

Electric Vehicles (EVs)

A presentation
for the
ESET 441 Photovoltaics Class

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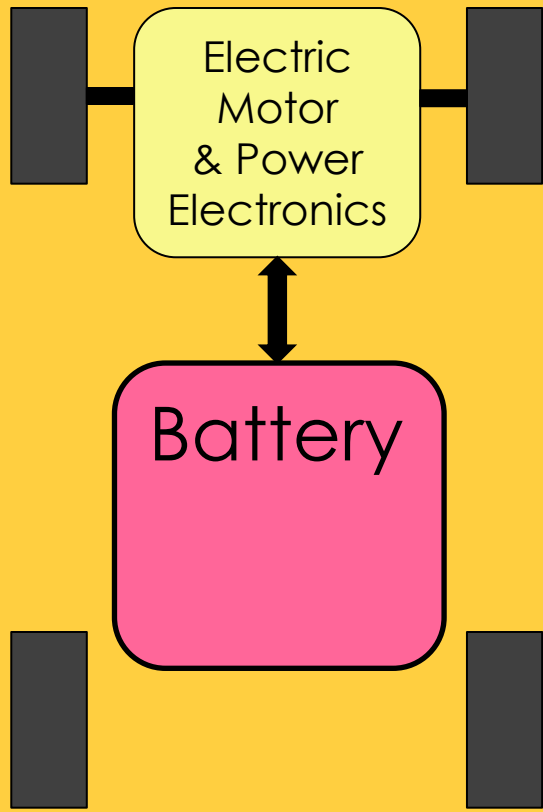
Carbontakedown.com



50 km

40 Minutes

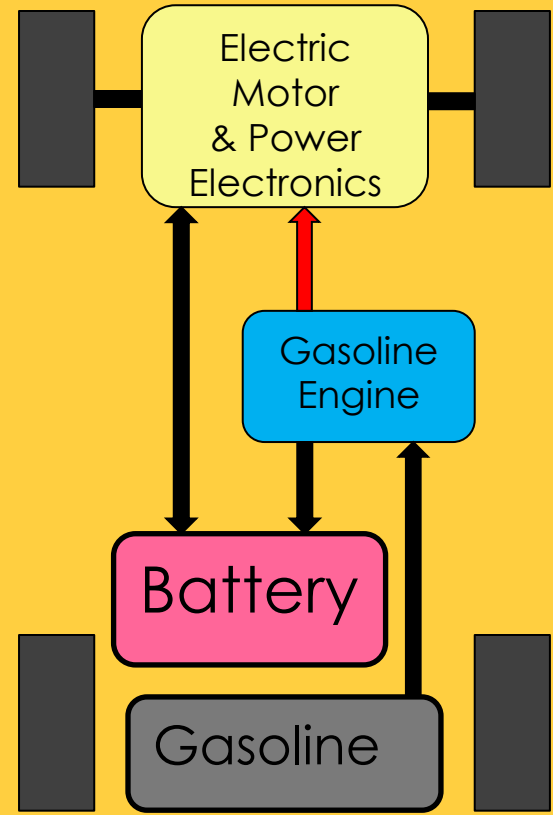
- You and EVs
 - Greenhouse Gas Emissions and EVs
 - Available Vehicles
 - Range
 - Charging
 - Batteries
 - Economics
- EVs and the World
 - The Electricity Grid
 - Manufacturing Impacts
- Your Questions



BEV

Battery Electric Vehicle

EV



PHEV

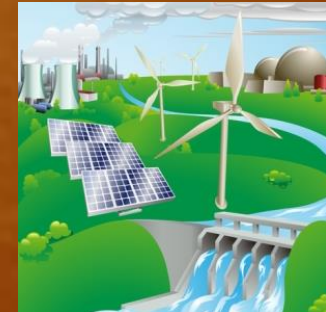
Plug-In Hybrid Electric Vehicle

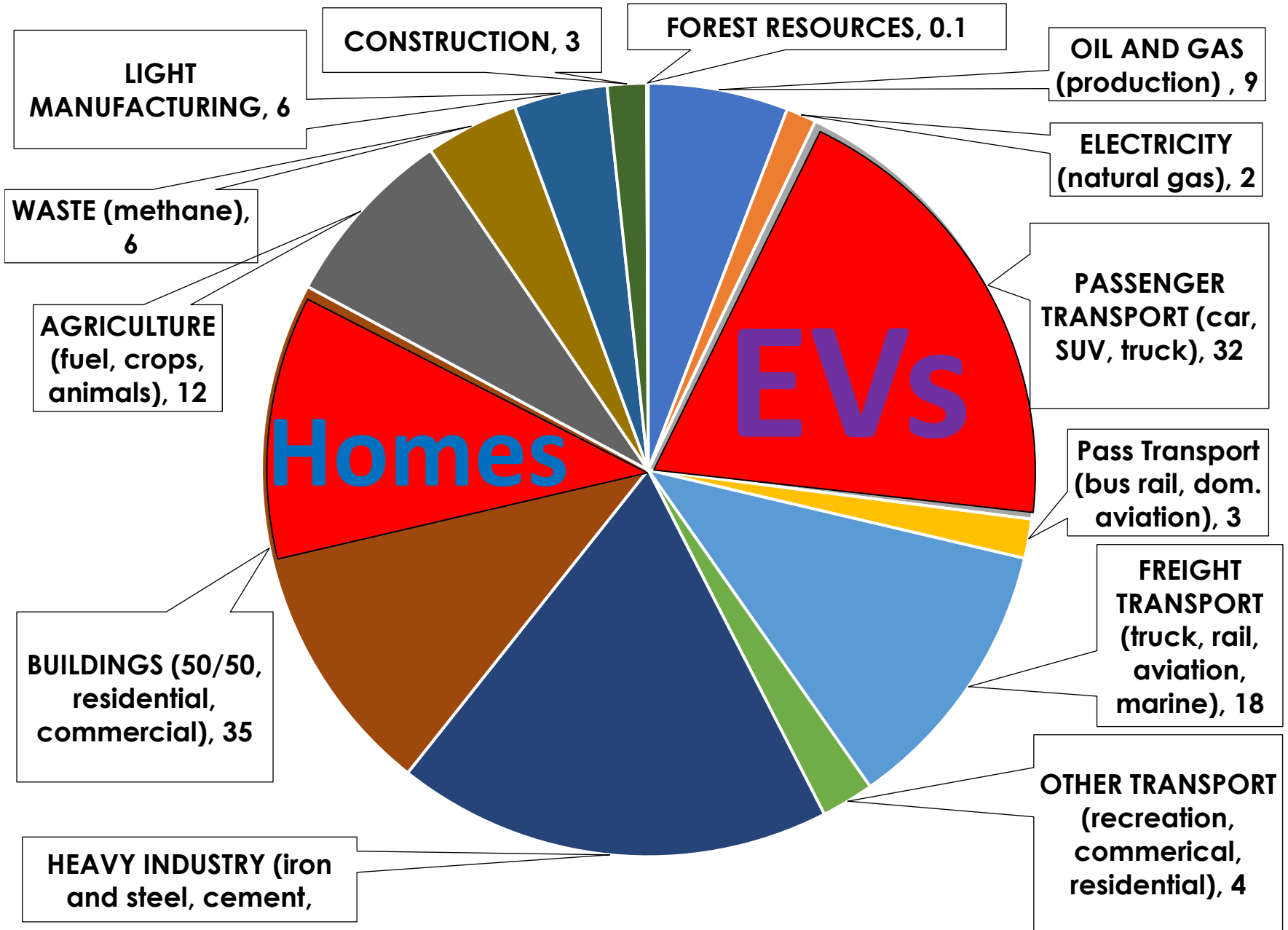
Gasoline Vehicles

- upstream emissions
- mining, extraction
- CO₂
- CO
- nitrogen oxides
- ozone
- hydrocarbons (unburned fuels)
- brake dust

EVs

- no tailpipe emissions
- what electricity source?
- less brake dust





Ontario 2017 159 Mt GHG/year

From 2017 NIR

Ontario's generation mix of hydro, nuclear, wind, solar and natural gas allows an EV in Ontario to have a very, very low GHG impact

0.013 to 0.044 kg GHG/kWh*



2 - 6 t GHG/year

*20,000 km/year

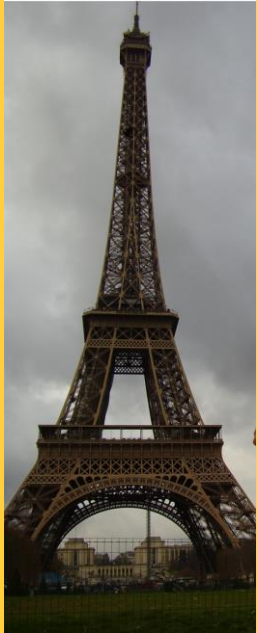


4 - 12 t GHG/year

2 t GHG/person
(return)



1 - 3 t GHG/year
(messy)

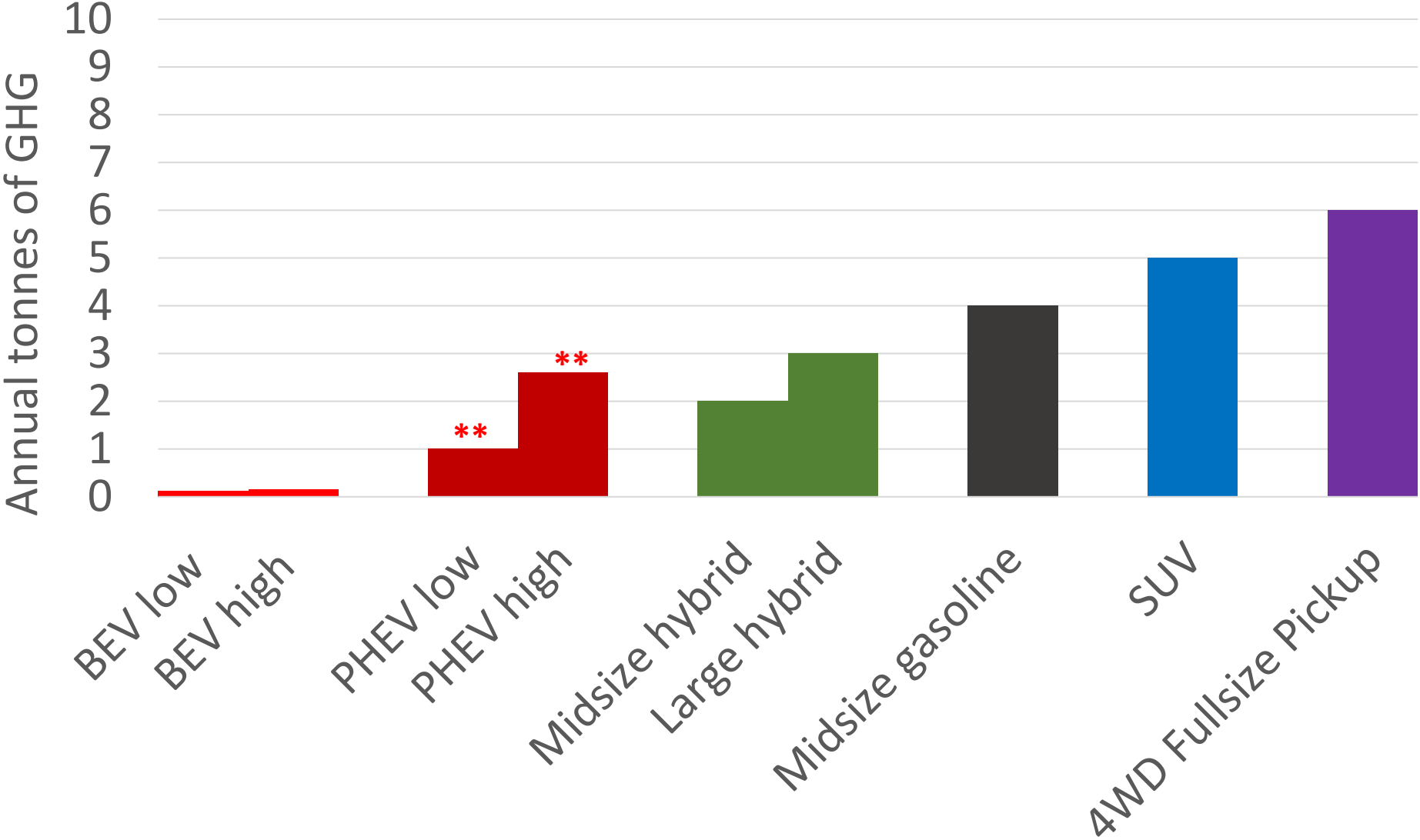


Total 9 - 23 t GHG/year

EV: 0.07 t GHG/year

** 2017 NIR

GHG Emissions per Year by Vehicle Type



20,000 km per year

* 0.04 kg CO₂e Ontario grid emissions

** depends on ratio of EV to gas operation

EV History

1970's
weird EVs



A 1980 Unique
Mobility
Electrek

A good effort,
not a good
car!

Lead acid
batteries not
up to task in
distance or
economics.



April 2014 – 3 models



320,000 Sold

Forces Driving the EV Market

- Enabling technologies of high performance batteries and electronics
- Public and political forces with worldwide goal of zero GHG by 2050
- Regulations in many countries to reduce GHG from:
 - transportation
 - electricity generation
 - industrial processes



2021 BEV
40+ models



6,000,000 Projected

70,000 Plug In Vehicles in Ontario

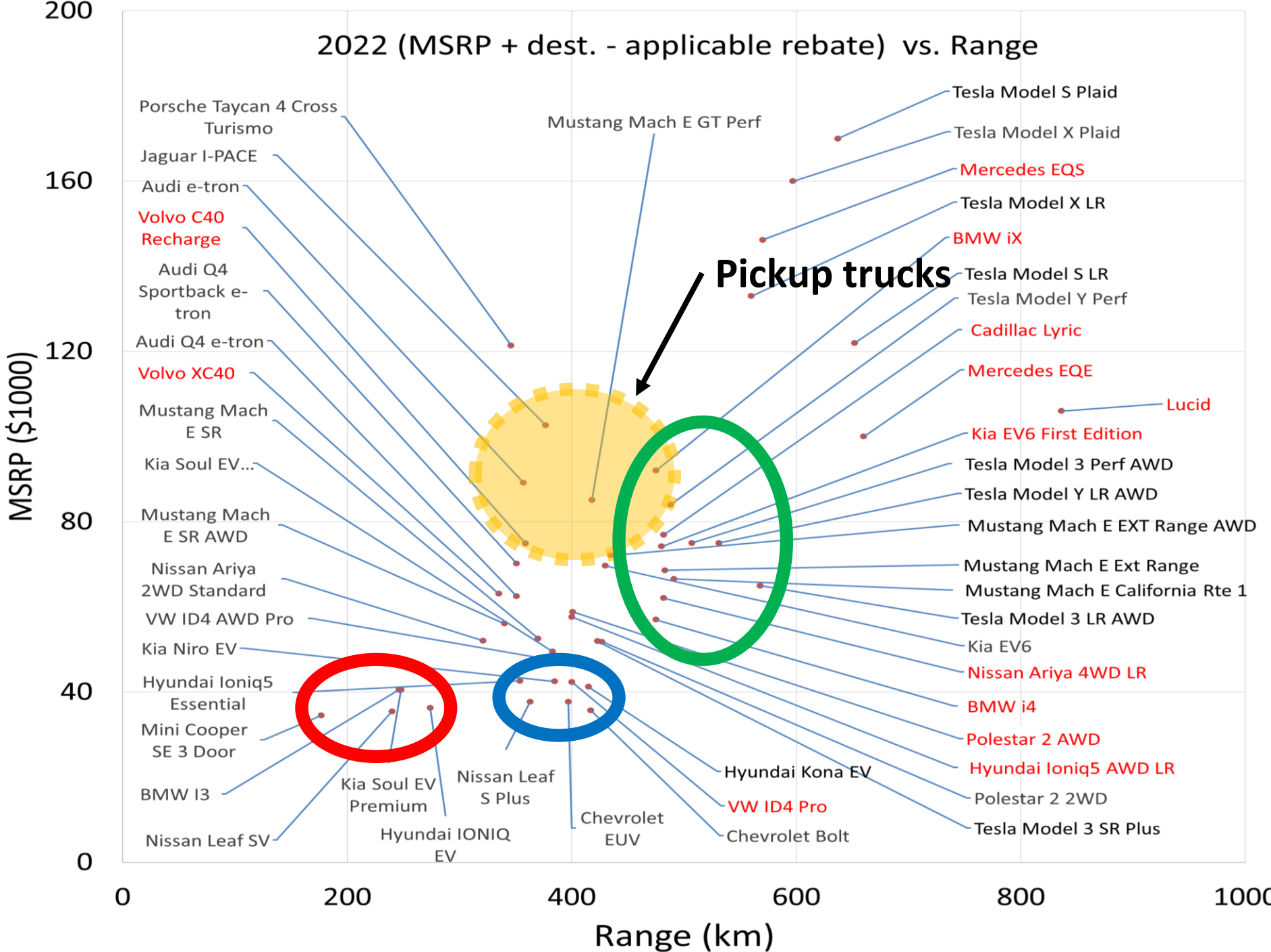
(IEA estimates 250 M
Worldwide by 2030)

Range and Price

2022 BEV (100% Electric) 49 +/- Models

100% Battery Electric Vehicles	Range (km)	Price in \$1000's inc. del.	MSRP (plugndrive) 1000s includes del.
Lucid	836	106.0	\$106,000
Mercedes EQE	660	100.0	\$100,000
Tesla Model S LR	652	122.0	\$121,990
Tesla Model S Plaid	637	170.0	\$169,990
Tesla Model X Plaid	597	160.0	\$159,990
Mercedes EQS	570	146.2	\$146,200
Tesla Model 3 LR AWD	568	65.0	\$64,990
Tesla Model X LR	560	133.0	\$132,990
Tesla Model Y LR AWD	531	75.0	\$74,990
Tesla Model 3 Perf AWD	507	75.0	\$74,990
Mustang Mach E California Rte 1	491	66.6	\$66,590
Tesla Model Y Perf	488	84.0	\$83,990
Mustang Mach E Ext Range	483	68.6	\$68,590
Nissan Ariya 4WD LR	482	62.1	\$62,050
Cadillac Lyric	482	77.0	\$76,950
Kia EV6 First Edition	480	74.2	\$74,200
BMW i4	475	57.0	\$56,990
BMW iX	475	92.0	\$91,990
Mustang Mach E EXT Range AWD	435	72.1	\$72,090
Kia EV6	430	69.7	\$69,654
Polestar 2 2WD	427	51.8	\$51,800
Tesla Model 3 SR Plus	423	52.0	\$56,380
Mustang Mach E GT Perf	418	85.1	\$85,090
Chevrolet Bolt	417	35.7	\$40,098
Hyundai Kona EV	415	41.2	\$45,651
Polestar 2 AWD	401	58.8	\$58,800
Hyundai Ioniq5 AWD LR	400	57.6	\$62,049
VW ID4 Pro	400	42.4	\$46,780
Chevrolet EUV	397	37.7	\$42,098
VW ID4 AWD Pro	386	47.4	\$51,780
Kia Niro EV	385	42.5	\$46,929
Kia Soul EV Limited	383	49.5	\$53,929
Jaguar I-PACE (CO)	377	102.6	\$102,626
Mustang Mach E SR	370	52.6	\$52,590
Nissan Leaf S Plus	363	37.7	\$42,174
Volvo C40 Recharge	359	74.9	\$74,900
Audi e-tron	357	89.2	\$89,150
Hyundai Ioniq5 Essential	354	42.6	\$47,049
Audi Q4 e-tron	351	62.5	\$62,500
Audi Q4 Sportback e-tron	351	70.2	\$70,150
Porsche Taycan 4 Cross Turismo	346	121.4	\$121,400
Mustang Mach E SR AWD	340	56.1	\$56,090
Volvo XC40	335	63.1	\$63,070
Porsche Taycan S Cross Turismo	325	219.5	\$219,500
Nissan Ariya 2WD Standard	321	52.1	\$52,050
Hyundai IONIQ EV	274	36.3	\$40,726
Kia Soul EV Premium	248	40.5	\$44,929
BMW i3	246	40.5	\$44,950
Nissan Leaf SV	240	35.4	\$39,874
Mini Cooper SE 3 Door	177	34.5	\$38,956

2022 (MSRP + dest. - applicable rebate) vs. Range



2022 PHEV 40 +/- Models

Plug In Hybrids (PHEV) 2021/2022	100% EV Range (NRCAN)
BMW i3 Rex	203
Polestar 1	84
Honda Clarity PHEV	77
Toyota Rav4 Prime	68
Lexus NX 450h+ PHEV	61
Ford Escape PHEV	60
Fiat Chrysler Pacifica PHEV	51
BMW X5 xDrive45e	50
Hyundi Santa Fe PHEV	50
Hyundai IONIQ PHEV	47
Lincoln Corsair Grand Touring	45
Kia Optima PHEV	45
Kia Niro PHEV	42
Audi A7 Sportback 55 TFSI e	42
Toyota Prius Prime	40
Mitsubishi Outlander PHEV	39
Audi Q5 55 TFSIe	37
BMW 330e	37
Volvo S60 T8 AWD Recharge	35
Jeep Wrangler 4xe	35

Plug In Hybrids (PHEV) 2021/2022	100% EV Range (NRCAN)
Lincoln Aviator Grand Touring	34
Volvo S90 T8 AWD Recharge	34
BMW 530e	34
Land Rover RR PHEV	31
Volvo SV60 T8 AWD Recharge	31
Volvo XC60 T8 AWD	31
BMW 530e xDrive	31
Porsche Panamera 4E-Hybrid	31
Bently Bentaga	29
Audi A8 L 60 TFSIe	29
BMW X3 xDrive 30e	29
Mini Cooper SE Countryman All4	29
Volvo XC 90 T8 AWD Recharge	29
BMW X3 xDrive30e	29
Subaru Crosstrek Hybrid AWD	27
Subaru Crosstek PHEV	27
BMW 745Le xDrive	27
Porsche Cayenne E-Hybrid	27
Porsche Panemara Turbo SE-Hybrid	27
Porsche Cayenne Turbo SE-Hybrid	24
Mercedes GLC350e	21

Range Change

- On mild spring and fall days range may be better than NRCAN on non-highway trips, “400” km may be 450 km
- kWh consumption increases with speed²
- BEV worst day (-25°C, snow) range at 110 kph could be 40 - 50% reduced.
- PHEV range ½ in winter, engine for heat
- A few percent a year range decrease due to battery aging
- Older model EVs, good value, less range

Batteries

Batteries

Lithium is the fundamental element in all current EV batteries. But Nickel, Cobalt Oxide, Manganese, Iron, Titanate and Aluminium also:

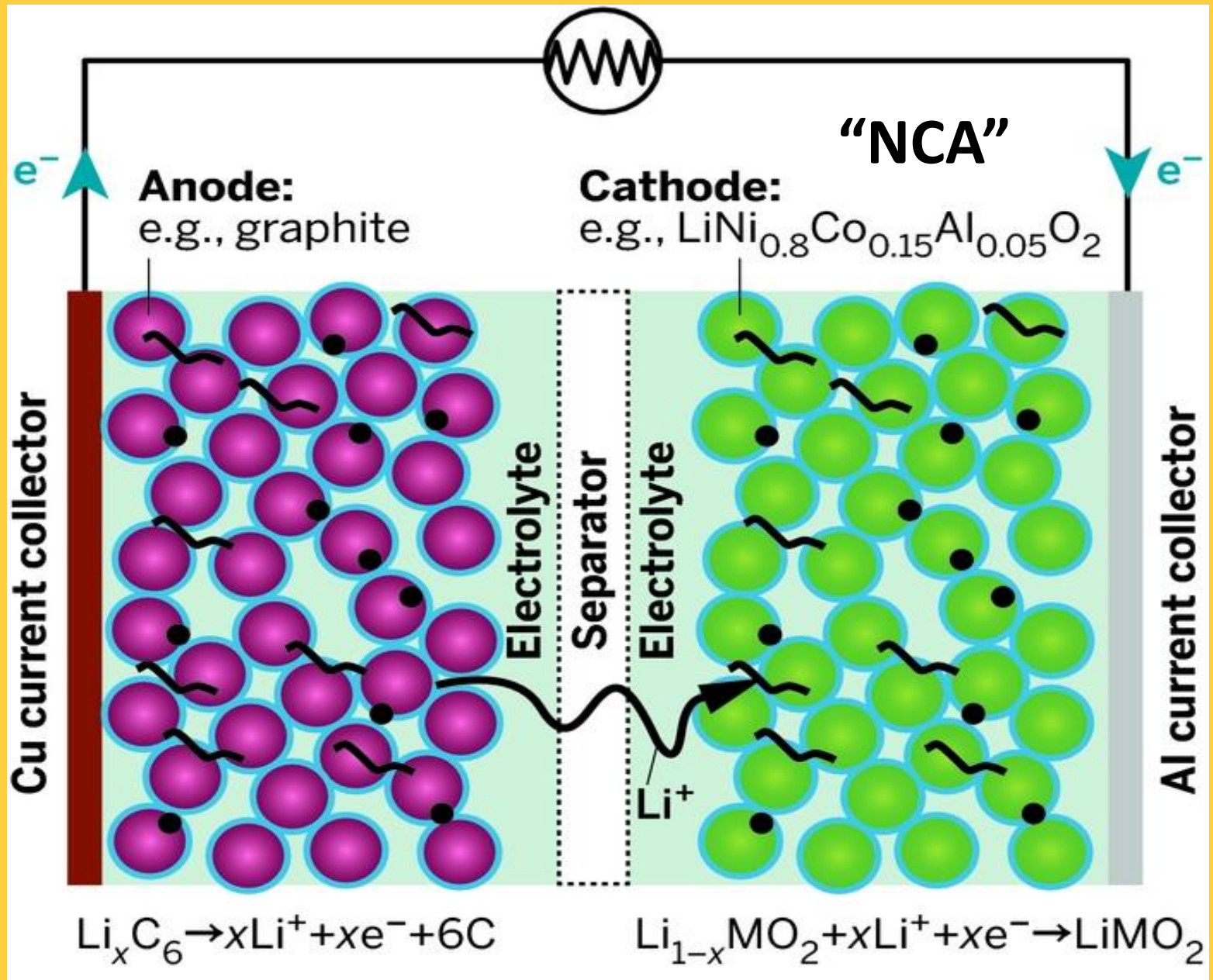
- EVs have from 24 kWh to 118 kWh battery capacity.
- Typical EV Energy Usage is from 15 kWh/100 km to 25 kWh/100 km
- Range = $66 \text{ kWh} / (18 \text{ kWh}/100 \text{ km}) * 100 = 366.7 \text{ km}$

“Lithium” Batteries

Automotive EV Batteries:

Characteristics needed:

- High energy density kWh/kg
- High specific power kW/kg
- Good safety – overcharge and accident safety
- Low cost
- Good cycle life – 1000 to 3000 cycles



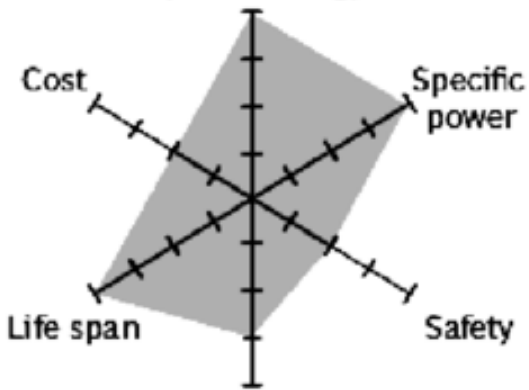
IF Ni, Co and Al are used in equal proportions, "NCA111"

Li-ion Technology Comparisons (Energy Application)

Parameter	LCO	LMO	NMC	NCA	LFP	LTO
Efficiency	90%	95%	93%	90%	95%	97%
C Rates	C/4- 1C	C/4-3C	C/4- 2C	C/4-1C	C/4- 2C	C/4-10C
DOD	80%	80%	90%	80%	90%	90%
Wh/Kg (ED)	160-177	140-158	180-196	200-213	130-143	75-84
Wh/L (ED)	380-400	350-358	420-433	450-466	270-282	175-186
W/Kg (PD)	30-50	30-60	40-60	40-60	25-45	600-800
Cycle Life	800-1000	800-1000	3800-4000	3300-3500	3800-4000	7500-8000
Chemistry	Li, Co	Li, Mn	Li, Mn, Ni, Co	Li, Ni, Co, Al	Li, Fe	Li, Ti, Mn
Toxicity	High	Medium	High	High	Low	Medium
Max. Temp.	45	55	55	55	55	65

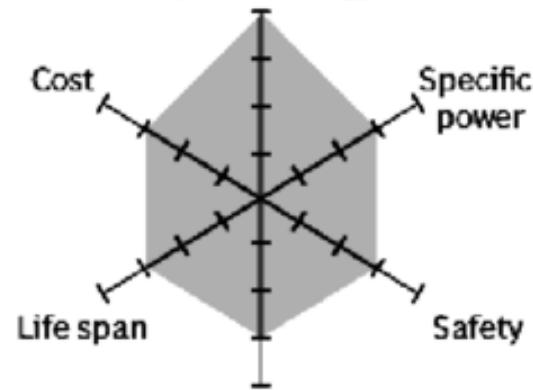
Lithium-nickel-cobalt-aluminum (NCA)

Specific energy



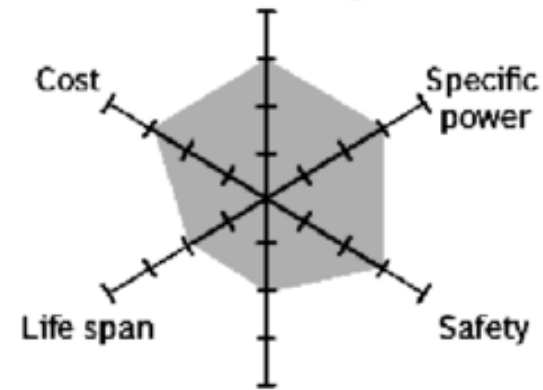
Lithium-nickel-manganese-cobalt (NMC)

Specific energy



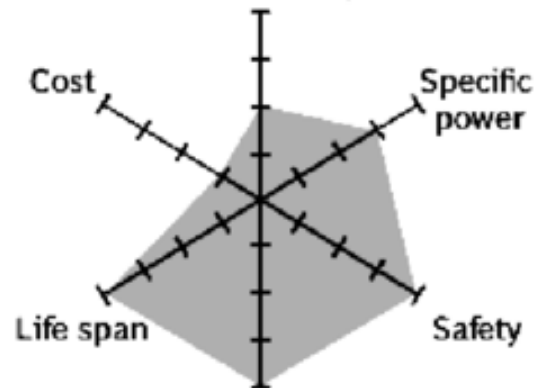
Lithium-manganese spinel (LMO)

Specific energy



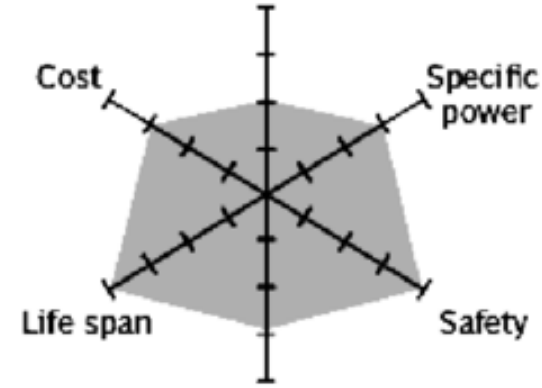
Lithium titanate (LTO)

Specific energy



Lithium-iron phosphate (LFP)

Specific energy



Performance

Performance

Charging

LEVEL 3 (Petro Canada)





**Level 3 High
Power “CCS”**

**Level 1 and 2
at home or
away “J1772”**



Other Connectors



Tesla



**CHAdeMO
Level 3
Leaf, Soul**

**SAE J1772
Level 2**

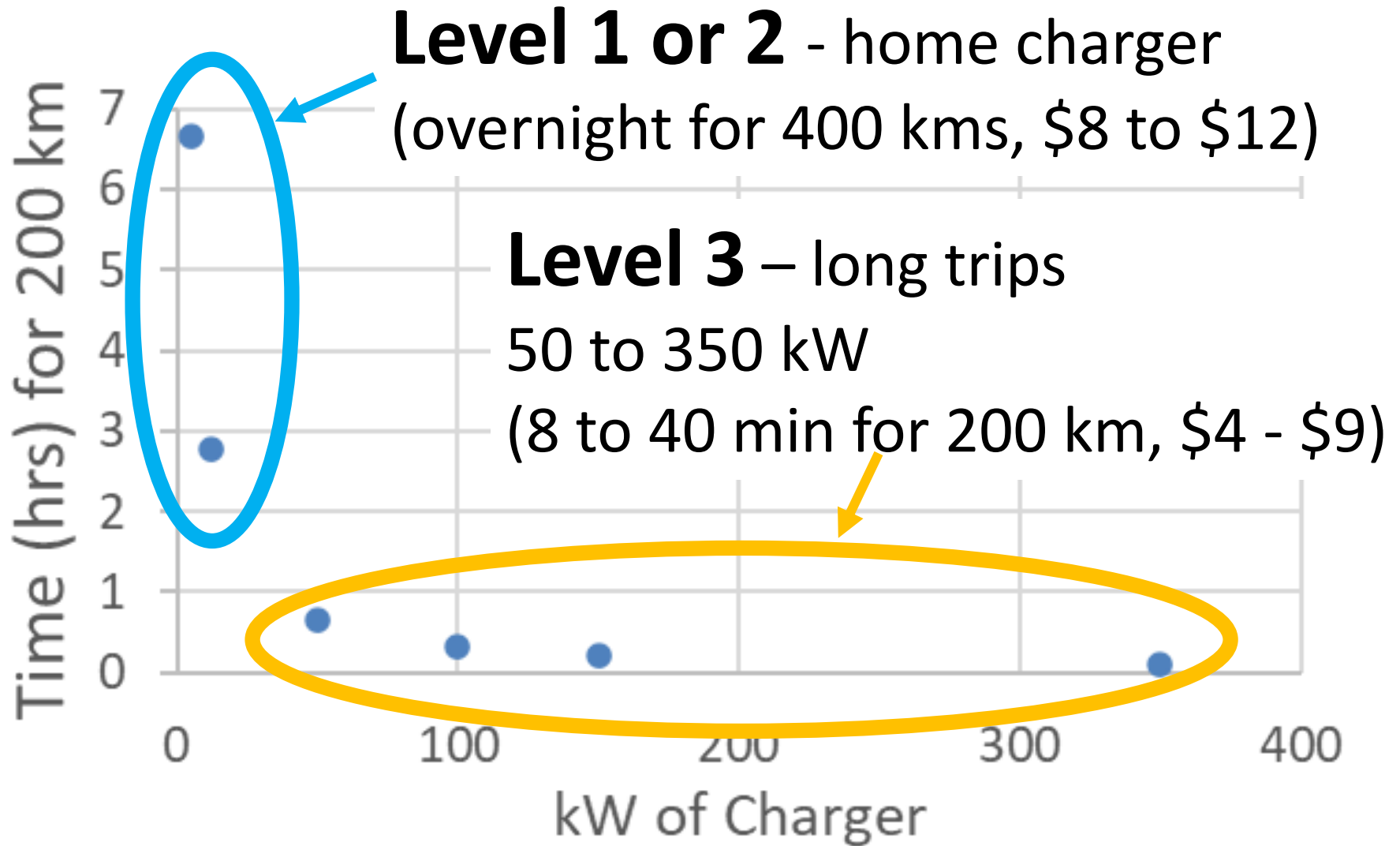


CHAdeMO

Charging

- The vast majority of charging will be done at night at your residence, inside or outside (condos?)
- On trips of more than 300 - 400 km you'll use Level 3 for fee chargers
- On the longer trips you will need some apps to access all chargers (over 15 companies), but some take credit card taps
- PHEVs only have Level 2 charging

Charging time/km/\$



Charging Curves

https://www.youtube.com/watch?v=FgqCyy53C_g&t=301s

Battery Degradation

<https://www.geotab.com/file-management-solutions/ev-battery-degradation-tool/>



AAC-00075

[Back](#)

Network: FLO

FLO - Cadillac Fairview - Fairview Mall1800 Sheppard Ave E , North York, ON,
M2J 5A7

CHAdeMO & CCS Combo

FAST DC



Directions



Favorite

STATION AVAILABLE**\$20.00 (CAD) per hour**

CHAdeMO connector

\$20.00 (CAD) per hour

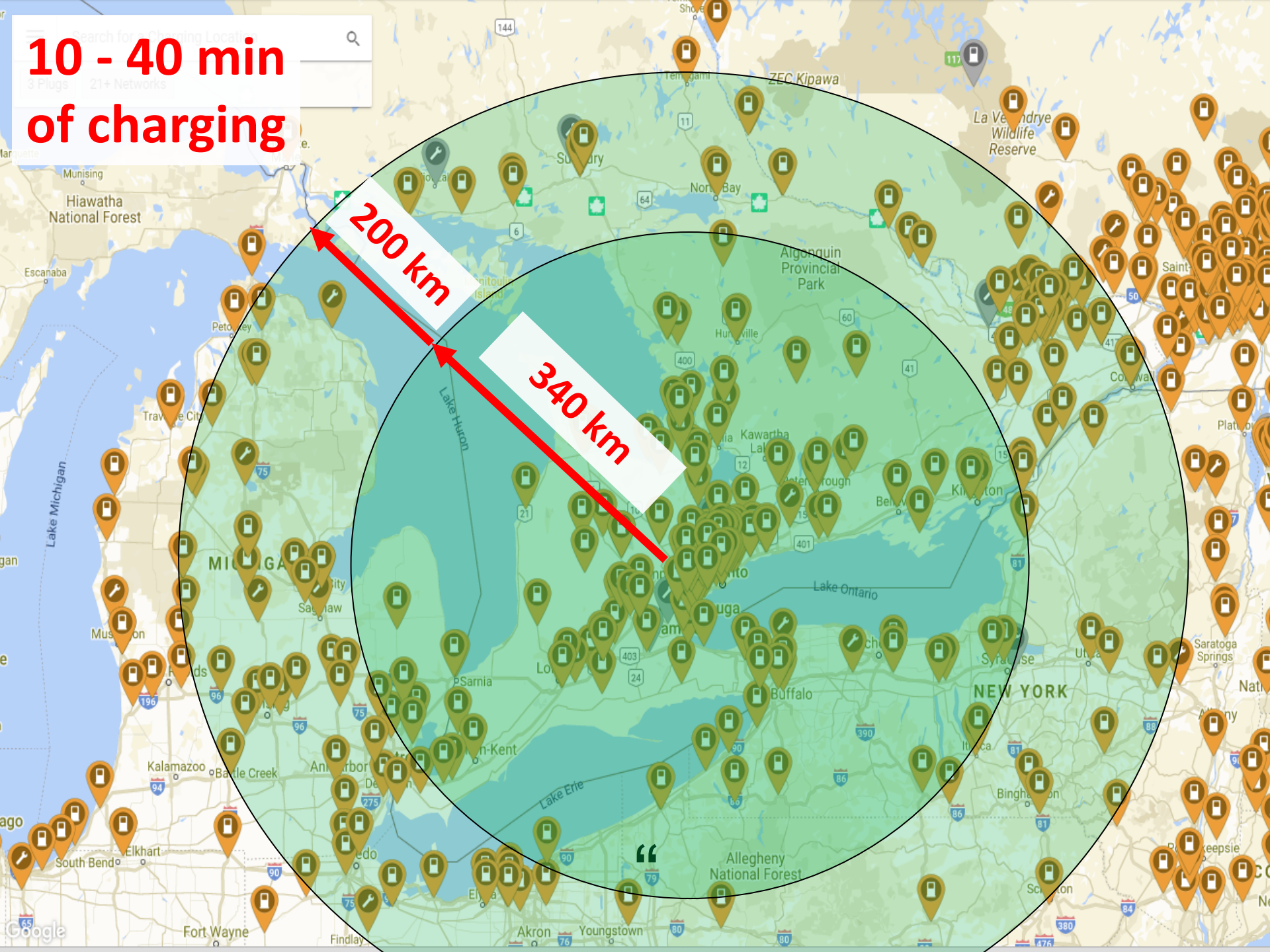
SAE Combo connector

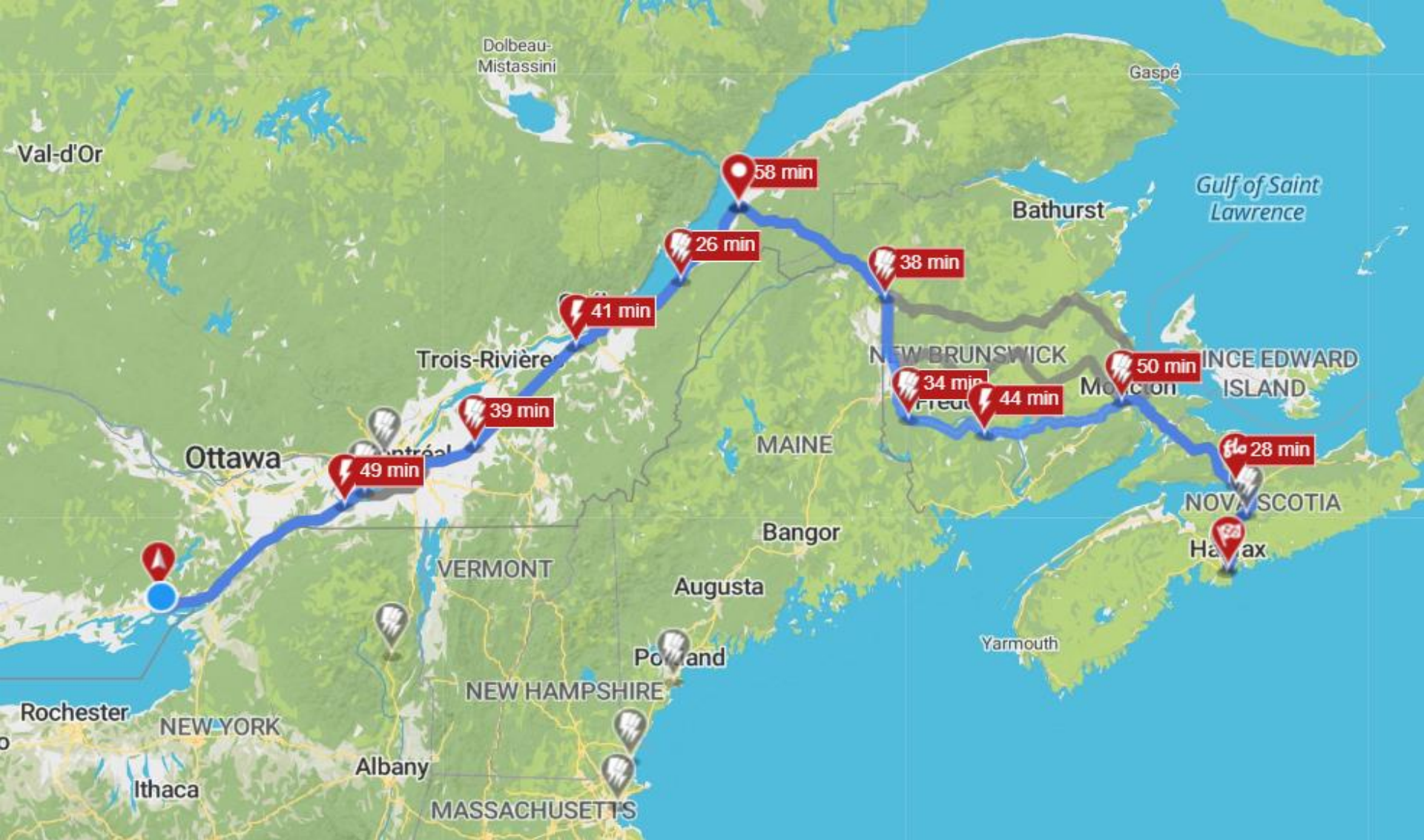
Start session

Search for Charging Location

**10 - 40 min
of charging**

3 Plugs 21+ Networks





Trip Planning Software ("A Better Routeplanner")

Costs

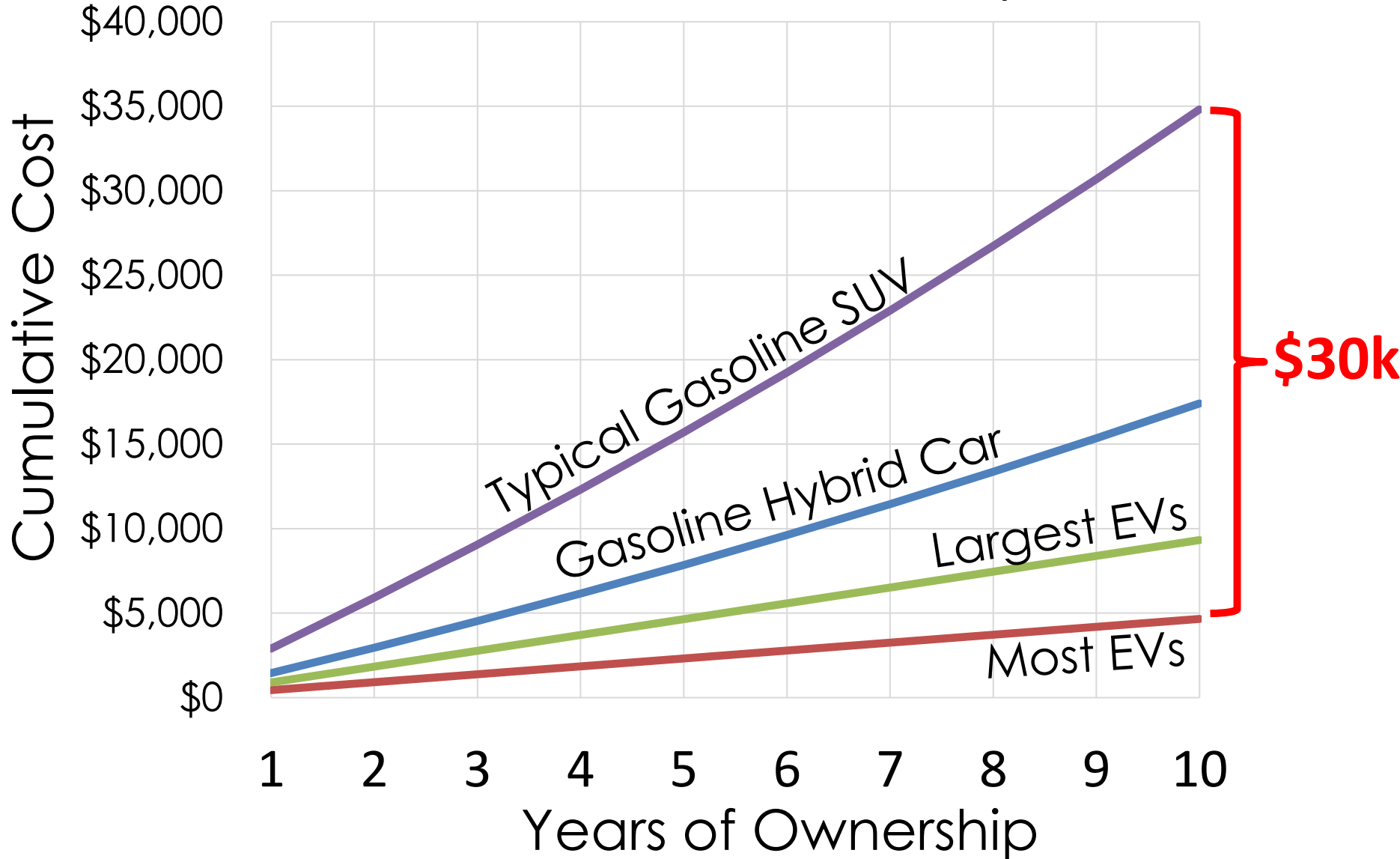


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3,000 to 4,000 kWh/year

Cumulative Fuel/Electricity Cost



(\$1.45/litre, \$0.15/kWh, 20,000 km/year, 4% infl.)

5 Year Net Vehicle Cost

	Kona Gas	Prius	Kona EV	Chevy Bolt EV
MSRP+Dest.	\$ 26,154	\$ 31,071	\$ 45,651	\$ 40,098
Tax	\$ 3,400	\$ 4,039	\$ 5,935	\$ 5,213
Federal rebate	\$ -	\$ -	\$ 5,000	\$ 5,000
Energy (Gasoline or Electricity)				
1st Year	\$ 2,212	\$ 1,260	\$ 513	\$ 513
2nd "	\$ 2,300	\$ 1,310	\$ 533	\$ 533
3rd "	\$ 2,392	\$ 1,363	\$ 555	\$ 555
4th "	\$ 2,488	\$ 1,417	\$ 577	\$ 577
5th "	\$ 2,588	\$ 1,474	\$ 600	\$ 600
5 year insurance	\$ 4,000	\$ 4,000	\$ 5,000	\$ 5,000
5 year maintenance	\$ 5,000	\$ 5,000	\$ 2,500	\$ 2,500
Trade in Value	\$ 13,299	\$ 15,800	\$ 21,374	\$ 16,251
Net Expense	\$37,236	\$35,135	\$36,402	\$30,140
5 Year GHG tonnes Emitted	18.2	10.4	0.68	0.68

Plus \$1000 to \$1500 one time \$ for a charger at home

The Bigger Picture



Impact of EVs on the Ontario Electricity Grid

1,000,000 EVs each going 20,000
km/year would create a

2.5%

increase in Ontario's total 137
TWh of electricity generation

The vast majority of charging
can be programmed to be in
off peak nighttime periods

Batteries
Manufacturing
Recycling

Battery Materials

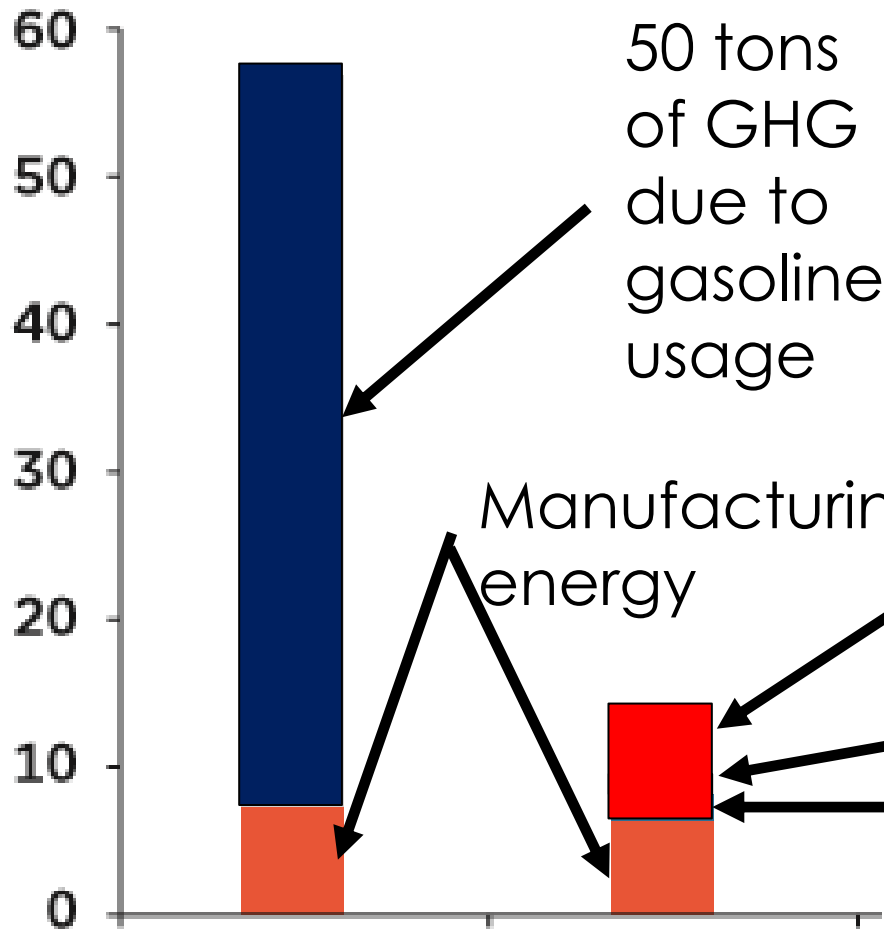
- 10 kg Lithium per EV = 5.3 billion batteries (1.3 B pass. vehicles world)*
- Other battery chemistries are in use, some require no conflict (Cobalt) minerals

Human Rights / Environmental Impact

- Fossil fuel extraction/use has climate change plus large scale human rights and environmental impacts
- Mining of battery minerals has negative impacts and they can be addressed with policy, laws and through activist pressure and corporate action – all happening
- Virtually every EV maker has ethical supply chain policies
- Recycling being developed in many places

*U.S. Geological Survey, Mineral Commodity Summaries, January 2018

Life Cycle Global Warming Emissions (tons CO₂e)



50 tons of GHG due to gasoline usage

• 220,000 km vehicle life

Manufacturing energy

Worst case larger battery

Ontario electricity (for 220,000 km)

EV Battery

Midsize Average Gasoline Car

Midsize 84-mile-range BEV (1 Li-ion Battery)

Base data from 2015
Union of Concerned Scientists – Cradle to Grave, includes upstream fuel production emissions

Wrap-up

EVs and the World

- We humans must virtually eliminate the burning of fossil fuels, that is job one.....EVs address the existential nature of global warming and local pollution
- Global deployment of EVs using low carbon electricity will eliminate 1000's of millions of tonnes of GHG
- Automakers are working to source conflict free minerals and commercialize new battery chemistries, Cobalt already eliminated in some batteries.
- EVs, like all consumer purchases, have impacts, they do not solve every problem

EVs and you

- An EV in Ontario offers a dramatically reduced personal vehicle GHG footprint
- Basic EVs have similar ownership cost to equivalent fossil fuel cars
- Use your gas or electric car as little as possible, walk, bike, public transport
- Make it last as long as possible = less resource extraction
- Long distance travel entirely feasible, requires app use and time to charge

Thank you for your attention.

Questions?

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Carbontakedown.com