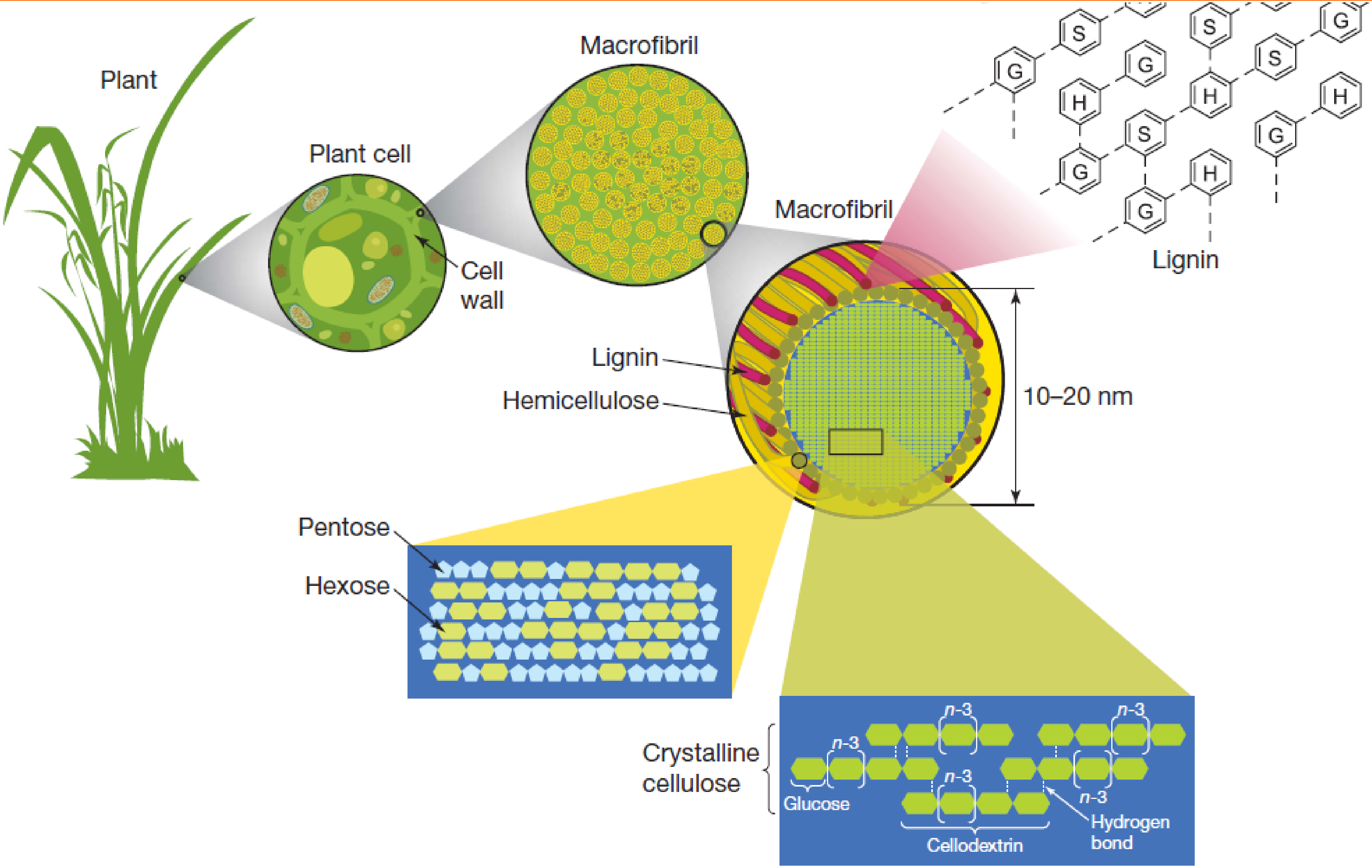
Topic Three

Lecture Four

Feedstock Potential Evaluation

Summary of Topic Two



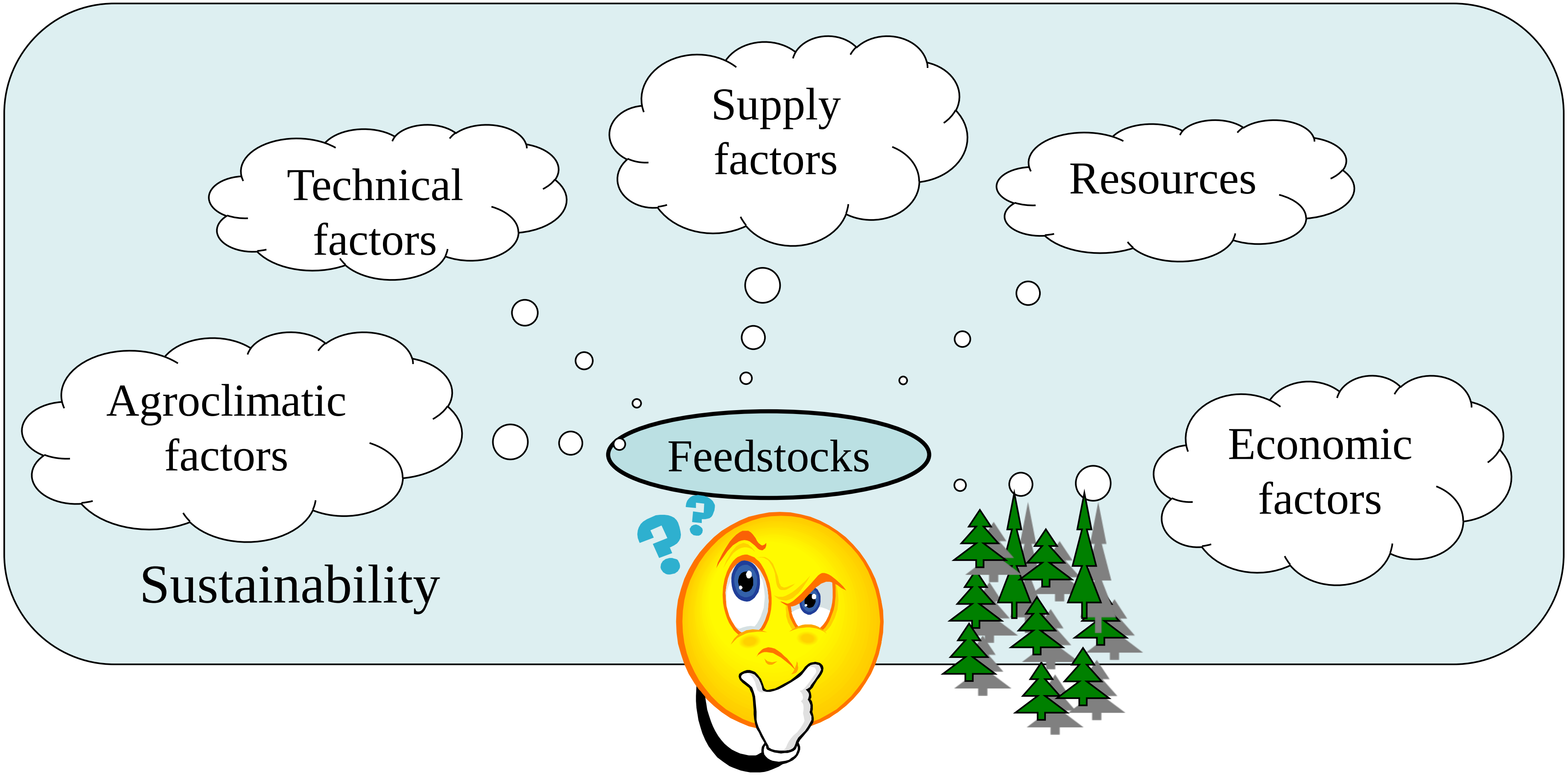
Feedstock Potential Evaluation

Ideal biomass feedstock

- High energy content
- Low recalcitrance
- Available in large quantities in many types of geographical areas
- Requires very low amount of resources to grow
- Easy to harvest and transport
- Cheap compared to other similar feedstocks
- Fairly standard and simple conversion technologies
- Sequesters CO_2 and does not cause pollution

Feedstock Potential Evaluation

What are the critical factors that must be considered in evaluating/comparing feedstocks?



Feedstock Potential Evaluation

Technical factors

- Chemical and physical properties
  - Chemical composition of feedstocks
  - Feedstock recalcitrance
  - Yield of biofuel and coproduct.
- Conversion processes technologies :
  - Unit operations required to grow, harvest and transport feedstocks.
  - Are these technologies available commercially? How mature is the technology?

Feedstock Potential Evaluation

Technical factors

- Scale of operation
    - What is the scale of operation required to make the process practical Kg...Ton...or Million Tons?
    - Are there any significant issues in scaling up the process?

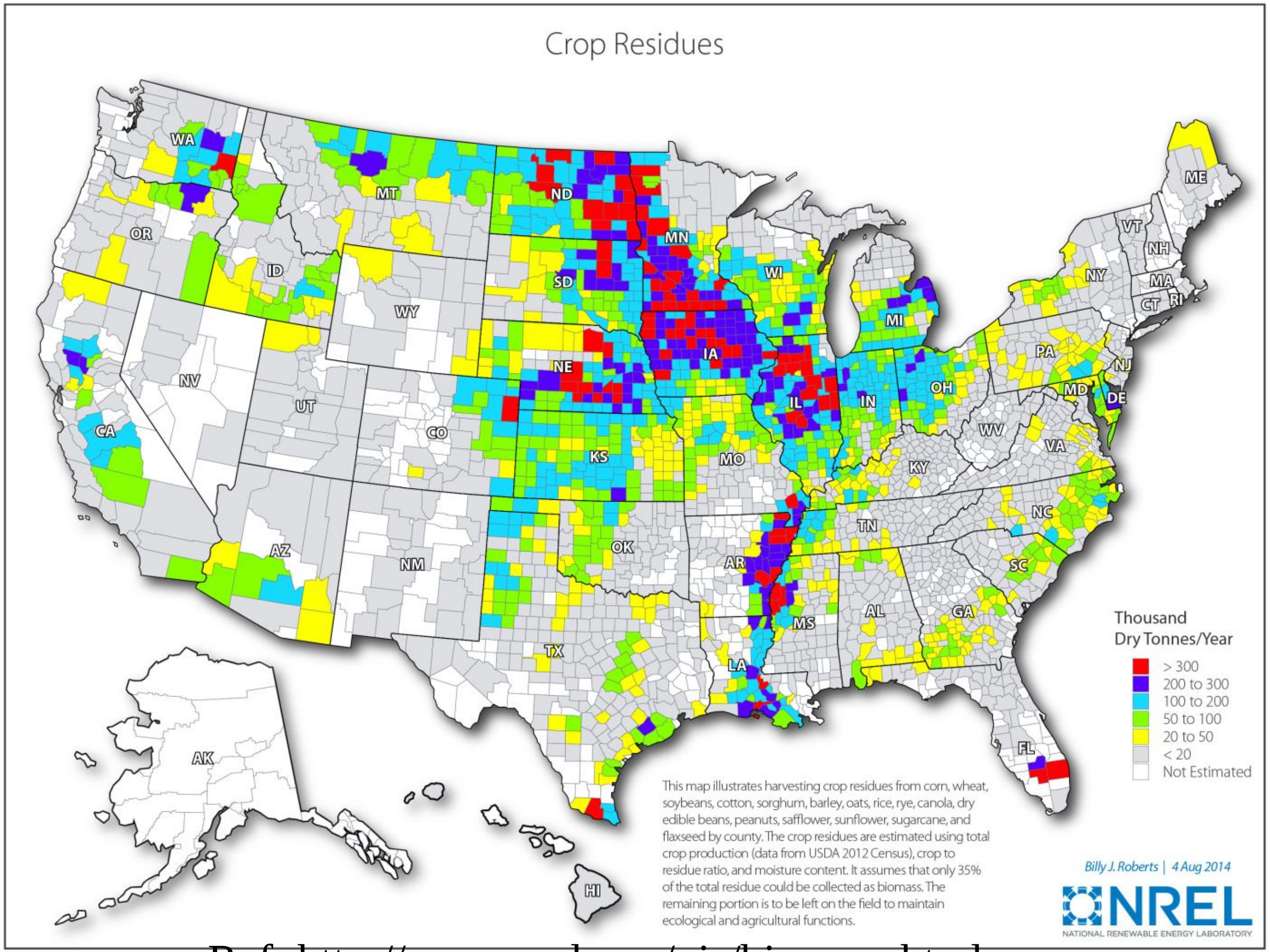
Supply chain management

- Present availability and future forecast
- Geographical distribution

Feedstock Evaluation Factors

- Composition
- Climate
- Water requirement
- Fertilizer use
- Current production levels and future trends
- Supply chain factors
- Conversion Technologies
- Coproducts and their use

Distribution of Crop Residues



Ref: http://www.nrel.gov/gis/biomass.html

Feedstock Potential Evaluation

Resources: Water, nutrients and cultivation practices.

Two important raw materials in the manufacture of nitrogen fertilizers are natural gas and energy

Intensive agriculture practices also use a lot of energy inputs in field preparation, planting, irrigation, harvesting and transportation.

Some of these resources, especially water is important not only in producing feedstock but also in processing it to fuels and chemicals.

Impact of biofuels on water resources can be estimated using amount of water needed per unit energy generated.

Average, Minimum and Maximum Nutrients in Soils

Element	Absorption forms	Average	Deficiency	Adequate
Macronutrients	*%*	*ppm*	*ppm*	*ppm*
Nitrogen	NO^{3-}, NH^{4+}	1-50	Na	Na
Potassium	K^+	50-200	<50	100
Calcium	Ca^{2+}	500-8000	<200	500
Magnesium	Mg^{2+}	2-100	<10	>50
Phosphorus	H_2PO^{4-}, HPO_4^{2-}	0-1000	<50	200
Sulfur	SO_4^{2-}	10	<7	>12
Micronutrients	*ppm*	*ppm*	*ppm*	*ppm*
Iron	Fe^{2+}, Fe^{3+}			
Manganese	Mn^{2+}	20-50	<10	
Boron	H_3BO_3	0.5-1.0	<0.1	>0.25
Copper	Cu^+, Cu^{2+}	10-30		
Zinc	Zn^{2+}	50-150	<1	>1.5
Molybdenum	$MoO4^{2-}$	50-150		
Nickel	Ni^{2+}	10-30		

Ref: Adapted from Forages: an Introduction to grassland Agriculture. R.B. Barnes et al.

Nutrient Requirements for Field Crops

Crop	Yield (t/ha)	Nutrient (Kg/ha)					
		N	P	K	Ca	Mg	S
Wheat	8 (3+5)	125	22	92	16	14	14
Barley	5.4 (grain)	168	27	139	-	19	22
Rice (IAC 25)	(3.256+ 4.073)	73	7	88			
Corn	9.5	152	28.5	28.5			

Ref: Adapted from Growth and mineral nutrition of field crops: Fageria, N.K. et al.

Best Management Practices for optimum nitrogen use

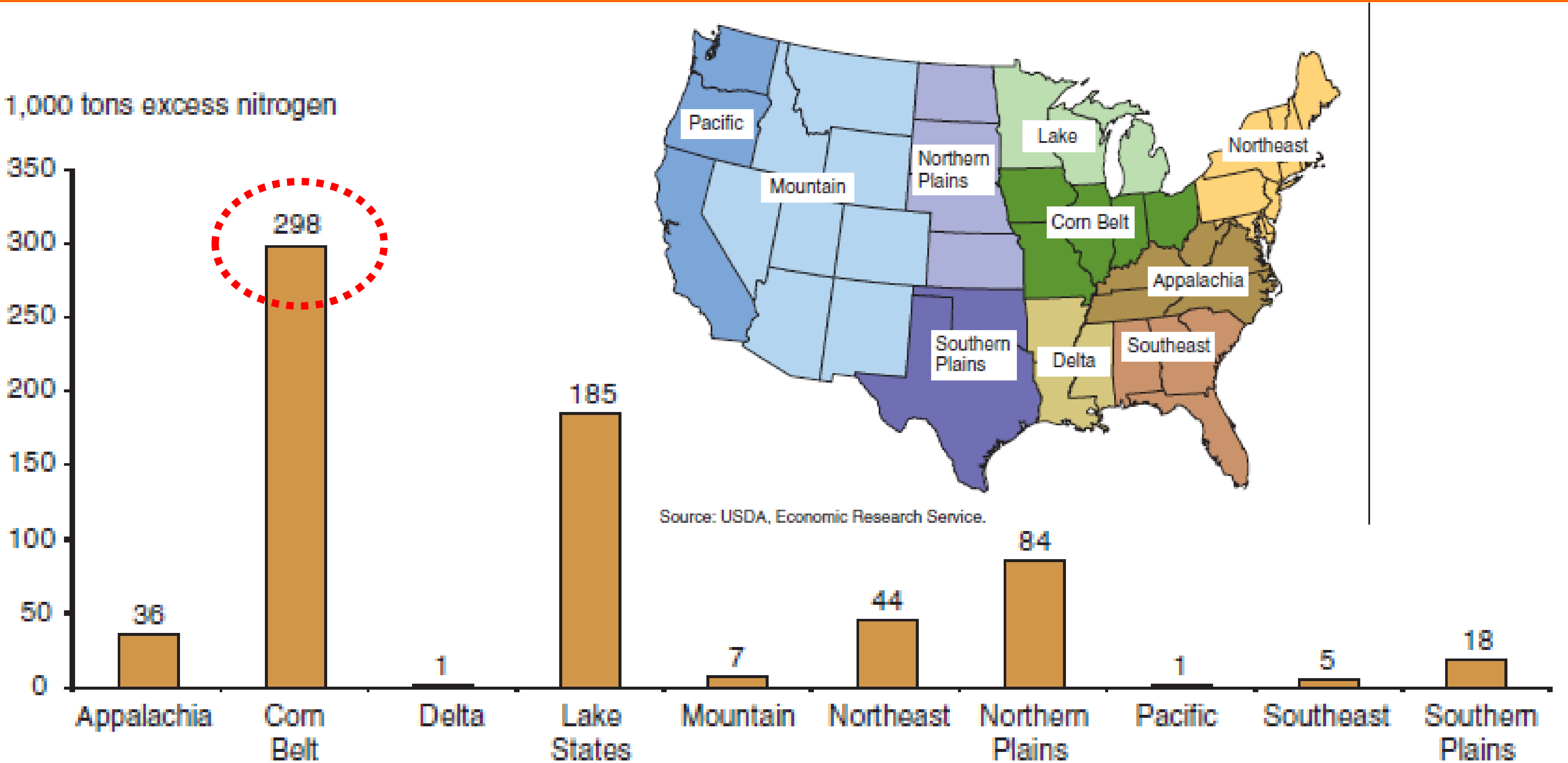
- Rate: Applying nitrogen at a rate that accounts for all other sources of nitrogen and soil-climate-plant interactions.
- Timing: Applying nitrogen on a need based strategy
- Method: Injecting or applying nutrients to prevent losses.

Why are BMPs difficult to implement:

- Ideal growth conditions: 179 lbs/acre nitrogen; 170 bushels of corn
- Non-ideal growth conditions: 165 lbs/acre nitrogen; 148 bushels/acre
- Economic risk factor : $0.50 /lbs nitrogen is $7/acre additional investment for a potential and economic payoff $4.50 /bu is $99/acre

http://www.ers.usda.gov/media/117596/err127.pdf

Resources: Nutrients

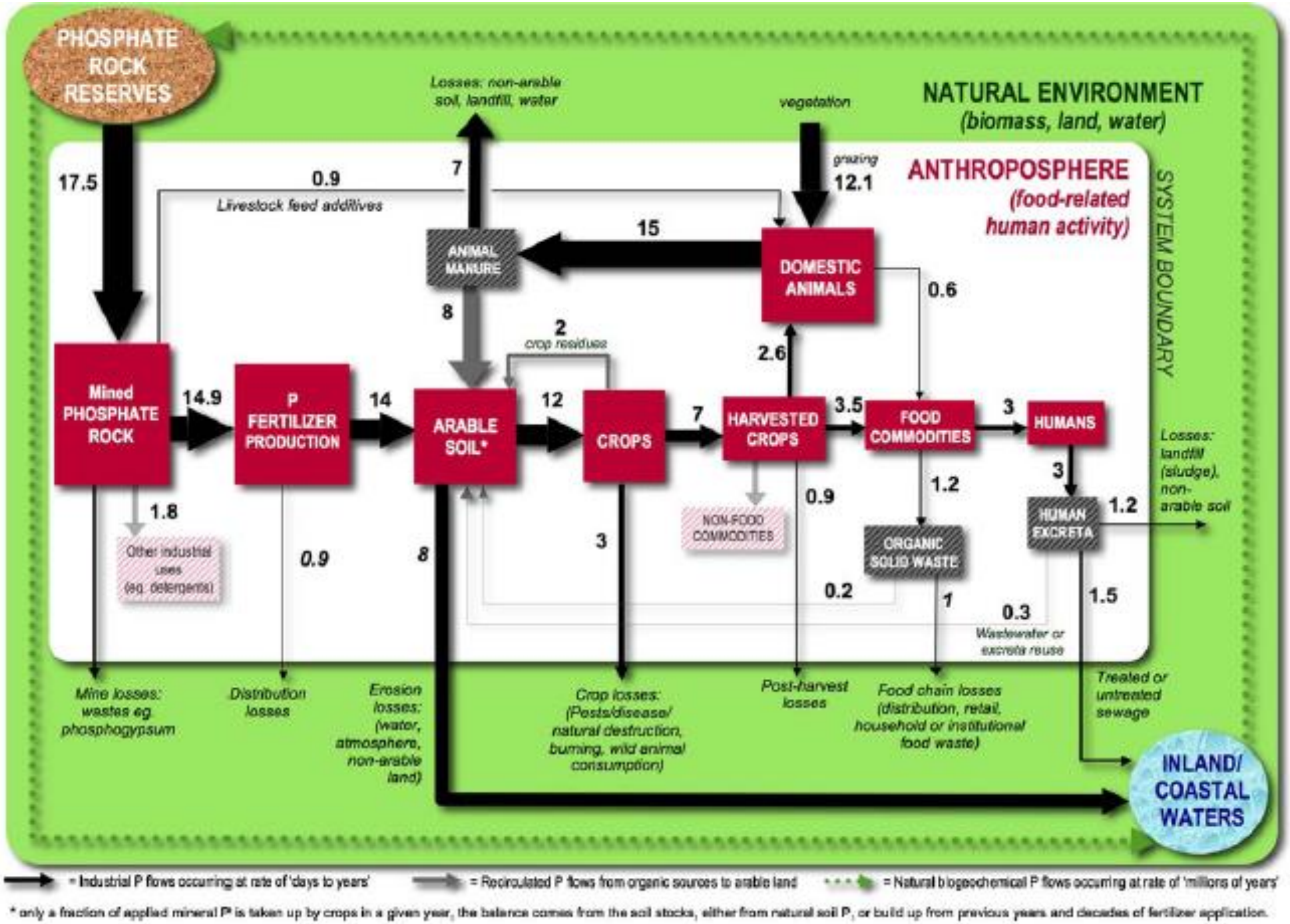


Note: Criterion rate defined as nitrogen removed at harvest plus 40 percent.
Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06).

http://www.ers.usda.gov/media/117596/err127.pdf

~78.6 million gal of Gasoline or $275 million

Resources: Nutrients



Ref: Cordell et al. 2009. Global Env. Change. 19:292-305.

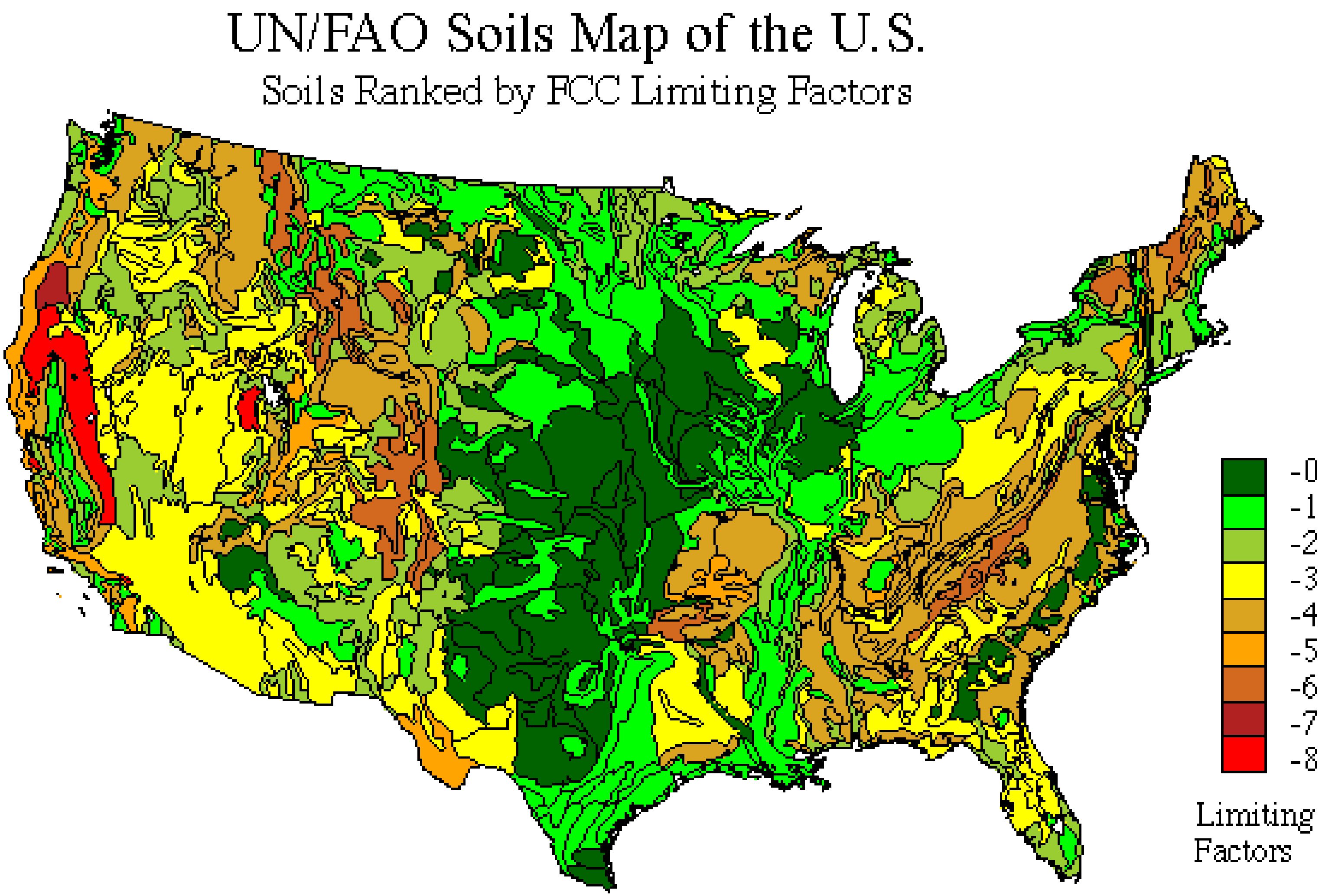
Feedstock Potential Evaluation

Agro climatic factors

- Soil type determines the supply of nutrients and fertilizer requirements.

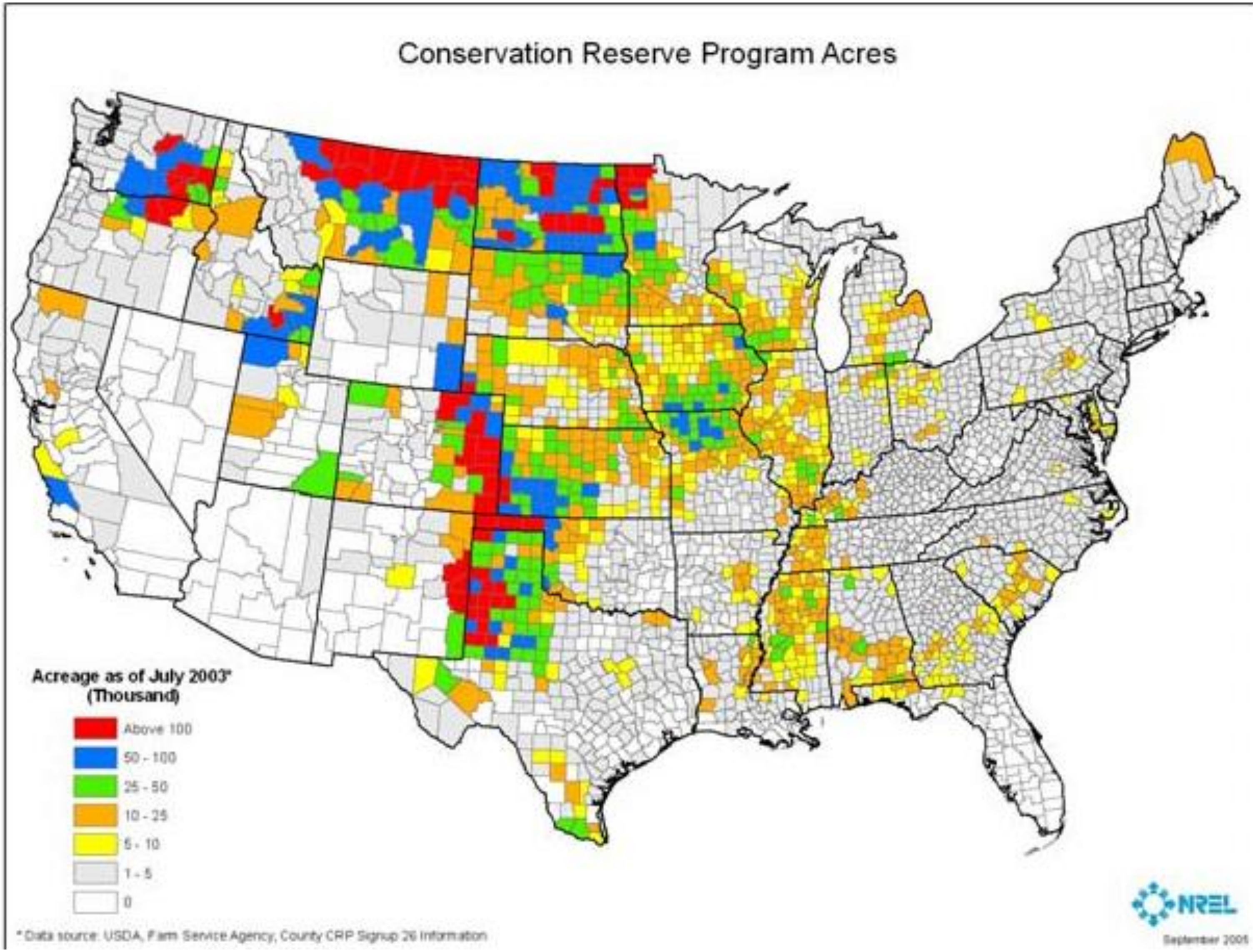
- Climate has an influence on water requirements for the crops. Ex. Local temperature and humidity determine the Evapotranspiration (ET) which in turn dictates the crop water requirements.

Feedstock Potential Evaluation: Soil Types



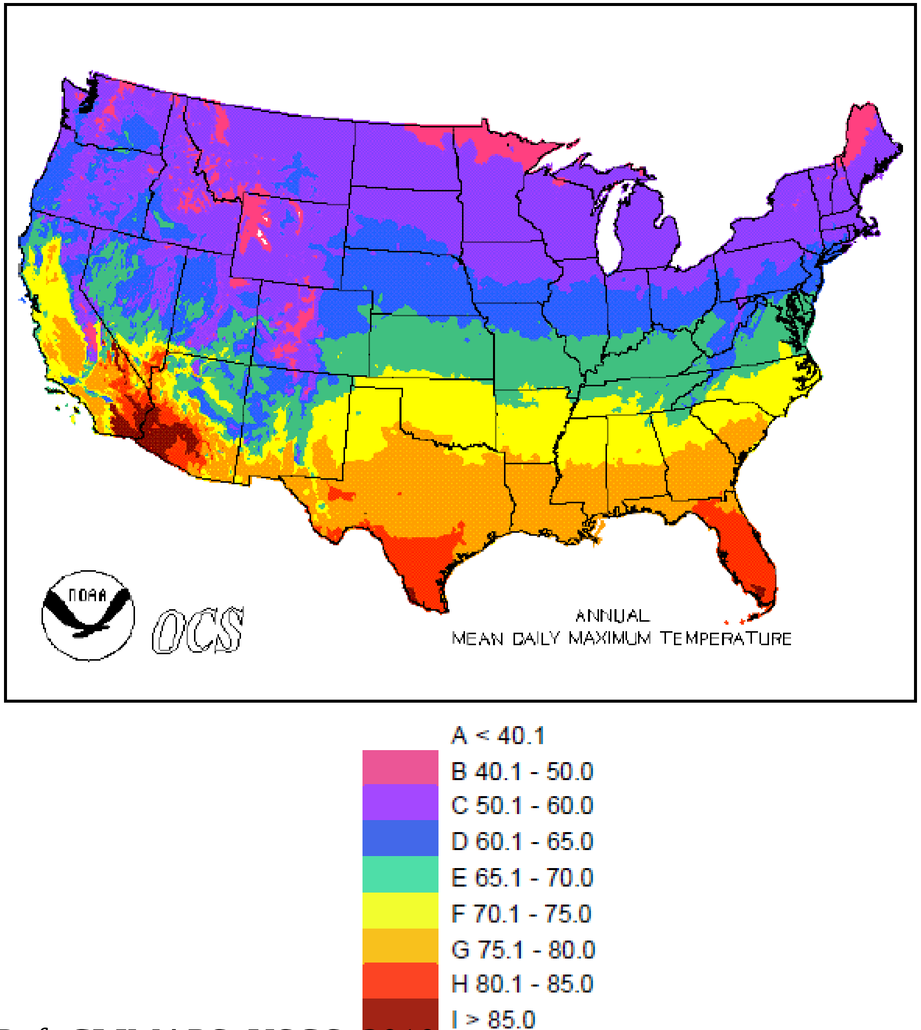
Ref : http://biology.usgs.gov/luhna/chap3.html

Conservation Reserve Program Lands in the US

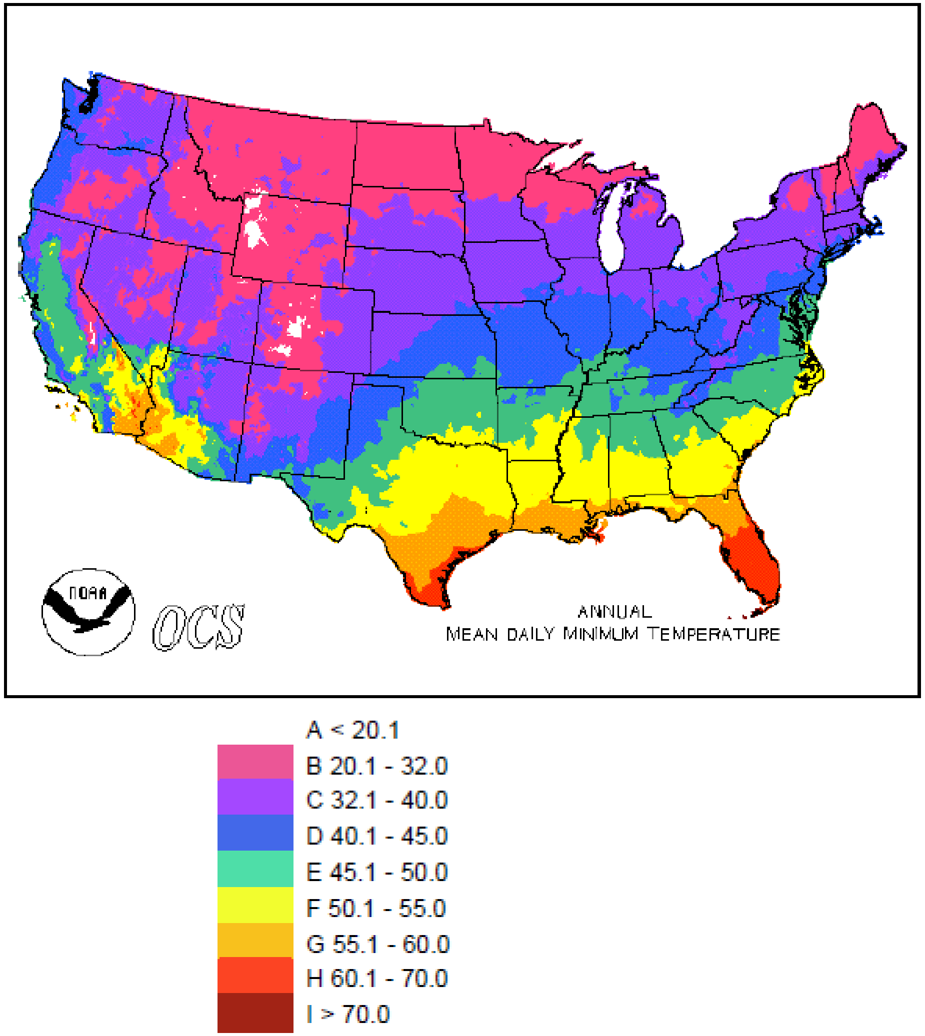


Resources: Climate

Daily Mean Maximum Temperature (F)



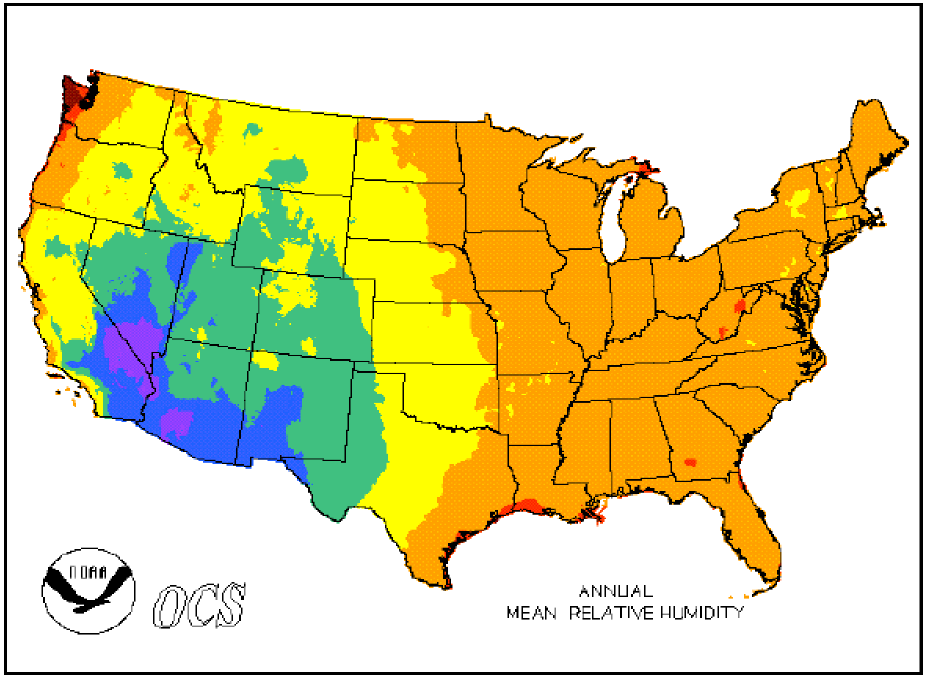
Daily Mean Minimum Temperature (F)

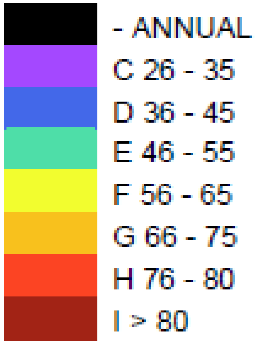


Ref: CLIMAPS, USGS, 2010

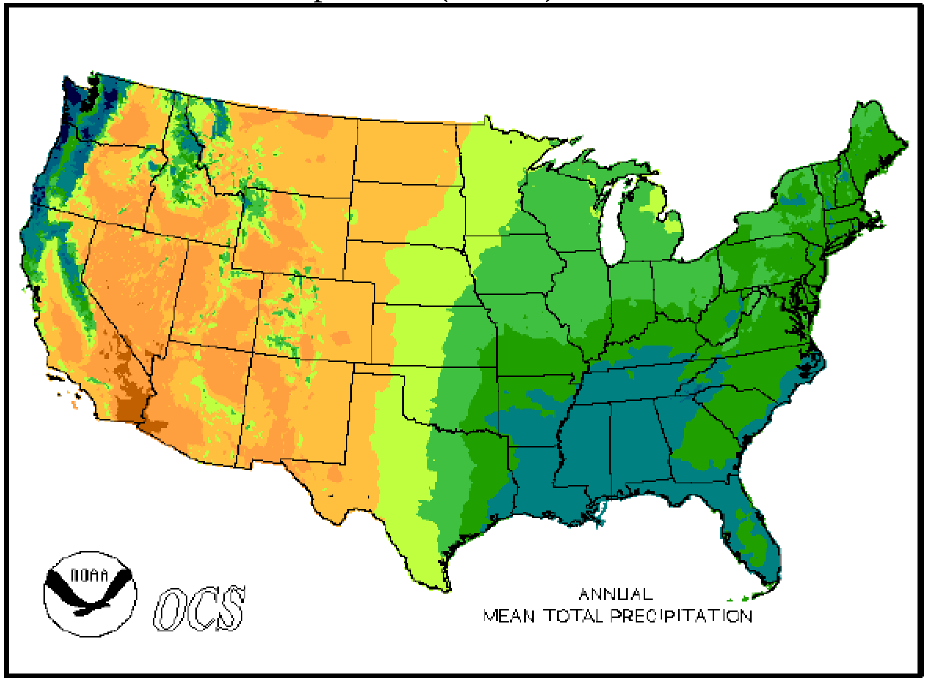
Resources: Climate

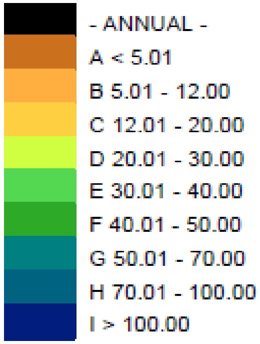
Daily Mean relative Humidity (%)





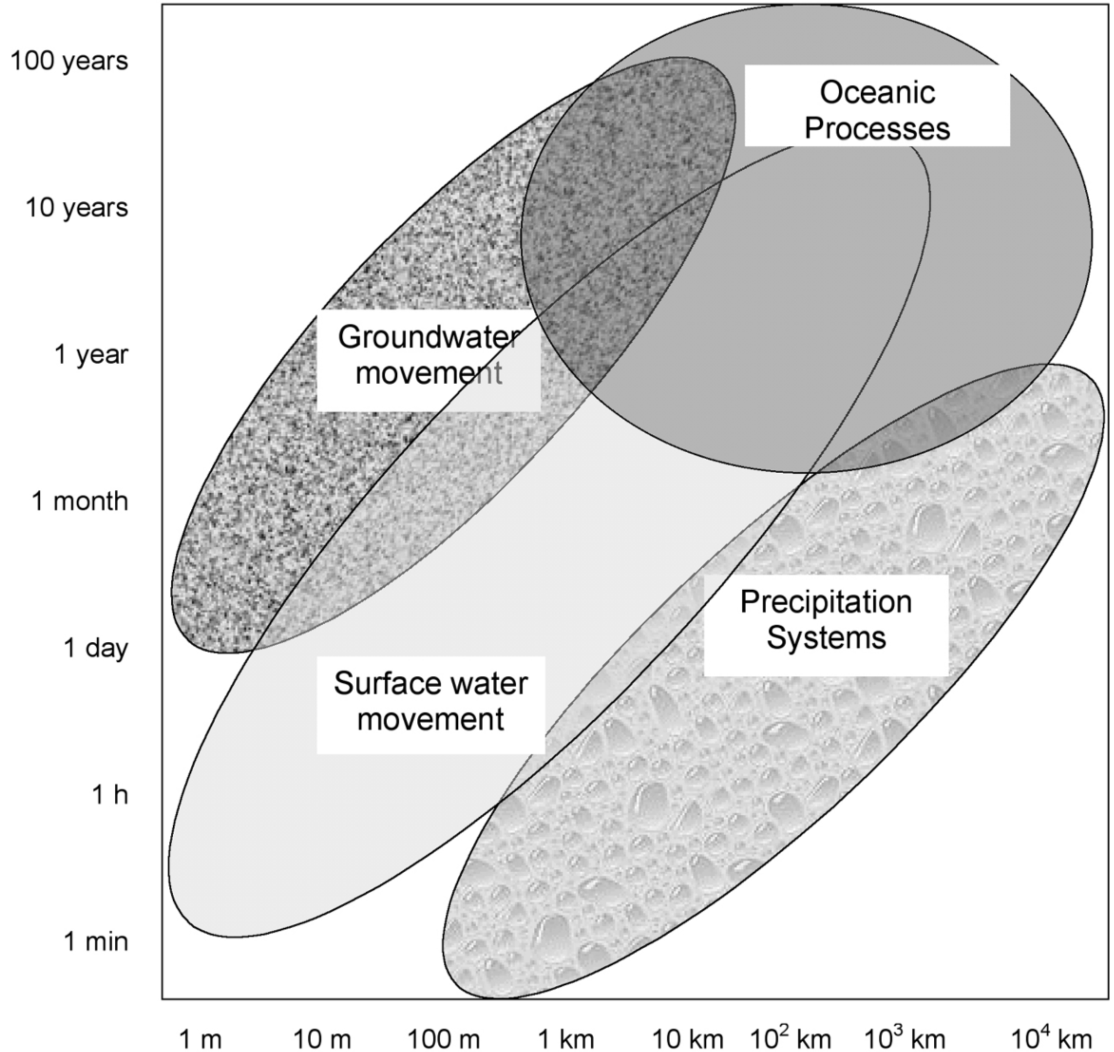
Annual Mean Precipitation (inches)





Ref: CLIMAPS, USGS, 2010

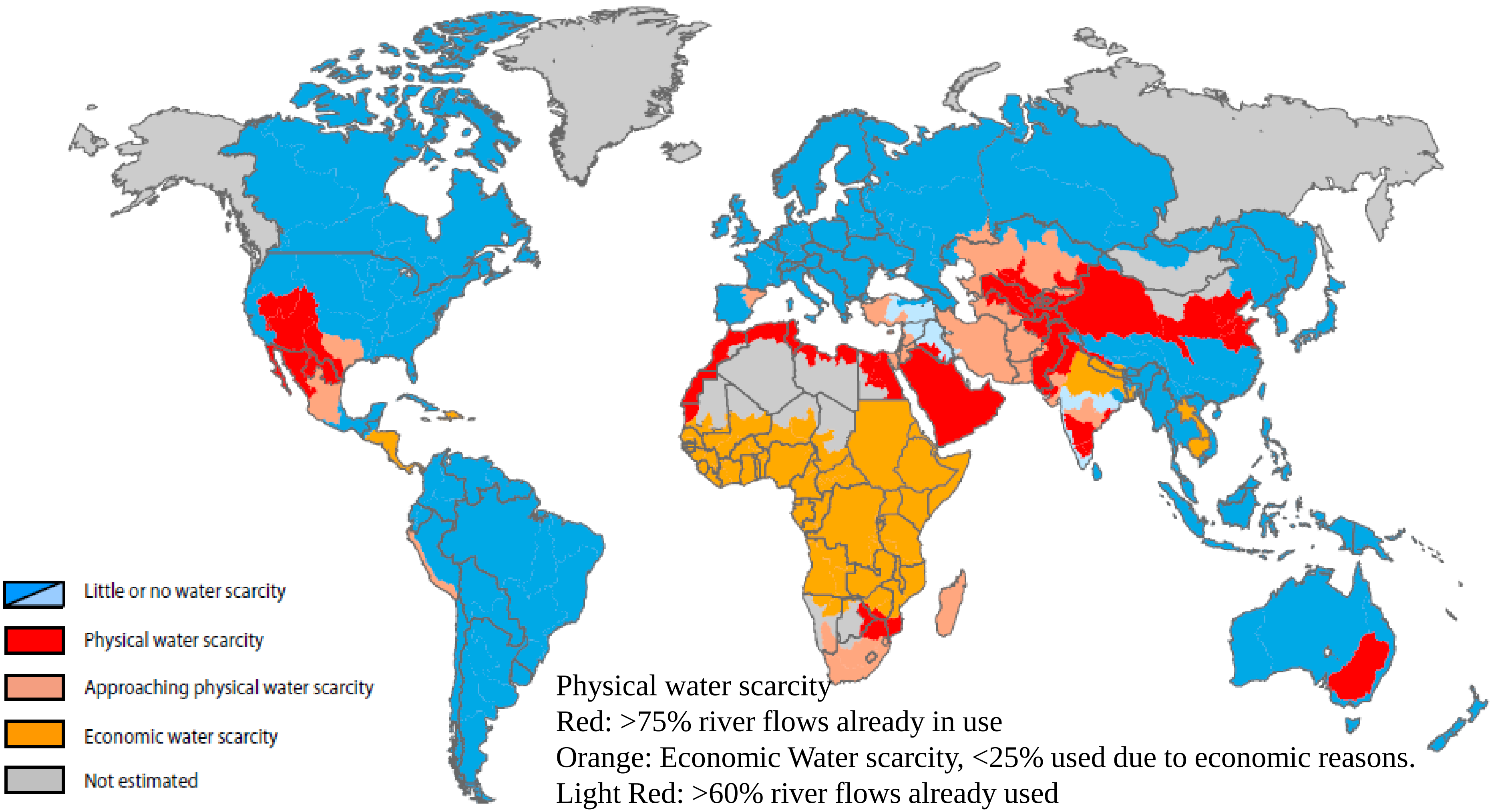
Spatial and Temporal Variation of Hydrologic Processes



Ref :http://www.usgcrp.gov/usgcrp/Library/watercycle/wcsgreport2001/wcsg2001chapter3.htm

Feedstock Potential Evaluation: Water Resources

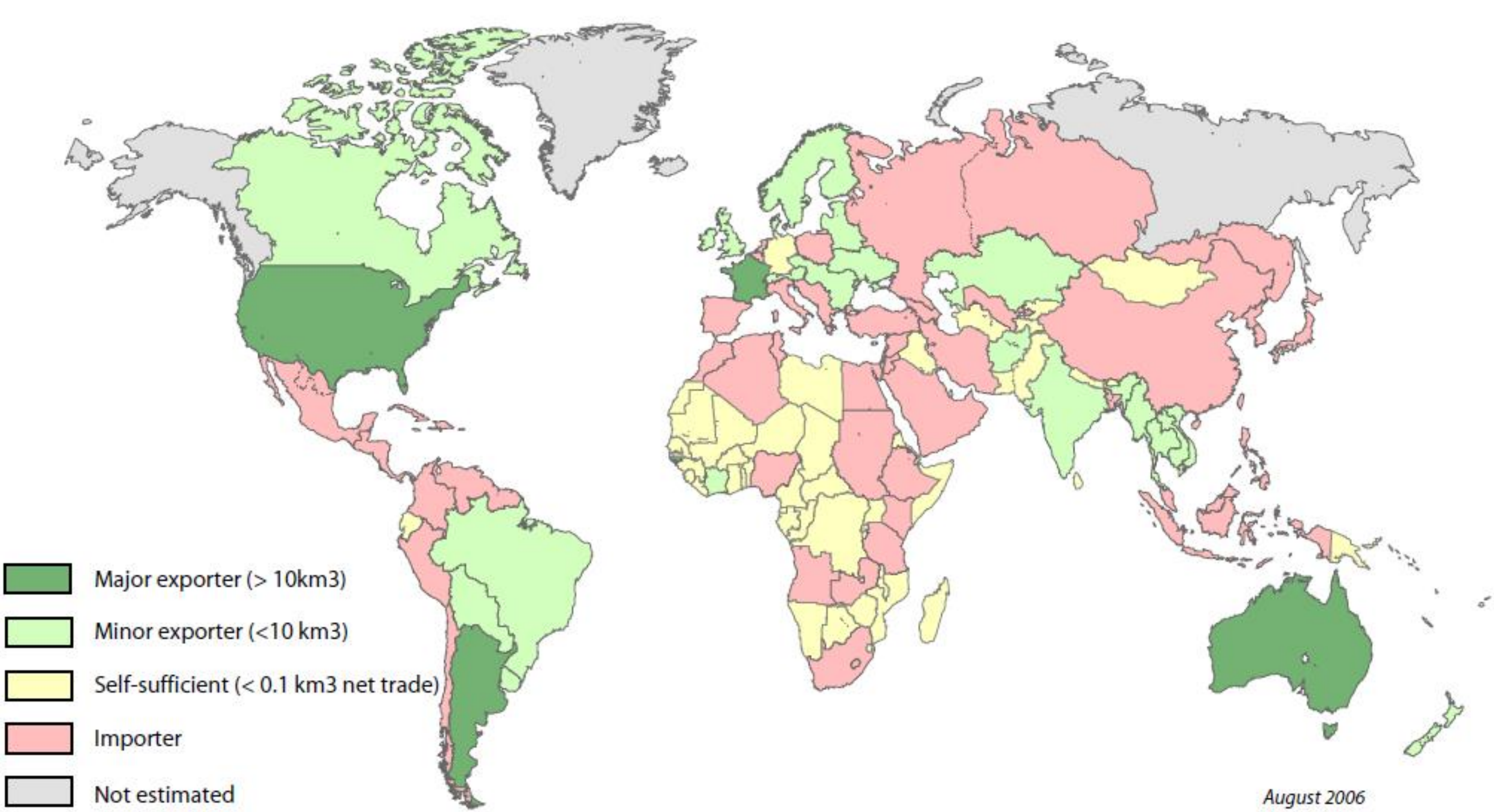
Resources: World Water Stress



Physical water scarcity
Red: >75% river flows already in use
Orange: Economic Water scarcity, <25% used due to economic reasons.
Light Red: >60% river flows already used
Blue: Water resources available.<25% is withdrawn for human purposes.

Ref: .Comprehensive Assessment of Water Management in Agriculture, International Water Management Institute, 2006.

Resources: Movement of Virtual Water

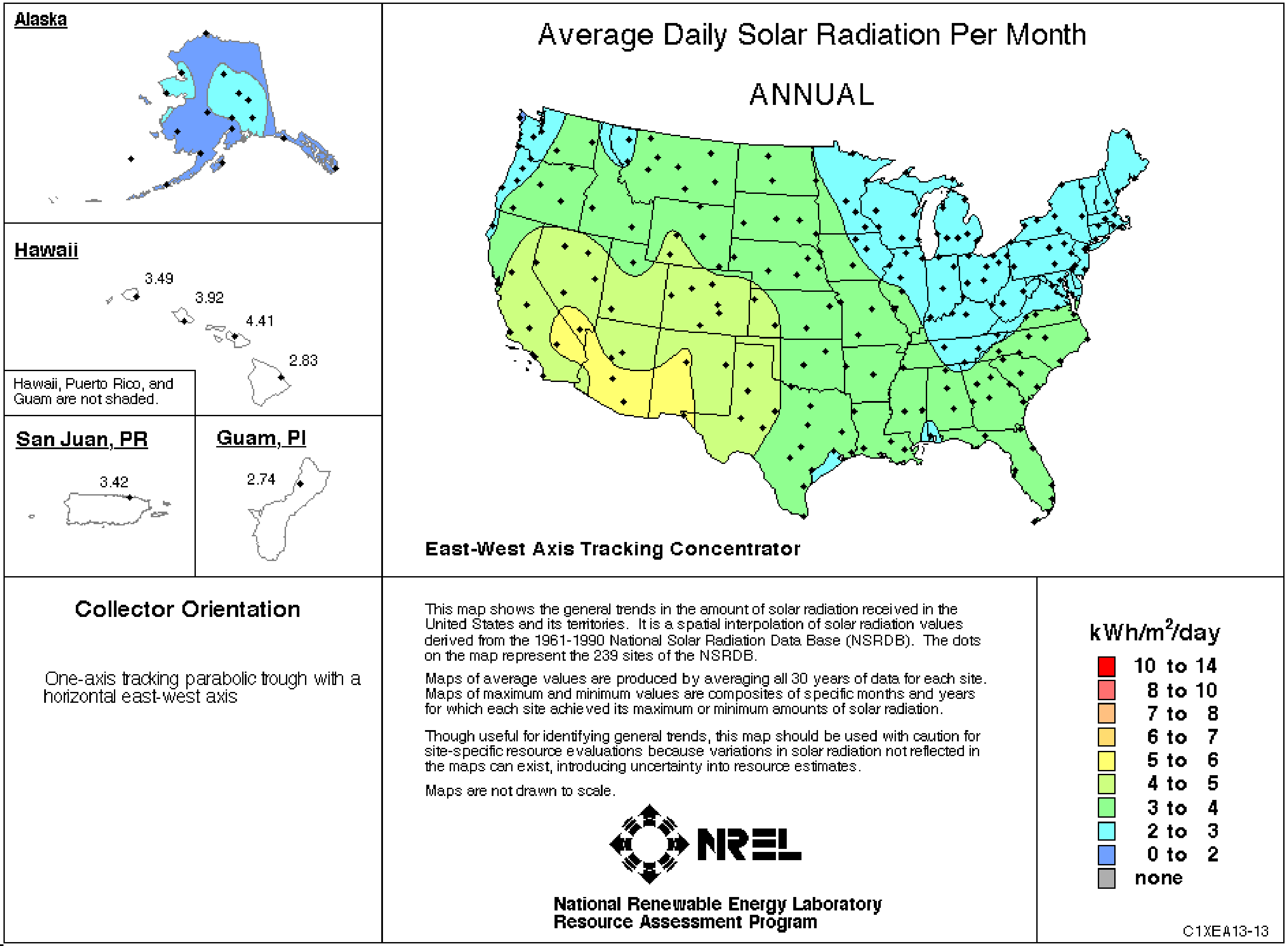


Ref: .Comprehensive Assessment of Water Management in Agriculture, International Water Management Institute, 2006.

EROEI and EROWI for Different Fuels

	Water usage (L/MJ)	EROWI (MJ/L)	EROEI (MJ/MJ)	Net EROWI
Nuclear Electric	1.162(0.145)	0.861(1.517)	10	0.775 (1.137)
Coal Electric	0.560(0.488)	1.786 (2.049)	-	-
Conv. Diesel	0.0035	285.3	5.01	228.4
Biodiesel				
Rapeseed	100-175	0.010-0.0057	2.33	0.0057-0.0033
Algae (Ponds)	20.142*	0.004965	3.33	0.03475
Ethanol				
Sugarcane	38-156	0.026-0.0065	8.3	0.023-0.0057
Corn	73-346	0.014-0.0029	1.38	0.0039-0.00081
Lignocellulosic Crops				
Ethanol	11-171	0.091-0.0058	4.55	0.0071-0.0045
Hydrogen	15-129	0.067-0.0078	4.67	0.053-0.0062
Electricity	13-195	0.077-0.0051	5.0	0.062-0.0041

Feedstock Potential Evaluation: Solar Insolation



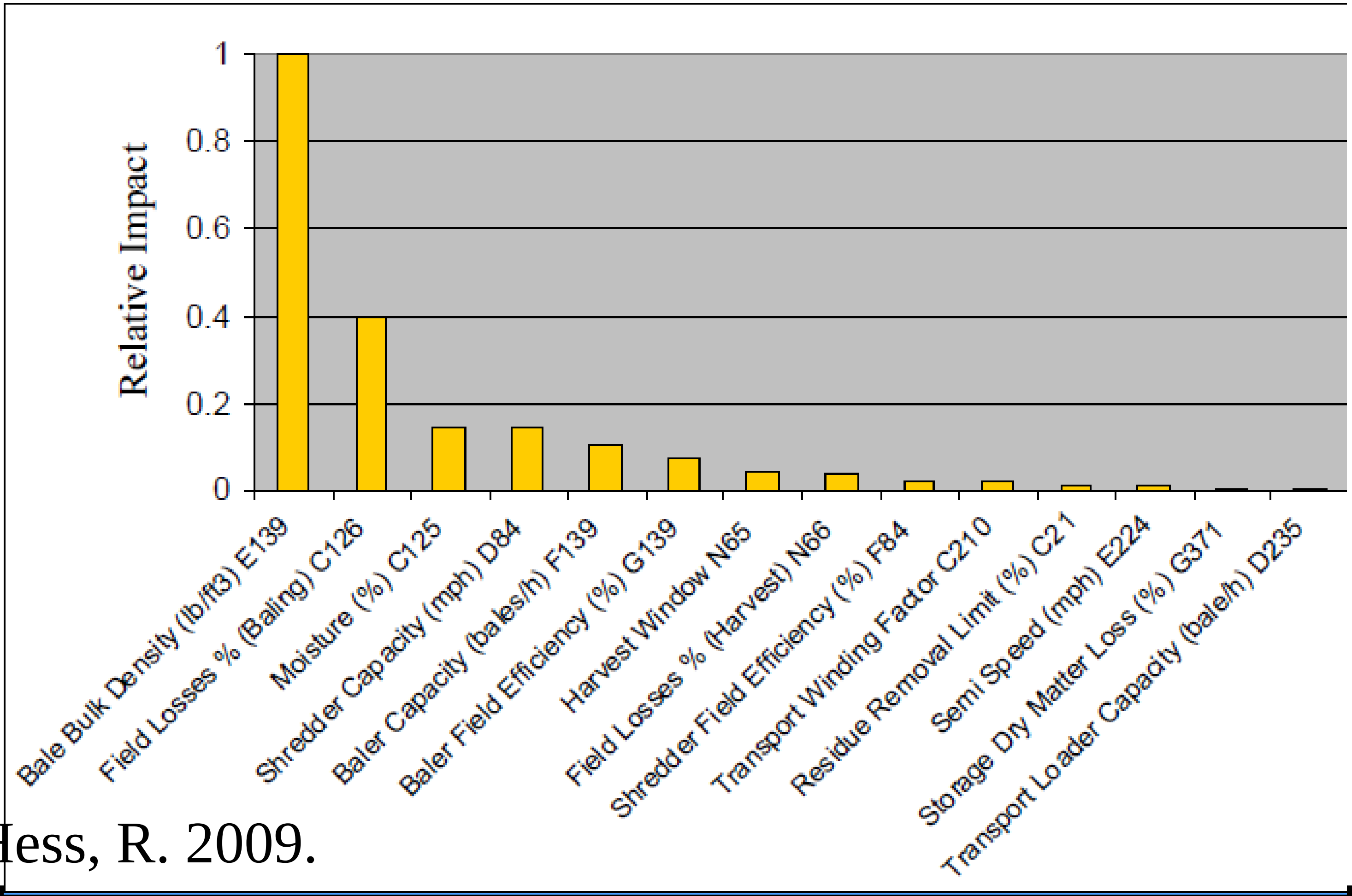
Feedstock Potential Evaluation

Economic factors

- Can the feedstock be produced in large quantities cheaply?
- What is the opportunity cost of producing the feedstock?
- What is the cost of delivering a unit mass of feedstock to the plant?

Feedstock Logistics

Harvesting, collection, preprocessing (optional) and transportation to factory gate are important steps in feedstock logistics.



Ref: Hess, R. 2009.

Feedstock Evaluation Factors

- Composition
- Climate
- Water requirement
- Fertilizer use
- Current production levels and future trends
- Supply chain factors
- Conversion Technologies
- Coproducts and their use

Case Study: Ethanol Potential in Oregon

- Estimate the ethanol production potential for a potential ethanol plant site. Assume the following.
  - The ethanol plant location is in Eastern Oregon.
  - The operational radius to obtain feedstock is 40 km.

Case 1: The ethanol plant has feedstock flexibility and can use agricultural residues and herbaceous biomass.

Case 2: The ethanol plant is designed to use wheat straw as the sole feedstock.

Case Study: Ethanol Potential in Oregon

Solution steps:

1. Estimate the available feedstock.
2. Estimate the composition of the feedstock
3. Estimate the ethanol production per ton of feedstock using the chemical composition.
4. Estimate the ethanol potential using the ethanol production per ton of feedstock and total available feedstock.

Additional Resources

- NREL Biofuels Atlas : http://maps.nrel.gov/biomass
- DOE Biomass composition database: http://www.afdc.energy.gov/biomass/progs/search1.cgi
- US DOE Bioenergy KDF: https://www.bioenergykdf.net/
- DOE Alternative Fuels Data Center: http://www.afdc.energy.gov/fuels/ethanol_feedstocks.html
- AQUASTAT database: http://www.fao.org/nr/water/aquastat/data/query/results.html
- NREL Biomass Research : http://www.nrel.gov/biomass/
- NREL GIS Tools: http://www.nrel.gov/gis/tools.html
- Bioenergy Feedstock Information Network: http://bioenergy.ornl.gov/main.aspx
- US DOE, EERE Bioenergy Technologies Office: http://www.energy.gov/eere/bioenergy/bioenergy-technologies-office
- Cellulosic Ethanol Plants information around the world (maintained by EIA):

  http://biofuels.abc-energy.at/demoplants/

Thank you