HIVED

As the first European venture capital fund, Planet A relies on its own scientific team to assess the environmental and climate impact of an innovation. Prior to an investment, a life cycle assessment, like this one, is conducted and integral part of the investment decision. All assessments as well as the methodology is published for maximum transparency.

Terminology and abbreviations

B2C	business-to-customer
CED_f	Cumulative fossil energy demand
CO_2-eq.	Carbon dioxide equivalents
Functional unit	Quantified performance of a product system for use as a reference unit
GHG	Greenhouse gas
GWP	Global warming potential
ICE	Internal combustion engine
LCA	Life Cycle Assessment
UK	United Kingdom

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About HIVED

[HIVED](#) offers the next generation of efficient delivery services and logistics, reducing costs and congestion while drastically reducing delivery time and lowering emissions. The London-based startup offers a vertically integrated end-to-end approach for parcel delivery using decentralized sorting mini-hubs. HIVED additionally developed a proprietary AI-powered last-mile routing software.

Summary

The quantity of delivered parcels has been increasing in recent years and is predicted to substantially increase in the coming years. Incumbent players try to lower their environmental impact, but research shows that efforts are insufficient to meet climate targets. Aside from climate change, cities face additional challenges arising from ever increasing volumes of parcels: traffic congestion, local tailpipe emissions and noise. HIVED offers an alternative, more sustainable business model. HIVED's last mile delivery alleviates these pressures and our LCA shows that HIVEDs approach **can result in a net reduction in GHG emissions of 0.13 to 0.17 kg CO_2-eq. and a reduction in fossil energy demand of 2.14 to 2.85 MJ per parcel delivered. The individual methods of parcel delivery offered by HIVED result in a net decrease in GHG emissions ranging from 56 to 76%.** In addition, HIVED's business model includes strategies to enable circular business models. A literature review reveals that this approach will ultimately result in a further reduction in GHG emissions as well as resources needed and wastes to be handled.

About this study

This study assesses the impact of last mile parcel delivery. In Part I, the status quo of last mile delivery is discussed. In Part II, a life cycle assessment (LCA) is presented assessing the impact of switching from conventional parcel delivery to a more sustainable parcel delivery model. Lastly, additional aspects of HIVED's business model affecting sustainability of last mile parcel delivery are discussed in Part III.

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1. Part I: Current status of the parcel delivery system and last mile delivery

1.1. Current status of parcel delivery

Over the last years the global parcel delivery market has increased significantly, with 159 billion packages being shipped across 13 major markets in 2021 (Pitney Bowes 2021), with a forecast of 256 billion packages shipped globally by 2027 (Statista 2022). Europe saw a 13% revenue growth in 2021 (Effigy Consulting 2021), reaching 88 billion euros with the B2C (business-to-customer) segment soaring. A combined growth in internet based services and an increase in international trade across regions has led to an exploding demand for delivery services. One of the factors contributing to this increase has been the Covid-19 pandemic, which has caused the e-commerce sector to see a substantial rise in parcel shipping volumes.

Large courier companies are now trying to cut emissions in every step of the delivery process, to meet net zero targets by 2050. Achieving net zero operations involves increasing alternative fuels for heavy goods vehicles, generating and purchasing 100% renewable electricity, reducing heating fuel usage, as well as fleet electrification and route delivery efficiency increases. Big industry names like Amazon and UPS have purchased over 100,000 (Amazon 2022) and 10,000 (UPS 2020) electric vehicles respectively. Many other players have also pledged to become net zero by 2050, however their lack of rapid EV adoption and clean energy consumption indicates otherwise. Current efforts are insufficient to meet climate change targets and to alleviate other pressures exerted by last mile delivery (Somo 2021; World Economic Forum 2020). Royal Mail (UK), DPD (EU) and DHL (global) report an increase in net GHG emissions of 28, 11 and 17% from 2020 to 2021, respectively. At the same time, Royal Mail and DPD managed to reduce the carbon intensity by 1.9 and 2.6% only (DPD Group 2021; Royal Mail plc 2020, 2021). The carbon intensity of DHL goods delivered as well as absolute carbon emissions increased; the latter by 17% from 2020 to 2021[1] (Deutsche Post DHL Group 2023). These numbers indicate that despite efforts to reduce emissions, absolute GHG emissions are increasing.

1.2. Last mile delivery

In the past decade e-commerce has risen significantly due to several factors such as urbanization and a wider range of products available to be bought online. Combined with a growth in the space of delivery services, demand for last-mile delivery is soaring and is expected to grow by 78% globally by 2030 (World Economic Forum 2020). Last mile delivery refers to the last step of the delivery process in which a parcel is delivered to its final destination from the transportation hub. Compared to the total journey of a parcel, the last mile portion of delivery logistics covers a fraction of it. However, it represents 40 - 50% of a shipment's total cost and is the most time consuming step (Greg Higgs 2022). Moreover, last mile emissions can account for up to 50% of total GHG emissions of parcel delivery. Using fossil-fueled vehicles with internal combustion engines (ICE) combined with inefficient route planning, outdated technologies and reverse logistics, exacerbates emissions.

The negative impacts of last mile delivery are more severe in urban areas and large cities. Due to traffic congestion and increase of delivery vehicles, they face increasing greenhouse gas (GHG) emissions. Interventions and different delivery strategies implemented will play a major role in reducing the total emissions of last mile delivery. Changing to electric vehicles and involving customer movements such

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[1] Most recent numbers show a decrease from 2021 to 2022 in absolute terms. However, the 2022 emission level is still about 10% higher than 2021 and 11% higher than the 2019 level.

as using lockers are potential interventions that can reduce impact. Last mile delivery allows the use of electric vehicles due to shorter distances required to be traveled. Specifically, electric cargo bikes have become popular in the last mile delivery, with the electric cargo bike market expected to achieve 1,935 million Euros by 2030 (Acumen Consulting 2022). Also, last leg changes also affect economics and impacts of last mile deliveries. One option is centralized dispatching in which deliveries are dispatched from a single hub location. In this strategy, delivery vehicles usually follow a singular route in which parcels are dropped off consecutively. Even though this system lowers operation costs, it can lead to high delivery times for destinations that are further away. Another mode of delivery is that of decentralized dispatching, which involves several depots and dispatchers in multiple locations. This strategy can lower delivery times significantly and if combined with optimized routes, lowers overall GHG emissions by using greener transportation such as bikes. Decentralized dispatching is optimal in high population density areas, where there are many deliveries per stop and the distance between stops is short.

Large retail, e-commerce and parcel delivery companies have become aware of the negative environmental effects of their business models and have set their own emissions targets. Fleet electrification, adoption of two wheel and three wheeler vehicles and investing in logistical planning have been the most common actions taken. Royal mail has set a net zero emission target by 2040 and has plans on rolling out more electric vans for final mile deliveries, with 5,500 vans by spring 2023 (Royal Mail 2022). Deutsche Post DHL Group works on electrifying its fleet. By the end of 2020, the company's fleet comprised just over 15,000 electric vehicles, equalling 14.5 percent of their entire fleet (Somo 2021). DPD has achieved an all electric fleet in 10 UK cities (DPD 2022). Hermes falls behind by having ordered 168 fully electric delivery vans and committing to going full electric (Hermes 2021). This indicates that conventional ICE vehicles are still the most common method of last mile delivery and even though efforts are being made, adoption rates and progress is lagging and companies need to accelerate their efforts, if they want to meet their targets (Somo 2021; World Economic Forum 2020). Moreover, there are a number of issues along the sector which are not taken into account such as Scope 3 emissions related to the environmental impact of the production of vehicles and components used.

2. Part II: LCA of last mile delivery

HIVED's last mile delivery system is likely to displace conventional parcel delivery. The aim of this LCA study is to assess the potential systemic changes of switching from conventional parcel delivery to HIVED. This approach follows a consequential LCA approach, seeking to assess (marginal) changes in environmental impact as a consequence of a change in the entire system (Ekvall et al. 2016). To account for marginal changes, marginal data is used wherever possible, e.g. marginal suppliers are identified and the change in their production output is considered (in contrast to using market averages).

2.1. System description

At present, parcel delivery is mainly accomplished using fossil-fueled ICE vehicles. HIVED offers last mile parcel delivery services using only renewable energy and zero emission vehicles. The assessment therefore compares conventional last mile delivery with HIVED's business model and assesses the net benefit of displacing the former by the latter. A key challenge in the assessment arises from the lack of first hand data of incumbent players. There is no data on current last mile delivery, such as location of warehouses and depots, routing, vehicles used, distance per parcel traveled, fuel consumptions under real world conditions etc., available. Therefore, we followed the methodology used by (Shahmohammadi et al. 2020). A literature review was conducted to obtain the most comprehensive sample of the most crucial parameters under real world conditions. Based on these, a parameterized model was developed and a Monte-Carlo simulation was conducted to assess most likely ranges of impacts for each last-mile delivery option. In total, four different options were considered with different vehicles types for each leg of the delivery process (Figure 1):

1) **Conventional last mile delivery**
   - warehouse → local depot: fossil-fueled ICE truck
   - local depot → delivery zone:fossil-fueled ICE delivery van
   - delivery: ICE delivery van

2) **Last mile delivery using electric vans (HIVED)**
   - warehouse → local depot: electric van
   - local depot → delivery zone: electric van
   - delivery: electric van

3) **Last mile delivery using electric vehicles (HIVED)**
   - warehouse → local depot: electric van
   - local depot → delivery zone: electric car
   - delivery: electric car

4) **Last mile delivery using electric cargo bikes (HIVED)**
   - warehouse → local depot: electric van
   - local depot → delivery zone: electric van
   - delivery: electric cargo bike

The functional unit used to assess the impact of HIVED is one parcel delivered in a metropolitan area, such as London. The impact is assessed using the indicators **global warming potential** (GWP) (Masson-Delmotte et al. 2021) and **cumulative fossil energy demand** (CED$_f$) (Verein Deutscher Ingenieure (VDI) (ed.) 2012). The results are expressed for each individual method of parcel delivery and as a net change in emissions, if conventional parcel delivery (option 1) is replaced by alternative methods (options 2-4 above).
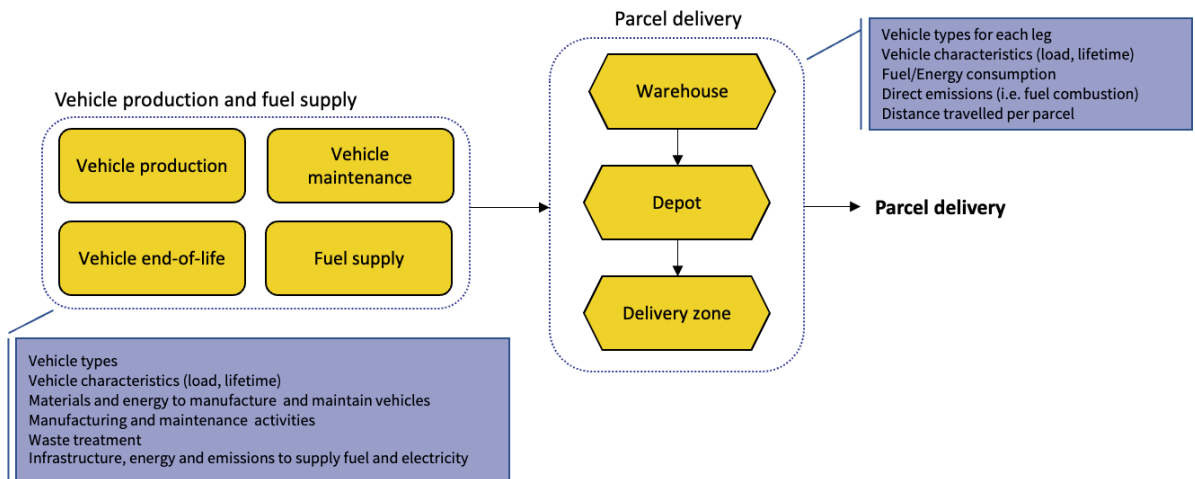
Figure 1 *Assessed system and most important parameters (blue boxes). The key components of the system are the vehicles used to deliver the parcel, fuel supply and the parcel delivery itself. The last mile parcel delivery system consists of transportation from a warehouse to a local depot and from a local depot to the delivery zone where the final parcel delivery takes place.*

2.2. Life cycle inventory

In the following sections, we explain the data used to model the impact of HIVED. Most crucial parameters were defined as probability distributions using most likely parameter ranges. If not stated otherwise, uniform distributions were used. The uncertainty related to input data was modeled using the ecoinvent pedigree matrix in all cases in which no parameter range is specified explicitly in the text (Ciroth et al. 2016).

2.2.1. Vehicles, fuel and electricity supply

Primary vehicle data of commercially available vehicles was used to model the vehicle production of the ICE van, the electric van and the e-cargo bike (Temporelli et al. 2022)[2]. The ICE truck and electric car were modeled using data provided by the ecoinvent database 3.8 (Wernet et al. 2016). The mean lifetime of the different vehicle types is 540,000 km (ICE truck), 240,000 km (ICE and electric vans), 150,000 km (electric car) and 33,620 km (electric cargo bike). All electric vehicles use lithium ion batteries. The energy density of lithium ion batteries is 250 (200 to 300) kWh/kg and a capacity 150 (30 to 300 kWh) and 75 (50 to 100) kWh in case of an electric van and an electric car, respectively (BloombergNEF 2021; Link and Plötz 2022). The fossil fuel supply was modeled with the ecoinvent database (Wernet et al. 2016). The different load capacities of vehicles is accounted for by assuming a parcel weight of 1 kg (0.5 to 10 kg, triangular distribution) and considering the load capacity of each vehicle type as listed in Table 2. Additionally, the distance covered per parcel varies per delivery method. This implicitly includes a difference in transport requirements per parcel to be delivered (e.g. longer distances to be covered with vehicles with lower carrying capacities).

HIVED operates in London (UK) and uses only electricity from renewable sources. The switch from fossil fuels to electricity from renewable sources results in a net increase in demand for electricity from renewable sources. A marginal electricity mix was constructed using current and planned generation capacities of electricity from renewable sources (Table 1).

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[2] All data is available in the supplementary material on the journal's website (Temporelli et al. 2022).

Table 1 *Key parameters of the marginal supply mix of electricity from renewable sources. Data obtained from (Forrester 2022; UK Government (ed.) 2022).*

	Capacity [GW]		Load factor	Marginal mix
	2022	**2035**		
Offshore wind	11.3	45	40.2%	59%
Onshore wind	14.5	35	26.3%	23%
Solar PV	13.8	54	10.0%	18%

2.2.2. Parcel delivery

The key parameters of parcel delivery depend on many variables, such as the number of parcels delivered, the density of customers, the location of warehouses, depots and customers, the routing, local traffic conditions, etc. Due to a high uncertainty in all of these variables and the lack of first hand data of incumbent parcel delivery companies, a literature review was conducted and parameter ranges for most important parameters were defined (Table 2). Notably, the distance traveled per parcel is longer for electric vehicles. This finding revealed by the literature review is confirmed by other scientific publications, cf. literature cited in (Patella et al. 2020). Based on Shahmohammadi et al. (2020), a transport distance from the warehouse to the depot is 100 (50 to 250) km is assumed.

Table 2 *Key parameters of last mile parcel delivery. Parameter ranges defined based on data obtained from HIVED and (Shahmohammadi et al. 2020; Elbert and Friedrich 2020; Fraselle, Limbourg, and Vidal 2021; Gonzalez-Calderon et al. 2022; Groot et al. 2017; Krause et al. 2020; Llorca and Moeckel 2021; Nielsen and Jørgensen 2023; Stolaroff et al. 2018; Temporelli et al. 2022; Weiss, Cloos, and Helmers 2020; Browne, Allen, and Leonardi 2011).*

	Conventional ICE Van	Electric vehicles	Electric cargo bike
Distance per parcel [km/parcel]			
Min	0.15	0.27	0.42
Max	0.80	1.28	1.00
Average	0.36	0.59	0.71
Fuel/electricity consumption [MJ/ km]			
Min	2.51	0.79	0.03
Max	4.60	1.08	0.34
Average	3.69	0.91	0.11
Weight [t]			
Min	1.35	1.54	0.05
Max	2.80	2.80	0.36
Average	2.10	2.10	0.17
Load volume [m³]			
Min	3.60	3.00	1.00
Max	12.00	12.00	2.00
Average	7.80	7.80	1.58
Load weight [kg]			
Min	700.00	445.00	18.50
Max	1000.00	1000.00	300.00
Average	875.50	875.50	197.70

2.3. Results

All delivery methods using electric vehicles perform better than conventional parcel delivery using ICE vehicles (Figure 2). **The last mile parcel delivery results in average GHG emissions of 0.22, 0.08, 0.10 and 0.05 kg CO_2-eq. per parcel if the parcel is delivered with conventional ICE vans, electric vans, electric cars and electric cargo bikes, respectively** (Table 3). **Thus, electric parcel delivery emits between 56 and 76% less GHG emissions than conventional parcel delivery.** The average fossil energy required to deliver a parcel is 3.43, 0.66, 1.22, 0.59 MJ per parcel delivered with conventional ICE vans, electric vans, electric cars and electric cargo bikes, respectively. **The displacement of conventional last mile parcel delivery results in net reductions in GHG emissions of 0.13 to 0.17 kg CO_2-eq. and reductions in fossil energy demand of 2.14 to 2.85 MJ per parcel delivered.** The cargo bike performs best among all options despite longer distances covered per bike. The low weight of the bike, very low emissions of the bike manufacturing and low energy consumption are the main reasons for the good performance of the electric cargo bike. The electric car results in the highest emissions among the electric vehicles due to the comparably low load capacity and a higher electricity consumption per parcel delivered and more emissions resulting from the vehicle manufacturing.

It is important to note that in contrast to conventional parcel delivery vehicles, smaller electric vehicles do not emit local tailpipe emissions, such as particulate matter, nitrogen oxides, etc. The noise emitted by electric vehicles is substantially lower than by ICE vehicles. In addition, small vehicles, such as cargo bikes can reduce the curb-side occupation and reduce traffic in urban areas.
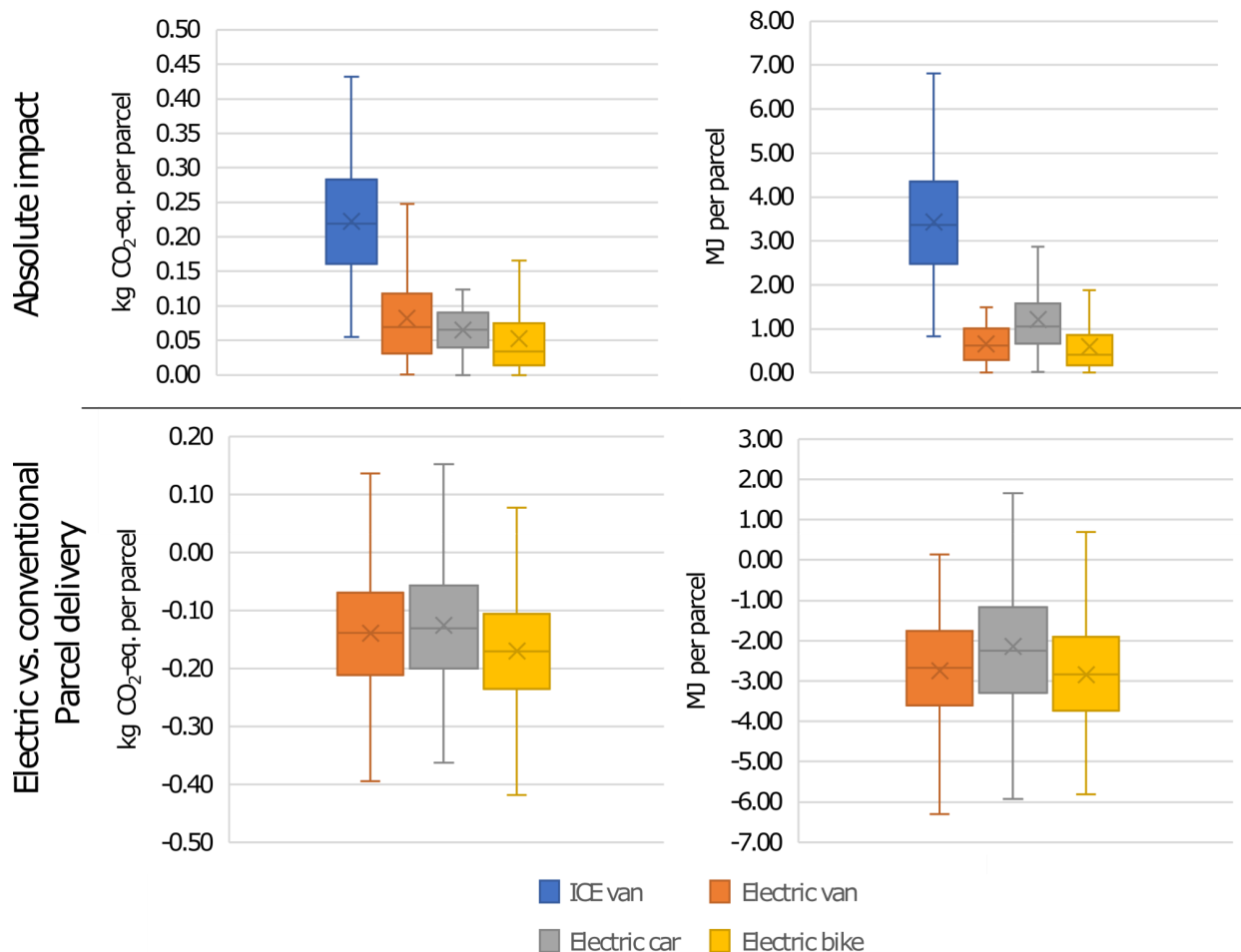

Figure 2 *Top: GHG emissions and fossil energy demand of last mile parcel delivery in kg CO_2-eq. and MJ per parcel. Bottom: Net change in GHG emissions and fossil energy demand if conventional parcel delivery is replaced by electric parcel delivery.*

Table 3 *Results of the Monte-Carlo simulations showing GHG emissions (GWP) and fossil energy demand (CED$_f$) of last mile parcel delivery. The upper half of the table shows absolute emissions per delivery method. The lower half shows the net change in emissions if conventional parcel delivery is displaced by electric delivery methods.*

	Indicator	Vehicle	Median	Average	Std. dev.	5% Percentile	95% Percentile
Absolute	GWP	Conv. ICE van	0.22	0.22	0.08	0.10	0.36
		Electric van	0.07	0.08	0.06	0.01	0.21
		Electric car	0.08	0.10	0.07	0.02	0.24
		Electric cargo bicycle	0.03	0.05	0.05	0.00	0.17
	CED$_f$	Conv. ICE van	3.37	3.43	1.24	1.54	5.52
		Electric van	0.63	0.66	0.42	0.04	1.38
		Electric car	1.06	1.22	0.78	0.25	2.79
		Electric cargo bicycle	0.41	0.59	0.56	0.04	1.75
Net change	GWP	Electric van	-0.14	-0.14	0.10	-0.30	0.03
		Electric car	-0.13	-0.13	0.11	-0.29	0.05
		Electric cargo bicycle	-0.17	-0.17	0.09	-0.32	-0.02
	CED$_f$	Electric van	-2.67	-2.75	1.32	-4.93	-0.78
		Electric car	-2.25	-2.14	2.65	-4.58	0.19
		Electric cargo bicycle	-2.83	-2.85	1.30	-5.08	-0.86

2.4. Limitations

There are several limitations in this study that havent been addressed but influence the final results:

- Data: Data used in this study stems from scientific literature and other reports. It therefore comprises specific case studies on last mile delivery and vehicles. Over time, vehicle characteristics and manufacturing processes change. Additionally, there is no first hand data of routing of incumbent players available. All these parameters change over time. This shortcoming cannot be overcome. In order to account for this uncertainty, the Monte-Carlo simulation was chosen as the most appropriate modeling approach.
- Modeling approach: Due to the lack of first-hand data of last mile parcel delivery accomplished by incumbent players as well as due to the high flexibility of how the future parcel delivery of HIVED and the incumbent players will look like, a Monte-Carlo simulation using a wide range of scientific literature was chosen as the most appropriate approach. The advantage of this approach is that even if the system is largely unknown, impacts can be determined based on the data available. The results show the likely range of potential impacts of last mile parcel delivery. Yet, it is not a representation of the exact system in place at a specific location.
- Several aspects were not considered in this study:

- ○ Delivery failures: It is estimated that delivery failures amount to up to 14% of parcels delivered (Allen et al. 2018). These parcels require additional delivery attempts or are either returned to the sender or sent to a central facility (e.g., a locker box or a pickup store) to be picked up. Again, data of incumbent players is missing. Thus, this aspect was excluded from the assessment.
  - ○ Efficient routing: HIVED uses efficient routing and microhubs to decrease stem mileage and to allow a more efficient parcel delivery (see below). Since routing of incumbent players is missing, this aspect was not modeled explicitly. Yet, the data used in the model contains studies with microhubs and a wide range of efficiencies. Therefore, these aspects are implicitly included in the model.
  - ○ Calories burned because of manual effort: Walking (in all cases) and cycling (electric cargo bike) require physical activity. The additional physical activity results in an increase in calories needed. The provision of additional nutrition to compensate for the increase in energy expenditure is not accounted for in this study.
- ● The role of incumbent players: Incumbent players already implement strategies to lower GHG emissions and to alleviate other pressures caused by them. However, research shows that these efforts are insufficient to reach international climate targets. A fundamental shift away from all conventional parcel delivery is required (regardless if this is done by HIVED or the incumbents). The results shown in this study refer to a shift from conventional, fossil-fueled ICE parcel delivery to more sustainable vehicles. If HIVED gains market shares from incumbent players, they will also displace the (small) share of sustainably delivered parcels by these incumbent players. In such a case, the impact depends on the characteristics of each delivery model. Due to the lack of data (see above), such a case cannot be assessed in detail. Instead, the easiest way to get a rough estimate, is to assume a certain share of sustainable parcel delivery conducted by incumbent players and to subtract this share from the net change in impacts estimated in this study. E.g., if a 15% share of parcel delivery by electric vehicles is assumed, the estimated impact is 15% lower than estimated here (neglecting system efficiencies, vehicles used, routing etc., all of which cannot be accounted for due to the lack of data).

3. Part III: Additional aspects of HIVED's business model affecting the environmental impact of parcel delivery

In addition to the aspects covered by the LCA, HIVED's business model implements several aspects that improve the status quo of existing last mile delivery.

3.1. Improvements in last mile delivery logistics

HIVED covers a distinct number of contiguous areas with a high delivery density (parcels per km^2). In addition, HIVED uses micro-hubs and sequential routing to allow efficient routing. This allows the use of small electric vehicles, such as cargo bikes and reduces stem journeys. Additionally, microhubs can be replenished at night or in times of low traffic. All these methods combined result in less traffic and lower emissions compared to conventional last mile delivery (World Economic Forum 2020).
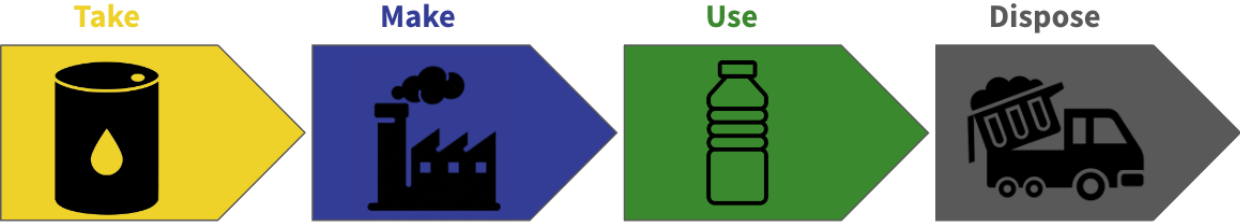
3.2. Circular economy

HIVED's long term vision is to enable a truly circular economy by leveraging the density of their network. By building an a logistics network to enable a reliable and cost efficient circular movement of goods and

items to and from individual addresses. Our economy is currently dependent on the traditional take-make-consume-dispose approach. This linear model relies on the extraction of raw materials, manufacturing of products and disposal of waste in an unsustainable manner, leading to resource depletion, pollution, waste generation as well as loss of biodiversity. To mitigate the environmental damage caused by this approach, the circular model is able to create a closed loop system that supports sustainable economic growth. Figure 3 below summarizes the two approaches.

Linear Economy

Materials in a Linear Economy create waste after use

Circular Economy

Materials in a Circular Economy are collected and reused after each use
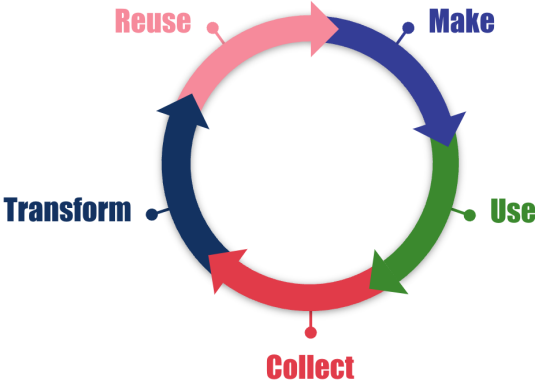

Figure 3 *Linear vs Circular Economy schematics.*

Increasingly more research is undertaken to refine our understanding of the concept of circular economy and demonstrate the possibilities of a sustainable production-consumption culture (Korhonen, Honkasalo, and Seppälä 2018). However, only a limited number of countries have taken action towards adopting more circular economy models and many researchers are expressing the need for stronger commitments (Vania Ivanova and Sonia Chipeva 2019). New policies and players will have to enter the market to enable the adoption of such circular models along the value chain. One of the most important ones is transportation, which plays a critical role and is responsible for the continuous

movement of goods between the different circularity stages. HIVED is positioned well to fit into such a model and tackle different industries.

To date, there is no study available assessing multiple circular business models. This is due to the novelty of the topic, as well as the very case specific conditions resulting from the business models as well as local conditions. Table 4 below summarizes a list of assessments on individual circular business models and comparing them with linear models.

Table 4 *Circular economy case studies.*

Study	Case study	Results
(Emma Johnson 2020)	Rental clothing	Consistent benefit in freshwater, marine and human carcinogenic toxicity
(Schwarz et al. 2021)	Recycling of plastics	80% GHG emission reduction
(Kerdlap, Gheewala, and Ramakrishna 2021)	Pram rental	29-46% lower impact between all environmental impact categories
(Yoon-Young Chun and Kun-Mo Lee 2017)	Water purifier rental	32-37% improvements in selected environmental impact categories
(Pérez-Martínez et al. 2021)	Repurposed electronic equipment	25-80% less environmental impact in selected categories
(Tua, Grosso, and Rigamonti 2020)	Reconditioning glass bottles	30-65% better environmental performance in selected environmental impact categories

HIVED's business model strongly focuses on the enablement of circular business practices. This will enable others to operate circular business models, resulting in lower GHG emissions, lower resource demand and less wastes generated.

4. Conclusion

The volume and quantity of delivered parcels has been increasing in recent years and is predicted to substantially increase in the coming years. Urban environments suffer from noise, GHG emissions and tail-pipe emissions of other pollutants (e.g. particulate matter, NOx, etc.) caused by higher freight volumes and increasing traffic. Alternative business models in the parcel delivery sector are needed to alleviate these pressures. HIVED offers a more sustainable approach to last mile delivery. **The LCA shows that last mile delivery with electric vehicles can result in a net reduction in GHG emissions and fossil energy demand ranging from 0.13 to 0.17 kg CO_2-eq. and 2.14 to 2.85 MJ per parcel delivered, respectively.** HIVED's business model includes additional aspects, such as efficient routing, the use of microhubs and the enablement of circular business models. These aspects result in additional benefits, such as lower GHG emissions, lower emissions of other pollutants as well as less wastes and material use.

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