Diesel vs Fuel Cell

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Hydrogen H_2

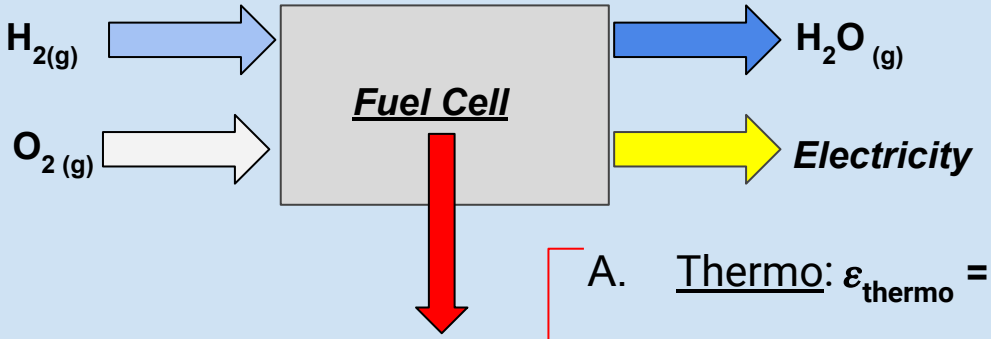
A) Steam Reforming

B) Gasification

C) Electrolysis

What is a Fuel Cell?

- Electrochemical energy conversion device
  chemical energy ⟶ electrical energy



A. Thermo: $\varepsilon_{thermo} = \Delta \hat{g}rxn / \Delta \hat{h}rxn$

B. Voltage: $\varepsilon_{volt} =$ Vcell / Erev

C. Fuel: $\varepsilon_{fuel} = \dot{n}_{\text{Fuel req for current I}} / \dot{n}_{\text{Fuel actual}}$

$$\varepsilon_{FC} = \varepsilon_{thermo} * \varepsilon_{voltage} * \varepsilon_{fuel} = (P_{out}) / (\dot{n}_{Fuel} * \Delta \hat{h}_{rxn})$$

* Problem Statement

Diesel Engine vs Fuel Cell Engine:

- ➔ Design
- ➔ Operation & Performance
- ➔ Maintenance

} Trade-offs

Diesel Analysis: *Chemical Balance*

Balanced equation with 50% excess air :

$$C_{12.226}H_{23.29} + 1.5 * 24.24 * (O_2 + 3.76N_2)$$
$$\rightarrow 12.16 * CO_2 + 0.066 * CO + 23.29 * H_2O + 0.8 * NO + 12.12 * O_2 + 136.31 * N_2$$

Assumptions

- Dry air is the oxidizer
- Ideal Gas Model used for air and exhaust
- Fuel is pure
- Combustion is complete
- Engine operates @ STD conditions
- Neglect products of Sulfur Due to its low content in diesel.

Diesel Exergy Analysis: Literature Review

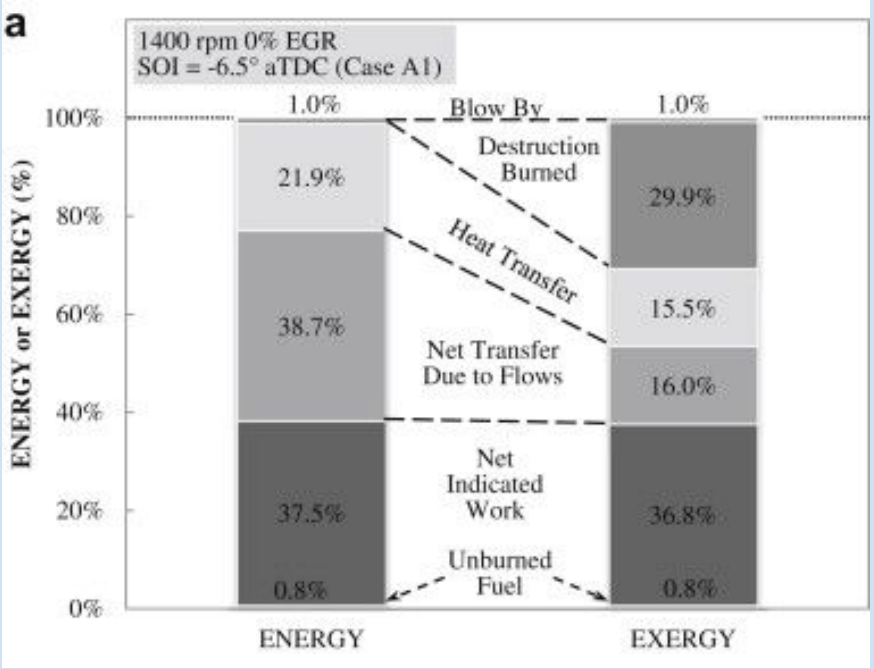
- Diesel has some options to improve performance such as exhaust gas recirculation (EGR)
  - This just means some of the exhaust gas is brought back to the cylinders

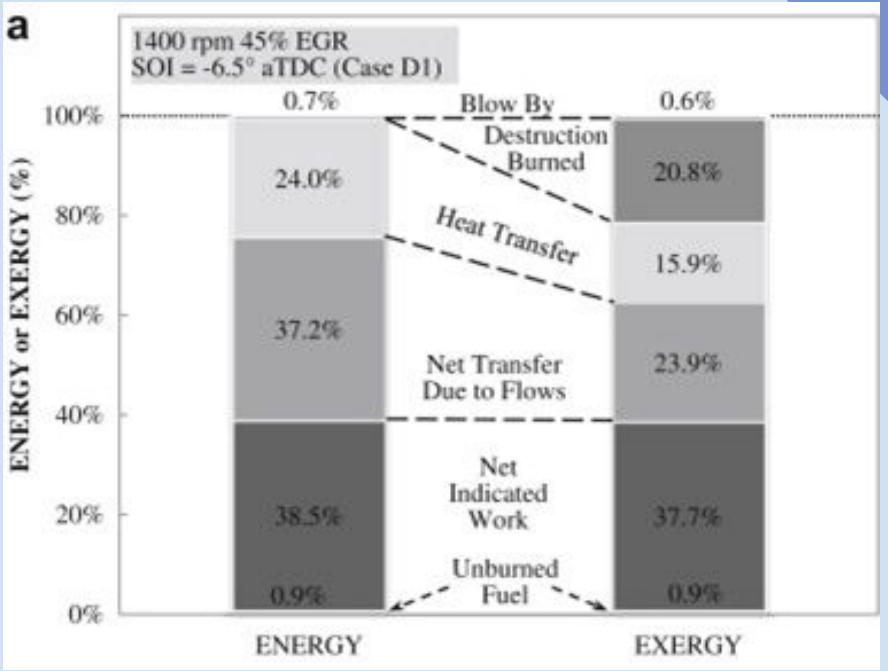
- Much of the exergy of the fuel is lost through exhaust, heat transfer, and destruction through irreversible processes such as air-fuel mixing, turbulence within the cylinders, and the chemical reaction itself

- Even though exergy destruction can be reduced through methods such as EGR, fuel exergy that gets turned into power seems to stay in the range of 30 – 40%

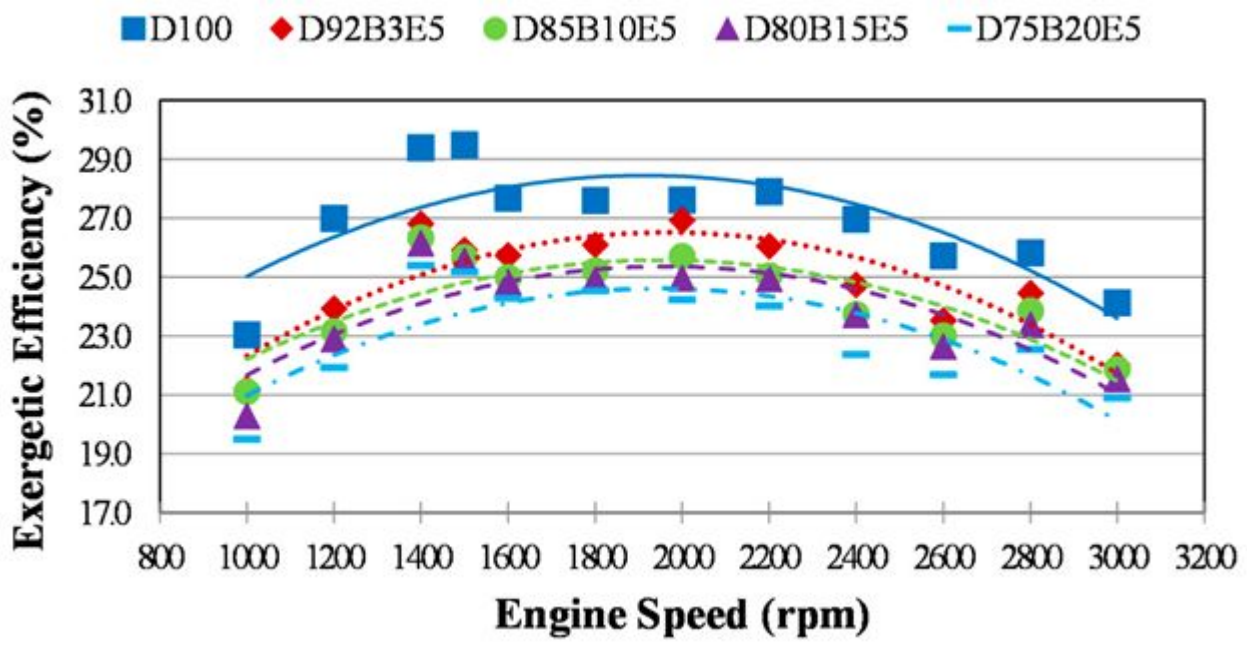
- However, the less exergy destruction, the more opportunity to convert exergy from fuel to power output

Exhaust Gas Recirculation





RPM

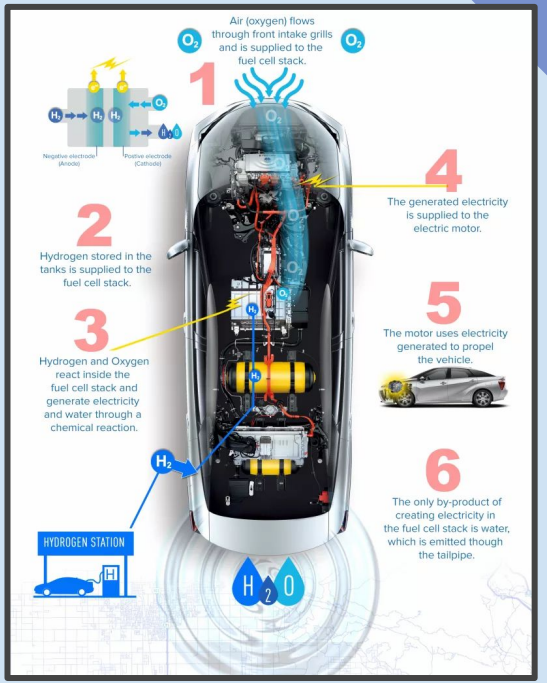

D100
D92B3E5
D85B10E5
D80B15E5
D75B20E5
Exergetic Efficiency (%)
31.0
29.0
27.0
25.0
23.0
21.0
19.0
17.0
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
Engine Speed (rpm)

*FC Analysis: *Toyota Mirai*

Parameters:

n_{cells} = 370 cells
P_{stack} = 114 kW
V_{stack} = 650 V

p_{H2} = 70 MPa =10000 psi
T = 80°C = 353 K



Assumptions:

- Pure H_2 from H_2O electrolysis
- Excess fuel recycled
- 100% fuel utilization (ε_{fuel}= 1)
- Air is O_2+3.76N_2

*FC Analysis: *Toyota Mirai*

$$\varepsilon_{FC} = \frac{\dot{W}_{elec}}{\dot{n}_{H2} * \Delta\hat{h}_{rxn}}$$

$$\dot{n}_{H2} = \frac{(\dot{W}_{elec} / V_{cell})}{n_{elec} * F}$$

$$\Delta\hat{h}_{rxn} = \hat{h}_{H20\ @70MPa} - \hat{h}_{H2\ @70MPa} - \hat{h}_{O2\ @70MPa}$$

ε_{FC}= 47 %

ε_{FC} = Fuel Cell Efficiency of Mirai

$\dot{W}_{elec} = P_{stack}$ = 114 kW

$\dot{n}_{H2}$= molar fuel flow rate [mol H_2/s]

$\Delta\hat{h}_{rxn}$= enthalpy of rxn [kJ/mol]

n_{elec} = # electrons produced = 2

F = Faraday's constant = 96485 [C/mol e^-]

*FC Analysis: *Toyota Mirai*

- Zero Emissions Vehicle
- 3-5 minutes to fill
- About $15 to fill up

Cruising Range	312 miles (EPA estimated range)
Maximum Speed	111 mph
Acceleration Performance	0 – 60 mph: 9.0 seconds
Coefficient of Drag (C_d)	0.29
Cold Start Capability	-22°F (-30°C)

ADVANTAGES

Fuel Cell

- Reduced Particulate Emissions
- Avoid Carnot Cycle Limitations
- Higher Potential Efficiencies
- Quiet
- Scalable/Dispatchable

Diesel

- Capital cost efficient (Cheaper to build)
- Higher engine capacity (torque)
- Long life expectancy
- Less bounds in operation conditions (such as temperature)

DISADVANTAGES

Fuel Cell

- Fuel Accessibility
- Expensive [Pt]
- Durability & Reliability
- Public Education

Diesel

- High engine noise
- Less efficient use of fuel
- Requires more maintenance
- Higher O&M cost

*Recommendations:

Future projects:

- Take our own measurements instead of relying on commercialized data

Choosing a vehicle:

- Fuel cell for more efficient energy use
- Diesel for greater engine capacity

& Final thoughts on the future of FCVs...

"If you drive your car off a cliff
and then step on the brakes...

...it's ***too*** late"

Thank You!

Questions?

References

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