Liverpool Live Labs 2

Carbon Baseline Report

November 2024

Contents

1. Introduction

The Liverpool Live Lab is a three-year project funded by the UK Department for Transport (DfT) as part of the wider Live Labs 2 programme for decarbonising local roads, run by the Association of Directors of Environment, Economy, Planning, & Transport (ADEPT). The project focuses on decarbonising Liverpool's road network - the largest physical asset owned by Liverpool City Council (LCC) - in order to meet the Council's ambitious target of achieving net zero emissions by 2030.

To address the challenge of funding repairs on the city's highways network, LCC launched a Highways Investment Programme (HIP) to deliver improvements in highways condition, safety, accessibility, and facilitation of sustainable travel. The first phase of HIP schemes (HIP1) was delivered in 2022-2023, followed by the second phase of HIP schemes (HIP2) which began in November 2023, delivered by three contractors: Dowhigh, Huyton Asphalt Civils (HA Civils), and Tarmac. These HIP schemes are a central focus of the decarbonisation activity facilitated by the Liverpool Live Lab.

The project aims to create an 'Ecosystem of Things': a scalable and transferrable system of holistic activities and interventions, inspired by the 'internet of things'. This will treat Liverpool's highways network as a holistic 'system of systems' enabling decarbonisation and addressing existing barriers to change. The Ecosystem of Things represents an interlinking of elements which in isolation would be unlikely to achieve the required carbon reduction, but when combined in an intelligent way – to target the highest-emitting 'carbon hotspots' within individual schemes – have potential to achieve the significant carbon savings needed to drive Liverpool's trajectory to net zero by 2030. It is therefore vital that a baseline carbon assessment is conducted for a representative variety of schemes, in order to identify which carbon hotspots are priorities for decarbonisation, and to create a benchmark against which progress from 'business as usual' to 'net zero as usual' can be measured.

This report illustrates our carbon baselining journey to date within the Liverpool Live Lab, highlighting our progress against the commitments made in the initial Strategic Outline Business Case (SOBC).[1]
The journey progresses from the development of our methodology to the establishment of a 'business-as-usual' baselining process for previously completed HIP schemes, as well as the creation of a carbon baseline for the first demonstrator scheme against which the decarbonisation potential of various innovative low-carbon options will be measured. Key findings, challenges, lessons learned, and caveats & limitations of our approach will also be explored, followed by a summary of our next steps. To ensure that this process remains as meaningful as possible to the wider sector, we see the carbon footprinting and baselining as a dynamic exercise, and therefore all data remains subject to change based on new data and knowledge which becomes available during the course of the project.

[1] See https://www.adeptnet.org.uk/sites/default/files/media/2023-08/Liverpool%20Live%20Lab%20SOBC%20-%20REDACTED_0.pdf

2. Delivery of Strategic Outline Business Case (SOBC) commitments

2.1. Scheme-level baselines

"Leveraging the built-in baselining within the Carbon Hierarchy Lens (CHL) as a virtual optioneering tool, as well as support of the Future Highways Research Group (FHRG), we will first shadow 5 representative schemes clustered within the East Speke ward to determine an initial carbon baseline for each demonstrator neighbourhood context."

Outline Business Case: Liverpool 'Ecosystem of Things' driving a low-carbon economy, Page 4

In the first year of the project (2023-24), a carbon baseline was created for three schemes which were completed prior to any influence of the Live Labs project upon the scheme design. These schemes were each selected to be representative of a 'typical' scheme carried out as business-as-usual (BAU) by a given contractor. This included one scheme for each contractor across the three city regions:

- Scarisbrick Crescent in North Liverpool (Dowhigh, HIP1)
- Chatterton Road in Central Liverpool (HA Civils, HIP1)
- East Mains in South Liverpool (Tarmac, HIP2).

Contrary to the SOBC, the geographical scope of these schemes was broader than the East Speke ward, in order to capture the diversity of approaches across the three contractors and regional environments in a more representative manner. These scheme-level baselines were calculated using the FHRG Carbon Analyser tool - as the Pell Frischmann CHL tool was still in development at the time – and were carried out in accordance with the FHRG Carbon Calculation & Accounting Standards (CCAS) protocols. The initial intention was to select three completed schemes from HIP1, for which data was already available for the incumbent contractors Dowhigh and HA Civils. However, as Tarmac was new to the HIP2 contract, data for their first HIP scheme only became available once they had completed the East Mains scheme in March 2024.

Two further schemes (Princess Drive and Alderfield Drive) have had a provisional carbon baseline calculated using the Pell Frischmann CHL tool, as part of the material-based optioneering process for the comparison and selection of low-carbon innovations to apply to the demonstrator schemes. These demonstrators are part of the upcoming HIP2 works, as opposed to completed works. As this carbon baseline focused purely on materials (EN15978 lifecycle stages A1-A3)[2], an extended carbon baseline was also calculated for Princess Drive in Carbon Analyser which included estimated values for onsite energy consumption, staff travel, vehicles & plant, transportation, waste, and other purchased services. This carbon baseline will be updated retrospectively once more information becomes available during or after scheme completion. As a full carbon baseline has not yet been calculated for Alderfield Drive, and the results of the optioneering process have not yet been finalised, Alderfield Drive will be excluded from this report.

[2]See https://www.structuresinsider.com/post/life-cycle-stages-in-construction-works-as-per-bs-en-15978-2011

2.2. Partner cities

"Vital to the scalability of the outcomes, the Liverpool programme will be delivered in collaboration with our 'Peer City', Aberdeen City Council, which… will benefit from collective learning, best practice share and policy sharing."

"The aim is to then include/bring on-line additional partners within a Leader-Follower model, including Newcastle City Council, Royal Borough of Kensington & Chelsea and adjacent authorities within the Liverpool City Region."

Outline Business Case: Liverpool 'Ecosystem of Things' driving a low-carbon economy, Page 13

We are collaborating with Aberdeen City Council to replicate LCC's approach to scheme-level carbon baselining, as well as carrying out a full-service carbon baseline in accordance with the CCAS protocols. (Note that the full-service baseline was not part of the SOBC commitments, but was requested by Aberdeen City Council as part of the FHRG's rollout of the CCAS process, as opposed to being a Live Labs requirement). Learning, resources, and best practices will be shared multilaterally between the two City Councils and their project partners. For example, we have shared with Aberdeen City Council the proforma template created specifically for gathering baseline data for Liverpool's HIP schemes, and Colas will be supporting Aberdeen by carrying out the necessary carbon calculations using Carbon Analyser.

Additional follower partners will also be brought onto the project to maximise the scalability of our approach. This is likely to include Newcastle City Council, as well as Portsmouth City Council (for whom a full-service carbon baseline is already being calculated separately to the Live Labs project) in place of the Royal Borough of Kensington & Chelsea.

3. Scheme descriptions

3.1. Completed BAU schemes

Figure 1. Location and surface area of the three BAU baseline schemes across the three Liverpool city regions.

The three completed BAU schemes were distributed across each of the major Liverpool city regions (**Figure 1.**). Whilst all three were primarily carriageway resurfacing schemes in residential neighbourhoods, the scope and extent of the works varied from scheme to scheme.

Scarisbrick Crescent was the largest of the three schemes (approx. 6100m^2), with works commencing in October 2022 and reaching completion in March 2023. The site is located in a residential area next to Leamington Community Primary School. Works included the resurfacing of the carriageway and footways; the provision and installation of new kerbs and tactiles; the replacement of road markings; and improvements to drainage in the area.

Chatterton Road was the smallest scheme at 87m^2, located in a residential area near to the Alder Hey Hospital. Works included carriageway resurfacing (binder and surface courses); the installation of new kerbs and paving; and the renewal of road markings. HA Civils' proprietary warm mix asphalt product HALO was used for the binder and surface courses, supplemented with a standard asphaltic concrete (AC) surface course.

East Mains is located alongside an area of recreational greenspace (The Mains) in the East Speke area. Works took place over the course of three weeks in February-March 2024, including 1,463m^2 of carriageway resurfacing (binder and surface courses), 152m^2 of footway reconstruction, and 487m of kerb replacements. HALO was used for the binder course, whilst a standard AC was used for the surface course.

3.2. Demonstrator scheme (Princess Drive)

Princess Drive is located in the north-eastern region of Liverpool, approximately 1.5 miles to the east of Chatterton Road. The Princess Drive resurfacing scheme covers two main sections of carriageway: Section 1, a dual carriageway with an existing rigid pavement construction which runs for approx. 950m from Deysbrook Lane to the junction with Rothbury Road and Snowberry Road; and Section 2, a single carriageway with an existing flexible pavement construction which runs for approx. 560m from the Rothbury Road/Snowberry Road junction to the bifurcation back to a dual carriageway (**Figure 2.**).

The original proposal by HA Civils was to overlay 90mm of HALO surface & binder course on the rigid Section 1, and inlay 90mm of HALO surface & binder course on the flexible Section 2. In addition, approx. 4,440m of kerbing and 800m^2 of driveway accesses were proposed across the two sections (**Figure 2.**). Ancillary items (pedestrian guardrails and plastic drainage) were also included.

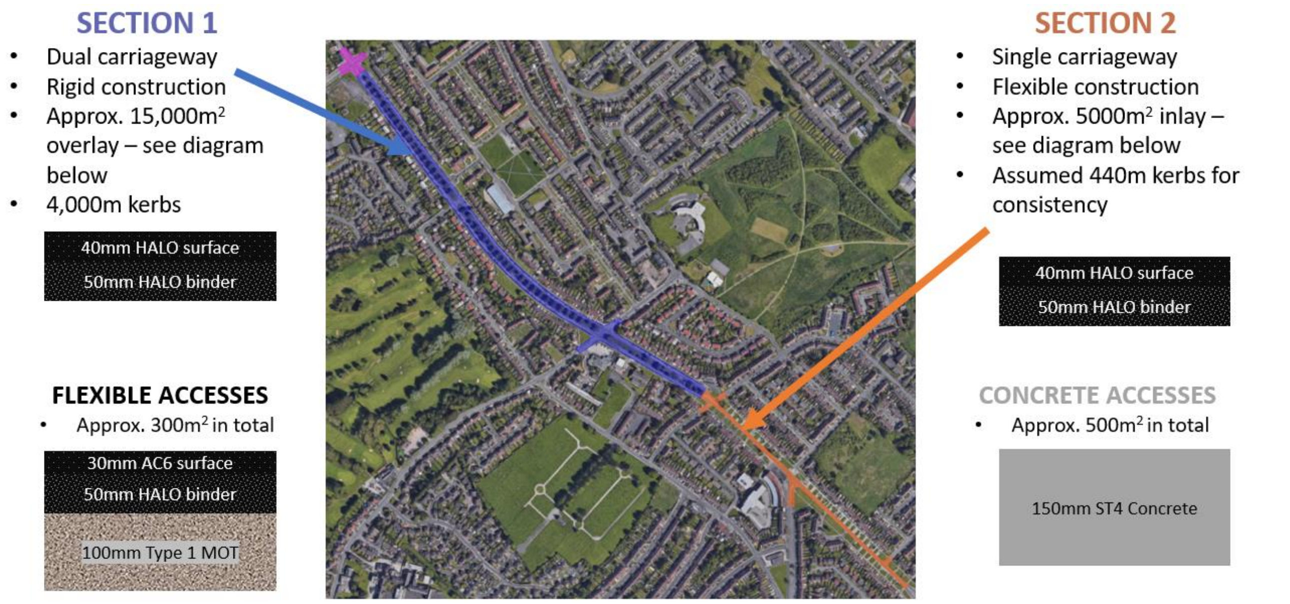

Figure 2. Layout of Princess Drive and the works originally proposed on each of the two carriageway sections.

Alderfield Drive is located in the East Speke area of South Liverpool, approx. 0.1 miles away from East Mains. The carriageway runs for approx. 2,000m around the eastern edge of the Speke residential neighbourhood, intersecting with Eastern Avenue at the junctions with Clough Road and Hale Drive to the north and south of the estate. It is bordered by a footway on the residential (west) side and at the entrance to St. Ambrose Catholic Academy on the east side, which is otherwise comprised of woodland, open fields, and dense vegetation.

Whilst a final scheme design for Alderfield Drive has not yet been established, the original specification was to resurface 12,513m^2 of the main carriageway with 40mm of AC10 surface course and 50mm of AC20 HDM binder course. Footway resurfacing was assumed to consist of a 30mm surface course, 50mm binder course, and a conventional sub-base comprising 100mm of aggregates, sand, and/or general fill material. Up to three of the connecting side roads may also be included in the final scheme as testbeds for alternative material types, taking the total surface area up to 19,040m^2.

4. Methodology

4.1. Baselining of completed BAU schemes

A proforma template was created in MS Excel and shared with the three HIP2 contractors to gather data on each of the three selected HIP schemes in accordance with the CCAS protocols. This included the outline scheme metrics and each of the four CCAS inventories within the scope of the scheme (see **Table 1.** below).

Category	Information	
Activity details	• Scheme name/location • Asset type & activity type	• Area / Quantity • Scheme value
Premises & Sites	• Site/asset (e.g. onsite generator) • Gas consumption & units	• % of site dedicated to service • Electricity consumption & units
Staff & Contractors	• ID or role • No. days commuting to site • No. days working from home • Primary commute mode	• Vehicle type & size • Fuel type • Average daily commute miles • Business miles in same vehicle
Vehicles & Plant	• Reg. no. or ID code • Vehicle/plant type & ownership • Function/description	• Engine size OR vehicle weight • Fuel type • Miles travelled OR litres of fuel
Products & Services	**Materials & Products** • Category & detailed description • Supplier • Quantity & units • Expected longevity **Transport & Plant as a service** • Transport mode • Fuel type • Supplier • Mileage OR fuel usage & units	**Purchased Services** • Office-based, network-based, or digital • Description & provider • Quantity & units **Waste Management** • Waste type • Disposal method • Provider • Quantity & units

Table 1. Variables included within the proforma template for HIP scheme baseline data collection.

Data was returned in the proforma template by two of the contractors. The third contractor had already carried out a 'BAU' carbon baseline and 'as-built' carbon assessment for their chosen scheme; as this only included materials and waste, the additional carbon inventories required were determined through conversations with the contractor. Since the 'as-built' carbon emissions were considered to be BAU for the other two contractors, the 'as-built' carbon assessment was selected as the baseline for this contractor, to reflect how works were carried out prior to the influence of the Live Labs programme without artificially inflating the carbon baseline.

The returned data was entered into the Projects & Configurations module of the FHRG Carbon Analyser by the project Carbon Analyst. Where specific material products were used, a product-specific carbon factor was sought from the contractor; otherwise, an appropriate carbon factor was selected from the inbuilt database in Carbon Analyser to calculate the carbon footprint of each item. To avoid double-counting, any staff & contractors listed as using an employer-owned vehicle were excluded from Staff & Contractors, as their vehicle would have already been recorded under Vehicles & Plant. Once an overall carbon baseline had been calculated for each scheme, the baselines were normalised by dividing the total emissions by the scheme area (m2) and by the scheme value (£K) for comparability to future schemes. For Scarisbrick Crescent, the scheme value was approximated from the combined value of Scarisbrick Crescent and Scarisbrick Drive, multiplied by the area of Scarisbrick Crescent as a percentage of the area of the two schemes.

4.2. Baselining of demonstrator schemes

An initial carbon baseline for the Princess Drive scheme was calculated by Pell Frischmann using the CHL optioneering tool, focusing on materials (lifecycle stages A1-A3) only, as this was the primary focus of the optioneering process. This carbon baseline was extended in Carbon Analyser to align with the CCAS protocols, using the original scheme proposal to calculate material quantities required, with the addition of estimated values for onsite energy consumption, staff travel, vehicles & plant, transportation, waste, and other purchased services. Quantities of onsite energy consumption, staff travel, and vehicles & plant were scaled up from the data provided for Chatterton Road (as both schemes were carried out by HA Civils), but the fuel type was converted from diesel to HVO (except for private vehicles) to reflect the contractor's adoption of HVO as a standard option. Transportation was calculated based on the distance from the specified asphalt plant to site and the quantity of asphalt required; this was converted from m^2 to tonnes using the stated layer depth and the density factor inferred from the product brochure, as was also the case with waste. Other purchased services were scaled up from East Mains, as this was the only scheme where data on purchased services was provided in units for which a carbon factor was available in Carbon Analyser (operative-days).

An initial carbon baseline has also been calculated for the Alderfield Drive scheme using the CHL optioneering tool, including lifecycle stages A1-A3 (plus A4-A5 where data was available). This is likely to be developed into a fully CCAS-compliant baseline when sufficient data becomes available.

5. Results & Key Findings

5.1. Completed BAU schemes – headline findings

Overall, Products & Services was the highest-carbon inventory for all three of the selected schemes, accounting for 71-89% of total CO_2e emissions per scheme (**Figure 3.**, right). Approximately 52-86% of total CO_2e emissions came from purchased materials, with asphalt and concrete being the most significant carbon hotspots. As was to be expected, CO_2e emissions increased with scheme area and value. East Mains and Scarisbrick Crescent were fairly similar in terms of CO_2e per m^2 and per £K; in contrast, CO_2e emissions were higher per m^2 but lower per £K for Chatterton Road (**Figure 3.**, left). As Chatterton Road was a much smaller scheme (87m^2 as opposed to >1000m^2), this may imply an economy of scale in terms of the cost and carbon efficiency of carrying out larger schemes.

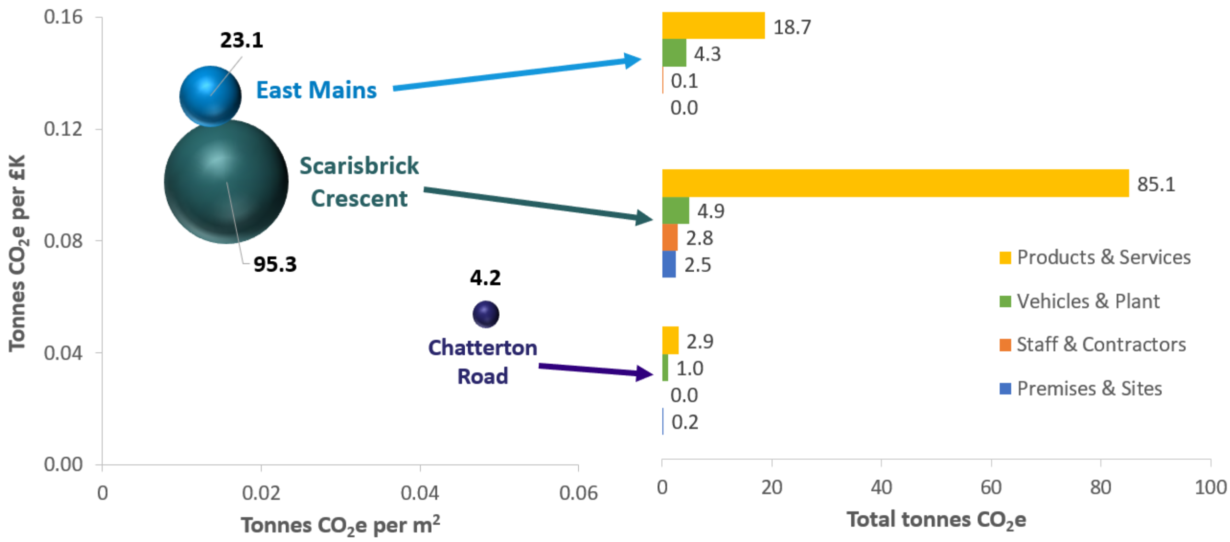

Figure 3. Left: CO_2e emissions for each scheme (represented by the volume of each sphere), normalised by the area (m^2) and value (£K) of each scheme. **Right:** Total CO_2e emissions of each scheme within each of the four carbon inventories.

5.1.1. Scarisbrick Crescent

The carbon footprint of the Scarisbrick Crescent scheme was approximately 95.3 tonnes of CO_2e, 89% of which came from purchased Products & Services (see **Figure 4.**). Asphalt was a major carbon hotspot, accounting for approximately 70% (67.1 tonnes) of total emissions; 35% (30.2 tonnes) of this was attributable to the binder course. Precast concrete was also a minor carbon hotspot, at 12% (11.3 tonnes) of total emissions.

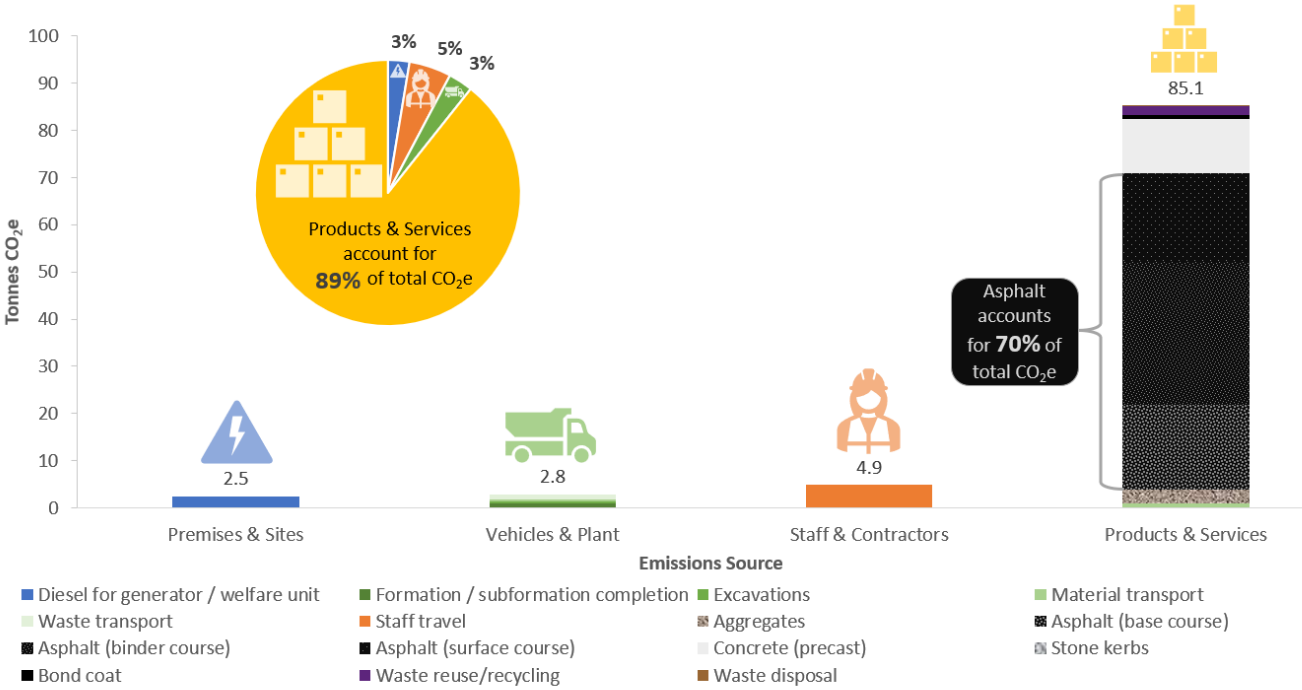

Figure 4. Baseline carbon data for the Scarisbrick Crescent scheme.

2.1.1. Chatterton Road

The carbon footprint of the Chatterton Road scheme was approximately 4.2 tonnes of CO_2e, 71% of which came from purchased Products & Services (see **Figure 5.**). The most significant carbon hotspot was concrete, accounting for approximately 36% (1.5 tonnes) of total emissions; 73% (1.1 tonnes) of this came from ready-mixed concrete. Other minor carbon hotspots on this scheme included diesel plant items at 26% (1.1 tonnes) and asphalt at 25% (1.1 tonnes) of total emissions. 53% (0.6 tonnes) of the emissions from asphalt were attributable to HALO, as this was the main resurfacing material used on the scheme. No CO_2e emissions were attributable to Staff & Contractors, as all operatives used company vehicles which had already been recorded under Vehicles & Plant to avoid double-counting.

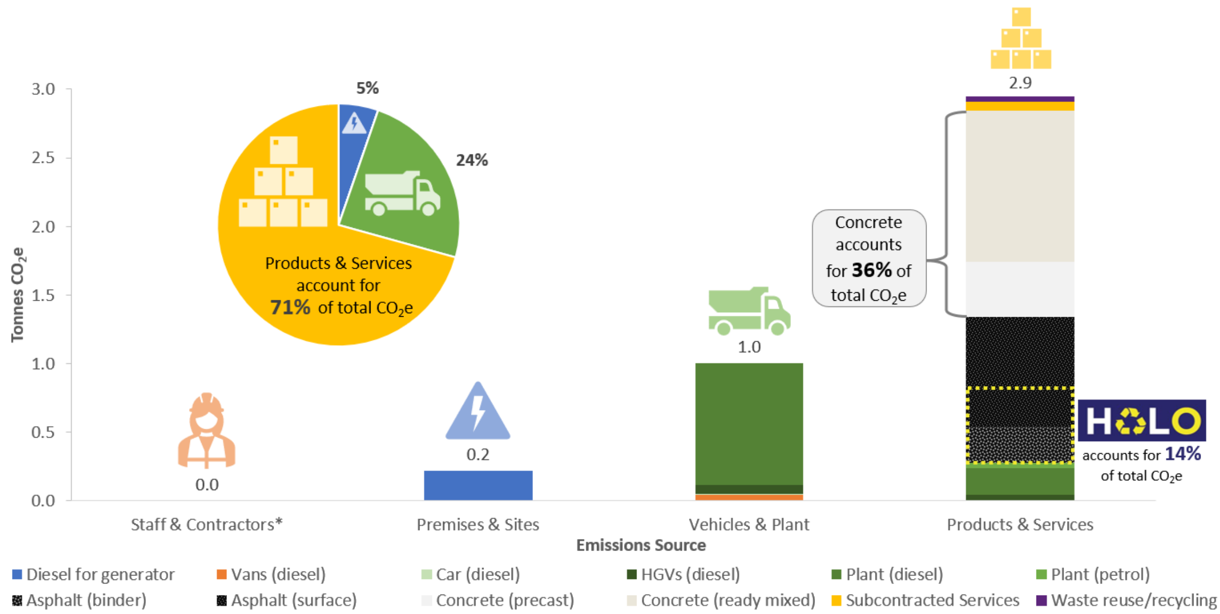

Figure 5. Baseline carbon data for the Chatterton Road scheme.

2.1.2. *East Mains*

The carbon footprint of the East Mains scheme was approximately 23.1 tonnes of CO_2e, 81% of which came from purchased Products & Services (see **Figure 6.**). The most significant carbon hotspot was asphalt, accounting for approximately 37% (8.5 tonnes) of total emissions; 43% (3.7 tonnes) of this was attributable to the use of HALO. Other minor carbon hotspots included diesel plant items at 35% (8.2 tonnes) and concrete at 15% (3.4 tonnes) of total emissions. No CO_2e emissions were attributable to Premises & Sites, as the welfare van used had already been recorded under Vehicles & Plant to avoid double-counting.

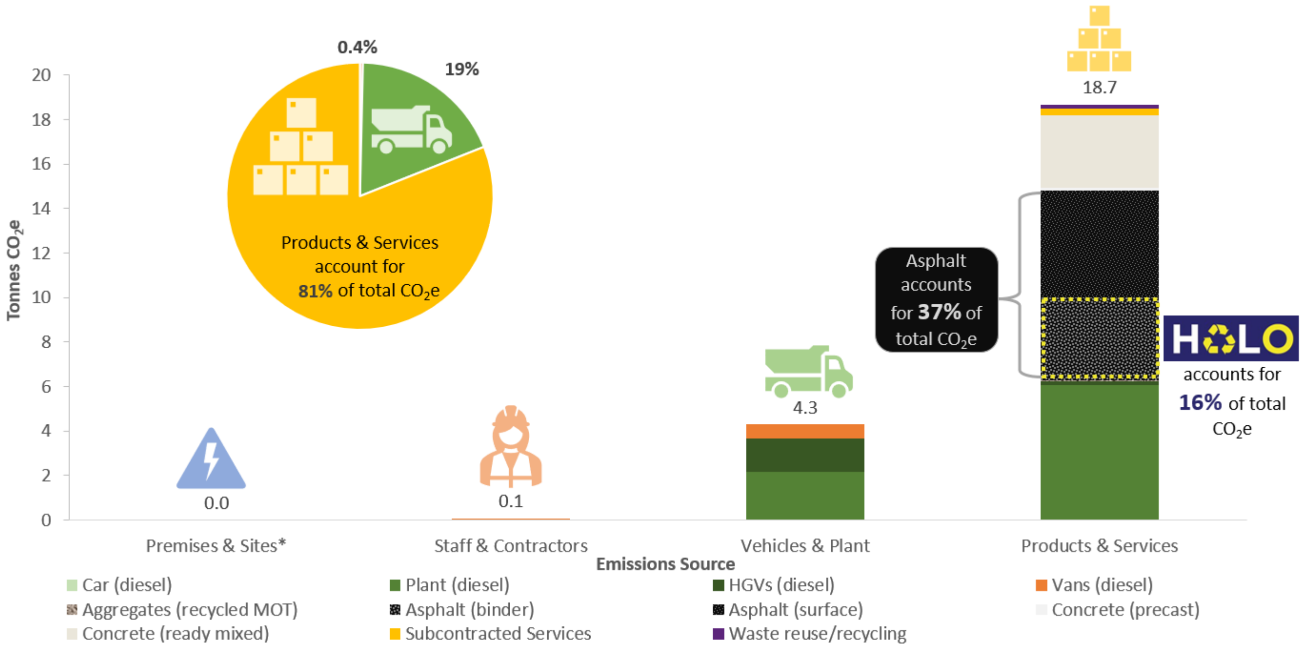

Figure 6. Baseline carbon data for the East Mains scheme.

2.2. Demonstrator scheme (Princess Drive)

The total carbon baseline for the Princess Drive scheme was approximately 308.9 tonnes of CO_2e, 77% of which came from purchased Products & Services (see **Figure 7.**). Asphalt was the main carbon hotspot, accounting for 48% (128.3 tonnes) of CO_2e emissions. Other minor carbon hotspots included concrete at 16% (48.7 tonnes) and HVO plant items at 15% (47.3 tonnes) of total emissions.

The majority of CO_2e emissions (46%, or 141.4 tonnes) were attributable to Section 1, including 122.8 tonnes CO_2e from the resurfacing of the carriageway and 18.6 tonnes CO_2e from the installation of the concrete driveway accesses. 12% (37.8 tonnes) of CO_2e was attributable to Section 2, including 35.6 tonnes from carriageway resurfacing and 2.2 tonnes from installing the flexible driveway accesses. The remaining 42% of CO_2e emissions came from items generally applicable to the scheme as a whole, predominantly from plant and transportation (see **Figure 8.**).

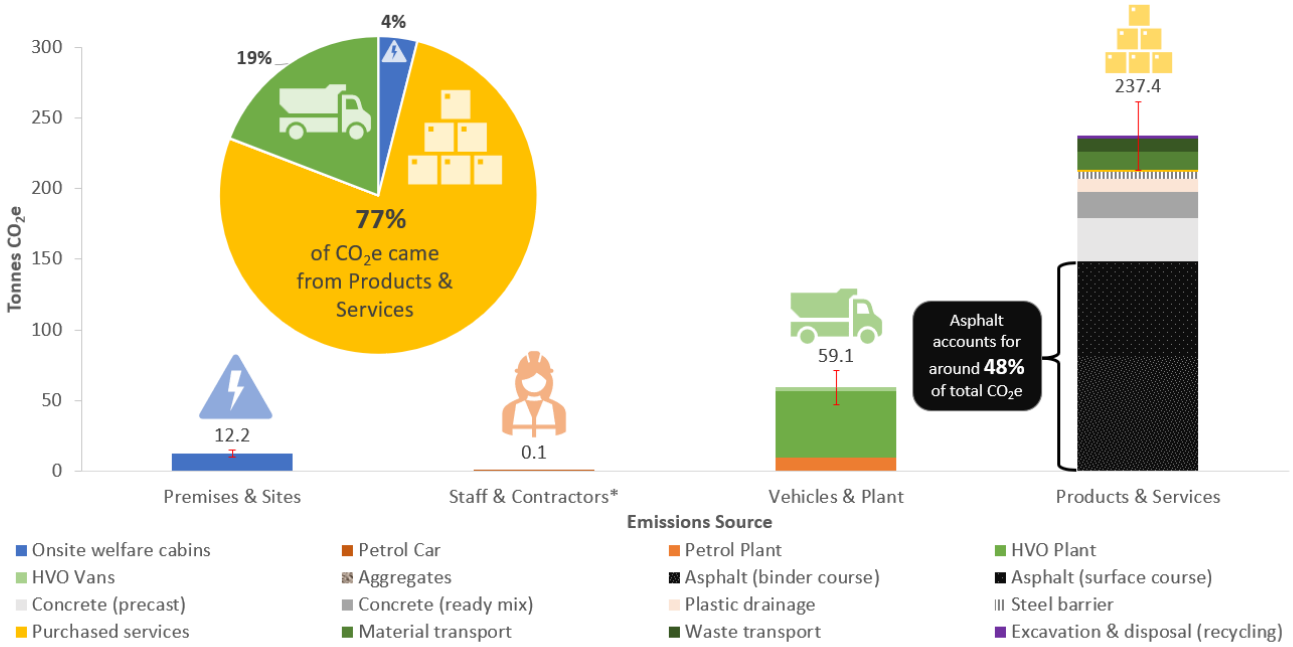

Figure 7. Baseline carbon data for the Princess Drive Scheme, broken down by CCAS carbon inventory. Excluding one car user, all Staff & Contractors were assumed to use company vans, which have been recorded under 'Vehicles & Plant' to avoid double counting.

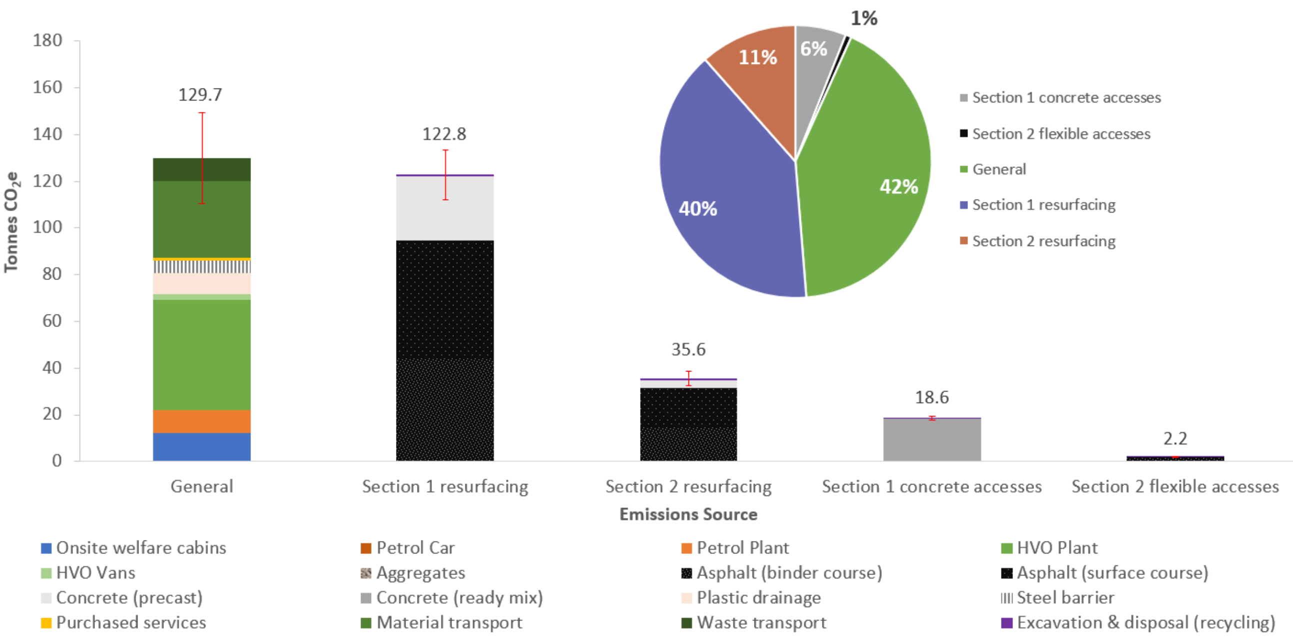

Figure 8. Baseline carbon data for the Princess Drive Scheme, broken down by carriageway section.

6. Caveats & Limitations

As a general caveat to all carbon baselines, the carbon footprinting and baselining process is a dynamic exercise, and therefore all data remains subject to change based on new data and knowledge which becomes available during the course of the project.

All three contractors provided carbon factors for specific materials as part of the data submission; these were generally accepted with reduced confidence, as no Environmental Product Declaration (EPD) was available to verify them, and are likely to increase substantially once the new carbon factor for bitumen is released by Eurobitume. Consequently, the carbon baselines for these schemes may increase in future.

6.1. Scarisbrick Crescent

As data was initially only provided for materials, waste, and operational processes (assumed to represent plant usage), the following assumptions were made to fill the remaining gaps, with verification from the contractors:

- A generator / welfare unit would have been used for the duration of the scheme (assumed 78 working days), consuming 9.6 litres diesel per day, as for Chatterton Road.
- All operatives commuted 18 miles/day (as per the default value in Carbon Analyser) in average diesel vans. 5 out of 11 operatives only commuted for 30% of the scheme duration.
- Two additional staff commuted to site for 1 day only. They were assumed to travel 18 miles each: one in an average diesel van, and one in a car of average size & fuel type, based on their roles.
- Asphalt was assumed to be transported in equal proportions from Dowhigh's two nearest typical asphalt suppliers – half by 32t rigid HGV and half by 46t artic, based on the fleet shown on the suppliers' websites.
- All other materials were assumed to be transported in 20t loads by average diesel HGV from Dowhigh's Park Lane depot (or the Hawthorne Road recycling plant for aggregates).
- All waste was assumed to be transported in 20t loads by an average diesel HGV to Dowhigh's Hawthorne Road recycling plant.

6.2. Chatterton Road

Data on fuel consumption / miles travelled were unavailable for certain hired plant items (dumper & sweeper), so this was estimated based on the return distance between the suppliers' depots and the worksite. Kerb sizes were also unspecified, so the dimensions of each kerb were assumed to be 125mm x 255mm x 914mm, being the larger of the two standard straight kerbs offered by the named supplier.

Furthermore, data for purchased services were only available in units of £ spend, for which there are currently no carbon factors in Carbon Analyser. This was converted to:

- operative-days (for traffic management & white lining) based on the number of operative-days per £ for the East Mains
- miles to & from the subcontractor's depot in an 8x4 diesel tipper (for waste management), as specified by HA Civils, or in an average diesel van (for 3rd-party transport).

6.3. East Mains

Mileages were unavailable for several vehicles, so this was estimated based on:

- the average of recorded mileages for vans (for cars and vans)
- the return distance between the Kirby depot & the site, repeated over 15 days (for HGVs)

As with Chatterton Road, fuel consumption data were not available for some hired plant items (dumpers). These were used for approximately the same duration as the hired excavators, so were assumed to consume the same quantity of diesel.

As was also the case on the Chatterton Road scheme, data for waste management was only available in £ spend, for which there are no carbon factors in Carbon Analyser. To align with the assumptions made for Chatterton Road, this was converted to the return distance between the site and the waste management provider's depot in an 8x4 diesel tipper, multiplied by the assumed no. of trips (based on the difference in the cost of waste management between East Mains & Chatterton Road, as the same waste management provider was used for both schemes).

6.4. Princess Drive

As the provisional carbon baseline for Princess Drive was based on an initial outline scheme proposal rather than a completed scheme, what would have been done as 'business as usual' without the influence of Live Labs is purely theoretical. Consequently, quantitative data was only available for materials (lifecycle stages A1-A3). Emissions from Premises & Sites, Staff & Contractors, Vehicles & Plant, and purchased services have therefore been estimated by scaling up from Chatterton Road and/or East Mains, based on scheme area.

Due to the large difference in scheme area (87m^2 for Chatterton Road vs. approx. 21,000m^2 for Princess Drive), these extrapolations are likely to be inaccurate. Transport was not included for ancillary items such as steel barriers or plastic drainage due to a lack of data; other ancillary items such as bollards, tactiles, and electrical assets have been excluded altogether due to a lack of data and relevance, in line with the original Pell Frischmann optioneering report. This will be improved upon retrospectively once more accurate data is available post-scheme completion.

It is assumed that the surface course variant of HALO used on this scheme would have the same carbon factor as that used for Chatterton Road and East Mains. However, this has not yet been confirmed.

7. Key challenges & lessons learned

The results of our carbon baseline assessments highlight the need to focus on reducing and decarbonising material usage, particularly asphalt and concrete. As the main material used for carriageway resurfacing, asphalt was by far the largest carbon hotspot for most schemes, even where a warm mix with added recycled content such as HALO was used. This illustrates the need to go further and determine how deeper carbon reductions may be achieved - for instance, by introducing more locally recycled materials, or reducing the usage of bituminous binder. It is also worth noting that whilst this may seem to be an intuitive assumption, the significance of materials is now validated and evidenced with data. Whilst concrete was only the largest carbon hotspot on the Chatterton Road scheme (where the area of carriageway resurfacing, and hence asphalt usage, was relatively low), carbon emissions from concrete usage will still need to be addressed in order to fully decarbonise future schemes.

Initially, approaches to data collection and provision varied between contractors, leading to discrepancies in data availability. This meant that some schemes lacked data for certain lifecycle stages (e.g., transportation in the A4 and C2 stages, or plant usage in the A5 stage). The development of a scheme-level data collection template in alignment with the FHRG CCAS guidance helped to improve consistency, demonstrating the value of having consistent protocols and resources for data provision.

However, determining the correct carbon factors for specific materials has remained a persistent challenge. Whilst all of the contractors were able to provide a carbon factor for most or all of the products used on their schemes, it was not feasible to obtain evidence with regards to how these carbon factors had been calculated. As a result, it was not always clear whether one variant of a product was analogous to another, and if so, whether it should have the same carbon factor. Much of the difficulty around obtaining carbon factors for bituminous materials was due to the fact that the 2024 carbon factor for bitumen had not yet been released by Eurobitume, so suppliers were often reluctant to provide carbon factors which would soon become outdated. We intend to resolve this issue by encouraging contractors to provide the updated carbon factors as soon as possible, and will mark product-specific carbon factors with a low confidence score unless they are supported by a third-party-verified Environmental Product Declaration (EPD). As the Live Labs project is designed to promote openness and collaboration, we encourage engagement with the project partners if further details are required, or if new data becomes available which may be of interest for the Liverpool Live Lab.

Data on vehicle and plant usage proved challenging to collect at scheme level, as not all vehicles have telematic tracking, and the fuel consumption rates of individual plant items are not always monitored - especially if they are not directly owned by the contractor. This proved particularly difficult to determine for Princess Drive, as the outline scheme proposal only focused on materials. However, this also highlighted the value of using pre-completed schemes as the initial baseline, as this provided some information on vehicle and plant usage which could be extrapolated to the demonstrators. Discussing these data gaps with the contractors in one-to-one meetings also helped to determine and validate any assumptions that could reasonably be made to fill the gaps. In future, increased scheme-level monitoring of fuel consumption and vehicle telematics could be implemented to improve data availability.

We also discovered the importance of clear communication regarding scheme design and what is considered to be 'business as usual'. One challenge we faced was determining which version of the scheme design should be used as the baseline - especially for the demonstrator schemes, where the baseline was purely theoretical and would never actually be implemented as part of the Live Labs programme. For example, it was initially assumed that a standard hot mix asphalt should be used as the baseline. However, if contractors are already using lower-carbon products (as mentioned above), then this would artificially inflate the carbon savings achieved by continuing to use the same or similar products. By liaising with the HIP contract project manager and other project partners to determine what works would have realistically been implemented without Live Labs funding, we have mostly overcome this issue.

Alignment between the optioneering and carbon baselining workstreams of the project is also key to validating the carbon saving potential of selected innovations/solutions. Miscommunication can lead to work being duplicated between project partners, sometimes leading to contradictory results if the data inputs and assumptions made are not the same. Again, clarity regarding what data should be used as the baseline is crucial. In the Liverpool Live Lab, communication and data sharing between the stakeholders responsible for these two workstreams has helped to alleviate this issue. Going forwards, we will work to establish greater integration of the optioneering process into the other project workstreams, and ultimately aim to embed this into LCC's long-term decarbonisation strategy.

8. Next steps

We will continue to gather data on our demonstrator schemes in order to improve the accuracy of the carbon baseline. Metrics which are not part of the scheme design, such as vehicle & plant usage, will be retrospectively updated post-completion to ensure a fair comparison between BAU and lower-carbon approaches. In addition to the BAU baseline, one or more experimental profiles will also be created to illustrate the carbon savings achieved by implementing the innovation(s) selected through the optioneering process. This will be calculated both pre- and post-scheme completion to capture both the predicted and as-built carbon savings. Once the new carbon factor for bitumen is available from Eurobitume, we will communicate with the contractors and material suppliers to ensure that we are using the most accurate and up-to-date carbon factors for specific materials.

Going forwards, we will work to establish greater integration of the optioneering process into the other project workstreams, and ultimately aim to embed this into LCC's long-term decarbonisation strategy. By liaising with our project partners who are working on the carbon baselining and optioneering workstreams, we will seek greater clarity on the division of responsibilities so that work will not be duplicated, and communicate openly on the details of the demonstrator schemes to ensure that we are working with the same data inputs and assumptions.

We also need to agree upon how asset lifecycle horizons will be considered within the carbon baseline, in order to accurately represent the long-term carbon savings achievable by adopting longer-lasting materials. We will liaise with other Live Labs who have considered the full asset lifespan in their carbon calculations – including the Devon Live Lab and the East Riding of Yorkshire Live Lab – to determine best practices for achieving this. From preliminary conversations, a standardised lifecycle horizon of 40 years is being considered, but this is yet to be confirmed.

We will work with our partner Local Authorities to replicate our approach to scheme-level carbon accounting, starting with Aberdeen City Council, who have already begun to gather data for both a scheme-level and a full service-level carbon baseline. Full service-level carbon baselining will be carried out separately to the Live Labs project. The process will then be extended to other partner cities including Portsmouth (for whom a separate full-service baseline is currently being calculated), Newcastle, and/or any other follower cities who may join in future. Knowledge, resources, and best practices will be shared between LCC and our partner Local Authorities to ensure that all stakeholders benefit from a collaborative and consistent approach to measuring and managing scheme-level carbon emissions.

9. Summary

The Liverpool Live Lab has established a standard process for quantifying the carbon emissions associated with local highways improvement schemes, allowing for the identification of key 'carbon hotspots' and consistent comparisons between different scheme designs. Calculating a carbon baseline for completed 'business-as-usual' schemes as well as upcoming demonstrator schemes has provided a greater understanding of the commonalities and key carbon sources across schemes, as well as improving the validity of assumptions made to fill current data gaps. Whilst some challenges and uncertainties remain, continued collaboration between project partners and other Live Labs will help to resolve these issues, creating a robust and scalable process for carbon accounting which will contribute to the long-term decarbonisation of highways improvement schemes across Liverpool and beyond.