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Science & Technology Group

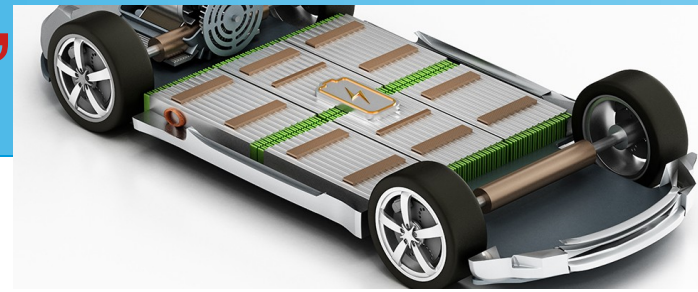
LIVING WITH AN ELECTRIC CAR

The Ups and Downs of a BEV
...3 years on

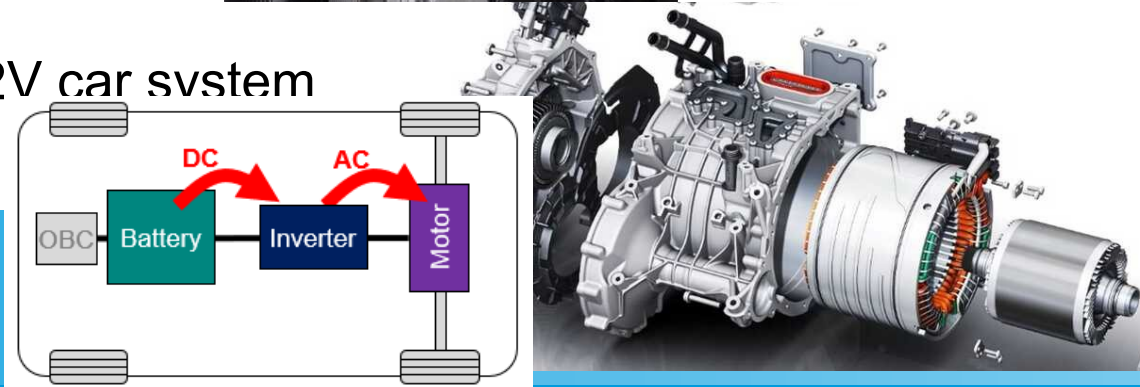
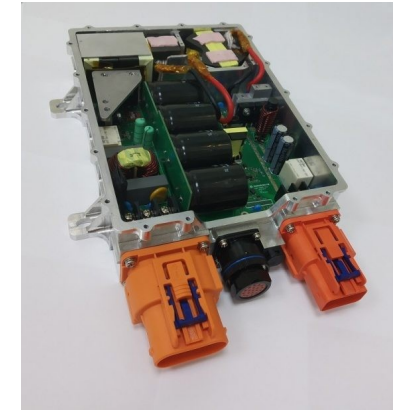
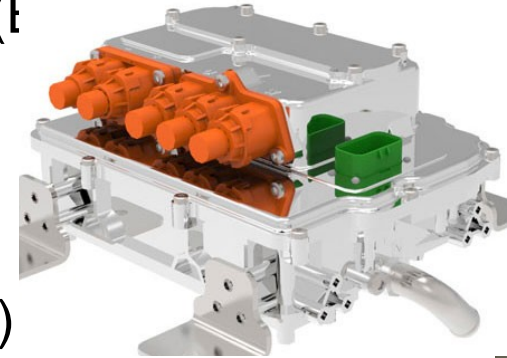


By Barry James July 2024

What's in a BEV – that'



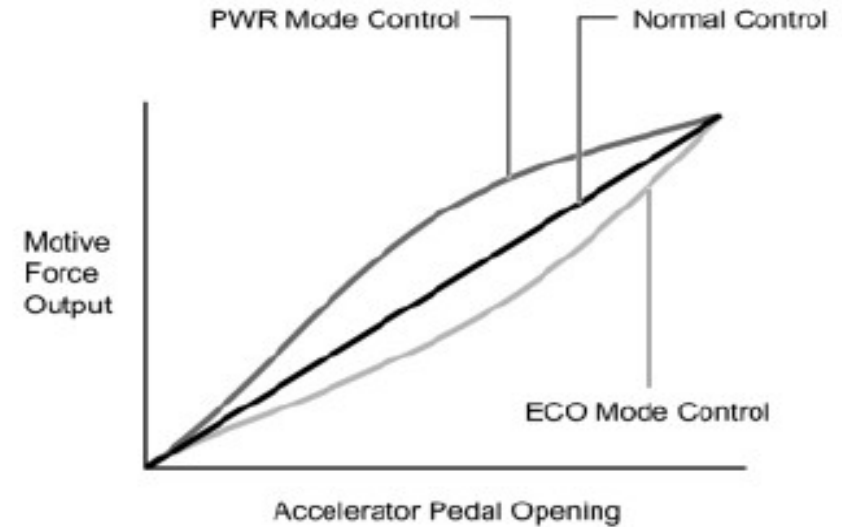
- High Voltage Battery (+ Standard 12V lead acid)
 - Lithium based + Battery Management System (BMS)
- Electric Motor, 3 phase brushless + differential
- Power inverter electronics (DC to 3 phase AC)
- Charge port – for AC and DC charging leads (CCS)
- 230V AC to 400V DC on-board charger module (& V2L), rating
- DC to DC converter module supporting 12V loads ($400V \gg 14V$)
- Electrical heater, or heat pump
- Brake vacuum pump (for brake servo)
- High voltage AirCon pump & system
- All the rest is similar to any other 12V car system
 - But no gears or gearbox to shift



EV Features

- Quiet, smooth (no gears), quick
- Drive Mode, KERS & App
- **Drive Mode:**
 - ECO, Normal, Sport
- **Regenerative Braking (KERS)**
 - Motor turned into generator and recovers energy
 - Feels like engine braking on trailing throttle
 - Pressing brake lightly gives full regen
 - Usually 3 levels
 - Almost no use for mechanical brakes
 - Some have one pedal driving
- **App** can preheat or pre-cool, SOC%

Output Characteristics:

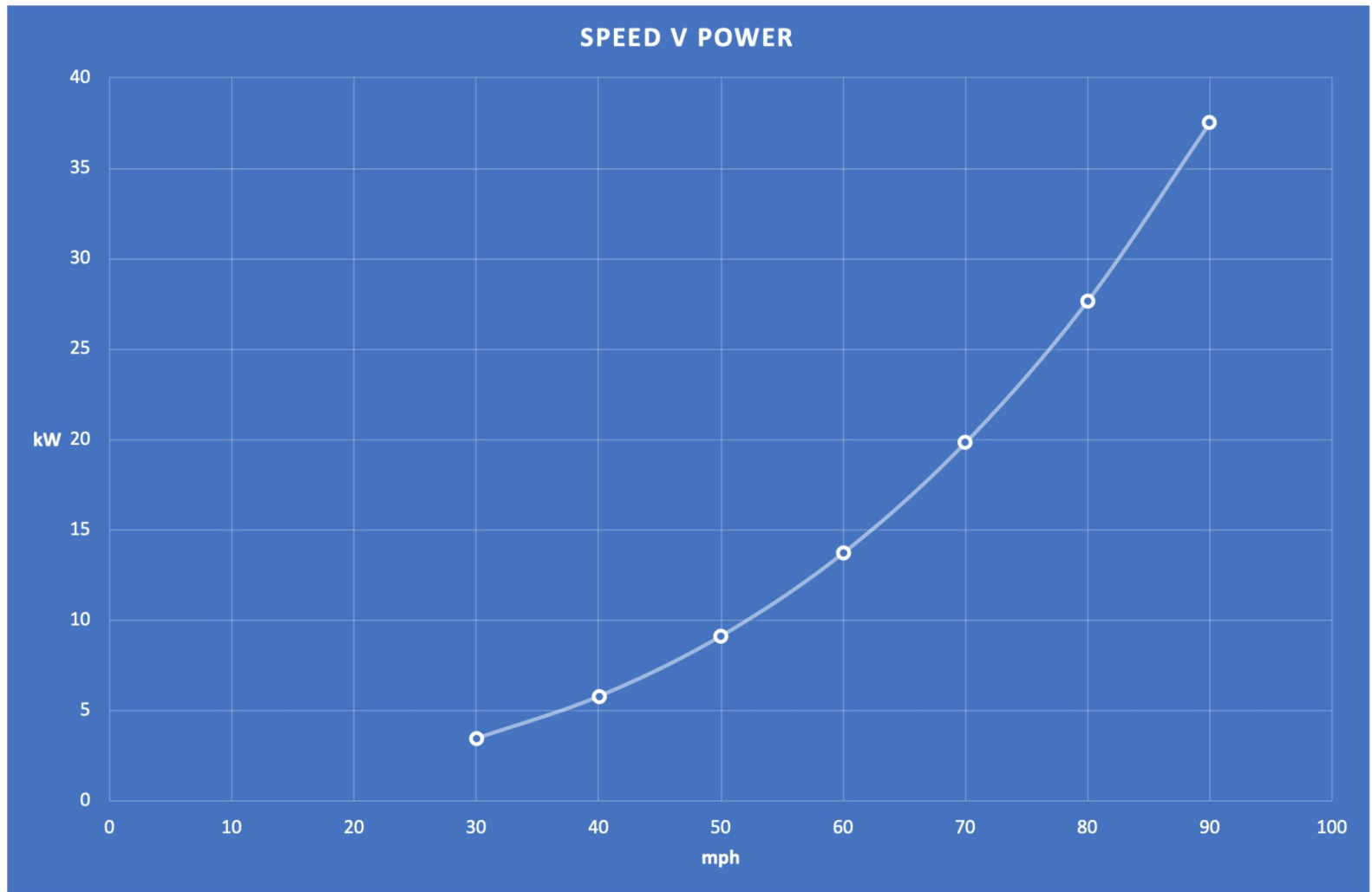


Electrical Terms – Let's Review

- DC battery **Volts** (V) and **Current** drawn out (Amps)
- **Power**
 - Unit of power being drawn out = **Watts** or kW
 - Power (Watts) = Volts x Amps
 - E.g, Power = 400V battery x 10Amps = 4000Watts or 4kW
- **Energy**
 - Is time related, so **Watts** used per **Hour** or kW per hour
 - So, 4kW load used for an hour, uses 4000Wh or 4kWh
 - kWh is what your home energy meter reads, and is an EV battery rating
- An AA cell will support around 1Wh
- So we need a traction battery to support a lot of energy in kWh
- An EV battery can be 40kWh to 100kWh

Speed vs Power needed

90 mph = 37.5 kW
80 mph = 27.6 kW
70 mph = 19.8 kW
60 mph = 13.7 kW
50 mph = 9.1 kW
40 mph = 5.7 kW
30 mph = 3.4 kW



So the highest kWh rating for the battery would seem sensible.

HV Battery Types (Chemistries)

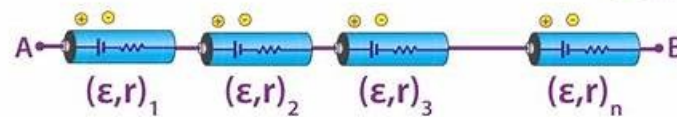
- **NMC**, the original Lithium Ion, LiNiMnCoO_2
 - contains Nickel, Manganese, Cobalt & Lithium
- **LFP**, a newer technology now used (LiFePO_4)
 - Contains Lithium Ferrous and Phosphates
- LFP is a safer type than NMC, but lower energy density (kWh/kg). More prone to cell imbalance.
- All elements are mined, but NMC components are more rare and cause more controversy.
- Always look for a model that has battery cooling, possibly battery heating for better charging cold.

Battery Ratings & Protection

- **Battery Energy** is rated in kWh (kilo Watt hours)
- The battery rating will give an indication of range:
 - On heavy large cars this may not apply so well
 - Energy ratings can be from **40kwh to 100+kwh**
 - Usually the larger energy rating should give more range

Fiat 500e is 21-42kWh
MG5 & ZOE are 52-61kWh
Kia EV6 is 86kWh
Jaguar I-Pace is 90kWh

The BMS system



- There could be over 100 pouch cells making up the battery, all connected in series to get the high voltage. Each cell is ~4V. [Over 7000 in a Tesla!]
 - There will be a BMS system within the battery which looks after the health of the battery, and importantly ensures all cells are balanced.
 - The BMS will monitor each cell's temp and voltage and apply limiting for charge or discharge when necessary, state of charge, & state of health.

08/11/2024 • The BMS will perform an equalisation charge.

Battery Range (WLTP vs Real World)

Manufacturers rate the range with the WLTP laboratory test

Different models can give <100 – 400 miles (wltp)

On the car display will be the magic “Miles/kWh”

So, if 4 miles/kwh is achieved, with a 50kwh battery:

$4 \times 50 = 200$ miles range. [Miles/kWh is driving dependent]

<https://ev-database.org/imp/cheatsheet/range-electric-car>

But manufacturers “hide” some of the battery capacity

E.g. 52kWh rated, but 50kWh Useable



Range Killers



- **Speed**

- 70mph is a no no. Wind resistance squares with speed

- **Cold weather**

- heater needed – look for model with heat pump
- performance of battery poorer when cold (mainly charging)

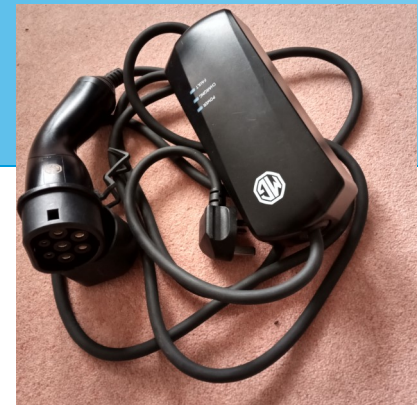
- **Hot weather**

- Aircon needed

- **Driving style**, too much acceleration

- Gentle driving, low accel and decel - better range

Charging the battery



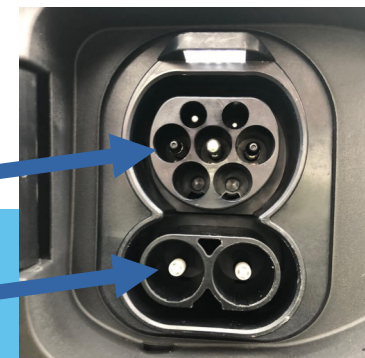
- Two types: **AC** (slow) and **DC** (rapid) chargers
- **At Home** (Type 2 cable AC only)
 - AC 3 pin plug at 2.5 kw (Granny charger)
 - AC Wall charger, 7.5 kw
- **Public Charge Points (AC & DC)**
 - **AC** 7.5kw or 3 phase 22kw using a Type 2 cable
 - **AC uses an on board charger** – so check the rating
 - Car charger module can be 6.6kW to 22kW (3 ph.)
 - **DC** rapid up to 150kw+ uses a CCS connector, tethered to the charger. Check car spec for max DC power



Granny lead AC



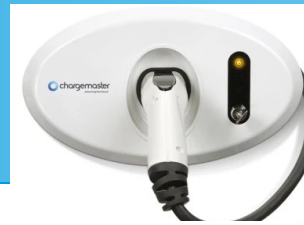
CCS Connector DC



AC

DC

AC Charging continued.



- **AC Wall chargers** can cost £1000+ (no grants now)
 - ... Commando wall socket is cheaper (£200-£300+ install)
 - ... Granny chargers come with the car, but very slow
 - ... But if you don't have access to any at home, then it's public charging
- **Solar Panels.... Great**
 - ... With Batteries even better. Dump excess generation into the car, free.
- **BMS Equalisation Charge**, once a month or so for cell balancing
 - ... Usually completed after 100% SOC on an AC slow charge
 - ... Leave charging after 100% point, reduces to ~300W charge
 - ... This is the main function of the BMS (temp + cell voltage equalisation)
- I personally prefer “Opportunity charging” – small amounts but often to top up.

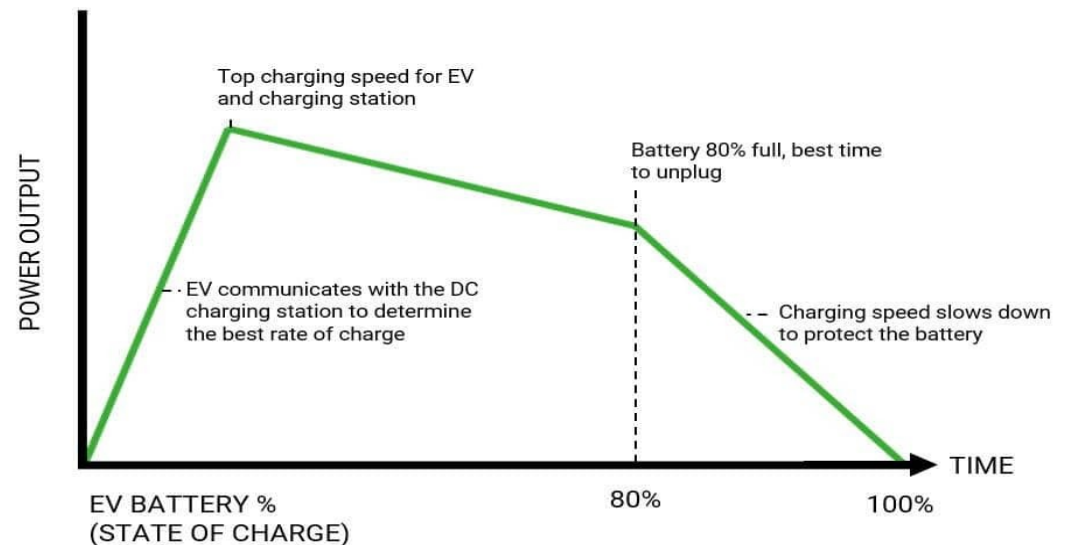
Public rapid DC charging



- 50kW to 150kW+
- After 80%, charge slows down, so holds up queue.
- Beware of car park time limits if there is a queue



DC fast charging curve



... Possible fines!

So, upshot for 50kWh battery is...

Takes <1 hour @ 50kW

Public Charging Access



- APPS, Accounts, RFID tags, Electroverse, contactless credit cards
- There are over 70 operators of charge points.
- New ones, should work with a contactless card, but I've found mainly motorway services chargers.
- Most require an account setting up, some even have to prepay into it, or register a credit card.
- Others require Apps, which is fine if there is a phone signal, and you have a phone capable of apps.
- Lots of planning required before a long journey.

Typical Accounts/Apps

Pod Point ac - account

Fuuse ac – app

Dragon Charging ac - app

City EV - app

EVC - app

BP Pulse subs or c'less

GeniePoint app or c'less

Instavolt app or c'less

Ionity - app or contactless

Osprey – app or c'less

Shell Recharge – account

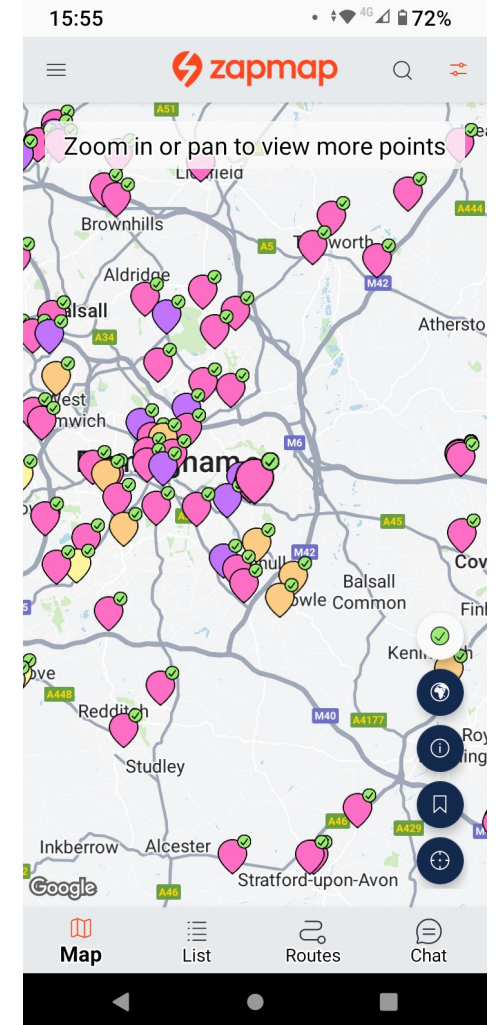
**ALL these can be
expensive**

Maybe your wall charger
and car apps as well.

Maps to help find chargers

However, there are maps to help you...

- Zap-Map
- Google maps > select ev chargers
- EV map
- PlugShare
- ABRP
- NextCharge
- WattsUp



What cost to charge?

- Take a 50kWh battery, 0% to 100% (around 200 mls)
 - ◆ Home: $50 \times 24\text{p} = \text{£}12$ [$\sim 6\text{p}/\text{mile}$]
 - ◆ Public Rapid: $50 \times 70\text{p} = \text{£}35$ [$\sim 18\text{p}/\text{mile}$]

Note: Public charging : 20%VAT, Home charging: 5% VAT

(Petrol equivalent at 40 mpg approx 16p/mile)

A 100kwh battery will cost double that to fill but could give 350-400 miles. Wow, would it be heavy (1 tonne)!

- ◆ Larger batteries are mostly on expensive models like BMW, Audi E-Tron, and Mercedes EQ

How long to Charge?

For a 50kWh average battery (that's empty)

Home Granny: 2.5kW AC, around 25 hours

Home wall: charger AC, 7.5kW, around 7- 8 hours

Public AC: 22kW, around 2 – 3 hours (if car has 3 phase charger)

Public Rapid DC: 50kW (CCS), less than 1 hour (OK for a toilet break and coffee)

Public Rapid DC: 100kW (CCS), around 30-45 minutes (if car has charge capability)

(Note that charge rate will fall off quickly above 80% on a rapid DC CCS)

Equalisation Charge

Series cells can develop small voltage differences over use.

Cell equalisation completed after 100% SOC reached. Can take up to 2 hours, but only once a month or less, if it's needed by BMS. AC charge only.

Battery degradation & SOH% (Via ISO diag socket or dealer)

Normal cycling of charge/discharge will slowly degrade capacity, especially rapids.

NMC batteries degrade if held at 100% SOC, LiFePo (LFP) type no problem.

Need to know SOH% at each service to evaluate degradation for warranty.

Battery Degradation – Loss of range

- Charge/Discharge and rapid public charge can increase the degradation. SOH% plotted over miles...



What Costs are Involved

- **Initial outlay** higher than most ICE cars
 - Mainly because of battery cost and scale
- Some are well above £40,000+ to £100,000
- Prices will fall with volume. Chinese £15k to £35k.
- Leasing is OK though (no battery issues).
- **Servicing** is a LOT cheaper – no oily bits
 - 1st service was under £50, £80 for 2nd, £80 for 3rd
- **Depreciation** possibly slightly worse for a BEV

If Buying, Remember to Ask

- Is there battery cooling?
- Is there a heat pump for cabin heating?
- What is the AC power rating of the on-board charger in kW?
 - ... Is it single phase or 3 phase (7kW, 11kW or 22 kW)?
- What is the WLTP stated range?
 - ... What's the real world range, Summer & Winter?
- What rapid DC charge rate will it support (CCS 50-150kW)?
- Warranty on battery and other power electronics?
- If buying second hand, **ask for the SOH%** of the battery
- Can an external service be added to the service record?

Software – Ugh!

- All cars have huge quantities of microprocessors.
- They all need software to run all the functionality, bells and whistles, especially electric motors & batteries.
- Like any computer, there will always be bugs that surface and need the software updating.
- Some bugs are worse than others, check if in warranty.
- BEV's have a lot of computer controlled items
- You may have to return to a main dealer if a software update is required. Only main dealers can do this.
- But this common to all new cars now.

ANTI – EV'ers and DoomMongers

- **Myth 1.** EVs are collapsing multi-storey car parks!
 - Rubbish, a Diesel Range Rover weighs 2.7 tonnes!
- **Myth 2.** EVs catch fire more often than ICE cars
 - Rubbish, records show 90% less fires than ICE
 - LexAuto lease 16,500 EVs, no fires and no drivetrain failures.

2035

AS FOR 2040 / 2030 / 2035 ??? WHO KNOWS

The grid capacity (EVs + Heat pumps)

The number of public charge points

The supply of BEVs to meet replacement vehicles

The recycling of BEVs

The manufacturers are clearly confused by the Govt delays. Why invest 5 years early. Need certainty.

Investment is crucial and needs time to implement new technology at the scale of ICE engines.

Not all are convinced of EVs yet.

In Summary

- **Pros**

- Perfect if retired and few very long journeys. Car tax zero until 2025
- Overnight low cost tariffs + free top-up charging with solar panels
- Amazing, quiet, smooth, loads of acceleration and no gears
- Regenerative braking – mechanical brakes hardly used
- Servicing costs minimal – mainly a check list, only pollen filter, no oil

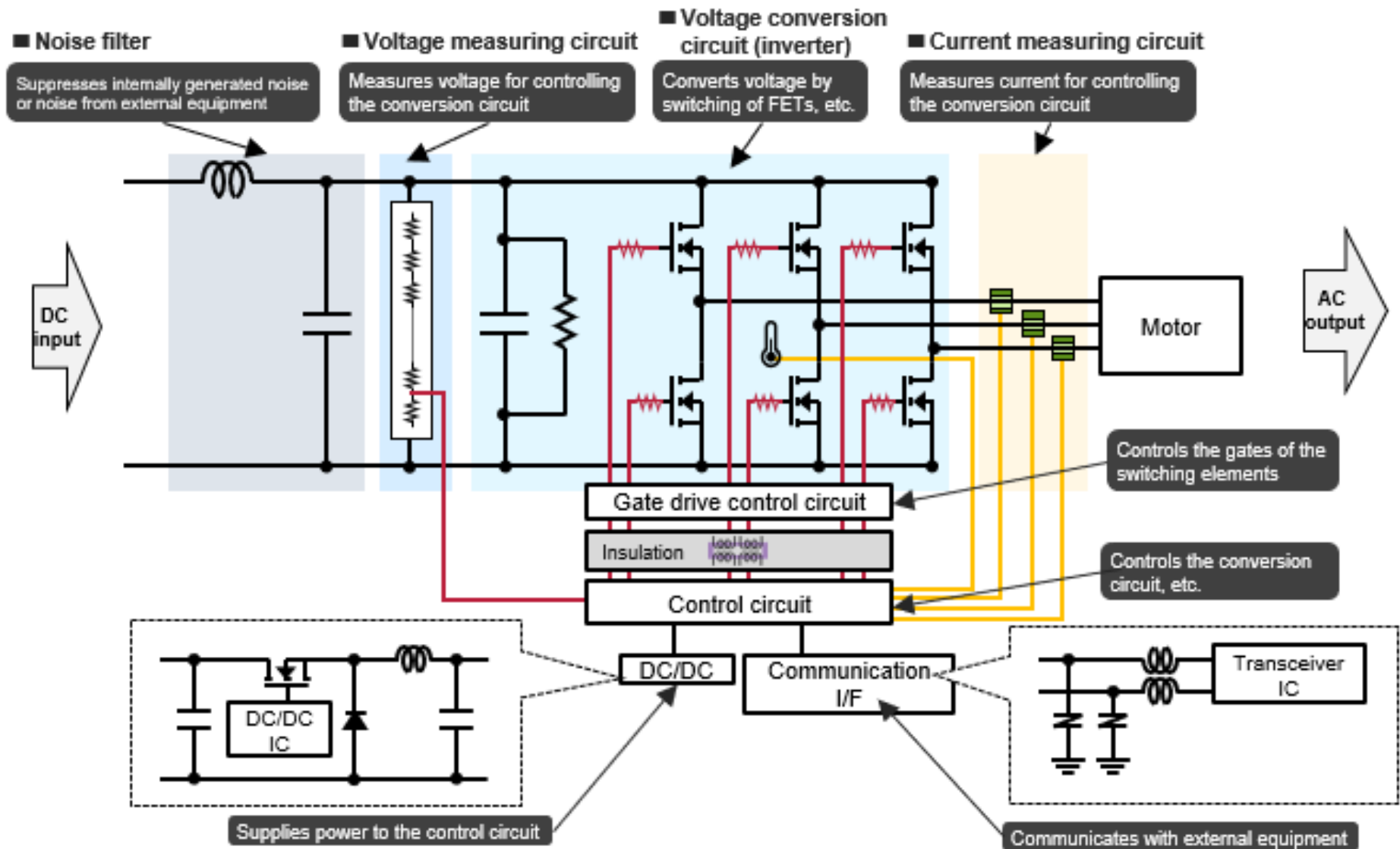
- **Cons**

- Rapid public chargers are expensive. Route-plan required for public chargers on long distance trips
- Lots of Apps or accounts required still for different chargers
- Not many public chargers accept contactless cards (although supposed to)
- Expensive to buy cars outright, now no Gov't incentive, but leasing still OK
- Residual values, battery state of health and lifetime

It's all about getting used to something new that is remarkably good...AND, save the planet!

That's it folks

The Inverter (Motor driver DC to AC)



Battery Chemistry – and the Future

- The key to BEVs is how good the battery is.
- Great strides forward with lithium batteries, but more needed:
- A lithium-ion battery will typically have a graphite electrode, a metal oxide electrode and an electrolyte of lithium salt dissolved in some sort of solvent
- In solid-state batteries, you might find one of a whole host of promising materials replacing the lithium, including ceramics and sulphides, all of which will be non-flammable.
- Solid electrolytes are less dense, so a solid-state battery can be smaller and lighter than its lithium-ion competitor. Up to 10 times higher energy density than Lithium Ion liquid electrolyte.
- Toyota says it has made a breakthrough with solid-state batteries to go into production before 2030.
 - Alleged charge time of 10 mins and 1200km range