Sustainable Hydrogen Production from Biomass by Fermentation

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Sustainable H_2 production technologies

- Electrolysis using electricity from renewables
- Gasification/pyrolysis of biomass
- Reforming biogas methane
- Photosynthesis (algae or bacteria)
- **Dark fermentation**

Fermentation

- A dark anaerobic process by which bacteria and yeasts gain energy from organic matter
- Requires wet, carbohydrate-rich biomass substrates
- Produces fermentation end products -gases, acids and alcohols
- A CO_2 neutral process

Fermentation of biomass to energy sources

- Ethanol
- Methane by anaerobic digestion
- Hydrogen?

Fermentative H_2 production

- property of many species of bacteria, particularly clostridia
- carbohydrates are favoured substrate
- involves hydrogenase
- H_2 yield depends on fermentation products

Fermentative H_2 yield

hexose → acetic acid + 4 H_2

(0.5 m^3 H_2 / kg carbohydrate)

hexose → butyric acid + 2 H_2

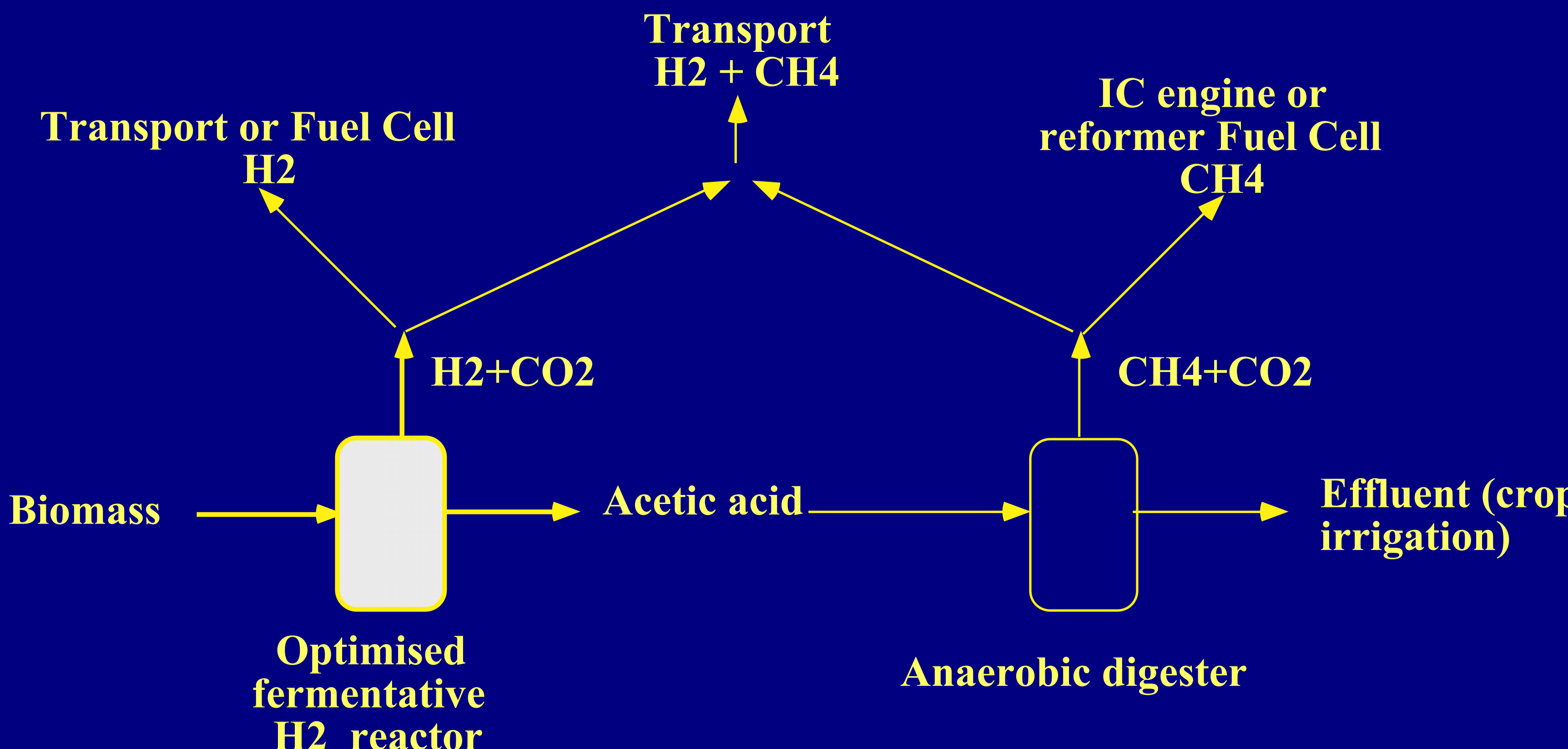
thermodynamically unfavourable as H_2 conc rises

Effect of lowering dissolved H_2 conc

	Non-sparging	Sparging
H_2 yield (mol/mol gluc)	0.85	1.43
acetic mgl^{-1}	773	785
butyric mgl^{-1}	1742	1929

Mizuno *et al*. Bioresource Technol. (2000)

Sustainable H_2 production from biomass



Requirements for fermentative H_2 producing technology

- Non-sterile operation
- Readily-available mixed microflora
- Operating conditions optimised for H_2 yield
- Process stability
- Fermentable biomass substrate year-round
- Net positive energy balance

Sustainable biohydrogen production: process optimisation - EPSRC funded

Inoculum selection and start-up

- *Clostridia* spore formers selected by heating anaerobically digested sewage sludge
- Batch start-up for spore germination (1-2 days)
- Specific reactor conditions (e.g. pH, retention time) required to prevent competitive growth

Fermentation reactions lowering H_2 yield

Hexose → acetone/butanol/ethanol

$CO_2 + H_2$ → acetic acid

Hexose + H_2 → propionic acid (non-spore formers)

Optimisation challenges for fermentative hydrogen production

- Feedstock selection
- Inoculum selection, start-up and re-start up
- Prevention of inhibition by H_2
- Prevention of shifts in metabolism and population
- Development of sustainable process technology (LCA)

University of Glamorgan H_2 research

- Sustainable biohydrogen production: process optimisation. EPSRC.
- A sustainable energy supply for Wales:towards the hydrogen economy. EU Objective 1.
- Feasibility of sustainable hydrogen production from wheat starch-based food industry co-products. Carbon Trust.
- Biological generation of hydrogen from renewable resources using fermentation. EPSRC SUPERGEN.

Conclusions

- Batch start-up with heat treated sewage sludge seed is successful
- Continuous operation on starch co-product is possible with H_2 yield of 1.9 moles H_2/mole hexose consumed (48% of theoretical)
- Requires H_2 stripping, on-line monitoring and control