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- Improving our members knowledge in technologies thru Technical talks
- Mixers for networking

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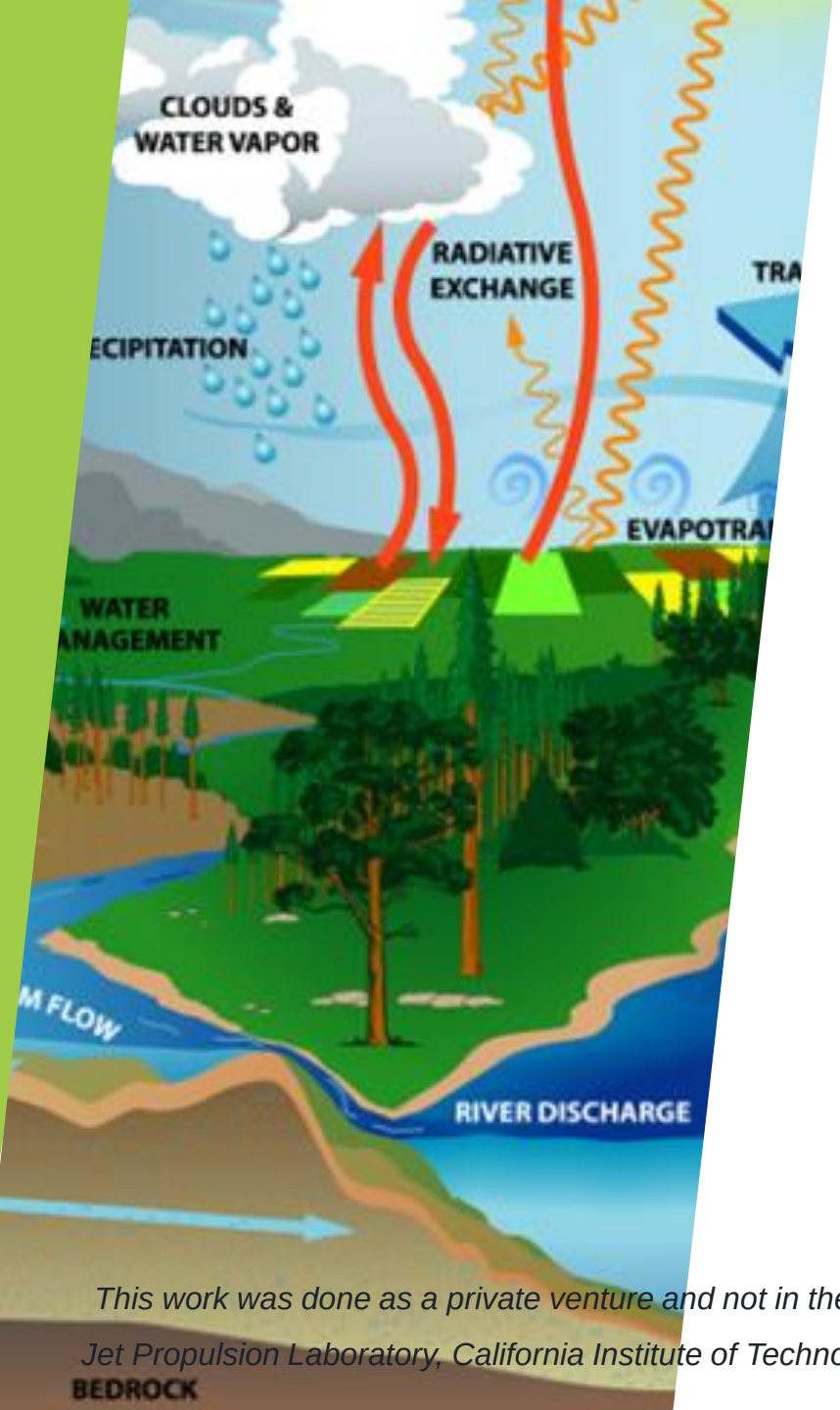


# EV (Electric Vehicle): technology and its implications on Climate Change

Momin Quddus

*Senior Member, IEEE*

*This work was done as a private venture and not in the author's capacity as an employee of the Jet Propulsion Laboratory, California Institute of Technology*.

# Significant Interest in Electric Vehicles

There has been a lot of interest in EVs from various segments of our economy.
Namely,

- Consumers (Potential EV buyer)
- Environmental Activists (Sierra Club etc)
- Investors (Financial Markets)
- Government Officials (Politicians, policy maker)

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# In this lecture

Automotive Technologies

Fuel and Energy

Environmental Impact

Financial Opportunities

# EV - Definition

- An **electric vehicle** (**EV**) is a vehicle that uses one or more electric motors or traction motors for propulsion.. (Wikipedia)

This is a traditional definition. There are other types of vehicles that employ electric motors, these are,

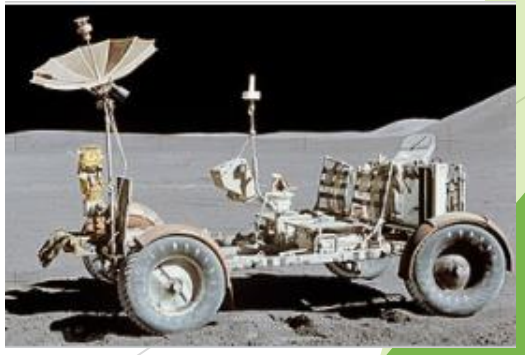
a) Hybrid car,
b) Plug-in hybrid car
c) Hydrogen car.

# Some History

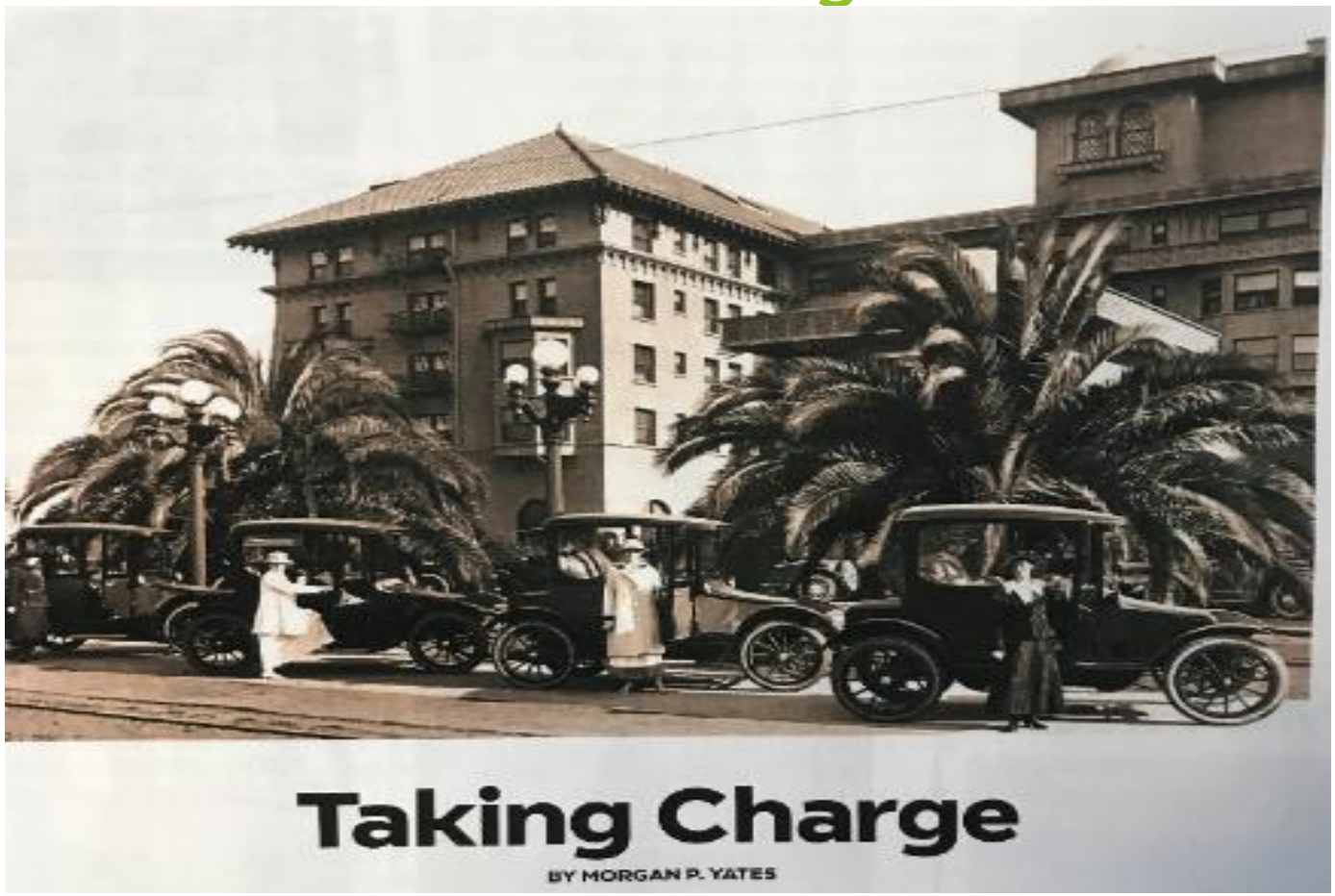
- **First Electric Car was built by French Electrical Engineer named Gustav Trouve in 1881.**

- **Belgian vehicle La Jamais Contente was the first electric car to reach 100kmh in 1899.**


- The Lunar Roving Vehicle (LRV) is the most well known electric vehicle. It was driven on the moon's surface. It was most popularly known as Moon Buggy.



# Beardsley Electric Car Rally in 1919 for ladies in Long Beach



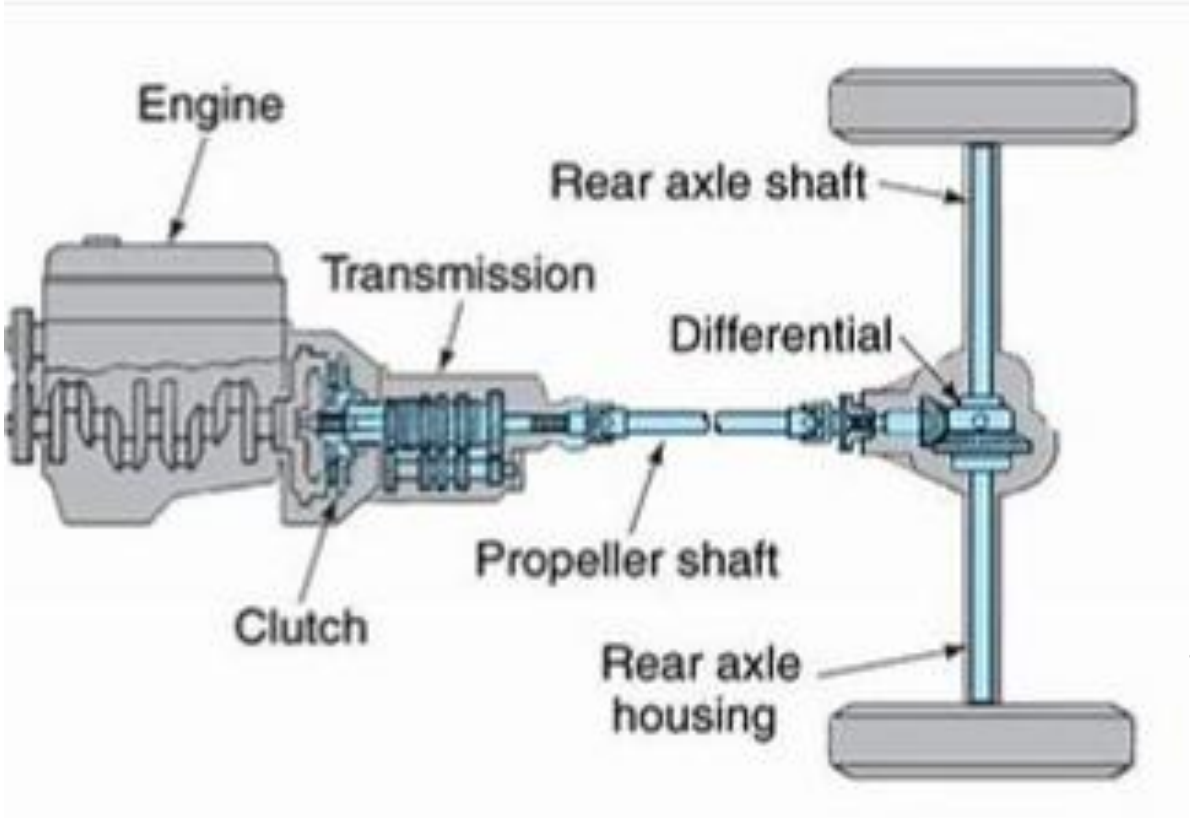

Beardsley Electric Cars were gaining popularity among women in 1920s because starting an ICE car with a crank shaft was difficult & dangerous.

Cadillac installed electric starters in its cars which reduced the appeal of electric cars.

# Automotive Technology

# Gasoline Vehicle - ICEV: Internal Combustion Engine Vehicle

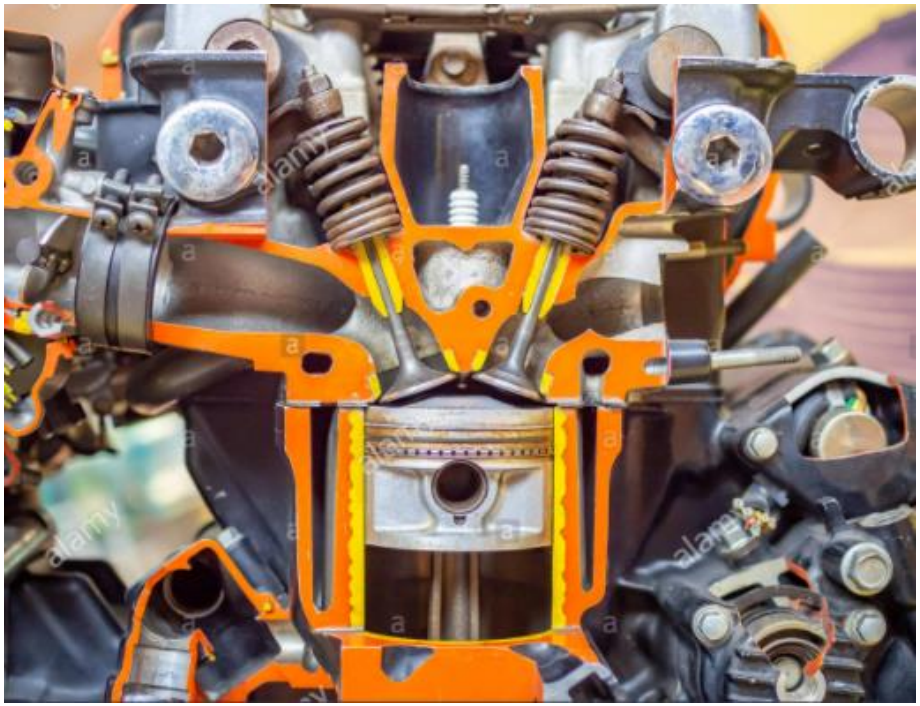
## ICE Drive Train



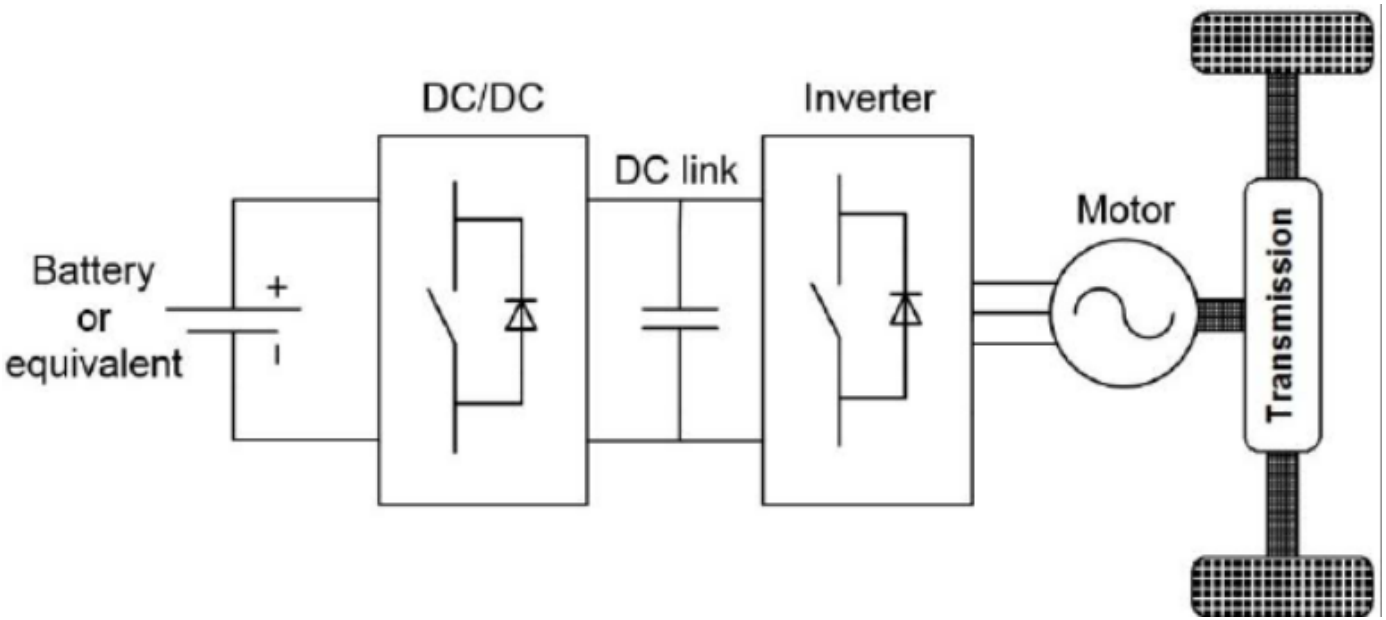
# Part Descriptions

- Engine: Engine converts energy in fuel to rotational mechanical motion.
- Transmission : Transmission converts torque and speed of rotational motion of the engine axle to the required torque and speed of the wheel axle.
- Differential : Differential splits the torque from the transmission between two wheels. This allows the two wheels to spin independently at different speeds.
- Wheels : Wheels carry the weight of the car. They also spin to move the car forward or backward.

# Internal Combustion Engine or ICE



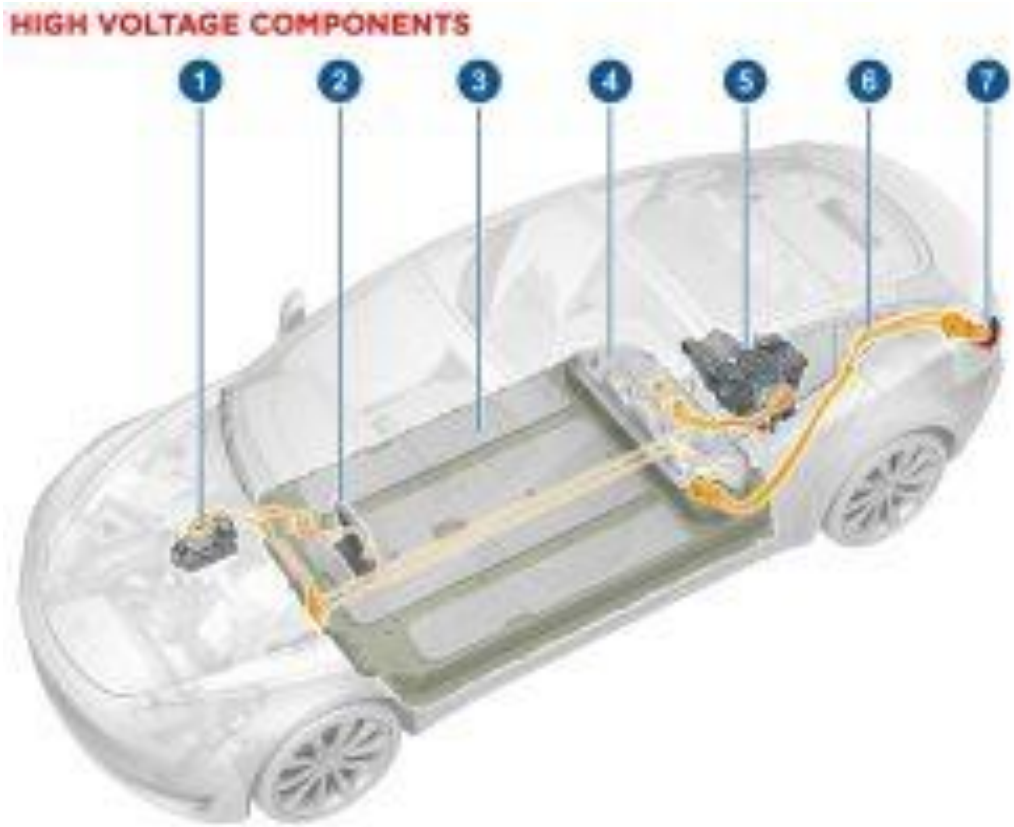
# Electric Power Train



# EV Part Descriptions

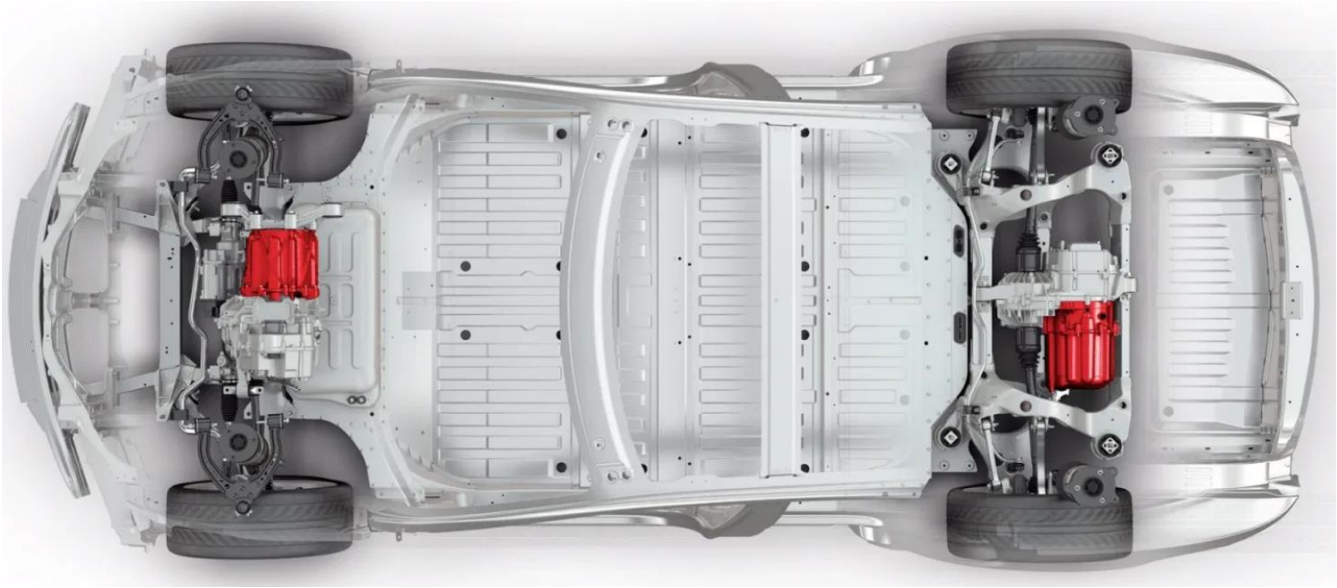
- Battery: Battery stores energy in the form of electric charge
- Electric Motor: Motor converts energy (Charge) in the battery to rotational mechanical motion.
- Transmission: Transmission converts torque and speed of rotational motion of the engine axle to the required torque and speed of the wheel axle.
- Differential : Differential splits the torque from the transmission between two wheels . This allows the two wheels to spin independently at different speeds.
- Wheels : Wheels carry the weight of the car. They also spin to move the car forward or backward.

# Electric Vehicle



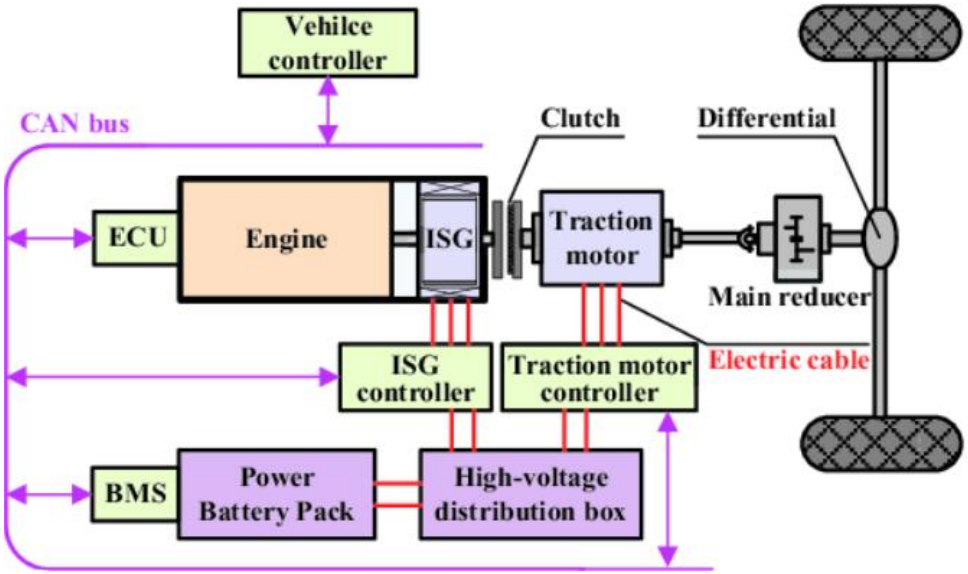

1. A/C Compressor
2. Cabin Heater
3. High Voltage Battery
4. High Voltage Battery Service Panel
5. Rear Drive Unit
6. High Voltage Cabling
7. Charge Port

# Four wheel drive EV



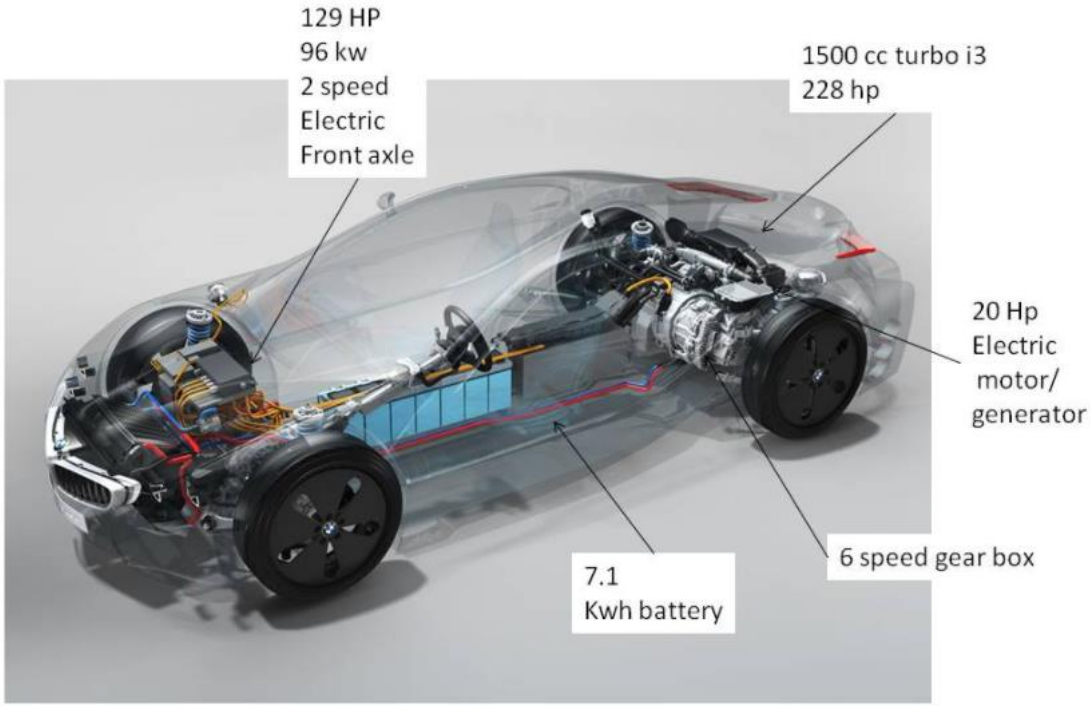
- Four wheel drive used for acceleration
- Motor drive to two wheels can be turned off at high speeds to save energy.
- Better traction and control slippery conditions.

# ICE + EV Hybrid




- Hybrid vehicles have electric and combustion engines.
- Each engine is used to drive the wheel at the speed where they are most efficient.
- Hybrid cars have onboard generators driven by combustion engines.
- When the combustion engine is idling it drives the generator to charge the batteries.
- Hybrid vehicles have regenerative breaking. When brakes are applied the electric engine is rotated by the wheels turning it into a electric generator. The electricity generated charges the batteries.

# BMW i8 Hybrid Car




BMW i8 Powertrain Layout

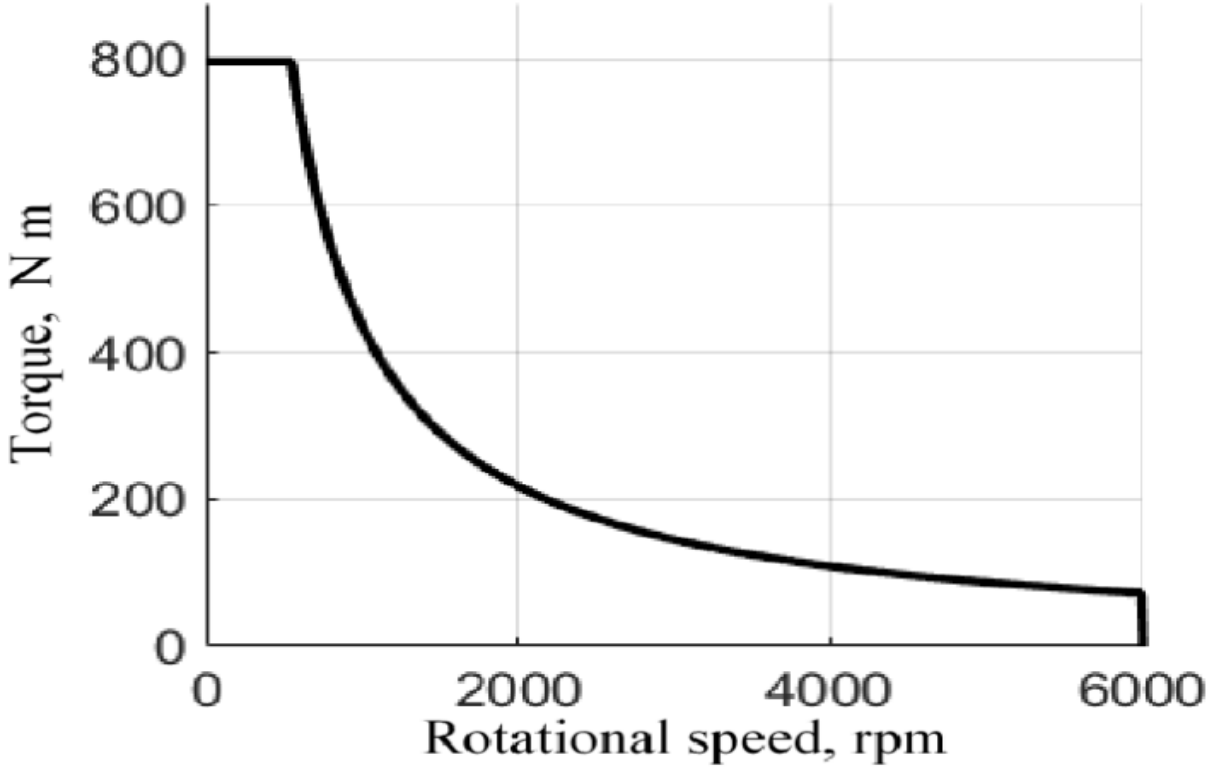
# Questions ?/ Discussion

# Some Definitions

- **Torque** : Torque is defined as rotational force. The unit of torque is N-m in metric system. lbs-force-ft in English system.
- **Rotational Speed** : Rotational speed is defined as the speed at which an axle turns. Unit of rotational speed is rpm or rotation per minute.
- Example: Closest example to our every day life is turning a screwdriver.
- Torque is how hard you turn a screwdriver.
- Speed is how fast you turn the screwdriver.

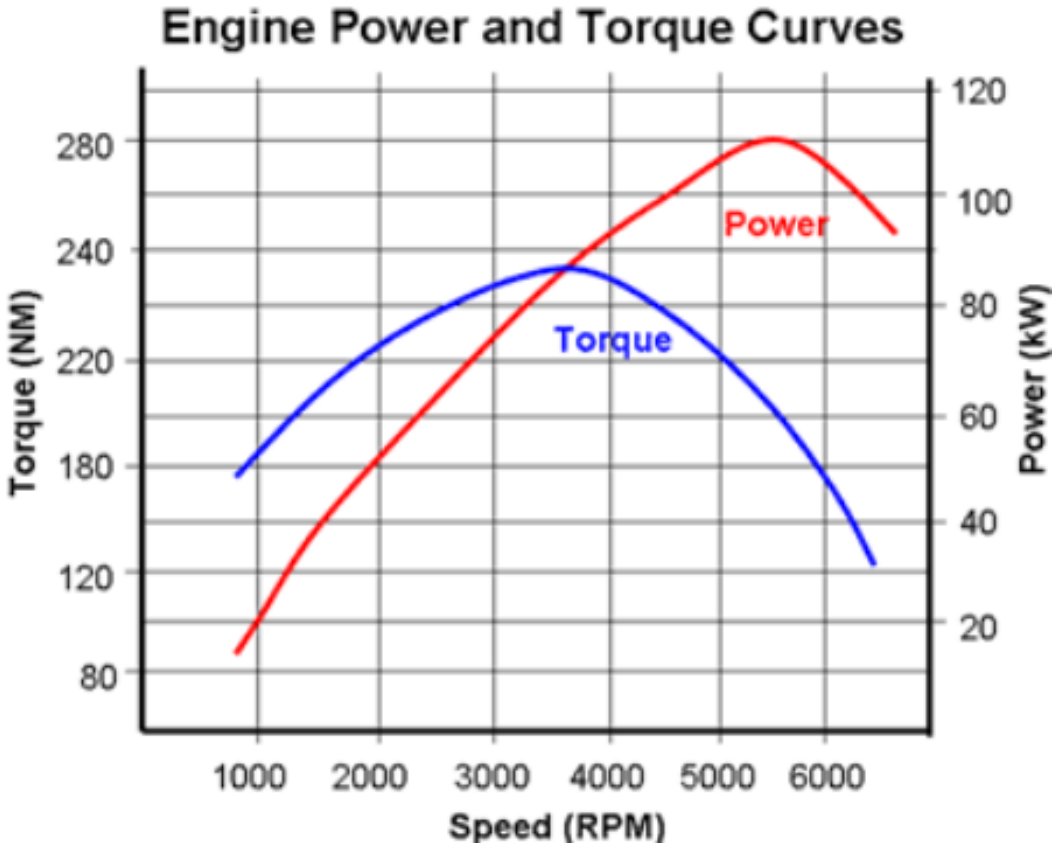

- **Horsepower** : Horsepower is the measure of rate at which work is done. A HP equivalent to lifting 33000 lbs, 1 ft in 1 minute

# Torque requirement for a car



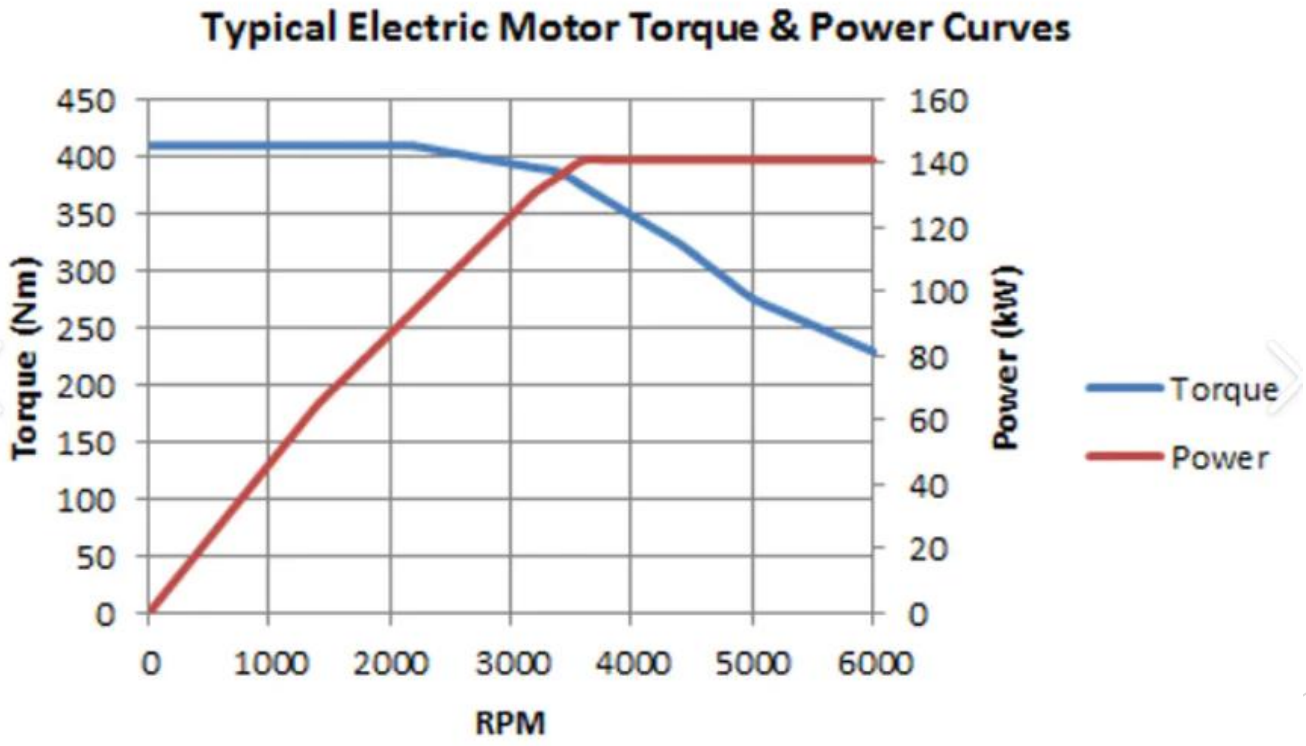

0 mph → 70 mph

# Torque Vs speed for ICE




- **Idle Speed** : ICE can generate useful torque at speeds greater then 800 rpm.
- **Torque :** ICE generates maximum torque near 3000 rpm

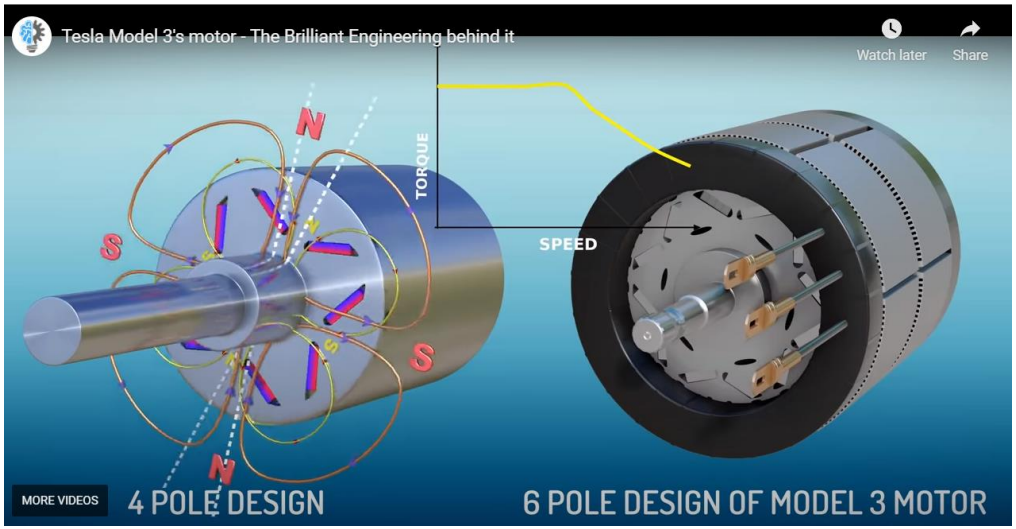
# Torque Vs speed curve for Electric motor

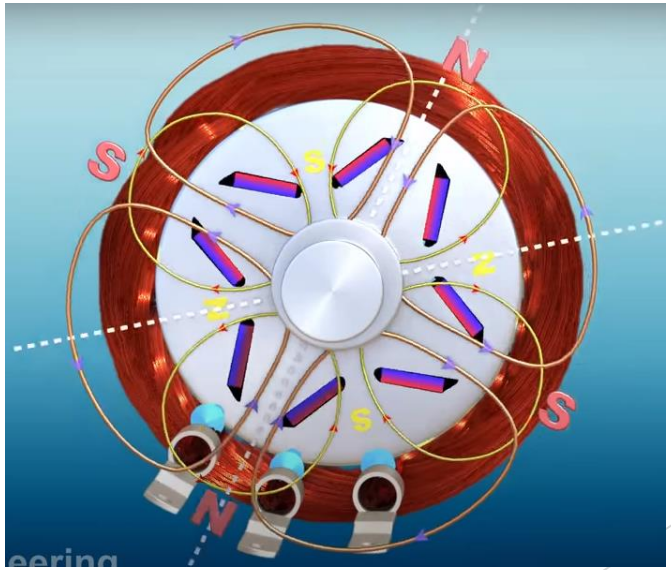


# Electric Motor

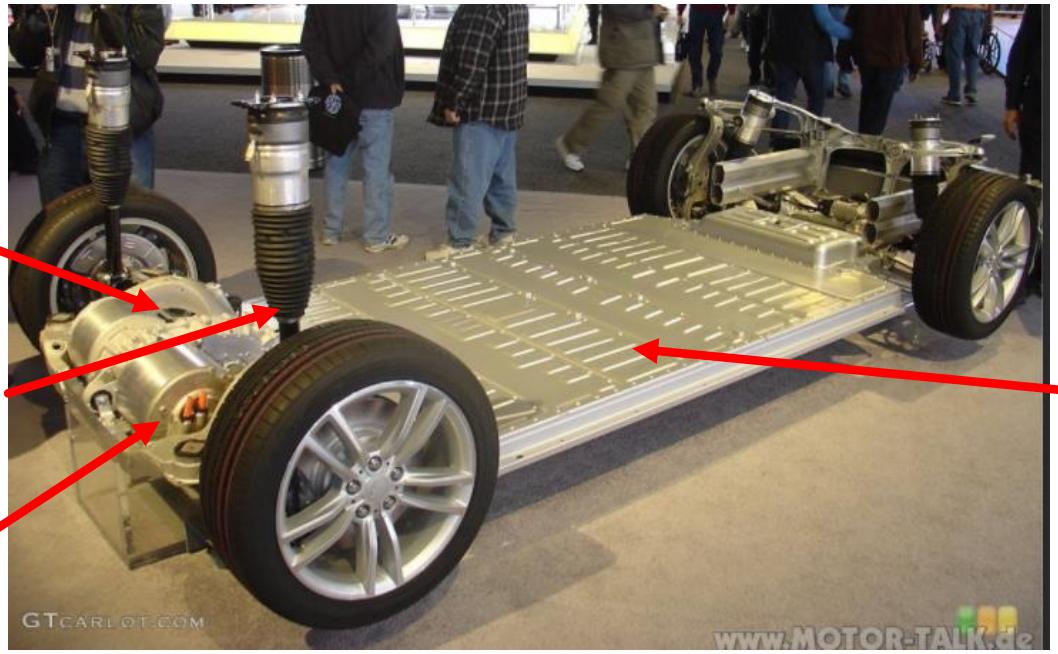
## Efficiency 97%

Tesla Model 3's IPM-SynRM Electric Motor Explained



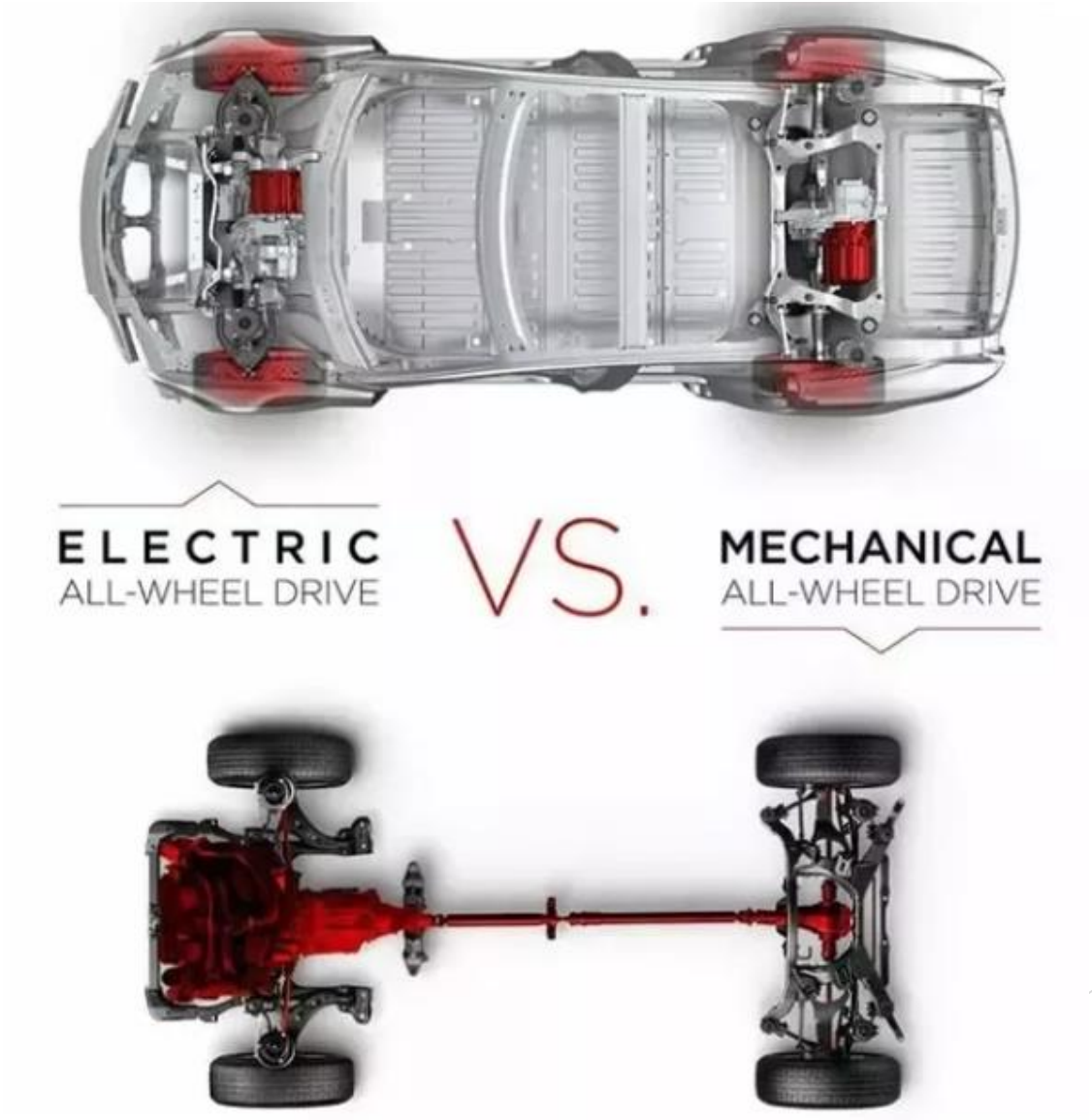
# Tesla Chassis with Electric Drive Train (The Skateboard)



Question: You mentioned that EVs have transmission. But I read that EVs don’t have transmission . The electric motor is directly connected to the wheels.

Answer: EVs don’t have transmissions in traditional sense. In traditional transmission the gear ratio between the engine drive shaft and the wheel axle is dynamically changed based on the torque requirement.
In an EV the gear ratio is fixed between motor shaft and the wheel axle. So EVs have a fixed gear box. These are much more efficient and reliable.

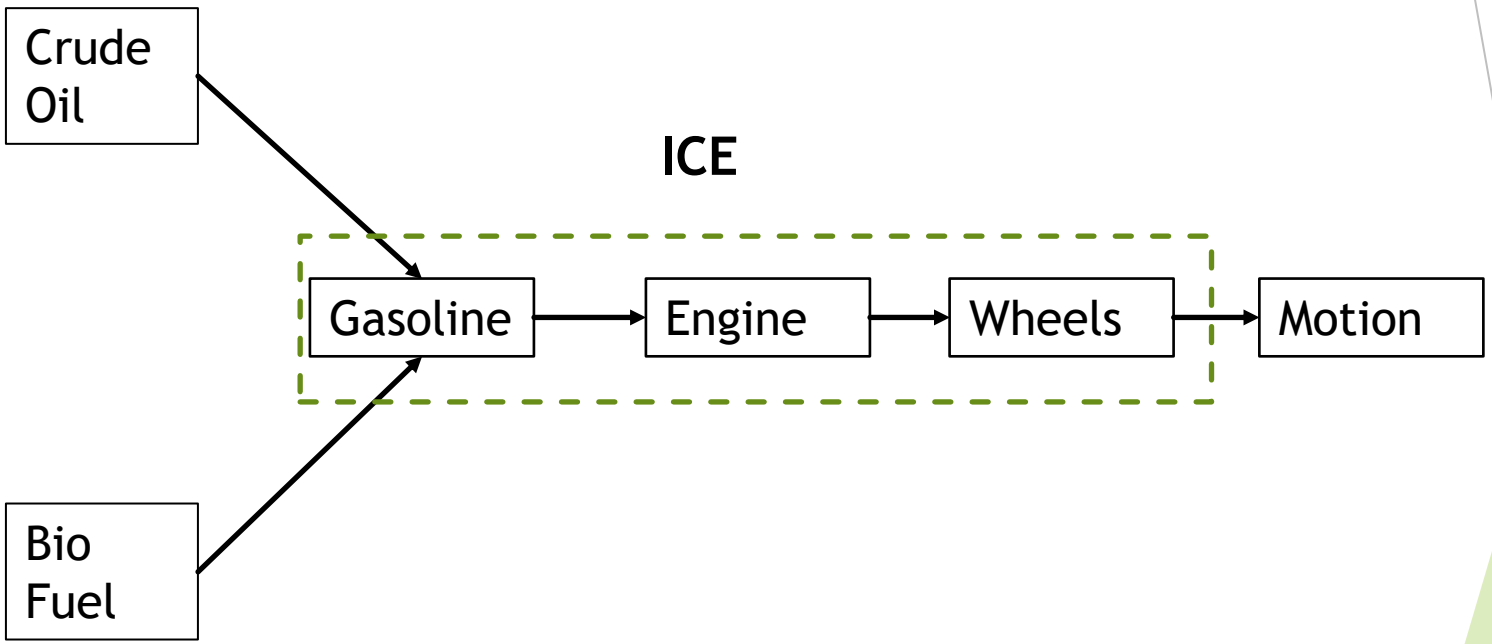
# Electric Vs Mechanical Drive train



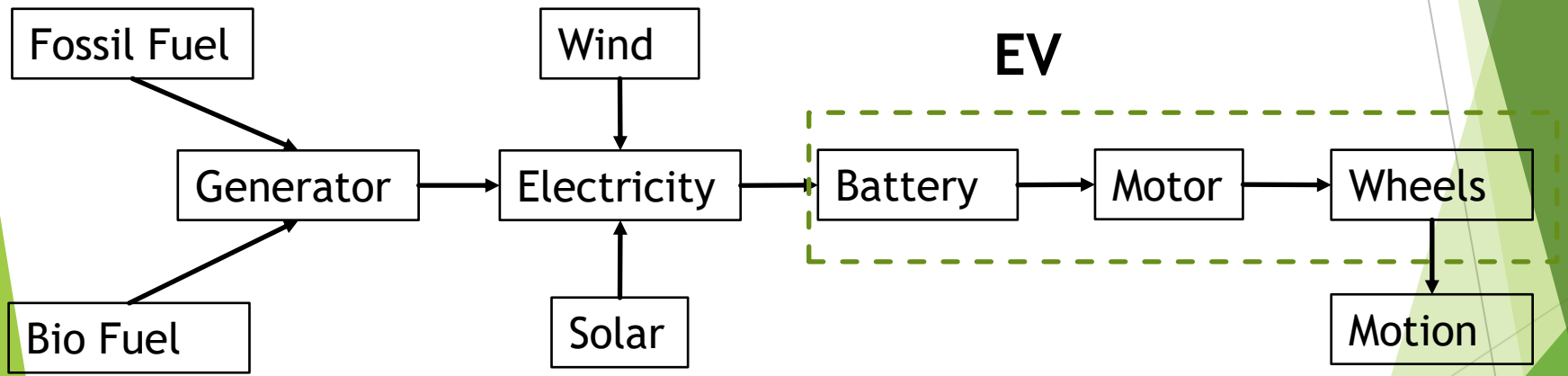
# Electric Vs Mechanical Drive train

| No | Part Description | Weight (lbs) | |
|---|---|---|---|
| | | Electric | Mechanical |
| 1 | Engine/Motor | 60-80 | 300-500 |
| 2 | Transmission | 100-200 | 200-400 |
| 3 | Differential | 175 | 175 |
| 4 | invertor | 50-100 | - |
| 5 | Battery | 1200 | - |
| 6 | Gas + Tank | | 125 |

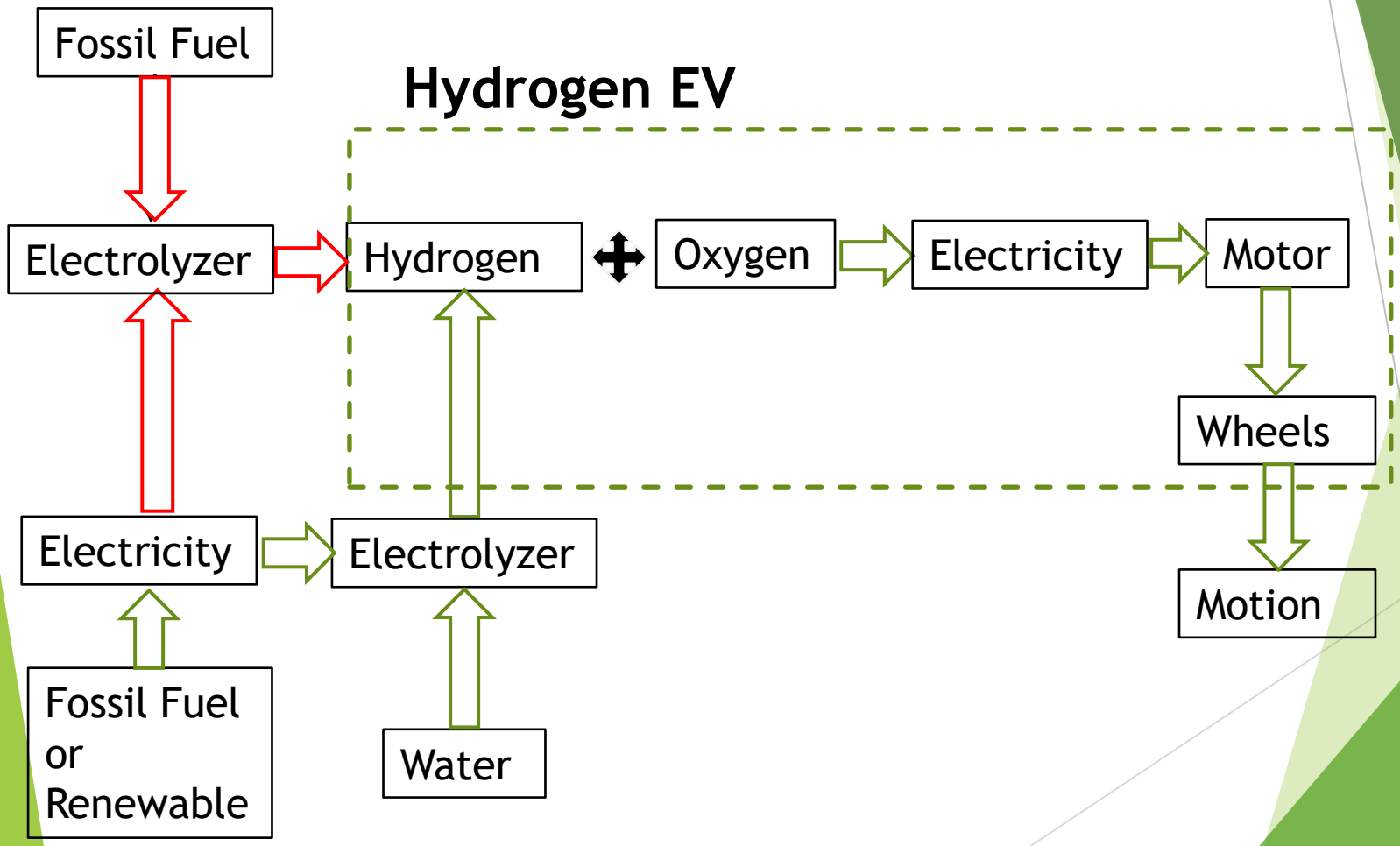
# Fuel Cycle for ICE



# Fuel Cycle for EV



# Hydrogen Fuel Cycle



# Questions ?/ Discussion

# Fuel and Energy

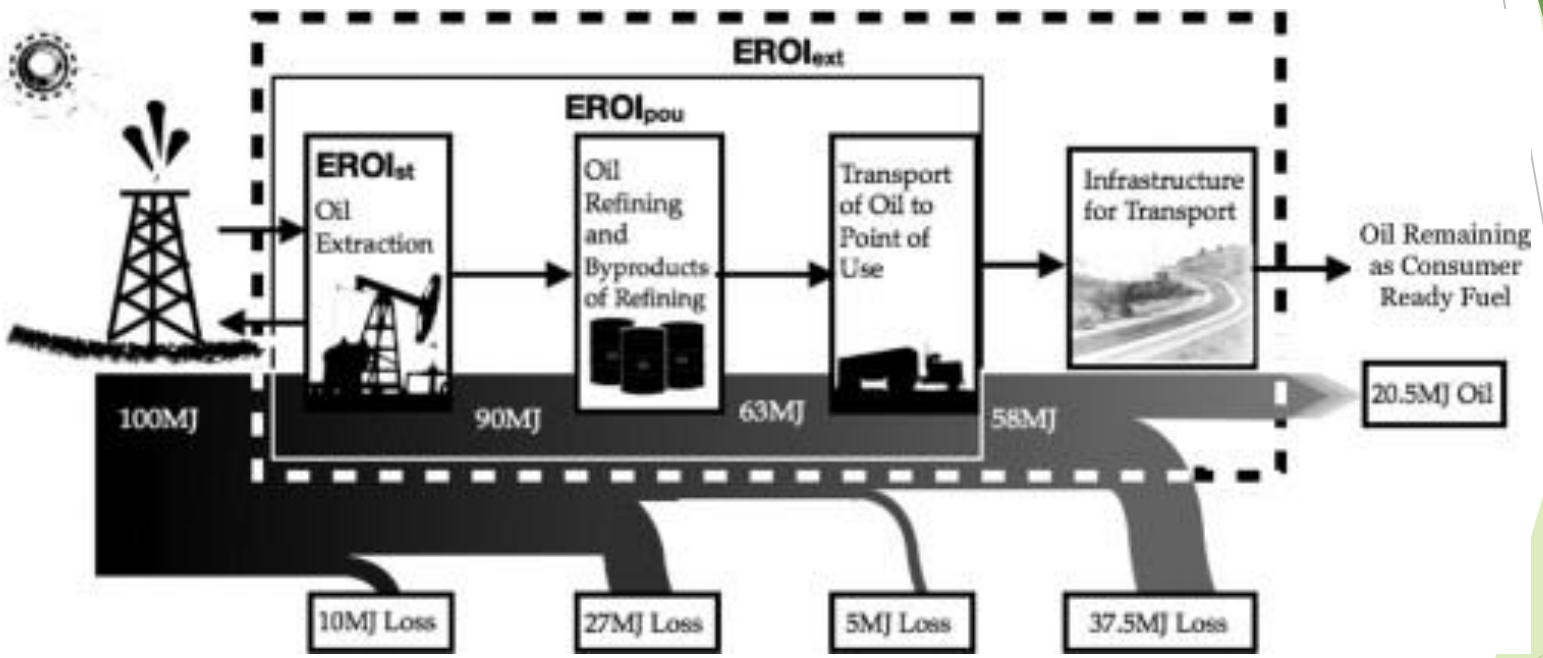
- Gasoline : Extracted from crude oil. It is a type of fossil fuel. Most ICE automobiles use gasoline as fuel.
- Electricity : Generated from burning Fossil fuel or Nuclear or Alternate Energy
- Alternate Energy = Wind + Geothermal + Solar + Bio fuels + Hydro Electric + Ocean
- Hydrogen : Hydrogen is generated by splitting water or fossil fuels with electrolyzers. Electrolyzers use electricity .

# Crude Oil Reserves

## Crude oil is finite resource

| Proven reserves (millions of barrels) | U.S. EIA (start of 2020)[2] | | Reserves-to-production ratio | |
|---|---|---|---|---|
| **Country** | **Rank** | **Reserves** | **Production (million bbl/year, 2016)[1]** | **Years** |
| Venezuela | 1 | 302,809 | 831.1 | 362 |
| Saudi Arabia | 2 | 267,026 | 3818.1 | 78 |
| Canada | 3 | 167,896 | 1336.8 | 126 |
| Iran | 4 | 155,600 | 1452.9 | 109 |
| Iraq | 5 | 145,019 | 1624.8 | 88 |
| Kuwait | 6 | 104,000 | 1067.2 | 95 |
| UAE | 7 | 98,630 | 1133.7 | 86 |
| Russia | 8 | 80,000 | 3851.3 | 21 |
| Libya | 9 | 48,363 | 366.1 | 131 |
| United States | 10 | 47,053 | 3239.7 | 10 |

# Crude to gas extraction efficiency (20.5%)



# Energy Return on Energy Investment (EROEI) for Oil

- Middle Eastern Oil – 30 : 1
- Shale Oil (Colorado, Wyoming)– 3: 1
- Heavy Oil ( Venezuela, Canada)-7:1
- Deep Sea Offshore- 3:1
- Abandoned Wells – 20:1

# Efficiency of Engines

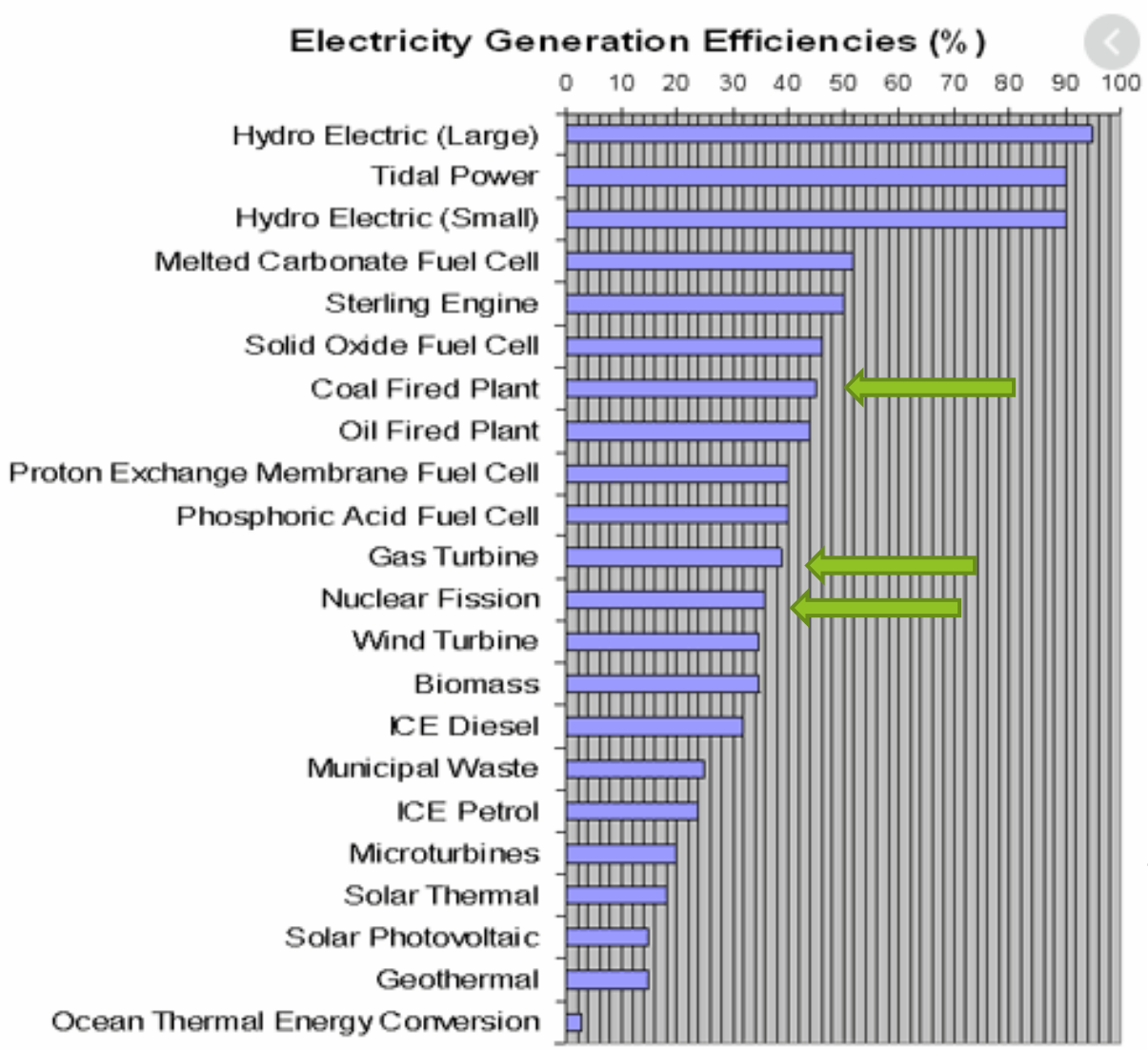
- Efficiency is calculated by :

  (Mechanical energy/Energy in fuel) x 100
- ICE : 33% - 36%
- Diesel : 40%-44%
- Electric Motor : 97% (Tesla Claims)

# Units of Energy & Power

- Energy : Joules , Calorie
- Power : Watt=Joules/s
- Kilowatt = 1000 Watts
- Kilowatt-hour = Energy consumed when one kilowatt of power is used for 1 hour = 3.6 Mega Joules.
- I.e 100 W bulb left on for 10 hours will consume (100x10) 1 Kilowatt-hour of energy

# Electric Power generation Efficiency

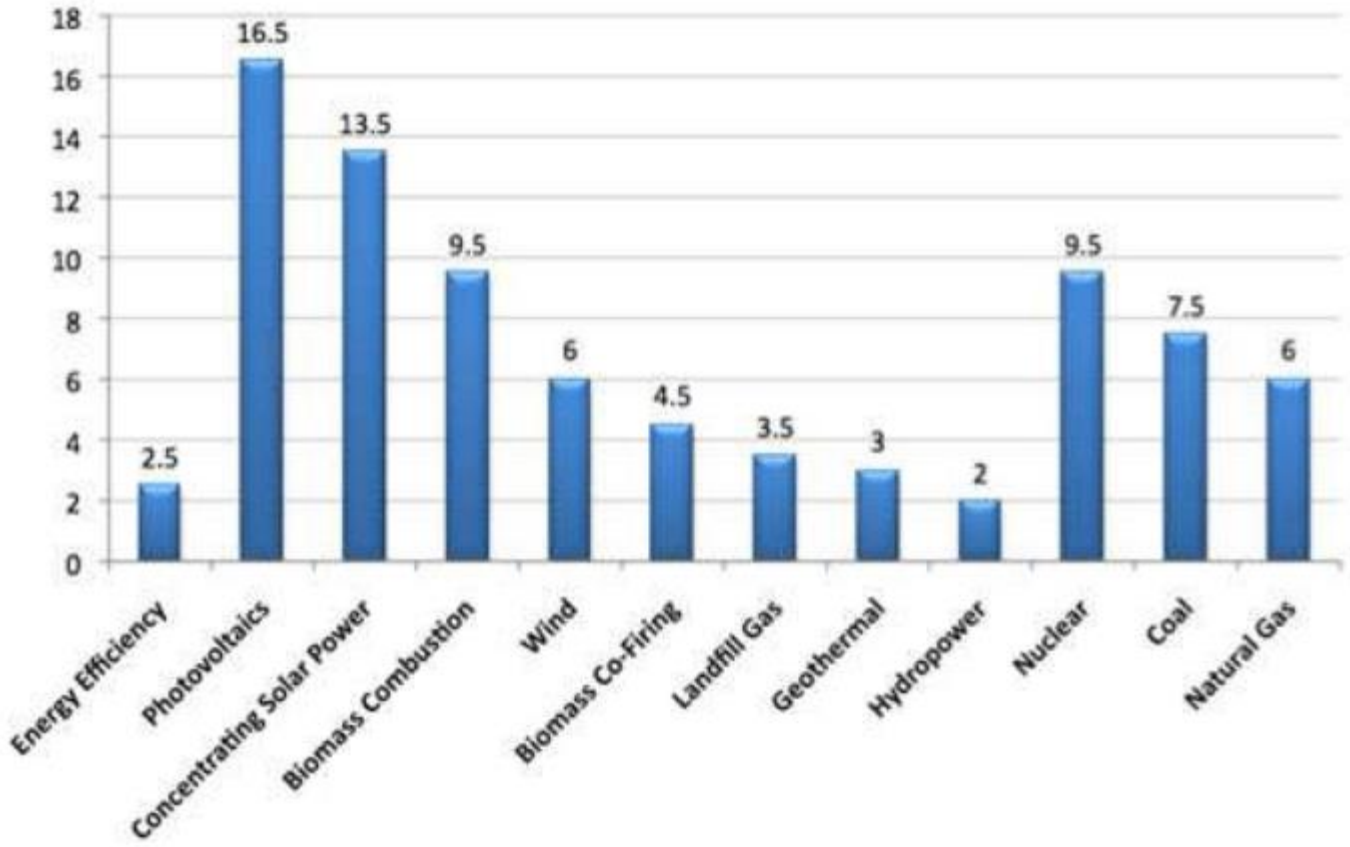


# Gas, Electricity and battery

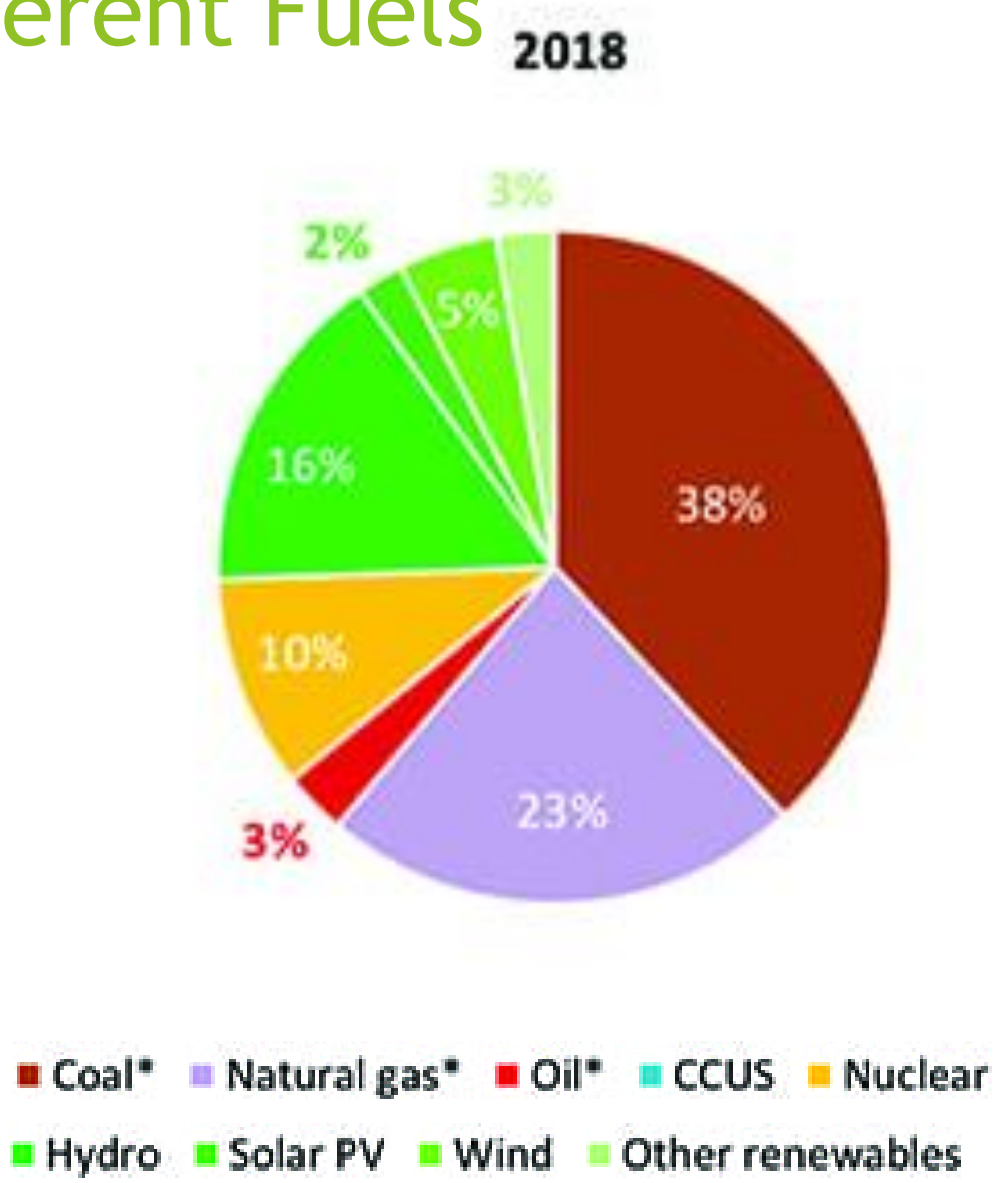
- 1 gallon of gas contains 33.7 kWh of energy
- 1 gallon of gas weighs 6 pounds
- 1 gallon of gas costs $3.35 in California, $2.15 in Texas
- 33.7 kWh of energy @ $0.18/kWh costs $6.07
- A 33.7 kWh battery weighs 475.5 lbs.

# Questions ?/ Discussion

# Cost Breakdown in per kWh



# Power generation from different Fuels

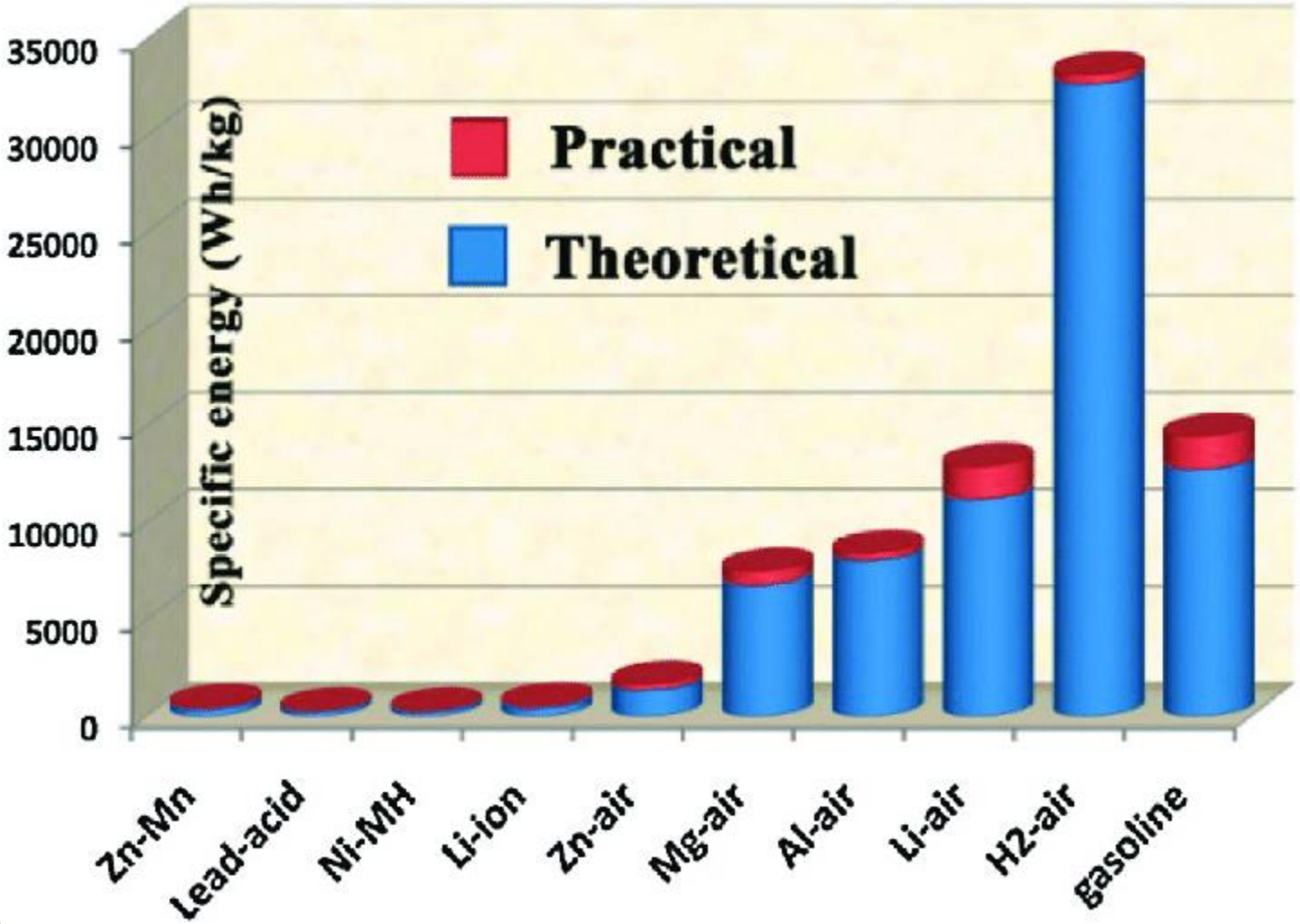


# Specific Energy, Energy Density & CO2

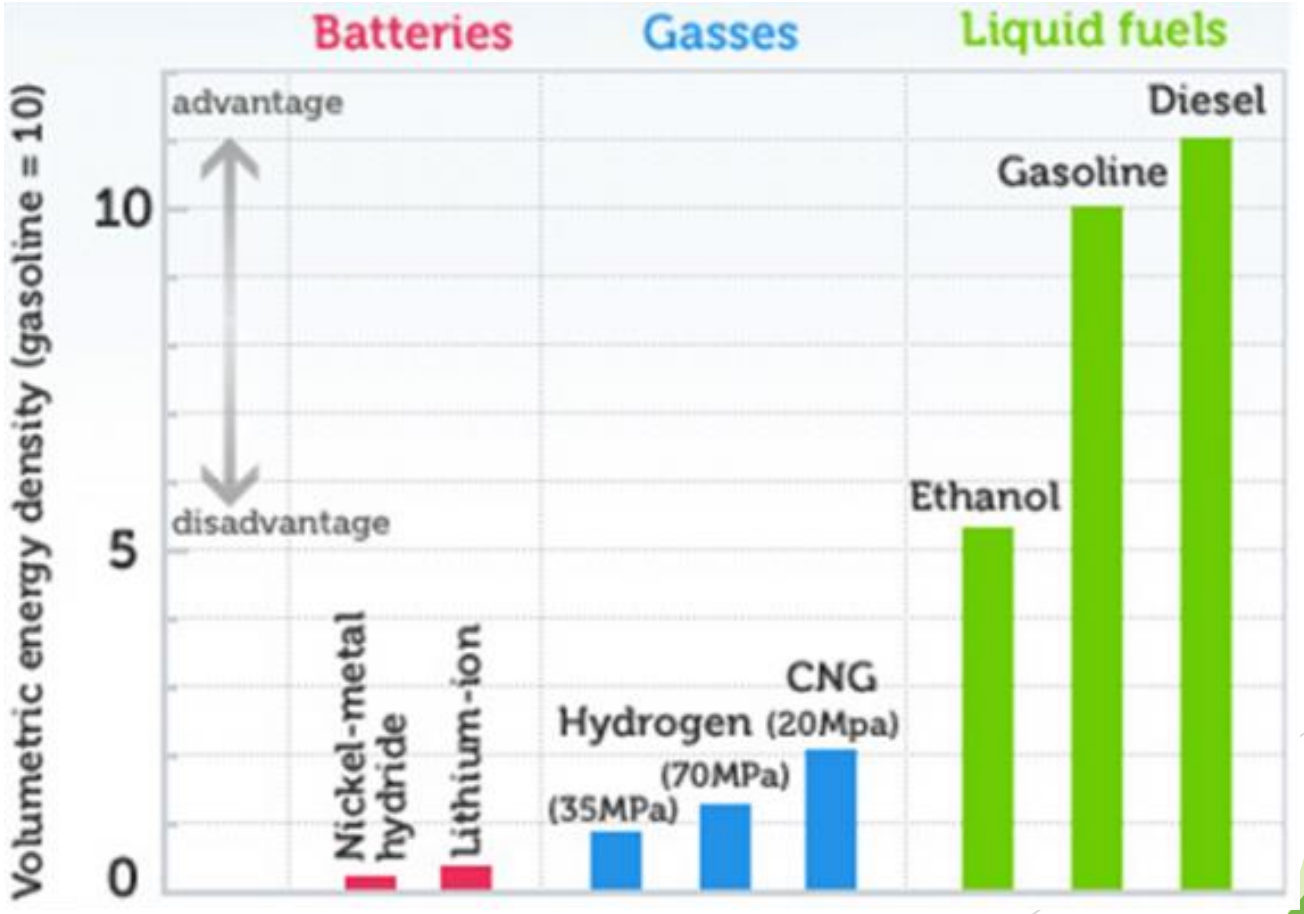
| Fuel | Specific Energy kj/g | Density KWH/gal | Chemical Formula | lbs CO2/gal |
|---|---|---|---|---|
| Propane | 50.4 | 26.8 | C3H8 | 13 |
| Ethanol | 29.7 | 24.7 | C2H5OH | 13 |
| Gasoline | 46.5 | 36.6 | C7H16 | 20 |
| Diesel | 45.8 | 40.6 | C12H26 | 22 |
| Biodiesel | 39.6 | 35.0 | C18H32O2 | 19 |
| Methane | 55.8 | 27.0 | CH4 | 3 |
| Oil | 47.9 | 40.5 | C14H30 | 20 |
| Wood | 14.9 | 11.3 | approx weight | 9 |
| Coal | 30.2 | 22.9 | approx weight | 19 |
| Hydrogen | 141.9 | 10.1 | H2 | 0 |

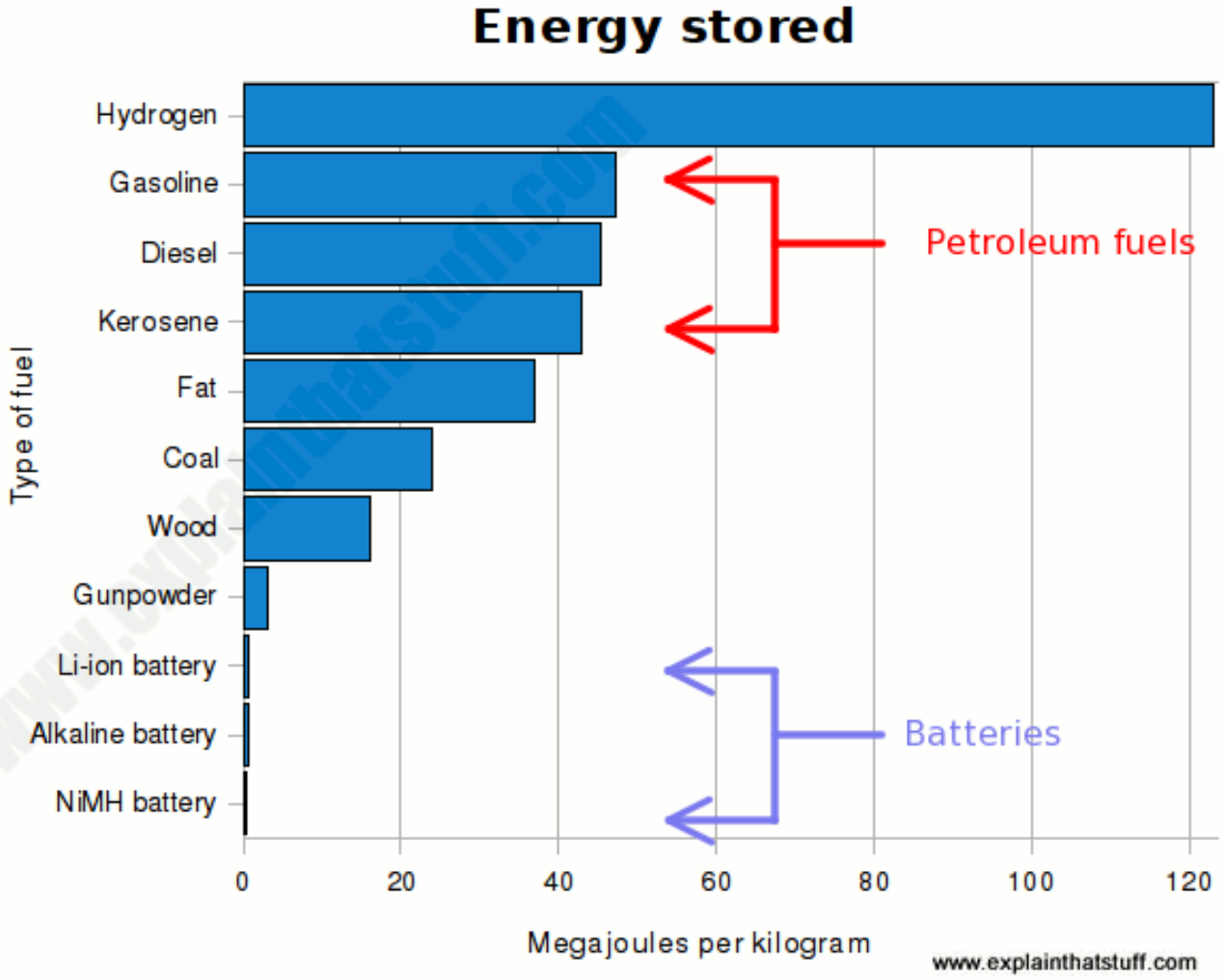
energy density of gasoline - Google Search

# Specific Energy of Fuels/Battery



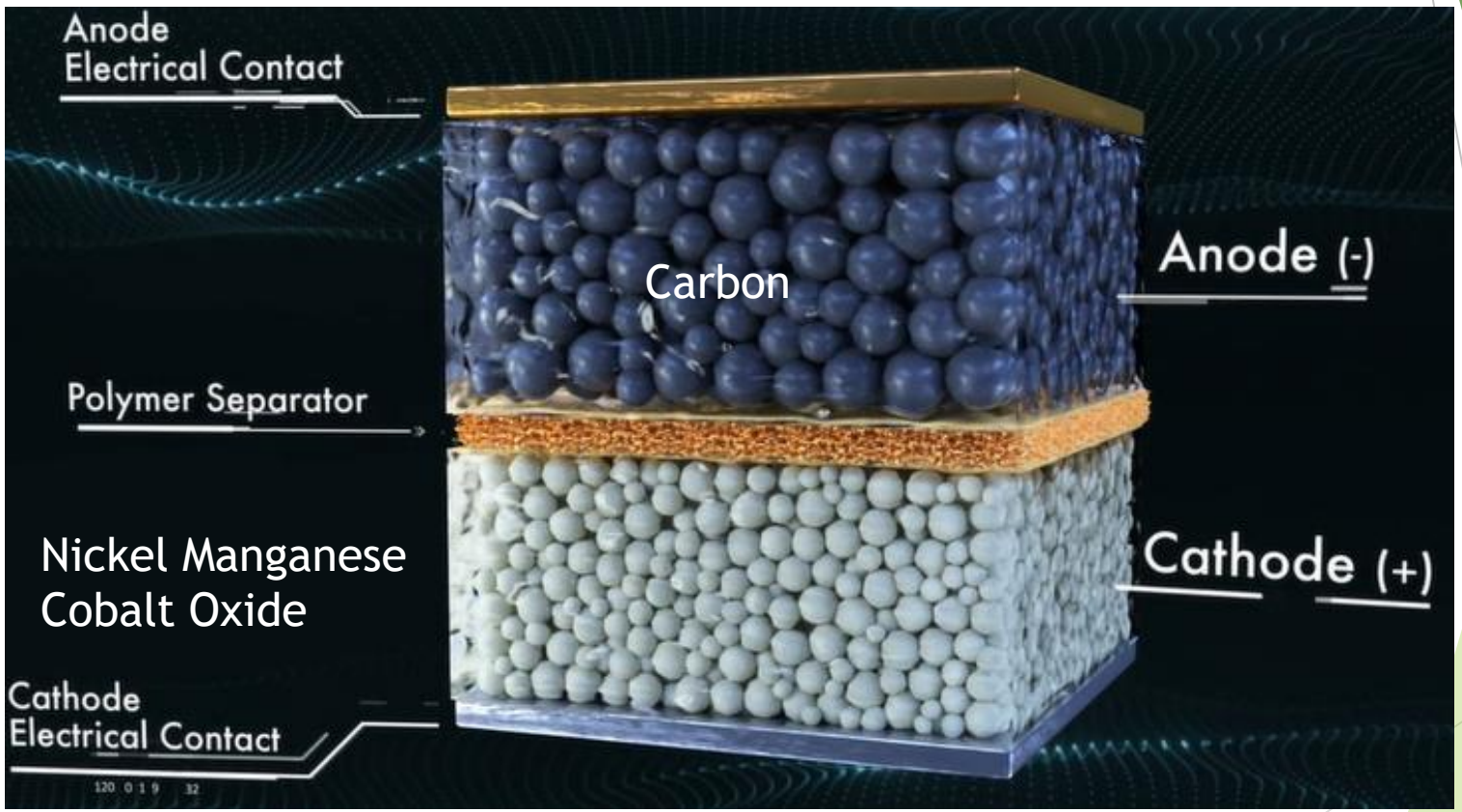
# Volumetric  Energy density of Fuels and battery



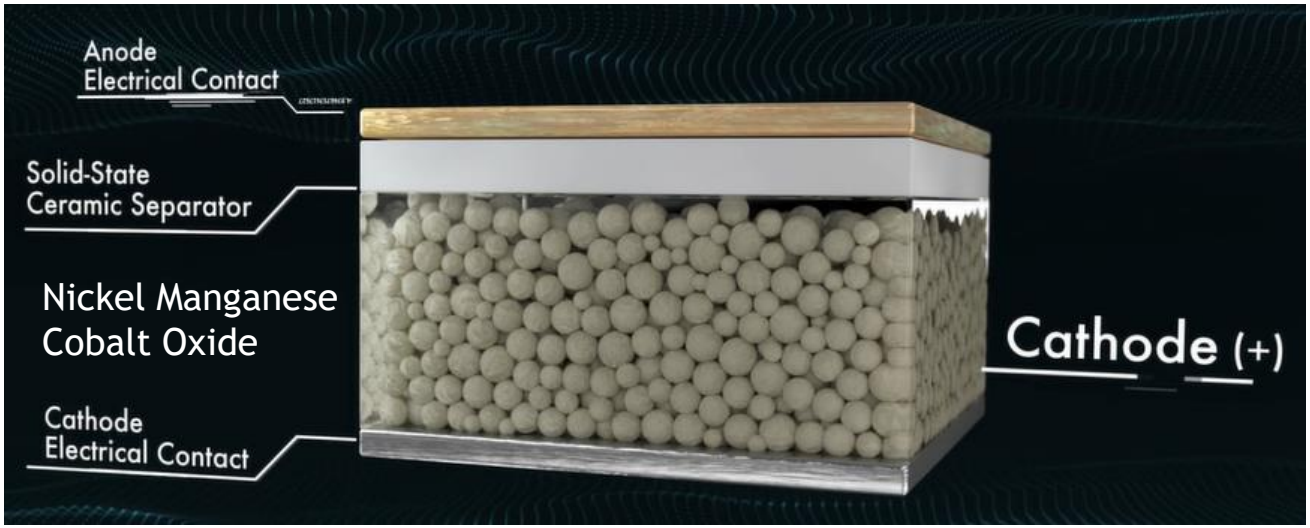

Energy stored
Hydrogen
Gasoline
Diesel
Kerosene
Fat
Coal
Wood
Gunpowder
Li-ion battery
Alkaline battery
NiMH battery
Type of fuel
Petroleum fuels
Batteries
0
20
40
60
80
100
120
Megajoules per kilogram
www.explainthatstuff.com

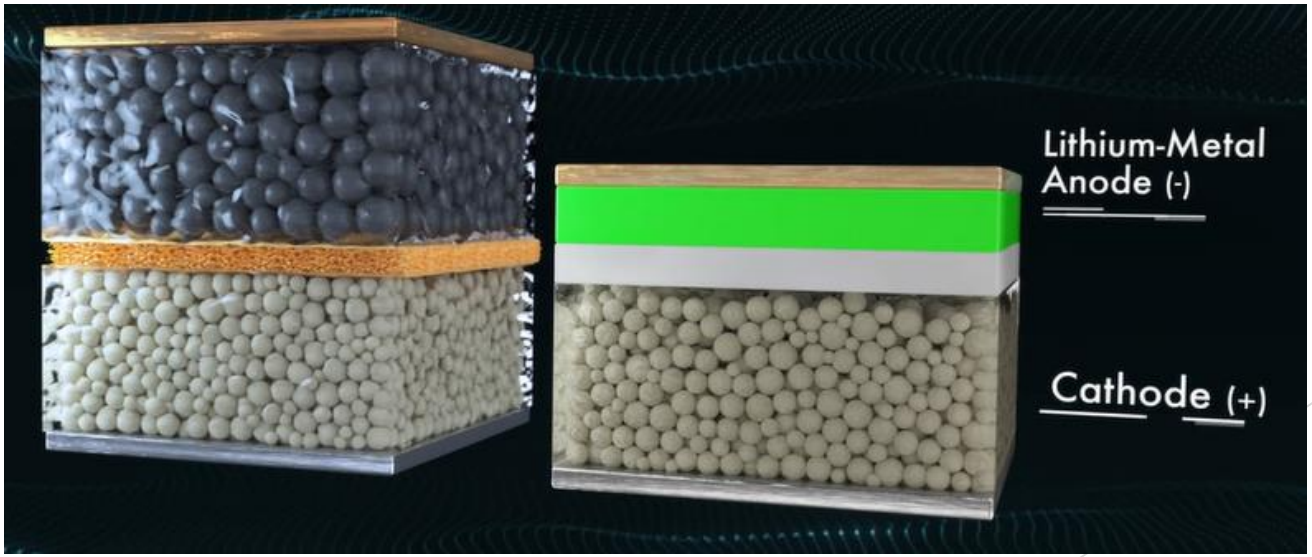
# Questions ?/ Discussion

# Battery Tech : Lithium Ion

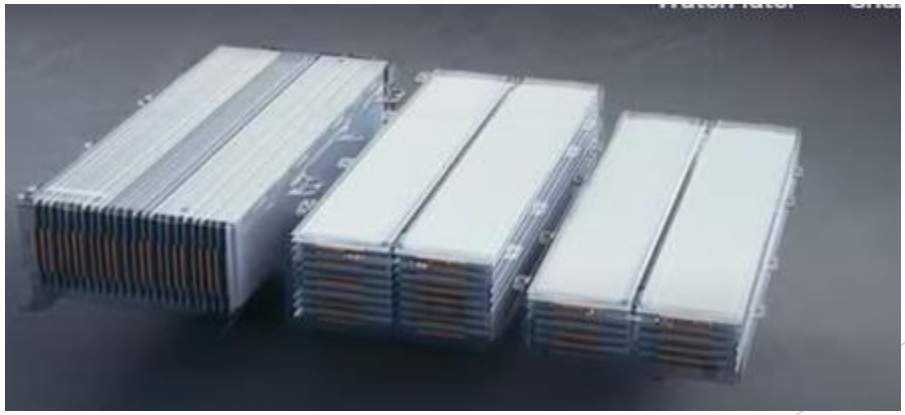


# Battery Tech : Solid State Lithium Metal (Quantumscape, Inc)



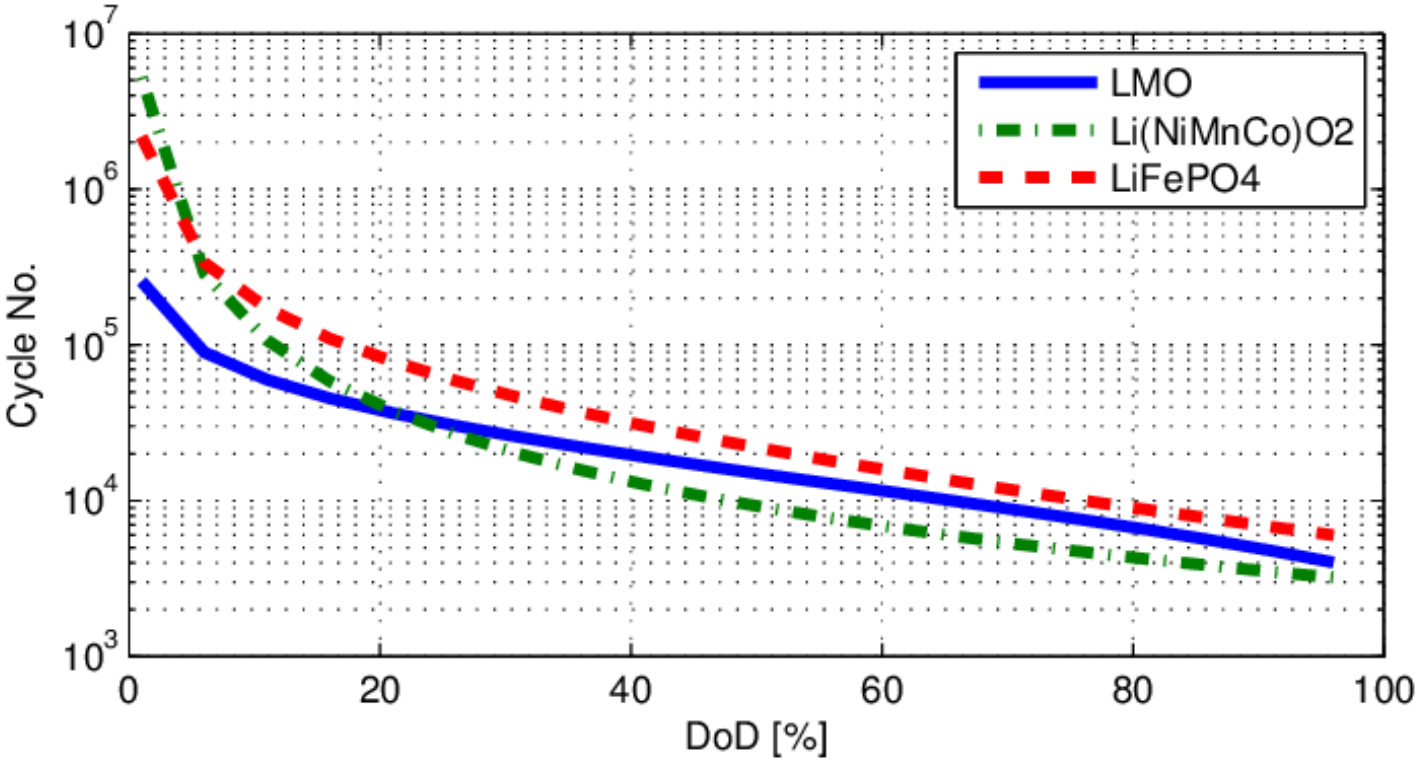



# Battery Form factor : Tesla Lithium Ion vs GM Ultium

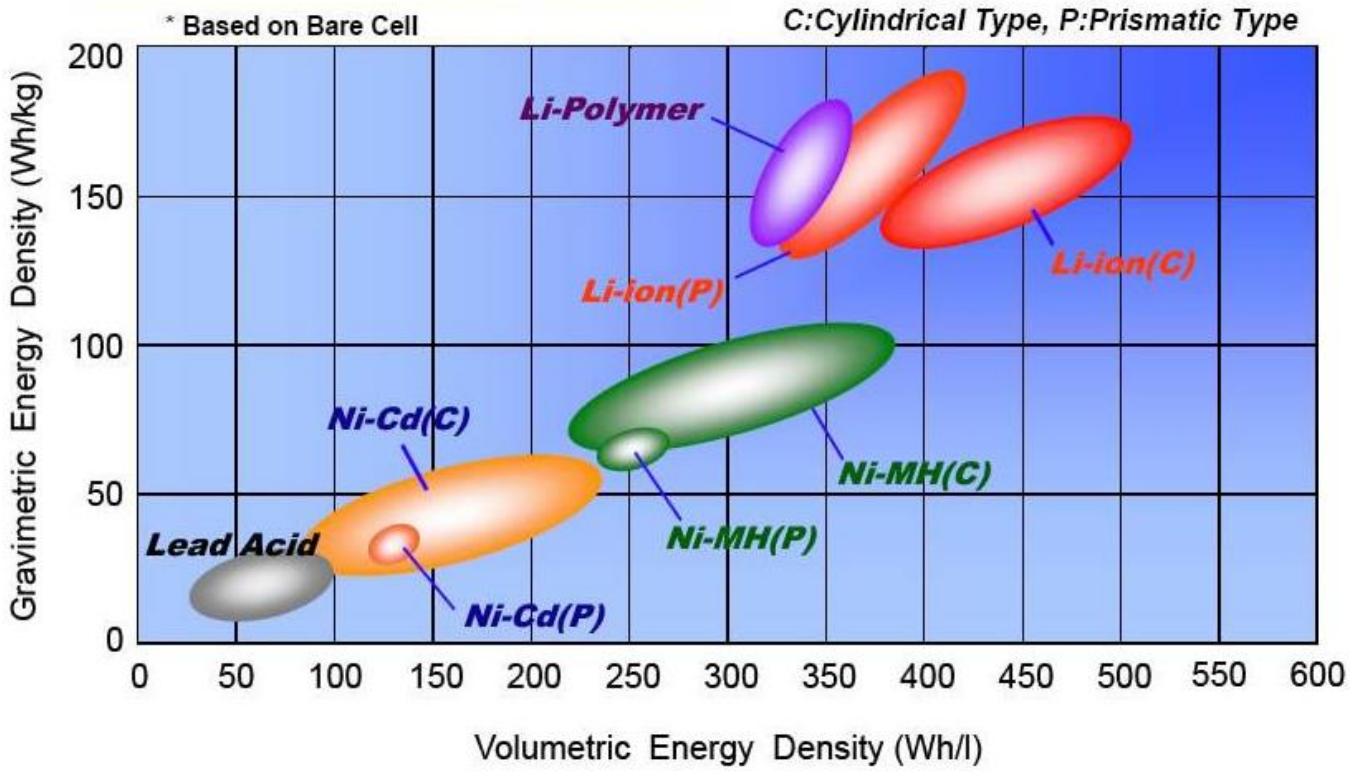



# Questions ?/ Discussion

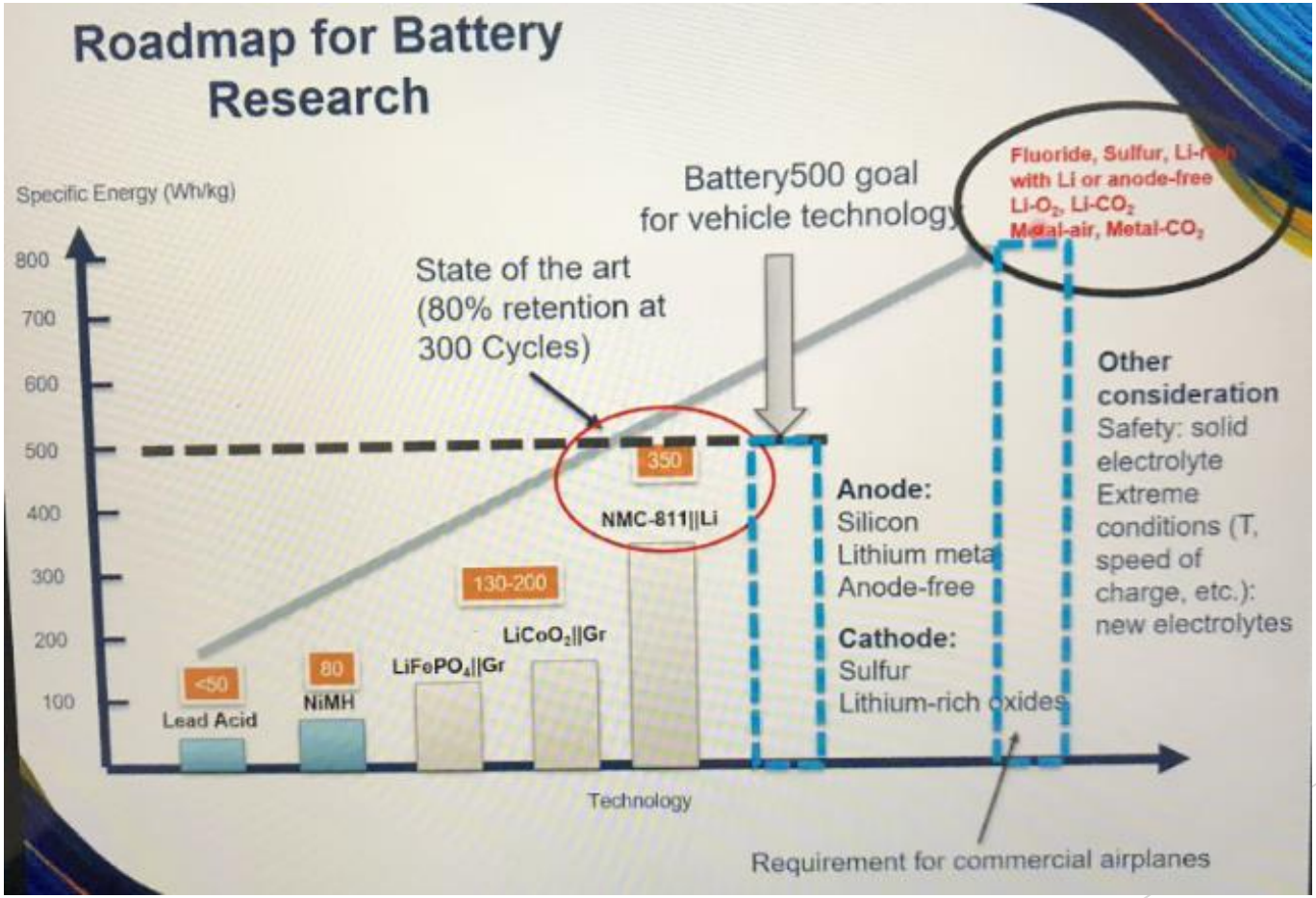
# Battery life Vs Depth of discharge



# Battery Gravimetric Energy Density Vs Volumetric Energy Density



# Battery Tech: Future work



# Summary

- Electric Motors are more efficient in converting (Electrical) energy to mechanical motion than ICE are converting energy in gasoline to mechanical motion.
- Generation of electricity has a large carbon footprint if generated from fossil fuels.
- EV and ICEV have similar carbon footprint if electricity is generated from fossil fuels
- Pollution can be shifted away from populated areas by replacing ICEVs with EVs.

Questions: You showed that efficiency of and ICE is ~35% whereas efficiency of Electric motor is 97%. So, if efficiency of a power plant is 45% than EVs should have a lower carbon footprint.

Answer: True that there is a slightly lower carbon footprint of an EV in terms of fuel consumption. How ever the carbon of the manufacturing process of EV is much higher than that of an ICEV.

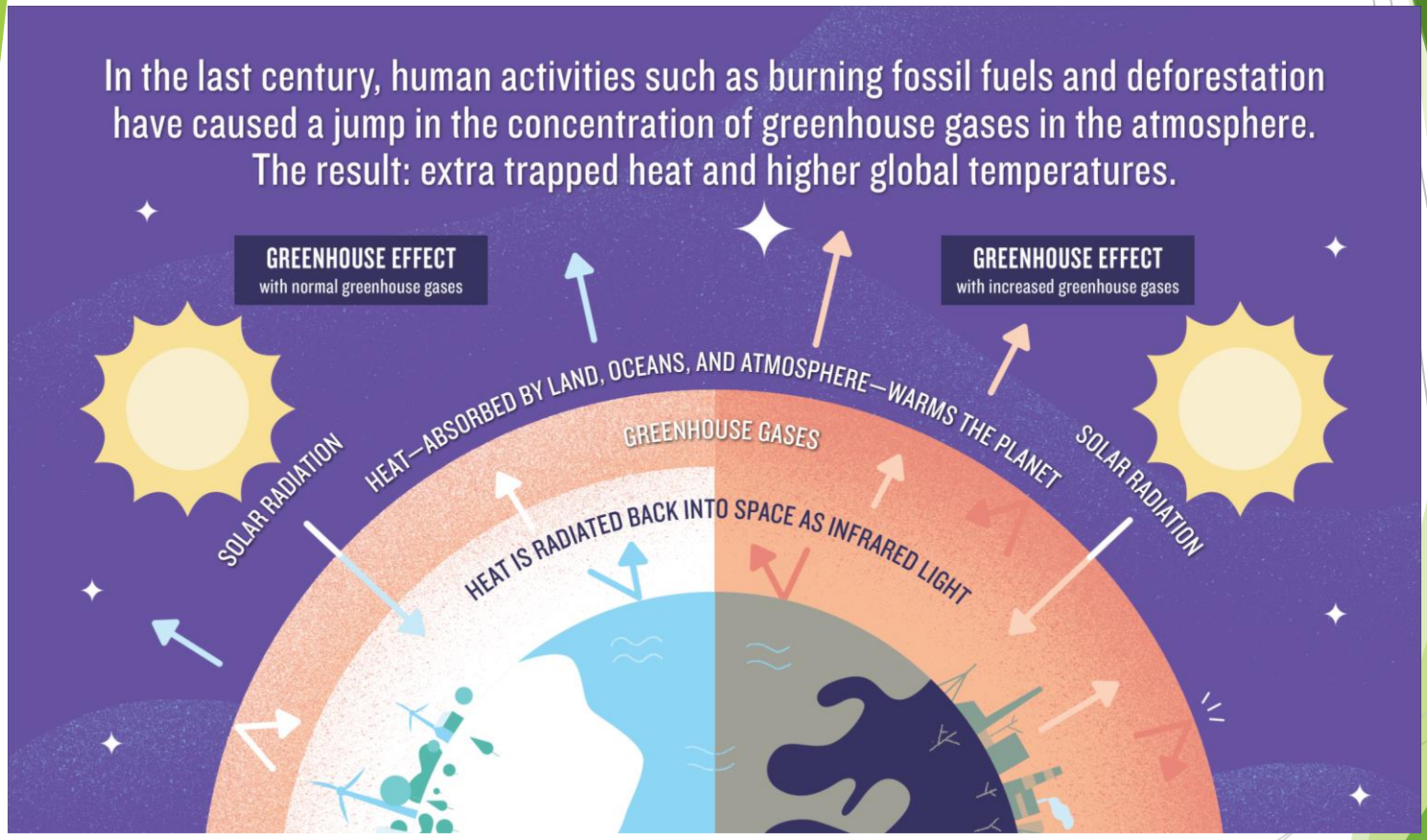
# Climate change and CO2

- Emissions

# Atmospheric Composition

- **According to NASA, the gases in Earth's atmosphere include:**
- Nitrogen — 78 percent
- Oxygen — 21 percent
- Argon — 0.93 percent
- Carbon dioxide — 0.04 percent  (400ppm)
- Trace amounts of neon, helium, methane, krypton and hydrogen, as well as water vapor

# Green house Effect



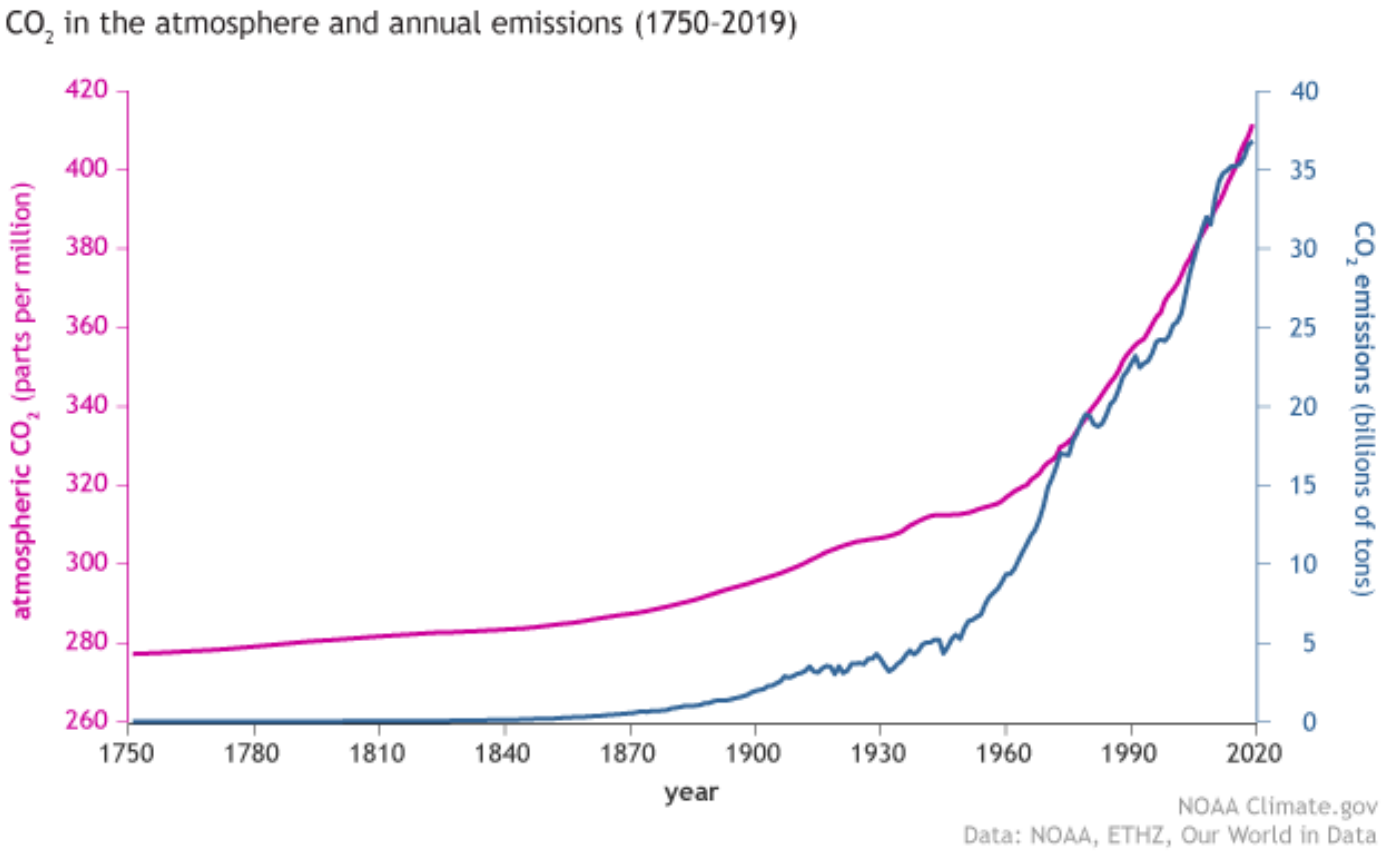
# Gasoline Facts

- Gasoline is derived by refining crude oil
- 1 barrel of crude (42 gallons) yields 19 gallon of gasoline after refining.
- Gasoline consists of 150 different types of hydrocarbons including butane, pentane, isopentane and alkane.
- It also contains BTEX compounds (benzene, ethylbenzene, toluene, and xylenes).
- These chemicals are known to cause cancer.
- Gasoline can also contain Sulphur and other impurities.
- Gasoline + $O_2$ = Heat + $CO_2$+CO+$NO_2$+$SO_2$+$H_2O$+ Unburned hydrocarbons.
- 1 gallon of gasoline creates 19.5 lbs of $CO_2$ when burned
- 1.139 Billion tones of $CO_2$ released due to gasoline combustion.

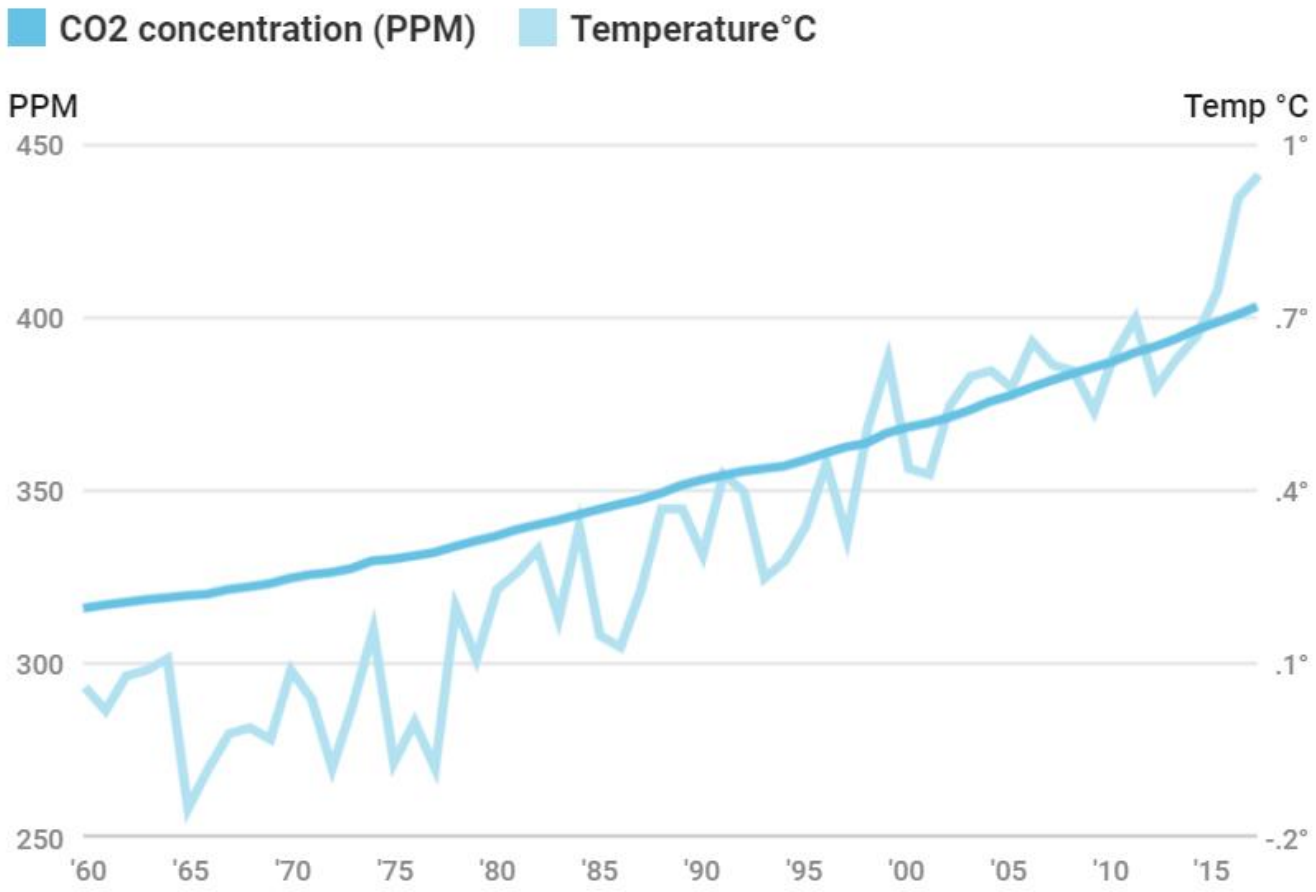
# Oxygen is a Resource

- Oxygen is essential for the survival of all animal live including humans.
- Free Oxygen has not been detected in any planet other then Earth.
- A human consumes 13.3 cubic feet (1.1 lb) of oxygen per day
- Burning 1 gallon of gasoline consumes 178 cubic feet (14.6 lbs) of oxygen
- So burning 1 gallon of gas consumes enough oxygen that would sustain a human for 13 days.

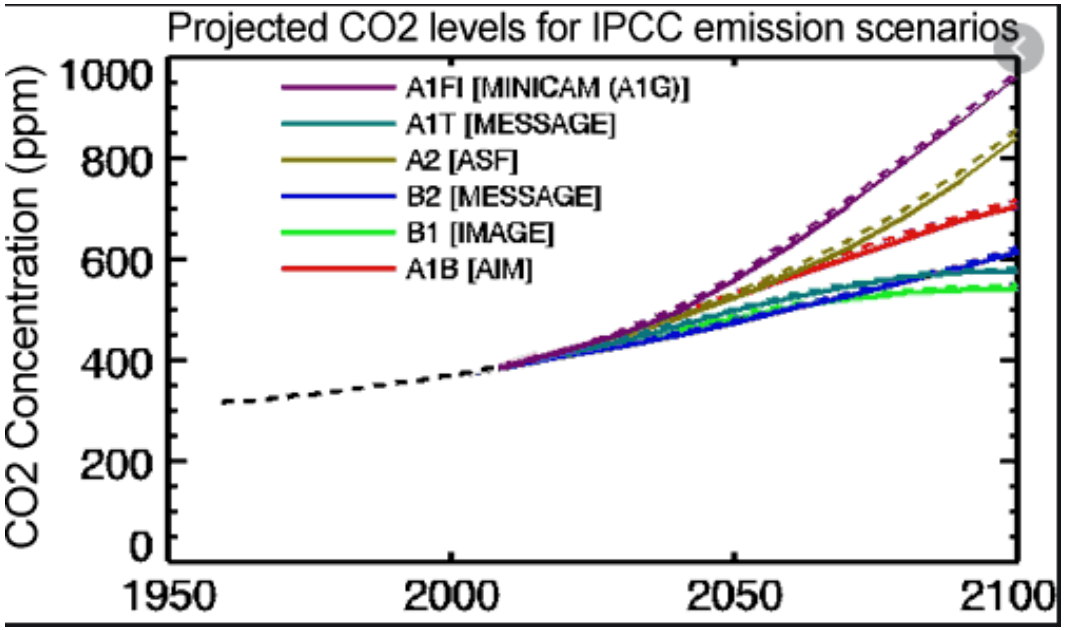
# CO2 Emissions (Historical Data) & Atmospheric CO2

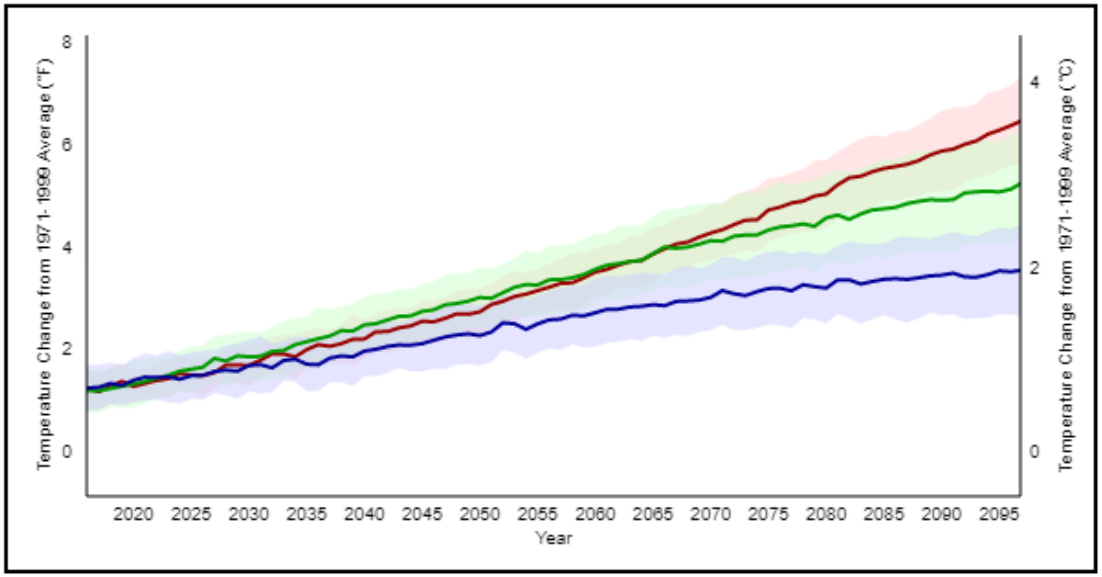


# CO2 and Global Temperature

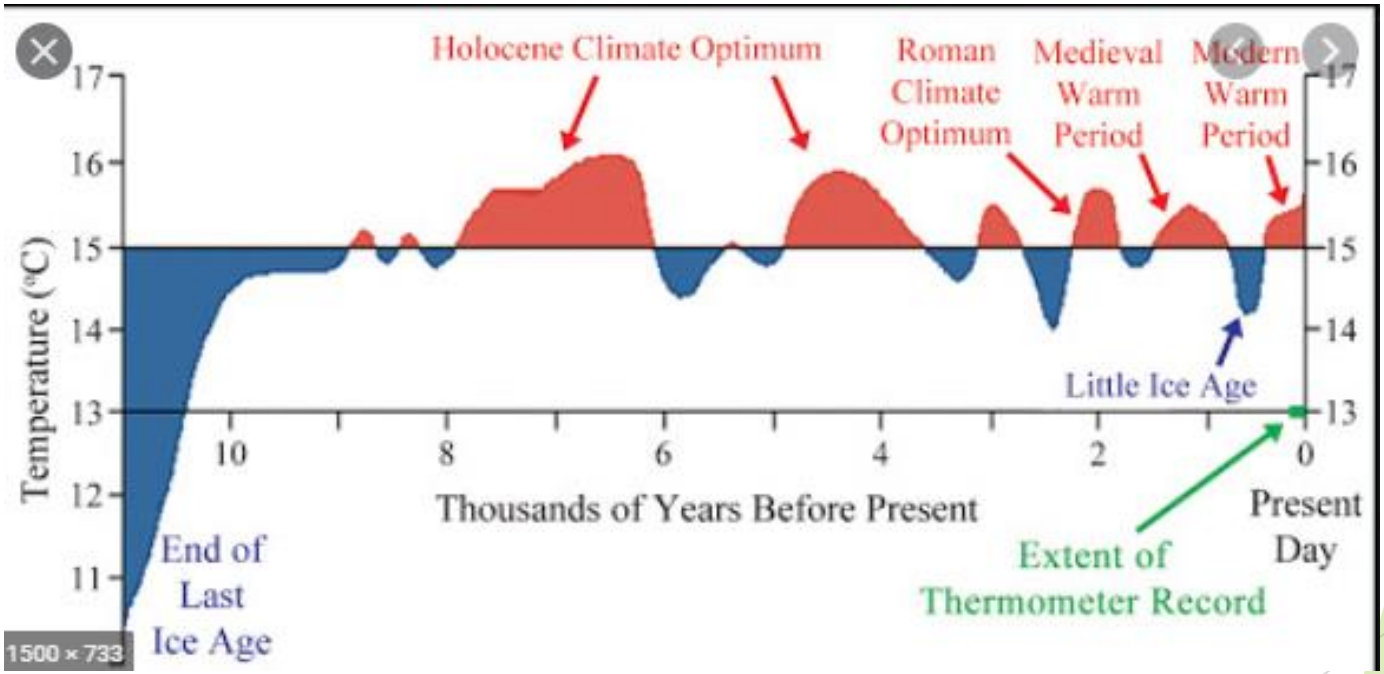


# Global Temperature Projection

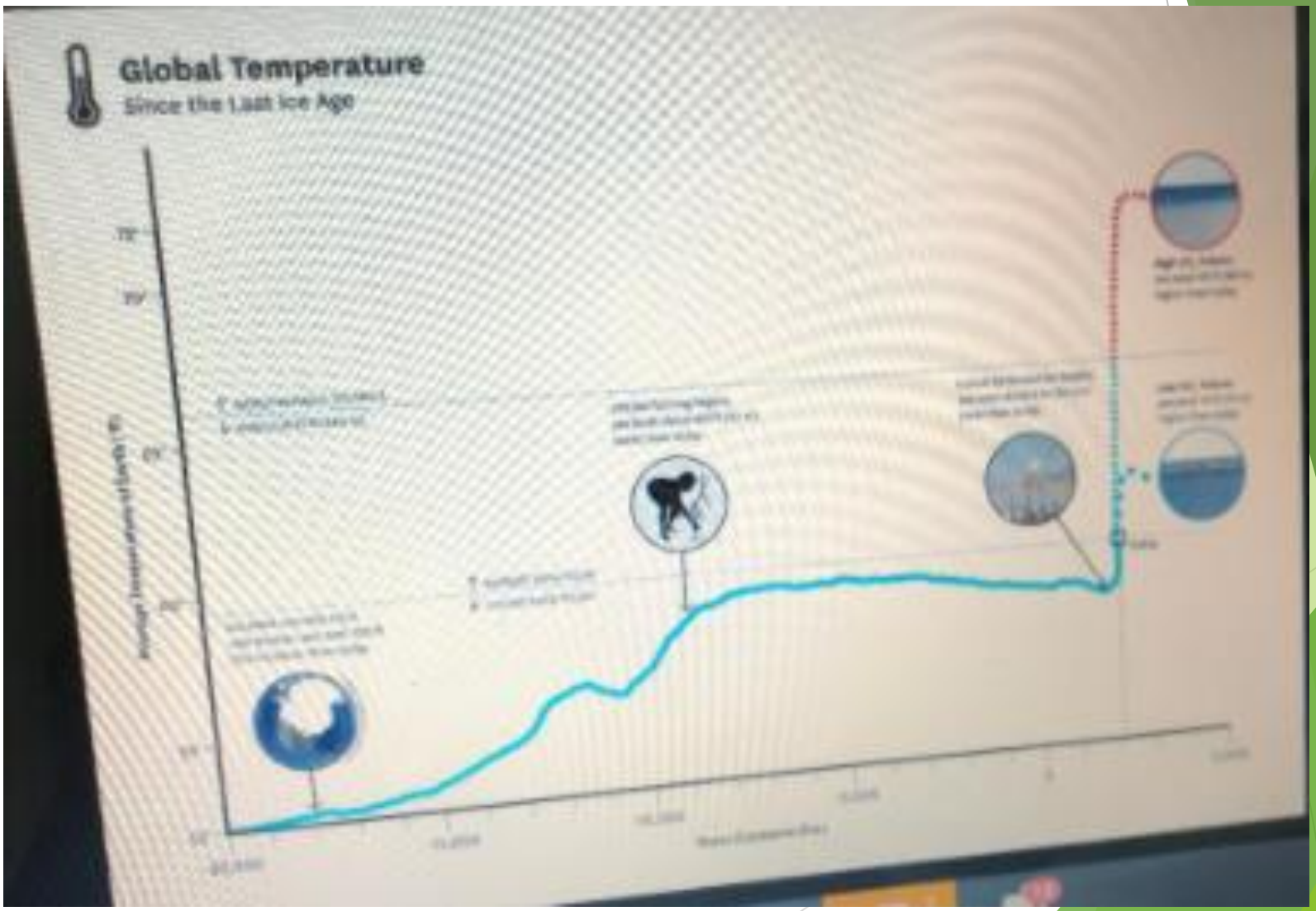


# Anthropogenic Global Temperature



# Temperature since last Ice age



# Questions ?/ Discussion

Who cares that Global temperature is rising?

Why does it matter ?

Answer:

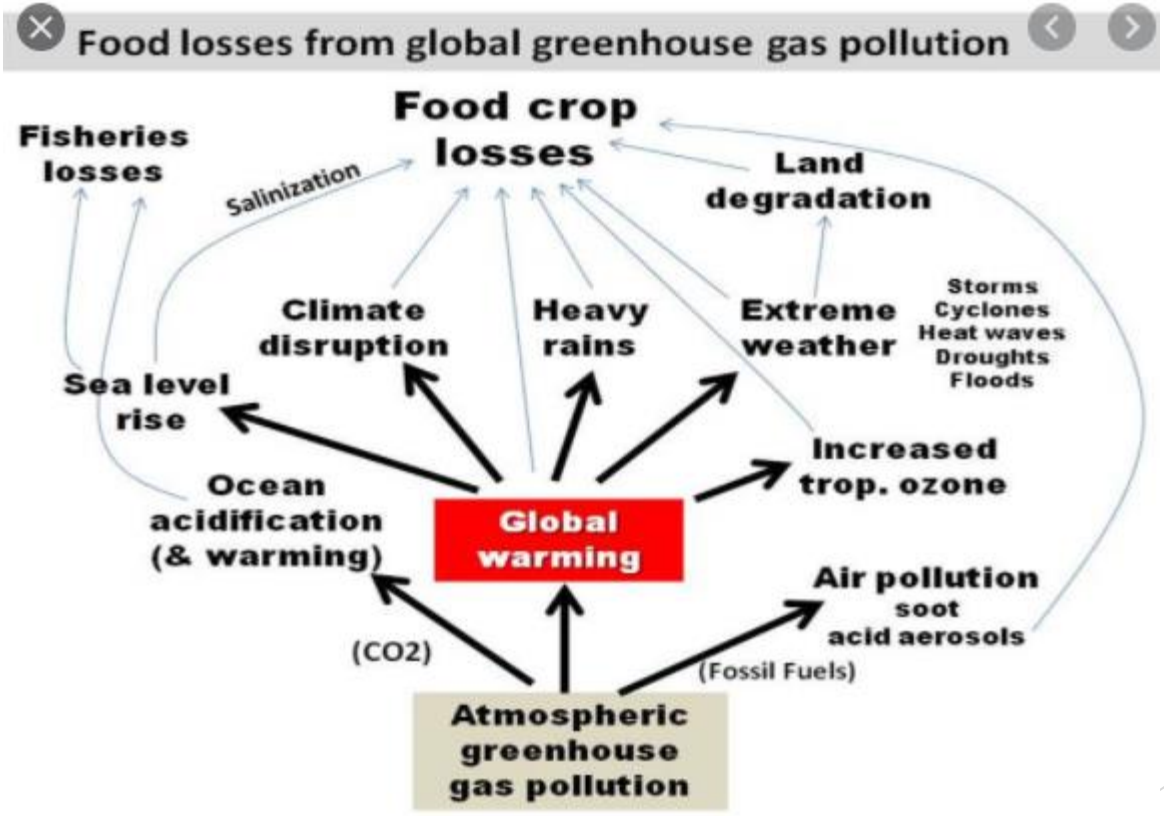
Humans need,

1) Habitable Land mass

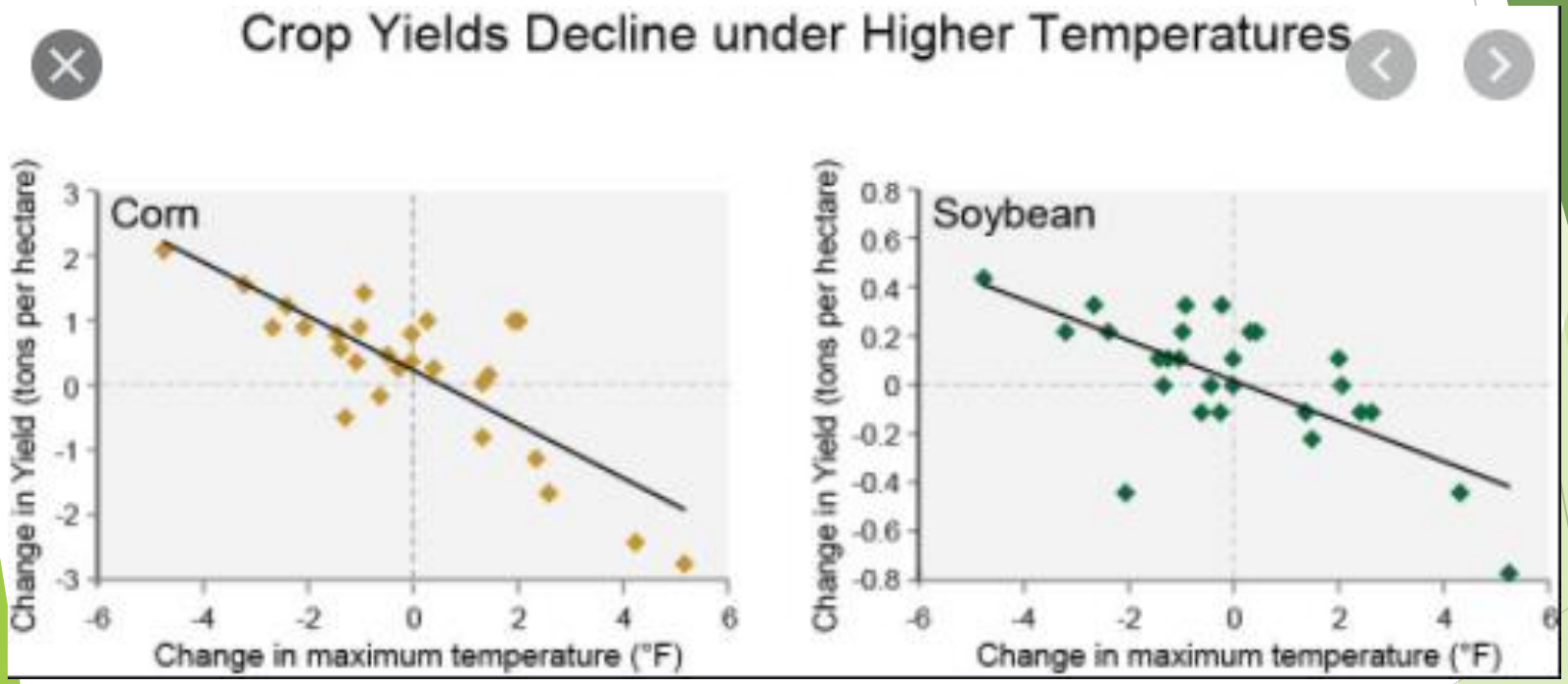
&

2) Food Security

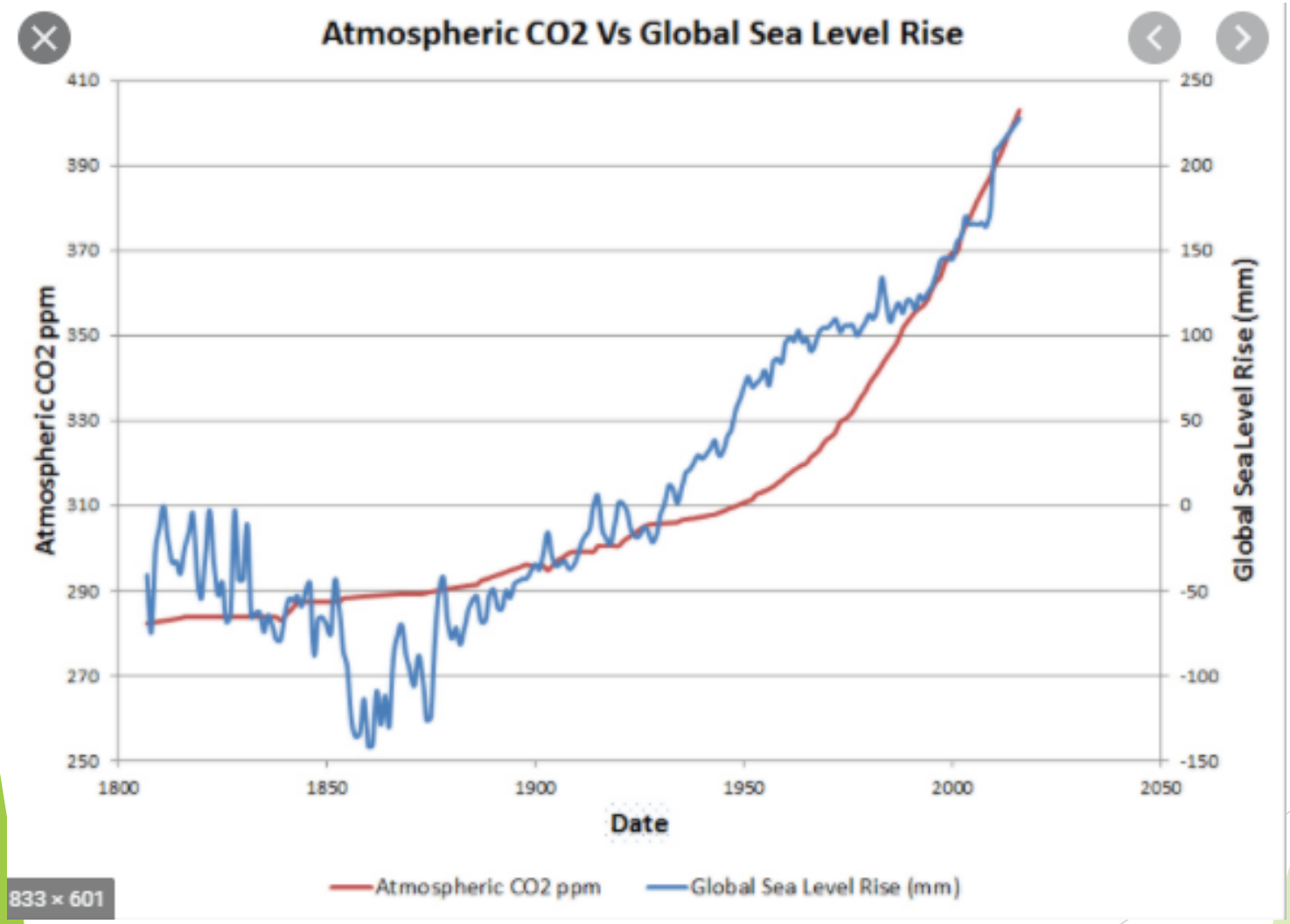
# Climate Change and food production



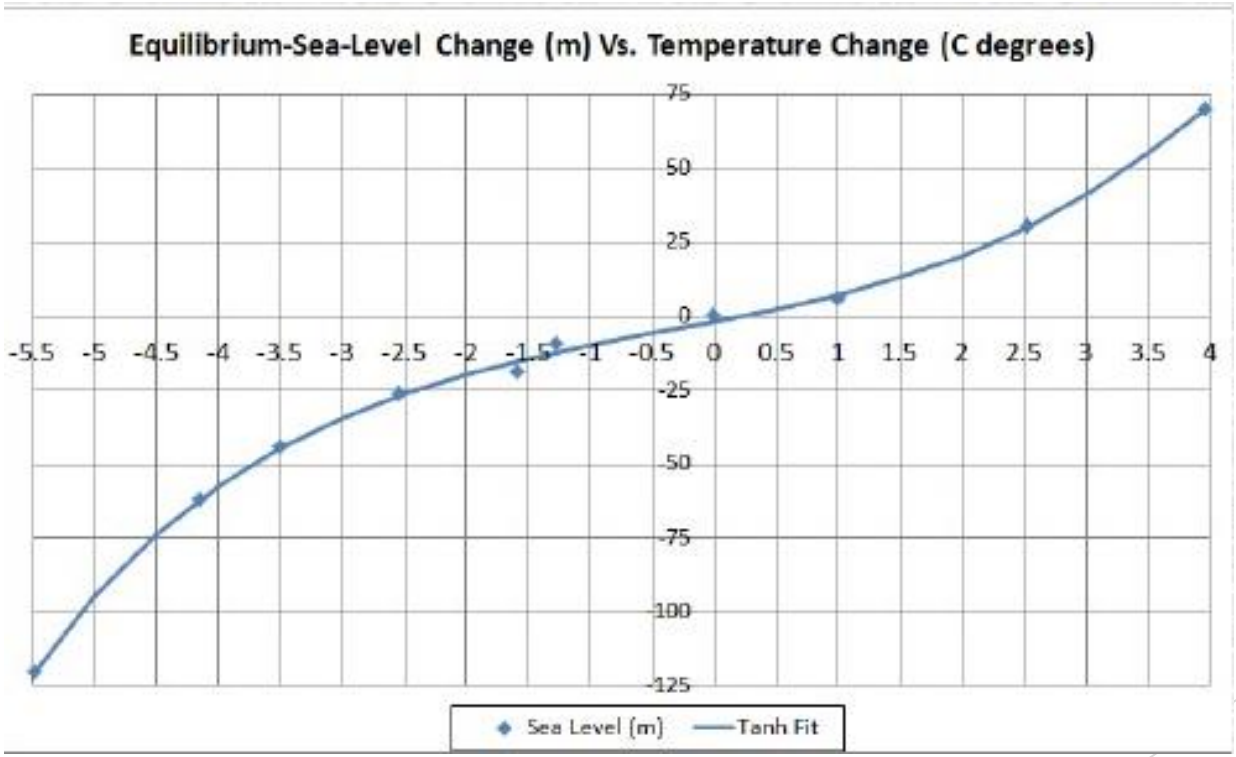
# Food Production and Temperature



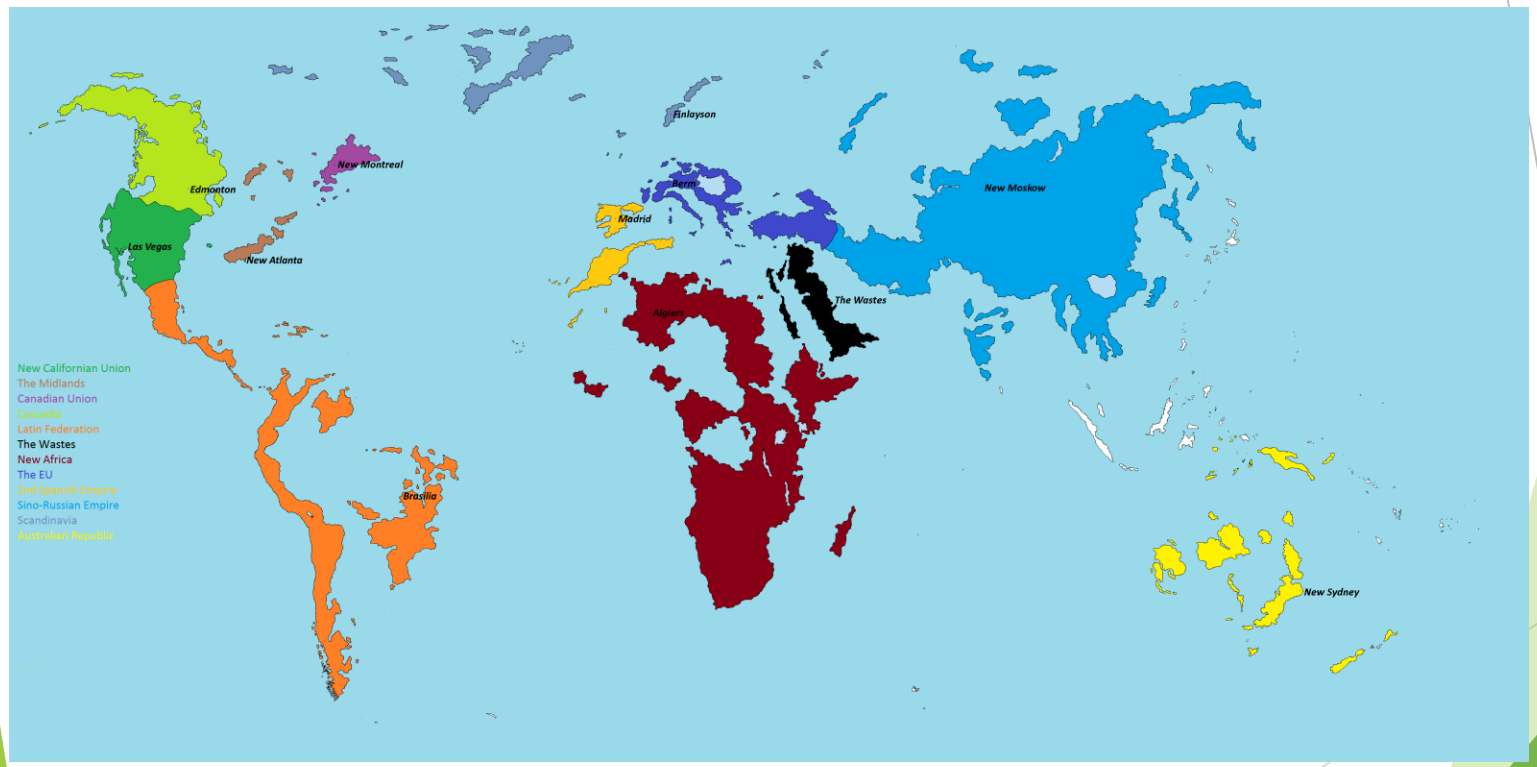
# Sea Level Vs CO2



# Sea Level Vs Temperature



# Land left when all glacier ice has melted



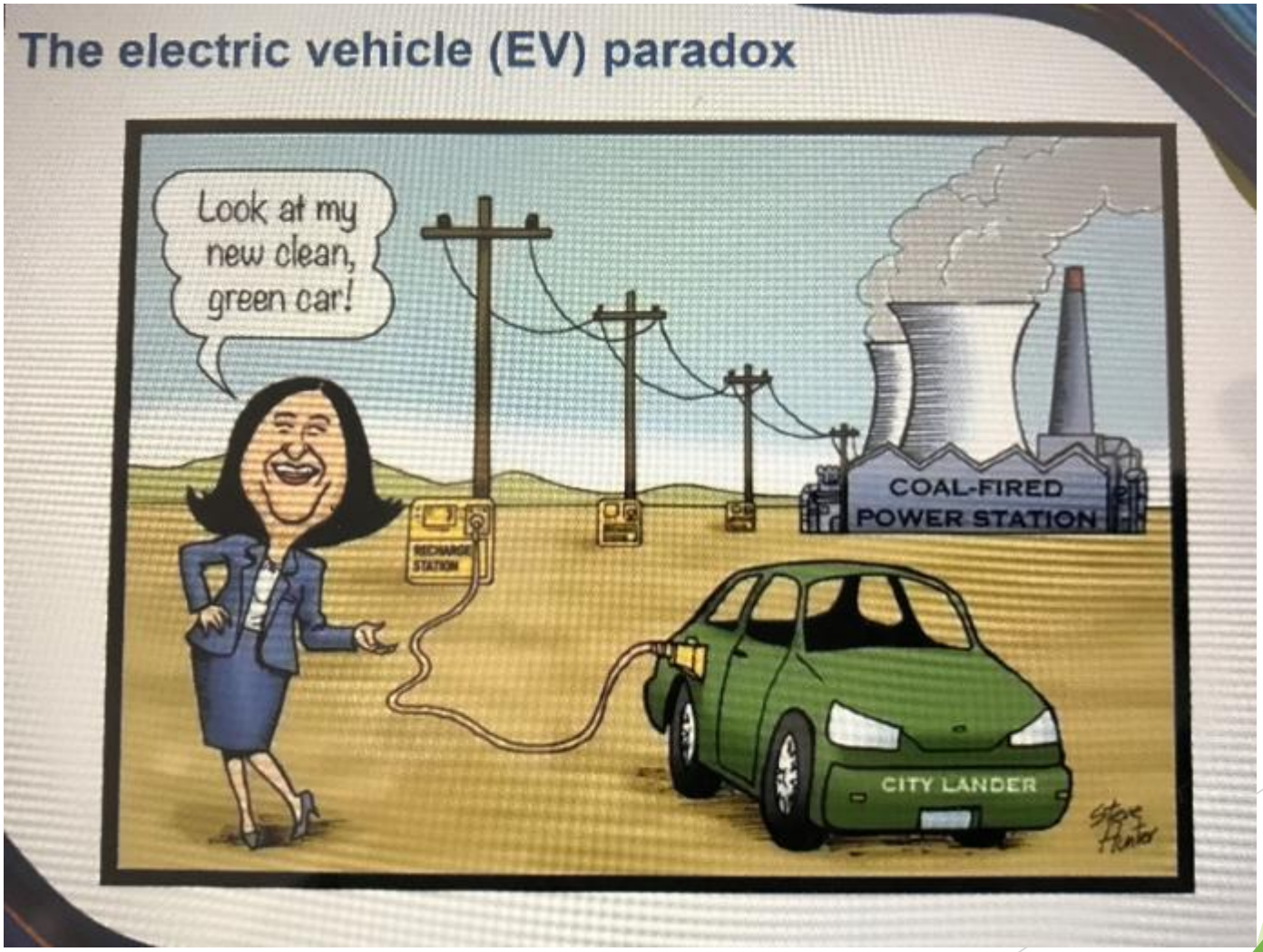
# Conclusions

- CO2 is a green house gas
- Atmospheric CO2 causes global warming
- Warmer temperatures reduces food production
- Global warming causes sea level rise

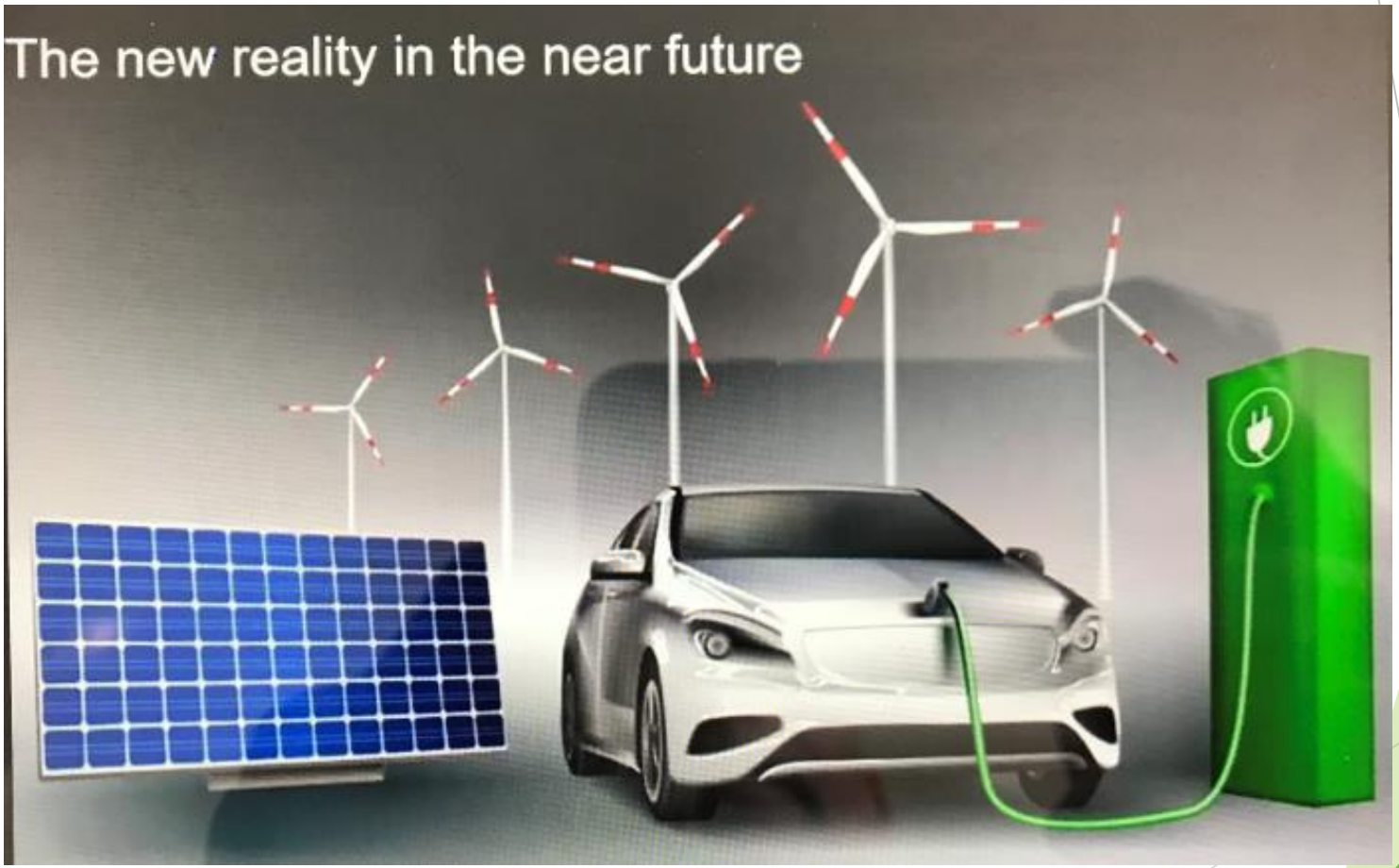
# Questions ?/ Discussion

# Path to Sustainability

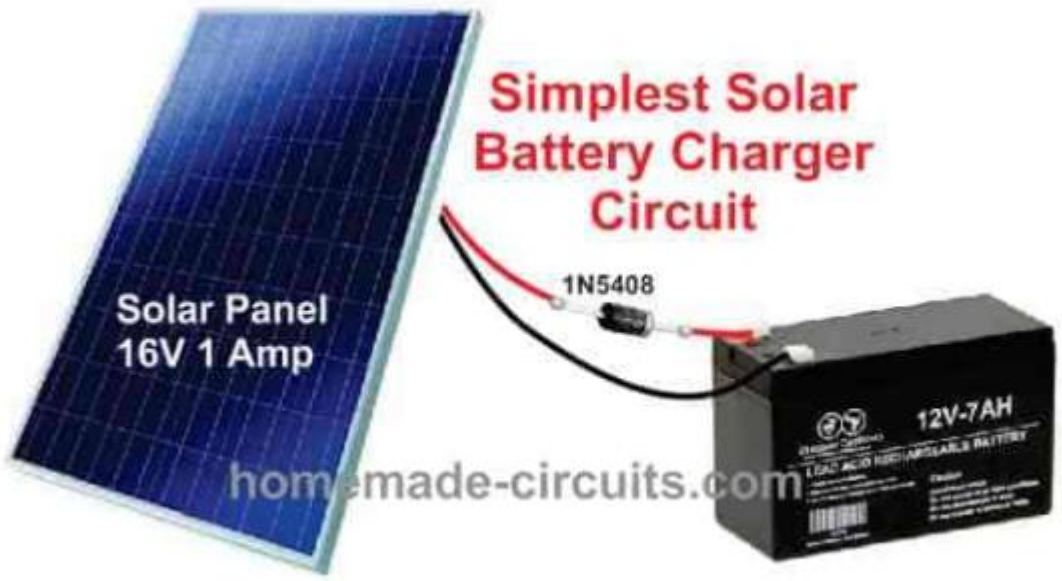
# Present


The electric vehicle (EV) paradox
Look at my new clean, green car!
COAL-FIRED POWER STATION
RECHARGE STATION
CITY LANDER

# Future

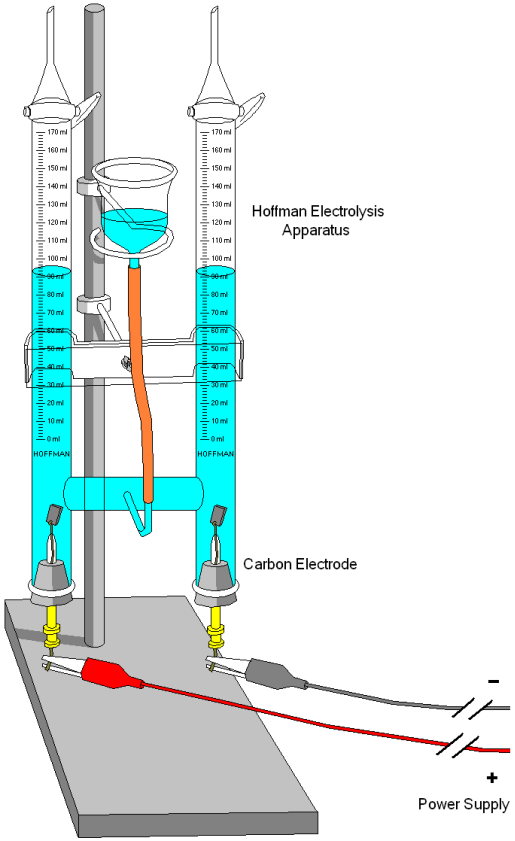


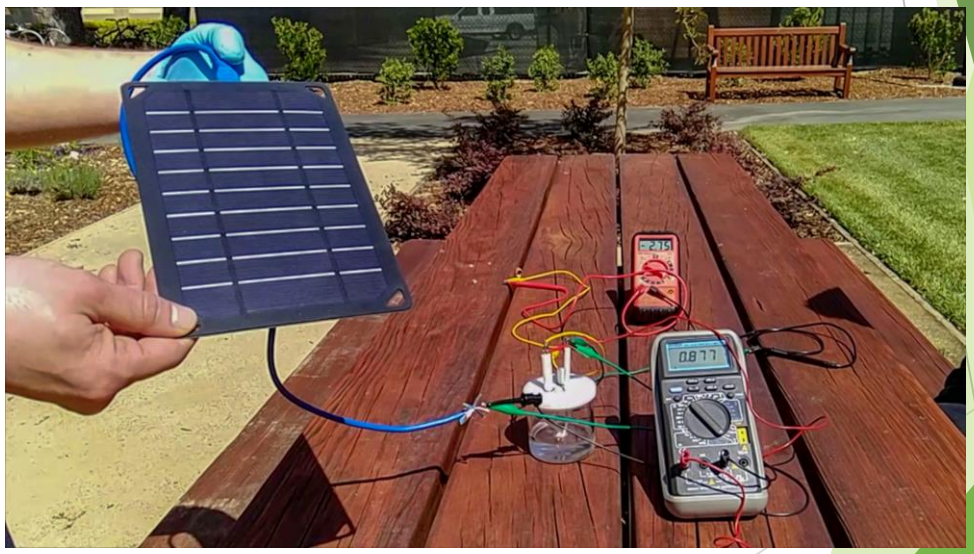
# Zero Emission EVs
# Solar to battery charging



# Zero Emission Hydrogen EVs Electrolyzer

**Electrolysis is the passing of a direct electric current through an electrolyte producing chemical reactions at the electrodes and decomposition of the materials.**



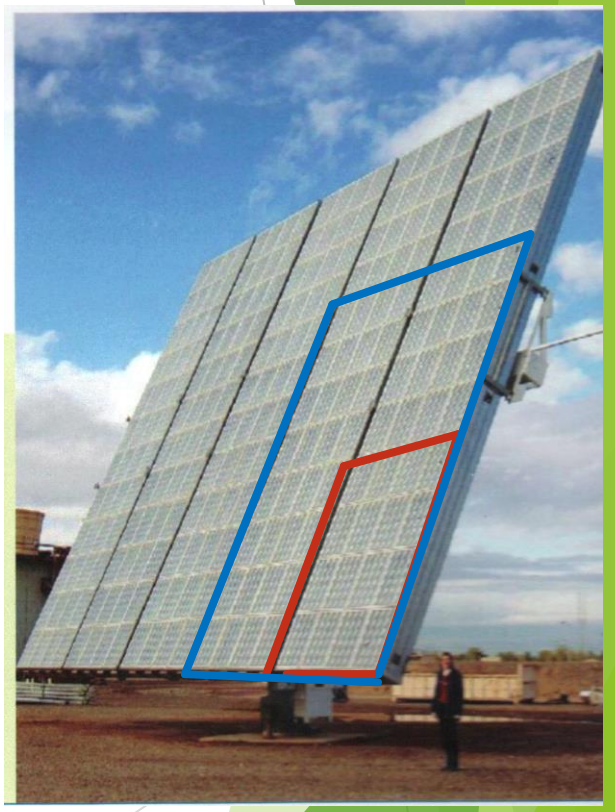
# Questions ?/ Discussion

# Path to zero Emission Transportation Today

- Drive an EV
- Install rooftop solar (Pay as little as possible!!!)
- If you drive 12,000 miles/year or 33 miles/day then install 2 kWh for charging the car. Cost : $5300 (w/rebate)
- Scale up if you drive more.

# Solar Power for sustainable future

- For a 12000mile/year commute an EV will need 2 KWh solar system.
- (2 kWh/0.15/sqm)= 13.34 sqm = ~143 sft.
- A typical 2000 sqft home has ~2500sqft of roof area.
- For a family of four with two EVs would need to install (2x2) 4 kWh solar system.
- Add another 4 kWh for household electric use.
- 8 kWh system is : 572 sqft.
- Cost of 8 kWh Solar System: ~$22000 (With rebates)
- This will eliminate electric and gasoline bill for 15-20 years.
- $22000 loan for 15 years with 3.25% interest will have a monthly payment $154.



# Questions ?/ Discussion

# EVs & Financial Markets

# EV Manufacturers

- Tesla (USA)– Cars , SUVs
- GM (USA) – Chevy Bolt, GMC Hummer
- Nissan (Japan)- Leaf
- Toyota(Japan) – RAV4, Prius Prime
- Honda(Japan) – Clarity
- Nio (China) –
- Volks wagon -

# Tesla the big Kahuna

NASDAQ Symbol : TSLA
Market Cap: $586 Billion
P/E: 995
Price/Sales : 18.8
Char: Stylish, Multiple models , long range,Quality

# Other manufacturers

- GM : Ultium Battery, Established Manufacturer, Commitment to go all electric in 20 years.
- Toyota : Established manufacturer, Hybrid experience, quality
- Nio : Startup Chinese company, low cost, replaceable battery.
- Nissan : Established manufacturer, early entry
- Volks wagon : Established manufacturer, Well funded
- BMW : Established manufacturer, Well funded, Luxury market
- Kia : Established manufacturer, Well funded, low cost
- Workhorse : Startup - Delivery Vans
- Ride : Startup – Trucks
- Nikola : Startup – Semi Tractor Trailers
- Fisker Karma : Startup – Sport Cars

# Battery Manufacturers

- Tesla – Li Ion , Lithium Ion Cobalt Battery
- GM – Ultium Battery – Lithium Ion
- LG Chem – ALL types of batteries including Li Ion
- Panasonic – Largest Battery Manufacturer- Tesla Partner.


## Start ups :

Quantumscape : Solid state Lithium Ion

Store Dot : Fast charging “Li Ion Flash” Battery

NOHM : Safety- non-flammable electrolytes

Lithium Werks : Lithium cobalt oxide cathode and a graphite anode

Faradion : Sodium Ion Technology

# Quantumscape

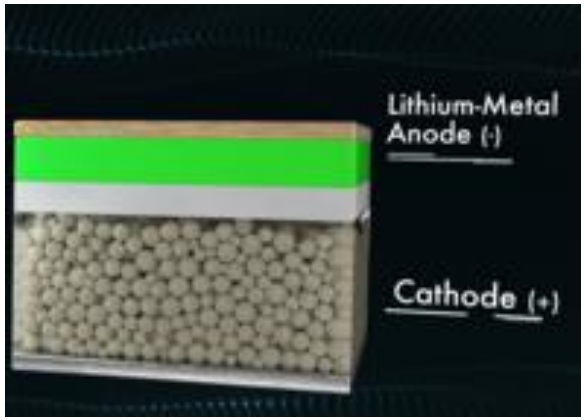
NYSE Symbol : QS

Market Cap: $17 Billion

P/E: -48

Price/Sales : No sales

Char: Solid State Li Ion

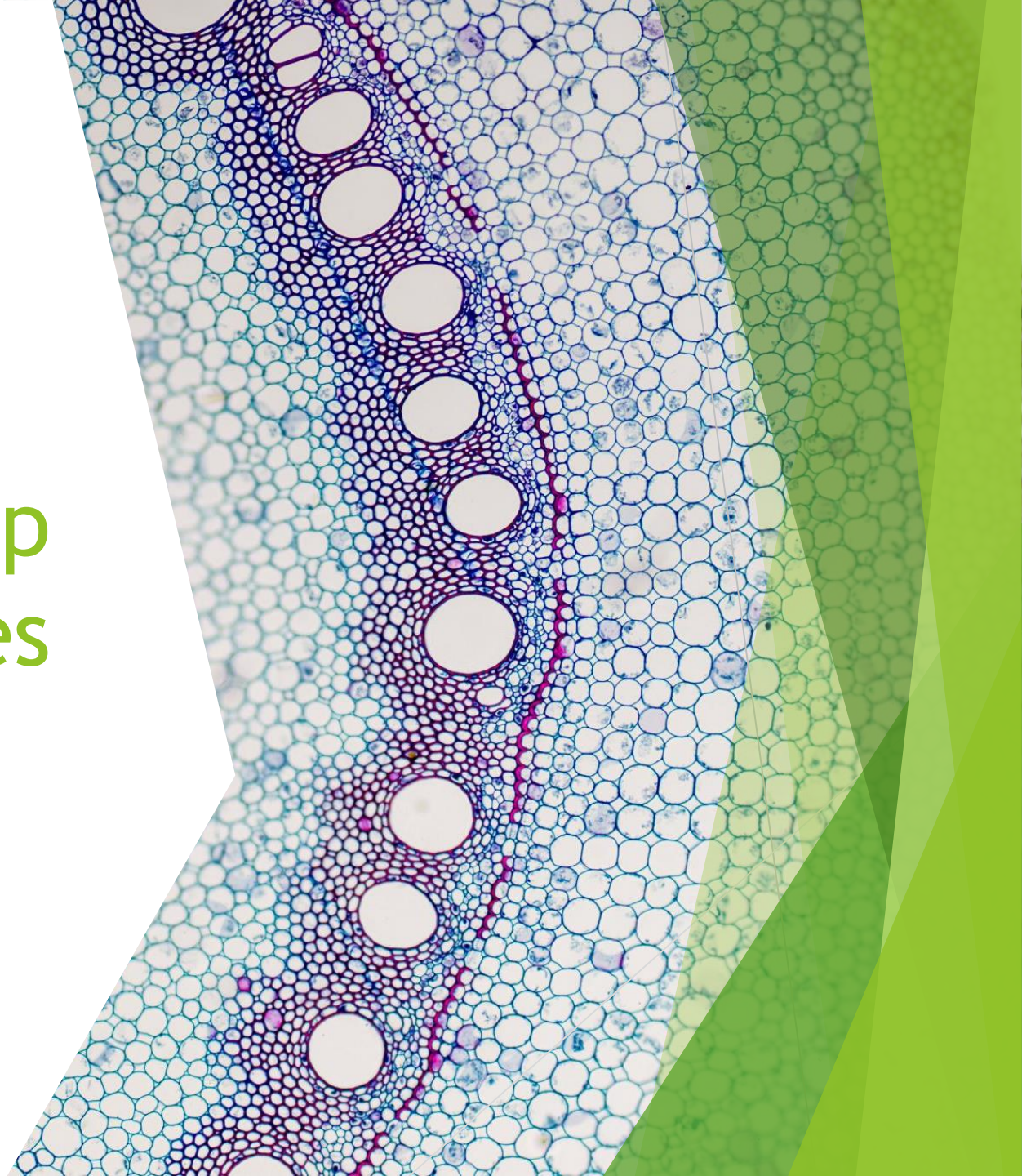



Discussion : Climate change is a political issue. Even if reduce our carbon footprint , the developing countries will continue to pollute. So state department needs to negotiate with other governments to reduce pollution.

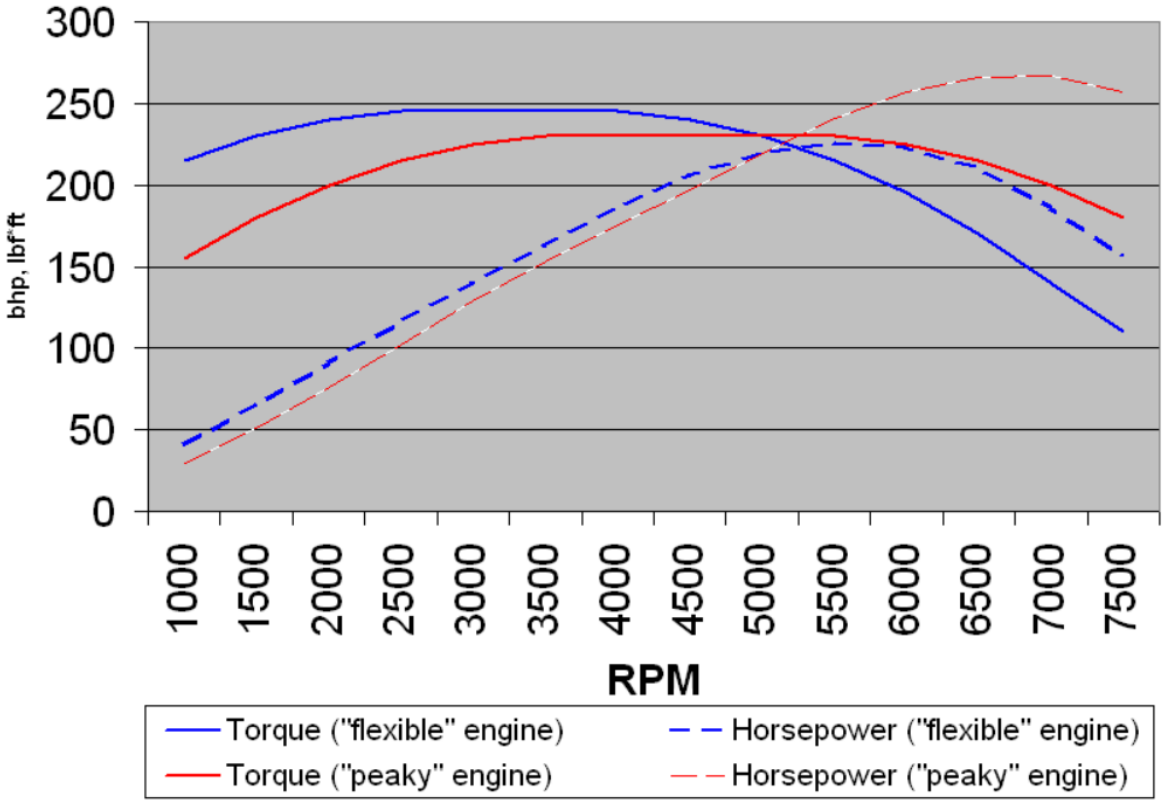
Comment: It is true that developing countries have become major  carbon emiters. However as a member of human race we should do our part to reduce our carbon footprint.

# Thank you !

# Back up Slides



# German Solar/Agricultural Farm


300
250
200
150
100
50
0
bhp, lbf*ft
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
RPM
Torque ("flexible" engine)
Horsepower ("flexible" engine)
Torque ("peaky" engine)
Horsepower ("peaky" engine)

# US Crude Oil Reserves

- **Proven Reserves** *(EIA)* -19.4 Billion Barrels

- **Prospective Reserve**-*(USDI-MMS,USGS)*
  -***Offshore*** *(OCS) : 85.9 Billion Barrels*
  1.Gulf- 44.9 Billion Barrels 2) Alaska - 38.8 Billion Barrel
  -***Onshore*** : 48.5 Billion Barrels
  1.Alaska-a) ANWR-10.4 BB & b) NPRA-10.6BB
  2. Bakken Oil Formation-4.5BB (150BB) 3. Other – 23 BB

- **Unconventional Prospective Reserves**-*(BLM)* -
- Shale Oil (Colorado,Wyoming)–2.15 Trillion Barrels.
  -Commercial Production – None.

# Traditional Energy –Natural Gas

- **Natural Gas Reserves by Country**

1. Russia – 55 Trillion Cubic Meters
2. Iran - 33 Trillion Cubic Meters
3. Turkmenistan - 26 Trillion Cubic Meters
4. Qatar – 25 Trillion Cubic Meters

5 USA– 8 Trillion Cubic Meters

6. Saudi Arabia – 7 Trillion Cubic Meters
8. Venezuela – 5.5 Trillion Cubic Meters

# Solar Power

- With current solar technology each person in USA will need 208 sq meters of solar cells to meet his or her energy needs.
- (250kWh/8h)/0.15kW/sqm)=208 sqm=~2400sqft
- For a 12000mile/year commute an EV will need 2KWh solar system.
- (2 kWh/0.15/sqm)= 13.34 sqm = ~143 sft.
- A typical 2000 sqft home has ~2500sqft of roof area.
- For a family of four with two EVs would need to install (2x2) 4 kWh solar system.
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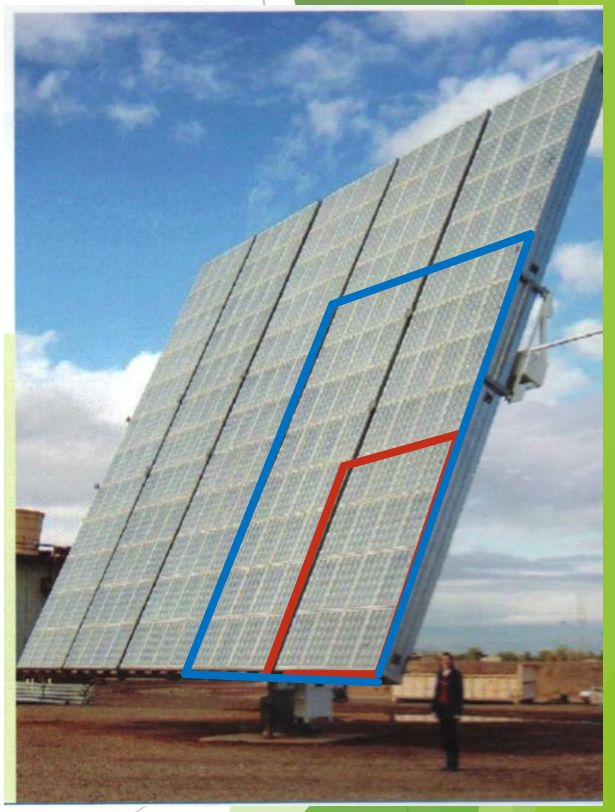
- Cost of 8 kWh Solar System: ~$22000



# Energy Facts

- A car that gets 25 mpg will consume 80 kWh for a 60 mile commute.
- A typical American household uses 8 kWh per day per person for air-conditioning, Appliances, lighting, cooking etc.
- A human produces 1 kWh of mechanical energy per day.
- Each of us have 250 energy servants working for us!!!!!

# Energy Density (kWH/lb)

- Coal : 4.48 kWH/lb
- Gasoline :  6.16 kWH/lb
- Uranium-235 = 10.4 MWH/lb
- Li Ion Battery:  0.059 kWH/lb
- LNG : 6.16 kWH/lb
- CNG: 6.16 kWH/lb
- Gasoline/gallon:33.7 kWH
- Ethenol/gallon: 4.5 kWH
- Diesel/gallon: 6.96 kWH/lb
- Liquid Hydrogen: 19.7 kWH/lb

# Energy Content

- Gasoline/gallon: 130 Mega J= 36.4 kWH
- LNG/gallon: 130 Mega J= 36.4 kWH
- CNG/gallon: 130 Mega J= 36.4 kWH
- Ethenol/gallon: 94.9 Mega J=26.6 kWH
- Diesel/gallon: 146.9 Mega J= 41.1 kWH

- Tesla Model S
- Cost : $70620
- Mileage/kWh : 3.36 m/kWh
- kWh for 100k miles: 30000 kWh
- Cost of gas @ $0.18/kWh : $5400
- Cost/mile (Electricity) : $0.054/mile
- Range : 373miles

# ICE Vehicle (Full Size Car)

- Toyota Camry
- Cost : $26170
- Gas Mileage : 32 mpg
- Fuel for 100k miles: 3000 gallons
- Cost of gas @ 3.33/gal : $10000
- Cost/mile (Fuel) : $0.10/mile
- Range : 500miles

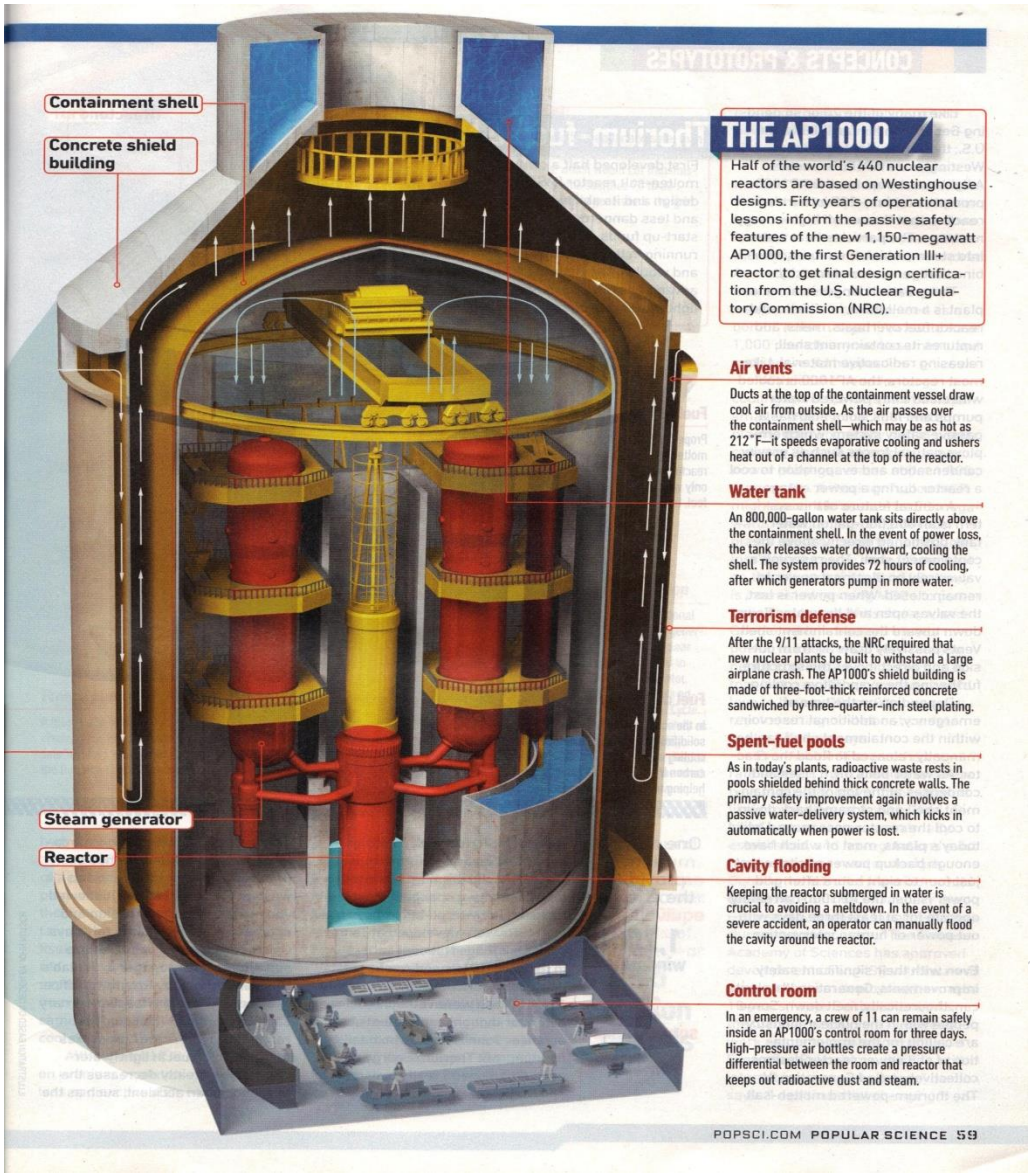
# Hybrid Vehicle (Full Size Car)

- Toyota Camry Hybrid
- Cost : $32720
- Gas Mileage : 50 mpg
- Fuel for 100k miles: 2000 gallons
- Cost of gas @ 3.33/gal : $6660
- Cost/mile (Fuel) : $0.066/mile
- Range : 600miles

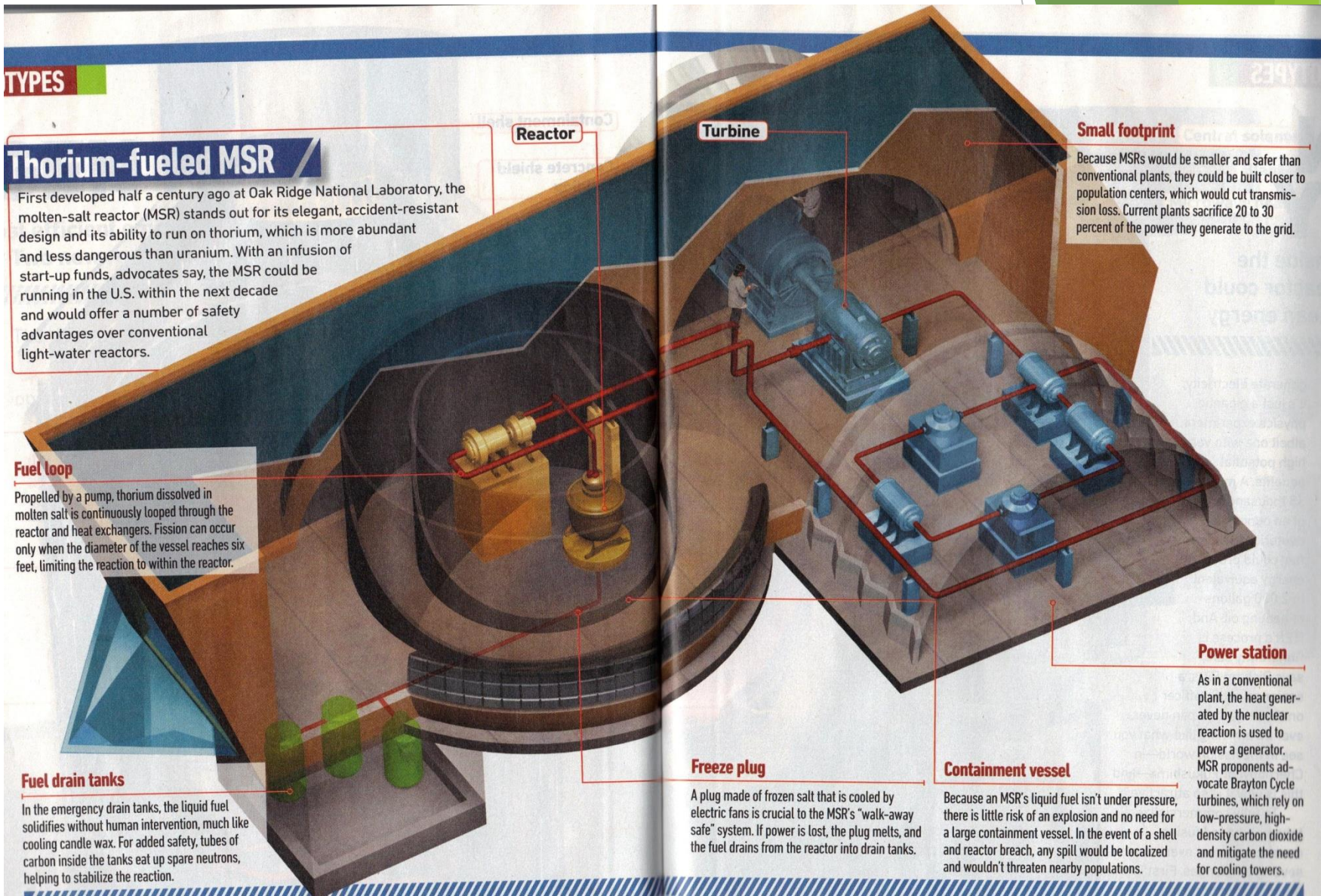
# Why the push for electric cars

- **Economies of Scale**
- **Development of technology**
- Technology is developed by government organizations. I.e MITI, DARPA, FFRDC , DOE etc
- Technology is developed by businesses.
- Technology is developed by business due to government incentives. I.e. Tax incentives, price control  etc.

# Nuclear Energy-Fission Reactor

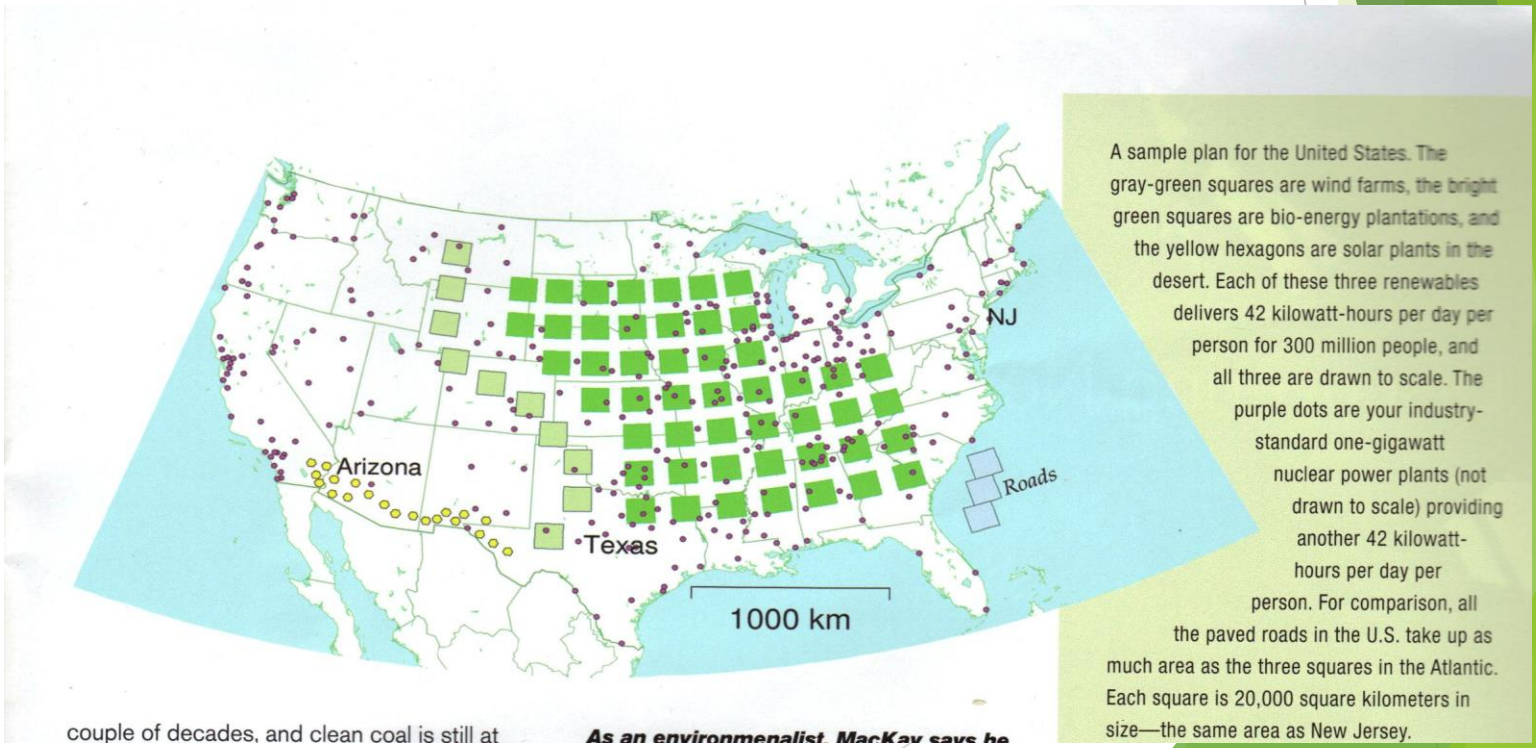


# Nuclear Energy-Thorium Reactor



# Alternate Energy Plan for USA

- Green Square – Bio-energy Plantation
- Light Green – Wind Farms
- Yellow Dots – Solar Farms

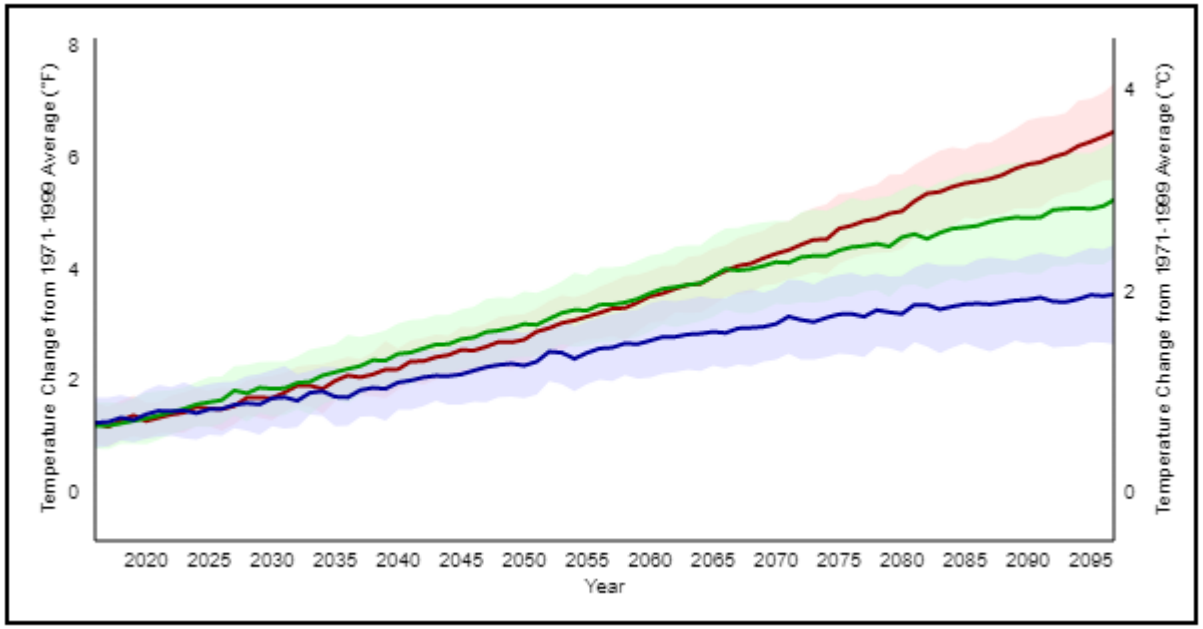


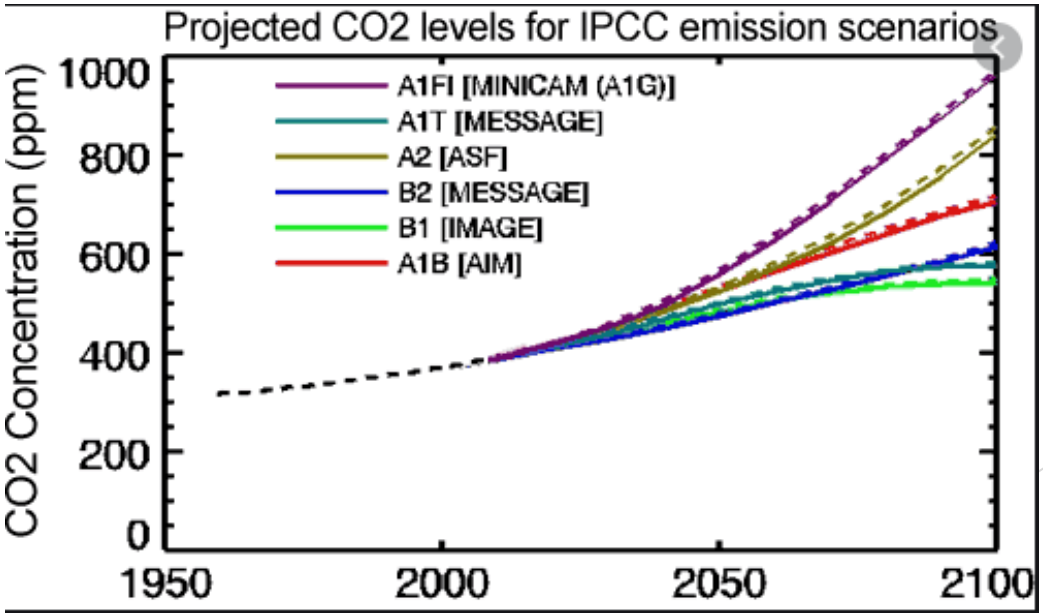

A sample plan for the United States. The gray-green squares are wind farms, the bright green squares are bio-energy plantations, and the yellow hexagons are solar plants in the desert. Each of these three renewables delivers 42 kilowatt-hours per day per person for 300 million people, and all three are drawn to scale. The purple dots are your industry-standard one-gigawatt nuclear power plants (not drawn to scale) providing another 42 kilowatt-hours per day per person. For comparison, all the paved roads in the U.S. take up as much area as the three squares in the Atlantic. Each square is 20,000 square kilometers in size—the same area as New Jersey.

couple of decades, and clean coal is still at

**As an environmenalist, MacKay says he**

# Global Temperature Projection



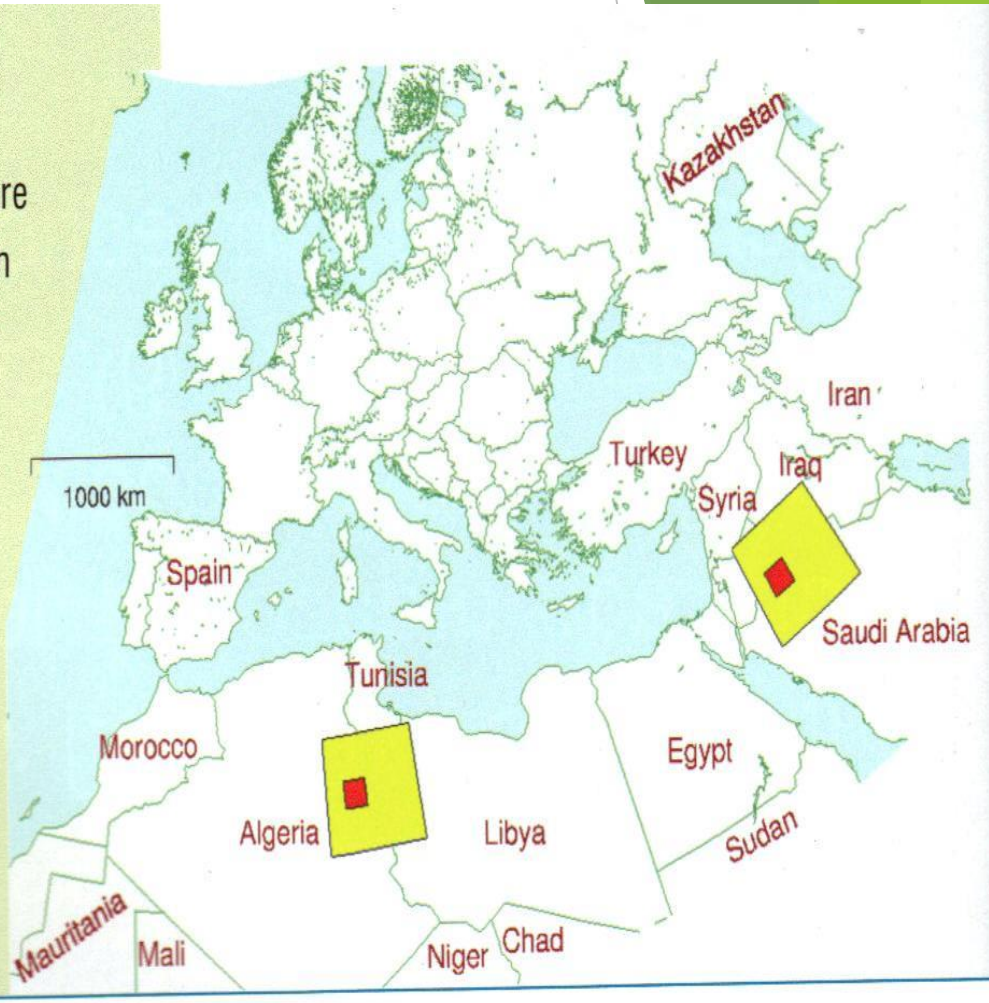



# Energy Consumption Facts

- Energy Consumption in Kilowatt per day per person,
- USA : 250 kWh/day/Person
- Europe : 125 kWh/day/Person
- Middle East : 115 kWh/day/Person
- World : 60 kWh/day/Person
- China : 50 kWh/day/Person
- India : 17 kWh/day/Person
- Bangladesh : 5 kWh/day/Person

# Alternate Energy Plan for Europe

At an average of 15 watts per square meter, harvesting concentrated solar power in the desert is our best option among the renewables. The yellow squares on this map are 600 kilometers on a side. Completely filling one of them with solar concentrators would supply power for a billion people at the European standard of consumption; doing the same for the world would require *two* such squares 1,000 kilometers on a side.



# Thank You

- Questions- Discussion ?

# Global Temperature (Historical Data)