Cellulosic Biomass for Bioenergy: Economic and Analytical Issues

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Outline of presentation

1 Bioenergy applications: Current status

2 Bioenergy targets and limits of current technology

3 Next generation bioenergy processes: Role of cellulosic biomass

4 Biomass feedstock: Technical versus economic potential

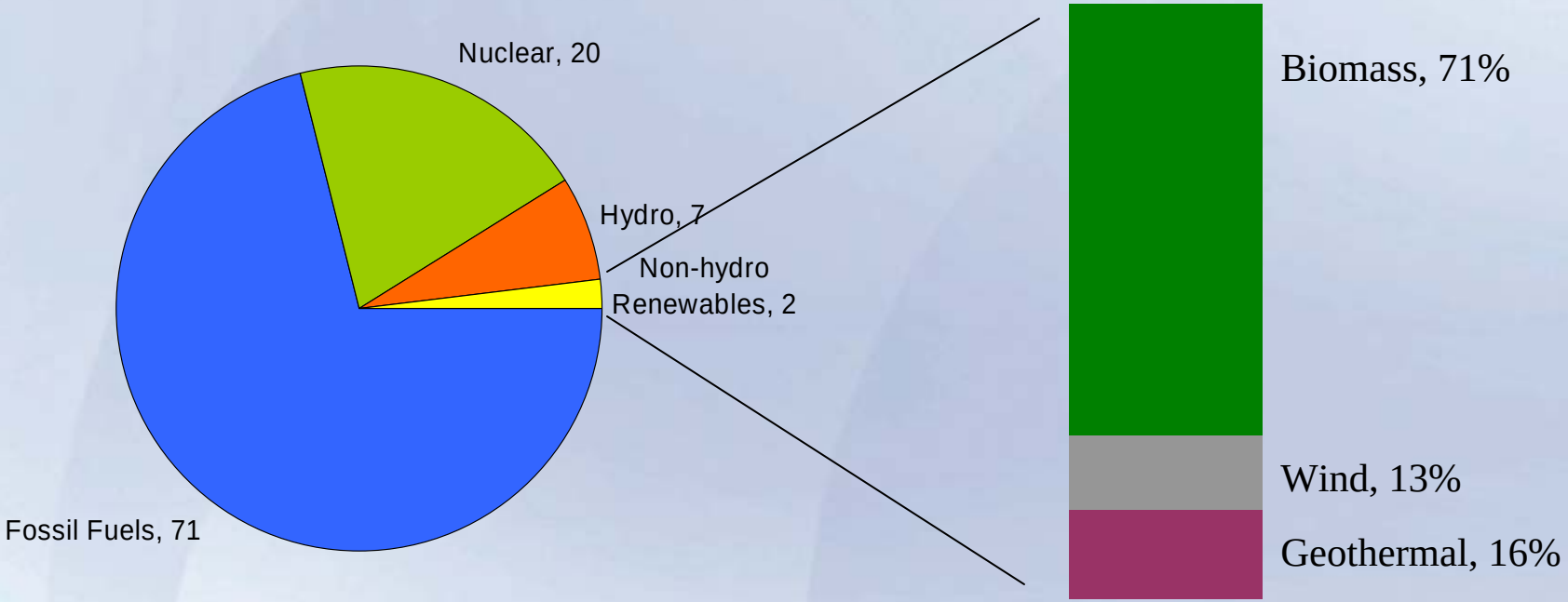
5 Policy incentives for bioenergy markets: Reconciling multiple goals

6 Potential for global trade in bioenergy markets

Current biomass resources and product markets- A snapshot

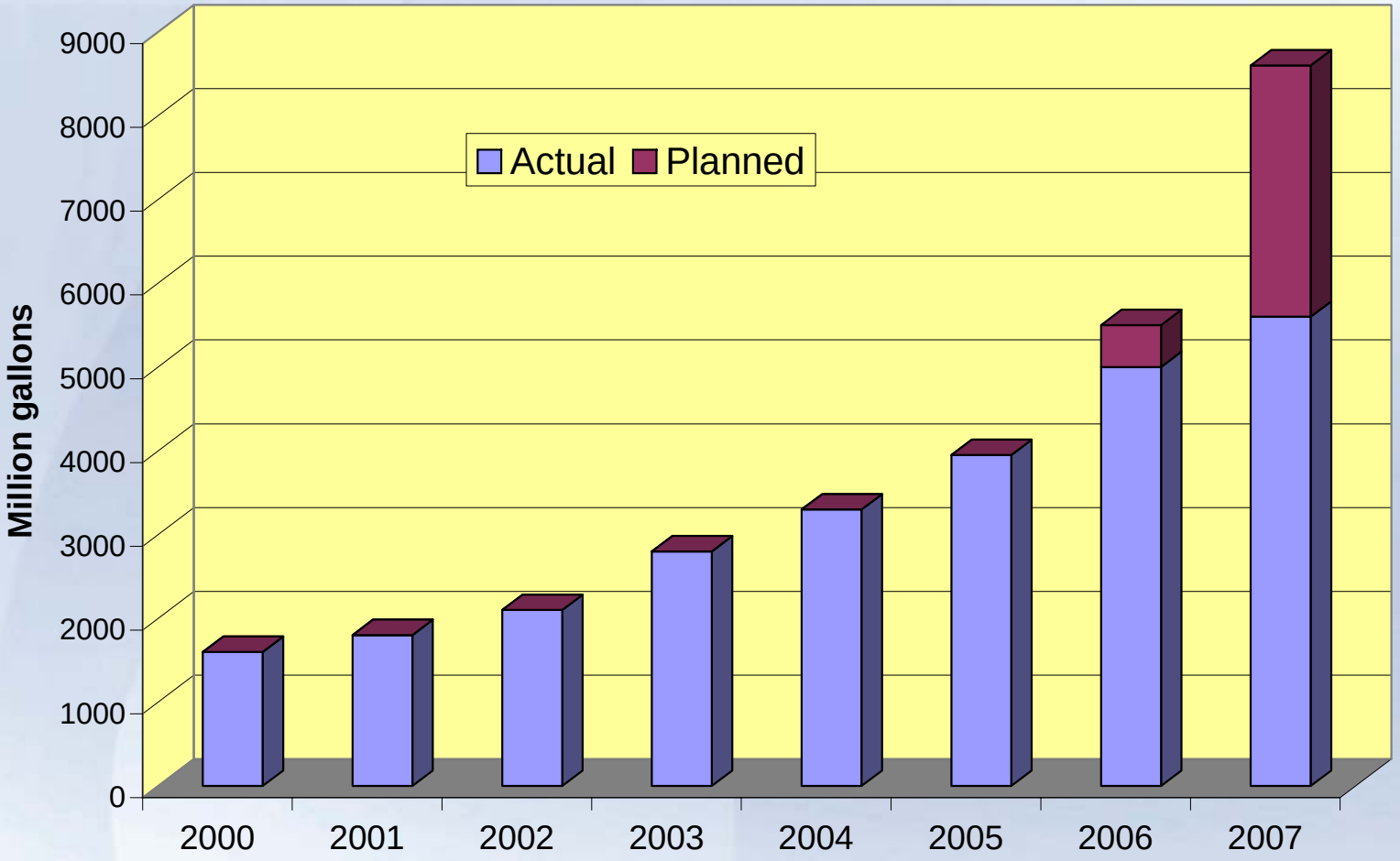
Feedstock Source	PRODUCT MARKETS		
	Transportation Fuels	***Chemicals and Materials***	***Electricity***
Grains (corn, wheat) Sugar crops	Ethanol	Starches, Sugars, Animal feeds, Organic chemicals	
Oilseed Crops	Biodiesel	Industrial oils, Animal feeds, Organic chemicals	
Wood		Paper, pulp, Wood products	Steam cycle, C-firing with coal Anaerobic digestion, Landfill Gas, Combustion with steam cycle,

US Electricity generation, 2003

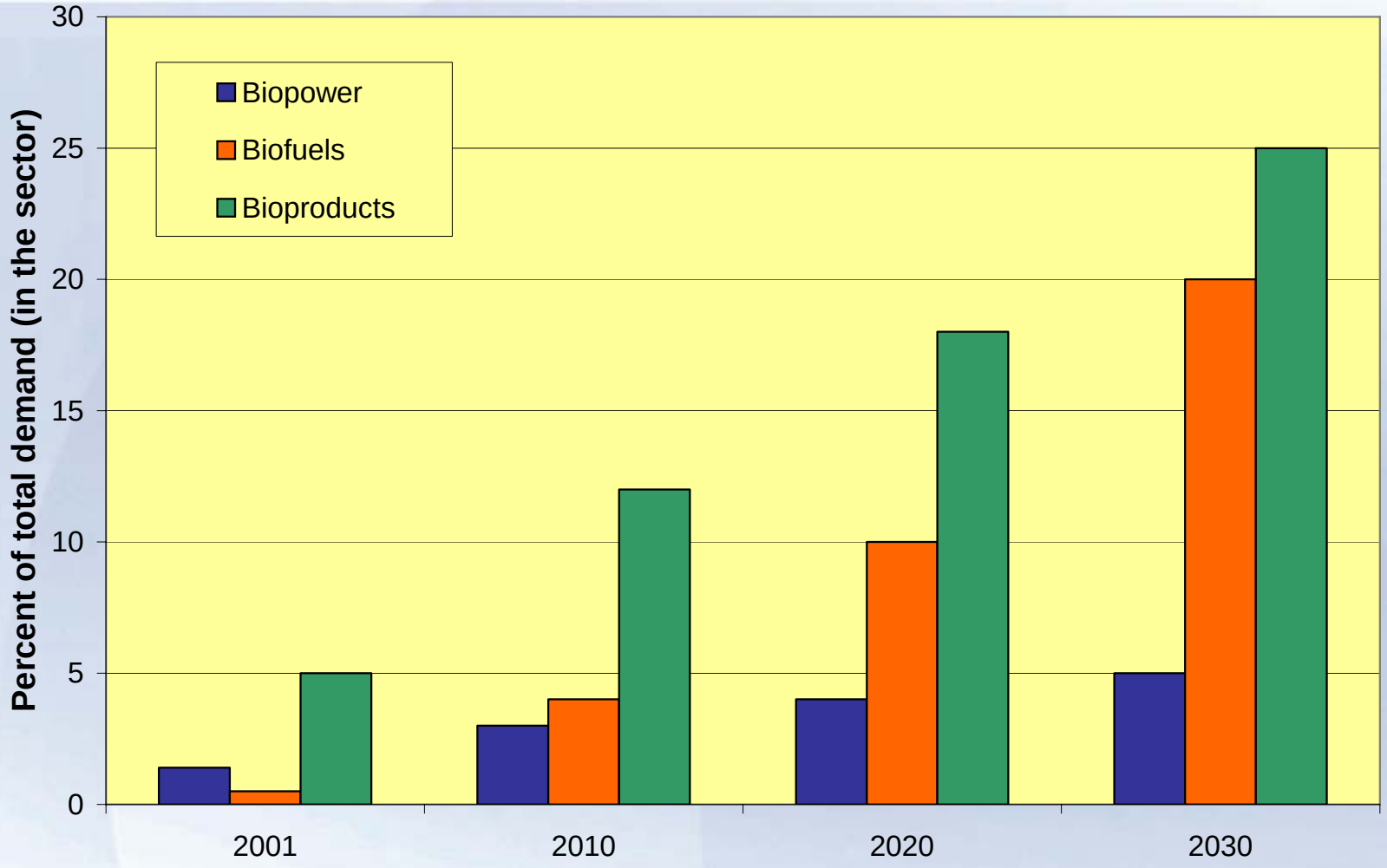


Source: EIA, 2004

U.S. ethanol production trends



Ambitious targets for future biomass & bioenergy uses (USDOE)

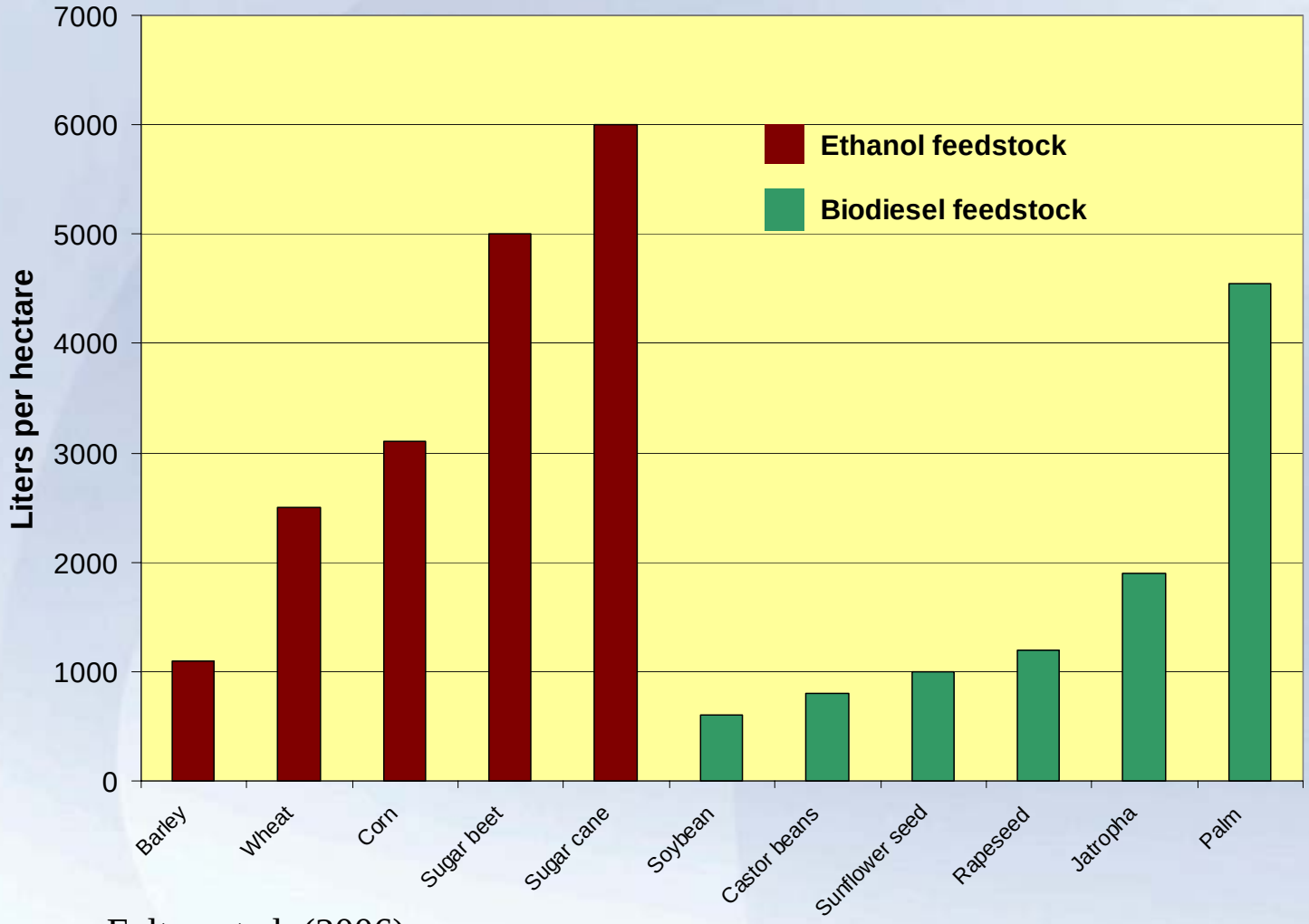


Current technologies not enough to meet DOE ambitious targets

Assessing the limits of current grain-to-ethanol technologies in terms of:

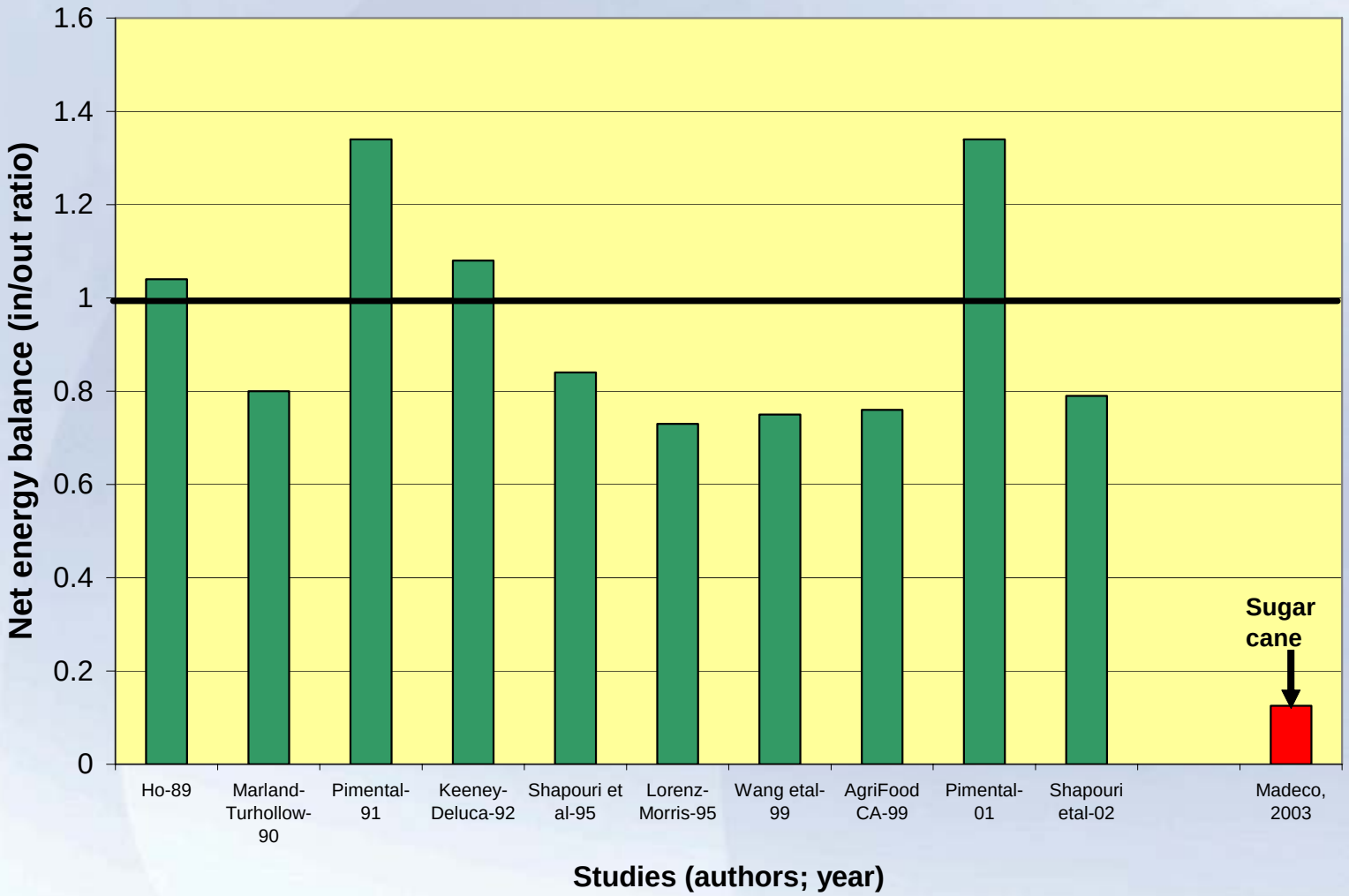
- **Yield (energy/acre)**
- **Cost ($/unit of energy)**
- **Net Energy balance (energy in/energy out)**
- **Greenhouse Gas (GHG) emission savings**

Biofuel yields vary across grain/oil/sugar crops--require lots of land to meet targets



Source: Fulton et al. (2006)

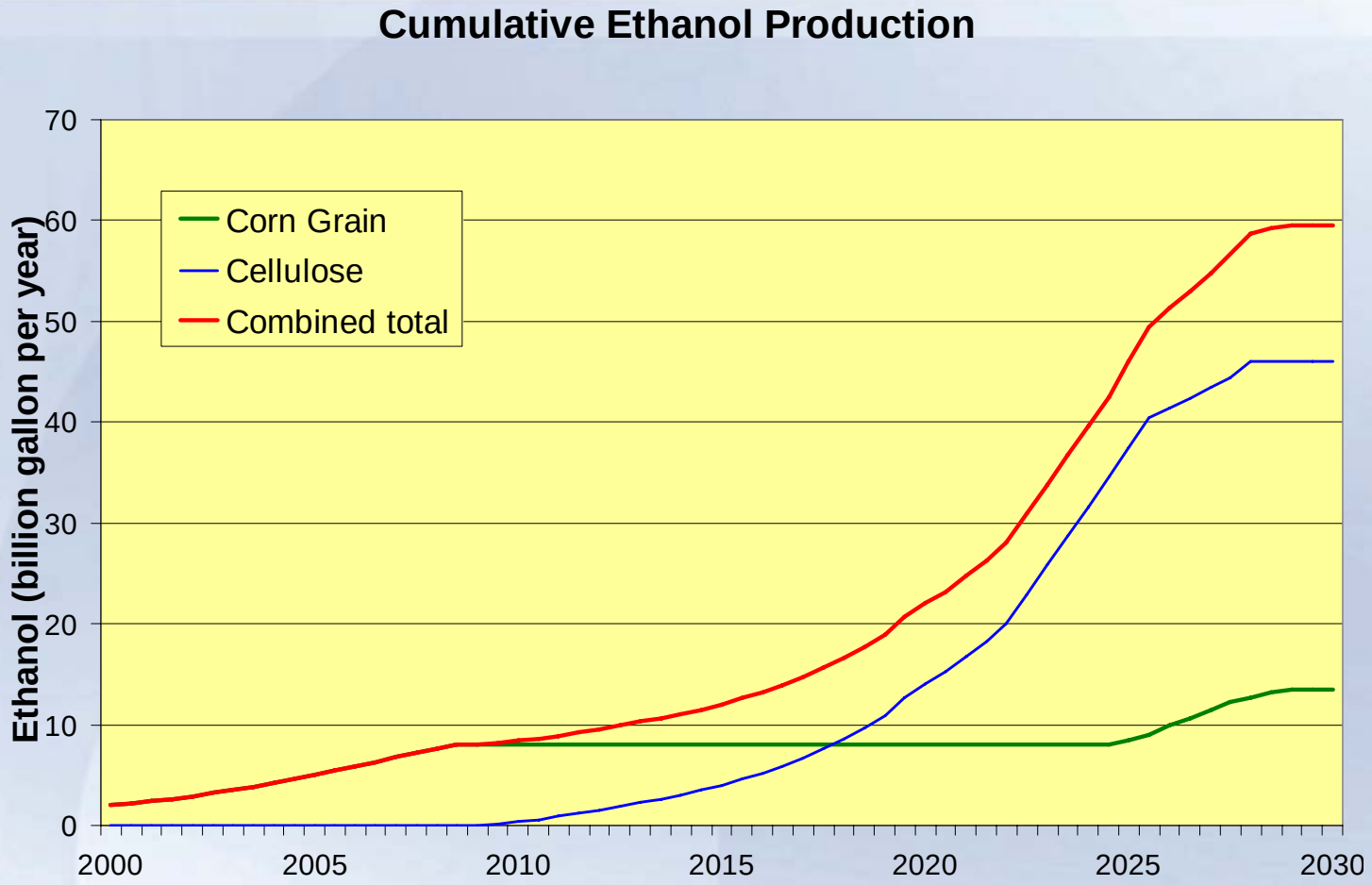
Net Energy Balance for Corn-to-Ethanol: On balance positive (out > in), but small



Next generation bioenergy: Advantages of CELLULOSIC BIOMASS

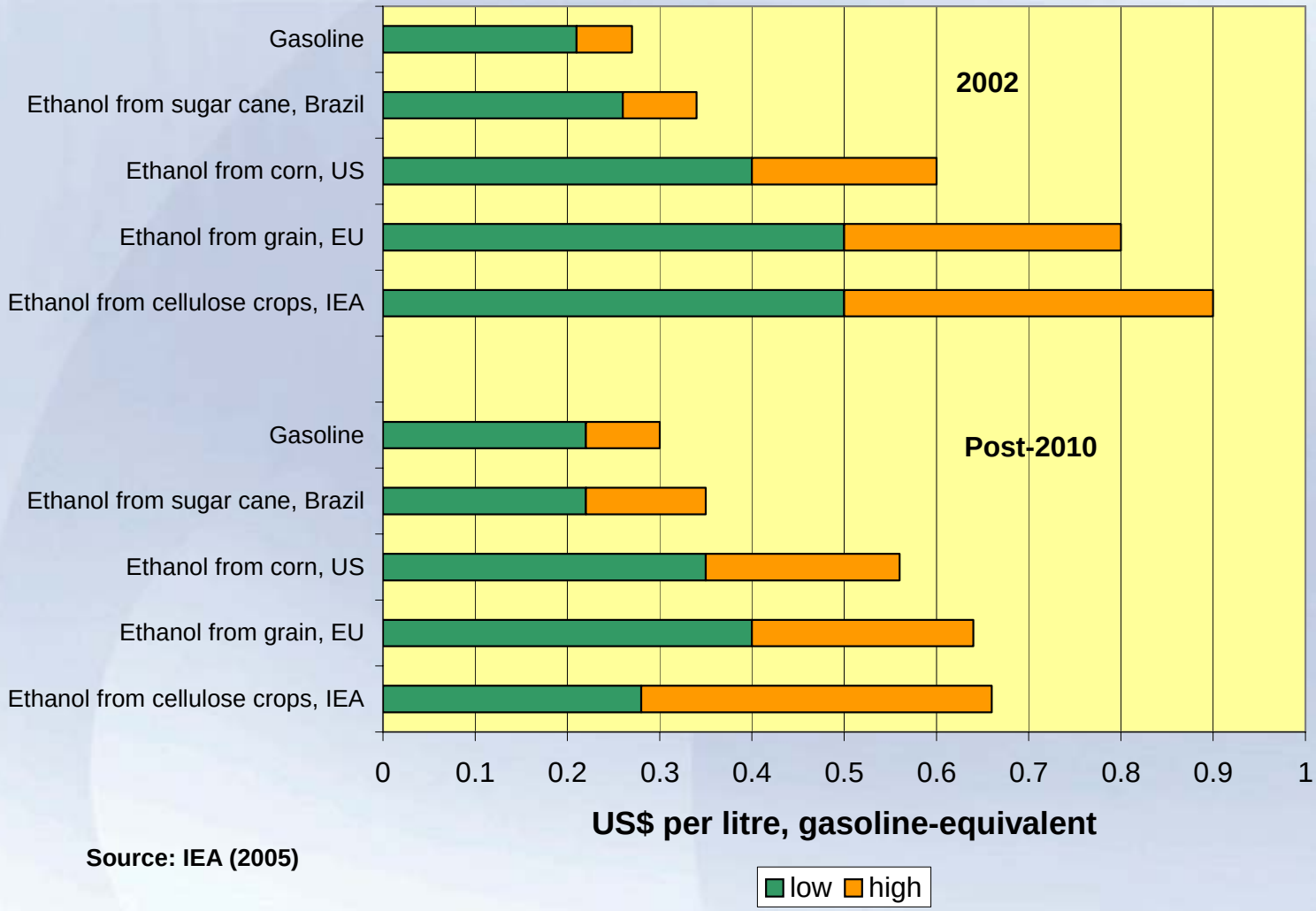
- Potential for large widespread energy supply from plants
- Significant potential for fossil energy displacement
- Diverse and ample supply of biomass feedstocks
- Multiple conversion processes and products
- Higher performance for energy balance & GHG reductions
- Possible opportunities for participation across all U.S. regions

High potential ethanol production from cellulose: Estimated scenario under high oil prices



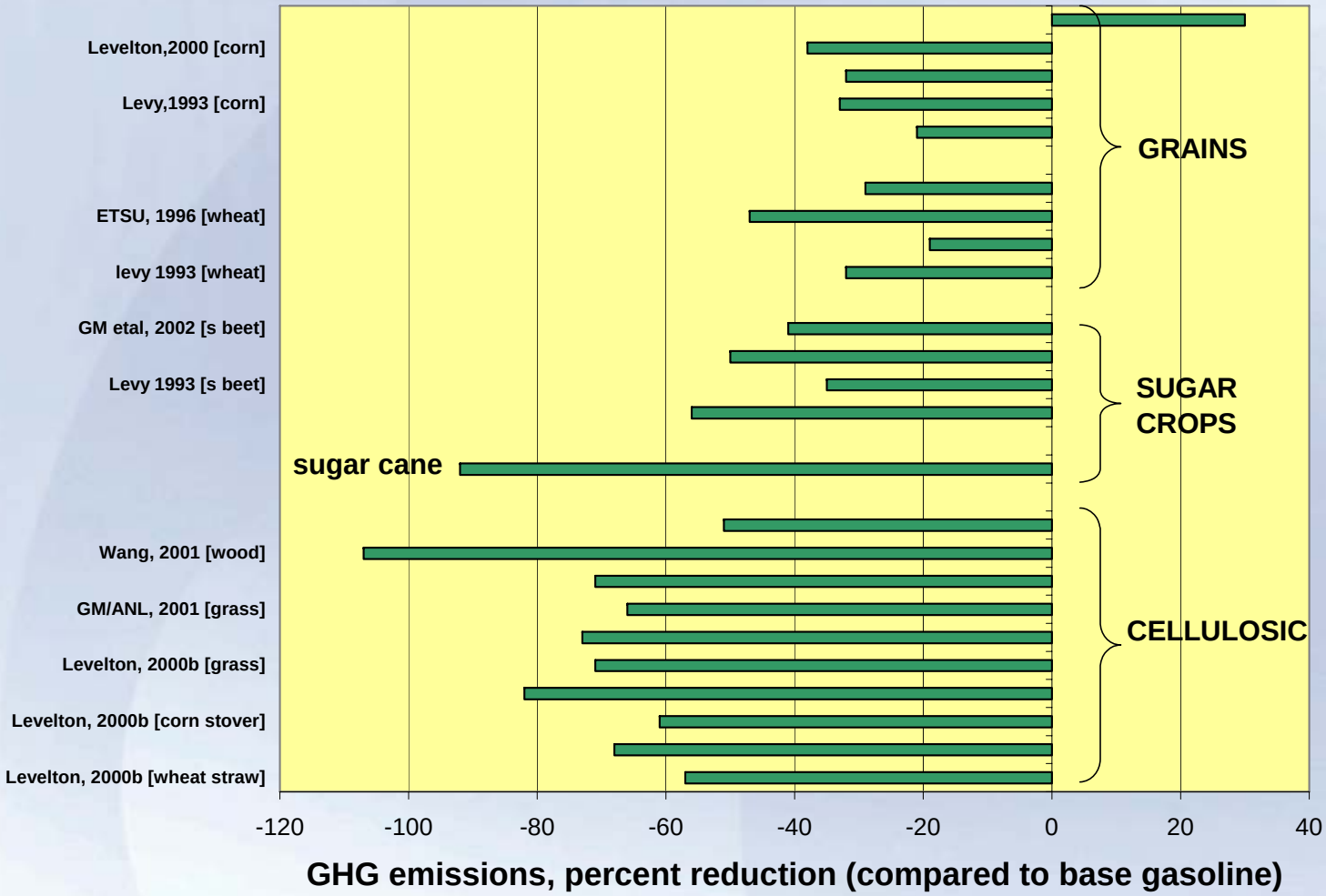
Source: National Renewable Energy Laboratory (2006)

Cost of ethanol production relatively high for current technologies

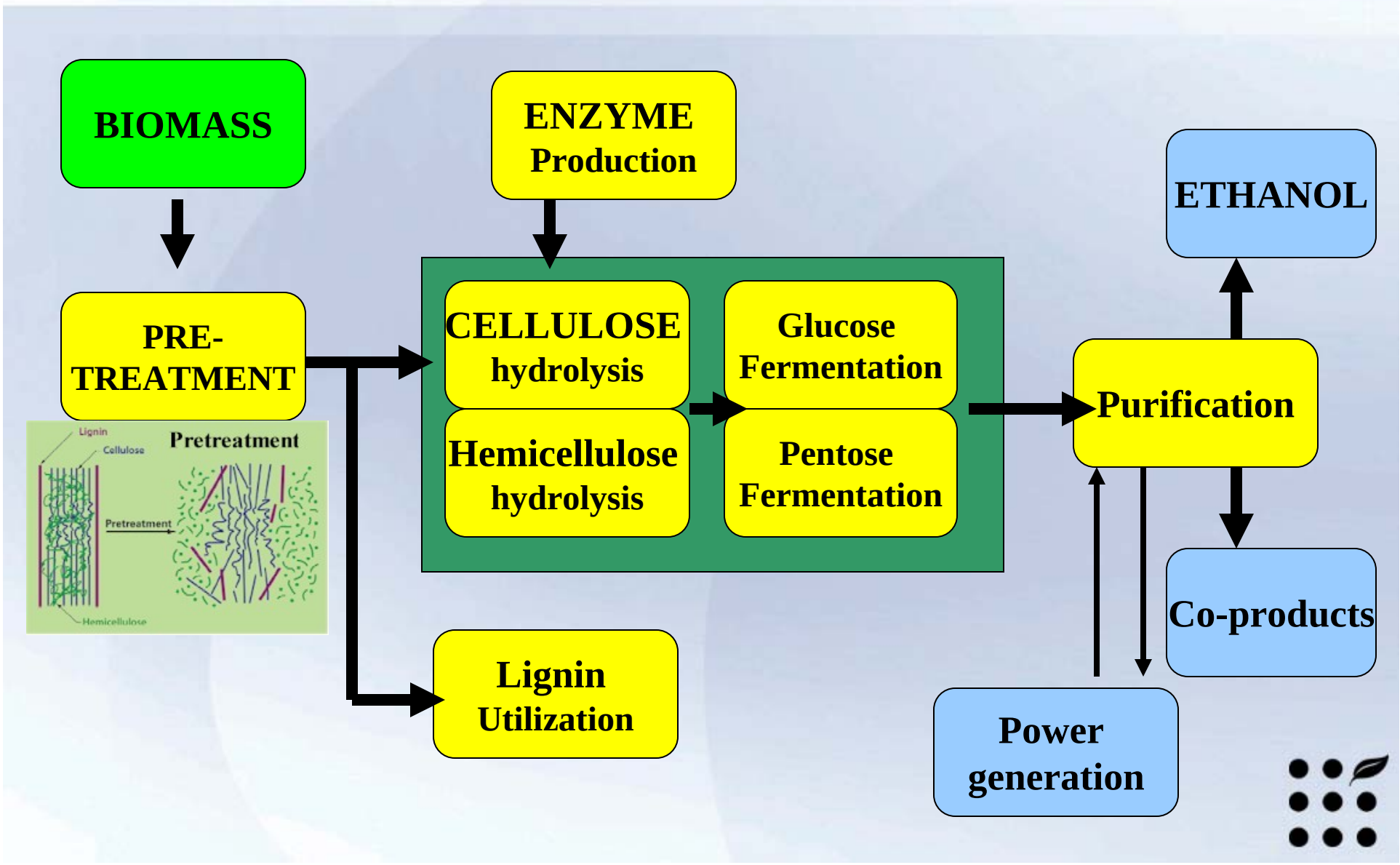


Source: IEA (2005)

Reductions in GHG emissions– Larger gains from cellulosic compared to grain/oil crop sources



Cellulosic ethanol conversion– Technological progress and challenges



Cellulosic ethanol conversion: Current process and cost challenges

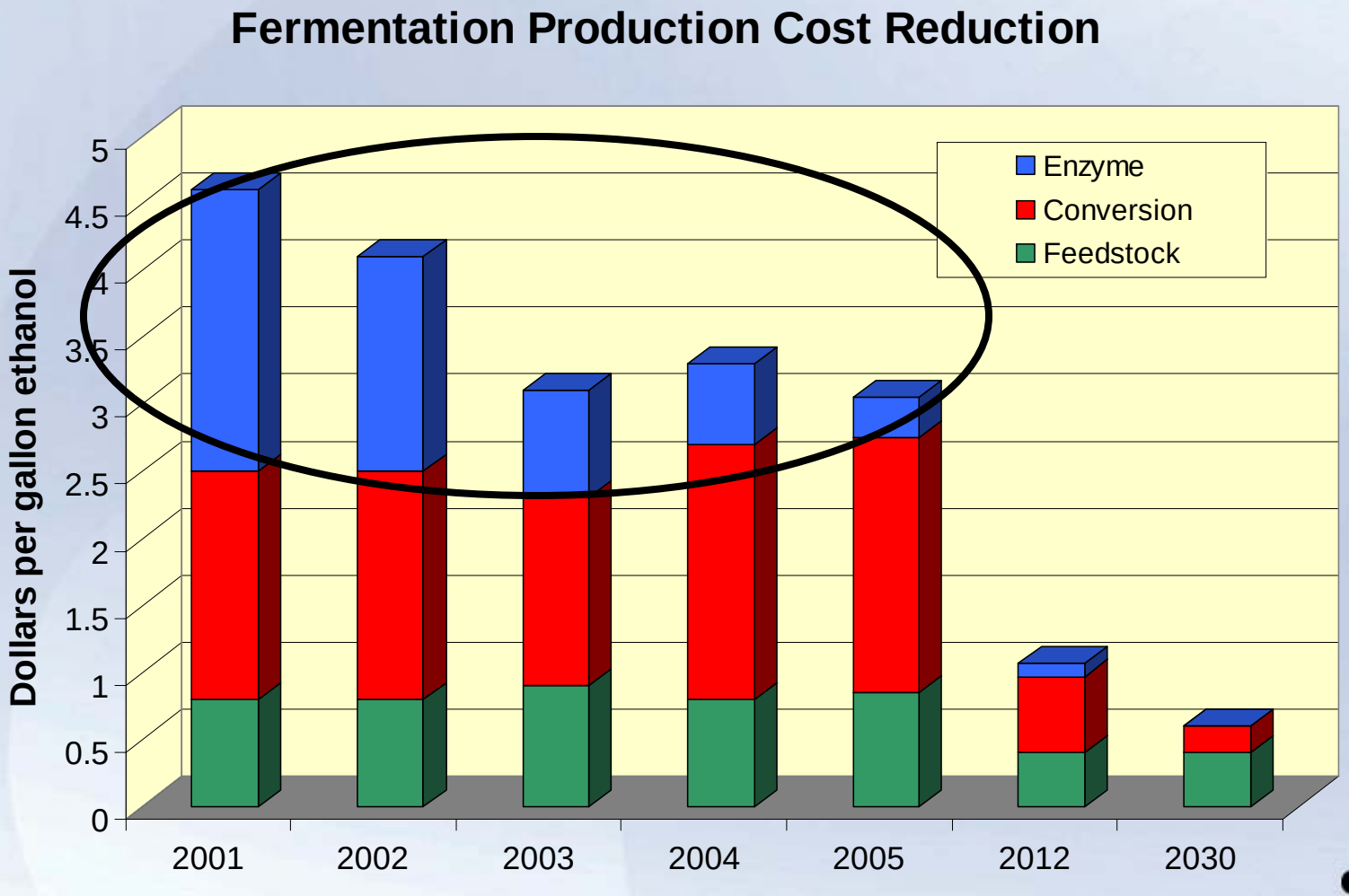
Key processing cost elements (%):

Biomass Feedstock	**33**
Feed handling	5
Pretreatment/conditioning	**18**
Enzymatic hydrolysis	**12**
Enzyme production (Cellulase)	**9**
Distillation and solids recovery	10
Wastewater treatment	4
Boiler/Turbogenerator (net 4%)	4
Utilities	4
Storage	1

Pretreatment and biological elements – key to cost

Source: NREL (2006)

Recent biotech advances in enzyme technology: Significant cost reductions



Source: Russo (2006)

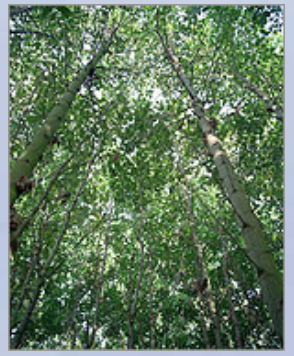
Early movers into cellulosic ethanol commercialization ("Learning-by-doing")

Biomass diverse feedstock: Many advantages; but also challenges…



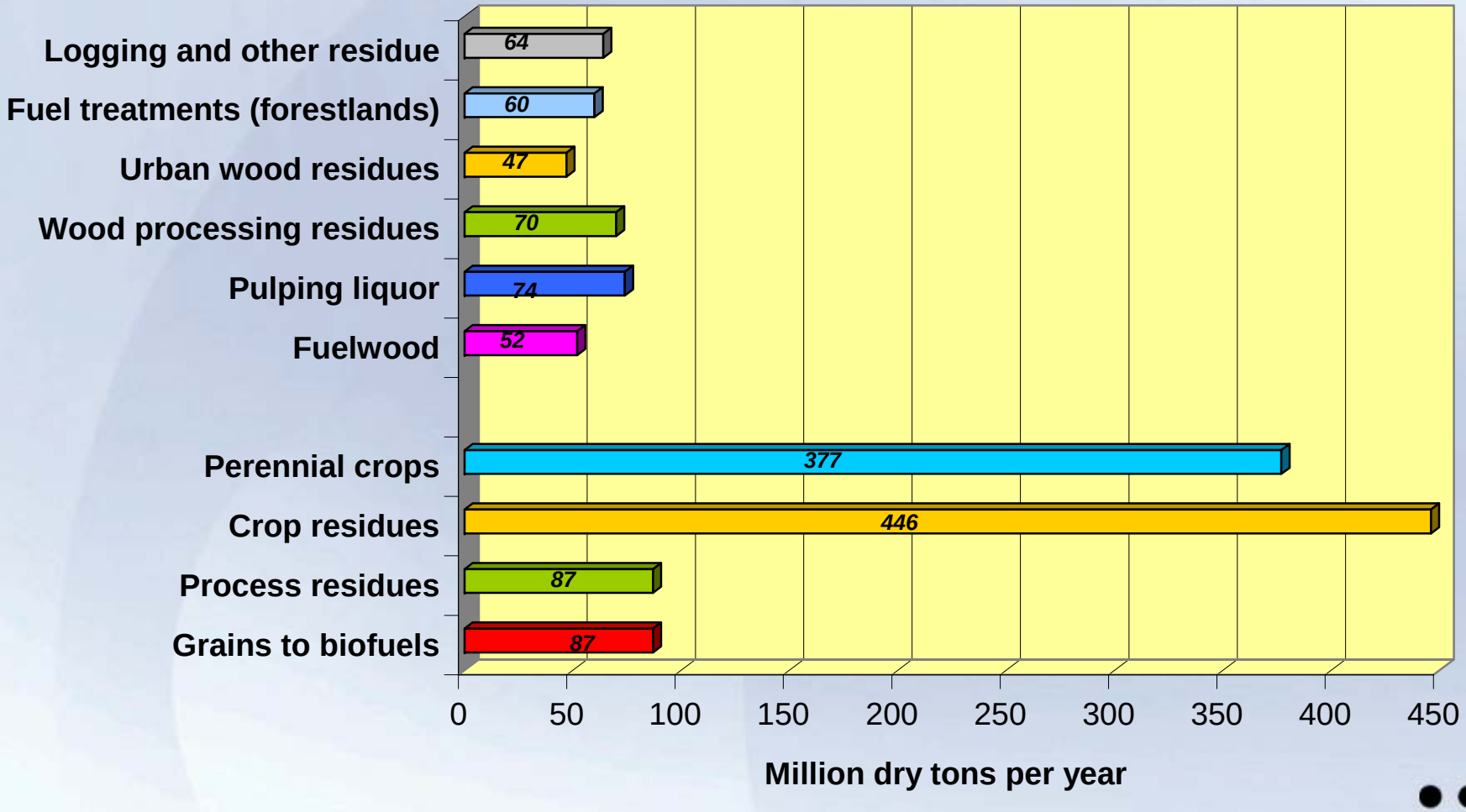






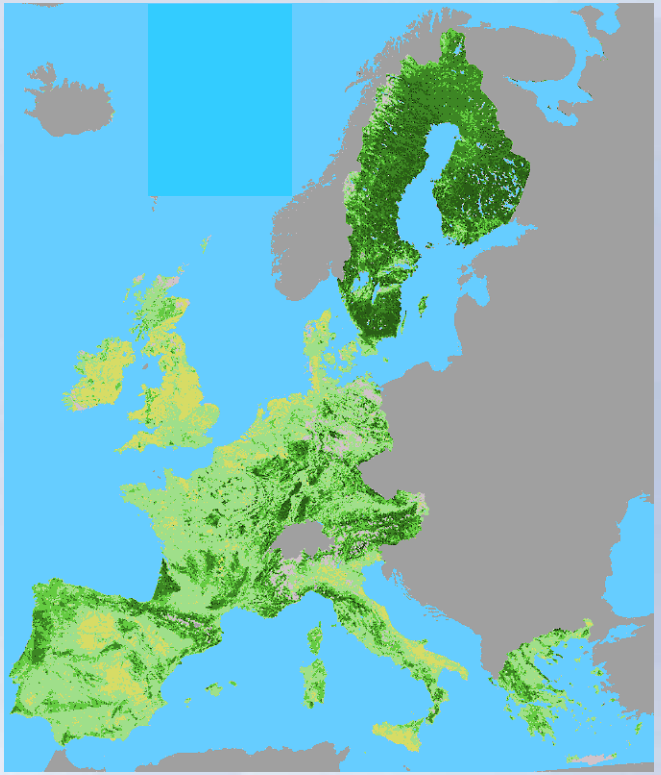
ENERGY CROPS	AGRICULTURAL RESIDUES	FOREST RESOURCES	OTHER SOURCES
Switchgrass	Corn stover	Forest growth	Municipal solid waste
Woody crop (poplar)	Wheat straw	Forest industry wastes	Landfill gases
Willow tree	Small grain residues	Fuelwood	
	Grain to biofuels	Fuel treatments	
	Manures	Logging residues	
	Other residues	Urban wood residues	

Potential available agricultural and forestry biomass in U.S. [USDA-DOE ("Billion ton study")]

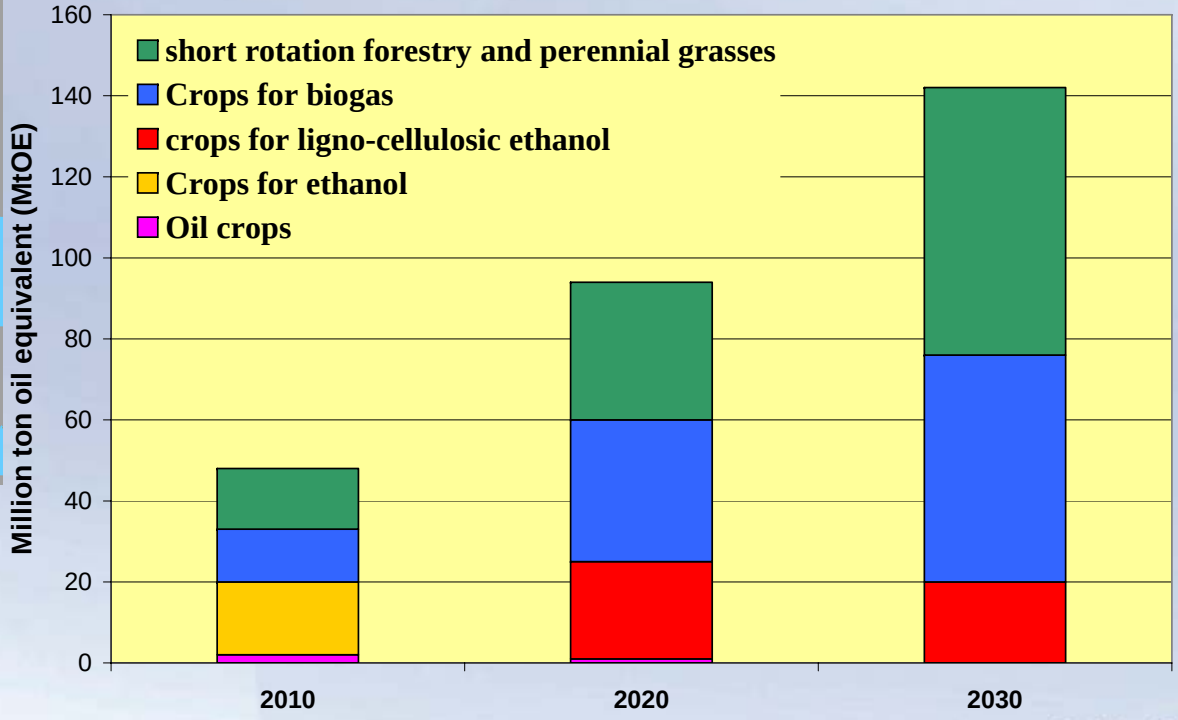


Source: Perlack et al.; USDA-DOE, 2005

European Union biomass assessment potential

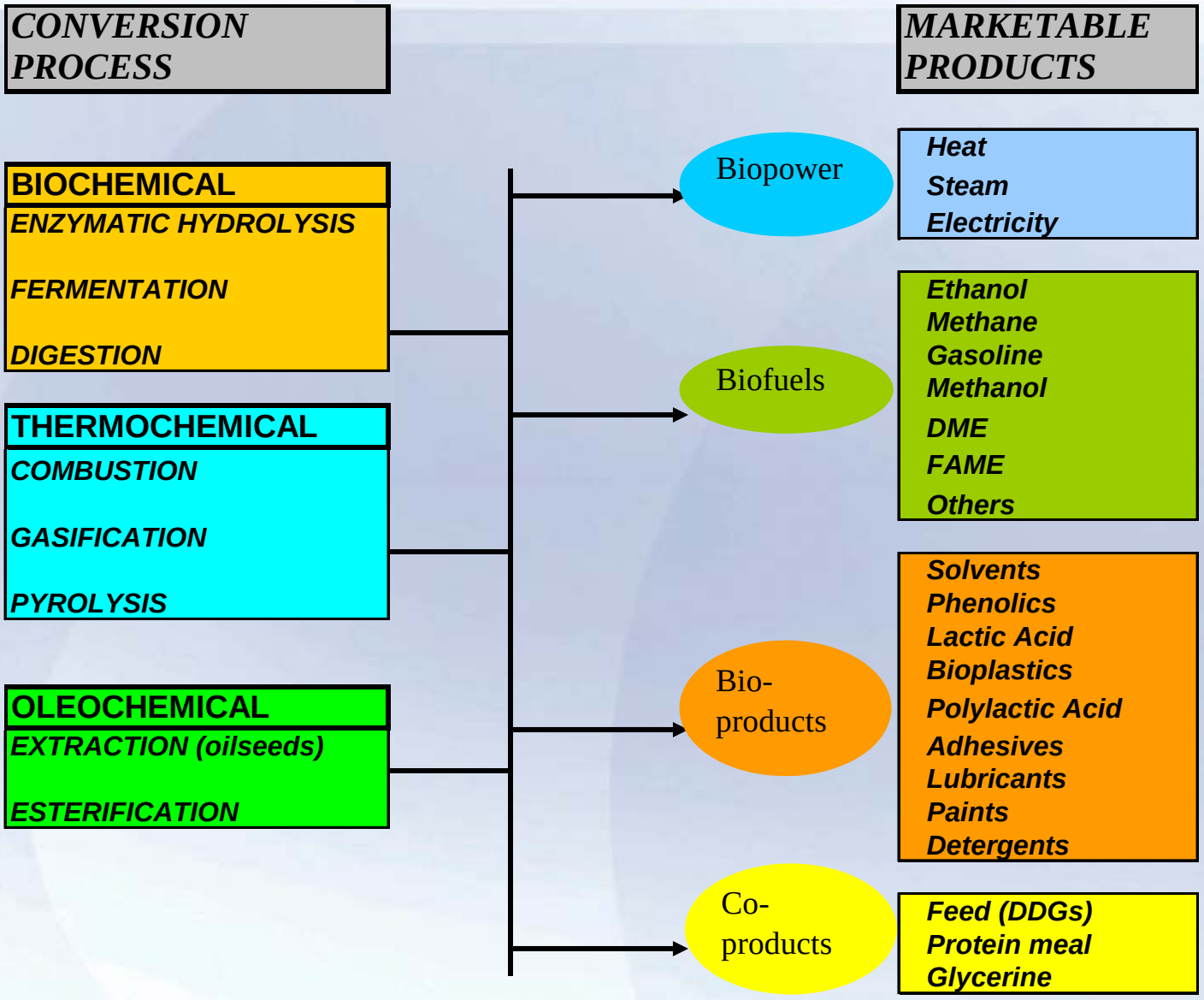


European Environmental Agency Study- Assessment of an environmentally compatible agricultural bioenergy potential (EU-25)



Source: EEA (2006)

Biomass-to-bioenergy: Many conversion processes and marketable products



Biomass and demand for land – Determining factors

FACTORS RAISING LAND DEMAND:

- High bioenergy targets
- Technological advances
- New technologies and pathways
- Incentives for a more intense use of agricultural land and forests
- Use of marginal/pasture lands

FACTORS EASING LAND DEMAND:

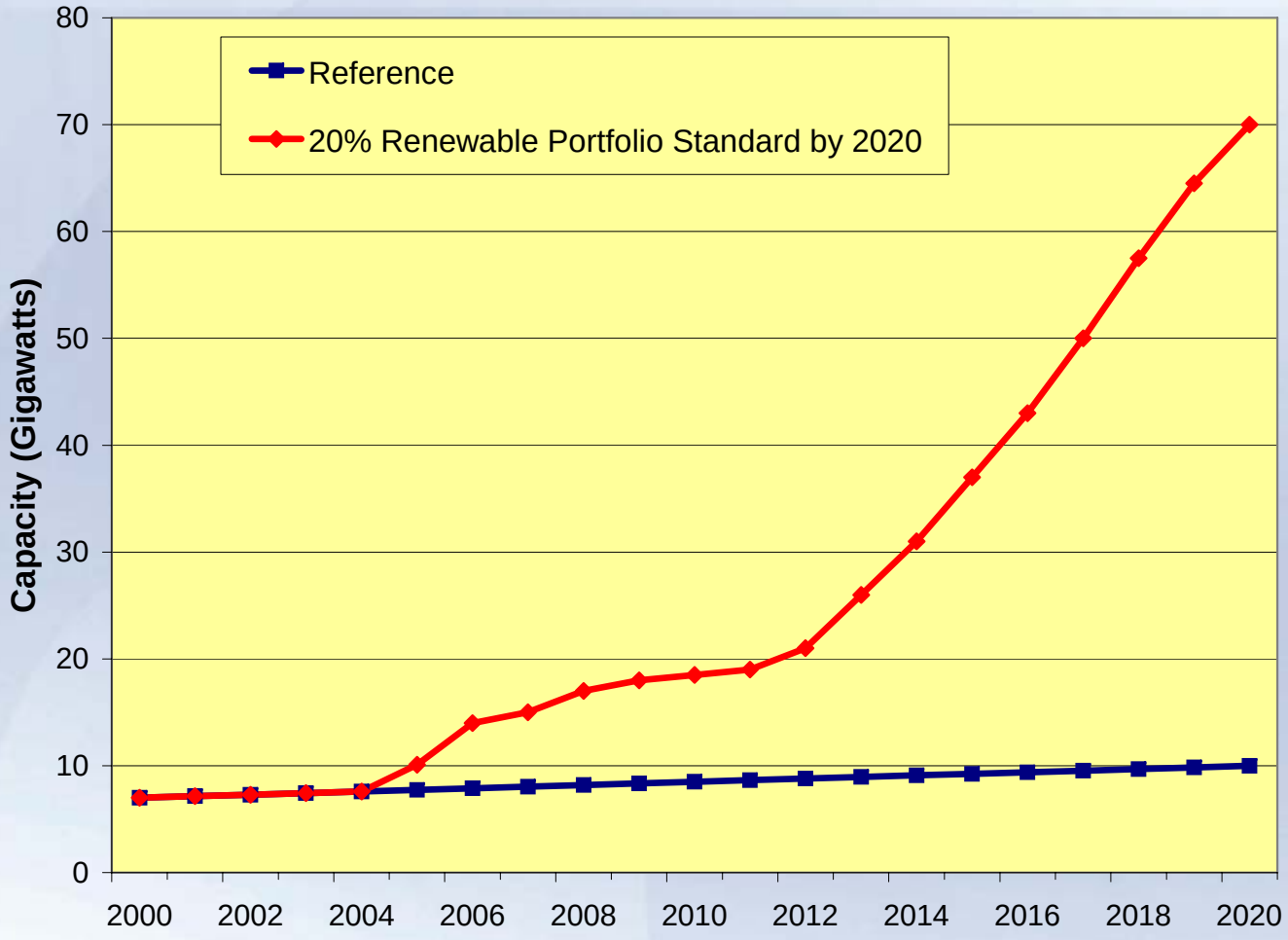
- Increased yield
- Higher Energy Yield
- Higher vehicle efficiencies
- Synergies in bioenergy products
- Feed by-products
- Feedstock from existing crops
- Advances in alternative renewable energy

Policy incentives – Linkages between agriculture-energy-environment goals

	Policy Goals			
Policy Tools	Energy Security	Economic Development	Environment Protection	Agricultural Support
Tax Incentives	♦	♦		
Regulations			♦	♦
Mandated purchases			♦	♦
Federal Procurement		♦		♦
Subsidies				♦
Loan Guarantees				♦
Market Development		♦		
Support for R&D	♦		♦	♦

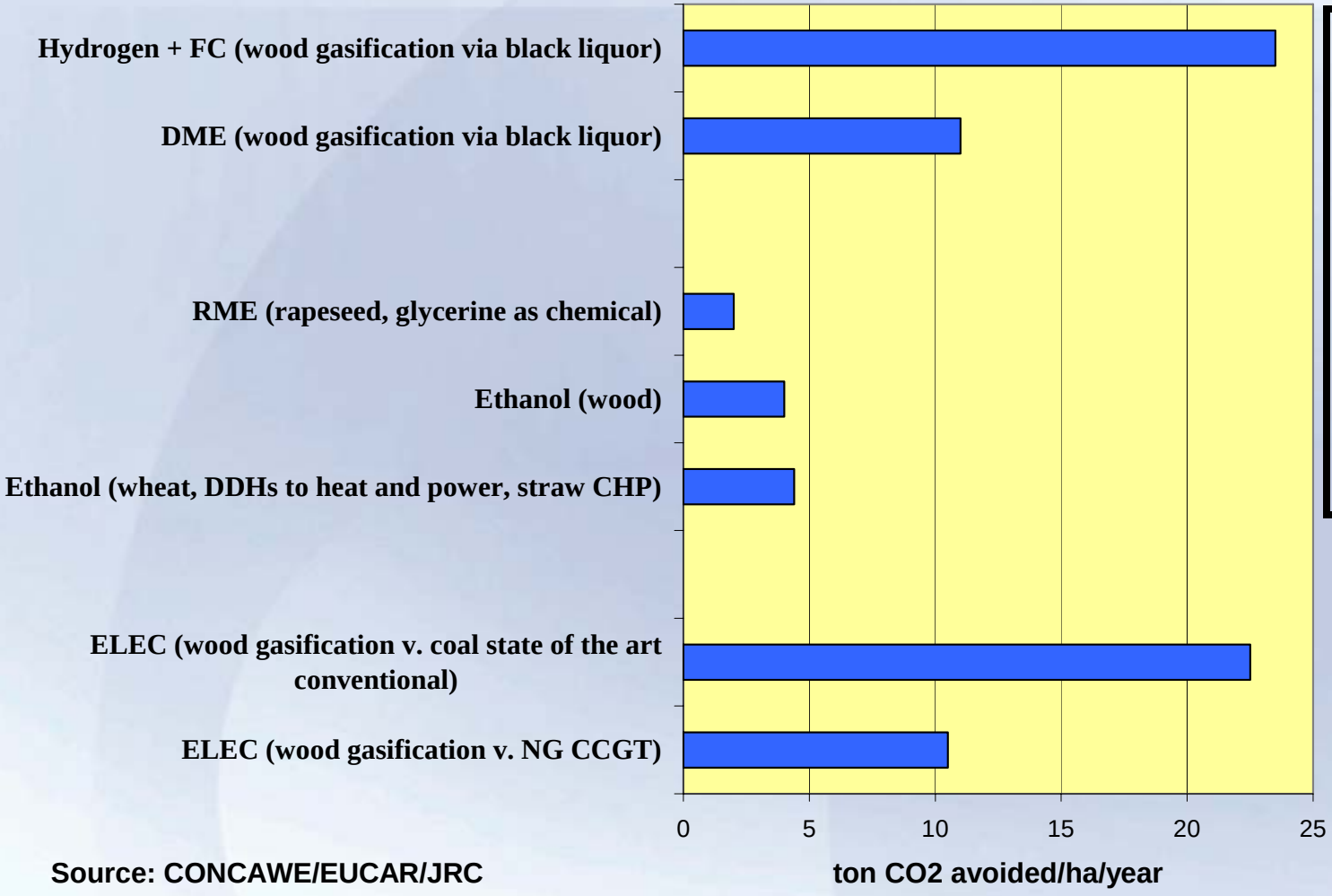
Source: Adapted from Nipp (2004)

Policy incentives: Renewable targets for electricity can boost biomass-based options



Source: Haq (2002)

Environmental criteria affect ranking of biomass-bioenergy options



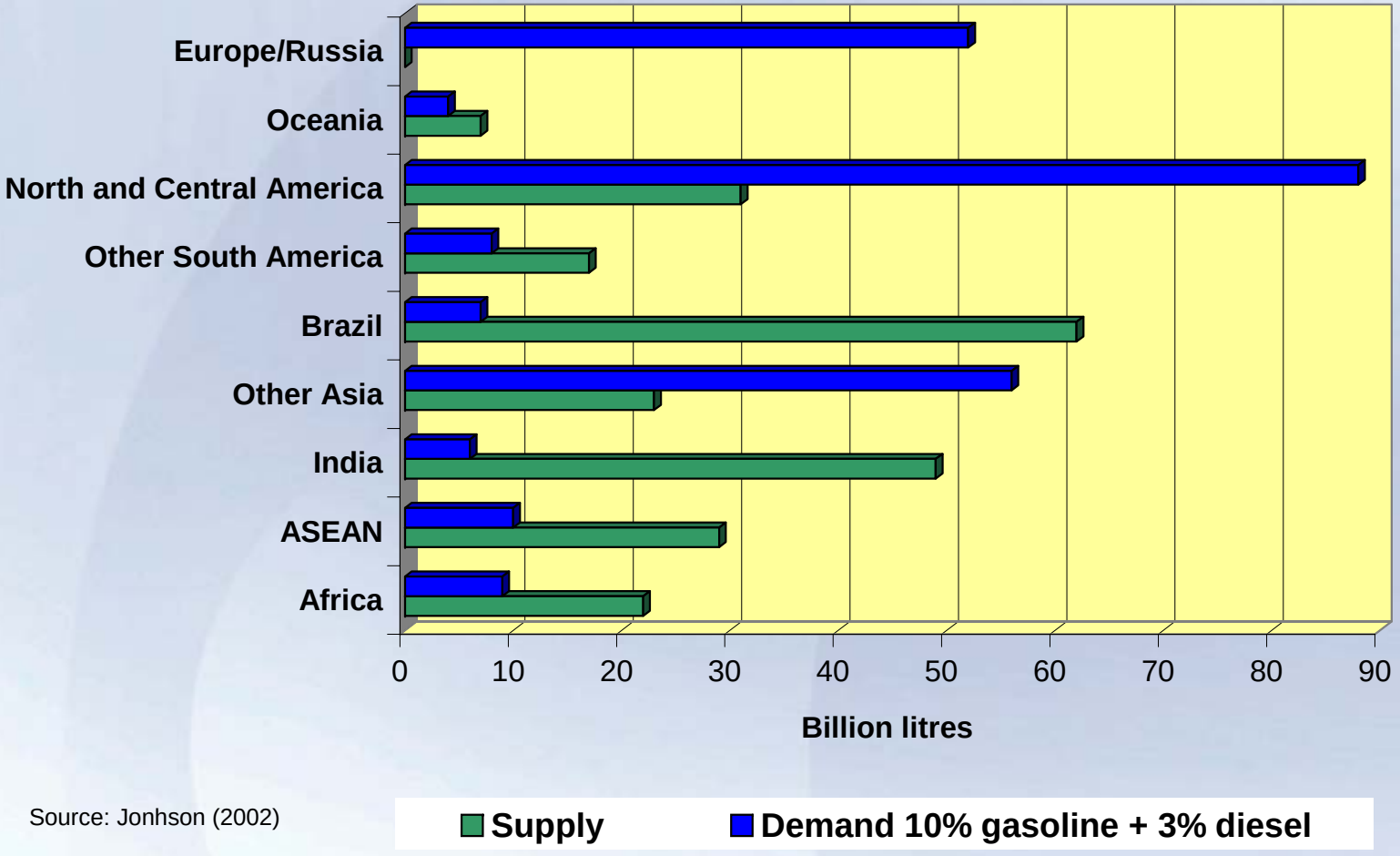
EU Well-to-wheels study comparing alternative biomass uses

Source: CONCAWE/EUCAR/JRC

Bioenergy markets going global? Potential trade spillovers

- Dozen or more countries are producing bioefuels
- Is production is for domestic or exports ?
- Policies based on domestic economic and resources situations
- Need to consider impacts on other countries
- Impact of international trade on domestic biofuel markets
- Opportunity for exporting biofuel technology by leading countries (US, EU, Brazil)

Estimated global potential for Sugar cane-to-ethanol in 2020 & trade opportunities



Source: Jonhson (2002)

Conclusions

- **Ambitious bioenergy targets and future biofuels production require more advanced technologies**
- **Future bioenergy markets are more complex given the diversity of biomass feedstock, conversion technologies, marketable products, and potential global spillovers**
- **Need better understanding of the economic biomass potential given potential competition/synergies among bioenergy uses**
- **Need a better assessment of factors affecting demand for land for bioenergy uses**
- **Need new and adapted economic models to assess the multi-market implications of expanding biomass-based energy uses**