Optimizing Commercial Freight

A Climate Technology White Paper

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BloombergNEF

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Optimizing commercial freight: an introduction

Introduction

Optimizing commercial freight

In this paper we show that there are some important and urgent challenges to decarbonizing commercial freight (road and marine), *beyond drivetrain electrification and clean fuels*.

Specifically, we analyze technology innovations, and the early-stage companies developing them, that would contribute significantly to tackling these problems:

1. **Eliminating empty miles:** How can we optimize freight-matching, load plans and returns management? (Slides 8-15)
2. **Optimizing the journey:** How can dynamic route planning support more efficient journeys? How can we optimize the last mile, and reduce idling and waiting time? (Slides 16-23)
3. **Transforming cold chain:** How can we better monitor and care for perishable goods? And what innovations in refrigeration as well as cooling materials can help reduce emissions? (Slides 24-31)

This paper provides data and context on the challenges, evaluates some of the proposed innovations and suggests ways to overcome potential blockers. We also highlight 65 startups that are leading the charge in these areas. The final section examines cross-cutting technologies that could accelerate innovation and outlines early-stage investment trends for each of the three technology gaps.

BNEF Pioneers: hunting for innovation

This is one of three reports to be published following the 2021 BNEF Pioneers awards.

BloombergNEF's annual Pioneers competition identifies and recognizes innovators developing new technologies to tackle some of the most important challenges in the fight against climate change.

Each year, the Pioneers competition focuses on three innovation challenges.

In 2021 the challenges are:

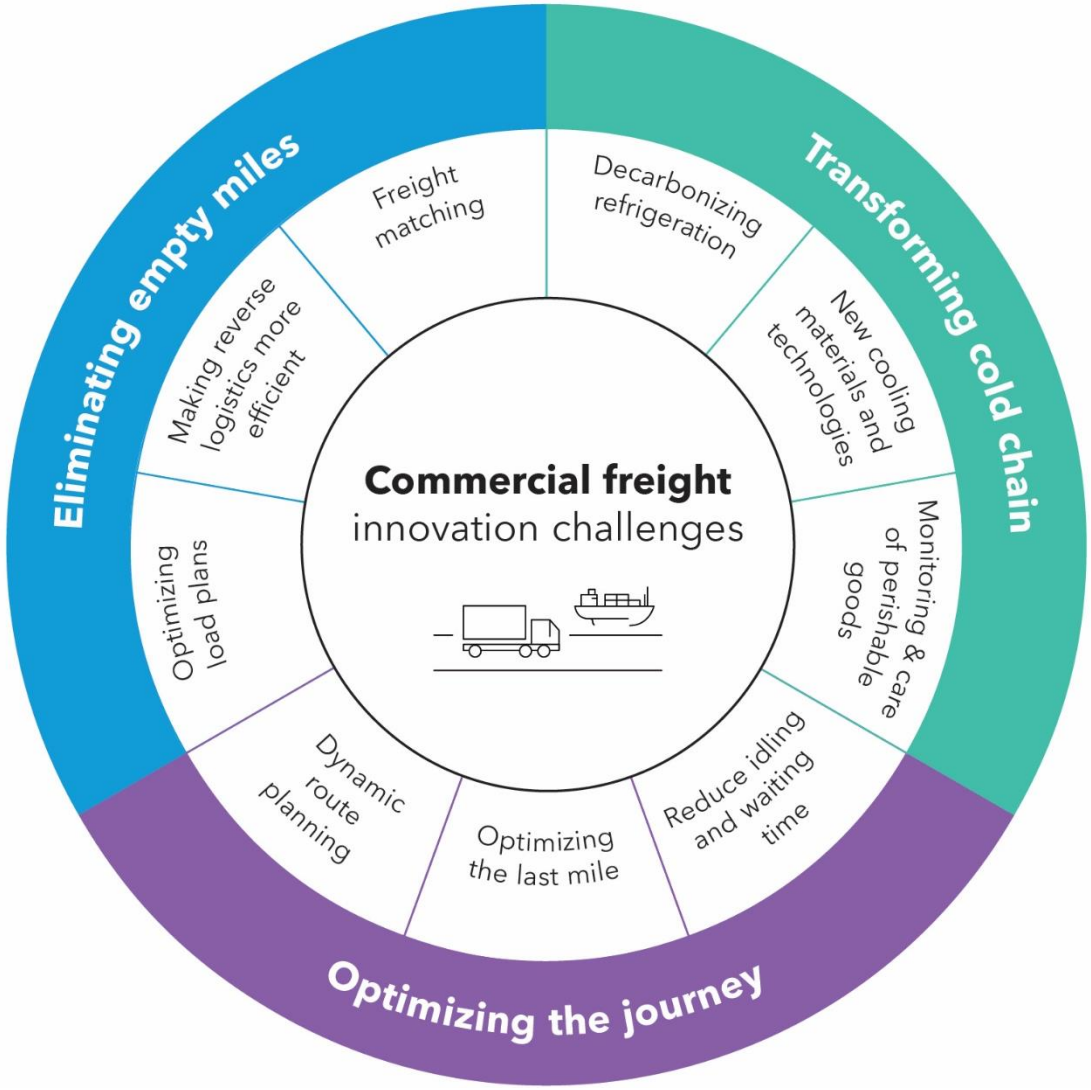
1. **Optimizing commercial freight** (the focus of this research note)
2. Advancing materials and techniques for sustainable products (research note available here)
3. Monitoring and understanding our changing planet (research note available here)

For more information about the Pioneers competition, please visit https://about.bnef.com/bnefpioneers/

Challenges in optimizing commercial freight

Road freight and shipping account for about 40% of transportation emissions, and are among the hard-to-abate sectors that will either be slow or difficult to electrify. This report highlights three key challenges areas in optimizing commercial freight:

- **Eliminating empty miles:** A significant amount of energy is used to power empty trucks because of poor matching, or part-empty containers because of poor packing. Digital platforms can match empty or part-empty trucks with shipment needs; analytics can optimize the use of space in containers; and innovations in reverse logistics can decarbonize retail returns.
- **Optimizing the journey:** Inefficient journeys mean more mileage than necessary to transport goods to their final destinations. Planning the most efficient route is too difficult to solve manually or with spreadsheets yet over 72% of local delivery businesses in the U.S. still plan routes manually. Innovations can reduce emissions by improving route planning, optimizing the often-complex last-mile delivery steps, and reducing idling and waiting times.
- **Transforming cold chain:** Refrigerators in trucks or ships are powered by burning fossil fuels, and powering refrigeration of perishable goods accounts for about 3.5% of global GHG emissions. Refrigerated cargo in transit is poorly monitored because humidity and temperature sensors are not commonplace. Innovations include IoT monitoring of perishable goods, innovations in cooling materials and decarbonization of refrigeration itself.



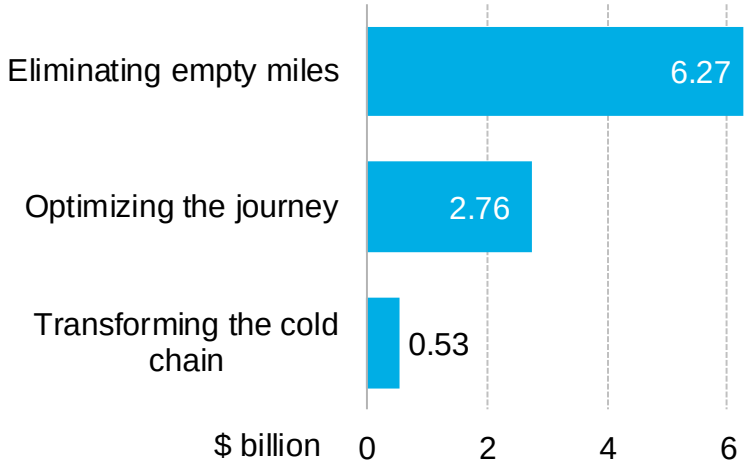
Source: BloombergNEF

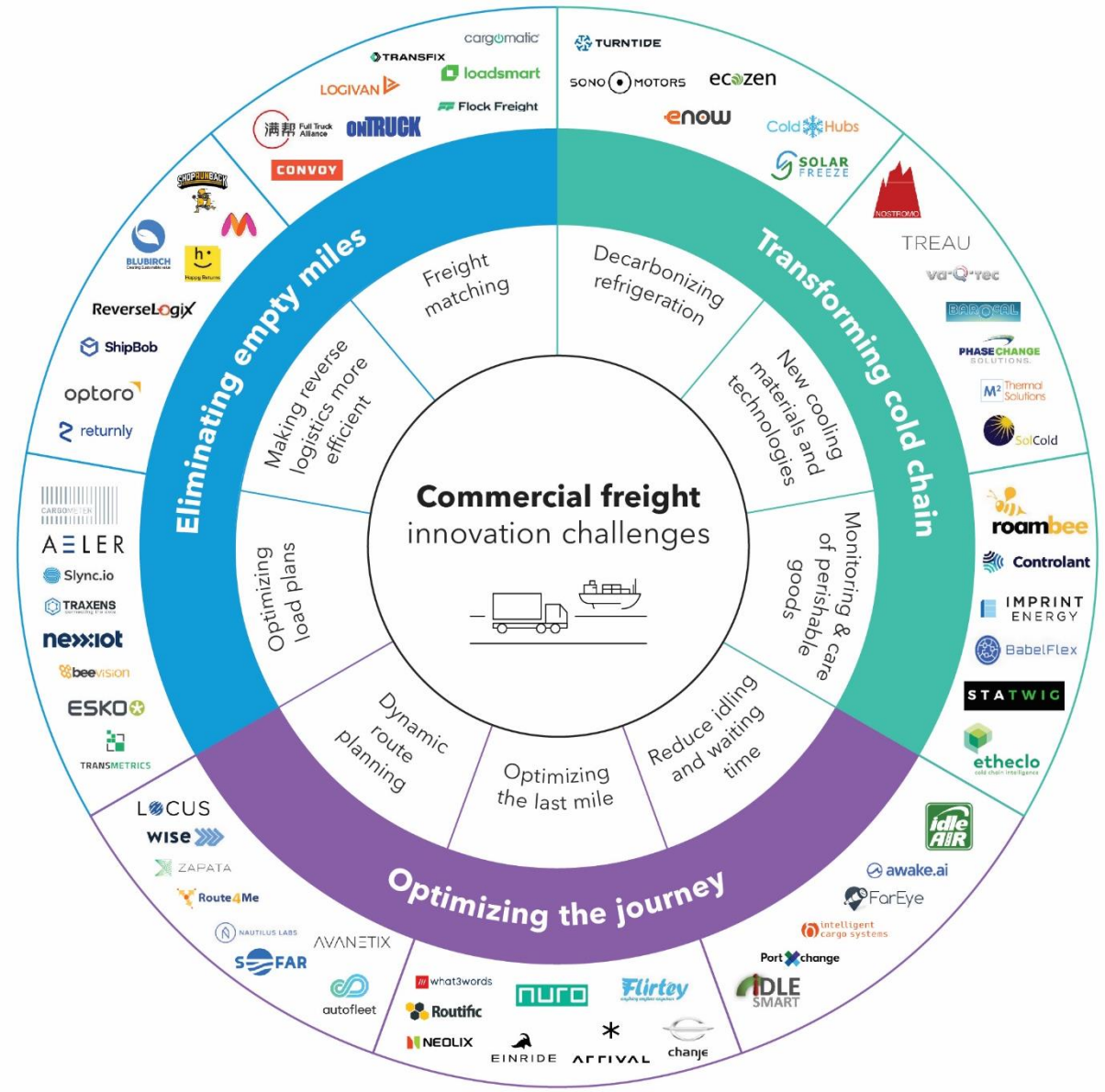
Challenges in optimizing commercial freight

BNEF tracked 130 startups with technologies for optimizing commercial freight. They have raised a combined $9.5 billion in early-stage investment from 2018 to 1Q 2021. with the majority going to startups solving for digitalizing freight brokerage.

This paper describes 65 of these start-ups in more detail, under nine innovation areas that contribute to tackling the three overarching challenge areas.

VCPE raised to decarbonize commercial freight (2018 – 1Q 2021)





Source: BloombergNEF

BNEF Pioneers 2021 Winners

Challenge 1: Managing and optimizing long-haul freight

Tackles the challenge of eliminating empty miles

Convoy operates a digital freight network that uses machine learning and automation to connect carriers (trucks) with shippers. This makes carrier-shipper matching more efficient, increases truck capacity utilization, reduces the distance traveled between loads and thereby helps to reduce road freight emissions. Convoy hopes to eliminate some of the 2 billion miles trucks drive in the U.S. each year without any cargo

Tackles the challenge of eliminating empty miles

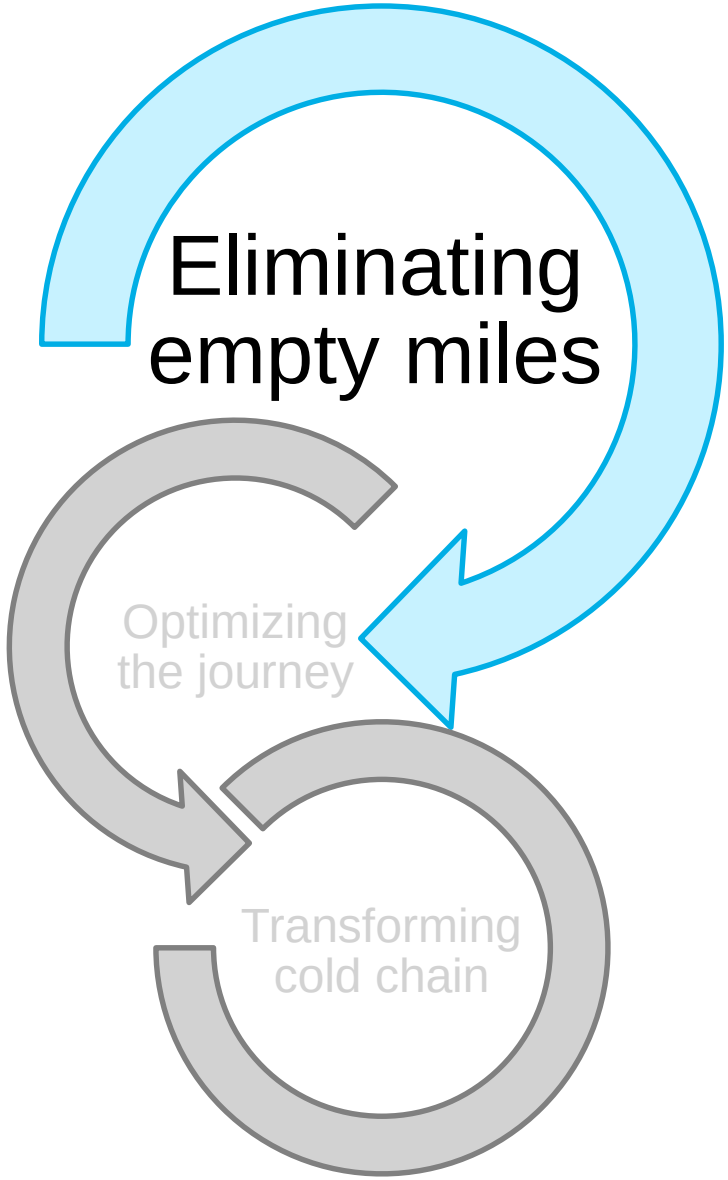
Ontruck offers digital freight brokerage in Europe, specifically targeting palletized cargo in medium-haul trucking (less than 150 km). It uses machine learning to optimize load-matching of shipments with carriers. This helps to reduce empty miles traveled, making road freight more efficient and reducing emissions.

Tackles the challenge of optimizing the journey

Nautilus Labs provides a predictive analytics tool for maritime freight. It uses third-party data, such as weather, and real-time data from IoT sensors in vessel control units. Machine learning algorithms use this data to optimize voyages, ship speeds and fleet performance. This helps to reduce voyage time, fuel use and emissions.

Technology challenges

Routes to decarbonizing commercial freight


Eliminating empty miles
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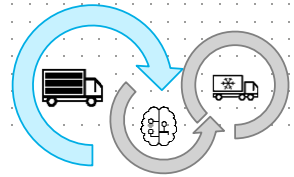
Transforming cold chain



The problem of empty miles

There are many inefficiencies in the commercial freight sector, on land, sea or in the air. Today, a significant amount of energy is used to power empty trucks or part-empty containers. This is because commercial freight companies do not have the systems or markets in place to combine different client orders in one vehicle and/or pick up additional jobs on a return journey. Inefficiency is also found in the way containers are packed – whether through poor planning or bad packaging design.

How big a problem is it?

20-40% of road carrier distances are traveled with no load. If carriers were to eliminate these empty miles, they could achieve a 6.4-12.8% reduction in all equivalent freight ton kilometers. Convoy states that in the U.S. alone, 72 million metric tons of CO2 are emitted each year due to empty miles. This is about 4% of U.S. transport emissions.

The problem of empty miles is less acute, but still significant, for marine freight. According to xChange, about 70% of maritime freight is containerized, and about 33% moves empty.

The number of online shoppers making at least one purchase per two months increased by 6-10% during the pandemic. With the rise of online shopping there are increasingly small and disparate packages being shipped, leading to more complex packaging and routes. If carriers cannot optimize these deliveries, vehicles will have more empty space. According to DHL, about 24% of e-commerce parcel volume is empty space.

What should we tackle first?

Fleets with more empty miles, due to matching inefficiency, tend to be small carriers that move loads over long distances. The majority of carrier fleets are small- or medium-scale, and carriers with long-haul drive cycles (trucks cover over 100,000 miles per year) have the greatest share of empty miles.

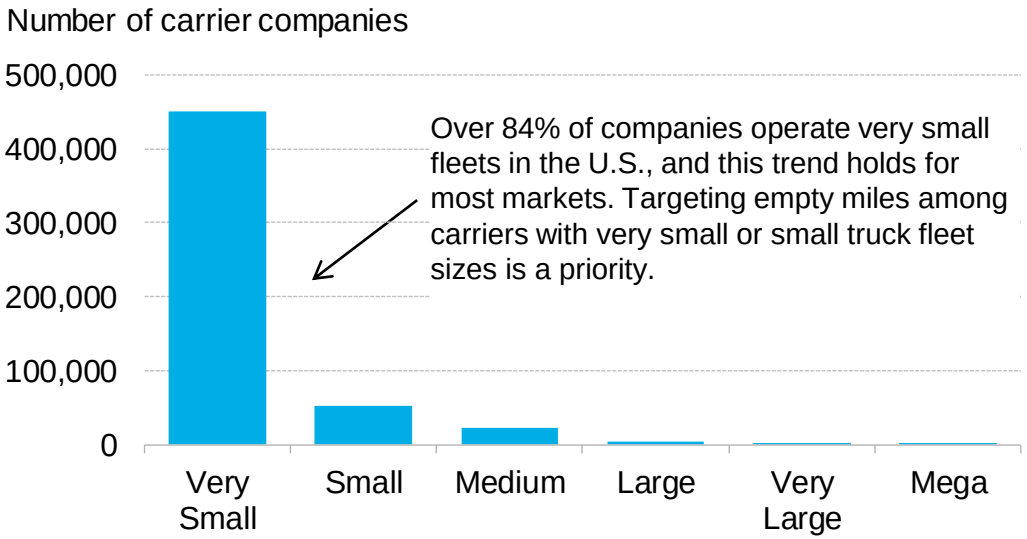
Larger commercial companies that own their own fleets, such as Walmart or PepsiCo, are less likely to have empty miles but might still suffer from inefficiency due to packing and package design.

Why is it difficult to solve?

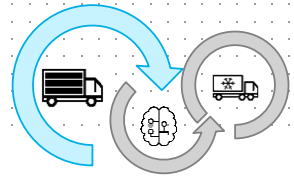
Many freight operators still use a phone-based broker market, picking up single jobs for clients. Where freight brokerage has gone online it is still not common to use complex algorithms to ensure a full truck, because this can prolong the procurement process and result in vehicles taking longer to deliver the goods.

The freight business is built on personal relationships among freight brokers, shippers and carriers. Shippers may keep working with brokers due to built-up trust, even if this leads to empty miles.

Number of U.S. carrier firms by truck fleet size



Source: BloombergNEF (web | terminal)



Freight matching

Matching shippers with carriers is often done manually by brokerage firms, but shippers are looking for more efficient ways to procure freight and improve profits. According to Convoy, brokerage commission fees can range from 15% to 20%. Digital freight brokerages reduce empty miles by optimally matching demand with supply. This helps to bring down operational fees by eliminating intermediaries.

Digital platforms can be more transparent and easier to use than coordinating shipments via phone, email and fax. As more matching takes place on a platform, AI can be improved to match the most suitable loads. Startups like Convoy and OnTruck use AI to optimize matching. Digital freight brokers usually focus on full truck-loads, but some also tackle less-than-load (LTL) shipments. While this innovation has had success, the freight industry is slow to change and technology providers have hit problems with a lack of digital culture and difficulties in optimizing LTL freight. To scale, startups should keep switching costs low and offer pricing flexibility.

New approaches & technologies

Digital freight brokerages: Data and AI can be used to automate shipper-carrier matching. This speeds up the contracting process, optimizes journeys and reduces empty miles. This service is paid by the shipper and the brokers work to attract carriers to the platform.

Multiple kinds of new data types: These, if fed into the platform, could help improve matching, eg, based on commodity type, shipping costs, destination, traffic patterns, weather and social media.

Services for different loads: Companies mainly target full-truck-load shipments (FTL). Some also provide less-than-load (LTL) services, though this is a harder challenge.

Limitations

Digital adoption: The trucking industry has been slow-moving in digital training and culture, and in adopting new technologies

Relationship-based business: Carriers and shippers often have long-standing business relationships with freight brokers, and this built-up trust may inhibit them from switching to a digital platform. This is an obstacle in attracting users and building network effects that would make the platform valuable and support lower shipping prices.

LTL optimization: LTL shipments often have various final destinations in the same vicinity which makes optimization computationally heavy.

Potential solutions

Reduce platform adoption costs: A simple user interface, transferable across different freight modes, with the ability to integrate legacy systems can bring down switching costs and encourage adoption.

Keep pricing flexible: For example, Flock Freight (pools truckloads) offers up to 40% lower truck rates for shippers with freight that's 44 linear feet or less.

Predictive shipping: AI and supply chain data can be used to estimate downstream demands ahead of time. This can be an added feature of digital freight to attract users, as it can help simplify planning and optimization of FTL and LTL.

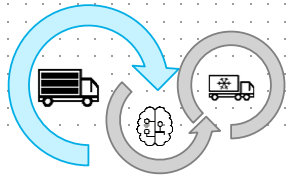
Full vs. less-than-load trucks

Full truckload (FTL)
Goods fill up the truck, contracted to 1 customer

Less-than-load (LTL)
Small freight, long distances

Source: BloombergNEF (web | terminal)

Freight matching



Full-truck-load

Loadsmart has AI-based pricing and matching for dry vans and reefers in the U.S. The startup reportedly contributes to 0.7 million tons of CO2 emissions reduction each year. Loadsmart is also exploring autonomous trucks.

Full-truck-load and less-than-load

Logivan uses AI to sell empty returning truck capacity. It aims to help Vietnamese businesses cut logistics costs, and claims that it can help increase truck owner income by up to 30%.

Cargomatic's innovation is to use AI and local freight data to match carriers and shippers. Its technology integrates with the back end of an inter-modal network, including trucks, trains, ships and airlines. Cargomatics states that it helps to reduce carbon emissions by up to 40% for corporate fleets.

TRANSFIX

Full Truck Alliance

loadsmart

CONVOY

LOGIVAN

Flock Freight

cargomatic

ONTRUCK

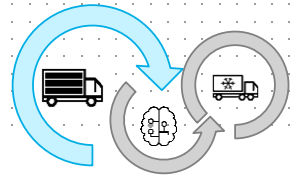
Convoy uses AI to match carriers and shippers in the U.S., and supports load bidding. Its drop-and-hook system for pre-loaded trailers and automated reloads with batched routes is a differentiator. Convoy estimates that it could reduce trucking CO2 emissions by 32 million metric tons if adopted throughout the U.S.

Convoy was named as a BNEF Pioneer in 2021.

Flock Freight uses AI to pool shipments into full, shared truckloads. It says it can cut freight-related carbon emissions by up to 40%. The startups services the lower 48 states in the U.S.

Ontruck's innovation is to find a way of making money from matching LTL medium-haul trips –historically unprofitable for brokers. It's platform has avoided 1.9 million empty kilometers (3,749 tons CO2). The startup services Europe (Spain, France, the U.K.).

Ontruck was named as a BNEF Pioneer in 2021.



Optimizing load plans

Containers are often not as full as they might be because packing of the container is not effective and/or the boxing of the goods leaves empty space inside the packages. For example, according to DHL about 24% of e-commerce parcel space is empty. If this could be improved, the fuel used to transport an item could be reduced. Innovations here include software that optimizes space in a truck, machines to design and build boxes that fit the shipped item, or IoT and blockchain to track a supply chain in real time, helping plan a vehicle's packing. For example, Amazon uses product data and machine learning in packaging decisions, which has helped to avoid 1.6 billion shipping boxes since 2015. Products like these often require buy-in from stakeholders across the supply chain, which we think will be most attainable among companies with clear sustainability agendas.

New approaches & technologies

Load optimization: startups are using sensors, AI, blockchain and cloud to monitor, track and plan cargo. With improved visibility of cargo, this data can be used for more accurate load optimization. See: *Vehicle Fleets: A Moving Target for the Internet of Things (web | terminal)*

Freight dimensioning: Startups like Cargometer and Beevision are using new technologies, such as AI, to dimension packages more efficiently.

Smart containers: IoT sensors can produce real-time data that feeds algorithms to optimize loads.

Automation: real-time cargo data can support automation in packing and unpacking. This can avoid human error, support optimized loads while facing increasing time pressures in logistics and improve safety by avoiding heavy-lifting.

Limitations

Data: Digital solutions to optimize load plans require high-quality, real-time cargo data. This is not often available.

Multi-stakeholder: To optimize load plans across multi-modal carriers, a digital platform would need buy-in from all players involved in the supply chain. If only one player adopts a technology to optimize loads, efficiency gains are lost downstream in the supply chain.

Speed of delivery trumps optimizing spacing: Products are usually put in boxes of standardized sizes to pack, move and ship goods quickly. While tailored box shapes and sizes would save space, because speed of delivery is so important to customers, it has not been shippers' priority to optimize filling and packing if it delays delivery.

Potential solutions

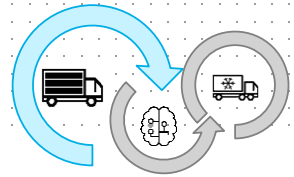
Smaller, cheaper IoT tags: This is needed to track goods down to a parcel level. For example, Troverlo has developed a 7x7mm IoT tag that can record data on the cloud.

Corporate sustainability goals will elevate this issue. Load optimization can reduce emissions, and firms with a clear sustainability agenda will drive supply chain optimization. According to DHL, Asia Pacific dominates packaging consumption by spend, accounting for 44% in 2018. This is expected to grow by 4.5% annually in Asia Pacific and Africa (compared to 1% in Europe and North America). Companies with Asian supply chains (most consumer goods) should target load optimization in these markets.

Machine learning (ML) for fast packaging decisions: By integrating product data and customer feedback about packaging, ML can help to streamline package decision-making at scale.

Different packaging choices: Not all products need to be boxed, and can instead be shipped in mailers (padded envelopes). For example, Amazon used this method to reduce the weight of packaging by over 33% since 2015 (1.6 billion shipping boxes). This means lower volumes per shipment, reducing empty miles.

Optimizing load plans



Freight dimensioning

Beevision is a Turkish startup using AI to automate parcel and pallet dimensioning. It cites measurement speeds of 0.1ms and accuracy of 0.5 cm or better.

Austrian startup Cargometer created a system that makes 3D models of palletized freight on moving forklifts. The startup cites a customer revenue increase of up to 5% due to correct tariff classification.

Smart container

Traxens is a French startup with a smart container, using IoT sensors to monitor, track and plan cargo. Traxens is a partner in the Port of Rotterdam Container 42 initiative, alongside IBM, Cisco and others. The initiative aims to improve data accuracy in maritime supply chains.

ESKO

nexxiot

beevision

TRANSMETRICS

CARGOMETER

Slync.io

TRAXENS
connecting the dots

AELER

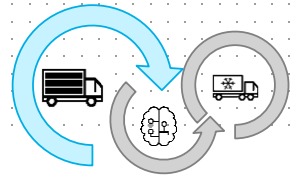
AI to optimize capacity use

Transmetrics is a Bulgarian startup with an AI platform to predict cargo volumes and optimize capacity use. It cites an increase in fleet utilization of up to 14% for client Speedy.

Blockchain and AI to optimize loads

Slync is a U.S.-based startup that uses blockchain and AI to track goods in multi-modal transport. Using blockchain it supports multi-party interaction and avoids information lag. This can contribute to getting the timely information carriers need to optimize load plans. Customers include DHL and Kuehne + Nagel.

Aeler is a Swiss startup, creating a lightweight smart container for cargo protection and data collection. Aeler cites up to 20% end-to-end lifecycle CO2 emissions reduction, and a 4% road fuel consumption reduction.



Making reverse logistics more efficient

Return volumes are growing as shopping moves online, which is making reverse logistics an increasingly important focal point. Mobisoft estimated that returns cost $642 billion worldwide, with the U.S. accounting for 57%. According to Happy Returns, return rates rise to 15-40% for online purchases, as opposed to 5-10% of store-bought products. Retailers overspend on traditional reverse logistics, for which returns typically mean a loss of profits and a gain for landfills. Startups are using AI and software to help retailers sort, process and resell returns. This helps reduce empty miles by streamlining returns, and also avoids landfill. Retailers relax return polices to stay competitive online, which makes the number of return scenarios high. Advancements in machine learning and predictive analytics will be important to understand these scenarios and support efficient returns management.

New approaches & technologies

AI for routing: AI is useful to route returns to their next best homes at the lowest cost. By shipping directly to the next best home, landfills as well as inefficient empty miles are avoided.

Shipping in bulk: Startups, such as Happy Returns, are developing networks to receive returns, aggregate and ship returns in bulk. This cuts shipping fees and empty miles.

Limitations

Inadequate labor: To set up flexible reverse logistics**,** firms will need to hire more people to handle returns. For example, Happy Returns has over 2,500 in-person 'return bars' in the U.S. Many firms have insufficient centers and not enough people to manage returns.

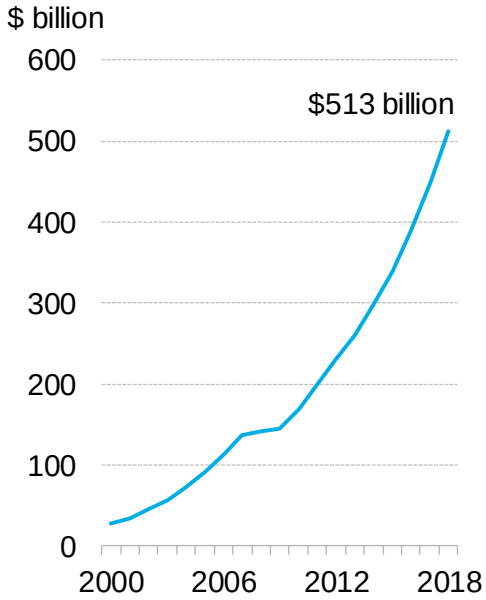
Relaxed return policies are fashionable: This is a strategy for retailers to attract consumers, eg, Asos' "try before you buy" and free returns policy. This increases the number of possible return scenarios, making returns more difficult to optimize or aggregate.

Potential solutions

Predict returns: Machine learning can be applied to returns data to forecast volumes, understand return scenarios and adjust staff. This approach is used in UPS Returns. Myntra Designs, the Indian online retailer, teamed up with Google to explore AI to predict a return before it happens based on shopper preferences, purchase frequency, cart size and other variables.

Integrate APIs to expand platform: Integrating supply chain data among shippers, carriers and technology providers would help to improve transparency, align stakeholders and support multi-channel returns. For example, ShipBob (third-party logistics) integrated the Happy Returns (returns management) API. In this way, returns can be sent via ShipBob's centers or dropped off at Happy Returns' in-person 'return bars'.

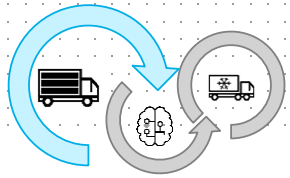
U.S. online retail sales



Source: St. Louis Federal Reserve FRED, BloombergNEF (web | terminal).

User interface and experience: Having a good returns policy is a customer service tool. Optoro found that 97% of consumers are more likely to buy again if they have a positive return experience. Designing optimal customer interfaces and digital tools can help involve customers in the decarbonization of product returns, for instance directing them to options that have a lower carbon footprint.

Making reverse logistics more efficient



Software to optimize returns management

Blubirch is an Indian startup that offers a SaaS platform to automate multi-channel returns and remarketing of IT assets. The startup claims it helps reduce transport of returned products by 25%.

Returns management software + physical network

U.S. startup Happy Returns offers a network to collect returns, and software for returns management. It has over 2,500 U.S. return locations, from which shipping in bulk helps customers save on average 20% on shipping in their first year. The startup's cardboard-free returns reportedly reduce 54 grams of CO2 emissions per return.

AI to predict returns

Research by India's e-commerce firm Myntra used AI to predict if an online purchase will be returned. The model could do so with 74% precision. This can improve efficiency in returns management, and even help to avoid returns altogether.

ShipBob

returnly

BLUBIRCH
Creating Sustainable value

optoro

Happy Returns

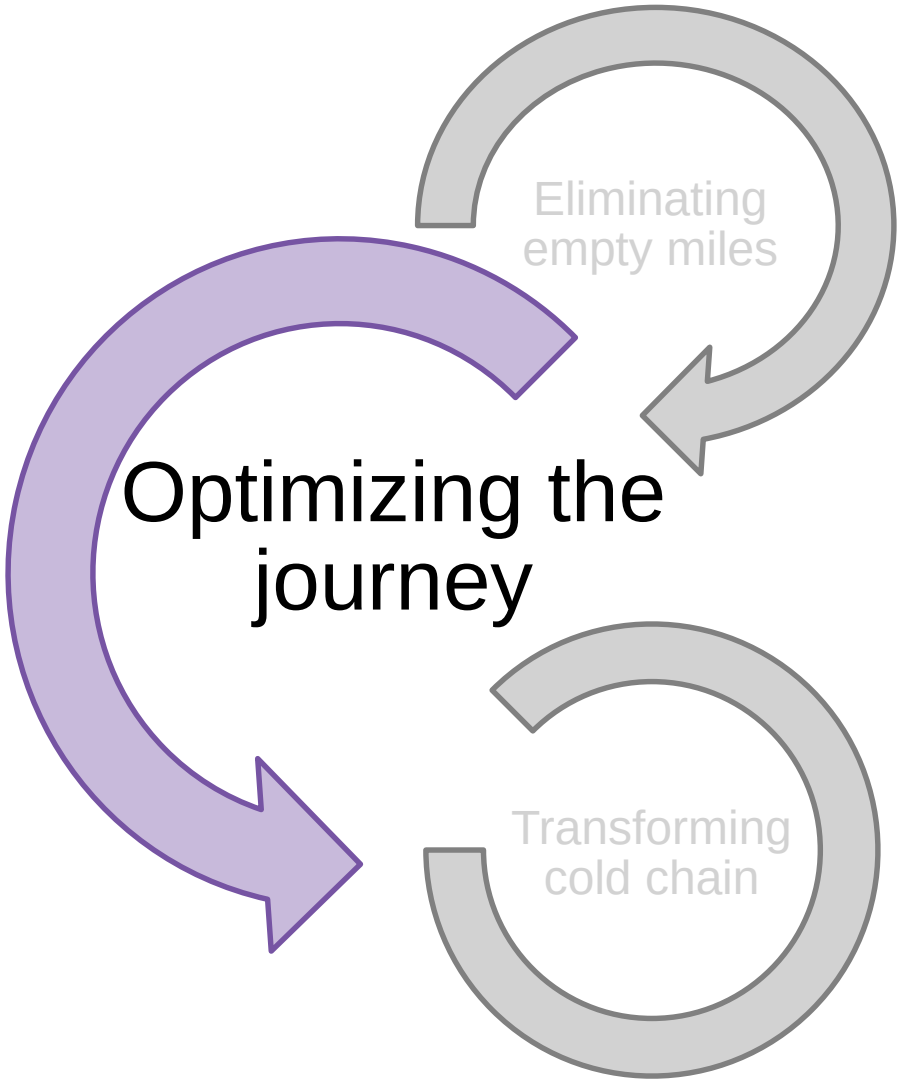
SHOPRUNBACK

ReverseLogix

Optoro is a U.S. startup offering AI-based SaaS that routes returns to their next best homes. Optoro reportedly avoided 8.5 million pounds carbon emission in 2019 by more efficient returns management and minimized shipments. Partners include IKEA, Best Buy and UPS.

ShopRunBack is a French-Cambodian startup offering a plug-and-play software platform to consolidate return parcels at local warehouses and support bulk shipments. It has processed over 2 million returns, and aims to make Cambodia a regional logistics hub.

ReverseLogix is a U.S. startup offering cloud-based SaaS to optimize returns and reduce waste. The platform provides access to owned and third-party facilities to receive and process returns. Its customers include FedEx, Samsonite and Electrolux.


Eliminating empty miles
Optimizing the journey
Transforming cold chain

The problem of journey inefficiency

While the majority of miles travelled by HGVs are on major highways, 53% of cargo delivery costs are in the last mile, where city roads and multi-stop deliveries make route planning complex. Inefficient journeys mean more mileage than necessary to transport goods to their final destinations, leading to more emissions. Planning the most efficient route is too difficult to solve manually or with spreadsheets. However, according to a study by Routific, over 72% of local delivery businesses in the U.S. still plan routes manually. This problem is an urgent one for two reasons: if technology innovations outlined on previous slides are adopted, inter-modal transit and reverse logistics will make journey optimization harder, and cities are increasingly implementing zero-emissions zones and trying to reduce HGV access. This will make optimization (and decarbonization) of last-mile delivery even more important.

How big a problem is it?

Road freight and shipping account for about 40% of global transportation emissions, according to IEA 2018 data.

By improving journey efficiency, trucks and ships can cover less mileage and avoid emissions. For example, Frozen Food Express could reduce its truck fleet size by 10% after implementing Paragon's routing software. Routific claims its route optimization software can shorten delivery routes by an average of 20%, enabling a GHG emissions reduction of 11,322 metric tons in 2019.

Route optimization also generates cost savings. Paragon calculated that moving from manual planning to route optimization software can reduce transport costs by 10-30%. For example, with improved route optimization, UPS could save $50 million in annual fuel and driver costs.

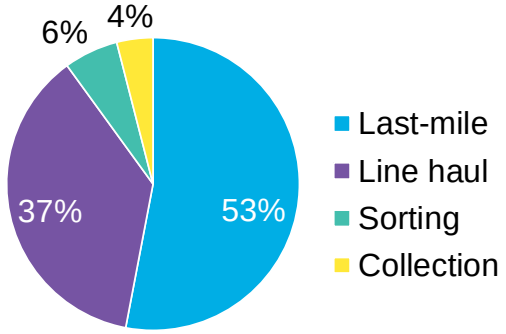
Why is it difficult to solve?

Fleet operators have access to data from telematics systems for speed and location, and can also access free route planning from mapping apps like Google. However, these do not support journeys affected by variables such as time windows for deliveries, same-day delivery deadlines, weather, traffic and customer availability. Operators need to build or buy this software as an additional service.

This might be feasible by established fleet companies, but for smaller carriers the financial or human resources at hand may not be sufficient. The rise in online shopping is increasing the volume of deliveries, adding to the constraints that need to feed into optimization models. These variables exponentially increase the computational power and time needed to optimize routes.

Logistics companies do not own supercomputers, nor large teams of data scientists. And the cost benefit for a fully optimized route plan is not significant enough, especially for smaller fleets, to invest in this. For instance, a journey with 10 stops can have over 300,000 round-trip routes, and with 15 stops this increases to over 87 billion.

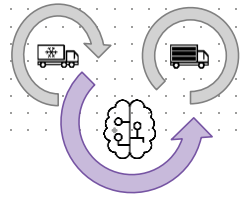
Share of total delivery costs by part of cargo journey



Source: Honeywell, BloombergNEF

What should we tackle first?

Fleets with more stops are the most complex. Last-mile deliveries are usually the most expensive and time-consuming part of the journey. Last-mile drop-off density makes deliveries prone to errors such as incorrect addresses. In rural areas, remote deliveries increase last-mile costs. The last mile accounts for over 50% of total delivery costs while line-haul (moving freight between cities) accounts for about 40%.



Dynamic route planning

Most fleets use static route optimization, where the journey is planned before the vehicle departs. Smaller fleets even plan routes manually. To optimize journeys, some larger fleets are moving to dynamic models that use AI and real-time data to route and re-route. This reduces the miles travelled while achieving the same deliveries. Both startups, such as Routific, and corporates, including UPS and Fedex, are developing route optimization tools. Dynamic models require more data and computing power as the number of variables increase, such as driver preferences, time limitations, traffic and weather. Consolidating services on cloud-based marketplaces can help startups access customers and data. Quantum computing and natural language processing will be useful to advance analytics in route optimization software.

New approaches & technologies

Dynamic route-planning software: This innovation feeds conventional data (eg, traffic, fuel levels) and unconventional data (eg, weather, social media, package IoT data) into AI algorithms to update routes. This helps to find the shortest routes among deliveries.

Prediction software: Route optimization platforms use machine learning to predict conditions that would affect journeys, such as traffic or weather.

Limitations

Computational intensity: The demand for computing and power increase exponentially with constraints, such as driver preferences.

Significant data requirements: Accurate AI models require a lot of data. Fleets with a variety of vehicle ages and types may struggle with standardizing data collection and formatting. This inhibits making route optimization models faster, cheaper and more accurate.

Unconventional data is hard to collect: To make route optimization more accurate, platforms need to collect data from sources like driver speech or handwritten notes, which are difficult to analyze.

Data and platform integration issues: One tech provider might offer telematics while another sells mapping services and another offers AI. These do not integrate naturally and can make the process of dynamic route optimization quite challenging to set up.

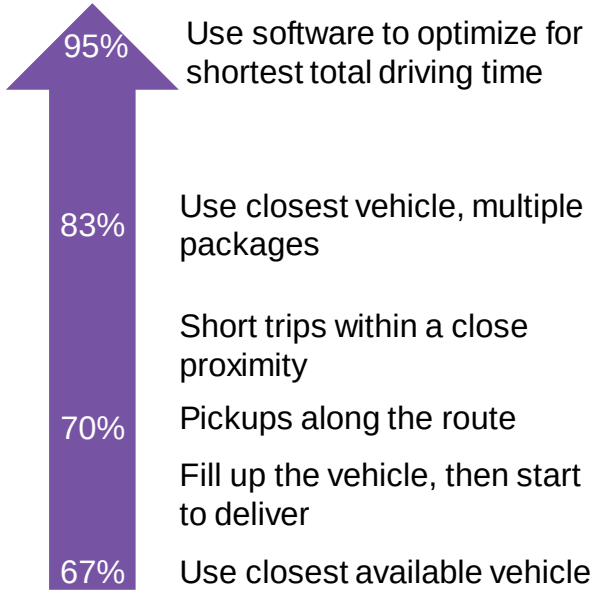
Potential solutions

Marketplaces: Application marketplaces, such as Geotab, may provide one platform for all fleet management needs. Marketplaces can also support data-sharing and aggregation, which can help to improve AI.

Quantum computing: Though not yet commercialized, quantum computing solves complex math problems by running many equations in parallel. This could support the computational power needed to integrate an increasing number of variables in dynamic route optimization models.

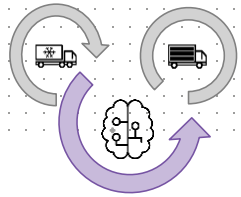
Natural language processing (NLP): NLP is a field of AI allowing computers to process text and spoken words. This can support integration of non-conventional data, such as handwritten notes or driver speech.

Efficiency of dispatch models to ensure on-time, same-day delivery



Source: Routific, BloombergNEF. Note: This is based on simplified simulations by Routific.

Dynamic route planning



AI-driven routing

Locus is a U.S. startup using machine learning to optimize and automate route-planning. Locus also integrates NLP to capture multiple address formats and scripts. The startup claims it has helped reduce over 6,300 metric tons of GHG emissions, and that its software can decrease operational costs by 27%.

Quantum computing

Zapata Computing is a U.S. quantum computing startup. One of its use cases is route optimization. Quantum may improve irregular operation predictions, and supervised learning (AI) for predictive analytics. Investors include Bosch and BASF.

Avanetix is a German startup using quantum computing and machine learning to optimize supply chains. This can enable improved responsiveness to changes, exponentially faster simulations and more accurate optimization.

autofleet

Route4Me

LOCUS

NAUTILUS LABS

ZAPATA

wise

AVANETIX

SOFAR

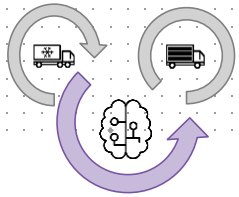
Nautilus Labs is a U.S. startup using machine learning in predictive maritime voyage optimization. It cites reduced fuel waste of 3% and 10% profit increases due to journey optimization.

Nautilus Labs was named as a BNEF Pioneer in 2021.

WISE Systems is a U.S.-based startup with an AI-driven dispatch and routing platform. It cites a 15% reduction in fleet miles.

Improving marine data collection

Sofar Ocean is a U.S. startup feeding data from an ocean sensor network (buoys) into a weather model to produce wave and swell forecasts. This feeds into its routing app, called Wayfinder, to avoid weather issues and reduce voyage time. Sofar claims it can support 50% more accurate forecasts for dynamic ship routing, vs. the National Oceanographic and Atmospheric Administration (NOAA).



Optimizing the last mile

The last mile of commercial fleet journeys is the most expensive and often the most complex. The rise of congestion charges and pedestrian zones in cities also mean fleet operators are looking for alternatives to heavy goods vehicles (HGVs). Consumer behavior/errors, increasing urban density and shopper expectations of rapid/same-day delivery are adding variables to already complex last-mile optimization problems. This is making the last-mile more technically difficult, and more expensive to optimize. Innovations include alternative transport modes such as drones or robots, effective communication platforms and new business models to ensure affordability. Predictive analytics can help firms understand future demands, increase operational efficiency and reduce delivery times.

New approaches & technologies

Specialized software: Last-mile delivery software can help optimize the journey of a product from the warehouse to the buyer's front door. This is based on real-time data and customer alerts.

Drones and robots: Low-density, smaller, remote deliveries can done by drones and robots.

Limitations

Consumer nuances: The efficiency of the last mile is directly linked to consumers – events like incorrect addresses or absence of customer to receive the package cause delays.

Delivery density: Remote, low-density delivery areas can have higher costs. At the same time, high-density, urban areas are highly complex to optimize.

Customer expectations: Online shoppers expect cheap, fast or same-day deliveries, transparency in package tracking and effective communication.

Potential solutions

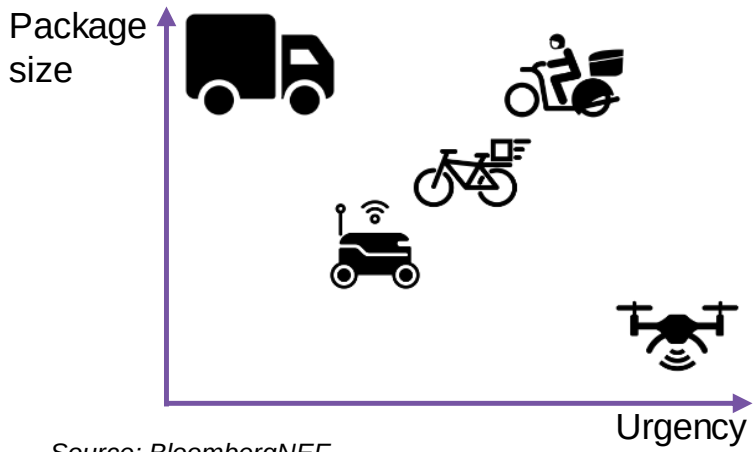
Better communication platforms: Companies can use platforms to communicate with customers to keep up with customer demands and better understand customer availability to receive packages.

Business model innovations to cut costs: As customers are expecting cheap or free delivery, last-mile solutions need to be low-cost. For example, the short-haul electric truck startup Arrival reduced total cost of ownership by 50%, by operating micro-factories near customer hubs.

Predictive analytics: By understanding future demands, companies can plan better and increase operational efficiency, driving down delivery costs. For example, Amazon's patented 'anticipatory shipping' system uses predictive analytics to

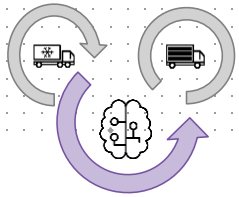
automatically ship and pre-position a product before the customer places the order. This is based on AI, fed by the company's huge database of customer preferences and habits, and can be used to plan deliveries pro-actively as opposed to reactively.

Delivery vehicle options based on package size and urgency



Source: BloombergNEF

Optimizing the last mile



Mapping technology

UK startup What3words created a geo-coding system based on 3-meter resolutions. Each 3-meter square has a unique 3-word code. This could help logistics firms overcome inaccurate addresses in last-mile deliveries. IKEA invested 12 million pounds ($16 million) this year.

New business models for electric vans

Arrival is a UK-based electric vehicle startup. It uses micro-factories near customers to flexibly follow changing demands and vehicle requirements. This could make the upfront cost of vehicles lower, the same as diesel counterparts. Arrival cites a potential 50% reduction in total cost of ownership.

Drones

Flirtey sells drones for last-mile delivery. It ran the first autonomous store-to-home drone delivery in the U.S. If the drones consume clean power, and support remote low-density deliveries, Flirtey can make the last mile more efficient and reduce emissions.

nuro

EINRIDE

what3words

NEOLIX

ARRIVAL

Routific

Flirtey
anything anytime anywhere

chanje

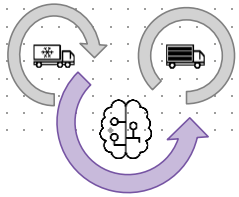
Autonomous delivery vans

Neolix is a Chinese startup creating electric autonomous vans for last-mile delivery. It aims to mass-produce highly autonomous vehicles, which means the vans will likely become cheaper. If clean power is used to power the vans, and last-mile logistics can be made more efficient as Neolix claims, this can contribute to emissions reduction.

Optimization of local delivery

Routific is developing software to optimize routes for last-mile delivery fleets. It cites up to a 40% reduction in driving time and fuel when a driver switches from manual planning to its platform.

U.S. startup Chanje offers EVs as well as charging infrastructure for last-mile deliveries. Its model is based on charging-as-a-service. Fleets can pay by mile, by kWh or by time. This can lower the barrier to adopting electric vehicles for fleets. Customers include FedEx, which uses more than 1,000 Chanje vehicles.



Reducing idling and waiting time

Truck and ship idling time increases fuel use, emissions and operating costs. Idling and waiting happens when vehicles are in traffic, are being loaded, or are keeping their engine on to regulate interior temperature (even while stationary). According to Smartrak, idling time accounts for about 25% of a vehicle's operational time. The U.S. Department of Energy estimated that an average heavy-duty truck burns 0.8 gallons of fuel each hour idling, and annually idles about 1,800 hours. This adds up. Rest-period truck idling consumes 1 billion gallons of fuel each year in the U.S. alone, resulting in about 11 million tons of carbon emissions. This is also an issue in maritime logistics. PortXchange estimates that about 30% of global shipping is delayed at ports or between ports. Reducing idling can tackle both efficiency and emissions issues. This might involve information-sharing platforms to align players, AI to minimize waits or software to monitor vehicle movement.

New approaches & technologies

Accessing supply chain data: If all stakeholders could see data across the supply chain, in near-real time, they could better plan operations and avoid idling and waits. Examples include dashboards and APIs to share port berth availability data among ships, or delays in customs processing.

Machine learning to predict waiting: Startups, such as FarEye and Awake.AI, are using predictive analytics to reduce waiting times for ships and trucks. Insights are used to adjust routes and sailing/driving speeds to arrive at the right time. Slower, stable speeds can reduce fuel use.

Limitations

Complex causes: Trucks idle for various reasons, such as traffic and driver comfort, cabin temperature or entertainment needs. These are difficult to monitor and therefore hard to integrate into predictive systems.

Engines are needed for multiple things: Engines power multiple systems, such as refrigeration, heating and lift gates. This means that even if the vehicle is parked or ship is at berth, the engine may still need to be running.

Potential solutions

Mild hybrid trucks: Automatic engine starts/stops can help reduce fuel use and idling, especially useful in heavy traffic conditions. For example, IdleSmart provides this kind of solution to maintain cabin temperature and bring down fuel consumption.

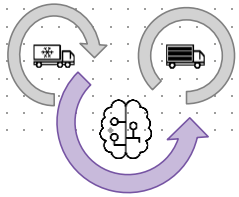
Truck stop electrification (TSE): TSE can help power heating, AC or electric devices via external plugins as opposed to keeping the engine going while parked. For example, IdleAir and Shorepower are developing TSE.

Shore-to-ship power: By providing on-shore electricity to a ship at berth, it can turn off its main engines while keeping refrigeration, lights and other equipment on.

Average environmental impact due to idling of one heavy-duty truck in one year

Source: BloombergNEF, U.S. Department of Energy, U.S. Energy Information Administration, U.S. Environmental Protection Agency.

Reducing idling and waiting time



Real-time data to align maritime players

PortXchange provides a platform to share real-time data on port shipping calls to align maritime logistics players (shippers, carriers, agents, terminals and authorities). This is done via a dashboard or API. In a trial at APM Terminals Rotterdam, the platform helped reduce average idling time from 47 to 32 minutes.

Intelligent Cargo Systems provides a platform to share real-time data about ships, port calls and cargo, as well as forecasting on cargo completion. This allows vessels to sail sooner and slower. The startup states that a 10% reduction in voyage speed reduces CO2 emissions by 19%.

AI for predictive analytics

Awake.AI provides an open AI platform that supports predictive analytics and an overview of sea, port and land transport. It can act as a marketplace for service providers and integrates APIs that can enable autonomous ships. It targets a 40% reduction in emissions by decreasing ships' waiting time at ports and increasing capacity use.

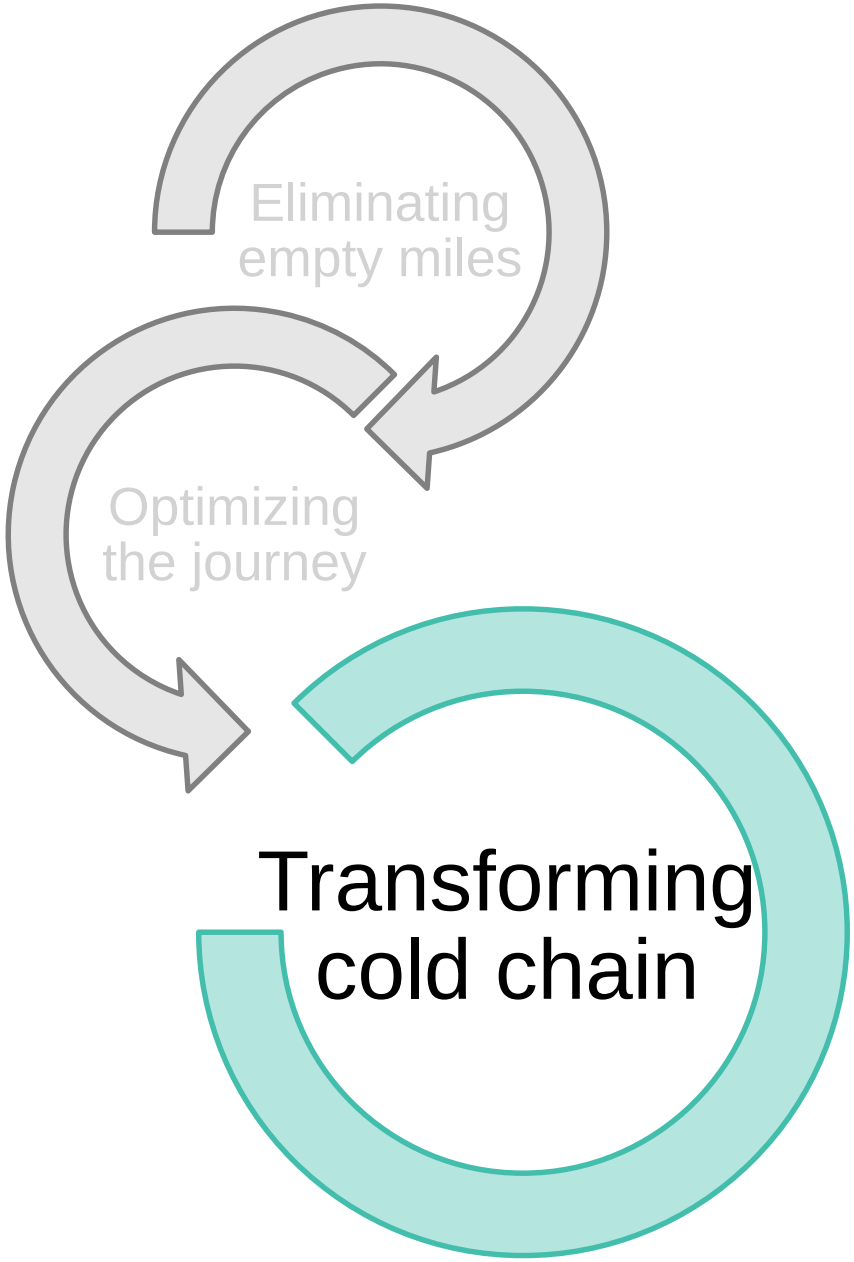
Fleet diagnostics, automatic start/stop

Idle Smart provides a fleet management platform for real-time metrics of the fleet, truck and batteries. It provides an automatic engine start/stop solution to maintain cabin temperature. It cites a reduction in idle fuel costs of 50-70%, leading to over 22,000 pounds of CO2 reduced per truck each year.

Logistics startup FarEye uses machine learning in predictive analytics for logistics. Its SaaS supports real-time visibility and finding efficient routes, which can help eliminate idling time. The software can handle real-time updates, such as schedule changes.

Truck stop electrification

IdleAir provides truck stop electrification (TSE) technology and no-retrofit adapter which allows drivers to use the vehicle's AC, TV, radio and other devices without keeping the engine on. IdleAir has helped to avoid over 600,000 tons of GHG emissions by reducing idling.


Eliminating
empty miles
Optimizing
the journey
Transforming
cold chain

The problem of transforming cold chain

Efficient cold-chain management is essential for temperature-sensitive products such as medicine and food. Refrigerators in trucks or ships are powered by burning fossil fuels, and powering refrigeration of perishable goods accounts for about 3.5% of global GHG emissions. Refrigerated cargo in transit is poorly monitored because humidity and temperature sensors are not commonplace. At points of transition, and when the vehicle is stationary, the temperature can spike meaning entire shipments can go bad leading to financial losses (and a wasted environmental footprint). Solving this problem is hard because effective cold chain can be expensive, and there are few low-carbon refrigeration alternatives.

How big a problem is it?

There are two problems with the sustainability of cold chain. First, refrigeration of goods in transit is almost entirely powered by diesel from a vehicle's tank. Second, badly managed cold chain infrastructure leads to overuse of energy and spoiled goods. The BCG Henderson Institute found that $1.2 trillion worth of food goes to waste each year, with poor cold chain management being a key factor. And the pharmaceutical industry faces losses of about $35 billion each year due to failures in temperature-controlled logistics. However, without cold-chain the post-harvest losses of farm produce, especially in emerging markets, are substantial. BNEF estimates that losses exceed $14 billion in India alone.

What should we tackle first?

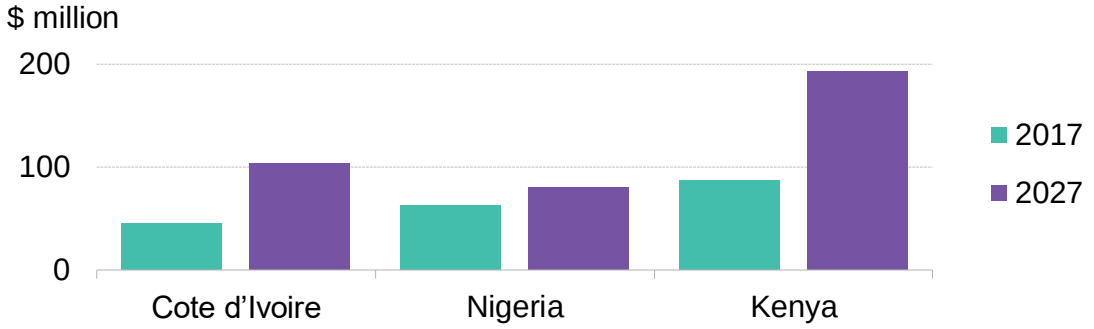
About 70% of food in the U.S. is moved through cold chains, with China and India expected to reach similar numbers in the near future. Goods are particularly vulnerable to over-heating or over-cooling at points of transfer, when goods move from warehouse to trucks. Cargo is also at risk when a truck's engine is turned off, at a rest stop for instance. The waste of food and medicine is especially an issue in emerging countries, due to poor infrastructure and a lack of budget.

Why is it difficult to solve?

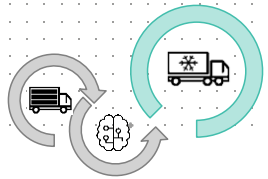
Large refrigerated trucks use a separate engine, powered by diesel, to run the compressor that keeps the trailer cold. However, refrigeration on small- to mid-size trucks are usually powered by the vehicle's engine, so when the truck engine is off, the fridge is not working. This causes large temperature spikes for the cargo. Today there are few sensors in refrigerated vehicles, so operators and shippers cannot see how the cargo is faring while in transit. Different perishable products require different temperature and humidity parameters, making optimization and handling more difficult.

In addition, cold chain solutions are not always affordable, especially in developing countries. And countries have their own regulations for handling perishable goods, leading to legal, compliance and customs clearance issues in international freight. Even if cold chain were optimized, using less energy, it would still consume a large amount of fossil fuels. There are no immediate (affordable) alternatives to burning diesel to power the fridges.

Cold-chain market growth potential



Source: IFC, BloombergNEF



Better monitoring and care of perishable goods

Cold chain monitoring uses digital technology to collect and share information on the conditions of goods, such as humidity and temperature. This can increase energy efficiency and avoid the loss of perishable goods. Carriers can see fridge performance in real time and manage cooling conditions. Temperature data loggers are currently used in cold chains, but only provide post-shipment audit trails, not helpful for real-time management and not sufficient to pinpoint blind spots. This is not useful when protecting high-value products, such as vaccines. With more data, AI-driven predictive analytics can warn of cold-chain failures (whether fridge malfunctions or human errors) before they take place, thereby eliminating food waste and reducing unnecessary burning of fossil fuel to over-cool fridges.

New approaches & technologies

IoT sensors and cloud management: By using IoT sensors monitoring the temperature and humidity of perishable goods, and sending the data to the cloud regularly, conditions can be tracked and shared in real time. This would allow the cargo owners, and the logistics company, to see weak points in their cold-chain design and to work on improvements.

Predictive analytics: Real-time, high-quality data can be used to provide advanced warning to operators of fridge failures or produce spoiling. This is done through AI-based predictive analytics. Fixing these issues before they happen would reduce the amount of wasted goods, eliminating the energy and water use in making replacement produce.

Limitations

Security: Poor cybersecurity is a central concern. If IoT data is applied to monitor sensitive goods, such as vaccines, smart fridges could be a target for ransomware hackers.

Affordability: Cold-chain technologies are not always affordable, especially in emerging markets where cold-chain improvements are most needed. There are many moving parts in a cold chain, making it difficult and expensive to digitalize. IoT systems and analytics may not economically feasible for many businesses.

Connectivity and technology availability: Internet connectivity is limited to certain countries. To implement cold-chain monitoring in emerging markets, technology providers need to find an alternative to 4G/5G.

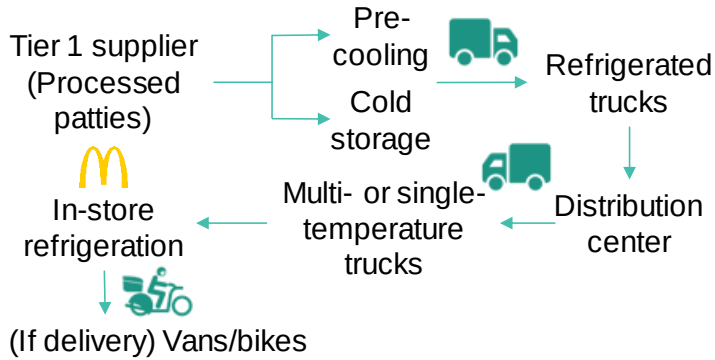
Potential solutions

Effective cybersecurity: Cybersecurity must improve. Blockchain could help with distributed security in cold chain sensor networks. IBM offers an IoT blockchain solution that it says can be useful in cold-chain monitoring.

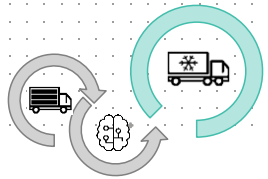
Cloud-enabled cold chain as a service (CCaaS): CCaaS is a business model that might help avoid investing in new systems upfront. For example, Controlant offers CCaaS using IoT and cloud. This also means systems can be rolled out slowly, managing both security and affordability concerns.

Lower-cost, disposable, sensors: This can help make monitoring cheaper and accessible. Disposable sensors would likely make it easier to add sensors to individual packages.

Simplified McDonald's patty cold chain



Source: BloombergNEF. Note: This diagram is simplified and for illustrative purposes.



Better monitoring and care of perishable goods

Printed, efficient IoT sensors

Babelflex makes 3D printable sensors that use 1/7th of the power required by traditional MEMs, and the material is recyclable. Currently Babelflex targets power, electric vehicles and agricultural monitoring but has the potential to be used in other areas for cold chain.

Imprint Energy has developed flexible, thin (0.5 mm), printed, zinc-based batteries for IoT devices and sensors. This can contribute to more accurate, cheaper cold-chain monitoring. And by using zinc, Imprint avoids safety and compliance issues related to lithium-ion batteries in transport.

Etheclo creates isothermal boxes with sensors that monitor and record cargo temperatures in the cloud. The platform sends alerts when goods surpass condition thresholds. Its box has been validated for trips of up to 36 hours.

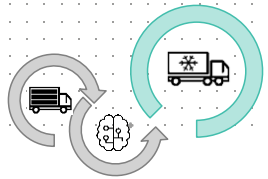
IoT platform for real-time monitoring and alerts

Controlant offers CCaaS that can be integrated via APIs. Its system can service warehouses, road, air, rail and sea. It offers real-time information and alerts, and uses data to optimize shipment lanes. The CCaaS reportedly helped pharmaceutical firm Allergan save products worth about $50 million during a pilot with Controlant.

StaTwig was founded to tackle vaccine cold-chain issues using blockchain, IoT and AI. The technologies are used to enhance traceability, ensure tamper-proof data and improve data insights. The open-source platform can be used in cold chains in other areas, such as food. StatWig is a startup in the UNICEF Innovation Fund portfolio.

Roambee provides a real-time cold chain monitoring system that tracks conditions and locations of goods. It uses a tamper-proof IoT sensor, and creates an audit trail of data on the cloud. The system enables predictive analysis for where cold chains may go wrong in the future.

Decarbonizing refrigeration



Refrigeration in cold chains typically relies on diesel, both during transport and in off-grid stationary use. According to the Birmingham Energy Institute, a refrigeration unit can consume up to 20% of a vehicle's diesel. Dearman estimated that there may be as many as 9.6 million refrigerated trucks globally by 2025, up from 2 million in 2015. Decarbonizing refrigeration involves making electric motors more efficient and/or using clean energy to power the fridges. This might mean drawing power from solar panels on board the vehicle, or pre-cooling the perishable goods before they are put on the vehicle. This increased need for electricity on vehicles might help encourage drivetrain electrification, but it would likely need substantially larger batteries on the vehicle, and a separate electric motor just for the cooling trailer unit. Pre-cooling is an alternative, but not something many farmers in emerging markets can afford.

New approaches & technologies

Improved refrigeration efficiency: Intelligent controls and/or new motor designs can help to reduce energy use and improve refrigeration efficiency. For example, new electric motors developed by Turntide, LinearLabs and Yasa can reduce energy use in refrigeration equipment by up to 2/3rds.

Pre-cooling: By pre-cooling perishable goods (using electricity), diesel-powered refrigeration requirements in transit can be reduced.

Battery-powered cooling: Clean power and batteries can replace diesel to cool cargo. For instance, solar panels on the roof of trucks can generate power that (via batteries) can power cooling on refrigerated trucks (reefers). As corporates, including Nestle, Walmart and PepsiCo, move towards freight drivetrain electrification they should also consider electrifying the cooling trailer unit.

Limitations

Other applications are more attractive: For companies developing new motors, it is likely air conditioning will be the first market to benefit from more effective electricity generation, not trucks' fridges.

Charging station availability: Solar panel on trucks would not be able to power fridges for a full trip. Grid power would still be needed, and the availability of fast-charging infrastructure for trucks is not yet sufficient.

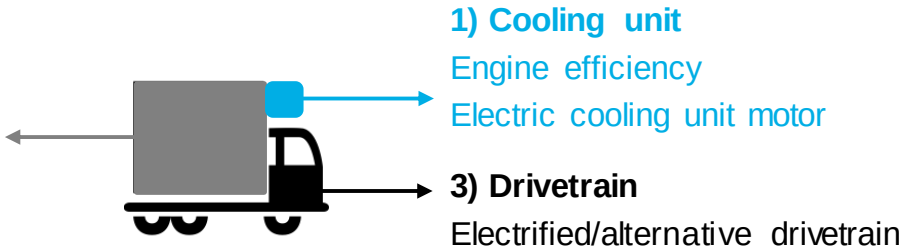
Potential solutions

Transitioning to diesel-electric hybrid trucks: Hybrid trucks can be a stepping stone prior to fully electrified fleets

Integrating solar cells: Electric vehicle bodies can integrate solar cells to reduce how frequently they need charging. For example, Sono Motors added solar body panels to a trailer prototype, able to produce 80 kWh a day. This can help electrify reefers and decarbonize refrigeration, while tackling issues of charging station availability.

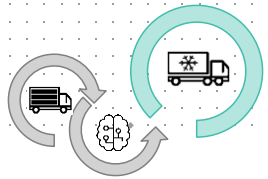
IoT platforms for service-based payments: Some startups, such as Solar Freeze, integrate IoT sensors into their cold storage solutions. This enables both goods monitoring, and the ability to charge per unit of cooling provided. This can help with affordability issues by aggregating goods to be cooled and accurately charging for goods cooled.

Potential decarbonization steps and options for refrigerated trucks



Source: BloombergNEF

Decarbonizing refrigeration



Solar-powered cooling

ColdHubs is a solar cold room for off-grid refrigeration in developing countries. The system uses batteries to ensure 24/7 cooling, and a pay-as-you-store model to stay affordable. In 2019, ColdHubs reportedly helped avoid 20,400 tons of food from spoiling.

Ecozen creates solar cold storage rooms, along with an IoT platform to monitor goods. Ecozen has reportedly helped avoid 100,000 liters of diesel per day, and serviced over 20,000 farms (with its solar cold storage as well as its solar water pump).

Enowenergy makes solar-electric systems for trucks, reefers and buses. Its solar panels can be customized for various vehicles. Enowenergy claims it can support zero-emission reefers and halve operational costs by cutting diesel.

Smart motor technology

Turntide creates a smart motor system that reduces power use by adopting switched reluctance motors (SRM). SRM uses pulses of power as opposed to a continuous power flow. This can be applied to air-cooled condensers to increase refrigeration efficiency. Turntide states its system is 71% more energy efficient than fixed speed induction motors.

Kenyan startup Solar Freeze applies the sharing economy model to cold chain. It rents out solar mobile cold storage units to small-scale farmers. This allows them to frequently ship small quantities by 'ubering'. The startup offers an IoT platform for real-time monitoring of goods. Solar Freeze reportedly helped reduce waste of fresh produce by 90%.

Vehicle-integrated solar cells

Sono Motors creates electric vehicles with solar cells integrated into the vehicle's body. Its battery is charged by the grid as well as its solar cells. Using solar cells reportedly adds 245km to the weekly driving range. This could be applied to fleet vehicles, enabling clean power use in transport as well as refrigeration.

New cooling materials and technologies

Current refrigerants are highly potent GHGs, such as hydrofluorcarbons (HFCs). Besides the CO2 emissions from powering fridges, up to 30% of refrigerant volumes may leak, meaning more GHGs released into the air. Styrofoam, the main portable packaging used in cold chains, is also unsustainable. While it is low-cost, it is only useful for short-term storage, made from oil and not recyclable. New cooling materials can help replace refrigerants and also better protect goods due to temperature change at transition points or when truck engines are off. Phase-change materials (PCM) absorb and release thermal energy during melting and freezing, such as ice-to-water phase changes. This is useful for cooling as PCMs can absorb large amounts of latent heat within adjustable temperature ranges, which depend on the material. But PCMs are still in early-stage development and produced at small scales, not yet at the economies of scale needed to make them cheap.

New approaches & technologies

Phase change material (PCM): These are materials that can absorb, store and release latent heat. PCMs can be bio-based, meaning they absorb some carbon in their production. They are also less polluting than other refrigerants when released. PCMs are water-based, salt hydrates or organic (containing carbon). Examples include water, paraffin wax and sodium sulfate. Typically solid or gel, they do not release gases easily and can help decarbonize cooling by reducing energy use for refrigeration, decreasing waste from spoilage (and associated energy waste). They remove the need for styrofoam.

Curbside recyclable packaging: Vericool and TemperPack use insulating, natural, biodegradable materials instead of styrofoam. Vericool's package is water-soluble and non-toxic. Temperpack claims it helped avoid over 26,000 metric tons of CO2 emissions in 2020, by switching out styrofoam to their natural package. These materials insulate as efficiently as styrofoam.

Limitations

Most PCMs are petrochemical-based: These are difficult-to-recycle, a long-term environmental issue.

Willingness to change: Replacement risk is high for companies. Cold chain products are typically high-value which companies do not want to lose, especially pharmaceuticals.

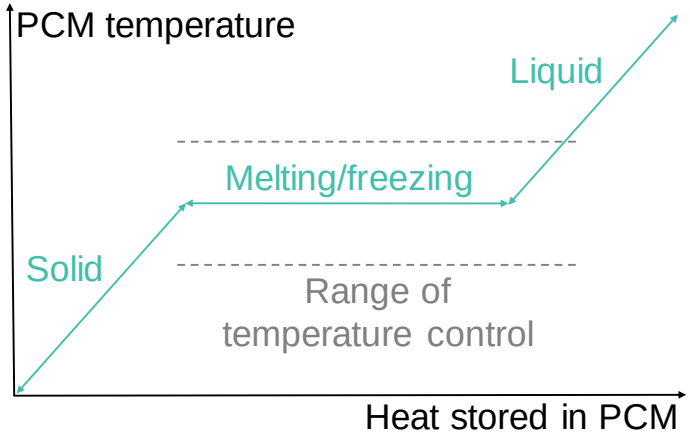
High cost: New materials for cold-chain packaging do not yet have economies of scale, and therefore come only in a few standard sizes. However, packaging must come in diverse sizes to avoid empty miles, which would be costly for new materials.

Potential solutions

Coating technology: New coating technologies for cooling could eliminate the issue of packaging dimensions. For instance, SolCold is developing a nanotech coating that generates cooling from solar radiation.

Vegetable-based PCM: Research sponsored by the U.S. Department of Agriculture and the National Science Foundation indicated that vegetable oil-based PCMs could range from -90 to 150 degrees. Vegetable-based PCM is gaining traction as it is non-toxic and bio-degradable when discarded in landfills.

How phase change material works



Source: BloombergNEF. Note: PCM (Phase Change Material).

New cooling materials and technologies

Nanotech coating

SolCold developed a material that uses sunlight to reduce surface temperature by up to 20 degrees. It uses a nanotech coating with active cooling mechanisms induced by solar radiation. SolCold says it can reduce power use for cooling by up to 60%.

Treau develops AC units that use low global warming potential (GWP) refrigerants (propane). Its light polymer membrane increases thermal surface area in heat exchangers, improving efficiency. The startup claims its system can increase HVAC efficiency five-fold, and mitigate up to 1.1 billion metric tons of GHG emissions by 2050.

Thermal storage cells

Nostromo developed the world's first modular thermal energy storage cell, called IceBrick. Its main elements are water and proprietary nucleate, as opposed to using more expensive battery materials. This helps reduce its cost per kWh by up to 80%, compared to leading ice storage systems.

Membrane technologies

M2 Thermal Solutions combines evaporative cooling and membrane technologies to cool and dehumidify air. This requires no refrigerants, which means it can completely avoid refrigerant GHG emissions.

Phase change material

Va-Q-tec offers cold storage with PCM based on paraffin and salts to regulate products within a temperature range of -50 to 37 degrees. This can help avoid cold-chain product loss as well as bring down energy use for refrigeration, helping to reduce cold chain emissions.

Va-Q-tec was named as a BNEF Pioneer in 2012.

Phase Change Solutions designs and manufactures PCMs from food-grade, plant-based raw materials. Its patented PCM is non-toxic, can be tuned to target temperatures ranging from -180 to 25 degrees and uniquely enables solid-to-solid phase change. To date, about 10 million cold chain packages, and $2.5 billion worth of food has been transported using the company's PCM.

Phase Change Solutions was named as a BNEF Pioneer in 2020.

Early-stage investment trends

For decarbonizing commercial freight

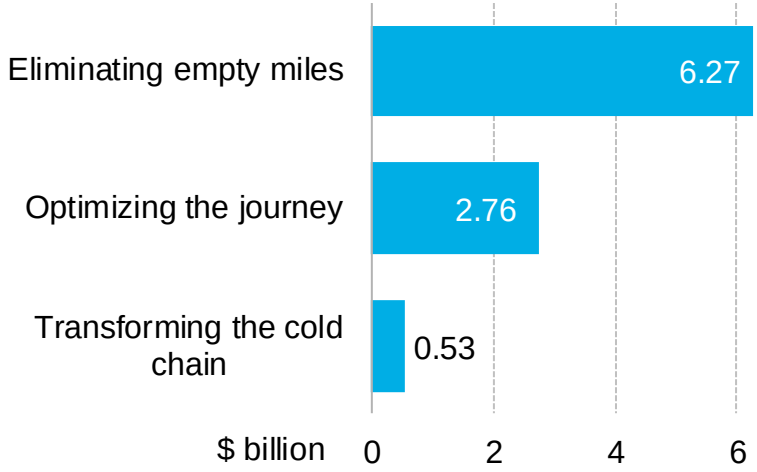
Funding for commercial freight decarbonization takes off

Between 2018-1Q 2021, early-stage investment in commercial freight optimization startups was 12 times that of the prior three years. Most notably, software-based freight matching startups have pulled in billions of dollars in investment to eliminate the empty miles that trucks drive and vessels sail. There were also several large funding rounds for startups optimizing freight journeys, led by last-mile delivery technology.

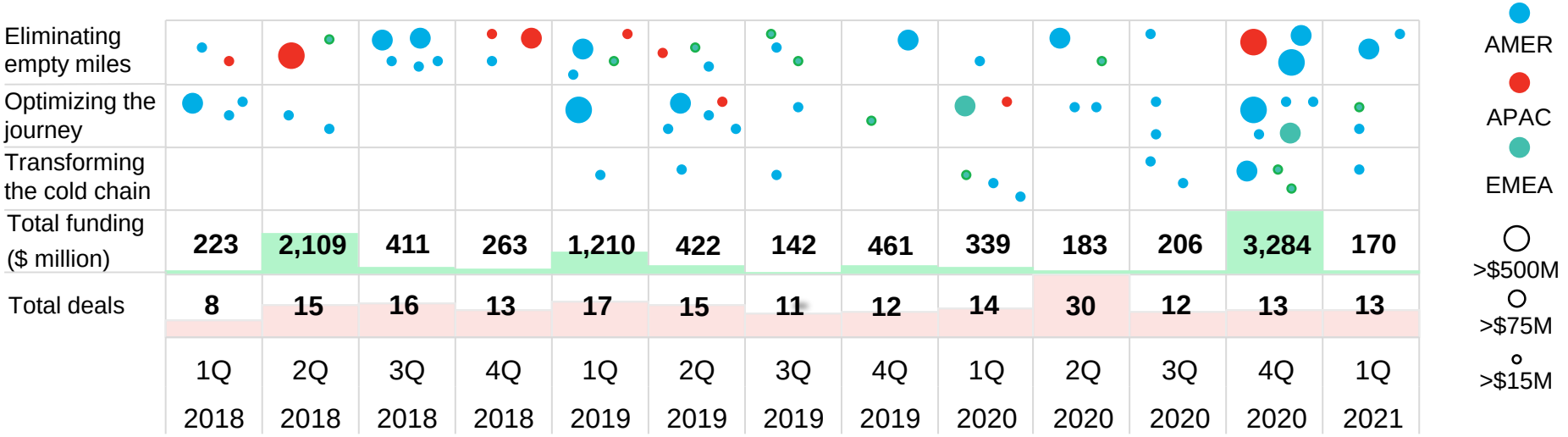
Investors are placing large bets on eliminating empty miles. In 2020, the average deal size was $85 million for eliminating empty miles, compared to $26 million for optimizing the journey and $14 million for transforming the cold chain. Freight matching startups attracted over 65% of all the funding (see the right-hand chart).

Venture investors are partially attracted to freight matching because it is scalable with a large addressable market. Freight matching companies succeed by creating strong network effects, and there has been a race by startups and their investors to grow fast and establish regional dominance.

VCPE raised to decarbonize commercial freight (2018 – 1Q 2021)



Largest VCPE deals for commercial freight decarbonization

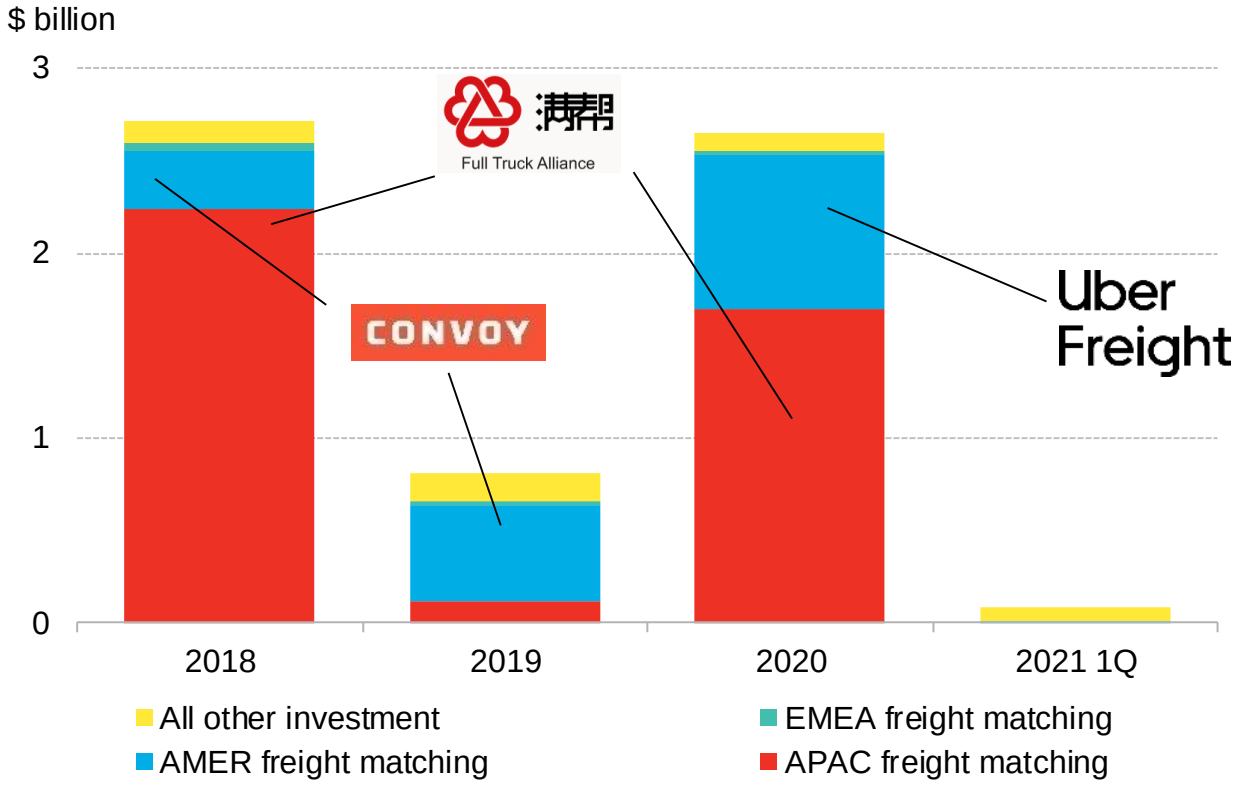


Source: BloombergNEF, CB Insights. Note: bubbles represent deals over $5 million in each quarter.

VCPE investment trends for eliminating empty miles

In the past four years, freight-matching startup funding has dominated the 'eliminating empty miles' category – accounting for over 90% of the $6.3 billion of VC investment. Within the freight-matching segment, roughly 80% of VC investment between 2018 and 1Q 2021 was invested in the four largest freight matching companies: China's **Full Truck Alliance** ($3.7 billion), U.S.-based **Convoy** ($645 million), **Uber Freight** ($500 million) and Indian **Blackbuck** ($230 million). Since freight-matching service quality depends on how many shippers and carriers you serve, startups are using the capital they have raised to establish regional dominance. The five largest freight brokers have all raised at least one large deal (>$100 million) in the last two years. 2021 could be a low year for additional investment as these large firms put this new capital to work.

VCPE investments into eliminating empty miles



Investor spotlight: Softbank Group

Technologies that eliminate empty miles, especially freight matching companies, have attracted mainstream venture investors. The top five freight matching companies garnered investments from early-stage financers like Sequoia Capital and Greylock Partners and larger generalized financiers like Goldman Sachs and Blackstone.

Softbank Group, the giant Japanese conglomerate holding company, has recently become active in the space through its Vision Fund.

- The Vision Fund is one of the most well-funded venture capital groups globally and makes significant investments across multiple industries. Softbank has recently started to invest in freight-matching startups.
- The firm invested in the China-based Full Truck Alliance twice in 2018 and 2020 and the U.S.-based Flock Freight in 2020.

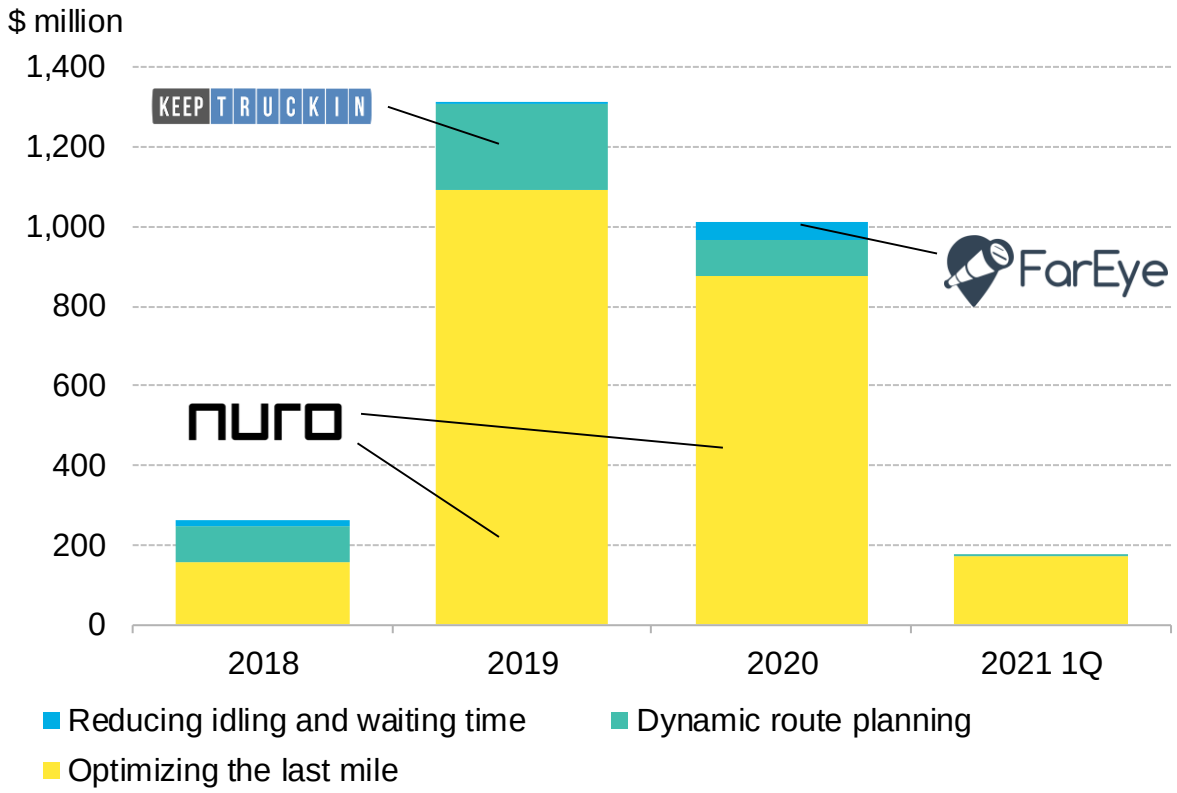
Source: BloombergNEF, CB Insights. Note: Logos indicate most funded companies each year.

VCPE investment trends for optimizing the journey

Last-mile delivery technology has attracted the most investment in this category, driven by the $1.4 billion raised by U.S.-based **Nuro**. Nuro raised two large deals in 2019 and 2020, which dominated the market in those years. Nuro has raised money at similar levels to other autonomous vehicle startups.

Investors have a small but increasing appetite for technologies that can reduce idling time and increase efficiency in route planning. These business models are enabled by increased digitalization at transit points, such as ports and loading docks, and increased access to geospatial and weather-related data.

VCPE investments into optimizing the journey



Source: BloombergNEF, CB Insights. Note: Logos indicate most funded companies each year.

Corporate investor spotlight: Daimler

Many of the investors in startups attempting to optimize freight journeys are corporate VCs, including VC arms of automakers.

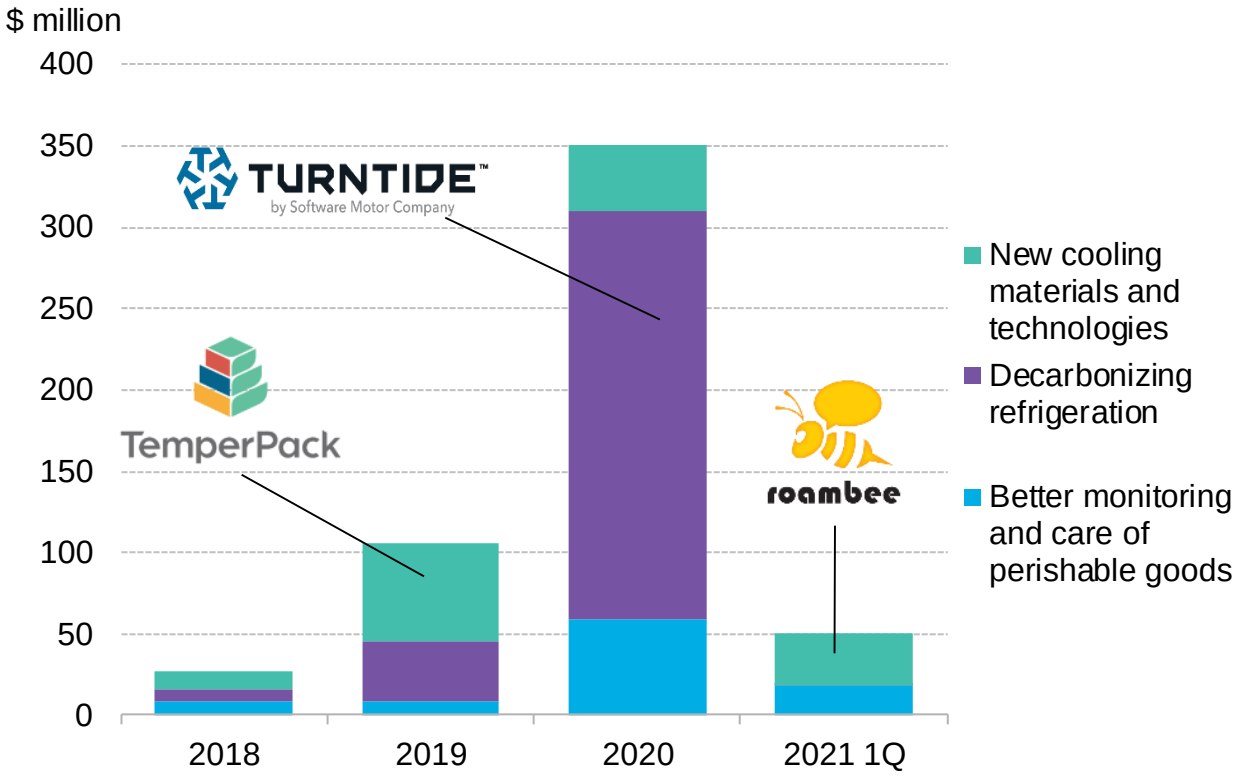
Daimler is a German-based automaker and leader in commercial truck production. Daimler has invested in a range of early-stage mobility startups that can accelerate the transition to a low-carbon future.

- Daimler has invested roughly $2.8 billion in the mobility space over the past five years. Its largest investment categories are urban air mobility, autonomous technology and energy storage.
- In 2021, Daimler invested nearly $800 million, which is already higher than its average yearly spend. This investment is split into two significant follow-on deals: one with Momenta, an autonomous technology startup, and one with Volocopter, an urban air mobility startup.

VCPE investment trends for decarbonizing cold chain

Since 2018, VCPE investors have spent $0.6 billion on cold chain startups. Compared to the other two areas discussed above, this sector has a higher percentage of hardware and materials startups, which tend not to fit the conventional venture capital model as well as software-based applications. Two large deals, one with U.S.-based **Turntide** and one with German-based **Sono Motors**, caused an investment spike in 2020. However, these startups focus on decarbonizing air conditioning and general automotive tech rather than looking solely at the transportation cold chain. While improving the cold chain is viewed as necessary, much of the funding for new materials is at the academic and R&D stages, earlier than VCs tend to be involved.

VCPE investments into transforming the cold chain



Source: BloombergNEF, CB Insights. Note: Logos indicate most funded companies each year.

Investor spotlight: SJF Ventures

Very few transport-focused investors have put money into cold chain startups. To date, cold chain startups have received more investment from climate-focused or healthcare-focused investors.

An example is SJF Ventures (Sustainable Jobs Fund), a U.S.-based climate technology investor. SJF Ventures was started in 2001, and is one of the first venture capital firms to focus on impact investing. SJF now primarily invests in climate-related technologies, funding startups across energy, mobility, circular economy and food.

SJF grew substantially after 2013, since investing $900 million in 68 deals across different areas of sustainability. It most recently raised $175 million in its fifth fund to support founders in clean energy, circular economy, mobility, sustainable food, health & education tech.

- SJF has led multiple rounds in Temperpack, a startup focused on new materials in the cold chain.

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