Drop-in Transportation Fuels from Carbon Dioxide and Solar Hydrogen

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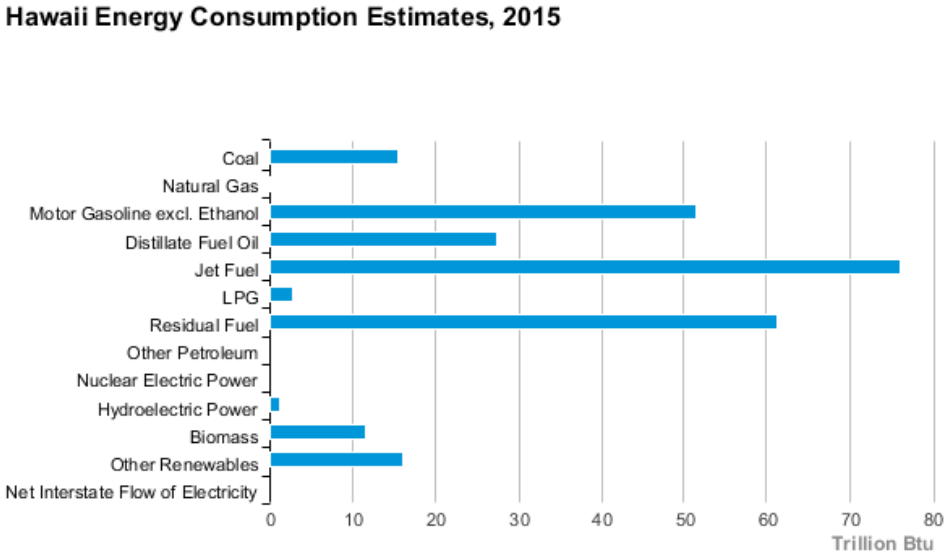
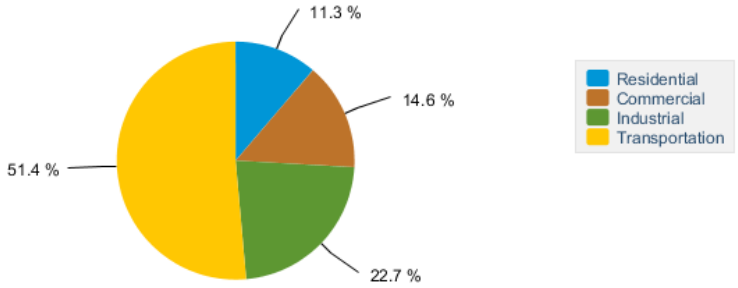
Energy Consumption & CO_2 Emission

Hawaii Energy Consumption by End-Use Sector, 2015



eia Source: Energy Information Administration, State Energy Data System

Energy per capita (#48 in 50 states)

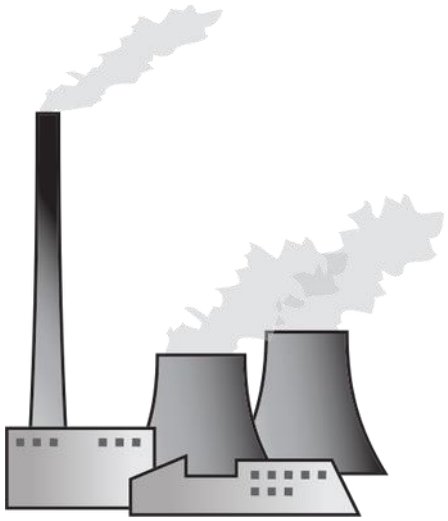


eia Source: Energy Information Administration, State Energy Data System

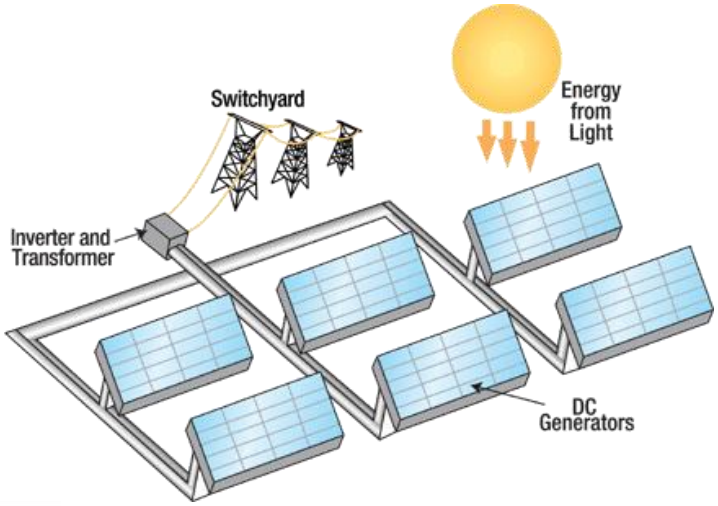
CO_2 emission (million metric tonnes)

- Total annual: 18.4 mmt
- Transportation 9.9 mmt or 54%
- Electric: 6.7 mmt or 36% (point source)
- Others: 1.8 mmt or 10%

A Green Factory for Renewable Fuels



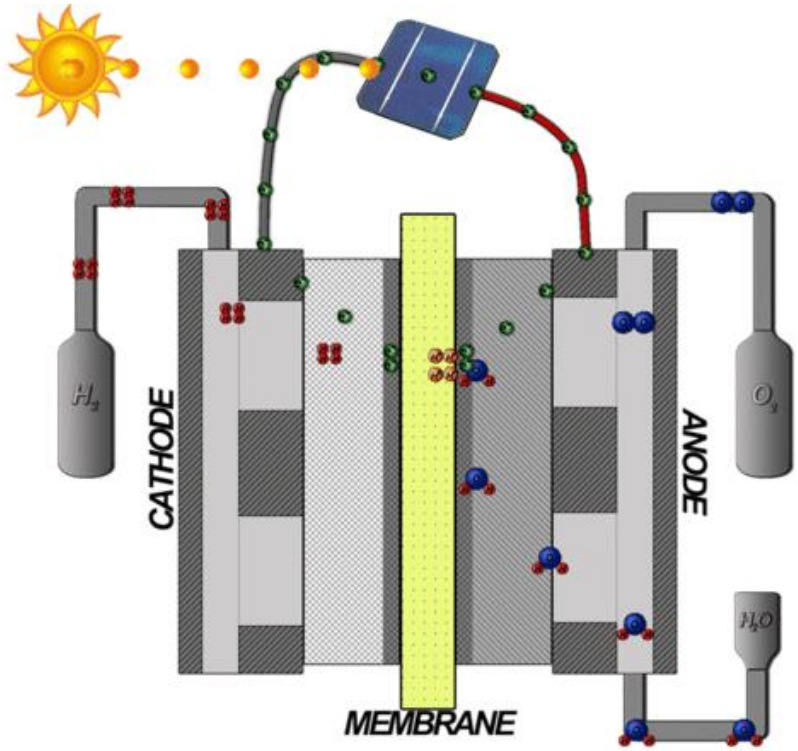
Electricity



CO_2

Fuels
Chemicals
Plastics

Solar Hydrogen from Water Electrolysis

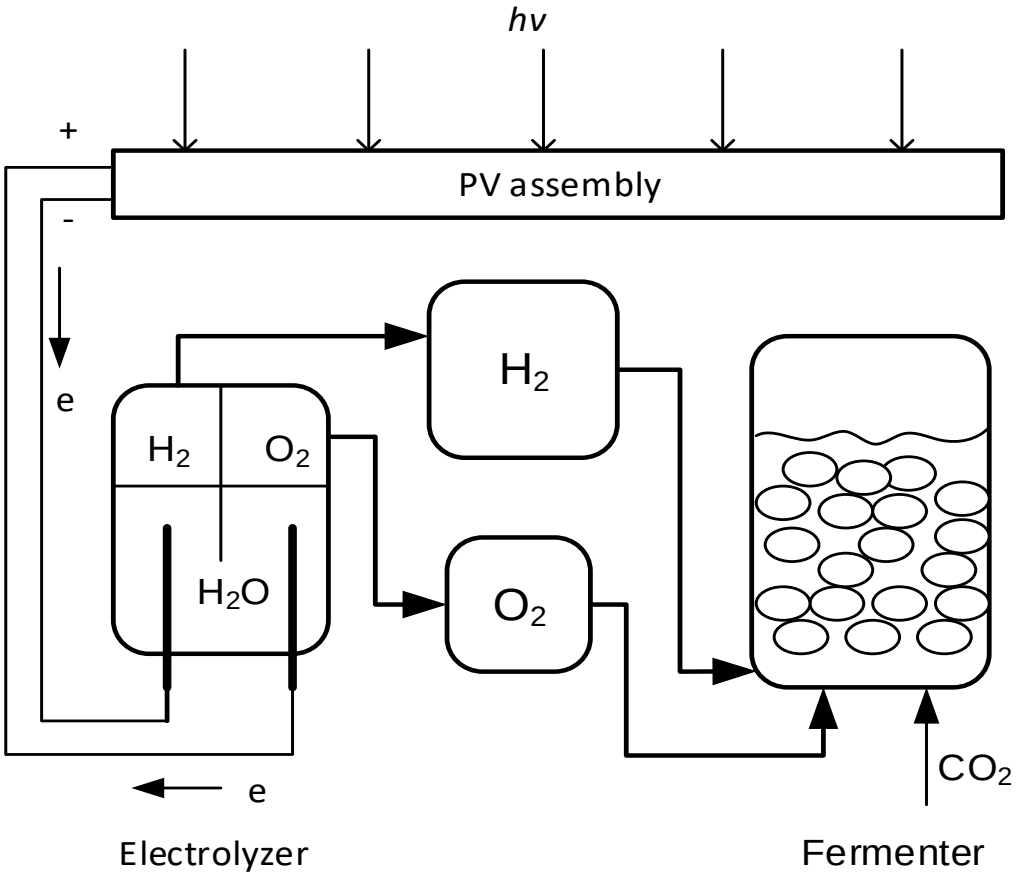


Anode: $2H_2O\ (l) \rightarrow O_2\ (g) + 4H^+(aq) + 4e$

Cathode: $4H^+(aq) + 4e \rightarrow 2H_2\ (g)$

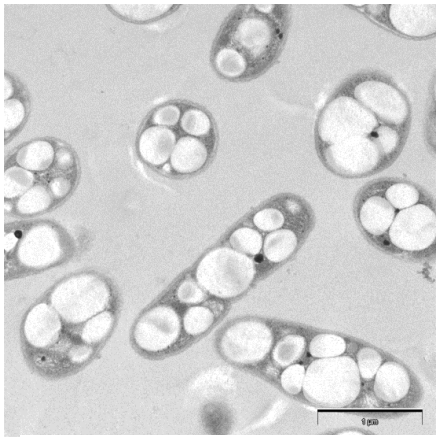
Overall: $2H_2O(l) \rightarrow O_2(g) + 2H_2\ (g)$

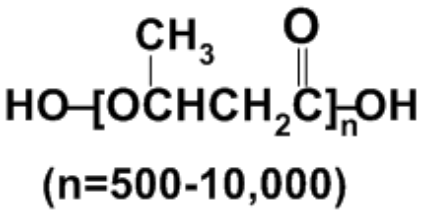
Artificial Photosynthetic System

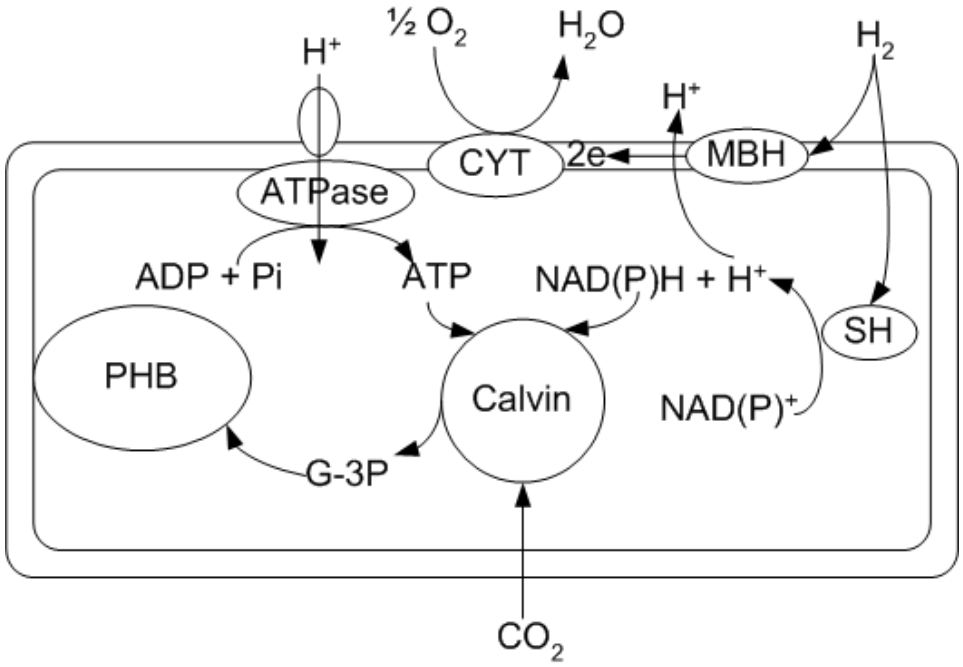


$$CO_2 + H_2O + h\nu \rightarrow CH_2O \text{ (biomass)}$$

CO_2 Fixation with H_2 & PHB Formation



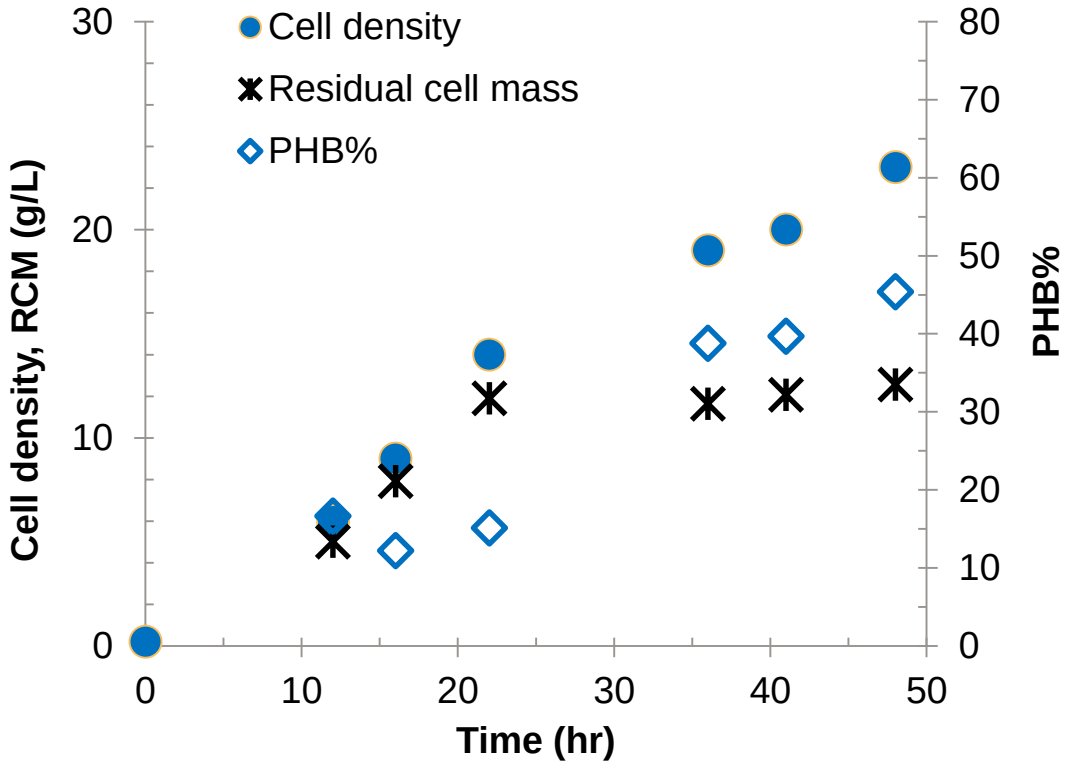




Autotrophic hydrogen-oxidizing bacterium

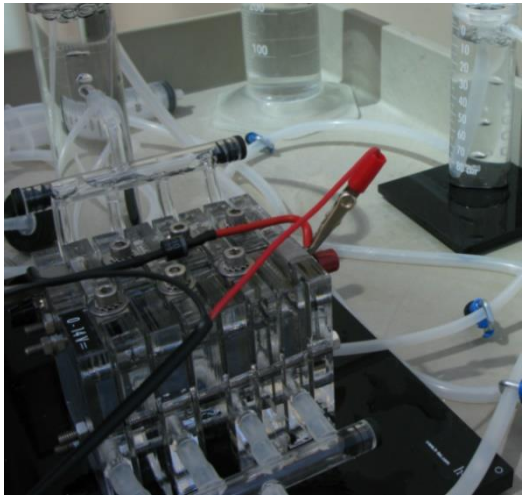
Granules of polyhydroxybutyrate (50-70 wt%) accumulated in bacterial cells as carbon and energy storage material

Gas Fermentation & PHB Production



- Cell mass doubled in 8 hours
- High cell density of 23 g/L
- 45-60% of PHB, a biopolyester material
- H_2 energy efficiency 20%

Solar Energy Efficiency



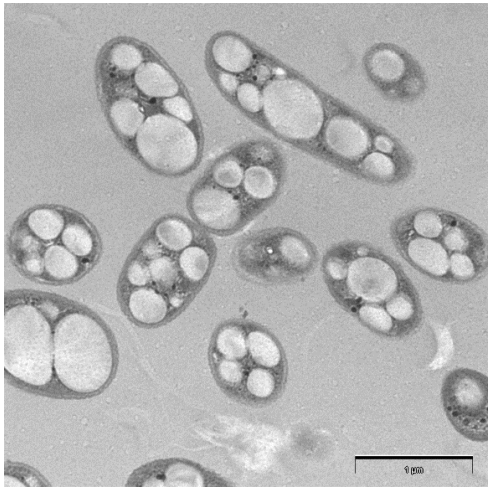
PV module 20%
(high efficiency 35%)

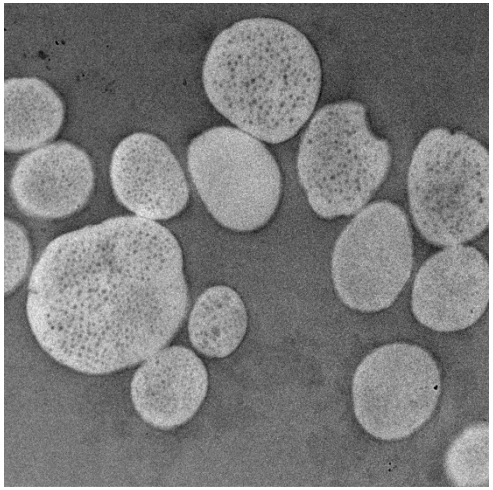
Water electrolysis 70%
(high efficiency 80%)

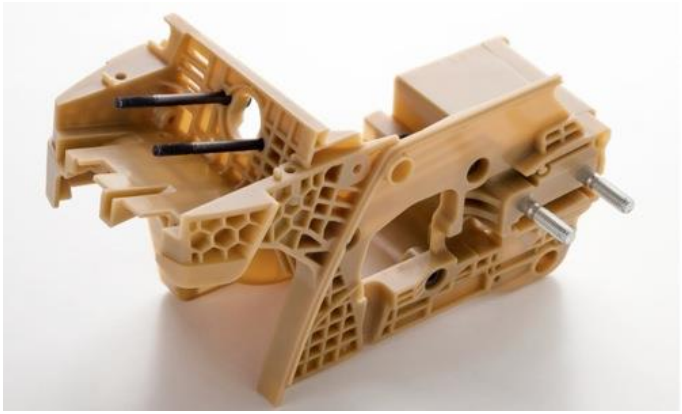
CO_2 fixation 20%
(high efficiency 28%)

- ✓ **The energy efficiency is 3% (3 times higher than high plants and crops)**
- ✓ **Higher efficiency (8%) is achievable in the future!**

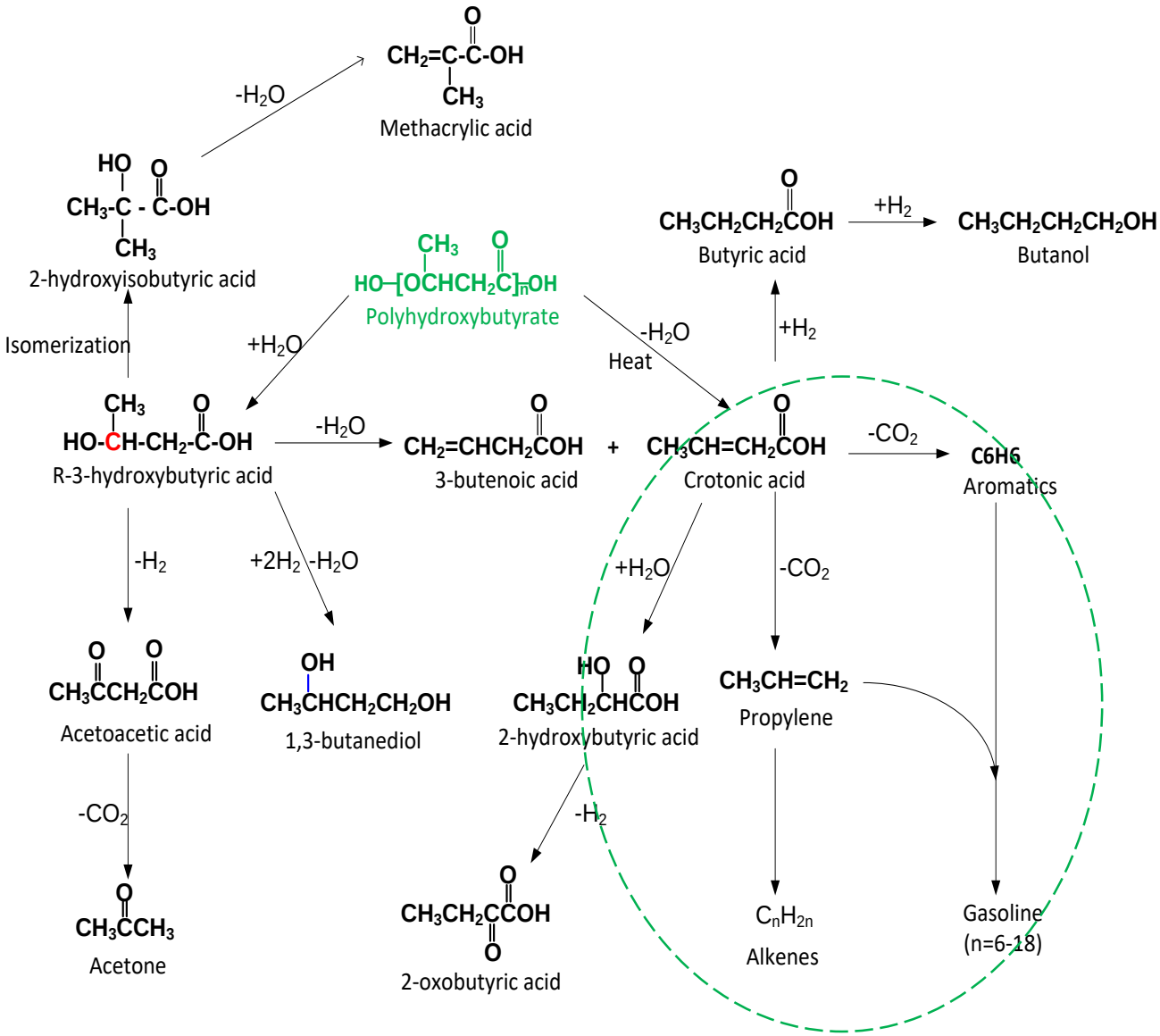
A Bioplastic of 100% CO_2 carbon



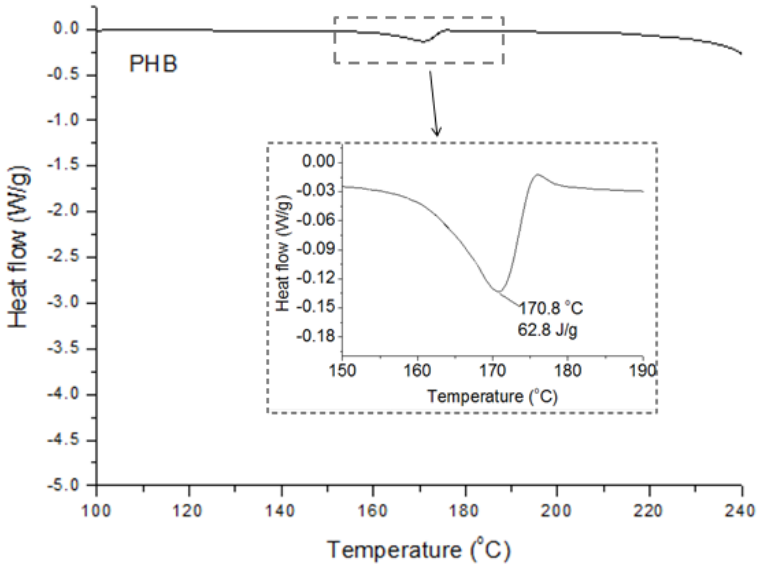


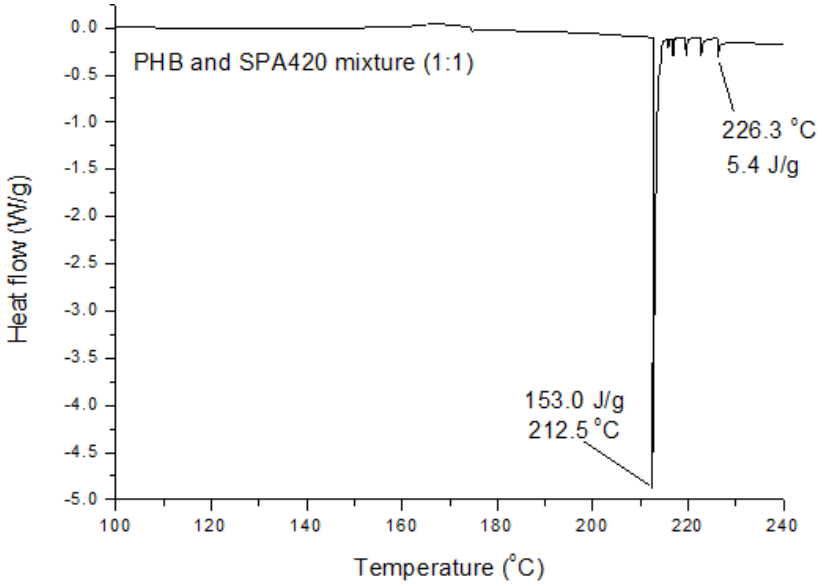


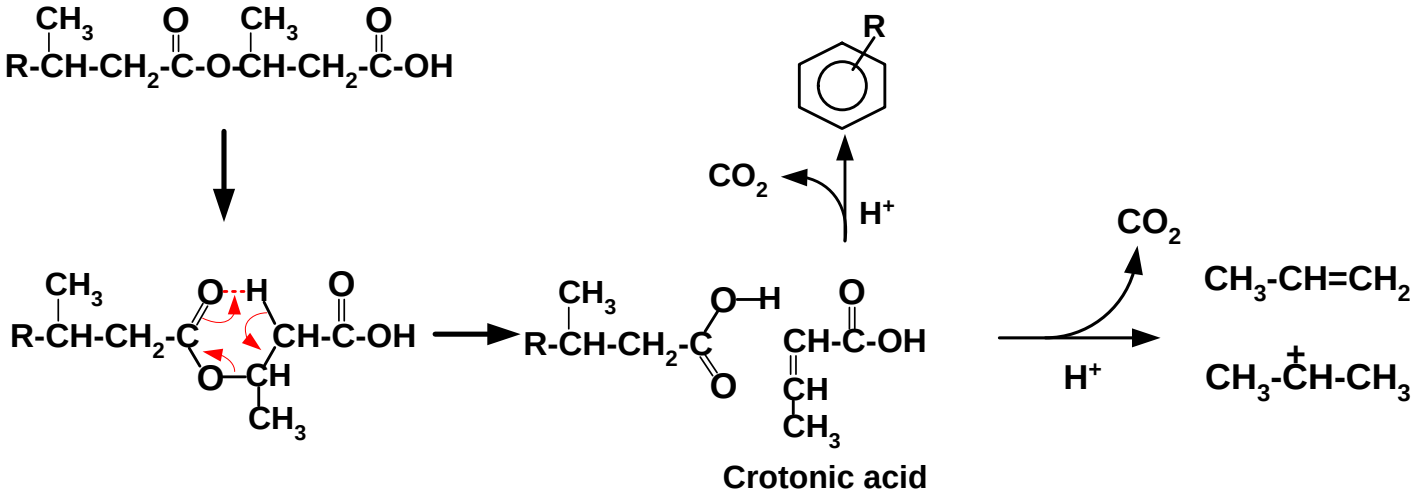
Hydrocarbon Oil from PHB



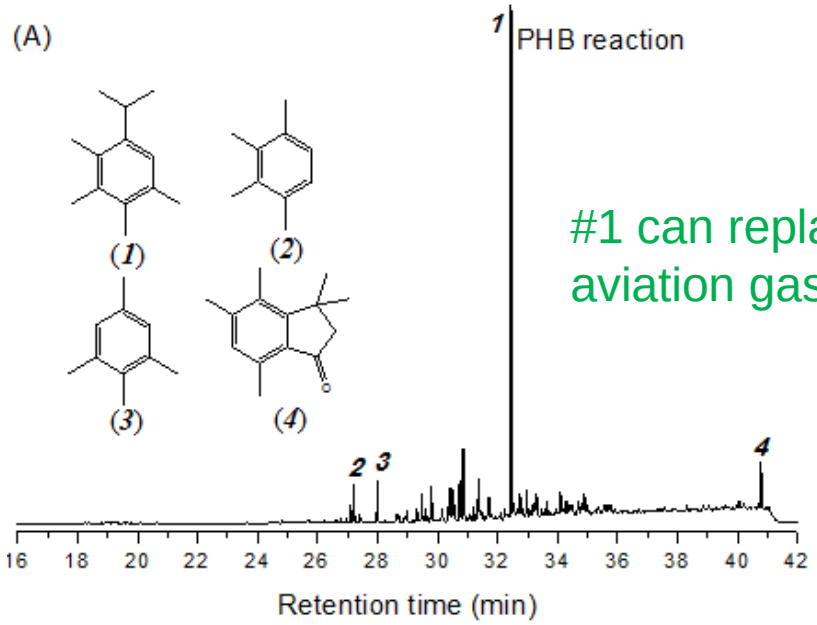
PHB Melting & Catalytic Reform in DSC



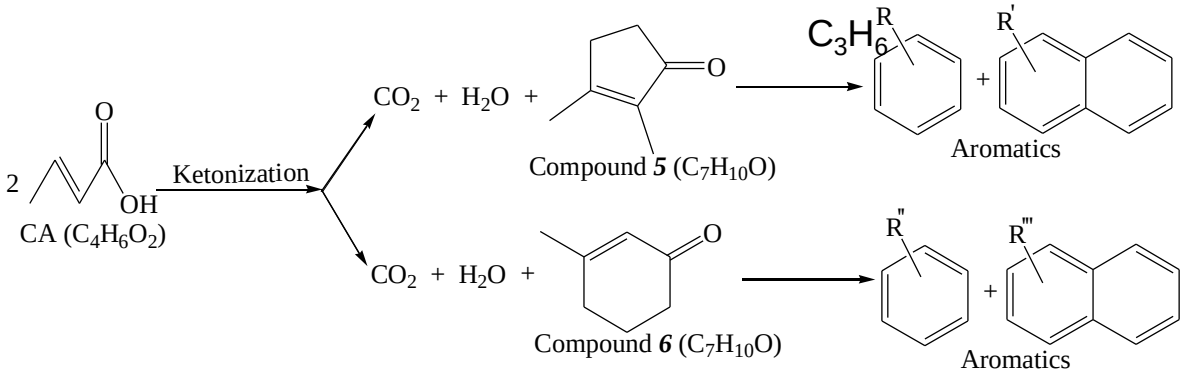




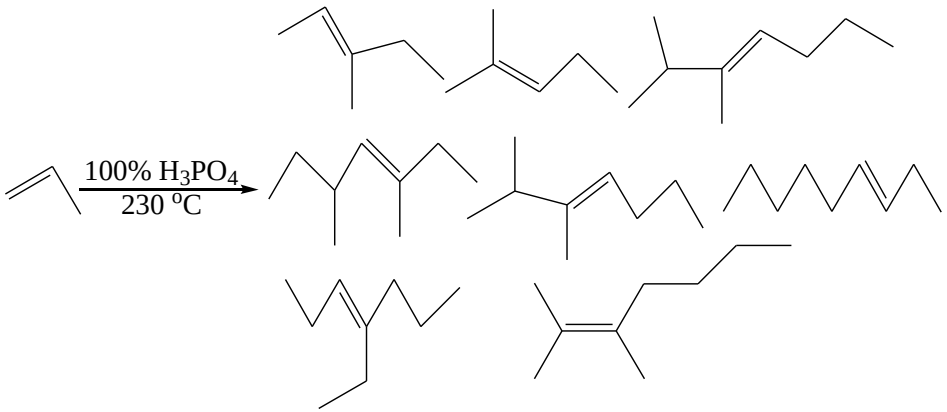
Aromatics from PHB: GCMS Analysis



#1 can replace lead for high octane (100+) aviation gasoline



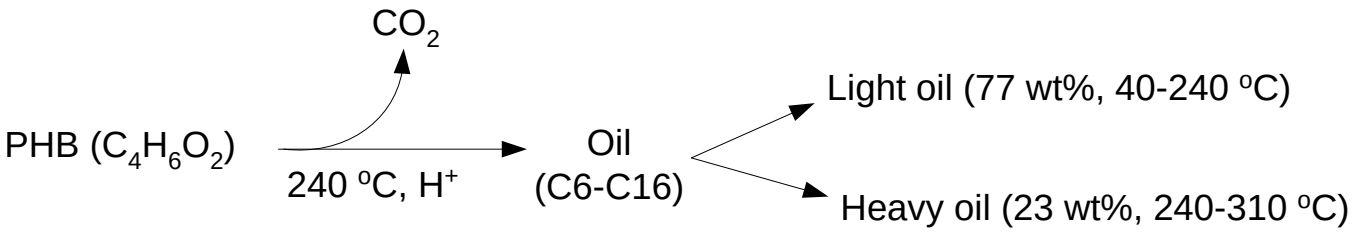
Alkenes from PHB

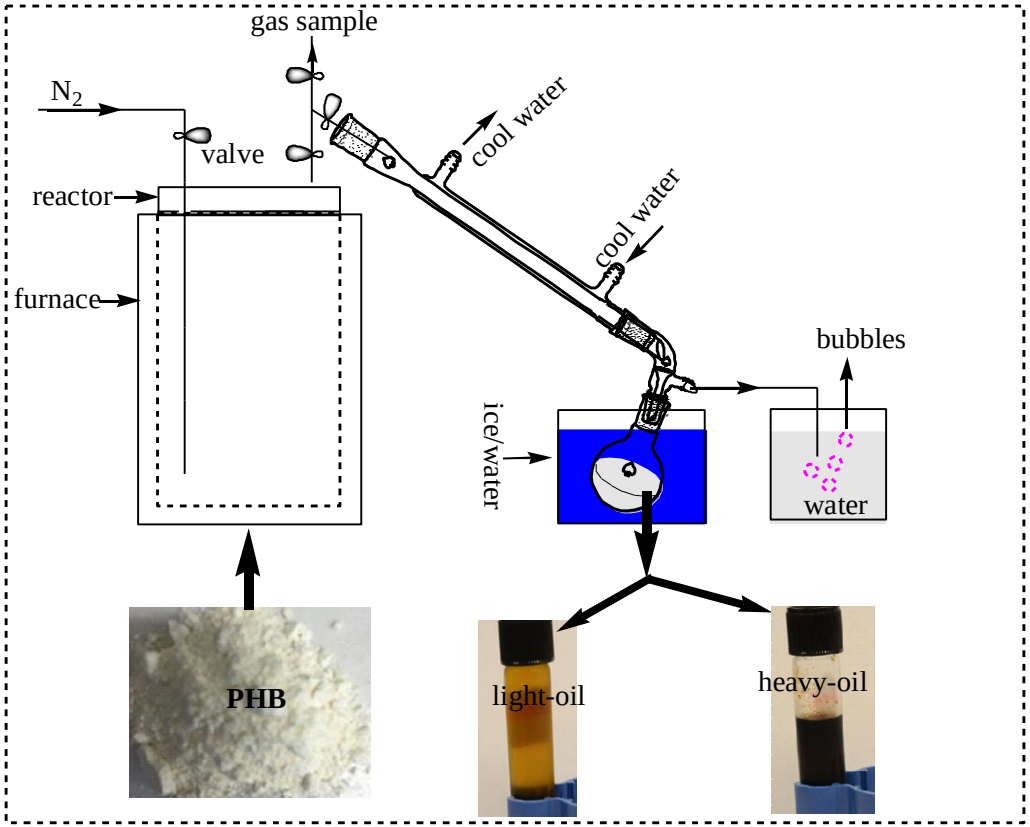


Catalyst	O-containing Chemicals (%)*	Alkenes (%)*	Benzenes (%)*	Naphthalenes (%)*
A	19.6	2.6	65.8	11.2
B	9.9	57.0	31.1	2.0

*Based on percentage of peak areas in GCMS chromatograms

Oils from Reaction & Distillation





Drop-in Biofuels

Fuels	Gasoline[a]	Light-oil	Heavy-oil	Biodiesel [b]
BP (ºC)	40-240	40-240	240-310	182-338
C (wt%)	80.40	81.37	79.38	76.96
H (wt%)	12.30	11.30	9.67	11.85
N (wt%)	0.15	0.14	0.23	-
O (wt%)[c]	6.35	7.19	10.72	9.41
HHV (MJ/kg)[d]	41.8	41.4	38.4	39.7

[a] Commercial gasoline from a local station
[b] Biodiesel from plant oil (FAME)
[c] Estimated by elemental balance
[d] Measured by Hazen Research Inc.

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Thank You !!!