

SUSTAINABLE TRANSPORTATION: ARE BIOFUELS STILL AN OPTION?

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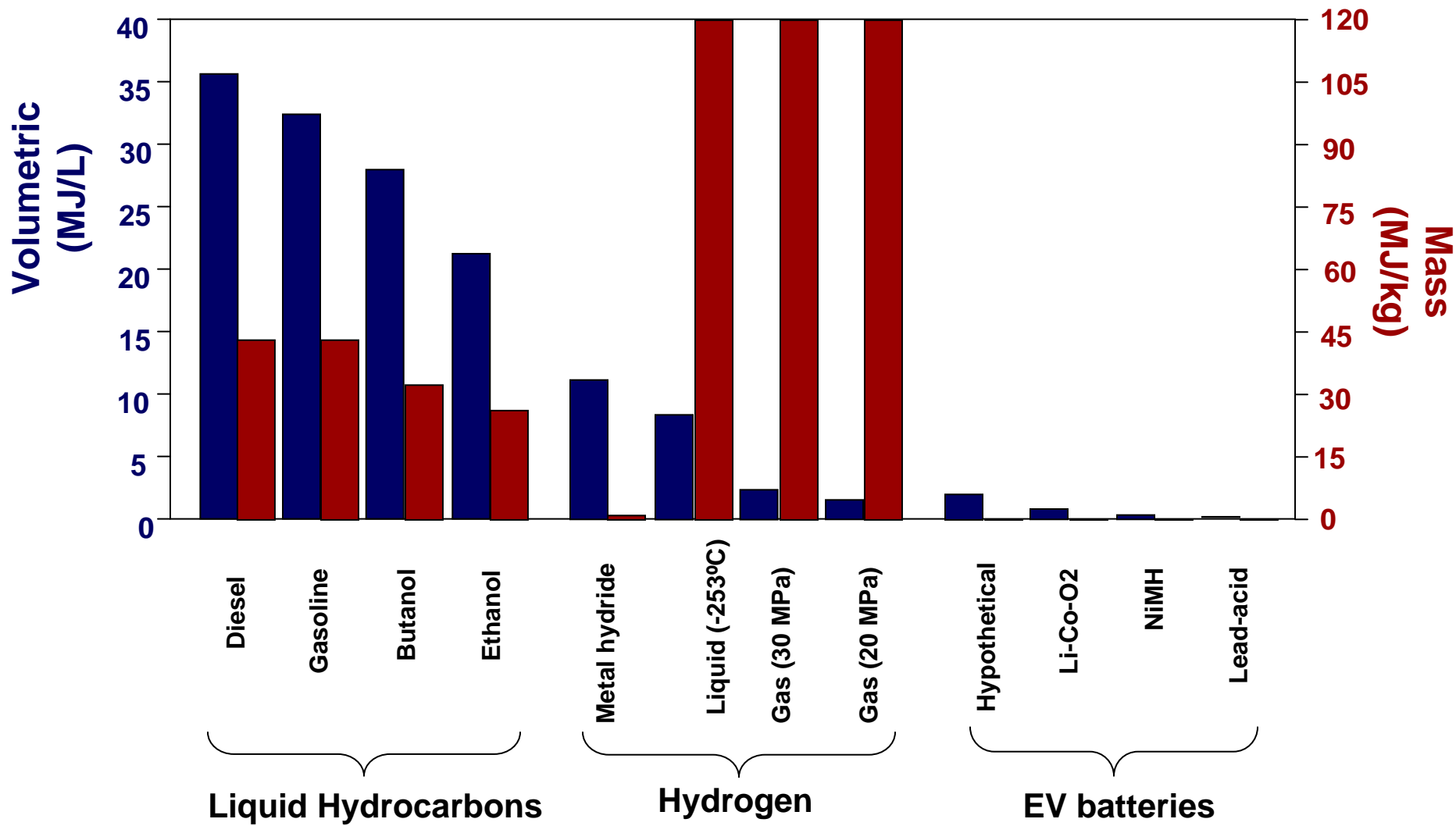
Sustainability Challenges of the Next Decades

- Diversify transportation fuels & end disruptive role of petroleum in the world
- Provide food (actually animal **feed**) for growing & wealthier population (eating more meat & dairy)
- Control greenhouse gases, limit other human emissions, protect & enhance ecosystems
- *These challenges & opportunities **connect** at biofuels, particularly cellulosic biofuels*
- *Some recent analysis/commentary sees biofuels as part of the problem, not part of the solution to these challenges*

Perceived Problems with Biofuels

- Food vs. Fuel: we don't have enough land for both food and biofuels
- Biofuels will contribute to environmental problems, not help resolve them
- Biofuels will always cost too much
- Instead of biofuels, we can use
 - Conservation
 - Electricity
 - Hydrogen
 - A lot of luck



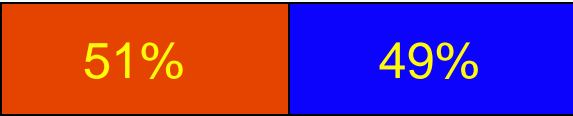
Transportation Energy Storage: A Closer Look



Sources:
<http://www.transportation.anl.gov/software/GREET/index.html>
<http://www.hydrogen.org/Knowledge/w-i-energiew-eng2.html>
http://gcep.stanford.edu/pdfs/assessments/ev_battery_assessment.pdf

Courtesy Dr. Lee Lynd

What About Electrification?

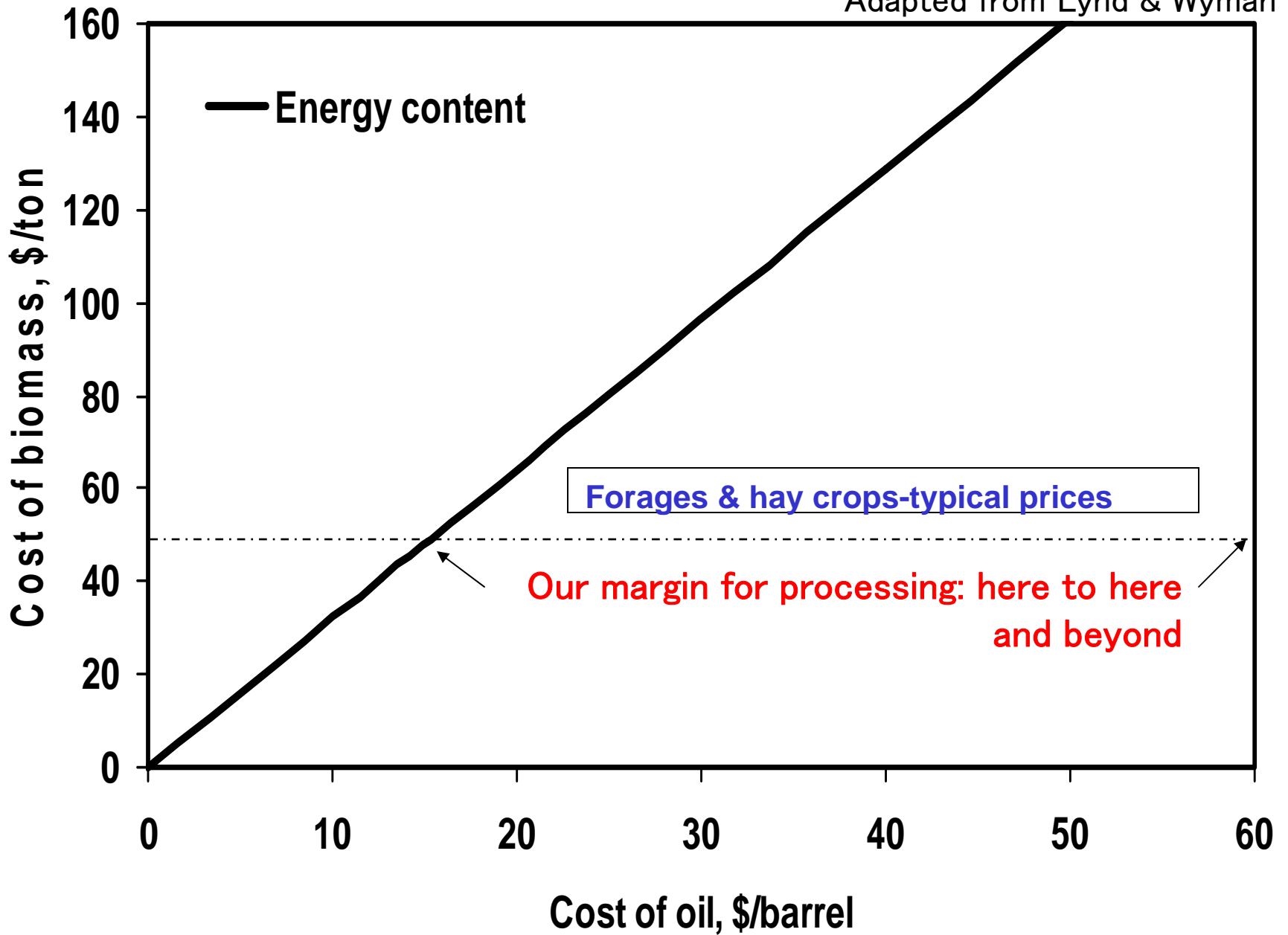
Scenario (Personal Vehicles)	Transportation Energy: Electricity, Liquid Fuels	Increased power generation
All plug-in hybrids, 40 mi radius* (PHEV ₄₀)		23%
1/3 EV, 1/3 PHEV ₄₀ , 1/3 ICE		19%
1/2 EV, 1/2 PHEV ₄₀		29%

*Upper bound in EPRI/NRDC 2050 forecast, providing 64% LDV energy

Liquid fuels are very likely to provide a substantial fraction, probably $\geq 50\%$, of transportation sector energy utilization for the indefinite future.

To achieve a sustainable transportation sector, we very likely must produce biofuels in large amounts. They are not optional.

Courtesy Dr. Lee Lynd



Cellulosic biomass is the cheapest carbon in a carbon constrained world

What's Going on in Michigan?

Progress with Cellulosic Biofuels

- Great Lakes Bioenergy Research Center (GLBRC)
 - \$25 million per year, focus on discovery
 - MSU and U. of Wisconsin
 - Unique program on sustainability
- Mascoma Inc.
 - Building 20 million gallon/yr plant in UP
 - A recognized leader, some exciting technology
- MBI International
 - Helping new biofuel technologies to cross the “valley of death”
 - Drive down cost and risk
 - Example: AFEX pretreatment focus of \$28 million proposal to DOE for a pilot plant

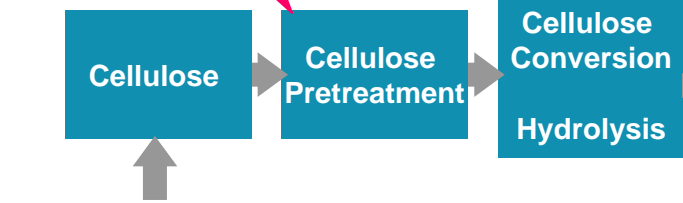
Biofuel Production Flowchart: Sugar Platform

Cellulose Process

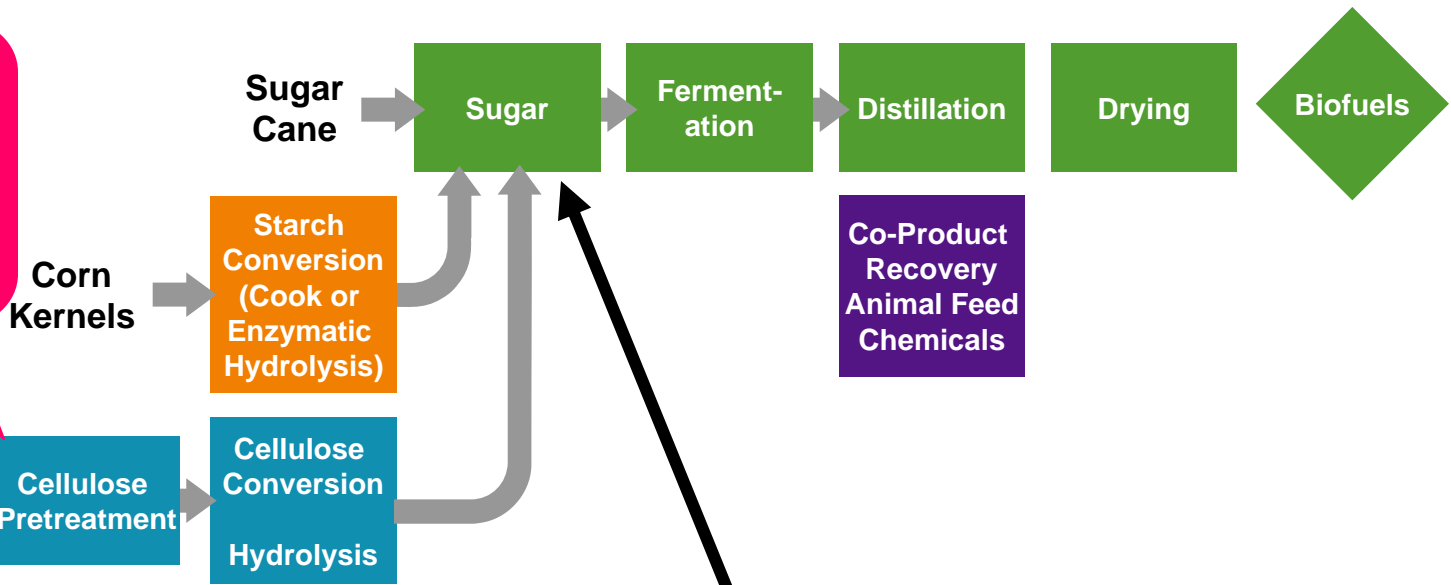
Corn Process

Sugar Cane Process

MY LAB WORKS HERE- AFEX PROCESS



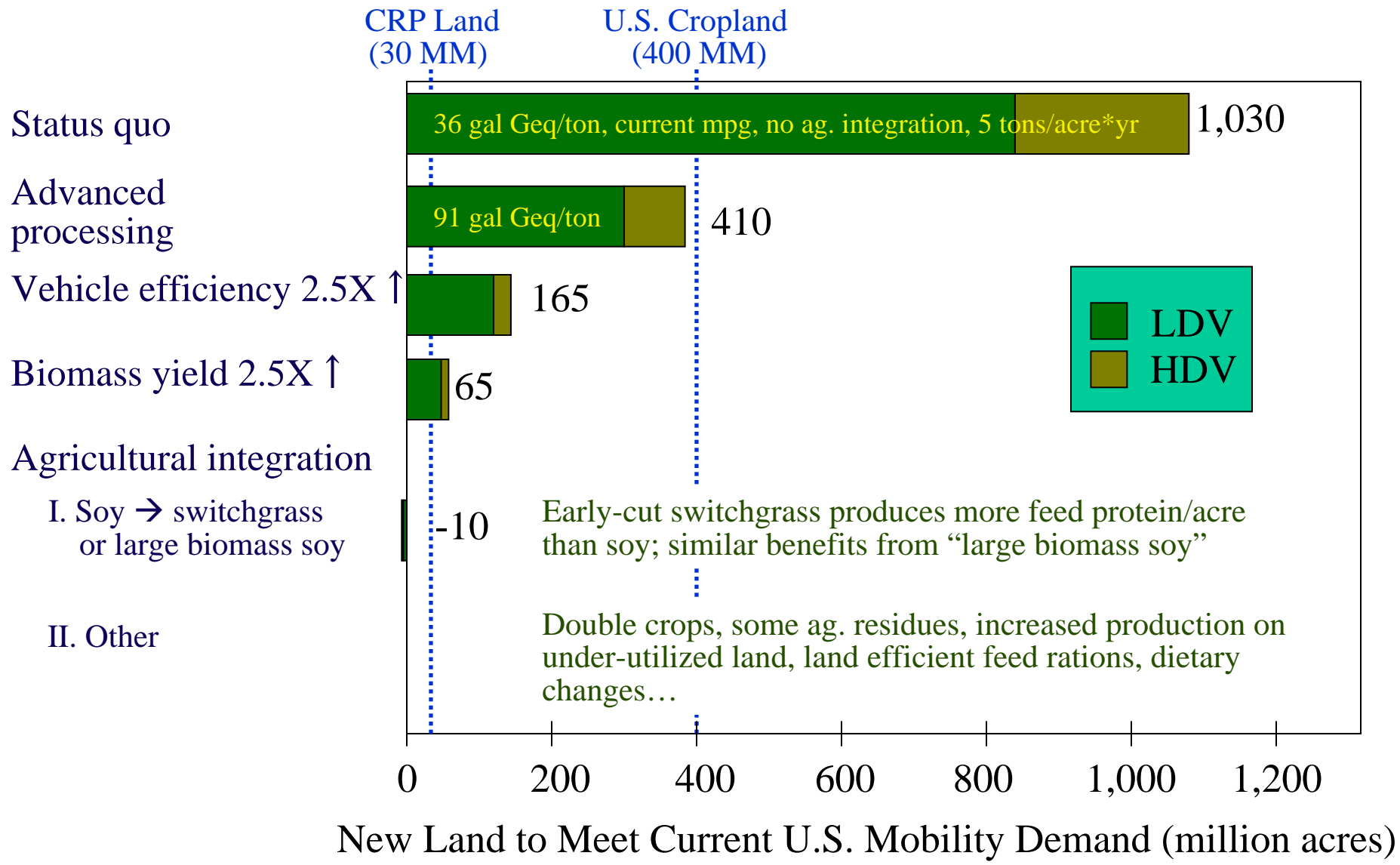
- Corn Stover
- Grasses
- MSW
- Forest Residues
- Ag Residues
- Wood Chips



Objective is to generate clean, fermentable sugars @ about **6¢ per pound**- big challenge!

Can we produce enough biofuel to make a difference while feeding humanity, protecting wild-life habitat, and avoiding large land conversion carbon debts?

U.S., longer term, larger scale, more extensive innovation & change



Early-cut switchgrass produces more feed protein/acre than soy; similar benefits from "large biomass soy"

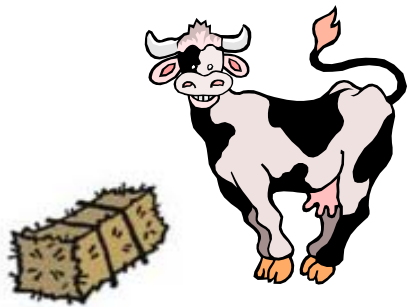
Double crops, some ag. residues, increased production on under-utilized land, land efficient feed rations, dietary changes...

We Don't "Grow Food", We Grow Feed

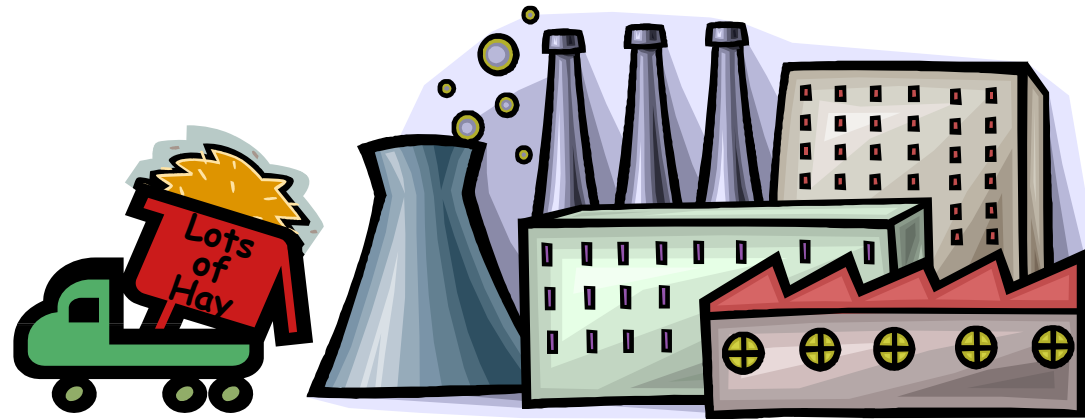
- Three major U.S. crops *alone* (corn, soy, wheat) produce 1300 trillion kcal & 51 trillion grams protein/yr
- **Could meet U.S. human demand for protein & calories with 25 million acres of corn (~5% of our cropland)**
- *Most U. S. agricultural production (inc. exports) is fed to animals-- i.e., we are meeting their protein/calorie needs from our land resources. Their needs are:*
 - 1040 trillion kcal/yr (**6 times** human demand)
 - 56.6 trillion gm protein/yr (**10 times** human demand)
- Thus we can address perceived “food vs. fuel” conflict by providing animal feeds more efficiently, on less land
- Dairy & beef cattle consume **more than 70%** of all calories and protein fed to livestock
- Cattle are well suited to consume grasses & cellulosic materials—particularly high digestibility grasses

Two Cellulosic Biorefining Systems

**Mobile Cellulose Biorefinery:
A consolidated
bioprocessing organism**

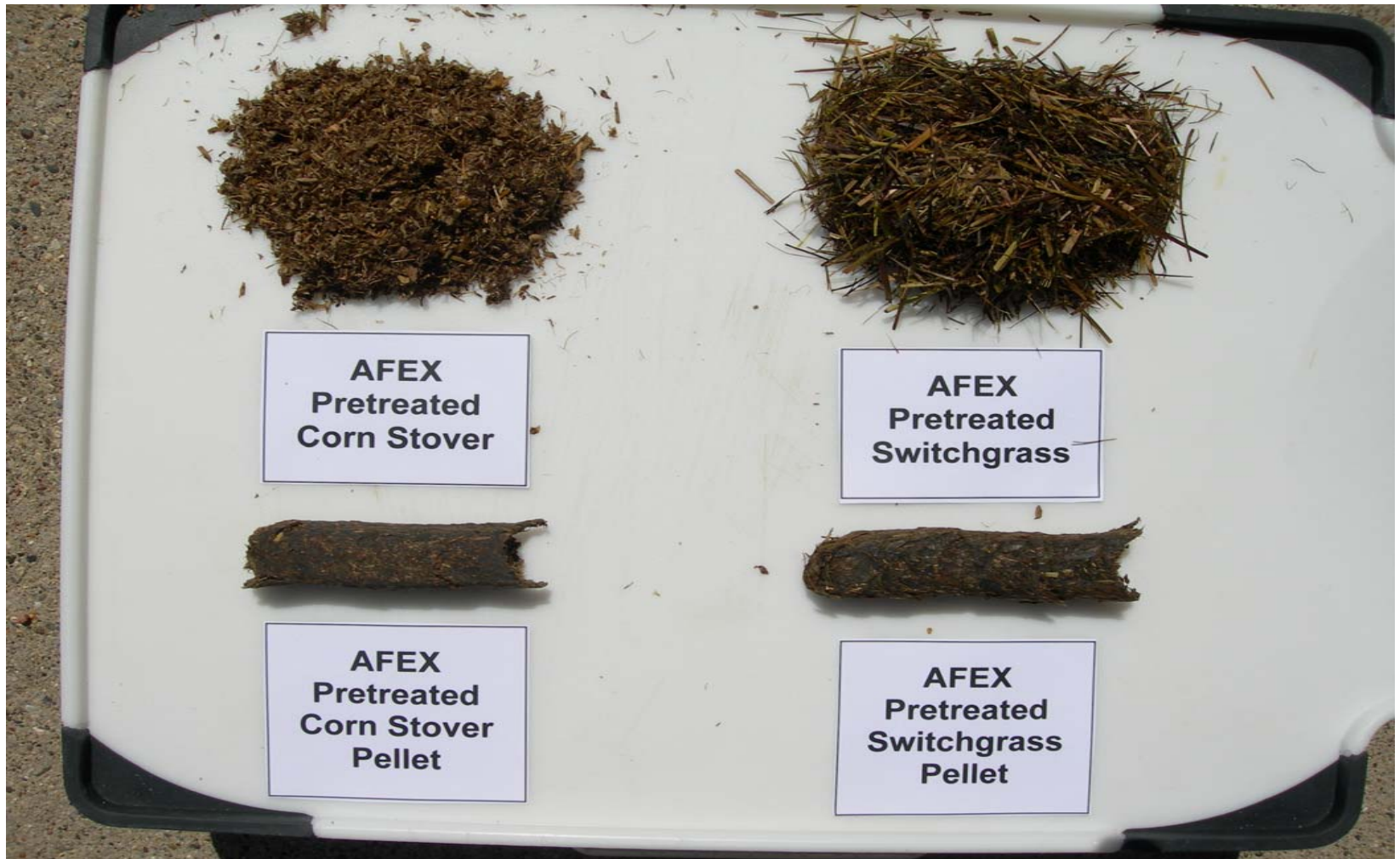


**Stationary Cellulose
Biorefinery**



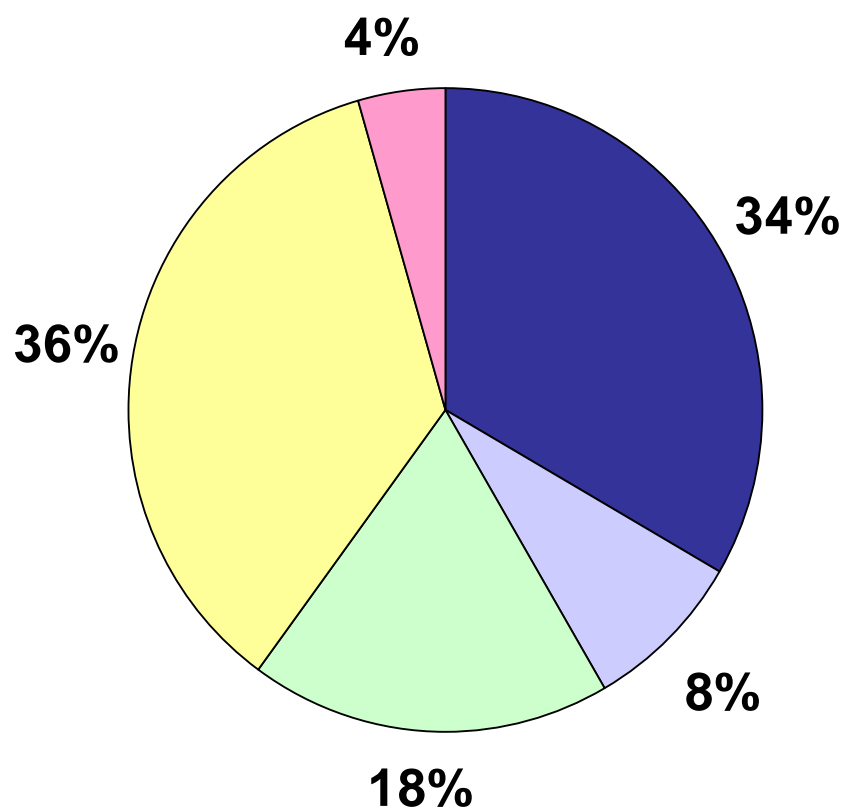
***Improve Cellulose Conversion for Biorefinery
= Improve Cellulose Digestibility for Cows***

AFEX Biomass Pellets: No Binder

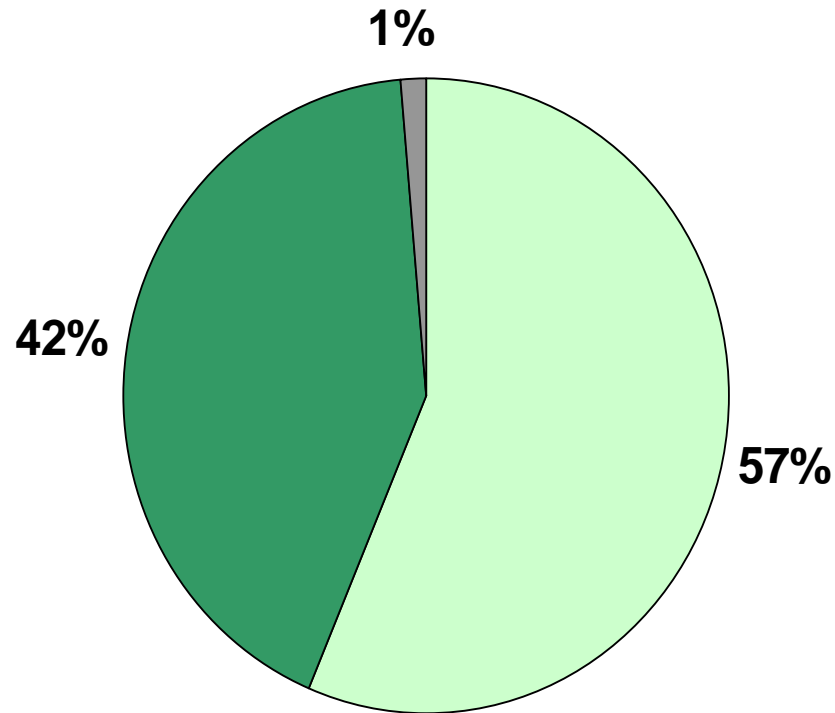


Dairy Diet- Black Hawk County Iowa Farm

- Alfalfa Silage
- Alfalfa Hay
- Grain Silage
- Dry Grain
- Soybean Meal, 44%
- AFEX Treated Switchgrass
- Protein Supplement

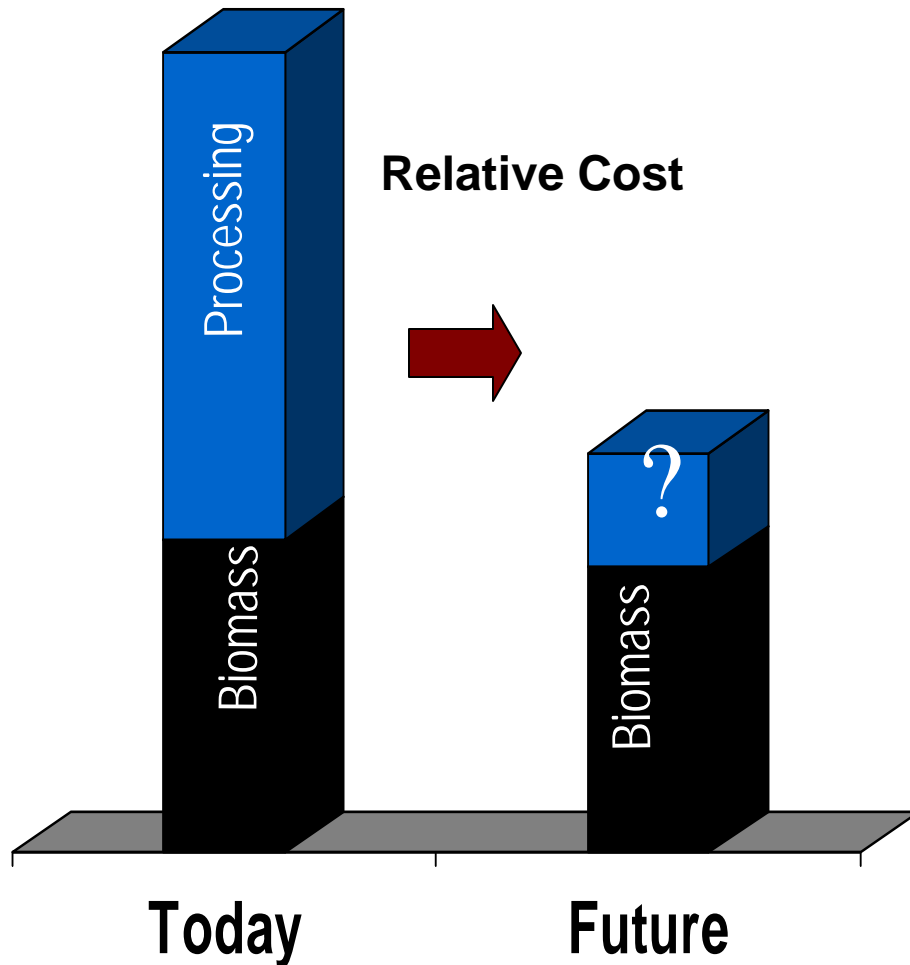


\$150,242/yr
265 acres/yr



\$92,388/yr
167 acres/yr

Impact of Processing Improvements: The Future of Biomass Conversion

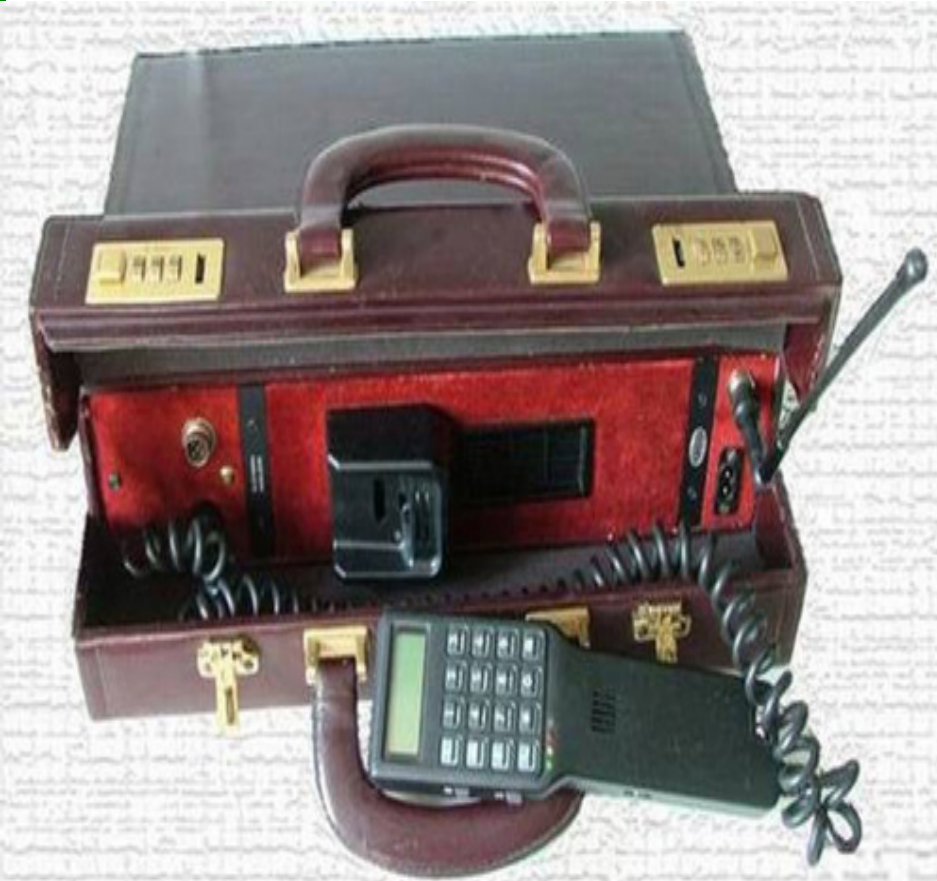


- Processing is dominant cost of cellulosic biofuels today
- Cellulosic raw material costs should be stable or decrease
- Processing costs dominated by pretreatment, enzymes & fermentation
- Biomass processing costs will decrease: deserves high priority to make it happen sooner rather than later
- **Much more attractive future**
 - Domestically produced fuels
 - Environmental improvements
 - Rural/regional economic development

What Happens Because of Inexpensive Biofuels?

- Petroleum dominance declines
 - *Reduce petroleum's influence on prosperity & politics*
 - *Less chance for international conflict*
 - *Greater economic growth opportunities for poor nations*
- **Environmental improvements possible**
 - *Reduced greenhouse gases*
 - *Reduced nitrogen & phosphorus-related pollution*
 - *Improved soil fertility*
- **Rural economic development possible**
 - *Local cellulosic biomass processing*
 - *Greater wealth accumulation in rural areas*
 - *Less migration to cities to find economic opportunity*
- **Less expensive food (animal feed) possible**
 - *Improved animal feeds: **protein** & calories*
 - *Less expensive, more abundant human food*

**From This Immature
“Cell Phone”ca 1985**



Clunky, didn't work well
Only one function

**To this Mature One
ca 2008**



Excellent properties
Multiple functions