Journey to a More Sustainable Food System

Part 1: An introduction to investment opportunities addressing sustainability in the food supply chain

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Executive summary

The food supply chain, also called the food system, refers to the network of systems and processes that transform raw materials such as livestock and crops into consumable foods, then transports them from farms and warehouses to consumers. While technological advances in the supply chain have increased the speed at which consumers can access fresh foods year-round, there remain vulnerabilities that drive up food waste and contribute to other health and environmental-related concerns.

Food waste is estimated to amount to $285 billion annually in the US. While most food waste derives from unused food, recalls due to foodborne illnesses and contamination also contribute to the problem. Food waste also contributes to climate change. Rotting food in landfills and farms is a significant source of greenhouse gas (GHG) emissions. Food packaging waste is also on the rise, fueled in part by the rise of food delivery during the pandemic. In addition to its environmental impact, wasted food can be linked to societal issues. According to the USDA, 10.5% of US households are food insecure, meaning that there is limited access to adequate, healthy food due to a lack of money or resources.[1] Optimization and reallocation of surplus food could help address this growing problem.

Pressure to curb food waste has spurred both corporates and governments to act. Large food corporations such as Nestlé and Sysco have committed to reducing waste and emissions throughout their value chains. In 2015 the USDA launched the "US 2030 Food Loss and Waste Reduction Goal" to cut food waste in half in alignment with the UN Sustainable Development Goals (SDGs)[2]. Growing public support to reduce waste along with corporate and government-led efforts should help ensure ongoing funding for projects and startups focused on optimizing food supply chains and reducing waste. This report is the first in a five-part series exploring the technologies helping to tackle waste reduction and sustainability objectives within the food system. This note provides a high-level overview of the food system supply chain and explains the relevant food sustainability issues. It also provides an overview of the various venture-backed startups seeking to provide solutions to these problems.

1: "Food Security and Nutrition Assistance," USDA Economic Research Service, December 16, 2020.
2: "United States 2030 Food Loss and Waste Reduction Goal," EPA, April 15, 2021.

Food supply chain overview

Global agricultural trade amounted to roughly $1 trillion per annum with growth in the mid-single digits[3]. The largest food-consuming countries include Austria, United States, and Greece, which consume, respectively, an average of 3,800, 3,750, and 3,710 kilocalories per capita daily[4]. The largest food-producing companies are China, India, United States, and Brazil[5]. The largest single food crop in the world is sugar cane, with a global output of 1.9 billion tons.

There are many different systems and processes that facilitate the functioning of the food supply chain, which relies on a vast landscape of traditional as well as emerging technologies. Supply chain technologies have made considerable advancement in recent years and are being powered by new technologies stemming from artificial intelligence (AI), the internet of things (IoT) and blockchain.

We have segmented the food supply chain into five distinct processes:

- Agriculture: The source of produce, meats, and raw materials used to manufacture food products
- Food processing: Processing and manufacturing facilities where ingredients are transformed into finished goods
- Packaging: Materials and technologies used to prepare finished foods for distribution and sale
- Transportation: Services that transport food and raw materials throughout the food system from the farm to the consumer
- Distribution & storage: Warehousing and storage facilities to store fresh foods as they are transported through the supply chain
- Retail: Physical or online end markets where food is sold to consumers

3: : "The Global Landscape of Agricultural Trade, 1995-2014," USDA, Jayson Beckman, John Dyck, and Kari E.R. Heerman, November 2017.
4: "Food Consumption by Country," WorldAtlas, Joseph Kiprop, July 9, 2018.
5: "4 Countries That Produce the Most Food," Investopedia, Sean Ross, July 19, 2020.


Last-mile transportation
Drone delivery
zipline
Skydio
3DR
DJI
DroneDeploy
PRECISIONHAWK
SKYCATCH
DRONE RACING LEAGUE
SAILDRONE
makeblock
Clobotics
AIRMAP
Dedrone
kespry
YUNEEC
FORTEM TECHNOLOGIES
SKYSPECS
DELAIR
FLYPRO Just Move
D-FEND SOLUTIONS
IRIS AUTOMATION
WINGCOPTER
Automated delivery
nuro
STARSHIP
autox
CLEARPATH ROBOTICS
新石器
Agility Robotics
boxbot
marble
REFRACTION AI
kiwibot
robby
CONNECT ROBOTICS
robomart
swisslog
真机智能 ZhenRobotics
Electric delivery vehicles
RIVIAN
ARRIVAL
XLFleet
indigo Technologies
chanje
LIGHTNING eMOTORS
Sustainable packaging
zume
ECOVATIVE DESIGN
TemperPack
TERRACYCLE
Polymateria
Notpla
smartplanet technologies
dropwater
SANA PACKAGING
DO EAT
Valentis
envoPAP
MI TERRO
Sealstrip
LEAN ORB
Active Difference
BAMBREW
bettereath


Middle-mile transportation
Autonomous trucks
Aurora
tusimple
Plus
INCEPTIO
EMBARK
einride
kodiak
LOCOMATION
STARSKY ROBOTICS
isee
Electric trucks
NIKOLA
HYZON
SMITH
WRIGHTSPEED
WORKHORSE
HYLIION
TEVVA
VOLTA TRUCKS
Food waste
Shelf-life extension
Apeel
AgroFresh
Prevenio
bluwrap
mori
hazel technologies inc.
RUBENS
S2G BioChem
Upcycling
WISErg
CSS
Pleuzette
Re-Nuble
THE COFFEE CHERRY CO.
Inventory management
Afresh
wasteless
winnow
Flashfood
COPIA
Oversight
Quality control
CORVIUM
safetraces
INTELLO LABS
CLARIFRUIT
AgShift
brytemap
farmQA
Farm with control
AfriCert
Nebulaa
Traceability
Centaur
TieUp Farming
checkplant
QUALIBOO
Sensire
CLOUDLEAF
CONNECTING FOOD
TRACERS
dffsolutions

Consumers preferring more sustainable products

Relative to past consumer behavior, today's consumers care more about how their food is produced and have more interest in supporting businesses committed to sustainability. A recent NYU Stern and IRI study showed that millennials are the age group most likely to purchase sustainable consumer packaged goods (CPG) even during the COVID-19 pandemic, indicating the staying power of sustainability.[6]

In response to these changing consumer preferences, many large corporations have announced food sustainability initiatives. In 2014, Walmart announced a commitment to creating a more sustainable food system by improving the affordability of food, increasing access to food, making healthy eating easier, and improving the safety and transparency of the food supply chain. In 2020, Nestlé announced it would electrify its trucking fleet as part of the company's goal to reduce greenhouse gas emissions by one-half by 2030. Nestlé is aiming for 100% recyclable or reusable packaging by 2025[7] and has committed to a 50% reduction in operational food loss and waste.[8] Unilever has announced plans to sell €1 billion in plant-based meat and dairy products over the next five to seven years as part of its healthy eating initiative. The company also committed to continue lowering calorie, salt, and sugar levels across its product line and cut food waste in half across global operations by 2025. Mars Wrigley recently partnered with Danimer Scientific to develop biodegradable packaging as part of a $1.0 billion project called Sustainable in a Generation Plan. In 2018, Sysco Corporation set a corporate social responsibility goal of diverting 90% of operational food waste from landfills by 2025.[9]

Select corporate sustainability initiatives

Company	Target Date	Goal
General Mills	2030	Reduce GHG emissions by 30% over 10 years
Whole Foods	N/A	Donate uneaten food to food banks
PepsiCo	2025	Improve water use efficiency by 15% in agricultural supply chain
Nestlé	2025	100% recyclable or reusable packaging
Mondelez	2025	10% reduction in end-to-end CO2 emissions
Ahold Delhaize	2030	Reduce food waste in brands' operations by 50%

6: "Latest Research from NYU Stern Center for Sustainable Business and IRI Shows That Sustainability Is Surviving COVID-19", NYU Stern Center for Sustainable Business and IRI, July 16, 2020.
7: "Nestlé Aiming at 100% Recyclable or Reusable Packaging by 2025," Nestlé, April 10, 2018.
8: "IRIS+ Thematic Taxonomy," Global Impact Investing Network, May 2019.
9: "Sysco Announces 2025 Corporate Social Responsibility Goals," Sysco, August 13, 2018.

Policy & regulation intended to reduce waste and improve health

Regulation that seeks to reduce food waste and improve consumer health outcomes represents a significant driver of food supply chain improvements. According to the Centers for Disease Control (CDC), 48 million Americans get sick, and 3,000 die from foodborne diseases each year. The Food Safety Modernization Act (FSMA) passed in 2011 mandates more preventative controls on food processing systems, including inspections, compliance with regulations, and more traceability of food products.

However, excessive regulation can contribute to the food waste issue and prevent food companies from donating or upcycling food. For example, federal and local laws prevent food scraps from being used as animal feed due to health concerns. And many companies choose to destroy at-risk food instead of donating it for fear of legal liability. The Federal Bill Emerson Good Samaritan Food Donation Act protects food companies from criminal and civil liability due to donating food that later causes harm to recipients. Tax policies can provide incentives for food businesses to redirect at-risk foods from the landfill to donation centers.

Potential benefits of reducing food waste

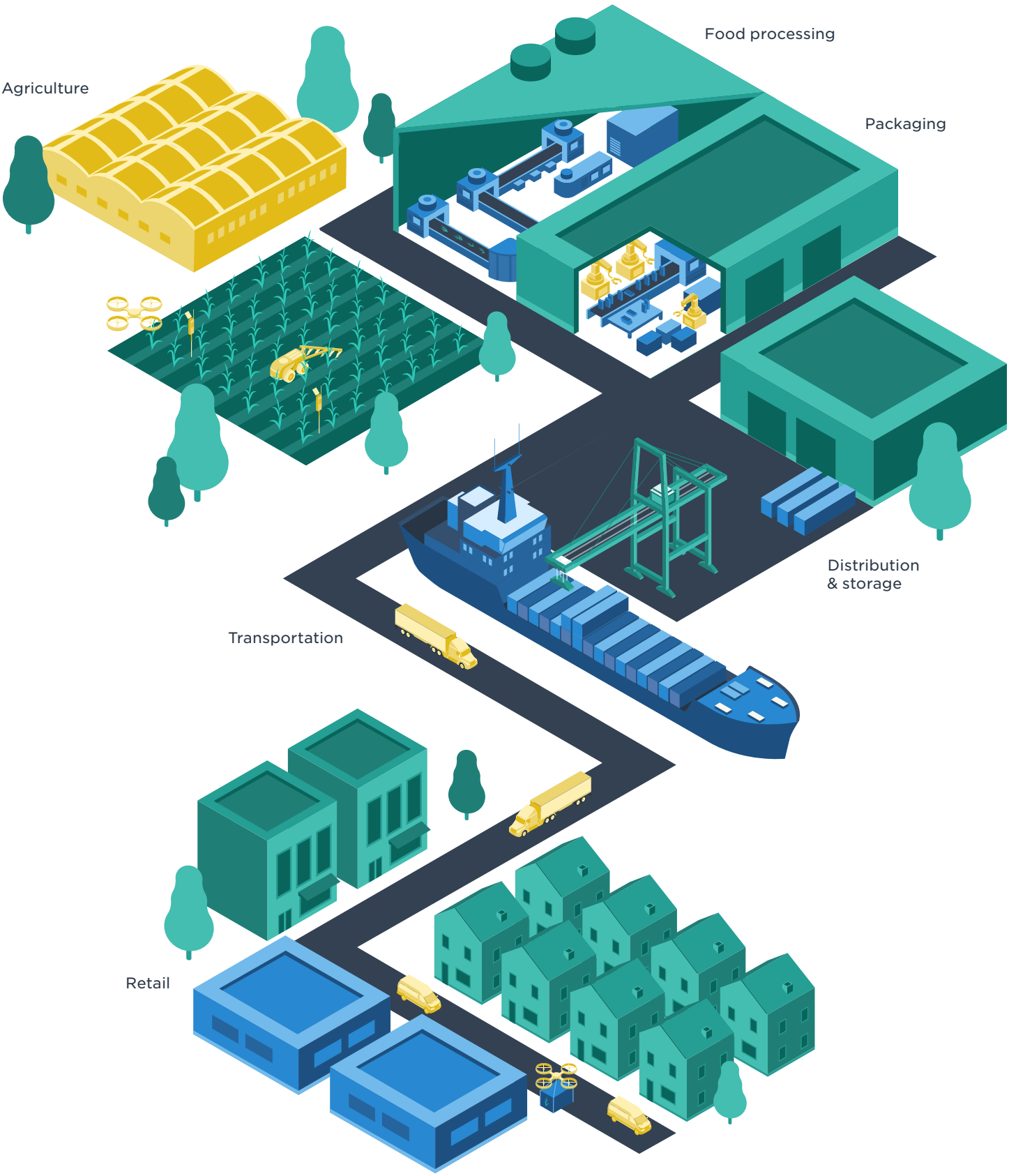
Food waste reduces profitability, harms the environment, and exacerbates food insecurity. In the US, 54 million tons of food are wasted each year throughout the food system.[10] This food ends up in landfills or is left unharvested in fields. Another 26 million tons of food is unsold and ends up recycled or donated. Wasted food represents a financial cost for food businesses totaling $285 billion,[11] compressing margins and elevating consumer costs.

Surplus food could also be used more effectively to address social need. Only a small portion of surplus food—3.6 billion pounds—is donated to Feeding America and its network of food banks each year.[12] In addition to helping address food insecurity, food producers can receive tax benefits from donating fresh food.

Food waste has environmental repercussions as well. Growing and producing food requires limited resources, including water, land, and energy. Food waste accounts for 14% of all freshwater use and 18% of cropland use. It is also estimated that food waste contributes 4% of total US greenhouse gas emissions[13] and makes up 24% of total landfill contributions, more than any other municipal solid waste material.[14] Reducing food waste represents a key approach to addressing growing demand for climate-conscious products and policies that address climate change.

10: "ReFED Insights Engine," ReFed, March 25, 2021.
11: "Roadmap to 2030: Reducing US Food Waste by 50% and the ReFED Insights Engine," ReFed, March 25, 2021.
12: "Why Should We Care About Food Waste?" USDA, March 25, 2021.
13: "ReFED's Insights Engine: Your Source for Data and Solutions to Reduce Food Waste," ReFed, March 25, 2021.
14: "2018 Wasted Food Report", EPA, November 2020.

An overview of the food supply ecosystem



Agriculture

Agriculture, food, and related industries are a $1.1 trillion market in the US, roughly 5.2% of US GDP in 2019.[15] They are also the origin of many health and environmental concerns including greenhouse gas emissions, food waste, water pollution, and foodborne illnesses. The food supply chain begins on the farm, and agricultural activities are a significant contributor to GHG and account for an estimated 11% to 15% of all GHG emissions. Sources of emissions include fertilizers, irrigation practices, livestock digestive processes, and manure management.

Emerging agricultural technologies are helping improve farm productivity while addressing sustainability issues. Ag BioTech solutions using genetics and microbiomics help achieve more resilient, productive crops without harming the environment. Electronic farm equipment reduces GHG emissions, while regenerative farming practices such as no-till farming capture carbon in the soil, enabling the creation of agricultural carbon credit markets.

Significant food waste occurs on the farm as well. One major contributor is imperfect produce. Many consumers will reject healthy produce found in retail due to blemishes, bruises or bug bites. For this reason, ugly produce, called "seconds," is often passed over during harvest and ends up as animal feed or is left on the field to rot. Startups such as Hungry Harvest, Misfits Market, and Imperfect Foods sell these seconds at a discount to consumers via home-delivered produce boxes. Precision ag tools that can provide real-time crop health data are another approach to reducing seconds at harvest.

Produce can also be wasted when there is insufficient farm labor to harvest crops. During the height of the pandemic in 2020, many farms faced severe challenges finding workers to pick crops. With restaurants and foodservice providers closed, demand for some crops unexpectedly plummeted. Automation tools such as the robotic tomato harvester from Automato Robotics help farmers maintain productivity with less reliance on a dwindling farm workforce.

Lastly, food safety issues that originate on farms not only represent significant health concerns but can lead to significant waste when large batches of food are recalled or destroyed. Food contamination on the farm can occur for various reasons, such as tainted irrigation water or animal sickness caused by unsanitary conditions. When an illness is traced back to food, large quantities are usually destroyed to prevent further illness. Supply chain software can help address food safety issues. Centaur Analytics helps farms trace food from farm to table, increasing farmers' ability to track potential issues. Additionally, biotech innovations are helping maintain animal health and replacing harmful chemicals with crop treatments that are safe for human consumption.

15: "Ag and Food Sectors and the Economy," USDA, December 16, 2020.

Food processing

After food leaves the farm as raw materials, the food processing stage is where it is converted into finished food products. Foods can be minimally processed, such as packaged produce, or they can be heavily processed into many types of consumer-packaged goods such as breakfast cereals. Food processing waste primarily consists of food scraps that go unused in the final product such as bones, cores, and peels. While many food processing derivatives end up in the landfill, some companies repurpose or upcycle them into new foods or valuable materials. Startups focused on the upcycling opportunity include California Safe Soil, Outcast, ReGrained, and GoodFish. Together these companies have raised a combined $51.9 million in venture capital as of April 21, 2021.

Food safety represents a mission-critical focus area of the food processing industry and a key contributor to food waste given the potential for foods to be recalled or destroyed for health reasons. Contaminated foods can have potentially dangerous health implications, resulting in expensive product recalls and liability risk. Traditional quality control processes tend to include fast—but imprecise—visual inspections, and accurate—but slow and costly—lab analysis. However, several startups are leveraging AI-related technologies to improve the speed and accuracy of legacy processes. Five startups we have identified that are focused on this opportunity include Agshift, Seebo, Corvium, Clarifruit, and SafeTraces. These companies have raised a combined $121.0 million in venture capital as of April 21, 2021.

Packaging

Packaging is a significant component of landfill waste and represents a significant waste reduction opportunity. The pandemic has led to a surge in packaging waste as more restaurant takeout and delivery has increased demand for single-use plastics, and a rise in shipped fresh foods, such as groceries and meal-kits, has required more packaging materials such as insulation, cushioning, ice packs, and individual ingredient packaging. A push to reduce packaging waste is being driven both by consumer demand and public sustainability initiatives such as the United Nations Sustainable Development Goals (SDGs). Corporate stakeholders are also investing in sustainable packaging options. Mars Wrigley recently partnered with Danimer Scientific to develop biodegradable packaging as part of its $1.0 billion company-side "Sustainable in a Generation Plan."

The global food packaging market was estimated to total $303.3 billion in 2019 with growth in the mid-single digits through 2027.[16] The packaging industry is primarily dominated by large incumbent producers that rely on traditional packaging materials such as plastics and cardboard. Plastics have become a preferred packaging material due to ease of use, lighter weight, lower cost, and durability. While paper is a popular packaging material, it has come under criticism from consumers and environmentalists as a contributor to deforestation, giving rise to "tree-free" alternatives.

16: "Food Packaging Market Size, Share & Trends Analysis Report by Type (Rigid, Flexible), By Material (Paper, Plastic), By Application (Bakery and Confectionery, Dairy Products), By Region, and Segment Forecasts, 2020 – 2027," Grand View Research, March 2020.

Other new types of packaging that are recyclable, reusable, or compostable represent a growing disruptive threat to industry incumbents.

Many startups and traditional food providers are finding ways to use alternative packaging products such as terra cotta, mycelium, or edible materials that are more environmentally friendly. These include plant-based dairy provider UNNICO, which plans to launch single-serve yogurts in terra cotta containers; and PE-backed TerraCycle, which has partnered with McDonald's and Burger King to pilot reusable food and beverage containers. Upcycled agricultural waste is another innovative source for packaging. For example, startup Mi Terro repurposes milk waste into a fiber that replaces transparent plastic film. Innovation is also occurring in labeling, an oft-ignored packaging component that can contain plastics and chemical adhesives. Biodegradable, compostable, and water-soluble labels are helping to provide a comprehensive sustainable packaging solution.

A shift to sustainable packing will likely be a long-term process. Packaging is highly intertwined with branding and brand strategy, requiring significant collaboration and planning. It will likely take time for packaging companies to build capabilities including infrastructure and supplier relationships to offer sustainable packaging at scale.

Distribution & storage

Distribution and storage providers focus on these essential tasks: storage, transport, and handling. Maintaining integrity of the food involves temperature monitoring and maintenance, reducing unnecessary handling, and optimizing the supply chain to reduce spoilage.

One of the largest challenges facing this segment of the food supply chain is the growing number of products (or SKUs) that need to be stored and distributed. Growing SKUs are a result of expanding consumer demand for new types of foods and flavors as well as producers' willingness to bring new products to market. In addition to simply finding adequate storage space, the rise in SKUs also makes it harder to ensure freshness as food moves through distribution hubs.

Warehouse automation systems are helping address these challenges. These systems can improve the throughput of facilities and increase storage capacity by 50%–100%, helping alleviate storage concerns. According to ABI Research, more than 4 million commercial robots will be installed in 50,000 warehouses by 2025, up from around 4,000 robotic warehouses in 2018.[17] Warehouse automation startups such as Geek+, Berkshire Grey, GreyOrange, Vicarious, and Fabric provide scalable robotic systems to transport, store, and pick goods.

Automation can also enable social distancing in the event of future pandemics as it allows warehouses to operate with fewer staff, potentially reducing the contagion risk to employees. In addition, fewer people in warehouses could reduce safety-related incidents as well as human-

17: "50,000 Warehouses to Use Robots by 2025 as Barriers to Entry Fall and AI Innovation Accelerates," Businesswire, March 26, 2019.

transmitted illnesses that could affect food, thereby improving the safety and security of the food supply chain. Automation can also address current labor shortages, which were exacerbated by the COVID-19 outbreak.[18]

In addition to automation, digital warehouse marketplaces can alleviate storage constraints for companies storing seasonally sensitive food items. Digital platforms such as Flexe, Stord, and Darkstore operate digital marketplaces where external warehouse space can be acquired. These companies provide a flexible logistics solution for asset-intensive enterprises struggling to place inventory. For example, Stord helps match grocery and food stores with cold storage warehouses in its network. These platforms can help add flexibility and scalability for small businesses, enterprises, and other shipping intermediaries so they can maintain steady operational performance during periods of fluctuating inventory demand. Digital marketplaces also increase price transparency and allow for more consumption-based spend. This segment appears to be gaining traction with investors. In January 2021, Flexe raised an $80.0 million Series C from Prologis Ventures, Redpoint Ventures, and Activate Capital Partners, putting the company's pre-money valuation at $430.0 million. In September 2020, Norwegian warehousing marketplace raised an undisclosed amount of pre-seed funding from TRK Group, StartupLab, Innovasion Norge, and Antler.

Transportation

According to NAFTA, 70.5% of food transportation in the US occurs via trucks.[19] The trucking industry generated $791.7 billion in revenue in 2019. According to the US Department of Transportation, $1.5 trillion of mixed freight (primarily food) was moved in 2018 in the US.[20] There are several areas of opportunity where emerging technologies are poised to help modernize food transportation and address sustainability concerns. These include the conversion of gas fleets to electric, the eventual introduction of autonomous driving technology, the use of drone delivery systems, and continued improvement in vehicle telematics. Additionally, several new startups are addressing opportunities to help monitor and even tend to food during shipment to ensure safety and freshness.

The trucking industry is responsible for an outsized portion of emissions; the EPA estimates that medium- and heavy-duty trucks are responsible for 23% of US transportation emissions, or 6.4% of total US emissions.[21] For this reason, we view electric truck technology as imperative to sustainability efforts. Relative to traditional diesel-powered trucks, electric trucks offer several benefits including zero emissions, reduced fuel costs, up to 20% lower maintenance costs given fewer moving parts to service, fewer specialized equipment and labor needs, longer warrantied lifetimes, and steadily declining battery costs.

18: "Warehouse Worker Scarcity Crimping US Transloading Capacity", JOC.com, August 13, 2020.
19: "Kan-Haul's Food Transportation US Statistics Infographic," Kan-Haul, July 29, 2013.
20: "Freight Facts and Figures" US Department of Transportation, Bureau of Transportation Statistics, 2019.
21: "Fast Facts on Transportation Greenhouse Gas Emissions," EPA. June 2020.

Key companies developing truck electrification technology include Daimler, Tesla, Nikola, Hyliion, Hyzon Motors, Lightning Motors, Wrightspeed Powertrains, VIA, Volvo, and XOS Trucks. Whereas most providers are focused on battery-electric powertrains, others such as Nikola, Hyliion, and Hyzon Motors are developing hydrogen fuel-cell-based powertrains. It remains to be seen how competitive fuel cell technology will be in electrifying freight compared to battery-electric options. Barriers to hydrogen fuel cell adoption include the need for capital-intensive infrastructure rollouts. Nevertheless, the technology could have advantages over batteries owing to inherent technical advantages related to energy density.

Government regulation is a driving force behind electrification. In June 2020, California announced that it would require all new trucks sold in the state to be zero-emissions. In another example, New York City has partnered with electric powertrain startup MOVE Systems to provide 500 solar-powered food carts to street food vendors. President Biden has proposed $174.0 billion be invested in electric vehicles as part of his infrastructure plan. The plans calls for building 500,000 EV chargers by 2030 and electrifying 50,000 diesel transit vehicles and the federal fleet.

In addition to electrifying trucks, autonomous trucking technology will help make the industry safer by reducing human-caused collisions. As trucks are 20–30 times heavier than passenger vehicles, accidents can often be fatal. In 2019, 4,119 people died in collisions involving trucks, and 82% of fatalities were passenger vehicle occupants, pedestrians, bicyclists, or motorcyclists.[22]

The relative simplicity of automating highway driving compared to urban driving will accelerate the deployment of this technology. Unlike using autonomous vehicles for consumer transport, transporting commercial goods is not beholden to customer expectations about passenger experience, has lower safety hurdles, and is less sensitive to delays. Moreover, many commercial vehicles operate on fixed routes instead of dynamic routes, which makes autonomy less complicated for AI-based systems. Leaders in the self-driving space include Waymo, Aurora, TuSimple, and Embark, which announced a self-driving trucking platform in March 2021. Established automakers are also entering the fray. Volvo is developing a cabless, fully autonomous truck, while Daimler Trucks, which acquired Torc Robotics in 2019, is investing heavily in the space.

In addition to long-haul trucking, middle-mile food transportation automation will be key to improving safety and sustainability. Middle-mile transport refers to the movement of goods to, from, and among warehouses or shipping facilities in urban and rural locations. Often these routes are in closed-off locations away from the public where collision risks are lower. These environments enable lower success thresholds relative to consumer applications of autonomous vehicles, increasing the likelihood of adoption over a shorter time horizon. Walmart, which pioneered the retail hub-and-spoke distribution model, is now working on automating its last-mile logistics network through a partnership with startup Gatik AI.

22: “Large Trucks,” IIHS, April 2021.

The electrification and automation of last-mile delivery using electric and autonomous vehicles, robots, and drones could improve on-demand food delivery sustainability. Favorable economics and more regulations are leading to increased spending on commercial electric vehicles. Startups such as Canoo, Arrival, and Chanje are developing electric delivery vans. Amazon has placed an order for 100,000 electric delivery vans from Rivian and 1,800 Mercedes-Benz electric vans. In April 2020, UPS ordered 10,000 electric delivery vans from Arrival. Ford and Daimler have announced new models of electric delivery vans.

Food delivery electrification will not be constrained to just commercial vans. The growth in on-demand food delivery has propelled companies including Amazon, Uber, and DoorDash to rely on networks of gig economy couriers that are likely to drive emission-creating internal combustion engine vehicles. Evidence suggests this shift could have contributed to an increase in neighborhood emissions. For example, San Francisco's smart parking project SFPark found that neighborhood emissions dropped by 30% when drivers spent less time needlessly idling while searching for free parking spots. As miles driven by gig economy workers increase, companies such as Uber and Lyft face pressure to electrify their fleets; for example, Uber has committed to a fully zero-emission fleet in US, Canadian, and European cities by 2030 by partnering with policymakers to incentivize drivers to move to electric vehicles.

In our view, purpose-built vehicles tailored for the gig economy (not just large commercial vans) will be key to improving the food delivery space's sustainability. Indigo Tech is a US-based developer of robotic wheel propulsion and active suspension technology, which underpins the company's upcoming commercial delivery vehicles. Unlike most other commercial EV companies in the space, Indigo focuses on gig economy workers' needs, providing a small, light electric vehicle that is highly efficient, maximizes cargo space, and costs 20% less per mile to operate.

Electric and autonomous delivery drones will also be key to reducing emissions in cities while enabling speedy delivery of food items. Drone delivery companies include Zipline International, Matternet, Flirtey, and Flytrex, while electric take-off and landing (eVTOL) aircraft developers EHang and Volocopter (partnered with logistics giant DB Schenker) are developing large cargo drones for middle-mile logistics applications.

Tracking and traceability technology is also a key component of ensuring food safety during transportation. The Food Safety Modernization Act (FSMA) mandates preventative controls, inspection, compliance, and—crucially—stricter traceability of food products. Stricter controls have led to increased investment in technologies that can improve food security. Aanika, which raised a $2.5 million seed round in February 2020, has developed microbial-based tags that act as microscopic barcodes, enabling large food and agricultural companies to ensure the integrity of supply chains and reduce potential losses. Additional startups providing food supply chain traceability products include Cloudleaf, Connecting Food, and Muddy Boots Software (acquired by Telus).

Cold chain monitoring is a crucial component of food safety. Maintaining visibility of frozen items as they progress through different value chain steps is a significant challenge faced by the industry. Cold chain monitoring startups such as Sensire, Tracers Technology, DFF Solutions, and CloudTrack provide real-time monitoring of frozen goods, sending alerts when temperatures fall outside of preset thresholds.

Biotech solutions are increasingly playing a vital role in extending the shelf-life of produce throughout the supply chain. Startup Hazel Technologies has developed a sachet that is added to produce packaging to delay decomposition. One product works by neutralizing a plant hormone that triggers ripening, while another contains an anti-fungal agent that prevents mold. The sachets protect produce as it travels through the supply chain and maintain freshness in storage conditions, reducing waste throughout.

Retail

Retail markets represent the last step in the food supply chain where consumers ultimately buy food. The stage is segmented into two buckets:

1. Food at home (FAH): Also called "off-premise" or retail in the food and beverage industry, this segment includes grocery, convenience, warehouse clubs, and direct selling from farmers and manufacturers.

2. Food away from home (FAFH), also called "on-premise": This segment includes restaurants, dining places, schools, and other foodservice establishments.

There are roughly 40,000 grocery stores and 647,000 restaurants in the US. In 2019, $799.4 billion was spent on food and alcohol in grocery stores and other off-premise retailers for at-home consumption. $969.4 billion was spent in restaurants and other foodservice establishments. Over the past decade, consumers have increased the number of meals purchased from restaurants, slowly shifting dollar share of total food expenditures towards FAFH. That trend reversed sharply in March 2020 at the onset of the pandemic as consumers began sheltering in place and as restaurant dining rooms were closed. This trend has held through the remainder of 2020 with consumers consistently spending more at FAH retailers.

Retail is a significant source of food waste and surplus food, contributing 10 million tons in the US annually with an estimated total value of $37 million.[23] Food waste in grocery stores primarily stems from consumer preference as well as the challenge of forecasting the demand for thousands of perishable goods. Highly perishable goods such as milk and leafy greens have limited shelf life, with consumers preferring the freshest items with the most extended shelf life.

Imperfect produce and products with shorter expiration dates are often discarded when fresher products are available. Startup Wasteless has

23: "Roadmap to 2030: Reducing US Food Waste by 50% and the ReFED Insights Engine," ReFed, March 31, 2021.

developed a dynamic pricing engine and smart price tags that discount products based on the expiration date, ensuring older goods are sold. Startup Afresh offers a different point solution focused on surmounting the challenge of managing inventory for perishables. The company provides an inventory management platform customized for the complexities of produce, such as perishability, seasonality, and inventory variability. Understanding and seizing control over the root sources of retail food waste is key to improving sustainability.

In restaurants and foodservice, most food waste occurs from plate waste. Overproduction is another source. The first step to reducing these waste sources is to quantify them. Startup Winnow combines weighted scales and computer vision with an AI-powered software solution to identify and measure discarded food, informing better planning and menu decisions.

Consumer software solutions may also help reduce at-risk inventory. Startup Feedback App enables restaurants to offer time-sensitive deals and dynamic pricing to sell food that would otherwise go to waste. On the grocery side, startup Flashfood is a grocery ordering app that enables merchants to discount surplus foods for pickup. And if restaurants and grocers are unable to sell at-risk food, startup Copia provides a software platform to donate food quickly and efficiently to non-profits. These software providers build customer allegiance while salvaging revenues (or tax benefits) from food that would otherwise be wasted.