Dr. Russ Jessup

TEXAS A&M UNIVERSITY

ASSISTANT PROFESSOR

DEPARTMENT OF SOIL & CROP SCIENCES

Plant Breeding Symposium
TEXAS A&M UNIVERSITY
2015

Biorefining Perennial Grasses:

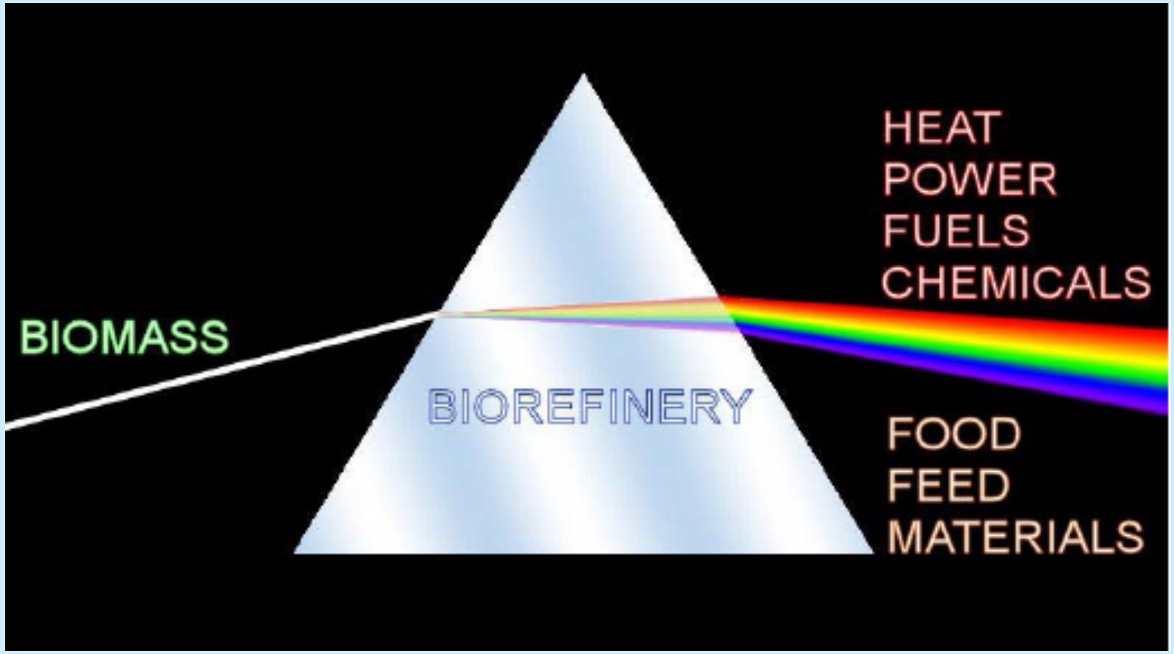
Biofuels

Bioproducts

Forages

Turfgrass

Ornamentals



Industrial
Corrosion inhibitors, dust control, boiler water treatment, gas purification, emission abatement, specialty lubricants, hoses, seals

Transportation
Fuels, oxygenates, anti-freeze, wiper fluids molded plastics, car seats, belts hoses, bumpers, corrosion inhibitors

Textiles
Carpets, Fibers, fabrics, fabric coatings, foam cushions, upholstery, drapes, lycra, spandex

Safe Food Supply
Food packaging, preservatives, fertilizers, pesticides, beverage bottles, appliances, beverage can coatings, vitamins

Environment
Water chemicals, flocculants, chelators, cleaners and detergents

Communication
Molded plastics, computer casings, optical fiber coatings, liquid crystal displays, pens, pencils, inks, dyes, paper products

Housing
Paints, resins, siding, insulation, cements, coatings, varnishes, flame retardents, adhesives, carpeting

Recreation
Footgear, protective equipment, camera and film, bicycle parts & tires, wet suits, tapes-CD's-DVD's, golf equipment, camping gear, boats

Health and Hygiene
Plastic eyeglasses, cosmetics, detergents, pharmaceuticals, suntan lotion, medical-dental products, disinfectants, aspirin

Sustainability via Disruptive Breeding

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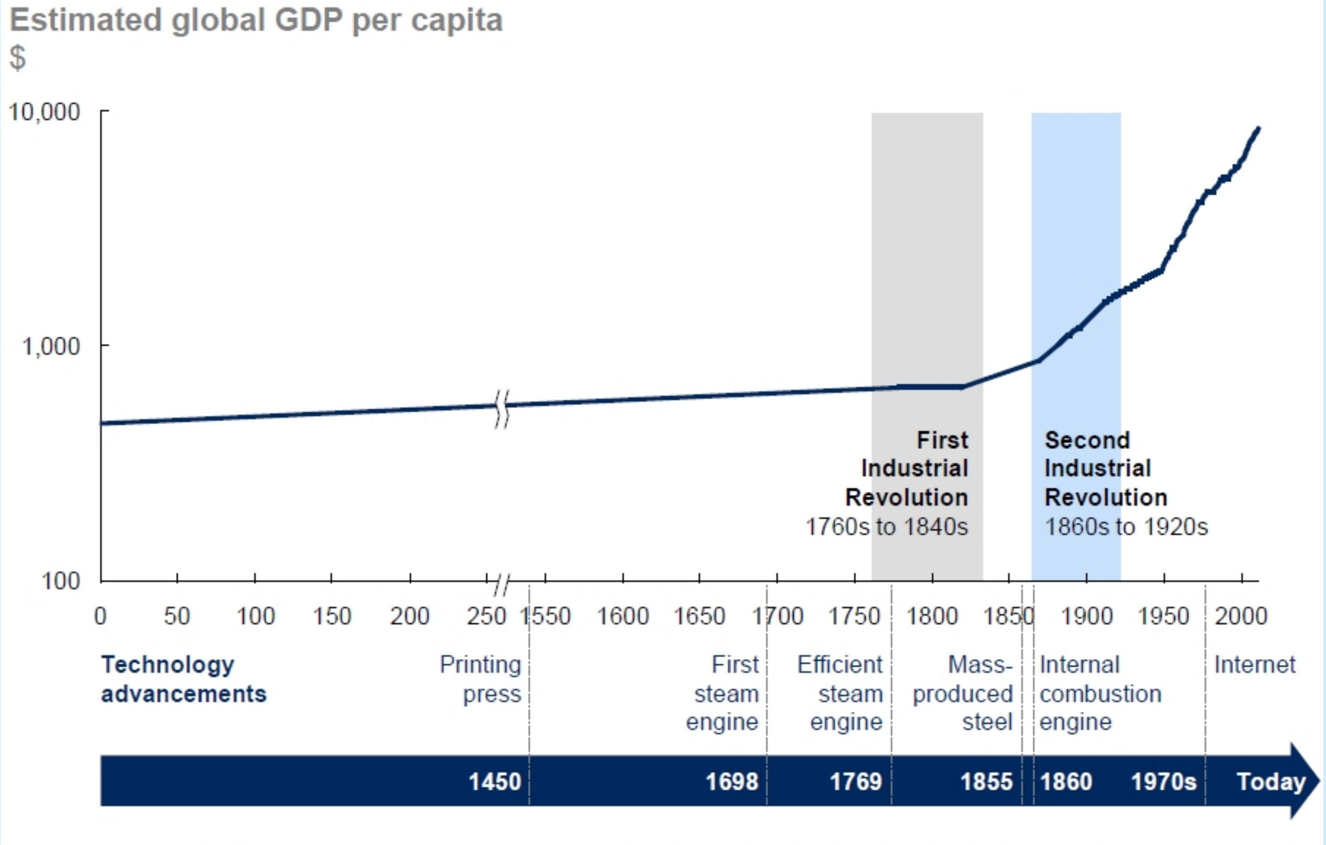
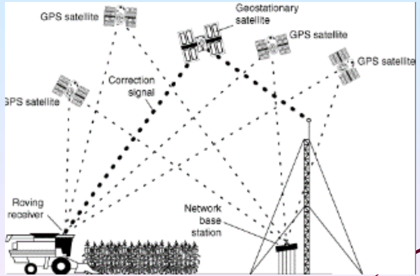
‘Progress’ vs. ‘Sustainability’



SOURCE: Angus Maddison, “Statistics on world population, GDP and per capita GDP, 1–2008 AD,” the Maddison Project database; McKinsey Global Institute analysis



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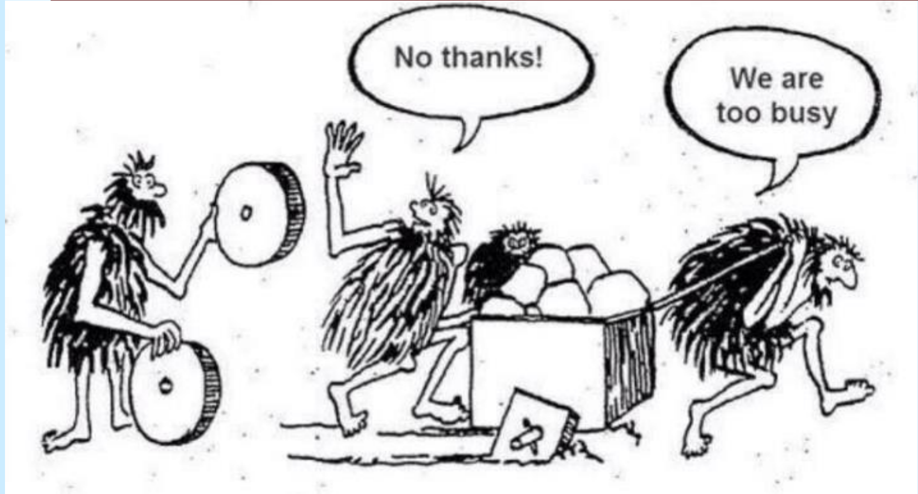
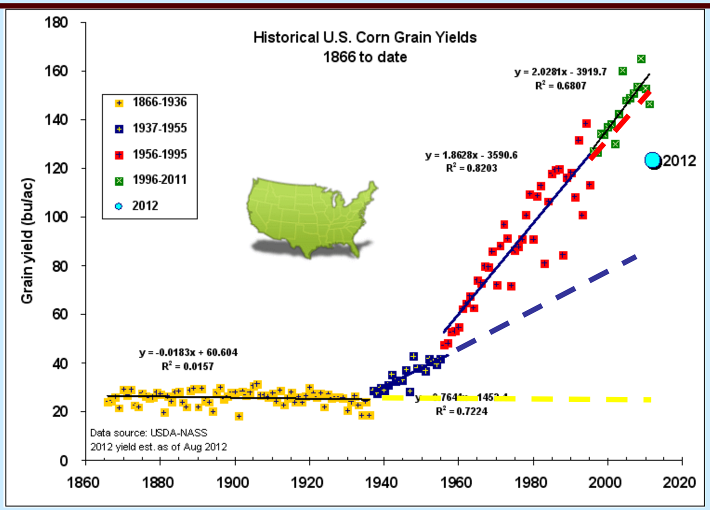
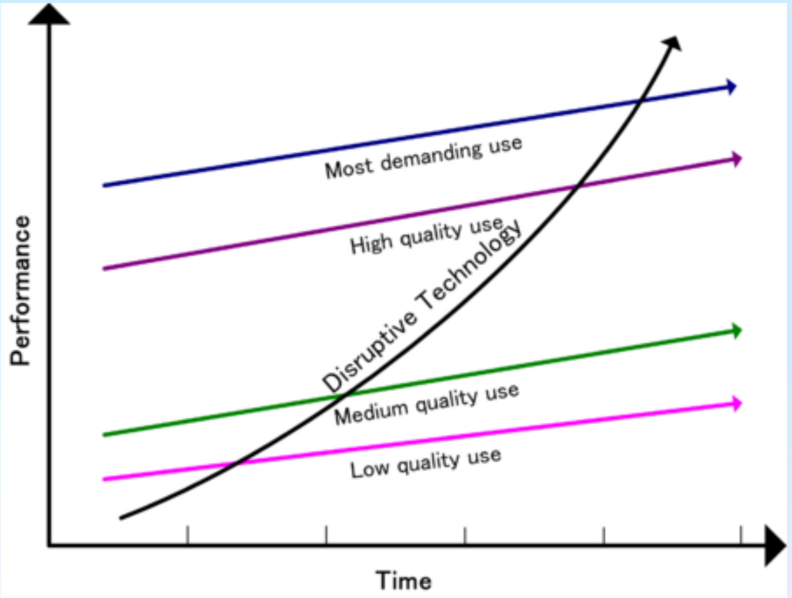
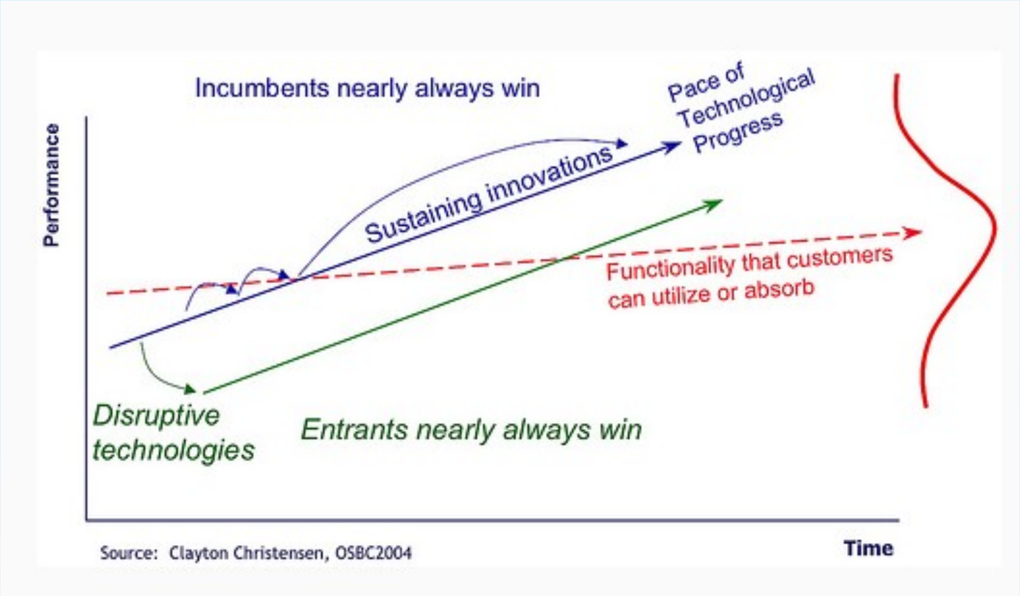
‘Incremental’ vs. ‘Disruptive’









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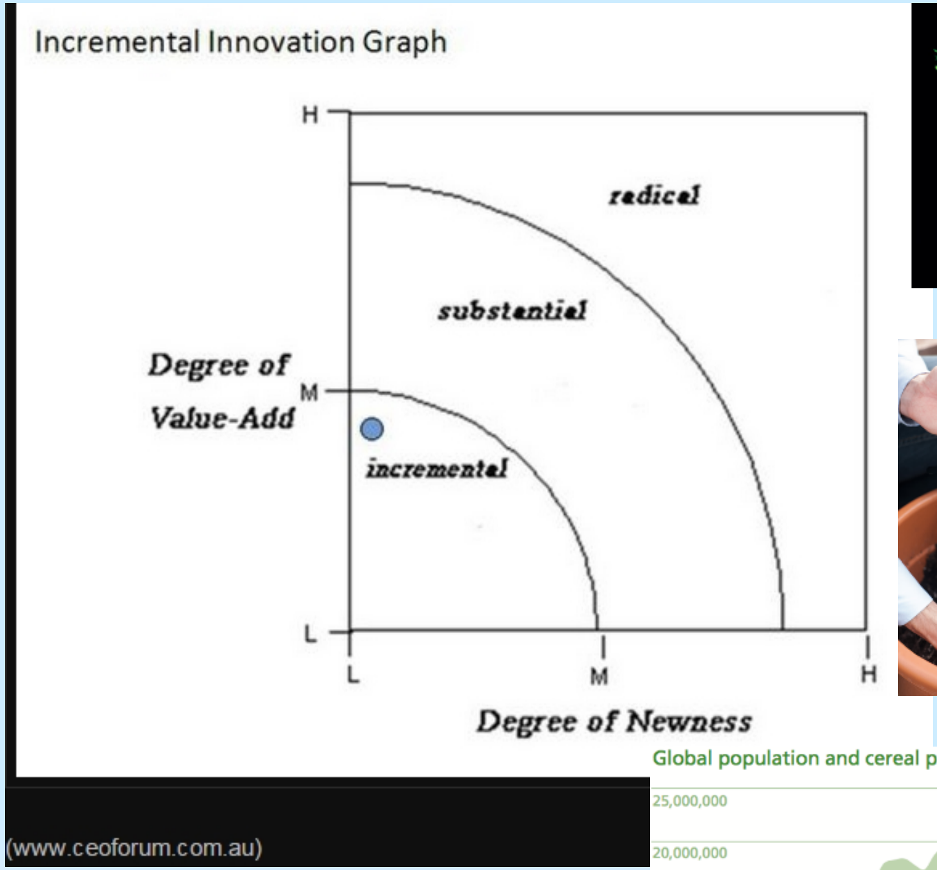
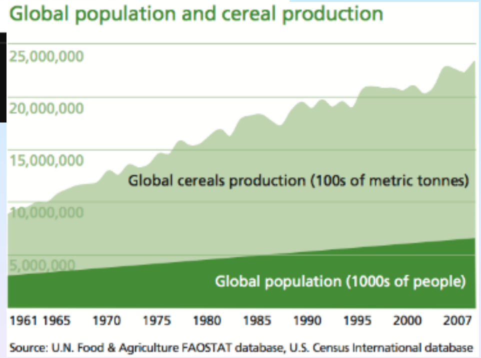
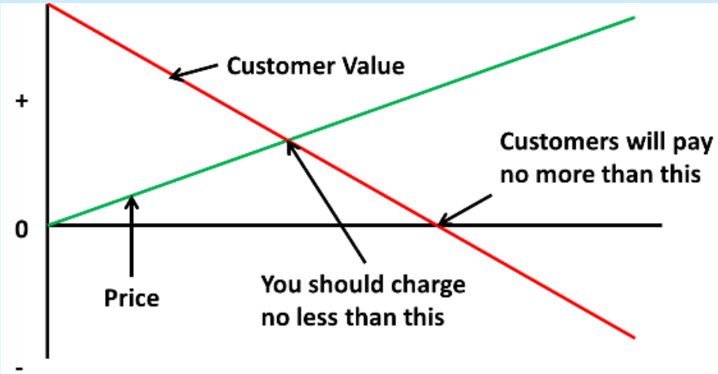
‘Value Creation’ vs. ‘Value Capture’

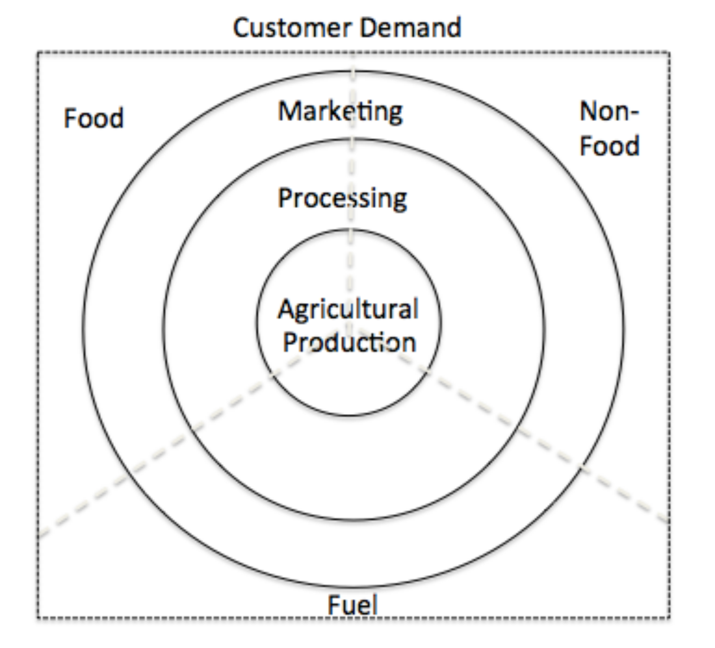
Technology Driven





Consumer Driven





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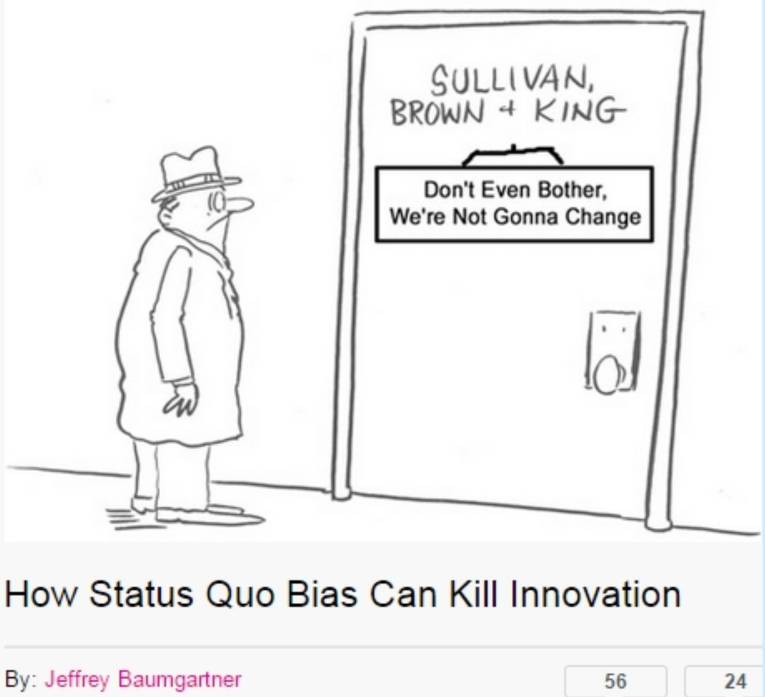
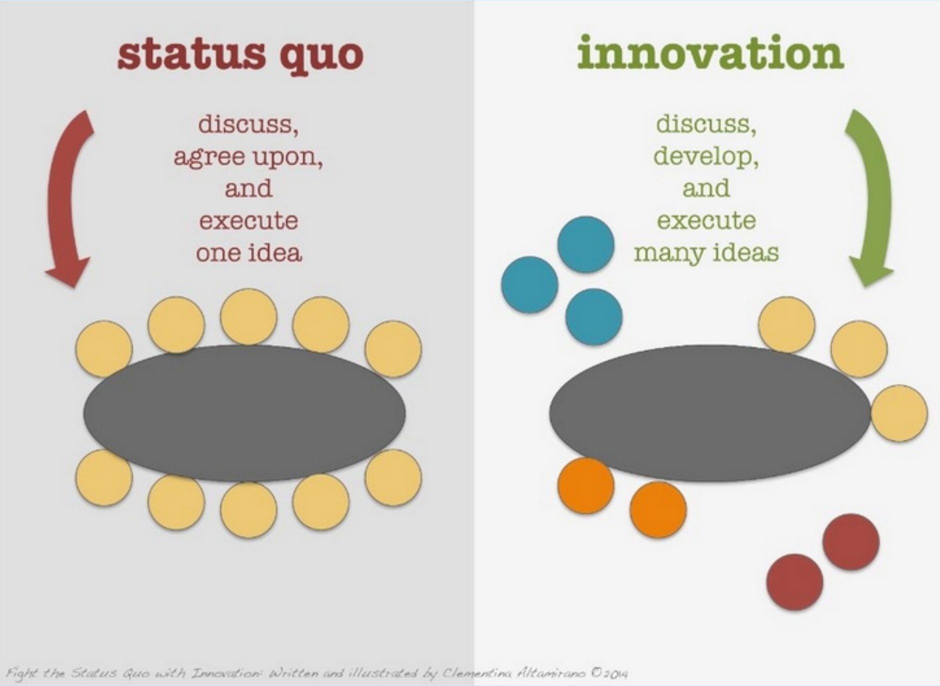
‘Establishment’ vs. ‘Innovation’



Complex Established Legacy Sectors (CELS)



- Perennial Grain Crops
- Polyculture Cropping Systems
- BIOREFINERIES
- …

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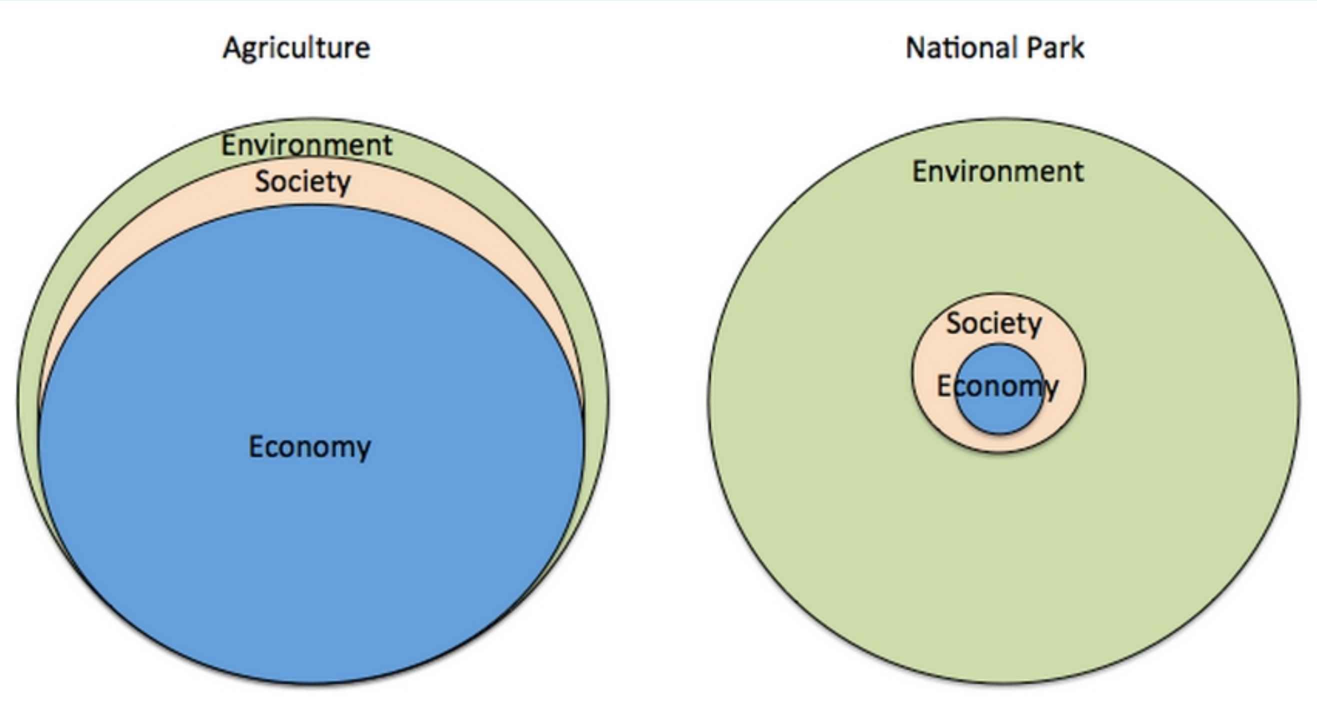
‘Value…$$$’ vs. ‘Value Systems’



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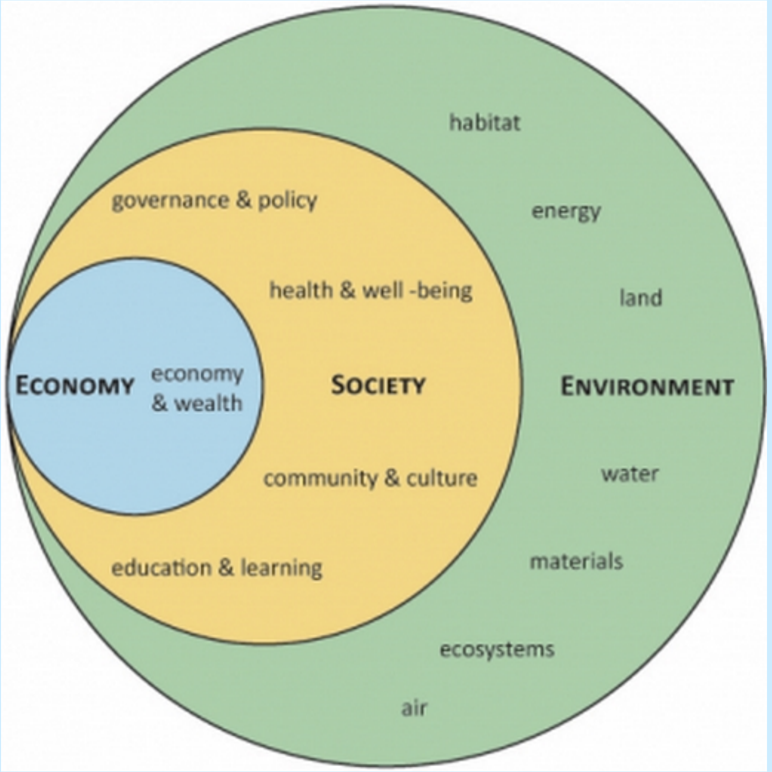
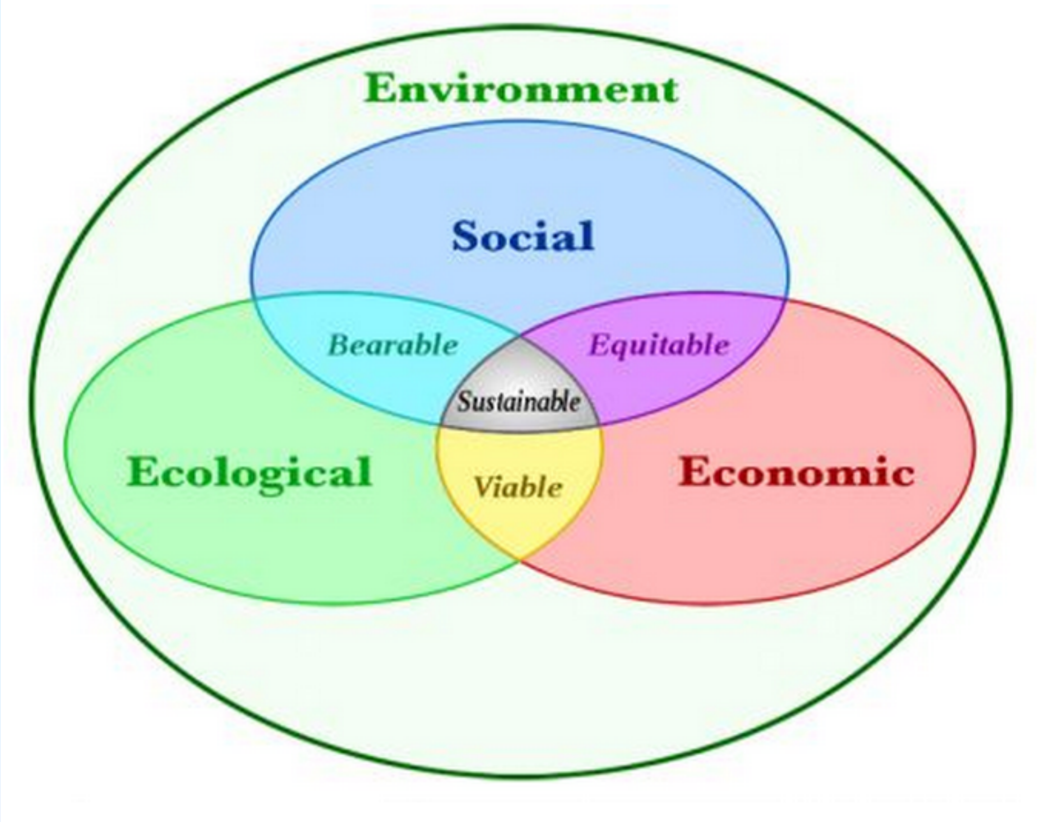
‘Sustainability’ vs. ‘Achievability’





Credit: Andrew Sunray/WikiMedia

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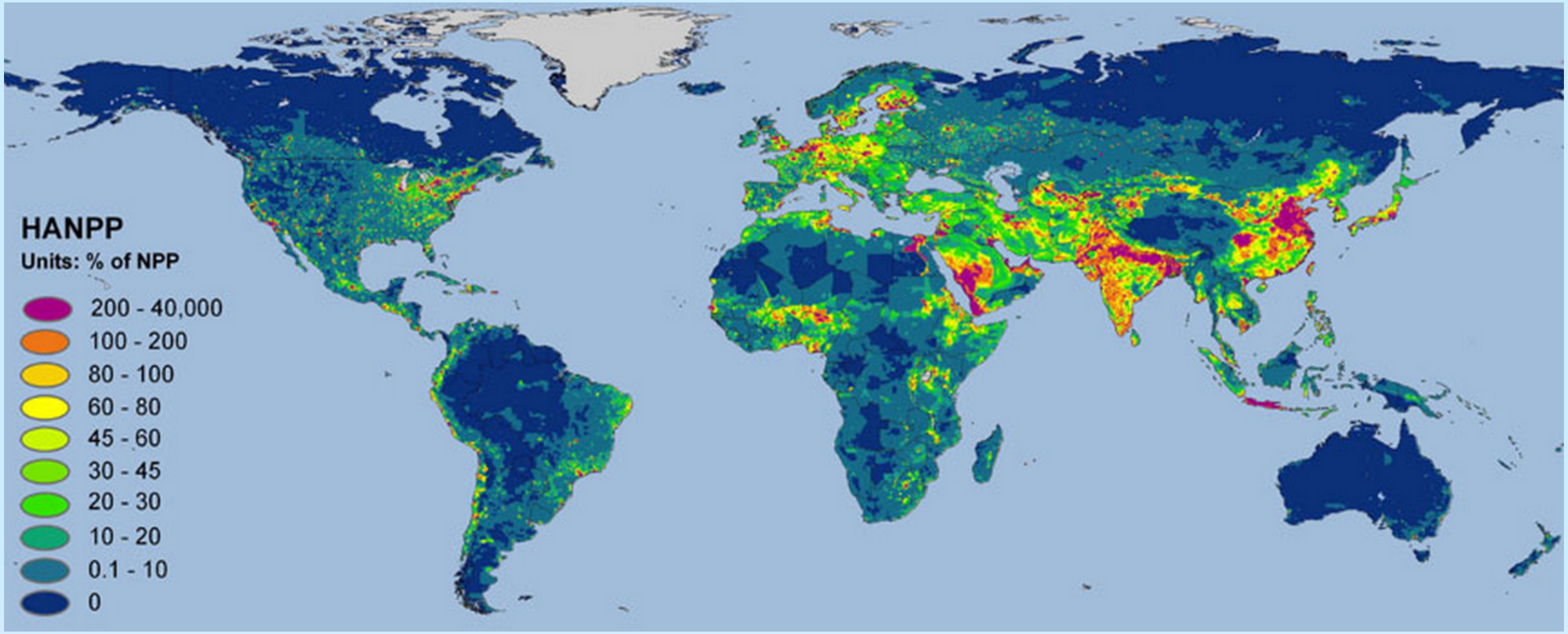
Biomass?

Global Net

Primary Production: 2015

Human Appropriation of Net Primary Production



http://www.nasa.gov/images/content/61350main_hanpp2.jpg

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World Biomass demand in 2050

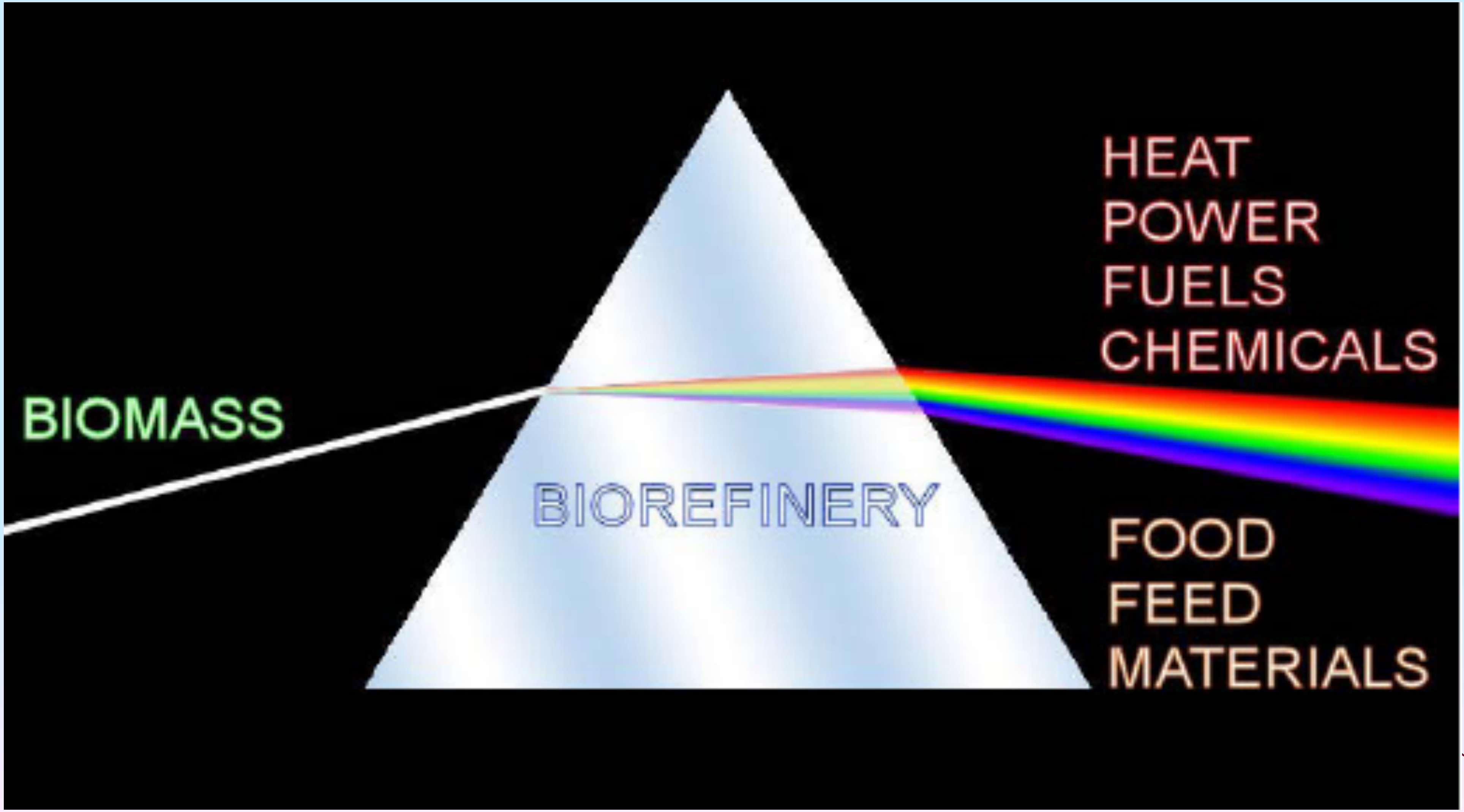
Food / Feed	10 billion ton biomass for 3 billion ton food
Energy	10 billion ton equivalent to 160 EJ
Chemical industry	1 billion ton for 0.3 billion top product
Specialties	1 million ton
Wood and composites	2 to 3 billion ton
	24

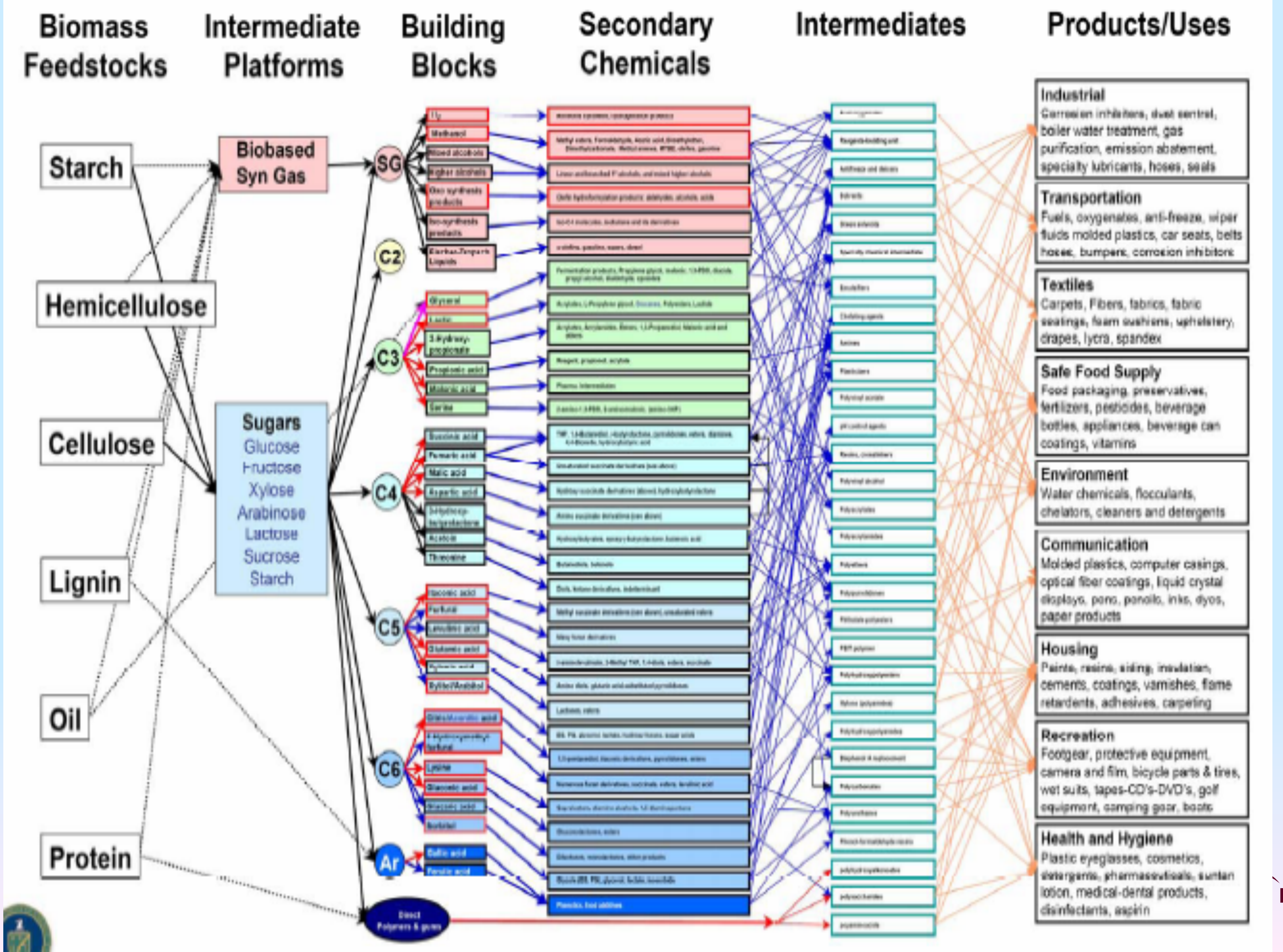
4% (2015) → 14% (2050)

Current production 170 billion ton biomass of which 6 billion ton is used:

- 1,8 grains
- 2,2 other food (sugar, vegetables, starch, etc.)
- 2 wood
- 0,01 other non-food

Biorefining Perennial Grass Feedstocks





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Bioplastics

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Bioplastics

starch

sugar (PLAs)

starch or sugar (PHAs, PHBs, PHHs)

lignin (cellulose acetate)

biopolymers...etc.

Bioplastics are not a new idea

Classic film clip of Henry Ford, 1941
whacking an early *soy composite* bumper

Why didn't they take off then?
What's driving their adoption now?
Who is leading?

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Specialty Chemical Platforms

- resins
- adhesives
- lubricants
- solvents
- cosmetics

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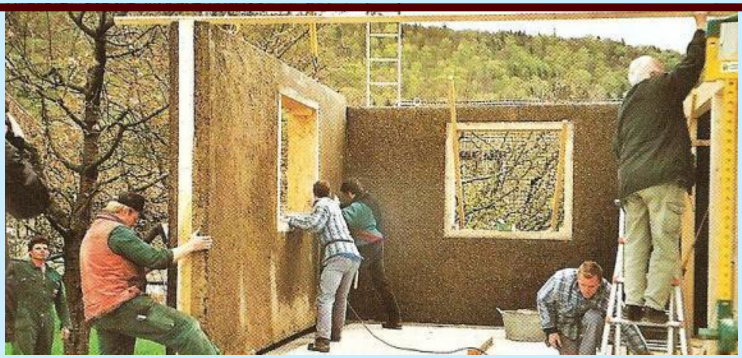
Bio-Industrial Evolution

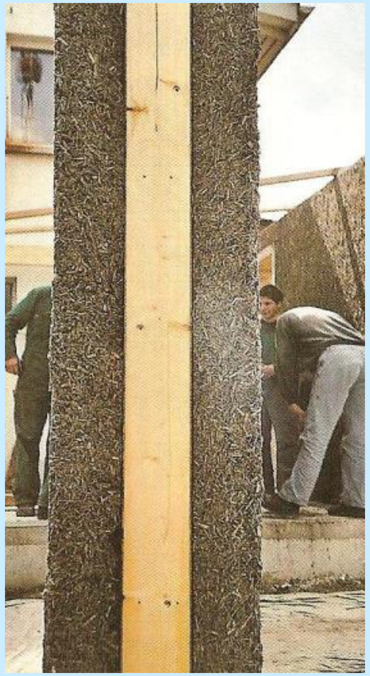
GEMTEK
Products

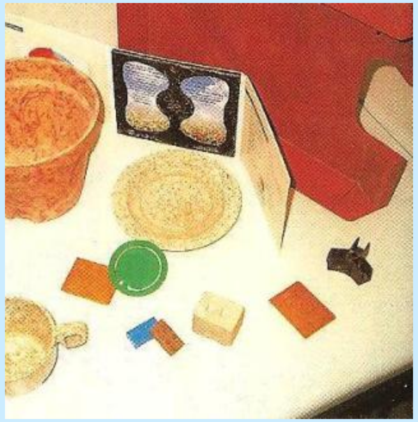
GlycosBio
RENEWABLE BIOPRODUCTS

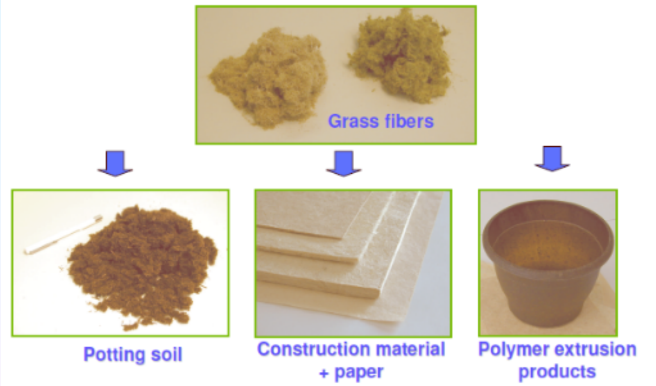
Fiber

- Fiber-crete
- Composites
- Insulation
- Textiles

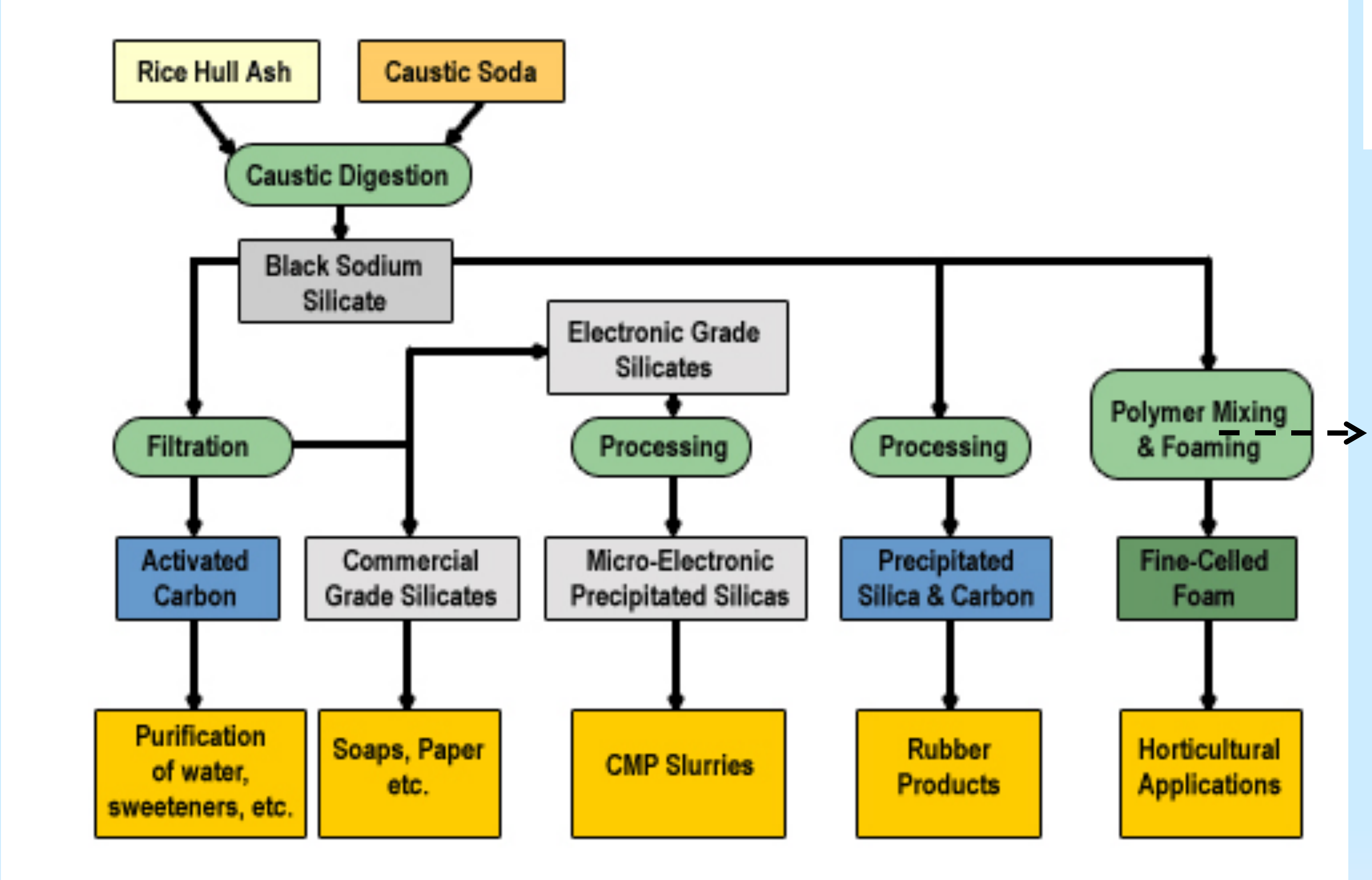






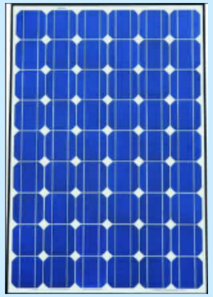


Silica



→ PV

→ Microchips



Protein

Leaf Protein Concentrate (LPC)

http://www.leafforlife.org/

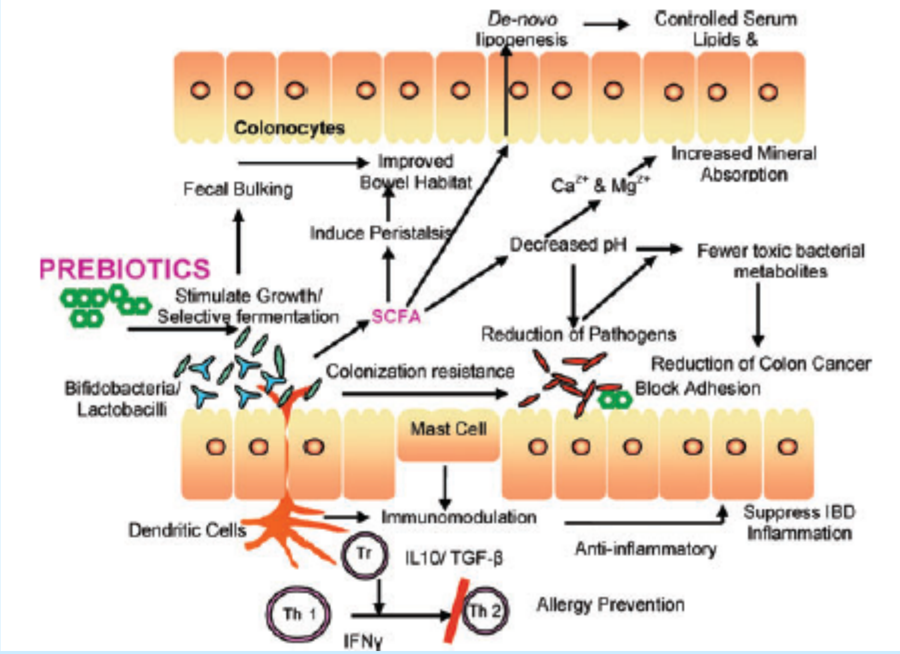
Cassava LPC fortification

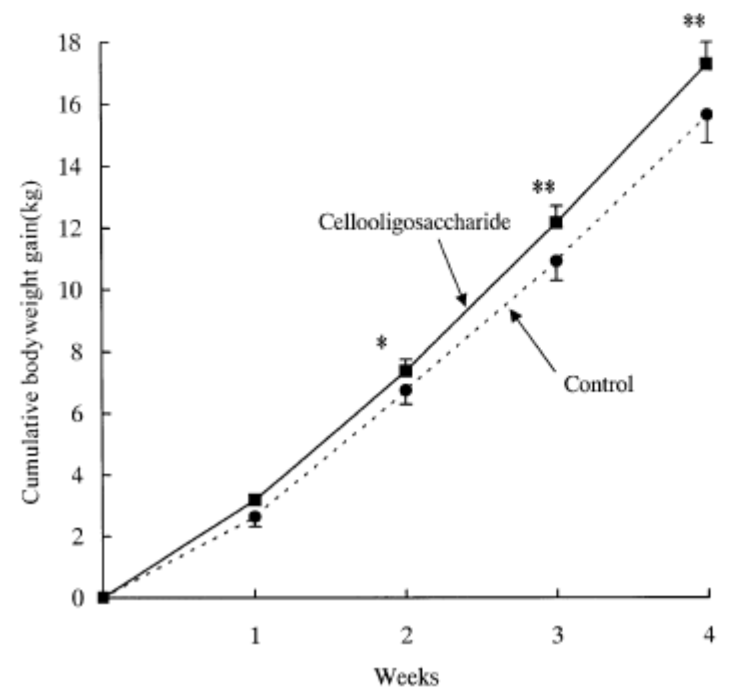
Grass	Productivity (tons/yr)	Protein content (%)*	Animal yield (animals/hectare**/yr)
Panicum maximum (Guinea grass)	12–40	8–12	1.5–2.5
Brachiaria radicans (Tanner grass)	20–25	8–12	2–2.5
Brachiaria humidicola	18–25	4–8	1.5–2
Pennisetum purpureum Schum cv. Mott (Dwarf elephant grass)	40–50	10–15	3–5

Leaf Meal Supplements

Functional Foods

Prebiotics





COS: Cello-oligosaccharides

XOS: Xylo-oligosaccharides

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Vitamins

- plant derived ‘whole-food’ vitamins
- feed ‘leaf meal’ supplements

Dietary survey of Sri Lankan pre-school children and the potential role of leaf concentrate supplementation

Table 3. Potential contribution of a leaf concentrate (LC) supplement[a] in ameliorating nutrient deficits

Nutrient	*Observed mean intake (% of RDA[b] (s.d.))*	*Deficit in mean intake (% of RDA)*	*Contribution provided by LC (% of RDA)[c]*	*Deficit met by LC (% of deficit)*
Energy	78 (16)	22	negligible	–
Protein	130 (33)	–	8	–
Vitamin A	51 (47)	49	93	>100
Ascorbic acid	138 (107)	–	–	–
Thiamin	99 (25)	1	12	>100
Riboflavin	90 (40)	10	25	>100
Niacin	72 (22)	28	16	57
Iron	150 (89)	–	82	–
Zinc	20 (7)	80	44	55
Calcium	105 (66)	–	negligible	–
Folic acid	159 (68)	–	158	–

[a] Based on a supplement per child of 19 g of moist leaf concentrate made from 333 g of leaf.

Cox et al. 1993

BILL & MELINDA GATES foundation

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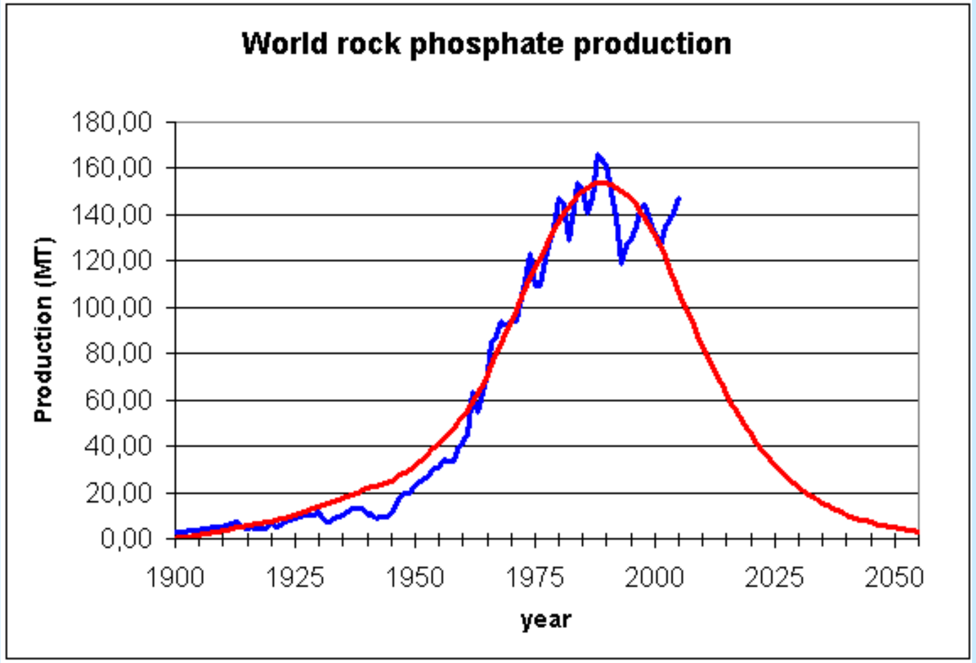
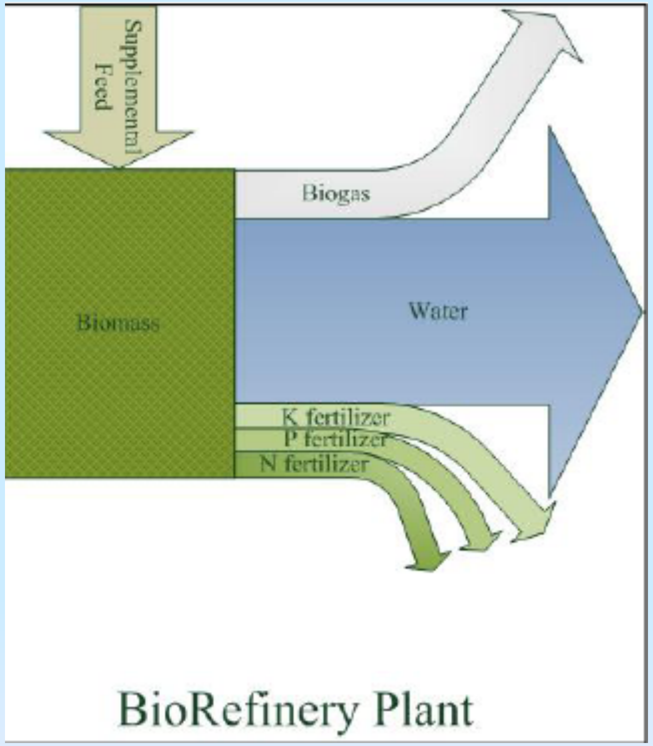
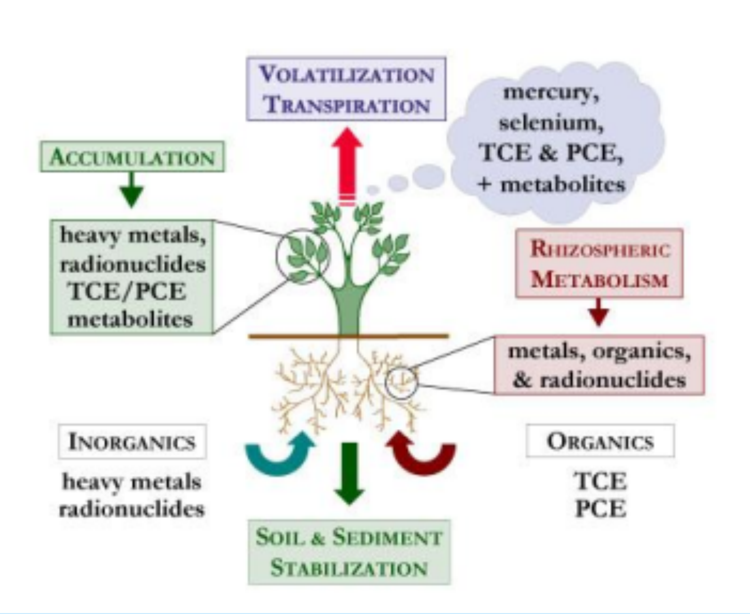
Fertilizer

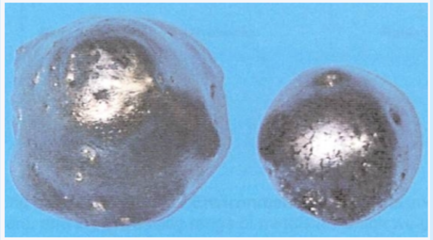


Renew energy

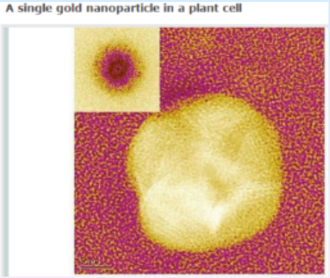


Phytoremediation → Phytomining



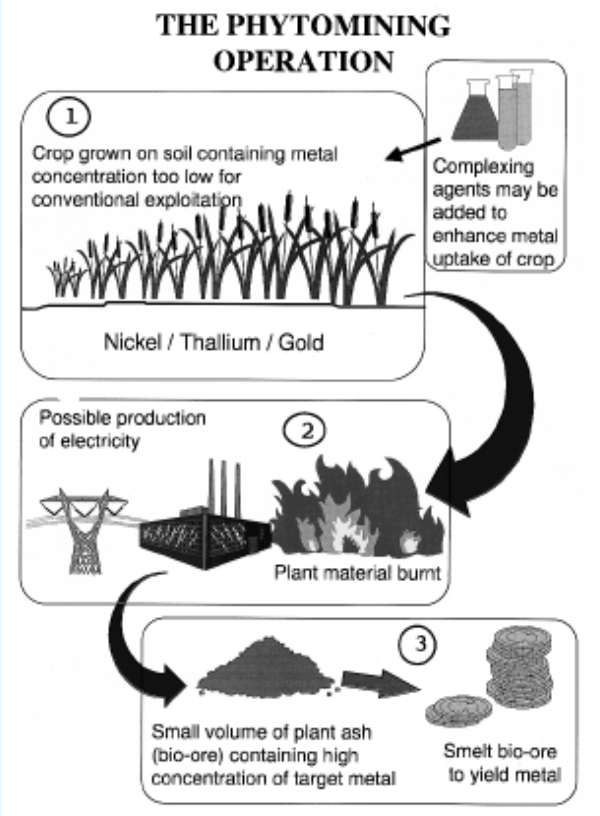


Nickel



Gold

'Nanoparticle' Portable Fuel Cells



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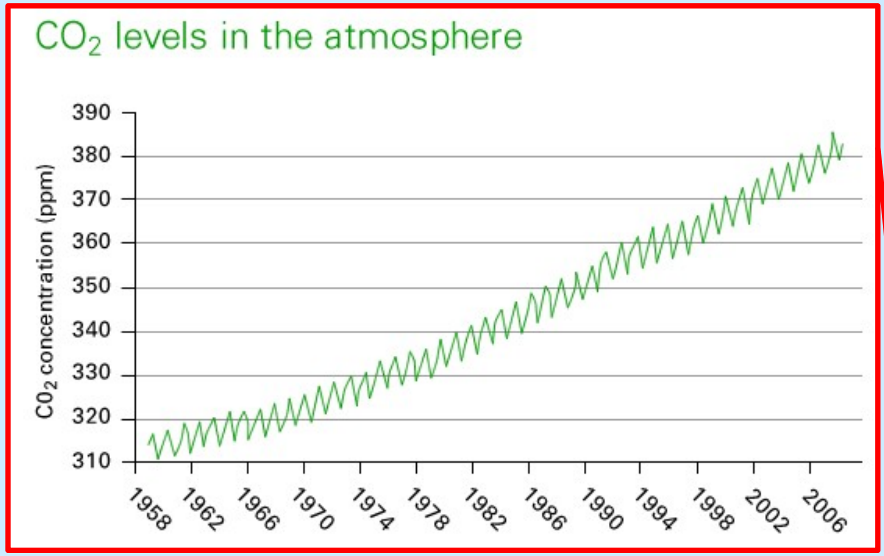
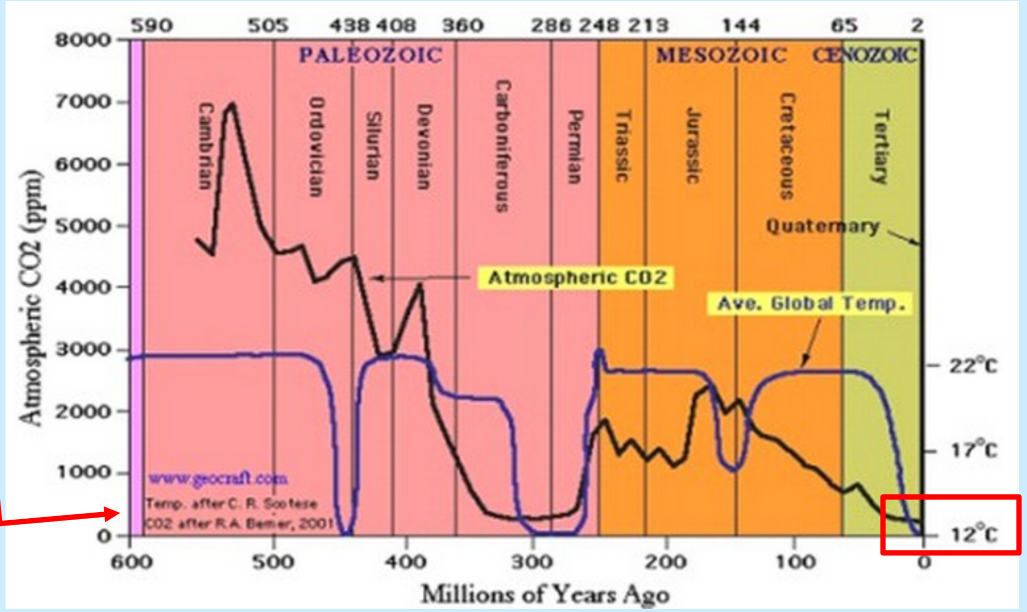
Carbon: Sequestration





80 ppm atm CO_2 = 167 Gt Carbon

Hold your breath?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Everyone in Britain could be given a personal 'carbon allowance'

Everyone in Britain should have an annual carbon ration and be penalised if they use too much fuel, the head of the Environment Agency will say.

<u>Soil Sequestration (10+ Yrs)</u>

Soil Density = 1.2

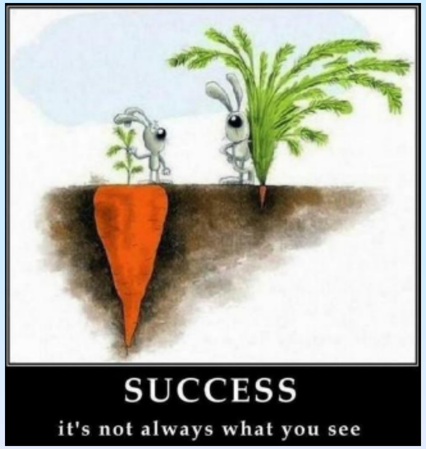
12” soil = 3,658 T/Ha

1% SOM = 36.58 T/Ha

SOM (58% C) = 21.21T C/Ha

5.1 B Ha cropland globally

1.56% SOM/Ha = 80 ppm atm C



<u>Rhizomatous Crops (1 Yr.)</u>

<u>Perennial S. Spp.</u>

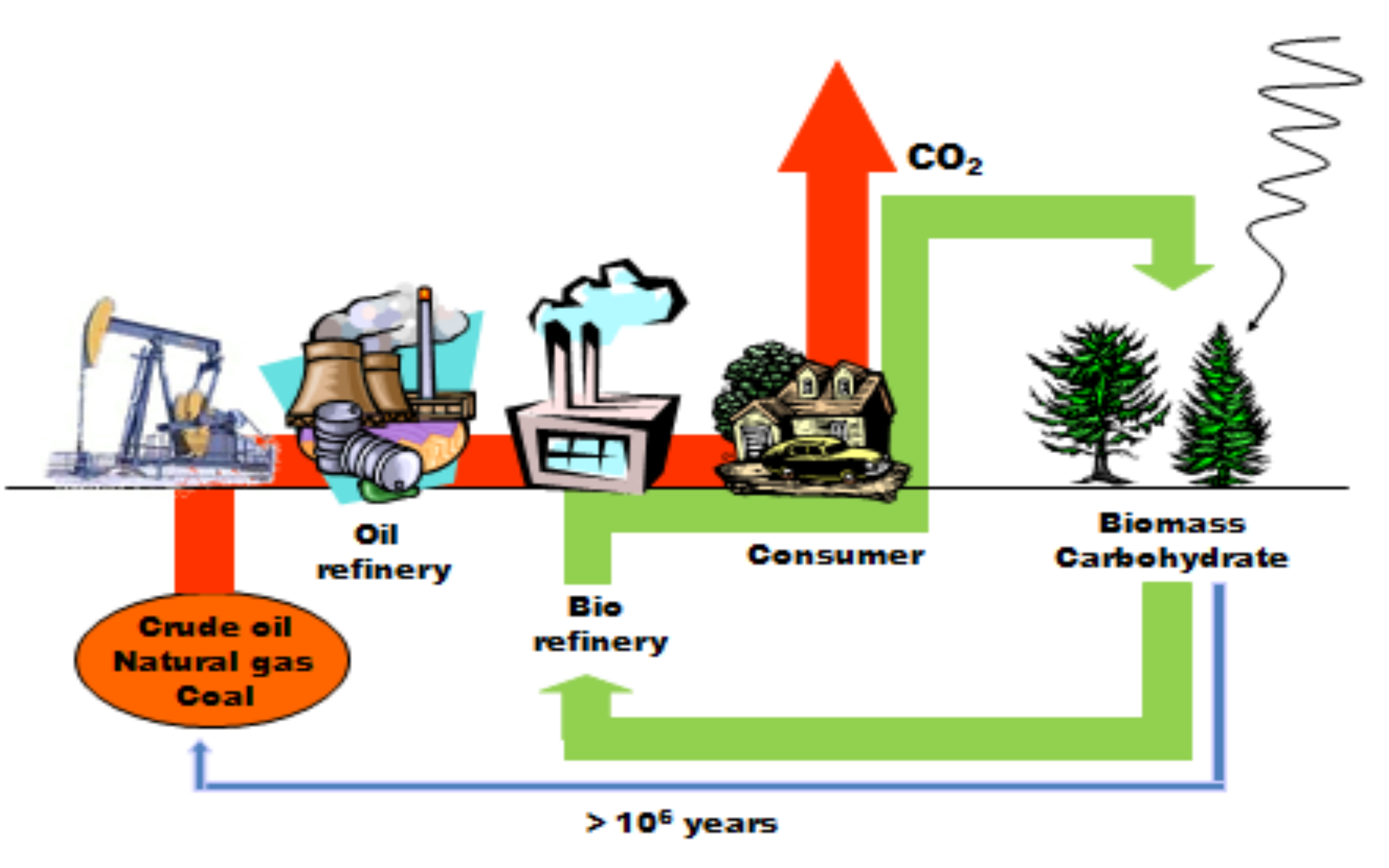
60-70% biomass belowground

18” soil = 26.7 dT rhizomes per Ha

Rhz (45% C) = 12 T C/Ha

Hydrocarbon vs. Carbohydrate

'Fossil' Biofuels vs. 'Renewable' Biofuels



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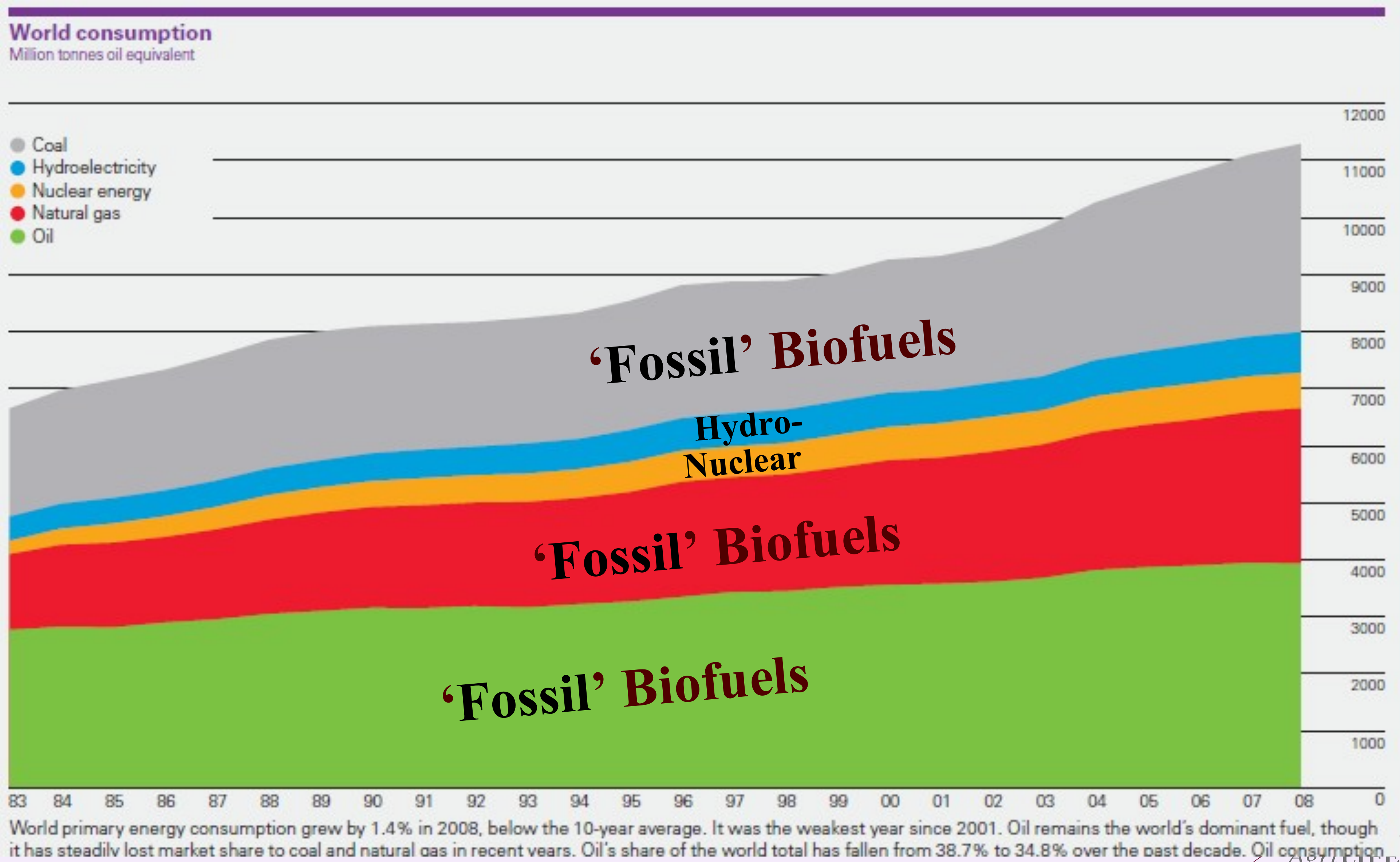
World Energy Consumption



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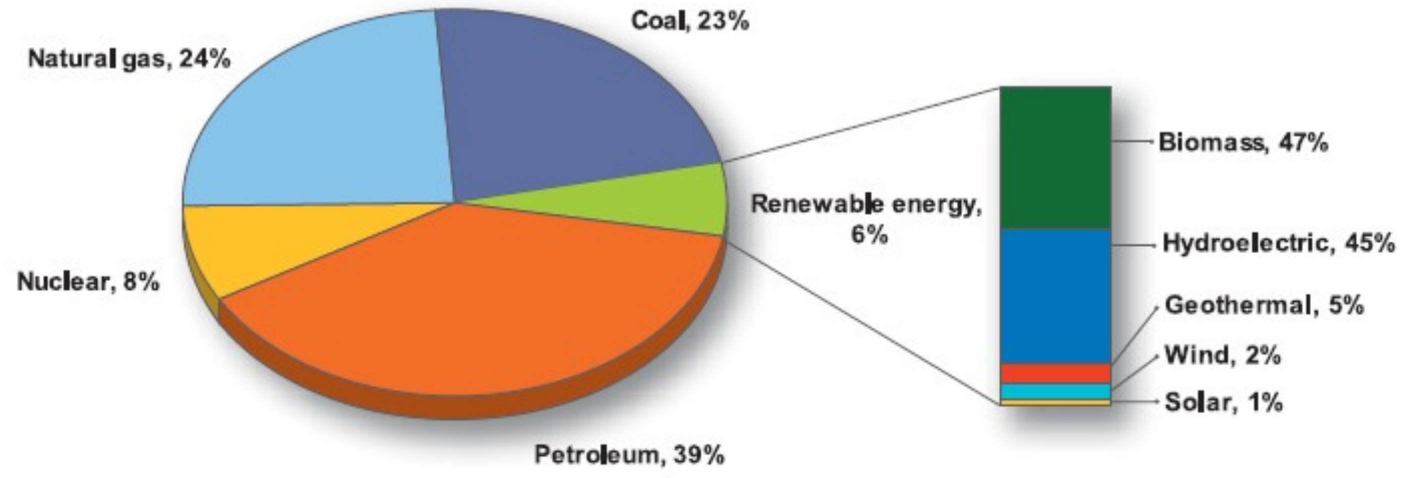
U.S. Renewable Energy Utilization



Biomass Consumption	Million dry tons/year
Forest products industry	
Wood residues	44
Pulping liquors	52
Urban wood and food & other process residues	35
Fuelwood (residential/commercial & electric utilities)	35
Biofuels	18
Bioproducts	6
Total	**190**

- Forestlands and agricultural lands contribute 190 million dry tons of biomass - 3% of America's current energy consumption.

Source: EIA, 2004a & b

Figure 2: Summary of biomass resource consumption

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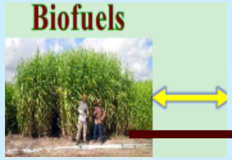
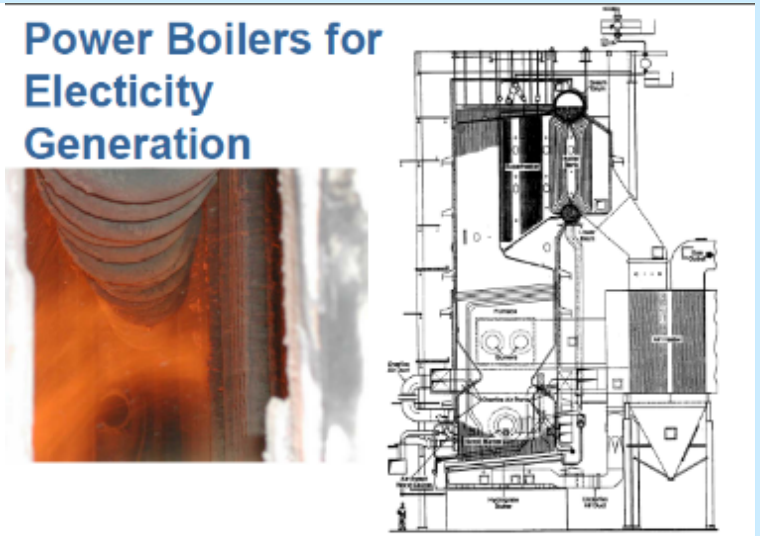
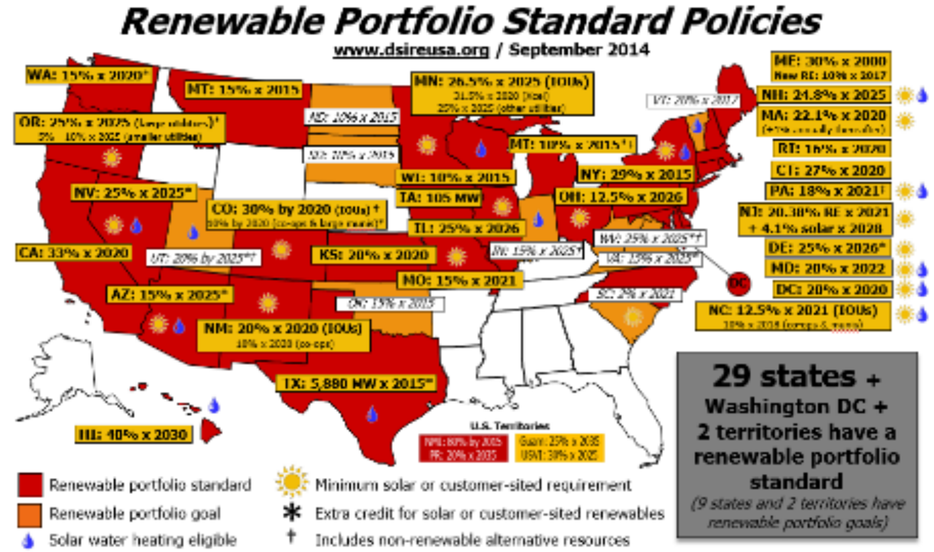


Biofuels: Biopower

- •Solid
    - biopower
- •Liquid
    - ethanol
    - butanol
    - biodiesel
- •Gas
    - Biogas/syngas





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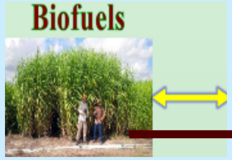
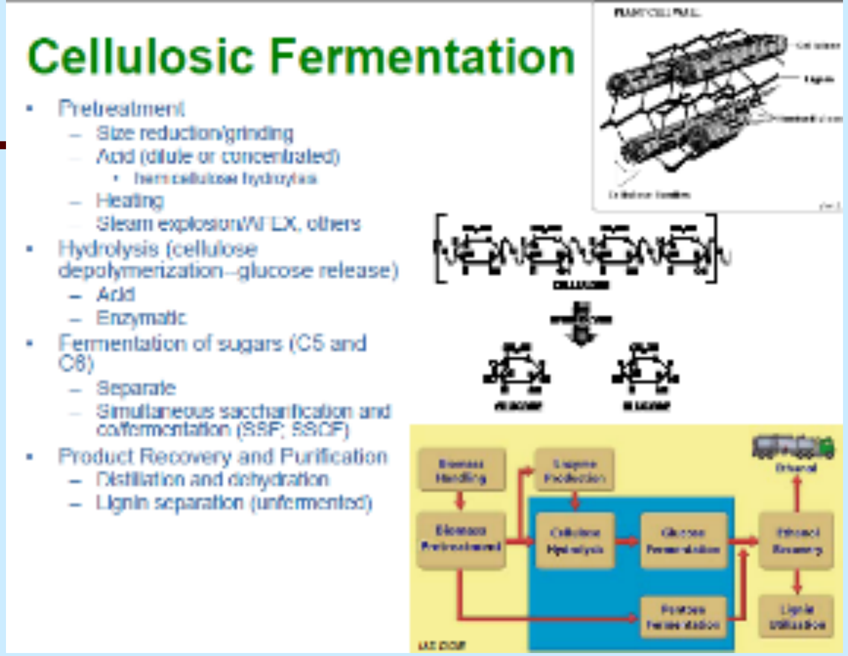
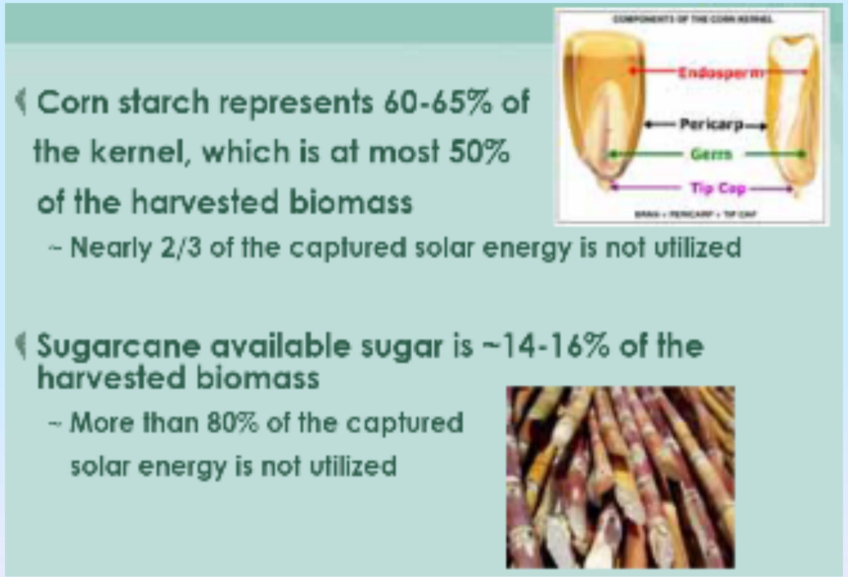


Biofuels: Ethanol

- Solid
  - biopower
- Liquid
  - ethanol
  - butanol
  - biodiesel
- Gas
  - Biogas/syngas





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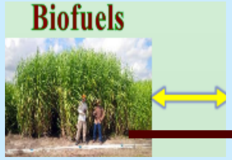
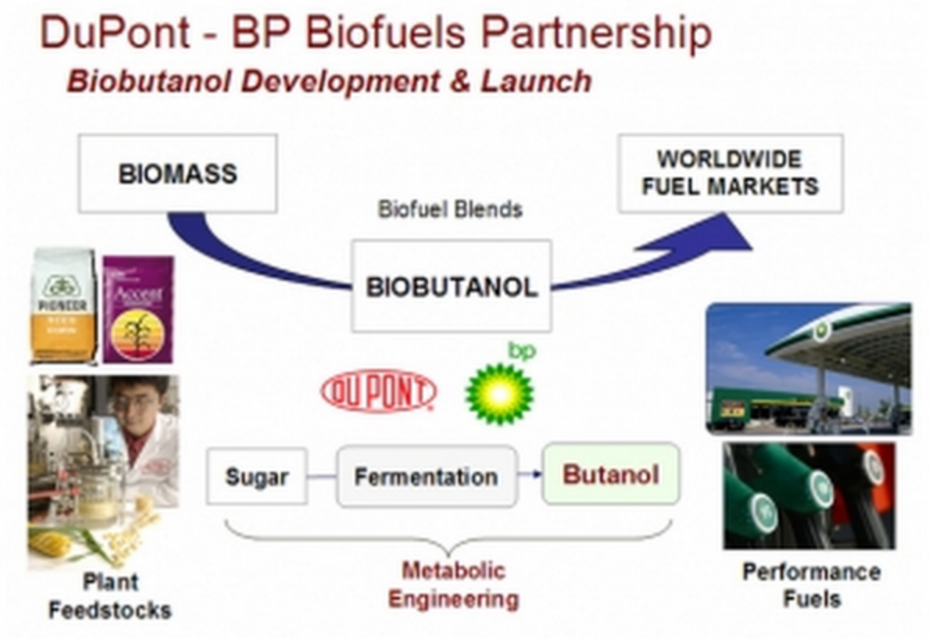


Biofuels: Butanol

- Solid
  - biopower
- Liquid
  - ethanol
  - butanol
  - biodiesel
- Gas
  - Biogas/syngas

Butanol fermentation

- Butanol ($CH_3(CH_2)_3OH$) has higher heating value per gallon (energy content) than ethanol and is less hygroscopic
- Acetone-Butanol-Ethanol fermentation pathway
- *Clostridium beijerinckii, C. acetobutylcium*
- Gas stripping



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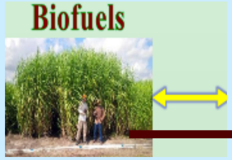
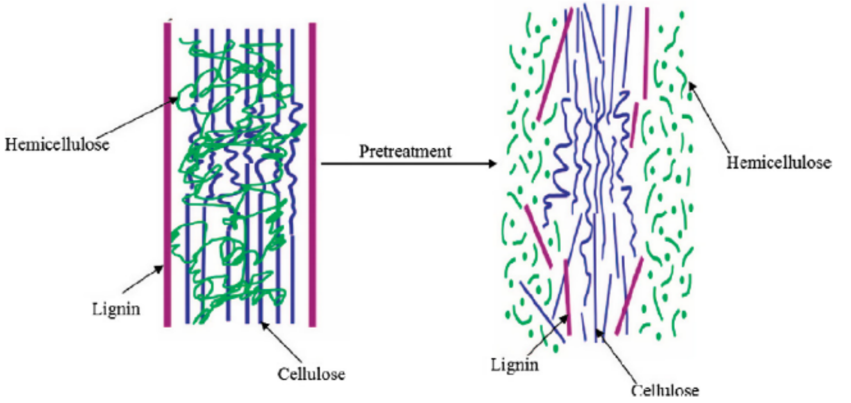


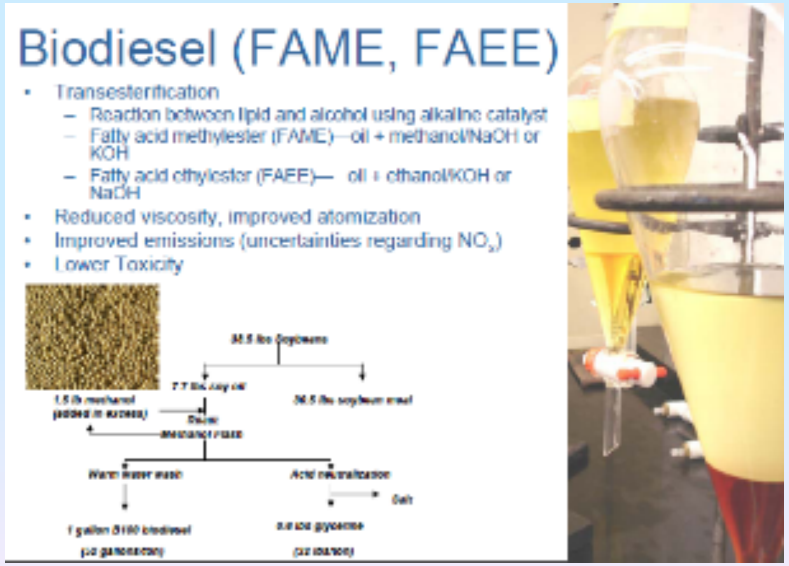
Biofuels: Biodiesel

- •Solid
  - biopower
- •Liquid
  - ethanol
  - butanol
  - biodiesel
- •Gas
  - Biogas/syngas

Pretreatment



'Lipid Accumulating' Microbes



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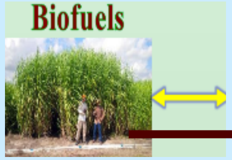
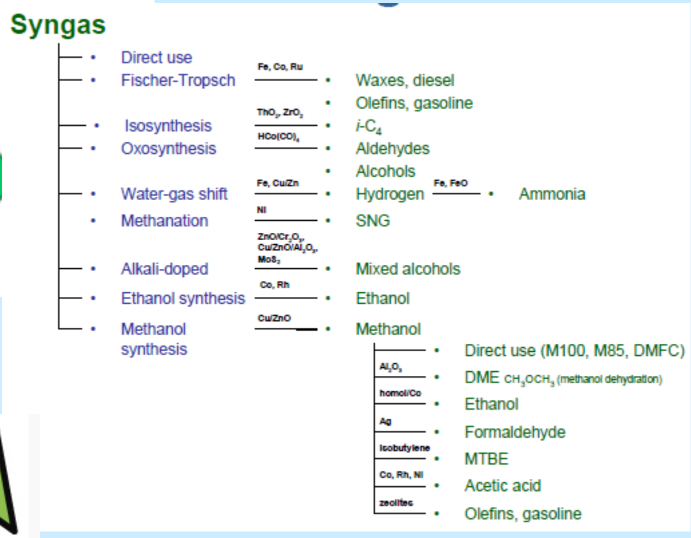
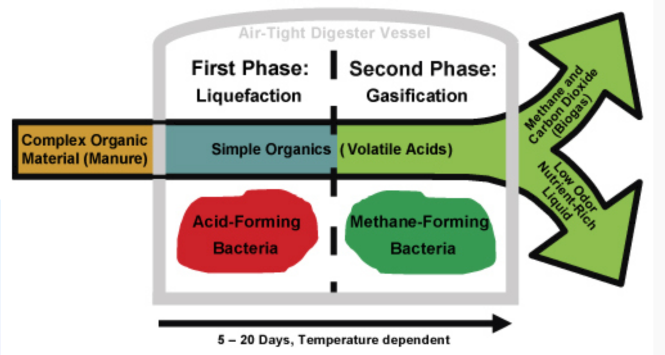


Biofuels: Syngas

- Solid
  - biopower
- Liquid
  - ethanol
  - butanol
  - biodiesel
- Gas
  - Biogas/syngas





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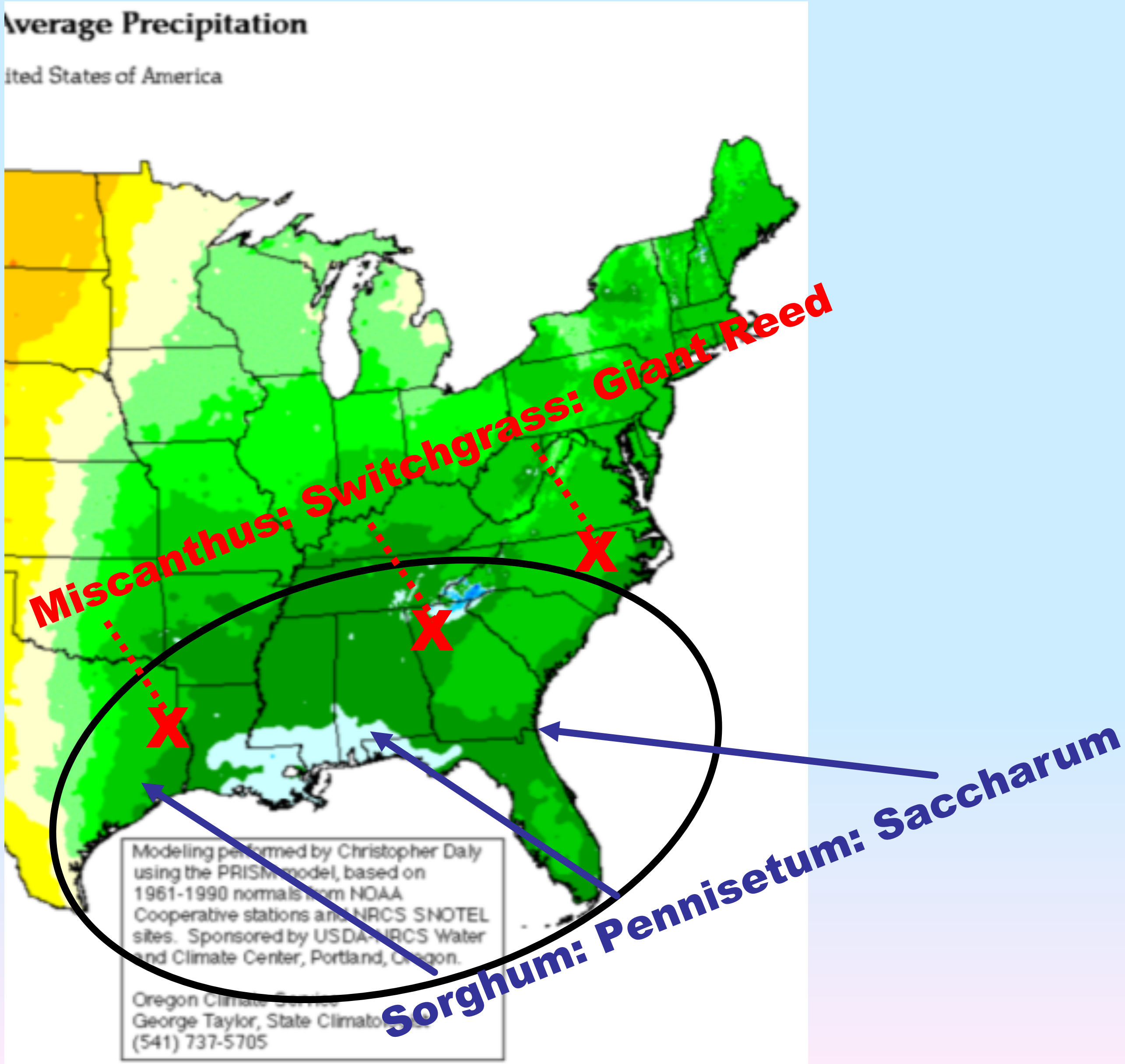
'Bioenergy Belt': Tropical vs. Temperate Feedstocks



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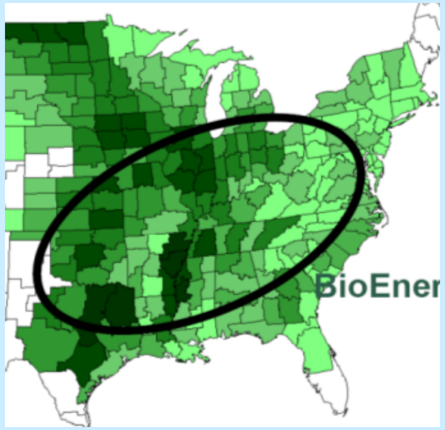
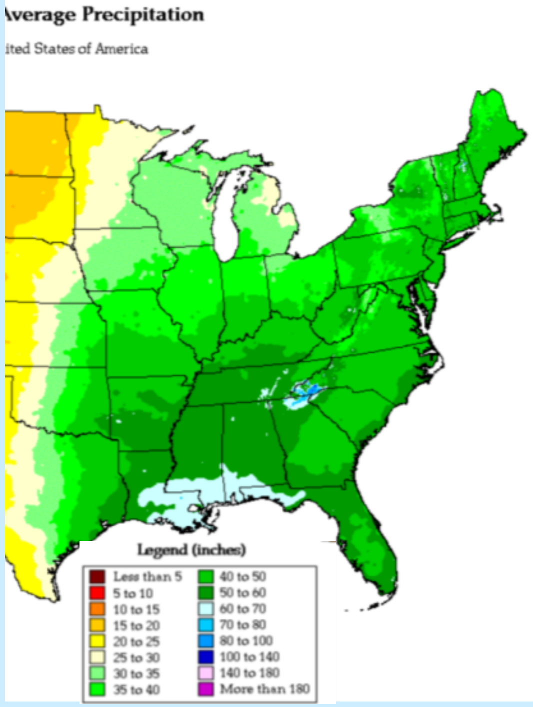
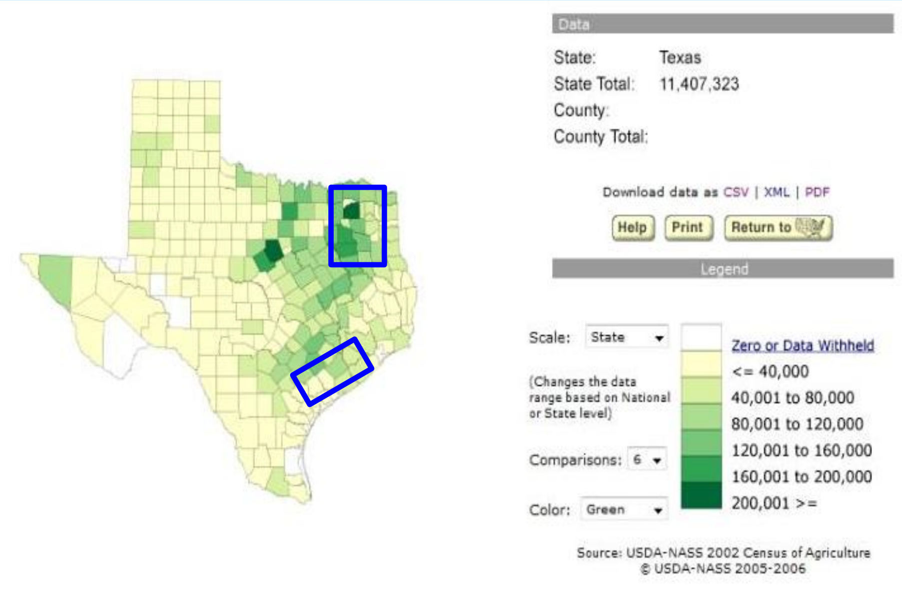
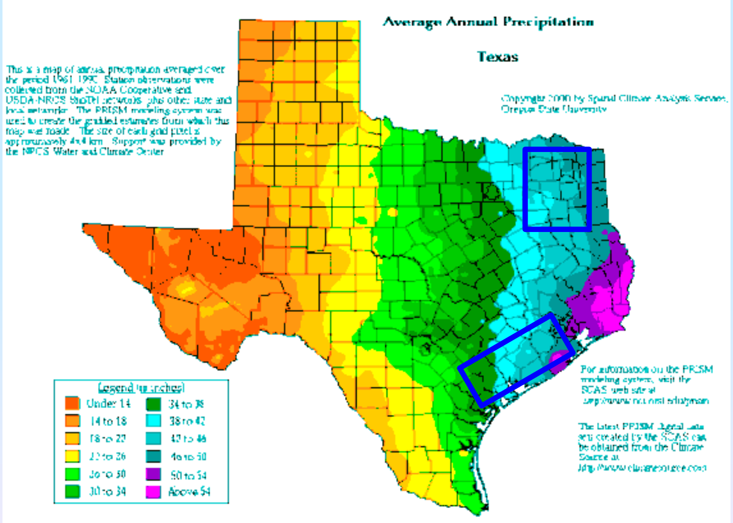
‘Bioenergy Belt’









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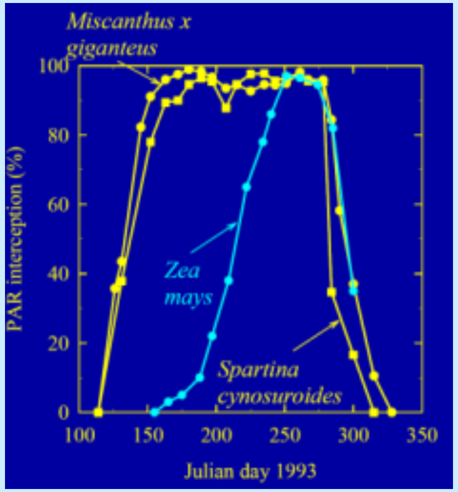
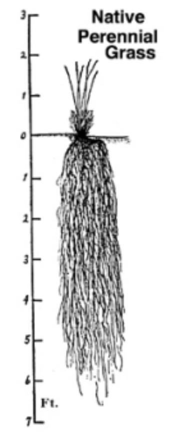
Perennial Grasses

Biomass Production

10 - 30
dt/ac/yr



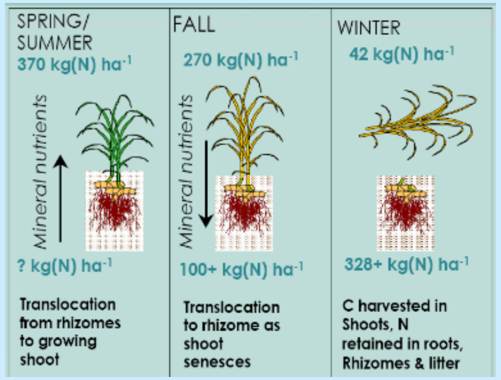


Carbon Sequestration

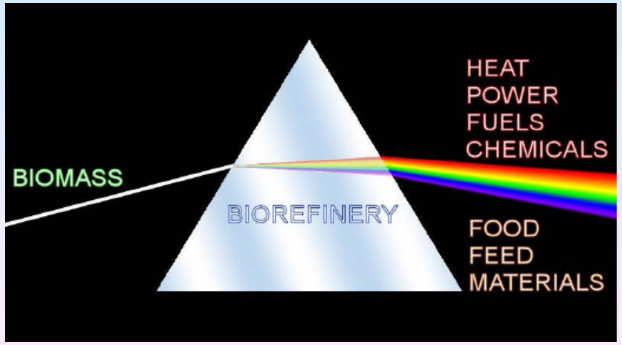
3 – 4
dt/ac/yr

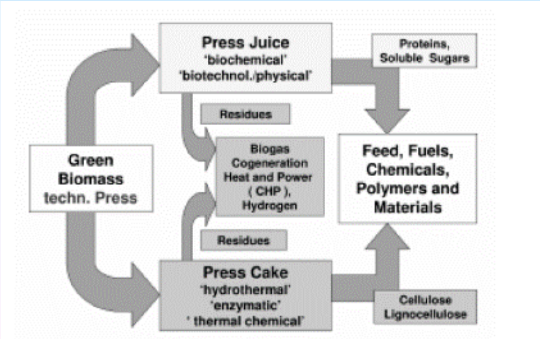
Low Inputs

(Resource Use Efficiency)



Alternative Uses
(Biorefineries)





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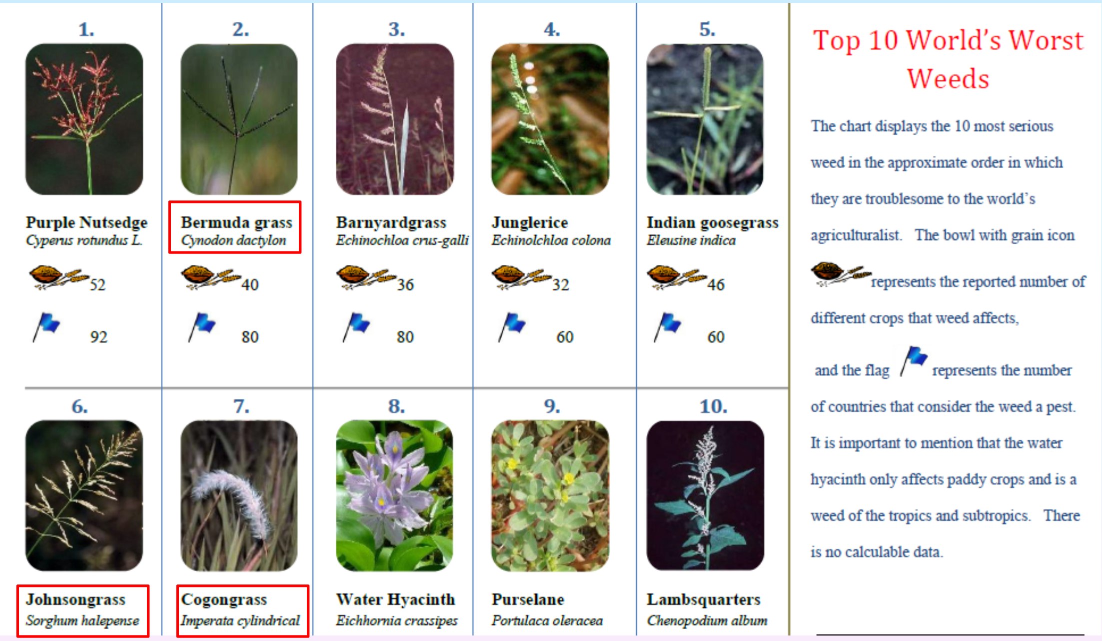
Sustainability VS. Invasiveness

- **Soil**: GHGs, Carbon Sequestration, Erosion

- **Water**: Quality, WUE, Phytoremediation

- **Biodiversity**: Wildlife Habitat



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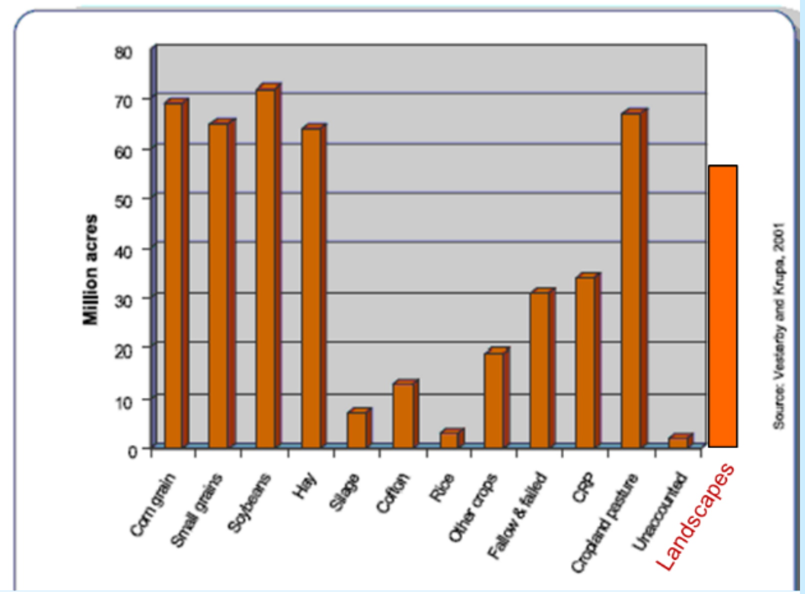
Land VS. Water Resources

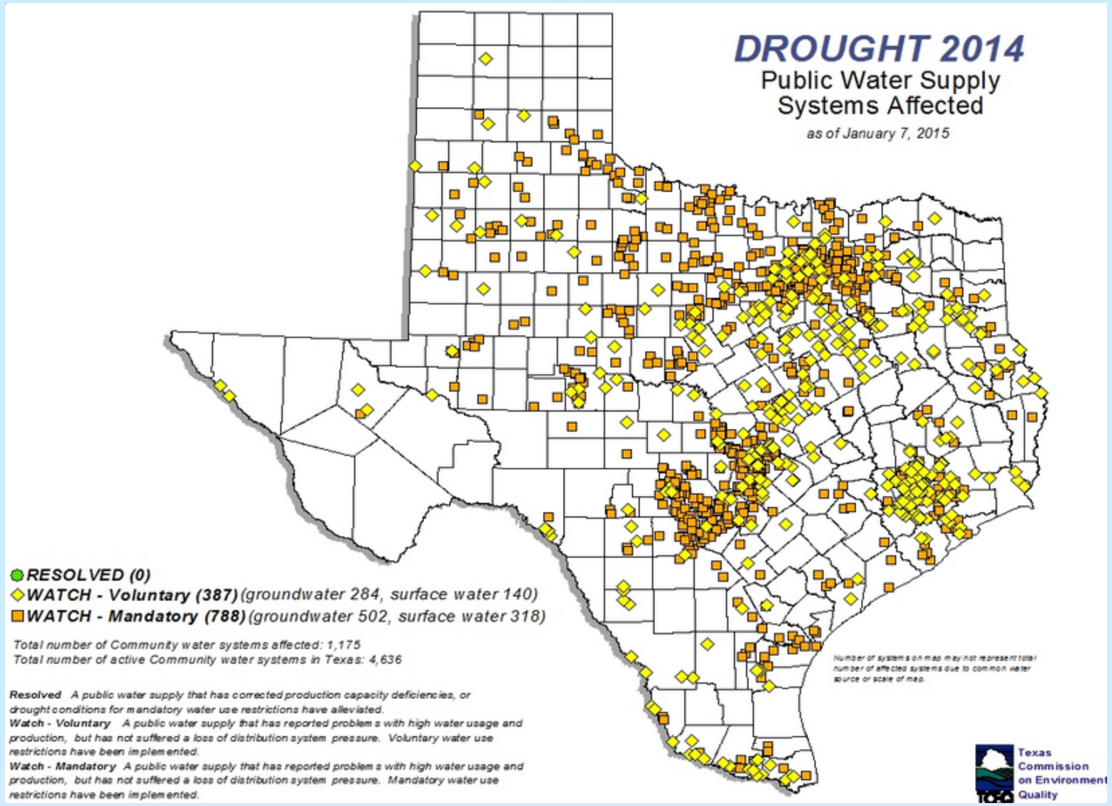


Grasslands

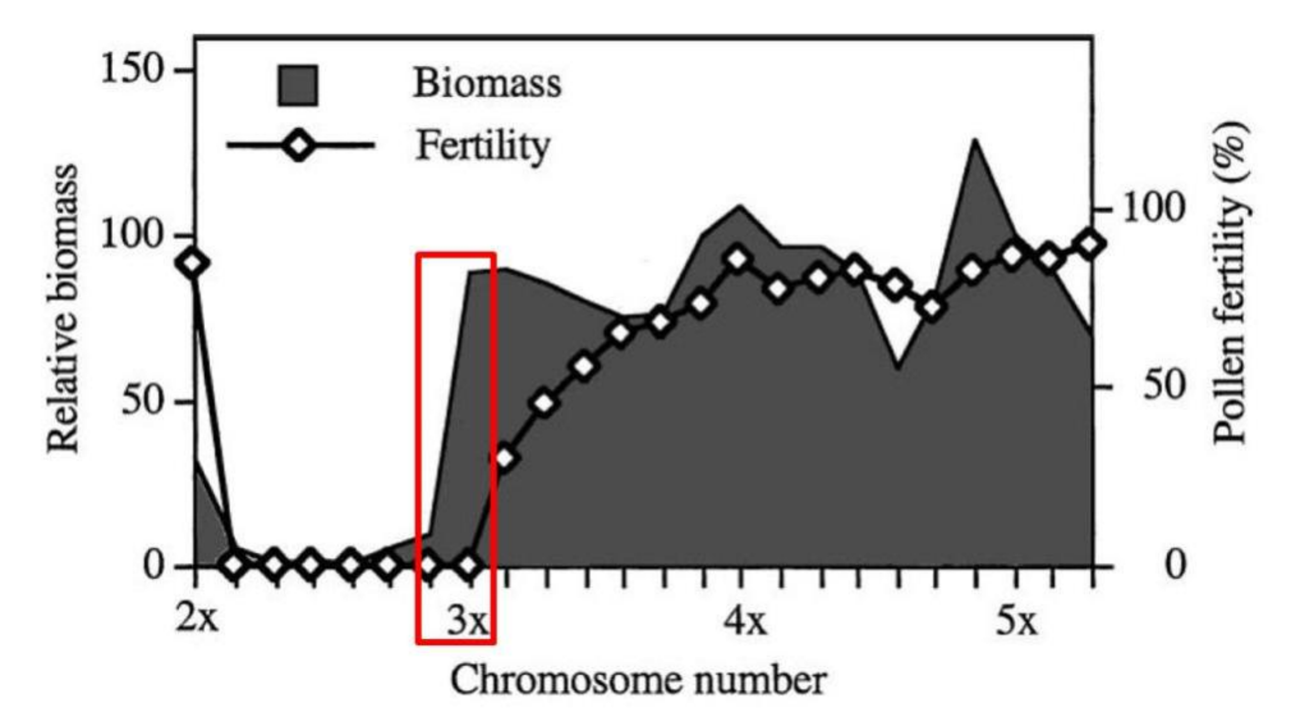
~80 million acres (TX)

>300 million acres (US)

>50 million acres of 'landscapes' (US)



Sterile, Seeded, High Biomass Feedstocks



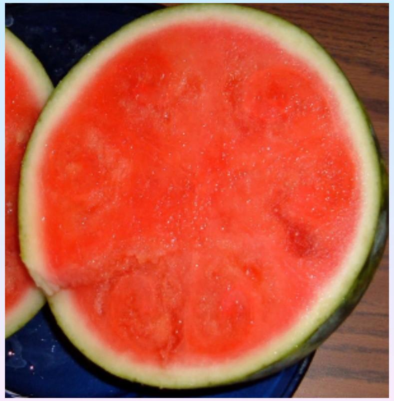
<u>Triploid Sterility (Seedless Crops)</u>

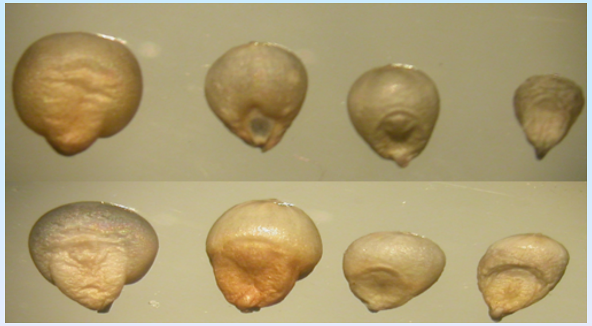
Grapes

Watermelon

Banana

(Apples)





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Improved PMN (Seeded)

Pearl Millet
2n=2x

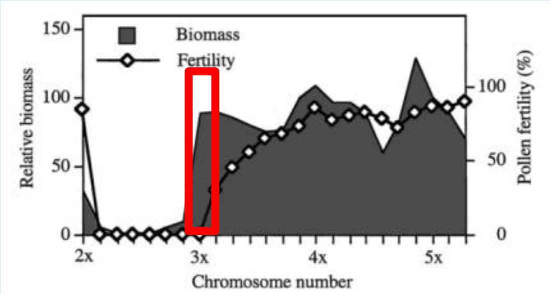
X

Napiergrass
2n=4x

PMN

Seeded-Yet-Sterile (3x) hybrid

***<u>Hybrid Seed Production:</u> 1700 lbs/ac



<u>Yield:</u> 17+ dt/ac
(10+ dt/ac in Yr. 1)

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Improved PMN (Seeded)

Field PMN seed production feasibility trial (Weslaco)

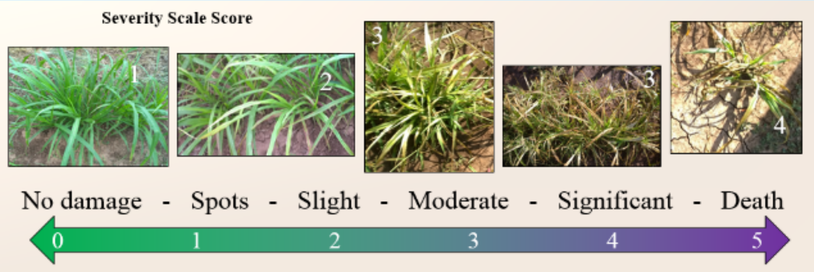
Pearl Millet ID	Seeding Date	Flowering Date	Napiergrass ID	Flowering Date
PEGL 09TX04	8/19/2013	11/10/2013	Merkeron	11/5/2013
PEGL 508273	9/2/2013	11/6/2013		
PEGL 09TX04	8/26/2013	11/22/2013	PEPU09FL03	11/20/2013
PEGL 508273	9/10/2013	11/21/2013		

- Floral nicking—seeded pearl millet & vegetative napiergrass

Improved PMN (Seeded)

PMN herbicide phytotoxicity trials

- Hardened plants (greenhouse: completed)
- Seedlings (greenhouse: completed)
- Seed (growth chamber: completed)
- Seed (field: 2014)



Herbicide	(% safety; survival and leaf chlorophyll)
Prowl, Atrazine, Permit, Plateau, Aim	91-100
Guardsman, Warrant	81-90
Metribuzin	61-80
Direx	21-60
Huskie, Dual	0-20

- PMN eradication trials (2013-2014, 2014-2015)
- Concep (fluxofenim) ‘protectant’ lethality

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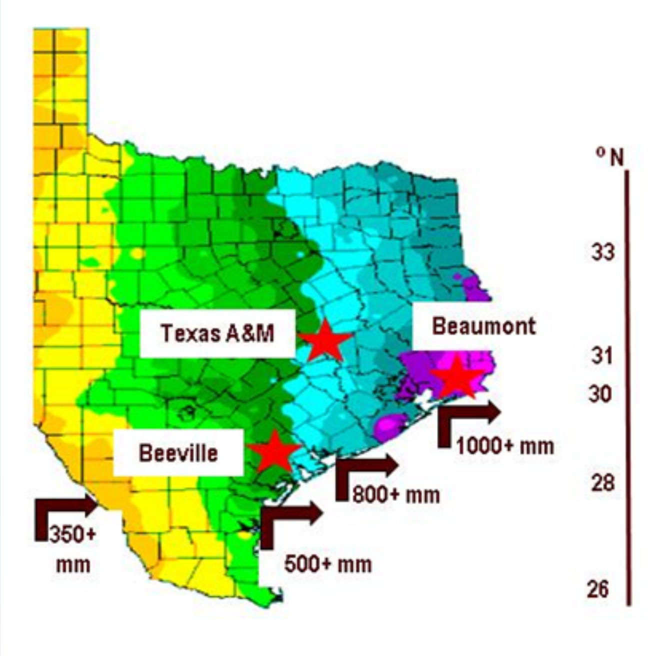
Improved PMN (Seeded)

- Yield Trials: 2011, 2012, 2013
- 3 locations
- 1 harvest (Dec.)

- 17.1 dta

Release: 'Commercial Variety' or 'Selected Plant Materials'



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PMN: Resource Use Efficiency

- College Station: Beeville
- NUE, WUE
- PMN, Sorghum, (Switchgrass)
- 2 harvests (July, Nov.)

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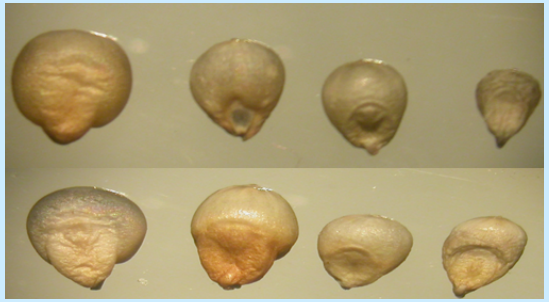
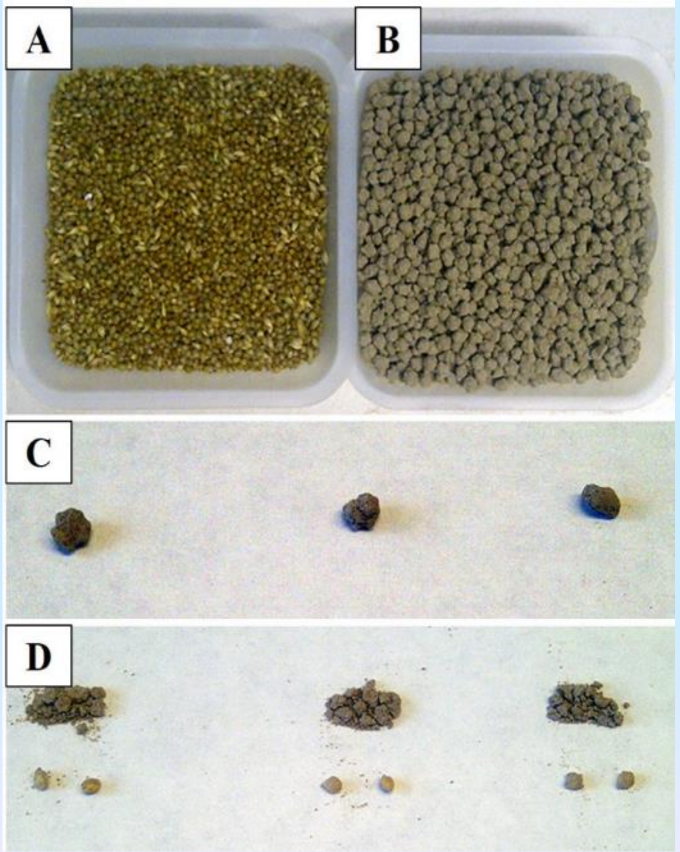
Improved PMN (Seeded)

- **PMN Seed Pelleting**





PMN 'multiple-seed pellet'

A, dehulled PMN seed

B, bulked PMN pellets

C, representative PMN pellets

D, deconstructed PMN pellets and isolated seed

Improved KG (Seeded)

Napiergrass
2n=4x

X

Pearl Millet
2n=2x

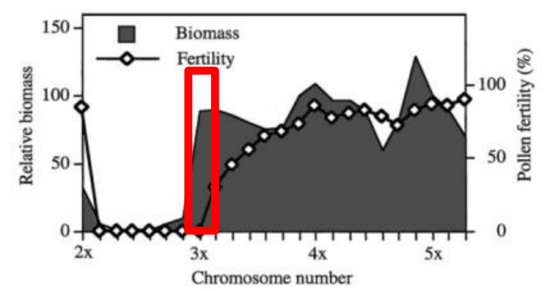
Kinggrass

Seeded-Yet-Sterile (3x) hybrid

***Hybrid Seed Production: Undetermined

Yield: 20+ dt/ac

+20% vs. Napiergrass
+10% vs. PMN



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Napiergrass Sterility System

PEPU 09TX01

- Novel hybridizations

  KG: Objs. 2.1 & 2.2
  (Merkeron x PEGL09TX04, PI508273)
  (seeded KG, pop. dev.)

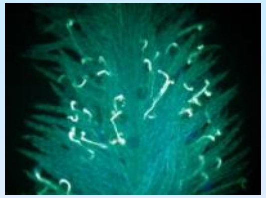
  P. spp. hybrids: Objs. 2.1 & 2.3
  (PEPU09TX01 x *P. spp.*)

- Male-sterile population

  (PEPU09TX01 x Merkeron)

  80 novel F_1 MS accessions

  - Selfed-seed capacity (completed)
  - Pollen fertility (in progress)
  - Genetic mapping (in progress)
  - Improved biomass male-sterile selections (2014)
    - Improved Kinggrass hybrids



Improved KG (Seeded)

- Hybrid KG Seed Production

KG

Male-Sterile Napiergrass

Pearl Millet

- KG12TX08
- Seed pelleting / coating

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Molecular Tool Development

Spp. specific (hybrid verification):

P. orientale

P. flaccidum

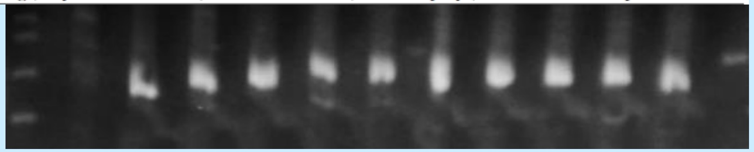
P. purpureum (PMN)

AJPS (2013)

American Journal of Plant Sciences, 2013, 4, 1004-1012
doi:10.4236/ajps.2013.45124 Published Online May 2013 (http://www.scirp.org/journal/ajps)
Scientific Research

Confirmation of Pearl Millet-Napiergrass Hybrids Using EST-Derived Simple Sequence Repeat (SSR) Markers

Charlie D. Dowling[1], Byron L. Burson[2], Jamie L. Foster[3], Lee Tarpley[4], Russell W. Jessup[1]



P. glaucum (Kinggrass)

Plant Omics Journal POJ
POJ 7(2):72-79 (2014) ISSN:1836-3644

Marker-assisted verification of Kinggrass (*Pennisetum purpureum* Schumach. x *Pennisetum glaucum* [L.] R. Br.)

Charlie D. Dowling[1], Byron L. Burson[2], and Russell W. Jessup[1]

Plant Omics Journal (2014)

Kinggrass: PMN

	Kinggrass: PMN	Switchgrass	Energy Cane	Miscanthus x giganteus	Miscanthus sinensis	Sorghum
Sterile F_1 Hybrid Seed	✓					
Yr. 1 Harvest	✓		✓			✓
Yield > 10 dt/ac/yr (single harvest)	✓		✓	✓	✓	✓
Perennial	✓	✓	✓	✓	✓	
Marginal Land Adaptation	✓	✓		✓	✓	✓
Soil C-Sequestration	✓	✓	✓	✓	✓	
Low Establishment Costs (seeded)	✓	✓			?	✓
Low Production Costs	✓	✓		✓	✓	
Polyculture	✓	✓			✓	
Winter Standability	✓	✓	✓	✓	✓	
Non-invasive (seed)	✓		✓	✓		?
Non-invasive (vegetative)	?	?	?	?	?	✓
Apomixis Introgression Potential	✓					

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Improved Pearl Millet

- Very late flowering (Oct. - Nov.), prolific tillering pearl millet

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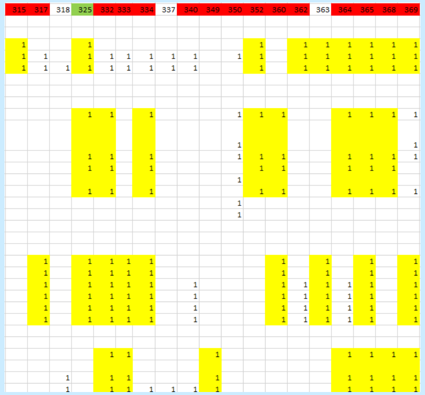
cms Biofuel Pearl Millet

X

Pearl Millet
(*cms* lines)

Pearl Millet
(Prolific Tillering)

Marker-Assisted Introgression



- 1100 F_1: 2 selections (70+% recurrent parent introgression) selected
- BC_1: 430 plants evaluated (85+% recurrent parent introgression)
- BC_2: 160 plants: ongoing evaluations
- Biofuel A:B-pair pearl millet selection and seed increase (2015)

Release: 'Breeding Line' or 'Inbred Line'

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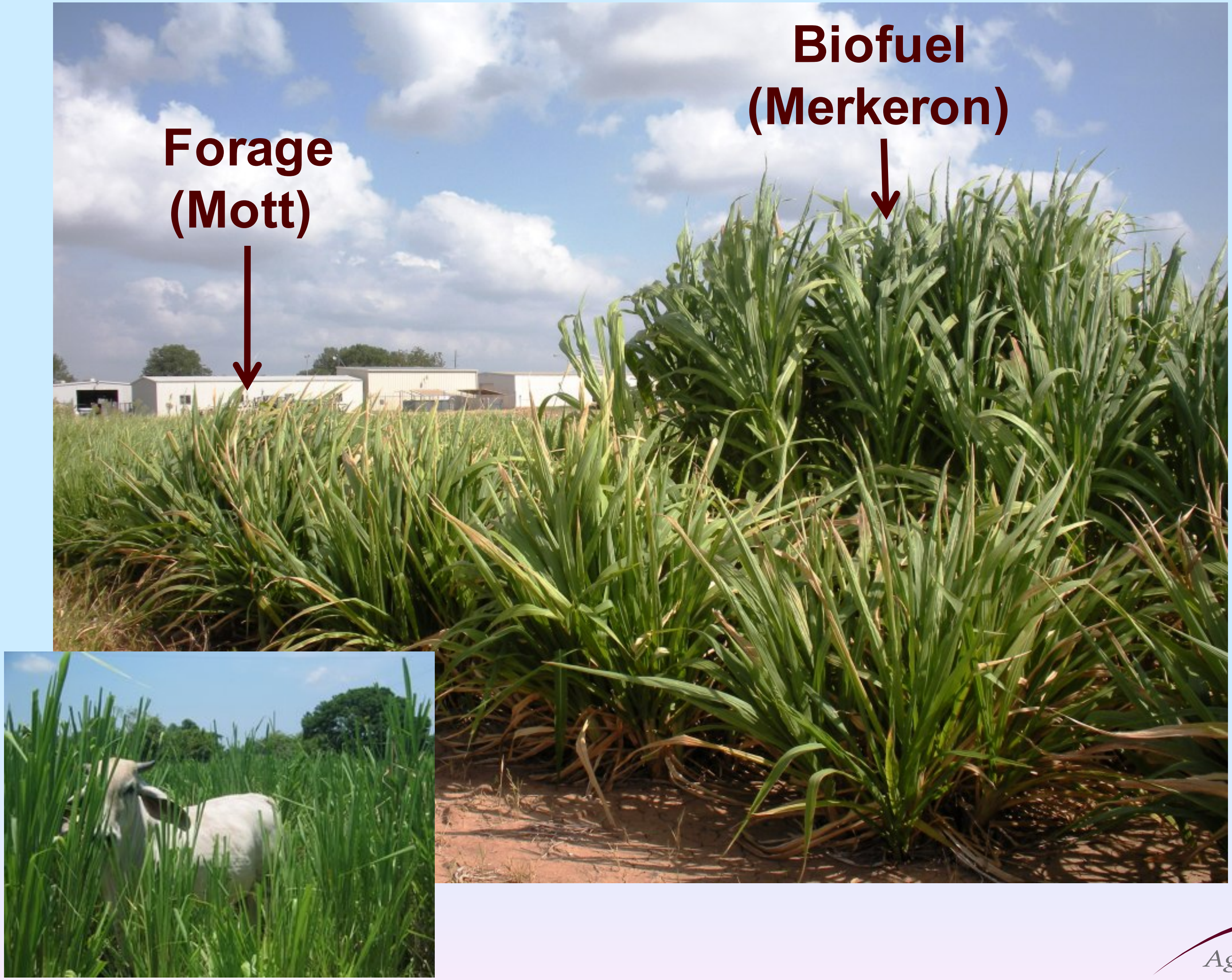
Improved Napiergrass



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Improved Napiergrass

- Diverse, late flowering napiergrass collection

- Advanced hybrids (>1400)

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Improved Napiergrass

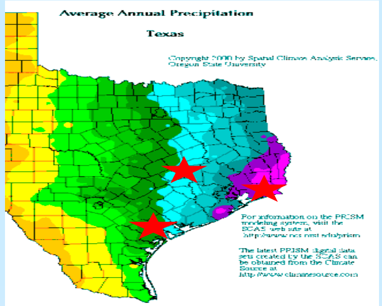
- Inbreds

- S_1 (>900; 2011)
- S_2 (>800; 2014)
- S_3 (2015…)

Improved Napiergrass

	Yield (dta)	Moisture Content (%)	Plant Height (cm)	Tiller # per Plant
Beaumont, TX	17.7	48	290	30
Beeville, TX	16.8	56	318	31
College Station, TX	19.8	47	305	33
AVERAGE	**18.1**	**51**	**305**	**31**

Release: 'Commercial Variety' or 'Selected Plant Materials'



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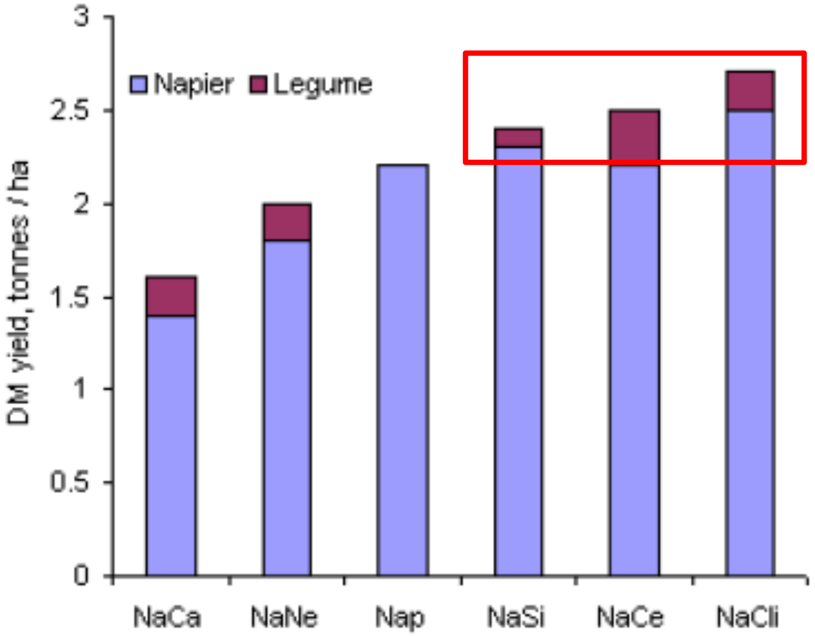
Napiergrass: Legume Intercrops



NaCa=Napier grass + Calopo, NaNe=Napier grass + Neonotonia, Nap=Napier grass, NaSi=Napier grass + Siratro. NaCe=Napier grass + Centrosema, NaCli = Napier grass + Clitoria

***Legume N-contribution without biomass penalty

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Napiergrass: Legume Intercrops

Intercropping Trials

- College Station: Beeville

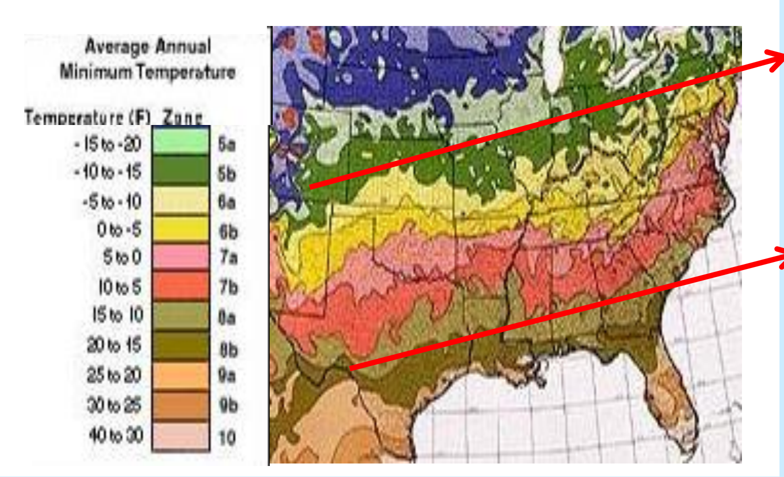
- Cowpea (Red Ripper, etc.)
- Butterfly Pea
- Lablab (Rio Verde)
- Wild Bean (Rio Rojo)
- Scarlet Runner Bean
- Spurred Butterfly Pea
- Milkpea
- American Wisteria
- Groundnut (potatobean; Apios)

NO climbing legume spp. with TX adaptation & PMN:Napiergrass compatability identified

Cold-Tolerant *P spp.* Hybrids

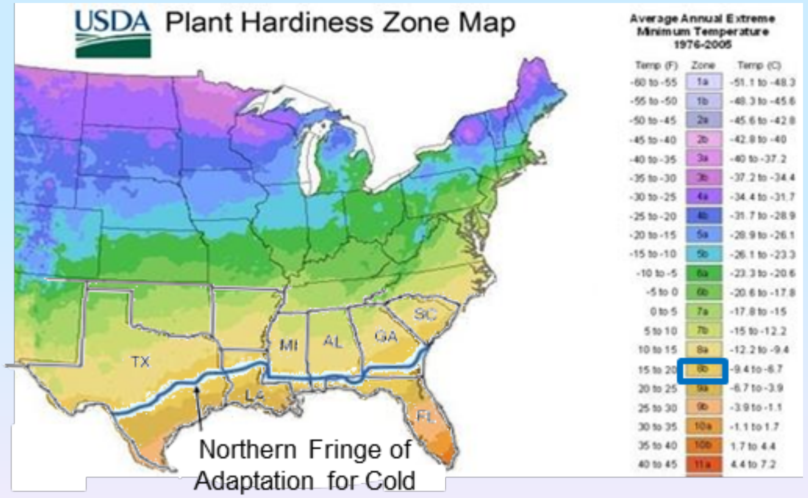
(Napiergrass X Pennisetum spp.)

- Cold tolerance



P. orientale, P. flaccidum, P. alopecuroides (zone 5)

PMN, Kinggrass, *P. purpureum* (zone 8)



Northern Fringe of Adaptation for Cold Tolerant Napiergrass (UFL 2012)

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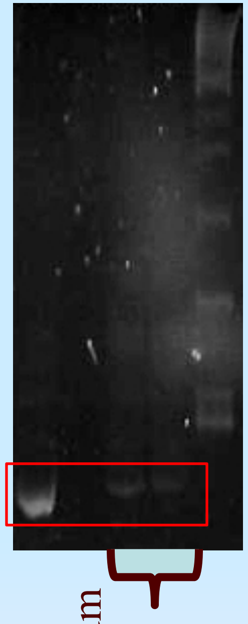
Cold-Tolerant *P spp.* Hybrids



- 2011-12
- 2 viable progeny
- Interspecific hybrid confirmed w/ parental spp. specific EST-SSRs
- Seedling lethality

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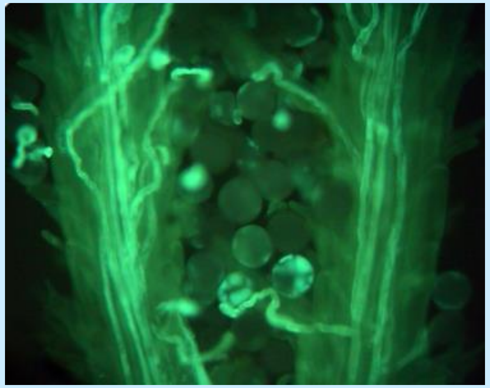
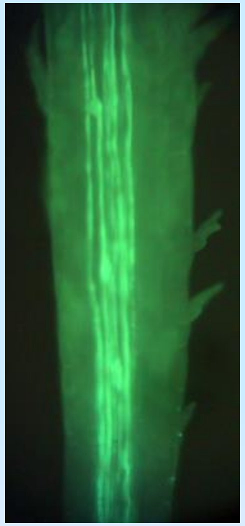
Cold-Tolerant *P spp.* Hybrids

- Pollen fertility

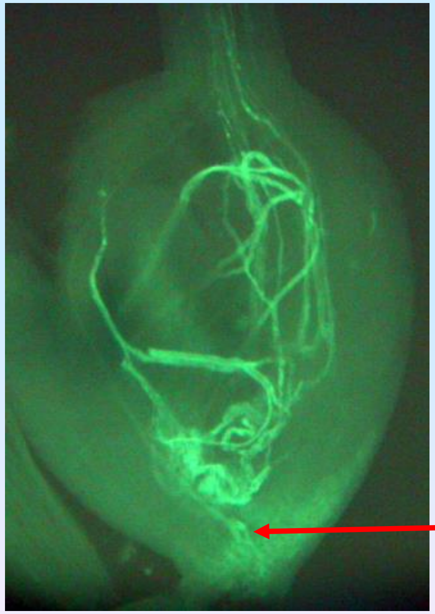
- Pollen tube assays



Stigma



Style



Ovary

- Successful entry into micropyle

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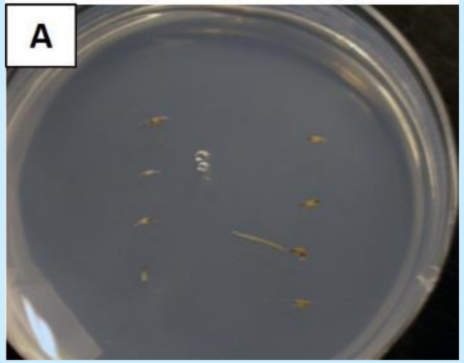
Cold-Tolerant *P spp.* Hybrids

- Embryo Rescue



A. *in-vitro* culture of pollinated (intact & stump), dissected ovaries of male-sterile napiergrass

- 4590 ovary dissections and culture completed.
- ‘Stump’ pollinations attempted.
- Unsuccessful to date.

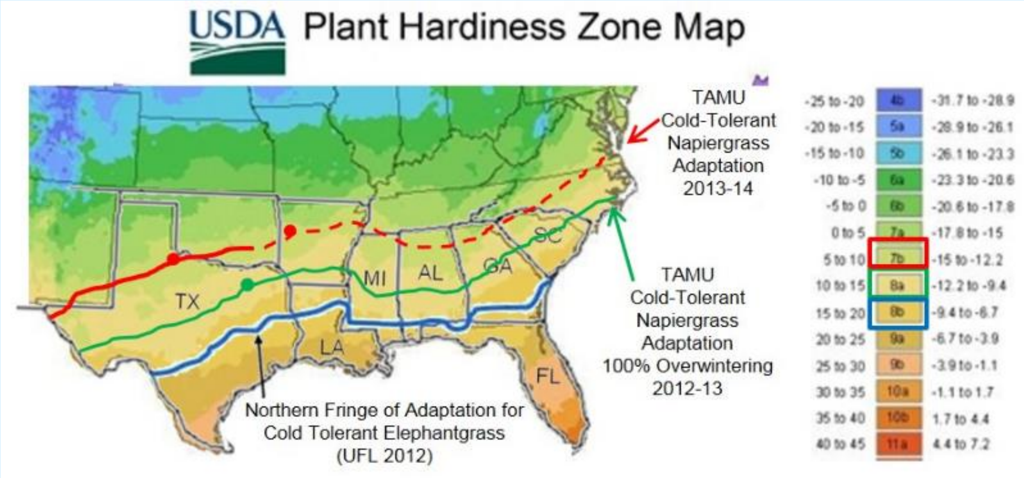
Cold-Tolerant *P. purpureum*

2012-13+

- Contingency (Increased Rhizomatousness)
- 28 Rhz selections in TAMU-Commerce trial
- N. TX overwintering accessions identified

Cold-Tolerant *P. purpureum*

- Elite cold-tolerant x cold-tolerant *P. purpureum*



Six 2012-2013 zone 8a trial overwintering selections

- Commerce, TX

Two 2013-2014 zone 7b trials established

- Vernon, TX
- Alma, AR

2013 Winter Severity

- Derived from 28 initial College Station, TX cold-tolerant selections.

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Cold-Tolerant *P. purpureum*

- Elite cold-tolerant x cold-tolerant *P. purpureum*

Vernon, TX (Sep. 2014)

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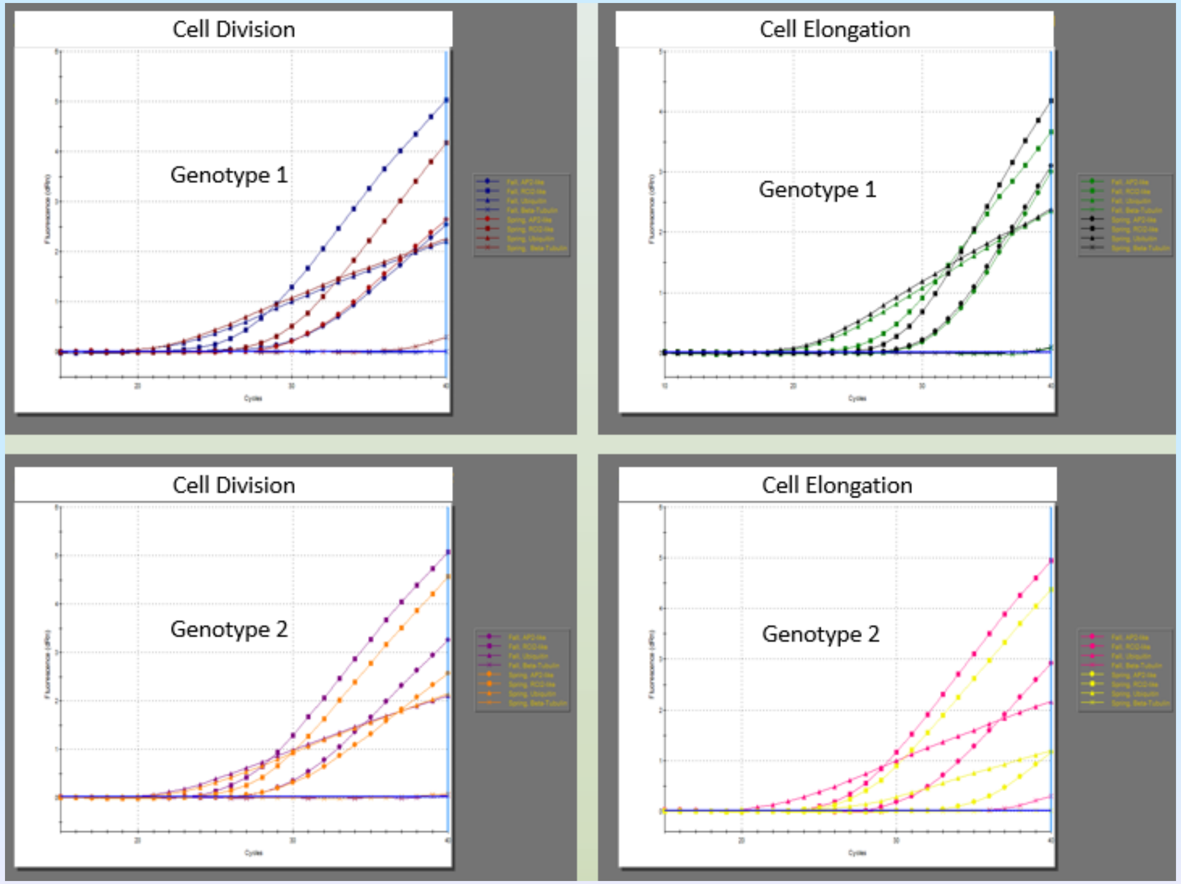
Cold-Tolerant *P. purpureum*

Characterization of Candidate Overwintering Genes in Forage: Biofuel Napiergrass (*Pennisetum purpureum* Schumach.)



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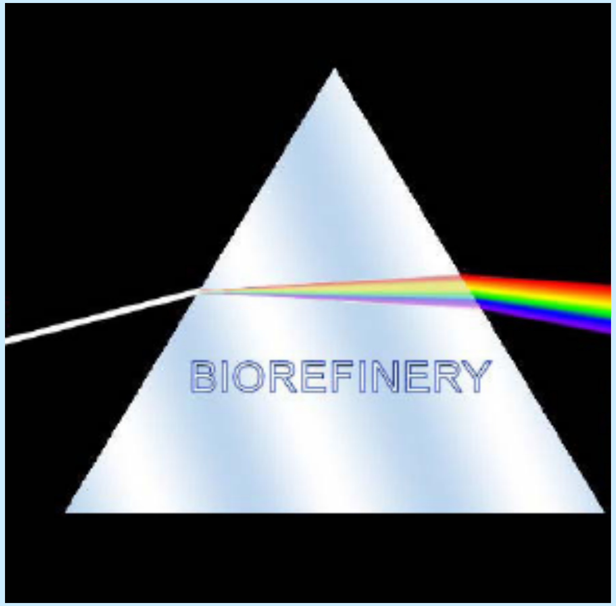
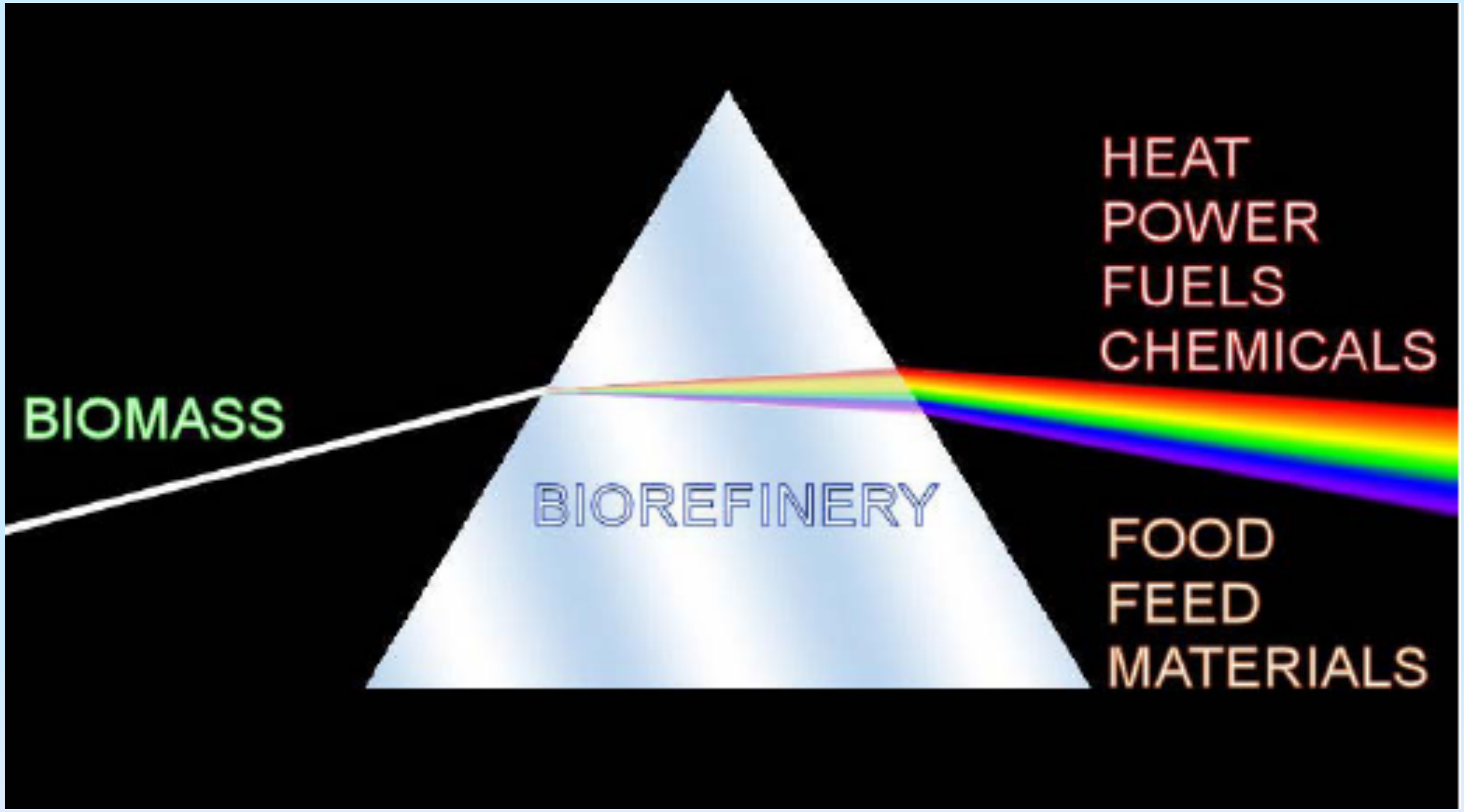
PMN Biorefineries



- Biofuels (biopower, ethanol, butanol, diesel,…)
- Silica (7+ %)
- Protein (15+ %)
- Fiber
- Bioplastics
- Functional Foods (COSs/XOSs)

Disruptive Ideotypes

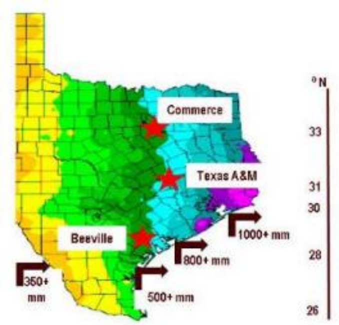


Perennial Sorghum Spp. Hybrids

Non-flowering

S. halepense x *S. bicolor*

- Putative 'No Head Mutant' (nhd1)
  - *S. bicolor*



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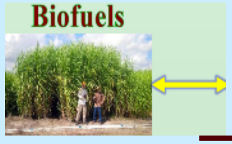

Perennial (Seeded) Sorghum

- Novel *S. bicolor x S. propinquum*
- 4.5 m plant height
- Winter standability (<10% lodging 1/31)
- Photoperiodic (Operational Sterility)
- Fertile, Diploid Hybrids
- Temperate-adapted 'Perenniality'

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‘Seeded’ St. Augustinegrass

Strategy

- Seed Production
  - Fertile plant materials (diploid; 2n=2x=18)
  - Selection (seed yield; germination)
  - Synchronous flowering time
- Seed Processing
  - Non-hulled seed (rachis fragments)
  - Hulled seed (seed priming; direct seeding)
- Uniformity
  - 1 cycle of self-hybridization
  - Selection (phenotypic uniformity)
    - Internode length/ color
    - Leaf width/ length
    - Flowering time
    - DNA markers (genetic uniformity)
- Vigor
  - Seedling vigor
  - Stress tolerance
    - Drought
    - Cold
    - Salinity

Precedence…previous attempts

- Seed fertility/ production
- Seed processing (embedded rachis)
- Non-uniformity (genetic heterogeneity)
- Low vigor (inbreeding depression)

- 2 Synthetic Hybrids
- 2014-2015 Polycross

- 2015 Seeded Hybrid Eval.

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‘Stay-Green’ Bermudagrass

- Rain-out drought trials

- 48 selections
  - Overton: M. Rouquette (23)
  - 2011 Drought ecotypes (21)
  - Mutants (2)
  - Checks (2; Tifton 85, Tifway 419)

- 2013 (90 day; 1 m root zone)
  - 36 surviving genotypes
- 2014 (60 day; 10 cm root zone)
  - 3 surviving genotypes

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Mutant Centipedegrass

- Chemical: Physical mutagenesis
- Dominant (M_0) mutants identified
- Putative 'Knotted-1' (Kn1)
    - Maize

Ornamentals

Miscanthus sinensis

X

'Strictus' 'Cabaret'

Novel Variegated Turfgrass (Synergistic Mutagenesis)

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DECENTralized Web Courses

SCSC 302

https://recturf.tonidoid.com/app/webshare/share/RECTURF/index.html

	12A			12B	12C			13A			13B	13C			14A			14B	14C				15A		
			0	0			0			0	0			0			0	0				0			0
Hall	83		83	0	83		83	83		83	21	83		83	82		82	56	81			81	83		83
Jessup	**81**	**51**	**132**	**46**	**78**	**58**	**136**	**83**	**69**	**152**	**33**	**83**	**69**	**152**	**78**	**81**	**159**	**40**	**78**	**82**	**2**	**162**	**79**	**103**	**182**
			215	46			219			235	54			235			241	96				243			265
							480							524								580			

SCSC 689

https://ipps.tonidoid.com/app/webshare/share/IPPS/index.html

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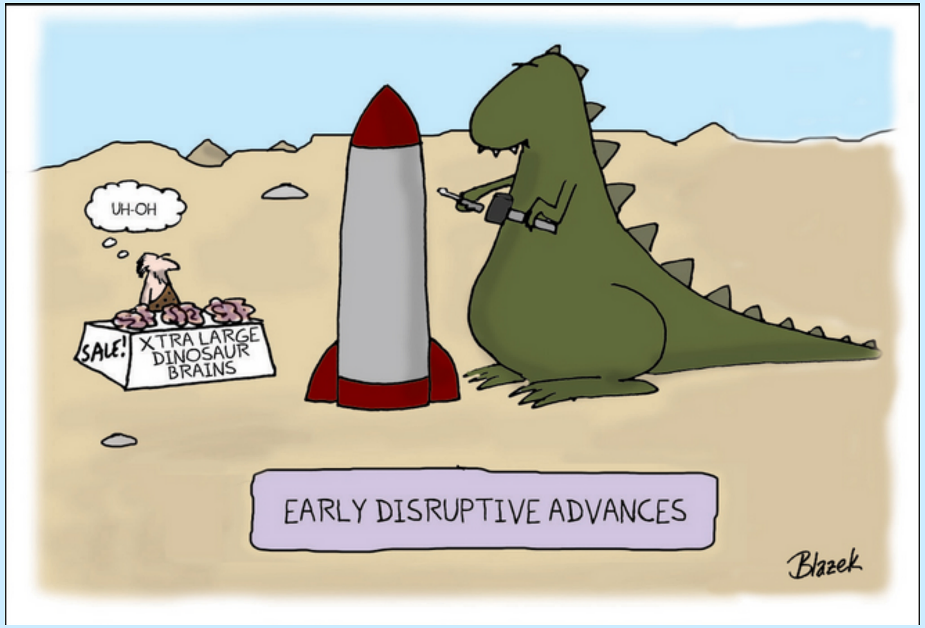
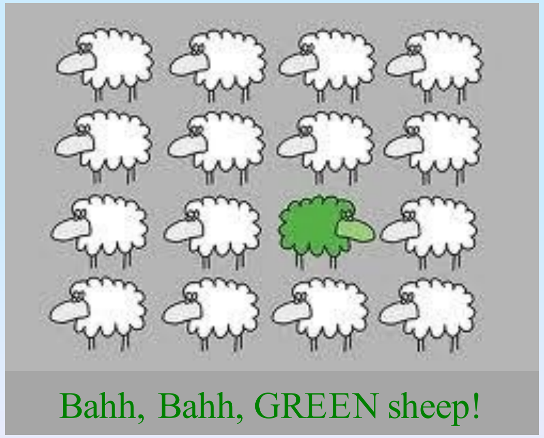
Feedback





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Question & Answer Session

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