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The Future of EV Charging Forecourts

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Industry Report for Project “UK-Saudi Electric Vehicles Enhanced Education and Research Network”.
A British Council project between Brunel and King Abdulaziz University, Kingdom of Saudi Arabia.

An Enertechnos Holdings Group Company

Current EV Charging Forecourts: Overview

New development led by a select few developers & operators primarily in the UK and Western Europe, due to an ideal culmination of factors:

- High & Growing utilization of EVs by diverse driver types
- Availability of relatively low-cost renewables-sourced energy
- Government subsidy and legislative support

Below table shows an overview of the current EV charging forecourt operators, their service geographies, operational models, and methods for sourcing energy:

Developer	*Geographies*	*Operational Model*	*Energy Sourcing*
Gridserve	UK	Retail Partner	Direct Generation/PPA
Shell	UK, NL & FR (EU)	Direct Management	Direct Generation/PPA
MFG	UK	Direct Management	PPA

Current EV Charging Forecourts: Issues

Installation:

Forecourt locations are already over-crowded & power constrained.

Over-Demand:

Demand for EV charging is growing beyond current capabilities for development of charging infrastructure.

Improper Use:

Proper education and planning of infrastructure is required for secure operation.

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Current EV Charging Forecourts: Business Models

Pricing for charging currently is relatively elastic, meaning cost is not as important as reliability and availability. But as charging becomes more available, charging cost will become more inelastic – making economies of energy generation and infrastructure development more important.

This table shows some current UK charging providers, two devoted forecourt operators and one fast charging CPO. Shown are the types of services provided, how the businesses are structured, and the pricing per charge type:

Network	*Regions*	*Location Types*	*Business Model*	*Charge Speed (as per UK definitions)*	*Cost per kWh (in GBP £)*
Gridserve	UK	Forecourts, En-route	Owned Assets (CPO)	Fast	0.49/kWh
				Rapid	0.62/kWh
				Ultra-Rapid	0.64/kWh
Shell Recharge	UK / EU	Forecourts, En-route	Owned Assets (CPO)	Rapid	0.79/kWh
				Ultra-Rapid	0.85/kWh
BP Pulse	UK	En-route	CPO, Subscription	Fast, Subscription	7.85/Month + 0.44/kWh
				Rapid, Subscription	7.85/Month + 0.55/kWh
				Ultra-Rapid, Subscription	7.85/Month + 0.65/kWh
				Fast, Open	0.57/kWh
				Rapid, Open	0.69/kWh
				Ultra-Rapid, Open	0.79/kWh

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Current EV Charging Forecourts: Amenities

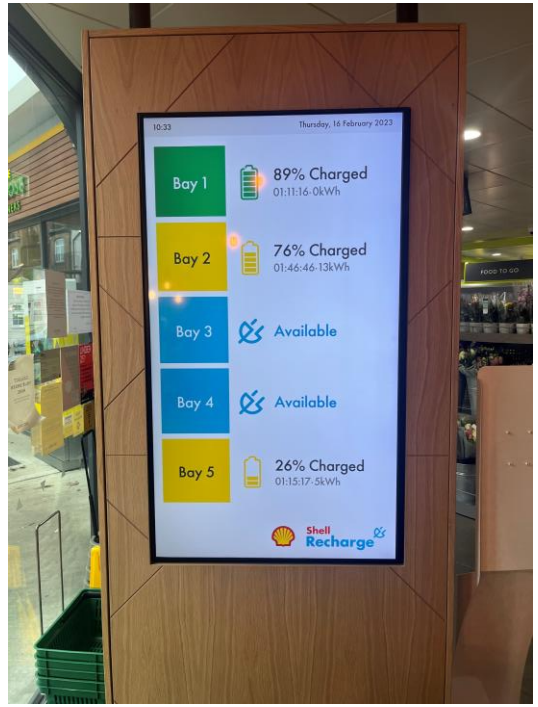
All the amenities one would expect from a highway rest-stop, in a cleaner and more premium facility.

At left are some nice Costa drinks looking out from a Shell Recharge forecourt.

At right is a charge status board in a Shell Recharge forecourt.

Below is a table of amenities available at a Gridserve forecourt in Braintree, UK:

Amenity Type	*Offering*
Food & Grocery	M&S Food, Costa Coffee
Shopping	WHSmith
Services	Post Office
	EV showroom + Leasing + Test drives
	Exercise Areas (Indoor + Outdoor)
Facilities	Co-working / office pods
	Fast WiFi
	Restrooms
	Child area
	Pet area



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Current EV Technology: Duty Cycles

As EV technology (batteries, drivetrains, etc) advances, not only do private vehicle offerings such as the Porsche Taycan at lower left become more practical and accessible for individuals, but electrification of larger vehicles such as the Tesco delivery trucks at center and the city transit bus at right grows into a significant trend for public and industrial sectors. Charging power, charging mechanisms, and availability of infrastructure must match the development of EV capabilities.

Source: EO Charging / Tesco

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Current Forecourt Technology: Energy

Onsite Battery storage, onsite Solar PV, generous Grid connection.

Solar PV Roof Canopy: 227kW peak
Insufficient for powering EV charging.

Onsite Storage Battery: 6mWh
Grid Connection: 5mW (33kV)
Import & Export capable, enabling energy services.

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Site: Gridserve Braintree, UK.

Future EV Charging Forecourts: Overview

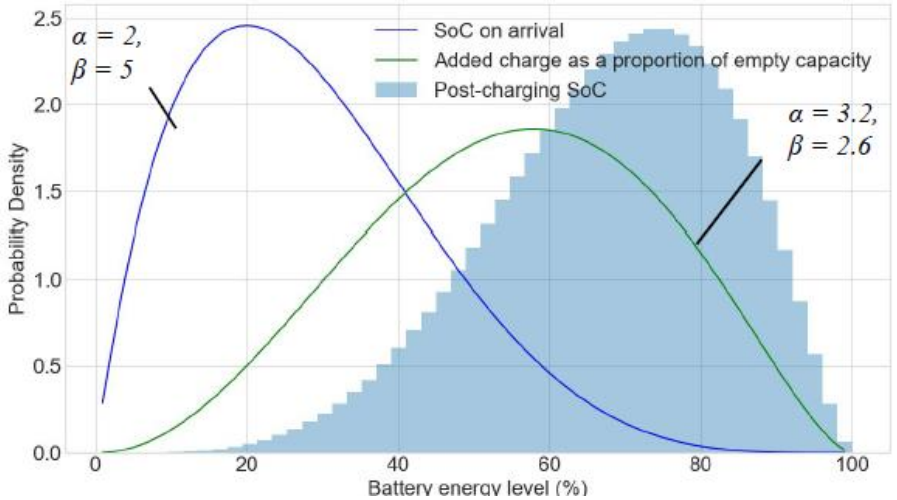
The future of EV charging forecourts serving long-distance travel and transportation will be shaped by a combination of factors - including the growth of renewable energy sources, the development of new charging technologies, the strategic location of charging stations, the user experience, and the implementation of smart charging systems:

- *Ultra-Fast Charging*
- *Distributed Energy Sources (Local Generation)*
- *Emerging Charging Technologies*
- *Conveniently Located Infrastructure*
- *Premium Charging Experience*
- *Safety & Reliability First*
- *Services catered to Dwell Time*
- *Smart Grid Charging*

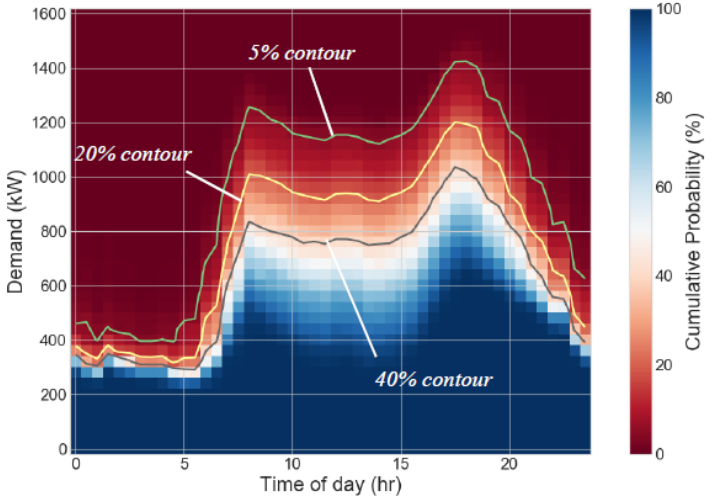
Source: Be.EV Concept. Manchester, UK

Future EV Technology: Duty Cycles

Average SoC at Arrival: 20%
Average SoC at Departure: 80%
Average Capacity Charged: 60%



Forecourt load demand is massive, peaking far above the rated charging capacity (shown is 800kW charging cap)



Not considering increase in volume of EVs, only considering **passenger** EV technology advancements (battery capacity & charge speed):

Near Future Required Forecourt Peak Power Capacity: **300% Growth**
Near Future Forecourt Average Power Demand: **200% Growth**

Not considering increase in volume of EVs, only considering **LDV & HGV** EV technology advancements (battery capacity & charge speed):

Near Future Required Forecourt Peak Power Capacity: **350% Growth**
Near Future Forecourt Total Power Demand: **700% Growth**

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Source: [Characterization of EV Charging Forecourt Demand, University of Strathclyde]

Future EV Charging Forecourts: Amenities

Future forecourt amenities must evolve with consumer trends - towards digitalization and mobilization, sophistication of retail offerings, and convenience of aggregated retail offerings.

Attending to multiple customer needs

	What are their needs?	What to offer?
Flex-working	▪ Wants a comfortable place to work outside home ▪ Values ambience and experience	▪ Sophistication in food & beverages, coffee and bakery ▪ Digital and value-added services ▪ Exclusive/VIP area ▪ Frequent-visitor deals
Agile driver	▪ Wants to streamline the fueling process ▪ If possible, avoid getting out of the vehicle	▪ Access to priority/fast-lane ▪ Package collection from e-commerce ▪ All-in-one e-payment and transactions
Digital native	▪ Wants to interact through their smartphone	▪ Mobile app platform ▪ Digital services ▪ Targeted marketing ▪ Package collection from e-commerce
Socializing	▪ The station is a meeting point	▪ Will probably spend in convenience store and/or coffee and bakery ▪ Entertainment services ▪ Parking
One-stop ecosystem	▪ Wants efficient use of time ▪ One stop for multiple purposes	▪ Convergence of retail stores ▪ Banking, pharmacy, grocery, laundry ▪ Package collection from e-commerce ▪ Cross-selling bundles ▪ Parking

Source: Arthur D. Little analysis

Convergence on all-in-one process e-transaction

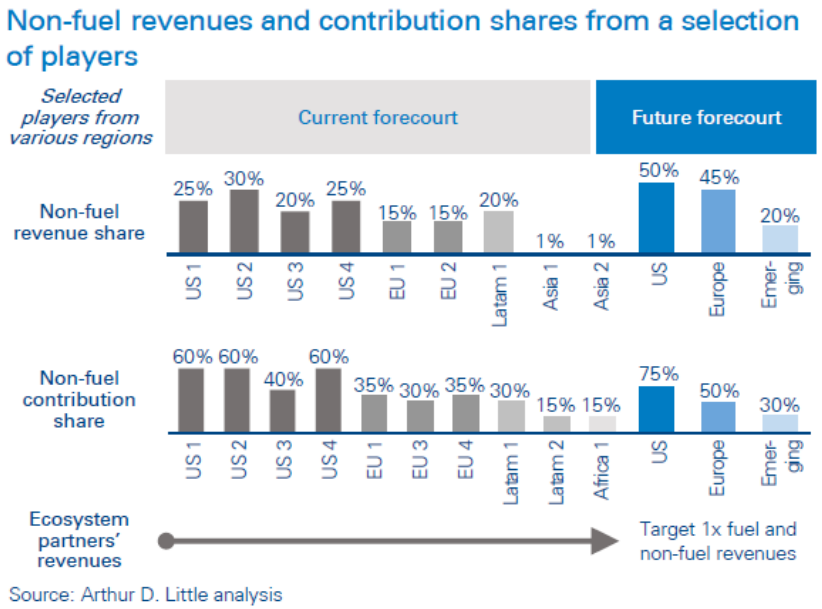
Source: Arthur D. Little analysis

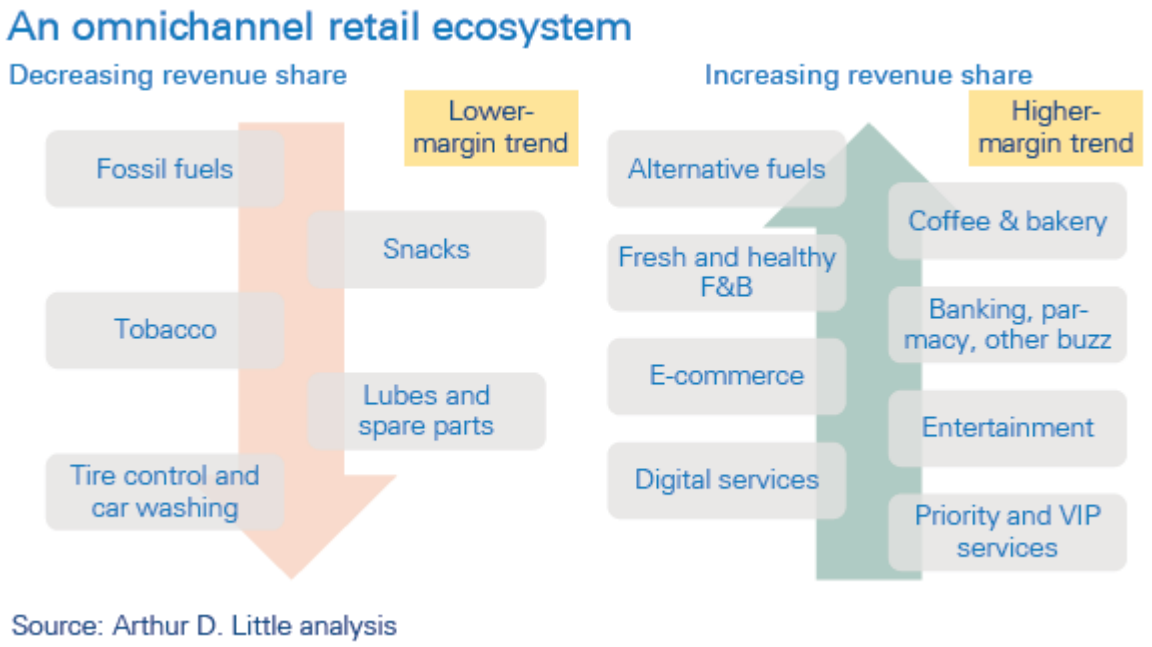
Source: [The Forecourt of the Future, Arthur D. Little]

Future EV Charging Forecourts: Business Models

Major Trends influencing functional Business Models in future charging forecourts include:

- Capital Intensive Development [of offgrid energy generation and storage systems]
- Inelastic Charging Pricing [saturated charging market requiring competitive rates]
- Enterprise Customers [servicing vehicle fleets]
- Non-Fuel Revenues [higher diversity in revenue channels]





Source: [The Forecourt of the Future, Arthur D. Little]

Future Forecourt Technology: Energy

Devoted renewables generation for full supply of charging forecourt demand.
Above is the Clayhill hybrid solar farm by Gridserve, in the UK.
Gridserve 'Sun-to-Wheel' ecosystem supplies forecourt charging from Solar PV.

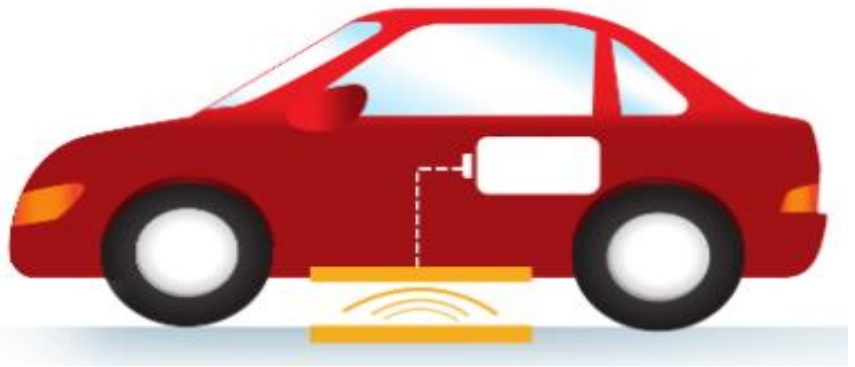
Future EV Charging Forecourts: Skills & Training

Developing & operating a charging forecourt is a novel proposition, requiring a unique combination of capabilities known from the fueling and motorway industries, public infrastructure industries, and hospitality & retail industries.

A few (but definitely not all) of these capabilities:

Civil Engineering	Facilities & Logistics
Electrical Installation & Design	Grid / Power Sourcing
Construction Contracting	Site Planning, Environmental
Facilities & Landscape Architecture	Site Planning, Legal
Electric Vehicle Engineering	Development Finance
Hospitality Management	Operating Finance

Wireless Charging



How it works:

Charging is enabled through a high frequency (up to 85kHz) inductive coupling established between coils inside a groundpad and an on-vehicle pad, then connected to the EV battery

Benefits:

- Wireless charging brings convenience to EV charging in the same way it has done for multiple consumer applications: WiFi, power tools, DECT phones and mobile phones.
- Removes the need to plug-in cables, removes trip hazards, simplifies the charging process, promotes accessibility, powers autonomous vehicles
- Facilitates ‘Opportunity Charging’ whereby vehicles can charge during daily operation, meaning smaller batteries can work & reduces reliance on expensive DC fast charging
- *Charge your car like it’s a phone!*

Limitations of existing wireless charging

Distance and cost barriers using conventional cable:

- In high frequency applications normally used Milliken type cables suffer from high Reactance, Skin Effect and Overheating
- Locks-in transmission distance limitations, requiring expensive high frequency converters at every parking spot

Electric Green's enabled solution solves both these issues & enables a 1-many architecture

- CTS has much lower net reactance, leading to lower voltage drop. thereby delivering distance & efficiency benefits
- CTS delivers high frequency power from a single converter, reducing system components and delivering economies of scale

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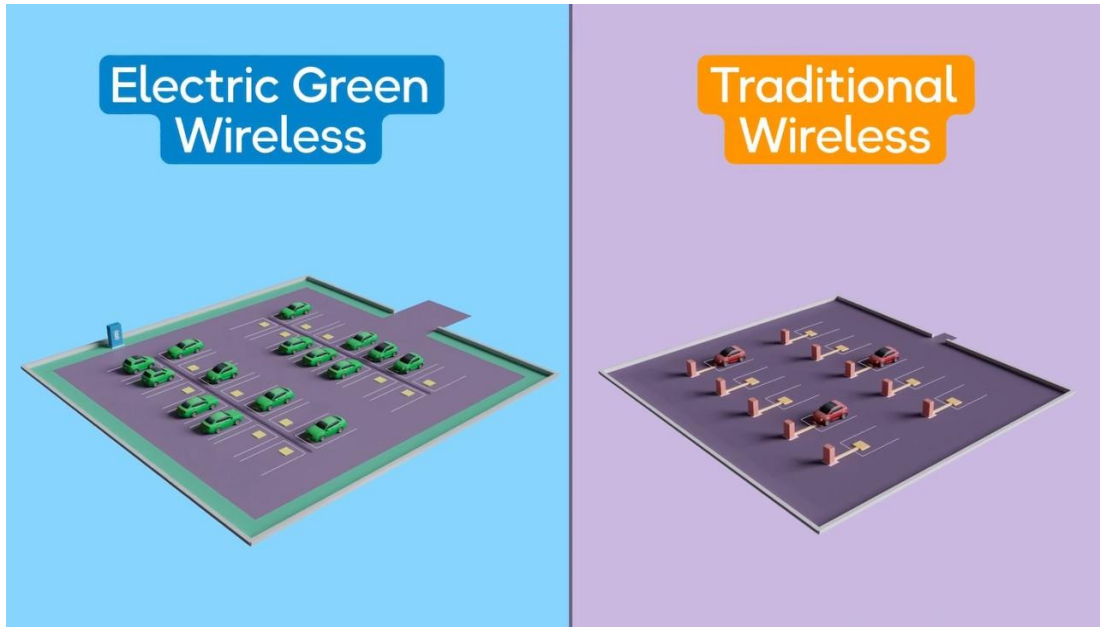
Electric Green vs Traditional Wireless

Technical benefits

- Easy vehicle integration – our solution presents to the EV just as a plugin EVSE does.
- ‘One-to-many' instead of 'one-to-one' offers significant economies of scale ideal for fleets, depots, taxi ranks etc.
- No street furniture at point of charge – 10 groundpads over 100metre backbone length
- Load balancing & Multiplexing system that reduces grid upgrades
- Allows heat recovery from a centralised converter and leverage heat-as-a-service



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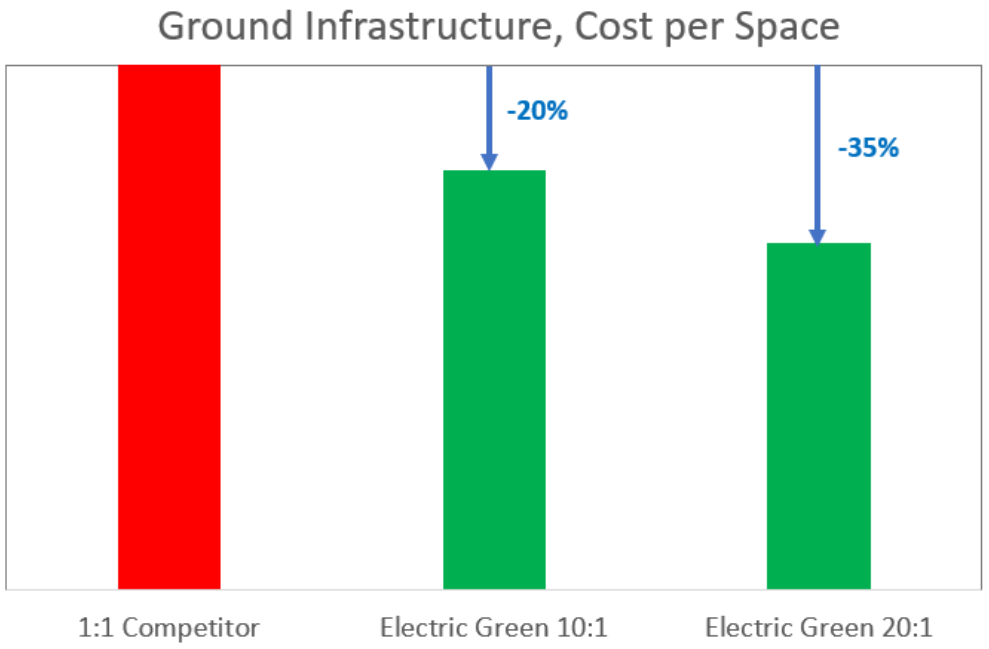
Business benefits of Electric Green's solution

- Will enable OEMs and CPOs to increase market share as customers transition to wireless
- Up to 35% lower CAPEX costs per chargepad from centralized power supply and multi-pad approach
- Smaller space requirement, no moving parts, less hazards, flexibility of designs
- Lower OPEX due to reduced maintenance requirements and easier accessibility
- Easily accessible for ALL consumers/drivers
- Allows for reduced power network connections
- Will increase participation in V2X applications



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