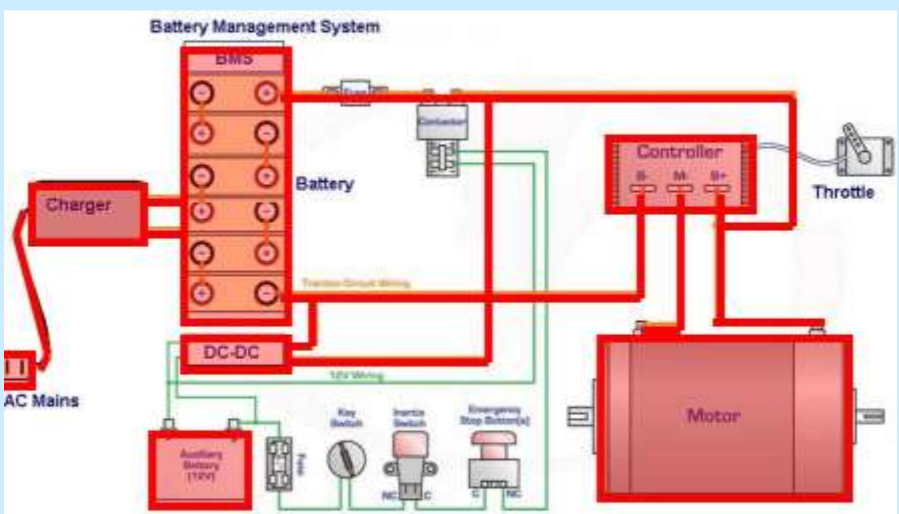
Electric Vehicle

SAFETY

Battery Handling

Sustainability

Dr. Horizon Gitano-Briggs
Focus Applied Technologies



Local EV Market: Dominated by China

China manufacturers make up 70% of the South Asia EV car market

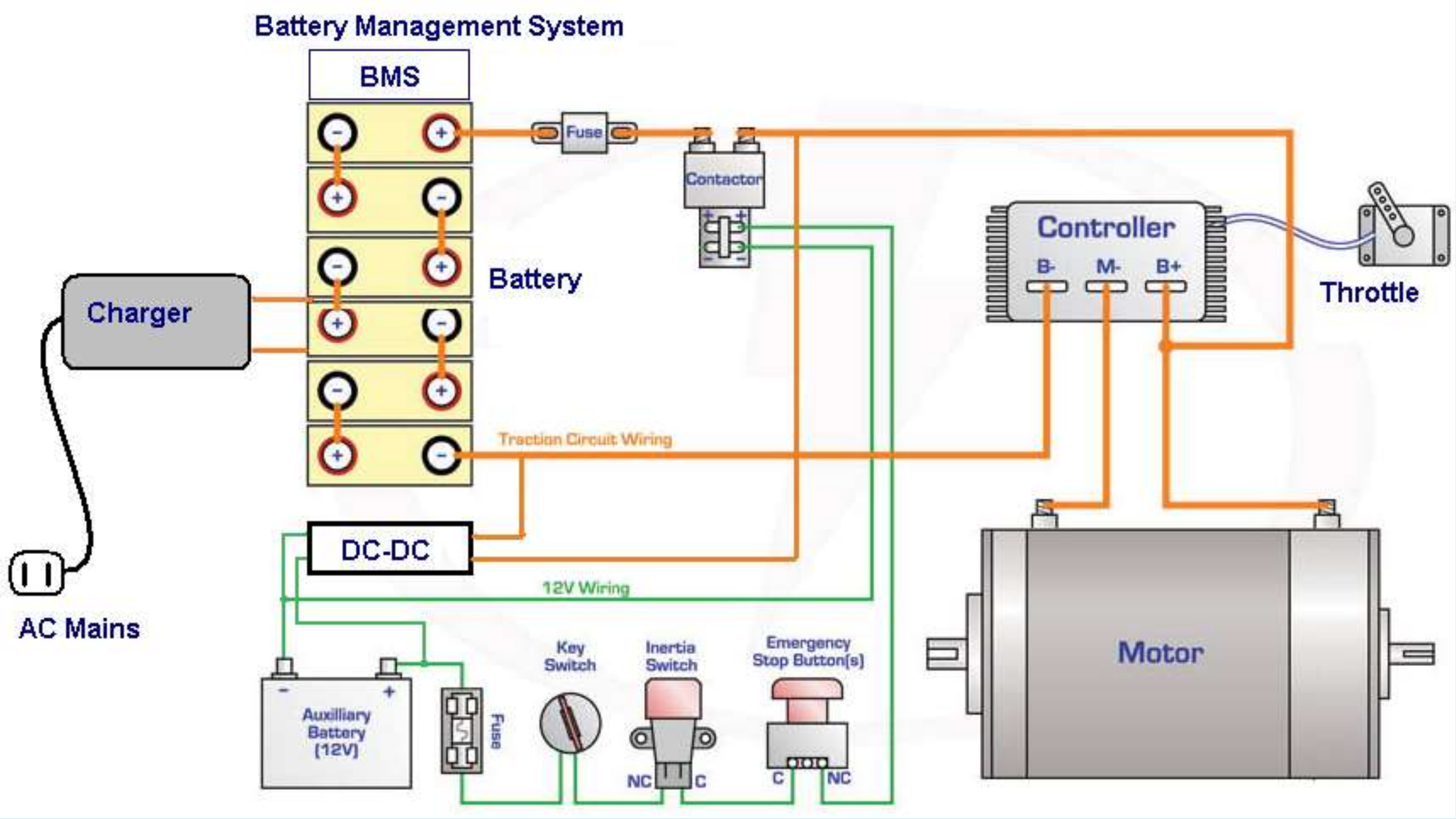
SE Asia has a HUGE market for 2- and 3-wheelers of "local" design!

VinFast – Vietnam: One Bike, 2 Models

50 kph, 80 km range
Lithium-ion battery $2,400
Lead-acid battery $1,460

~100km range
** probably less than 50km range*
Li-ion batteries are still much more expensive

Schematic Diagram of EV Main Components



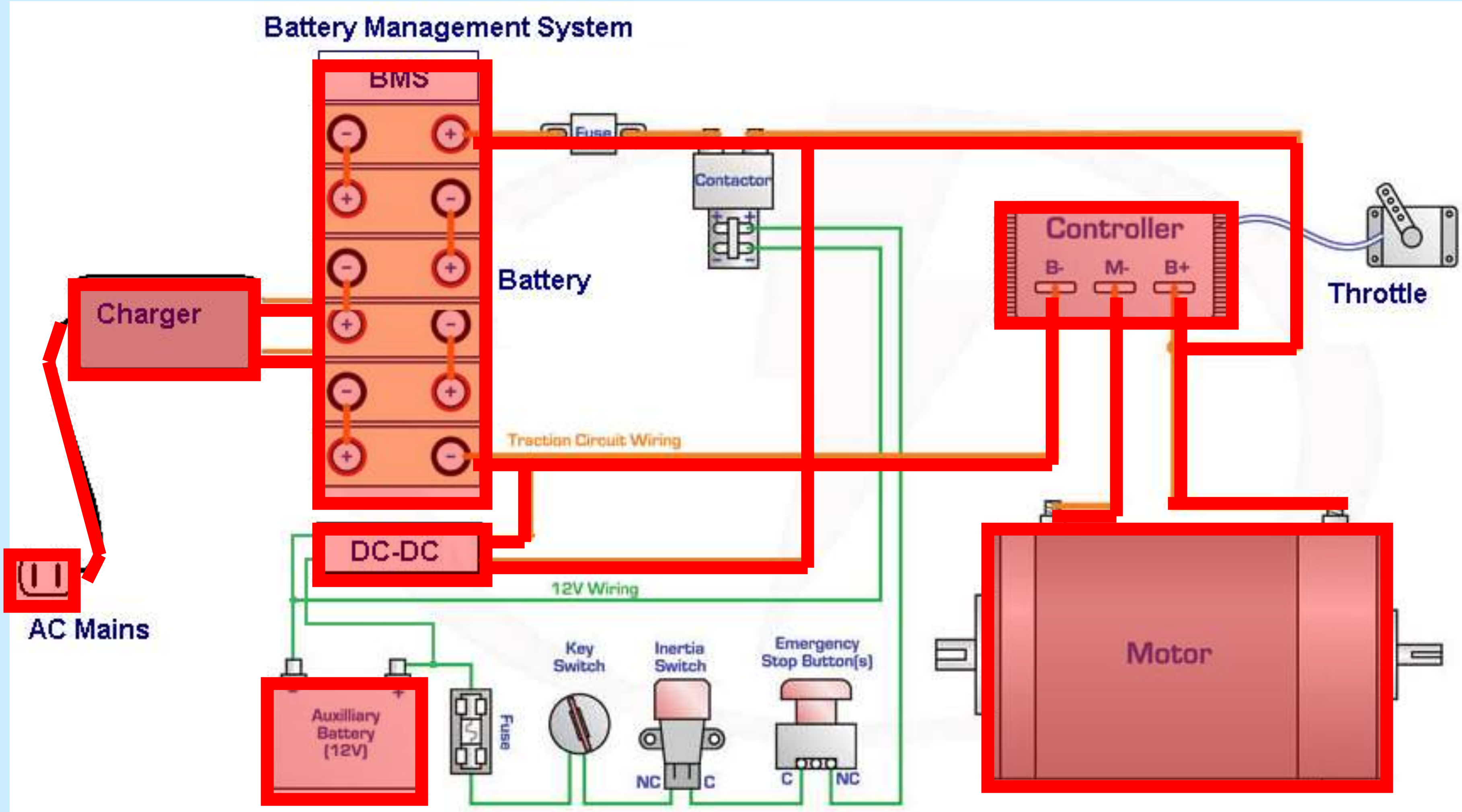
Charger (on-board or off board)

Battery – BMS

Motor Controller

Motor

DANGEROUS Components



Charger Battery – BMS Motor Controller Motor

PSYCHOLOGY of DANGER

ANYTHING that stores a large amount of energy can be dangerous.

We become "**habitualized**" to dangers we face regularly, reducing **fear**.

"New" thing are seen as more dangerous because they are… *NEW!*

Which of these things is the most dangerous?

BE CAREFUL WHERE YOU STEP!

Fatality rates:

55%

17%

2%

0%

EV FIRES: THE DATA

A study in Sweden, which has a high population of EVs and shows that **ICE vehicles are 20 times more likely** to suffer a fire than EVs

ICE Car

>

EV Charging

We still need to be prepared, and safe, but don't panic!

https://www.yahoo.com/news/study-uncovers-stunning-misconception-surrounding-141500201.html

MOST DANGEROUS PART OF EV: The DRIVER

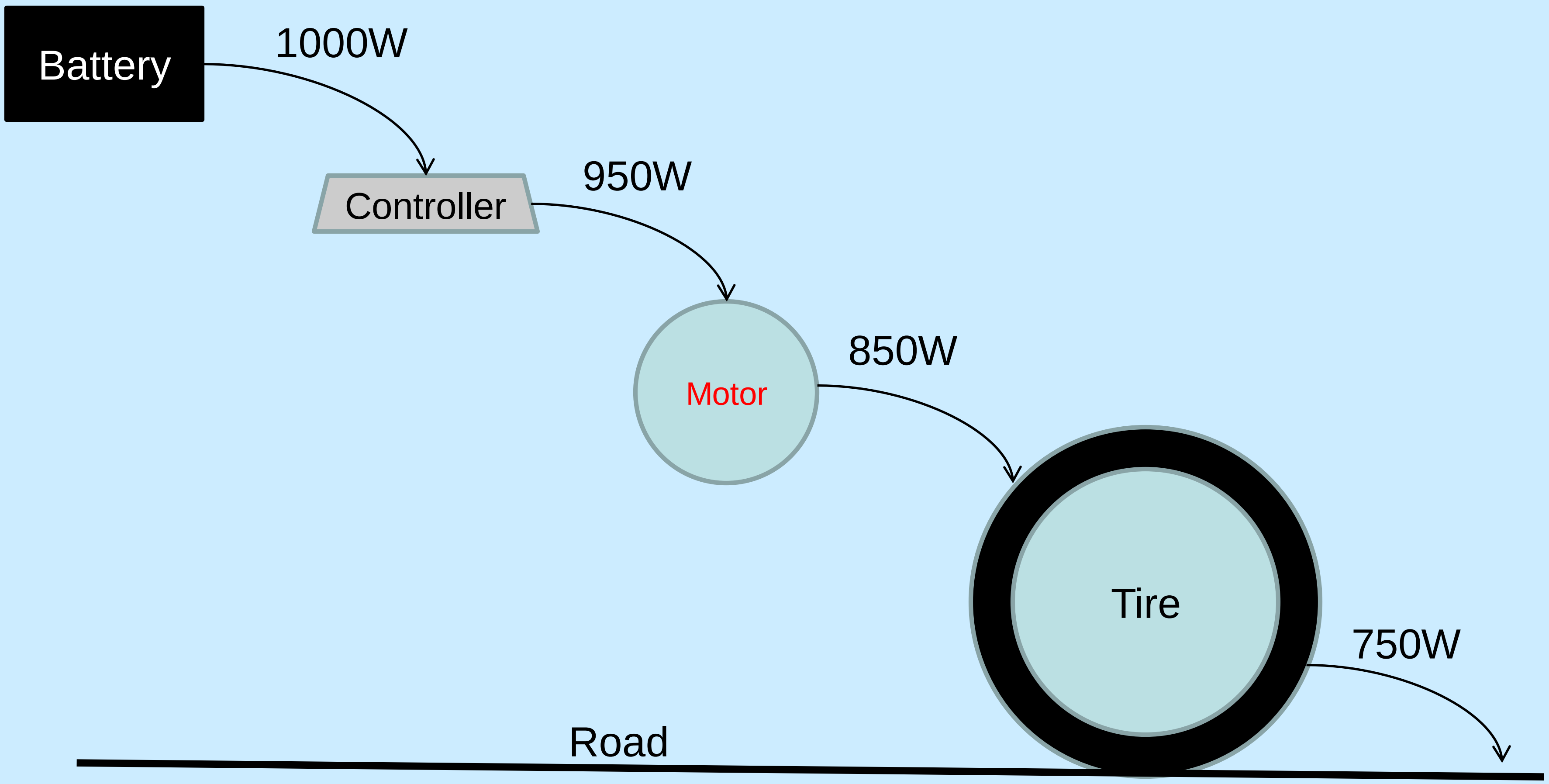
Electric Scooters:
They are ***too*** easy to ride.
They are ***too*** cheap.
They are ***too*** popular.

This encourages many unqualified riders to get on the roads.

Electric scooters and bikes have been blamed for rising death tolls amongst cyclists, mostly because **poor riders cause crashes**.

HEAT: Inefficiency and Danger

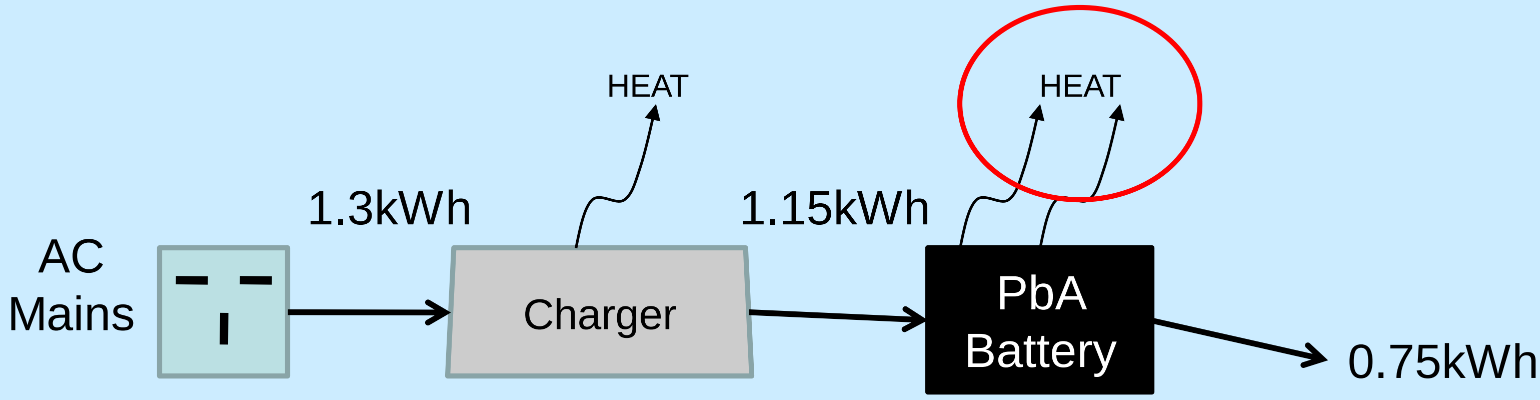
Power is lost at every stage of conversion, mostly as **heat**.

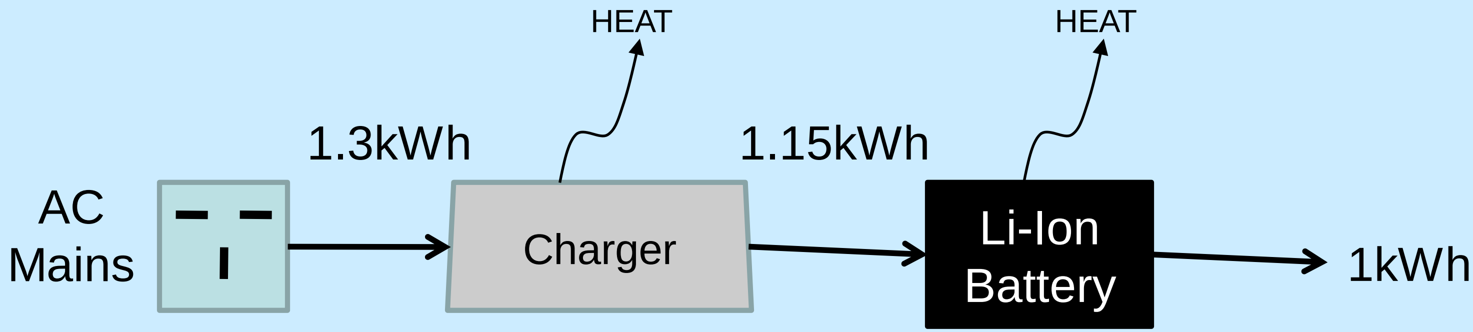


Wires and switch gear **SHOULD NOT** be ***HOT***.
If they are, this indicates a problem.

Charge-Discharge Losses

Power is lost at **every stage of conversion**, mostly in the battery as heat. Charge/Discharge efficiencies depend on battery chemistry and current. PbA is much less efficient than Li-Ion.





COMMON EV SAFETY FEATURES

GROUNDING

Insulation

Cooling

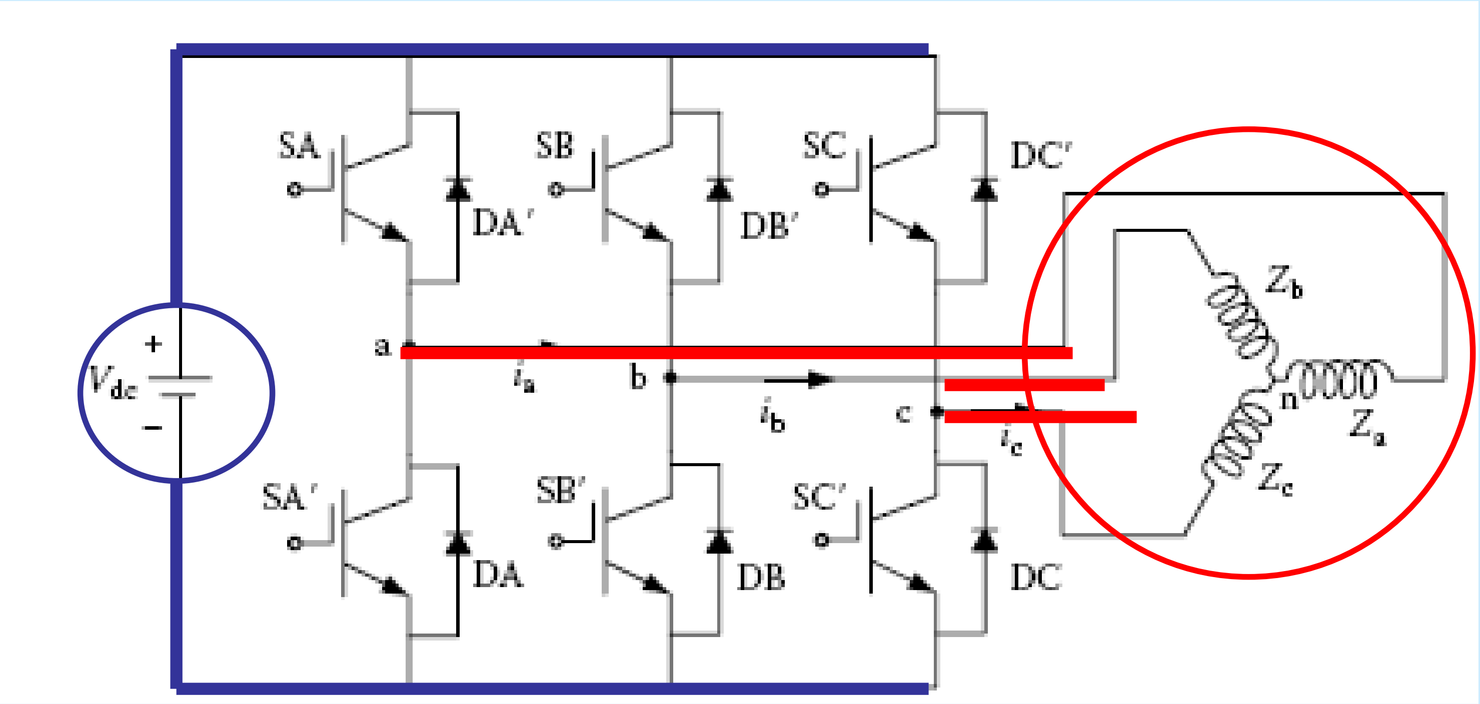
Color Coding

Fuse

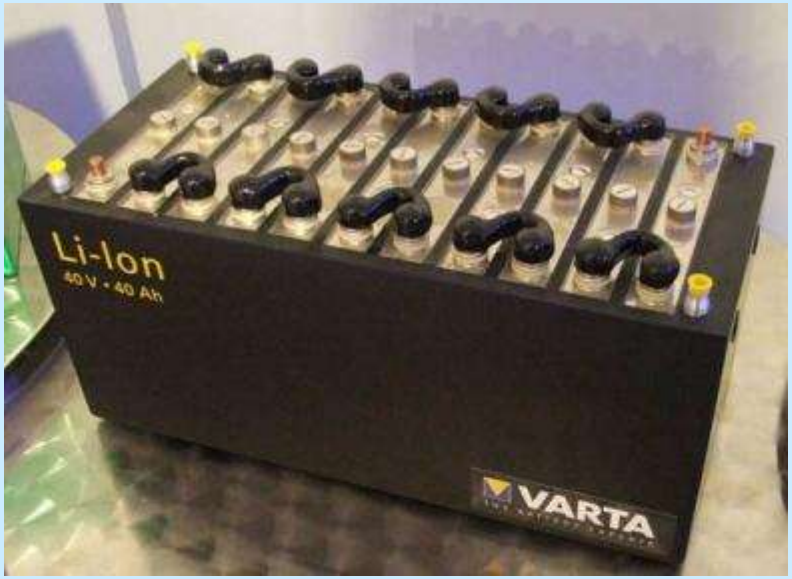
Bolted Connectors

MOTOR DRIVER: BLDC - INDUCTION

DC not as dangerous as AC, but still can be fatal.
The **AC** going to the motor, more lethal.



EV Batteries



General EV concerns and problems

Energy Density = Explosion Potential
The same holds true for batteries: more energy means more danger

Inefficiency = Heat
Controllers require cooling, some times with water
Motor require cooling, some times with water

High Voltages
Power = V x I, but losses are I^2R, so the trend is toward higher voltages

400V is not uncommon in EV's

Voltages over 60V nominal are considered "hazardous" and require special safeties

Battery Management Systems: Crucial Safety Component

Battery packs require BMS to prevent damage to the batteries.

Typical protections include:

- Cell Balancing
- Over-current Cutoff
- Over-voltage Cutoff (during charging)
- Under-voltage Cutoff (during discharging)
- Over-temperature

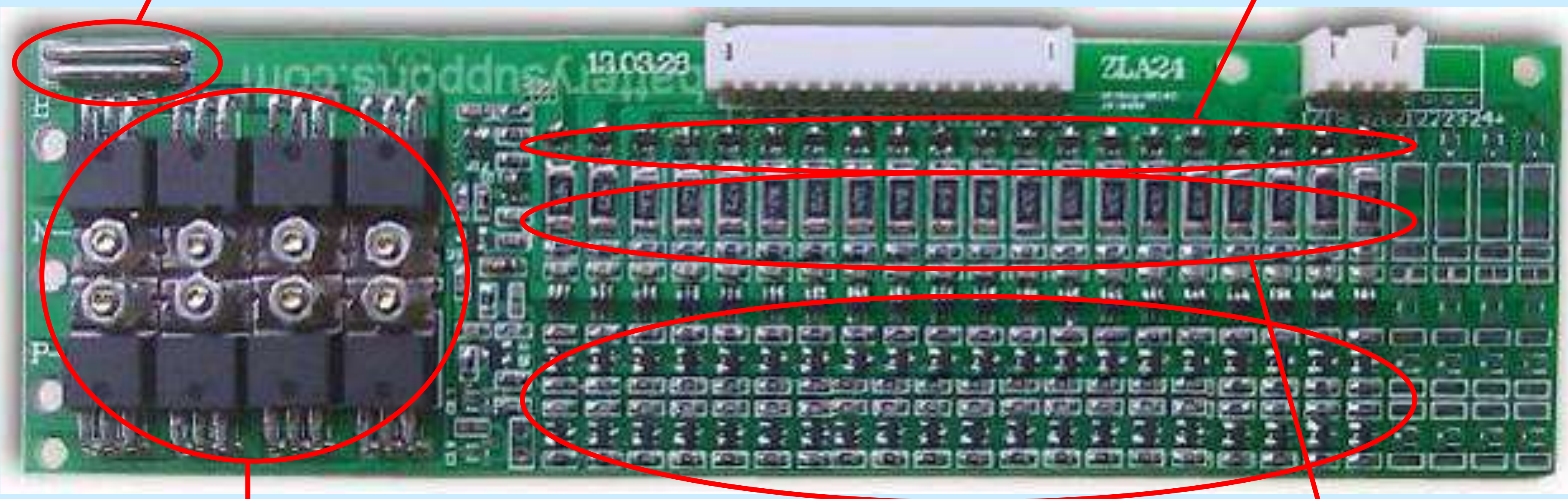
This is supposed to prevent dangerous shorting, but may be compromised in a crash.

Battery Management Systems

Low Resistance Current Sensor

Charge Bypass
Resistor Transistors

Connection to individual cells



Power FETs for cutting power

Differential Cell Voltage
Sensing Circuitry

Charge
Bypass
Resistors

LDEV Danger: Water Ingress during Charging

Most E2Ws can be charged from standard 110-220V AC outlets in 3-8 hours

High-density buildings (flats) do not have covered areas safe for charging, or power

Charging: Bigger vehicles require High Charging rates

Typical Motorcycle commute: 30km/day at ~50kph
50kph requires about 1-1.5kW, so about 1kWh total power output
This is more like 1.5kWh at the battery pack or 2kWh at the wall plug.

240V, 10A = 2.4kW, so you could theoretically charge in 1 hour
BUT: the batteries can't handle this high current and last

Cars consume ~10x the power, and can be recharged in ~10-20 hours from home.

For "on the road" charging they might need **MUCH more** power to recharge in an acceptable time.

7kW is common
Tesla Supercharger is **120kW**

MORE POWER = MORE DANGER

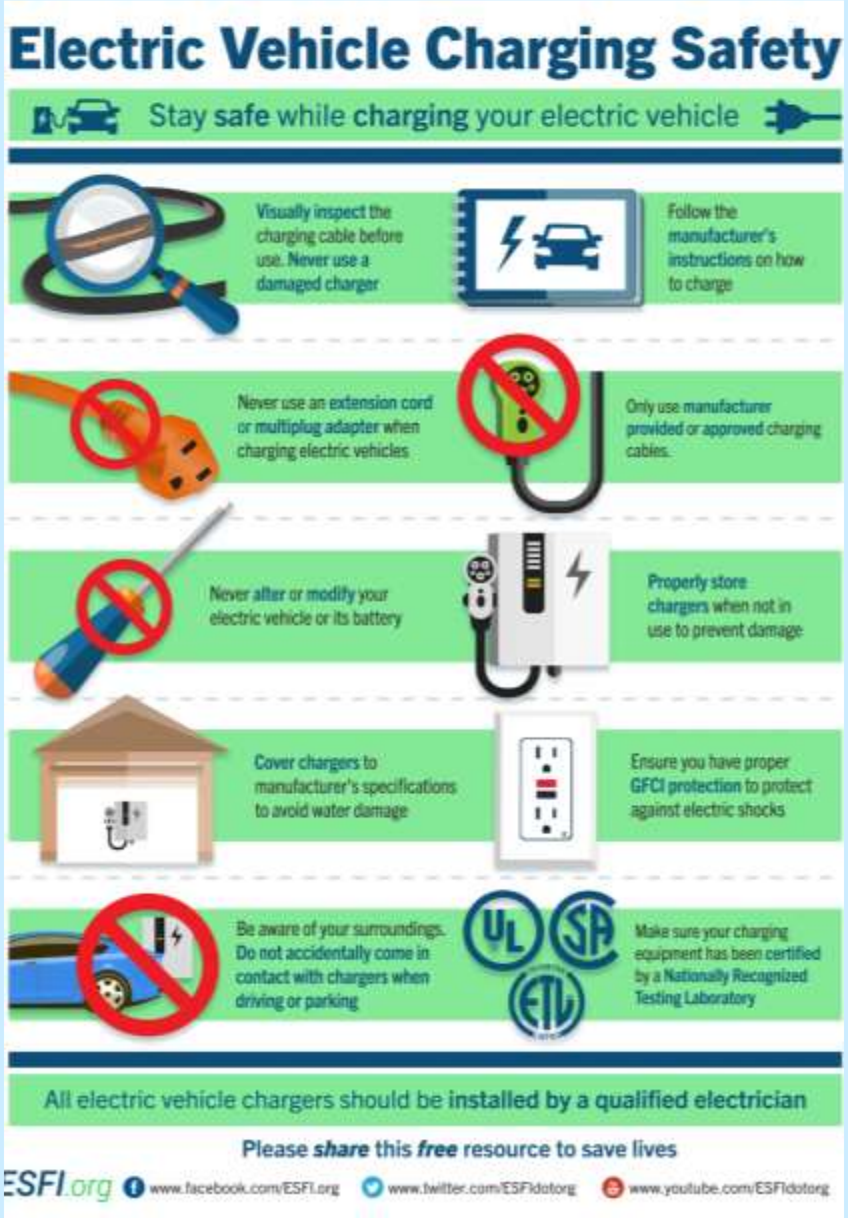
CHARGER SAFETY FACTORS

Manual Emergency Shutoff
Automatic Fault Detection and Shutoff:
- Thermal
- Over Current
- Short Circuit
- Current Leak

Proper Grounding
Ground Fault Protection

Ingress Protection (IP54 to IP65)
Wire Insulation/Robustness

Impact Resistance

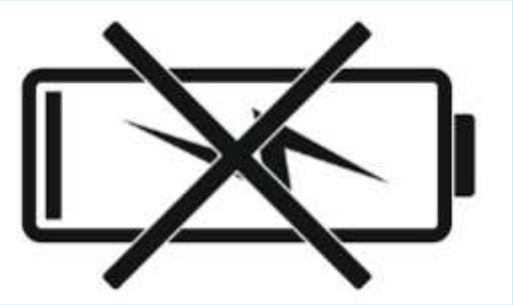


Electric Battery SAFETY

1. Batteries should only be handled by trained personnel.

The batteries hold the ENERGY so they can be very dangerous if improperly handled.

2. Batteries should be discharged before transporting. Discharge according to the battery specific chemistry (slowly!).



Electric Battery SAFETY

3. Electrical Power Connection Terminals should be secured, and insulated.

This is down to prevent short circuiting.

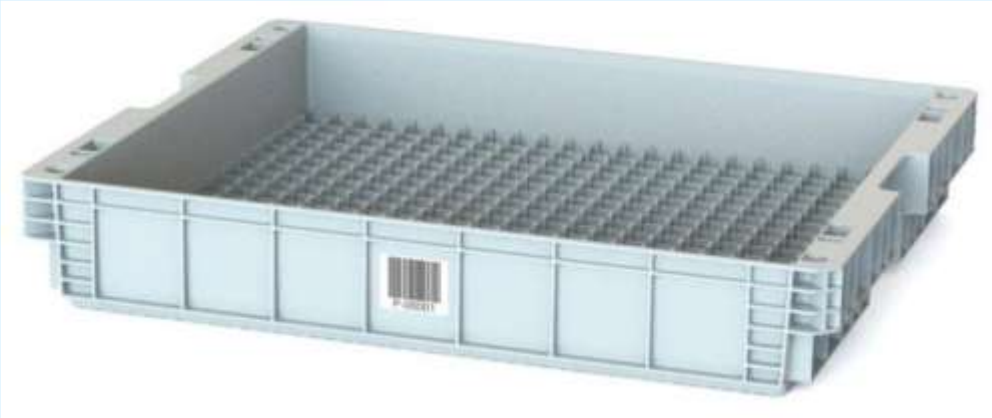
4. Batteries should be transported, as much as possible, on trolleys.

This is to prevent “dropping”.

Electric Vehicle Battery SAFETY

5. If batteries appear to be leaking, they should be placed in a leak-proof bag and tray.

Obvious: electrolyte may be corrosive



6. In case of contact with battery electrolyte, the personal should immediately wash their hands.

Obvious: electrolyte may be corrosive

Electric Vehicle Battery SAFETY

7. EV Batteries should never be transported in passenger cabins of vehicles.

They may outgas, spill, or explode…

8. EV Batteries should not be stored in habited areas.

They may outgas, spill, or explode…

Electric Vehicle Battery SAFETY

9. EV Storage areas should be clearly marked by an identifying sign.

10. EV Batteries should be stored in ventilated, flame proof metal containers away from flammable materials.

Assume they are going to burn, and store appropriately.

11. Keep the batteries as cool as possible.

Electric Vehicle Battery SAFETY

12. EV Battery storage areas should have appropriate fire fighting equipment on hand.

Again assume they will burn and prepare.

13. Type “D” fire extinguishers should be available to fight Lithium fueled fires.

Fire Blankets are becoming more common for EV fires.

Electric Vehicle Battery SAFETY

Damaged battery, especially after car crash, may result in fire or explosion hours or days later

- Isolate Battery in Flame Proof, Ventilated Area
- Keep Fire equipment close by
- If safe, discharge battery slowly

EV Crash Extra Steps

1. Identify the type of vehicle – EV or conventional
2. Shut OFF and Immobilize the vehicle
3. 12V ground line should be severed, if possible
4. Extract occupants

   Be careful not to contact any high-voltage components
5. Monitor the vehicle as fire may re-ignite hours or days later

Use appropriate safety equipment: High-Voltage Gloves

Fire extinguishing may require **large amounts** of water

EV Crash Extra Steps

Dangers:
Electric shock
Silent powered movement
Toxic/flammable gasses
Electrolyte contact
Battery fires and re-ignition
Vehicle Motion
Improper towing risks

Approach vehicle from "corners" to avoid explosion impacting your body

NEVER approach from Front/Back as vehicle may move unexpectedly

EVs are the future, but…

High Voltages and Electric Batteries pose new safety hazards for users

Reasonable precautions should be taken when handling EV Batteries (insulating, discharging, flame-proof storage…)

Damaged Batteries or EV Crashes require special attention

EV Fires can be HARD TO EXTINGUISH and may ignite/reignite after several days

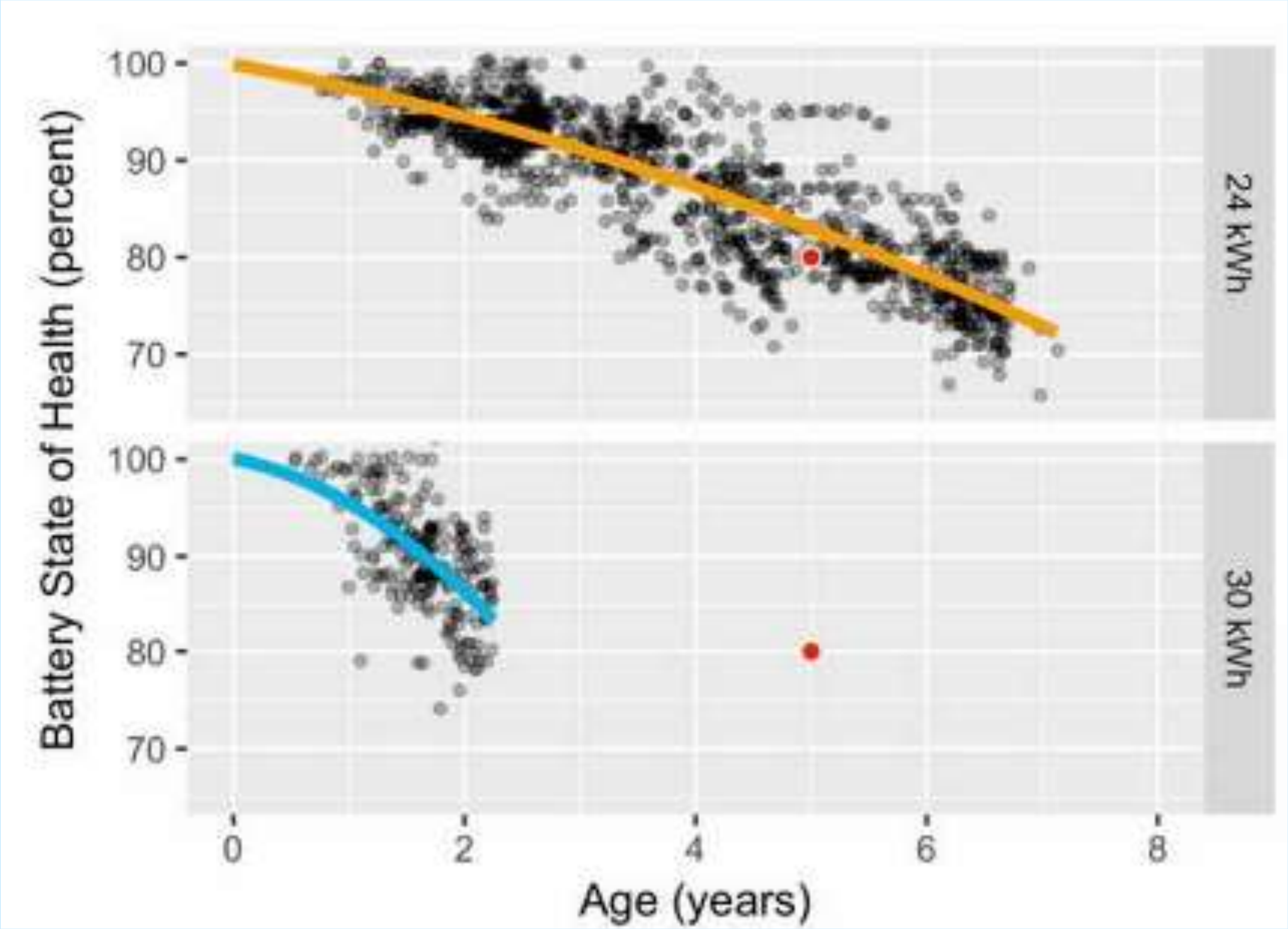
EV Charging poses potential electrical dangers

Focus Applied Technologies
Innovative Technology Product Development

EV Battery Recycling

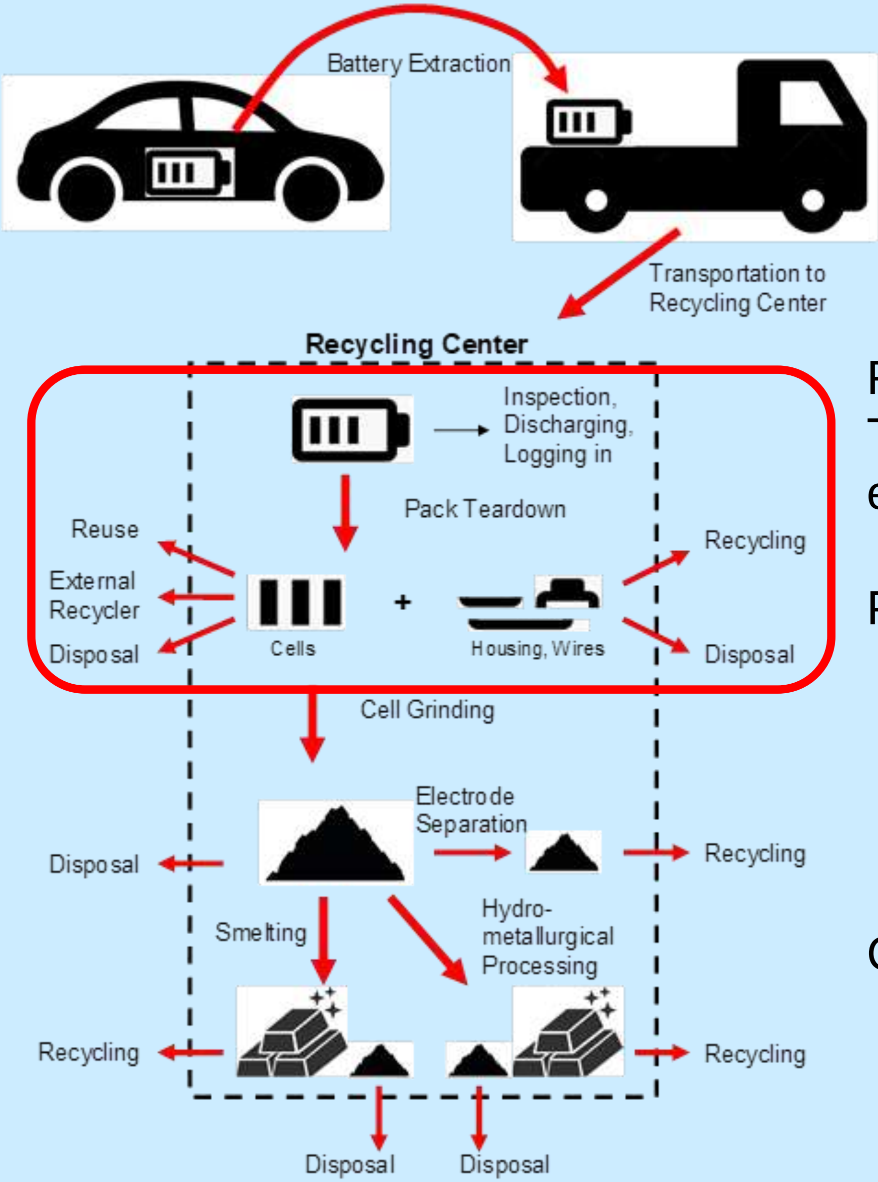
Prof. Dr. Horizon Gitano

Real-World Battery Life: Nissan Leaf



Expected battery life (to 80% SOH) is ~8 years.
Batteries are typically used long beyond this.

PACK RECYCLING RECUPERABLE VALUE



For most countries I recommend Pack Teardown and Recycling, as this can be done economically even at a small scale.

Potentially recovers **only 6-8%** of value.

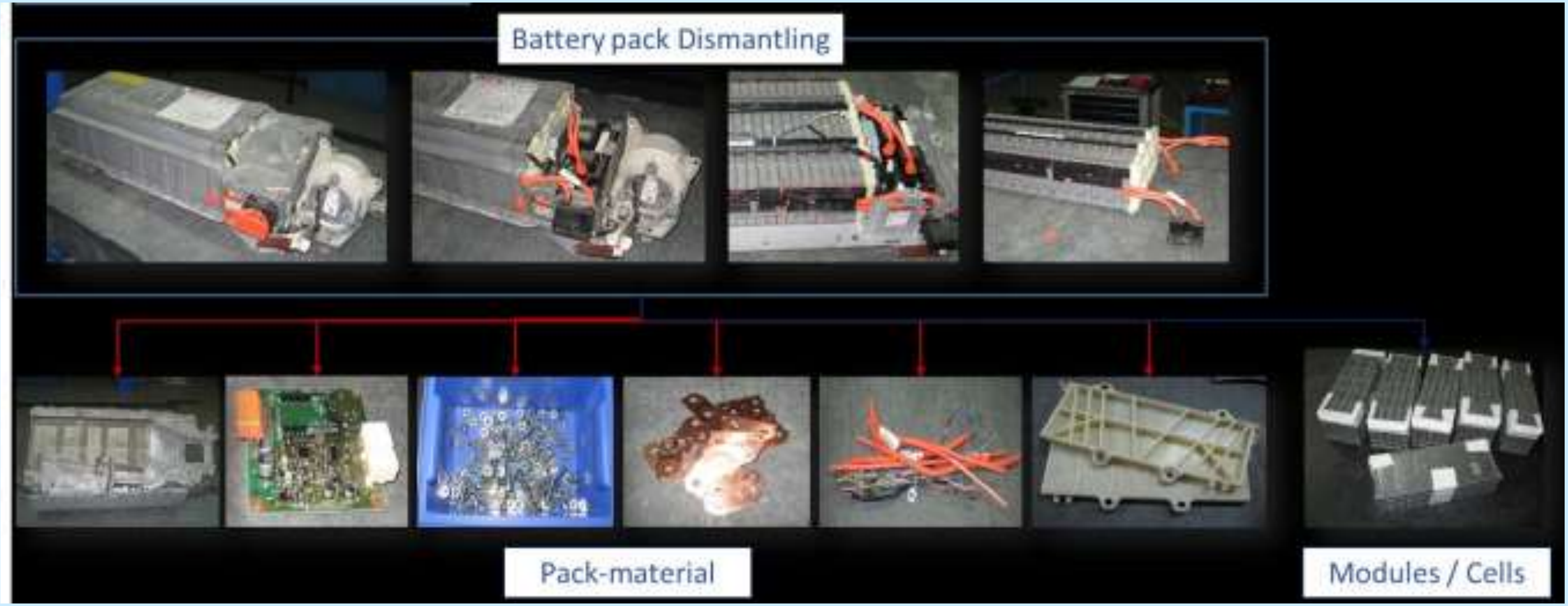
CELLS are **reused**, **exported** or **disposed** of.

PACK RECYCLING RECUPERABLE VALUE

Battery Cell	Material	Aluminum	Cobalt	Copper	Graphite	Lithium	Nickel	Total
Cost	USD/kg	1.79	32	5.7	1.8	13	15.7	
Low Content	g/kg	34.0	0.0	79.0	60.0	7.6	0.0	
High Content	g/kg	42.5	39.0	100.0	70.0	14.0	86.0	
Low Value	USD/kg	0.06	0.00	0.45	0.11	0.10	0.00	0.72
High Value	USD/kg	0.08	1.25	0.57	0.13	0.18	1.35	3.55
Anode/Cathode	Material	Aluminum		Copper				
Low Content	g/kg	34		60				
High Content	g/kg	40		70				
Low Value	USD/kg	0.061		0.342				0.40
High Value	USD/kg	0.072		0.399				0.47
Housing		Aluminum		Copper				
Low Content	USD/kg	17		13				
High Content	g/kg	21		38				
Low Value	g/kg	0.030		0.074				0.10
High Value	USD/kg	0.038		0.217				0.25
					Total All Components	(Low)	USD	1.23
						(High)	USD	4.28

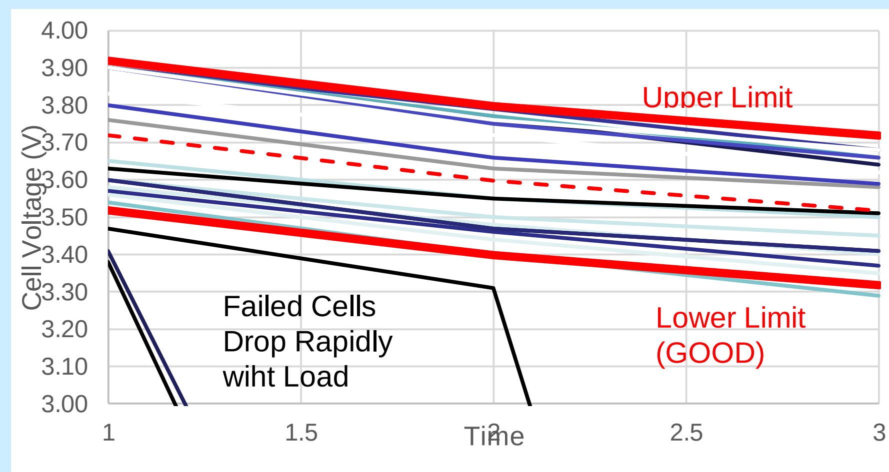
6-8%

Real-World Battery Life



Electric Vehicles Products and Services

Battery Life cycle testing
Controller Repair/Replacement
Battery and BMS Repair/Replacement



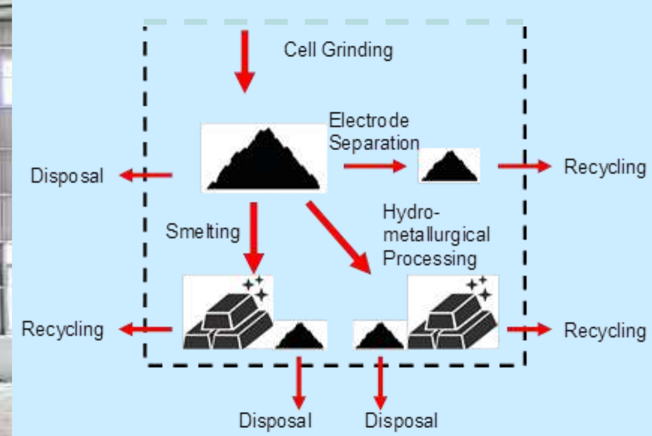
Development of 2nd Life Battery Usage

PbA Battery Replacements
Handfone Power Banks
Uninterruptable Power Supplies (single point)
Portable Utility Banks
Small Solar Applications
- **Ped Path Lighting**
- **Rural Road Lighting**

Household Grid Backup
Solar Aircon
Business Grid Backup (Africa, India, Philippians)

Increasing Energy Content

Cell Recycling: Plant costs are coming down



Cell Shreading. Aqueous Processes not shown

eCoNiL battery

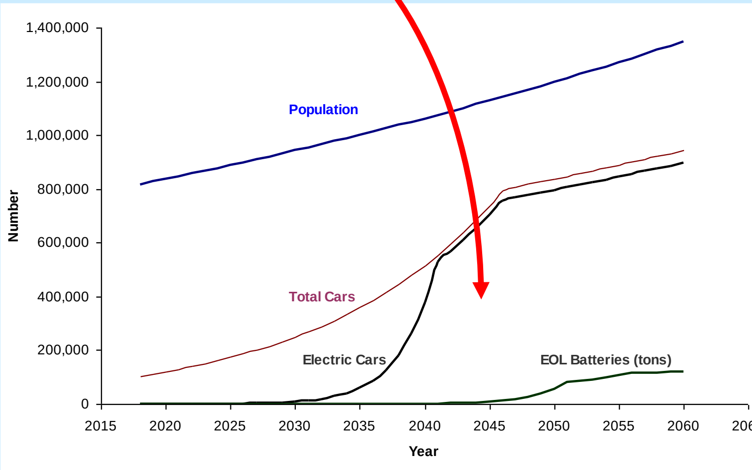
My Cell Recycling Plant Cost estimates:

YEAR	Tons/Year	COST (M$)	$/Ton
2020	100,000	60	600
2025	36,000	13	360

Note: this is plant setup cost per ton of capacity

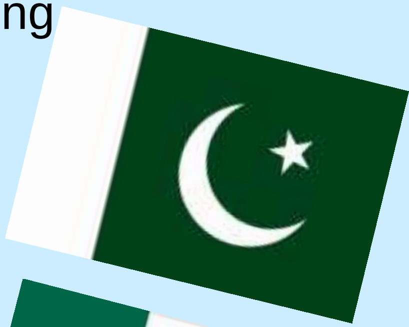
Cell Recycling: Perspective of various countries

BHUTAN
Never going to have the EV battery numbers sufficient to support a recycling plant



MALAYSIA
Already has a cell recycling plant
Not enough local EV batteries to make it profitable
Intends to IMPORT scrapped EV batteries

PAKISTAN
Setting up EV battery plants
Still several years from having enough used EV batteries for Recycling
Got significant mineral deposits



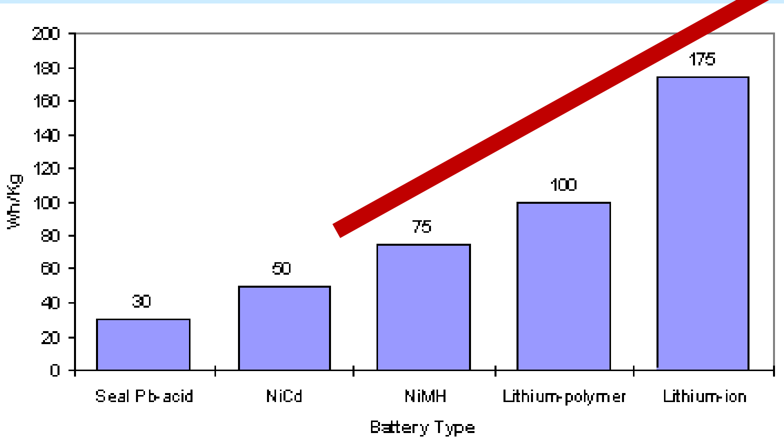
INDONESIA
Investing 6B USD in several EV battery plants
Got significant mineral deposits (including Nickel)

MEXICO
Lots of mineral Resources
EV battery plants coming up
Recycling plants: Setting up in north end to cater to North American EV market

Common EV Batteries

Chemistry		Pertinent Characteristics
Li-Co	Lithium Cobalt	Explosive/Flammable, Good Recovery value
LFP	Lithium	Generally considered safe, Recyclable
LMFP	+ Manganese	Better energy density, Recyclable
Silicon Composite		Higher energy density and charge currents
FUTURE		
Na-Ion	Sodium Ion	Safe, Less expensive, low recycle value
Ultra Capacitor		Instantaneous energy release

?



Battery recycling plants are BIG and EXPENSIVE and require long-term planning, and a LOT of batteries…

But what will we be using in 5 or 10 years?

CONTACT: Don’t Forget Us!

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