WiCET

Wireless Charging of Electric Taxis

EVS35

OSL2022

Charging of eTaxis by inductive power transfer: Lessons learned from demonstration of wireless charging for taxi operations

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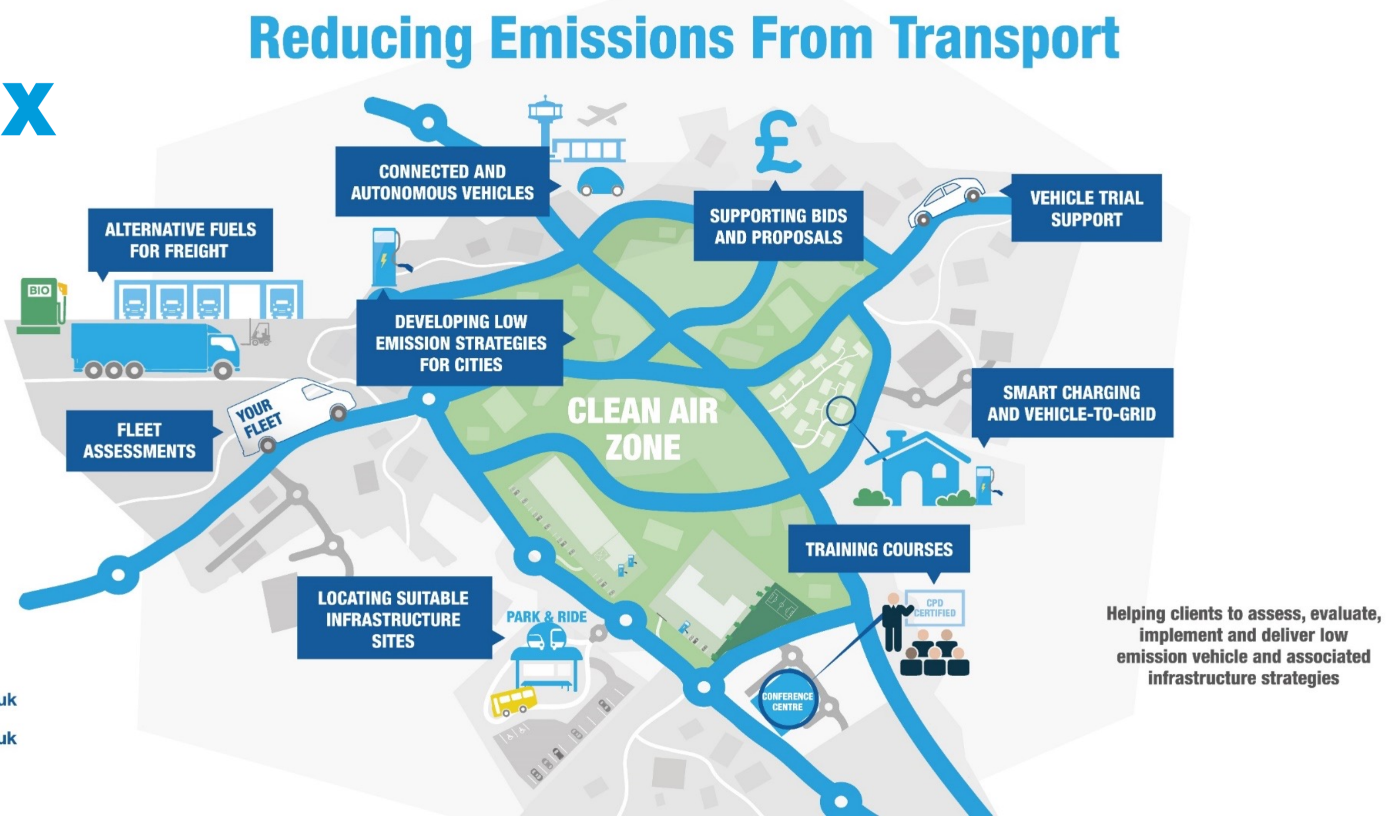

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WiCET Project Consortium

- Wireless Charging of Electric Taxis (WiCET) is a £4.6m consortium project.
- Grant funding from the Office for Zero Emission Vehicles (OZEV) supported by Innovate UK as part of the Wireless & On-street demonstration programme.
- Demonstration phase project running 06/2020 – 03/2023 with seven partners.

WiCET
WIRELESS CHARGING OF ELECTRIC TAXIS

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Consortium Roles

Cenex	Coventry University	Hangar-19	Nottingham City Council	Shell Research	Sprint Power	Transport for London
• Project lead. • Vehicle telemetry . • Technology use case scenarios. • Business case analysis.	• Human factors and research. • Taxi driver motivations, behaviours and attitudes.	• Vehicle identification. • Billing and back office systems. • Metering. • User app	• Host location for private pilot and public demonstration. • Licencing authority for taxi drivers.	• Pilot performance analysis. • Business case assessment. • Evidenced based business models.	• Wireless charging controls and power interface modules. • Driver HMI • Wireless hardware vehicle integration and conversion.	• Large city transport authority. • Business case support. • Transport policy, regulation and planning guidance.

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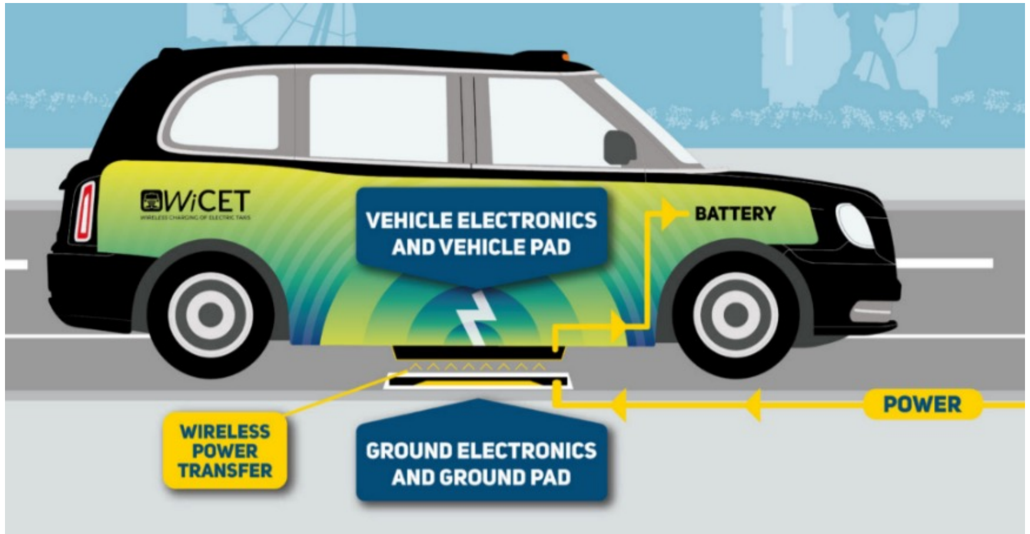
Why Wireless eTaxi Charging?

- **High duty cycles:** Taxis are typically high-duty cycle vehicles operating in urban centres with stronger environmental and economic case.
- **Maximising fee earning potential:** Taxis often can't be available for fee earning service while conductive charging.
- **Opportunistic on-the-stop charging:** top-ups during taxi rank wait times between customers.
- **Repeatability:** Taxi ranks are regular repeat visit locations.
- **Reduce IC engine use:** Top-up charging to reduce usage and running costs of IC engine in range-extended hybrids.
- **Double shifting:** Some vehicles double-shifted by more than one driver.
- **Range anxiety of drivers:** always want to be able to accept all jobs, even late in a working shift.
- **Taxi driver security concerns:** while charging, particularly late at night.



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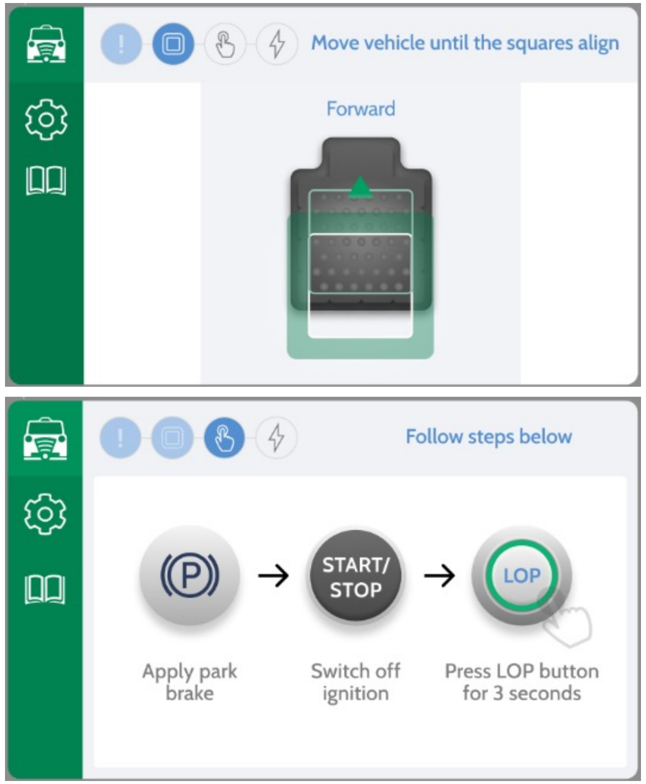
Project Overview

- Demonstration of inductive wireless power transfer (WPT) for charging Hackney carriage eTaxis to understand opportunity, practicality and business case for wireless technology.
- Trial taking place in Nottingham – a medium sized UK city with regional population of approximately 750,000
- Planned as a two stage project:
  1. preparation, private pilot and baselining phase;
  2. public wireless charging demonstration phase. Adapted to accommodate COVID impacts and semiconductor shortages.
- Using Lumen Freedom (Australia) wireless hardware technology rated at 11 kVA[1] for trial phase
- Five WPT charging pads installed into a taxi rank for top-up battery charging whilst queuing in the rank.
- Driver can use human management interface (HMI) to initiate charging from inside or outside the vehicle



Sample WiCET Human Management Interfaces

LUMEN FREEDOM

[1] SAE J2954 currently defines up to class WPT3 (11.1 kVA).

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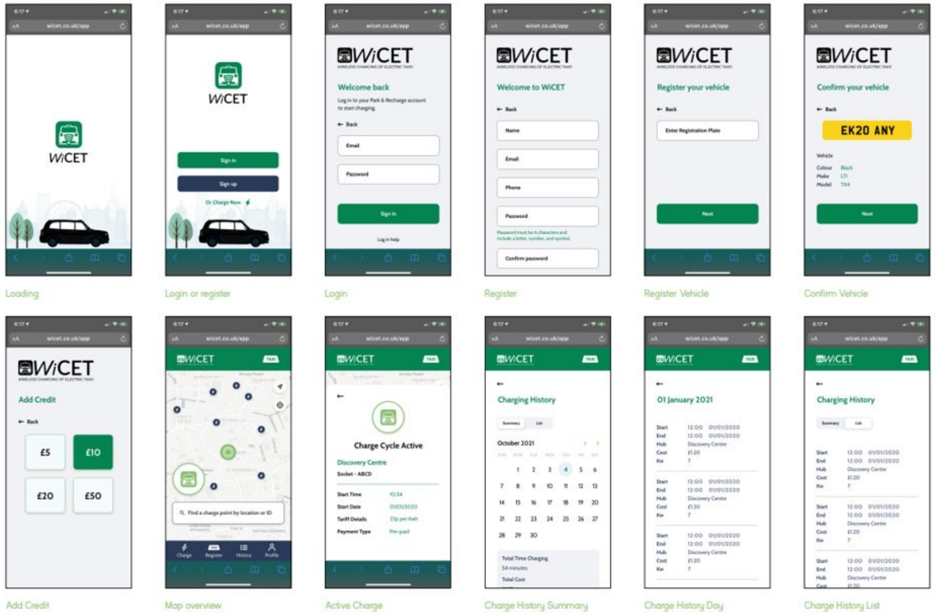
Innovation in WiCET

- First of its kind demonstration of wireless taxi rank charging in the UK.
- Two vehicle types included and used in parallel. – These are the only approved ULEV taxi vehicles in London and Nottingham
  - 4x Dynamo-Nissan E-NV200 - full BEV taxi vehicle conversion.
  - 5x LEVC TX – range extended hybrid electric vehicle.
- Implementation of vehicle identification, billing and back office system. Groundside hardware communication using OCPP. Billing for charging is automated with web/app interfaces for account management.



Driver billing control screens

Dynamo Nissan E-NV200

LEVC TX

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Project Status

- Private pilot ran Jun 2021 to May 2022 to test engineering, integration, and functional operation.
- Private pilot testing yielded within alignment tolerances defined in SAE J2954 yielded typically > 90% mains 50 Hz AC to on-vehicle efficiency.
- Trial in Nottingham to use the Trent Street taxi rank, adjacent to the main railway station. Rank design completed with installation starting in June (now!).
- Baseline telemetry data collection completed for 5 unconverted vehicles providing a comparison dataset. Data reduction and analysis ongoing.
- 9 vehicles – LEVC TX & Dynamo Nissan E-NV200 in final conversion.

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Lessons – Vehicle Integration

- Retrofitting of WPT hardware into donor vehicles requires integration of mechanical, power, communications, controls and cooling systems.
- In the UK, road features such as speed bumps, curbs can extend above ground plane by 100 mm.

  BUT

- Fitness for purpose and accessibility requirements limit floor and entranceway heights.
- Steering, suspension and drivetrain components mean it is not practically possible to retrofit WPT near the front of the chosen vehicles and maintain an acceptable ground clearance.

Trial mounting activity in pilot phase showing low position of the vehicle pad and EM shield

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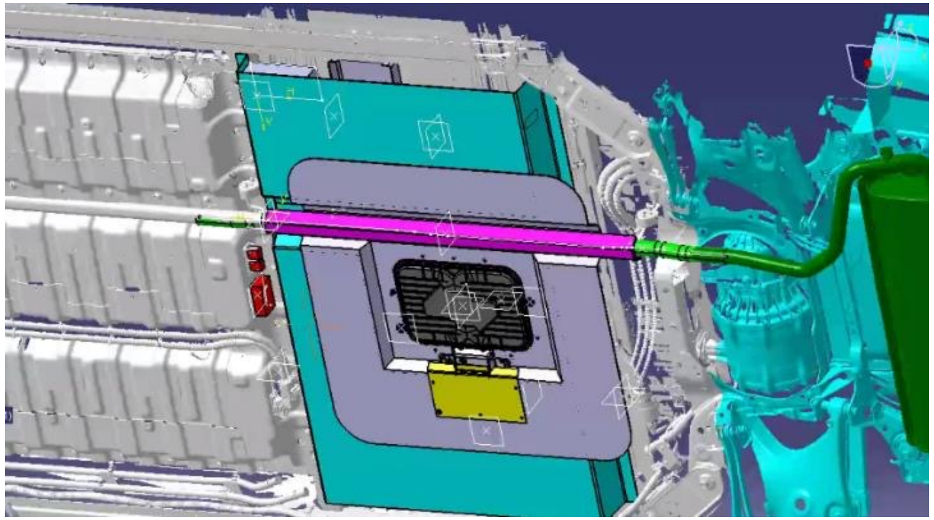
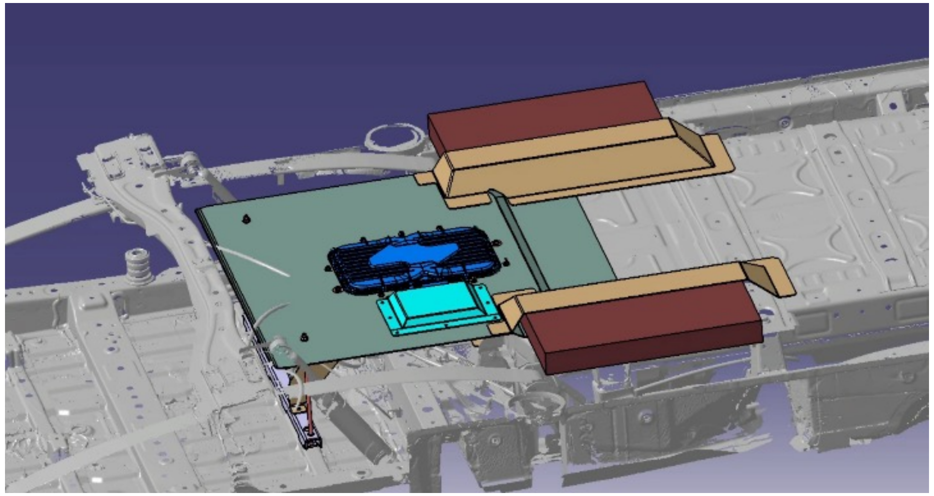
Lessons – Vehicle Integration

- For public demonstration, the only location on both vehicles to achieve suitable ground clearance at kerb and GVW is rearward behind traction battery pack.
- Exhaust systems, user steps/wheel chair access ramp systems create additional packaging challenges.
- Engineered solutions to retrofit WPT is possible for these vehicles, however achieving it cost-effectively at scale is very challenging for vehicles not designed to be WPT ready.

LEVC TX wireless mounting position



Dynamo Nissan wireless mounting position



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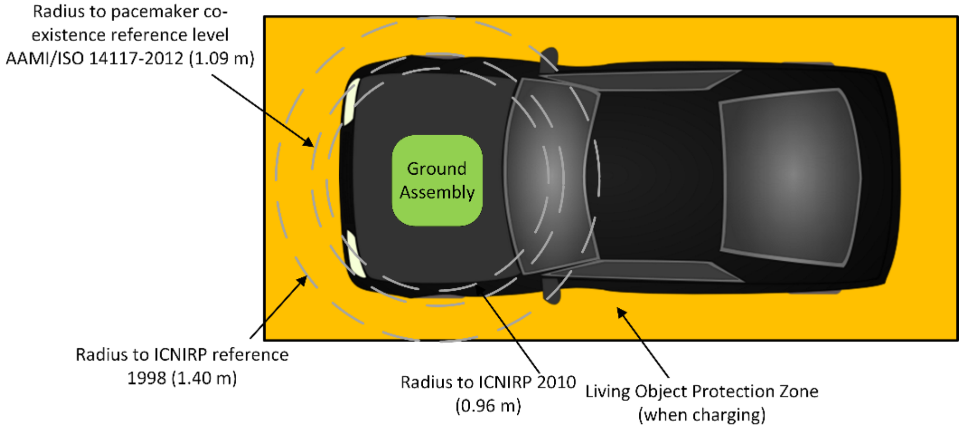
Lessons – Design of Taxi Rank

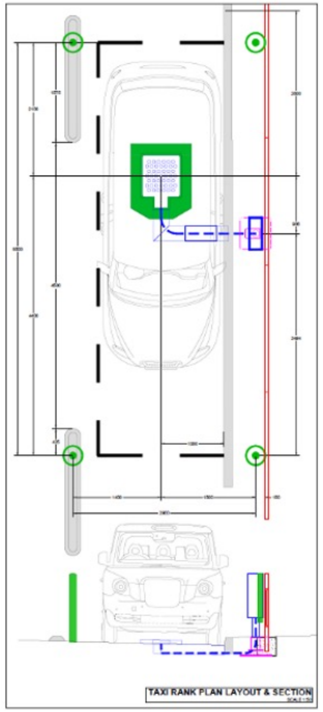
Living Object Protection

- Inductive power systems generate electromagnetic field emissions surrounding the transmitting and receiving coils.
- In the UK there is a government policy position that general public exposure must comply with the more restrictive limits in ICNIRP 1998.
- Testing of the hardware and coil design of the WiCET system means that at 11 kVA the field will extend beyond the ICNIRP 1998[1] values extending beyond the footprint perimeter of the vehicle.
- WiCET will require a taxi rank configuration that implements a living object protection (LOP) arrangement. Implemented as a light curtain arrangement in the public demo.

Taxi Rank Design

- For a static wireless charging arrangement, space utilisation efficiency is compromised by different longitudinal mounting positions of the wireless hardware on different vehicles.
- Different positions will require the length of the wireless charging bay to be extended. This is an application use case where dynamic systems will have an advantage.





Living object protection curtain arrangement

[1] ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz), Health Physics 74 (4):494 522, 1998

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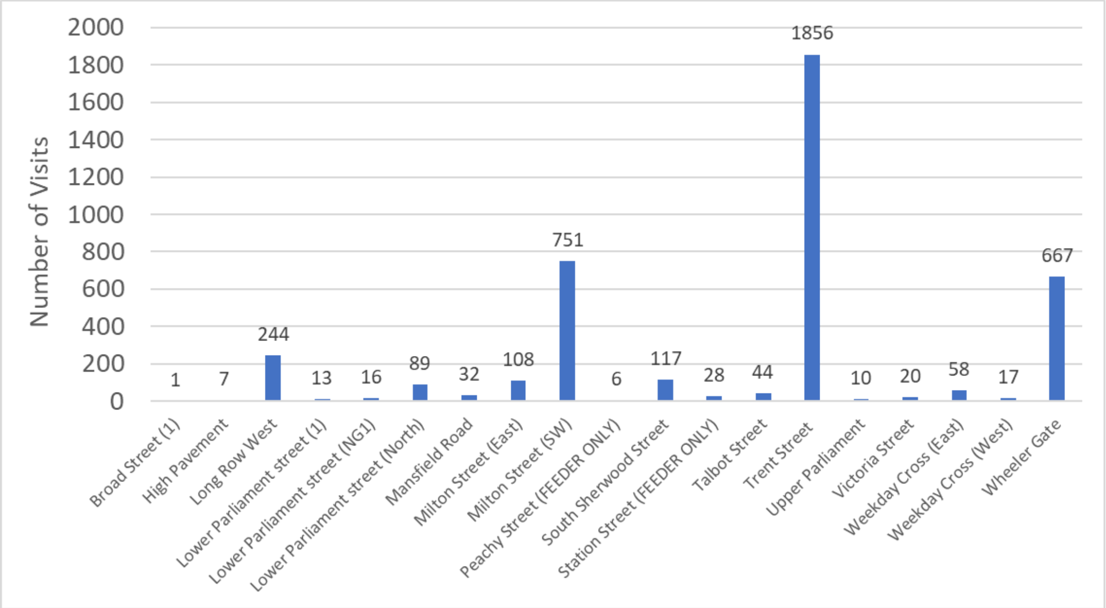
Baseline Data Collection

- **Data collection:** The phase 1 preparation include CAN based vehicle telemetry of five unconverted vehicles. Data for 15 drivers over 91 calendar days → 391 operational taxi days.
- **Data processing:** to reduce raw data into one of ten summary states at any one time for data analysis (ongoing).
- **Taxi rank usage:** is dominated by three that are well used, with Trent Street adjacent to the central station the most popular (20 taxi visits a day) with mean visit duration of 13 minutes.
- **Journey lengths:** Typical journeys are short averaging less than 5 km
- **Daily travel distances:** Mean daily journey distances of 126 km which is greater than the LEVC WLTP range. WLTP range would be insufficient on 58% of days.
- WLTP range (200 km) of Dynamo would be insufficient on 20% of days
- **Vehicle usage:** Status information from taxi meter shows only 24% of distance covered in "”Hired” state. Evidence suggests considerable hybrid operations with private hire usage. Can hypothesise that this is a trend accelerated by COVID pandemic.

State	Description
AC Charging	The taxi is connected to a public AC charger
AC Home Charging	The taxi is attached to a Mode 2 or Mode 3 home charging outlet.
DC Charging	The taxis is attached to a DC charging system
For Hire – Moving	The taxi is being driven with the “for hire” light on
For Hire – Static	The taxi is stationary with the “for hire” light on
Hired	The taxi fare meter is running (“for hire” light is off).
In Rank – Not Charging	The taxi is located in a recognised Nottingham taxi rank and not charging.
In Rank – Wireless Charging	The taxi is located in a recognised Nottingham taxi rank and wirelessly charging
Non-Work – Moving	The taxi is moving with the fare meter off and the “for hire” light is off.
Non-Work - Static	The taxi is stationary with the fare meter off and the “for hire” light is off.



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Next steps

- The public demonstration will run using all nine eTaxis from Aug – Dec 2022.
- Demonstration will include foreign object detection and living object protection systems to interrupt charging if triggered.
- Nottingham drivers will get the opportunity to use wireless charging technology and engaged to provide feedback on experience.
- All vehicles will record telemetry data to record vehicle usage as well as, wireless and conventional charging behaviours.
- Evidenced based business case development for different types of cities.

Conclusions

- **Need for "wireless ready" vehicles** to reduce component and fitting costs facilitating "bolt-on, plug-in" hardware retrofit.
- **Efficient use of the streetscape space**, particularly taxi ranks require consistent positioning of wireless pads on vehicles.
- **Choosing well used taxi ranks** is important. Nottingham experience shows that a small proportion of taxi ranks are well utilised.
- **Minimising street clutter**. For successful urban wireless charging systems, the power supply, living object protection, and other sub-systems need to be simple with minimal street clutter.
- **Changing working patterns.** Some evidence in baselining phase for hybrid working patterns involving private hire may require, and present opportunities for, other non-taxi rank locations.

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Thank you for listening

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