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LIFE CYCLE ANALYSIS OF BIOFUELS & LAND USE CHANGE

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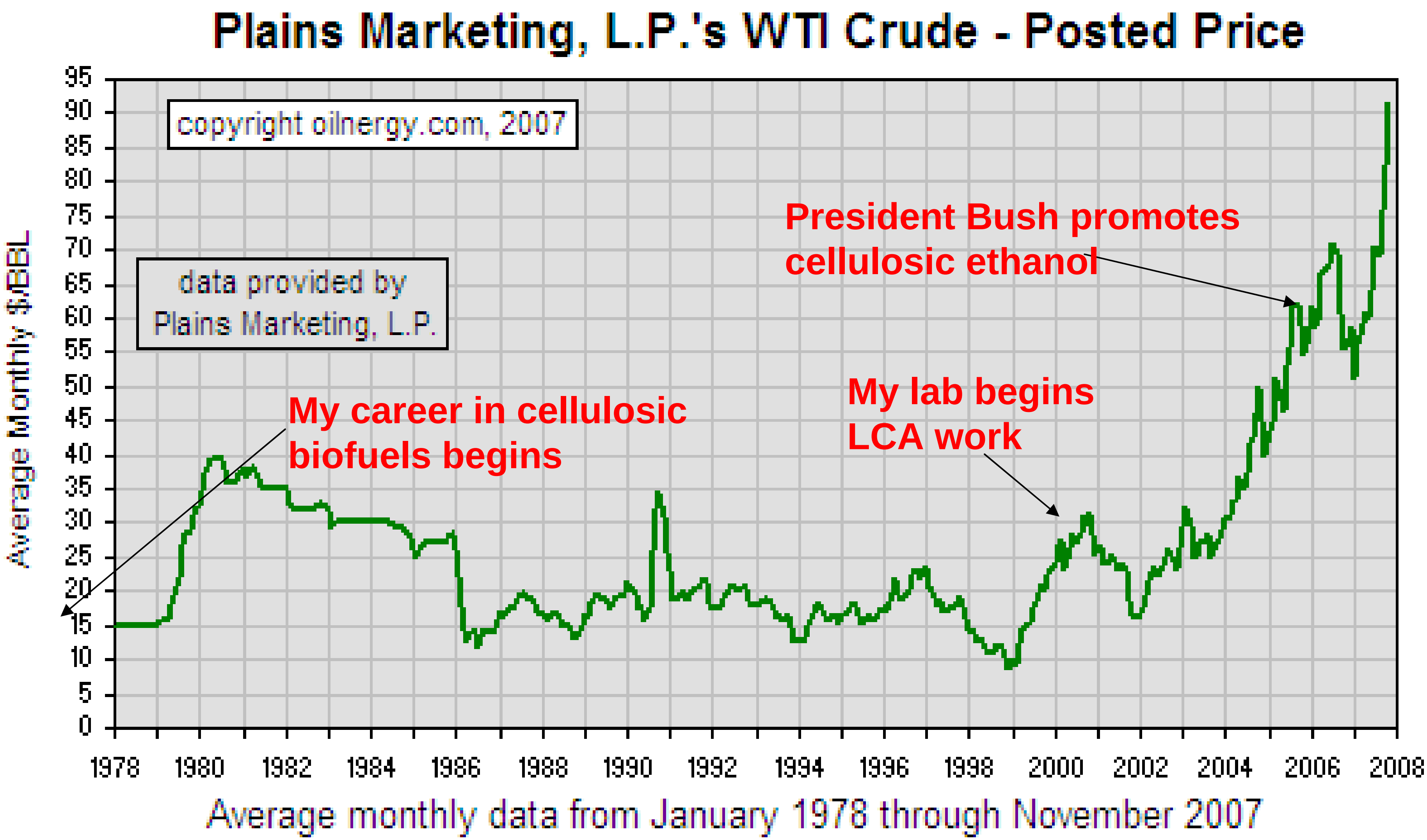
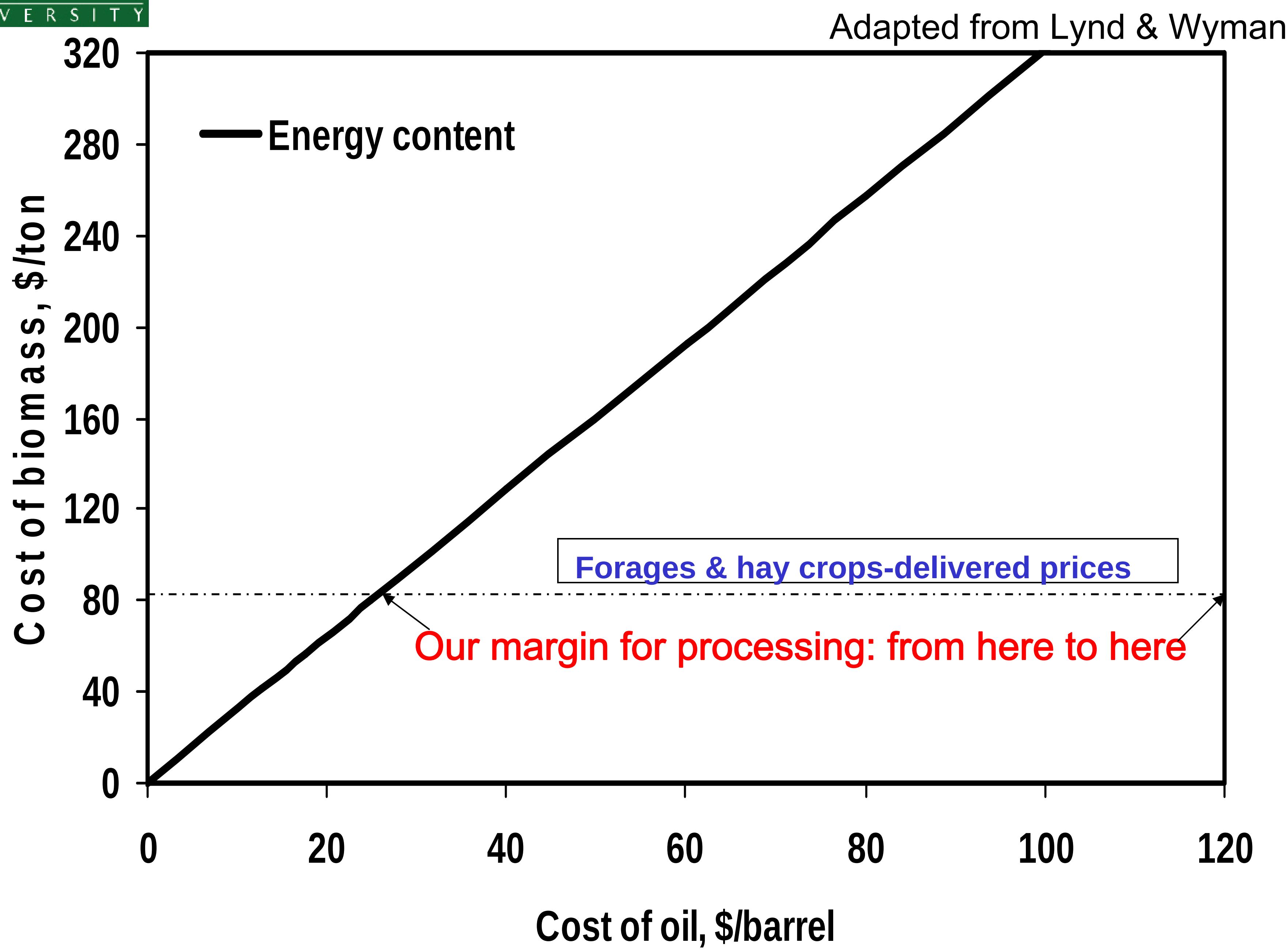
1978 – 2007 CRUDE OIL PRICES

IT PAYS TO BE PATIENT (OR STUBBORN)





Plant material is much, much cheaper than oil on both energy & mass basis

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My Assumptions/Points of Departure

- Inexpensive plant raw materials will catalyze the growth of new and existing biofuel industries– this is absolutely going to happen
- *We have a unique opportunity to design these industries for <u>better</u> environmental performance*
- One important tool: life cycle analysis (LCA)
- LCA has great value if used properly, but it is a limited tool
- LCA exists to *make comparisons*…LCA should not be done in the ideal or the abstract

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What Are Life Cycle (LCA) Models?

- Full system studies of material/energy inputs & outputs for both products & processes
- Inventory environmental impacts of products & processes (many possible impacts, select “key” ones)
- Objectives:
  - Benchmark, evaluate & improve environmental footprint
  - Compare with competition or alternatives
  - Comply with regulations, inform public policy
  - Eventually to meet consumer expectations?
- Relatively new field—”born” about 1990-still being developed
- *Allocation issues in LCA are both important and controversial*

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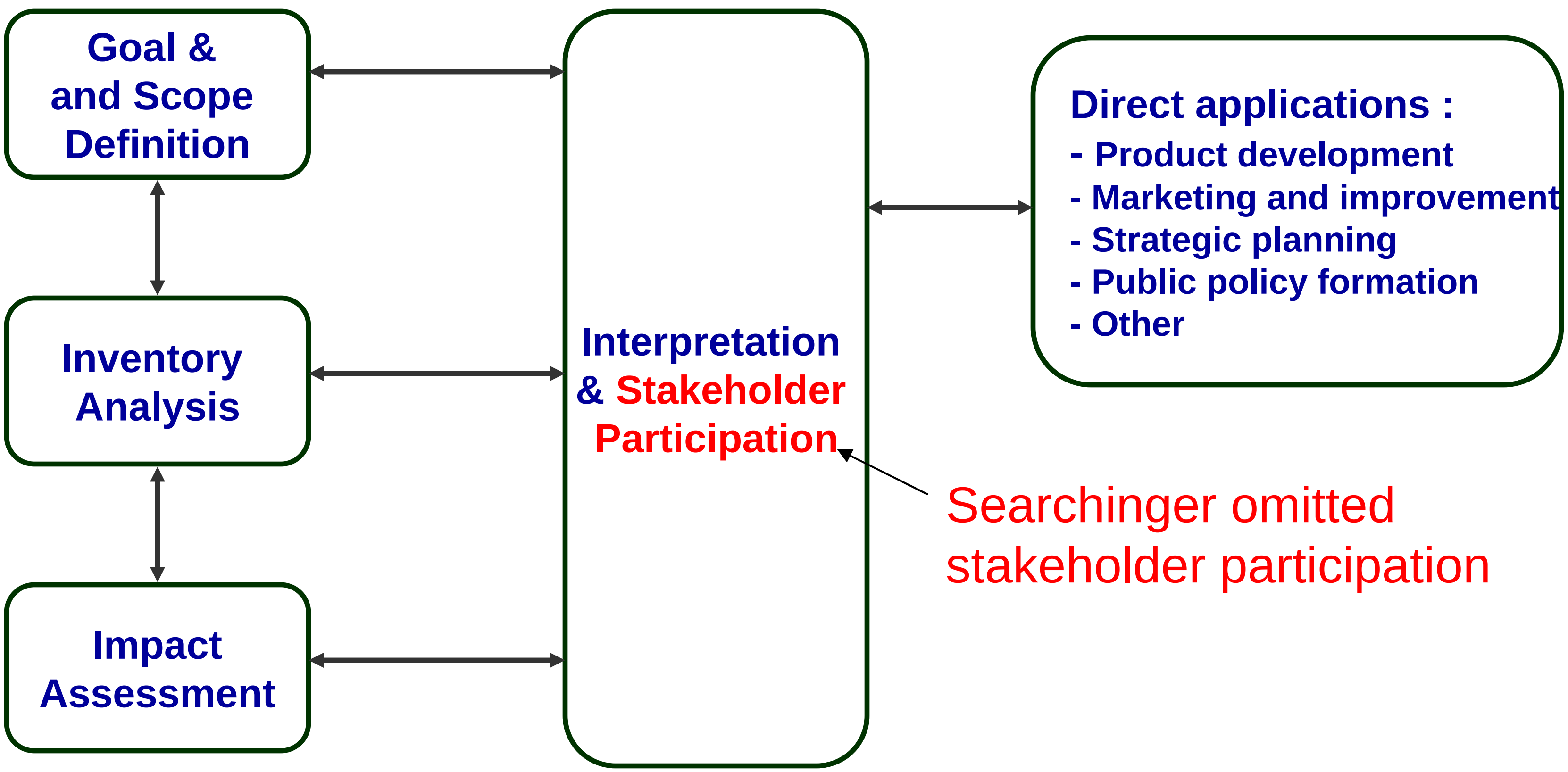
Life Cycle Assessment Framework



INTERNATIONAL STANDARD

ISO 14040

First edition
1997-06-15

Environmental management — Life cycle assessment — Principles and framework

Management environnemental — Analyse du cycle de vie — Principes et cadre

Reference number
ISO 14040:1997(E)

Some Life Cycle Analysis Standards: *In Plain English*

- Use the most recent/most accurate data possible
- Select the reference system/functional unit: what exactly are we comparing?
- Make it easy for others to check your data and methods= *transparency*
- Set clear system boundaries (physical & temporal)—must be equal or comparable for reference system and/or reference product of interest
- Multi-product systems must allocate environmental costs among all products
- Perform *sensitivity analysis*: how much do results vary if assumptions or data change?

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Now Let's Examine the Searchinger Work Using These Criteria

- Use the most recent/most accurate data possible
- Select the reference system/functional unit: what exactly are we comparing?
- Make it easy for others to check your data and methods= *transparency*
- Set clear system boundaries—must be equal or comparable for reference system and/or reference product of interest
- Multi-product systems must allocate environmental costs among all products
- Perform *sensitivity analysis*: how much do results vary if assumptions or data change?

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Use the most recent & most accurate data possible

- Land clearing from the 1990s—not checked by either modeling or more recent data
- Four linked models…no empirical data at all
    1. Ethanol demand to corn price
    2. Corn price to corn or soybean supply
    3. Corn or soybean supply to land use change
    4. Land use change to greenhouse gas consequences
    5. Land management post land use change- not considered by Searchinger (or Fargione, et al)
- Uncertainties in each model inputs/outputs lead to amplified uncertainties in final results ("propagation of errors")
- Searchinger uncertainty analysis is completely inadequate (Monte Carlo simulation is the standard)

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Select the reference system or functional unit: what exactly are we comparing?

- Ethanol vs. Gasoline?
- Corn ethanol vs. cellulosic ethanol vs. tar sands “oil” to gasoline?
- Backwards looking or forward looking (temporal boundaries)?
- Corn for ethanol vs. corn for animal feed?
- Allocation helps resolve Searchinger preference for feed vs. fuel uses of corn

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Set clear system boundaries (physical & temporal)—must be comparable for reference product of interest

1. Biofuels temporal: future (forward looking)
2. Biofuels physical: entire world land for biofuels (indirect effects on GHG considered)
3. Petroleum fuels (or other alternatives) temporal: past (GREET model)
4. Petroleum fuels physical: restricted (indirect effects on GHG not considered)

Multi-product systems must allocate environmental costs among all products

1. System is land use in the entire world
2. Land produces:
   - Animal feed (roughly 10x direct human food use)
   - Human food
   - Biofuels
   - Pulp, paper, lumber
   - Clothing (cotton, linen…)
   - Environmental services
3. Searchinger allocated the entire incremental land use "cost" of biofuel production to the biofuel—
4. Ignores the fact that the "replaced" agricultural production went to provide animal feed…
5. His analysis advantages animal feed production from land vs. biofuel production: animal feed is "sustainable" but biofuel production is not ("prior use trumps later claims" or "squatter's rights")

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Perform *sensitivity analysis*: how much do results vary if assumptions or data change?

- Productive use of existing forest (or grassland) did you make furniture or flooring from the tropical hardwoods or did you just burn the trees down?
- Decreased land clearing rates and/or different ecosystems converted
- Corn yields increase both in the U.S. and abroad
- "Carbon debt" compared with oil sands GHG in 2015 vs. GREET in ~1999
- Increasing efficiency of future ethanol plants
- Uncertainties in global equilibrium models…test through Monte Carlo simulation
- Allocation of environmental burdens among feed and fuel uses of corn—not just to fuel (livestock are responsible for 18% of worldwide GHG emissions)
- How is land managed after conversion?
- None of these factors were considered in the sensitivity analysis

Four linked Models in Searchinger and One He Omitted

1. Ethanol demand to corn price
2. Corn price to corn or soybean supply
3. Corn or soybean supply to land use change
4. Land use change to greenhouse gas consequences
5. Land management post land use change

Mr. Searchinger forgot or ignored this fifth one…but the land doesn't cease to be managed once the land use change is executed. Only ethanol's GHG contribution was "counted" in his analysis…but not the land's **continuing** ability to sequester carbon

What are the GHG consequences of post land change management options?

Soil Organic Carbon, CO_2 & Nitrogen Dynamics

- Simulated by the DAYCENT model
  - Predicting
    - Soil organic carbon level, CO_2
    - N_2O and NO_x emissions from soil, NO_3^- leaching
  - Information required
    - County-based soil textures
      - clay, slit, sand
    - County-based data
      - Daily maximum and minimum temperature
      - Daily precipitation
    - Cropping management
      - Tillage, application rate of nitrogen fertilizer, irrigation, etc

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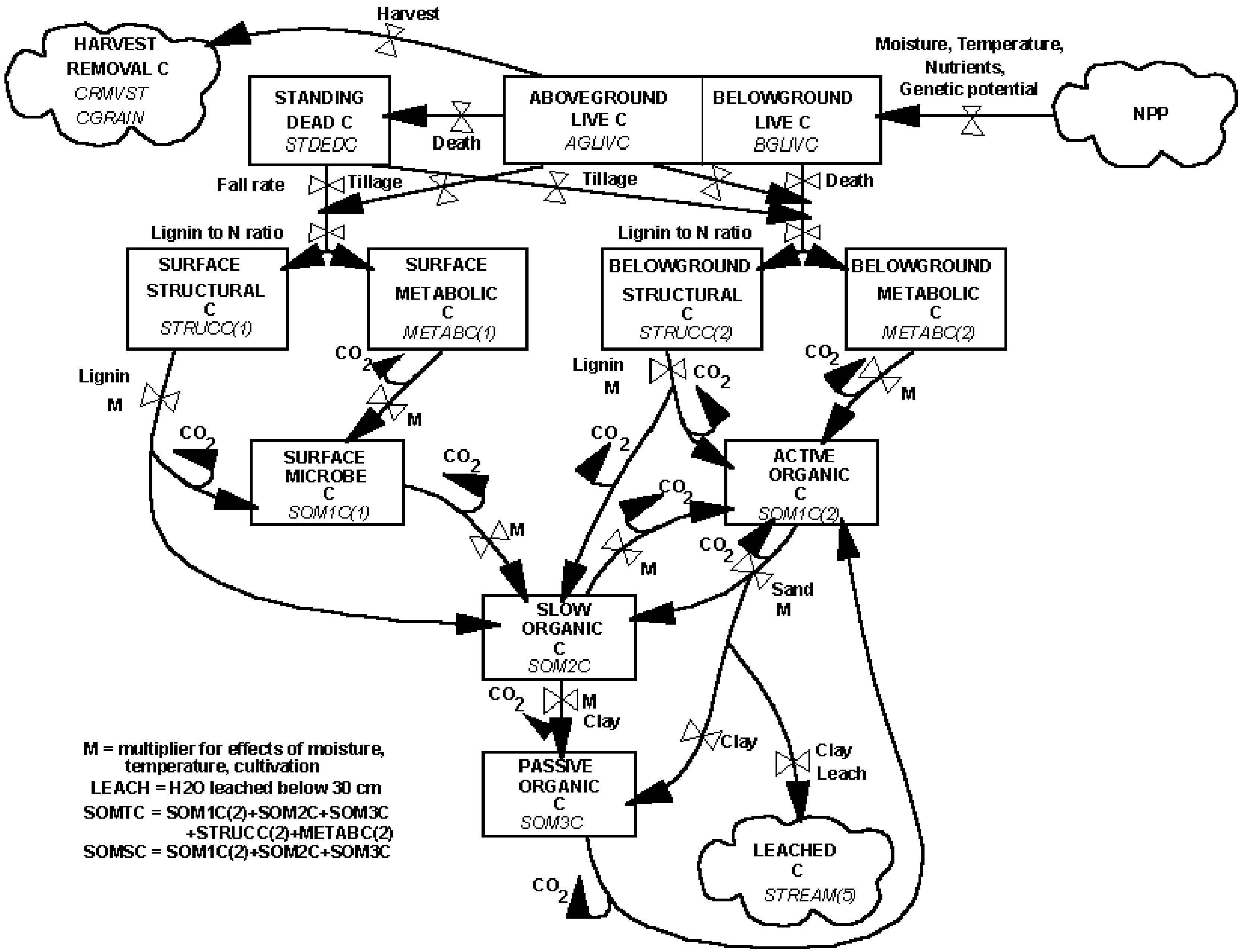
Carbon Flow in the CENTURY Model



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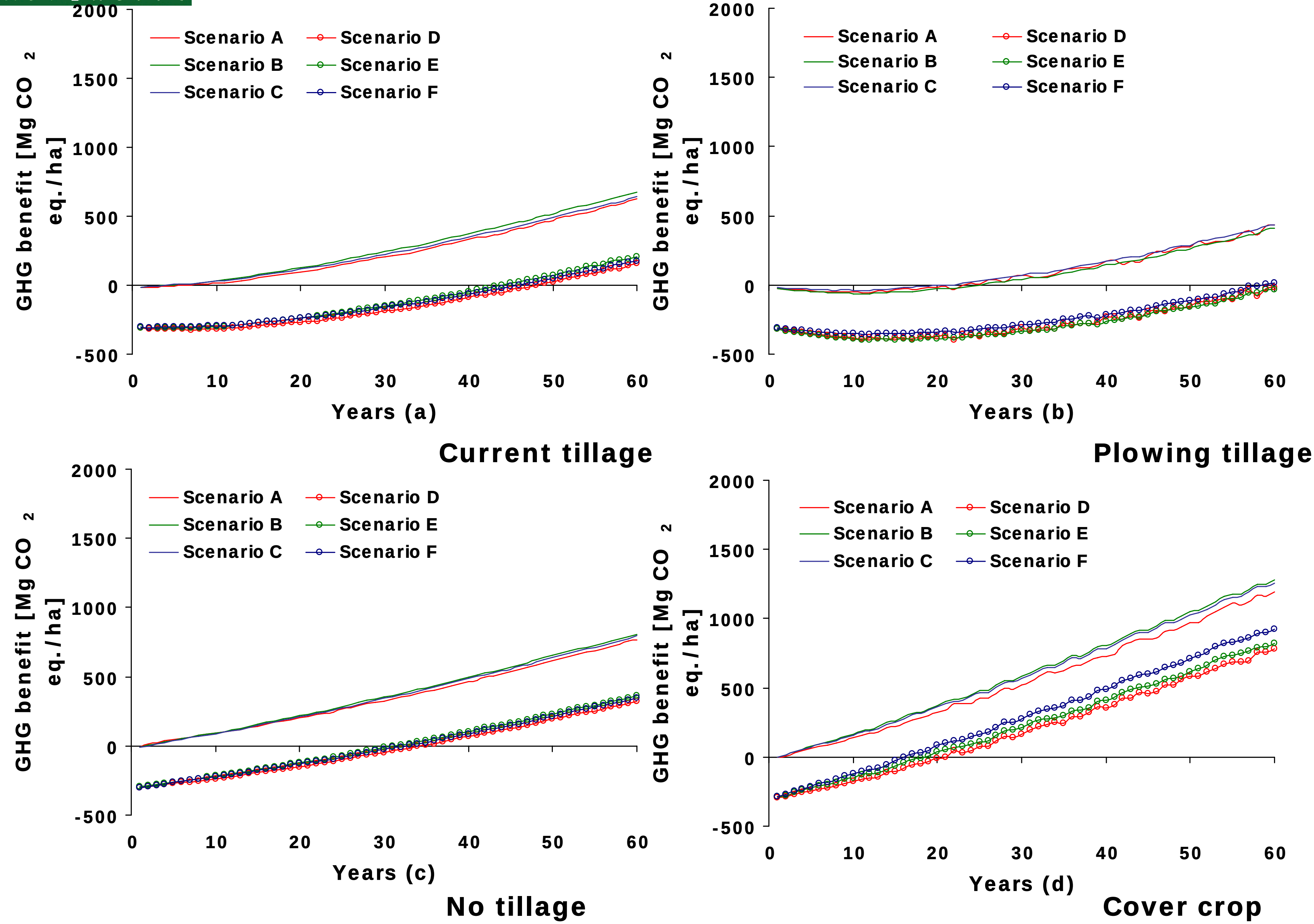
Land Management Post Land Use Change: Tillage Practices & Cover Crops

Scenario*	Description
A	Convert grassland to cornfield dedicated to ethanol production
B	Divert cornfield to ethanol production, Convert grassland to cornfield dedicated to animal feed production
C	Convert corn-soybean rotation to cornfield dedicated to ethanol production Convert grassland to corn-soybean rotation
D	Convert forest to cornfield dedicated to ethanol production
E	Divert cornfield to ethanol production, Convert forest to cornfield dedicated to animal feed production
F	Convert corn-soybean rotation to cornfield dedicated to ethanol production Convert forest to corn-soybean rotation

* Data for DAYCENT from 8 U. S. corn producing counties, different climates,etc.


Scenario A
Scenario B
Scenario C
Scenario D
Scenario E
Scenario F
GHG benefit [Mg CO2 eq./ha]
Years (a)
Current tillage
Years (b)
Plowing tillage
Years (c)
No tillage
Years (d)
Cover crop

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U.S. Livestock Consumption of Calories & Protein

ANIMAL CLASS	HERD SIZE (THOUSANDS)	TOTAL PROTEIN (MILLION KG/YR)	TOTAL ENERGY (TRILLION CAL/YR)
Dairy	15,350	10,400	184.8
Beef	72,645	25,100	525.3
Hogs	60,234	6,900	136.2
Sheep	10,006	461	10.6
Egg production	446,900	2,470	4.3
Broilers produced	8,542,000	9,540	150.3
Turkeys produced	269,500	1,760	28.6
Total consumed by U.S. livestock		56,630	1,040.00
Human requirements		5,114	205

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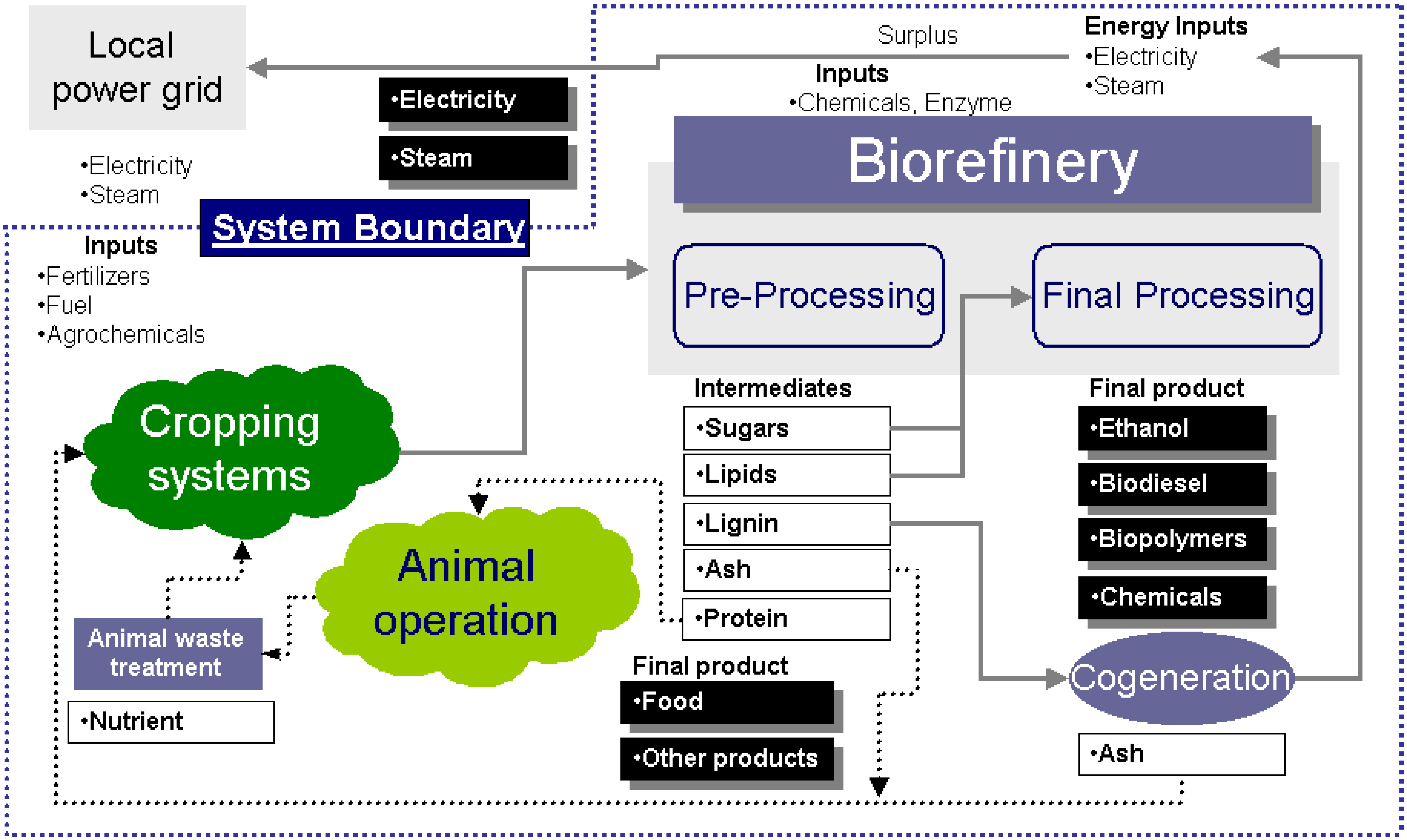
TOWARD A SUSTAINABLE ECONOMY

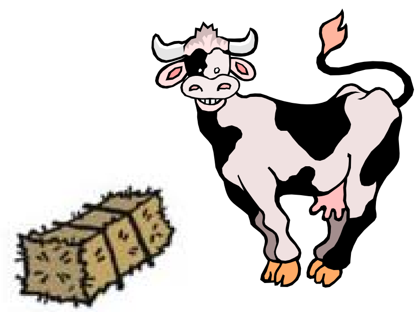


"ALL BIOMASS IS LOCAL"

Two Bioreactors

Mobile Cellulose Biorefinery (a.k.a. Cow)

Stationary Cellulose Biorefinery



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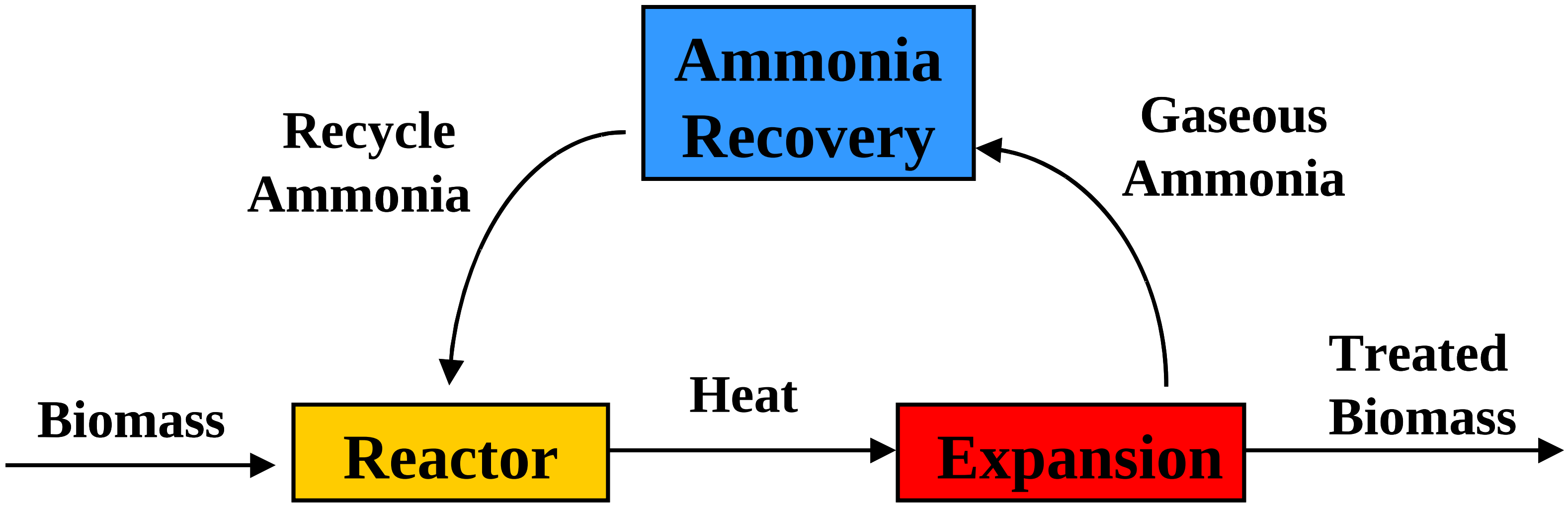
Improve Cellulose Conversion for Biorefinery = Improve Cellulose Digestibility for Cows

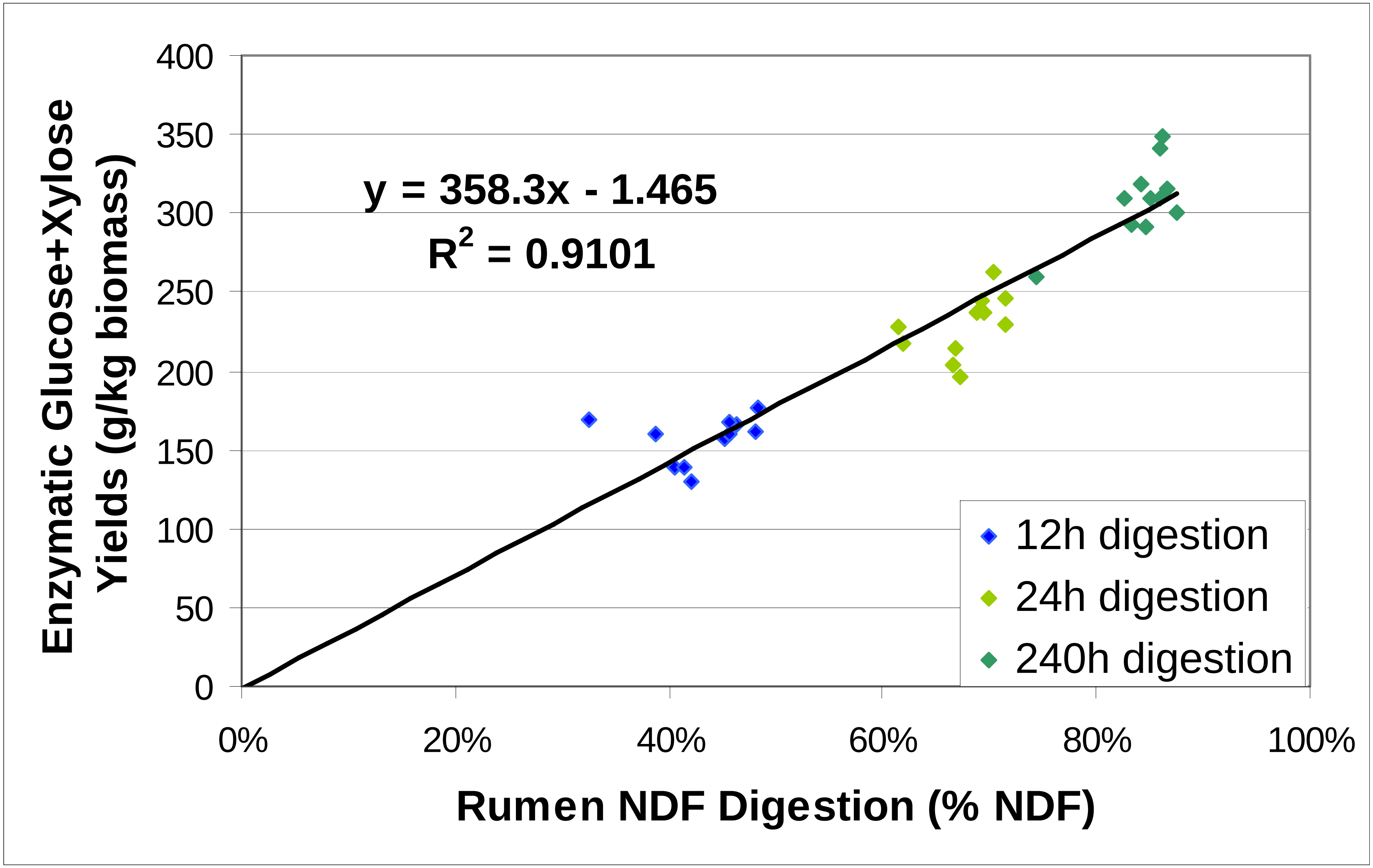
*Rasby, Rick. "Estimating Daily Forage Intake of Cows". University of Nebraska-Lincoln Institute of Agriculture and Natural Resources, http://beef.unl.edu/stories/200608210.shtml, 10/02/06.

What is AFEX?



- Biomass heated (~100 ^{o}C) with concentrated ammonia
- Rapid pressure release ends treatment
- Nearly all ammonia is recovered & reused, remainder serves as N source downstream for fermentation
- Minimize sugar degradation, relatively mild conditions

AFEX-Treated Grass



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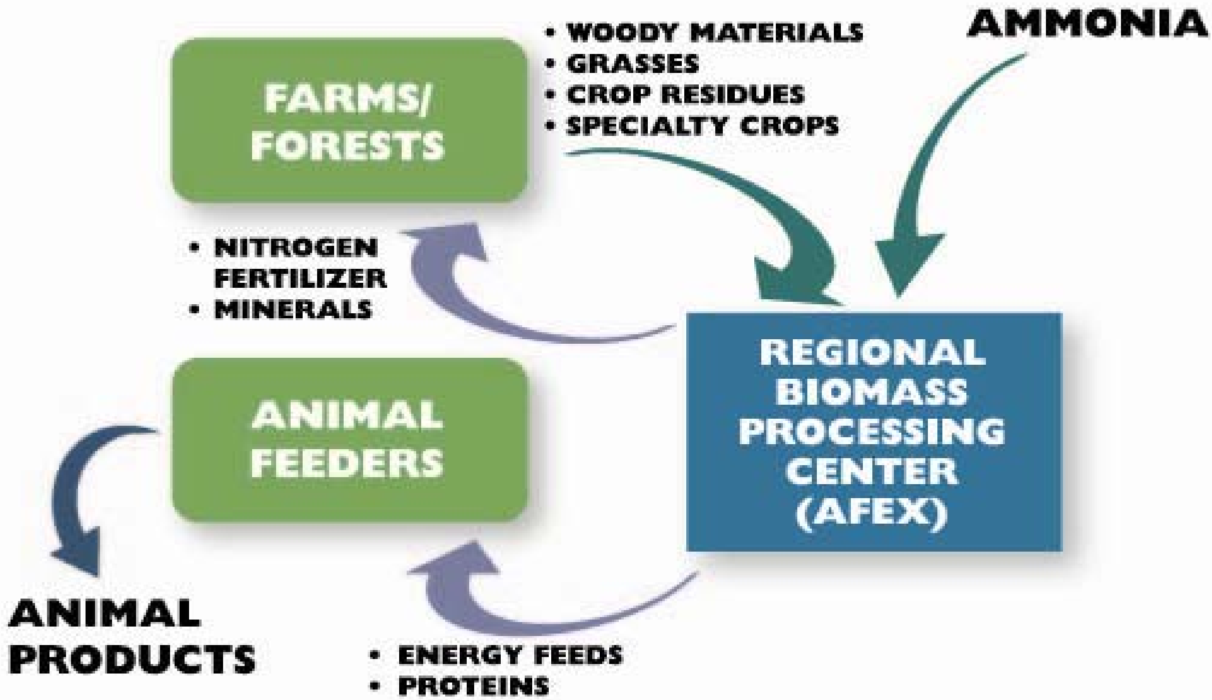
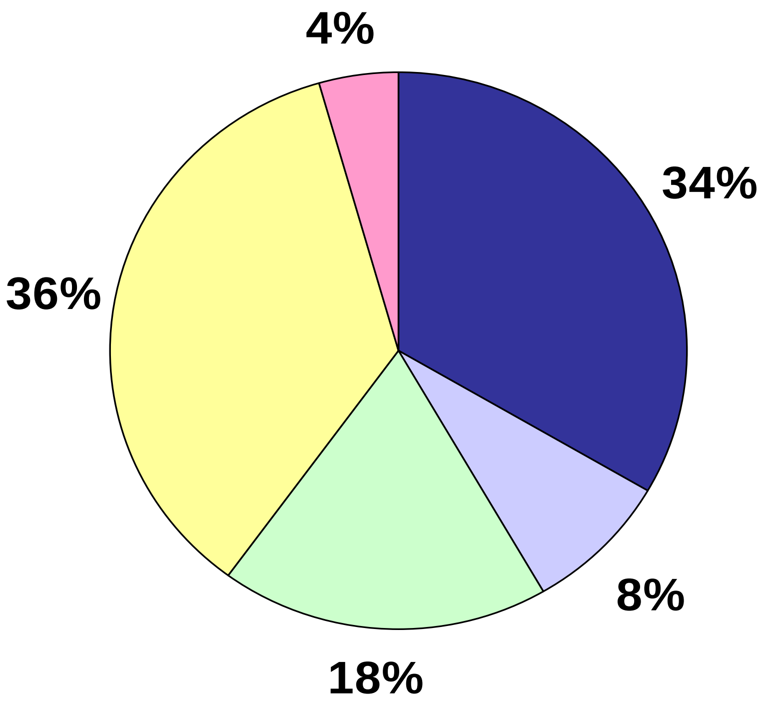
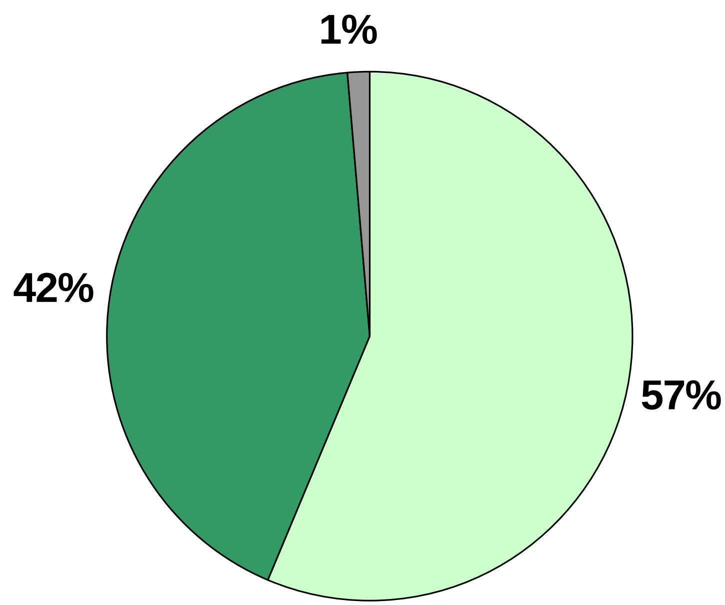
REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



Dairy Diet

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

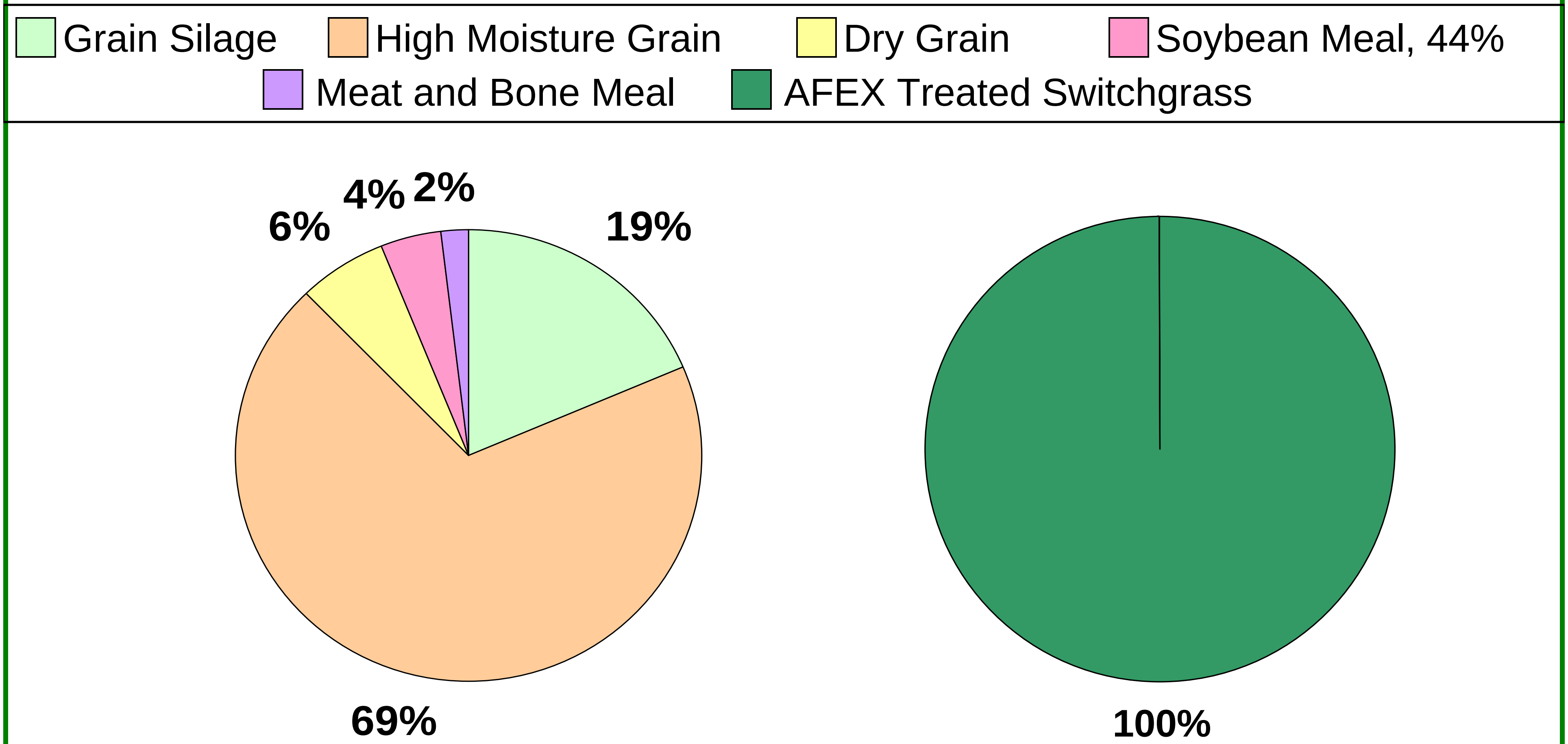




$150,242/yr
265 acres/yr

$92,388/yr
167 acres/yr

Beef Diet



$248,381/yr
436 acres/yr

$134,897/yr
227 acres/yr

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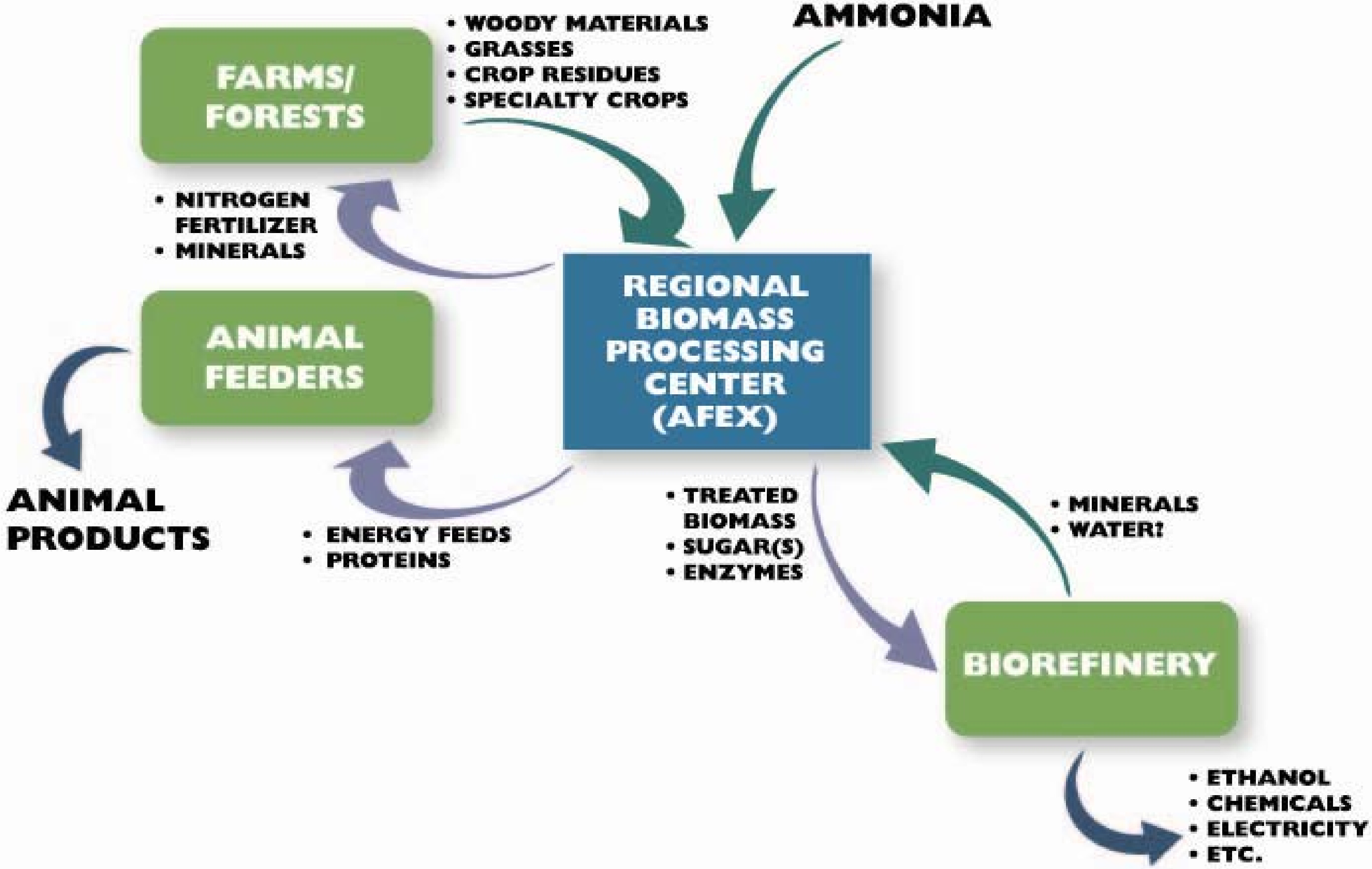
REGIONAL BIOMASS PROCESSING: SUPPLY CHAINS



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Why Regional Biomass Processing Centers?

- Concept: separate pretreatment operations from hydrolysis & fermentation ("distributed biorefining")
- Pretreatment enhances value of cellulosic biomass for animal feeding <u>and</u> biofuel production
- Advantages:
  - Logistics: aggregate, process, store, supply biomass
  - Densify biomass for easier transport
  - Homogenize different biomass materials by pretreatment—draw on larger supply area
  - Increase economic scale of biorefinery
  - Simplify contract issues
  - Provide locus for economic development/wealth creation
  - Coproduce animal feeds and biofuel feedstocks
  - Increase land use efficiency of biofuels
  - Provide vehicle for environmental certification of biomass production and processing

“The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil.”

Sheikh Zaki Yamani
Former Saudi Arabia Oil Minister