Tomorrow's Flexible Pavement Bio-Binder

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Mission Statement:

- **Create a flexible pavement binder which:**
  - is derived from sustainable renewable resources
  - enables the paving industry to achieve a negative carbon footprint (net reduction of atmospheric CO_2)
  - yields safe and economical high-performance pavements under all traffic and climatic conditions.
  - can be constructed, maintained, and recycled with minimal disruptions to traffic.
  - enables all existing environmental health and safety standards to be met and exceeded.

Define sustainable?

- **Annual asphalt use worldwide**
  - Approximately 100 million tons
- **Annual worldwide production of lipid grain oils (Soy, Palm, Rape, Sunflower – not Corn Oil)**
  - Approximately 100 million tons
  - Paving Products: Ecopave, Activate, Replay, ..
- **Find new land with fresh water**
  - South American rain forests
  - Rain forests on Pete (release CH_4) – High CO_{2e}
  - United Nations report defines issues for fuels

Grain oil as a raw material is not sustainable!

Guiding Principles for Research:
Sustainable Sources of Raw Materials

- **Biomass sources which preferably do not use land or fresh water resources now producing food.**
  - **Cellulosic biomass**
  - **Algae**
  - **Other fast growing biological species**
- **Prefer direct sourcing of raw materials rather than using by-products from other fuels technologies** (e.g. lignin, pyrolysis pitch).

Guiding Principles for Research

Competitive life-cycle costs

Assumptions:

- **Petroleum reserves will decrease and refinery coking capacity will increase**
  - reduced AC supply
  - gradually increasing AC prices
- **Synthetic binders will add value**
  - Reduced damage from moisture and oxidation
  - Stronger, thinner, more flexible pavements
- **Cap & Trade policy will provide economic incentive through carbon credits**

Guiding Principles for Research

Targeted Products

- **Flexible Paving Binder**
  - Replace asphalt as the primary paving material.
- **Asphalt Extender**
  - Extend asphalt and improve performance
- **Rejuvenating agent for use with RAP**
  - Restore asphalt quality in aged pavements
- **Special uses**
  - Pavement Preservation, including cold applications
  - Fuel-resistant sealers for airfield pavements

Guiding Principles for Research

Pavement Serviceability

- **Design & Construction**
  - Can current HMA technology be used?
- **Maintenance & Recyclability**
  - Materials: Cold applications to replace emulsions
- **Environmental, Health, & Safety**
  - Pavement Safety: Friction
  - Worker Safety: Fumes, H_2S
- **Performance over time**
  - Aging/Oxidation
  - Sensitivity to moisture: stripping or degradation

Guiding Principles for Research

Focus on Education

- Professor Training
- Teacher Training
- Internet Training
- Enrichment programs for elementary and HS students

Guiding Principles for Research

Potential Bio-technologies

- **Algal Biomass**
  - **Convert lipid oil to viscous liquid or resin -** Biospan
  - Fischer-Tropsch conversion of methane - SASOL
    - Anaerobic Digestion
    - Grow algae that excrete methane
  - Thermal Conversion to create gas/liquid/solid:
- **Cellulosic Biomass**
  - Thermal conversion
    - Fast Pyrolysis
    - Hydrothermal Liquefaction
  - Cellulose fermentation – Use lignin by-product

Paving Binders Through Molecular Engineering

Why Algae?

- **Voracious appetite for CO_2**
  - Sequester CO_2 at coal utilities & cement plants
- **Grows in salt water**
  - Concentrates can be shipped via pipeline
- **Grows in desert climates with constant sun**
  - Ideal temperature: 70°F
- **Nutrients:**
  - Preferred nutrient source is sewage sludge: N, K, P
- **Algae strains produce different lipids**
- **Estimated Oil Production: 2000 Gal/acre**
  - >Forty times more than soybeans (48 gal/acre)

Paving Binders Through Molecular Engineering

Algae-Phalt Pavements

- **Grow the right algae**
  - Genetic engineering for oil quality and yield
  - Enclosed production systems (NASA)
- **Recover oil from living algae**
  - Filter, dry, and extract with hexane
  - Grow Algae with magnetite – separate magnetically
  - Engineered Algae secrete oil or methane (Exxon JV)
  - Sponge-like mesoporous nanoparticles extract oil (Ames)
- **Convert algal lipids to paving binder**
  - Chemistry, Processing, Catalysts
- **Evaluate performance of paving materials**

Algae – Where are we now?

- **Bio-jet from algae:** DOD, Boeing, Continental
- **Bio-fuels from algae**
  - Ames labs
  - AlgaeLink – Netherlands firm
  - Joint Venture: Exxon & Synthetic Genomics
- **NASA: Grow algae in off-shore sewage bags**
- **Algal Biomass Organization: Website, Seminars**
  - promotes the development of viable commercial markets for renewable and sustainable commodities derived from algae.
- **Oilgae: Detailed website & commercial report**

Algae: Technology Limitations

- Oil quantity and type vary with algae species
  - No specificity for the chemistry of product oils
  - “Infect” open ponds with wrong algae
- Recovery of algal oil
  - Drying and extraction is very expensive
  - Host algae killed by the recovery process
  - Ultrasound avoids drying step; difficult scale-up
  - Genetic engineering: oil-secreting algae escape!
- No known conversion processes for paving

Algae to Methane to Binder

- **Produce Methane from Algae**
  - Anaerobic Digestion (Auburn)
  - Algae produce methane directly
  - Gas by-product of thermal conversion
- **Fischer-Tropsch conversion to high molecular weight hydrocarbons –** Sasol
  - Sasobit by-products are solid wax-like branched alkanes used as asphalt warm mix additives

Thermal Conversion of Biomass

- **Thermal Conversion processes**
  - Fast Pyrolysis
  - Hydrothermal Liquefaction
- **Raw material**
  - Cellulosic Biomass
  - Algal Biomass
  - Lignin as by-product of cellulose fermentation
- **Products**
  - Cracked oils
  - Gases
  - Lignin and other heavy solid-like bottoms

Fermentation of Biomass

- **Fermentation processes**
  - Ethanol from cellulose (WRI)
- **Raw material for bio-binder**
  - Lignin
- **Conversion options**
  - Bottoms from fast pyrolysis of lignin
  - Oils from fast pyrolysis of lignin

Research Objectives: Laboratory Scale

Create a synthetic paving binder

- **From Algal Biomass:**
  - Conversion of algal oil/lipids, including possible synthesis of bio-polymers (BIOSPAN)
  - Fischer-Tropsch conversion of methane (SASOL)
  - Use of gas/liquid/solid products of thermal conversion
- **From Cellulosic Biomass:**
  - Use of thermal conversion products
  - Conversion of lignin: chemical or thermal
  - Conversion of ethanol or other bio-fuels (WRI)

Research Objectives: Laboratory Scale
Evaluate Grain-oil Based Synthetic Binders

- **Measure binder properties**
- **Evaluate paving applications appropriate to binder rheology**
  - Standard HMA mixes
  - RAP blending agents
  - Pavement Preservation, including emulsion
- **Determine fit with current design criteria and construction practices**

Questions?

If Americans could put a man on the moon in a decade, we have the ingenuity to solve the energy crisis.   Obama