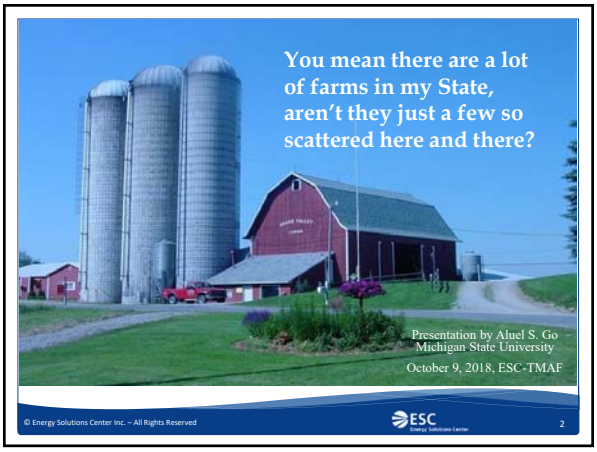

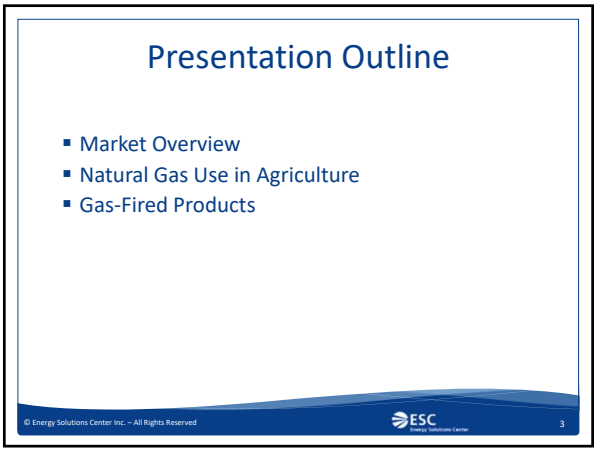

Natural Gas Marketed Production (2016)

USDA Energy Investments

The two major US Department of Agriculture (USDA) programs involved in farm energy are:

1. USDA-Rural Energy for America. Energy efficiency and renewable energy.
2. USDA-NRCS Environmental Quality Incentives Program (EQIP). Energy efficiency.

Potential Efficiency In Agriculture

2010-2016 Energy Efficiency Savings

No.	Operation	Savings (kWh)	% Savings	Total Annual Savings ($)	Total Owner Cost to Implement ($)	Payback Time (years)	Potential Average Annual Savings ($)
133	Dairy Farms	11,190,946	35	1,214,725	2,741,579	2.3	9,133
57	Grain Drying	14,302,450	28	999,482	6,836,135	6.8	17,535
35	Greenhouse	27,762,764	34	1,106,753	4,917,592	4.4	31,622
27	Food/Fruit Process	2,371,934	38	338,023	1,347,791	4.0	12,519
19	Irrigation	4,433,969	51	418,839	1,560,736	3.7	22,044
12	Crops	75,529	4	53,583	130,250	2.4	4,465
5	Beef	69,076	14	9,913	19,476	2.0	1,983
4	Hogs	198,264	14	18,002	59,718	3.3	4,501
2	Poultry	12,618,901	62	567,365	2,053,625	3.6	283,683
36	Rural Business	13,706,260	36	768,458	1,916,983	2.5	21,346
1	Integrated Farm	11,358	94	1,693	3,480	2.1	1,693
3	Fish Hatcheries	2,085,817	13	93,610	206,775	2.2	31,203
334	**Audit Total**	**89,127,267**	**34**	**5,590,446**	**21,794,140**	**3.9**	**16,738**

ESC Energy Solutions Center
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USDA Energy Efficiency Investment

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USDA Renewable Energy Investment

Wind, Solar and Hydroelectric

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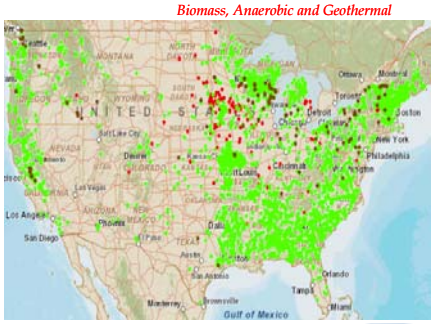
USDA Renewable Energy Investment

Biomass, Anaerobic and Geothermal



ESC Energy Solutions Center 9

Renewable Energy in Agriculture

- When you talk about renewable energy, you can't ignore the Ag. Sector and the vast potential that lies within it.
- Renewable technologies that are commercially available today can all be economically implemented in farms, ranches and rural communities that make-up this sector. No other sector or industry can make that claim.
  - Biofuels
  - Biopower
  - Bioproducts
  - Geothermal heat pumps
  - Geothermal direct use
  - Hydroelectric power
  - Passive solar heating
  - Photovoltaic (solar cell) systems
  - Solar hot water systems
  - Wind energy"

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Alvel S. Go, Michigan State University

Energy Trends in Agriculture

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Long-Day-Lighting

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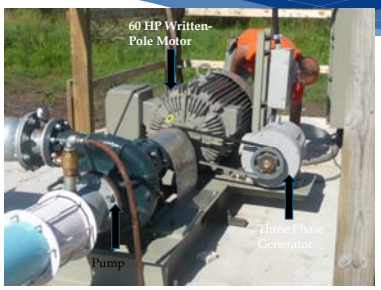
Alvel S. Go, Michigan State University

Written- Pole Motors
Large Motors in Single Phase Environments



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Abdel S. Ge, Michigan State University

Natural Gas Use in Agriculture

- Irrigation
- Water Pumping
- Greenhouse
- Drying
- Gain Mills
- Poultry & Dairy
- Irrigation
- Fertilizer & Pesticides
- Farm Vehicles and Equipment
- Ethanol Production

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Irrigation

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Irrigation

- It is quite common so see electric & diesel well pumps, such as the ones below, on many farms.


- These can be replaced, where infrastructure is available, with NG powered pumps that are available from several manufacturers.

Water Pumping

Advantages

- Lower cost to operate
- Clean/low emissions
- No need to order diesel or oil delivered to pump
  - Doesn't run out of fuel when needed
- No chance of toxic fuel spill on farm land

Disadvantages

- Gas line install cost
- Possible "floating up" of pipe over time
- Possible damage to pipe in tilling activities

Electric vs Nat. Gas Pumping Comparison

- Let's compare three options
  - Grid electric motor
  - Electric motor with on-site natural gas generator
  - Natural gas engine driven

Water Pumping Power = (Volumetric Flow Rate) x (ρ g) x (head)

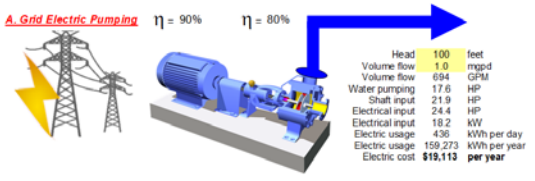
Pump Shaft Power = ηpump x (Water Pumping Power)

Electric Power Input = ηmotor x (Pump Shaft Power)

electric unit cost	$0.12	per kWh	ρ x g	62.4	lb per ft3
natural gas unit cost	$5.00	per MCF	conversion to gallons	7.48	gal per ft3
electric motor eff.	90%		conversion to HP	550	(ft-lb/sec) per HP
pump efficiency	80%		conversion to kW	0.7457	kW per HP
gas engine efficiency	35%		minutes per day	1,440	min per day

Electric vs Nat. Gas Pumping Comparison

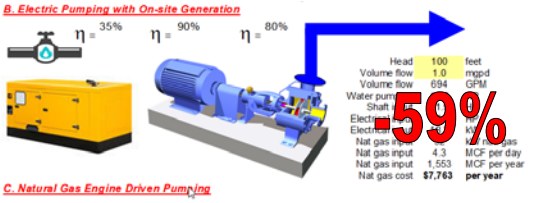
A. Grid Electric Pumping



Head	100	feet
Volume flow	1.0	mgpd
Volume flow	694	GPM
Water pumping	17.6	HP
Shaft input	21.9	HP
Electrical input	24.4	HP
Electrical input	18.2	kW
Electric usage	436	kWh per day
Electric usage	159,273	kWh per year
Electric cost	**$19,113**	**per year**

Electric vs Nat. Gas Pumping Comparison

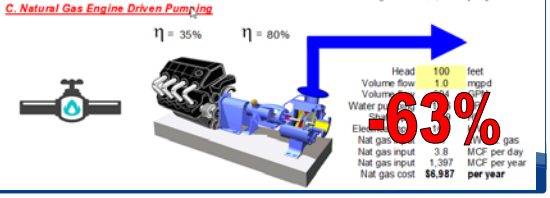
B. Electric Pumping with On-site Generation



Head	100	feet
Volume flow	1.0	mgpd
Volume flow	694	GPM
Water pump		
Shaft		
Electri		
Electri		kW
Nat gas i		gas
Nat gas input	4.3	MCF per day
Nat gas input	1,553	MCF per year
Nat gas cost	**$7,763**	**per year**

-59%

C. Natural Gas Engine Driven Pumping



Head	100	feet
Volume flow	1.0	mgpd
Volum		
Water p		
Shaf		
Elec		
Nat gas		gas
Nat gas input	3.8	MCF per day
Nat gas input	1,397	MCF per year
Nat gas cost	**$6,987**	**per year**

-63%

Three-Phase Electrical Service Access

Restrictions to Expansion & Efficiency

- An informal survey of electric utilities show about 90% of Michigan farm customers are on single phase service.
- The need for three-phase service usually occurs where large motors are present. Up to a motor size of about 10 horsepower (hp), single-phase service is usually adequate. Beyond 10 hp, the single-phase line may have trouble delivering the current needed to start the motor. Starting a motor can require six times as much current as it takes after it is running. A large motor start-up on a single-phase line can cause blinks and related problems for other customers on the line, as well as the farm in question.
- Connection/access cost are very expensive and rewiring is often required.
- Natural gas access expansion is also expensive and unavailable in most areas.
- Utility territorial restrictions have been detrimental most of the time for farmers to access the most efficient and affordable option.

Source: Consumers Energy - AgriCulture, Fall 2006

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Alan S. Go, Michigan State University

Natural Gas Engines

- Industrial Grade Engines
- Internal Combustion, both Rich & Lean Burn
- 30 to 40 year life
- Need to consider higher maintenance vs electric

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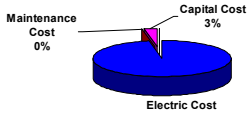
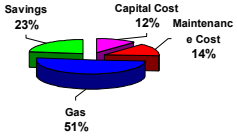
Life Cycle Cost

Electric Motor



Gas Engine



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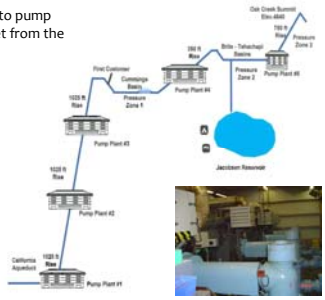
Tehachapi- Cummings – Case Study

Uses Natural Gas Engines to pump water more than 3000 feet from the Central Valley



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Glass Greenhouses and Indoor Grows

- Greenhouses: cut flowers, tomatoes, cucumbers.
- Indoor grows need high value crop due to energy intensity: cannabis, microgreens or lettuce crops
- Combined Heat and Power an efficient option
- Other gas solutions: gas engine heat pumps, engine driven chillers for grow rooms, condensing boilers or unit heaters
- Other energy efficiency considerations:
  - Building envelop, night curtains, LED lighting.

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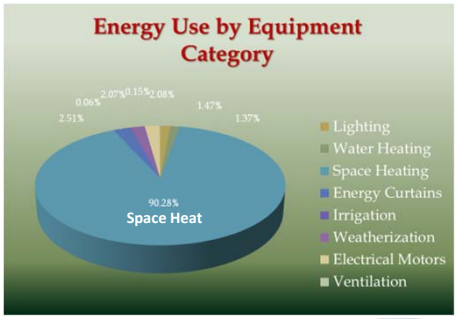
Greenhouse Energy Use



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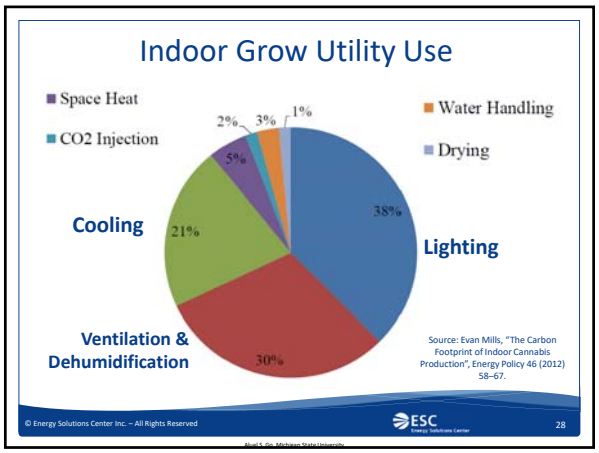
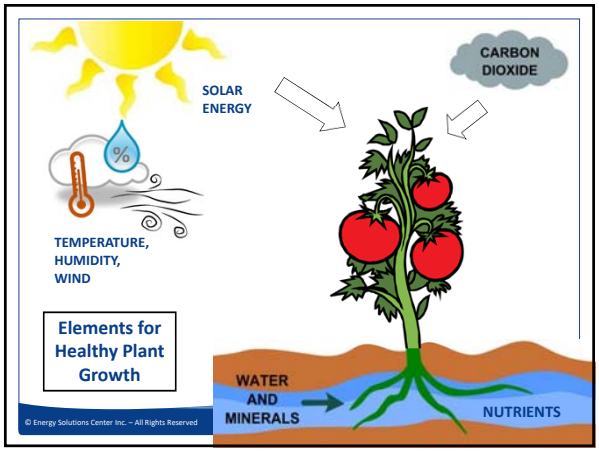
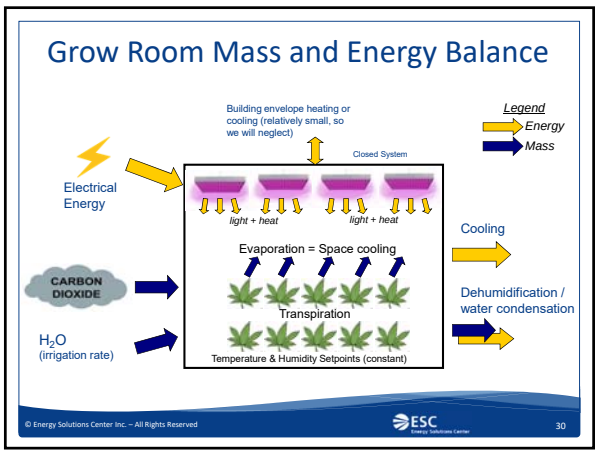
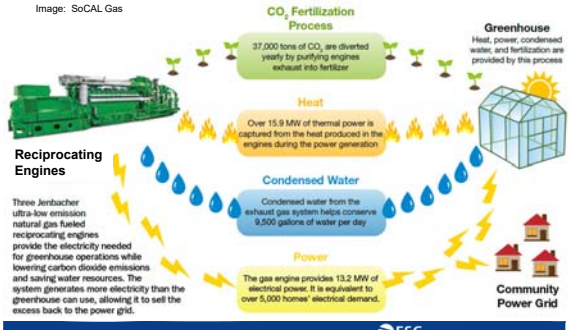






Houweling Tomatoes Glasshouse, Efficient CHP Grower in California

Image: SoCAL Gas



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Houweling Tomatoes Glasshouse

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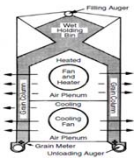
Crop Drying

- Crops such as wheat, corn, soybean, rice, sorghum, sunflower seeds, canola/rapeseed, barley, oats, etc. need to be dried before going to storage and/or market in order to inhibit microbial growth,
- Largest dryers are normally "Off-farm" in elevators of continuous type and are usually of the Cross Flow design.
- Other types are Concurrent Flow and Counter Flow dryers.



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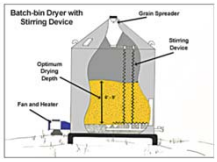
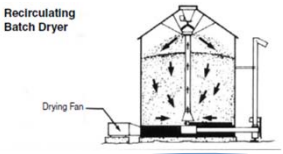
Drying-continued

- Batch dryers are generally "On-Farm" and are quite common. They consist of a bin with heated air flowing from an a internal source
- There are several types including roof, batch column dryers
- Low run hours per year





Grain Drying Energy Use

Poultry/Swine Houses

- Heating costs can be as much as 40% of a growers out-of-pocket expense
- Two types of heaters are generally used, radiant heaters and forced-air.
- Radiant heaters are preferred as they direct the heat to the floors better and the poultry directly absorb the heat.

Protein Processing

- Encompasses the slaughter of meat and poultry and the cutting and packaging of these meat products for sale to wholesalers and meat jobbers.
- Characterized by its diversification into other fields, such as the chemical, pharmaceutical and animal feed industries, in order to capitalize on the use of all animal byproducts.
- Companies are located around areas of high feed production and major market areas. Forty (40%) of the value of production occurs in the North Central Region of the U.S.
- Energy requirements demand a heavy reliance on natural gas--45-55% of total thermal energy used.
- Natural gas is primarily used as boiler fuel to produce hot water & steam for the processing and cleaning operations
- New plant construction requires ever-increasing refrigeration capacity due to market demand for frozen and prepared foods. This trend has increased over the last 10 years. Frozen food storage provides an opportunity for gas fired desiccant to control moisture and ice buildup
- Waste food products provide an opportunity to capture biogas, a renewable natural gas

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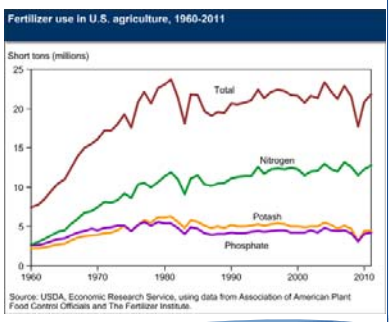
Fertilizer & Pesticides

- Indirectly the natural gas used in the production of nitrogen fertilizers is the largest use of natural gas. The market share of nitrogen solutions (31-0-0) increased from 7 to 27 percent since 1960 while others have decreased.



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Other Industrial Equipment

- Boilers & Steam System
- Desiccant Dehumidification
- Power Generation – Combined Heat & Power

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Industrial Equipment - Boilers

- There are many types of Boilers, and they are classified into Firetube and Watertube designs,
- Firetube: the combustion gases pass inside boiler tubes, and heat is transferred to water on the shell side. Scotch marine boilers are the most common type of industrial firetube boiler,
- Watertube: water passes through the tubes while the exhaust gases remain in the shell side, passing over the tube surfaces
- http://cleanboiler.org/

Industrial Equipment - Desiccant Dehumidification

- Dehumidifiers use specialized absorbing materials, or desiccants, to chemically remove moisture from air.
- The desiccant absorbs moisture from incoming air when the air comes in contact with it, then exhausts the moisture outside of the building.
- Gas-fired dehumidification uses either liquid or solid desiccants to remove water vapor from the air

Industrial Equipment – Distributed Power Generation – Combined Heat & Power (CHP)

- Distributed Generation (DG) is efficient on–site power production that generations electric power and thermal energy for heat, steam or air conditioning.
- When utilizing the heat we call it CHP.
- These systems capture and utilize the waste heat generated during the production of electric power.
- Compared to conventional gird power, CHP systems offer cost savings, low carbon electricity, low emissions, and the reliability of having onsite backup power.
- By capturing and using the waste heat from your on-site CHP, these systems substantially less fuel that what would have been consumed at a central powerplant plus your onsite boiler or furnace heating system, using low carbon natural gas.
- Because greenhouse gas emissions are related to the amount of fuel burned, CO2 production can also cut in half using a distributed CHP systems. See www.understandingchp.com for more information.