Energy Best Practices Guide | December 2020

METALCASTING

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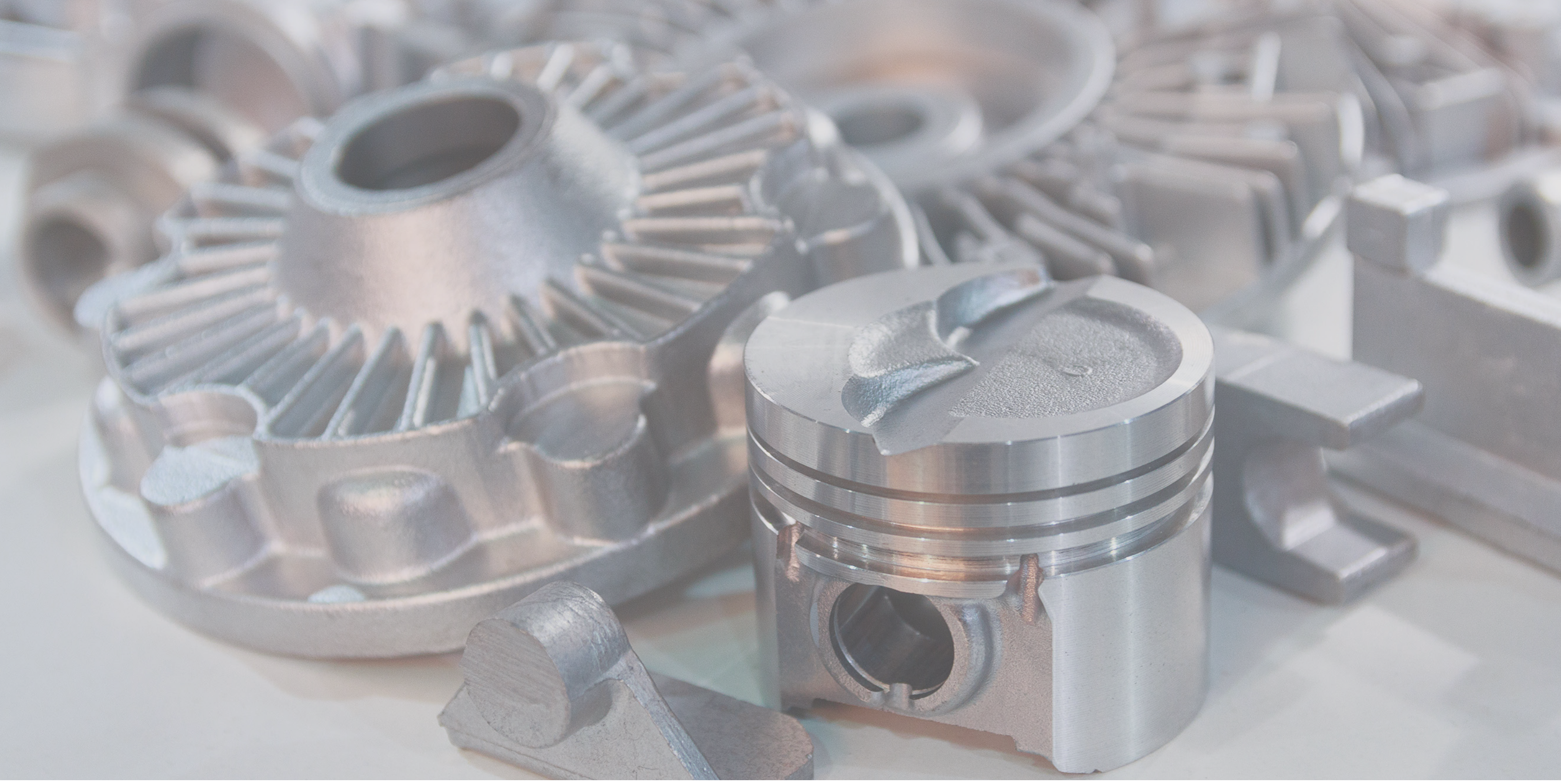

METALCASTING BEST PRACTICES GUIDEBOOK

FOCUS ON ENERGY®, Wisconsin utilities' statewide program for energy efficiency and renewable energy, helps eligible residents and businesses save energy and money while protecting the environment. Focus on Energy information, resources and financial incentives help to implement energy efficiency and renewable energy projects that otherwise would not be completed.

This guidebook in whole is the property of the State of Wisconsin, Department of Administration, Division of Energy, and was funded through the Focus on Energy Program.

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Introduction

This guidebook is one of a series of guidebooks developed to highlight industrial energy-efficiency best practices in common industrial sectors. The guidebook contains individual best practice descriptions and tips for overcoming common barriers encountered during implementation of these practices.

The information provided in the guidebook was identified and screened through site visits to industrial facilities within the targeted sector. This guidebook will be updated as new best practices are identified and screened for applicability. If you have an energy-related best practice for this industry sector that you believe should be included in this guidebook, please reach out to Focus on Energy at 888.623.2146.

Are you a world-class industrial energy user?

World-class energy users have:

1. Received firm commitments from management for plant-wide improvements in energy efficiency and demand reduction
2. Aligned their energy-using equipment decisions with their corporate goals
3. Baselined energy consumption in their plant
4. Benchmarked best-practice opportunities
5. Defined a quantifiable, affordable energy reduction goal
6. Established a multi-year plan to meet their energy reduction goals
7. Identified the necessary internal and external resources to meet these goals and to provide feedback to continuously improve the plan

If your plant lacks any of these essential ingredients, this guidebook will help you get there.

ENERGY MANAGEMENT BEST PRACTICES

Any organization can more effectively manage its energy use and costs by adopting a continual improvement approach to energy management, commonly known as an **energy management program** or **Strategic Energy Management (SEM)**. An energy management program provides a systematic and proactive approach to assessing and reducing the energy uses and costs of your organization.

An energy management program is not a single project but an ongoing process. It can be a stand-alone effort devoted exclusively to energy management or adapted to an existing management program such as existing quality assurance or environmental management programs at a facility. The most successful energy-management programs are developed and maintained by a team of individuals from various functions such as maintenance, engineering, production, financing and management.

Energy efficiency is a good investment. Typically, energy cost savings of as much as 15% can be achieved in three years by implementing a systematic energy-management program.

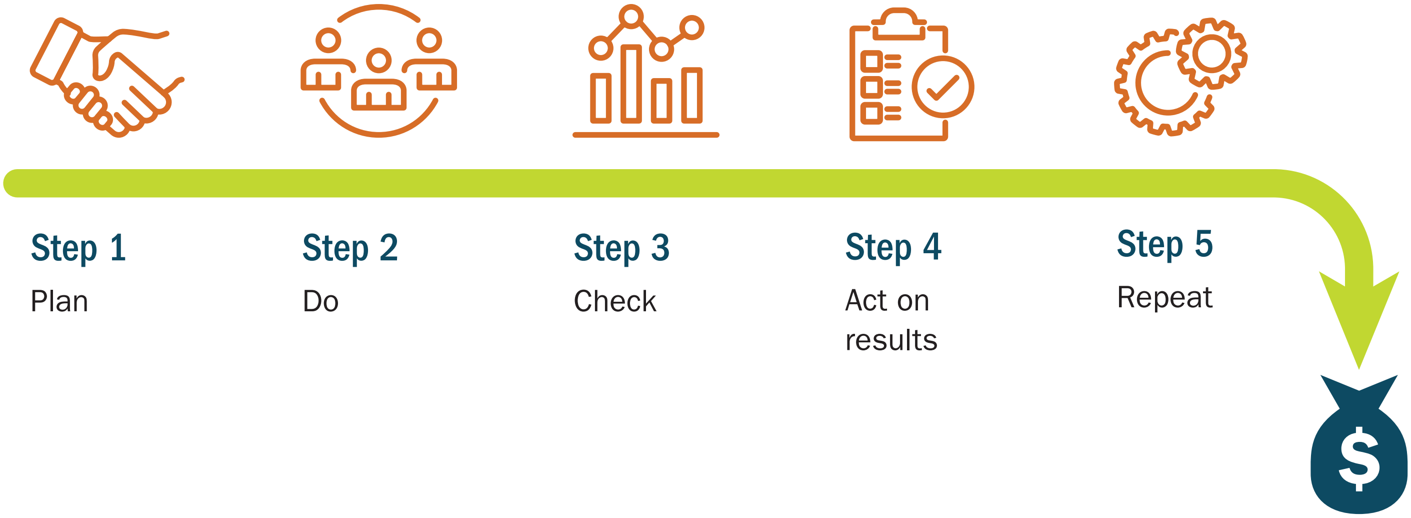
At first glance, creating and implementing an energy-management program may seem to be an overwhelming task, but it doesn't have to be. This chapter outlines simple steps following a Plan, Do, Check, Act continuous improvement cycle for putting the basic elements of energy management in place within your organization.

Steps to getting started

The next several pages outline the steps toward developing and implementing a continuous systematic energy management program. Focus on Energy can assist with completing any of these steps.

There are other well-established energy management protocols to consider including CEE's Strategic Energy Management Minimum Elements (www.cee1.org), the 50001 Ready program by the Department of Energy, or the ISO 50001 standard.

Basic steps in building an energy management program



Step 1
Plan

Step 2
Do

Step 3
Check

Step 4
Act on results

Step 5
Repeat

Step 1 – Plan

Obtain support from plant management

Start with discussing the need for better energy management with the decision makers at your facility. It is critical plant management support these efforts and are willing to allocate resources, both time and money, to achieve those goals and there is accountability for goal achievement.

It is helpful to prepare a business case for plant management. What is your total plant's annual energy spend? What is a reasonable/achievable reduction in annual energy costs because of better energy management? How much staff time can be justified by the estimated reasonable annual energy savings? Focus on Energy can help build this business case.

Establish your energy-performance baseline

Establishing a baseline is critical for goal setting and monitoring progress towards goal achievement. There are multiple ways to establish baseline energy consumption. The following list of possible baselines is in order of increasing effort but also increasing value.

Basic — Gross energy consumption

Using an average annual or monthly gross energy consumption is the easiest baseline to develop, but it is also the least useful. While this approach gives a rough baseline to track future performance against, it does not account for factors which may change your energy consumption based on business demands, like increased production, or reasons out of your control, like weather. This approach is most useful in a plant with stable energy-using processes not impacted by weather.

Better — Production energy intensity metric

By combining energy consumption and production data, you can build a baseline for energy intensity.

Building this baseline is done by dividing electricity consumption (kWh) and gas consumption (therms) by total production volume for the same time period. This can be tracked at any interval desired, such as daily or annually. See the second column in the example below.

MONTH	KWH/UNIT	CONSUMPTION (KWH)	PROD UNITS	BILLED DEMAND (KW)	TOTAL ELECTRIC POWER COST
Jan	2.61	2,253,240	862,560	4,953	$103,650
Feb	2.51	2,123,070	845,040	4,953	$97,661
Mar	2.57	2,198,420	855,090	4,953	$101,127
Apr	2.49	2,056,720	826,640	4,953	$94,609
May	2.42	1,989,730	821,970	4,953	$91,528
Jun	2.49	2,106,030	844,490	4,797	$96,877
Jul	2.45	2,034,040	831,540	4,794	$93,566
Aug	2.50	2,102,320	840,200	4,728	$96,707
Sep	2.45	2,060,210	839,310	4,771	$94,770
Oct	2.41	1,983,040	821,180	4,771	$91,220
Nov	2.45	1,964,920	801,040	4,771	$90,386
Dec	2.45	1,988,640	810,940	4,771	$91,477
Avg Total	**2.49**	**24,860,390**	**10,000,000**	**4,847**	**$1,143,578**

Electric rate $0.046/kWh

This approach is better than tracking gross energy consumption but results in a wide range of values because it only takes into consideration one driver of energy consumption – total production. Most production facilities have other important drivers such as product mix, weather and operational mode, among others. This can impact the usefulness of this information and can negatively impact employee buy-in to supporting energy improvements.

Best — Multi-variable regression modeling

Multi-variable regression modeling is often the most accurate and useful method of creating a baseline. This approach uses a mathematical equation, taking into consideration multiple variables including but not limited to product lines, temperature, humidity, days of the week, mode of operation and plant shutdown time.

Example regression model equation

$$\text{kWh/day} = 45{,}000 + 67*(\text{Cogs}) + 74*(\text{Wheels}) + (1{,}500*\text{Cooling Degree Days}) - 26{,}000*(\text{Weekend})$$

Once a model is established, it can be used to compare expected daily consumption against actual utility meter readings for each day. Differences between the model and actual energy consumption can be accumulated over time in a useful visual layout called a cumulative sum control chart. The value of this graph represents normalized savings to date, and the path of the graph over time can be useful in identifying unexpected energy performance impacts from operation adjustments.

Regression modeling can be done using any number of readily available tools such as Microsoft Excel or open-source statistical software. Effective regression modeling is best done by an experienced and trained statistical modeler. Contact Focus on Energy for assistance in developing a regression model.

Step 1 — Plan (continued)

Identify opportunities

Best practices are techniques or technologies recognized as being economical and more efficient than common practices. Review best practices in comparison to your equipment and system profiles to identify opportunities for energy efficiency improvements. Focus on Energy can assist you in identifying and prioritizing opportunities for your facility.

Quantify savings and costs of opportunities

Once opportunities are identified, the next step is to estimate the cost savings, including energy, maintenance and installation. Focus on Energy provides technical assistance for quantifying energy savings for projects as needed.

Prioritize projects

This step can be done with your energy team or upper management. Apply criteria such as return on investment, capital cost or ease of installation to help prioritize the projects identified. Select the highest-scoring projects for implementation to achieve your energy-saving goals within time and budget constraints.

Set a goal

Use the prioritized projects to inform a goal. What is achievable this year? The goal doesn’t necessarily have to be an amount of saved energy; it could be to maintain current plant performance. Most sources agree intentional plant management can save between 1% - 5% of a plant’s annual energy consumption depending on how much a facility has already invested in energy efficiency.

Form an energy team and establish meeting frequency

Effective energy management requires input from many levels of plant operations. The size of an energy team will depend on the magnitude of the annual energy spend. Plants with very large annual energy costs can justify a bigger energy team and more frequent meetings. Smaller plants may only be able to justify assigning the role of energy manager to a single staff person who reports to the general plant management team.

It helps to set a standard agenda to ensure meetings are efficient and effective. Typical energy team meeting agendas have at least two components:

1. Review progress on selected projects and initiatives.
2. Review and discuss performance to date against the baseline.

Step 2 – Do

Regular energy team meetings

The energy team should meet according to the frequency set forth in the planning phase and discuss progress and challenges for the projects identified.

Project management and implementation

Manage each energy project selected for implementation by clearly defining project parameters, assigning responsibilities for project implementation, setting deadlines and undertaking specific tasks needed to implement the project. Progress on projects should be reported during energy team meetings.

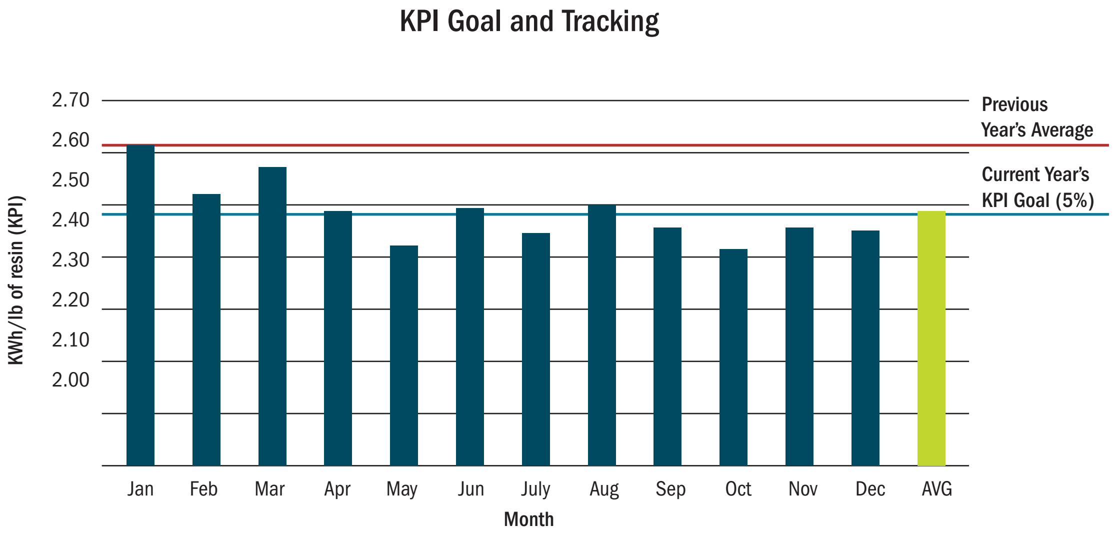
Step 3 – Check

Monitoring progress against baseline

At each meeting, the energy team should report on progress against the selected baseline. For a gross energy consumption baseline, how much energy has been consumed to-date and how does it compare to this time last year? For energy-intensity baseline, what was the energy consumed per unit of production last month and how does this compare to the baseline metric? And for regression-based baseline models, over the past month, did the plant consume more energy than the model expected? The team should discuss causes to explain results. Did any implemented projects result in the expected savings?

Figure 1: KPI goal and tracking

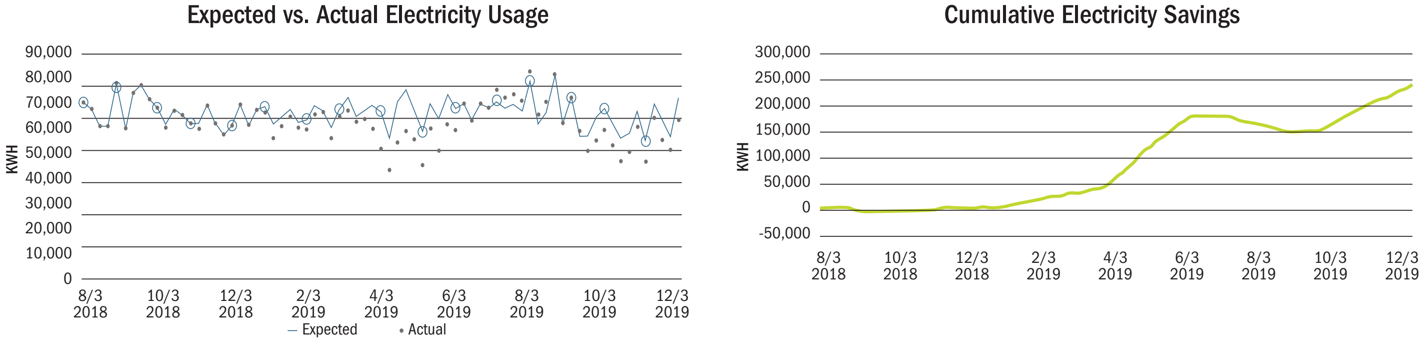
This graph depicts Key Performance Indicator (KPI) tracking of a simple energy intensity KPI.


KPI Goal and Tracking

Step 3 — Check (continued)

Figure 2: Tracking energy performance

This graph depicts tracking energy performance using a regression model approach.


Expected vs. Actual Electricity Usage

Cumulative Electricity Savings

Reports to management

The energy team should report to upper management at regular intervals. This can include reviewing projects completed, sharing results found using a baseline comparison and discussing progress towards goals.

Step 4 – Act

Acting on results

One of the primary benefits of an established energy management program is the opportunity for continuous improvement. Continuous improvement involves constantly adjusting tactics and strategies based on actionable data. Each energy team meeting and report to management is an opportunity to recognize a need to act. If the energy performance of the plant is degrading, determine why and what needs to be done. If the expected savings from a project are not being realized, assign a task to find out why. If an established goal is deemed too aggressive, reduce the goal and document lessons learned. Each cycle of continuous improvement will result in lessons learned and can be applied to the planning phase of the next cycle.

Step 5 – Repeat

Repeat the four steps above on a regular basis. Most plants revisit the planning phase at least annually during other regular annual planning cycles.

TECHNICAL BEST PRACTICES

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The table above details the best practices included in this guidebook. See Appendix D for details on simple payback and non-energy benefits for these opportunities.

Invert pouring ladles during preheat and standby

Best practice	Invert pouring ladles 900 degrees or 1,800 degrees prior to heating. This will improve ladle heat retention and reduce the amount of natural gas required for heating.
Primary area/process	The melting department, mold-pouring lines and ladle preparation/repair areas.
Productivity impact	None
Return on investment	Less than one year.
Energy savings	Saving 10% of a 250,000 British thermal units (Btu)/hour ladle heater would save 2,000 therms per year if used for 8,000 hours per year.
Applications and limitations	Not applicable if the facility uses fiber-ladle inserts instead of refractory-lined ladles.
Practical notes	Requires cleaning of ladle prior to inverting to prevent molten metal from running out of ladle.
Other benefits	None
Stage of acceptance	Not widely accepted due to additional effort required to clean and invert the ladle.

Use exhaust to preheat combustion air

Best Practice	Recover heat from high-temperature exhaust air to preheat incoming combustion air.
Primary area/process	Cupola hot blast, heat-treat furnaces, scrap dryers and charge preheaters.
Productivity impact	May increase process throughput via increasing output of burner.
Return on investment	One to two years.
Energy savings	With a 250,000 Btu/hour burner, this saves 2,250 - 4,500 therms per year.
Applications and limitations	Preheat combustion air by using exhaust heat from the same process.
Practical notes	Can preheat combustion air to 800°F. May require a burner retrofit.
Other benefits	None
Stage of acceptance	Well-known but not widely adopted.
Resources	Process Heating Assessment and Survey Tool (PHAST) https://www.energy.gov/eere/amo/articles/process-heating-assessment-and-survey-tool

Use variable speed drives on variably loaded motors

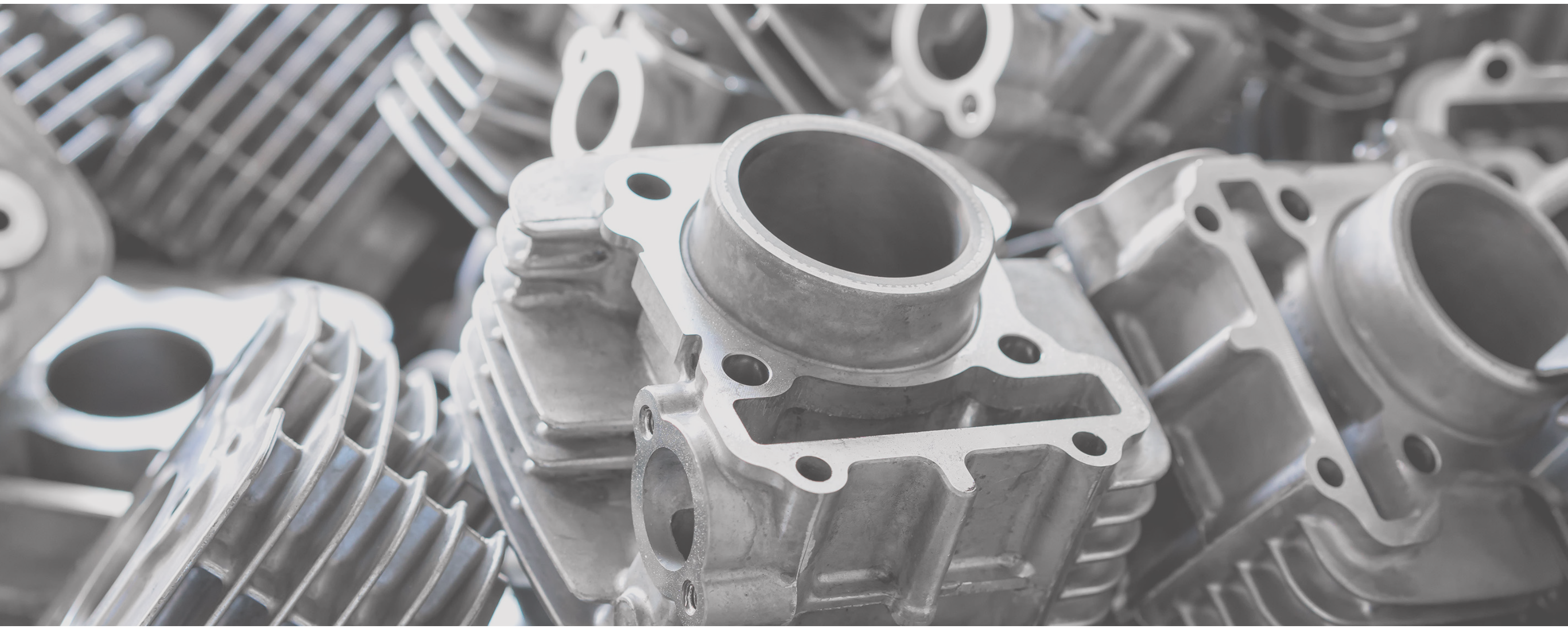
Best Practice	Use of variable speed drives (VSDs) on motors with variable loads.
Primary area/process	VSDs allow better load matching, where demand frequently varies below full capacity of the motor. The most noteworthy application of VSD units is on sand mulling applications, dust collectors and cooling towers.
Productivity impact	None
Return on investment	Varies among metalcasting operations. VSD technology has become affordable and can save up to 50% in energy costs.
Energy savings	Assuming a 50 horsepower (hp) motor spends 2,000 hours per year at 1/3 loading, 20,000 kWh would be saved by installing a VSD.
Applications and limitations	Metal casters accept the technology but lack the engineering resources to develop it within their own plant.
Practical notes	This technology is most beneficial for large horsepower motors (in excess of 75 hp). The cost of the VSD limits its application to loads varying over a wide part of the full motor capacity. The use of VSDs is not a substitute for prudent shutdown procedures able to save more energy and reduce power demand.
Other benefits	Reduction of motor repair and replacement costs.
Stage of acceptance	Not widely used as engineering resources to determine feasibility are often limited.

Recover exhaust heat

Best Practice	Install- air-to-air, air-to-water or air-to-oil types of heat exchangers to provide process heat or makeup air. The energy saving results from recovering exhaust-heat streams to offset a portion of the natural gas used for process or space heating.
Primary area/process	Used to preheat the combustion air on scrap preheaters and heat-treating loads and to preheat winter make-up air for main factory areas.
Productivity impact	None
Return on investment	One to two years.
Energy savings	Gas consumption will be reduced 18,000 therms for each 10,000 continuous cubic feet per minute (CFM) of makeup air heated with exhaust heat.
Applications and limitations	May be limited to opportunities with cleaner exhaust air; dirty exhaust air may plug the heat exchanger.
Practical notes	Current exchangers take advantage of newer metals, oils and designs able to improve efficiency and reduce maintenance costs.
Other benefits	None
Stage of acceptance	Growing level of acceptance due to increasing levels of awareness.
Resources	US Department of Energy - “*Theoretical/Best Practice Energy Use in Metal casting Operations*” May 2004, Page 71.

Modulate electric-furnace exhaust

Best Practice	Reduce the volume of electric-furnace exhaust by reducing the air flow (CFM) from the exhaust hood on the electric furnace. Energy is saved by reducing the amount of heated air exhausted and reducing the fan energy used to exhaust the air. This can be done in two ways: • By reducing the exhaust-fan speed when covers are closed. • By placing a partial damper in the exhaust stack when the cover is closed.
Primary area/process	Electric melting furnaces.
Productivity impact	None
Return on investment	Three to seven years.
Energy savings	Save 400 therms and 2,000 kWh for each 1,000 CFM reduced for every 2,000 hours of operation per year.
Applications and limitations	This practice applies only to close-capture hoods on electric furnaces in both iron and aluminum foundries. The best time for installation is during the installation of a new ventilation system for the furnace.
Practical notes	None
Other benefits	None
Stage of acceptance	Well-known but not widely adopted.



Improve mold yield to reduce amount of metal melted

Best Practice	Optimize gating and riser systems within the mold to reduce the amount of molten metal required to fill the mold.
Primary area/process	This will affect the melt area but may also affect the molding and cleaning areas of the casting process.
Productivity impact	With less metal melted, productivity will increase in the melting area. The finishing area will see improvements through reduced gating and proper riser connection sizing.
Return on investment	Less than one year.
Energy savings	A 1% improvement in yield represents significant savings in the number of BTUs required per gross ton of castings poured. See Appendix X for projected energy savings at various levels of yield.
Applications and limitations	This practice applies to any mold design. The limits to implement this best practice are production demands, tooling budget and the amount of time available for in-house analysis.
Practical notes	Inherited tooling and reluctance of the customer to pay for revisions and computer analysis prevents many metal casters from doing the necessary analysis and experimental work to obtain the desired results.
Other benefits	Reduced emissions.
Stage of acceptance	This is an accepted practice in the industry.
Resources	Determination of formulas from “*Theoretical/Best Practice Energy Use in Metal casting Operations*,” May 2004, Page 52, Table #30

Minimize scrap to reduce amount of metal poured

Best Practice	Optimize gating and riser systems and improve process control to reduce the scrap percentage for a given casting.
Primary area/process	Melting, molding and finishing areas of the casting process.
Productivity impact	Productivity will increase in the melting area as less metal is melted. The finishing area will see improvements by reducing the number of castings requiring finishing.
Return on investment	Less than one year.
Energy savings	A 0.5% reduction in scrap represents significant energy savings per gross ton of castings. See Appendix X for the energy savings at various levels of scrap reduction.
Applications and limitations	This practice will apply to any current mold design. The limits to implementing this best practice are production demands, tooling budget and the time available for in-house analysis.
Practical notes	Inherited tooling and reluctance to pay for revisions and computer analysis prevent many metal casters from doing the necessary analysis and experimental work to obtain the desired results.
Other benefits	Reduced emissions.
Stage of acceptance	This concept is a generally accepted practice in the industry.
Resources	Determination of formulas from "Theoretical/Best Practice Energy Use in Metal casting Operations," May 2004, Page 52, Table #30

Convert shell sand to cold-box core making

Best Practice	Use existing metal-shell core boxes in a cold-box process. Cold-box processes include sulfur dioxide (SO_2), dimethylethanolamine (DMEA), carbon dioxide (CO_2) and ecolotec.
Primary area/process	Core making department.
Productivity impact	Production increases can be as high as 300%.
Return on investment	See "Converting Shell Sand to Cold-Box Core Making" in Appendix X.
Energy savings	Estimated to be 1.7 Btus per pound (lb) of shell sand. One therm is saved for every 60,000-lb reduction in shell sand.
Applications and limitations	About 90% of all shell cores can be converted. The problems encountered include finished core size and pattern shop revisions to alter the boxes for the difference in sand conditions. Cores with very thin sections are not good candidates for conversion. Some customer specifications may require the shell process due to dimensional tolerances and surface-finish requirements.
Practical notes	Client specifications requiring the shell process may hinder this opportunity.
Other benefits	The release of certain toxic chemicals is eliminated. Employee safety is enhanced by reducing the exposure to burns from hot boxes and cores.
Stage of acceptance	Practiced in many plants and widely accepted when customer specifications and tolerances allow the conversion.
Resources	"Foundry Energy Conservation Workbook," Fall 1990

Reduce time induction furnace cover is open

Best Practice	Reduce heat loss by reducing the time the furnace cover is open. The molten-metal bath temperature is about 2,800°F, which can result in a significant amount of heat loss through radiation-heat transfer if not addressed.
Primary area/process	Melting department.
Productivity impact	None
Return on investment	Immediate
Energy savings	A 12-ton furnace loses 14 kWh for each minute the furnace cover is open. The heat-loss impact on larger furnaces can be extrapolated from this value.
Applications and limitations	This best practice is useful in any furnace operation. Discipline to maintain the practice over time is the greatest challenge.
Practical notes	Because this is an operational best practice, it is susceptible to creeping divergence away from the practice over time.
Other benefits	None
Stage of acceptance	Well established in many metalcasting operations.
Resources	“Theoretical/Best Practice Energy Use in Metal casting Operations,” May 2004, Section 2, Page 24, Recommendation #2

Optimize induction furnace tap temperature

Best Practice	Minimize the tap-out temperature to more closely match the final pouring temperature into the mold. This can be accomplished by closely monitoring the furnace temperature, metal-transfer distances and improved ladle insulation.
Primary area/process	Melt department and metal pourers.
Productivity impact	Heating metal to a lower temperature should require less time.
Return on investment	Immediate
Energy savings	This practice saves 13.15 kWh per ton poured for every 100°F reduction in tap temperature.
Applications and limitations	This practice applies to most metal pouring applications. In cases where there are multiple pouring locations requiring differential metal temperatures, the practice may not be beneficial due to potential scrap increase.
Practical notes	Accurate temperature measurement is required for this measure. One technology–infrared temperature measurement—has been available for many years. However, its cost and implementation have been barriers to its application by the metalcasting industry. Most metal casters use the dipstick method to measure temperatures.
Other benefits	None
Stage of acceptance	Accepted as beneficial, though implementation is hindered by lack of accurate temperature monitoring.
Resources	Energy (kWh) savings from "*Theoretical/Best Practice Energy Use in Metal casting Operations*," May 2004, Page 15, Table 12. Infrared technology from Land Co. (www.landinst.com)

Clean foundry returns to minimize melt energy

Best Practice	Clean foundry returns and gating systems to remove mold sand prior to melting. This is accomplished by shot blasting. This sand contaminant consumes melt energy, which is lost when the sand contaminant is removed as slag.
Primary area/process	Casting, finishing, molding and melt departments.
Productivity impact	The additional effort to clean the castings will be offset by a reduction of slag removal and reduced scrap.
Return on investment	Immediate. Assuming 150 lbs of sand can be eliminated per shift, the annual cost reduction will be approximately $2,500.
Energy savings	Heating sand requires twice as much energy per unit of weight as heating metal. Energy savings can be estimated by estimating the weight of sand currently introduced into the furnace. The energy saved equals the energy it takes to melt twice the same weight of metal.
Applications and limitations	Applies to all induction-melting operations except for those outsourcing cleaning and finishing.
Practical notes	Throughput restrictions in the casting and finishing areas often limit implementation of this practice.
Other benefits	Reduction of slag.
Stage of acceptance	Known and accepted by most foundries.
Resources	“*Theoretical/Best Practice Energy Use in Metal casting Operations*,” May 2004, Page 42

Use cleaned dust-collector air as makeup air

Best Practice	Take advantage of improvements in dust collection, air cleaning and air-quality sensing to recycle treated air for facility makeup air during heating months. Energy is saved by reducing the amount of outdoor air required to be heated for building conditioning.
Primary area/process	Duct-collection systems in the finishing and molding areas.
Productivity impact	None
Return on investment	2 to 4 years
Energy savings	Each 1,000 CFM reduction of outdoor air saves $1.40 per year.
Applications and limitations	Air contaminated with toxic fumes is not a candidate for particulate cleaning and recirculation.
Practical notes	The energy savings do not occur if the facility does not also reduce the amount of incoming outdoor makeup air.
Other benefits	Potential for reduced maintenance of makeup heaters.
Stage of acceptance	Acceptance has grown as more data has become available showing air can be cleaned to quality necessary for use as makeup air.

Mull to energy

Best Practice	Convert from a time-based mulling cycle to basing mulling time on when the maximum strength of that batch is achieved.
Primary area/process	Sand preparation.
Productivity impact	Basing mulling time on when maximum strength is achieved will produce a more consistent, better quality sand. Mulling times can be decreased by 45% or more. Reducing sand-related scrap will improve man-hours per unit of castings.
Return on investment	Depends on the length of time the mulling cycle has been reduced and the reduction in sand-related scrap.
Energy savings	Determined by the reduction in mull time per batch.
Applications and limitations	Does not replace the existing control scheme. It is added to the existing control logic.
Practical notes	Final mull time will be determined by maximum strength or the preset mull time, whichever occurs first.
Other benefits	Additional sand capacity can be a benefit as overall mull time is reduced. Mold lines with multiple mullers have experienced the ability to eliminate the operation of one of the mullers, which reduces muller maintenance. Additional energy savings will result from the reduction of sand-related scrap. Reduction in scrap results in less metal being melted and decreased kWh/unit of castings shipped.
Stage of acceptance	Gaining acceptance by facilities experiencing increased sand quality and reduced sand-related casting scrap.

Advanced oxidation green sand and dust reclamation

Best Practice	A green sand and dust wet-reclamation process strips the bond from the silica grains to create a rich methylene blue (MB) clay slurry known as blackwater. Advanced oxidation processes clean the surface of the silica sand and the bond. Blackwater then replaces the city water addition in mullers, mixers, coolers, etc. Silica sand processed by the system is then added to the sand system or processed further for use in the core room.
Primary area/process	Sand system.
Productivity impact	Sand throughput is increased because bond is being added in wet rather than dry and therefore takes less time to activate and develop strength. Sand throughput is optimized further if processes are implemented alongside mull to energy-control system at muller.
Return on investment	1 to 2 years
Energy savings	On-site energy savings are realized by decreased sand-related scrap. Reduction in scrap results in less metal being melted and decreased kWh/unit of castings shipped.
Applications and limitations	Bond recovery can be realized from reclamation of bag-house dust or excess green sand from the sand system. Green sand reclamation offers the opportunity for silica sand recovery and increased bond reductions but requires more capital and a larger equipment footprint. Recovery from dust and sand can be implemented in stages. The amount processed is limited by the water required to process green sand.
Practical notes	The process is integrated into the facility’s existing sand processing and waste disposal systems. Equipment locations, material flows and bond content of various waste streams have a significant impact of system design.
Other benefits	Reduces premix clay usage by 20% - 40%, sand-related scrap, hazardous air emissions and solid waste.
Stage of acceptance	Several facilities in Wisconsin have been operating systems for more than 10 years.

APPENDICES

Appendices

Appendix A

Appendix B

Appendix C

Appendix D

Appendix E

Appendix A

Industrial support system best practices

The following are key energy best practices for common supporting systems in industrial facilities. Contact Focus on Energy for more information on these best practices, free technical support to estimate the best practice energy savings for your systems and possible financial incentives.

Compressed air	• Reduce system pressure • Repair leaks • SS vs. TS	• Variable inlet volume • Variable speed control • Energy-efficient motor
Lighting	• Light meter used to verify levels • LED lighting • Occupancy sensors • Lights off during process shutdown	• Task lighting is maximized • Night lighting is turned off • LED exit signs
Motors	• Premium efficiency motor vs. repair • Cogged belts vs. V-belts	• Premium efficiency motors specified on new equipment
Pumps	• Trim impeller to meet maximum load • Use variable speed drive (VSD) instead of throttled control • Use VSD instead of bypass control	
Area comfort heating	• Reduce waste heat • De-stratify heated air in plant • Control heating to desired temperature • Use infrared heating	• Optimize cubic feet per minute air exhausted • Automatic temperature control • Minimize heat to storage areas
Comfort cooling	• Install removable insulation • Minimize unnecessary ventilation • Minimize moisture released	• Higher efficiency air conditioning • Optimize room air temperature
Dehumidification	• Reduce humidity load • Accurately controlling humidity • Optimize ventilation	• Desiccant dehumidification • Minimize reheat energy
Refrigeration	• Thermosiphon • Evaporator fan control • Floating head pressure • Scheduled maintenance – Clean filters – Low refrigerant charge	• Automatic air purge • Recover flash steam

Steam systems	• Reduce steam pressure • Steam trap maintenance • Minimize blowdown • Insulate pipes	• Improve boiler efficiency • Heat recovery for boiler blowdown • Increase condensate return • Stack economizer
Ventilation	• Direct fired makeup units • Better ventilation management	• De-stratified air
Wastewater	• Fine-bubble diffusers • Automatic controlled DO sensors/VSDs	• Heat recovery on anaerobic digester • Unneeded aeration basins are shut off
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	• Use VFDs • Float head pressure • Use of free cooling (fluid cooler) • Use of free cooling (cooling tower)	• Match chilled water pumps • Insulate pipes and vessels • Process to process heat recovery
Process heating	• Optimize combustion air fuel ratios • Preheat combustion air • Insulate pipes and vessels • Schedule cleaning of heat exchangers	• Condensing heat recovery • Process to process heat recovery • Ultra-filtration for condensation
Vacuum	• Optimize total cost for conveying • Choose appropriate vacuum pump	• Optimize vacuum pressure • Eliminate vacuum leaks

Appendix B

Metalcasting energy performance benchmark data

The following tables are taken from the US Department of Energy report, Theoretical/Best Practices Energy Use in Metal casting Operations, J.F. Schifo and J.T. Radia, 2004. The tables provide average energy use for different metalcasting operations. The facilities selected for the sampling do not necessarily represent optimum energy use for these groups. The table values are for entire facility use, including electricity and natural-gas use.

Table 1: Cast-iron foundry energy use per shipped ton

PROCESS TYPE	IRON TYPE	ELECTRICITY (KWH/TON)	NATURAL GAS (THERMS/TON)	COKE (MMBTU/TON)	TOTAL (MMBTU/TON)
Cupola*	Gray iron	6,061	23.69	51.00	95.84
Cupola, green-sand molding	Gray iron	4,065	10.69	38.43	64.24
Cupola, green-sand molding	Gray iron and ductile	5,240	11.48	43.15	73.21
Cupola, green-sand average	Gray and ductile	8,862	49.17	53.31	133.61
Gray-iron cupola average		**6,993**	**32.23**	**48.75**	**105.69**
Induction*	Gray Iron	34,573	58.90		176.87
Gray-iron average**		**20,782**	**45.56**	**24.38**	**141.28**
Cupola*	Ductile Iron	6,521	20.21	58.72	101.26
Cupola*, centrifugal	Ductile pipe	1,342	26.48	27.87	59.82
Cupola, centrifugal	Ductile pipe	1,709	31.17	27.37	65.4
Ductile pipe avg.		**1,527**	**28.83**	**27.62**	**62.61**
Induction*	Ductile Iron	25,037	59.70		145.13
Induction green-sand molding	Ductile-d	15,911	18.01		72.30
Induction green-sand molding	Ductile-d	16,391	16.24		72.17
Ductile-d average		**16,151**	**17.13**		**72.24**
Ductile average		**20,594**	**38.41**		**108.68**

*Participated in “Energy Use in Selected Metal Casting Facilities,” DOE, 2003(2). Other facilities did not directly participate in the study.

**Cupola melt shops shipments at 62% and induction melt 38% per modified numbers from EPA-453/R-2-013.

Table 2: Steel-foundry energy use per shipped ton

PROCESS TYPE	NATURAL GAS THERMS/TON (BTU X 10^5)	ELECTRICAL (KWH/TON)	TOTAL (BTU X 10^5)/TON
Induction melt, stainless, airset molding*	267	65,706	491
Arc melt, low carbon, green sand and airset*	115	27,021	207
Induction melt, low carbon, airset*	104	20,193	173
Average steel (used only low carbon)	**109**	**23,607**	**190**

*Participated in "Energy Use in Selected Metal Casting Facilities," DOE, 2003(2). Other facilities did not directly participate in the study.

Table 3: Aluminum-foundry energy use per shipped ton

PROCESS TYPE	NATURAL GAS THERMS/TON (BTU X 10^5)	ELECTRICAL (KWH/TON)	TOTAL (BTU X 10^5)/TON
High-pressure die casting*	253	19,346	319
High-pressure die casting, automotive*	117	58,380	316
High-pressure casting average	**185**	**38,864**	**317**
Permanent mold, sand casting**	598	35,526	719
Lost foam, automotive*	552	55,217	741
Adjusted lost foam, automotive	313	55,217	502
Estimated non-automotive lost foam	211	51,853	388
Lost foam average	**245**	**52,972**	**426**

*Participated in "Energy Use in Selected Metal Casting Facilities," DOE, 2003(2). Other facilities did not directly participate in the study.

Appendix C

Savings calculators

Converting shell sand to cold-box core making

In this best practice, the metal caster converts hot-box phenolic-resin cores (shell process) to a cold-box process requiring no natural gas in the curing process. This conversion can be done to most cold-box processes, including CO_2, SO_2 and DMEA catalyzed resins. The conversion depends on customer specifications, core configuration, surface-finish demands and the quantity of cores required.

EXAMPLE: The metal caster decides to convert as many shell boxes to the SO_2 process as possible. After the conversion, shell sand purchases are reduced by 80,000 lbs. of shell sand per month. While the energy reduction is small, the productivity improvement is significant and should be calculated separately.

	EXAMPLE	YOUR DATA	
Monthly shell-sand reduction (lbs)	80,000		From foundry records
Annual shell-sand reduction (lbs)	960,000		Monthly x 12
Natural gas saved per lb (Btus)	1.70	1.70	
Annual energy savings (Btus)	1,632,000		Annual reduction x 1.7
Conversion factor (Btus per therm)	100,000	100,000	
Annual savings (therms)	16.32		Annual Btu savings / 100,000
Cost per therm	$0.80		From foundry records
Annual savings	$13.06		

Note: This calculation does not include the production increase resulting from the reduced heating time for the elimination box. The ancillary energy savings from lower space heat and lighting requirements due to reduced production time is also not included in the calculation above.

Optimizing induction furnace tap temperature

Metal casters frequently overheat the induction furnace by as much as 100°F. This is sometimes done because of past practices to assure metal arrives at the pouring line sufficiently heated to avoid cold-iron defects. In many cases, chill iron is used to cool molten metal in the ladle prior to pouring to assure the temperature meets the quality standards specified for the casting. This causes production delays as well as additional temperature measurements.

EXAMPLE: An iron foundry discovers, through testing and analysis of temperature sampling, it is superheating the molten metal in the coreless induction furnace an average of 60°F every time they tap metal from the furnace. By reducing this superheating of the molten metal an average of 60°F, the resulting reduction in energy consumption is determined.

	EXAMPLE	YOUR DATA	
Average °F overheated	60		
Furnace capacity (tons)	9		
Number of heats per shift	20		
Shifts per day	2		
Operating days per year	240		
Number of heats per year	9,600		Heats per shift x shifts per day x operating days per year
kWh required to melt 1 ton by 1°F	0.1315	0.1315	Constant (kWh/°F/ton)
kWh required for overheat per degree per ton	7.89		°F overheated x constant capacity (tons) x number of heats per year x kWh required to overheat furnace iron = annual kWh saved
Annual kWh required to overheat furnace iron	681,696		
Cost per kWh	$0.06		
Annual energy savings	$40,901		Annual kWh saved x cost per kWh

Appendix D

Metal and energy savings potential

The attached tables present projected metal and energy savings for all metals and processes.

1% yield improvement for various existing process gross yields

						ENERGY SAVED PER CAST TON (BTUs*)						
						IRON	ALUMINUM MELT**					
PERCENT YIELD		TONS MELTED****		TOTAL MELT SAVINGS [TONS]	SAVINGS/ TON MELT [TON]		REVERB WET		REV – DRY	CRUCIBLE		CORELESS INDUCT
PRESENT	PROPOSED	PRESENT	PROPOSED				GAS (THERMS)	ELE (KWH)	GAS (THERMS)	ELE (KWH)	ELE (KWH)	ELE (KWH)
45%	46%	22,222	21,739	483	0.048	57,488	130,435	70,386	106,280	458,937	85,749	70,386
50%	51%	20,000	19,608	392	0.039	46,667	105,882	57,137	86,275	372,549	69,608	57,137
55%	56%	18,182	17,857	325	0.032	38,636	87,662	47,305	71,429	308,442	57,630	47,305
60%	61%	16,667	16,393	273	0.027	32,514	73,770	39,809	60,109	259,563	48,497	39,809
65%	66%	15,385	15,152	233	0.023	27,739	62,937	33,963	51,282	221,445	41,375	33,963
70%	71%	14,286	14,085	201	0.020	23,944	54,326	29,316	44,266	191,147	35,714	29,316
75%	76%	13,333	13,158	175	0.018	20,877	47,368	25,561	38,596	166,667	31,140	25,561
80%	81%	12,500	12,346	154	0.015	18,364	41,667	22,485	33,951	146,605	27,392	22,485

Based on casting 10,000 gross tons

*3,413 Btus = 1 kWh

**Energy values derived from “Theoretical/Best Practice Energy Use in Metal casting Operations,” Page 37, Table 19 and Page 15, Table 2

***Gross tons of castings represent the gross cast tons of production, before scrap

****Tons melted = the total melt required to cast the gross tons

Example: If ACME Iron Castings Inc. casts 10,000 gross tons at a current yield of 45%, they are melting 22,222 tons of raw metal. If ACME increases gross yield by 1% to 46%, the total melt is reduced by 483 tons—an improvement of 4.8% per ton melted. From the table, the net savings are 57,488 Btus.

Scrap reduction through improved mold design and process optimization

			ENERGY SAVED PER CAST TON (BTUs*)						
			IRON	ALUMINUM MELT**					
SCRAP REDUCTION	TOTAL MELT SAVINGS [TONS]	SAVINGS/ TON MELT [TON]		REVERB WET		REV – DRY	CRUCIBLE		CORELESS INDUCT ELE (KWH)
				GAS (THERMS)	ELE (KWH)	GAS (THERMS)	GAS (THERMS)	ELE (KWH)	
0.50%	50	0.005	5,950	13,500	7,285	11,000	47,500	8,875	7,285
0.75%	75	0.008	8,925	20,250	10,928	16,500	71,250	13,313	10,928
1.00%	100	0.010	11,900	27,000	14,570	22,000	95,000	17,750	14,570
1.25%	125	0.013	14,875	33,750	18,213	27,500	118,750	22,188	18,213
1.50%	150	0.015	17,850	40,500	21,855	33,000	142,500	26,625	21,855
1.75%	175	0.018	20,825	47,250	25,498	38,500	166,250	31,063	25,498
2.00%	200	0.020	23,800	54,000	29,140	44,000	190,000	35,500	29,140
2.25%	225	0.023	26,775	60,750	32,783	49,500	213,750	39,938	32,783

Based on casting 10,000 gross tons

*3,413 BTU = 1 kWh

**Energy values taken from “Theoretical/Best Practice Energy Use in Metal casting Operations,” Page 37, Table 19 and Page 15, Table 12

***Gross tons of castings represents the gross cast tons of production before scrap

Example: If ACME Iron Castings Inc. casts 10,000 gross tons and reduces total gross tons by 0.5% through scrap reduction, ACME will save 0.005 tons of metal and 5,950 Btus for each ton poured. If ACME is an aluminum caster and uses a reverb wet process, it will save 13,500 therms of gas and 7,285 kWh per ton poured.

Appendix E

Potential non-energy benefits of technical best practices

BEST PRACTICE #	DESCRIPTION	SIMPLE PAYBACK (YRS)	WASTE HANDLING	AIR EMISSIONS	WATER USE	WASTEWATER HANDLING	MAINTENANCE AND HOUSEKEEPING	RAW-MATERIAL USE	EFFICIENCY AND CAPACITY
1	Invert pouring ladles during preheat and standby	< 1	N	Y	N	N	Y	N	Y
2	Use exhaust to preheat combustion air	1-2	N	Y	N	N	Y	Y	Y
3	Use variable speed drives on variably loaded motors	Variable	N	Y	N	N	Y	N	Y
4	Recover exhaust heat	1-2	N	Y	N	N	Y	Y	N
5	Modulate electric-furnace exhaust	3-7	N	Y	N	N	Y	N	N
6	Improve mold yield to reduce amount of melted metal	< 1	Y	Y	Y	N	Y	Y	Y
7	Reduce scrap to reduce amount of metal poured	< 1	Y	Y	Y	Y	Y	Y	Y
8	Convert shell sand to cold-box core making	Variable	Y	Y	Y	Y	Y	Y	Y
9	Reduce time that induction-furnace cover is open	Instant	Y	Y	N	N	N	Y	Y
10	Optimize induction-furnace tap temperature	Instant	N	Y	Y	N	Y	Y	Y
11	Clean foundry returns to minimize melt energy	Instant	Y	Y	N	N	Y	Y	Y
12	Use cleaned dust-collector air as makeup air	2-4	Y	Y	N	N	Y	Y	Y
13	Mull to energy	Variable	Y	N	Y	Y	Y	Y	Y
14	Advanced oxidation green sand and dust reclamation	Variable	Y	Y	Y	Y	Y	Y	Y

N = No, it is very unlikely implementing the best practice will result in a non-energy savings or cost.
Y = Yes, there is a strong possibility implementing the best practice will result in a non-energy savings or cost.

Note: This table of potential opportunities came from the experience and consensus of 40 members of the Wisconsin metalcasting industry during a Wisconsin Cast Metals Association energy conference held in Stevens Point, Wisconsin, on May 24, 2006.

Notes

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