Life-Cycle Water Consumption of Biofuels

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Sneak Preview

• Bioenergy policy overview – how we got from petrol to “sustainable” biofuel
• Life-Cycle water use modeling
• Importance of agricultural consumption
• Analytical tools development
• 1/3 of Less Developed Countries predicted to have insufficient water resources to meet their needs by 2025
• Agriculture = 70% of withdrawn water, 90% in some places
• Lots of biofuel = lots of water. We’re talking lots of biofuel
Biofuel Policy Primer

1. Biofuels are a good thing – GHG, Energy security, Farm livelihoods
   – Volumetric standards
   – Still exist in some places/cases

2. All biofuels are not created equal – LCA-based policies – CA LCFS

3. But a good GHG LCA does not a responsible product make - “Sustainability” standards
   – Land-use/deforestation, food vs. fuel, biodiversity, labor, WATER...etc.
Sustainability Policies

• EU: “report to the commission on “the estimated impact of biofuel production on biodiversity, water resources, water quality”

• UK – RTFO: “Biomass production should not lead to the contamination or depletion of water sources”

• CA:
  – AB118: preferences “projects that 1) use water efficiency and water use reduction measures, 2) use recycled or reclaimed water, and 3) reduce/eliminate point and nonpoint source wastewater discharge”
  – LCFS: leaves to AB118 (opposite for iLUC)

This language is insufficient
“Sustainable”

• Unlike for GHG – different things in different places
• Need two numbers
  – How much water was used
  – How much could responsibly be used in location
Water Use

• Shouldn’t focus only on biorefineries
  – Much of current research and regulation does
  – Agricultural consumption is the lion’s share – 99%
• My colleague’s influential paper expands this to irrigation water
• 80% of global agriculture is rainfed – most potential WP improvement is on these lands
• Worth considering rainwater as a resource as well
Water Resources in the Biofuel Life Cycle

- Evaporation/transpiration (ET)
- Irrigation
- Rainfall
- Industrial Intakes
- Evaporation

Agricultural Production
- Infiltration/Runoff
- Erosion/Pollution

Industrial Processing
- Return flow
- Pollution
- Water Content of Fuel

Re-capture

Consumptive use
Non-consumptive use
How these calculations are done...

*FAO - Penman-Monteith Model*

\[
ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)}
\]

- **Climate**
  - Heat loss into soil
  - Solar radiation
  - Evapotranspiration
  - Constant related to humidity
  - Crop Characteristics
  - Temperatur Climate characteristics
  - Vapor pressure deficit
- **Wind speed**
- **Constant related to humidity**
CA Low Carbon Fuel Standard Case

• Fuel volumes from Low Carbon Fuel Standard study
• Scenarios:
  – Feedstock
    • Corn, Sugar beets, High-Yield Biomass (HYB), Low-Yield Biomass (LYB), waste biomass (crop residues, forestry, MSW)
  – Displacements
    • Field crops
Fuel Embedded Water

![Bar chart showing gal H2O/gal EtOH for different sources: Corn Grain, Sugar Beets, Low-Yield Biomass, High-Yield Biomass. The chart compares industrial and agricultural production.]
Yield and ET by County

- High-Yield Biomass
- Corn Grain
- Sugar Beets
- Low-Yield Biomass

The graph shows the relationship between ET (ac-ft/ac) and EOH Yield (gal/ac) for different crops in various counties. The data points indicate a trend where higher ET values are associated with lower EOH Yield values, especially for High-Yield Biomass and Corn Grain.
Spatial Problem
Different metrics are important in different contexts

Ethanol Embedded Water (gallons per gallon ethanol)

Per-acre consumption (ac-ft)

Water consumption (ET) for “low-yield biomass” cellulosic ethanol - analogous to Tilman’s diverse grasslands.
Potentially Relevant Metrics

- Water embedded in fuel \((L \ H_2O/L \ EtOH)\)
- Water consumed per unit area \((L \ H_2O/\text{acre})\)
- Water applied \((L \ H_2O/L \ EtOH)\)
- Change in water applied/consumed
- Displacement – Indirect “WUC”
- Pollution
Chemical Inputs

"Bad Actor" Pesticide Change

Scenario 1, Scenario 2, Scenario 3

average croppin
thirstiest
least thirsty
pastureland

Scenario 1, Scenario 2, Scenario 3

N fertilizer change

Scenario 1, Scenario 2, Scenario 3
Expanding analysis

• Developing a tool to estimate the water footprint of a *specific* batch of fuel
• Need spatial resolution
• North American Regional Reanalysis
  – NCAR
  – Climatic data
  – 32km grid
  – 20 years of data
Thank You!

- Dan Kammen
- Margaret Torn
- Michael O’Hare
- Jim McKinney (CA Energy Commission)
- CA Air Resources Board (ARB)
- Morteza Orang (CA Department of Water Resources)
- Rich Plevin, Andy Jones, Avery Cohn

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Monte Carlo Simulation

- These modeling outputs are still point estimates of ET
- Need to know confidence levels/sensitivities for policy applications
- Extracted climate data from NARR - 20 points in CA
- Generated factor probability density functions (pdfs)
- Performed 10,000 sample Monte Carlo simulations using the shape/correlation of these pdfs

![Graphs for Shasta and Imperial Counties showing ET distributions.](image-url)
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“Vapor pressure deficit”