Renewable fuel: can be replenished or replaced by natural processes within a relatively short period of time. Sustainable = continually replenish fuel, reduced chance of running out of fuel.

	FOSSIL FUELS	BIOFUELS
Nature	Non-renewable (coal, oil, natural gas)	Renewable (biogas, bioethanol, biodiesel)
Sustainability	Are used at a rate faster than can be replenished, will be exhausted.	Current production levels = sustainable.
Formation	• Formation over millions of years, using organic matter left behind by ancient plants, animals and microorganisms. • Trapped under high pressures due to layers of sand, dirt, minerals. • Trapped solar/chemical energy.	• Derived from grains, sugar cane, vegetable waste/oil. • Creates less impact than burning fossil fuel where the process of creating fuels removes atmospheric CO_2.
Types	**COAL:** wood and other plants, consist of carbon, hydrogen, nitrogen and sulfur (acid rain). Carbonic acid = weak, sulfuric/nitric acids = strong. Black coal contains least water, highest % of carbon. Strong hydrogen bonds between water molecules = more energy to first evaporate → high specific heat capacity. Quality = pressure, temp, heat. **CRUDE OIL:** hydrocarbons (alkanes), fractional distillation. • Separates alkanes, the lighter the substance (less C atoms), the higher in the column. Weaker intermolecular forces. • Gases: meth-, eth-, but-, prop- • Liquid: pent-, hex-, hept-, oct- **NATURAL GAS:** meth-, eth-, prop- May also contain H_2O, hydrogen deposits, sulfur, CO_2, nitrogen. **Coal seam gas:** pressure of water keeps adsorbed to coal surface. **Shale gas:** trapped in shale rock. Fracking = fracture rock to release gas.	**BIOETHANOL:** formed when anaerobic bacteria converts starch or sugars to ethanol (fermentation). E10: reduces consumption of petrol. $CO_{2(g)} + H_2O_{(l)} \xrightarrow{\text{sunlight}} C_6H_{12}O_6 + O_{2(g)}$ $C_6H_{12}O_6 \rightarrow C_2H_5OH + CO_{2(g)}$ Lower E content due to presence of O – partially oxidised. **BIODIESEL:** larger hydrocarbon molecule, carbonyl functional group. Formed by reacting plant oils/animal fats with an alcohol (ester). **BIOGAS:** produced when food, organic or biological waste is broken down by anaerobic bacteria. Converts methane to CO_2 – better for environment. Biowaste---> simpler molecular compound (covalently bonded molecule) ---> CH_4 complex sugars (polysaccharides) carbs & proteins
Energy content	HIGHER	LOWER
Environment	Air pollution, large amounts of greenhouse gases (CO_2 + SO_2), land degradation due to extensive digging, transport = higher possibility spills.	Smaller carbon footprint, land clearing for growth of biofuels, high water usage to grow crops, less particulates.

- **combustion of fuels as exothermic reactions with reference to the use of the joule as the SI unit of energy, energy transformations and their efficiencies and measurement of enthalpy change including symbol (ΔH) and common units (kJ mol-1, kJ g-1, MJ/tonne)**

Exothermic: releases heat (eg. combustion), chemical energy from products is less than reactants. Often release energy as heat.

Endothermic: absorb heat from environment (eg. decomposition), chemical energy in products is more than reactants. Surrounding temperature decreases as energy is absorbed.

Energy released = energy absorbed (can be transferred into different types). Often is not 100% efficient as heat can be lost to the surroundings.

Chemical heat = enthalpy (H), the energy released or absorbed during a chemical reaction is the heat of reaction. **$\Delta H = H(products) – H(reactants)$**

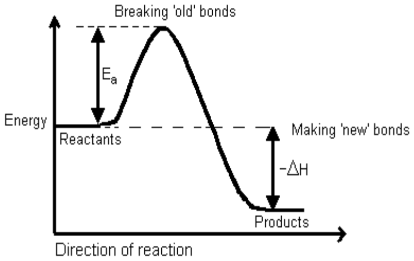
- exothermic: Δ H = < 0
- endothermic: , Δ H = > 0

System = experiment, surrounding environment = everything outside of reaction/experiment

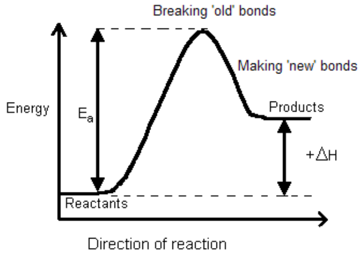
- **the comparison of exothermic and endothermic reactions including their enthalpy changes and representations in energy profile diagrams**

Activation Energy (E_A): energy required to break the bonds of reactants so that a reaction can proceed. Higher = harder to initiate a reaction*. The E_A for the reverse reaction is the difference between the products and the highest part of the energy profile.*

Exothermic



Endothermic



COMBUSTION: complete = sufficient oxygen, carbon dioxide and water are produced. Incomplete = insufficient oxygen, carbon monoxide and water are produced (less E).

- **the writing of balanced thermochemical equations, including states, for the complete and incomplete combustion of hydrocarbons, methanol and ethanol, using experimental data and data tables**

Thermochemical equations:

- coefficients = amounts of mole
- ΔH must be adjusted due to the mole ratio present in the balanced equation.
- ΔH placed at the end of a balanced equation.
- Must show correct states
- Reverse reaction has opposite sign in front of ΔH

Heat of combustion (ΔHc): the energy released when a specified amount (1 mol/1g/1L) of a substance completely burns in oxygen. Usually measured in 298K and 101.3kPa (*water = liquid in these conditions*)

Energy released (kJ) = n x ΔHc **ΔHc = kJ/mol (fuel)**

Energy released (per g or per tonne) = ΔHc/M

Density = mass (g)/volume (mL) **kJ/L = energy (kJ)/volume (L)**

kJ/g $\underset{\div M_r}{\overset{\times M_r}{\rightleftharpoons}}$ kJ/mol **1 kJ g^{-1} = 10^{-3} MJ/10^{-6} t**

- **the definition of gas pressure including units, the universal gas equation and standard laboratory conditions (SLC) at 25 °C and 100 kPa**

Gas pressure: force exerted by gaseous molecules as they collide with the walls of their container.

Universal gas equation: P V = n R T

- P – pressure, measured in kPa (1 atm = 101.3kPa = 760mmHg)
- V – volume, measured in L
- n – moles of the gas, measured in mol
- R – gas constant = 8.31 J K-1 mol-1
- T – temperature, measured in Kelvin (temp in K = temp in C + 273)

Universal gas equation at SLC (100kPa and 298 K): n = V/24.8 or n = V/V_m

- Where V_m = molar volume of a gas (24.8 L mol-1)

- **calculations related to the combustion of fuels including use of mass-mass, mass-volume and volume-volume stoichiometry in calculations of enthalpy change (excluding solution stoichiometry) to determine heat energy released, reactant and product amounts and net volume of greenhouse gases at a given temperature and pressure (or net mass) released per MJ of energy obtained**

Stoichiometry

n = m/M n = N (no. of particles)/N_A (Avogadro's number)

Specific heat capacity: the amount of energy required to raise the temperature of one gram of a substance by 1°C.

q = m x C x ΔT where: q = energy (J) m = mass (g)
C = specific heat capacity (J g^{-1} $^oC^{-1}$)
ΔT = change in temperature (^{o}C)

When calculating heat of combustion for fuels, use this as the energy (/1000 for kJ).

- **the use of specific heat capacity of water to determine the approximate amount of heat energy released in the combustion of a fuel.**

Determination of Heat of Combustion by experiment

- Thermal energy released during combustion heats up water.
- ΔT and mass of water are used to help calculate the heat of combustion of the fuel.

STEPS: *to calculate heat of combustion*

1. Use data book for water, C, m and ΔT to find q – energy given to water.
2. Put q value into kJ.
3. Since exothermic – value is negative.
4. Determine number of mole of the fuel used.
5. Calculate heat of combustion of the fuel by dividing q by number of mole- answer will be in kJ mol.

Assumption: that all of the energy released from the combustion of fuel is used to heat the water, however in reality heat is lost to surroundings as well as to the metal can.

Fuel choices

- **the comparison of fossil fuels (coal, crude oil, petroleum gas, coal seam gas) and biofuels (biogas, bioethanol, biodiesel) with reference to energy content, renewability and environmental impacts related to sourcing and combustion**

Electricity from coal:

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ 32kJ/g

Coal-fired power station: energy **efficiency 30~40%**

1. Coal burning: *Chemical energy--->* thermal energy
2. Boil water: heat → kinetic → electricity
3. Steam is passed through the turbine
4. Electricity generates

Electricity from natural gas:

$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$ 55.6kJ/g (890kJ/mol) less efficient

Gas fired plant: energy efficiency **slightly over 40%**

Petrol:

1. Combustion reaction of octane

$2C_8H_{18(l)} + 25O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(l)}$ 47.8kJ/g

2. Energy efficiency ~25%

Liquid petroleum gas:

1. Combustion reaction of propane

$C_3H_{8(l)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$ 50.5kJ/g

2. Cheaper but not as popular because
   a. Most vehicles are designed to run on petrol
   b. LPG fuel tank took up boot space
   c. LPG tank may explode if car crashes
   d. Fuel price fluctuates, hence hard to make meaning comparisons

Natural gas: gases are burnt, hot gases produced by combustion → air expands in combustion turbine to generate electrical energy. More efficient than coal-fired, and output can be varied at short notice to adjust for fluctuating power usage.

Coal-fired plant: coal is burnt (chemical → thermal), boils water (thermal → thermal – steam), steam turns turbines (thermal → mechanical), electricity (mechanical → electrical).

Electricity from biogas:

$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

1. Usually in small scale generators
2. Located at site where biogas is produced

E per gram = less as methane content is lower.

fermentation of carbohydrates/starch

Bioethanol (E10):

1. Combustion reaction of ethanol

$C_2H_5OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$ 29.7kJ/g

2. Reduces emissions of particulates and harmful gases
3. Energy content is ~62% of petrol
4. Carbon atoms in ethanol is partially oxidized due to the presence of oxygen atoms

Carbon dioxide = greenhouse gas, stores and traps energy from the Sun.