Michigan Tech's Wood to Wheels Initiative

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Vice President for Research

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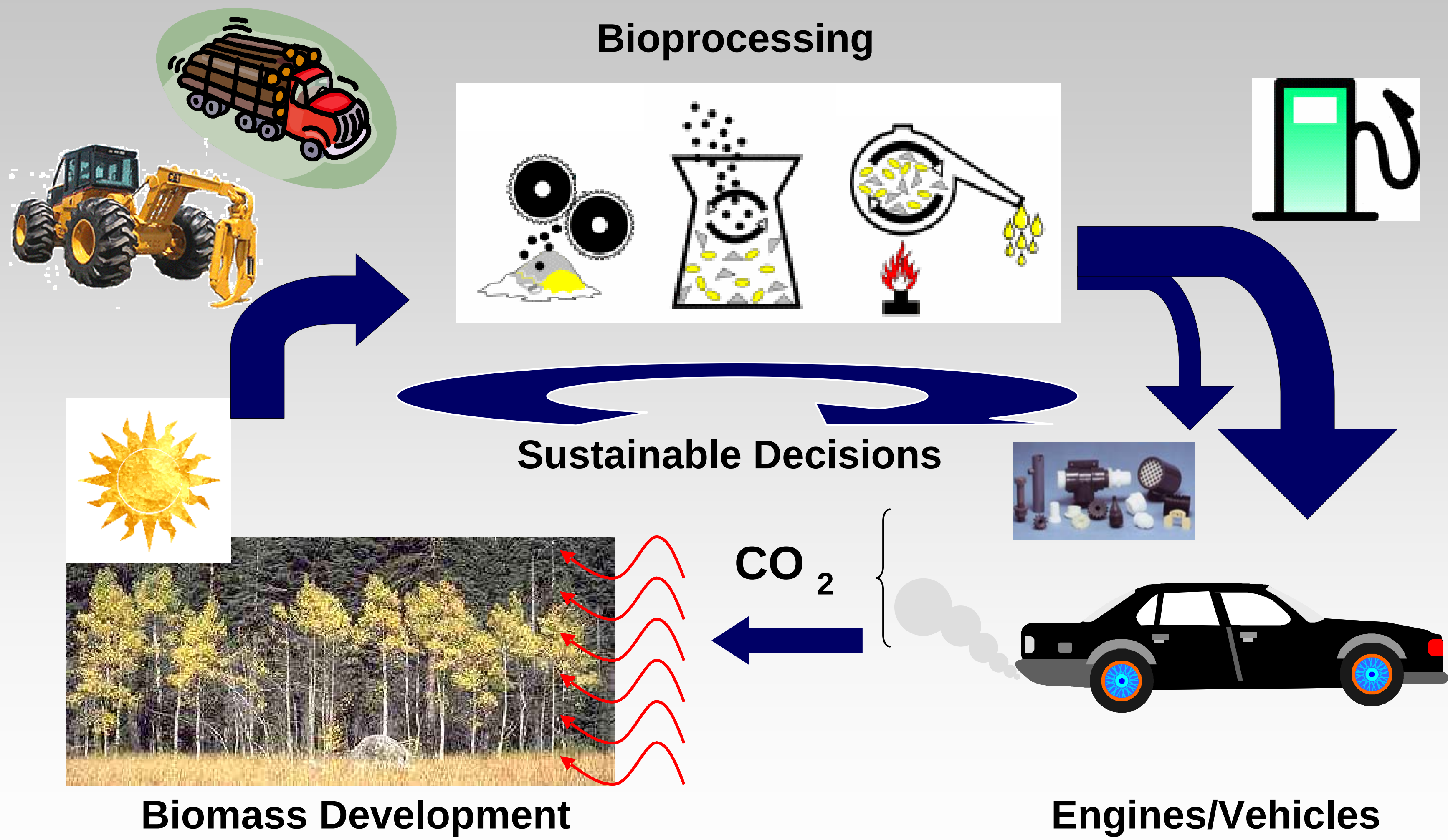
Wood-to-Wheels (W2W)



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W2W Mission

- To create and disseminate knowledge/ technologies related to W2W
  - Woody Biomass Development/Recovery
  - Biochemical/Thermochemical Processing
  - Engine/Vehicle Systems
  - Sustainable Decisions

- To facilitate the creation and promote the growth of businesses engaged in the W2W value chain

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What is W2W?

- **Research initiatives:**
  - Address the entire W2W value chain:
    Forest resources → Harvesting/logistics → Biochemical Processing → Biofueled vehicles
  - Engaging researchers from across entire Michigan Tech campus: Forestry, Engineering, Sciences, Business

- **Educational programs:**
  - New multi-disciplinary approach to graduate education
  - Broader issues: professional development, leadership, entrepreneurship, sustainability concepts
  - Impact on undergraduate curricula and courses

- **Technologies that support commercial-scale production**

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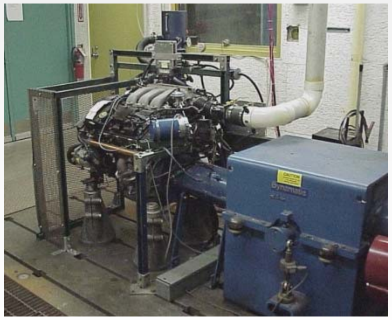
Woody Biomass Development

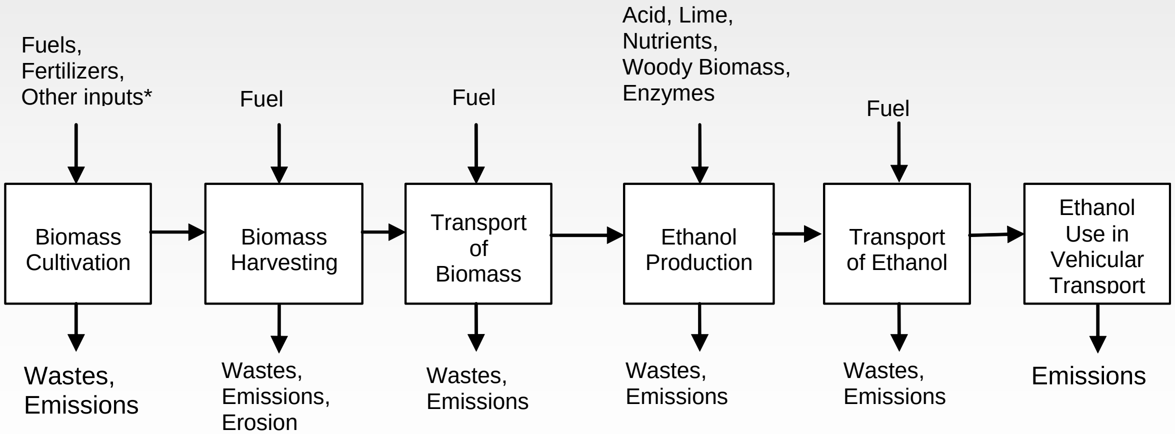
Bio-Processing

Wood-to-Wheels

Vehicle/Engine Systems



Sustainable Decisions



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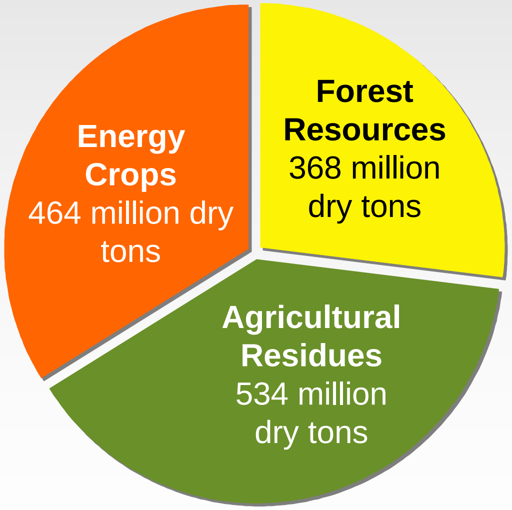
Biomass Development: Inventory – How much gasoline could biofuels replace?

The "Billion Ton Vision"

Enough biomass is available in the US to replace 30% of current gasoline consumption



The "1.8 Million Ton Vision"

If on average the 315,000 UP residents use 482 gal/yr, this corresponds to:

- **151.7 mil gal gasoline**
- **182.7 mil gal E85**
- **155.3 mil gal ethanol**
- **1.8 mil dry tons of lignocellulosic biomass**

Can we recover this much biomass?

Prof. Robert Froese
School of Forest Resources and Environmental Science

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Just forest residues can replace 75% of U.P. gasoline consumption with E85

Biomass Feedstock Supply in the Michigan Upper Peninsula, in dry tons per year and $2005

Biomass Feedstock		Potential Supply	Currently Available and Unutilized	Available at $25/ton Farmgate Price
Forestry	Sawmill and pulp mill residues	1,493,601	Negl.	343,528
	Logging residues	503,243	503,243	65,422
	Thinning residues	853,800	853,800	110,994
Forestry Total		2,850,644	1,357,043	519,944
Urban Wood Waste		41,962	41,962	5,455
Dedicated Energy Crops		606,219	Negl.	6,062
Grand Total		3,498,825	1,399,005	531,461

Sources: USDA, DOE, Walsh (2006, unpublished) and MTU Forest Resources and Environmental Science

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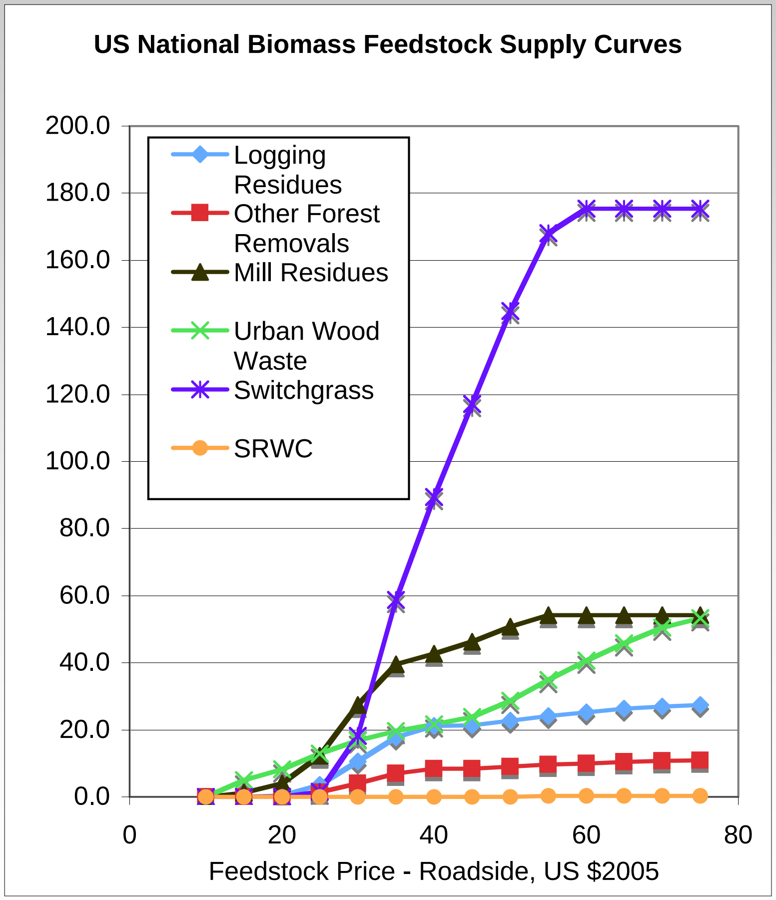
A successful biofuel industry depends on a reliable and sustainable feedstock supply



“The lack of credible data on price, location, quality and quantity of biomass creates uncertainty for investors and developers of emerging biorefinery technologies.” (Office of the Biomass Program, U.S. Dept. of Energy 2005)

"Feedstock cost and potential supply are very sensitive to tradeoffs among competing land uses and competing resource values, such as wildlife habitat." (De La Torre Ugarte et al. 2006)

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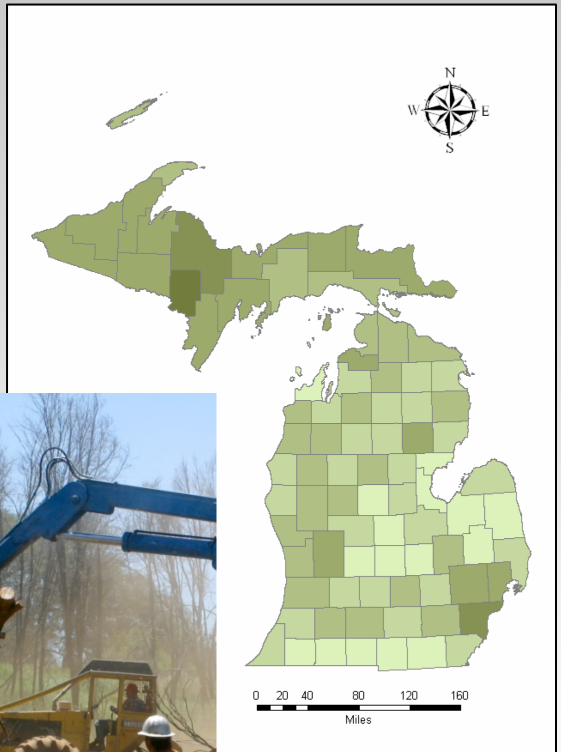
Initiatives relating to Woody Biomass:



- **Geographic Information System (GIS) Analysis and Modeling**
  - Land use/cover maps
  - Spatial inventory of available woody biomass
  - Optimization and validation of forestry models for biomass and carbon
- **Biotechnology**
  - Faster growing trees
  - Optimized woody components for cellulose based enzyme consumption

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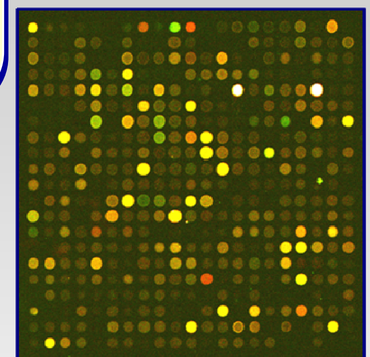
Forest Functional Genomics & Biotechnology

Our expertise:

Micropropagation
Gene transformation
Molecular biochemistry
Whole-genome microarray and metabolite profiling



Microarray Gene Expression Analysis

Research areas:

Wood formation
Defense & fitness
Natural variations
Carbon sequestration

Metabolite Profiling
&
Chemical Fingerprinting

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Biotech Research Center
Forest Resources & Environmental Science
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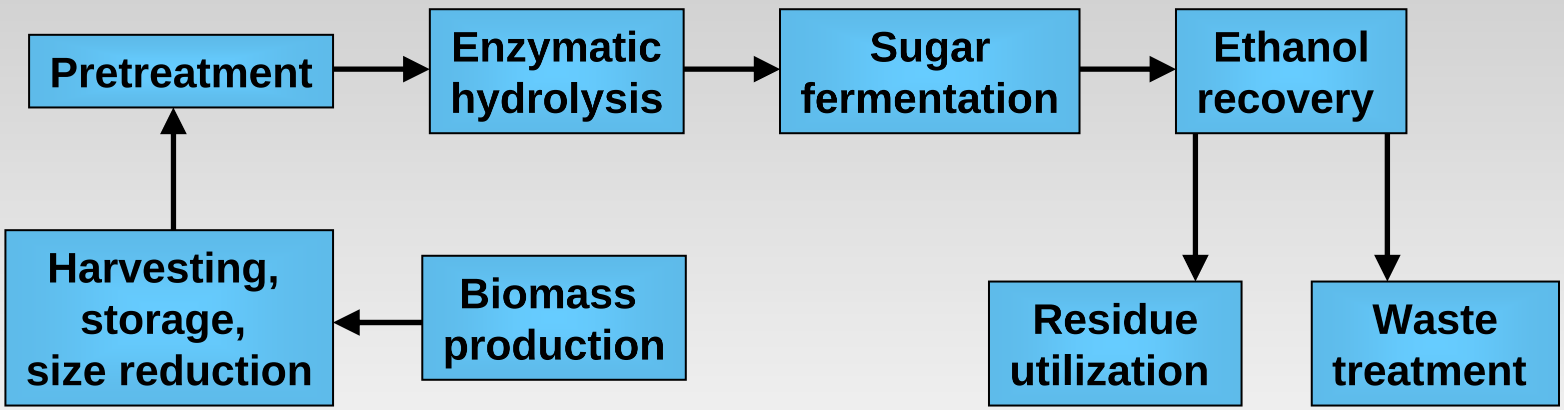
Cellulosic Biomass Conversion to Ethanol



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Goals of Bioprocessing Research

- **Increase efficiency and yields:**
  - **Increase ethanol yields from 70-100 gal / dry ton**
  - **Decrease processing time from 7 days to 2 days**
  - **Flexible processes to handle biomass mixtures**
  - **Optimize use of process energy, water, & nutrients**
  - **Reduce production costs for ethanol**
- **Technological Innovations:**
  - **Establish pretreatment conditions to maximize sugar yields**
  - **Engineer more active and selective enzymes**
  - **Discover / develop better microbial strains**

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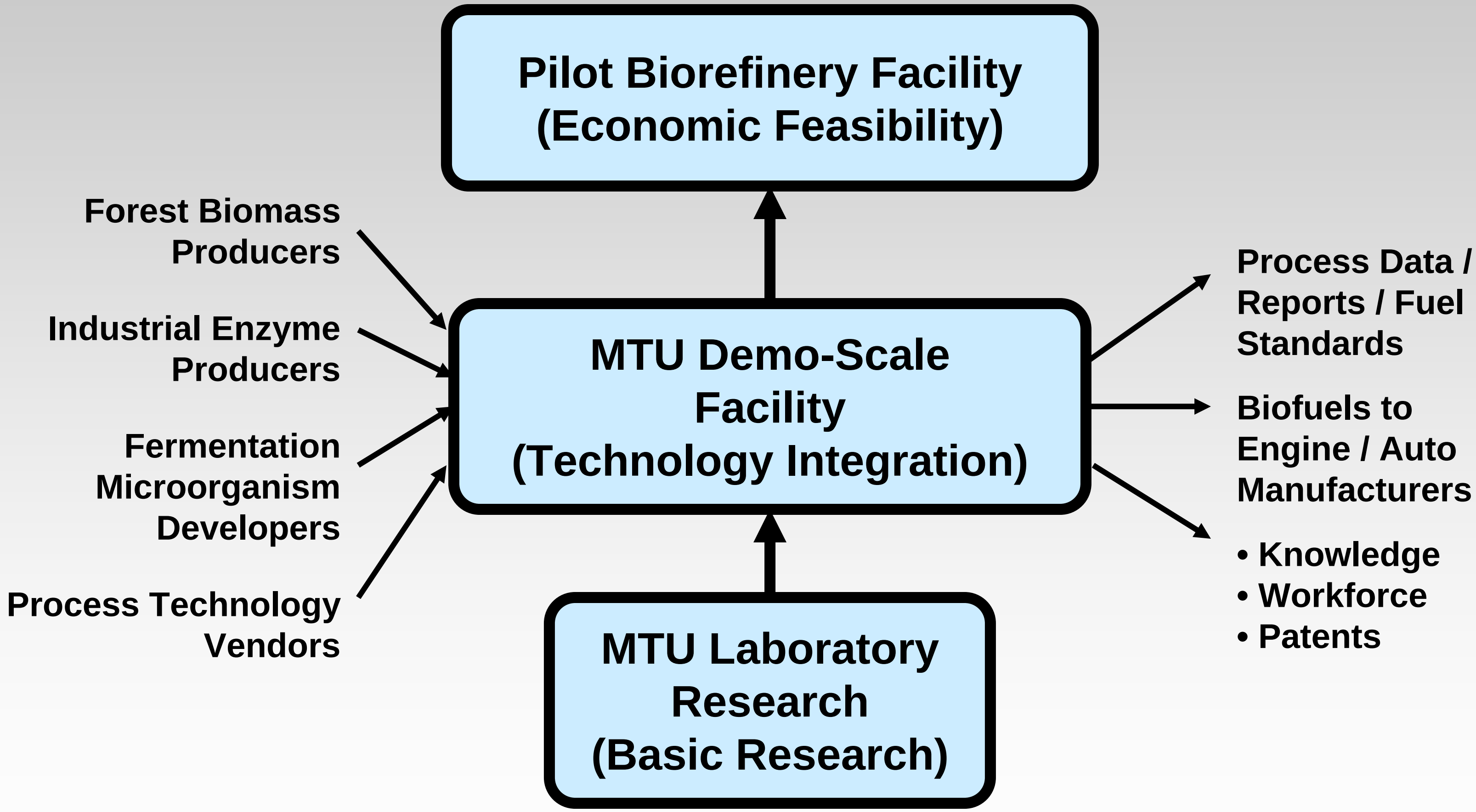
Size Scales for Bioprocessing Facilities



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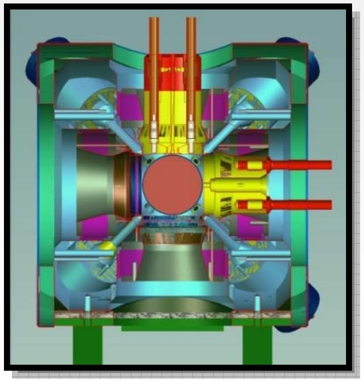
Engine/Vehicle Initiatives

Prof. Jeff Naber
Dept. of Mechanical Engineering



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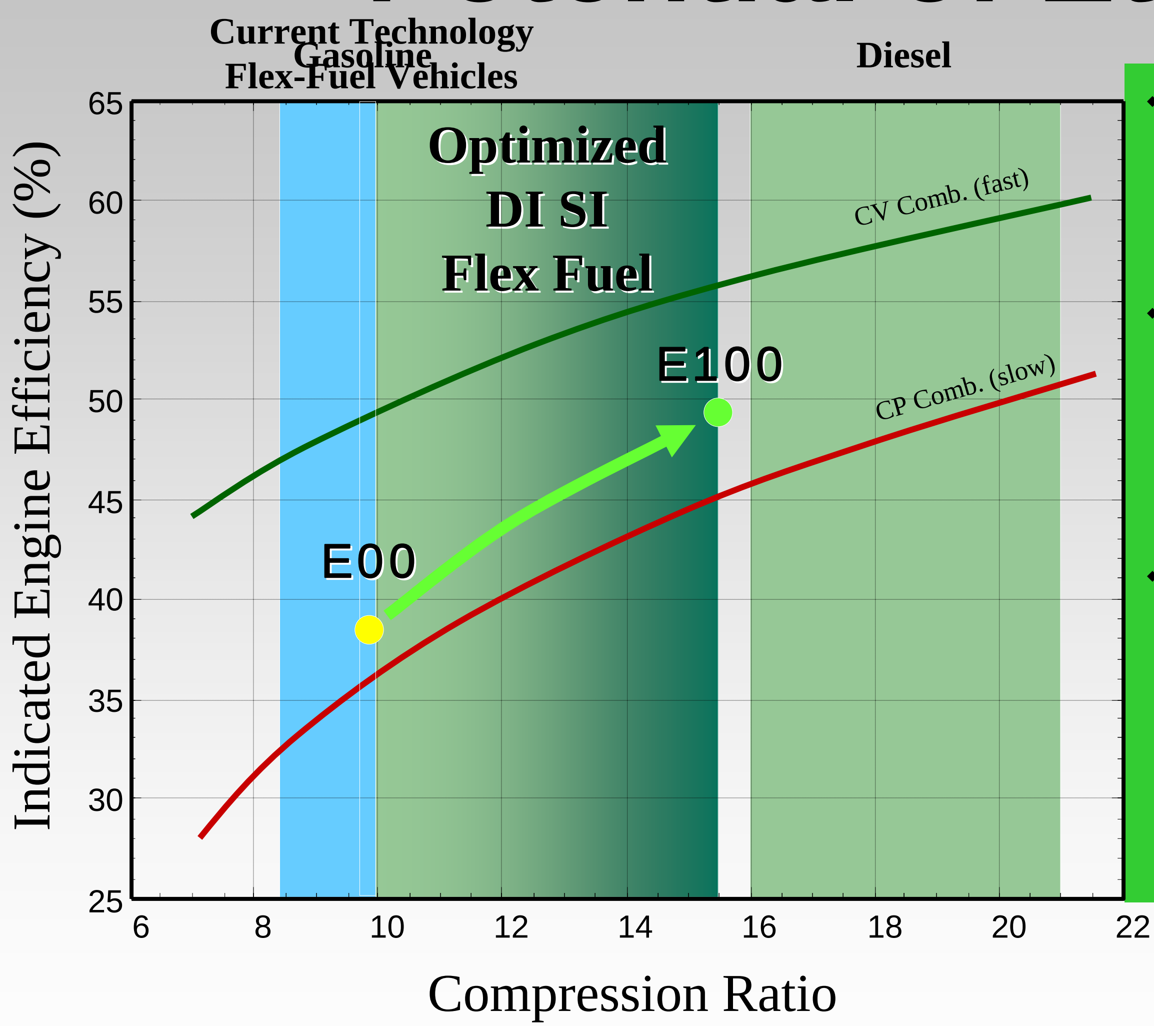
Ethanol as a Fuel

Property[1]	Gasoline	Ethanol	Impact of Ethanol
Chemical Formula	C4 – C12	C_2H_5OH	Oxygenated fuel
Composition, Weight % (C, H, O)	(86, 14, 0)	(52, 13, 35)	Slightly lower combustion temp.
Lower Heating Value (Btu/gal)	115,000	76,000	Reduced MPG
Octane Number (R+M)/2	86-90	100	Reduced knock, Improved efficiency
Reid Vapor Pressure (psi)	8-15	2.3	Reduced start-ability
Latent Heat of Vaporization (Btu/gal)	150	396	Increased charge cooling, Reduced start-ability
Volume % fuel in Stoich Mixture	2	6.5	Requires increase fuel vaporization & mixing
Stoich air/fuel (weight)	14.7	9	Requires increased fuel vaporization & mixing
Laminar Flame Speed (cm/s)[2]	27	42	Increased thermal efficiency, Increased EGR tolerance

- **Ethanol: better SI engine fuel than gasoline from combustion standpoint**
- **Significant challenges in fuel preparation for E100**
- **E85 helps but doesn't eliminate the problem.**

- **→ Engine & fuel system should change for ethanol.**

Potential of Ethanol

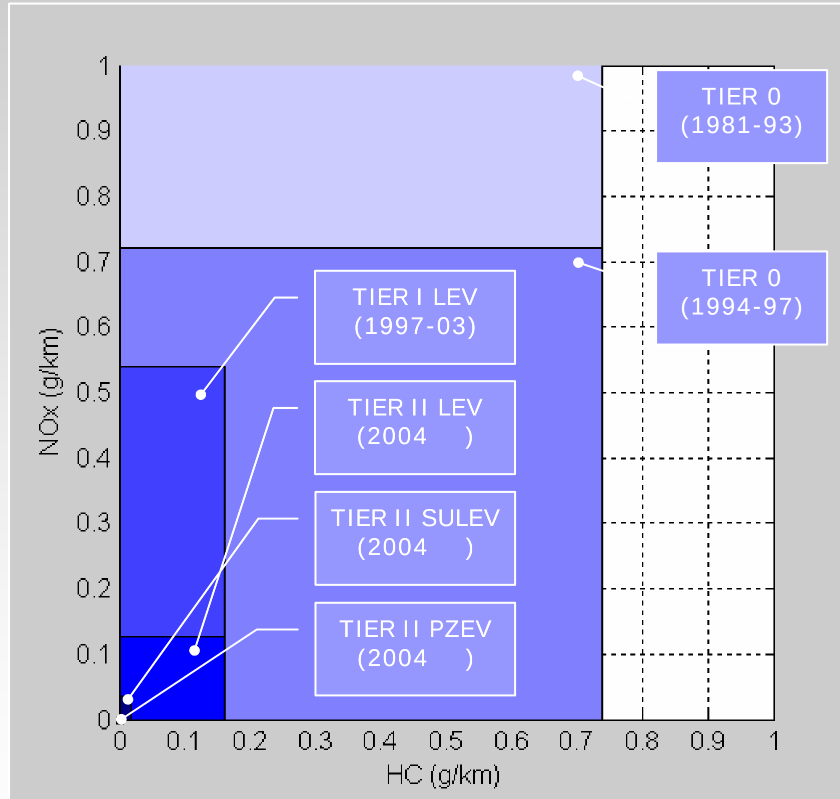


- EPA has demonstrated a 20% improvement with E85, high CR and EGR
- MIT estimates 30% improvement with DI SI Gasoline/Ethanol, turbocharging & downsizing
- E85/E100 optimized SI engines should be nearly as efficient as diesels
  - Lower engine cost
  - Lower toxic emissions

Technology Solution for Flex-Fuel Hybrids is Required

- Current flex-fuel vehicles do not meet PZEV standards because of crank-start HC emissions.
- Hybrid applications amplify the problem because of increased start-stop cycles.
- Legislation requires hybrids to meet the PZEV standard.
- Technical solution required for PZEV Flex-Fuel Hybrid
  - Company that develops robust cost effective solution will have market advantage

US Emissions Standards*



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Commercialization Status of Cellulosic Ethanol

- 15-20 Pilot Plants Worldwide, Mostly Small Batch Operations
- 2 Demonstration Plants Opened (Ottawa & Japan) with 2-3 Others to Open Later in 2007
- 15-20 Commercial Plants Being Built Worldwide
- Large Range of Feedstocks Proposed - Mostly Agricultural & Forestry Residues

Prof. Barry Solomon
Department of Social Sciences

State Interest: Regional Economic Effects

- Largest Cost Items: Capital & Feedstocks
- Capital Cost for Cellulosic Plants Higher than for Grain Ethanol
- Employment Needs Modest, Except During Construction Phase
- Very Few Studies Have Estimated Regional Economic Effects (Most Studies National)
- High Risk & Uncertainty with Cellulosic Ethanol Plants Owing to Lack of Commercial Experience

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Results for one Scenario

- Assumes: 52 MGY & 20 Yr. Operations
- Jobs: 1,647 / yr. During Construction Phase
- Jobs: 526 / yr. During O & M Phase
  - Mostly in Manufacturing, Services, Transportation, Trade
- Increased Real Disposable Income: Avg. $32 Million / yr
- Economic Output: $148 Million / yr
- Gross Regional Product: $65.9 Million / yr

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Regional Economic Effect Conclusions:

- Effects of Commercial Cellulosic Ethanol Plants Increase with Scale of Production
  - Range studied (.26 – 52 million gallons EtOH/yr)
- While MI is Behind MN & WI in Grain Ethanol it Can Catch up via Cellulosic Ethanol Industry
  - Will not happen without strategic initiatives of State Government

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W2W Summary: Outcomes

- Contribute to technical workforce with highly-skilled graduates -- balance perspective on research, life-cycle, and business issues.
- Trees and forests with increased productivity, carbon sequestration, and solar energy efficiency.
- Integrated bioprocesses, improved microorganisms and enzymes for the production of bio-based fuels.
- Vehicle systems that are optimized for bio-based fuels.

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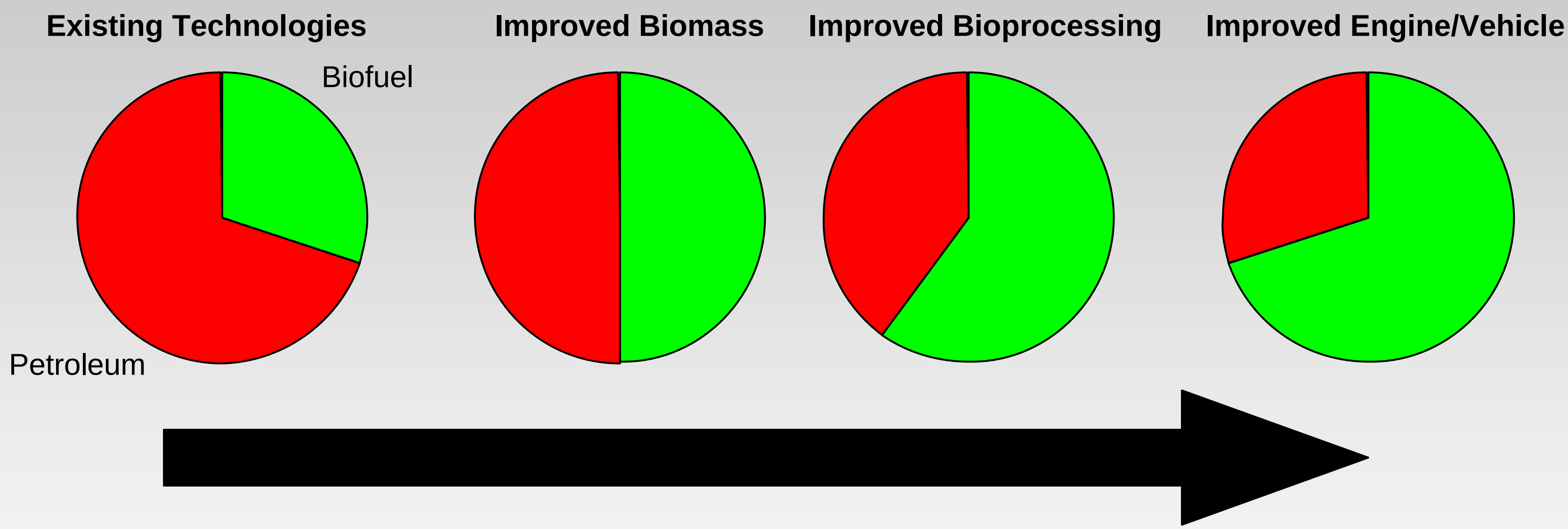
Displacement of Petroleum via Wood-to-Wheels



The life-cycle and multi-disciplinary nature of W2W will allow us to realize a tremendous reduction in petroleum usage.

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