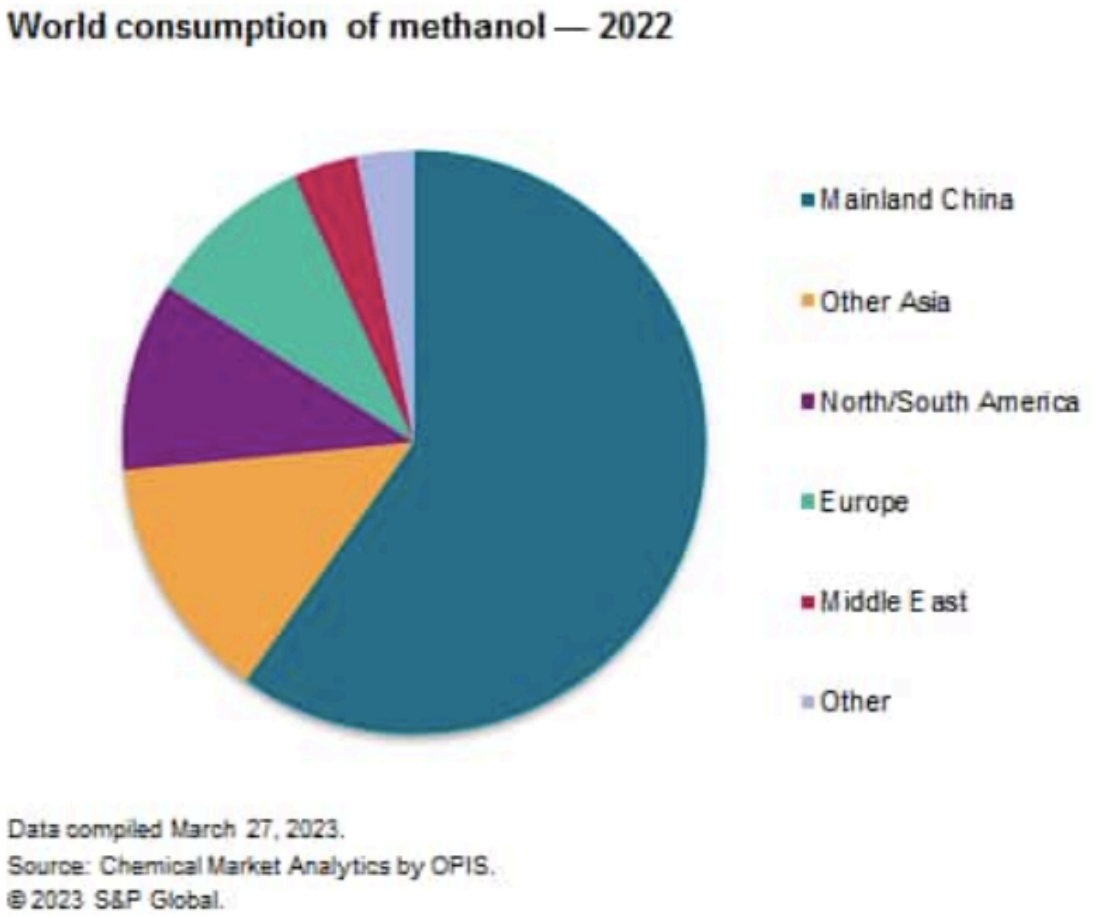
Methanol: Production and Applications

Toan VU

Methanol consumption

- 2007: 40 mil. tons;
- 2017: 88.7 mil. tons;
- 2022: 111 mil. Tons.



Methanol production

- **Brown** methanol: from Coal (conventional);
- **Grey** methanol: from Natural Gas (conventional);
- **Blue** methanol: uses Carbon Capture and Storage;
- **E-methanol** (green, renewable): uses H2 from renewable electricity with CO2 captured from renewable sourses;
- **Bio-methanol**: natural gas from sewage plant/animal manure.

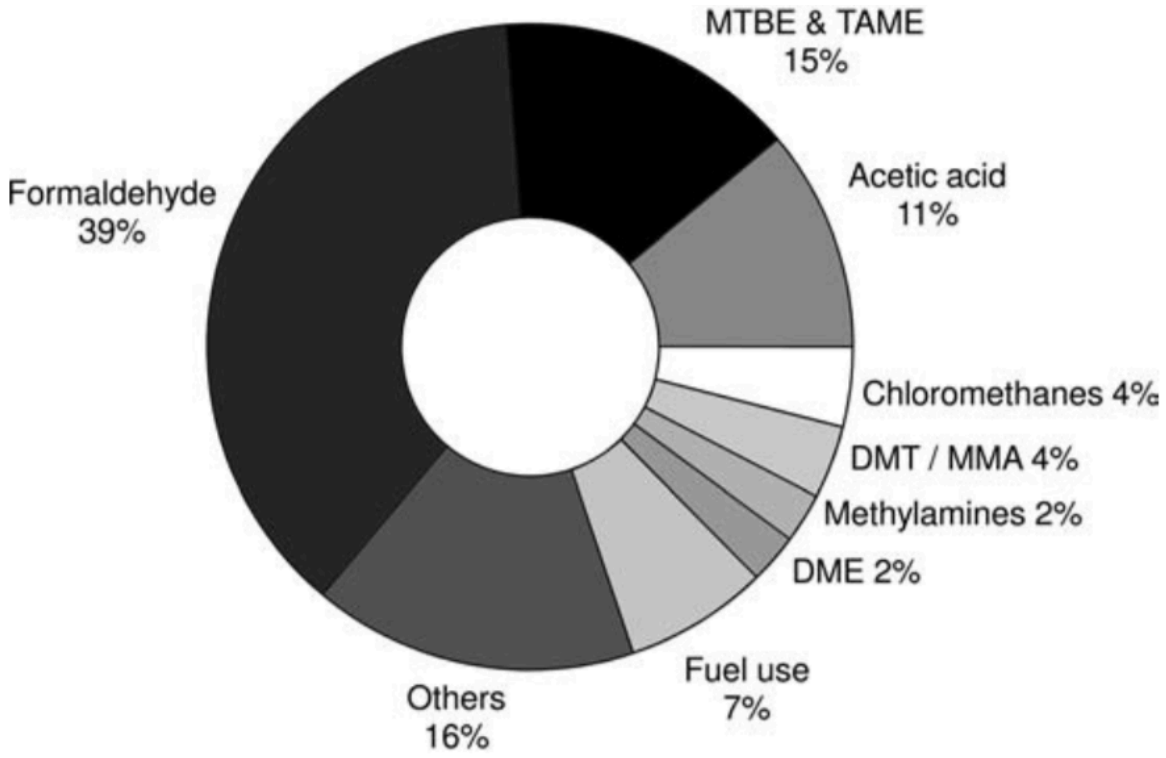
Methanol application

- Methanol is primarily converted to **formaldehyde** (oxidation), which is widely used in many areas, especially polymers;

$$CH_3OH + O_2 \rightarrow CH_2O + H_2O$$

- About 75% of **acetic acid** made for use in the chemical industry is made by the carbonylation of methanol;
- Methanol and isobutene are combined to give methyl *tert*-butyl ether (**MTBE**);
- Methanol to **HCs, olefins, gasoline**;
- Gasoline **additive (**EU allows to blend up to 3% methanol. China uses more than 4.5 billion liters/year);
- **Fuels** (direct/ blending): for ICE, marine, racing, model engines;
- **Fuel cells**

Methanol application



MTBE: Methyl *tert*-butyl ether
TAME: Tertiary-amyl methyl ether

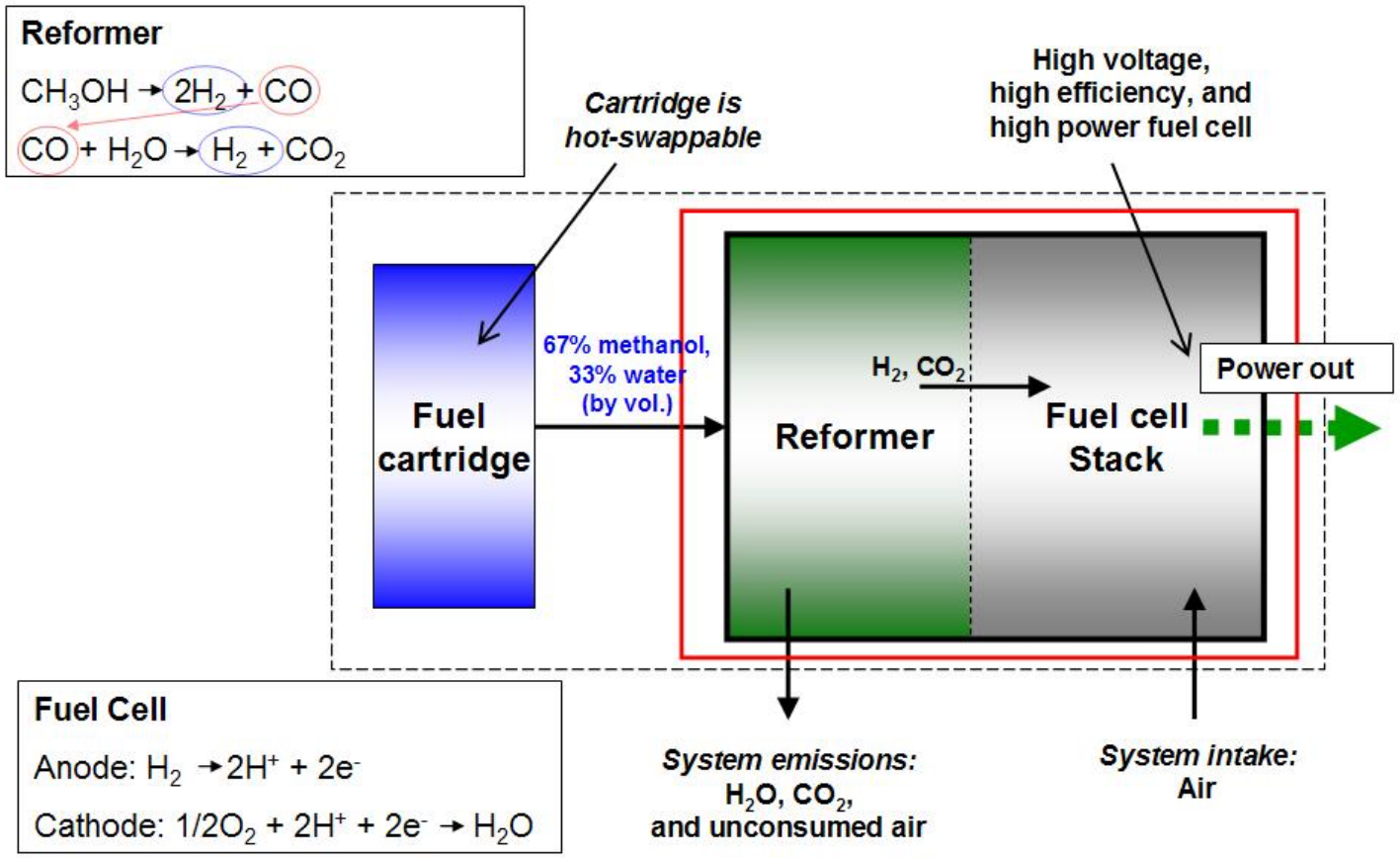
Figure 11.1 World demand for methanol in 2007. (Based on data from the Methanol Institute, PCI Ockerbloom & Co., Inc.)

Methanol application, FUEL CELLS

- Reformed Methanol Fuel Cell (RMFC)
- Direct Methanol Fuel Cell (DMFC)

Methanol application, FUEL CELLS

- RMFC or IMFC systems are a subcategory of proton-exchange fuel cells where, the fuel, methanol (CH3OH), is reformed, before being fed into the fuel cell.



Methanol application, FUEL CELLS

- DMFC relies upon the oxidation of methanol on a catalyst layer to form carbon dioxide.
- Water is consumed at the anode and produced at the cathode.
- Protons (H+) are transported across the proton exchange membrane - often made from Nafion - to the cathode where they react with oxygen to produce water.
- Electrons are transported through an external circuit from anode to cathode, providing power to connected devices.

	Equation
Anode	$\mathrm{CH_3OH + H_2O \rightarrow 6\,H^+ + 6\,e^- + CO_2}$ oxidation
Cathode	$\mathrm{\frac{3}{2}O_2 + 6\,H^+ + 6\,e^- \rightarrow 3\,H_2O}$ reduction
Overall reaction	$\mathrm{CH_3OH + \frac{3}{2}O_2 \rightarrow 2\,H_2O + CO_2}$ redox reaction

Methanol application, FUEL CELLS

- RMFCs are better DMFCs: higher efficiency, smaller cell stacks, less requirement on methanol purity, no water management, better operation at low temperatures, and storage at sub-zero temperatures (liquid: -97.0 °C to 64.7 °C) and as there is no liquid methanol-water mixture in the cells which can destroy the membrane of DMFC in case of frost.

Storage and Fuel Costs

- The fuel cartridge stores the methanol fuel. Depending on the system design either 100 % methanol or a mixture of methanol and water (up to 40 vol%) is usually used as fuel for the RMFC system. 100 % methanol results in lower fuel consumption than water-methanol mixture but goes along with higher fuel cell system complexity for condensing of cathode moisture.
- Fuel Costs for RMFC typically are about 0.4-1.1 USD/kWh (conventional methanol) resp. 0.45-1.3 USD/kWh (renewable methanol) produced from municipal waste or renewable electricity). By comparison, for a hydrogen fueled Low Temperature-PEM fuel cell costs for conventional hydrogen (in bundle of bottles) are about 4.5-10 USD/kWh.

Outlook

- Whilst the thermodynamic theoretical energy conversion efficiency of a DMFC is 97%; the currently achievable energy conversion efficiency for operational cells attains 30 – 40%;
- DMFCs are limited in the power they can produce.