Applied Intellectual Capital
VENTURES IN SUSTAINABLE TECHNOLOGY

Liquid Fuels from Cellulose
Alkyl Furans

Robert Clarke and Martin Peacock

AIC labs, 2450 Mariner Square Loop, Alameda, CA94501

Alameda, California

- Develop and commercialize applied science technologies for:
  - Clean & renewable energy
  - water & water recycling
  - Resource recovery and sustainable mining

- Leverage a common core of related technologies, facilities and equipment to form "spin-offs" and/or generate licensing revenues

  - **Topic today**

  - Methyl furan & dimethyl furan from cellulose based waste streams

  We are not a one-trick pony here are some of our other ventures

  - EverClear – Sustainable mining and Acid Mine Drainage

  - "BatteryCo" – Hybrid vehicle batteries, electric bicycles, traction

  - Plurion – High capacity electricity storage for renewables

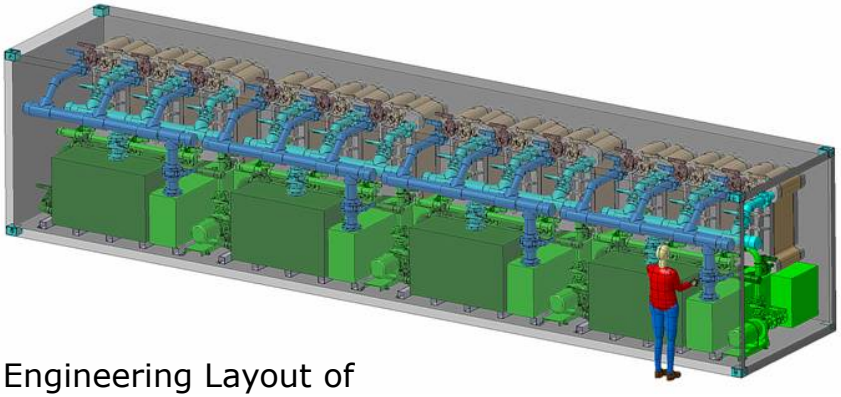
Metals Recovery Technology from Pit lakes and Mine Spoil Heaps

- Conventional copper mining technology wastes ~20% of the $100 billion of Cu produced annually
  - Historical tailings stocks containing ~$200-400 billion of "unrecoverable" Cu
  - $20 billion of additional Cu added annually
- We can recover 99.999% LME grade Cu using our modular transportable equipment
  - Large on-site demonstrations completed and underway
  - ~$800 million first project (Tsumeb, Namibia)
  - ~$16 billion of qualified sales leads
  - Earnings model includes share of value and Reserve Assets

Pit lakes and dry tailings dams

Recovered Cu Berkeley Pit, Montana

Plurion: High capacity electricity storage



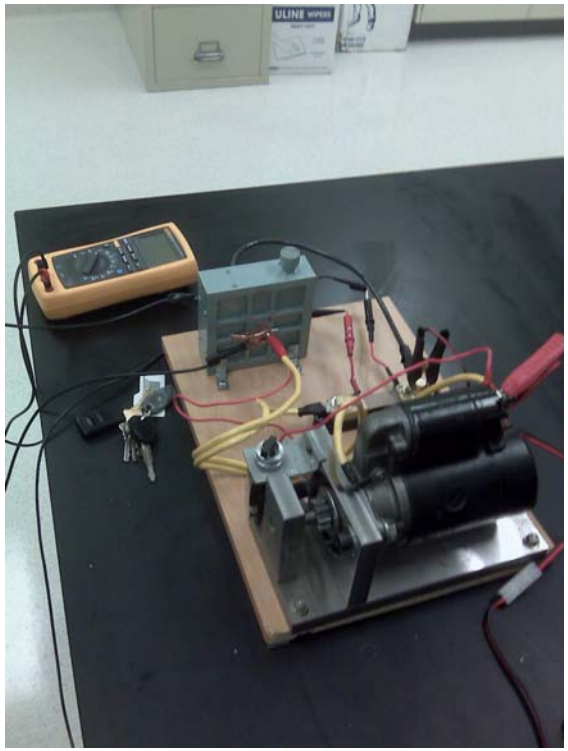
Engineering Layout of
250kW module

- Patented high capacity flow battery technology platform
  - Multiple chemistries covered, two complementary products
  - Up to 8hs of discharge capacity
  - 2.4 Volts/cell OC
  - Common electrolyte based on Cerium and Zinc
  - At 1000-1500 amps/m^2 it is the most powerful flow battery

  - **Studied developed and patented in California!**

BLAB: Automotive batteries

- Technology
  - Bi-Polar Lead Acid Battery
  - Sealed, oxygen recombinant, high voltage battery stack with gel electrolyte and opposite terminals
  - Low internal resistance – high power
  - High compression – long cycle life
- Wide market application
  - Hybrid Electric Vehicles
  - Light Electric Vehicles
  - Automotive SLI
- Products
  - QB-LAB: 150W/kg; 48Wh/kg
  - B-LAB: 1200W/kg; 60Wh/kg
  - HB-LAB: 6000W/kg; 10Wh/kg



RedOx: Clean fuels from waste

- Metal Mediated RedOx
  - Proprietary chemical synthesis technology
  - replaces enzymes with direct coordination catalysis and reduction oxidation chemistry
- Uses electrolysers and other equipment already developed by AIC
- Key Markets:
  - **Ethanol** using waste bio-mass
  - **Furans** and other high value fuels from hexoses and pentoses.
  - **High value chemicals** (vanillin, furfural, phenols, humic acid, from waste
  - **Alternative treatment to sewage and farm manures**

  - **"Depolarized H2"** hydrogen produced using ~40% less energy than conventional water electrolysis

~$8M in electrolyser and system development across several projects

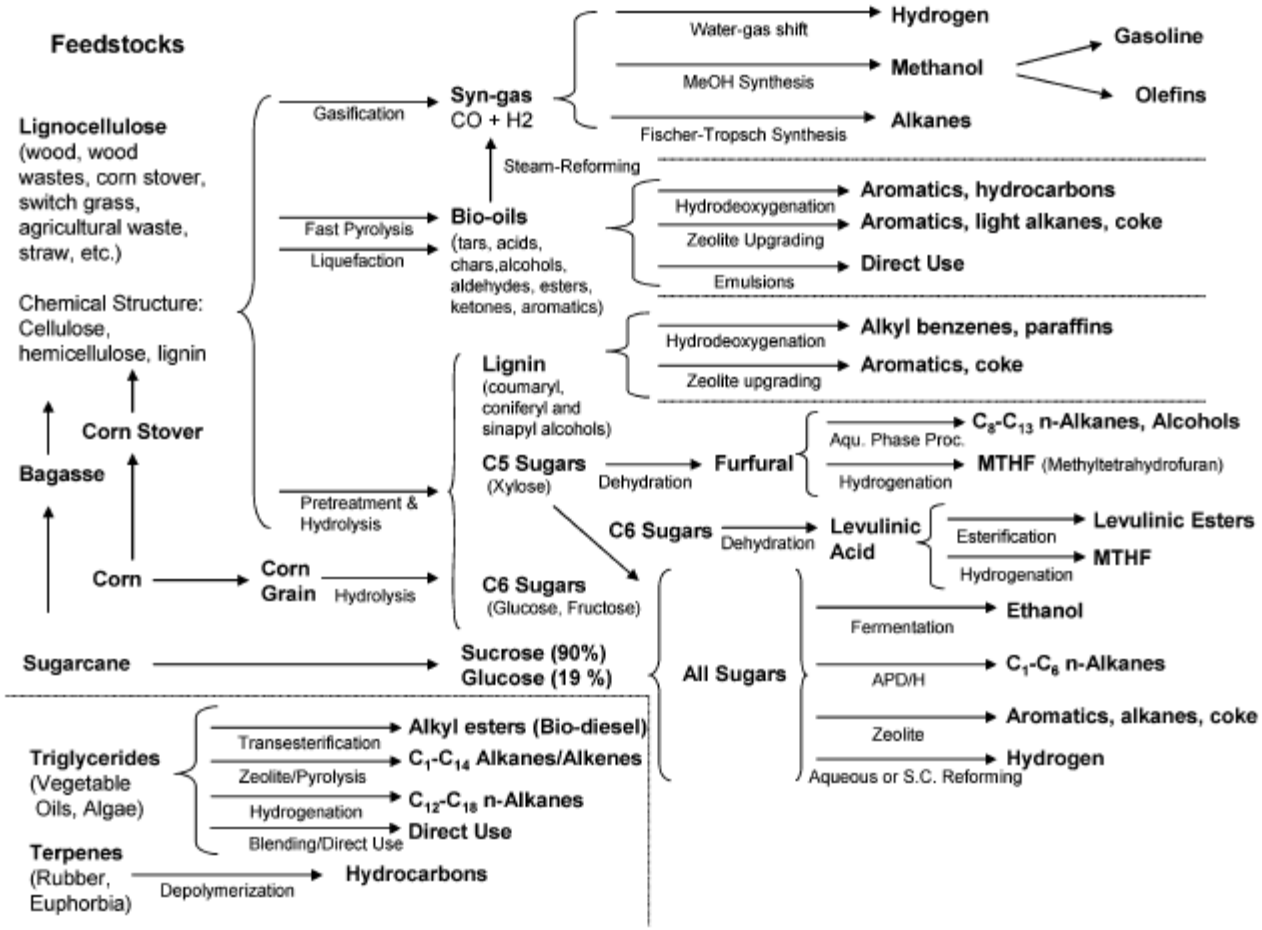


Figure 42. Known routes for production of liquid fuels from biomass.

… and partnering extends our reach.

- Lawrence Berkeley National Laboratory
  - DOE insights, Thin film batteries and RedOx
- UC Davis
  - Vehicle batteries and bio-fuels
- University College Dublin
  - Chemistry to Bio-technology interface
- Lotus Engineering
  - CFD, product design, automotive applications
- Rohm & Haas
  - Co-developed products for water markets
- Plasma Quest Ltd.,
  - Electrode materials
- Siemens
  - Water Treatment market partner, power electronics
- Mitsubishi
  - Clean fuels and Asian markets
- BASF
  - RedOx Electrolytes and specialty materials

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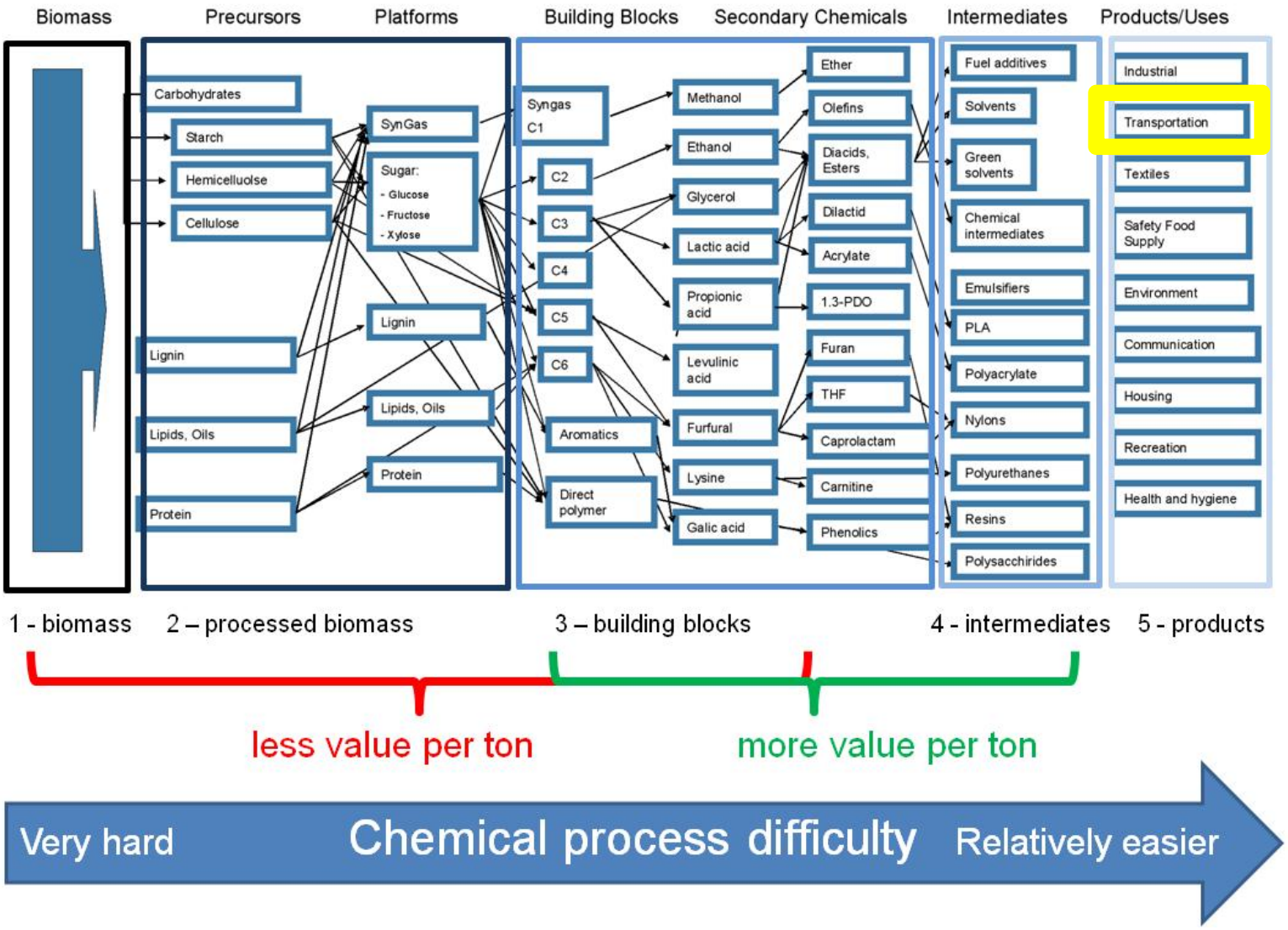
Biomass to HMF to DMF

Electro-synthesis of bio-fuels and high value chemicals

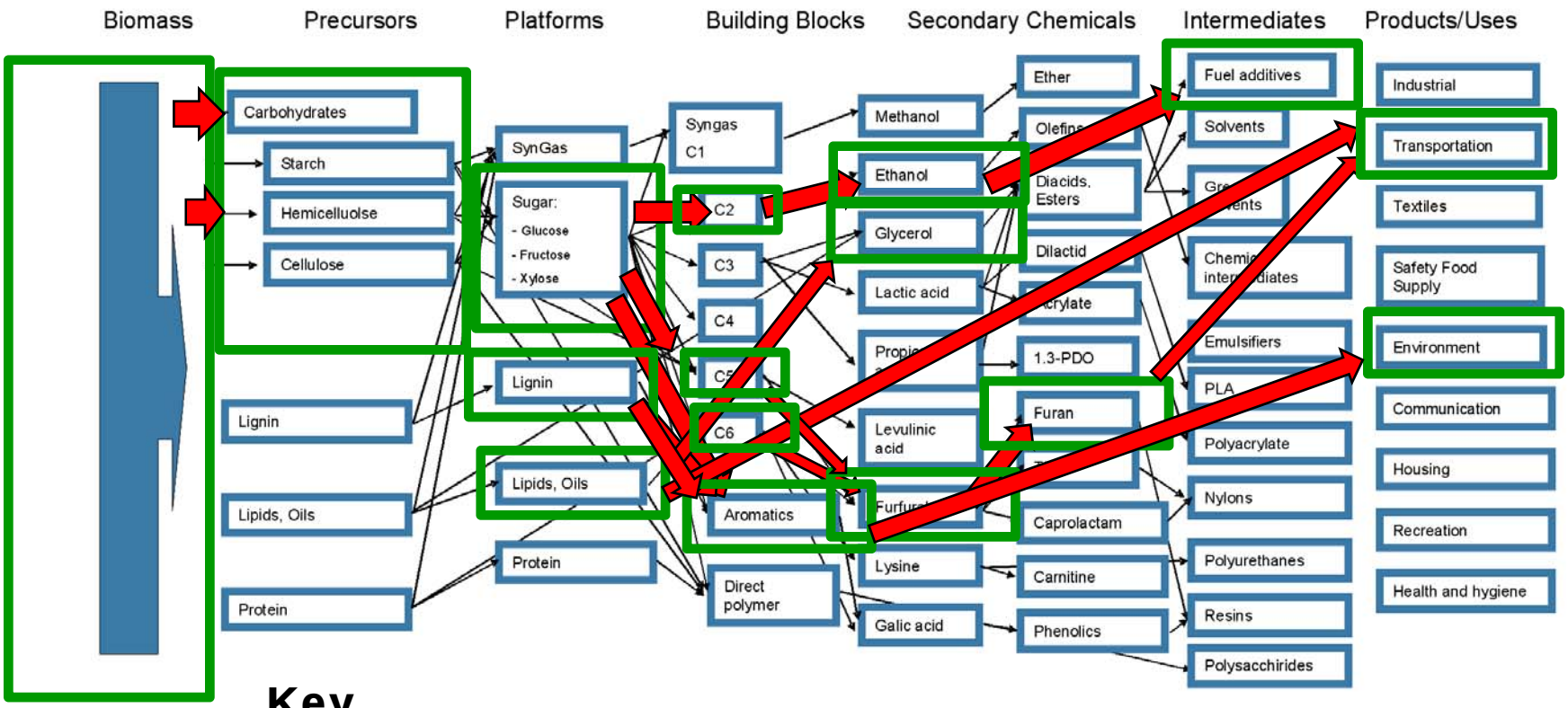
Powered by E-cell

www.apicap.com

Value in the biorefinery roadmap



AIC's strengths and success on the roadmap

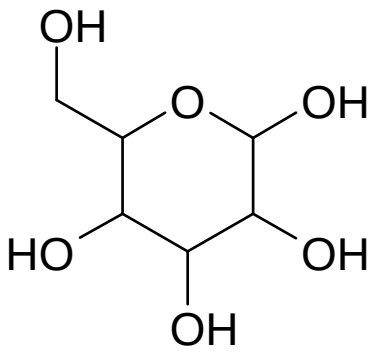


Key

Materials/chemicals or commodities in the AIC tool box

Process or transformation in the AIC tool box

Fermentation of glucose to ethanol



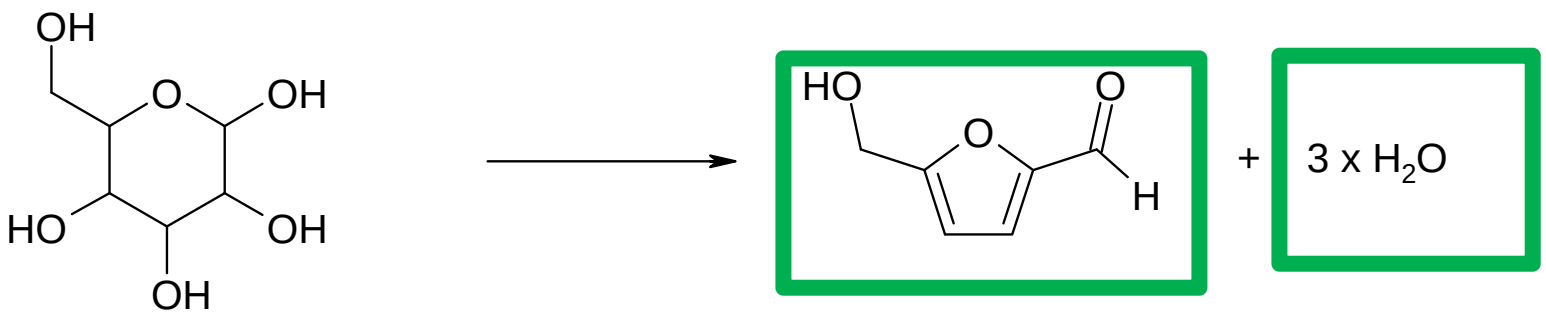
$C_6H_{12}O_6$

$$\longrightarrow \quad \boxed{2 \times \ CH_3CH_2OH} \ + \ \boxed{2 \times CO_2}$$

Issues with ethanol

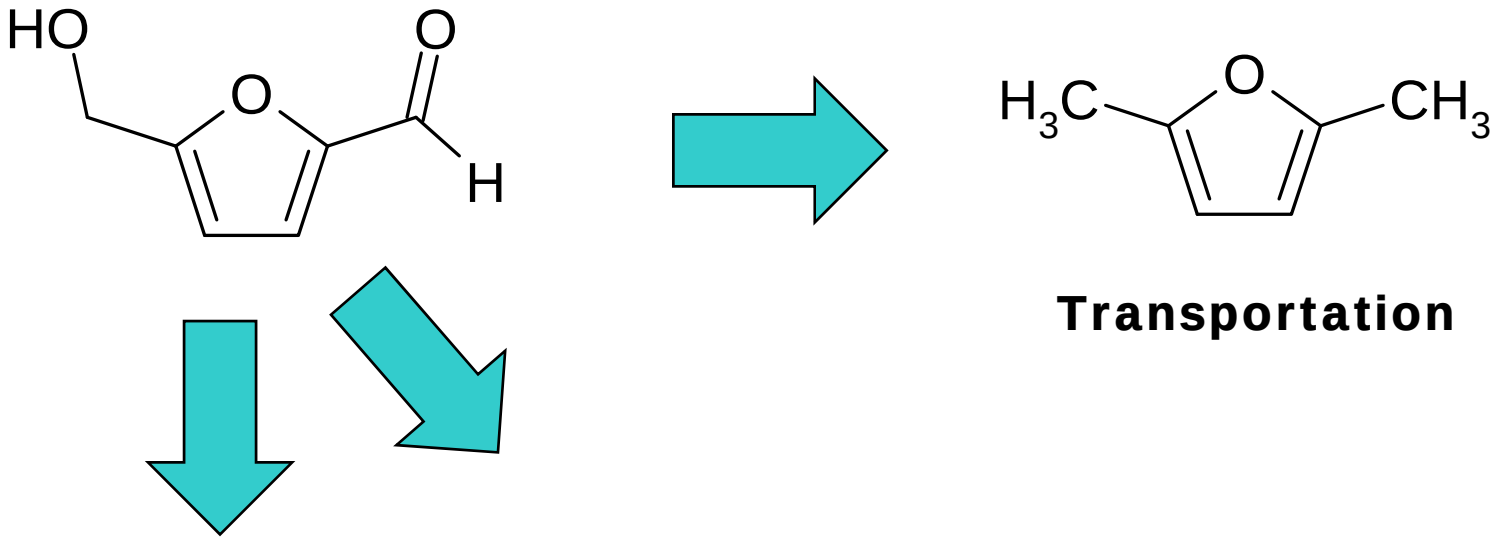
- Ethanol production through fermentation requires separation of water (energy intensive)
- The maximum concentration of ethanol you can produce is 20%, with the remaining 80 % mostly difficult to remove water
- You throw away 2 carbon atoms via the fermentation process
- Ethanol production by fermentation suffers the burden of CO_2 emissions during production
- Microbial bioreactions have poor yields and intrinsically slow, very good for high value biopharmaceuticals

Glucose to HMF



$C_6H_{12}O_6$ $C_6H_6O_3$

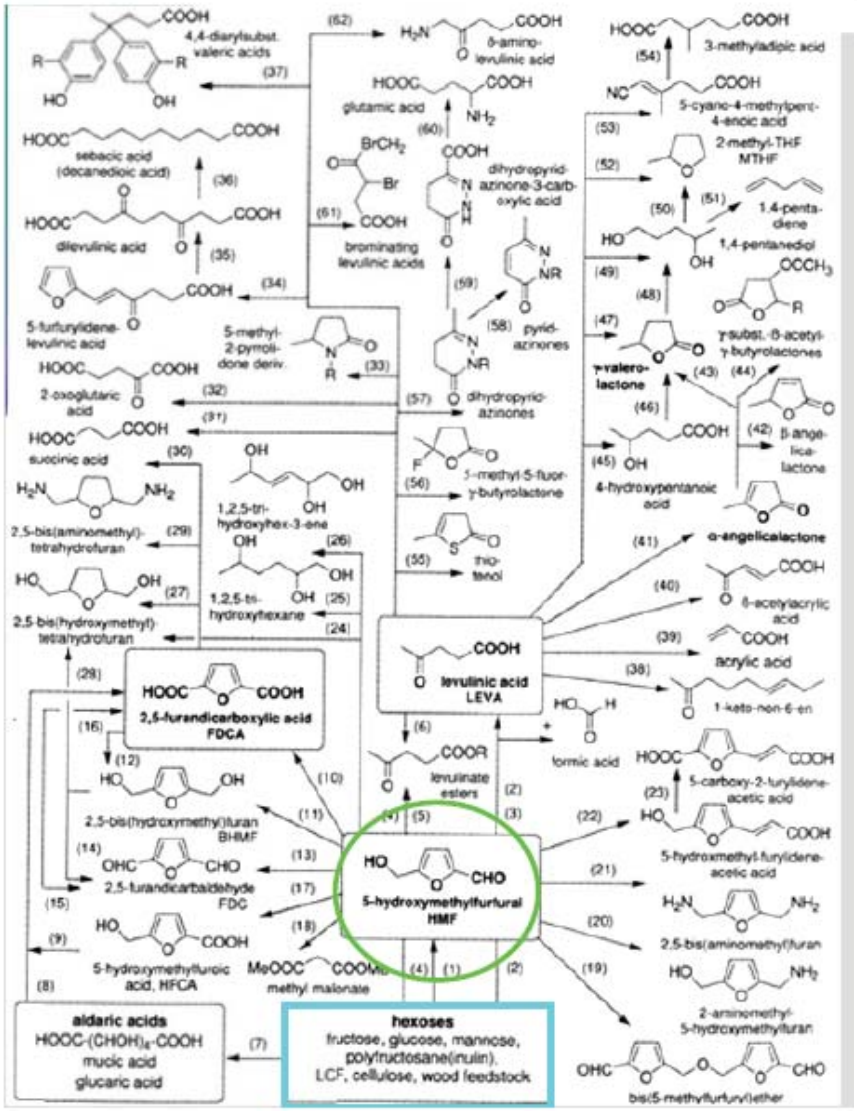
HMF



Transportation

polymers **pharmaceuticals**

HMF is the strategic molecule



DMF fuel from HMF

- DMF spontaneously separates from water
- 100 % DMF production stream
- The side product in synthesizing DMF is water
- No CO_2 emissions
- Simple high speed high yielding chemistry
- HMF is the most important strategic biomass chemical for the future of the US' green chemicals, green polymers, green solvents, green fuels industries

Summary

- AIC has key technologies on the biorefinery roadmap
- AIC is running plant/pilot plant scale processes on its commercial E-cell Technology
- AIC has identified the value and strategically vital chemicals on the roadmap: HMF and DMF