Reducing Fresh Water Use in Dry-Grind Ethanol Manufacture

N. Rajagopalan
Champaign, Ill.-Area Leaders Express Doubts About Ethanol Plant

By Anne Cook, The News-Gazette, Champaign-Urbana, Ill.

May 10--CHAMPAIGN -- City council members in both Champaign and Urbana say they have doubts about plans to put an ethanol production plant in their back yard. They're worried about what effect that process might have on the local water supply the Mahomet Aquifer.

Ethanol expansion could hinge on water

BLAKE NICHOLSON
Associated Press

BISMARCK, N.D. - Ethanol plants need more than corn: If all the proposed factories in North Dakota were built, they would use more than 1 billion gallons of water.
• Cargill Plant Pipestone, Minnesota denied permit
  – Lincoln-Pipestone Rural Water System could not provide 350 gallons/year required by the 100 MGY ethanol plant
• Cargill Plant, Grand Island, Nebraska-required offsets in agricultural area 15 miles away
Water use intensity continues to decrease

Total water use expected to grow

http://www.agobservatory.org/library.cfm?RefID=89449

More recent plants in this band

Minnesota

National
Questions

• Can water use in ethanol plants be reduced even more?
• If so, by how much? How?
• Is Net Zero Water consumption achievable?
• What would it cost?
Water not a major cost component in ethanol production
Can water use in ethanol plants be reduced even more?
The process of making ethanol starts here.

1. **Corn** passes through a **Hammer mill** to create a slurry.
2. The slurry is fed into a **Fermentation** tank where **Enzymes** and **Yeast** convert it into **200 Proof Ethanol**.
3. The **200 Proof Ethanol** is then distilled through a **Distillation System** to produce **190 Proof Ethanol**.
4. **5% Gasoline** is separated and the remaining **Atmosphere** is vented.
5. **200 Proof Ethanol** is further purified through **Molecular Sieves**.
6. A portion of the **Slurry** is sent to an **Evaporator** for **Evaporation**.
7. The **Wet Grain** is dried in a **Ring Dryer**.
8. The **Thin Stillage** is centrifuged to separate the **Whole Stillage**.
9. **CO2** is removed through **RTO**.
10. **DDGS** is generated as a final product.

**Fresh Water & Recycled Water Sources** are used throughout the process.

**Ethanol Production – Block Flow Diagram**

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Water Use in 100 MGY Ethanol Plant

City Water
545 GPM

Cooling
248 GPM

Water Treatment
223 GPM

Process
75 GPM
Specific Water Consumption by Use

- Cooling Tower: 1.88
- Process Water: 0.41
- Boiler Water: 0.37
- Water Treatment Waste: 0.41

Total: 3.06 Gallons Water/ Gallon Ethanol

62% of the total consumption is due to Cooling Tower.
Minimize Water Treatment Waste

Water Treatment Process
222 GPM

RO Water
151 GPM

Waste
71 GPM

Waste
71 GPM

RO Reject
60 GPM

Backwash
11 GPM
Reuse Filter Backwash

Reusing backwash saves 4 Million Gallons/yr
Increase RO Recovery

Filtered Water
151 gpm

Current Baseline – 75%
Operating at 71%
Potential savings @ 75% - 5 MGY
Potential savings @ 85% - 17.6 MGY

Water In
211 gpm

RO Reject
60 gpm
Minimize Cooling Tower Waste

Make-up Water 336 gpm

Excess Process Heat

Blow down 85 gpm

336 gpm Make-up Water

85 gpm Blow down

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Minimize Cooling Tower Waste

- Current Cycle of Concentration is 3.96
- Increase to 5
- Savings realized: 11 MGY
### Impact of Waste Minimization

<table>
<thead>
<tr>
<th>Action</th>
<th>Impact (MGY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reuse Filter Backwash</td>
<td>4</td>
</tr>
<tr>
<td>Increase RO Recovery</td>
<td>5 @ 75%</td>
</tr>
<tr>
<td>Minimize Blow down</td>
<td>11</td>
</tr>
<tr>
<td>Total Reduction</td>
<td>20</td>
</tr>
<tr>
<td>% of Current Use (306 MGY)</td>
<td>6.5 %</td>
</tr>
</tbody>
</table>
To Go Further Must Reduce Use

- Process water uses 0.41 gallons H$_2$O/gal EtOH - ~39 MGY
- Can we use alternative sources of water within plant in process?
## Alternative Sources

<table>
<thead>
<tr>
<th>Stream</th>
<th>Quantity (gpm)</th>
<th>Quality TDS (mg/L)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter Backwash</td>
<td>11</td>
<td>~500</td>
<td>w/in plant</td>
</tr>
<tr>
<td>RO Reject</td>
<td>60@71% 50@75% 27@85%</td>
<td>1785 2000 3333</td>
<td>w/in plant</td>
</tr>
<tr>
<td>Cooling Tower Blow Down</td>
<td>62-85</td>
<td>1396-1765 (COC-3.96-5)</td>
<td>w/in plant</td>
</tr>
<tr>
<td>Evaporator Condensate</td>
<td>330 (used in plant already)</td>
<td>Conc. of organic acids important</td>
<td>w/in plant</td>
</tr>
</tbody>
</table>
Use of Alternative Water Source Example

Cooling Tower Blow down (62-85 gpm) → Process (75 gpm)
Potential to save about 40 Million gallons/year of water
Other Cascading Possibilities

71 MGY potential savings
• Can water use be reduced from current state of art?
  – YES

• If so, by how much?
  – 10% easily done; by as much as 25%
  – Regulatory hurdles to be overcome;
  – Too radical?

2.3 gallons $\text{H}_2\text{O}/\text{gallon EtOH}$
Process waste reduced/redirected
The Elephant in the room … cooling

- Cooling Tower: 1.88
- Water Treatment Waste: 0.41
- Boiler Water: 0.37
- Process Water: 0.41

Total: 3.06 Gallons Water/ Gallon Ethanol
• Why not use treated effluent for cooling tower?

1.3 gallons H$_2$O/gallon EtOH

Is using treated effluent legitimate water reduction?
TDS of effluent above current permit levels prevent use in CT unless sent back to utility.

Composition by Water Source

Treated waste water effluent
Alternatively, use air as cooling medium

- Will require supplemental wet tower
- Increase power consumption

Make-up Water
336 gpm

Excess Process Heat

Blow down
Alternatively,

Make-up Water
336 gpm

Reduce cooling load

Excess Process Heat

Thermotolerant yeast
Tighter process integration

Blow down
85 gpm
Finally, reduce the need for steam, increase ethanol/bushel, increase slurry concentration, and recover process water. The total water usage is 3.06 gallons per gallon.
Superheated steam dryer allows recovery of moisture

- Water 0.65 g/g EtOH
- Steam 0.32 g/g EtOH
- Corn Moisture 0.37 g/g EtOH

Moisture lost in exhaust

Moisture recovered

Steam reduced

Rest, DDGs, hydrolysis

Dryer Water 1.1 gallon/gal EtOH

Process Water

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So,

• Is Net Zero water consumption possible?
  – My guess <1 gal H₂O/gal EtOH definitely within reach
  – Net Zero – aspirational goal?
Reduce Water Use

PATHWAYS

- Reduce Cooling Load
- Alternative Cooling
- Alternative Sources of Water
- Water Conservation

PROCESSES

- Thermophilic Yeasts
- Integrate Heating/Cooling Loads
- Air Cooled Heat Exchangers
- Hybrid Wet/Dry Cooling
- Geothermal Cooling
- Municipal Effluent
- Ag. Runoff
- Stormwater
- Rainwater
- Mine Water
- CT Blowdown Recovery/Reuse
- Boiler Blowdown Recovery/Reuse

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Rochelle Municipal Utility

Dr. Vijay Singh, UIUC
Yes, Virginia. We can do better.

Dehydrates Ethanol

Desalination Plant As Heat Sink

Cooling Tower

Decarbonizes Water

Water Vapor

Degraded Water

Treated Water
<table>
<thead>
<tr>
<th>Item</th>
<th>Gallons of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ton of steel</td>
<td>62,000</td>
</tr>
<tr>
<td>1 pound of plastic</td>
<td>24</td>
</tr>
<tr>
<td>1 pound of wool or cotton</td>
<td>101 (for growing cotton)</td>
</tr>
<tr>
<td>1 Barrel of beer</td>
<td>1500</td>
</tr>
<tr>
<td>1 Barrel of refined crude</td>
<td>1851</td>
</tr>
<tr>
<td>1 ton of processed sugar from cane</td>
<td>28100</td>
</tr>
<tr>
<td>1 gallon of paint</td>
<td>13</td>
</tr>
<tr>
<td>1 car</td>
<td>39090</td>
</tr>
<tr>
<td>Process 1 chicken</td>
<td>11.6</td>
</tr>
<tr>
<td>Qtr pound hamburger</td>
<td>1</td>
</tr>
</tbody>
</table>

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