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All Biomass is Local: Environmental Impacts of Ethanol Derived from Corn Grain

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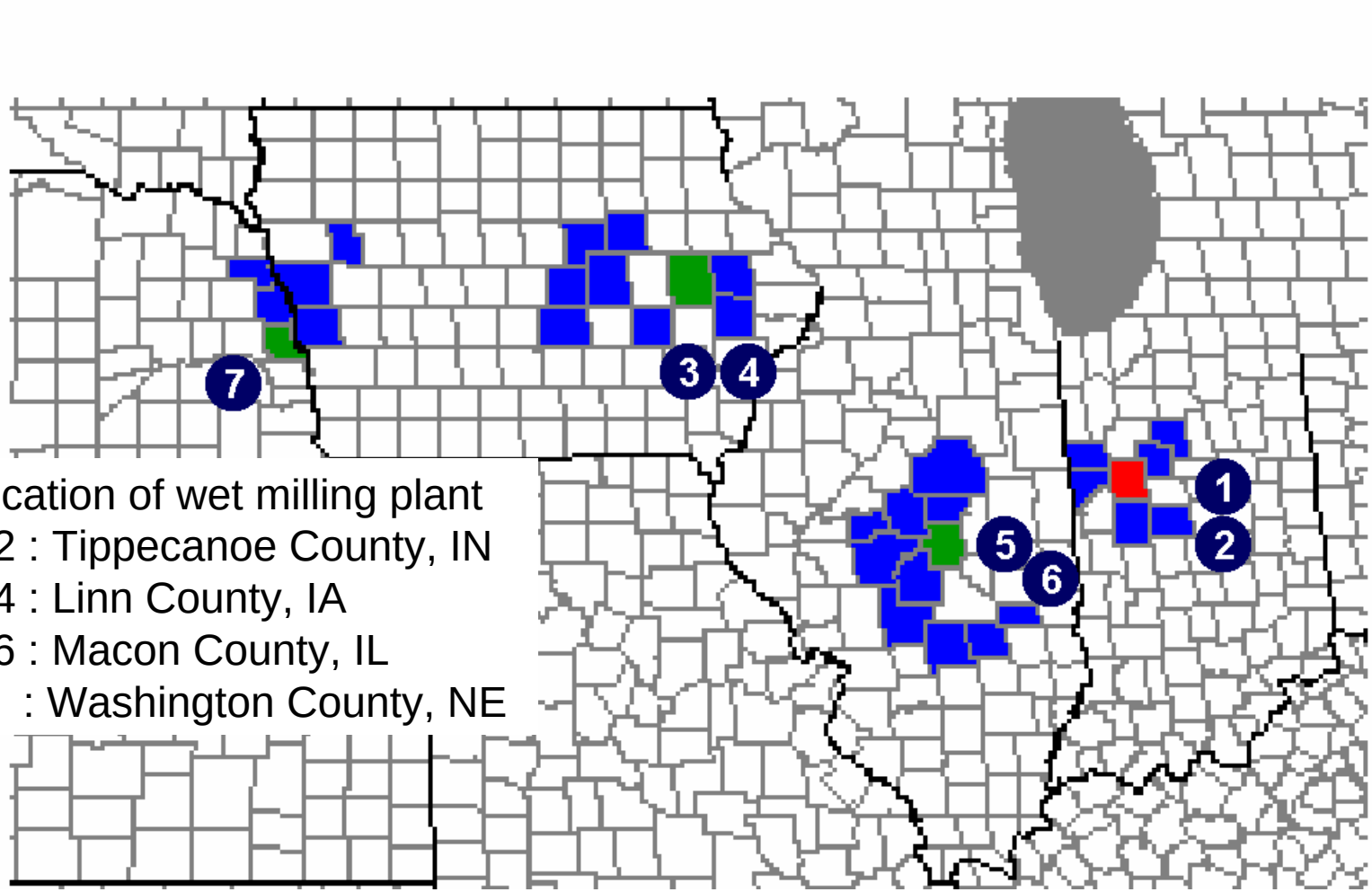
Goal of Study

- Identify **local effects** on environmental performance of ethanol fuel derived from corn grain - particularly **effects of farming sites**
  - yield
  - agronomic inputs
  - energy consumption
  - soil organic carbon level
  - other field emissions, etc

Farming Sites

- Chose seven wet milling plants (out of 28 wet milling plants in the US)
  - Illinois, Indiana, Iowa, Nebraska
    - representing a broad range of corn grain production in Corn Belt States
- Adjacent counties are selected as farming sites for supplying corn grain to a wet mill
  - based on corn price and transportation cost
    - About 30 counties in four states (IL, IN, IA, NE)

Corn Farming Counties



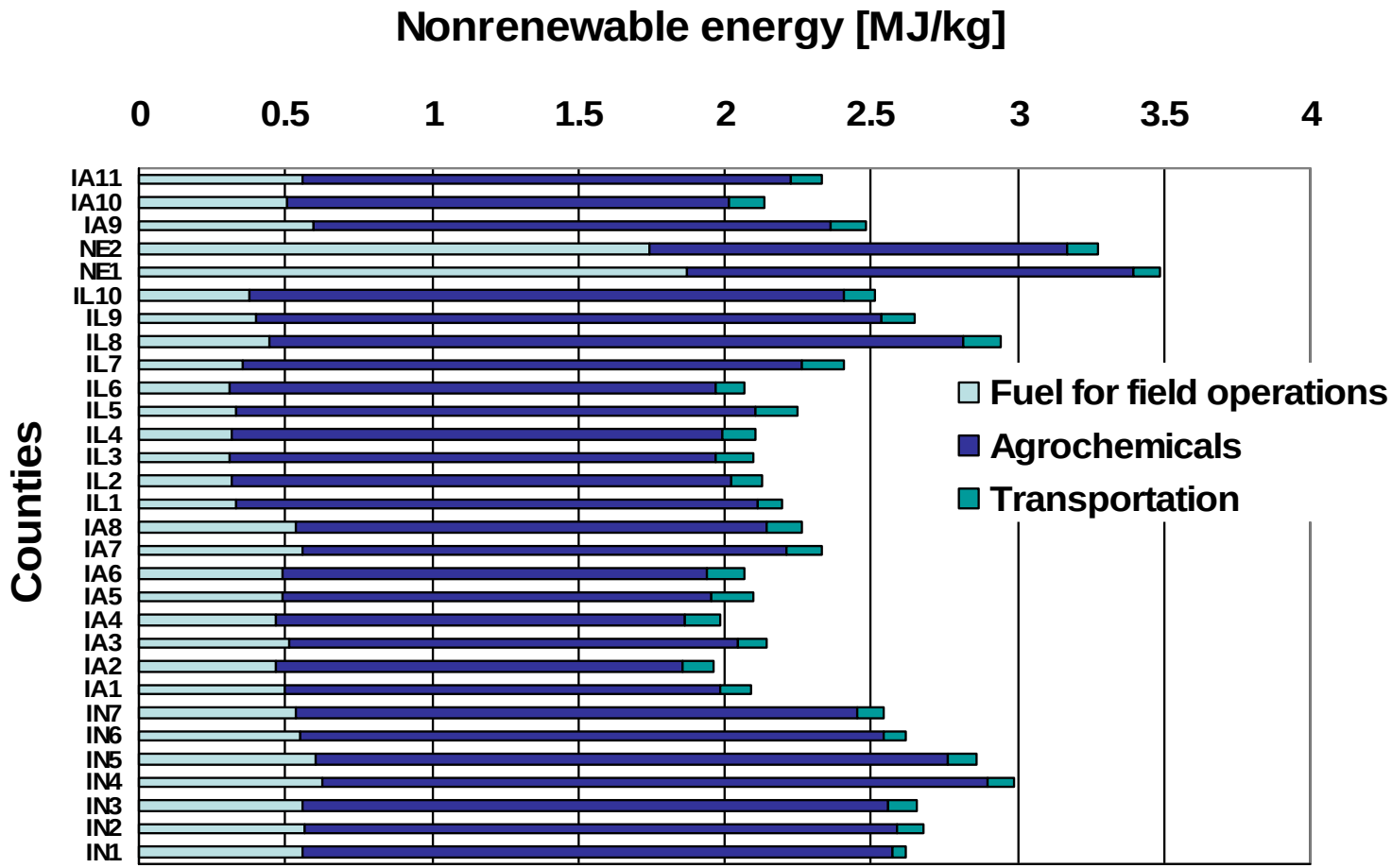
Location of wet milling plant
1 & 2 : Tippecanoe County, IN
3 & 4 : Linn County, IA
5 & 6 : Macon County, IL
7 : Washington County, NE

Red: County, in which a wet milling plant is located, and its corn is utilized as feedstock for wet milling,
Green: County, in which a wet milling plant is located, and its corn is not utilized as feedstock for wet milling,
Blue: Adjacent Counties, in which their corn is utilized as feedstock for wet milling

Cropping System

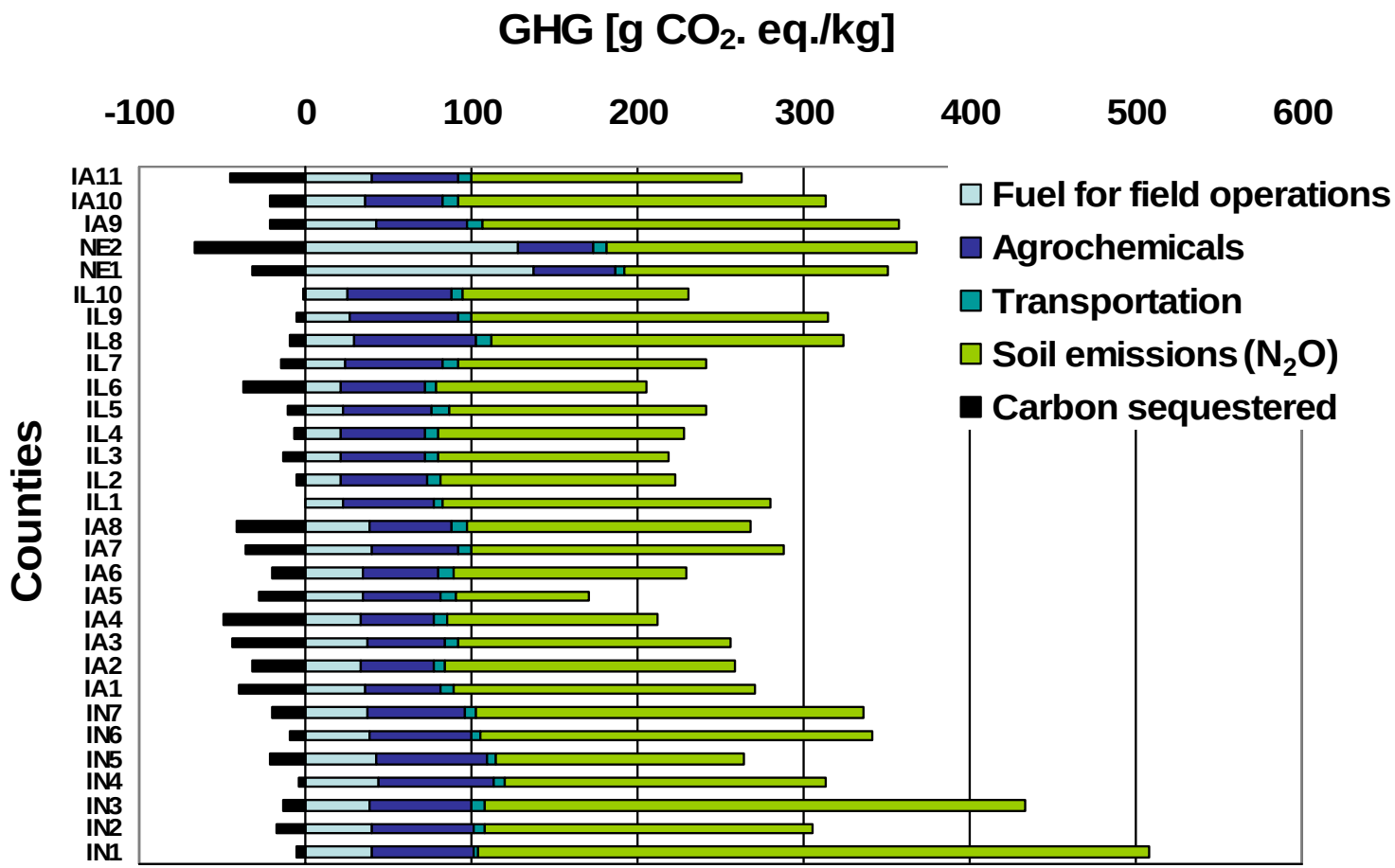
- Agronomic inputs and energy consumption are available from USDA and literature
- Current tillage practices are used
- Soil organic carbon and nitrogen dynamics are simulated by an agro-ecosystem model – DAYCENT model
- Information on the upstream processes is obtained from literature
- All impacts are normalized per kg of corn produced in that county

Nonrenewable Energy Use



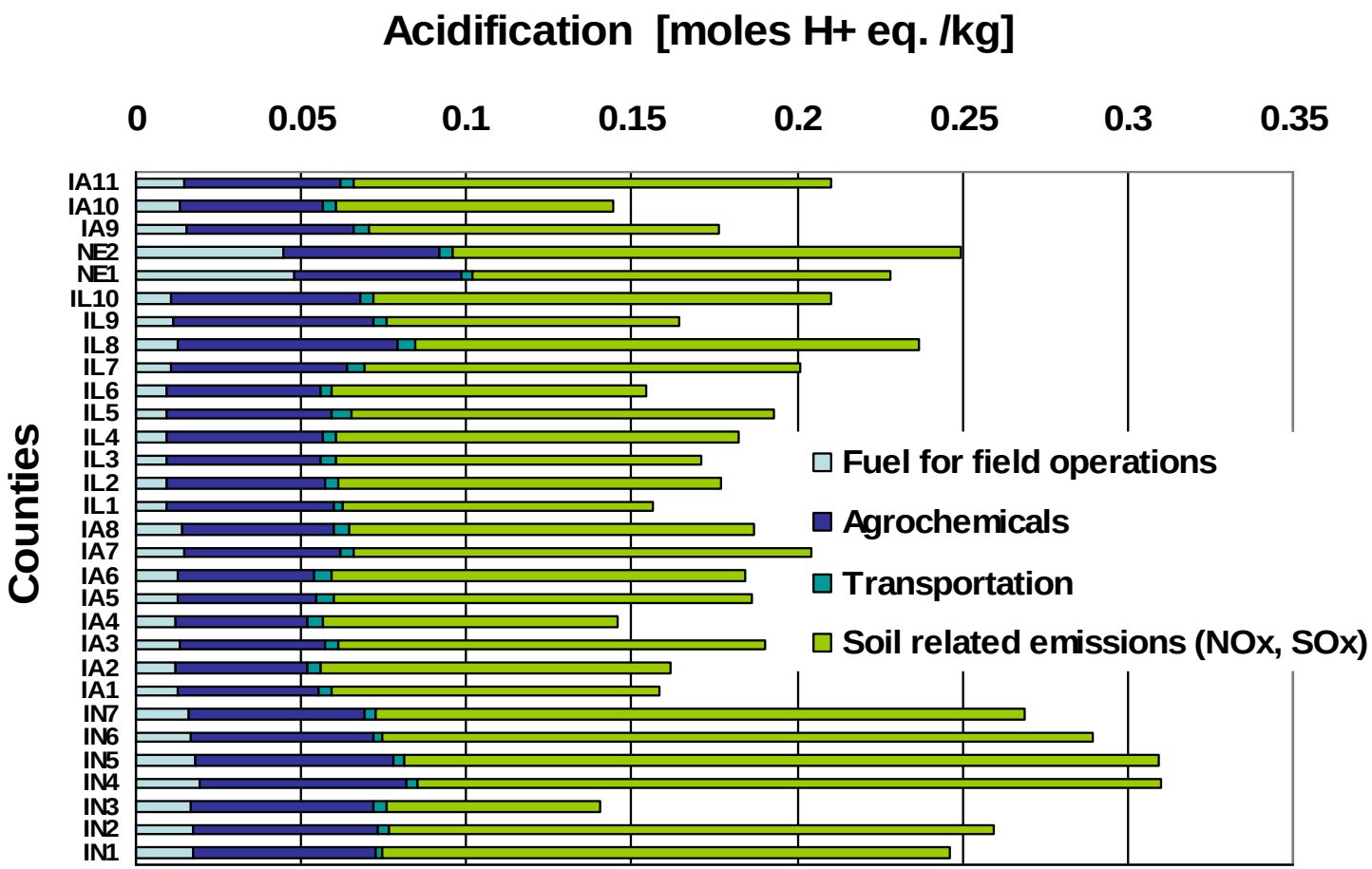
Nonrenewable energy: sum of fossil energy and nuclear energy
Transportation: transportation of corn grain to a wet mill

GHG Emissions

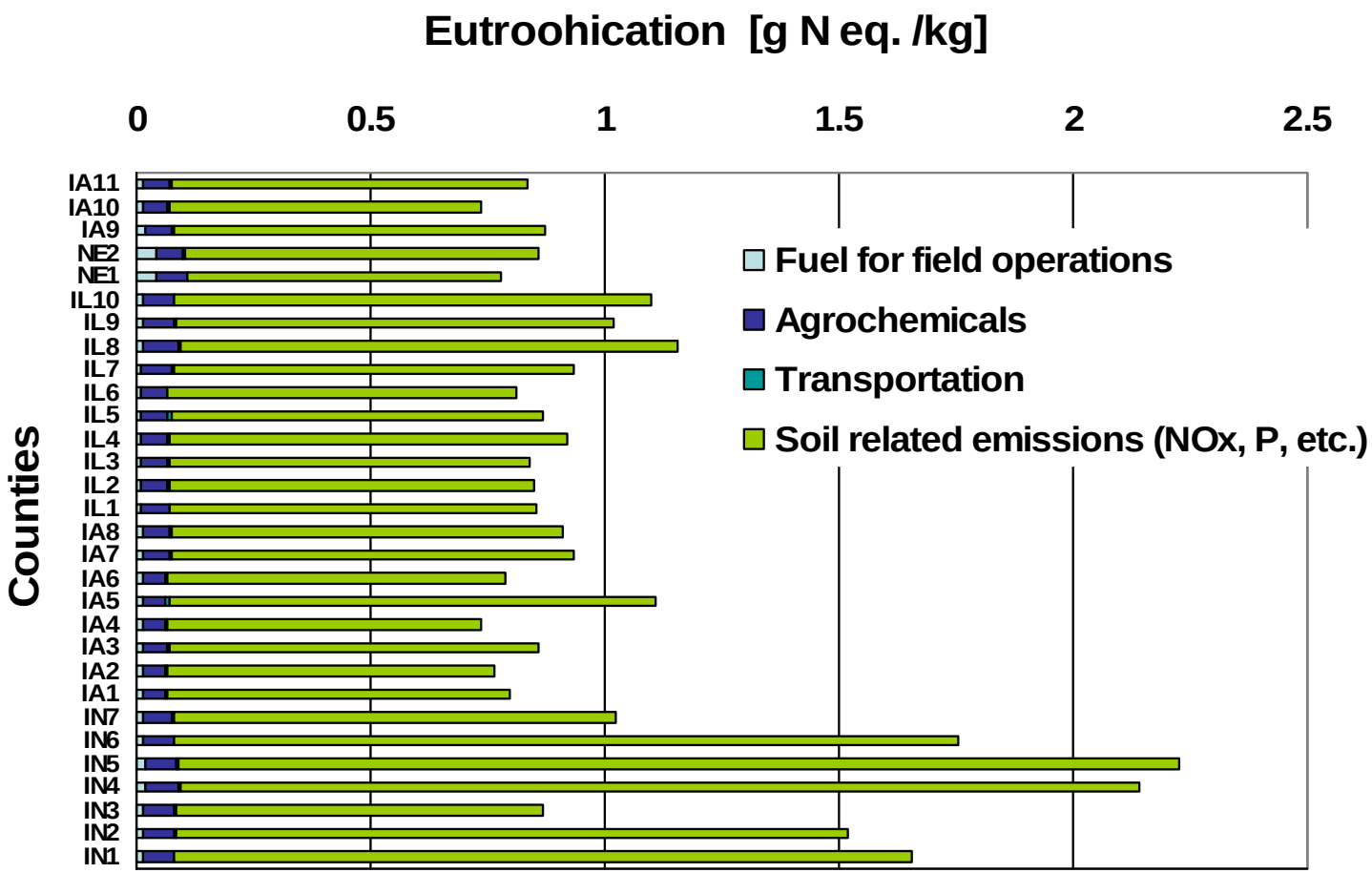


Carbon sequestered : Carbon sequestered by soil

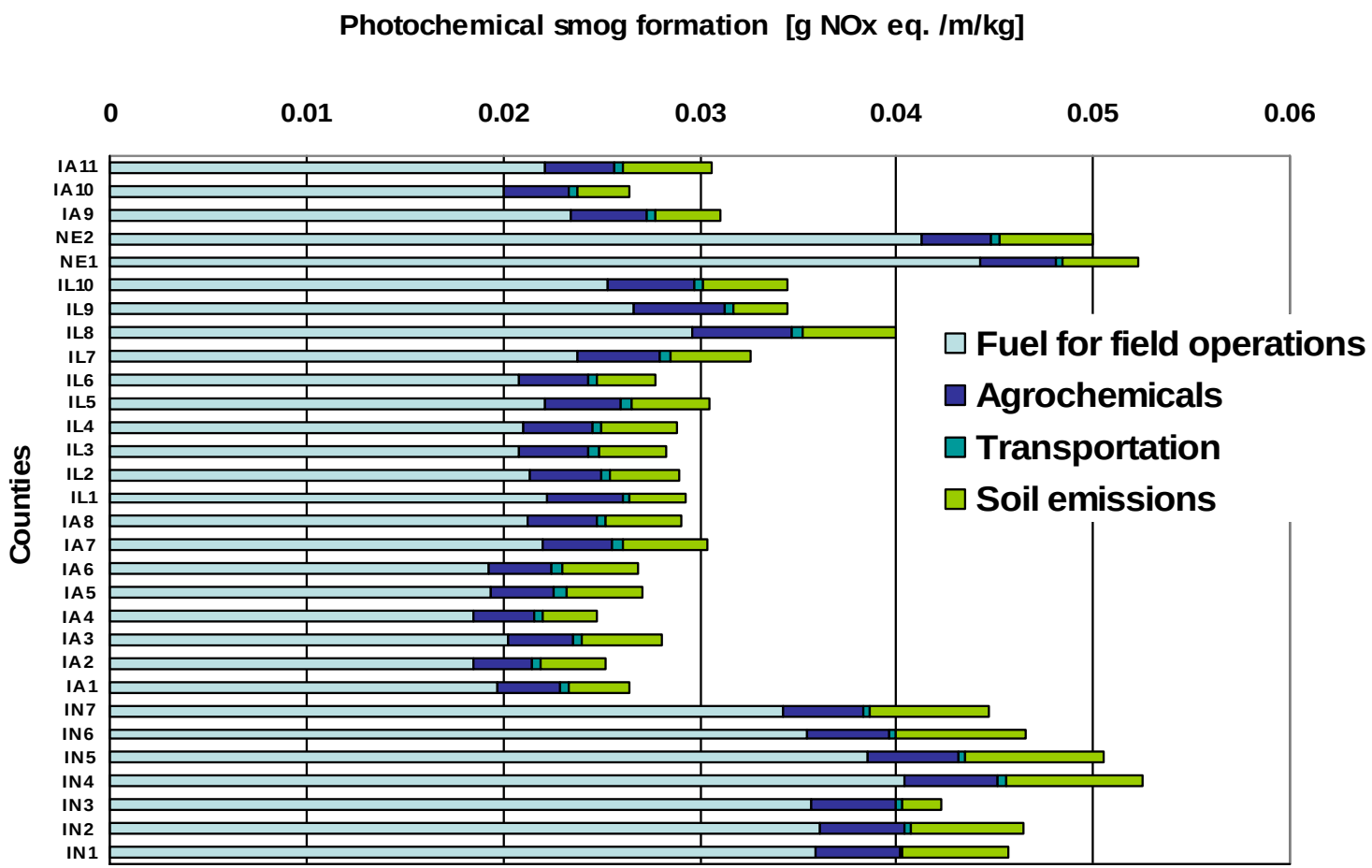
Acidification Impacts



Eutrophication Impacts



Photochemical Smog Formation



Summary: Environmental Impacts of Corn Production

- Environmental performance of corn grain
  - Nonrenewable energy : **2 ~ 3.5 MJ kg^{-1}**
  - GWP : **143 ~502 g CO_2 eq.kg^{-1}**
  - Acidification: **0.14 ~ 0.31 moles H^+ eq.kg^{-1}**
  - Eutrophication: **0.74 ~ 2.23 g N eq.kg^{-1}**
  - Photochemical smog: **0.02 ~ 0.05 g NOx eq. $m^{-1}kg^{-1}$**
- Farming location greatly affects the environmental performance of corn grain production
  - Caused by: yield, agronomic inputs, fuel consumption, soil quality, climate, etc.

Ethanol Production & Application

- Ethanol produced via a wet mill
  - Yield: 295 kg of ethanol per dry ton
  - Co-products
    - Corn gluten meal
    - Corn gluten feed
    - Corn oil
- Ethanol is used in E10 fuel (10 % ethanol and 90 % gasoline by vol.)
  - Tailpipe emissions: EPA certificate data

Assumptions

- Functional unit: one kg of ethanol
- Allocation for co-products
  - System expansion approach
    - Avoided systems for product and co-products
      - CGM & CGF: **corn grain** and **nitrogen in urea**
      - Corn oil: **soybean oil**
      - E10 fueled vehicle operation: **gasoline fueled vehicle operation**
- Ethanol losses during distribution: about 2.3 %
- No local differences in wet milling technology (except for power grid)

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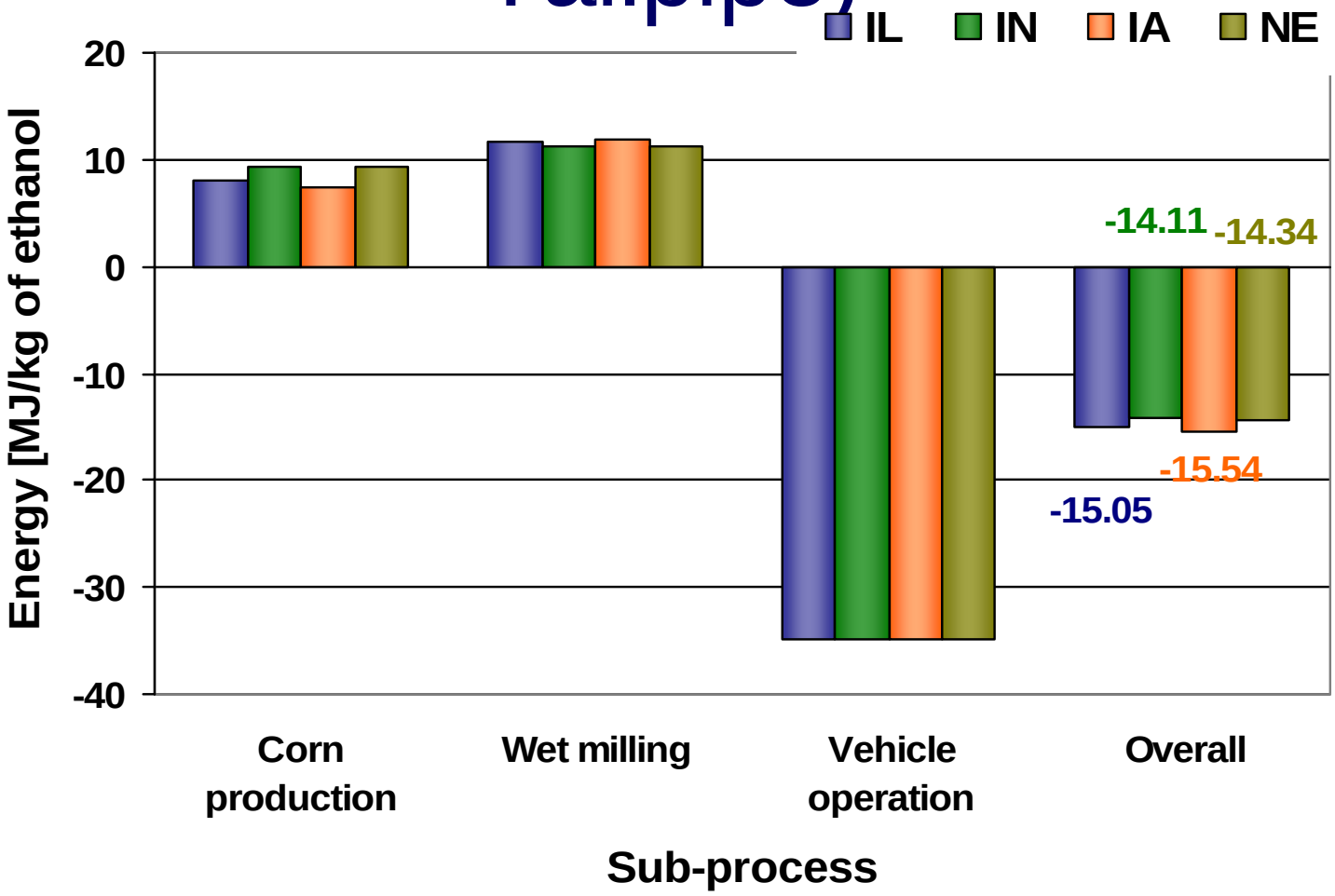
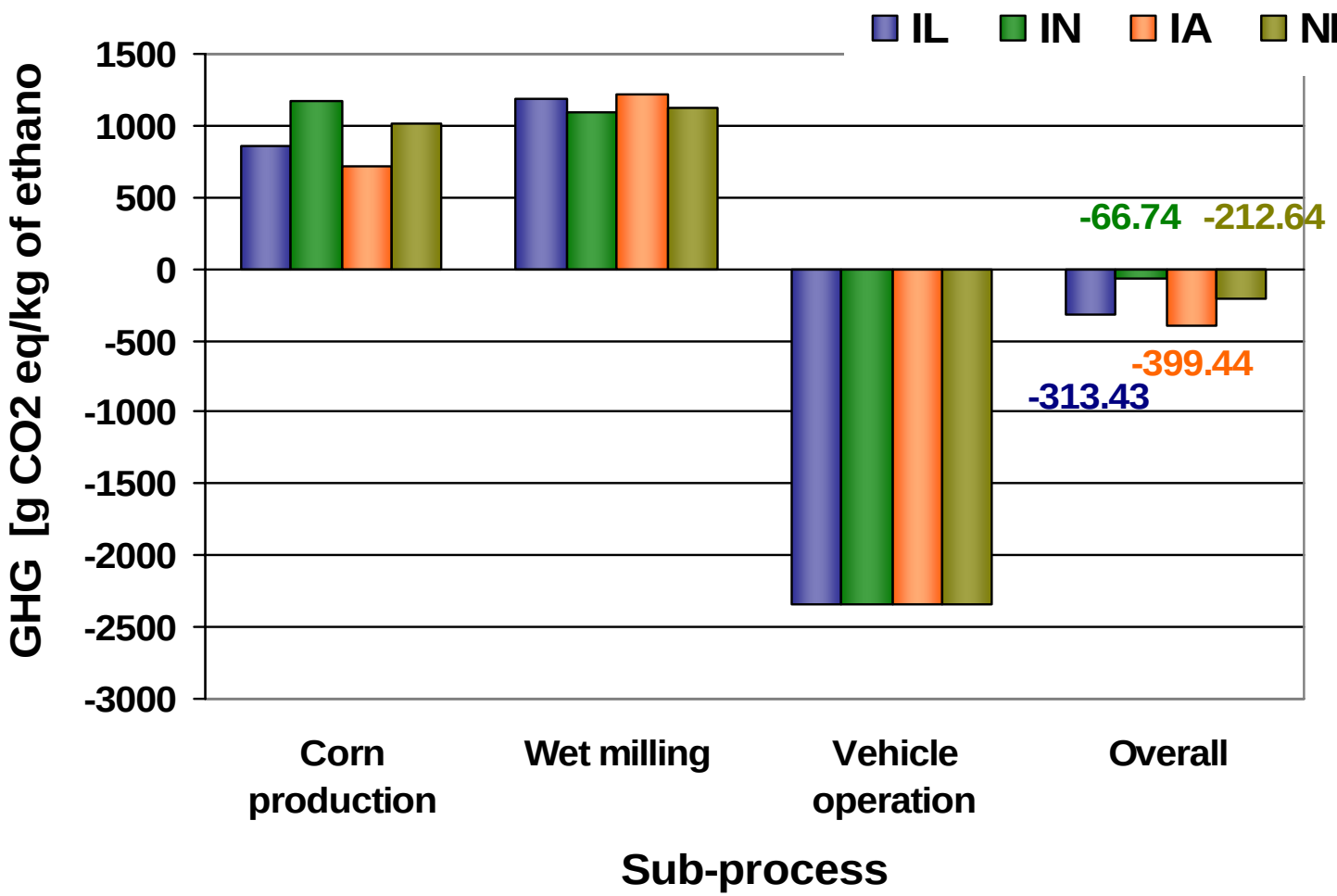
Nonrenewable Energy Use in Overall Ethanol System (Farm to Tailpipe)

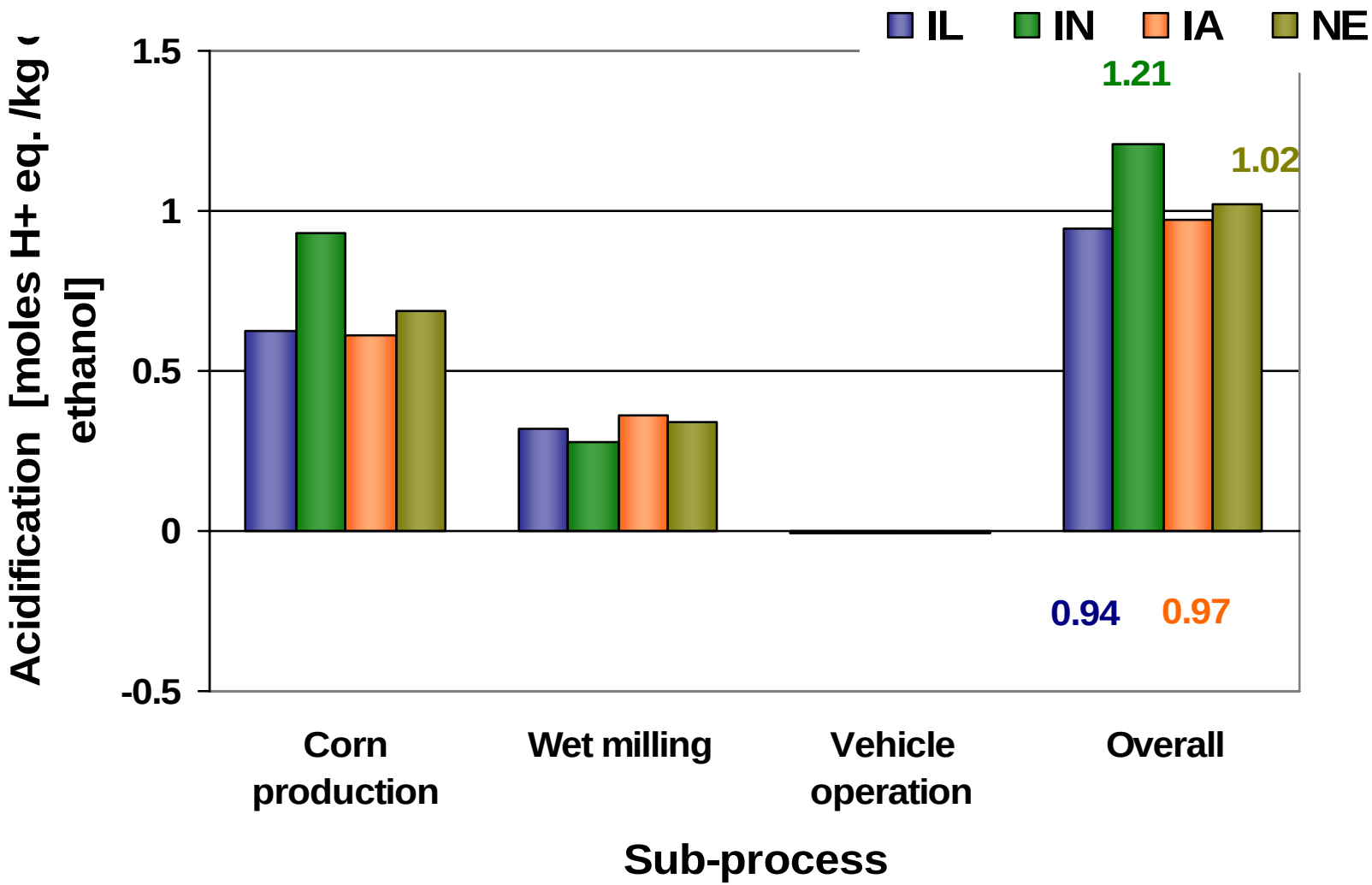


Sub-processes include the avoided systems if applicable

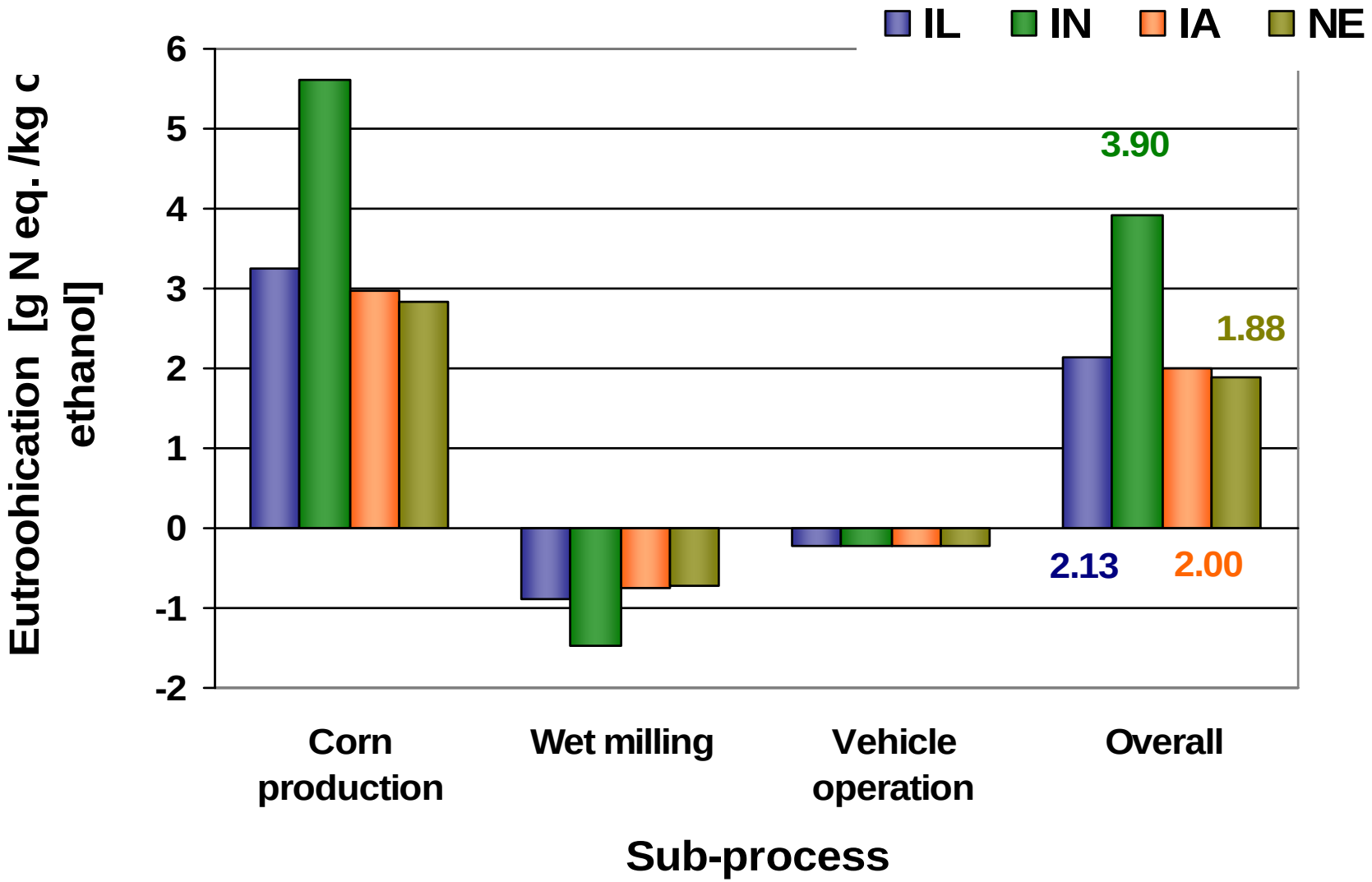
GHG Emissions in Overall Ethanol System



Acidification Impacts in Overall Ethanol System



Eutrophication Impacts in Overall Ethanol System



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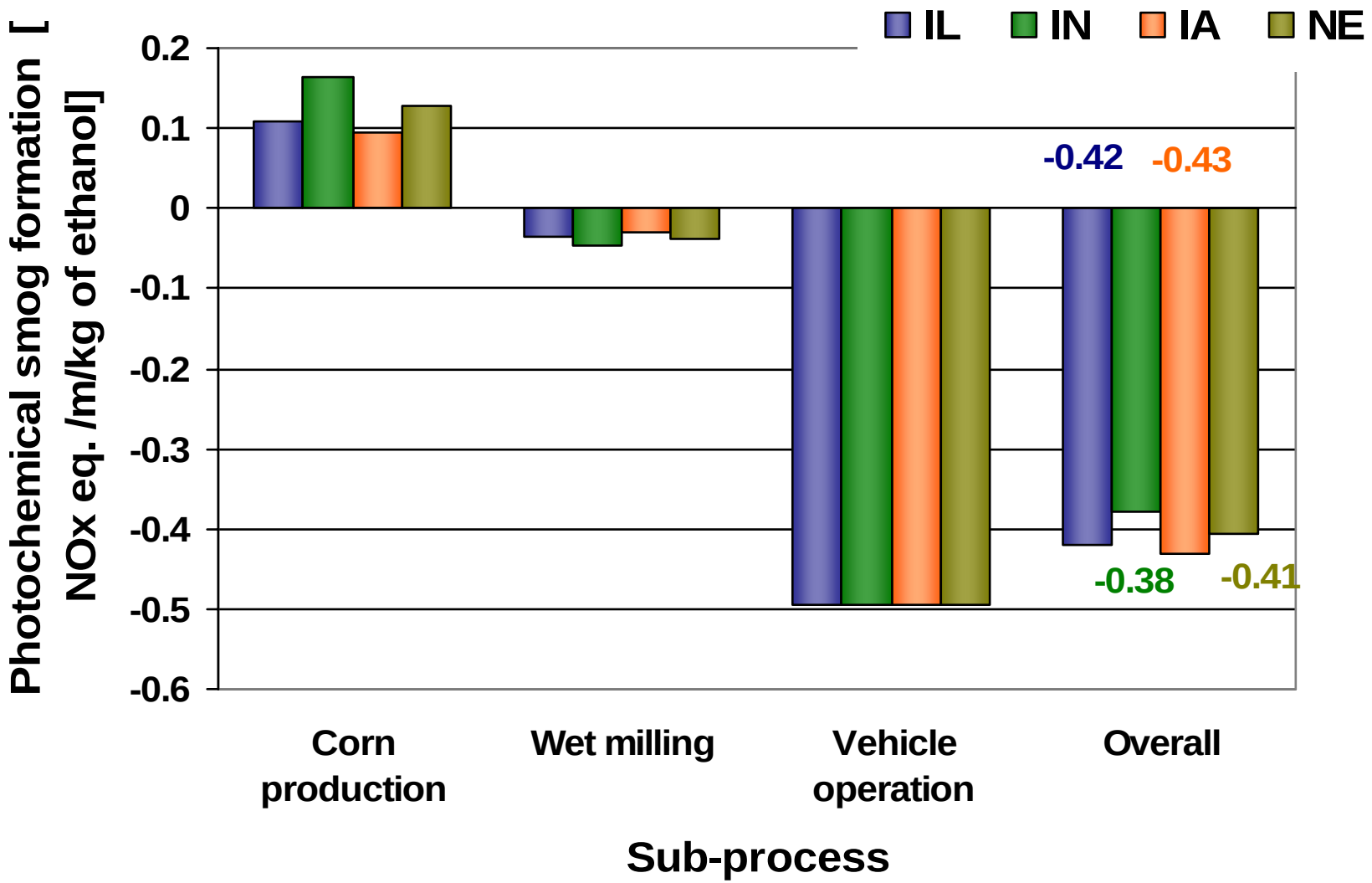
Photochemical Smog Formation in Overall Ethanol System



Conclusions

- The environmental performance of overall ethanol system (farm to tailpipe) varies with corn production location, even though sites for vehicle operations are not specified.
  - Particularly for greenhouse gas emissions, acidification, and eutrophication
- Location of future ethanol plants will affect both environmental and economic performance
- Utilization of ethanol derived from corn grain as liquid fuel offers environmental credits for:
  - nonrenewable energy consumption
  - greenhouse gas emissions
  - photochemical smog

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