Energy Audits
Michigan Farm Energy Program

MICHIGAN STATE UNIVERSITY

- Agricultural operations significant energy usages
  - Opportunity to reduce costs
- Utility rates increasing 1% per year or more
  - 2009 - $0.09/kWh
  - 2021 - $0.15/kWh

- Created within MSU Biosystems & Engineering Department
  - **Truman Surbrook, PhD**
  - **Aluel Go, Outreach Specialist**
- Developed training & certification program

- MSU Certified Energy Auditor, 2009
  - Dan Schrauben, PE
  - Schrauben Associates, LLC

MI Farm Energy Program

- Michigan only State with Certified EA training
- Tier 2 EA per ASABE/ANSI S16 Standard
- Recognized by USDA, State, & utility programs
- MI FEP protocols adopted as part of USDA national guidelines
- Secured funding for energy auditor compensation

Utility Program Participation

- Utilities had energy efficiency program for Residential, Commercial, & Industrial
- Convinced & assisted utilities to develop agricultural component into EE programs
- Utilities incorporated over 40 agricultural-related measures
- Utilities provided farm energy audit rebate
- Pushed for utilities to reduce cost burden for utility extensions

Michigan Farm Energy Program

- Initially training for Dairy & Greenhouses
- Followed by Irrigation & Grain Drying
- Methodology applicable to variety of entities
- Including – poultry, swine, sheep, beef, equine, popcorn, flower bulbs, organic farms, potatoes, beans, fish hatcheries, blueberries, maple syrup, apiary, & Rural Businesses

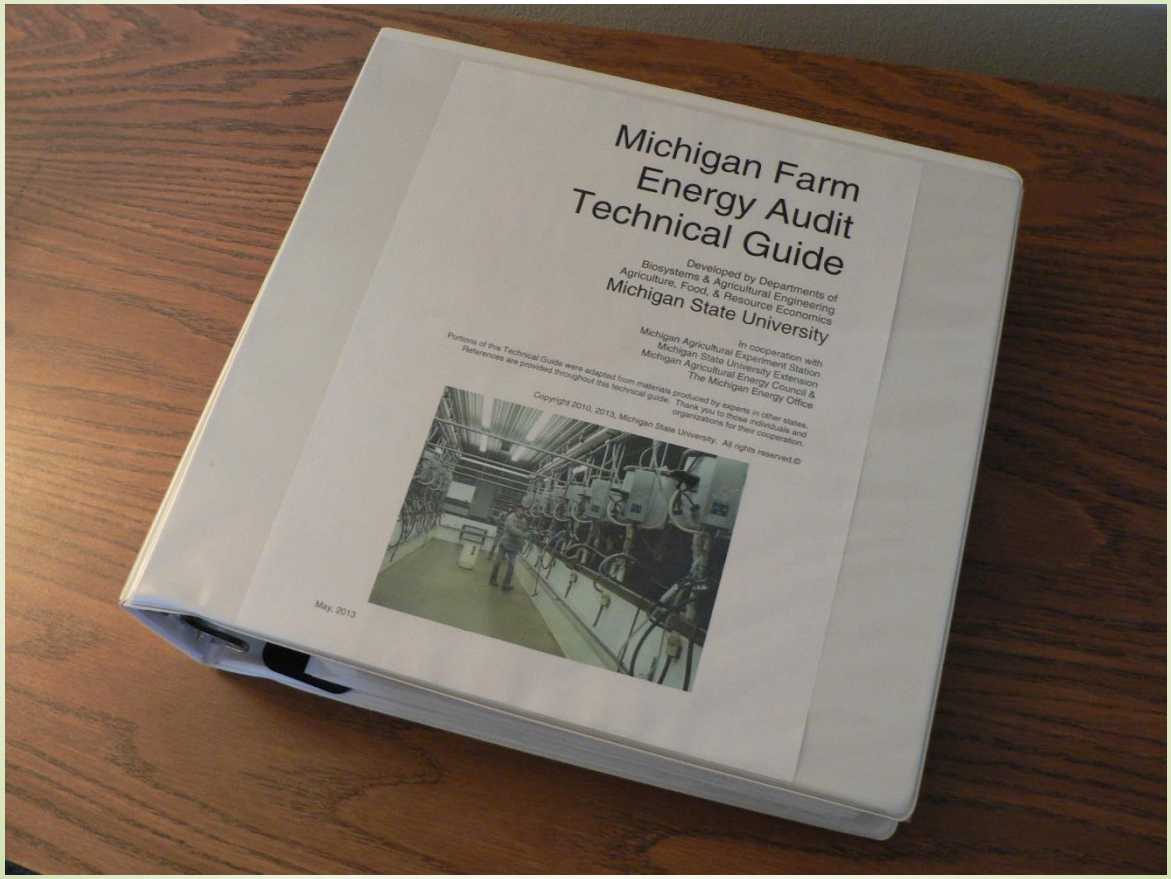
Rural Businesses

- Rural Business – population < 50,000 (per USDA REAP requirement), some exceptions
- Manufacturing - rubber & plastic products, automotive products, injection molding
- Food Processing – fruits, meats, vegetables, hard cider, wine, cheese
- Retail – farm markets, hardware, discount store, resort, lumber, movie theatre, aerial spraying, bulk farm supplies, car wash, & others

MI Farm Energy Program Training

- **Phase I – 3 days of presentations**
  - MSU staff
  - MSU Extension staff
  - Industry representatives
  - Technical manuals
- **Phase II – On site visit to a facility**
  - Obtain data for a group energy audit
  - Prepare group energy audit
- **Phase III –** Present EA, critique, finalize & deliver
- **Phase IV –** Independently perform energy audit
- **Certification upon completion of all 4 phases**

Technical Guide



United States Dept. of Agriculture Rural Energy for America Program

- Prior MI FEP, Michigan ranked 46th for REAP funding among United States
- Energy auditors incorporated technical data into applications & assisted with forms
- Ranking rose to 5th by 2012
- Top 10 ranking maintained to date

Dairy Farms

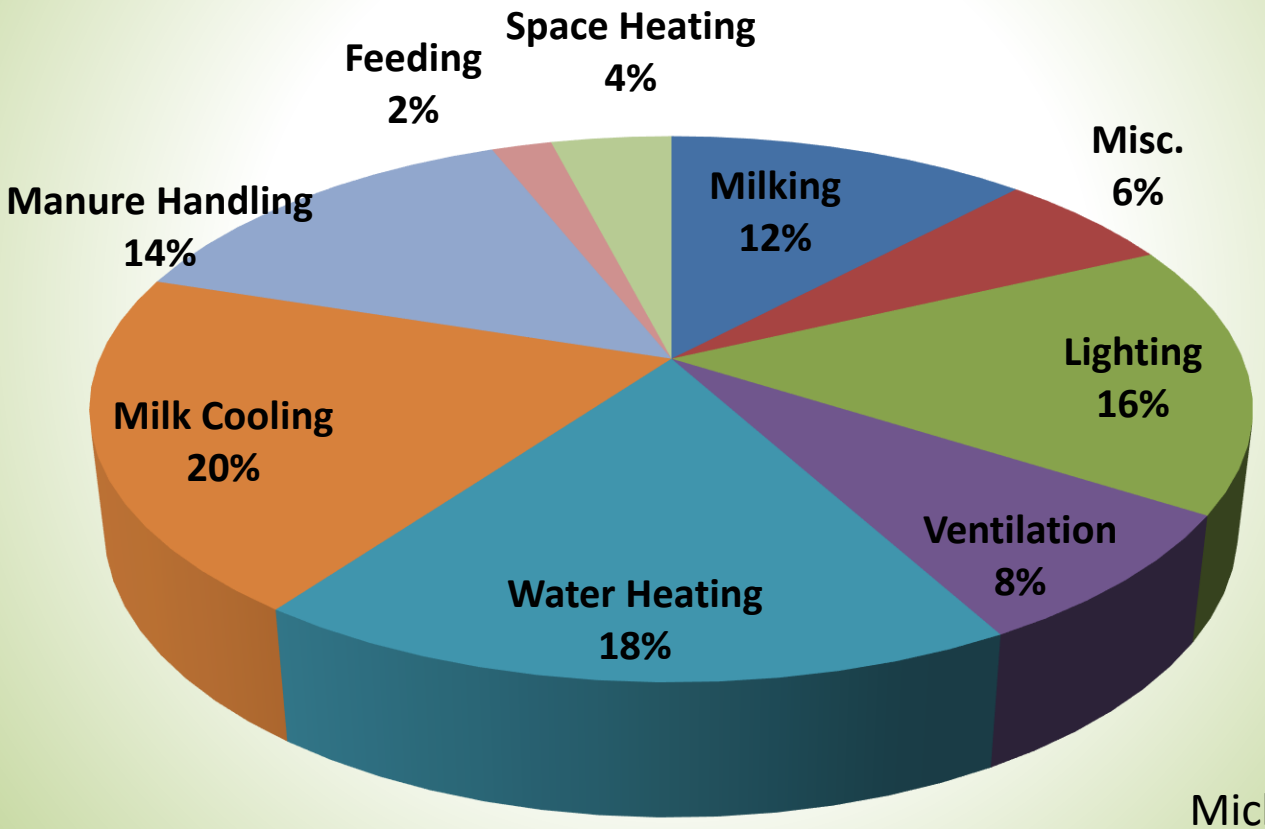
- **“All put milk into the tank”**
- **Operations & systems vary**
- **Be observant**
- **Take photos (lots) with permission**
- **Listen**

Dairy Farms
Variety of Operations

- **Large operations >1,000 head**
- **Smaller operations <50 head**
- **Fully focused on dairy**
- **Crop farming with dairy**
- **Multi-generational operations**

Dairy Farms
Variety of Facilities

Dairy Energy Usages



Michigan 2010

Dairy - Challenges & Opportunities

- Numerous energy components
- Ranges of equipment
- Facility variations
- Facility layouts
- Parlor configurations
  - Parallel
  - Herringbone
  - Carousel (Rotary)

- Lighting
- Cooling
- Pre-heating
- Water heating
- Variable frequency drives
- Ventilation

Energy Audit List

1. Three-years of utility bills
2. Monthly milk production records
3. Building, labels, and dimensions.
4. Milking parlor & milking times
5. Milk tank & size
6. Feed cost/cow/day.
7. Diesel/gas usage
8. Plate cooler information
9. Vacuum pump horsepower
10. Condensing units
11. Milk receiver pump
12. Water usage /day
13. Watering tanks & heaters
14. Hot water heater & storage
15. Preheater
16. Pumps/compressors
17. Other motors & uses
18. Manure lagoon, gallons
19. PTO operations
20. Block heaters
21. Ventilation fans
22. Space heaters
23. Lighting & lighting levels
24. Exterior lighting, type

Energy Audit Reports

- Summary & conclusions
- Existing & proposed conditions
- Production records & utilities
- Twenty sections - 20 to 50 pages
- Data & calculations - 20 to 40 tables
- Figures & photos – 15 to 20

Energy Audit Report

Energy Conservation Measures Summary (Dairy, 1,400 milking)

Electricity Energy Source	Savings/Year			Cost to Replace	Payback (Years)
	Energy (kWh)	Energy (MMBtu)	Revenue ($)		
Lighting	124,606	425.2	$17,694	$45,502	2.6
Occupancy Sensors	30,358	103.6	$4,311	$4,350	1.0
Vending Machines	4,205	14.3	$597	$200	0.3
New Slurry Pumps	684,093	2,334.1	$96,947	$164,901	1.7
Parlor Vacuum Pumps VFD	98,856	337.3	$13,840	$6,699	0.5
Special Needs Vacuum Pumps VFD	3,684	12.6	$523	$5,586	10.7
Calf Barn & Old Milk Hse Water Heaters	66,334	226.3	$4,660	$4,500	1.0
Liquid Propane Energy Source	Savings/Year			Cost to Replace	Payback (Years)
	Energy (Gallons)	Energy (MMBtu)	Revenue ($)		
New Pre-Heaters	2,110	193.0	$4,220	$11,441	2.7
Parlor Tankless Water Heater	505	46.2	$1,009	$4,500	4.5
Calf Barn & Old Milk New Water Htrs	(2,380)	(217.7)	($4,759)		
Hot Water Pipe Insulation	1,024	93.7	$2,048	$159	0.1
Energy Star Washing Machine	110	10.1	$221	$900	4.1
Totals - Electricity & Liquid Propane		3,578.7	$141,311	$248,739	1.8

Production & Operation Improvements

- Additional Lighting
  - Improve Lighting Conditions
  - Achieve Recommended Lighting Levels
- Long-day Lighting
  - Milk production – Maximized at 16 hours/day lighting
  - Increases feed & lighting costs
  - Increased Milk Production > lighting & feed $
- Additional Ventilation
  - Heat Stress = 10% to 20% milk production drop
  - Additional Fans & Controls
  - Increased Milk Production > fan & energy $
- Proper electric fence grounding
- Document savings for already installed EE features
- Recommend utility rate analyses

Grain Drying

- Cropping operations, primarily corn
- Soybeans sometimes, may become more typical
- Range of sizes – Cropping 500 acres to 25,000 acres
- Grain drying equipment & facilities vary
- Older equipment upgrading to new equipment with more sophisticated control systems

Batch Grain Drying

Continuous Flow Grain Drying
Horizontal - Vertical

Continuous Flow – Mixed Flow Grain Drying

Methodology

- Purdue University simulations
- Purdue simulations accepted for REAP funding
- Grain dryer manufacturer simulations
- Now both considered acceptable
- If no simulation (older dryer), then energy auditor makes determination based on data

Energy Audit Information

- Inventory facilities – dryer(s) & storage
- Loading, unloading, motors, & transfer rates
- Energy usage records – 3 years
- Cropping & drying records – 3 years
  - Bushels
  - Moisture ranges
- Diesel PTO operations vs electric motors
- Shop energy usages, heating & lighting

Existing Facilities – 1,300 Acres

Corn, Wheat & Oats

Energy Conservation Measures Summary

System	Energy Savings (MMBtu/Year)			Savings ($/Year)	Cost to Implement	Payback (Years)
	Total	Savings	Savings %			
Existing Grain Drying	751.0					
Proposed Grain Drying	387.7	363.4	48.4%	$13,533	$113,514	8.4
PTO Operation	29.0					
Electric Motor in lieu PTO	0.4	28.6	98.5%	$713	$657	0.9
Grain Drying Subtotal			50.2%	$14,246	$114,171	8.0
Existing Lighting	8.3					
Proposed Lighting	2.1	6.2	75.2%	$292	$1,250	4.3
Combined Energy Savings		398.1	50.5%	$14,538	$115,421	7.9

Existing Grain Facilities
7,000 Acres - 600,000 bu. corn
Corn, wheat, & soybeans

Existing Grain Dryers

Kan Sun & Meyer Morton Tower Dryers – 1970 Models

New GSI Tower Dryer

New Grain Drying Facilities
New Location
Shop, Equipment & Storage Buildings

Grain Drying Energy Audit

- Cropping 7,000 Acres
- 600,000 bu/yr of corn
- Purdue University simulation
- 40% energy savings
- $200,000 project
  - Tower grain dryer
  - Installation
- 5.7-year payback

Grain Dryer Selection

- Energy Auditor does not select grain dryer
- Owner determines proposed system
  - Owner review of various brands
  - Others' experiences
  - Long-standing working relationship with a particular supplier

Grain Drying Controls

- Remote monitoring and control
- Touch screen, animated, graphical interface
- Control box installed remotely in a separate control room
- Control multiple augers emptying each cycle for easy start-up
- Adjustable staged starting of fans and heaters
- Grain-temperature sensors for moisture control
- Memory recall for running history & troubleshooting

Grain Drying Energy Audit

- 1990 vintage top dryers
- 140,000 bushels/yr
- Updated controls & electrical panels
- Keep existing grain dryers
- Added generator for 3-phase electricity
- ~$80,000 project
- ~60% energy savings
- <3 years payback

Non-Energy Considerations

- Improved operating conditions
- Improved and more consistent grain quality
- Easier to operate, even operate remotely
- Increased drying capacity
- Allow harvesting operations to proceed in a timely manner

Greenhouses

- Michigan 3rd in the nation for bedding plants
- Celery - primary field crop
- Evolved to enclosed operations & bedding plants
- Southwest MI and Western MI numerous greenhouse operations

Greenhouses

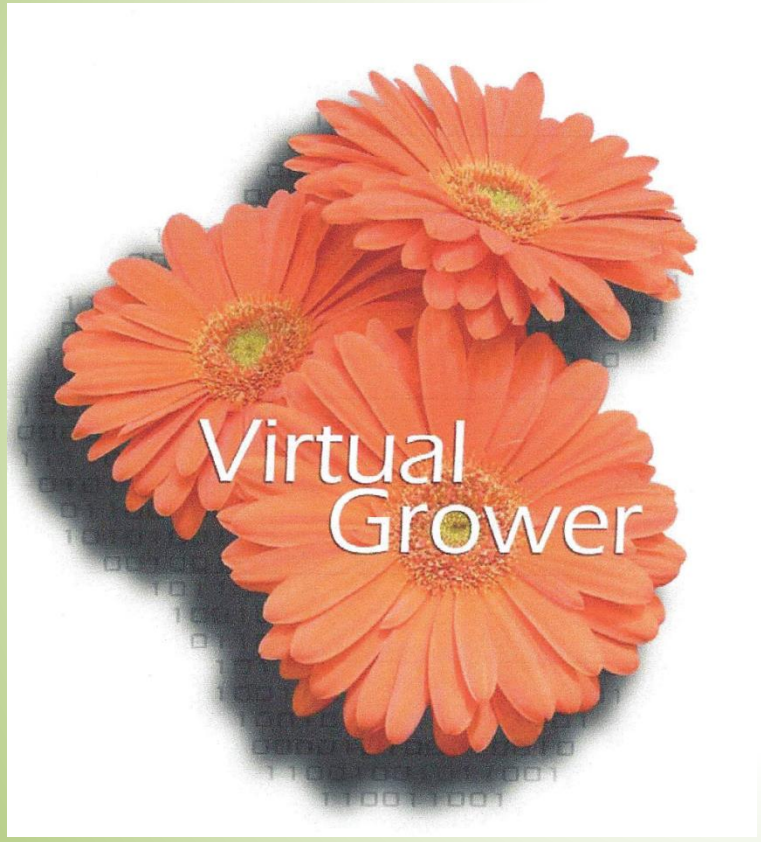
Greenhouse – 10 Acres
Bedding Plants – Wholesale
Natural Gas - $250,000/year

Organic Farm – 12 field acres
Wind & solar power
Greenhouse – 1,200 sf
Area Heating to Bench Heating
$13,000 – 0.4-year payback

Energy Audit

- MSU Extension staff
- Greenhouse operators
- MSU technical data
- University publications
- Virtual Grower simulation

Greenhouse Energy Simulation



- Computer simulation for greenhouses
- Available from USDA website
- Developed by University of Toledo
- Released in 2006
- Updated and upgraded (MSU input)
- Version 3.0

Virtual Grower

- Planning tool for greenhouse users & growers
- Operating variables impact on heating costs
- Input information – existing & proposed
  - Temperature settings
  - Heating days
  - Heating degree days (on-line or VG)
  - Types of heating systems
  - Fuel types
  - Greenhouse shape & construction

Energy Conservation Measures Summary
6 acres – indoor, 7 acres - outdoor

Item	Energy Savings (MMBTU)	Savings ($/year)	Cost to Implement	Payback (years)
Hi. Eff. Unit Htrs	2,797.7	$19,530	$152,600	7.8
Weatherization	4,046.3	$28,245	$69,751	2.5
IR Film Covering	1,931.8	$13,485	$5,580	0.4
Energy Curtains	1,000.1	$6,982	$62,124	8.9
LED Lighting	290.1	$10,372	$32,407	3.1
Water Heaters	1.5	$53	$400	7.6
Pipe Insulation	2.4	$87	$25	0.3
Wtr Htr Blankets	8.8	$313	$60	0.2
New Refrigerator	5.0	$177	$450	2.5
Vending Miser	14.3	$513	$400	0.8
Occupancy Sensors	159.7	$5,709	$1,200	0.2
Totals	10,257.7	$85,466	$324,997	3.8

Irrigation

IRRIGATION

- Irrigation Equipment Options
- Energy Options – Fuel Types
  - Diesel
  - Electricity
  - Natural Gas
  - Propane
  - Gasoline
- Electricity & Power Issues – 1 phase or 3 phase
- Phase Converters
- Variable Frequency Drives
- Lower pressure sprinklers

Diesel Fuel to Electric Motor

- Diesel fuel was choice when irrigation systems started being utilized in the 1970's
- Fuel cost was about $0.70/gallon
- Three-phase electricity was not readily available in rural areas (still the case in many areas)
- Diesel fuel prices increased to approaching $4/gallon
- **Under $2/gal – electricity is more efficient than diesel**

Discontinue Diesel Fuel Usage

- Diesel fuel spillage
  - Withdrawing water from watercourse
  - Wells in low-lying areas
- Diesel fuel theft

Electricity Extension

- Construction of power lines cost as much as $50,000 to $100,000 per mile
- Even when lines are nearby, the cost of installation is considerable.
- Utility had charged the customer for the full cost of installation
- Extension now based long-term revenue & other customers reducing costs
- One case – electricity extension from $40,000 to $4,000

Irrigation Energy Audit

- Five center pivot irrigation systems
- Converted from diesel to electric motors
- Added phase converters on all systems
- Added VFD on three systems
- ~$80,000 project cost
- 3.3-year payback
- >75% energy savings

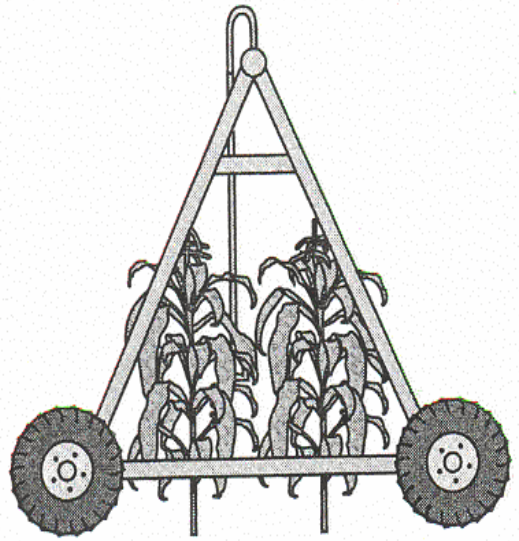
Data Acquisition

- Operator provided Irrigation Assessment information
- Irrigation flows and fuel usages for each irrigation system
- Cost estimates for proposed improvements
- Plat maps pinpointed system locations
- Location information used to provide aerial maps, elevation data, and USDA soils data

Replace Existing Pump

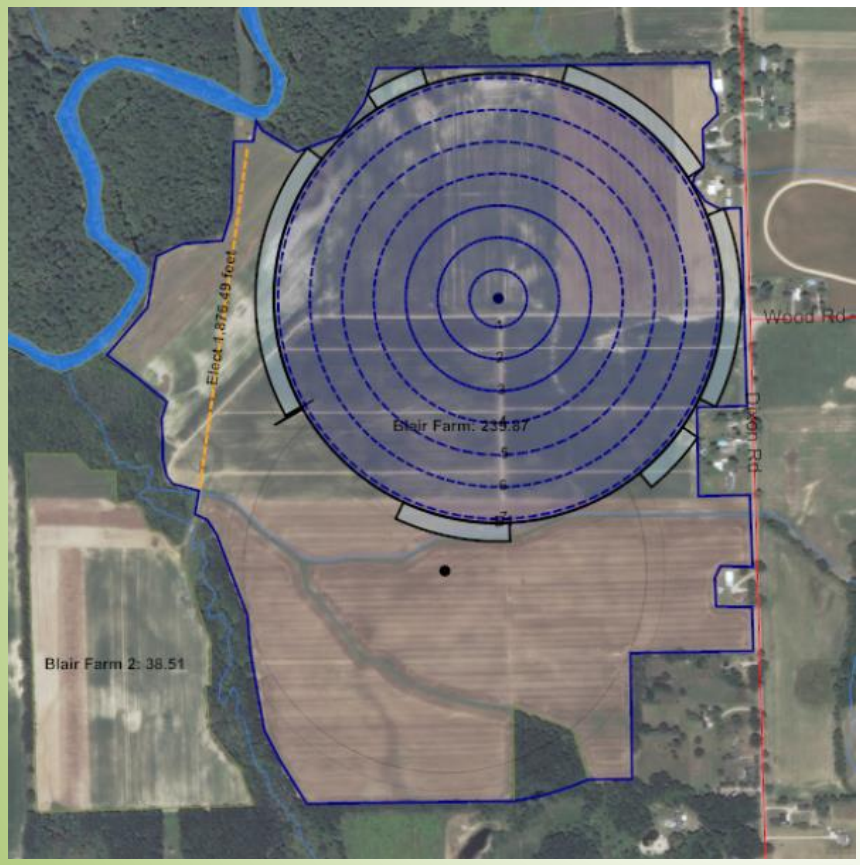
Proposed Irrigation Upgrade

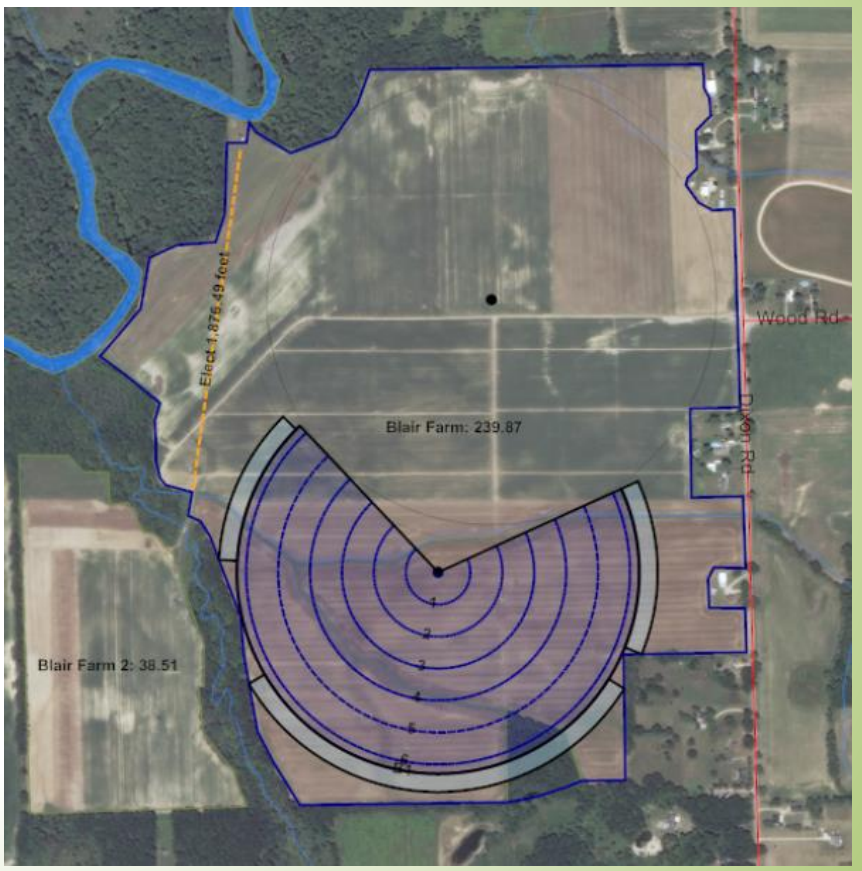
- Pressure reduction due to low head sprinklers that replace impact sprinklers.
- Operate the irrigation system at lower pressure, at 45 psi in lieu of 85 psi.
- Install 30 hp electric motor in lieu of existing 100 hp
- $25,000 project cost
- <2 years payback
- 67% energy savings



Sprinklers on drop tubes in crop canopy.

Proposed Center Pivot Coverages





Non-Energy Considerations

- Improved irrigation system operating condition
- Ability to provide irrigation according to system demand
- More uniform water application
- Ease of operation, less labor (elimination of the traveler rig method)
- Reduced runoff, reduced evapotranspiration & reduced erosion potential
- Better management of the water resources.

Food Processing

- Lighting
- Electric Motors
- Cooling Systems
- High Speed Doors

Lighting – Apple Storage Facility

- Over 200 T8 lighting fixtures installed in 2012, replacing T12 fluorescent
- Installed for energy savings
- Evaluated LED tube lighting in lieu of T8
- $45,000 estimate in 2013, 5-year payback
- LED prices reduced since 2013
- Eliminates need for enclosures (yellowing) for T8 glass
- Health Dept. considerations
  - Enclosures trapped insects
  - Eliminates potential mercury contamination
- LED longer life - reduces hi-bay maintenance

Cooling Systems

- Refrigeration energy control system (ENERSAVE LLC) (MSU alum)
- Installed for 8 million bushels of fruit in MI, NY & Canada
- Savings about 1.5 kWh/bushel/year
- 12,000,000 kWh/year
- Optimizes runtimes of compressors & evaporator fans

Energy Audit

- Energy Saved – 48,501 kWh
- Savings - $5,334/yr
- Cost - $16,200
- Payback – 3 years

Grading & Packing

- Sophisticated system
- Each apple – 16 photos
- Color, color variation, size, weight
- Individualized packing
- Within 2 oz. of listed package weight
- 700,000 bu/year
- 70,000 bu in frost year

Automated Hi-Speed Storage Doors

High Speed Doors

- Eliminates cooling losses associated with open doors
- Doors open 6 hours/day during loading & unloading
- Opening speeds up to 130” per second help to maintain critical temperatures
- Maximize workflow and reduce product spoilage
- ~$14,000 to $20,000/door
- Established as a prescriptive incentive by utility companies, rather than custom

- $107,000 cost
- 5 doors
- 75% energy savings
- 3.5-year payback

- $168,000
- 12 doors
- 30% energy savings
- 5-year payback

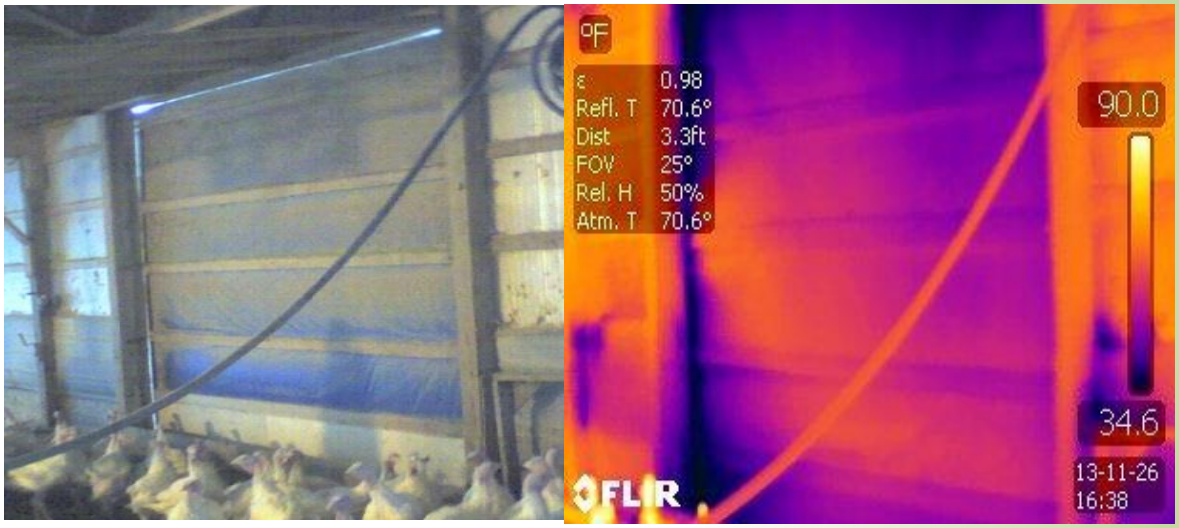
Turkey Farms

Turkey Facilities

- 1 Brooder Barn
- 4 Finishing Barns
- Rotating flocks
- 30,000 birds/flock
- 6 to 7 flocks/year

Energy Items

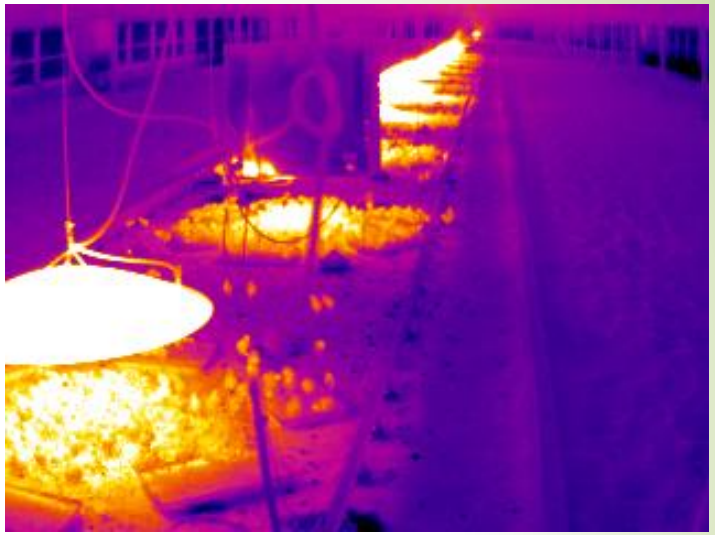
- Heating
- Lighting
- Insulation
  - Walls
  - Doors
- Air Circulation
  - Fans
  - Windbreaks

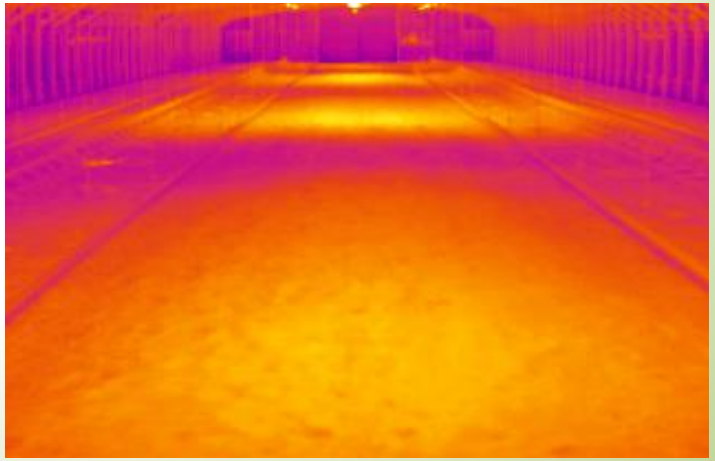


Infrared – Electrical Panels

Methodology

- Inventory – Finish Barns identical
- Unit Heaters or Pancake Heaters vs Infrared Heaters
- Additional Insulation
  - Walls
  - Doors
- LED Lighting
  - Energy savings
  - Behavioral impact
- Fan Efficiency
- Windbreaks



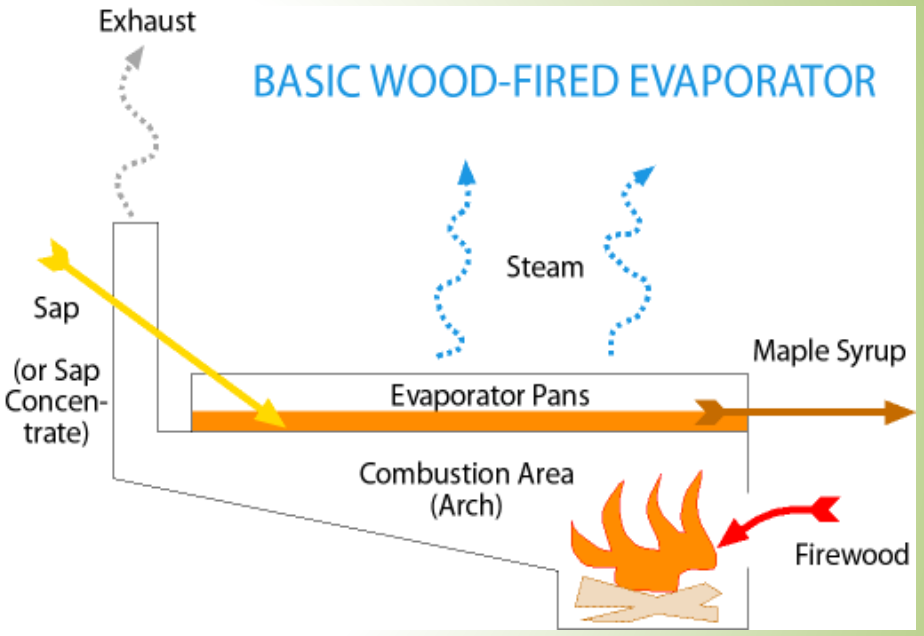


Turkey Farm - Benefits Achieved

- Budgeted $2,000,000
- Improvements to 5 facilities
- Energy savings
  - Natural gas
  - Electricity
- Reduced mortality
- Faster weight gain
- Labor savings

Maple Syrup Production

- Reverse Osmosis Filters
  - Reduce sap water content 50% to 75%
  - 40 gal of sap to produce 1 gallon syrup
  - Filtering – 10 gal to 1 gal
- Vacuum Assist Collection
  - 30-day season
  - Double sap/tree, 500 taps
  - Common collection point, reduced tractor collection
- $32,000 project, 4.2-year payback, >80% energy savings
- Michigan is ranked 5th in syrup production



Manufacturing Plant – Boiler Replacement

Energy Conservation Measures

Item	Energy Savings (MMBTU)	Savings ($/year)	Cost to Implement	Payback (years)
Boiler System	7,309	$106,077	$484,013	2.2
Steam Piping	16,556	$115,895		
Unit Heaters	4,401	$30,804	$38,000	1.2
Motors + VFD	1,653	$48,454	$31,500	0.7
Vending	52	$1,520	$1,600	1.1
Totals	29,971	$302,750	$555,113	1.8

Summation

- MI Farm Energy Audit Program is unique
- On-site data acquisition by energy auditor is key
  - Observe operation
  - Obtain first-hand information
  - Provides opportunity to gain insight from owners and operators
    - Issues specific to operations and facilities
    - Goals and potential improvement opportunities
- Training and other resources are important
- Methodology adaptable to any energy using operation or facility
- Innovations and technological advances ongoing

Michigan State University
Biosystems and Agricultural Engineering