist, it would need to be created. Where data does exist, it may need to be modified to meet concerns of consistency. The present report provides a first assessment of the extent of the gaps needed to be filled to provide complete LCI data for the assessment of packaging within TSC's SMRS. If not directly managing and providing data itself, TSC should also consider the challenge of consistency of data format that users of the SMRS will face.

In addition to these concerns about the existence of data, an equal amount of consideration should be given to the process by which data is selected for inclusion in the modeling of a product within the SMRS. Even if data were to exist with the desired attributes mentioned above, a system where users have a wide choice of data introduces a potential for either real or perceived errors to enter the system through inconsistency on the selection of data, or a bias on the part of the user toward selecting data which will give a lower result. In a system where the amount of data anticipated to be produced far exceeds what could be monitored by expert review, the only means of controlling for this problem is to be prescriptive about which data is to be used to represent a given context. For example, the production of a certain material through a certain technology within a given region in a given span of time would always be represented by a given set of data, without the potential for differentiation based on user choice. That is, a mapping would need to be provided that consistently leads the user from a clear definition of their context to a prescribed set of data.

Further complicating matters is the desire to create a system in which users can include data that is more specific to their supply chain than these prescribed data sets. This is necessary to allow users of the system to reflect within their reporting the results of effort they have made to improve the performance of their supply chain in ways that consider not only what is included in their supply chain, but also the conditions of its production. This requires a means for companies to enter into the system their own customized data. Ensuring credibility within that process is an important challenge that must also be overcome.

The conclusion resulting from these considerations is that a rather comprehensive and controlled system is needed for providing default data to be used within the SMRS and for governing the conditions under which participants can deviate from this prescribed path. The first element needed is a plan for improvement of the overall availability and quality of LCI data for packaging. A second element needed is a mapping of the pre-existing and newly developed data to the possible range of conditions under which production may occur in an SMRS users' product system. Beyond that, further effort is needed to ensure consistency in the format and availability of data for users. Finally, clear guidance and an assurance process is needed to support users who would make an exception to the prescribed data.

The creation of the data system in question is an effort requiring at least into the tens of millions of dollars of investment. While TSC may not now have the resources available to directly build the data structure needed, it may have means at its disposal to stimulate development of data to fill important gaps and to assemble and curate the existing data into a cohesive structure. It will take a significant amount of time to put this structure in place and so efforts in this direction are needed soon to further inform the vision of the SMRS framework.