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ORNL Alternative Fuels Initiative Overview:

Current Research and Paths Forward

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OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Energy Policy Act of 2005 (P.L. 109-58)

- Triples amount of biofuel (usually ethanol) in gasoline to 7.5 billion gallons (102 Million BOE*) by 2012 (EPA's Renewable Fuel Standard implements this)
- $50M annually for a biomass grant program
- $1.3B in tax breaks for alternative motor vehicles and fuels (ethanol, methane, liquefied natural gas, propane).
- … develop a program to coordinate and accelerate commercialization of strategic unconventional fuels, …oil shale and tar sands resources within the U.S. ...

*Barrels of oil equivalent

"Alternative Fuels" are receiving significant attention due to rising oil prices

- **ORNL has been active in Alternative Fuels for more than twenty years**
  - **Production of biomass and energy crops**
  - **Evaluation of alternative fuels as transportation fuels (methanol car and natural gas truck - right)**
  - **Development of coal-to-liquids technology**
  - **Involved with Synthetic Fuels Center ("synfuels") in 1980s**

- **To respond to latest emphasis, ORNL initiated an Alternative Fuel Initiative in 2005**
  - **Led by Ron Graves**
  - **Encourage communication and growth**
  - **Develop new or revitalized capabilities**
  - **Cover bio-fuels; "synfuels", and end-use research**

Alternative Fuels in Perspective (billion gallons oil equivalent, annual basis)

• **USA Energy use in transportation**	**194**
• **Canadian oil sands production**	**15**
• **Ethanol US production** (RFS mandates increase to 4.2 by 2012)	**3.4***
• **Biodiesel production last year**	**0.075**
• **Oil from shale**	**less**

***~Zero from cellulosic path**

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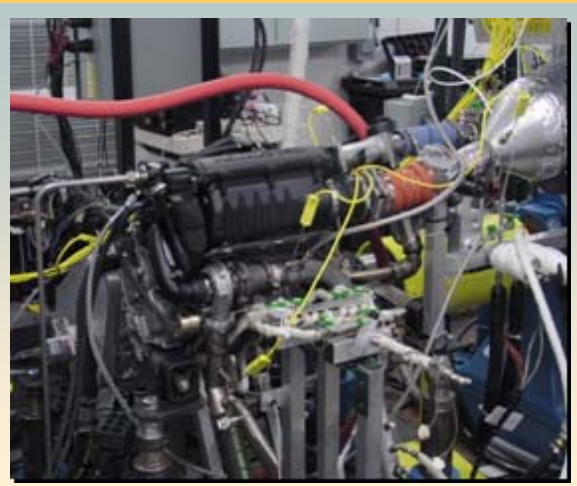
ORNL Contribution in Alternative Fuels Ranges from Production to Utilization

Extraction	Bio-Production	Fuels Utilization
		

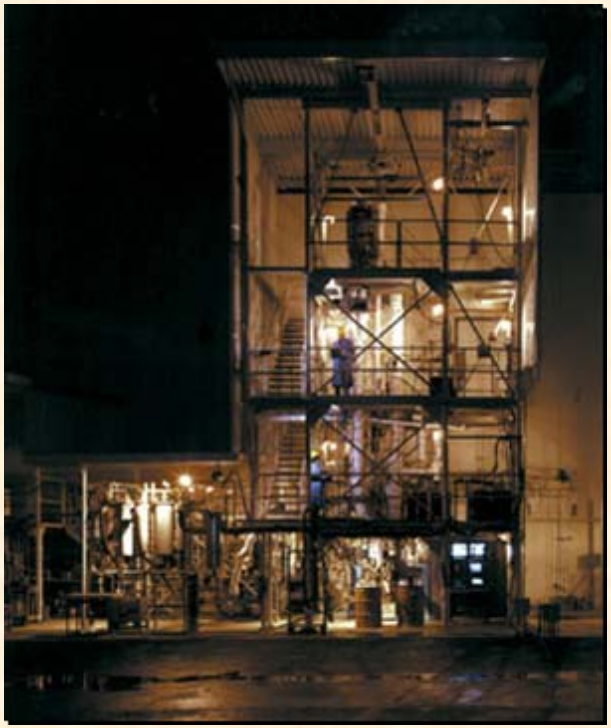
Summary

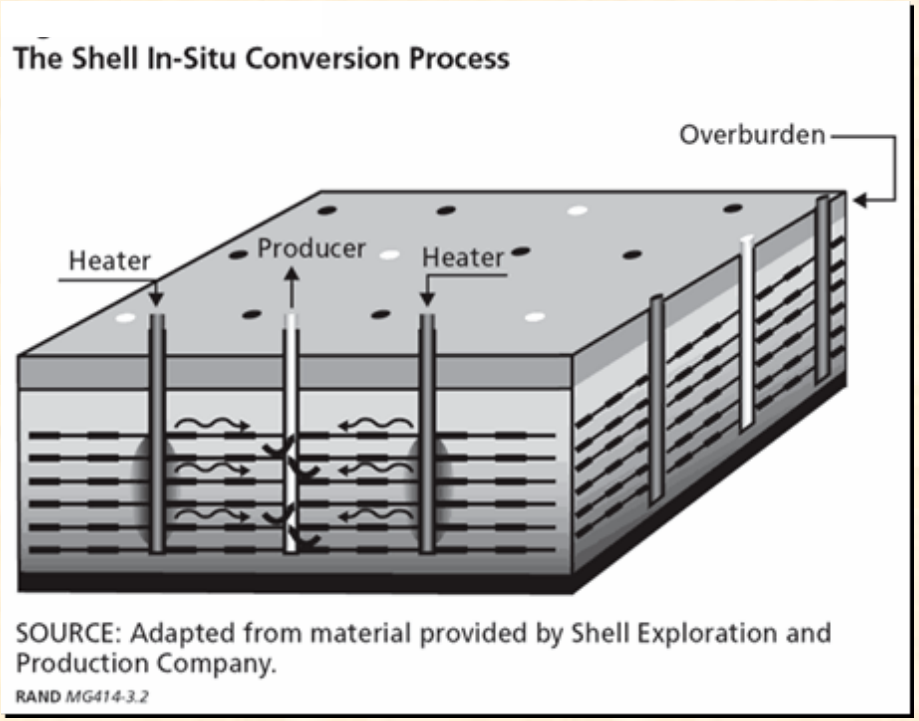
- **Significant WFO project in oil shale in-situ processing**
- **Developing materials able to withstand severe conditions**
- **Additional areas of interest possible**

- **Programs in EERE & Science**
- **Research disintegration of plants for energy and products**
- **Goal of 30% of gasoline replaced by ethanol by 2030**

- **Long-standing EERE sponsors**
- **Considering impact of different fuels on engine performance and emissions**
- **Examining economics of fuel transition**

ORNL is Involved in a Significant Oil Shale Extraction Project

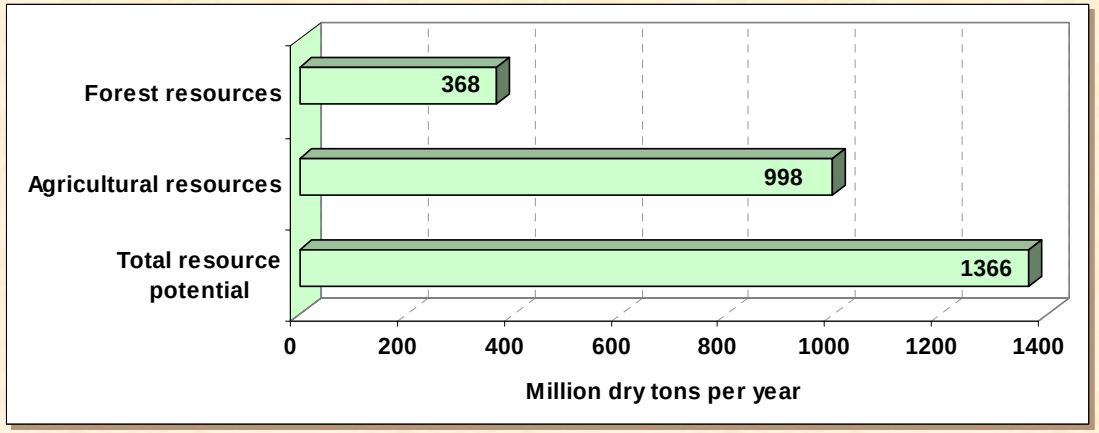




- **Shell's In-Situ Conversion (ICP) Offers the Potential for Production of High-Quality Transportation Fuels from Oil Shale**
- **The ICP Involves Heating of the Oil Shale with Electric or Gas Heaters for Several Years**
- **ORNL materials expertise is fundamental to Shell's process**
- **Shell is open to additional ORNL involvement**

Bio-Production Effort at ORNL Includes Bio-based Energy & Products

- **Biobased energy and products are derived from sunlight via plants and renewable in the short-term**
- **Office of Science Grand Challenge: Plant structural analysis to facilitate selective disintegration of plant components for efficient materials utilization**
- **New domestic biomass industry is being advocated that includes biomass feedstock, conversion technology and yields chemicals, fuels, and food products**
- **EERE Biofuels Initiative targets 30% of gasoline replaced with ethanol by 2030**
- **Ethanol has key benefits as renewable fuel, broad support, existing infrastructure, & help for rural economy**



"Billion ton study" concluded that land resources of the U.S. can sustainably supply more than 1.3 billion dry tons annually and still continue to meet food, feed, and export demands. This would allow the US to replace up to 50% of petroleum use with reasonable trends.

A New Domestic Bioindustry Is Gaining Acceptance

Biomass Feedstock

- Trees
- Grasses
- Agricultural Crops
- Agricultural Residues
- Forest Residues
- Animal Wastes
- Municipal Solid Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Pyrolysis
- Combustion
- Co-firing

Source: DOE OBP

PRODUCTS

Fuels:
- Ethanol
- Renewable Diesel
- Renewable Gasoline
- Hydrogen

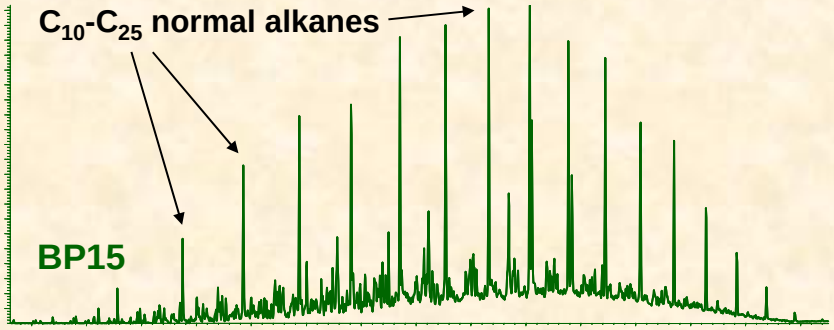
Power:
- Electricity
- Heat (co-generation)

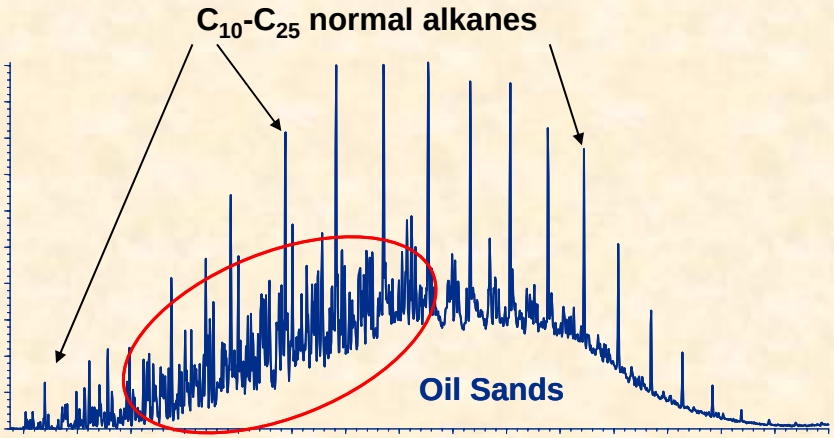
Chemicals
- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty acids
- Acetic Acid
- Carbon black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Food and Feed

ORNL is Investigating the Engine & Emissions Impact of Alternative Fuels

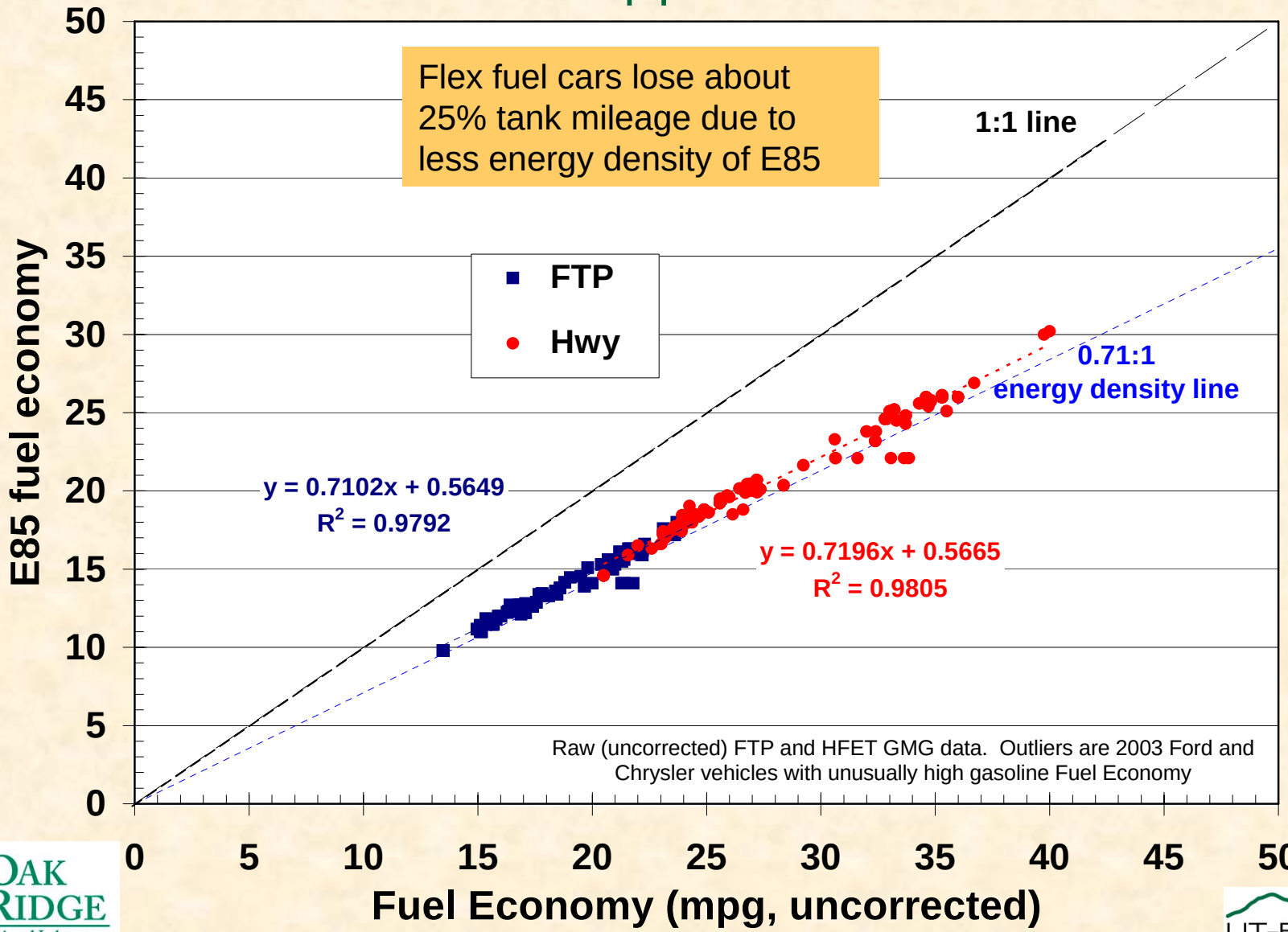
- **Fuel property effects on advanced combustion regimes**
- **Characterization methods for alternative fuels to support improved correlations between properties and end-use performance**
- **Fuel chemistries and blending strategies to reduce NOx in biodiesel blends**
- **Alt. Fuel property effects and enhancements on emission controls**
- **Technical studies, workshop organization, R&D plan preparation, IEA participation**
- **Impact of alternative fuels on health effects**
- **Economics of the transition from petroleum fuels to alternative fuels**





Different fuels being introduced into market can exhibit different properties. Developed analytical tools for measuring differences and determined that engine and emissions performance is comparable. In this case, we compared diesel from oil sands and a conventional low sulfur diesel.

ORNL research addressing loss of volumetric fuel economy with E85 via innovative engine and emission control approaches



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ORNL Alternative Fuel Initiative is fostering growth in multiple, somewhat disparate areas

- **Production - $4M/yr**
  - **Extraction - ($2M annually)**
    Largely a WFO effort (Shell)
  - **Bio-production - trying to re-grow a traditional ORNL strength**
    - **Biological Platform**
      - **Office of Science program - Brian Davison ($500k)**
      - **EERE Biomass program - John Mielenz (<$2M)**
    - **Thermo-chemical Platform - ??**
- **Processing, Upgrading - not much activity**
- **Utilization - traditionally $5M/yr (growth mode)**
  - **Fuel and lubricant effects on engines/vehicles - ($4.5M); Fuels/Engines group in ESTD**
  - **Environment & Health impacts of new fuels (ESD and ESTD working together; ~$500k)**
  - **Energy and Economics Analysis-ESTD (~$500k)**

There are several areas for growth ...

- **Extraction -**
  - **Shell is willing to work with us in other areas.**
  - **All major energy companies are working on oil shale - Battelle is brokering our services (POC set).**
  - **Little DOE involvement ("get out of way").**
- **Processing -**
  - **There are additional bio-processing paths beyond current ORNL focus.**
  - **NETL main resource in gas-to-liquids & coal-to-liquids. ORNL capabilities need revitalizing.**
- **Fuels Utilization -**
  - **Strong sponsor with new growth in fuel effects. Lots of interest in ethanol & biodiesel.**
  - **Health effects future work is unclear.**

Progress has been made in all 6 Alternative Fuel 2006 Objectives (1/2)

- Reconstruct and grow a sustainable R&D portfolio in biofuels production and processing
  - Two LDRDs awarded and in progress. One on enzyme R&D for ethanol and the other on Poplar genetic engineering for increased yield. Brian Davison leading bio-energy initiative and has oversight of these two LDRDs, co-funded by Biological & Energy Directorates. Well positioned for expected improved funding opportunities. Excellent "science to energy" example. Well positioned for upcoming Office of Science call. Biomass office requested proposals relating to end-use issues of ethanol.
- Develop an internal ORNL plan that focuses on the most promising alternative fuels pathway (e.g., coal-to-liquid versus gas-to-liquid)
  - In progress. More focus on oil sands and oil shale than other options. Working with Battelle to market services to major energy companies.
- Strengthen relationships DOE fuels processing programs (fuels cross-cut team)
  - DOE's fuels crosscut (Utilization, Biofuels, Fossil) resumed meeting. ORNL and NREL are invited to participate. Presenting work to National Biodiesel Board (NBB). Interaction between DOE Biomass & FreedomCAR.

Progress has been made in all 6 Alternative Fuel 2006 Objectives (2/2)

- Involve multiple laboratories, energy companies, and engine/auto manufacturers and coordinate their efforts in developing and implementing R&D approaches to the study of the effects of alternative fuels on advanced combustion processes.
  - A multi-lab, industry government working group was conceived by ORNL and has been kicked off under oversight of Coordinating Research Council, a non-profit, non-lobbying trade association. This is right venue for the effort. Working with NREL. Task completed.
- Establish new capabilities at the NTRC site for innovative research thrusts to reinforce ORNL's lead role in fuel end-use technologies R&D.
  - LDRD awarded to develop improved computational tools for predicting fuel property effects on combustion. Teamed with Univ. of Wisconsin. Involving multiple ORNL Divisions. Improved computational tools and hardware for research being commissioned.
- Engage the Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy in identifying new areas of opportunity and provide assistance with assessments and plans as needed.
  - The anticipated merger of EERE and FE did not occur, so in this objective we are continuing to work with both Offices. In EERE we have already increased attention to ethanol. In FE trying to build on industrial shale oil project and work with private energy companies.