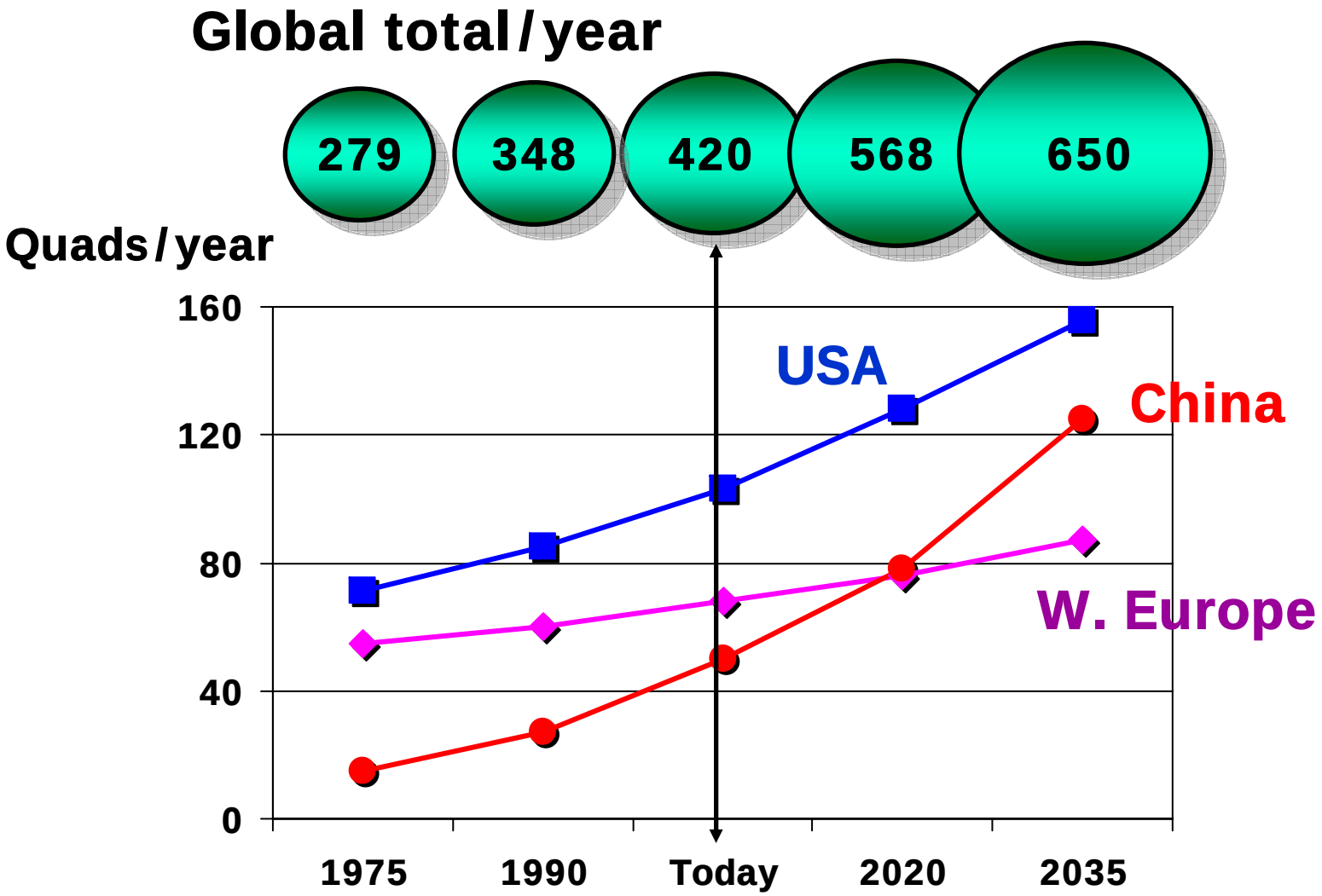
Growing the Bioeconomy

Residues and Dedicated Energy Crops:

Is there real commercial potential
or just more research?
Iowa State University, Ames, August, 2005

StrathKirn® Inc.

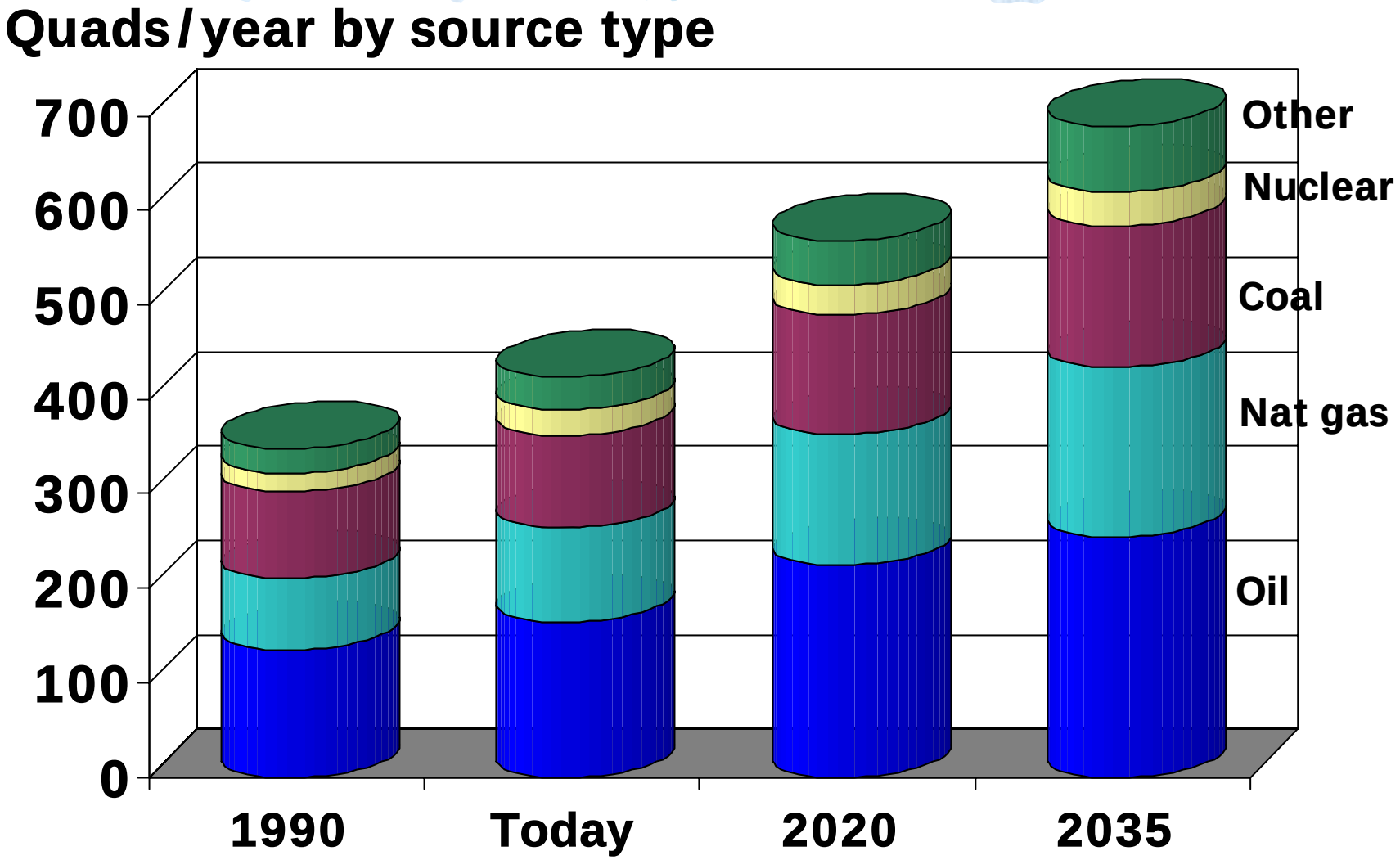
Predicted world energy demand….



StrathKirn® Inc.

Data Source: USDOE, International Energy Outlook, 2004

Current world energy consumption and source prediction….

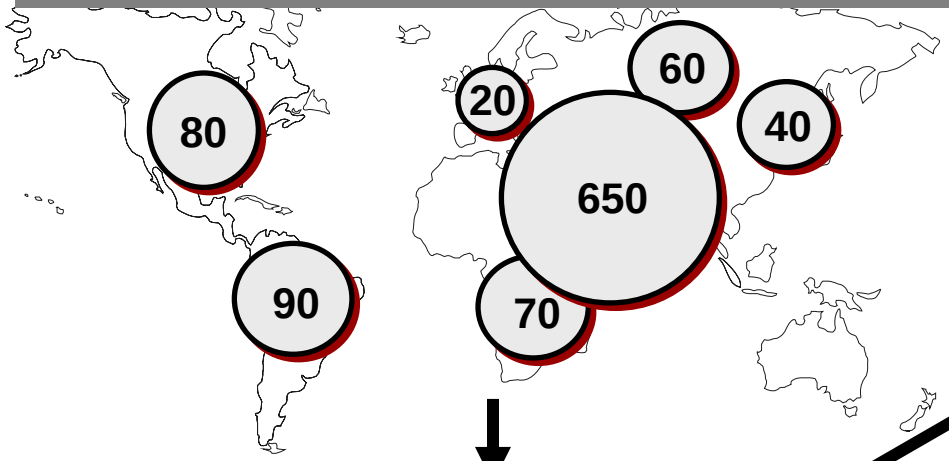


StrathKirn® Inc.

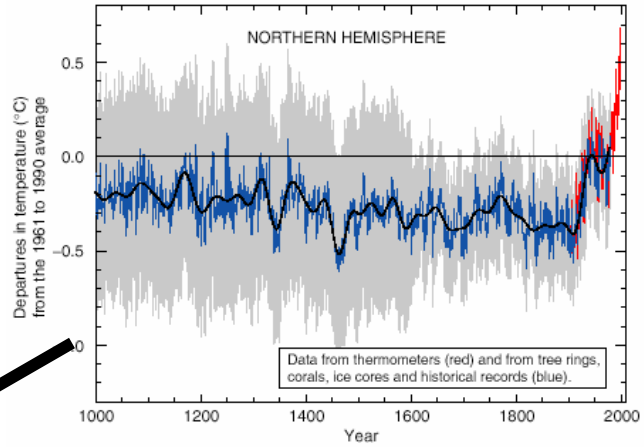
Data Source: USDOE, International Energy Outlook, 2004

Several issues around sustainability of current source situation…

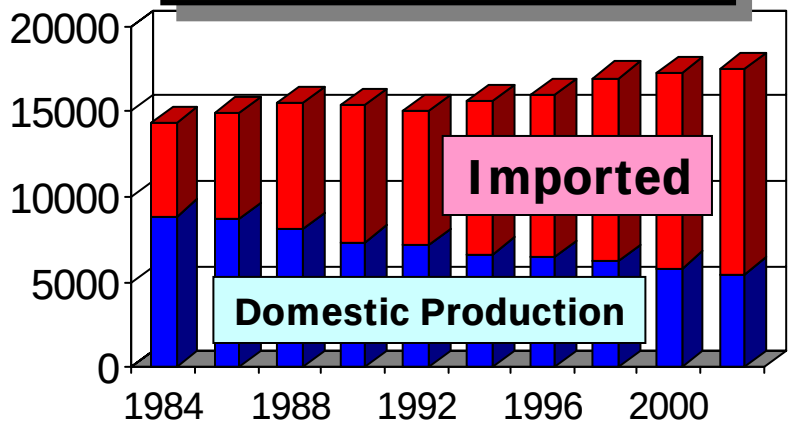
Finite & non-uniform distributed reserves
(Billions barrels known reserves of fossil oil)



Global Temperature



US Oil Supply, K bbl/day



StrathKirn® Inc.

Background...
(aka Myths and Mystery)

BioEnergy

BioEthanol

Chemical

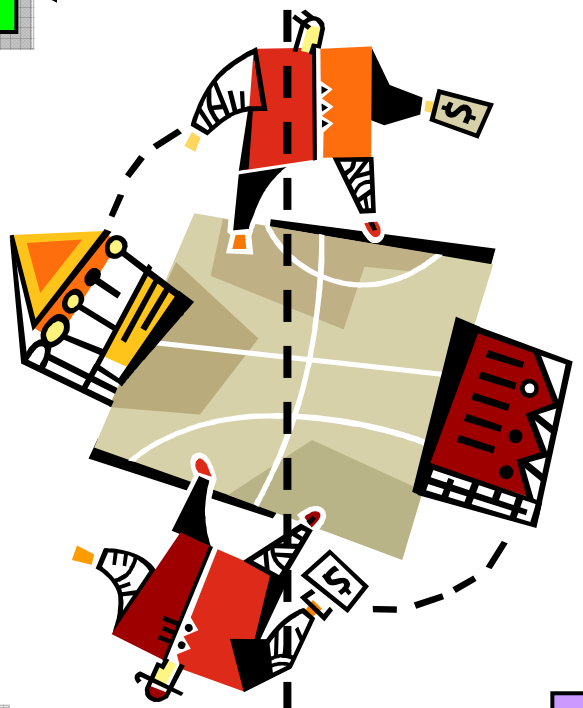
Lignocellulose

Enzyme

Wet mill

Starch

Dry mill



Oil

Coal

Fossil Fuels

Nat Gas

Solar

Hydrogen

Alternate Fuels

Nuclear

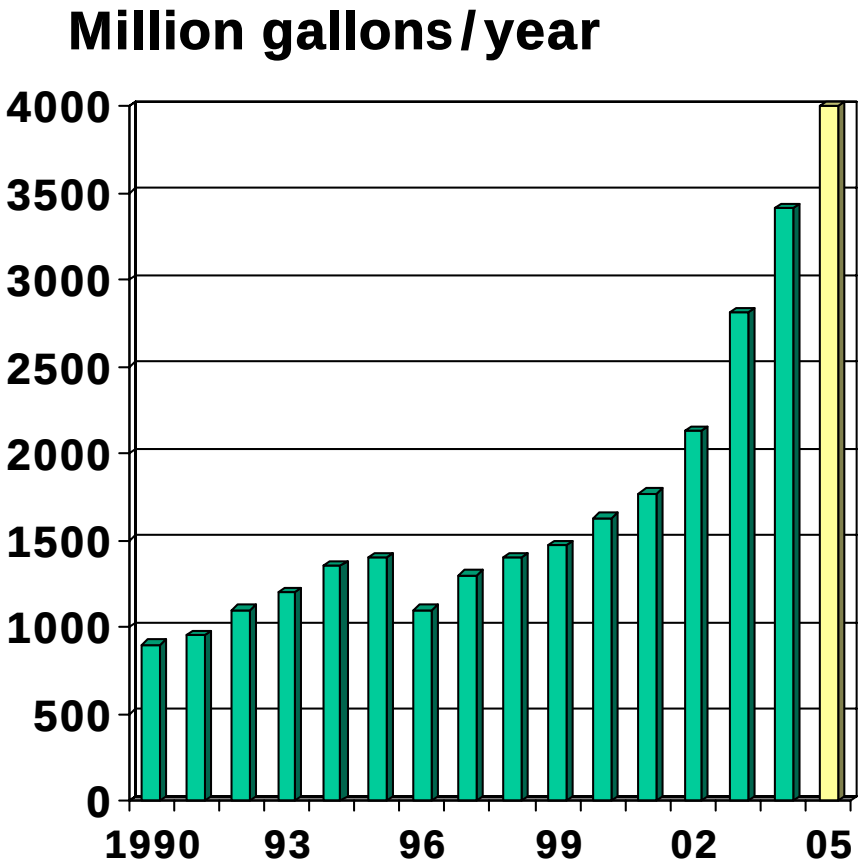
Gasoline

Conventional Energy

StrathKirn® Inc.

Current US ethanol production...

Oxygenate for gasoline: blended in ~30% of transport fuel
Alternative fuels: now >50K E-85 vehicles on the road



FOR 2004:
81 facilities
3.4 B gal EtOH

16 new plants
750 MMgal/yr

CAPACITY =
4397 MMgal/yr

Corn, sorghum

75% dry mill
25% wet mill

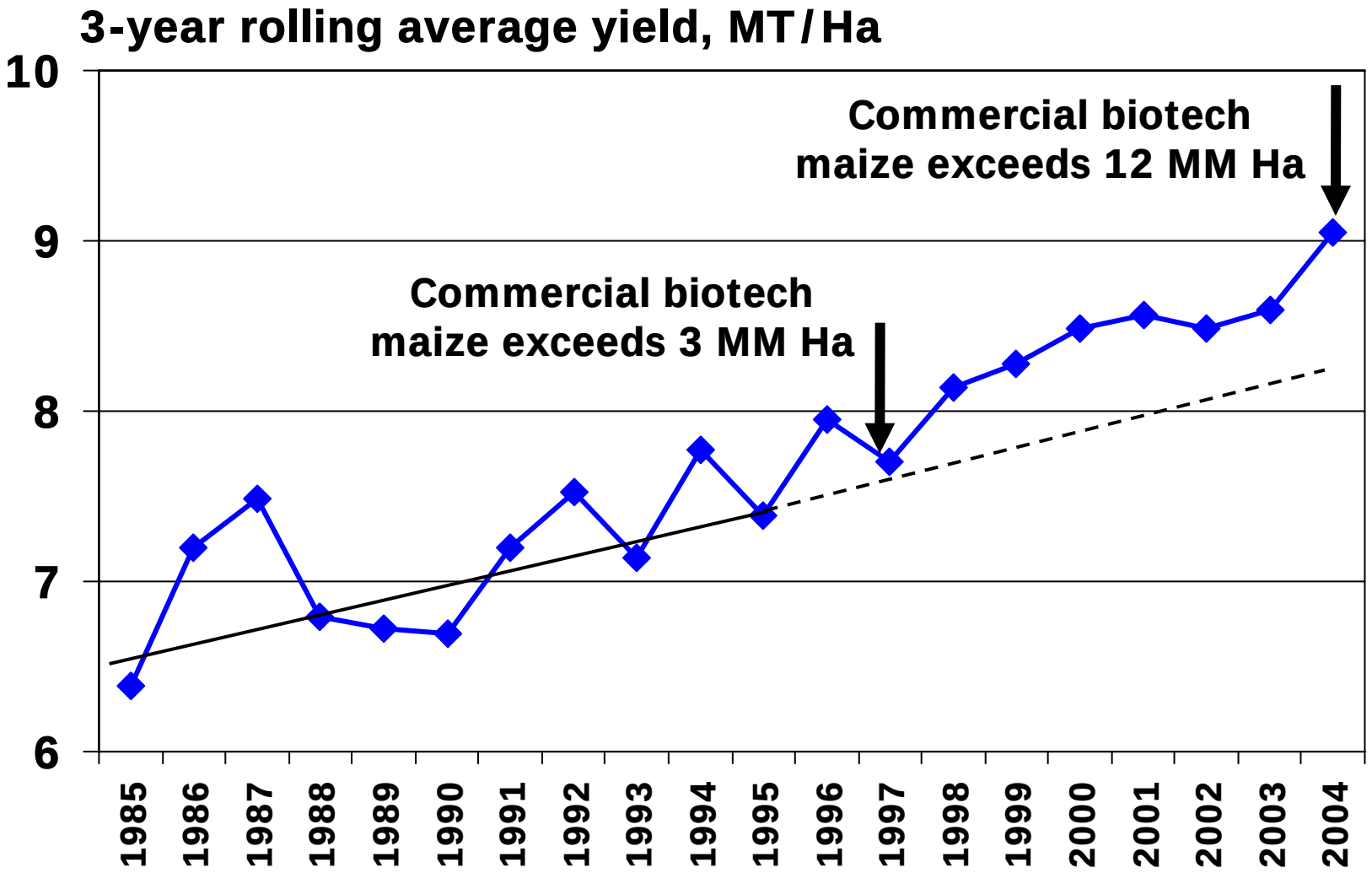
7.3 MM MT DDGS

0.4 MM MT gluten meal
2.4 MM MT gluten feed
0.3 MM MT oil

StrathKirn® Inc.

Data Source: Renewable Fuels Association & Industry Reports

Corn yield trend...



StrathKirn® Inc.

From McLaren (2005), Trends in Biotechnology

Future demand scenarios: the market perspective...

E-85 BMW Z4

US vehicle fuel market
Current volume = 120-130 B gal/yr

US vehicle future fuel market
Assume stabilizes at 130 B gal/yr
(More efficient ICE, hybrids, etc)

25 % market adopts E-85 approach

= 28 B gal EtOH

80 % market adopts a 10 % ethanol blend

= 10.4 B gal EtOH

StrathKirn® Inc.

Market impact requirements and theoretical solutions....

For previous scenario
Difference requirement is 7 - 25 B gallons EtOH

Add 25 MM acres corn @ 486 gal EtOH/acre
= 12 B gal EtOH
Increase yield by 25% = 608 gal EtOH/acre
= 9.8 B gal EtOH

Add lignocellulose use
Hybrid SR Poplar (5 dt/ac/yr, 20 MM acres) = 8 B gal
Switchgrass (4 dt/ac/yr, 20 MM acres) = 7 B gal EtOH
Corn stover (remove 4K lb/acre, 50% acres) = 6 B gal EtOH
Assumes 85 gal EtOH/dry ton lignocellulose can be achieved

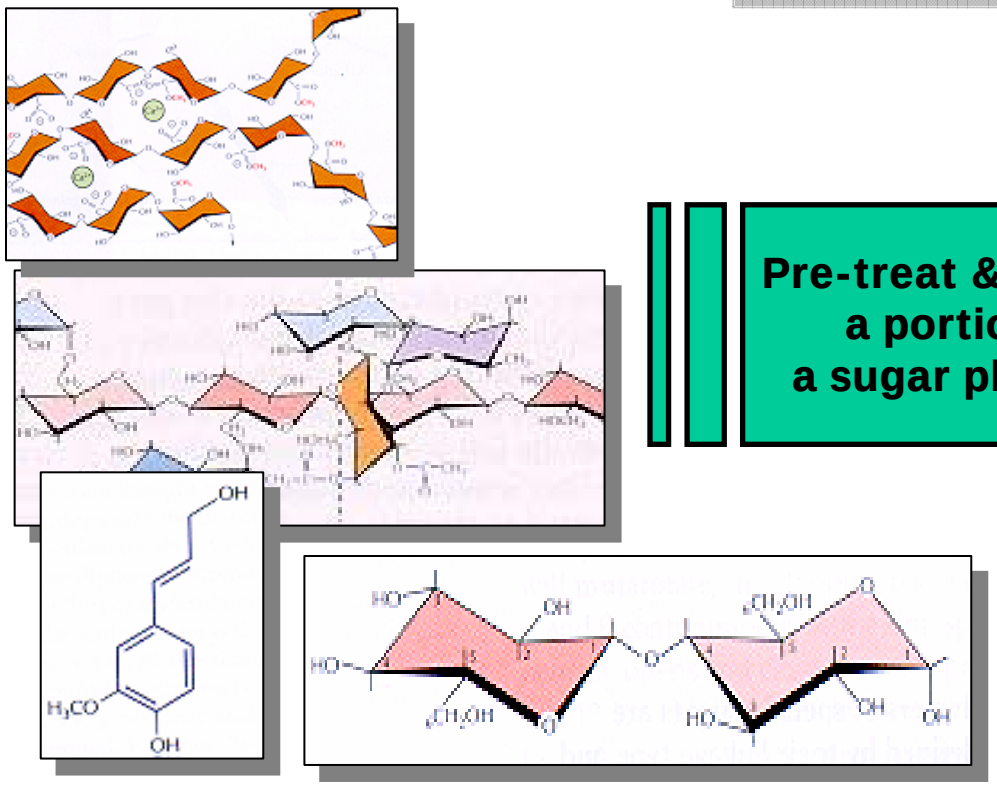
Increased corn contribution is probable
Adding a future lignocellulose base = ??

Lignocellulose = Plant cell walls

Some useful components some problem components

Lignocellulose biomass

Complex network of molecules



Cellulose (Cellobiose units).

1→4 glucan: grasses have 1→3 also

The recalcitrance of lignocellulose means this is not a trivial process.

Pre-treat & convert a portion to a sugar platform

Lignin
➔ burn

HemiC
➔ C5 sugar
➔ EtOH

Cellulose
➔ glucose
➔ EtOH

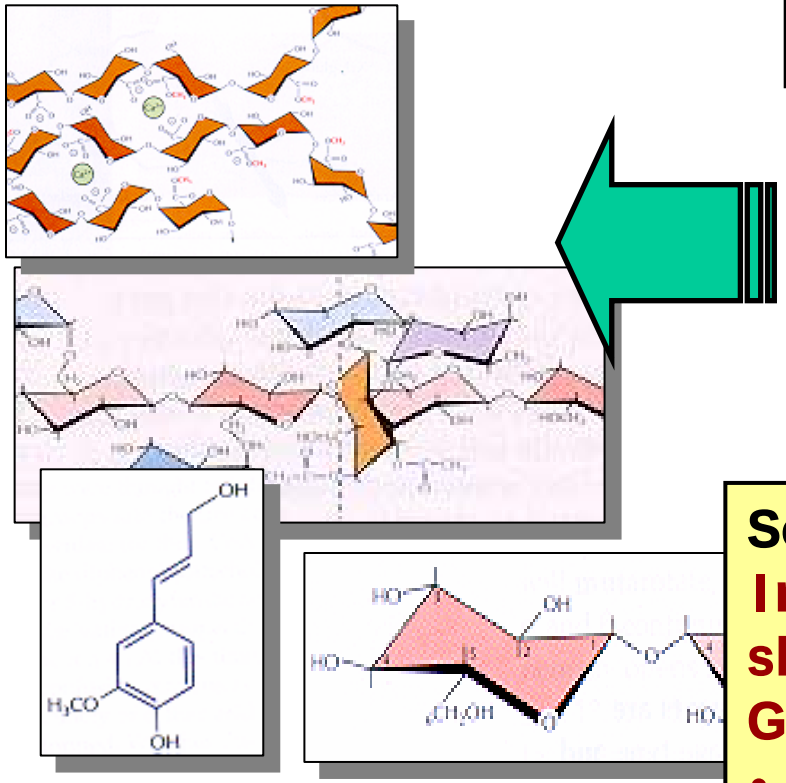
Gasification may be an option

StrathKirn® Inc.

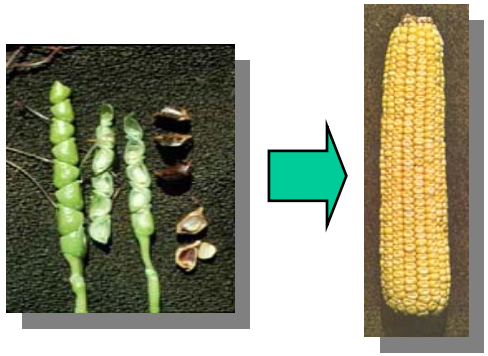
Biomass utilization: new solutions...

Lignocellulose biomass

Complex network of molecules



Is there potential to alter the starting material?



Solutions via biotech tools:

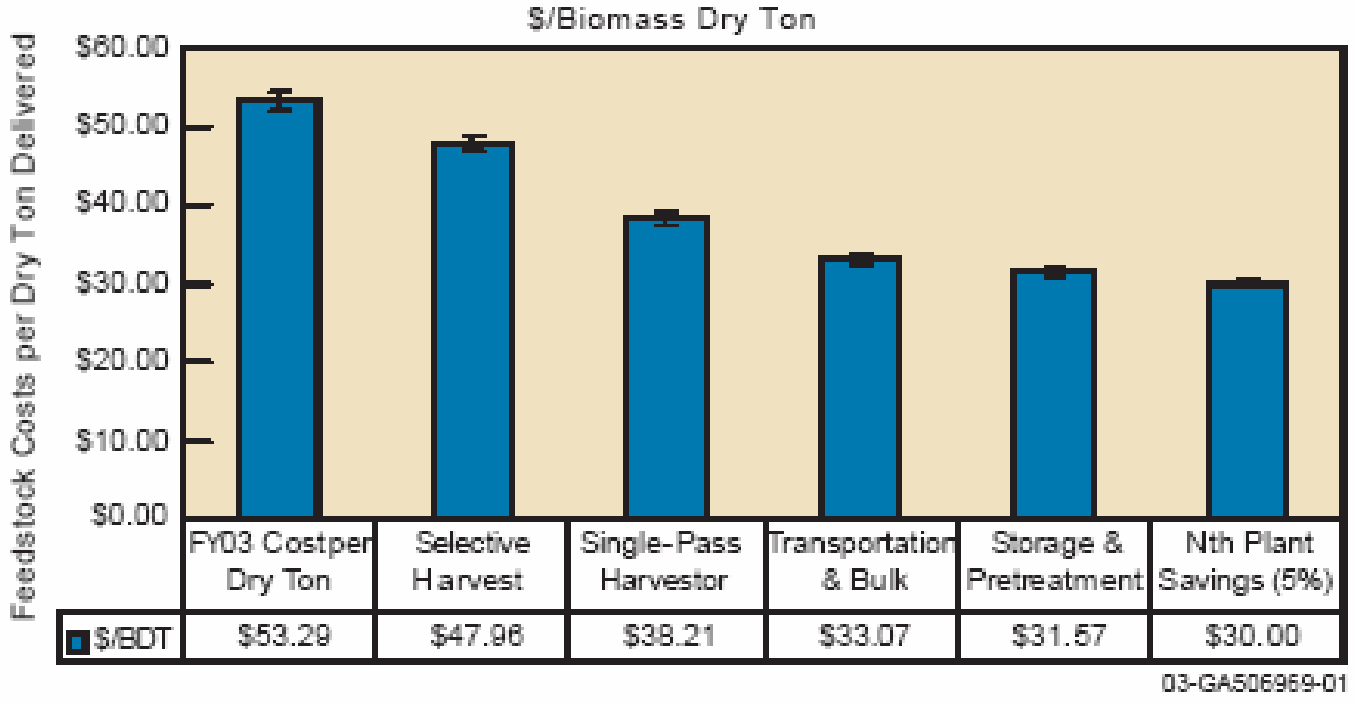
Improved raw feedstock on a short timeframe.

Genetic control of composition

- **Low lignin biotech trees**
- **Low lignin stover**
- **What other change?**

Current theoretical models for lignocellulose help identify some of the large hurdles (in addition to the processing issues)...

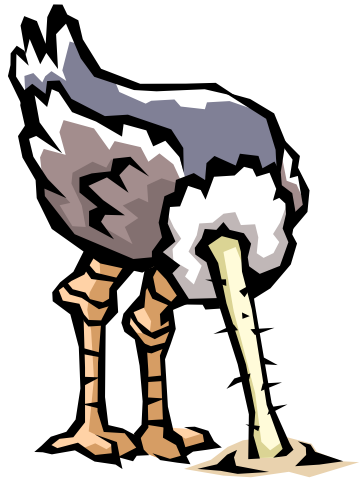
Residue	**Harvested/delivered (no soil damage)**
>$50/dry ton	**<$30/dry ton**
Complex pre-treat	**Separate lignin-cellulose**
Cellulases improved	**Another 5-10 fold?**
Almost zero investment	**$15B for process facilities**



StrathKirn® Inc.

From 2003 DOE Biomass Roadmap

The timeframe and other issues…



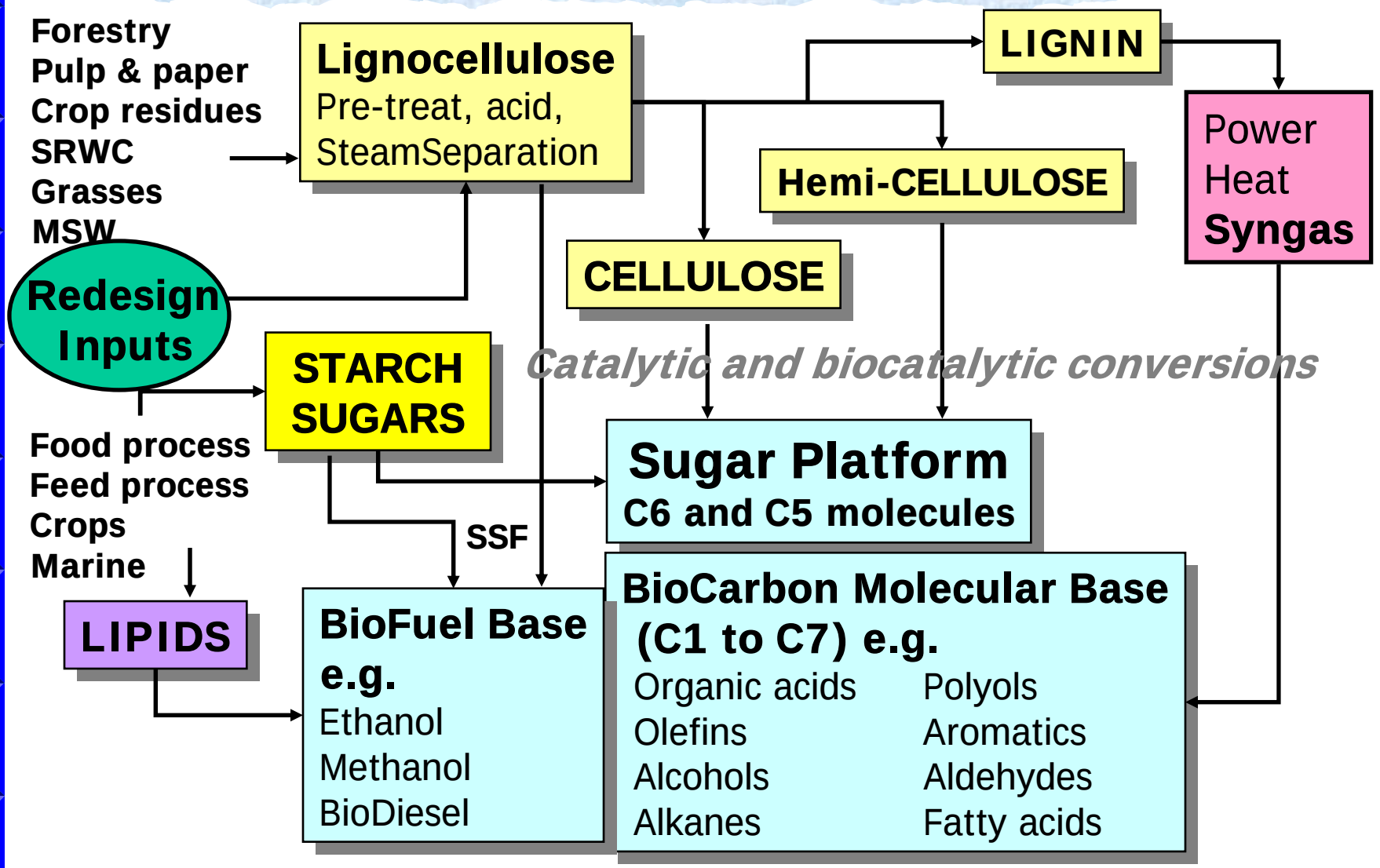
Corn ethanol today = 3 B gal
Corn ethanol 5 years = 8-9 B gal

LignoC ethanol today = 0 B gal
LignoC ethanol 5 years = 0.1 B gal
LignoC ethanol 25 years = 25 B gal

Need to understand timeframe
- **Research targets – milestones**
- **For application of research results (investment)**
- **For alternative approaches**

Is ethanol the target or an opportunity window?
Can ethanol be an energy source for hydrogen?

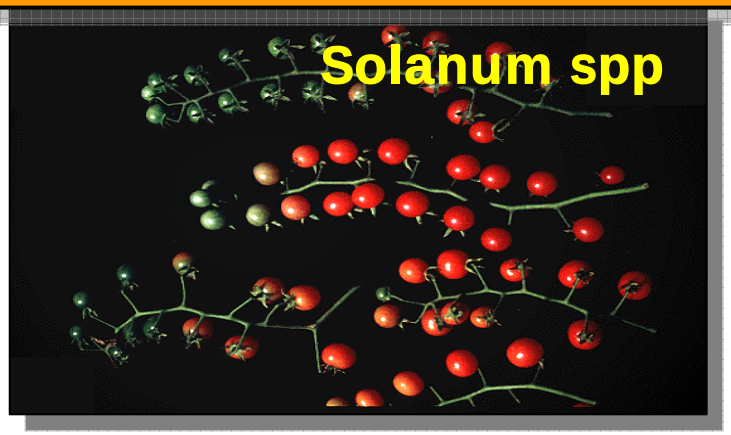
Beyond ethanol
Renewable BioCarbon Foundation...
Industrial biotech (monomers and enzymes):



StrathKirn® Inc.

Need to design the feedstock for particular uses...

How can we generate 5000 years of genetic change to make a feedstock that fits industrial needs?



StrathKirn® Inc.

On the verge of the next human advance: sustainable development...

Nomads

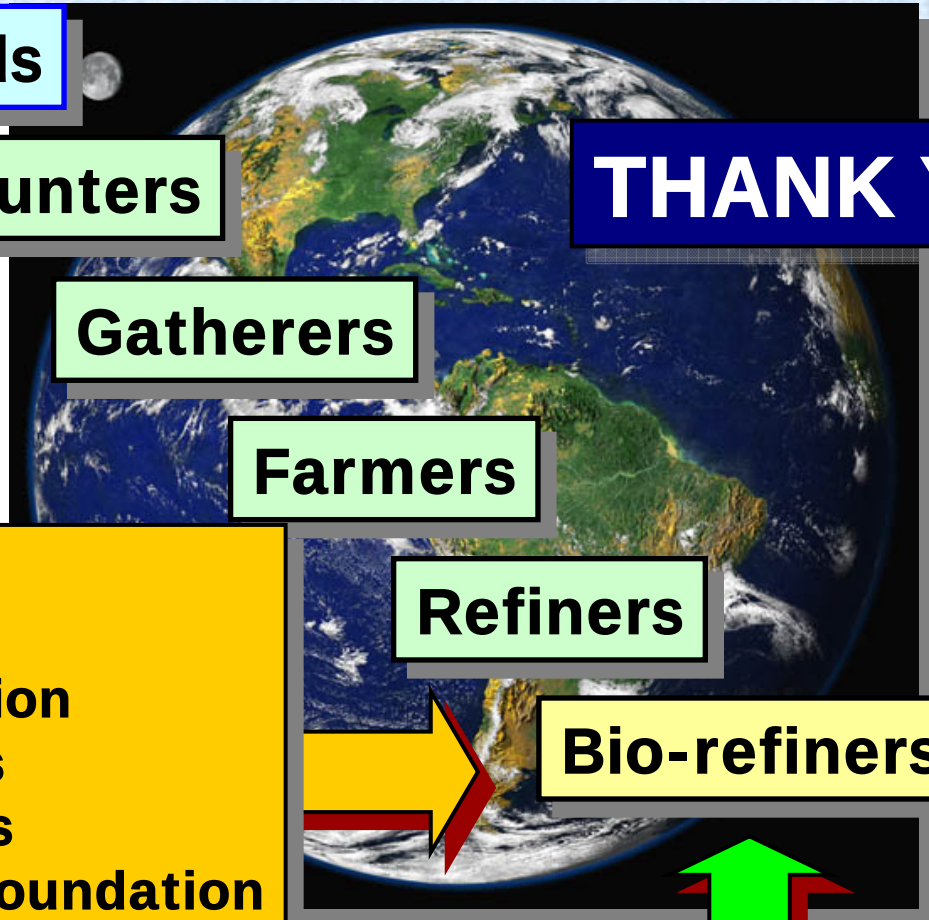
Hunters

Gatherers

Farmers

Refiners

Bio-refiners



THANK YOU

Bioprospecting
Biomimetics
Molecular evolution
- BioCatalysis
- BioMaterials
- BioCarbon foundation

Biotechnology applications.
Designed primary production.

StrathKirn® Inc.