Irrigation Energy Needs

Michigan Soil and Water Conservation Society
March 7, 2012

Steve A Miller
BioSystems & Agricultural Engineering
Factors Affecting Irrigation Pumping Costs

Factors One Can Control

Factors One Cannot Control

Cost to Irrigate a Field

Field Size
Crop Water Needs
Precipitation

Irrigation Scheduling

Acre-inches of water pumped

Application Efficiency

Cost to apply an acre-inch of water

Performance Rating of Pumping Plant

Pumping Pressure (for pivots)

Pumping Lift
Price of Energy

Factors One Cannot Control
Minimizing Irrigation Energy Cost

Lyndon Kelley
MSU Extension/Purdue University
Irrigation Management Agent
269-467-5511     Kelleyl.msu.edu

www.msue.msu.edu - find St. Joseph Co. - then hit the Irrigation button
Lowest irrigation power cost and least energy used results from:

Pumping only water that results in a yield increase over dry land. (Effective)

Lowest cost, most efficient energy source available

Minimum system pressure that results in uniform application with no runoff concerns
1. Irrigation Runoff
   - Comparing irrigation application rate to soil infiltration rate, 0-30% loss

2. Lack of system uniformity
   - 5-35% loss in effectiveness

3. Evaporative loss to the air
   - Minimal loss in our humid area
     - 0 – 6%
   - Estimated 4-6% loss in Nebraska

Catch Can Volume (ml)

Distance from Pivot (ft)
Water supply over or under design
Preventing Irrigation Runoff
(comparing irrigation instantaneous application rate to soil infiltration rate)

Sprinkler package or nozzle selection along with pressure dictates water application rate.

Factors that increase runoff:

- Small Wetted area or throw of sprinkler
- Low Pressure
- Larger applications volumes
- Soil compaction
- Heavy soils
- Slope
- Row hilling
Runoff Potential with Center Pivots

Infiltration Rate
How fast soil takes water in

Application Rate
How fast water is applied

Surface Storage
Amount ponded

Surface Saturates

Runoff Begins

RUNOFF POTENTIAL
Water that can move in or leave the field

Rate, inches/hour

Time, hours

Nebraska
Nebraska Extension
**Peak Application Rates**

- **Low Pressure Spray**: 30' Spray, 42% Potential Runoff
- **Rotating Spray**: 55' Spray, 26.3% Potential Runoff
- **Low Pressure Impact**: 90' Impact, 13.1% Potential Runoff
- **High Pressure Impact**: 120' Impact, 6.4% Potential Runoff

- **System Length**: 1340 ft
- **Flow Rate**: 800 gpm
- **Water Application**: 1.0 inch
- **Field Slope**: 6%

**Horizontal Axis**
- Water Application Time (min)

**Vertical Axis**
- Water Application Rate (in/hr)
Nozzle Position Does Matter
In-Canopy Water Distribution Patterns

- Corn Height: 8-10 ft.
- Nozzle Height: 42 in.
- Change in Soil Water Content (%)

Nozzle Spacing: 12.5 ft
Row Number:

Nebraska Extension
Irrigation Scheduling
Overview and Tools

Steve Miller
William Northcott
Department of Biosystems and Agricultural Engineering
Michigan State University
Water use Activities

- Michigan Court of Appeals Nestle (Ice Mountain) vs. local citizens
  - Impacts to stream flow must be considered when evaluating reasonable use

- St Lawrence River Basin Water Resources Compact (Annex 2001)
  - Signed Dec 2005
  - Final Approval 2008
The Water Withdrawal Assessment Tool (Assessment Tool) is designed to estimate the likely impact of a proposed water withdrawal on nearby streams and rivers. This is a test version. It is provided for the public to evaluate the Assessment Tool before it becomes effective on February 1, 2009 and use mandatory on July 9, 2009. Additions and updates will be added to the site over the next several weeks.

You may use this Assessment Tool test site to register a new or increased large quantity withdrawal. The results page provides a quick link to submitting a registration. A registration is valid for 18 months; the withdrawal capacity must be installed within that 18 months or the registration becomes void.

http://www.miwwwat.org/
Irrigation scheduling for each unit or field is an integral part of GAAMPs

Irrigation scheduling is the process of determining when it is necessary to irrigate and how much water to apply

Information from Record Keeping GAAMPs can be inputs to irrigation scheduling
Irrigation Scheduling

- Process of maintaining an optimum water balance in the soil profile for crop growth and production

- Irrigation decisions are based on an accounting method on the water content in the soil
Irrigation Scheduling

- Components
  - Plant Growth and Water Use
  - Soil Water Holding Capacity
  - Rainfall / Irrigation
  - RECORDKEEPING
Plant Growth and Water Use

- Fundamentally crops use water to facilitate cell growth, maintain turgor pressure, and for cooling.
- Crop water use is driven by the evaporative demand of the atmosphere.
- Function of temperature, solar radiation, wind, relative humidity.
- Example, a fully developed corn crop in Michigan can use as high as 0.35 inches per day. (~9,500 gallons / acre)
- Optimum crop growth and health occurs when the soil moisture content is held between 50 – 80% of the “plant available water”
Estimating Plant Water Use

- Crop water use = Evapotranspiration (ET).
- A “potential reference ET (PET)” can be calculated based on weather conditions.
- The standard method – Penman – Monteith.
  - Based on temperature, solar, humidity, wind, rainfall
  - “Well watered grass”
- Michigan Enviro-weather Program calculates hourly PET at each station.
http://www.enviro-weather.msu.edu/
Estimating ET for Different Crops

- Combining a “Crop Coefficient Curve” with the reference ET.
- Crop Curve is a relationship between the specific plants’ growth characteristics and its water use relationship to the reference crop.
Crop Curve

Figure 25: Generalized crop coefficient curve for the single crop coefficient approach.
Soil Water Holding Capacity

- Soil act as a reservoir to hold water for plant use.
- The capacity for a soil to hold water is primarily based on the soil's texture but can be modified by attributes such as soil organic matter.
Figure 2-4. Soil water content-moisture tension relationship.
Source: Irrigation Systems Management.
Determining Soil Moisture

- Actual soil water content measurement
- Indirectly by determining moisture tension
- Soil moisture estimation
- Next Slides from Dr. Ronold Goldy
Meet the Family!

WATERMARK FAMILY OF
SOIL MOISTURE SENSING
AND CONTROL PRODUCTS

Tensiometers

Solutions for Wise Water Management

For information on precision irrigation, contact us
on the web http://www.irrometer.com
phone: (909) 689-1701 fax: (909) 689-3706
E-Mail: irrometer@aol.com
Mail: P.O.Box 2424
Riverside, CA 92516

IRROMETER
Optimizing Irrigation, Worldwide
Evaluates Water in Top Layer

Evaluates Soil Water in Deeper Layer
Frequency
Domain
Reflectometry

IRRIGATION SCHEDULING METHODS, INC.
# SOIL WATER BALANCE SHEET

(Make copies as needed)

Field__________________________Crop__________________________Emergence date__________________________
Pumping Capacity_________________gpm per acre=_________________net application inches per day
Available Water Capacity__________inches in root zone of__________inches

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Vegetative</th>
<th>Critical Growth</th>
<th>Maturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Soil Water Deficit</td>
<td>_______ inches</td>
<td>_______ inches</td>
<td>_______ inches</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week after emergence</th>
<th>Date</th>
<th>Soil water field reading</th>
<th>Maximum temperature</th>
<th>Add</th>
<th>Subtract</th>
<th>Soil water deficit</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
<td></td>
<td>Crop water use</td>
<td>Rainfall</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|                       |      |   |   |                  |               |         |               |   |   |
|                       |      |   |   |                  |               |         |               |   |   |
|                       |      |   |   |                  |               |         |               |   |   |
|                       |      |   |   |                  |               |         |               |   |   |
|                       |      |   |   |                  |               |         |               |   |   |
|                       |      |   |   |                  |               |         |               |   |   |
Getting started

Select a weather station location from the map to view weather data, integrated pest management models, natural resource and production models, forecasts and related links for specific commodities. (View alphabetical list of stations or tutorial.)

Support Enviro-weather

Your suggestions and financial contributions are welcomed.

Latest Observation at East Lansing (Hancock Turfgrass Research Center), Michigan:
10/27/2008 8:00 AM
Air temperature: 40 F
Rainfall (10/27): 0 in.
Relative humidity: 89.1%
Dewpoint: 36.7 F
Wind speed: 8.85 mi./hr.
### Estimated crop evapotranspiration at Coldwater (Report issued 6/26/2009 9:35)

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Min</th>
<th>Max</th>
<th>Temperature (F)</th>
<th>GDD</th>
<th>Rainfall (in.)</th>
<th>Reference PET (in.)</th>
<th>GDD since 5/20</th>
<th>Percent total growth</th>
<th>Kc(coefficient)</th>
<th>PET today</th>
<th>PET since 5/20</th>
<th>Rainfall since 5/20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fri</td>
<td>6/19</td>
<td>63.8</td>
<td>80.8</td>
<td>22.2</td>
<td>475</td>
<td>1.75</td>
<td>0.1</td>
<td></td>
<td>19%</td>
<td>0.73</td>
<td>0.07</td>
<td>2.36</td>
<td>4.87</td>
</tr>
<tr>
<td>Sat</td>
<td>6/20</td>
<td>66.1</td>
<td>82.3</td>
<td>24.2</td>
<td>499</td>
<td>0.64</td>
<td>0.18</td>
<td></td>
<td>20%</td>
<td>0.76</td>
<td>0.14</td>
<td>2.5</td>
<td>5.51</td>
</tr>
<tr>
<td>Sun</td>
<td>6/21</td>
<td>63.2</td>
<td>87.3</td>
<td>24.6</td>
<td>524</td>
<td>0.19</td>
<td>0.19</td>
<td></td>
<td>21%</td>
<td>0.79</td>
<td>0.15</td>
<td>2.65</td>
<td>5.51</td>
</tr>
<tr>
<td>Mon</td>
<td>6/22</td>
<td>64.3</td>
<td>84.4</td>
<td>24.4</td>
<td>548</td>
<td>0.22</td>
<td>0.22</td>
<td></td>
<td>22%</td>
<td>0.81</td>
<td>0.18</td>
<td>2.83</td>
<td>5.51</td>
</tr>
<tr>
<td>Tues</td>
<td>6/23</td>
<td>64.9</td>
<td>89.1</td>
<td>25.5</td>
<td>574</td>
<td>0.21</td>
<td>0.21</td>
<td></td>
<td>23%</td>
<td>0.84</td>
<td>0.18</td>
<td>3.01</td>
<td>5.51</td>
</tr>
<tr>
<td>Wed</td>
<td>6/24</td>
<td>68.5</td>
<td>95.4</td>
<td>27.3</td>
<td>601</td>
<td>0.24</td>
<td>0.24</td>
<td></td>
<td>25%</td>
<td>0.9</td>
<td>0.21</td>
<td>3.22</td>
<td>5.51</td>
</tr>
<tr>
<td>Thu</td>
<td>6/25</td>
<td>69.2</td>
<td>91.8</td>
<td>27.6</td>
<td>629</td>
<td>0.22</td>
<td>0.22</td>
<td></td>
<td>26%</td>
<td>0.92</td>
<td>0.2</td>
<td>3.42</td>
<td>5.51</td>
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</table>

**Forecast data:**

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Min</th>
<th>Max</th>
<th>Temperature (F)</th>
<th>GDD</th>
<th>Rainfall (in.)</th>
<th>Reference PET (in.)</th>
<th>GDD since 5/20</th>
<th>Percent total growth</th>
<th>Kc(coefficient)</th>
<th>PET today</th>
<th>PET since 5/20</th>
<th>Rainfall since 5/20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fri</td>
<td>6/26</td>
<td>67</td>
<td>86</td>
<td>26.5</td>
<td>655</td>
<td>0.24</td>
<td>0.24</td>
<td></td>
<td>27%</td>
<td>0.95</td>
<td>0.23</td>
<td>3.65</td>
<td>5.51</td>
</tr>
<tr>
<td>Sat</td>
<td>6/27</td>
<td>65</td>
<td>83</td>
<td>22</td>
<td>676</td>
<td>0.21</td>
<td>0.21</td>
<td></td>
<td>28%</td>
<td>0.98</td>
<td>0.2</td>
<td>3.85</td>
<td>5.51</td>
</tr>
<tr>
<td>Sun</td>
<td>6/28</td>
<td>65</td>
<td>79</td>
<td>22</td>
<td>698</td>
<td>0.21</td>
<td>0.21</td>
<td></td>
<td>29%</td>
<td>1</td>
<td>0.21</td>
<td>4.06</td>
<td>5.51</td>
</tr>
<tr>
<td>Mon</td>
<td>6/29</td>
<td>60</td>
<td>71</td>
<td>15.5</td>
<td>714</td>
<td>0.15</td>
<td>0.15</td>
<td></td>
<td>29%</td>
<td>1</td>
<td>0.15</td>
<td>4.21</td>
<td>5.51</td>
</tr>
<tr>
<td>Tues</td>
<td>6/30</td>
<td>56</td>
<td>72</td>
<td>14</td>
<td>728</td>
<td>0.15</td>
<td>0.15</td>
<td></td>
<td>30%</td>
<td>1.03</td>
<td>0.15</td>
<td>4.36</td>
<td>5.51</td>
</tr>
<tr>
<td>Wed</td>
<td>7/1</td>
<td>58</td>
<td>79</td>
<td>18.5</td>
<td>746</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
<td>31%</td>
<td>1.05</td>
<td>0.21</td>
<td>4.57</td>
<td>5.51</td>
</tr>
<tr>
<td>Thu</td>
<td>7/2</td>
<td>63</td>
<td>82</td>
<td>22.5</td>
<td>769</td>
<td>0.17</td>
<td>0.17</td>
<td></td>
<td>32%</td>
<td>1.06</td>
<td>0.18</td>
<td>4.75</td>
<td>5.51</td>
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</tbody>
</table>
**Estimates of Potential ET can be found at the MSU AgWeather site:**
http://www.agweather.geo.msu.edu/mawn/irrigation/

**Depth and Canopy Cover Coeff, as a function of the percentage of the growing season.**

To use the Table, first determine the length of the growing season and rooting depth for the variety of your crop, then extrapolate data from emergence date.

For example, 120 day Corn36 (a corn variety with an effective rooting depth of 36 inches) and has an emergence date of May 15th, 10% of the growing season is May 27th.

10% of 120 = 12
15 + 12 = 27

<table>
<thead>
<tr>
<th>Date</th>
<th>Root Depth (inches)</th>
<th>Rainfall (inches)</th>
<th>Irrigation added (inches)</th>
<th>Potential ET (inches)</th>
<th>% Canopy Cover (Kc)</th>
<th>ET modified for crop (inches)</th>
<th>Capacity of root zone (inches)</th>
<th>Available Water in root zone (inches)</th>
<th>% capacity filled</th>
<th>Drainage (inches)</th>
<th>Additional capacity of root zone (inches)</th>
<th>Proj ETO</th>
<th>Proj ET</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-May</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0.057</td>
<td>0.24</td>
<td>0.01</td>
<td>0.82</td>
<td>0.80</td>
<td>97</td>
<td>0.00</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>16-May</td>
<td>6.4</td>
<td>0</td>
<td>0</td>
<td>0.134</td>
<td>0.24</td>
<td>0.03</td>
<td>0.87</td>
<td>0.88</td>
<td>101</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17-May</td>
<td>6.8</td>
<td>0.06</td>
<td>0</td>
<td>0.115</td>
<td>0.25</td>
<td>0.03</td>
<td>0.92</td>
<td>0.94</td>
<td>102</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
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<tr>
<td>18-May</td>
<td>7.2</td>
<td>0.04</td>
<td>0</td>
<td>0.115</td>
<td>0.25</td>
<td>0.03</td>
<td>0.92</td>
<td>0.94</td>
<td>102</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Dryland  21 inches/80 bushel     or 0.26”/bushel
With irrigation full yield 30 inches/200 bushels or 0.15”/bushel
Michigan Farm Energy Audit Program

Contact Us:

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http://farmenergy.canr.msu.edu
EVALUATING ENERGY USE FOR PUMPING IRRIGATION WATER

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Co-authors
Derrel Martin, Tom Dorn, Steve Melvin, Alan Corr
Farm Energy Audits
Surge of Energy Cost
How it got started – Rising Energy Cost

http://www.eia.doe.gov/emeu/states/state.html

Nebraska North Central Region  SARE Grant,  2011
A Farm Energy Audit is an essential management tool in developing a comprehensive energy plan for your farm or rural business.

- It can pinpoint areas for reducing energy costs and energy use.
- It helps prioritize implementation projects based on energy efficiency improvements, payback period, capital outlay or implementation duration and complexity.
- A farm energy audit can also improve operational efficiency as well as identify potential areas for renewable energy application.
- Certified Farm Energy Audits are required for participation in State, Federal and Utility energy efficiency programs.
Certified Farm Energy Audit Process

Farm
- Records Needed:
  - Utility bills for one year prior to audit.
  - Milk production for one year.
  - Age and technical information of equipment.

Certified Farm Energy Audit

Confidential Certified Energy Audit Report

Certified Energy Audits (ASABE S612)
- Professional Engineer (PE)
- Certified Energy Manager (CEM)
- State Certified Farm Energy Auditor
- USDA-NRCS Technical Service Provider

Alternative Energy
- Anaerobic digesters
- Biomass
- Geothermal
- Wind
- CHP

Set priorities & implement suggestions

Not all audits are the same.
Selling Points For A Tier II Farm or Rural Business Energy Audit
Selling Point #1:
Reduced Energy Costs/Increased Profits
Irrigation

Make: Caterpillar
Model: 3208, 225hp
Age: 1978 or 31 years old
Yearly maintenance cost: $238.92
2009 repair cost: $371.49
## Irrigation

<table>
<thead>
<tr>
<th>Recommended ECM</th>
<th>Energy Reduction (MMBTU)</th>
<th>Energy Reduction (kWh)</th>
<th>Energy Savings ($/yr)</th>
<th>Cost to Implement ($)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replace the well pump diesel engine with an electric motor and variable frequency drive.</td>
<td>395.304</td>
<td></td>
<td>$5,176</td>
<td>$40,221</td>
<td>7.8</td>
</tr>
</tbody>
</table>
Irrigation Energy Audit

Average Annual Diesel Cost – Existing System

<table>
<thead>
<tr>
<th>Pivot #</th>
<th>Average Annual Diesel Fuel Usage (gallons)</th>
<th>Average Annual Diesel Fuel Cost ($) 2.71</th>
<th>Average Annual Diesel Fuel Cost ($) 3.50</th>
<th>Electrical Cost ($/yr) at 0.1135/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,600</td>
<td>7,046</td>
<td>9,100</td>
<td>$2,834</td>
</tr>
<tr>
<td>2</td>
<td>775</td>
<td>2,100</td>
<td>2,712</td>
<td>$1,265</td>
</tr>
<tr>
<td>3</td>
<td>590</td>
<td>1,599</td>
<td>2,065</td>
<td>$1,023</td>
</tr>
<tr>
<td>4</td>
<td>225</td>
<td>610</td>
<td>788</td>
<td>$166</td>
</tr>
<tr>
<td>Total</td>
<td>4,190</td>
<td>11,355</td>
<td>14,665</td>
<td>$6,179</td>
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</tbody>
</table>
## Irrigation Energy Audit

### Electrical Use & Cost – Proposed Electrical Pump and VFD

<table>
<thead>
<tr>
<th>Pivot #</th>
<th>Total Dynamic Head</th>
<th>Water Pumped acre-ft/yr</th>
<th>kWh/ac-ft of water</th>
<th>Electrical Usage (kWh/yr)</th>
<th>Electrical Cost ($/yr) at 0.1135/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>279</td>
<td>57.7</td>
<td>432.7</td>
<td>24,968</td>
<td>$2,834</td>
</tr>
<tr>
<td>Pivot #1 w/ cornering retracted</td>
<td>253</td>
<td>28.4</td>
<td>392.4</td>
<td>11,144</td>
<td>$1,265</td>
</tr>
<tr>
<td>2</td>
<td>340</td>
<td>17.1</td>
<td>527.34</td>
<td>9,018</td>
<td>$1,023</td>
</tr>
<tr>
<td>3</td>
<td>315</td>
<td>12.6</td>
<td>488.57</td>
<td>6,156</td>
<td>$699</td>
</tr>
<tr>
<td>Pivot #3 w/ end gun off</td>
<td>296</td>
<td>3.7</td>
<td>458.32</td>
<td>1,696</td>
<td>$192</td>
</tr>
<tr>
<td>4</td>
<td>285</td>
<td>3.3</td>
<td>442.04</td>
<td>1,459</td>
<td>$166</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>54,441</strong></td>
<td><strong>$6,179</strong></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td>0</td>
<td>water savings</td>
<td>1 inches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>acres</td>
<td>130 acres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>water savings</td>
<td>130 ac-inch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>pumping lift</td>
<td>140 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>pressure at pump</td>
<td>50 psi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>total head</td>
<td>256 ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>energy source</td>
<td>Electricity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>performance rating</td>
<td>80 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>multiplier</td>
<td>14.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>energy use</td>
<td>41.04 kWh</td>
<td>per ac-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>cost of energy</td>
<td>$0.12 per kWh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$ savings per acre-inch</td>
<td>$4.92 per ac-inch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>$ savings per acre</td>
<td>$4.92 per ac</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>total dollar savings</td>
<td>$640</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Total Energy Saved</td>
<td>18,207,765 BTU</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Irrigation Energy Audit

<table>
<thead>
<tr>
<th>Recommended ECM</th>
<th>Energy Reduction (MMBTU)</th>
<th>Energy Reduction (kWh)</th>
<th>Energy Savings ($/yr)</th>
<th>Cost to Implement ($)</th>
<th>Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replace the well pump diesel engine with an electric motor</td>
<td>297.9</td>
<td></td>
<td>$3,600</td>
<td>$11,152</td>
<td>3.1</td>
</tr>
<tr>
<td>Total of ECM’s with Payback less than 5 years</td>
<td>297.6</td>
<td></td>
<td>$3,600</td>
<td>$11,152</td>
<td>3.1</td>
</tr>
</tbody>
</table>
**Pumps**

**Energy Consumption**

An index, called Performance Rating, is used to evaluate the performance and is calculated by:

Performance Rating = \( \frac{\text{Actual Fuel Used}}{\text{Criteria}} \)

\[ PR = \frac{\text{Actual Fuel Used}}{\text{Criteria}} \]
Pump with Worn Seal

Some water is re-pumped and re-pressurized
Impeller Adjustment is Key

Bottom Seal re-established, improving output and efficiency (may increase per hour energy use)
# Energy Content of Different Fuel Sources

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Average Energy Content BTU</th>
<th>Horsepower hour</th>
<th>Engine or Motor Performance hp-hr/unit</th>
<th>Pumping Plant Performance whp-hr/unit†</th>
<th>Engine or Motor Efficiency %</th>
<th>Pumping Plant Conversion %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 gallon of diesel fuel</td>
<td>138,690</td>
<td>54.5</td>
<td>16.7</td>
<td>12.5</td>
<td>31</td>
<td>23</td>
</tr>
<tr>
<td>1 gallon of gasoline</td>
<td>125,000</td>
<td>49.1</td>
<td>11.5</td>
<td>8.66</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>1 gallon of liquefied petroleum gas (LPG)</td>
<td>95,475</td>
<td>37.5</td>
<td>9.20</td>
<td>6.89</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>1 thousand cubic foot of natural gas</td>
<td>1,020,000</td>
<td>401</td>
<td>82.2</td>
<td>61.7</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>1 therm of natural gas</td>
<td>100,000</td>
<td>39.3</td>
<td>8.06</td>
<td>6.05</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>1 gallon of ethanol ☳</td>
<td>84,400</td>
<td>33.2</td>
<td>7.80</td>
<td>5.85</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1 gallon of gasohol (10% ethanol, 90% gasoline)</td>
<td>120,000</td>
<td>47.2</td>
<td>11.08</td>
<td>8.31</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>1 kilowatt-hour of electrical energy</td>
<td>3,412</td>
<td>1.34</td>
<td>1.18</td>
<td>0.885</td>
<td>88</td>
<td>66</td>
</tr>
</tbody>
</table>

‡ Conversions: 1 horsepower = 0.746 kilowatts, 1 kilowatt-hour = 3412 BTU, 1 horsepower-hour = 2,544 BTU
† Assumes an overall efficiency of 75% for the pump and drive.

.chomp	Nebraska Pumping Plant Criteria for fuels containing ethanol were estimated based on the BTU content of ethanol and the performance of gasoline engines.
## Pumping Plant Performance Criteria

**Amount of work produced per unit of energy used**

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Engine or Motor Output / Energy Use Rate (hp / (unit/hr))</th>
<th>Energy Added to Water / Energy Use Rate, whp / (unit/hr)</th>
<th>Energy Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>16.7</td>
<td>12.5</td>
<td>gallon</td>
</tr>
<tr>
<td>Gasoline</td>
<td>11.5</td>
<td>8.66</td>
<td>gallon</td>
</tr>
<tr>
<td>Propane</td>
<td>9.2</td>
<td>6.89</td>
<td>gallon</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>82.2</td>
<td>61.7</td>
<td>1000 ft³</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.18</td>
<td>0.885</td>
<td>kWh</td>
</tr>
</tbody>
</table>

*Pumping plants exceeded the NPC. (15% of 165 tests in 1980-81)*

North Central Region SARE Grant, 2011
Selling Point #2:

Operations Solutions by auditors who understand the farm operations.
Electric Service

Single Phase

Three Phase
Written- Pole Motors Single Phase Motors

60 HP Written- Pole Motor

Centrifugal Pump

Three Phase Generator
Written- Pole Motors
Selling Point #3:

Financial Options to Ease the Burden

$$$$
Selling Point #4:
Reduce the Operation’s Carbon Foot Print and Be Environmentally Responsive
Be Part of the 4TH Great Human Revolution

1. AGRICULTURAL
2. INDUSTRIAL
3. INFORMATION
4. ENERGY AUTONOMY

Be Green, Go Green
Questions