


Life Cycle Assessment of Fuel Ethanol Derived from Corn Grain via Dry Milling

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Goal of Study

- Assess the overall environmental performance of corn based ethanol production in a dry mill
- Estimate local effects due to farming sites on the ethanol fuel system
- Determine the effects of possible scenarios for reducing nitrogen losses from soil during corn cultivation

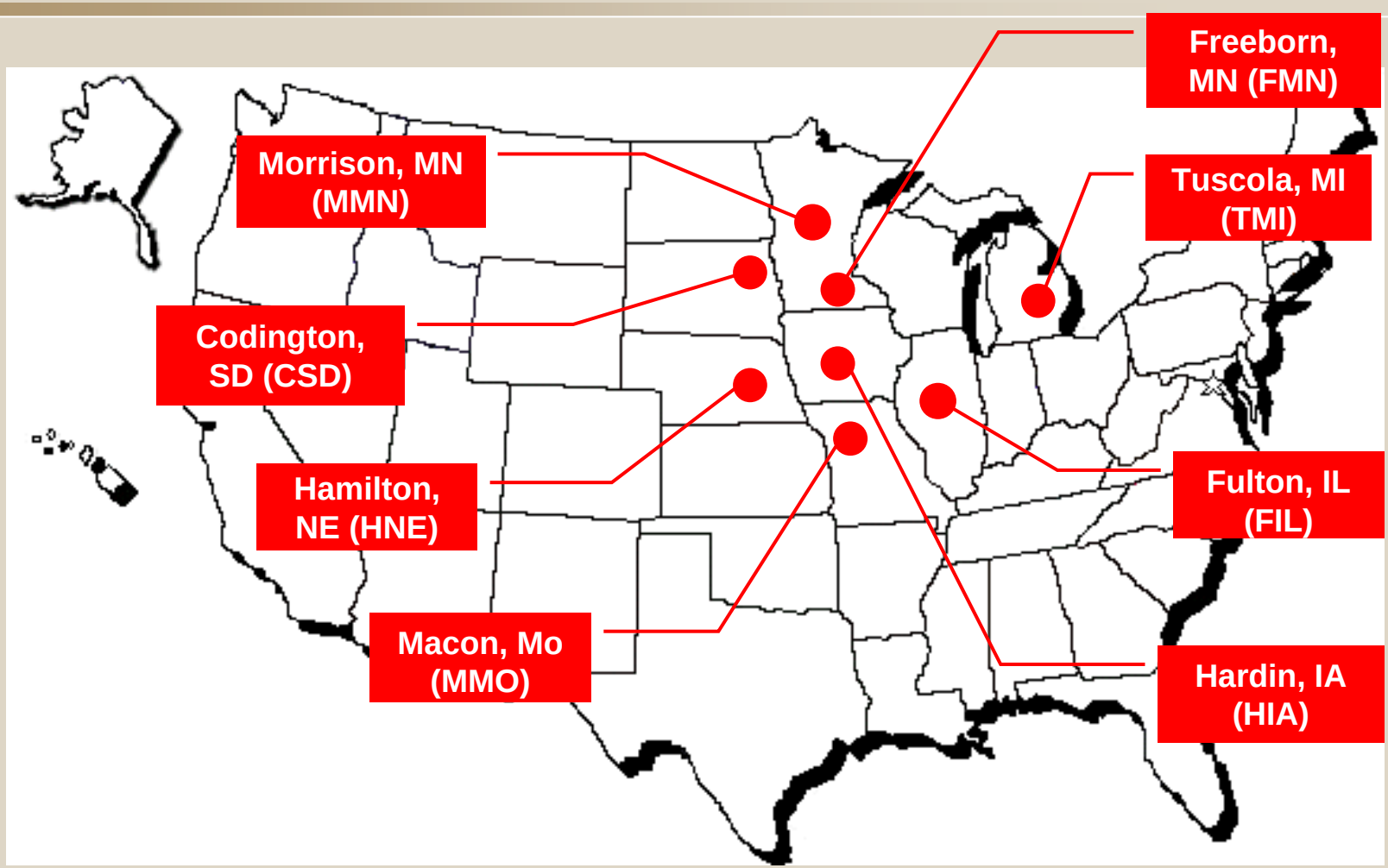
Scope

- Functional unit: bioethanol derived from corn grain used in an E10 fueled vehicle
  - reference flow: one kg of ethanol
- Overall system boundary
  - Corn production, dry milling, E10 fueled vehicle operation
- Environmental impacts
  - nonrenewable energy consumption, greenhouse gas emissions, acidification, eutrophication and photochemical smog formation
    - Local impacts estimated by the TRACI model (USEPA)

Corn Culture

- Farming sites: eight counties in seven different states
  - Each county has a dry milling plant.
- Soil organic carbon and nitrogen dynamics are simulated by the DAYCENT model
  - DAYCENT predicts soil organic carbon level and nitrogen related emissions from soil (i.e.,N_2O, NOx, NO_3^-)
  - Current tillage practices are applied to the simulation

Corn Farming Sites



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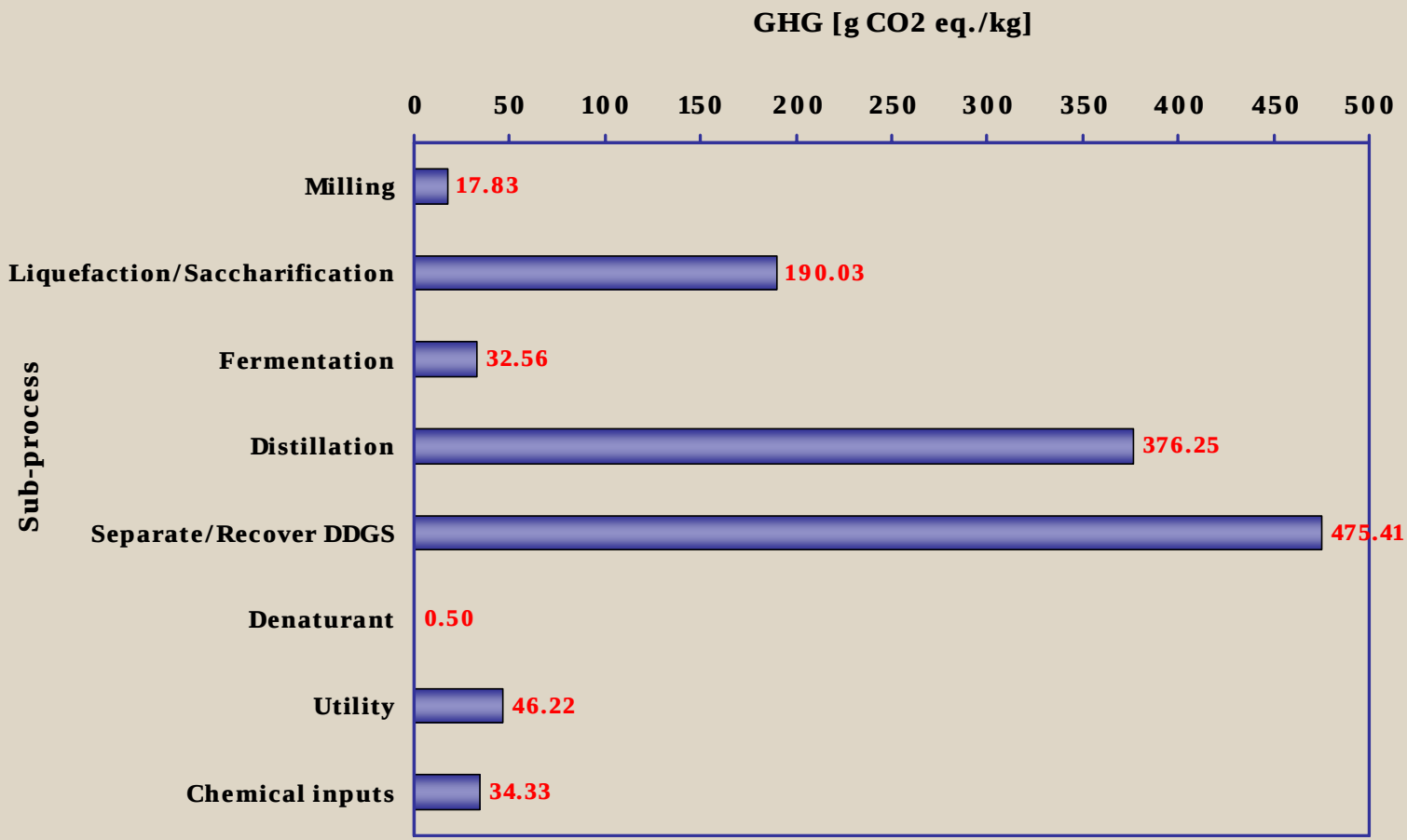
Dry Milling

- Process information: ASPEN PLUS models (NREL study, 2000)
  - Ethanol yield: 2.7 gal per bushel
  - DDGS: 8.4 kg per bushel
  - Energy consumption
    - Electricity: 0.80 kWh per gallon
    - Natural gas: 32,329 Btu per gallon
- Allocation: System expansion approach
  - Introducing alternative product systems for co-products
    - Alternative system for DDGS: corn grain and soybean meal

Greenhouse Gas Profiles in Dry Milling



Based on weighted average over corn production

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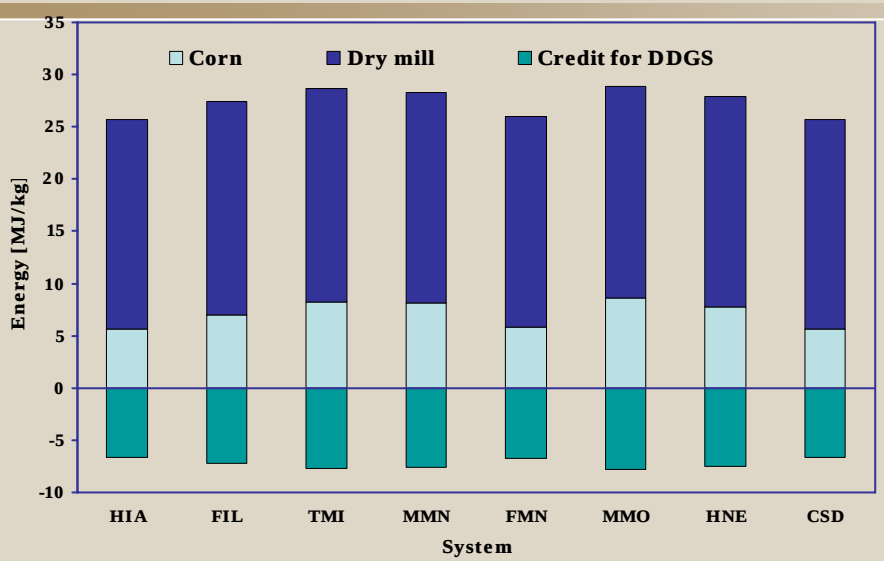
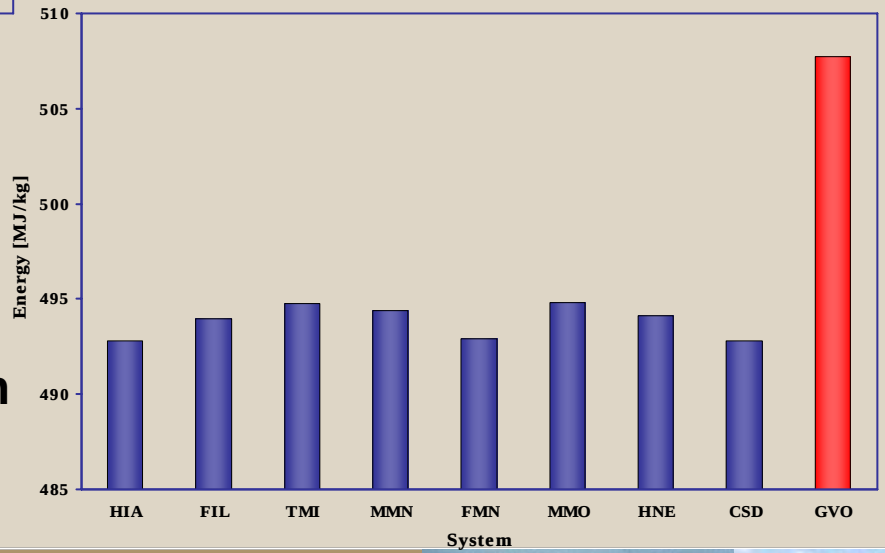
Nonrenewable Energy



System boundary: Corn and dry milling



System boundary:
Corn, dry milling and vehicle operation

GVO: gasoline fueled vehicle operation

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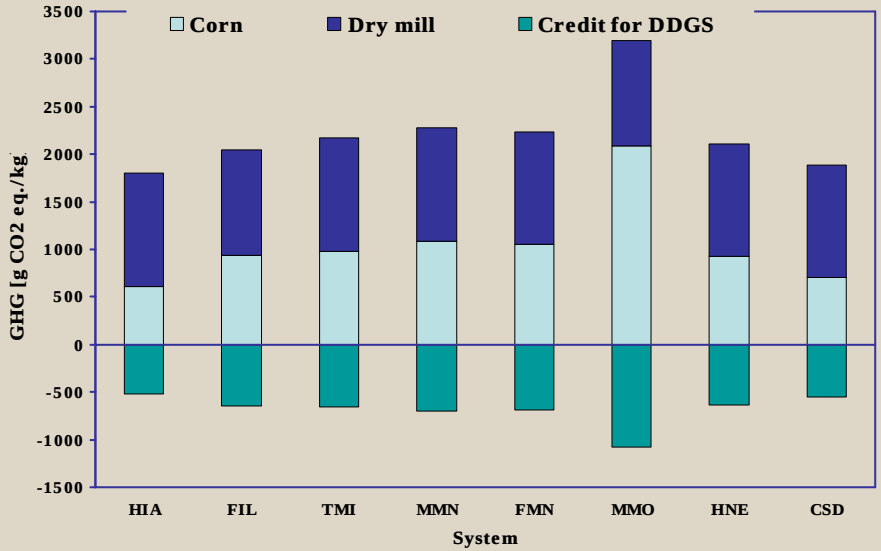
Greenhouse Gas Emissions



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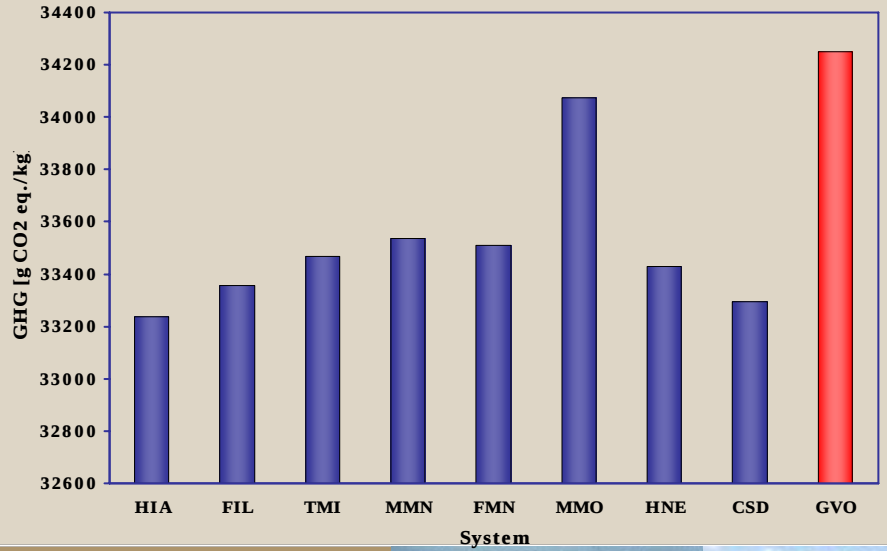

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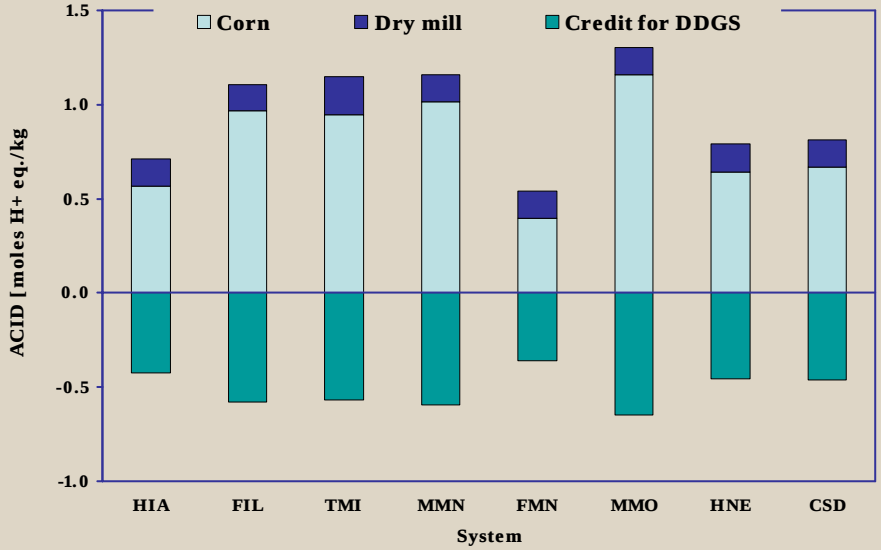
Acidification



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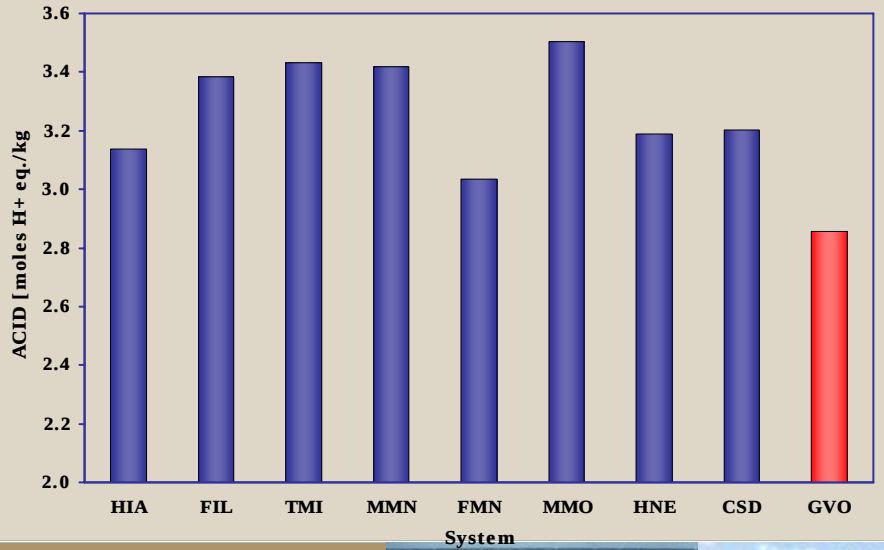

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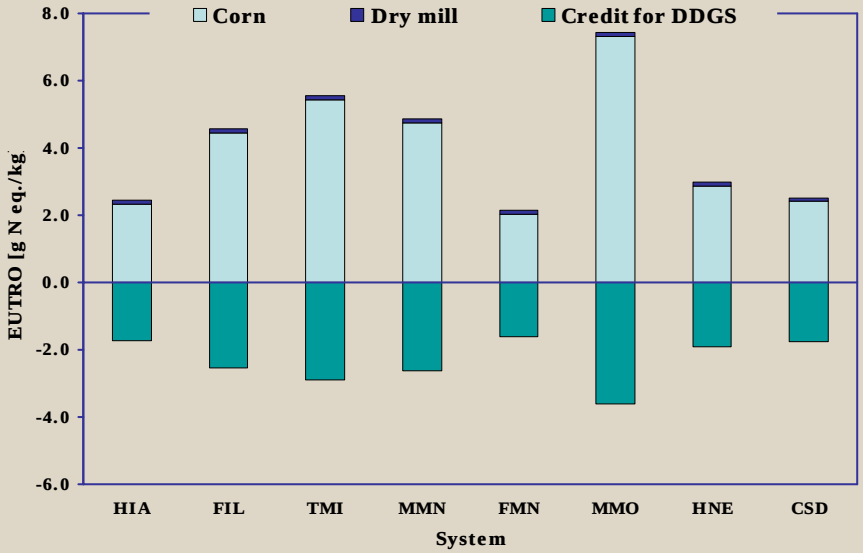
Eutrophication



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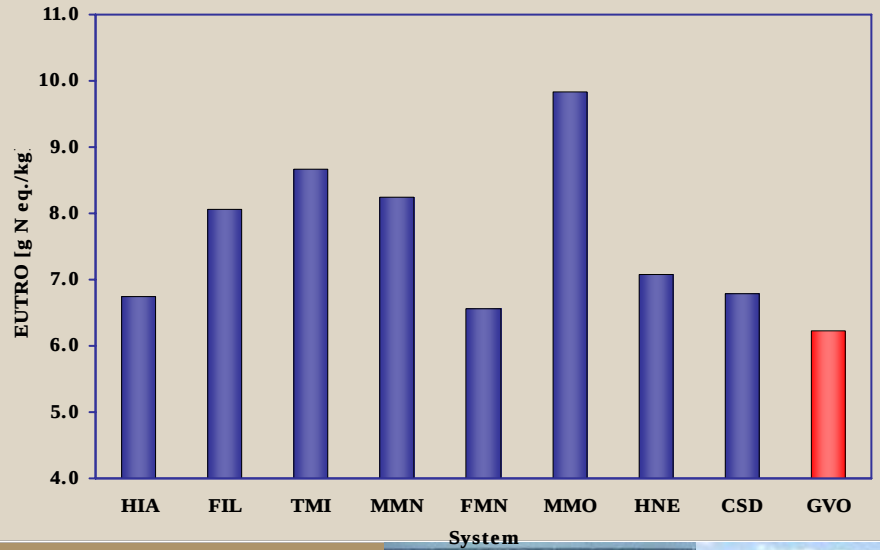

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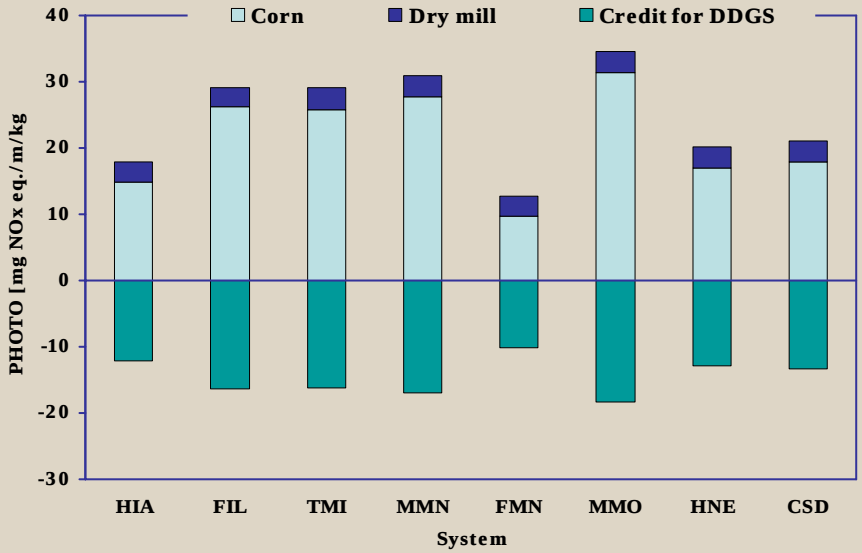
Photochemical Smog Formation



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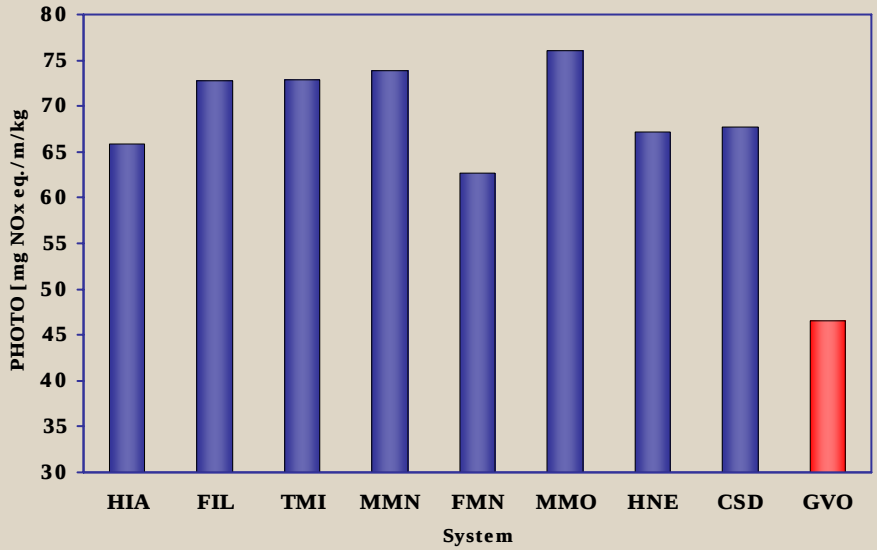

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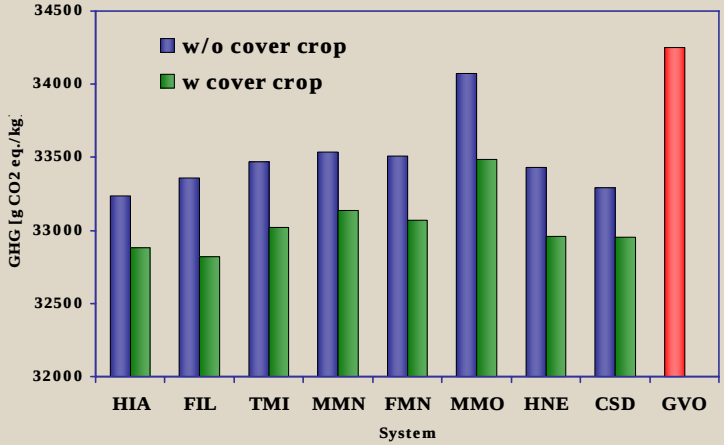
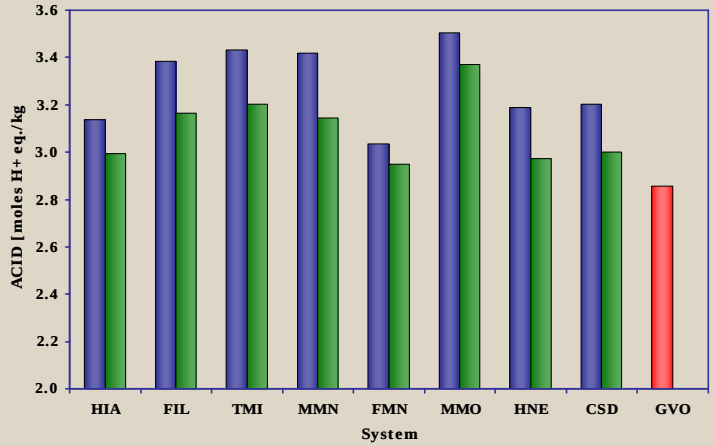
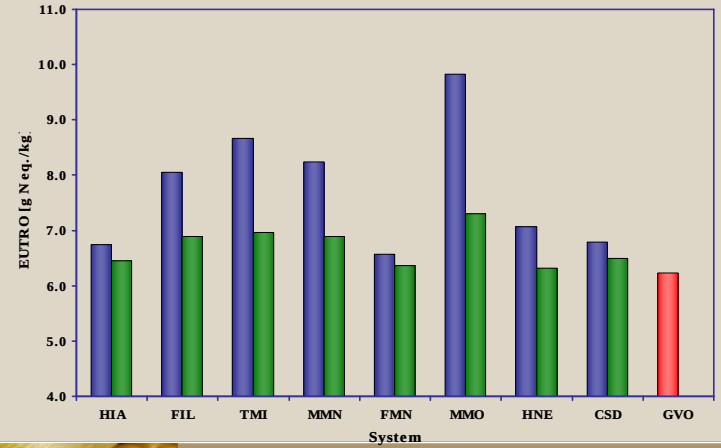
Scenario analysis

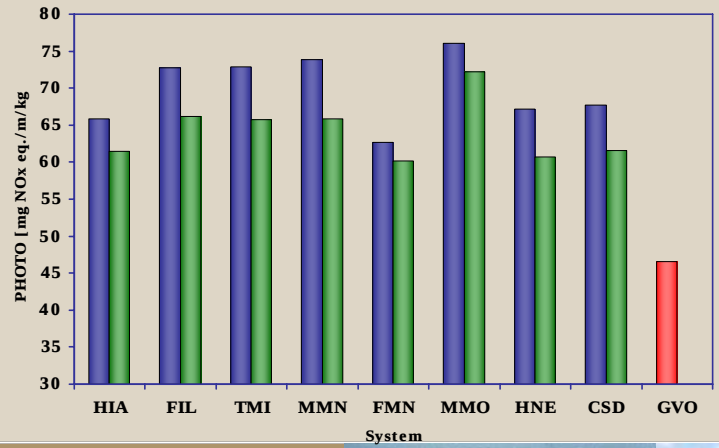
- Nitrogen losses from soil (i.e., N_2O, NOx, NO_3^{-1}) during corn cultivation are the dominant emissions influencing most environmental impacts considered here
- Possible approaches to reduce nitrogen losses from soil
  - precision farming technologies
  - planting winter cover crop
    - Investigate effects of winter cover crop practice in the overall ethanol fuel system

Winter Cover Crop Practice









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Conclusions

- The environmental performance of ethanol fuel system (farm to tailpipe) varies with its corn production sites
  - Particularly for local environmental impacts
- E10 fuel would reduce nonrenewable energy consumption and greenhouse gas emissions compared to gasoline fuel
- However, E10 fuel would have more impact on acidification, eutrophication and photochemical smog formation than gasoline fuel
  - Primary emission source: **nitrogen fertilizer** in corn cultivation

- Winter cover crop practices would improve the environmental performance of ethanol fuel system in terms of all of the environmental impacts considered here
  - due to less nitrogen losses from soil
- Separating/recovering DDGS process is the most environmentally sensitive sub-process in the dry milling process, followed by distillation process
  - Energy requirement in drying DDGS