Energy–Water Nexus: Irrigation
Agriculture – The first high tech industry

Irrigation adopted

- Egypt – 3,000 BC

- Archimedes Screw – C. 250 BC
Modern Irrigation

- Modern irrigation
  - Center pivot irrigation
  - Sub-surface irrigation
Nebraska – Home & Center of Irrigation

Top irrigation states

<table>
<thead>
<tr>
<th>States</th>
<th>Acres (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nebraska</td>
<td>8.3</td>
</tr>
<tr>
<td>California</td>
<td>7.5</td>
</tr>
<tr>
<td>Arkansas</td>
<td>5.0</td>
</tr>
<tr>
<td>Texas</td>
<td>4.5</td>
</tr>
<tr>
<td>Idaho</td>
<td>3.5</td>
</tr>
<tr>
<td>Kansas</td>
<td>2.9</td>
</tr>
<tr>
<td>Colorado</td>
<td>2.3</td>
</tr>
<tr>
<td>Montana</td>
<td>1.9</td>
</tr>
<tr>
<td>Mississippi</td>
<td>1.7</td>
</tr>
<tr>
<td>Washington</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Home to Irrigation Industry Founders & Leaders

- Four of top five US irrigation equipment manufacturers
  - Valmont
  - Lindsay
  - Reinke Irrigation
  - T&L Manufacturing

ELECTRIC POWER IN IRRIGATION

• Increasing load
• Changing Rate Options
Nebraska Public Power District
Connected Irrigation Horsepower

Source: Nebraska Public Power District
NPPD Total Irrigation* (GWh)

*Includes NPPD’s wholesale customers

Source: Nebraska Public Power District
NPPD Irrigation Energy* (GWh)

*Includes NPPD’s wholesale customers

Source: Nebraska Public Power District
NPPD's Summer Billable Peak

Source: Nebraska Public Power District
NPPD Irrigation Connected and Controlled Load* (MW)

*Includes NPPD’s wholesale customers

Source: Nebraska Public Power District
Rate Options For Irrigation

- **Standard Irrigation**
  Customer may operate anytime with a fixed electricity rate.
  *(A $55 conversion fee will be assessed if changing to this rate between April 15 and September 30)*

- **Time-of-Use**
  Customer may operate anytime, but receives lower rates by irrigating during mid and off-peak hours.

- **Interruptible Service**
  Customer pays a lower rate based on the interruptible control pattern selected (anytime or two-day). For program details, see back page.

Participants can choose from two control rates:

- **Two-Day Control** - NPPD can interrupt irrigation service only two, pre-assigned weekdays from 10 a.m. to 10 p.m. CDT, excluding Independence Day and Labor Day. *(Except during emergency situations.)*

- **Anytime Control** - NPPD can interrupt irrigation service any day from 10 a.m. to 10 p.m. CDT, excluding Independence Day and Labor Day. *(Except during emergency situations.)*

*Time of Use Hours*

- **On-Peak Hours** *(Highest Rate)*
  2:00 p.m. CDT each day, Monday-Friday

- **Mid-Peak Hours** *(Lower Rate)*
  10 a.m.-2 p.m. and 6-10 p.m. CDT each day, Monday-Friday

- **Off-Peak Hours** *(Lowest Rate)*
  10 p.m. to the following 10 a.m. CDT each day, Monday-Friday
  and all day Saturday, Sunday, Independence Day and Labor Day. The District reserves the right to revise these hours of operation should load conditions change but shall not reduce the operation hours below 12 hours per day for the Off-Peak Period.

Source: Nebraska Public Power District
Irrigation Rates

No Control Rates

Fixed Charge
kW - $37.39/kW
HP - $31.00/HP

Energy Charge - kW
Summer
24.96¢ - per kilowatt-hour for the first 60 kilowatt-hours per kW of maximum 30 minute demand in the current month.
12.28¢ - per kilowatt-hour for all additional use.

Interruptible Rates

Fixed Charge
$37.39/kW

Energy Charge
Interruptible - 2 day control
Summer
16.01¢ - per kilowatt-hour for the first 60 kilowatt-hours per kW of maximum 30 minute demand in the current month.
10.74¢ - per kilowatt-hour for all additional use.

Energy Charge
Interruptible - Anytime
Summer
8.09¢ - per kilowatt-hour for the first 60 kilowatt-hours per kW of maximum 30 minute demand in the current month.
6.55¢ - per kilowatt-hour for all additional use.

Time of Use Rate

Fixed Charge
$37.39/kW

Energy Charge
Summer
46.22¢ - per kilowatt-hour for all energy used in the On-Peak Period.
20.80¢ - per kilowatt-hour for all energy used in the Mid-Peak Period.
8.78¢ - per kilowatt-hour for all energy used in the Off-Peak Period.

Source: Nebraska Public Power District
## Sample Annual Irrigation Cost Comparisons

### EXAMPLES

<table>
<thead>
<tr>
<th>Rate Options</th>
<th>15 HP pump (8,500 kWh)</th>
<th>20 HP pump (13,500 kWh)</th>
<th>30 HP pump (24,000 kWh)</th>
<th>50 HP pump (40,000 kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong> (IRRIG-1)</td>
<td>$1,698</td>
<td>$2,530</td>
<td>$4,255</td>
<td>$7,092</td>
</tr>
<tr>
<td><strong>Time-of-Use</strong> (IRRIG-2)</td>
<td>$1,473</td>
<td>$2,221</td>
<td>$3,774</td>
<td>$6,291</td>
</tr>
<tr>
<td><strong>Interruptible</strong> (IRRIG-3) (two-day)</td>
<td>$1,457</td>
<td>$2,175</td>
<td>$3,664</td>
<td>$6,107</td>
</tr>
<tr>
<td><strong>Interruptible</strong> (IRRIG-3) (anytime)</td>
<td>$1,045</td>
<td>$1,535</td>
<td>$2,547</td>
<td>$4,246</td>
</tr>
</tbody>
</table>

Source: Nebraska Public Power District
Percentage of Irrigation Customers Enrolled in Load Management Irrigation

- Not Enrolled: 32.8%
- Every Day: 31.7%
- 4 Days Per Week: 13.5%
- 3 Days Per Week: 13.5%
- 2 Days Per Week: 11.8%
- 1 Day Per Week: 5.6%

Source: May 2016 Pre-Season Irrigation Survey

Source: Nebraska Public Power District
IRRIGATION EQUIPMENT TECHNOLOGY

- More efficient water use
- Variable application
WATER “LOSSES” WITH CENTER PIVOT IRRIGATION

- Droplet Evaporation
- Canopy Evaporation
- Soil Evaporation
- Runoff
- Deep Percolation

Graphic Courtesy of University of Nebraska Extension
Sprinkler water losses and application efficiency for 1-inch water application.

<table>
<thead>
<tr>
<th>Water Loss Component</th>
<th>Low-Angle Impact Sprinkler Water Loss</th>
<th>Spray Head Water loss</th>
<th>LEPA Water Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Evaporation and Drift</td>
<td>0.03 in.</td>
<td>0.01 in.</td>
<td>0.00 in.</td>
</tr>
<tr>
<td>Net Canopy Evaporation</td>
<td>0.08 in.</td>
<td>0.03 in.</td>
<td>0.00 in.</td>
</tr>
<tr>
<td>Plant Interception</td>
<td>0.04 in.</td>
<td>0.04 in.</td>
<td>0.00 in.</td>
</tr>
<tr>
<td>Evaporation From Soil</td>
<td>Negligible</td>
<td>Negligible</td>
<td>0.02 in.</td>
</tr>
<tr>
<td>Total Water Loss</td>
<td>0.15 in.</td>
<td>0.08 in.</td>
<td>0.02 in.</td>
</tr>
<tr>
<td>Application Efficiency</td>
<td>85%</td>
<td>92%</td>
<td>98%</td>
</tr>
</tbody>
</table>

Graphic Courtesy of University of Nebraska Extension
Soil Map – GIS Data Layers

Lighter Soils (Red)

Heavier Soils (Blue)

Source: Valmont
There’s an app for that...
Variable Rate Irrigation (VRI) Prescription Software

Source: Valmont
Custom VRI Prescriptions

A variety of companies provide elaborate agronomy and prescriptions services

Source: Valmont
CORN PRODUCTION

• Reduced Resource Use
• Capturing Carbon
Corn Producers Reducing Resource Use 1980-2011

Land used per bushel
- Reduced 30%

Soil Erosion
- Reduced 43% per acre
- Reduced 67% per bu.

Irrigation Water Applied
- Reduced 28% per acre
- Reduced 53% per bu.

Energy Use
- Reduced 6% per acre
- Reduced 44% per bu.

GHG Emissions
- Increased 8% per acre
- Reduced 36% per bu.

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**Corn Summary of Results:** Trends in U.S. Production, Resource Use / Impact, 1980-2011

<table>
<thead>
<tr>
<th>Resource Area</th>
<th>Indicator</th>
<th>Percent Change* 1980-2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Trend Direction</td>
</tr>
<tr>
<td>Crop Yield</td>
<td>Total Production</td>
<td>↑ 101</td>
</tr>
<tr>
<td></td>
<td>Bushels per Acre</td>
<td>↑ 64</td>
</tr>
<tr>
<td>Land Use</td>
<td>Total Planted Acres</td>
<td>↑ 21</td>
</tr>
<tr>
<td>Soil Erosion</td>
<td>Acres per Bushel</td>
<td>↓ (30)</td>
</tr>
<tr>
<td></td>
<td>Total Tons</td>
<td>↓ (31)</td>
</tr>
<tr>
<td></td>
<td>Tons per Acre</td>
<td>↓ (43)</td>
</tr>
<tr>
<td></td>
<td>Tons per Bushel</td>
<td>↓ (67)</td>
</tr>
<tr>
<td>Irrigation Water Applied</td>
<td>Total Volume</td>
<td>↑ 27</td>
</tr>
<tr>
<td></td>
<td>Volume per Irrigated Acre</td>
<td>↓ (28)</td>
</tr>
<tr>
<td></td>
<td>Volume per Bushel</td>
<td>↓ (53)</td>
</tr>
<tr>
<td>Energy Use</td>
<td>Total Btu</td>
<td>↑ 14</td>
</tr>
<tr>
<td></td>
<td>Btu per Acre</td>
<td>↓ (6)</td>
</tr>
<tr>
<td></td>
<td>Btu per Bushel</td>
<td>↓ (44)</td>
</tr>
<tr>
<td>GHG Emissions (CO₂ Equivalents)</td>
<td>Total Pounds</td>
<td>↑ 31</td>
</tr>
<tr>
<td></td>
<td>Pounds per Acre</td>
<td>↑ 8</td>
</tr>
<tr>
<td></td>
<td>Pounds per Bushel</td>
<td>↓ (36)</td>
</tr>
</tbody>
</table>

*Percent change results are based on a least squares trends analyses from 1980 - 2011


**Corn = Carbon Sequestration**

A comparison of calculated credits from 8 recent Mid-West corn SOC sequestration studies, with the Argonne GREET 2016 Model Base Case Carbon Intensity.

The Effect of Measured Soil Carbon Sequestration Credits on Corn Ethanol Life Cycle Carbon Intensity (Grams CO₂ eq./Megajoule)

Source: Ron Alverson, American Coalition for Ethanol