LONG RANGE PLAN 2024

VALUE CHAIN MAP ASSESSMENT

ASC

THE ADHESIVE AND SEALANT COUNCIL

SECURING THE FUTURE®

SustainableSolutions CORPORATION

Introduction

The Adhesive and Sealant Council (ASC) is non-profit trade association which represents North American manufacturers, suppliers, and distributors of adhesive and sealants. The ASC has three strategic priorities including (1) Advocacy, (2) End User Engagement, and (3) Sustainability. In 2021, the ASC's board approved their 2021-2024 Strategic Plan which includes a focus on sustainability.

The Strategic Plan includes three key priorities for which ASC would like to progress, including: (1) advancing the circular economy, (2) reducing environmental impact in operations and supply chain, and (3) making a positive impact for ASC's employees and communicates.

In 2022, the ASC commissioned Sustainable Solutions Corporation (SSC) to map the sustainability value chain to communicate the value of sustainability to ASC's member companies. This report details the value chain maps created for ASC. The value chain maps were developed for key industries including building and construction, transportation, and packaging. The purpose of creating the value chain maps is to clearly define key stakeholders to the ASC and outline where sustainability improvements can be made within different stages of the operation. Specifically, the aim is to map the inputs and outputs within the adhesive industry, to find opportunities for the industry to lower their environmental footprint, and to identify appropriate next steps.

The information used to complete this report and value chain maps were derived from available sustainability reporting throughout the industry, independent research, and interviews conducted with ASC members at various stages of the adhesive production process.

Value Chain Map: Adhesive and Sealant Industry

This report details the information and data collected to develop the value chain maps for the adhesive and sealant industry. The report includes various graphics for select industries including building and construction, transportation, and packaging.

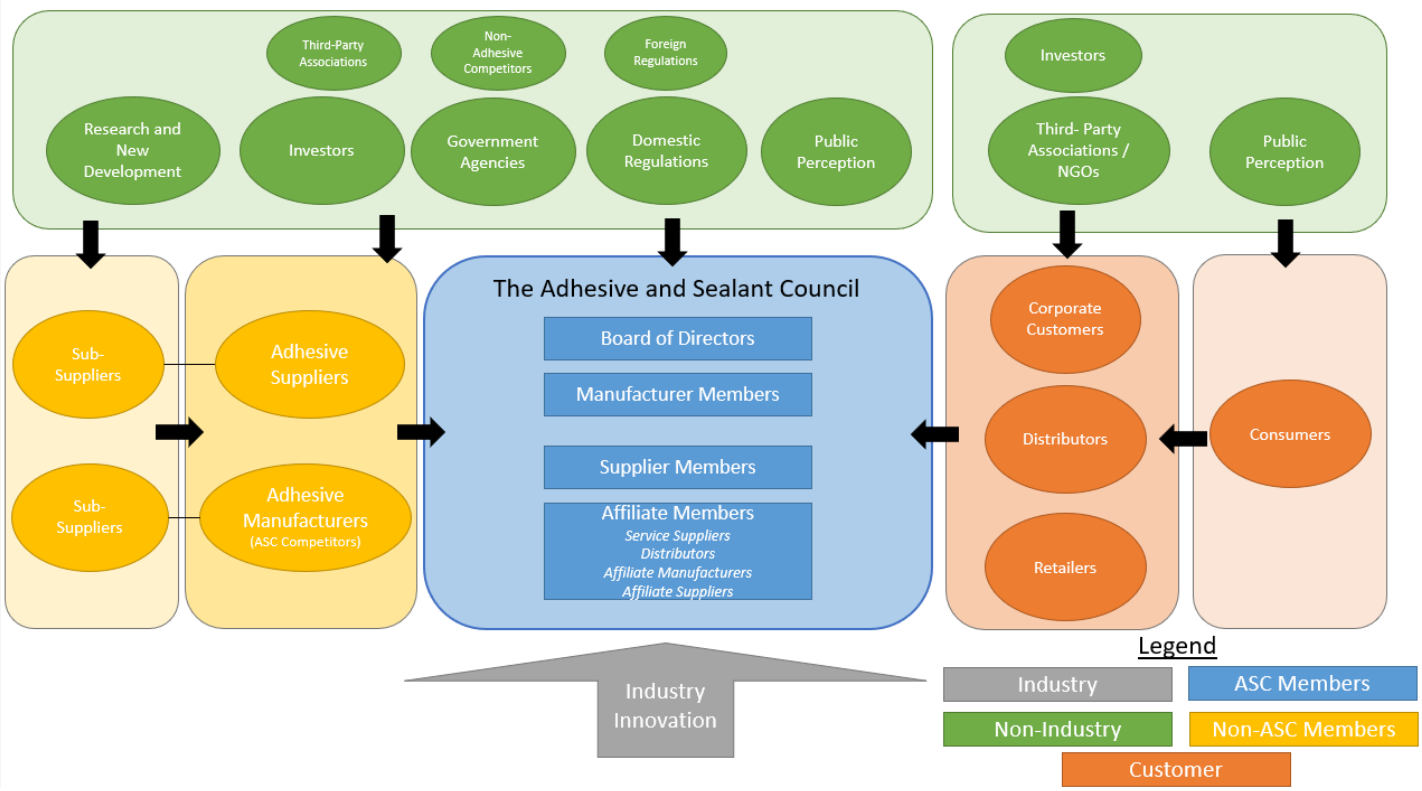

Figure 1 – Overview of Industry Value Chain

Figure 1 illustrates the industry specific influences (grey), non-industry influences (green), non-ASC member influences (yellow) and customer influences (orange) that act upon the ASC (blue). These groupings are left intentionally broad, additional figures shown throughout this report will provide greater clarity and detail as required.

All stakeholders outlined in the figure above have some degree of influence over the operations of ASC members. The general size of the ovals indicates the level of influence that that organization has within the value chain, for example foreign regulations may influence a company's decisions but generally domestic regulations will have a larger influence. Through the interviews conducted with ASC members it was determined that the main stakeholders influencing sustainability initiatives include downstream operations, government and industry regulations, and internal corporate initiatives.

Within the adhesives industry there are various sustainability criteria that companies focus on. One focus area includes internal corporate goals and the drive for continuous improvement corporate goals and continuous improvement. Companies with developed sustainability targets strive to reduce their carbon footprint, incorporate more sustainable materials into their product lines, and reduce water and waste. These goals are typically long term and align with corporate desire to commit to sustainability. A second focus area for ASC members include customer requests. A main objective within the industry is to fulfill customer requirements for product performance, cost, and sustainability.

For example, customers will present ASC members with specific criteria for the products they are specifying including, but not limited to, recyclability or composability at end of life, or have inquiries into different environmental and health documentation available for the products they purchase. When

adhesive companies notice trends within their markets their sustainability goals might shift to meet customer requests. Customer requests may arise from marketing personnel who are seeking products which may attract and retain more customers, meet regulatory requirements, or green building standards. Government and industry organizations have been focusing on sustainability more heavily in recent years. Regulations vary between different countries or regions, but the general trend is to increase product transparency, environmental stewardship, and disclose goals which demonstrate a company's commitment to environmental social governance (ESG) principles. With an increasing rise in external reporting requirements and stakeholder expectations for key performance indicators and metrics, corporations will be required to ensure their internal goals and metrics satisfy this demand. Industry associations often provide benefits for their members but require or encourage a certain standard of commitment to sustainability. Additional influence comes from investors, public perception, and competitors.

Key Stakeholders

ASC represents many members that are suppliers or manufacturers of adhesive products. These suppliers and manufacturers then provide their adhesives to a wide variety of markets. The primary market driver for product attributes typically comes from downstream requirements. Suppliers of adhesive additives must meet the requirements of adhesive manufacturers, who in turn must meet requirements from their end product users. Performance is always the key criteria which must be satisfied. Additional sustainability requests can come from downstream as well.

For example, each end market including packaging, transportation, and building and construction will have unique and varying drivers for sustainability which may range from environmental certifications such as environmental product declarations (EPDs) to increased focused on recyclability or circularity. End product manufacturers can also face external pushes from regulatory or government agencies which may drive their goals. Ultimately, this leads to adhesive suppliers and manufacturers receiving additional requests for products with certain properties, performance, or certifications.

The relationship between suppliers and manufacturers is critical to the overall sustainability of the industry. Manufacturers rely on suppliers to provide data to create more accurate life cycle assessments (LCAs) or scope 3 emission quantification, both of which are discussed in more detail within this report. Suppliers and end product manufacturers must work together to reduce the overall embodied carbon of the final product.

Additional stakeholders include investors, regulators, and other industry members.

Market Specific Value Chain Maps

Figures 2 through 4 below show value chain maps that focus on the life cycle of the adhesive products used in building and construction, transportation, and packaging. These figures overlap in many ways, they all contain similar stages, but a detailed discussion around the specifics for each value chain is provided below.

Within each of the figures below there are five main life cycle stages: chemical acquisition (getting the raw materials that go into adhesives), adhesive additive manufacturing, adhesive manufacturing, adhesive application, and the use and disposal of the end product. Between each stage there is transportation, and at each stage we have inputs and outputs.

At the chemical acquisition stage inputs include everything required to extract and produce raw materials. Some raw materials will need to be mined, extracted, refined, and further processed before they are usable for an additives or adhesive manufacturer. Additive and adhesive manufacturers have inputs of raw materials and energy, water, and support materials required for manufacturing. Adhesives are then applied to their end product and the product is distributed to customers. Within each stage outputs can include waste and emissions generated through chemical reactions between the materials or through manufacturing operations.

Building and Construction

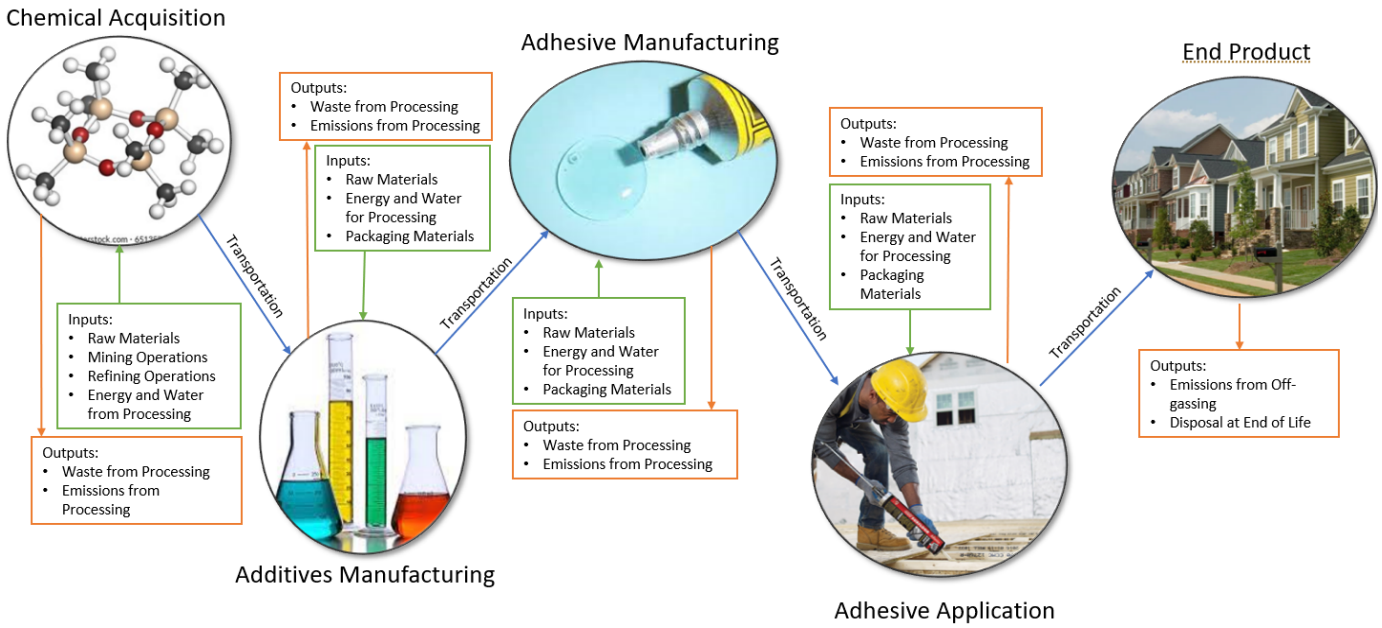

Figure 2 – Value Chain Map for Building and Construction Products

Figure 2 above details the stages within the building and construction adhesives market. This market typically sells adhesives directly to retailers or contractors who apply adhesive during the construction process.

Adhesives used in the building and construction sector are intended to be durable and long lasting. Structural adhesives have key requirements for strength, longevity, and performance, but even non-structural adhesives should focus on reducing the need for reapplications or replacements[1,2].

Adhesives can be used to improve the efficiencies of the building envelope by reducing energy losses from heating and cooling to the outside environment.

The building and construction sector have a particular focus on reducing volatile organic content (VOCs), carcinogens, and other potentially harmful materials. Emissions from adhesives can impact human health for the occupants in buildings and has certain threshold requirements in various building standards, including Leadership in Energy and Environmental Design (LEED) and the WELL Building

[1] "13 Types of Adhesives Used in Construction." BuilderSpace, 24 June 2021, https://www.builderspace.com/types-of-adhesives-used-in-construction#:~:text=The%20main%20types%20of%20adhesives,also%20types%20of%20construction%20adhesives.
[2] "Adhesives for Building and Construction - A Comprehensive Guide." Adhesives for Building and Construction - A Comprehensive Guide, SpecialChem, 2021, https://adhesives.specialchem.com/selection-guide/adhesives-for-building-and-construction.

Standard (WELL). Building products can aid in the procurement of LEED or WELL credits by meeting certain criteria. For example, products with low VOC content can contribute to the LEED Indoor Environmental Quality credits; furthermore, products with EPDs and health product declarations (HPDs) can contribute to LEED Material and Resources credits. Adhesive suppliers and manufacturers can aid in this development by supplying material information to end product manufacturers.

Adhesive packaging comes in a variety of formats and application methods which are also dependent upon the intended use of the product. Some building and construction adhesives can be sold in bulk, but this is dependent upon the quantity required and application method. Using bulk packaging reduces the amount of packaging required and can typically aid in reducing material and transportation impacts by reducing weight. Strides have been taken in the adhesive industry to innovate packaging to meet customer requirements and be environmentally conscious. A reduction in packaging weight and incorporation of more recycled or recyclable materials can reduce impact. Additionally, waste can be reduced through the implementation of easily resealable or reusable packaging. Packaging that requires the use of a dispenser or some other additional tool should be compatible with the already available and widely used tools on the market.

Transportation

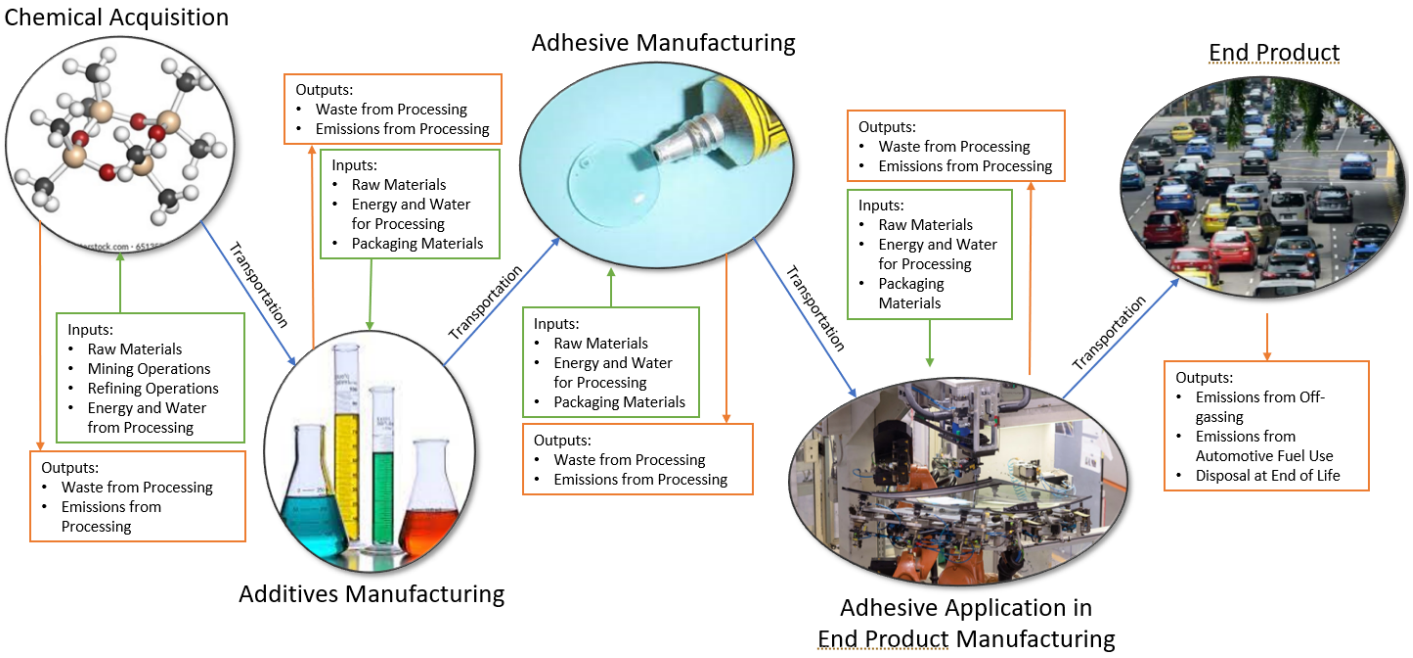

Figure 3 – Value Chain Map for Transportation Products

Figure 3 above details the stages involved in the transportation adhesives market. This market typically sells adhesive to automotive or aerospace manufacturers who apply adhesives at various stages of the end product manufacturing process.

Similarly to building and construction adhesives, transportation adhesives should be built to last. If reapplication and replacement can be reduced then environmental impacts associated with creating a new product, reapplication, and disposal can be avoided.

Increasingly, there has been more focus around reducing the VOCs in car interiors[3]. Automotive interiors are smaller, confined, and often heated which makes off-gassing more prevalent and can expose users to higher amounts of VOCs. Currently, Asian and European governments are at the forefront of VOC limitations within vehicle interiors[4]. These limitations include VOC testing, regulations around acceptable VOC limits, and avoidance of certain types of VOCs. VOCs like benzene, toluene, formaldehyde, styrene, xylene, and acetaldehyde can pose harm to human health. The International Standard Organization (ISO) has developed a draft of standards and test methods in order to standardize VOC testing within vehicle cabin interiors, ISO 12219-1:2021. More information on the regulations by various governments can be found in the Vehicle Interior Air Quality: Addressing Chemical Exposure in Automobiles paper published by UL Environment (UL).

The transportation industry has a focus on reducing vehicle weight to reduce emissions during vehicle use. A variety of adhesive types are used throughout vehicles and reducing weight across the board can help to reduce fuel consumption[5].

Packaging

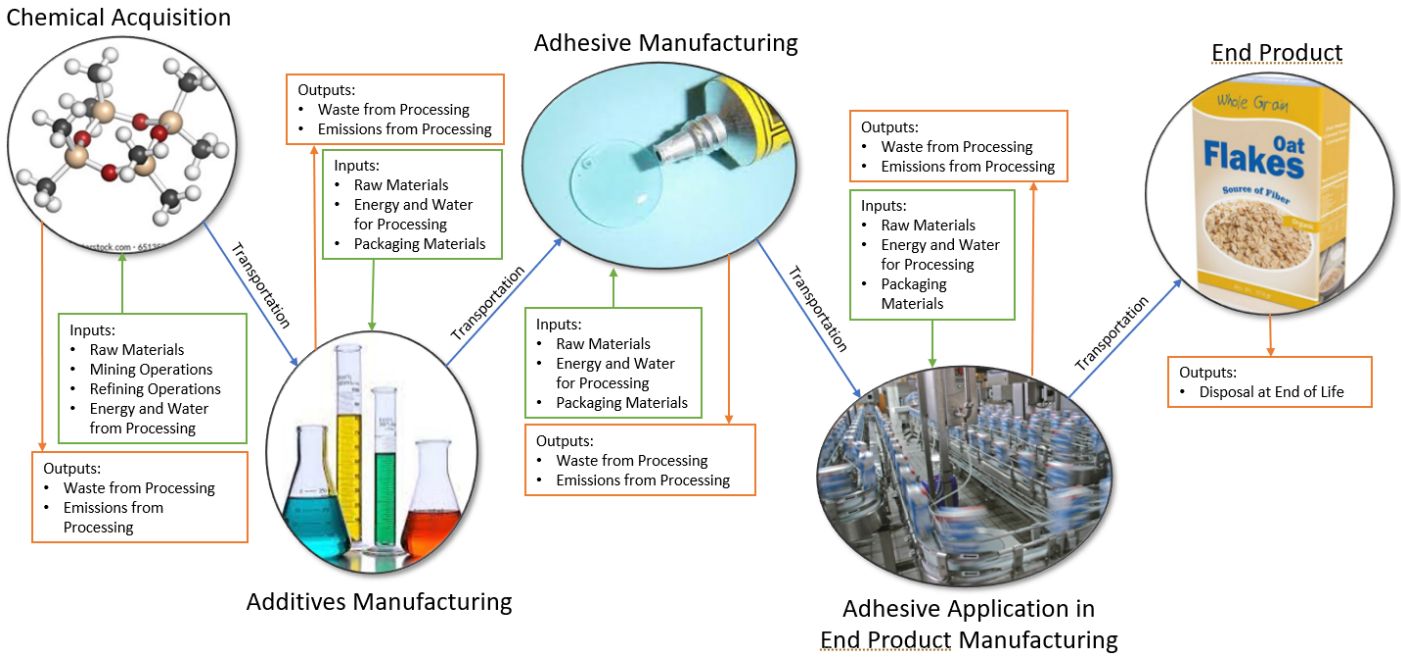

Figure 4 – Value Chain Map for Packaging Products

[3] "Less VOC Emission for Healthier Mobility Interior Air Quality." One 4 Leather, 5 June 2020, https://www.one4leather.com/article/less-voc-emission-for-healthier-mobility-interior-air-quality#:~:text=Over%2060%20different%20VOCs%20have,%2C%20xylenes%2C%20and%20trimethyl%20benzenes.

[4] "Examining the Unique Challenges of VOC in Automotive Interiors." 3M Science Applied to Life, 3M, https://www.3m.com/3M/en_US/oem-tier-us/automotive-interiors/examining-challenges-voc/.

[5] "Supporting Global Automotive Innovation with Adhesive Technology." Sunstar Group, Mar. 2020, https://www.sunstar.com/healthy-thinking/weld-bonding/.

Figure 4 above details the stages involved in the packaging adhesives market. Adhesive manufacturers generally sell product directly to packaging manufacturers, who then supply packaging to end product manufacturers.

Packaging has a focus on being durable during use, but typically has a shorter lifespan than adhesives used in the building and construction or transportation sectors. In this regard, packaging has less of a focus on longevity and instead puts more emphasis on recyclability or biodegradability. Packaging manufacturers and consumers want their packaging to be easily recyclable or compostable, and materials like adhesives could potentially hinder end of life options. Easily recyclable adhesives can either be dissolved in recycling process water, removed mechanically through screening, or separated through centrifugation[6]. Knowing the recycling process that will take place (glass, metal, plastic, and paper recycling all use different methods) can aid in the identification of a suitable adhesive[7,8].

A wide variety of products require packaging that incorporates adhesives and certain markets, like food packaging, must meet certain material safety and regulatory requirements. These regulations tend to be enforced by government organizations, like the Food and Drug Administration (FDA) in the United States[9]. The FDA regulations include specific sections detailing the requirements for adhesives. Requirements depend upon the level of contact between the adhesive and food and the toxicology of materials used within the adhesive.

[6] "Industry Insights: Making Sustainable Choices in the Adhesive Tape Market". ECHOtape, https://www.echotape.com/wp-content/uploads/2015/10/EchotapeSustainabilityWhitePaper.pdf
[7] Onusseit, Hermann. "The influence of adhesives on recycling". Resource, Conservation, and Recycling, Volume 46, Issue 2. 2006. https://www.sciencedirect.com/science/article/pii/S0921344905000984
[8] "Eco-Friendly Adhesives In the World of Sustainable Packaging". EcoEnclose. April 18, 2022. https://www.ecoenclose.com/blog/ecofriendly-adhesives-in-the-world-of-sustainable-packaging/
[9] "Packaging & Food Contact Substances (FCS)" U.S. Food & Drug Administration. https://www.fda.gov/food/food-ingredients-packaging/packaging-food-contact-substances-fcs

Environmental Areas of Focus

ASC has a wide range of members. There is variation in member roles, company sizes, and corporate sustainability goals. There are both publicly and privately traded companies, which face different pressures and have different requirements. Each member organization is unique and must evaluate their individual requirements to develop goals that are in alignment with stakeholder expectations, industry standards, and regulatory requirements. This section details some of the specific recurring sustainability themes that were encountered through industry research and discussions with ASC members.

Figure 5 below shows a visual representation of the most commonly mentioned sustainability goals among ASC members.

Figure 5 – World Cloud of Sustainability Focused Goals Among ASC Members

The words in the figure above are weighted so that the size represents how often a word was mentioned. All words were gathered through the publicly available information that ASC members have on their sustainability goals either on their website or within their annual reporting. The most commonly mentioned goal is to reduce greenhouse gas emissions, which was brought up as a goal or focus for at least 56 of ASC's members. Other commonly mentioned goals include reducing water use, reducing waste generation, aligning with the United Nations Sustainable Development Goals (UN SDG), incorporating more biobased materials into product formulations, focusing on the circular economy, increasing the recyclability of products, achieving net zero emissions, focusing on suppliers that can provide sustainable procurement, and developing life cycle assessments.

Figure 6 below shows a breakdown of the ASC member companies across three sets of criteria. The first chart shows that around 40% of ASC member companies have some form of in depth sustainability reporting, either through annual reports, clearly defined objectives on their website, or newsletters that provide measurable goals. The second chart shows that around 40% of ASC member companies are publicly owned and 60% are privately owned. The third chart shows that around 65% of ASC member companies have some form of sustainability information available, often through a specific section on their webpage.

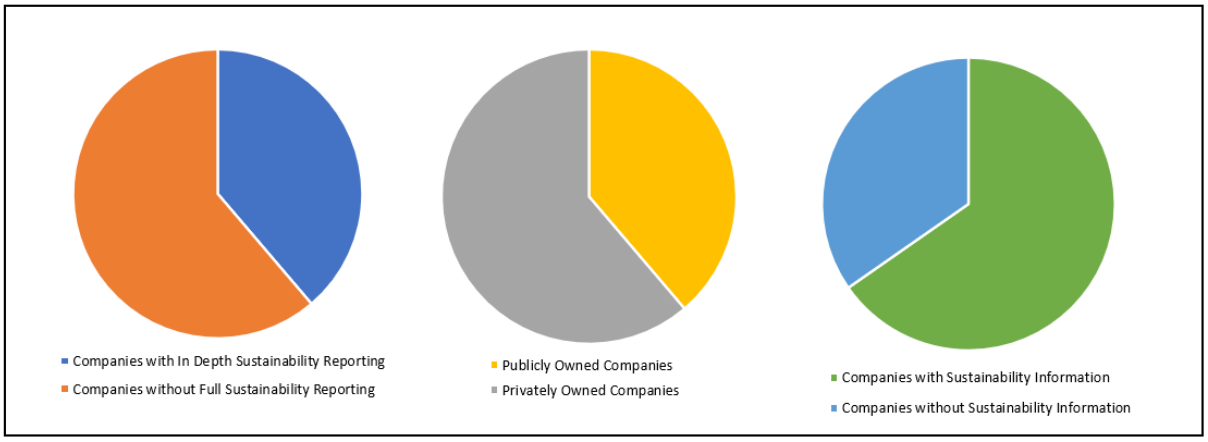

Figure 6 – Pie Charts Describing ASC Member Companies

Prioritize Carbon Footprint Reductions for Products and Operations

From the evaluation of currently available sustainability and corporate responsibility reports, a key focus area is prioritizing the reduction and mitigation of greenhouse gas (GHG) emissions. The importance of establishing a baseline, tracking yearly progress, and setting future goals has been identified by the majority of the industry.

Reducing greenhouse gas emissions can be achieved in multiple ways and typically incorporates a variety of reduction strategies.

Carbon footprint can be identified through LCA. LCA can be performed under multiple different system boundaries. The most common system boundaries include cradle-to-gate, cradle-to-gate with options, or cradle-to-grave. Cradle-to-gate refers to a system boundary that looks at the impact of a product from the extraction of the raw materials that go into that product through all of the stages up until the product is at the manufacturing gate and ready to be distributed. Cradle-to-gate with options looks at the same stages up until the product is at the manufacturing gate, but also looks at the impacts associated with the end-of-life stages associated with the disposal of that product. Cradle-to-grave refers to a system boundary that looks at the impacts of a product from raw material extraction through the end-of-life treatment of a product and includes the impacts associated with the distribution, installation, and use of the product.

The publicly available cradle-to-gate with options EPDs show that the raw material, manufacturing, and end-of-life disposal phases tend to be the most impactful. Raw materials tend to be the primary driver of impact. Reductions in carbon footprint can be made through sourcing raw materials with lower environmental impacts. Additional steps should be taken towards increasing manufacturing efficiencies to reduce energy and water consumption, and waste generation. Manufacturing efficiencies to improve adhesive processability can reduce scrap rates and improve excess processing. In many currently published studies, the end-of-life assumption for adhesive is incineration. Through material developments adhesives can aid in alternative disposal methods for their end products, like recycling. The focus within the adhesive industry is around making end products recyclable, typically through removing the adhesive, decomposing the adhesive, or having an adhesive with no impact on recyclability.

Figure 7 below shows the GHG Protocol scopes and emissions across the value chain. Scope 1 emissions account for the direct emissions that come from a company's owned resources, an example of scope 1 emissions would include the combustion of fuels used within the manufacturing operation. Scope 2 emissions account for the indirect emissions that come from the generation of purchased energy used by the company. Scope 3 emissions account for the indirect emissions from all other parts of the value chain, for example all impacts associated with the procurement of raw materials or the end-of-life treatment of sold products. Generally, many ASC member companies are tracking their scope 1 and 2 emissions and now have goals to further understand and track their scope 3 emissions.

Scope 3 is often the largest source of a company's overall emissions, but they are also often outside of the company's control. Many companies can find opportunities to reduce their organization's GHG emissions through scope 3 reductions. Selecting suppliers with lower emissions, using lower impact means of transportation between operations, or incorporating takeback programs to reduce end-of-life impacts are all strategies to reduce scope 3 impacts.

For more information on the GHG Protocol scopes and how they can be calculated see the tools available on the Greenhouse Gas Protocol website.

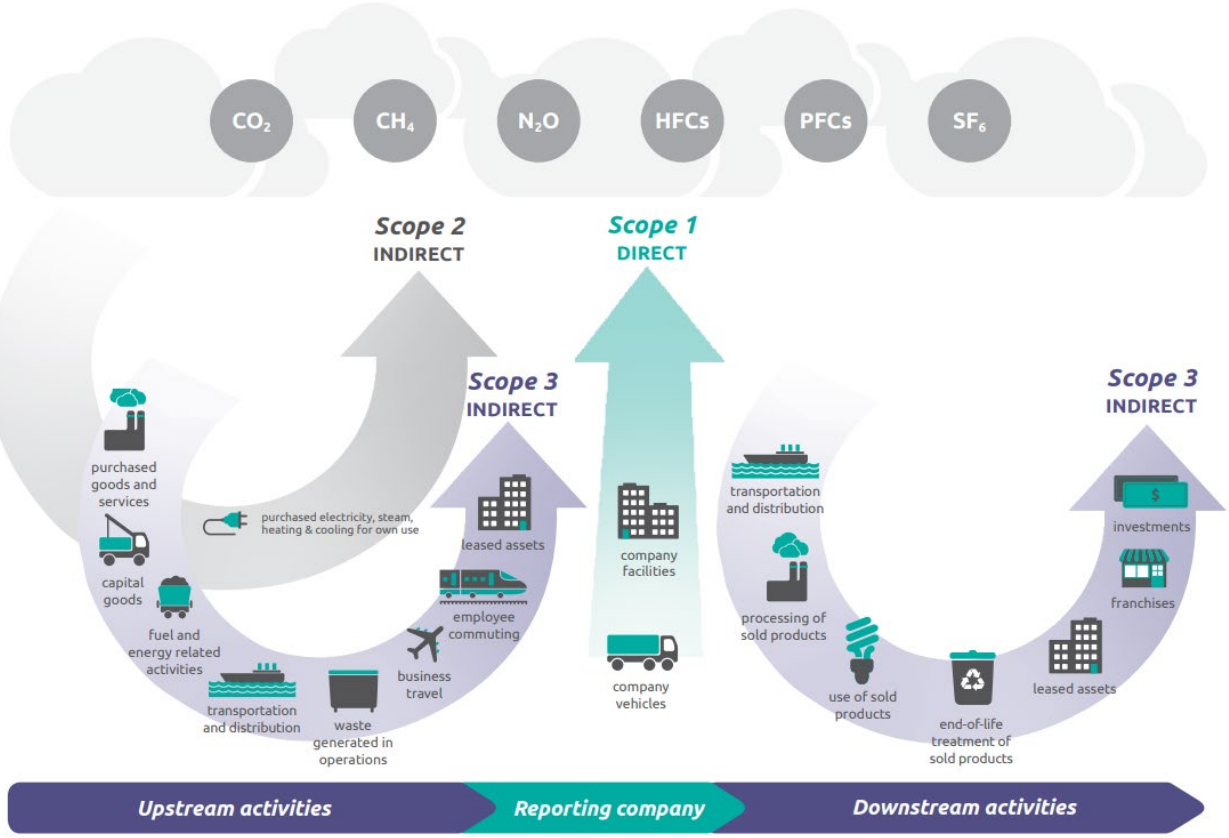

Figure 7 – Greenhouse Gas Emissions Across the Value Chain[10]

[10] World Resources Institute and World Business Council for Sustainable Development. "Corporate Value Chain (Scope 3) Accounting and Reporting Standard". Greenhouse Gas Protocol. September 2011. https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf

Bio-based and Alternative Materials

With recent trends towards reducing greenhouse gas emissions and carbon footprint, there is also growing interest in using alternative materials. There is currently a lot of development around incorporating more bio-based materials into product design and multiple ASC members have developed or are developing bio-based adhesives. There exist several studies which compare bio-based and petrochemical based adhesive; based on the findings of the studies, bio-based materials exhibit lower environmental impacts in carbon emissions[11,12]. Some important considerations for bio-based materials are that the material is readily renewable, responsibly harvested, and not contributing to food scarcity. Research into biobased adhesive strength is ongoing and continues to see improvements. Multiple studies have shown that biobased adhesives can be produced without loss of performance[13,14].

Biobased materials contain additional advantages other than the environmental and human health benefits from avoiding petroleum-based materials. For example, vegetable oil derived adhesives have additional water-resistant properties. Their lower toxicity opens adhesives to a wider array of applications. Different molecular structures can provide new functionalities and additional performance benefits, some biobased adhesives have higher strength, better chemical resistance, and lower volume reduction than petroleum-based adhesives. Utilizing biobased materials can also reduce material cost. More information on specific chemistries can be found in Heinrich's study, "Future opportunities for bio-based adhesives – advantages beyond renewability".[15]

Additional material considerations include the use of more easily recycled materials, materials which contain recycled content, compostable materials, and materials which exhibit lower environmental impacts than current formulations.

Research into alternative material types is ongoing. A recent report details the use of upcycled plastic to create strong adhesives[16], while research is also being conducted at the University of California, Berkeley to make adhesive from upcycled plastic bags[17].

[11] McDevitt, J.E., Grigsby, W.J. "Life Cycle Assessment of Bio- and Petro-Chemical Adhesives Used in Fiberboard Production". J Polym Environ 22, 537–544 (2014). https://doi.org/10.1007/s10924-014-0677-4

[12] Yang, Minliang and Kurt A. Rosentrater. "Environmental effects and economic analysis of adhesives: a review of life cycle assessment (LCA) and techno-economic analysis (TEA)." (2015).

[13] Li, Chunyin, et al. "Fully Biobased Adhesive from Glucose and Citric Acid for Plywood with High Performance". ACS Applied Materials & Interfaces 2022 14 (20), 23859-23867 DOI: 10.1021/acsami.2c02859

[14] Heather M. Siebert and Jonathan J. Wilker. "Deriving Commercial Level Adhesive Performance from a Bio-Based Mussel Mimetic Polymer". ACS Sustainable Chemistry & Engineering 2019 7 (15), 13315-13323
DOI: 10.1021/acssuschemeng.9b02547

[15] Heinrich, Lydia. "Future opportunities for bio-based adhesives – advantages beyond renewability". DOI: 10.1039/C8GC03746A (Critical Review) Green Chem., 2019, 21, 1866-1888. https://pubs.rsc.org/en/content/articlehtml/2019/gc/c8gc03746a

[16] Lavars, Nick. "Upcycled adhesive is one of the toughest materials ever reported". New Atlas. January 24, 2022. https://newatlas.com/materials/upcycled-adhesive-toughest-materials-plastic/

[17] Sanders, Robert. "Upcycling: Turning plastic bags into adhesives". UC Berkeley College of Chemistry. December, 18 2020. https://chemistry.berkeley.edu/news/upcycling-turning-plastic-bags-adhesives

Environmental, Social, and Governance (ESG) Goals

ESG is a holistic approach to measuring a company's commitment to sustainability with more defined guidelines, especially on the environmental side. Several companies within the ASC have some form of ESG goals, something that is strongly driven by investors. Developing ESG targets enables companies to measure year over year improvements, promotes accountability, and provides deeper insight into their commitments and key performance indicators. Some ESG goals include carbon footprint reductions or alternative material incorporation, while additional goals could include waste generation and water use reductions, product stewardship considerations and improvements through LCAs, and publication of external reports such as EPDs, health product declarations (HPDs), cradle to cradle (C2C) certificates, or certifying product claims. Many companies are following the triple bottom line framework by focusing on people, planet, and profit. Additionally, companies are also aligning their goals with the United Nations Sustainable Development Goals (UN SDG). Additional standards and target-based references include Science Based Targets (SBTi), the Global Reporting Initiative (GRI), the Task Force on Climate-related Financial Disclosures (TCFD), and the Sustainability Accounting Standards Board (SASB).

Information on Life Cycle Assessment

LCA is a tool for determining the impact of products by evaluating the inputs and outputs required at each stage of a product's life cycle. Environmental product declarations (EPDs) represent these results in a format made available to customers. EPDs include a range of environmental impact categories including global warming potential, acidification, eutrophication, ozone layer depletion, and fossil fuel depletion, among other reported parameters. To publish an EPD there must be a product category rule (PCR) that defines the methodology required for reporting on a certain product type. ASC aided in the development of a sealants PCR which has been published by UL.

EPDs are critical for manufacturers who wish to better understand the environmental impacts and hot spots of their product's life cycle. EPDs are most relevant to the building and construction sector. LCAs are used throughout every industry. Many automotive companies have sustainable procurement requirements and utilizing LCAs aids in the sourcing of lower impact materials.

Using a product with an EPD can increase the number of credits earned within several green building systems, like LEED or the International Green Construction Council (IgCC) for example. EPDs are conducted in accordance with ISO standards. Regulatory requirements that encourage or will start to require EPD reporting for construction products have also become more prevalent, especially in Europe. There has been a drive to decrease embodied carbon reporting. Embodied carbon accounts for the GHGs released from the manufacturing of building materials, while operational carbon accounts for the GHGs released through the use of a building.

Raw Material Analysis

An evaluation of various LCAs and EPDs was performed to further assess the raw materials impacts for adhesive and sealant products. As raw materials are the greatest contributor to the life cycle impacts, there exists an increasing necessity for end product manufacturers to increase engagement and communication with their upstream raw material suppliers in an effort to reduce their product's environmental impacts.

A study from McDevitt and Grigsby demonstrates bio-adhesives used in fiberboard production have a lower global warming potential than a petrochemical adhesive used in the same application[18]. Yang and Rosentrater have two published studies evaluating the life cycle of adhesives. One compares the environmental impact or urea-formaldehyde (UF) adhesive and phenol-formaldehyde (PF) adhesive.[19] In this study the UF adhesive was shown to have less global warming potential impact (around 70%) compared to PF adhesive. Yang and Rosentrater also have a study comparing petroleum-based glycerol and biodiesel-based glycerol.[20] In this study they found that the biodiesel-based glycerol has a smaller global warming potential (around 80%) compared to the petroleum-based glycerol.

A study by Favi (et al.) compared different polymer joining methods using adhesive bonding, looking at abrasion, primer, plasma, and laser application methods.[21] In this study the adhesive impact remains constant while the impact from the application method differs. It was shown remove that the global warming potential for primer application was the highest followed by the abrasion application. In this study, the primer used had a higher global warming potential than the adhesive itself, showing how support application materials may have a high impact as well and should be taken into consideration when developing a product.

Global warming potential is not the only criteria that needs to be considered when selecting a raw material. Within the building and construction and transportation industries specifically, products aim to be low in VOCs to meet regulatory requirements. Solvent and acrylic based adhesives tend to have the longest lasting off-gassing emissions.

FEICA has published a number of EPDs representing adhesives used for building and construction in Europe. These EPDs are expiring in 2022, but they include polyurethane-based adhesives, epoxy-based adhesives, dispersion-based products, modified mineral mortars, and silane-based sealants. These EPDs show the variance in impact among different product formulations and applications.

[18] McDevitt, J.E., Grigsby, W.J. "Life Cycle Assessment of Bio- and Petro-Chemical Adhesives Used in Fiberboard Production". J Polym Environ 22, 537–544 (2014). https://doi.org/10.1007/s10924-014-0677-4

[19] Yang, Minliang and Kurt A. Rosentrater. "Life Cycle Assessment of Urea-Formaldehyde Adhesive and Phenol-Formaldehyde Adhesives". Environmental Processes (2020) 7:553–561. https://doi.org/10.1007/s40710-020-00432-9

[20] Yang, Minliang and Kurt A. Rosentrater. "Cradle-to-gate life cycle assessment of structural bio-adhesives derived from glycerol". The International Journal of Life Cycle Assessment (2021) 26:799–806. https://doi.org/10.1007/s11367-020-01733-9

[21] Favi, Claudio, et al. "Life Cycle Analysis of Engineering Polymer Joining Methods Using Adhesive Bonding: Fatigue Performance and Environmental Implications." ScienceDirect, Procedia CIRP, 8 Mar. 2022, https://www.sciencedirect.com/science/article/pii/S2212827122000956.

Key Findings and Recommendations

Figure 8 below shows a summary of the industries evaluated in this study, their main applications, and the main considerations that should be accounted for when trying to reduce impact. Considerations in white of are particular interest within their specific applications. These considerations along with everything included in the bulleted list below should be considered when determining how products can be developed.

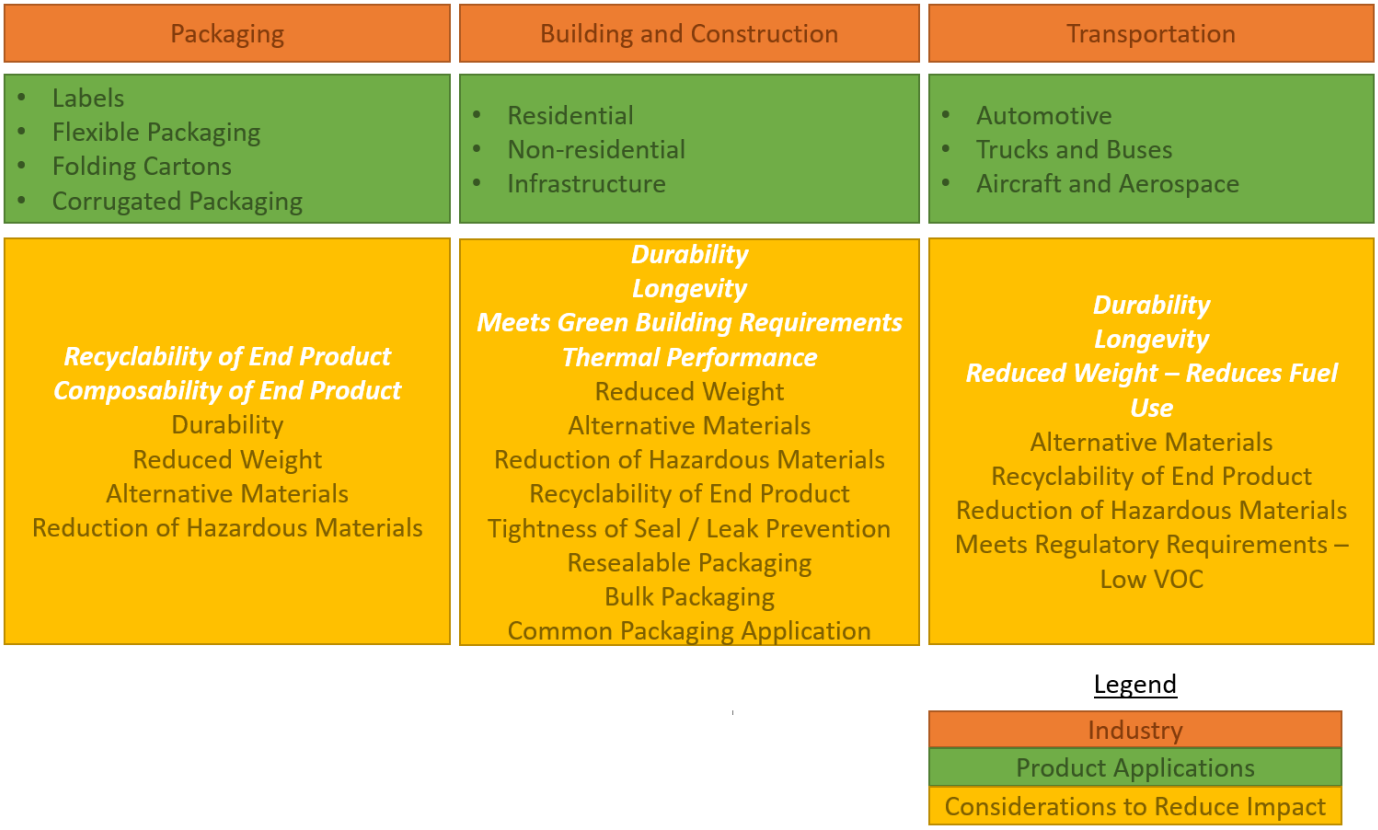

Figure 8 – Summary of Industries, Application, and Opportunities for Impact Reduction

Product Considerations

- Utilize materials with lower carbon footprint, reduced hazards, and lower VOCs
- Decrease weight of products by using lighter weight materials
- Utilize materials that increase the processability and reduce manufacturing scrap
- Increase recyclability or compostability at end of life
- Increase durability so that long lasting products (building and construction, transportation) will require fewer replacements
- Conduct analysis to find where manufacturing efficiencies can be made to reduce energy consumption, water consumption, waste generation, and scrap generation
- Create products that can utilize lower energy application processes
- Reduce packaging weight, use bulk packaging where applicable, make packaging easily resealable so product does not get wasted during use, use common packaging application if additional tools are required for application

Conclusion

In conclusion, there are a variety of ways that members of the adhesive value chain can contribute to the sustainability of the adhesive industry. Each company should evaluate their own specific situations to find the solutions that are most appropriate for them. Considerations must take into account the differences between adhesives used in various markets. This report details some of the main areas that adhesive industry members can focus on, including reducing greenhouse gas emissions, incorporating the use of alternative raw materials, reducing waste through increased processability and evaluation of the manufacturing process, and increasing end product durability and/or recyclability.

For more information on adhesive sustainability please contact the Adhesive and Sealant Council: https://www.ascouncil.org/.