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FOREWORD

ARE YOU A WORLD-CLASS ENERGY USER?

World-class energy users have:

1. Benchmarked energy consumption in their ethanol plant.
2. Defined quantifiable, affordable energy reduction goals.
3. Established a multi-year plan to meet their energy reduction goals.
4. Assigned a cross functional team to implement the plan.
5. Reporting, feedback, and renewal processes.
6. Obtained firm commitments from their facility managers for improvements in energy efficiency and demand reduction.

If your ethanol plant lacks any of these essential ingredients, this best practice guidebook will provide a basic framework to set these goals and plans. This systematic approach will help you evaluate the common industrial system best practices and ethanol plant technical best practices noted in the guidebook.

EXECUTIVE SUMMARY

The objective of this Corn-based Ethanol Production Energy Best Practice Guidebook is to provide resources and methods to reduce energy use and energy related costs in existing dry mill ethanol plants. Using this guidebook, ethanol plant managers will learn how to manage energy in their facility and uncover opportunities to significantly reduce facility energy consumption.

Contents include:

- Guidelines and tools for energy management best practices.
- Average energy use for typical corn-based ethanol facilities.
- Description of best practices for process energy use and common system energy use.
- Description of emerging technologies and the potential impact on energy use.
- References for further opportunities in ethanol production energy efficiency and energy demand reduction.

The intent of the guidebook binder format is to provide a document that can be updated continually with new best practices and case studies. Updates will be provided by the Focus on Energy program with direct input from the ethanol production industry leaders. In addition to this guidebook, the Focus on Energy program can provide technical assistance and possible financial incentives to support the implementation of energy efficient measures you may want to pursue. We encourage your staff to call 800.762.7077 or contact your Focus on Energy advisor to find out how we may be able to help you reach your energy cost reduction goals.

INTRODUCTION

Ethanol production has been growing at a fast pace. The industry has grown from 175 million gallons in 1980 to 1.4 billion gallons in 1998 to more than 9 billion in 2008. Each generation of plants has become more resource efficient and larger. The typical plant five years ago was 40 million to 50 million gallons per year (MGY), whereas most plants installed in 2008 were a minimum 50 MGY and the largest is well over 100 MGY. This substantial increase in ethanol production has been matched by an equal increase in distiller's grain co-product. Co-product production has outpaced regional demand for distiller's grain and many plants have installed processes designed to maximize saleable products available in the distiller's grain. The oversupply of these products has required that distiller's grain be processed, stored and transported greater distances. Due to greater transportation distances, a higher sale price is required for the co-product because of the additional costs of shipping.

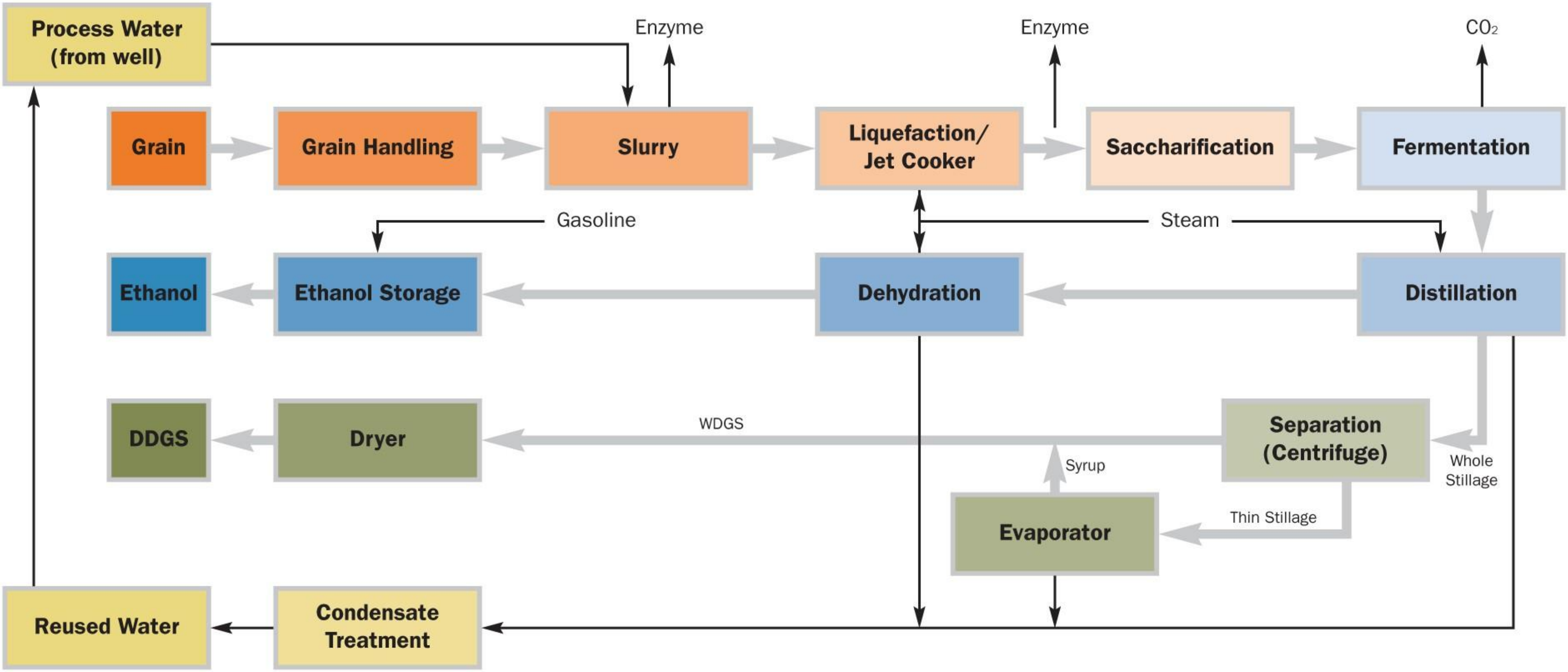
Carbon dioxide (CO_2) is produced at a rate of 18 pounds per bushel of corn produced. This is equal to the amount of CO_2 that was absorbed by the corn plant and stored in the kernel. The standard practice is to release the CO_2 to the atmosphere. This is not considered a release of excess CO_2 because the next planting of corn will absorb an equal amount. Some facilities collect some or all of the CO_2 gas; process and package it for sale. A CO_2 collection system and processing facility is not covered in this guidebook.

The majority of the ethanol plants constructed in the past 10 years have been dry mill facilities, which is the basis for analysis of this guidebook. Many of the practices included in this report are applicable to wet mill facilities, although their effectiveness has not been evaluated from the wet mill perspective. With either wet mill or dry mill facilities, the ethanol industry is facing greater risk and uncertainty due to increased volatility in feedstock, energy, and product prices.

This guidebook focuses on electricity and natural gas use savings opportunities at ethanol production plants. The installation costs are compared to the operating savings at the plant to determine a simple payback period. Also considered are water use, maintenance costs, and impacts on other aspects of facilities. Further discussions about cellulosic ethanol, greenhouse gas emissions, or corn production are not included here, but are additional considerations when making energy efficiency decisions.

Dry mill ethanol plants are evolving and the processes are being revised with each new plant and retrofit. For this report, the process shown in Figure 1 is considered the base plant. The benchmarking section describes the electricity and natural gas use for each of these processes and for the plant as a whole. The base plant is receiving electricity from the local electrical grid and natural gas from an underground regulated distribution system. Solid fuel, such as coal or biomass, is not considered as a base condition.

FIGURE 1: CORN-BASED ETHANOL PROCESS DIAGRAM



DEVELOPMENT OF THE GUIDEBOOK

Funding for this best practice guidebook was provided by Focus on Energy. The following members of the Focus on Energy biofuels team contributed to the development of this guidebook.

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BENCHMARKING

PLANT BENCHMARKING

The first step to determining an energy plan is to benchmark your ethanol plant energy use against those that are considered the best in the business. Since the corn-based ethanol industry is still rapidly evolving, the benchmark provided is based on standard plants (see Figure 1, above) that were designed in 2007 and constructed in 2008 based upon proven technologies. This timeframe was selected because there are many plants experimenting with technologies while operating as production plants, which may or may not be more energy efficient than a standard plant. The benchmark will allow previously constructed plants to compare their energy use to those recently constructed, and serves as an energy Key Performance Indicator (KPI) goal for these plants. The opportunity for improvement through adoption of the best management practices can bring older plants energy use in line with newer designs. The most advanced best practices may also provide the opportunity for older plants to outperform the recently designed plants. Best practices also provide an opportunity for new plants to improve their performance.

The following benchmark information was synthesized from a variety of sources, including actual plant energy-use data, Ethanol Benchmarking and Best Practice (MnTAP 2008), U.S. Ethanol Industry Efficiency Improvements 2004 to 2007 (Christianson @ Assoc. 2008), SEC filing information, and performance guarantees from design firms. It was confirmed by comparison to various modeling programs and standard assumptions made by industry professionals.

The benchmarking of ethanol plants is based on a plant that is producing ethanol and dried distiller's grains with solubles (DDGS), and venting CO_2 to the atmosphere. Table 1, below, shows benchmark energy and water use for the standard new 50 MGY plant. As the plants increase in size, efficiencies of scale often show that these benchmark estimates will decrease with similar designs, indicating greater efficiency.

TABLE 1: BENCHMARK PLANT ENERGY USE

	Standard Energy Use per gallon of 200-proof Ethanol	50 MGY Plant
Electricity:	0.57 kWh/gal.	28,500,000 kWh/yr.
Thermal:	0.28 therm/gal.	1,400,000 MMBtu/yr.
Total Energy (elec. & thermal):	30,000 Btu/gal.	1,500,000 MMBtu/yr.
Make-up Water:	3.00 gallons/gal.	150,000,000 gal./yr.

PROCESS BENCHMARKING

The benchmark information is used to establish the best practices based upon the energy used in the total plant. Through the use of existing modeling and theoretical calculations, the following table is provided to estimate the energy usage of different standard processes within a plant.

TABLE 2: TYPICAL ENERGY CONSUMPTION PER PROCESS[1]

Process	Major Equipment	Elec. kW	Nat. gas Therms	Elec. Btu/gal[2]	Thermal Btu/gal[2]	Total Energy percent	Total Cost percent
Grain Handling	Hammermills, Conveyors, Dust Collectors Fans	443	0	251	0	1%	2%
Starch Conversion	Pumps, Jet Cooker, Agitators	167	3,180,622	95	6,361	21%	19%
Fermentation	Agitators, Pumps	292	0	165	0	1%	1%
Distillation	Reboilers, Columns	25	3,395,074	14	6,790	23%	20%
Dehydration	Mole Sieve, Pumps	16	107,900	9	216	1%	1%
Separation[3]	Centrifuge, Evaporators	1,168	320,949	662	642	4%	8%
Drying	Rotary Drum Dryers(1400Btu/lb)	1,176	6,950,000	666	13,900	48%	46%
Utilities[4]	Thermal Oxidizer, Cooling tower, Air compressor, Boiler	570	0	323	0	1%	3%
Totals		3,857	13,954,544	2,186	27,909		

Notes:

1) Assumed plant production is 50 MGY. Assumed annual run time is 8,300 hours.
2) This is a measurement of energy per gallon of 200-proof ethanol.
3) The majority evaporator steam use is allocated to the distillation process because steam is recovered from the rectifier at a rate of 70% of input steam.
4) This process assumes a Thermal Oxidizer/Heat Recovery Steam Generator (TO/HRSG) combination. Natural gas use from the TO is not shown because HRSG uses waste heat reclaimed from the TO exhaust. Electrical energy for utilities is allocated over the total process.

FEEDSTOCK BENCHMARKING

Feedstock benchmarking, or yield, is the amount of products produced per bushel of corn. Generally, the following statements can be made about ethanol production from a corn kernel feedstock;

- Ethanol yield can rise or fall slightly with little variation in energy use.
- Distiller's grain co-product yield is a trade off with the amount of the material converted to soluble products and ethanol.
- The water in the corn is a function of the moisture content when utilized.

The largest factor to the energy and water usage benchmark numbers is the efficiency with which the plant utilizes the feedstock, or product yield. Below are the yields utilized for the base plant in this guidebook. Contact your Focus on Energy representative if your plant's yields vary and would like an estimate of savings potential based upon your product diversity at your plant.

TABLE 3: BENCHMARK YIELD

Feedstock Yield per bushel of dry corn		50 MGY Plant
200-proof Ethanol:	2.77 gal./bu.	50,000,000 gal./yr.
WDGS (35% solids):	43 lbs./bu.	380,500 tons/yr.
DDGS (90% solids):	17.0 lbs./bu.	150,000 tons/yr.
Bushels of dry corn:		17.7 Million bu./yr.
Water (15.5% m.c.):	1.04 gal./bu.	18,400,000 gal./yr.

The ethanol yield per bushel is the most critical Key Performance Indicator (KPI) for a plant. The cost of the corn feedstock is the majority expenditure for an ethanol plant and the sale of ethanol is the primary saleable product. A plant that can increase the ethanol yield per bushel will create more income at nearly the same input expense. The table below shows the annual increase in yield and associated increase in gallons and sales receipts of ethanol.

TABLE 4: EFFECT OF ETHANOL YIELD INCREASE

Annual increase in yield (gal./bu.)	0.01 (2.68)	0.05 (2.72)	0.1 (2.77)
Annual increase in ethanol (gal.)	187,266	936,330	1,872,659
Annual increase in receipts ($)	$374,532	$1,872,659	$3,745,318
Assumed base = 2.67 gal./bu. producing 50 MGY and $2/gal. 200-proof ethanol			

The profitability of the plant is also closely tied to the handling of the distiller's grain co-product. There are many ways to handle the distiller's grain, and each can be profitable provided they are done efficiently. Distiller's grain can be marketed and sold as:

- Wet distiller's grain (WDG) – At the solids outlet of the decanter.
- Wet distiller's grain with solubles (WDGS) – At the outlet of the decanter with the condensed distiller's solubles.
- Dried distiller's grain (DDG) – dried WDG.
- Dried distiller's grain with solubles (DDGS) – dried WDGS.
- Modified distiller's grain (MDG) – partially dried WDG.
- Modified distiller's grain with solubles (MDGS) – partially dried WDGS.
- Syrup – The condensed distiller's solubles that originated from the decanter. This can only be sold in conjunction with WDG, MDG and DDG.

The process of drying the distiller's grain is an energy-intensive process generally completed by thermal convection heating. Although as the product becomes more dried, it is less likely to spoil and gains value resulting in similar income generation. For example, the typical energy to create 75% WDGS and 25% DDGS is 9,650 Btu/gal. of ethanol less than plants create 100% DDGS. The ultimate energy savings is contingent on the heat flow of an individual plant.

The syrup is created from the decanter condensate stream (solubles) after it is passed through an evaporator. The syrup contains nutrients that are valuable to most consumers of distiller's grain, and therefore is regularly included in the product. It can also be sold individually with additional handling and storage systems.

CALCULATION ASSUMPTIONS

The assumptions below are used for the calculations in this guidebook. They are based upon typical prices in fall 2008. Contact your Focus on Energy representative if you would like the calculations completed based upon a different set of assumptions.

TABLE 5: CALCULATION ASSUMPTIONS

Yearly Hours of Operation	8,300 hours
Annual Plant Production	50 MGY 200-proof ethanol
Annual Yield	2.70 gal./bu.
Annual Feedstock	18.5 million bu.
Electricity Cost	$ 0.06/kWh
Electricity Peak Cost	$ 200/kW (per year)
Natural Gas	$ 0.60/therm
Water - Well or Municipal	$ 2.00/1,000 gallon
Water - Wastewater	$ 3.00/1,000 gallon
Corn	$ 4.50/bu.
Ethanol	$ 2.00/gallon
DDGS	$ 105.00/ton
WDG	$ 33.60/ton

MANAGEMENT BEST PRACTICES

Any organization can more effectively manage its energy use and costs by adopting a continual improvement approach to energy management or by developing an energy management program. An energy management program provides a systematic approach to assessing and reducing the energy uses and costs of your organization. An energy management program is a proactive approach instead of just “putting out fires” when energy costs increase.

An energy management program is not an energy improvement project (a one-time event) but an ongoing process. It can be a standalone effort devoted exclusively to energy management or part of an existing management program such as quality assurance or environmental management. The most successful energy management programs are developed and maintained by a cross-functional team of individuals from various functions such as maintenance, engineering, production, financing and management.

At first glance, creating and implementing an energy management program may seem to be an overwhelming task that pulls your attention away from the demands of daily operations. Yet taking that time up front can save you time, money, and energy in both the short and long term. Once in place, your energy management program will deliver benefits year after year. Many plants have realized collateral benefits of energy management programs including: increased plant production capability, improved safety, and increased yields.

Increasingly, energy efficiency is viewed as a good investment. Many energy efficiency projects provide a high return on investment (as much as 100% or more) and are relatively low risk. When compared to other investment opportunities, these projects can be very attractive. Typically, you can achieve 10% to 15% energy cost savings in three years by implementing a systematic energy management program. The following are the first steps to getting started with a systematic energy management approach and Focus on Energy can assist you with completing any of these steps. Focus on Energy has developed a set of tools called Practical Energy Management© that can make these steps even easier.

STEPS TO GETTING STARTED

Step 1: Establishing the Baseline Energy Use: Compile your monthly utility bills to develop an overall energy profile of your facility. Put energy in the context of overall organizational operations by comparing it to more widely tracked measures such as profit, sales or labor (see example in Figure 2). Then graph energy use per month verses production during the same periods. This will set your present baseline for your energy key performance indicator (KPI) (see examples in
Figure 3 and

Figure 4). Tracking this energy KPI over time provides an indication of the effectiveness of your energy efficiency efforts. Projecting the KPI forward provides a method to set targets and goals for energy use. A typical goal is to meet the indicators noted in Table 1 of the benchmarking section of this guidebook.

Related to the energy KPI is the measurement of ethanol yield per bushel of feedstock. This table and graph will provide an indication of the effectiveness of the energy consumed in transforming the starch into fuel.

Step 2: Estimate Energy Use for Major Systems: Determine the energy used by major equipment and energy-using systems. Most control system of ethanol plants has a historical energy use logger which can help determine consumption of systems that are major energy users. The interconnected heat flow characteristics of the individual plant will require that each system graph the energy consumed and energy recovered to get a net consumption. This can point the way to your largest energy users and the best places to focus your attention. Table 2: Typical Energy Consumption per Process provides an estimate of energy consumption that can identify individual processes to be tracked. Further, the development of a thorough process flow diagram outside the control system to include flow rates and associates temperatures for all key processes will help reset the operations after many small adjustments.

Step 3: Identify Best Practice Opportunities: Best practices are techniques or technologies generally recognized as being economical and more energy efficient than common or typical practices. Review best practices in comparison to your equipment and system profiles to identify opportunities for energy efficiency improvement. The next chapter highlights many best practices for the ethanol industry which should be undertaken along with standard industrial best practices.

Step 4: Quantify Savings and Project Costs of Best Practice Opportunities: Once the best practice opportunities are determined, the next step is to estimate the cost savings for the key projects including energy and maintenance, and the installed cost of the project. Focus on Energy can provide technical assistance to quantifying energy savings for projects as needed.

Step 5: Prioritize Projects: Apply criteria such as ROI (return on investment), capital cost or ease of installation to help you prioritize among all the possible energy savings projects you've identified. Select the highest scoring projects for implementation to achieve your energy savings goals within time and budget constraints. Operational risk should also be considered during the process of prioritizing projects. Those projects that have the greatest ROI with the least operational risk should receive the highest priority for implementation. One way to prioritize projects is to categorize them as follows:

Category 1 – Operation changes with no capital investment

Category 2 – Capital projects with under $5,000 worth of equipment cost

- You can expense capital items between $3,000 and $5,000 in the year they are purchased.
- Labor for these projects can generally be moved into an expensed maintenance budget.
- You can sequence projects to do one at a time to keep them from becoming capital projects. Variable frequency drive projects are an example that can often be handled in this approach.

Category 3 – Capital projects from $5K to $100K

- These projects generally can be locally approved, making them more likely to go forward.

Category 4 – Capital projects over $100K

Step 6: Project Management: Manage each identified energy project as you would any other project within your organization by clearly defining the project parameters, assigning responsibilities for the project implementation, and undertaking specific tasks needed to implement the project.

STEPS FOR ONGOING ENERGY MANAGEMENT

Step 1: Strong commitment from management: Critical to the success of long-term energy management is strong commitment from the management, as well as engagement from all plant personnel. Without this, the time spent on other steps may not significantly enhance energy efficiency.

Step 2: Track the Energy KPI: An energy KPI measures your energy use per a critical factor such as units of production. Tracking a KPI over time provides an indication of the effectiveness of your energy efficiency efforts. Projecting a KPI forward provides a method to set targets and goals for energy use.

Step 3: Form an Energy Team: A cross-company energy team should include personnel from maintenance, engineering, production, management and financing. This team should meet periodically as needed to review progress on the energy management plan and set new direction.

Step 4: Develop a long-term energy management plan: The first task for the energy team will be to develop a long term energy management plan. This plan should define the goals, tasks and responsibilities for implementing and operating an energy management program within your organization.

Step 5: Establish a system for continual improvement: Maintaining an effective energy management program requires management commitment, ongoing project planning and implementation, and communication of program and project results. To the extent possible, integrate the administration of the energy management program with existing management programs such as quality control, safety or environmental management.

Figures 2 to 5 on the following pages are examples of tools included in the Practical Energy Management approach that can be obtained from Focus on Energy by eligible Wisconsin Industries for free.

FIGURE 2: TRACKING NATURAL GAS USE

Natural Ethanol

Natural Gas Cost:
$0.60/therm

Month	Therms/Gal.	Consumption (therms)	Production Unit Gallons Ethanol	Total Natural Gas Cost
Jan	0.287	1,191,817	4,152,673	$715,090
Feb	0.285	1,188,046	4,168,582	$712,828
Mar	0.283	1,217,374	4,301,674	$730,424
Apr	0.280	1,205,066	4,303,806	$723,039
May	0.284	1,221,439	4,300,840	$732,863
Jun	0.279	1,148,987	4,118,233	$689,392
Jul	0.279	1,191,001	4,268,821	$714,601
Aug	0.277	1,187,409	4,286,676	$712,446
Sep	0.280	1,181,989	4,221,388	$709,193
Oct	0.281	1,209,038	4,302,628	$725,423
Nov	0.280	1,197,629	4,277,246	$718,577
Dec	0.290	956,256	3,297,433	$573,753
AVG	**0.282**			
5% Goal	**0.268**			**-$422,881**
TOTAL		**14,096,050**	**50,000,000**	**$8,457,630**

FIGURE 3: FACILITY ENERGY PROFILE – SUMMARY

(Does not include electricity, water or other utilities that should also be tracked)

Natural Ethanol Energy Profile - Summary

Natural Gas	2008 (Annualized)	2007 (Actual)	2006 (Actual)	% Change 2007 to 2008
Consumption (Therms)	13,685,344	14,096,050	14,168,953	-2.91%
Total Natural Gas Cost ($)	$11,230,601	$11,038,194	$10,597,382	1.74%
$ per MMBtu of Natural Gas	$0.82063	$0.78307	$0.74793	4.80%
Key Performance Indicators	2008 (Annualized)	2007 (Actual)	2006 (Actual)	% Change 2007 to 2008
Gallons Product	51,038,247	50,000,000	49,975,252	2.08%
Gas $ per Gallon Product	$0.220	$0.221	$0.212	-0.45%
Gas Therms per Gallon Product	0.268	0.281	0.284	4.63%

FIGURE 4: NATURAL GAS KPI GOAL AND TRACKING

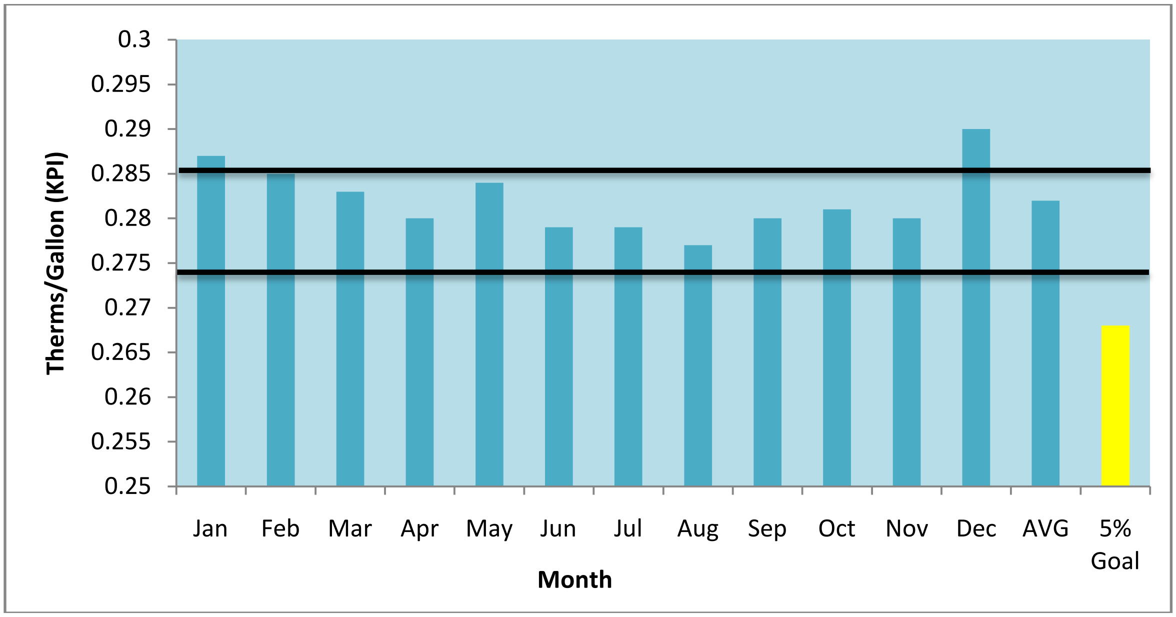
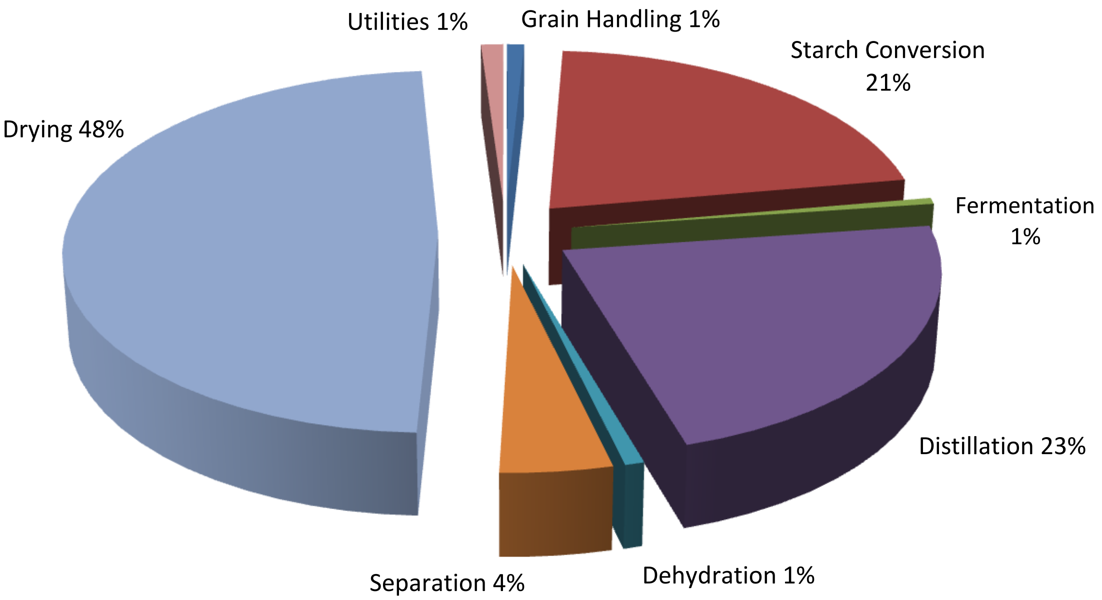


FIGURE 5: ENERGY USES IN A TYPICAL ETHANOL PLANT



The above graph is based upon the Btu per gallon of both electricity and natural gas. Electric consumption is converted to Btu by the simple formula:
1 kWh = 3412 Btu. See Table 2 in the benchmarking section for breakdown between electricity and natural gas and cost percentages.

TECHNICAL BEST PRACTICES

This section of the guidebook presents technical best practices. The information presented in the previous section addressed understanding your plant energy use, management best practices and benchmarking current practices. These are the first steps to improve plant energy performance. To facilitate improving the efficiency of ethanol plant operations, Focus on Energy has cultivated proven technical best practices that reduce both thermal and electrical energy consumption associated with a wide arrange of ethanol operations. The ethanol production industry best practices included in this document were compiled by the development team from literature reviews, personal experience and interviews with both ethanol production facilities and vendor personnel. In most cases, resources for additional information are provided. Review the best practices to see if there may be similar opportunities within your plant. Contact Focus on Energy if you need assistance or further information on reducing your plant's energy usage.

Table 6 is a list of all the best practices included in this guidebook. A **checklist** for these best practices that could be used to ensure proper consideration can be found in **Appendix A**. The best practices in this section primarily relate to process energy use typically unique to a corn-based ethanol dry mill facility for ethanol production. Additional best practices for common support systems that are found in most industrial facilities, such as lighting and compressed air systems, are located in **Appendix B**. These should also be reviewed for energy cost-reduction opportunities for these common systems.

TABLE 6: ETHANOL PRODUCTION ENERGY BEST PRACTICES

Area	#	Title
Process Heat	1	Combined Heat and Power
Process Heat	2	Optimize Heat Exchangers
Process Heat	3	Thermal Oxidizer Heat Recovery
Process Heat	4	Increase Boiler Combustion Air Temperature
Starch Conversion	1	Raw Starch Hydrolysis
Fermentation	1	Yeast Propagation
Fermentation	2	Direct Yeast Injection
Fermentation	3	Improve Yeast Performance
Evaporator	1	Replace Vacuum Eductor with Liquid Ring Vacuum Pump

Co-Product	1	Pre-Process Fractionation
Co-Product	2	Wet Distiller's Grain Co-Product
Co-Product	3	Maximize Mechanical Drying of Wet Cake
Co-Product	4	Indirect Dryer
Process Controls	1	Predictive Modeling Control
Process Controls	2	Temperature Gauge Calibration
Emerging Technology	1	Membrane Ethanol/Water Separation
Emerging Technology	2	Anaerobic Digestion of Thin Stillage
Emerging Technology	3	Electric Drying of Distiller's Grain
Emerging Technology	4	Gasification of Co-Product
Emerging Technology	5	Waste Heat or Pressure Differential Electrical Generation

DEFINITIONS

See the benchmarking section and Table 2 for base plant and energy unit costs.

Productivity Impact	Details expected increased or decreased ethanol or co-product yields or production potential.
Economic Benefit	Approximates the economic impact of the best practice.
Energy Savings	Approximates the electricity and natural gas demand reduction from the best practice. This section approximates the expected heat flow within the plant. Each facility has a unique heat flow that must be evaluated to confirm calculations.
Water Savings	Approximates the water savings of the best practice.
Other Resource Savings	Notes any other potential resource impacts of the best practice.
Stage of Acceptance	Provides background to the overall acceptance of the best practice in the ethanol industry and beyond.
Resources	Plant personnel can contact listed resources themselves or work with a Focus on Energy representative.
Synergies	This lists the other processes which may be affected by the best practice. This section does not include plant heat flow impacts.

Process Heat 1 – Combined Heat and Power

Best Practice	Combined heat and power (CHP) uses the steam generation equipment to create electricity in the process of creating the steam to meet plant needs.
Process	CHP is integral to the process steam generation.
Productivity Impact	There is no productivity impact. Increased O&M costs associates with the added generators are $100,000 (est.).
Economic Benefit	Both the standard boiler and CHP system provide the same amount of thermal energy for use by the plant, but CHP systems also generate electricity from additional fuel input. An additional investment of $3.5 million for a generator, higher pressure boiler with superheater, and additional mechanical work will result in reduced electricity purchases of approximately $0.7 million, reduced demand charge of $0.25 million, and reduced natural gas purchases of $0.3 million. The turbine and higher pressure boiler will increase maintenance by an estimated $100,000. The estimated payback on the incremental cost for a new installation will likely range from 3 to 5 years.
Energy Savings	A typical plant will be able to provide 35% to 40% of it's electricity by increasing natural gas fuel use by about 10%.
Water Savings	There is no expected water savings.
Other Resource Savings	A CHP provides increased plant power reliability by utilizing the grid as backup and storage for electricity. The CHP will also reduce the carbon dioxide emissions associated with the plant power usage.
Stage of Acceptance	CHP processes are common throughout the world and are becoming more common in ethanol plant installations.
Applications and Limitations	Boiler will be required to operate at 650 lbs./hr. to produce 150 lbs./hr. steam for plant use after a standard steam turbine. CHP operation will not be able to match both thermal and electrical demands of the ethanol plant.
Practical Notes	Coordinate with electrical grid operator. Personnel will need to be trained on operation of power generation equipment.
Resources	EPA CHP Partnership - http://www.epa.gov/CHP/markets/ethanol.html, U.S. Dept. of Energy Regional CHP Application Centers and ITP program for industrial distributed energy.

Synergies	The CHP can be run off boilers powered by any available fuel (fossil or biomass) or the process may be run from gasification of the bran if fractionation is practiced.

Process Heat 2 – Optimize Heat Exchangers

Best Practice	Match heat exchanger size and type to the process application and ensure proper maintenance.
Process	In plants that use interchangers to cool mash while preheating beer prior to a beer column heater, it is important to optimize the exchangers without causing excessive fouling to decrease cooling and steam loads. However, other exchangers are also possible candidates.
Productivity Impact	A more effective heat exchanger system has the potential to reduce bottlenecks.
Economic Benefit	A 1°F decrease in beer temperature out of the mash/beer exchanger will increase steam cost by about $23,000 for a 50 MGY plant. The cooling tower load decrease is approximately $800 a year per ^{O}F that must be cooled in the mash. A management system that will determine the proper cleaning interval can have a payback of less than one year. Additional heat exchangers provide annual savings which can be compared against the cost of the equipment and additional O&M, for example if a new exchanger decreases mash and increases beer temperature by an additional 5^{O}F, the annual expected energy savings is $120,000.
Energy Savings	Regularly cleaning and maintaining the existing heat exchanger will keep it operating as intended, which results in about 4,000 MMBtu per year decrease in boiler demand and 16,000 kWh decrease in cooling tower demand per degree F transferred from the mash to the beer.
Water Savings	Decreasing the cooling tower load will decrease the water used by approximately 0.40 MGY per mash reduced degree.
Other Resource Savings	The increase O&M from additional heat exchangers will be approximately offset by the O&M avoided in the steam or chilled water systems.
Stage of Acceptance	Both frame and plate and shell and tube heat exchanger properties and performance are well documented and accepted. However, fluid properties play a significant role in heat exchanger performance, including how often CIP must be applied.
Applications and Limitations	Proper maintenance of heat exchangers is critical to efficient operation; See Appendix B. Ensure the process fluids are not corrosive to the heat exchanger materials.

Practical Notes	When updating heat exchangers, ensure that revising inlet/outlet temperature is not shifting the steam or chilling load from one point to another location in the facility.
Resources	Commercial resources, Focus on Energy representatives.
Synergies	None.

Process Heat 3 – Thermal Oxidizer Heat Recovery

Best Practice	Recover heat from the thermal oxidizer (TO) or regenerative TO (RTO) exhaust for preheating.
Process	The exhaust from the TO or RTO is hot and contains a significant amount of water vapor from dryers, making it suitable for recovery with a condensing economizer (CHR). The high dew point typical of RTO exhaust allows recovery heat from condensation of water vapor (latent heat) at higher temperatures than is possible with boiler applications.
Productivity Impact	There is no productivity impact.
Economic Benefit	Installed cost will range from $1.5 million to $2.5 million for a 50 MGY plant, which includes a “runaround” loop to circulate the heated fluid. The payback ranges from 2 to 5 years depending on the heat sink properties. When a feed heater is present, heating of beer after the interchangers is one application.
Energy Savings	When used for beer column feed preheating, utilizing the excess heat can displace approximately 950,000 therms of natural gas per year in the boiler if the beer feed can be raised by 30$^{\text{O}}$F. This is partially offset by operation of an additional pumping system loop for exchanger fluid and a fan on the CHR.
Water Savings	The condensate formed may be suitable for reclamation and reuse in the plant with pre-treatment.
Other Resource Savings	Depending on loads, it may be possible to recover additional heat from the same CHR system to preheat dryer inlet air and/or boiler combustion air, with a minimal additional investment.
Stage of Acceptance	All equipment is standard.
Applications and Limitations	This measure could be considered a modification of a pollution control system. Check with authorities’ prior to installation to determine if the air or water permit is affected.
Practical Notes	In order to decrease the maintenance on the CHR and improve reliability, it is recommended that a “runaround” loop be used to transfer heat between the CHR unit and the fluid to be heated. This will incur additional cost (included in estimated cost above) but will improve reliability.
Resources	Focus on Energy representatives.
Synergies	More efficient heat recovery.

Process Heat 4 – Increase Boiler Combustion Air Temperature

Best Practice	When possible, draw combustion air from the ceiling to the floor or directly from the ceiling. Use the ambient conditions to remove heat or add heat to process streams without the aid of a chiller or boiler.
Process	Some facilities have louvers near the floor that allow cool ambient air to be drawn directly into the combustion air fan. Use of deflectors to send the air to the ceiling first will help remove waste heat from the boiler room and increase the combustion air temperature.
Productivity Impact	No productivity increases.
Economic Benefit	Increasing the combustion air temperature adds energy to the inlet side of the boiler. For a boiler with a steam output of 85,000 pounds per hour (pph), increasing the combustion air temperature by 10^{O}F rise on average will save about $11,500 annually.
Energy Savings	An increase in ambient temperature from 70^{O}F to 80^{O}F will reduce the boiler gas consumption 0.2% or 1,900 MMBtu for a 50 MGY plant.
Water Savings	There are no appreciable water savings.
Other Resource Savings	None.
Stage of Acceptance	This is a well established best practice.
Applications and Limitations	Implementation of this improvement will often not require any additional capital improvements, but rather changes to operational procedures or minor modifications to wall vents. Also, in some cases, a duct will be necessary to allow the warm combustion air to be efficiently drawn from the ceiling area. The impact of the duct on combustion air fan performance (pressure drop) must be considered in these cases.
Practical Notes	None, provided that temperature increases are not too high.
Resources	Focus on Energy representatives, U.S. Department of Energy tip sheets.

Synergies	None.

Starch Conversion 1 – Raw Starch Hydrolysis

Best Practice	Utilize only enzymes to convert uncooked starch to glucose.
Process	The alpha-amylase and glucoamylase enzymes for liquefaction and saccharification are developed to work at similar process conditions, therefore eliminating the need to adjust the mash between the two processes.
Productivity Impact	There is no direct correlation to ethanol productivity increase. Although the process generally increases the quality of the co-product, DDGS.
Economic Benefit	Eliminates the need for chemicals and energy to alter the temperature, pH, and concentration between the two stages, which is partially offset by the higher enzyme cost. Newer generations of these enzymes can be injected into the piping to the fermentation tanks and have shown an increase in protein in the DDGS co-product. Energy cost savings will be approximately $20,000.
Energy Savings	Replacing the jet cooker eliminates the need to raise the slurry to 230^{O}F though steam injection. The majority of this heat is flashed for steam to the distillation process and further recovered to preheat the jet cooker. Assuming a 20-foot high, 20-foot diameter jet cooker insulated holding tanks and 1,000 feet of insulated piping, 250 MMBtu/year heat loss is eliminated. Eliminating the jet cooker will reduce head loss on the slurry pumping system by 5 psi. Eliminating two plate heat exchangers will eliminate the need for approximately a 60 HP motor and pump. Dependant on pump curves, this will eliminate approximately 300,000 kWh/yr.
Water Savings	The removal of the jet cooker eliminates losses in the steam system and decrease the amount of makeup water to the boiler. The water injected at the jet cooker is recovered at the centrifuge, although the loss of condensate will require more frequent boiler blowdown, which increases the water use.
Other Resource Savings	Operations and maintenance costs are reduced by minimizing the number of testing and injection points for chemicals.
Stage of Acceptance	This process is operating in many plants facilities, but they are under the same management company. No facilities have retrofitted this technology into an existing plant.

Applications and Limitations	There are few suppliers of the necessary raw material enzymes necessary.
Practical Notes	Utilizing raw starch hydrolysis requires a different management process of the slurry to ensure proper fermentation.
Resources	Genencor International - Stargen; Poet - BPX; Novozymes; Verenium
Synergies	A continuous dosing of raw starch hydrolysis enzymes can also include yeast and other nutrients which eliminate slurry holding tanks and yeast propagation tanks, improve mixing, and reduce the potential time for process contamination.

Fermentation 1 – Yeast Propagation

Best Practice	Utilize the lowest-cost means of providing minimum dissolved oxygen content and agitation in yeast propagation tank.
Process	Evaluate and optimize the yeast propagation air supply delivery to the yeast propagation tanks.
Productivity Impact	There is no productivity impact provided that current conditions allow the yeast to reach a sufficient level of growth and activity prior to entering the fermentation tanks.
Economic Benefit	Compressed air provides four to six times the necessary pressure to provide air to the yeast propagation tanks. Blowers and venturi jets are much more suited to provide air at the right pressure, thereby decreasing the amount of horsepower needed per volume provided. The expected payback is four years dependent upon necessary piping replacement.
Energy Savings	The capacity of the yeast slurry to retain the dissolved oxygen in the propagation mix is a function of the amount of air added, bubble size, and consistency of the mix. Thick propagation slurries (80:20 mash-to-water ratio and higher) often require the addition of compressed air to make up for the lowered capacity for retaining dissolved oxygen. Slurry mixes can be reduced to equal parts mash and water. For 3,200 cubic feet of 80:20 yeast slurry aerated at 1 cfm/cf for 1,328 hours a year through air compression. The effective usage in the air compressor utility is 900,000 kWh ($54,000). Diluting the slurry mix with 20% more water, a comparative blower system can be installed for approximately $100,000 and use 450,000 kWh ($27,000) A venturi jet induction system with oxygen monitoring has the opportunity to reduce the electricity cost up to 40% more due to increased oxygen transfer ($16,000) although the tank will have to be re-piped.
Water Savings	No additional water is needed in the process. By increasing the water proportion of the yeast slurry mix, 0.5 MGY of additional water is added to the yeast propagation tank. This water should be offset by an equal reduction in the corn slurry entering the fermentation tanks to keep the optimum fermentation slurry consistency.

Other Resource Savings	The venturi injection system is relatively maintenance free because it has large nozzles. A coarse air bubbler diffuser has a tendency to become clogged, which increases the load on the blower and oxygen flow through the piping.
Stage of Acceptance	Adequate aeration is commonly achieved by air inductors installed on the piping going into the propagation tank that pull air into the propagation mix as the tank fills and during recirculation.
Applications and Limitations	The cost of installation will vary depending on the existing set-up of the aeration system and potential reuse of the existing piping.
Practical Notes	Yeast propagation is designed to rehydrate, condition and increase yeast populations using their natural reproduction capabilities as living organisms. Aeration is required to increase the dissolved oxygen levels to a point where exponential growth of yeast cells occurs. One sign of inadequate aeration is increased ethanol production in the propagation tank. Limiting the amount of ethanol produced in propagation is a good sign that the yeast is respiring aerobically.
Resources	Commercial resources.
Synergies	Air compressor load reduction, yeast optimization.

Fermentation 2 – Direct Yeast Injection

Best Practice

Direct injection of cream or liquid yeast into fermentation tanks.

Process

Direct Injection of yeast into fermentation tanks from a sterile environment replaces the yeast propagation or dry yeast hydration. By direct yeast injection, the plant can inject the exact yeast strain for maximized alcohol production into the fermentation tank.

Productivity Impact

Limited studies have shown a 3% to 5% increase in plant throughput. There is also a slight increase (<0.5%) in ethanol yield per bushel through better optimization of fermentation through flexibility in handling and dosing and eliminating the need for feedstock to propagate yeast.

Economic Benefit

Assume your dry yeast costs $X and the operating costs for propagation and chemical additions is $1.5X. Cream yeast is approximately $4.5X with minimal operations and maintenance costs. Therefore, it is about two times more expensive to buy and inject cream yeast than it is to propagate from dry yeast. This cost is offset by an increase in yield. Capital costs for a cream yeast system varies based on operations and system design. Basic assumptions about the system should include a dosing system and temporary storage tanks.

Plant Size (MGY)	Approximate Costs ($)		
	Dry yeast material[+]	Cream yeast system add. cost[+]	Yield increase of 0.1%
50	($150,000)	($300,000)	$645,000*
100	($300,000)	($600,000)	$1,290,000*

[+] Does not include operations or infrastructure costs

** Lalleland Ethanol Technology based on $2 per gallon ethanol*

Energy Savings

The propagation tank(s) are replaced by a dosing system, eliminating the 250,000 to 900,000 kWh/year of the aeration system and 60 MMBtu/year heat loss from an insulated propagation tank. Some cream yeasts may require cooling on hot days, approximate at 15,000 kWh/year from the existing chiller.

Water Savings

There are no direct water savings.

Other Resource Savings

O&M costs are reduced by eliminating the yeast propagation tanks and the associated cleaning and anti-microbial growth regimens. Furthermore, the lag phase associated with dry yeast is eliminated thereby decreasing the time when microbial growth can occur.

Stage of Acceptance	Cream or liquid yeast is used for approximately 85% of the yeast in the U.S. baking industry.
Applications and Limitations	Cream or liquid yeast can only be stored a short time (two to four weeks) under standard conditions. It can be stored up to three months when refrigerated. Dry yeast can be stored up to 24 months.
	Productivity increases are not guaranteed. It is recommended that plants run trials of cream yeast prior to investment.
Practical Notes	A 50 MGY plant will require one tanker truckload every 10 to 14 days.
Resources	Lallemand Ethanol Technologies & Fermentis market cream yeast directly to ethanol plants, although many other suppliers of dry yeast currently supply cream yeast to the baking industry. A test system can be completed with a tanker truck manual dosing system.
Synergies	Enhanced control software automation, decreased air compressor load.

Fermentation 3 – Improve Yeast Performance

Best Practice	Use yeast that has high thermal, alcohol, and osmotic tolerance to decrease fermentation time, increase feed concentration, and increase alcohol concentration.
Process	Purchase yeast that has the highest thermal and alcohol tolerance and operate the fermentation near to the maximum tolerated levels.
Productivity Impact	Purchase yeast that can live under higher temperatures and higher alcohol contents to allow operators to decrease fermentation times and increase ethanol yield per bushel.
Economic Benefit	According to kinetics theory, additional heat will reduce fermentation time by approximately 25% when the temperature is raised from 95 ^{O}F to 140 ^{O}F. Increasing alcohol tolerance in yeast means it is less likely to pass sugars through the fermentation basin without converting them to alcohol.
Energy Savings	Increasing fermentation temperature will reduce the need to cool the mash and heat the beer (see Optimize Heat Exchangers). A slight amount of additional heat loss through the fermentation tank walls will increase heating load by 1.25 therms per fermentation batch, but will produce more alcohol per batch.
Water Savings	Increased limits on alcohol concentration mean that less water is needed to dilute the mash and beer, reducing water volume to be added to the slurry.
Other Resource Savings	None.
Stage of Acceptance	Yeast strains are improving continually and newer versions are brought into the marketplace relatively easily.
Applications and Limitations	Monitoring the propagation and fermentation tanks is necessary to operate near the yeast limits and determine if yeast is not performing to expected results. Contact yeast supplier or fermentation specialist if yeast is not performing to specifications.
Practical Notes	
Resources	Commercial yeast suppliers.
Synergies	Optimize heat exchangers.

Evaporator 1 – Replace Vacuum Eductor with Liquid Ring Vacuum Pump

Best Practice	Use a liquid ring vacuum pump (LRVP) in place of liquid eductors in the vacuum system to create the vacuum necessary for the thin stillage evaporators.
Process	The evaporator normally requires a vacuum pressure that is more efficiently provided by a LRVP. The vacuum system must be redesigned to ensure the vapor condenser matches the revised LRVP. Prior to deciding to replace pumps, the plant operator should compare system curves for specific plant characteristics.
Productivity Impact	There is no productivity impact.
Economic Benefit	The payback is expected to be approximately 2 years or less.
Energy Savings	The pump motor power necessary can be reduced by as much as a factor of 4. Both the LRVP and eductor pump can operate on a variable frequency drive although control must be carefully considered to avoid erratic evaporator operation.
Water Savings	There is minimal expected water savings.
Other Resource Savings	None.
Stage of Acceptance	LRVP are common for processes requiring medium vacuum pressure and are often used on evaporators in other industries.
Applications and Limitations	The LRVP must be properly matched to the condenser. Sizing is more involved that simply "changing a pump."
Practical Notes	A properly operating vacuum system will dictate evaporator performance.
Resources	Focus on Energy representatives.
Synergies	

Co-Product 1 – Pre-Process Fractionation

Best Practice	This practice breaks the corn kernel into germ, pericarp, and endosperm prior to processing.
	Germ can produce oil, high-protein lower-fat feed, heat, or cellulosic ethanol.
	Pericarp (starch) can produce ethanol, feed, or food.
	Endosperm (bran) can produce fiber or can produce power through gasification.
Process	The pre-processing replaces the hammer mill at the front end of the ethanol process with a dry fractionation grinder, separation equipment, and two additional silos.
Productivity Impact	The fractionation process is not 100% efficient separating the starch from the germ and bran (unfermentable material). Therefore when the unfermentable material is removed from the ethanol production process, less starch per bushel is available for fermentation. This results in a reduction of ethanol produced per bushel of approximately 5%. Including this reduction, the capacity of the existing ethanol production process is increased by 10% to 15% because of the increased starch content of the slurry by processing more bushels of corn and removing the unfermentable materials. The whole stillage volume is decreased by 40% to 50% and both bran and germ are produced separately.
Economic Benefit	The potential payback ranges from 1 to 10 years based upon assumptions of average prices for ethanol and 4 additional co-products (see attached pricing assumptions calculations). The capital costs of retrofitting may cost as much as the plant construction but are typically between $25 and $30 Million.
Energy Savings	Energy is saved throughout the ethanol production process by eliminating the heating, cooling, drying, and pumping of unfermentable material at a rate equal to the percentage increase in ethanol; represented by increase in the bushels processed by a similar amount of energy consumed. This does not include any energy process loads for co-products from the fractionation. The thermal load is decreased 2,775 Btu/gallon and the electrical load is decreased by 0.07 kWh/gallon, which equates to an approximate reduction of 420 kW demand for a 50 MGY plant.
Water Savings	The reduction in pass-through material will reduce the water usage per gallon of ethanol by a similar percentage as the energy per unit: approximately 0.3 gallons water/gallon

	ethanol or 15 MGY water for a 50 MGY plant.
Other Resource Savings	The fractionated material that is not passed through the ethanol processing plant is dry and stable, as opposed to being part of the distiller's grain.
Stage of Acceptance	Fractionation is a common procedure in many other grain processing facilities, but is generally a wet process. Newly constructed ethanol plants are including dry fractionation and several retrofits are underway.
Applications and Limitations	The de-braned/de-germed distiller's grain has a different physical and chemical makeup than standard distiller's grains.
Practical Notes	There is a steep learning curve when changing to fermenting with fractionated material; it is different than fermenting whole corn.
Resources	Potential Suppliers: ICM, CPT, Poet, Delta T, FWS Technologies, Renessen Process, Maize Processer Innovators
Synergies	Thin stillage digestion, gasification of the bran, decreased enzyme usage, co-product improvement and opportunity to expand plant to cellulosic ethanol.

Pre-Process Fractionation Plant Calculations

Existing Ethanol Production (MGY):	50	
Annual Feedstock (bu.):	18,000,000	
Construction Costs:	$550,000	
Additional Cost of Fractionation	$25,000,000	
Additional Cost of Corn oil Extraction	$6,500,000	
Proposed Ethanol Production (MGY):	56	11% Increase
Proposed Annual Feedstock (bu.):	21,102,662	5% reduction in ethanol yield

Product Sales	Costs (12/2008)	Production Rate Units	Production Rate	Existing Conditions
Ethanol (gal)	$1.90	gal./bu.	2.78	$95,000,000
DDGS (ton)	$115	lb./bu.	17	$17,595,000
Total Sales				**$112,595,000**
Affected Operating Expenses				
Feedstock (bu)	$4.00			$72,000,000
Other Raw Materials (total)	0.57	$/bu.		$10,260,000
Utilities (total)	1.30	$/bu.		$23,400,000
Labor, Supplies and Overhead (total)	0.26	$/bu.		$4,680,000
Total Affected Operating Expenses				**$110,340,000**
		Annual Simple Income		**$2,255,000**

			Std. Fractionation		Fractionation w/ Corn Oil	
Product Sales	Costs (12/2008)	Production Rate Units	Production Rate	Proposed Conditions	Production Rate	Proposed Conditions
Ethanol (gal)	$1.90	gal/bu.	2.63	$105,450,000	2.63	$105,450,000
DDGS (ton)	$115	lb/bu.	0.00	$0	0.00	$0
DDC-DDGS (ton)	$200	lb/bu.	11.00	$23,212,928	11.00	$23,212,928
Corn Fiber (ton)	$75	lb/bu.	3.50	$2,769,724	3.50	$2,769,724
Corn germ (ton)	$130	lb/bu.	5.40	$7,407,034	0.00	$0
Corn Oil (lb)	$0.30	lb/bu.	0.00	$0	0.86	$5,444,487
De-oiled Corn Germ (ton)	$160	lb/bu.	0.00	$0	4.50	$7,596,958
Total Sales				**$138,839,686**		**$144,474,097**
Affected Operating Expenses						
Feedstock (bu.)	$4.00			$84,410,646		$84,410,646
Other Raw Materials (total)	0.57	$/bu.	+ 1%	$12,148,802	+ 1%	$12,148,802
Utilities (total)	1.30	$/bu.	+ 20%	$28,080,000	+ 22%	$28,548,000
Labor, Supplies and Overhead (total)	0.26	$/bu.	- 11%	$4,883,156	- 10%	$4,938,023
Total Affected Operating Expenses				**$129,522,605**		**$130,045,471**
	Annual Simple Income:			**$9,317,082**		**$14,428,625**
	Annual Income Increase:			$7,062,082		$12,173,625
	Estimated Capital Cost:			$25,000,000		$31,500,000
		Payback Period:		**3.5**		**2.6**

Co-Product 2 – Wet Distiller's Grain Co-Product

Best Practice

Selling the wet distiller's grain (WDG or WDGS) to local customers eliminates the need to dry the material.

Process

Wet distiller's grain is produced from decanting of whole stillage to approximately 30% to 40% solids. This product has a shelf life that varies from 3 days to 14 days dependent on weather. Facilities can develop relationships with local agricultural producers as an outlet to sell their WDG. Several studies have looked at the potential for land spreading, although this has not been approved by environmental agencies.

Productivity Impact

The production of ethanol and WDG is not affected by this operation, but there is a need to handle the delivery to customers on a nearly "just-in-time" basis. Without an efficient distribution system, the cost of this operation will increase because of the necessary storage and handling.

Economic Benefit

Distributing WDGS eliminates the need to dry the co-product beyond the decanter and thin stillage evaporator to provide a saleable product. This is offset by the increased amount of material transported to the customer. The transportation costs are based upon a 200-mile average delivery for dry distiller's grain with soluables (DDGS) and 80-mile average delivery for WDGS.

	DDGS	WDGS
Material Weight (tons)	157,600	405,000
Material Sale Price ($/ton)	$105.00	$33.60
Sale Revenues	**$16,550,000**	**$13,610,000**
Thermal Drying Energy (1300 btu/lb. water)	$3,850,000	$0
Electric Dryer Energy	$150,000	$0
Evaporator Steam Load	$70,000	$70,000
Load Out Material Handling	$400,000	$800,000
Transportation ($12/ton for 100 miles)	$3,780,000	$3,890,000
Quality Assurance (1 test per batch)	$700,000	$700,000
Transaction Costs ($5/load)	$40,000	$100,000
Total Costs	**$8,990,000**	**$5,560,000**
Est. Gross Income	**$7,560,000**	**$7,600,000**

Note: A sensitivity analysis on the input energy prices shows that a 5% increase in energy prices correlates to a 25% reduction of DDGS gross income compared to 1% reduction for WDGS.

Energy Savings	Approximately 650,000 MMBtu of natural gas consumption per year is eliminated at a 50 MGY plant with a drum dryer, that switches from DDGS to 100% WDGS. This does not include heat recapture on the dryer, oxidizer or material cooling. The electric energy reduction is primarily associated with the dryer and exhaust system which is turned off when WDGS is produced, estimated at 1.8 million kWh per year.
Water Savings	There is no water savings for the ethanol plant, although the water contained within the wet distiller's grain is conserved as a liquid.
Other Resource Savings	Distiller's grain dryers are generally responsible for 60% of the air emissions at a typical ethanol plant. Reducing the amount of material dried will drastically reduce overall air emissions.
Stage of Acceptance	A nationwide analysis of the U.S. ethanol industry by the Renewable Fuels Association determined that 37% of distiller's grain with solubles was sold as wet feed in 2007. Approximately 35% of dairy producers in Wisconsin are utilizing distiller's grains (DG). If all the Wisconsin dairy producers in Wisconsin utilized WDG, all of the WDG produced by Wisconsin ethanol plants could be utilized, based upon current recommendations for inclusion of DG.
Applications and Limitations	Spoilage is a major concern for WDG and WDGS. Several options exist to increase the shelf life of the material, although none have been universally recognized as the optimal solution. The most cost-effective option is an effective "just-in-time" delivery system with the option to include other methods. Other methods include vacuum preservation, preservative addition, ensilage with crop residue, and land spreading. Steps should be taken to prevent freezing.
Practical Notes	Typical assumptions put the maximum delivery area of WDG at 100 miles because of the shelf life, although deliveries have been noted as far as 250 miles with preservatives. Shorter trips are preferable to retain product quality and minimize the chance of spoilage. If heat recovery is used to recover heat from a dryer or regenerative thermal oxidizer (RTO), any offset of energy recovered will need consideration as this may reduce cost savings due to reduction in exhaust water vapor. This can affect condensing and non-condensing heat recovery systems.
Resources	University of Nebraska Extension, South Dakota State University Cooperative Extension Service, Purdue University Cooperative Extension Service.
Synergies	Additional mechanical drying will increase solids and theoretically increase shelf life with minimal additional energy consumption.

Co-Product 3 – Maximize Mechanical Drying of Wet Cake

Best Practice	Maximize the solids content in wet cake prior to drying.
Process	Mechanical drying is the process of physically separating suspended solids from liquid (e.g. centrifuge, screw press, filter press, or dissolved air flotation).
Productivity Impact	Productivity of a revised drying system must meet or exceed existing productivity of co-product drying to match plant co-product production.
Economic Benefit	Increasing the wet cake solids content from 32% to 40% is equivalent to a 30% reduction in amount of water to be removed in the dryer to achieve standard dry distiller's grain (DDG). This equates to $1 million annual savings of natural gas a year at a 50 MGY plant with a 60% efficient rotary drum dryer ($710,000/year savings for a 70% efficient dryer). This savings will be offset slightly by any chemical, mechanical and electrical demand of additional drying equipment. Assumed prices include $20,000 for polymer and $4,000 electric charge per year for a screw press installation. A $500,000 installation will have a payback of less than one year.
Energy Savings	Increasing the solids in wet cake will decrease natural gas use and slightly increase electricity use. Standard centrifuges provide wet distiller's grain (WDG) at about 30% to 35% solids. Screw presses have been tested to prepare WDG at about 40% solids using a lower speed/higher torque rotation, although these require GRAS polymers.
Water Savings	The water that is removed by mechanical drying can be reused in the process, as opposed to being converted to gaseous form. Increasing from 32% to 40% increases stillage condensate by 10 million gallons per year (MGY).
Other Resource Savings	If dryer exhaust heat is currently recovered and used in a process, this best practice will lower the heat available for both condensing and other heat recovery. If such heat recovery is already installed, the effect of dewatering should be considered.
Stage of Acceptance	Mechanical means of dewatering are common in many industries that do not require drying. GRAS polymers have not been widely accepted by the agricultural community.
Applications and Limitations	Mechanical equipment requires regular maintenance, although generally, fewer moving parts and slower operation will be more reliable.

Practical Notes	High efficiency stillage concentration (HESC) systems are mechanical vapor recompression systems that retrofit the existing thin stillage evaporator system and that can increase syrup concentrations to 50% solids. This is an alternate way to reduce load to the dryer.
Resources	University of Nebraska Extension.
Synergies	Additional mechanical drying can produce a modified distiller's grain that may be preferred by local customers.

Co-Product 4 – Indirect Dryer

Best Practice	An indirect steam tube dryer eliminates combustibles from the dryer exhaust, allowing removal of the thermal oxidizer.
Process	A closed pressurized steam loop created by the evaporated water vapor is circulated with heat input through an air to air heat exchanger. Electrical heating for steam is also possible. A side stream of steam is removed from the drum which is condensable to recover the additional heat for preheating.
Productivity Impact	There is no productivity impact.
Economic Benefit	The capital cost of an indirect dryer is approximately the same as a direct fired dryer and regenerative thermal oxidizer (RTO) unit for a 50 MGY plant. Adding a heat recovery system to an indirect dryer for pre-drying WDG has a payback of 2 years for a 50 MGY plant. Considering the full cost of a retrofit with additional heat recovery on an operational direct fired system, the payback would be approximately 5 years.
Energy Savings	Thermal energy consumption to evaporate water is approximately equal to that of standard dryers, but the exhaust heat is more accessible because it does not include combustibles. When used for preheating the wet distiller's grain it can reduce the overall heating load, after startup, by approximately 40% of a conventional direct fired drum dryer. Once started and warmed up, the recaptured heat will reduce the overall heat required to be supplied by the boiler. The fans and pumps associated with an indirect dryer use a significant amount of energy, so it is important to evaluate the electrical usage of any indirect dryer system prior to purchasing. There can be as much as a 30% difference in energy usage between systems, or approximately $150,000. This is normally offset by removal of the thermal oxidizer fan.
Water Savings	None.
Other Resource Savings	The protein within the DDGS is not denatured during the indirect heating process and the potential for burning the material is reduced; however, the temperature is high enough to deactivate bacteria. These items increase the value of DDGS as a livestock feed (this value is not included in the economic benefit calculation).

Stage of Acceptance	The non-contact system eliminates combustible material and oxygen within the dryer, greatly reducing the risk for fire or explosion.
Applications and Limitations	Indirect dryers have been installed in several plants designed in 2007. Indirect steam dryers have been in operation in grain drying, baking, and industrial other drying industries for decades.
Practical Notes	An indirect dryer cannot be retrofitted within the existing dryer.
Resources	
Synergies	The economic benefit is decreased when increasing portions of the co-product are sold as wet distiller’s grain.

Process Controls 1 – Predictive Modeling Control

Best Practice

Utilize a modeling program for plant operator decisions that optimizes the entire ethanol production process based upon multiple processes.

Process

The software controls all of the processes in the plant and has directions to optimize efficiency of the plant through automatic adjustments based upon current operating conditions.

Productivity Impact

Each process will be managed based upon optimizing the plant productivity while reducing energy costs.

Economic Benefit

The predictive modeling is generally sold in modules that address a certain portion of the process. The system will keep processes coordinated, thereby reducing the operating costs associated with those processes. Generally, the software designers will look for the opportunities where the payback is less than 1 year based upon an estimated cost of $250,000 per module.

Energy Savings

The software reduces the cost of energy used per gallon of ethanol based upon operating processes and the cost of energy. These savings vary depending on operating conditions, but typical savings can be measured in yield improvements.

Plant Size (MGY)	Value of annual yield improvement		
	0.01 gal./bu.	0.05 gal./bu.	0.10 gal./bu.
50	$377,000	$1,890,000	$3,780,000
100	$754,000	$3,780,000	$7,560,000

Source: Lalleland Ethanol Technology, based on $2/gal ethanol.

Water Savings

The software can utilize the cost of water as a variable in the calculations and reduce use when economically feasible.

Other Resource Savings

An increase in alcohol yield per bushel will increase saleable ethanol with a minor increase in other production costs.

Stage of Acceptance

All plants have some version of software controls for operation and most have some level of predictive control. The greatest energy savings will come from a full predictive control with multi-variable input that is optimized for an individual plant. The paper industry has customized and utilized this type of programming for many years.

Applications and Limitations	The modeling software controls and automated reactions are only as strong as the original program, so ensure that the designer is familiar with ethanol production process.
Practical Notes	All plants are unique and generally cannot find an “off-the-shelf” software program. This makes the purchase and installation of the control software more expensive than standard operating software.
Resources	Commercial resources.
Synergies	A properly operating control system will optimize all processes.

Process Controls 2 – Temperature Gauge Calibration

Best Practice	Regularly maintain and recalibrate temperature gauges.
Process	Maintain temperature gauges to ensure correct measurements for control system.
Productivity Impact	There is no productivity impact.
Economic Benefit	A temperature measurement in the liquefaction tank that is 1^{O}F lower than actual temperature requires $23,000 of thermal energy per year to maintain the additional temperature in the slurry flow. The beer exiting the fermentation tank will require an additional amount of thermal energy per year if the measurement is one degree higher than the actual temperature in the fermenter. The overall annual economic benefit will vary dependent on condition of the gauges.
Energy Savings	The thermal energy necessary per degree additional thermal energy needed because of an inexact temperature reading is approximately 4,000 MMBtu/year. If additional cooling is necessary, the cooling tower will require an additional 16,000 kWh/year.
Water Savings	There is minimal water savings associated with minimizing use of the cooling tower.
Other Resource Savings	More accurate temperature readings will help operators maintain optimum temperature for biological processes.
Stage of Acceptance	Maintenance of temperature sensors is standard practice, although the task is many times overlooked by operators.
Applications and Limitations	
Practical Notes	ASTM International provides several laboratory procedures for calibrating different thermometers. In most instances, a handheld calibrator or multiple thermometer readings can identify an incorrect measurement.
Resources	
Synergies	Optimize heat exchangers.

Emerging Technology 1 – Membrane Ethanol - Water Separation

Best Practice	Replace dehydration with a membrane that separates ethanol from water.
Simple Payback	0.5 years to 6 years.

Background
Membranes have been developed that will draw water through the material and not allow ethanol to pass, creating 200-proof ethanol. Pretreatment is required on the process flow prior to contacting the membrane to ensure operability. Once pretreated, testing has shown that membranes are capable of purifying an ethanol-and-water solution from 60-proof alcohol to 200 proof for the storage tank. This emerging best practice has the opportunity to replace a portion of the distillation columns and the mole sieve dehydration. This would replace a large portion of total steam use in the plant. Currently, most manufacturers are targeting smaller installations to purify 190-proof ethanol, replacing mole sieve dehydration. It is estimated that replacing these items will save 5% to 10% of the total energy usage in the plant.

Manufacturers are also offering a partial flow (pilot) system that can take a side stream from a beer column and pretreat it prior to entering the membrane. Estimated costs for the pilot test are $950,000.

A second option is a system that will purify the mole sieve regeneration-recycle stream, which needs minimal pretreatment prior to entering the mole sieve. Assuming that the recycle rate is 33%, this will increase capacity of the mole sieve by approximately 20%. This system costs approximately $750,000.

The units have minimal operations and maintenance costs with no moving parts or cycling and no need to clean the membranes with proper pretreatment. It is expected that the membranes can operate up to 6 years before first service. The pretreatment filtering will require regular maintenance.

The installation of the membrane separation will revise the heat flow within the facility. The opportunity to rebalance the heat flow within the plant may provide additional savings or increased waste dependent on existing and proposed plant configuration and operation.

Emerging Technology 2 – Anaerobic Digestion of Thin Stillage

Emerging Best Practice	Treat thin stillage through anaerobic digestion instead of evaporation and drying with distiller's grain.
Plant Size	100 MGY
Dryer (estimated values)	Electricity Savings = 3,000,000 kWh/yr Natural Gas Savings = 607,000 MMBtu/yr Energy Cost Savings = $ 3.8 million
Biogas (estimated values)	Biogas Production = 970,000 MMBtu/yr Biogas Value = $ 5.8 million Recycled Process Water = 56 MGY (requires treatment)
TOTAL (estimated values)	Energy Cost Savings = $ 5.8 to $ 9.6 million Implementation Cost = $14 - $18 million Simple Payback = approximately 1.5 to 3 years

Background

Anaerobic digestion is the biological conversion of organic material in the absence of oxygen to digested solids, biogas (methane) and recovered water. Very little energy is required for stillage pumping, mixing, and material removal. The influent solids concentration is generally the limiting factor for current technologies and revisions to the thin stillage may be required to meet the operating conditions. Digesters also have a long startup time including filling and developing the microorganism populations; therefore, the first-year payback will include only minimal biogas production. This delay in operation is not factored into the payback period listed above.

Thin stillage digestion will eliminate most or all of the evaporation and a partial load on the dryer if syrup is added to wet cake prior to drying. The thermal energy used to operate the evaporator is generally shared with the dehydration steps of the process. Therefore the calculations do not account for energy savings in the evaporator, although they do account for the decreased dryer load assuming that the syrup was added to create DDGS in the base plant. The condensed distiller's solubles created from thin stillage accounts for approximately 40% of the dryer load.

Removing the evaporator from the process will disrupt the heat flow from the facility. The heat flow will have to be addressed prior to taking the evaporator offline.

The primary benefit of the digester is production of methane to displace natural gas and filtrate water to reuse as process water in the plant. Several digester companies are claiming that nearly all of the boilers' natural gas load can be displaced by the biogas produced. As most solids are destroyed and settle within the anaerobic digester, the filtrate will be available for reclamation and reuse as process water. Through the use of water treatment technologies, this water can be treated to minimize the recirculation of solids and provide the correct amount of ammonia to the front end of the process (reusing that chemical).

The following table is based upon information supplied by Procorp Enterprises LLC using their advanced-technology digester and water technology design numbers and a theoretical 100 MGY plant from spring 2008.

Plant Design Inputs	Process Input	Digestion Output (to replace Inputs)	Plant Redesign Inputs
$0.5 Million	Sulfuric Acid	$0.5 Million (saleable)	Zero
$15 Million	Energy	$14 Million	$1 Million
$2.0 Million	NH_3	$1.0 Million	$1 Million
1.5 MGD ($250k)	Water	1.0 MGD ($166k)	0.5 MGD ($83k)
$13.6 Million	Evaporative Energy	Process Bypassed	$13.6 Million
- $4.5 Million	Syrup Sales	No Saleable Syrup	$0
$30.9 Million	**TOTALS**	**$15.7 Million**	**$16.4 Million**

Digesters have also been developed to utilize the whole stillage in the anaerobic digestion process. Estimated production is 11.6 MMBtu biogas per ton of DDGS or 5.8 tons of whole stillage. The co-products are 103 lbs. of ammonia and 266 lbs. of digested organic material. Digesting the whole stillage will bypass the centrifuge decanters, evaporator, and dryer, but also eliminate the DDGS by co-product.

Emerging Technology 3 – Electric Drying of Distiller's Grain

Best Practice	Replace thermal drying with electric drying for distiller's grain.
Plant Size	50 MGY
Estimated Savings	Natural Gas = $5.9 million Water = $29,000
Estimated Charges	Electricity (kWh) = ($ 8.6 million) Electricity Demand (kW) = ($ 3.4 million)
Total Estimated Savings	($ 6.0 million)

Background

Several different electric drying technologies, such as microwave or infrared, provide a 30% increase in efficiency in heating the material per energy unit used. Microwave drying is currently in field tests with a unit that has a 54-inch conveyor in a recycled heat environment that reclaims 20% of the water evaporated. Early indications show that this process uses one half to one third the energy of a drum dryer to create DDGS, and it eliminates the VOC production in drying.

A microwave dryer uses electricity as opposed to a natural gas fueled drum drier. The scale of this fuel switch requires that the electrical system back to the utility grid be analyzed to determine if it can handle the proposed load. Below are the proposed increases in efficiency over drum drying and the expected electricity demand.

- Drum Dryer Replacement
    - Natural gas demand decreased by 978,000 MMBtu
- 30% Increased Efficiency (1 MMBtu = 205 kWh)
    - Electrical demand increased by 17,000 kW and 142,500,000 kWh
- 50% Increased Efficiency (1MMBtu = 147 kWh)
    - Electrical demand increased by 12,000 kW and 102,000,000 kWh
- 66% Increased Efficiency (1MMBtu = 97 kWh)
    - Electrical demand increased by 8,000 kW and 67,500,000 kWh

A pilot installation in Minnesota proved to be cost effective based upon the local utility rates of $0.75/therm and $0.05/kWh. The payback was estimated to be less than 5 years based upon those operating conditions. Dependent on the plants individual pricing structure, this application of this best practice may be economically feasible. There are also synergies with combined heat and power best practice, because this change will better balance the electrical and heat plant loads.

Emerging Technology 4 – Gasification of Co-Product

Best Practice	The co-product of ethanol is an organic material and will produce a combustible gas when gasified.

Background

The process of gasification transforms the organic solids into combustible gases (O_2, H_2O, CO_2) at high temperatures. The process has the opportunity to act as the dryer of the co-product which will substitute decreased gas producing efficiency for dryer use reduction. The co-product of gasification is char. This material is a nitrogen-rich fertilizer when produced from ethanol co-products. It has been tested to have more available nutrients than corn stover and has an increased water-holding capacity (Nature Vol. 447, 10 May 2007 & Nature Vol. 442, 10 Aug. 2007).

This is an alternate way of efficiently utilizing the co-product, although full-scale testing information is not available. When evaluating the economics of co-product utilization, be sure that savings fully offset the existing saleable product.

Emerging Technology 5 – ORC Electricity Generation

Best Practice	Recover low-grade waste heat or utilize a pressure drop to produce electricity using an organic rankin cycle generator.
Implementation Costs	Estimated = $200,000 to $400,000
Simple Payback	2 to 4 years

Background

An organic rankin cycle (ORC) generator can capture and utilize energy normally dissipated by a pressure differential or low-grade outlet. These units are generally small, and are sized based upon the existing operating conditions. In most applications they are not efficient enough to operate as a main power-generating facility, but rather as a waste-energy recovery unit.

Low-grade waste heat (250 ^{O}F) recovered can be utilized to produce electricity at about 10% efficiency. Based upon this efficiency, this emerging best practice should only be installed on “waste” heat streams that are not recoverable for thermal energy.

The system can also operate solely on a pressure drop of at least 15 psi in a plant. A sales representative provided the example that a plant is connected to a high-pressure natural gas line and needs to reduce it anywhere for 10 to 30 psig at the plant. Large natural gas line pressures for ethanol plants are as high as 650 psig and plant fuel use around 250,000 MM cubic feet per month. The turbo expander can provide the regulated pressure reduction and generate 500 kW and about 140 tons of cooling via the Joule-Thompson cooling effect.

To date, very few organic rankin cycle electricity generation units have been installed in the United States.

APPENDIX A

SUMMARY CHECKLIST FOR CORN-BASED ETHANOL PLANT ENERGY BEST PRACTICES

Best Practice Analyzed? (Date)	Further Review Needed? Yes/No	Best Practice Possible? Yes/No	Area	#	Title	Typical ROI
			Process Heat	1	Combined Heat and Power	20% - 33%
			Process Heat	2	Optimize Heat Exchangers	+ 100%
			Process Heat	3	Thermal Oxidizer Heat Recovery	20% - 50%
			Process Heat	4	Increase Boiler Combustion Air Temperature	+ 100%
			Starch Conversion	1	Raw Starch Hydrolysis	N/A
			Fermentation	1	Yeast Propagation	25%
			Fermentation	2	Direct Yeast Injection	0% - 500%
			Fermentation	3	Improve Yeast Performance	100% - 1000%
			Evaporator	1	Replace Vacuum Eductor with Liquid Ring Vacuum Pump	50%
			Co-Product	1	Pre-Process Fractionation	10% - 100%
			Co-Product	2	Wet Distiller's Grain Co-Product	N/A
Best Practice Analyzed? (Date)	**Further Review Needed? Yes/No**	**Best Practice Possible? Yes/No**	**Area**	**#**	**Title**	**Typical**

						ROI
			Co-Product	3	Maximize Mechanical Drying of Wet Cake	100% - 200%
			Co-Product	4	Indirect Dryer	20% - 50%
			Process Controls	1	Predictive Modeling Control	100% - 200%
			Process Controls	2	Temperature Gauge Calibration	Immed-iate
			Emerging Technology	1	Membrane Ethanol/Water Separation	15% - 200%
			Emerging Technology	2	Anaerobic Digestion of Thin Stillage	33% - 66%
			Emerging Technology	3	Electric Drying of Distiller’s Grain	0%
			Emerging Technology	4	Gasification of Co-Product	N/A
			Emerging Technology	5	ORC Electrical Generation	25% - 50%

APPENDIX B

The following are key energy best practices within common systems in industrial facilities. For more information on these best practices, free technical support to estimate the best practice energy savings for your systems, and possible project incentives, call Focus on Energy at 800.762.7077.

BEST PRACTICES FOR COMMON INDUSTRIAL SYSTEMS

Compressed Air System

- Reduce system pressure
- Repair leaks
- Single verses two-stage
- Variable inlet volume
- Variable speed control
- Energy efficient motor

Lighting System

- Light meter used to verify levels
- T8 or pulse start MH lighting are considered
- Occupancy sensors
- Lights off during process shutdown
- Task lighting is maximized
- Night lighting is turned off
- LED lamps in exit signs

Motor Systems

- Cogged belts vs. V-belts
- Premium efficiency motors specified
- Premium efficiency motor vs. repair

Pump Systems

- Use VSD instead of throttled control
- Use VSD instead of bypass control
- Trim impeller to meet maximum load

Cooling Comfort System

- Install removable insulation
- Minimize unnecessary ventilation
- Minimize moisture released
- Higher efficiency AC
- Optimize room air temperature

Area Comfort Heating System

- Reduce waste heat
- De-stratify heated air in plant
- Minimize heat to storage areas
- Use infrared heating
- Optimize CFM air exhausted
- Automatic temperature control
- Control heating to desired temperature

Dehumidification System

- Minimize reheat energy
- Optimize ventilation
- Reduce humidity load
- Accurately controlling humidity
- Desiccant dehumidification

Best Practices for Common Industrial Systems (cont.)

Refrigeration Systems

- Scheduled maintenance
  - Clean filters
  - Low refrigerant charge
- Automatic air purge
- Thermo siphon
- Evaporator fan control
- Floating head pressure

Steam System

- Reduce steam pressure
- Steam trap maintenance
- Minimize blow down
- Insulate pipes
- Improve boiler efficiency
- Heat recovery for boiler blow down
- Increase condensate return
- Stack economizer
- Recover flash steam

Ventilation Systems

- Direct fired make-up units
- De-stratified air
- Better ventilation management

Wastewater System

- Automatic controlled DO sensors/VSDs
- Heat recovery on anaerobic digester
- Unneeded aeration basins are shut off
- Fine bubble diffusers

Fan Systems

- Reduce excess flow
- Eliminate flow restrictions
- Correct poor system effects
- Optimize efficiency of components
- Correct leaks in system
- Optimize fan output control

Process Cooling System

- Insulate pipes and vessels
- Use variable frequency drives
- Float head pressure
- Use of free cooling - fluid cooler
- Use of free cooling - cooling tower
- Match chilled water pumps
- Process to process heat recovery

Process Heating System

- Preheat combustion air
- Optimize combustion air/fuel ratio
- Insulate pipes and vessels
- Ultra filtration for condensation
- Schedule cleaning of heat exchangers
- Condensing heat recovery
- Process to process heat recovery

Vacuum System

- Eliminate vacuum leaks
- Optimize total cost for conveying
- Choose appropriate vacuum pump
- Optimize vacuum pressure

APPENDIX C

FOCUS ON ENERGY BIOFUEL TEAM MEMBER CONTACT INFORMATION

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APPENDIX D

ADDITIONAL RESOURCES FOR THE CORN-BASED ETHANOL INDUSTRY

FOCUS ON ENERGY: focusonenergy.com - offers financial incentives to eligible customers for installing qualifying energy efficiency measures. These measures include energy efficient lighting and HVAC equipment, and “custom” projects such as motor and compressed air system upgrades, process improvements and especially implementing the best practices. Incentives are also available for maintaining equipment and studying the feasibility of a proposed energy efficiency project.

- Work with a Focus on Energy advisor to obtain approval for custom incentives prior to ordering equipment. If you do not currently have an advisor, please call 800.762.7077.
- Incentives are available for new projects, not those that have been previously installed. Applications must be submitted before commencement of the project. See the program rules and qualifications at focusonenergy.com for more information.
- All custom project incentives are calculated based on first-year energy savings.
- Custom incentives are provided to cover no more than 30% of a project’s cost without special approval.
- Projects with less than a 1.5-year payback are not eligible for custom incentives without special approval.
- A comprehensive bonus incentive of an additional 30% may be available for partners who implement multiple projects that increase overall facility energy efficiency.
- Maximum incentive for a custom project is $250,000.
- Bid programs are available for producers to provide alternatives to the custom incentive structure.

CleanTech Partners: cleantechpartners.org - CleanTech Partners (CTP) is a Wisconsin-based, private, nonprofit organization that invests in emerging, energy-saving technologies. CTP helps companies reduce energy consumption in Wisconsin by investing money and business resources in:

- The **development and commercialization** of technology – CTP supports early-stage companies in their growth by providing debt and equity financing, grant-writing, business mentoring and intellectual property advice.
- The **implementation** of technology – CTP assists Wisconsin businesses to implement new energy efficient technologies that can lower their operating costs.

CTP investment clients are eligible for a number of services; many free of charge; including technology evaluation, business and financial planning, finding additional investment, government support, business partners and customers.

CTP is unique in its ability to provide this depth and breadth of assistance to its clients because CTP staff have been there and know what it takes. The majority of it's staff have entrepreneurial experience – starting, securing financing, and running their own businesses. Their expertise includes:

- Commercial banking
- Venture investment
- Economic development
- Executive management
- Professional engineering
- Manufacturing engineering
- Agricultural economy

Kinergetics, LLC: kinergetics.net – Tom Tucker, a registered professional engineer and Qualified Steam Specialist with the U.S. Department of Energy (DOE), is founder and principal of Kinergetics, LLC. His experience includes steam and process system optimization, evaporation and drying systems, energy measurement and verification, heat recovery system analysis and design, evaluation of renewable energy technologies, combined heat and power assessment, and the technical and economic feasibility of new technologies.

He has performed over 250 energy and process efficiency assessments in the ethanol, food/dairy, pulp/paper and metals industries across the United States. Mr. Tucker is actively involved with the DOE's "Save Energy Now" initiative and has served as lead process energy engineer supporting the Focus on Energy Program.

In addition to founding Kinergetics, Mr. Tucker is co-founder of two energy technology firms involved in the development of software technologies and energy measurement and verification equipment.

Mr. Tucker has a bachelor's degree in chemical engineering from the University of Wisconsin-Madison and is a Wisconsin registered professional engineer.

U.S. DEPARTMENT OF ENERGY – ENERGY EFFICIENCY AND RENEWABLE ENERGY (EERE) - EERE offers valuable tools and publications to help industrial companies improve productivity and energy efficiency (see below). You can learn more by visiting the best practices website at eere.energy.gov/industry/bestpractices or by calling the EERE Information Center at 877.337.3463.

Publications :
http://www1.eere.energy.gov/industry/bestpractices/publications.asp
Whether you’re looking for information on how to recover waste heat from your steam system or wondering about the market potential of efficient motors, the best practices library has the publication for you:

- DOE G 414.1-2, Quality Assurance Management System Guide – systems for conducting best practices.
  http://www.directives.doe.gov/pdfs/doe/doetext/neword/414/g4141-2.pdf

- Case Studies – Profiles of companies and organizations that have made energy savings improvements and how they did it through plant-wide assessments, management best practices or software analysis.
  http://www1.eere.energy.gov/industry/bestpractices/case_studies.html

- Technical Publications – Materials on purchasing, analyzing, and maintaining industrial systems and components. Others provide a detailed look at the markets available to industrial energy efficiency.
  http://www1.eere.energy.gov/industry/bestpractices/technical.html

    - *S*ourcebooks - These reference books detail industrial systems, including compressed air, steam, fan, and other systems, giving the technical information necessary for comprehensive understanding. Providing detailed overviews of system components, analysis of plant and facility nee*ds, technical advice on optimizing performance, and guidance on ide*ntifying and implementing energy-efficiency and productivity improvements, these are essential reference tools.

    - Tip Sheets - Quick and to the point, these two-page tip sheets give engineers, technicians, equipment operators, and others technical advice to eliminate voltage unbala*nce, reduce compressed air leaks, inspect and repair steam traps, b*enchmark the fuel cost of steam generation, and handle a host of other practical issues.

    - Technical Fact Sheets and Handbooks - Written for engineers, technicians, equipment operators, and others needing hands-on advice on compressed air, motor, process heating, and steam systems, these fact sheets and handbooks provide the detailed information necessary to assess and squeeze the greatest efficiency out of industrial systems.

    - Market Assessments - Need information on the state of the market for industrial systems and components and for industrial energy-efficiency services? These market assessments cover a range of industrial products, systems, and energy-efficiency services, including compressed air, motor, and steam. Comprehensive in scope, these assessments describe the current state of the market, customer awareness of and desire for efficient systems, and potential for increased market penetration of efficient equipment and system components.

- Energy Matters – The best practices quarterly for the U.S. Department of Energy’s Industrial Technologies Program, provides in-depth articles to help industry professionals save energy, reduce costs, and increase productivity. http://apps1.eere.energy.gov/industry/bestpractices/energymatters/

- Industrial technologies program (ITP) E-Bulletin – Monthly online connection to news and resources from ITP—including announcements about new tools and resources. Subscribe by sending an e-mail to itpbulletin@ee.doe.gov

- Training Materials – A range of materials, notebooks, CDs, and viewgraphs designed to spread the word about the benefits of industrial energy efficiency and how to achieve it. http://www1.eere.energy.gov/industry/bestpractices/training.html

Training:
http://www1.eere.energy.gov/industry/bestpractices/training.html
EERE best practices offers system-wide and component-specific training programs to help you run your plant more efficiently. The training is offered throughout the year and around the country.

- End-User Training for compressed air, motor, process heating, pump and steam systems.

- Specialist Qualification Training offers additional training in the use of specific assessment and analysis software tools developed by DOE.

Plant Assessments:
http://www1.eere.energy.gov/industry/bestpractices/plant_assessments.html
Plant assessment assistance is available to help you and your customers identify opportunities to improve the bottom line by reducing energy use and enhancing productivity.

- Plant-wide Assessments investigate overall energy use in industrial facilities and highlight opportunities for best energy management practices. Approximately once per year, plants are selected through a competitive solicitation process and agree to a minimum 50% cost-share for implementing the assessment. The DOE also provides no-cost energy savings assessments through the Save Energy Now initiative, http://www1.eere.energy.gov/industry/saveenergynow/

- Industrial Assessment Centers (IAC) are aimed at small- to medium-sized manufacturers and provide a comprehensive industrial assessment at no cost. Engineering faculty and students conduct energy audits or industrial assessments to identify opportunities to improve productivity, reduce waste and save energy.

Software:
http://www1.eere.energy.gov/industry/bestpractices/software.html
ITP's comprehensive suite of software tools can help your organization identify and analyze energy savings opportunities. Visit the Web site to learn more and download these tools, free of charge, to improve industrial compressed air, motor, fan, pump, process heating and steam systems:

- AIRMaster+ Version 1.2.3
- Chilled Water System Analysis Tool (CWSAT)
- Combined Heat and Power Application Tool (CHP)
- Fan System Assessment Tool (FSAT)
- MotorMaster+
- NOx and Energy Assessment Tool (NxEAT)
- Plant Energy Profiler for the Chemical Industry (ChemPEP Tool)
- Process Heating Assessment and Survey Tool (PHAST) Version 2.0
- Pumping System Assessment Tool (PSAT) 2008
- Steam System Tool Suite

Databases:
http://www1.eere.energy.gov/industry/bestpractices/databases.html
ITP's on-line databases can help you make contact with best practices service providers, review results of plant assessments, and find a variety of additional tools.

- The Industrial Assessment Center (IAC) Database contains the actual results of approximately 7,000 assessments conducted by the IACs. The database includes details including fuel type, base plant energy consumption, and recommended energy efficiency improvements, in addition to projected energy savings, cost savings, implementation cost, and simple payback. http://iac.rutgers.edu/database/

- The Thermodynamics Resource Database helps industries engaged in high-temperature processing address critical technology challenges. This database was created to aid industry in modeling and exploring processing solutions involving high-temperature materials and corrosion. This free resource on thermochemistry for gas-phase and condensed species currently includes pages specifically for the glass manufacturing and petrochemical industries; similar pages focused on the chemical, forest products, steel, and aluminum industries will be added soon. http://www.ca.sandia.gov/HiTempThermo/index.html

Alliance to Save Energy - Founded in 1977, the Alliance to Save Energy is a non-profit coalition of business, government, environmental and consumer leaders. The Alliance to Save Energy supports energy efficiency as a cost-effective energy resource under existing market conditions and advocates energy-efficiency policies that minimize costs to society and individual consumers, and that lessen greenhouse gas emissions and their impact on the global climate. To carry out its mission, the Alliance to Save Energy undertakes research, educational programs, and policy advocacy, designs and implements energy-efficiency projects, promotes technology development and deployment, and builds public-private partnerships, in the U.S. and other countries.

- *Corporate Energy Management Case Studies - These case studies can help decision makers examine the bottom line benefits that result from successful applications of energy efficient practices and technologies.* www.ase.org/section/topic/industry/corporate/cemcases/
- *Industrial Energy Efficiency Clearinghouse.* http://www.ase.org/section/topic/industry/clearinghouse

Associations and Trade Organizations

American Coalition for Ethanol
    http://www.ethanol.org/
American Coalition on Renewable Energy
    http://www.acore.org/
Corn Refiners Association
    http://www.corn.org/
Governor's Ethanol Coalition
    http://www.ethanol-gec.org/
International Ethanol Trade Association
    http://www.ietha.org/ethanol/index.php
National Corn Growers Association
    http://www.ncga.com/index.asp
National Ethanol Vehicle Coalition
    http://www.e85fuel.com
Renewable Fuels Association
    http://www.ethanolrfa.org/
Wisconsin Bio Industry Alliance
    http://www.wisconsinbioindustry.com/

Other

Energy Center of Wisconsin
    http://www.ecw.org
Wisconsin Office of Energy Independence, Biofuels segment
    http://power.wisconsin.gov/
Energy Consumption by Manufacturer-MECS data for 1998
    http://www.eia.doe.gov/emeu/mecs/

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