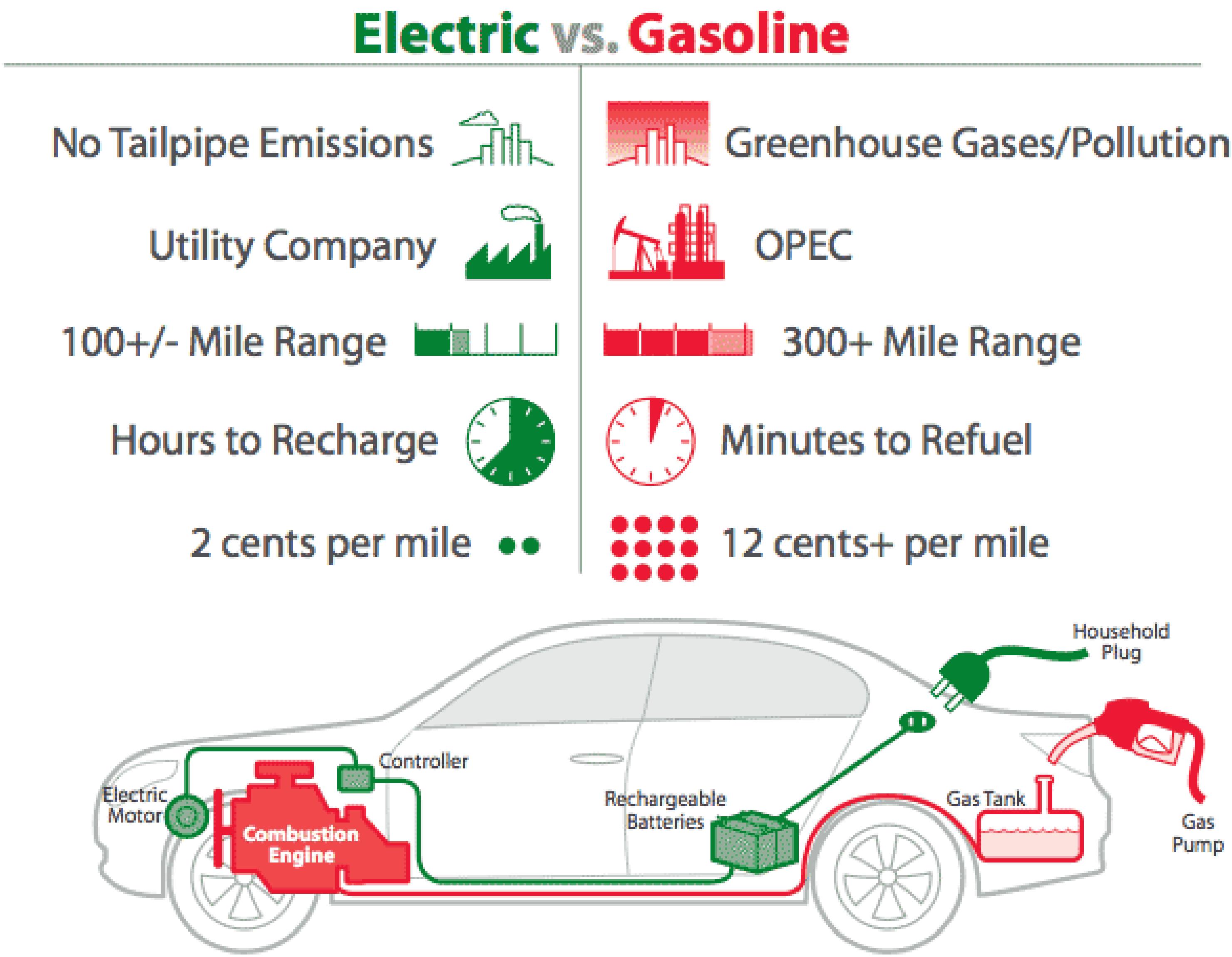
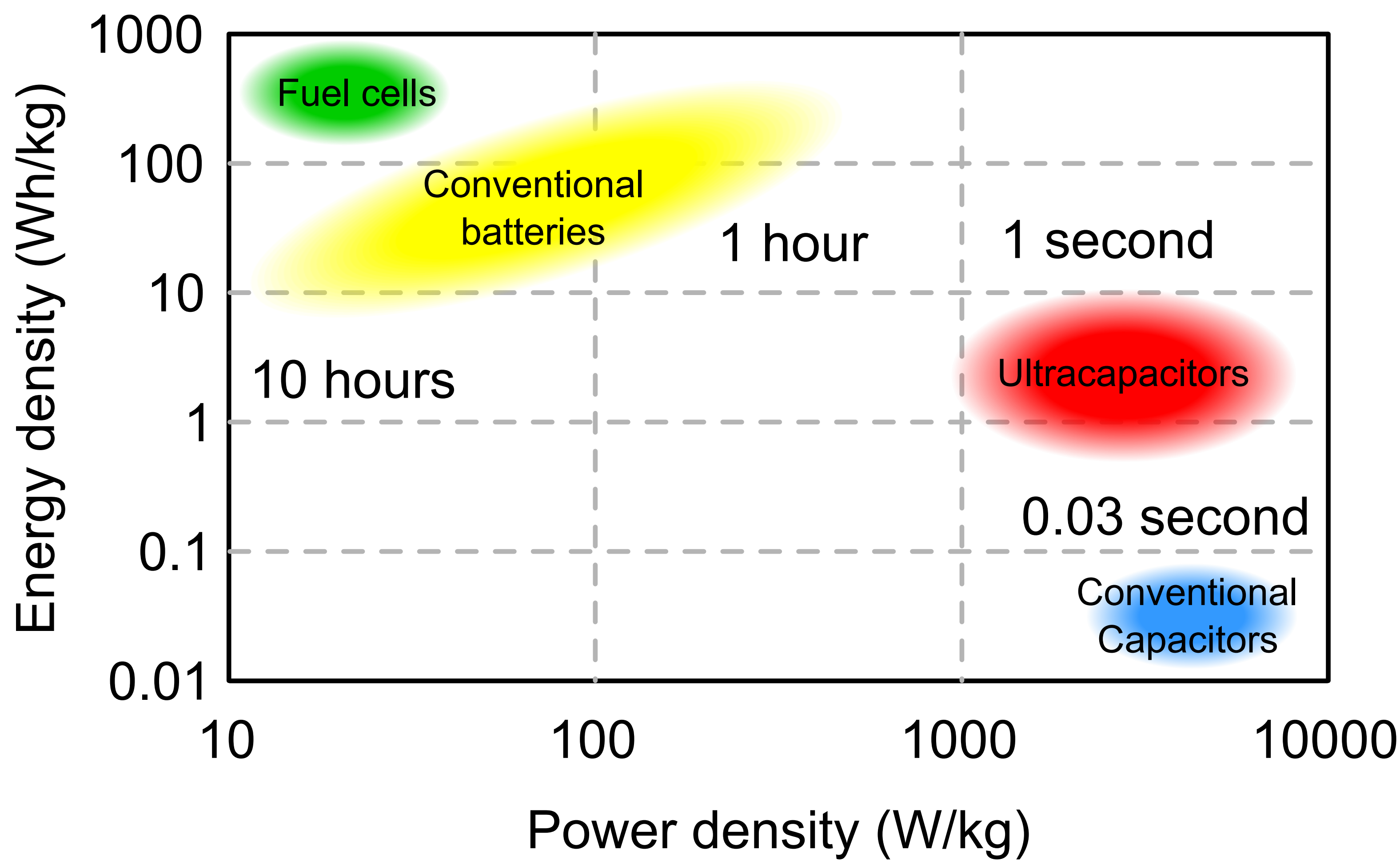
New capacitors to improve electric vehicles

What is electric vehicle?



Energy storage devices



Issues need to be solved for Capacitors used in EV

- The permittivity is a function of temperature, hence the capacitor, and the output voltage when using.

$$V = \frac{Q}{C}$$

- To keep the capacitor temperature at optimum temperature, cooling system is required, which will add weight onto the vehicle.

Solution: Use ceramic dielectric material that could operate at 200 C without changing capacitance significantly.

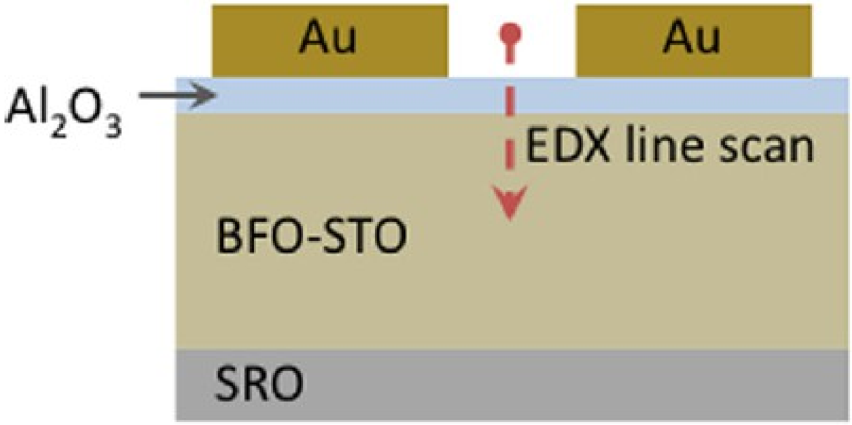
Comparison to other materials

Material	Operating Temperature Range	Dielectric Constant	temperature capacitance change (%)
C0G	-55 to 125 °C	10 - 100	0.3 % (-55 to 125 °C)
X7R	-55 to 125	2000 - 4000	+/-15 % (-55 to 125 °C)
Y5V	-55 to 125 °C	> 16000	< 82 % (-30 % to 85 °C)
HITECA	**-55 to 200 °C**	**> 1200**	**+/-10 % (-55 to 200 °C)**

Potential markets

- Pulsed power
- Harsh environments
- Automotive
- Renewable energy
- Space
- Integrated circuits

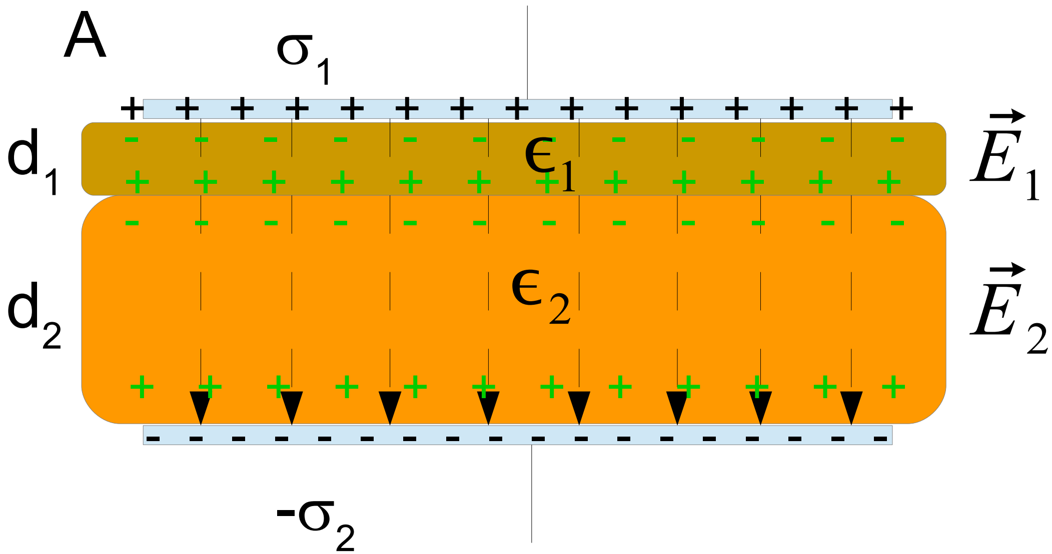
How they do it?



Au: Top Electrode
Al_2O_3: Dielectric Material 1
BFO-STO: Dielectric Material 2
SRO: Bottom Electrode

BFO-STO: $(BiFeO_3)_{0.6}$-$(SrTiO_3)_{0.4}$
SRO: $SrRuO_3$

Based on what you learn, do you know the capacitance?



In their case, $\varepsilon_1 < \varepsilon_2$

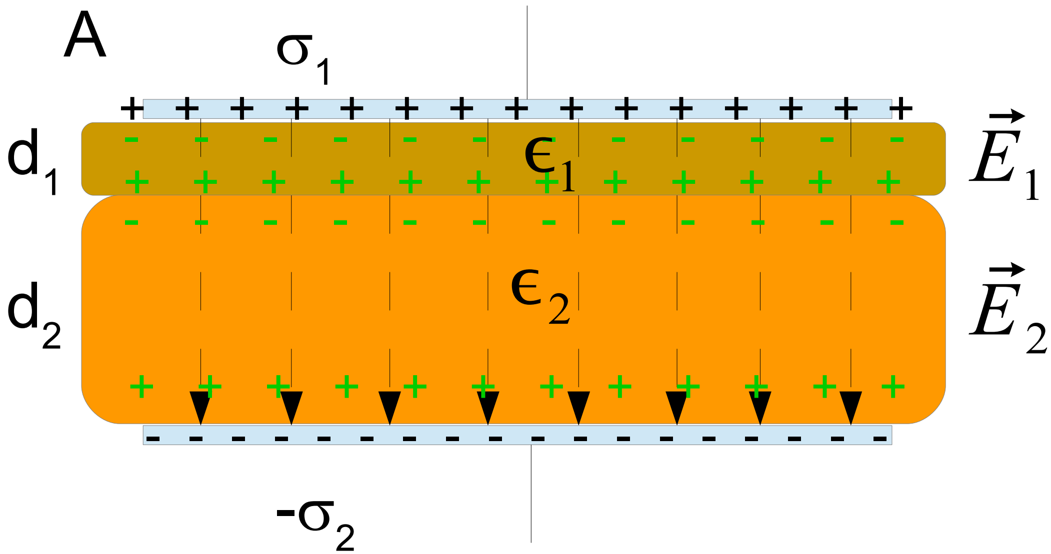
Quiz: What is the relationship between the magnitude of σ_1 and σ_2

(a) $\sigma_1 > \sigma_2$

(b) $\sigma_1 = \sigma_2$

(c) $\sigma_1 < \sigma_2$

Based on what you learn, do you know the capacitance?



In their case, $\varepsilon_1 < \varepsilon_2$

Quiz: What is the relationship between the magnitude of σ_1 and σ_2

Answer: $\sigma_1 = \sigma_2 = \sigma$

$$\vec{E}_1 = \frac{\sigma}{\epsilon_1}$$

$$\vec{E}_2 = \frac{\sigma}{\epsilon_2}$$

$$V = \int \vec{E} \cdot d\vec{l} = |\vec{E}_1| d_1 + |\vec{E}_2| d_2$$

$$V = \frac{\sigma}{\epsilon_1} d_1 + \frac{\sigma}{\epsilon_2} d_2 = \frac{Q}{A\epsilon_1} d_1 + \frac{Q}{A\epsilon_2} d_2$$

$$C = \frac{Q}{V} = \frac{A}{\frac{d_1}{\epsilon_1} + \frac{d_2}{\epsilon_2}}$$