With new gasoline (petrol) and diesel cars banned from 2040, how is the electricity infrastructure going to cope with millions of new battery electric vehicles?

How is the cost of running a battery electric vehicle going to compare, if electricity prices have to rise to pay for new infrastructure?
Both the UK and France have announced a total ban on the sale of new gasoline and diesel vehicles from 2040. Other major countries are likely to follow, particularly Italy and Germany.

Volvo recently announced that it would only make hybrid or pure electric vehicles from 2019. VW have targeted 25% of all vehicle sales will be electric plug-in by 2025.

Norway has announced a ban on non-electric vehicles from 2025.

New York City have announced that 20% of new motor vehicles sold in the city will be electric by 2025.

Tesla have announced their ‘affordable’ Model 3 to great fanfare, and claim an initial order book of 500,000 vehicles.

When superstorm Sandy hit New York City in 2012, the fuel shortages resulted in long lines at gas stations and some very ugly scenes. To support millions of new electric vehicles, there have to be millions of new charging points. Zap&Go offers a way of providing this infrastructure without the billions of new investment required... and avoiding a long line of angry drivers.
What is going to happen when gasoline and diesel cars are banned in the UK & France?

The UK Government is committed to a total ban of new gasoline and diesel vehicles by 2040 to improve air quality.

- The UK Government is also committed to improving air quality in major cities by banning diesel cars at certain times from 2018. This will drive adoption of electric vehicles more quickly in inner city areas.

- Very few people who live in big cities like London have their own driveway or garage, so will be totally reliant on public charging points.

- The UK has some of the highest fuel prices in the world, because fuel duty (tax) is around 70%, so gallon equivalents at the pumps are about $6 per gallon (approx £1.22 per litre) (2x to 3x typical US prices).

- As a consequence, the UK Government also has to figure out how to collect the equivalent of $33bn (£26bn) per annum in tax revenue from electricity instead of gasoline and diesel. Electricity today is only taxed at 5%.

Zap&Go proposes to set-up a network of 500 ultra-fast charge charging points at filling stations across the UK to enable fast charging of electric vehicles, without stressing the national electricity grid and also maintaining the Government’s ability to tax electricity for cars effectively.

In total a 500 MWh (Mega Watt hour) electrical storage capability.

Uptake of electric vehicles will increase rapidly

**Annual global light duty vehicle sales**

<table>
<thead>
<tr>
<th>Year</th>
<th>ICE sales</th>
<th>EV sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>140</td>
<td>1%</td>
</tr>
<tr>
<td>2020</td>
<td>120</td>
<td>3%</td>
</tr>
<tr>
<td>2025</td>
<td>100</td>
<td>8%</td>
</tr>
<tr>
<td>2030</td>
<td>80</td>
<td>24%</td>
</tr>
<tr>
<td>2035</td>
<td>60</td>
<td>43%</td>
</tr>
<tr>
<td>2040</td>
<td>40</td>
<td>54%</td>
</tr>
</tbody>
</table>

**Global light duty vehicle fleet**

<table>
<thead>
<tr>
<th>Year</th>
<th>ICE sales</th>
<th>EV sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>1,800</td>
<td>0%</td>
</tr>
<tr>
<td>2020</td>
<td>1,600</td>
<td>1%</td>
</tr>
<tr>
<td>2025</td>
<td>1,400</td>
<td>2%</td>
</tr>
<tr>
<td>2030</td>
<td>1,200</td>
<td>7%</td>
</tr>
<tr>
<td>2035</td>
<td>1,000</td>
<td>18%</td>
</tr>
<tr>
<td>2040</td>
<td>800</td>
<td>33%</td>
</tr>
</tbody>
</table>
BNEF (Bloomberg New Energy Finance) now estimate that sales of electric vehicles will represent up to 5% of new vehicle sales in the UK by 2021, compared to around 0.5% today. As a point of reference around 2.5 million new vehicles were registered in the UK in 2016, with an estimated 38 million vehicles currently in use. Only about 100,000 of these are currently plug-in electric.

According to the SMMT (Society of Motor Manufacturers & Traders) in the month following the UK Government announcement of the ban by 2040, sales of new diesel vehicles fell 25%.

But many drivers are currently confused about what to do.

The current generation of affordable battery electric vehicles (BEV’s) such as the Nissan Leaf or VW Electric Golf can take hours to recharge and have a limited range. The Nissan Leaf has a 30kWh (kilo Watt hour) battery pack, and can be charged overnight yielding approximately a 100-mile (160km) range.

Performance electric cars like the Tesla Model S has a 90kWh battery pack, and can provide a range of up to 300 miles (500km).

However, the BEV ranges can be substantially reduced, if driven at high speed or if heating or air conditioning are used.

So, hybrid vehicles such as the Toyota Prius, that have both an electric drive and a conventional engine out sell BEV’s because the conventional gasoline or diesel engines provide a longer range.
For air quality reasons, the UK Government has followed France, by announcing a total ban on new gasoline and diesel vehicles starting in 2040. As there are particular health concerns about the emissions from diesel vehicles, they also announced a $300m (£250m) scheme for local authorities to come up with innovative ways to restrict the use of diesel in city centres. This is likely to include banning diesel vehicles in certain places or restricting when they can be driven – or totally banning their use during certain days of the week.

Other UK cities are likely to follow London by announcing congestion charging linked to vehicle emissions, making driving gasoline or diesel vehicles increasingly expensive. Whereas electric vehicles are currently exempt from the congestion charge and often qualify for other benefits such as free parking.

This is intended to accelerate the switch to electric vehicles, especially in cities.
Most people that live in cities will rely on public charging points

Few people in cities like London have their own driveway or garage. Most people live in apartments and rely on street parking.

Very few would have the ability to charge at home and would rely on public charging points.

Existing fillings stations provide a familiar 5-10 minute visit experience

The UK has around 8,500 filling stations serving 38 million road vehicles. Most use gasoline or diesel. The number has reduced from 35,000 some 20 years ago. The existing locations are on prime sites, that rely on high turnover and quick through put.

These filling stations provide a familiar experience. Most visits are 5-10 minutes, that includes filling with fuel and often visiting the on-site store. Drivers may also use additional services like buying a cup of coffee, a visit to the rest room, a cash machine, a car wash or air for their tyres.

These filling station locations are convenient, and would be ideal locations for public charge points. Drivers of electric cars will still want to buy their groceries, and on occasion use a car wash and need air for their tyres. But they also want the convenience of the 5-10 minute familiar visit experience.

What drivers do not want, nor does the service station operator, is for their visit to take hours while waiting to recharge an electric vehicle.

5 mins v 8 hours
If a BEV is slow charged over an 8 hour period then a single charge point can only be used by 3 vehicles a day. In practice, probably only 1 or 2, but let’s be generous and say 3 - so to support 19 million vehicles the UK would need 6.3 million charge points.

Today the UK has 13,000 electric vehicle charge points supporting about 100,000 plug in vehicles. This means to meet the target of 6.3 million, over 300,000 new charge points would have to be installed in the UK every year for the next 20 years if 8 hours charge time was the norm.

If we could reduce the recharge time down to 5 minutes, or the same time it takes to fill a tank with gasoline or diesel today, then each charge point could support many more vehicles. In fact, it is probably not unreasonable to assume it would be about the same ratio of all vehicles (38 million, to 8,500 filling stations). So, each filling station supports about 4,500 vehicles.

This means that if all the charge stations were upgraded today to support 5 minute charging, then there would be enough charging stations already to support a fleet of 19 million EV’s.

They are just not the right type of chargers.

BNEF\(^1\) estimate that 72% of new cars in France and 79% of new cars in UK will be plug-in electric by 2040. So, let’s assume that half of all cars in UK are BEV’s by 2040, or 19 million vehicles.

\(^1\) Bloomberg New Energy Finance: [https://www.bnef.com/ViewEmail/dd9fcb37-ddf5-cd8a-9ea6-15fb30de0a5b-6600ff073252-11528a5?e=VIP%20Comment](https://www.bnef.com/ViewEmail/dd9fcb37-ddf5-cd8a-9ea6-15fb30de0a5b-6600ff073252-11528a5?e=VIP%20Comment)
Most people who have a garage no longer use it for their car

There are 25 million homes in the UK, and around 10.6 million have garages. Nearly 60% of homes do not.

But according to the RAC and This is Money, around 4.6 million are used for storage or have been converted to another room.

This means only about 5 million are usable to park a car, or 22% of car owners could actually use them to charge an electric vehicle overnight.

So, if we are all going to drive an electric car, 80% or 4 out of 5 drivers will have to use public charging points.

Just 22% of motorists in the UK could use a garage to plug in an electric vehicle and charge overnight.

- 8 -
There is a myth that the energy stored in electric car batteries could be used to put energy back into the national grid.

This myth suggests that if electric car owners were to leave their cars plugged in overnight, then the national grid could take out the energy when required and use it to balance the demand.

The electricity companies would buy-back the electricity, providing a financial incentive to the driver.

This is only going to be possible with 1 in 5 drivers anyway, who have a garage. Chances are this group of drivers are likely to be wealthier and less concerned about the cost of electricity.

Also, human nature is likely to get in the way. Drivers will ask, ‘What happens if I need to drive to the hospital in an emergency in the middle of the night?’

No driver of a conventional gasoline or diesel car would allow someone to syphon out or ‘borrow’ some fuel from their tank during the night, with the promise of returning it by morning.

That is why all filler caps have locks.

The key question is, can the national electricity grid support all of these electric vehicles and their charging?

For example, if New York City took 3,000 yellow cabs, or about 20% of the current fleet, according to numbers published by the NYC Taxi & Limousine Commission, and then charged them all at the same time, it would be the energy equivalent of adding 216,000 new apartments to the electricity grid. Put another way—if it is assumed that two or more people live in every new apartment—it would be as if the New York City population grew by close to 500,000 people in terms of electricity use. Just for 3,000 cabs. If the entire 15,000-cab fleet went electric, it would be as if the population grew by 2.5 million people in terms of electricity use!
The billions of people driving gasoline and diesel vehicles every day are used to a conventional vehicle duty cycle. This conventional duty cycle means vehicles can travel long distances between refueling, and then refuel in around 5 minutes at a multitude of filling stations.

However, all these vehicles produce emissions and there is a desire to switch to zero emission vehicles (ZEV). Typically, ZEVs are battery electric vehicles (BEV) that use lithium-ion batteries (Li-ion). Drivers of these vehicles experience a different duty cycle. They can drive reasonable distances between recharging, but when they need to recharge the batteries, this can take as long as 8 hours.

Today less than 1% of all road vehicles are battery electric vehicles (BEV's). But if these total bans on new gasoline and diesel vehicles announced in UK and France are repeated worldwide, then in just 20 years, the electrical charging infrastructure has to transform to support all new road vehicles.

**Charger types and batteries – the geeky bit**

A domestic plug socket produces AC or Alternating Current electricity at a maximum rate of 3kW (kilo-Watts). This AC must be converted to Direct Current or DC electricity to charge the batteries in the vehicle. This is similar to the function of a typical laptop ‘brick’ charger, that converts the AC from the plug to DC to charge the batteries in the laptop.

Today electric vehicles such as the Tesla Model S use similar rechargeable batteries that are used in laptops and mobile phones. These are called lithium-ion (Li-ion) and use a complex electrochemical reaction to charge and discharge. Each charge and discharge is a ‘cycle’ and every time they cycle some of the chemicals inside are used up.

So typically, after 500 to 1,000 charge & discharge cycles, there is a noticeable loss of performance.

Mobile phone users sometimes call this the “memory effect”, when the phone battery indicator says 100% but the amount of actual usage time that the phone delivers is noticeably less.

Many people replace their mobile phone when the memory effect becomes noticeable. This usually occurs after about 12-18 months, because if the phone is charged once or twice every day, it soon reaches the 500 cycle threshold. Also, if the batteries inside are stressed by being charged rapidly at their maximum safe rate, this will accelerate the memory effect.

Every BEV must have the equivalent of a laptop brick charger to charge from an AC supply, and these are never 100% efficient. So, the amount of energy passing into the batteries is never at the maximum rated amount.

Li-ion batteries do not charge linearly, so the charge rates are often quoted as the time it takes to get to 30% or the time it takes to get to 80% capacity. As Li-ion batteries get closer to their 100% level, more and more energy is required.
The charge rate will also depend on how charged your battery pack is when you start. So, for example, it will be much quicker to go the twenty percent from 10% charged to 30% charged, than it will be to charge from 80% to 100%.

What also matters is the usable capacity in your battery pack, because for safety reasons Li-ion packs are never allowed to fully discharge. When the charge indicator says 0%, there is probably still about 30% charge in the pack, it is just not usable. So a vehicle specification that says a 30kWh battery pack, may actually only allow about 20kWh to be used.

An industry benchmark for a Li-ion battery is 200Wh/kg (Watt hours per Kilo-gram). That is to say that if your battery weighed 1kg or about 2 pounds, it could deliver 200 Wh (Watt hours) of electrical energy. However, as an example, if used in an electric car the batteries have to be enclosed in fire proof boxes and have safety engineering such as burst valves and voltage limitators, so at the pack level, the actual real-world performance is typically 50 to 100Wh/kg.

Other rechargeable batteries such as Lead Acid (lead-acid), NiMH (Nickel Metal Hydride) and Nickel Cadmium (NiCd) at the cell level typically achieve 20 to 80 Wh/kg.

As an example, Boeing went to great lengths on the 787 Dreamliner to replace much heavier lead-acid batteries with Li-ion. But after the Dreamliner fires, because of the extra safety engineering required to meet the Federal Aviation Authority (FAA) rules, Boeing found that they may as well have just used lead-acid batteries in the first place.

Some Li-ion chemistries can operate at much higher energy densities, even 800 Wh/Kg have been claimed. But these batteries almost always have some other constraint such as high cost, the temperature of operation is restricted, the cell voltage can be low, the cycle life can be short or at the end of life they are very difficult to recycle.
By contrast a supercapacitor has no electrochemical reaction, so there are no chemicals to use up and therefore no memory effect. Supercapacitors use an ionic reaction, storing charge a bit like static electricity. Most are rated at 100,000 charge/discharge cycles, or 20 to 30 years if they are used once a day.

However, existing supercapacitors cannot hold onto their charge for very long as they tend to self-discharge. So, a mobile phone based on a supercapacitor would charge in a few seconds, but would only give a few minutes of use before it needed recharging. This is because the supercapacitors are built to maximize power density, using a combination of organic electrolytes mixed with chemical solvents, and high surface area carbons called activated carbon. The voltage of operation is typically limited to 2.7V (Volts) because the electrolyte and chemical solvents break down above this voltage.

The Carbon-Ion (C-Ion) cells from Zap&Go, work like supercapacitors using an ionic reaction, but use different carbon materials and electrolytes. Instead of activated carbon which have random sized pores, nano-carbons are used such as graphene, that can be designed with a very specific pore size.

These pores are tiny holes that work optimally with a different type of electrolyte called an ionic electrolyte, so conductive ions can fit precisely into the carbon pores at the microscopic nano scale level. Unlike conventional supercapacitors, no chemical solvents are used, which makes the C-Ion cells easier to recycle than conventional supercapacitors or Li-ion batteries, and entirely non-flammable.

In addition, Ionic electrolytes can operate at much higher voltages than organic electrolytes. Carbon-ion cells are no longer restricted to 2.7V and can operate at 3V, 4V or even as high as 6V. This is important when looking to maximize energy density, because the amount of energy stored is proportional to the voltage squared (V²). So a 3V system has a factor of 9 (3 squared), while a 6V system would have a factor of 36 (6 squared).

In this way, the Carbon-Ion cells overcome the traditional weakness of supercapacitors by providing an energy storage device that not only has fast charging, but also has high energy density. Carbon-Ion could not only recharge a phone in seconds, but also allows the phone to be used all day similar to a Li-ion battery, but with none of the memory effect or flammability issues.
The electricity grid infrastructure differs widely from country to country. However, a common theme is that the trillions of dollars of investment over many decades in power stations, switching equipment and transmission lines are all geared towards delivering electricity in the form of Alternating Current (AC).

New renewable energy systems such as solar panels produce electricity in the form of Direct Current (DC) and electric vehicles all need DC to charge their batteries. Converting decades of investment in AC infrastructure to operate in this new DC way would require unthinkable amounts of new investment. Even if this investment were available, which in many countries is unlikely, digging up miles and miles streets to install new cables, or to install new large scale switching equipment would take many years.

Where new high cost infrastructure is installed to support DC, the cost has to be recovered through increases in electricity prices or tariffs.

Also as charging an electric vehicle requires a lot of energy delivered over a short period of time, new tariff structures are being introduced, typically called Critical Peak pricing. The cost Critical Peak can be 5x to 10x times higher than the standard electricity tariff rates.

### Examples of Tariff Structure in US to accommodate high rate DC charging:

<table>
<thead>
<tr>
<th>Tariff Structure</th>
<th>Description</th>
<th>Price per kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-Peak</td>
<td>Usually available at night or in periods of low demand. Typically, half the normal Peak rate</td>
<td>$0.09</td>
</tr>
<tr>
<td>Peak</td>
<td>Normal price of electricity paid by most consumers on a standard tariff, and most charge points for electric vehicles that use low rate AC Mode 1 or Mode 2 charging</td>
<td>$0.18</td>
</tr>
<tr>
<td>Critical Peak</td>
<td>Charged for large burst of electrical used over a short period of time, rates charged in California for Tesla Super Chargers (high-rate DC chargers)</td>
<td>$0.90</td>
</tr>
</tbody>
</table>
Can I charge an electric vehicle at home?

Each of the BEV’s can be charged at home. If a normal 3kW domestic plug socket were used the Tesla Model S would take 30 hours to recharge. This is too long.

So, most homes are equipped with a Level 2 or (Mode 2 or Type 2) charger that provides up to 43kW. This reduces the recharge time to 4 to 8 hours and is designed to recharge a vehicle overnight.

How much does the electricity cost?

Electricity used at home for EV charging is charged today at normal domestic rates, which is about 14p per kWh in the UK (typically 18 cents per kWh in the US). UK rate includes 5% tax.

This means for an average EV driver their fuel cost equivalent of driving is about 10% to 20% of the cost of driving the same distance in a gasoline or diesel car, and in the US about 30% to 40%.

There can be further savings if the electricity is purchased at off-peak rates.

But if Critical Peak pricing were charged then it would make the relative cost of running an electric car considerably more expensive than running a gasoline or diesel car.

<table>
<thead>
<tr>
<th>kWh Pricing</th>
<th>Equivalent Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.90 Critical Peak</td>
<td>$7.68</td>
</tr>
<tr>
<td></td>
<td>£1.56</td>
</tr>
<tr>
<td>$0.80 Mid price</td>
<td>$6.84</td>
</tr>
<tr>
<td></td>
<td>£1.39</td>
</tr>
<tr>
<td>$0.70 with Tax Gasoline equivalent</td>
<td>$6.00</td>
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<td></td>
<td>£1.22</td>
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<tr>
<td>$0.35 No Tax Gasoline equivalent</td>
<td>$3.00</td>
</tr>
<tr>
<td></td>
<td>£0.61</td>
</tr>
<tr>
<td>$0.27 Mid-Price</td>
<td>$2.27</td>
</tr>
<tr>
<td></td>
<td>£0.46</td>
</tr>
</tbody>
</table>
Most chargers installed today are Mode 2 that use conventional AC or Alternating Current electricity. Tesla have pioneered a network of high-rate DC or Direct Current chargers.

Tesla have installed a network of Super Chargers that use DC or Direct Current electricity. The DC chargers can operate at much higher charge rates (50kW to 150kW). Tesla claim that a Model S with a 90kWh battery pack can be charged to about 80% capacity in 40 minutes.

Tesla have installed about 6,000 Super Chargers worldwide. Most are at motorway service stations or at out of town locations because the Super Chargers require a special type of electricity grid connection that is not typically available in city centres.

When a BEV is plugged into a DC charger the charging mechanism is different. The DC charger by-passes a circuit on board the vehicle for AC charging. This is like the ‘brick’ charger that most people have with a laptop that converts the AC from the wall plug into DC used by the batteries on the laptop.

Laptop users know that this brick charger can become warm during use, this is because the AC to DC conversion is never 100% efficient and the energy wasted produces heat. This loss of efficiency is magnified when the power is increased on an electric vehicle.

This is why DC charging is more efficient.
The automotive industry is now working on new standards for this more efficient high-rate DC charging called CCS and CHAdeMO. These can currently operate at up to 170kW and there are plans to increase this to 350kW. These chargers require different grid scale electricity connections not available for home use.

Although the plugs that connect to the vehicles differ, the fundamental charging mechanism for high rate DC charging is the same with CCS, CHAdeMO and for Tesla. Direct Current is delivered directly from the electricity grid into the on-board batteries via a DC to DC converter on board the vehicle.

The rate of charge is controlled through data pins on the plugs. The charge rate is limited by the maximum safe rate that the batteries can be charged, not by the amount of electricity from the grid.

These high-rate DC chargers are good news for drivers because it could make possible the goal of charging a BEV in 5 minutes, the same time it takes to fill a tank on a gasoline or diesel vehicle today.

Of course, this 5-minute charge would also require suitable energy storage systems on board the vehicle like Carbon-Ion that can be safely charged this quickly. It would not work with the current generation of Lithium-ion batteries in existing BEV’s because it would be dangerous to charge these batteries this fast.

This is good news for the UK Government, which realizes that the convenience of high speed charging will encourage BEV uptake, and as these types of chargers for technical reasons will tend to be located at central sites, also makes collecting tax revenue from them more achievable.

But this is a significant challenge for the national grid because fast charging a Tesla Model S in 5 minutes is the equivalent to having about 800 homes or even a hospital suddenly connected to the electricity grid. Multiply this by millions of vehicles and if we are not careful the lights start going out.
Installing 5-minute charging at existing filling station sites

At every filling station (gas station or petrol station), there are large storage tanks under the ground that contain reservoirs of gasoline (petrol) and diesel fuels. These tanks are replenished by delivery tankers or sometimes connected to underground pipelines.

Drivers fill up from the pumps, taking a few gallons or liters out of the large underground tanks each time.

The filling station business model is to make money based on the difference between the wholesale price of fuel delivered by the tankers, and the retail price paid by each driver.

In 2016, the UK Government received $33bn (£26bn) in fuel duty.

Governments take tax revenue or fuel duty on the fuel purchased. The filling station operator effectively acts as the tax collection point.

In the UK this is about 70% tax, so for every £1 or 100p spent on fuel, 70p goes to the UK Government.

The filling station operator makes very little margin despite the fact that the price of fuel is high, and this is one of the reasons that in the last 20 years the number of filling stations in the UK has reduced from 35,000 to about 8,500 today.
In the US, tax on fuel is typically 20-25%, but varies in different States. Today fuel prices at the pumps are around $2.80 to $3.50 a US Gallon. The price equivalent in the UK would be $6.00 to $7.00 per US Gallon. The actual equivalent price in the UK (at the time of writing) based on the price per litre in pounds sterling is around £1.20 to £1.30 per litre.

If filling stations are to be used for public BEV charging then high rate DC chargers will be required to offer the same 5 minute visit experience as today.

In the UK parts of the electricity grid are 70 years old, and were never designed to provide this very high rate DC charging. Few existing filling station sites are in locations where the new type of electrical grid connections for high-speed DC chargers could be easily installed, nor would the cost of this be justified.

Drivers would not want to pay more for the electricity to drive an electric car than they do for fuel today. This would be necessary if the grid infrastructure had to be upgraded at every filling station.

It would cost billions of dollars to upgrade the electric infra-structure to cope with widespread DC charging, not necessarily because the capacity or power generation isn’t available, but because streets all over the country would have to be dug up to install new cables. On top of this all the switching gear and sub-stations would have to be upgraded, in every town and on every street.

This is why the current generation of super chargers are in out of town locations, where it is possible to have these expensive new grid connections.

To recover the high cost of installing these high-rate DC chargers, the electricity companies typically charge electricity at what is called critical peak tariffs or rates to recoup their costs. These critical peak rates can be 5 or 10 times current peak electricity prices. As the DC chargers are used infrequently today, these costs are subsidized and not yet passed on to the driver.

At some point, this subsidy will cease making driving an electric car more expensive than driving a gasoline or diesel car.

Clearly if this were the case, these increased costs would significantly reduce the uptake of electric cars and not meet Government targets to improve air quality.
How does it work with Carbon-Ion

Today most filling stations are in convenient locations so it follows that they are also a good place to go to recharge an electric vehicle.

All sites have standard electricity connections to power the fuel pumps, shop, car wash and so on that could be used to install standard mode 2 AC chargers. However, all this would do is turn the fillings stations into parking lots, while drivers waited for their vehicles to charge.

Instead this standard electricity connection can be connected to a bank of Carbon-Ion cells that are installed in similar underground storage tanks used to contain the gasoline and diesel fuels. Instead the Carbon-Ion bank is used to store energy from the electricity grid.

The Carbon-Ion bank is then filled up with electricity, typically at off-peak rates to act as the store or reservoir. This is akin to the fuel tanker arriving to deliver fuel to the filling station and filling the underground storage tanks.

Then as each driver arrives to charge their vehicle, it is recharged using electricity not directly from the electricity grid, but from the Carbon-Ion bank. This means each vehicle can be recharged at high-rate DC charging speeds, in 5-10 minutes, without stressing the grid infrastructure.

The filling station operator can now charge a reasonable rate for the electricity and make a reasonable profit. The driver pays a rate much lower than they would for critical peak pricing, and Governments can collect tax revenue in the normal way.
Zap&Go is planning to put banks of Carbon-Ion cells that act as energy storage banks in the ground that are similar to those used for gasoline and diesel. This is possible because Carbon-Ion does not catch fire, will last 30 years, does not heat up, does not expand or contract during charging and discharging, and can be charged and discharged very quickly.

The cost of doing this ground work is small in comparison to the much higher costs of installing electrical infrastructure.
Electricity from the national grid is used to fill-up the Carbon-Ion banks in a similar way to the tankers arriving to fill-up the gasoline or diesel tanks, or the underground fuel pipelines that are sometimes used.

**How does the business model work?**

1. ZapGo install all chargers and energy storage equipment on filling station sites, and retains ownership of all equipment;
2. ZapGo is responsible for all maintenance;
3. ZapGo displays energy price on a real time basis;
4. Retailer collects payments for electricity used, and passes payment to ZapGo less agreed margin; and
5. ZapGo pays for electricity used.

This electricity is purchased at off-peak rates when prices are low, and then can be sold to drivers of electric cars at a price per kWh (kilo-Watt hour) for the electricity used. Electricity is taxed at much lower rates than gasoline or diesel, sometimes not at all, but in the UK, this is 5% compared to 70% fuel duty. However, Governments can continue to use the filling stations as tax collection points for the electricity used to charge vehicles.

**VHS v Betamax, protecting the investment**

The significant part of the capital expenditure in the Zap&Go solution is installing the Carbon-Ion banks of energy storage at the filling station sites or charging locations. However, Zap&Go retains ownership of this and all the other charging equipment on site, including the cables and physical plugs that attach to the vehicle.

This stored energy is required whatever electric vehicle plugs in.

The VHS v Betamax bit only actually comes from the physical plugs that are the end of the cables, that attach to the vehicles. These can be changed or adaptors provided as relatively low-cost consumer items. The plugs are intelligent in that ‘data signals’ are used to connect to the vehicle that determines the type and rate of charge. In future, these ‘plugs’ could become ‘wireless’, but the energy stored is still required to buffer the grid.

The Zap&Go solution will work best if Carbon-Ion is also installed on the vehicles. But if it is not, then the Carbon-Ion banks in the ground will still operate and electric vehicles can still be charged, albeit less quickly.

By retaining the ownership of the end to end solution, including the plugs, Zap&Go can upgrade them when necessary and control the entire end-to-end pricing and distribution model across the entire charging eco-system.
How does it work on a vehicle?

Most BEV's already use software that allows them to navigate to an available charger. The arrival time at the charging point is predictable and the charging slot reserved.

Prior to arriving at the charger, the state of charge of the BEV is known and therefore the energy required to recharge it to full capacity is also known.

As the BEV is travelling to the charge point, Carbon-Ion technology in the charger begins to charge with available energy from the electricity grid. This operation could have been performed well in advance if off-peak electricity was available. In either case there is no stress to the grid infrastructure.

When the vehicle arrives at the charging point it is recharged directly from the Carbon-Ion cells in the charger directly into corresponding Carbon-Ion cells on board the vehicle, in 5 minutes or less.

The driver can then detach from the charging cable and be on their way in the same time it would have taken a driver of a gasoline or diesel vehicle to fill their tank with fuel.

While the vehicle is being driven the Carbon-Ion cells on board the vehicle discharge into the on-board Li-ion cells. But they do this at a slow rate. This preserves the life of the Li-ion cells.
Carbon-ion cells are built into the chassis of the vehicle. This example configuration is a 30kWh system that is installed in body panels used rigid carbon polymers.

**Summary**

- ZapGo has the only technical solution that can provide this 5-10 minute charge from a standard electricity grid connection. In most cases installation would only require a spur off the existing power connection on site that already powers the pumps, shop, car wash and so on.

- ZapGo cells would be housed in the ground in the same type of container used to ‘bulk store’ gasoline and diesel today. Filling stations are familiar with this arrangement and none of the existing tanks would have to be removed as the Carbon-Ion cells will not catch fire. This would be unthinkable with lithium batteries.

- If the filling station has existing Mode 2 chargers on site, these can be upgraded to facilitate the ZapGo fast charge solution.

- We would act as a one-stop-shop to the filling station operator, providing all the installation and maintenance required. They would act as the same revenue collection point as with gasoline and diesel fuels today.

- ZapGo would arbitrage the electricity purchased through a demand side response mechanism offering the electricity operators a 500MWh storage capability and control the price that the electricity sold in real time through a Artificial Intelligence (AI) network that can allocate available electricity to the planned time that a vehicle arrives to charge.

- Government tax revenue on the electricity purchased would be collected by the Filling Station in the same way as they do today with gasoline (petrol) and diesel at whatever tax rates the UK Government decides to impose.
ZapGo Ltd was founded in 2013 with the goal of producing the next generation of batteries or energy storage products that are faster charging, safer, longer lasting and ultimately easier to recycle than the current alternatives.

Zap&Go’s progress has been rapid from inception. In less than 5 years, the company has now entered their large scale production phase for the Generation 3 (Gen 3) Carbon-Ion™ or C-Ion® technology with the lithium-ion (Li-ion) battery manufacturer Li-Fun in China\textsuperscript{5}.

This is a highly significant milestone, because so many new battery companies never make the transition from the lab to a production ready product. It is also significant because although the Gen 3 cells contain no lithium, they can be made on existing Li-ion production lines with little or no modification, and largely using materials from existing supply chains.

The first commercial products that will contain the C-Ion cells ‘inside’ are expected to be in stores and sold on-line in the first half of 2018. These will be an electric scooter, a cordless power tool product and an automotive after-market product.

These products will be marketed with the “Powered By Zap&Go” logo on the box in a similar way to “Intel Inside”.

Zap&Go’s business model is a licensing model similar to Qualcomm (QCOM). For the first products, Zap&Go will receive a license fee or royalty on each product made or sold.

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Electric vehicle sales will exceed 1 million units this year for the first time, according to our Advanced Transport team’s latest estimates (client link at web). New EV commitments are being announced with increasing regularity, with Volvo being the most recent addition: the Swedish (but Chinese-owned) car maker has recently announced that all of its new models will include electric drive by 2019. VW has targeted 25 percent of its sales to be EVs by 2025, while Daimler and BMW are aiming at 15-25 percent by 2025.

**References**

https://www.bnef.com/ViewEmail/dd9fcb37-ddf5-cd8a-9ea6-15fb30de0a5b-6600ff073252-11528a5?e=VIP%20Comment

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*http://www.nextgreencar.com/electric-cars/statistics/


*WHO Global Urban Ambient Air Pollution Database
http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

*Tesla Model S https://www.tesla.com/models


*With a Super Charger claim that a 90kWh (kilo-Watt Hour) Model S can recharge to 80% in 40 minutes and provide a 300 (c.500km) range http://www.tesla.com


*https://forums.tesla.com/forum/forums/updated-how-it-works-supercharger-station

UPDATED: ‘How it works’ - SuperCharger Station
Submitted by nickhowe on July 24, 2013

For your info, here’s how a typical (in this case the Port St Lucie, FL) supercharger infrastructure is configured:

The eight bay setup takes a 12kV, 750kVA feed from the utility, steps it down to 480V three phase on site, pushes that into 2000A switchgear which feeds four (one for each pair of bays) SuperCharger units at 480V/200A. Each unit contains 12 [Model S] 10kW rectifiers for 120kW.

For safety reasons the 'pod' that the car plugs into is not energized until the cable has done a handshake, so if something accidentally flattens a pod or the cable is cut there is no danger.

Each unit is 120kW and will load balance between two bays - if two cars are at the same SOC they'll each get 60kW, whereas if one is empty and one is close to full it will split it 90/30. So...if you come into an SC station and there are several empty bays DO NOT park next to an existing car unless you first check the label on the SC - each one should be labeled 1A, 1B, 2A, 2B, etc. Avoid taking the same number if you can so you can get the full 120kW.

Strictly speaking all old SCs are only 90kW, but are being upgraded. All new SCs are 120kW but will only push 90kW right now because the cars require a firmware update to take 120kW, and a tweak is needed at the SC station. No date on when the change is going to happen.

Tesla is exploring pushing the units to 150kW in the future.

*https://electrek.co/2017/07/14/porsche-350-kw-ev-charging-station/

*https://electrek.co/2016/07/20/tesla-supercharger-capacity-increase-145-kw/

*http://www.thisismoney.co.uk/money/cars/article-3315204/3-9m-home-owners-converted-garage-living-space-20-years.html

*https://www.scientificamerican.com/article/how-lithium-ion-batteries-grounded-the-dreamliner/

*Assumptions

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