



**Low Carbon Fuel Advisory Committee  
December 3, 2009**

**Agenda Item B**

**Oregon's Approach to Life Cycle  
Analysis**

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**Presentation Overview**

- Role of life cycle analysis in LCFS
- Components of carbon intensity values
- The GREET Model
  - What it does
  - How we will use it in Oregon
  - Examples
- Adjustments to life cycle analysis



## Life Cycle Analysis

- Why is life cycle analysis used in setting a low carbon fuel standard?
  - Tailpipe emissions are only a portion of the total emissions related to fuel use by vehicles



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## House Bill 2186 Language

“(b) The commission may adopt the following related to the standards, including but not limited to:  
(B) Standards for greenhouse gas emissions attributable to the fuels throughout their **lifecycles**, including but not limited to emissions from the **production, storage, transportation and combustion of the fuels and from changes in land use associated with the fuels;**”

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## Carbon Intensity Values

- Expressed in emissions per unit of fuel energy (g/MJ)
- Components:
  - Fuel Life Cycle
    - Production/Storage/Transportation/Use
  - Adjustments
    - Co-products (included in GREET)
    - Indirect effects, including land use change
    - Energy Economy Ratios or EERs (e.g., drive train efficiencies)

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## **GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation)**

- GREET is a life-cycle model sponsored by the Argonne National Laboratory
- GREET is designed to calculate the energy use and greenhouse gas (GHG) emissions associated with production and use of fuels
- The most recent version is GREET 1.8c, available at <http://www.transportation.anl.gov/software/GREET>

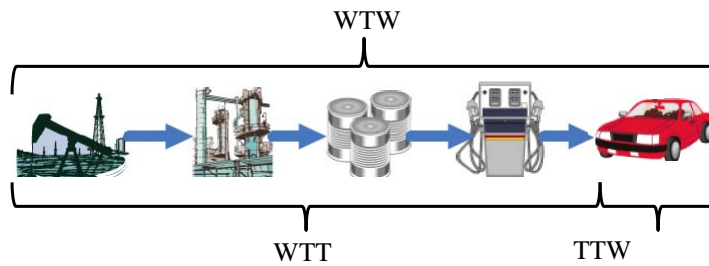
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## Low Carbon Fuel Standard – Life Cycle Analysis

### Life Cycle Analysis in GREET

- **Well to Tank (WTT):** Life Cycle Analysis of fuel pathway from feedstock production to finished product
- **Tank to Wheels (TTW):** actual combustion of fuel in a motor vehicle for motive power
- **Well to Wheels (WTW):** combination of WTT and TTW

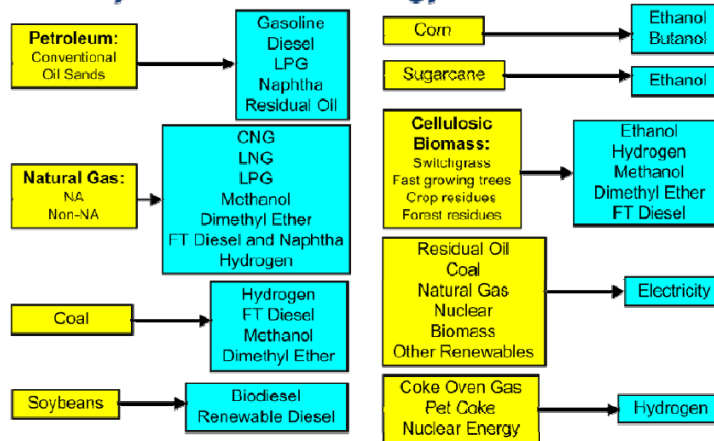


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## Low Carbon Fuel Standard – Life Cycle Analysis

### GREET Includes More Than 100 Fuel Production Pathways from Various Energy Feedstocks



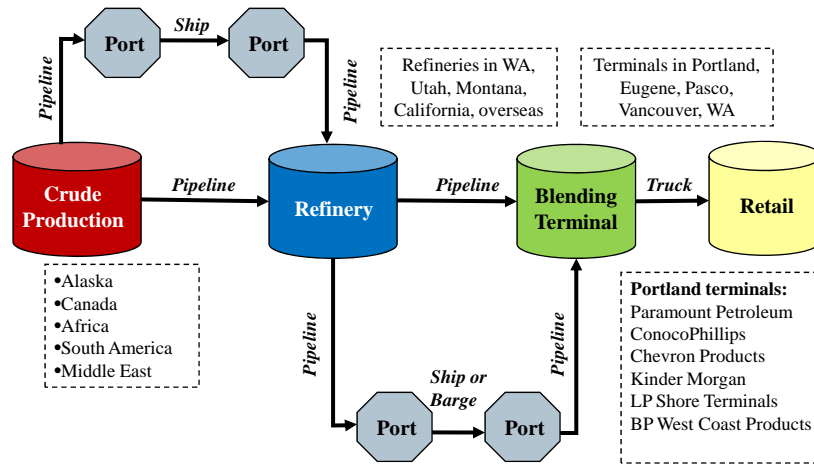
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Source: Argonne National Laboratory



## Low Carbon Fuel Standard – Life Cycle Analysis

### Oregon Petroleum Pathways



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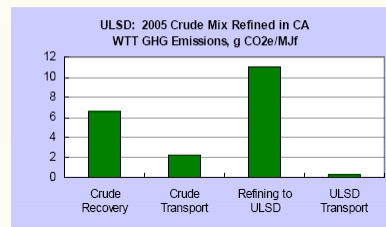
Source: TIAX LLC, modified for Oregon



## Low Carbon Fuel Standard – Life Cycle Analysis

### Petroleum Fuel Pathways - Key Inputs/Assumptions

- **Process Efficiency**
  - Crude Recovery Energy Consumption
  - Refining Energy Consumption
- **Fuel and Equipment Mixes**
  - Crude Recovery
  - Refining
- **Losses (recovery, refining)**
- **Transport**
  - Distances by mode
  - Tanker/Truck Inputs
    - Payload
    - Horsepower
    - Fuel economy
    - Speed
  - Pipeline Inputs
    - Energy intensity (Btu/ton-mile)
    - Compressor station fuel mix
    - Prime mover mix at compressor stations
  - Losses



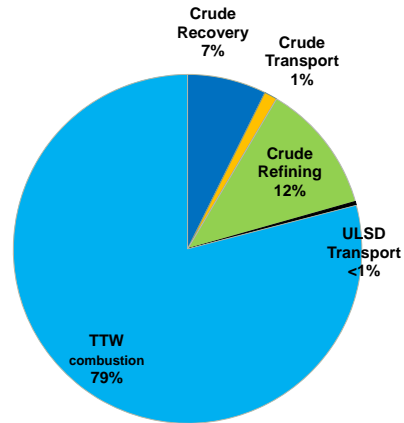
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Source: TIAX LLC



### Example: California Ultra Low Sulfur Diesel

- **Well to Tank = 19.81 gCO<sub>2</sub>e/MJ**
  - Crude Recovery = 6.93 gCO<sub>2</sub>e/MJ
  - Crude Transportation = 1.14 gCO<sub>2</sub>e/MJ
  - Crude Refining to ULSD = 11.48 gCO<sub>2</sub>e/MJ
  - ULSD Transportation, Storage, Distribution = 0.33 gCO<sub>2</sub>e/MJ
- **Tank to Wheels = 74.9 gCO<sub>2</sub>e/MJ**
- **Total Well to Wheels = 94.7 gCO<sub>2</sub>e/MJ**

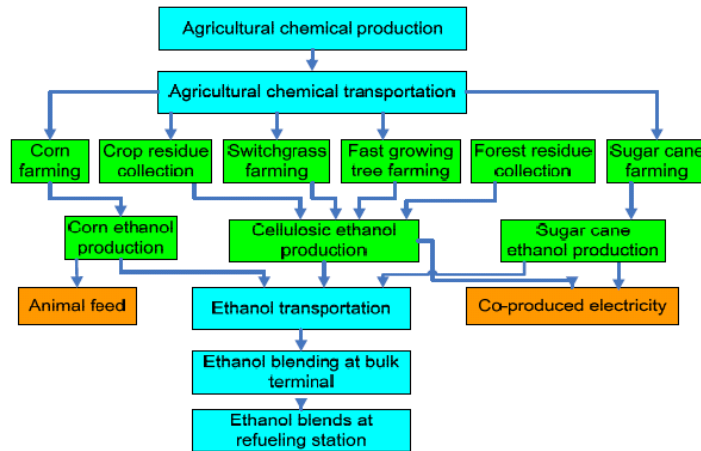


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Source: California Air Resources Board



### REET Ethanol Life-Cycle Analysis Includes Activities from Fertilizer to Ethanol at Stations



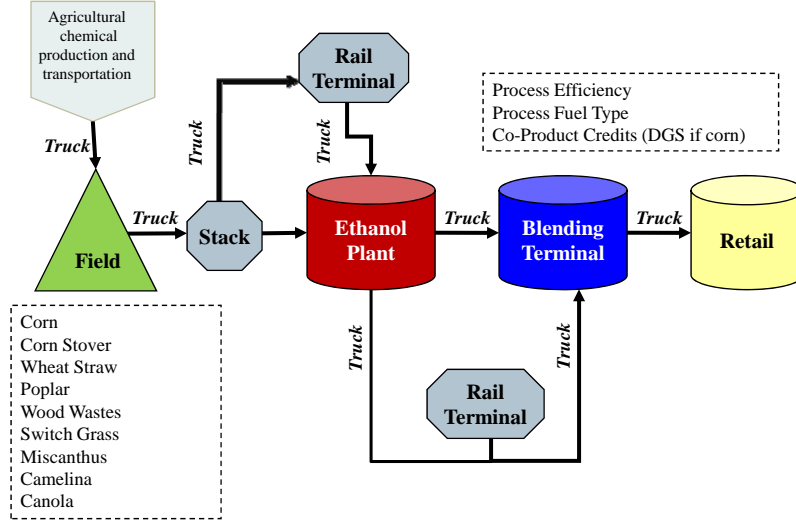
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Source: Argonne National Laboratory



## Low Carbon Fuel Standard – Life Cycle Analysis

### Ethanol Pathways



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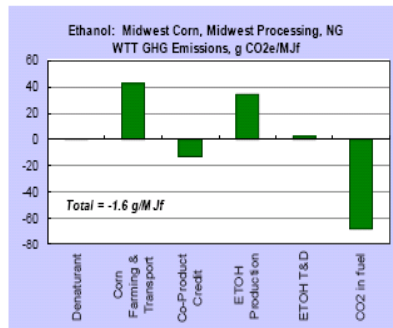
Source: TIAX LLC, modified for Oregon



## Low Carbon Fuel Standard – Life Cycle Analysis

### Ethanol Pathways - Key Inputs/Assumptions

- Feedstock Assumptions
  - Material (corn, farmed trees, herbaceous, corn stover, forest residue)
  - Farming/collection energy use
    - Split by fuel type
    - Split by combustion device
  - Fertilizer/pesticide/herbicide
    - Amounts by type
    - Production energy consumption
    - Transport modes and distances
    - % of N in fertilizer emitted as N<sub>2</sub>O
  - Crop yields
  - Feedstock transport modes and distances
- Ethanol Production
  - Process efficiency (energy use)
    - Split by fuel type
    - Split by combustion device
  - Process yield (gal/bu)
  - Co-product credits (DGS substituted for feed corn & soybean meal)
  - Transport modes and distance



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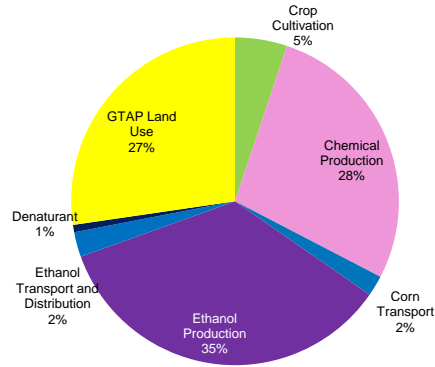
Source: TIAX LLC



## Low Carbon Fuel Standard – Life Cycle Analysis

### Example: California Corn Ethanol (Mid-West using Dry Mill Process)

- **Well to Tank = 68.4 gCO<sub>2</sub>e/MJ**
  - Crop Cultivation = 5.65 gCO<sub>2</sub>e/MJ
  - Chemical production (farm inputs) = 30.2 gCO<sub>2</sub>e/MJ
  - Corn Transport = 2.22 gCO<sub>2</sub>e/MJ
  - Ethanol Production = 38.3 gCO<sub>2</sub>e/MJ
  - Denaturant = 0.8 gCO<sub>2</sub>e/MJ
  - Ethanol Transport and distribution = 2.7 gCO<sub>2</sub>e/MJ
  - Co-product credit = -11.5 gCO<sub>2</sub>e/MJ
- **Tank to Wheels = 0 gCO<sub>2</sub>e/MJ**
- Adjustments:
  - GTAP Land Use = 30 gCO<sub>2</sub>e/MJ
- **Total Well to Wheels = 98.4 gCO<sub>2</sub>e/MJ**



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Source: California Air Resources Board



## Low Carbon Fuel Standard – Life Cycle Analysis

### Oregon Approach Summary

- Use GREET for Full Fuel WTW analysis
- Leverage WA and CA work (where applicable)
- Modify GREET to reflect local feedstock, fuel, electricity mix, and transportation distances
- Make adjustments for indirect effects, drive train efficiencies

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## Co-Products

- Refining of biomass into fuels also creates co-products with economic value
- Ethanol examples:
  - Dry-mill process: One bushel of corn (56 lbs) yields
    - 2.8 gallons of ethanol
    - 17.5 lbs of animal feed (dried distillers grains)
  - Wet-mill process: One bushel of corn yields
    - 2.8 gallons of ethanol
    - 13-15.6 lbs of animal feed (corn gluten and corn gluten meal)
    - 1.6 lbs of corn oil

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## Indirect Effects

- Land use changes: Emissions associated with modifying the vegetation on a plot of land in order to grow feedstocks for biofuel production
- Other indirect effects
- Topic for future advisory committee meetings

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## Energy Economy Ratios

- Adopted by California to take into account differences in drive train efficiencies of vehicles using alternative low carbon fuels compared to gasoline- and diesel-powered vehicles
- House Bill 2186 language:  
“(b) The commission may adopt the following related to the standards, including but not limited to:  
(G) Adjustments to the amounts of greenhouse gas emissions per unit of fuel energy assigned to fuels for combustion and drive train efficiency.”
- Examples: Battery Electric Vehicles, CNG-powered vehicles, Fuel Cell Vehicles

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## Questions?



For more information on the GREET model, please visit:  
[http://www.transportation.anl.gov/modeling\\_simulation/GREET/index.html](http://www.transportation.anl.gov/modeling_simulation/GREET/index.html)

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## Low Carbon Fuel Standard – Life Cycle Analysis

### GREET

- Recursive methodology to calculate energy consumption and emissions, i.e. if crude oil is used as process fuel to recover crude oil, the total crude oil recovery energy consumption includes the direct crude oil consumption plus the energy associated with crude recovery.
- Carbon Intensity  $\text{gCO}_2\text{e/MJ}$  – total GHG emissions as  $\text{CO}_2$  equivalent per unit of energy for a given fuel.  $\text{CH}_4$  and  $\text{N}_2\text{O}$  converted to  $\text{CO}_2$  using IPCC global warming potential values.
- VOC and CO converted using molecular weight ratios.
- Process efficiency =  $\text{energy output} / (\text{energy output} + \text{energy consumed})$

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### Model Settings

- CA transport distances for fuel pathways
- CA crude oil extraction and refinery efficiency
- Revised LNG boil off and recovery rates
- 85% dry mill corn ethanol, with 32,330 Btu/gal heat rate, default wet mill inputs and agricultural inputs, MidWest to CA transport distance
- Set DGS/corn displacement ratio to 1 and DGS/SBM displacement factor to 0; urea factor set to 0, methane credit for DGS set to 0
- Revised CNG compression to 100%  
electric NG compression, 98% efficiency
- Set hydrogen to 100% on site steam reformers from natural gas, 100% central plant liquid hydrogen
- Revised coal energy inputs to reflect new coal mining data
- Revised BD oil extraction energy and fuel shares
- Set CA marginal electricity to 78.7% NG with 100% CCGT and 21.3% renewables

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