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CA-GREET and Fuel Pathways
Updated California-GREET Model

- New GREET model released September 2008 by ANL

- Updated CA-GREET model released Dec 2008 (modified by Life Cycle Associates)
  - LFCS inputs were changed individually for each pathway
  - All CI values reported here are in gCO$_2$e/MJ
Updated California-GREET Model (cont.)

- Updated 9 fuel pathways
- Created 5 new pathways (Sugarcane Ethanol, LNG, Soy Renewable Diesel, Farmed Trees Ethanol, and Forest Residue Ethanol)
- Latest documents do not reflect some minor CA-GREET model modifications and will be updated
- Remaining pathway documents will be published early February 2009
Changes in CA-GREET

- CH$_4$ and N$_2$O GWPs updated
- Heating value and carbon content of coal
- Regional electricity mixes used (CA, MW, etc.)
- Updated shipping and transportation distances
Factors Leading to Changes for Gasoline and Diesel Baseline

Crude Recovery
- Updated CA crude mix analysis including TEOR
- Updated transport distances
- Updated fuel shares based on aggregate energy

Crude Refining
- Electricity emissions updated

Tailpipe
- EMFAC emission factors
<table>
<thead>
<tr>
<th>Fuels</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARBOB</td>
<td>95.86</td>
</tr>
<tr>
<td>CaRFG</td>
<td>95.85</td>
</tr>
<tr>
<td>ULSD</td>
<td>94.71</td>
</tr>
</tbody>
</table>

CaRFG is modeled as nominally 10% corn ethanol using 80% Mid-West average corn ethanol and 20% CA Dry mill wet DGS corn ethanol. For the Mid-West, we assume 95% dry mill DDGS and 5% dry mill wet DGS. Blending EtOH CI = 95.66 gCO2/MJ. CARBOB values are WTW inclusive of tailpipe emission factors.
Factors Leading to Changes for Corn Ethanol

Corn Production
- Decreased energy input and % fuel shares in corn farming

Ethanol Production & Transport
- Electricity emissions updated for MW and CA mix
- Eliminate medium duty truck in ethanol transport
- Credit now for 1lb DDGS = 1 lb of feed corn

LUC Analysis
- iLUC of 30 gCO₂/MJ from GTAP analysis
## Mid-West Corn Ethanol-Carbon Intensity (gCO$_2$e/MJ)

<table>
<thead>
<tr>
<th>Source</th>
<th>Technology and Details</th>
<th>Fuel</th>
<th>CA-GREET</th>
<th>LUC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-West</td>
<td>Dry Mill, DDGS</td>
<td>100% NG</td>
<td>68.40</td>
<td>30.0</td>
<td>98.40</td>
</tr>
<tr>
<td></td>
<td>Wet Mill</td>
<td>60% NG 40% Coal</td>
<td>75.10</td>
<td>30.0</td>
<td>105.10</td>
</tr>
<tr>
<td></td>
<td>Dry Mill, WDGS</td>
<td>100% NG</td>
<td>60.10</td>
<td>30.0</td>
<td>90.10</td>
</tr>
<tr>
<td></td>
<td>Dry Mill, DDGS</td>
<td>80% NG, 20% biomass</td>
<td>63.60</td>
<td>30.0</td>
<td>93.60</td>
</tr>
<tr>
<td></td>
<td>Dry Mill, WDGS</td>
<td>80% NG, 20% biomass</td>
<td>56.60</td>
<td>30.0</td>
<td>86.60</td>
</tr>
<tr>
<td>Mid-West Ave.</td>
<td>80% Dry Mill (95% DDGS, 5% WDGS) 20% Wet Mill</td>
<td></td>
<td></td>
<td></td>
<td>99.40</td>
</tr>
</tbody>
</table>
CA Corn Ethanol-Carbon Intensity (gCO$_2$e/MJ)

<table>
<thead>
<tr>
<th>Source</th>
<th>Technology and Details</th>
<th>Fuel</th>
<th>CA-GREET</th>
<th>LUC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>Dry Mill, DDGS</td>
<td>100% NG</td>
<td>58.90</td>
<td>30.0</td>
<td>88.90</td>
</tr>
<tr>
<td></td>
<td>Dry Mill, WDGS</td>
<td>100% NG</td>
<td>50.70</td>
<td>30.0</td>
<td>80.70</td>
</tr>
<tr>
<td></td>
<td>Dry Mill, DDGS</td>
<td>80% NG, 20% biomass</td>
<td>54.20</td>
<td>30.0</td>
<td>84.20</td>
</tr>
<tr>
<td></td>
<td>Dry Mill, WDGS</td>
<td>80% NG, 20% biomass</td>
<td>47.40</td>
<td>30.0</td>
<td>77.40</td>
</tr>
<tr>
<td></td>
<td>LCFS Corn Ethanol Ave (80% Mid-West Average and 20% CA Dry Mill WDGS)</td>
<td></td>
<td></td>
<td></td>
<td>95.66</td>
</tr>
</tbody>
</table>
## Sugarcane and Cellulosic Ethanol – Carbon Intensity (gCO₂e/MJ)

<table>
<thead>
<tr>
<th>Source</th>
<th>Feedstock/Technology</th>
<th>CA-GREET</th>
<th>LUC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>Sugar Cane, Fermentation</td>
<td>27.40</td>
<td>46.0</td>
<td>73.40</td>
</tr>
<tr>
<td>Mid-West</td>
<td>Forest Residue, Gasification</td>
<td>22.20</td>
<td>0*</td>
<td>22.20</td>
</tr>
</tbody>
</table>

* Currently assumes no Land Use Change impacts
Factors Leading to Changes for H₂

- Electricity GHG intensity affects compression and liquefaction
- Fixed formula for efficiency
- Added compression step to liquid H₂
- On-site reformation scenario provided
- SB1505 scenario added
## H₂ – Carbon Intensity (gCO₂e/MJ)

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Feedstock</th>
<th>Technology</th>
<th>CA-GREET</th>
<th>With EER= 2.3 for LDVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂ (liquid)</td>
<td>NG</td>
<td>Central Reforming</td>
<td>133.00</td>
<td>57.83</td>
</tr>
<tr>
<td></td>
<td>NG</td>
<td>Central Reforming Liquid Delivery</td>
<td>142.20</td>
<td>61.83</td>
</tr>
<tr>
<td>H₂ (gaseous)</td>
<td>NG</td>
<td>Onsite Reforming</td>
<td>98.30</td>
<td>42.74</td>
</tr>
<tr>
<td></td>
<td>NG + Renewables</td>
<td>Onsite Reforming (compliant with SB1505)</td>
<td>76.10</td>
<td>33.09</td>
</tr>
</tbody>
</table>
Factors Leading to Changes for Electricity

Electricity

- Fixed error in earlier CA-GREET model
- Added marginal power generation scenario
- Marginal includes all combined cycle natural gas generation with 21.3% new renewables
### Electricity - Carbon Intensity (gCO$_2$e/MJ)

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Feedstock</th>
<th>CA-GREET</th>
<th>With EER= 3.0 for LDVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity CA Ave.</td>
<td>CA Ave. Mix</td>
<td>124.10</td>
<td>41.37</td>
</tr>
<tr>
<td>Electricity, Marginal</td>
<td>NG</td>
<td>104.70</td>
<td>34.90</td>
</tr>
</tbody>
</table>
### CNG - Carbon Intensity (gCO₂e/MJ)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Feedstock</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNG</td>
<td>CA Ave. NG</td>
<td>68.00</td>
</tr>
<tr>
<td>CNG</td>
<td>Land Fill Gas (Bio-methane)</td>
<td>11.40</td>
</tr>
</tbody>
</table>