Sustainable Energy Efficiency

User Guide

EMERSON™

Energy Efficiency in the Process Industries

A User-guide to Sustainable Energy Efficiency

Revision 2.0

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EMERSON™

1. Introduction

1.1. Preface

The impact of energy efficiency on industrial process plant business performance continues to grow as companies attempt to reduce the energy component of their costs. This is compounded by the related factor of complying with ever stricter environmental and emissions constraints. Around the world, new legislation is driving new standards in industrial energy efficiency.

Managing and optimizing energy use is typically a tough and complex task, but it is one that almost certainly must be undertaken by everyone in the future. Experience has shown that to be successful over the long term, virtually all industrial sites must develop and administer an energy management system that is appropriate to that particular location and business. This provides the foundation for securing efficiency gains.

There is not a ‘one method fits all’ approach to implementing an energy management strategy for an industrial site. There certainly are, however, a set of best practices and known successful approaches to energy programs that can be leveraged in most every instance. This manual has been expressly developed to document a variety of these best practices in order to facilitate the initial creation or further development of energy management in the industrial process community.

1.2. Intended Audience

This guide has two prime readerships:
First, Operations and Technology Managers who wish to understand how current best practice can be put to use to develop a sustainable plan leading to long term energy efficient operation. It will also be of use to Corporate Energy Managers who are looking at developing a company-wide energy strategy.

Second, it is targeted at Energy Managers and Engineers who have been charged with bringing such a program into reality and need a framework around which to develop the detailed site initiatives, activities and projects.

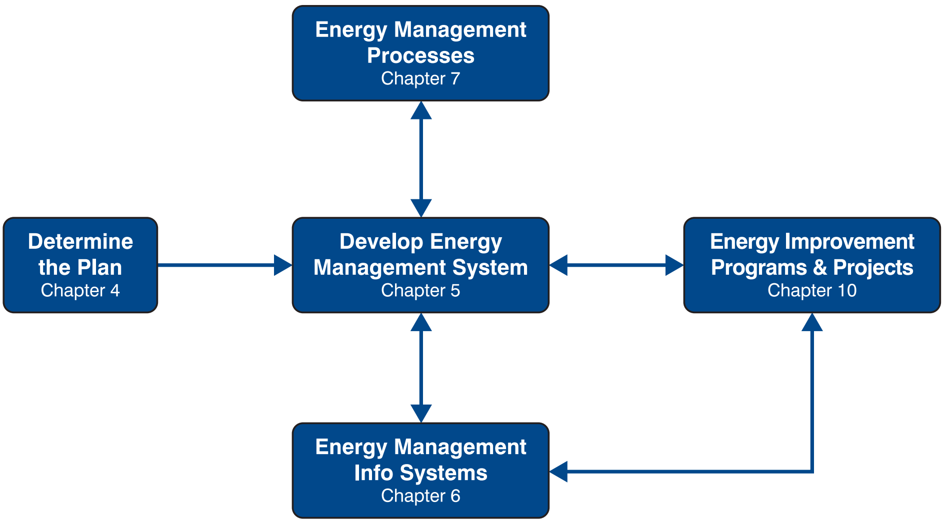
In developing this guide a mental model of a typical mid-range process or chemical site has been used. This will have a traditional well-known organizational structure – Site Management Team, Operations Department (perhaps several plants), Maintenance Department (perhaps a few zones), Technical Support, Finance, HR, IT, etc. This may or may not apply to the reader’s particular circumstances, but it is hoped to be a recognizable entity and that the reader can draw parallels with his/her own site and organization.

1.3. How to Use the Guide

The guide is not intended as a definitive recipe book. Local circumstances, business types and organizations will have a large influence in the actual practice employed. However the guide should enable a company or location to determine a credible framework in which to operate.

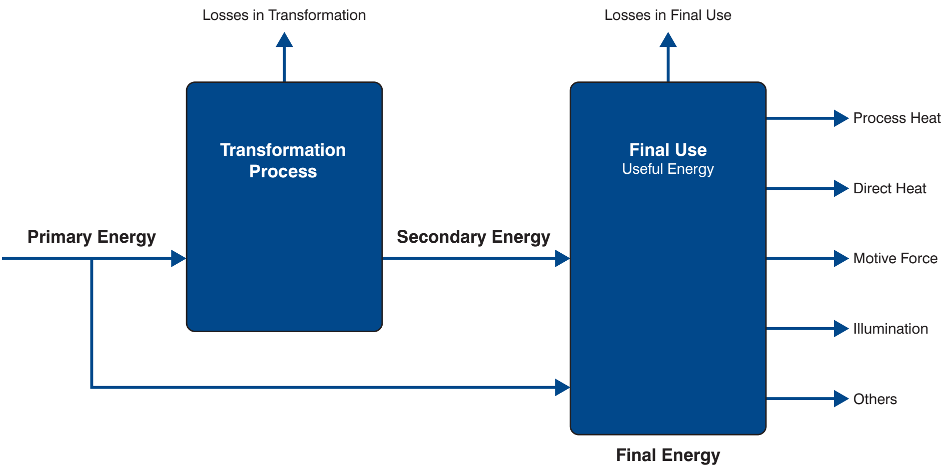
Chapters 4 to 8 form the core of the guide – assessing the energy issues on-site, developing an Energy Management System, building an Energy Management Information System and running audits and improvement programs. These can be read as a complete picture, particularly useful if the reader is coming from a site with no existing energy management structures in place. However the individual chapters are designed as far as possible to be stand-alone in their own right and can be read as such.

Alongside this are supporting chapters on energy efficiency techniques, financial benefits, case studies, and various detailed appendices.



2. Definitions, Acronyms and Terminology

The Concept of Industrial Energy Distribution:



BReF	**Best Available Technology Reference Documents.** Best practice documents prepared under the IPPC (European Integrated Pollution Prevention and Control Directive.
Carbon Trust	A non-profit company, established by the UK government that helps organizations reduce their carbon emissions and become more resource efficient. Its stated mission is to accelerate the move to a sustainable, low carbon economy and reinvests surpluses from its commercial activities to this aim.
Class of Energy	A generic descriptor for different types of energy used in manufacturing – fuel gas, electricity, steam, etc.
DCS	**Distributed Control System.** The generic name for a typical microprocessor-based control system used to control the production line in the process industries. The entire system of controllers is connected by networks for communication and monitoring.
EII	**Energy Intensity Index.** A benchmarking index, widely used in the Oil Refining Industry, which allows comparison for energy performance between sites and companies. Fundamentally an energy/feed ratio with many industry-specific corrections.

EMS	**Energy Management System.** A documented system of work processes which defines how a particular location will manage energy in an efficient manner (strategy, responsibilities, actions, checks).
EMIS	**Energy Management Information System.** The data storage and reporting system, typically part of the Process Historian, which provides energy data, calculations, reporting and the foundation for energy consumption analysis.
ETS	**Emissions Trading System.** A market-based approach using cap and trade methods to control greenhouse gases by providing economic incentives for achieving reductions in the emissions.
Energy Drivers	The plant variables (flows, temperatures) which have a direct impact on the energy consumption of a particular unit.
Energy Project Assessment	A detailed assessment of a unit energy performance leading to a set of priced and prioritized project recommendations.
Energy Walkthrough	A short assessment of a location's energy strategy, performance and outline scope for improvement.
HPS	**High Pressure Steam.** Typically the highest pressure level steam generated in the Boiler House on a manufacturing complex. Normally used for electricity generation in turbo-alternator sets.
ISO 50001	The International Standard for Energy Management Systems.
ISO 14001	The International Standard for Environmental Management Systems.
KPI	**Key Performance Indicator.** A calculated measure of performance for comparison and benchmarking purposes, e.g. tons fuel/ton feed processed.
LC(C)A	Life Cycle (Cost) Analysis. Economic project evaluation techniques which look to total costs and benefits and their phasing over the installed life of a project investment.
LHV	**Lower Heating Value.** The effective sensible heat available from a combustible fuel.
LPS	**Low Pressure Steam.** The lowest pressure steam on-site – produced as let-down from MPS consumers. Used for all general steam utilities, tracing, low temperature process users.
MPS	**Medium Pressure Steam.** Often produced as the let-down steam from electricity generation, MPS is used typically for drives, ejectors, and key processes uses needing a high steam condensing temperature.
Pinch Analysis	A methodology for minimizing energy consumption of process units by calculating thermodynamically feasible energy targets and achieving them by optimizing heat recovery systems, energy supply methods, and process operating conditions.
Plan-Do-Check-Act	The basic stages in the ISO series of Management Systems.
Primary Energy Conversion	The initial transformation of external fuels into energy streams, either directly to the process or in a boiler house/utilities complex.

Process Historian	A long term storage vehicle for process data (flows, temperatures), often integrated into the DCS. Allows easy data retrieval, report building, and calculations and programming using historical plant data. Nowadays accessed through Window/PC applications
SCADA	**Supervisory Control and Data Acquisition.** A form of computer control typically used for multiple sites and remote locations.
Secondary Energy Conversion	The subsequent utilization of energy already transformed into steam and electricity by the process.
Stoichiometric Combustion	The theoretical point at which exactly enough combustion air is provided to burn a given quantity of fuel. Below this point, partial or incomplete combustion takes place.
Utilities Systems	The generic term for the collection of plants, normally boilers and power generators, which provide site-wide common energy steams (steam, electricity, nitrogen, compressed air, etc.) for subsequent use by the processing units.
Wireless Technology	In this instance, the use of wireless technology to communicate between field instrumentation devices and control rooms, replacing the conventional 4–20mA wiring systems.

3. Current Energy Efficiency Challenges

3.1. Background

Energy saving initiatives in the Process Industry have had a checkered history. A regular part of industrial life, especially since the end of ‘cheap oil’ in the mid-1970s, the tools and techniques are well-known and can generate an attractive earning power. But Industry has not moved on to new higher levels of energy efficiency. Universal feedback from suppliers and customers points to issues surrounding the long term sustainability of energy improvement programs. Benefits erosion is common. Yet in simple terms, energy saving appears attractive with solid, understandable technology and good payback.

How does this come about?

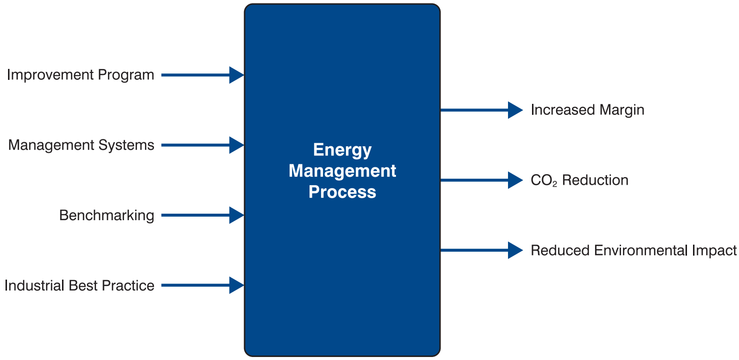
While single large capex items can make a structural change in energy performance (e.g. installation of a co-gen unit) a plant’s energy performance is generally driven by a large set of (sometimes conflicting) factors:

- Adherence to operational targets
- Maintenance activities (equipment efficiency and reliability)
- Employed technology
- Design standards
- Culture and competency
- Balancing yield/margin/energy

There is no single factor that ‘sets’ energy. Operating environments continually change. Energy efficient operation requires continual attention to all these factors. As a result, energy has often ‘slipped through the gaps’ and has deteriorated at the expense of short term gains and budgetary pressures. This was not helped by low energy prices in the early 2000s. Priorities were elsewhere.

There is no magic ‘silver bullet’. Sustainable energy efficiency requires a combination of technology plus procedural and housekeeping approaches and is being encapsulated in the new standards on energy and emissions management (e.g. ISO 50001). Detailed point solutions are typically simple and well-known, but the overall management is a more complex picture.

Fundamentally it is a control problem; at management level – using process data to analyze performance and drive improvement, and at operational level – using modern control techniques to operate closer to (energy efficient) constraints. Accurate, reliable plant energy measurements plus a Distributed Control System and Process Historian provide the foundation to build a consistent approach to energy management.



This must be complemented by systematic management to ensure long term sustainability and drive improvement. This sets the entire corporate framework in which the differing levels of control operate. ISO 50001 specifies requirements for an organization to establish, implement, maintain, and improve an Energy Management System. It applies to all aspects affecting energy use which can be monitored and influenced by the organization.

The key approach is adopting a fit-for-purpose vision, which defines the aims and provides the basic checks on management commitment and organization together with a step-by-step approach to operational improvement:

- Review current energy management effectiveness
- Define management responsibilities
- Develop simple performance review
- Identify and implement initial low level applications, and quick wins
- Review and improve

The picture emerges of high quality process energy measurements, archived in a site-wide process historian, accessed through user-oriented (PC) interfaces. Modern control, modeling and data analysis tools utilize this data. New measurement techniques (e.g. wireless technology) allow easy access to energy variables which were traditionally excluded from plant instrumentation. Surrounding this is a formalized management process which determines the accountabilities and processes to ensure continuous performance appraisal and improvement.

This then provides the environment for sustainable energy projects and improvement programs. Audits, plant assessments, opportunity developments, and capital projects can proceed with a foundation that will address the on-going support and assessment needed to ensure continual generation of benefits.

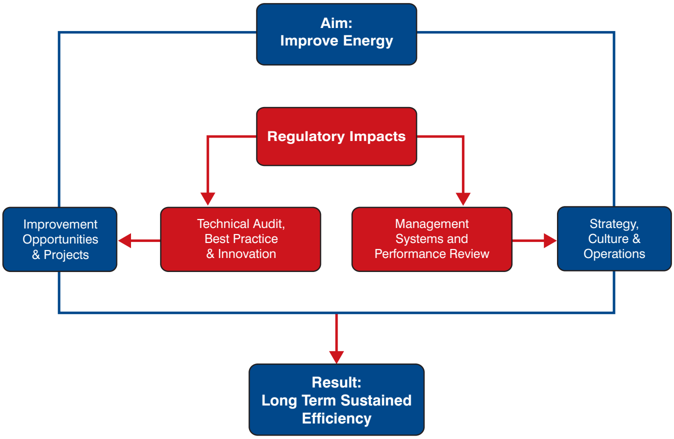
3.2. Process Industry Potential

In a future of uncertain energy supplies, volatile prices, and continuing focus on emissions, managing the efficient energy consumption of industrial plants has to become an important 'must do' activity. This complexity and uncertainty means that carbon, climate change, and energy efficiency are becoming important board level issues with key impacts on competitiveness, product strategies, brand, and reputation. It can be foreseen that industrial attitudes to energy efficiency could be transformed in a similar way to that of health and safety.

Industrial energy efficiency is influenced by a wide variety of factors in all aspects of operation – technology, maintenance activities, operational excellence, design, skills, competencies, and training. While industry has undertaken a variety of energy saving initiatives over many years, they have shown varied success and, historically, problems of sustainability have been reported. Efficiency gains have failed to be sustained as long term energy savings. This is a reflection of the complexity of this multifaceted problem and an inconsistent historical focus on energy in the light of varying energy costs and shifting industrial priorities over time.

Fundamentally, to successfully maintain long term energy savings, it is necessary to address the core issues of energy strategy and management within an industrial organization. The priorities need to be raised and energy issues embedded across all levels of an organization. Are the accountabilities, processes, and practices in place to ensure the long term realization of the energy saving initiatives? These provide the backbone to the successful realization of technological improvements.

4. Developing the Way Forward



Traditional energy improvement projects have concentrated on the technology – typically some form of energy audit/opportunity identification coupled with a project implementation. Perhaps run as a turnkey project. As has been discussed, there have been issues with continued operation and sustaining long term energy savings. It can be treated as a solution in isolation and the more complex issues in the operational environment that surround the application are not addressed. Focus can be lost. Similarly, auditing and energy project identification can be a sterile activity producing a 'shopping list' of projects which stand little chance of successful realization if there is no clear strategy, organization, and commitment to seeing them through.

Thus when a process plant or company embarks on a program aimed at improving its energy efficiency performance a wider picture has to be addressed for these and other reasons already outlined in section 3. Best practice, technology and projects need to be exploited in an environment which addresses the company energy strategy and ensures that all the supporting elements of that strategy – the Energy Management System – are in place. Without this approach there is a clear risk that well-earned efficiency gains can fade and efficiency opportunities will not be picked up. Improvement methodologies such as ISO 50001 recognize this and promote both technical auditing and opportunity identification as well as supporting the introduction of Energy Management Systems.

These complementary issues will be picked up in the forthcoming chapters.

4.1. The Overall Program

The scenario that will now be presented assumes the case of a typical manufacturing site that wishes to establish a sustainable energy efficiency program. This may have been driven by one of several reasons – some competitive benchmarking, a corporate initiative, an analysis of operating costs which highlighted energy costs, or something as simple as a new manager bringing in external experience. Anyway, the site wishes to embark on an energy improvement initiative.

Of course all sites are different and some may be driven by certain dominant considerations – a constrained utilities network, a particular fuel supply, local emissions regulations, etc. The specific detailed solutions to those are beyond the scope of this work, however the overall approach to the improvement program is common to all and sets the scene from which to tackle the local issues.

In general the program will be built around the following basic elements:

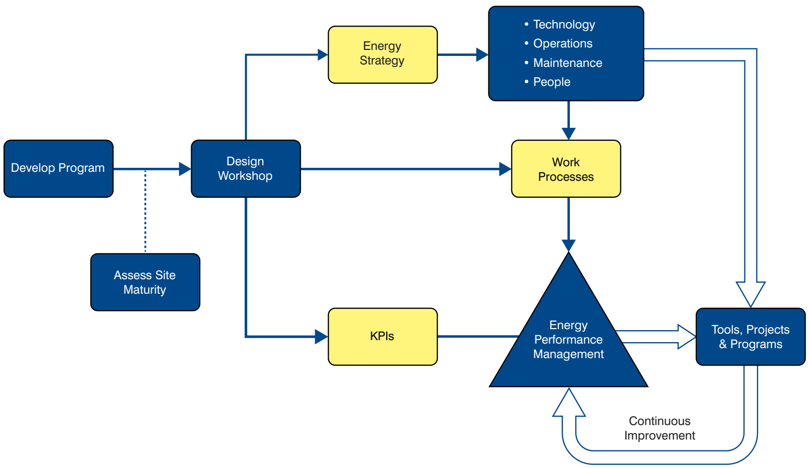
- Capital investment on energy saving technology
- Plant change and operational excellence items
- Systems for energy management (strategies, organization, processes, competencies)
- Energy reporting and analysis tools (metrics, targets, reports, etc.)

Depending on the maturity of the site, more or less of these may be in place or partly developed.

The aim of the exercise is to establish the correct foundation of management systems and supporting tools which then enables improvement and investment programs and activities to be developed and executed in a sustainable and profitable manner. All carried out under an agreed clear strategy and vision for site energy performance.

The overall process is as follows:

1. Assess site’s energy performance and priorities
2. Develop strategy
3. Develop management systems and tools
4. Kick-off energy improvement audit, identify projects, and implement



Ideally, a full improvement process and project roll-out program should materialize as a natural consequence of the EMS and strategy, however it can be desirable to start a ‘quick wins’ program of projects at an early stage to gain results momentum and buy-in from good speedy successes.

4.2. Assessment of Site Energy Maturity – the Initial Health Check

In developing the energy program, a key first step is an initial assessment of the energy priorities and also the maturity of a manufacturing site's energy management. Typically a short (2–3 day) walkthrough exercise by an experienced energy management specialist can suffice. This will be used to shape the roll-out and priorities of the program.

Inputs to this process will be:

- Interviews with key management and operational staff
- Benchmarking and historical performance data
- Review of future energy constraints, external business drivers, and expected impacts
- Completion of maturity assessment (e.g. Carbon Trust model)

The aim is to understand the site's energy maturity and be able to design and shape the program. A typical health check assessment agenda and data request form is given in Appendix B.

Outputs of the assessment will be:

- Understanding of key energy issues and opportunities facing the site
- Basic map of energy utilization across the site
- Understanding of constraints and drivers affecting future energy efficiency strategy
- Extent of, and strengths and weaknesses of the site's current energy management processes

This should be in sufficient detail so as to be able to design an outline improvement program and, importantly, scope the design workshop so as to best reflect the key elements of the site situation.

The maturity assessment is a powerful tool in understanding how advanced a site's strategic and organizational attitudes are towards energy management. Various models are available, although most are variations on the same basic theme. Examples include the Carbon Trust model[1] and also the Energy Star Plant Managers Guide[2]. Appendix B shows the Carbon Trust maturity matrix. The results of the assessment will play an important role in determining the improvement program priorities and also the design/evaluation of the site Energy Management System (see section 5.2).

Both guides give more comprehensive guidance on how to use the assessment methodology and develop the programs.

1. Good Practice Guide: A Strategic Approach to Energy & Environmental Management. The Carbon Trust, GPG376.
2. An Energy Star Guide for Energy & Plant Managers. Berkeley National Laboratory, LBNL-56183.

4.3. Energy Program Skills and Resources

Two positions are essential to any energy improvement program: a sponsor on the site management team and a (full-time) Program Manager. These will lead implementation activity (full-time or part-time) supported by specialist resources on an as-needs basis. Beyond the implementation program the position of Site Energy Manager is a key long-term requirement.

The Management Team representation is vital to ensure that the inevitable cross-departmental issues and priorities that any energy program inevitably raises are resolved at the right level. It also promotes the correct gravitas and commitment to the program and should be maintained in the long term as a permanent responsibility (e.g. *Refer to Maturity Assessment Matrix in Appendix B*).

The Program Manager's role is to run the program on a day-to-day basis and deliver the changes. Whether this is a single role or running a team on a larger project will vary depending on the scale of activities.

Implementation Team core skills:

- Process engineering
- Operations management awareness – how does the site operate, understanding the responsibilities, information flows with lines of communication, and delegation
- Basic control and instrumentation knowledge
- Appreciation of business economics and scheduling
- Program management, project planning

Specialist areas (access on an as-needs basis):

- Utilities engineering
- Process specialists
- Combustion design and operation
- Heat transfer (e.g. Pinch technology)
- Power generation
- Compressed air
- Turbine specialist
- Advanced control and optimization
- Measurement specialist
- Process and statistical modeling

Operations Team representative

Particularly on larger projects an Operations Team representative is an important role. Perhaps a training foreman or a day operator, he/she can impart vital local operational knowledge and act as a guide and conduit for communications between the energy team and the plant.

Site Energy Manager

All organizations should have an Energy Manager or focal point as a permanent position with the following key responsibilities:

- Site performance monitoring and communications
- Owner of site energy data and records
- Initiation and tracking of energy improvement programs and initiatives
- Technology and good practice gate-keeping
- Site Energy liaison to external bodies (corporate, institutions)
- Owner of ISO 50001/EMS system

This position should be sufficiently senior in the organization to be able to communicate with and influence plant and departmental managers. There should be a clear link through to the Site Management Team representative.

5. Core Operation – The Energy Management System

Energy management forms the framework for an organization's energy decision-making – it is the glue that provides consistency and focus to this multifaceted problem which otherwise can prove difficult to address by normal operational structures. In developing an EMS the most important consideration is that it should be 'fit for purpose'. There is no one-size-fits-all. It must be a reflection of the facilities, priorities, strategy, and culture of the site or company in question.

In essence an Energy Management System is a documented description of how energy is managed at that location/company. It includes strategy, accountabilities, processes to be followed, and means of checking that the processes are adhered to. Typically it may follow the well-known Plan-Do-Check-Act philosophy that is encapsulated in the various ISO management models. Generally a set of tools and reports of energy and related parameters (the Energy Management Information System) support the management process (e.g. providing specific energy consumption data for performance review).

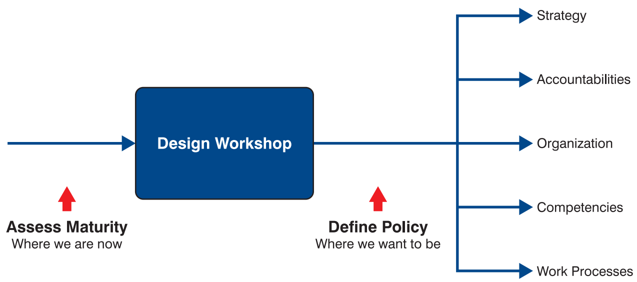
Reports such as ARC Advisory Group's 'Best Practices for Energy Management' (January 2009) highlight how the leading energy efficiency performers all adopt such an approach with clear understanding of strategy, accountabilities, and competencies, while applying work practices and technical solutions.

The following chapters provide guidance in establishing an energy management strategy and Energy Management Information System (EMIS). ISO 50001, the International Standard on Energy Management, can provide a useful framework for such developments and this is addressed in section 5.2. Accreditation to ISO 50001 also provides the compliance discipline and external recognition that some organizations may require. But this is by no means a mandatory step.

5.1. Developing an EMS

The prime elements in developing an EMS are:

1. Understanding how energy is currently managed
2. Developing an agreed vision of how energy will be managed in the future
3. Determining the actions to get there – defining the processes
4. Execution



While there are different ways to go through this, in the author's experience an EMS Workshop has proved to be the most efficient way to mobilize the process.

5.1.1. The EMS Design Workshop

The EMS Design Workshop defines the aims and outcomes of the EMS. Its outcome will be the basis of design for the system. It is essentially a team-oriented organization and process design process. Different companies and locations may have their own structured problem solving techniques which are used in such situations, in which case they should certainly be used.

5.1.1.1. Timing and organization

Typically a 1 to 2 day workshop would be sufficient, ideally held at an off-site location. It is best that the Energy Maturity Survey (section 4.2) has been carried out first and the results circulated to attendees. In preparation, the attendees should think about how their current position and how energy consumption is affected by the job/discipline they work in. A clear set of aims and outcomes for the workshop needs to be developed in advance.

5.1.1.2. Attendees

The aim is to get a cross-section of people who represent areas of the company which influence how energy is consumed by the operation. A key outcome will be arriving at a consensus as to how energy is managed and how this could be improved, so full representation is important.

Suggested attendees (for a fictitious typical manufacturing site):

- Site Management Team member with nominated energy responsibilities
- Energy Manager/Coordinator
- Operations Manager
- Process Engineer
- Operations representative(s)
- Maintenance Engineering representative(s)
- Planning/Scheduling
- Utilities Manager/Engineer
- Corporate Energy Focal
- Training Coordinator
- Finance/auditing/QA/data management
- External facilitator
- Other specialist engineers/roles as appropriate to the facilities

5.1.1.3. Agenda

Suggested items for the workshop agenda could include the following. These are suggested as topics for debate which may be for the whole team or break-out/syndicate groups. Not all will apply and there may be others, however the main strand is arriving at a consensus as to the current energy operation and for the workshop to have articulated the issues that need addressing (perhaps including suggested solutions) in the design of the EMS:

- Review of current energy performance
- The case for change
- How does the site/company manage energy now?
- Map out current energy planning and performance review flow chart
- Current blocks to good energy efficiency practice
- Future energy environment and constraints affecting it
- Describe good practice in 5 years' time: operations, technology, maintenance, people, etc.
- Identify new work practices and responsibilities
- How does the site energy operation fit into the bigger corporate model?
- Energy measurement and information structures
- ISO 50001 familiarization and requirements
- Competencies and training issues
- How to address wider engagement with the site community on energy Issues
- Take-away actions

5.1.1.4. Outcomes

The style and operation of the workshop will depend on local company culture and practices. **However the basic aim is to come away with a clear understanding of the current energy operation and the issues that need to be addressed to meet future business and corporate environments and constraints.** This will then feed the design of the individual EMS components. This design work may be done by a dedicated team or (partly) by subgroups with take-away actions from the workshop.

5.1.2. Basic Components of EMS – 'Essential Best Practice'

A comprehensive system following ISO 50001 can be developed, and reference is made to sections 5.2 and Appendix A should the user wish to go down this road. Otherwise the following areas comprise the core elements of 'Essential Best Practice' which any organization wishing to establish effective energy management activities should address.

5.1.2.1. Policy and Strategy

The Energy Policy provides the framework and environment to everything that follows. It is the mirror that should be used for testing energy activities and plans. There may be a Corporate Energy Policy that should be followed. It may need developing from scratch.

Policy Issues to be considered include:

- Long term energy targets
- Industry positioning (e.g. top quartile performer)
- Capital Investment Policy for energy
- Inviolable constraints to operation (e.g. a no-flaring policy)
- Business policies (e.g. to be robust from effects of local power supply irregularities)
- Staff competency and communication standards
- Working practice standards – safe operation – legal requirements
- Wider community targets and aspirations

Once the Policy is established, it invariably leads to the strategy document and the subsequent action plans. The strategy articulates the steps needed to achieve the policy and the subsequent action plan is the detailed realization of this.

In developing a site energy strategy it is vital that all relevant parts of the organization are addressed. We have seen that there are many influences on energy consumption, and hence to ensure sustainability, these must be reflected in the strategy. It is recommended that each major activity should be reflected in this to ensure cross-site recognition of the energy drivers. Typical of the issues that could be addressed are:

Site:

- Overall site energy targets and development of site roles and responsibilities for energy
- Key links to corporate energy strategy
- Major energy project delivery goals
- Community issues
- Financial provisions for energy
- Procurement standards
- Registration to ISO 50001

Operations:

- Development of target setting and performance review processes (EMIS)
- Key operational changes (e.g. removal of high sulfur fuel)
- Development of operational energy roles and accountabilities
- Targets for energy-related operational procedures (e.g. sootblowing frequency/operator rounds)
- Use of energy check lists

Maintenance:

- How do maintenance and availability activities affect energy consumption?
- Planning of contracts for servicing and cleaning
- Development of register and strategy for energy critical equipment
- Steam leaks, traps, and lagging
- Equipment condition and performance monitoring strategies

Technology:

- Energy efficient design standards
- New technology and R&D exploitation strategies
- Technical auditing and Benchmarking
- Plant improvement programs
- Awareness and gatekeeping of external developments, external initiatives/collaborative funding opportunities

Capital Investment:

- 5 year Capital Plan
- Development of capital planning metrics and hurdle criteria for energy projects
- Funding options
- Joint ventures

Culture and Communications:

- Energy targets in staff appraisal, communications, competency gap analysis
- Training and development courses (general and specific)

The foregoing is neither exhaustive nor mandatory – it is based on a few real-world cases – but gives a flavor for the sort of issues across the board that will need to be assembled into the site and departmental energy strategies. In each case the strategy should then be worked up into a (resourced) action plan aimed at delivering the strategic items over a given time frame. Again, documents like the Carbon Trust Best Practice Guide contain useful sections on Strategy Development.

5.1.2.2. Accountabilities

The Carbon Trust evaluation matrix (section 4.2) and the preceding discussion have highlighted a long standing issue concerning energy accountabilities. The cross-site influences on energy mean that there has to be accountability for energy issues at the highest level (Site Management Team). Only in this way can the correct span of control be achieved. Similarly, production managers, area managers and other staff with specific energy-related responsibilities need to be held accountable for the energy components of their jobs. These need describing in the documented Energy Management System.

5.1.2.3. Organization

Many organizations do have an Energy Manager or focal point. That is a good start. This has been observed in a variety of positions and backgrounds – the position may have been part of Operations, Process Engineering or sometimes as part of the book-keeping/Internal audit team. Incumbents have been engineers or sometimes finance analysts. It has been both a part-time and full-time position. Sadly, in too many cases, it has been observed as a low-ranking position without the influence and authority to address the issues raised so far. It is not simply a performance-metric position or benchmarking position. The Energy Manager has to be a catalyst for change with the mandate and spheres of influence to tackle the cross-discipline issues that affect energy efficiency. It should be ideally a significant position within the Process Engineering management structure.

In developing this position, the Carbon Trust Matrix can help define roles and responsibilities for this position. Section 11.1.1 discusses the job competencies for Energy Manager in more detail.

It does not stop there. Operational energy focal points with key ownership of the Departmental Energy Plan should be established within the various operational areas. A successful solution at one location in the author's experience was establishing one particular operational shift as 'the Energy Shift'. The Shift had specific energy-related responsibilities and developed ownership and skills in this field, in particular making use of the quieter night shift to pursue their tasks (other shifts had similar focuses – reliability, environment, etc.).

Fundamentally the development of an Energy Management System requires the company to develop and address the organizational responsibilities for energy. This is a basic need.

5.1.2.4. Competencies

The EMS will require the site to assess its competency needs to support the program and institute the relevant training to achieve those requirements. This will encompass several levels of expertise from specialist engineering skills to general staff appreciation. Local circumstances will dictate how certain skill or competency requirements are met – through in-house staff or calling on specialized energy skills from external or corporate providers.

Using the organization previously defined, there are many competency analysis and mapping tools commercially available which can be used for monitoring employee skill databases. It is highly likely that systems may already be in use as part of the company HR/staff appraisal system, in which case adding in energy-related competencies should be a relatively simple task.

Skills and training check list:

- Energy strategy and business
- CO and emissions trading
- Utilities engineering
- General energy efficiency techniques for Process Engineers
- Operator good practice techniques
- Specialized operator training – e.g. furnace operation
- Specialized technical training – e.g. Pinch Analysis and fouling abatement

Energy competencies and training will be looked at in more detail in Chapter 11.

5.1.2.5. Work Processes

With a strategy, organization and defined competencies in place the final key element of the basic EMS are the defined energy-related work processes. These do not need to be complex. The aim is to define and capture the important stages of those key activities without which the Energy Policy would be at risk. They also form the basis for the improvement loop – i.e. the documented process which can be improved and updated by a means of audit and experience so as to improve the operation.

The formats can and should be simple – perhaps just a flowchart. Clarity and simplicity are key in providing an understandable process that can be easily followed and executed. As always an important process is the audit/check task to ensure compliance.

Suggested processes that may be suitable in a typical chemical process site include:

- Target setting and performance review
- Energy efficient maintenance procedures
- Energy reporting
- Operational procedures
- Energy aspects of design and plant change
- Auditing energy performance
- Financial and accounting processes for energy (procurement/contracts)
- Handling energy within planning and scheduling
- Key energy calculations and correlations (e.g. fuel gas calorific value, meter compensations)
- Auditing the management system compliance

This list is neither proscriptive nor exhaustive. The first two topics will be examined in more detail in Chapter 7.

5.2. ISO 50001

The forgoing describes the basic development of an Energy Management System. These should fulfill the important requisites of this topic; given the right commitment and organizational discipline a company/site will be able to reap the major benefits of working this way.

However, especially if the company or site already has a strong culture of systematic process management (e.g. registrations to ISO 9001 and ISO 14001) then the development and formal registration to the new Energy Management standard is a logical step, and of course provides the discipline of external audit and system review which can play a major role in ensuring long term sustainability of the management processes.

Following development around the world of various local Energy Management Standards (EN16001:2009 in Europe and ANSI MSE 200:2005 in the USA), ISO 50001 was released by ISO in June 2011 and is suitable for any organization – whatever its size, sector, or geographical location. The system is modelled after the ISO 9001 Quality Management and ISO 14001 Environmental Management Standards and like those, ISO 50001 focuses on a continual improvement process to achieve the objectives related to the environmental performance of an organization. The process follows the same Plan-Do-Check-Act (PDCA) approach.

However, a significant new feature in ISO 50001 is the requirement to '... improve the EMS **and the resulting energy performance**' (clause 4.2.1 c). The other standards (ISO 9001 and ISO 14001) both require improvement to the effectiveness of the management system but not to quality of the product/service (ISO 9001) or environmental performance (ISO 14001). Of course it is anticipated that by implementing ISO 9001 and 14001 that an organization would, in fact, improve quality and environmental performance, but the Standards do not specify it as a requirement.

ISO 50001, therefore, has made a major leap forward in 'raising the bar' by requiring an organization to demonstrate that they have improved their energy performance. There are no quantitative targets specified – an organization chooses its own then creates an action plan to reach the targets. With this structured approach, an organization is more likely to see some tangible financial benefits.

5.2.1. Plan-Do-Check-Act

The 4 phases of the PDCA circle are:

PLAN: The overall responsibility for the installed energy management system must be located with top management. An energy officer and an energy team should be appointed. Furthermore the organization has to formulate the energy policy in form of a written statement which contains the intent and direction of energy policy. Energy policy must be communicated within the organization. The energy team is the connection between management and employees. In this phase, the organization has to identify the significant energy uses and prioritize the opportunities for energy performance improvement.

DO: The stated objectives and processes are now introduced and implemented. Resources are made available and responsibilities determined. Employees and other participants must be aware and capable of carrying out their energy management responsibilities. The realization of the energy management system starts.

CHECK: An energy management system requires a process for compliance and valuation of energy-related objectives. Internal audit can help to verify that the energy management system is functioning properly and generating the planned results. The processes are monitored with regard to legal and other requirements (customer requirements, internal policies) as well as to the goals of the organization’s energy management program. The results are documented and reported to top management.

ACT: Top management prepares a written valuation based on the internal audit. This document is called the management review. The results will be evaluated on their performance level. If necessary, corrective or preventive actions can be initiated. Energy-relevant processes are optimized and new strategic goals are derived.

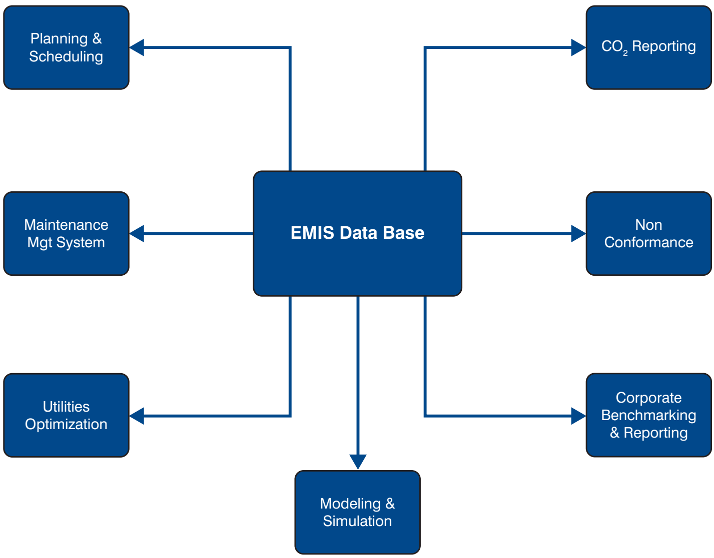
5.2.2. Benefits of Certification

Certification proves that the energy management system meets the requirements of ISO 50001. This gives customers, stakeholders, employees, and management more confidence that the organization is saving energy. It also helps to ensure that the energy management system is working throughout the organization.

Another advantage of certification is its emphasis on continual improvement. The organization will continue to get better at managing its energy. Additional cost savings can be generated over several years. Furthermore certifying an organization shows your public commitment to energy management.

5.3. Links to Corporate Systems

The picture painted so far has described an Energy Management System for a single manufacturing site. This may be part of a bigger corporate strategy contributing to an overall company policy and energy performance targets. In which case, some of the processes, roles, and information requirements may be given as part of the corporate system.



For instance, there may be requirements for standard periodic energy performance data returns and also the implementation of standard tools and packages. There may be specific roles and accountabilities. A lot will depend on the company culture and the degree of autonomy that individual sites have.

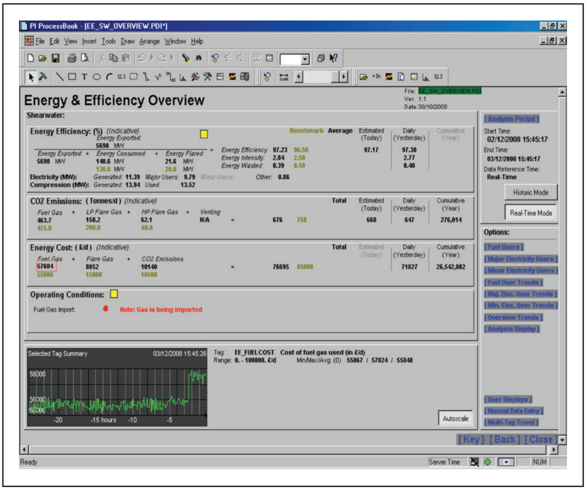
5.4. Development Support and Further Information

Further information on ISO 50001 including development and registration is provided in Appendix A.

6. Energy Management Information Systems

The Energy Management Information System (EMIS) is an essential component in managing energy on a manufacturing site. In format it may consist of a few simple spreadsheet reports through to a full-blown sophisticated graphics-based system with on-line models and reconciled energy balances. That choice is dictated by local circumstances. The important point is that pertinent plant and site-wide energy performance data are presented on a regular basis to those individuals who influence energy efficiency to enable them to make timely improvements.

To quote the well-known adage; ‘If you can’t measure then you can’t improve.’ In the drive to improved energy efficiency an EMIS is the single most important tool at a site’s disposal. Whether it be investigating yesterday’s performance, flagging an upcoming issue, or deep analysis of historical datasets as part of a fundamental (capital) improvement initiative, the concept of reliable and consistent energy data is the same. Given the disparate and cross-site nature of energy issues, the EMIS is the place that draws the energy performance together into a consistent and digestible form.



Features of an EMIS include the storage of data in a usable format, the calculation of effective targets for energy use, and comparison of actual consumption with these targets. Elements include sensors, energy meters, hardware, and software (these may already exist as process and business performance monitoring systems). Essential support includes management commitment, the allocation of responsibility, procedures, training, resources, and regular audits.

6.1. Objectives

There are a wide variety of users of energy performance data operating with different purposes, responsibilities, and on different timescales. There are often many different correlations and methodologies that can affect energy calculations (e.g. fuel gas calorific value correlations, key performance indicator methods).

The objective of the EMIS is to provide a standard data reporting structure as the basis for analysis and decision-making by the Energy Management System users. It should encompass:

- A single cross-site database
- Common agreed calculations, models, and correlations
- Flexible user-oriented reporting
- Agreed KPI hierarchy
- Easy access to historical records

This means that whether the user is a maintenance engineer investigating historical equipment fouling, an operator maintaining an efficient operating point, or a site manager looking at annual business performance, all users are working from a consistent set of data. It becomes the common-site energy language. Generic deliverables are as follows:

- Early detection of poor performance
- Support for decision-making
- Effective performance reporting
- Auditing of historical operations
- Identification and justification of energy projects
- Evidence of success
- Support for energy budgeting and management accounting
- Energy data to other systems

How these will be realized will depend on the local circumstances. The following sections should provide the background for the reader to specify the EMIS requirements for the particular site. A checklist on EMIS structure and functionality is provided in Appendix C.

6.2. The Components of EMIS

6.2.1. System Configuration – Hardware/Software

Typically the core of the EMIS will these days be a commercial process historian which scans process data from the instrumentation system (DCS, SCADA) on a regular basis. This may be an integrated part of the DCS structure. For most process unit energy variables (compressed) two-minute data are sufficient. The database may be a virtual structure – i.e. a slice across several existing databases. However it is important that it is effectively site-wide, thus enabling site-wide energy balances, KPIs, and reports to be easily assembled. For multi-location and/or remote operations, web-based/cloud solutions may be appropriate.

Interface to other manufacturing support systems including relational databases such as maintenance management systems like SAP, accounting, and corporate performance reporting may be considered.

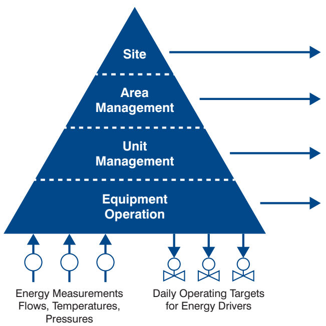
Over the last 10–15 years, Windows-based systems have become the norm allowing easy interface between the core energy data and the huge variety of modeling, reporting, and analysis tools that now all use Windows as their base operating systems. The requirements for the respective site management levels enables reporting and analysis to be very individual and customized; thus the Windows approach with intuitive interfaces is ideal.

Reporting options are again open to preference, be it 'fit for purpose' reports using Windows' standard tools such as Microsoft Excel or a sophisticated solution using any of the more complex graphics reporting packages that are now available.

6.2.2. Data Structures/KPI and Target Setting Philosophy

EMIS is fundamentally a cascaded target setting and reporting structure for energy data and operating variables. EMIS starts from high-level performance measures within the Site Manager's portfolio and cascades down through operational areas and structures to short-term control parameters at the plant operator level (e.g. Boiler/Furnace/Gas Turbine firing conditions). At all levels performance measures (Key Performance Indicators – KPIs), frequency of review, and appropriate corrective action loops need to be defined (the EMS processes). Supporting this, tools based on the analysis of (real-time) plant data are needed to present timely and appropriate information.

Generally, an EMIS will look to group units within a site by their commonalities (e.g. a common utility supply, common operating objectives, common operation management for line responsibility). Typically an energy balance is made around these units and KPIs are established and calculated on-line. KPIs could include Energy Index at a site, area, or unit level, total stack energy loss, energy/feed ratio, etc.



Target	Review Period	Calculation Frequency	Target Update Period	Support Tools
Site Energy Index	Monthly	Daily or Monthly	Annual with Monthly Revisit	LP Models, Business Plans
Aggregated Unit Data + Common Utilities	Monthly	Monthly	Monthly	Monthly
Plant Energy Index	Daily	Real Time	Monthly with Weekly Revisit	Energy Tools, Flowsheeters
Equipment Specific Energy or Loss	Real Time	Real Time	By Operating Mode	Energy Tools, Flowsheeters

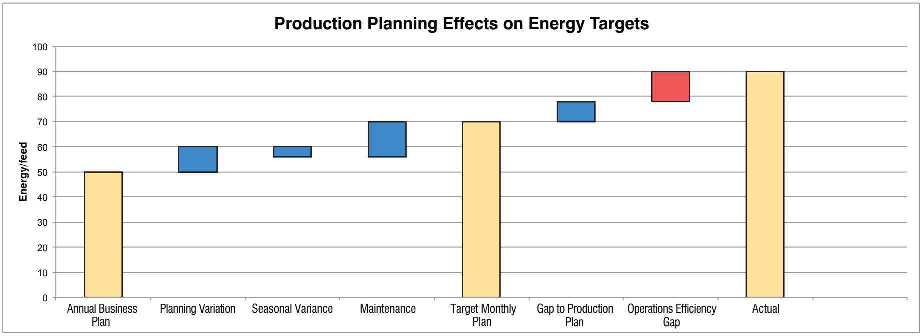
The site picture is built by aggregating the energy balances and KPIs from individual units, through operational areas to the overall site picture. It is important that this common approach is adopted since it will ultimately enable a consistent drill down of data (the energy picture 'adds up'). Similarly, it is important that a consistent set of correlations, engineering calculation assumptions, and economic values are used across the board – a standardized modeling philosophy is adopted.

The format of the KPIs that are adopted will be very much driven by the industry and local circumstances. Some industries have common (international) approaches (e.g. the EII, Energy Intensity Index, developed by Solomon Associates which is the de-facto standard in the Oil Industry). Typically they will be of some form of feedrate-adjusted energy consumption figure or ratio. Particularly at the site reporting level, consistency with or adoption of standard benchmarking calculations is a very good idea.

Other KPIs may be site or plant specific, perhaps reflecting a key energy related issue (e.g. percentage imported fuel gas) and there should be provision, if possible, for economic ‘price of non-conformance’ data. This should be readily calculated from the performance gaps from energy targets and the associated fuel costs. Having such data for each target and aggregating into unit and site reports also allows quick drill-down analysis to identify bad actors and root causes. Modern dashboard-type displays and reports can easily exploit such data to good effect.

The organizational processes of target setting and review will be covered on in Chapter 7. An important consideration is the timely update of KPIs and targets when new production planning data becomes available as the year progresses. In particular, the shift from annual headline targets to monthly operation targets reflecting actual production plans can be significant; different feedstocks and changes in production modes all affect energy consumption and should ideally be quantified in the target setting process.

The accompanying figure illustrates how an annual business plan target needs adjustment for the actual plan, seasonal averaging effects, and maintenance activities to arrive at a monthly energy target pertinent to the month ahead. The actual achieved production schedule (actual vs. plan) also accounts for part of the variation before the true operational energy inefficiency gap is shown, which then forms the basis for investigation and improvement.



The foregoing highlights a major issue in developing Energy KPIs and targets. Effects such as these can severely test the validity (and hence user acceptance) of targets. Similarly, variations between production modes may need attention in target setting. This has the potential to lead to a proliferation of advanced target-setting systems involving combinations of first principles and statistical modeling to account for the aforementioned variations. It can and has been done before, however caution is advised. The balance between modeling complexity, support levels, and end benefit is a fine one. It may be better to have simple target setting structures across a site with the use of more complex techniques limited to specific high-benefit areas. Sensible and ‘aware’ performance interpretation is important.

6.2.3. Energy Driver Variables

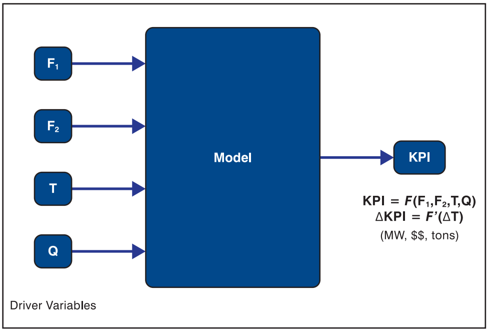
(Sometimes called Energy Influencing Variables)

While KPIs are the visible calculated manifestation of energy performance, the energy drivers are the process variables which are the main influences behind the changes and variability in the selected energy KPIs. Hence, they form the focus of attention in our attempts to optimize the KPIs against their target values.

KPIs can be classified broadly into two categories; non-actionable parameters and actionable variables which can be manipulated. Non-actionable are those influential variables that are beyond operator control. Examples include ambient temperature, feedstock quality, or product price. They impact on the energy consumption, but are not something that can be changed or corrected operationally. Actionable variables, on the other hand, are variables that operators can change to affect the operation. Examples are reflux ratios, reboil rates, recycle loops flow, and furnace air-fuel ratio. We use the term 'driver' for any causal and controllable variable that directly or indirectly influences the planned energy consumption (which will influence the KPIs).

Analytical tools (e.g. statistical data-mining) and/or process engineering experience are used to determine the controllable and most influential drivers to manage the energy loss. These drivers will be reviewed for constraints like product specifications, safety, and operational envelope of equipment. Targets will then be established for optimal energy use with due consideration to other hierarchical influences such as production demands, product specifications, etc.

If it is considered appropriate, models (process, statistical, or hybrid grey-box techniques which combine first principles and statistics) can be established linking the driver variables and the KPIs, perhaps including a cost penalty function. This will allow a more detailed analysis of the contributing cost of non-conformance on the KPIs and can be helpful in providing a drill-down and bad-actor structure.

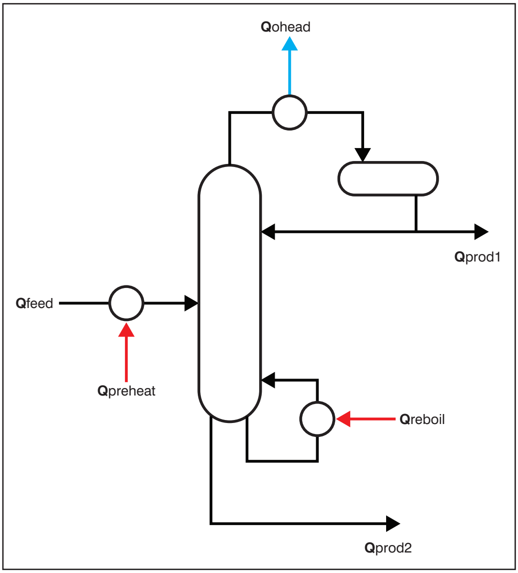


Although it is clearly not possible to set operational targets for non-actionable variables, it is still important to understand (and be able to model) their effects on energy consumption as these will play an important part in the performance analysis (and maybe in target setting if taken to a more sophisticated level).

6.2.4. Use of Energy Loss Points

Probably the most widespread KPI in use by industry is some form of specific energy consumption – e.g. energy/feed. This is well understood, logical to calculate, and accounts for one of the major impacts on energy consumption – throughput.

However there can be problems with this – for instance when the energy-to-feed ratio is non-linear. In particular when looking at unit and equipment performance, then the idea of establishing targets for energy loss can be considered. Obviously, the aim will be to minimize energy loss.



Consider a simple distillation column. Energy is input by feed preheat and reboil. Energy leaves the column as sensible heat in the product streams and the heat removed by the overhead condenser. Typically, this is lost to low-grade non-recoverable energy sinks (atmosphere, cooling water, etc.). The operating conditions of the column (temperature, pressure, reflux, etc.) determine this energy value. Hence, these are the drivers which influence the loss KPI.

For a furnace, the lost energy is the energy lost to atmosphere from the stack as opposed to that transferred as sensible heat to the product in the furnace tubes.

The concept of energy loss being the performance measure or KPI is the calculated energy loss from the unit, i.e. it is a direct measurement of energy waste. A target can be set for the normal acceptable loss value and models can be built for the relationships between the loss and operating conditions. Similarly, a price of non-conformance calculations can be included.

While loss points can be more complex to calculate and visualize in comparison with a simple energy consumption, they do focus on the wasted energy – energy consumption of course is the sum of wasted and useful energy.

6.3. Operating with EMIS and User Interfaces

The EMIS is effectively the energy hub for a manufacturing site, and as such will have a variety of users and purposes. These will vary from fixed formal multi-user reports to one-off customized and ad-hoc applications.

- Annual and monthly performance reports to management
- Real-time energy driver monitoring in the control room
- Specialist technical engineering applications, often integrated with modeling/optimization tools
- Ad-hoc data analysis and troubleshooting
- Data interfaces to other IT systems

Fortunately modern client-server and peer-to-peer Process Historians typically using a Windows interface are well suited to the variety of uses outlined.

It is important that a system manager and/or application guardian is appointed. The more formal reports need proper managing and are best developed using a reporting package which allows controls and consistency. Similarly, the integration of operational target setting with existing plant operating procedures and the DCS database needs careful consideration.

In recent years, application integration for tools and software running on Windows has become very easy. For instance, transfer of archived process data into a modeling or optimization package is now an easy exercise, and that fits in well with the concept of the EMIS as the energy hub. There is a fine line, however, between the use of software tools and development of correlations and models for one-off single user investigations and a sustainable situation where similar tools and calculations form the basis for repeatable longer term use. The well-known phenomenon of 'skunk' spreadsheets – complex, undocumented, and hence impossible to pass onto a new user – illustrates the problem.

Companies are starting to tackle these issues and may have standards and procedures in place. The EMIS guardian plays a key role in managing this process – there is a delicate balance between encouraging and facilitating energy data exploitation and sustainable long term applications.

6.3.1. User Interfaces

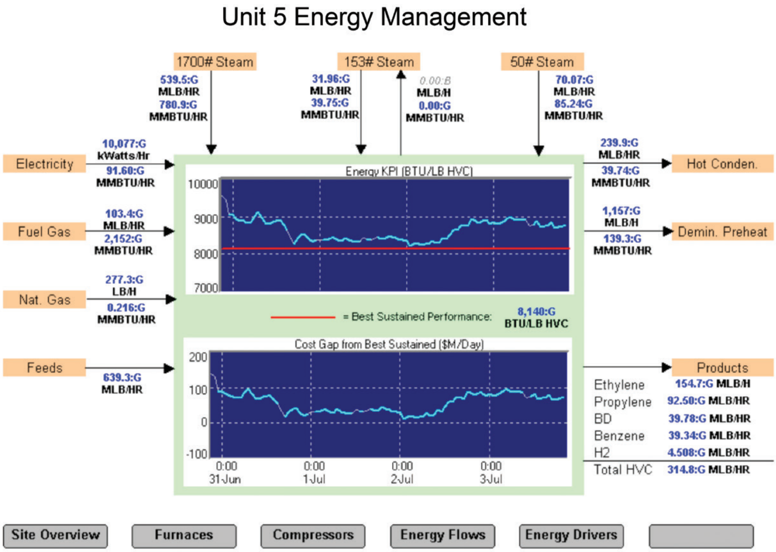
Many options are available in developing user information and interfaces with varying degrees of dynamic reports and displays. Modern screen building tools can be very powerful. Local standards and norms will play a part. The following guidelines are presented to assist in the design process:

- A clear vision is needed of who the report user will be
- Only display information that is relevant to, and can be impacted by, the user
- EMIS displays should be functionally consistent, this means that the intended functionality of each display must be clear and once the analysis is done on that display, it should give pointers to the next display to be accessed in order to complete the energy analysis
- Consider using drill-down techniques driven by energy indices or financial cost calculations to navigate multilayer nested reports from high level indices to individual items of energy equipment, dials or plus/minus bar charts can be useful in displaying the bad actors and linking up to the next level screen
- Multiple displays can be very useful for exception and pattern recognition, e.g. multiple trend displays for multiple (similar) furnaces
- Consider including causal information, for instance:
  - (On-line) calculations showing energy impact of off-target drivers
  - On-line adjusted KPIs (e.g. effect of external conditions on performance, load dependent targets)
  - Rule-based logic providing operator advice
- Quick links to trend information are very useful

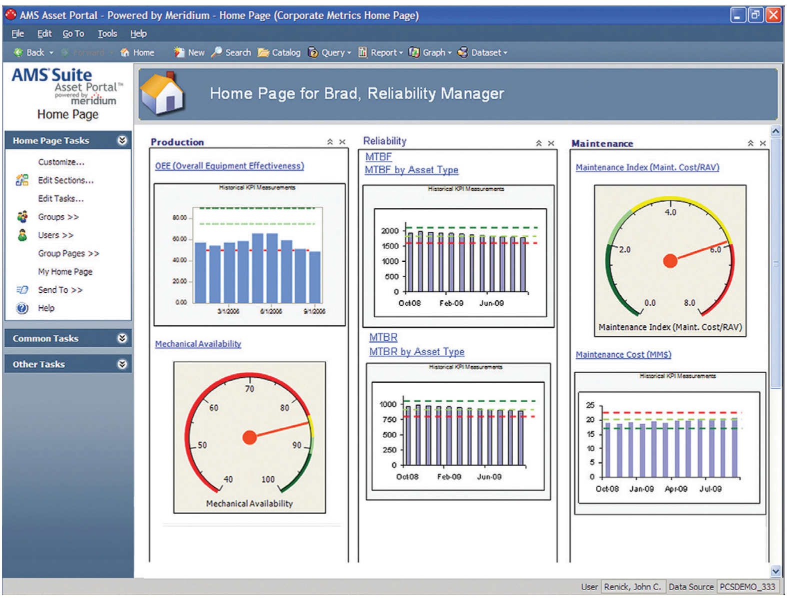
Many examples can be found – a small selection is provided to give guidance or inspiration to the designer. All have been built using real-time and historical plant data in PC-based user-display packages.

(The examples have been taken from sales literatures, conference presentations, etc.)

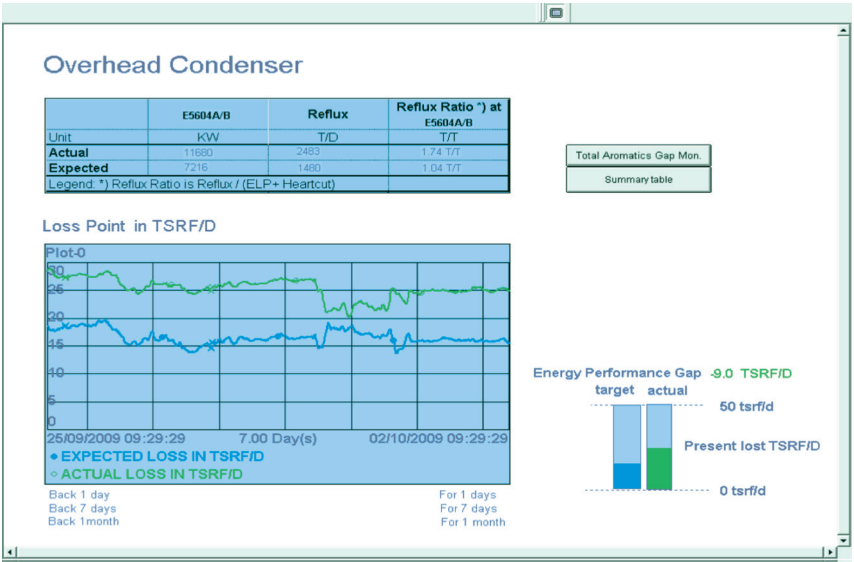
Plant overview with major energy classes:



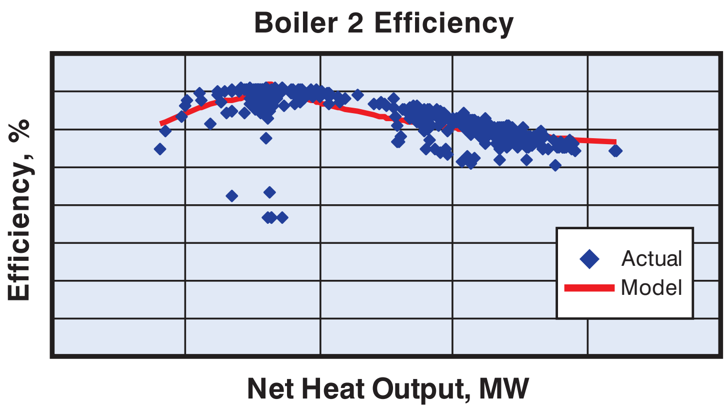
Historical KPI reporting plus dashboard:



Part of drill-down structure at energy driver level showing target, actual, and effect upon energy consumption:



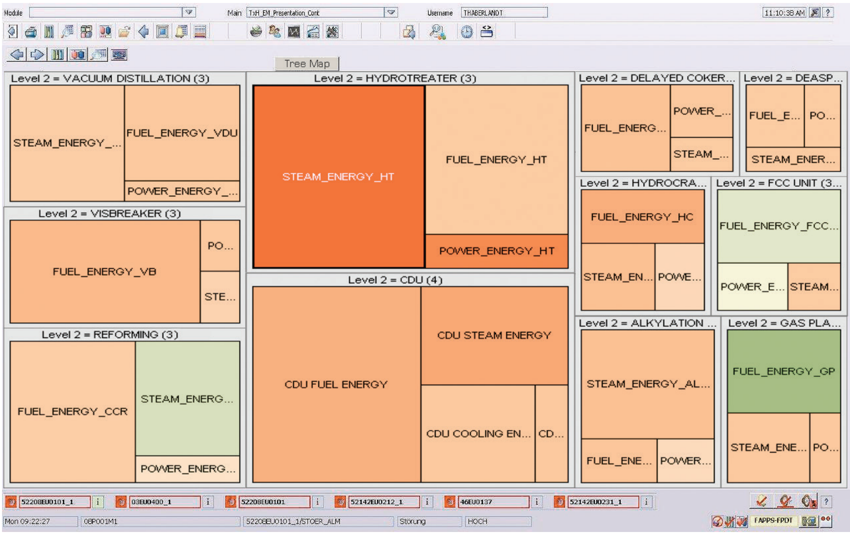
X-Y plot indicating actual performance against load/efficiency model:



Tabular/bar chart approach showing energy drivers and their contribution to gas turbine efficiency:

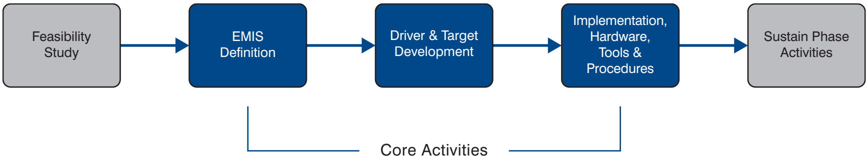
		Actual	Expected	Deviation MW	-3	-2	-1		+1	+2
MECHANICAL DEGRADATION										
Generator Output	MW	25.231	26.544	-1.313						
OPERATING PARAMETERS										
Inlet Temperature	deg C	485.1	520.0	-1.405						
Extraction Pressure	kPa	480.2	500.0	+0.108						
Exhaust Pressure	kPa	9.5	8.0	-0.878						
TOTAL DEVIATION				**-3.488**						

Dynamic overview display where size of panel indicates relative energy consumption of each area (color indicates deviation from target) and the display drills down to more detail using the panels:



6.4. Development of an EMIS

There follows a general set of guidelines for developing an EMIS. The scope may vary from simple fit for purpose reports through to a major modeling and graphics package, so the final plan will need adjusting. The program follows a typical project execution plan and should ideally be incorporated into an overall Energy Management System roll-out.



A short Feasibility Study is used to determine the main issues, opportunities, and blocks to an EMIS and whether it is a feasible proposition for the site. Typically a one week on-site activity, the purpose of the Feasibility Study is to make a preliminary assessment of the viability of the EMS implementation. Key issues, constraints, and the availability of crucial prerequisites which could impact project success need to be identified, together with the first pass project economics to indicate project viability. The EMS Design Workshop (section 5.1.1) can generate much of the information and site philosophies needed.

The Definition Phase is essentially the design process. The aim is to produce a detailed design that fully defines the EMIS in terms of structure, technical architecture, scope, interface, management system, etc., and is unique to the site in question. The site is split into EMIS areas where energy balances and KPIs are defined. It will allow a final (say) 10% project cost estimate to be prepared. Beyond this point the detailed work of coding, analysis, and final implementation can then take place. The specifics of project approvals and estimate levels will clearly depend on local procedures – the model presented is typical of a normal project development cycle.

The Driver and Target Development phase handles the detailed design and coding of the EMIS prior to final implementation and rollout. At the end of this phase all calculations will have been defined and checked, drivers, constraints and KPIs fully identified, as well as displays prepared – all in readiness for final commissioning in the operational system. Completion of this phase marks the end of development work.

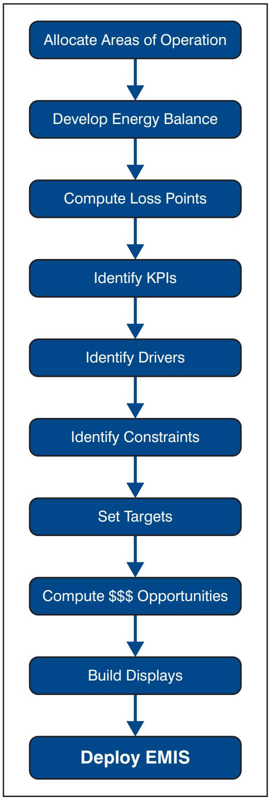
The final phase tackles the training, roll-out, and implementation of the finished system and brings it into operational use. This will clearly involve many parties and success at this point will inevitably determine the potential long term success of the project. It may be worth considering involving change management techniques to help design and support the process.

6.5. Core Activities – System Building

The rest of this section deals in more detail with a step-by-step approach to developing the EMIS.

6.5.1. Allocate Areas of Operation

Definition of the EMIS boundaries or areas of operation is required. The definition of an EMIS Area is dependent on several factors – commonality of purpose, common operational management, common utility supply, etc. Typically, groups of units which are tied together by some related function are allocated into an operational area. Mapping out the site into a logical set of areas is the first step in any EMIS design. It is likely to be influenced primarily by organizational and departmental limits.



For every EMIS area of operation the following streams need to be identified and their associated measurements (tag variables) listed. The aim is to identify all streams carrying energy across the area boundary, with associated tags, ways to estimate or calculate missing meters, and equations to determine their heat content.

All crucial measurements, together with type of meter, measurement range, design accuracy, and known problems should be listed. Missing meters have to be identified.

6.5.1.1. Feedstocks

All feedstocks entering the EMIS Area should be included. The heat content of feedstocks (sensible and latent heat) is required for an EMIS energy balance. Hence, suitable on-line measurements (e.g. temperatures) are needed if the heat content of feedstock significantly changes.

Meter Requirements:

Appropriate flow, temperature, pressure, and quality measurements to determine mass flow and heat content.

6.5.1.2. Products

Besides the feedstock, the distribution of products also determines the required process energy and the corresponding losses. All product flows leaving the EMIS Area thus have to be included. Product flows in this sense are flows to storage tanks or to other units outside the operational area. As with feedstocks, the products also carry a varying energy content that is relevant for an EMIS. Suitable on-line measurements are required if product conditions change.

Meter Requirements:

Appropriate flow, temperature, pressure, and quality measurements to determine mass flow and heat content.

6.5.1.3. Classes of Energy

All types of energy streams entering or leaving the system boundary that are influenced by plant operation are called Classes of Energy (CoE). It is possible that a CoE only virtually crosses the system boundary, as is the case in general, with indigenous fuel and own power production. Typical CoE are:

- Steam at different pressure levels
- Tempered water
- Fuel (fuel gas, fuel oil, natural gas, coke, etc.)
- Electricity
- Boiler feedwater and condensate
- Air (if significant)

All these Classes of Energy are required to build the energy balance of an area and unit.

Meter Requirements:

- **Steam and tempered water:**
  Flow, temperature, and pressure
- **Fuel gas:**
  Flow, (pressure, temperature, and molecular weight might be required for density compensation), Low Heating Value (LHV), or composition or density to be used in an LHV correlation
- **Fuel oil:**
  Flow, LHV, or alternatively density and sulfur content to be used in an LHV correlation
- **Electricity:**
  In general, all net electric power import will dissipate into heat (apart from any hydraulic head gain for product streams leaving the EMIS Area at higher pressures than the feed flows). Depending on the type of EMIS area, electricity might or might not be an important source of energy. Even when electricity is a significant source, sometimes only monthly integrator readings are available. In such cases a correlation between monthly area or unit load and average monthly power consumption may help. For EMIS purposes, this specific electricity consumption together with the on-line load can be used to substitute missing electricity meters

Another important consideration is the fact that the units supplied by a power distribution network do not necessarily match with the units inside the EMIS Area. Further, in most applications, there are not many energy savings opportunities in electricity. Hence, reasonable estimates of electricity consumption will suffice. However, in applications where significant energy savings will result from reduced electricity consumption (e.g. use of variable speed drives); at least localized electricity consumption meters are required for accurate monitoring and preservation of savings.

6.5.2. Energy Balances

The aforementioned boundary and variable analysis will allow the construction of energy balances for each area of operation. This is a key step in the design of an EMIS. We must ensure that all relevant energy flows are identified and available at sufficient accuracy. Trending the imbalance over a sufficient period in time (e.g. 1 year) gives a good means to assess the accuracy.

The overall site energy balance should include the energy loss points identified below (cooling water, ambient air, etc.). While it is not essential to have perfect closure of energy balance, it is preferred to close the balance as accurately as practically possible. The accuracy of closure depends on availability and quality of measurements, quality of estimates of physical properties, and on completeness of variable identification. If the lost energy cannot be quantified due to lack of measurements, at least the sum of all loss points has to be calculated as the difference between useful energy in and out.

6.5.3. Identification of Energy Loss Points

By understanding where energy is lost on a unit and what process parameters drive that loss, then we have a means to ensure that these losses are at a minimum. Alongside the unit/area energy balance it is necessary to identify the principal energy loss points in each area. Typical loss points are:

- Furnace stacks
- Air coolers
- Water coolers
- Blowdown/venting

In selecting the loss points a judgment has to be made between absolute size of a loss point, the feasibility or otherwise of impacting the loss, its relative size in terms of the unit energy balance, and the total number of loss points. Typically, we may consider loss points of >5% of the unit energy balance to be of interest, although this is not a hard figure. The key issue is that one should focus on controllable loss points – i.e. those which are affected by controllable drivers and also that show enough variation to be able to establish causal relationships.

Meter Requirements:

- **Furnace or boiler stack losses:**
  Stack oxygen and temperature plus fired or absorbed duty, or fired and absorbed duty
- **Air coolers:**
  Product flow plus inlet and outlet temperatures
- **Water coolers:**
  Product or water flow and corresponding inlet and outlet temperatures
- **Hot flows to cold storage:**
  Appropriate flow and temperature measurements

It is important to make clear that the metering does not have to be direct (though it definitely is preferred that way). For example flow rate may not be available on a stream being cooled. However, it may be possible to compute the flow using mass balance either upstream or downstream of the loss point itself.

6.5.4. Preliminary List of KPIs

Based on the above-mentioned existing accounting methods, energy loss points, etc., a list of typical energy related KPIs has to be developed. This list may include KPIs such as:

- Energy indices on a site, area or unit base
- Total throughput related losses in e.g. GJ/t, tons fuel/tons feed, etc.
- Loss point specific KPIs such as total loss at a specific water cooler, etc.

Refer to Section 6.2.2 for further discussion on KPI selection. Typically a 3-level KPI hierarchy (Site-Area-Unit) would be appropriate.

6.5.5. Driver Development and Identification

The drivers are the process variables which are the main forces behind the changes and variability in the selected energy KPIs. Therefore, these form the focus of attention in our attempts to optimize the KPIs against their target values. If we maintain the drivers at their targets, then we are likely to be operating efficiently. Conversely, deviating from target allows us to understand why energy efficiency is not what it should be.

There are many ways that drivers can be identified. In some cases, good engineering judgment and plant experience will be sufficient. In other cases, statistical analysis can provide insight and understanding beyond the simple 'rule of thumb' into the detection of non-obvious drivers. Of course, the results should be validated with experienced operating personnel. For these techniques to work there has to be sufficient variability in the potential driver data set.

As there may be several drivers that influence a particular KPI, sufficient effort should be spent to develop an understanding and model description of the correlations between them. While investigating constraints and targets for drivers, it is therefore important to bear in mind that not all drivers can be manipulated sufficiently – they may be tightly constrained or controlled, despite indication or even proof of lost opportunities to (further) improve the KPI(s).

Note that proper understanding of the underlying causality is crucial and therefore some form of cause-effect or what-if analysis needs to be performed. In case of insufficient data or poor data quality, flow sheet simulations can be considered. Again, the importance of operational involvement and buy in at this step cannot be overemphasized.

6.5.6. Constraint identification

Drivers can be manipulated to achieve the desired optimization of KPIs, however, it is essential to ensure that any change in driver targets does not push the plant to an operating region in violation of other constraints. The process constraints that will be encountered include operating process limits, material of construction limitations, best practices, product quality considerations, and safety limits. It is essential to ensure that all the constraints are identified and will not be violated while making recommendations for changes in drivers.

There is a growth in companies who are implementing integrated alarm and process monitoring systems where a single reconciled database tracks variables across the alarm spectrum, from operating windows through to hard safety-oriented trip alarms. Hence, it is important that as part of the constraint identification process, that limits and windows relating to drivers and associated variables identified in this database are checked for consistency.

Once established, the constraints should be included in the database of KPIs and drivers to ensure that target advice does not infringe these limits. Where practical they can be included in driver and KPI reports to indicate the limits that a driver can be pushed to (e.g. minimum stack oxygen content).

6.5.7. Setting Targets for KPIs and Drivers

There are several approaches to aid the setting of KPI and driver targets.

6.5.7.1. Historical Best Performance

A quick and effective method to set targets for KPIs at each level of the organizational hierarchy is to identify a period of 'best achievable' performance from an energy perspective. The average KPI accomplished over this continuous time span would be a good target for the KPI.

In the event that a site has natural or other operational scenarios that result in markedly different energy performance, it is imperative to account for the same by setting different targets for different scenarios. As an example, the winter to summer variations or whether a refinery is in diesel or gasoline mode will influence the energy performance of one or more units. A separate historical best performance should be determined for each scenario for the corresponding units.

Driver targets will generally come from the basic operational optimization of the unit and need to be developed consistently with the other aims and constraints that determine day-to-day process operation.

Thus, flow sheet tools, model-libraries, simulation techniques, and operational experience are used to determine the basic level driver targets.

Further, long term or permanent operational changes that influence the energy performance should also be accounted for by resetting targets opportunely.

6.5.7.2. Statistical Correlation

Often it is possible to develop a correlation between the KPI of interest and the driver process variables that influence the KPI. This is an indirect approach that is often useful in the absence of a clear first principles simulation model that describes the relationships between KPIs and drivers. Hence, a mathematical correlation between the KPIs and the drivers could be developed as follows:

$$KPI = f(Drivers)$$

Statistical and data-mining tools which can be used to develop these correlations are readily available. It is important, however, that the data sets used contain sufficient variation (or 'richness') to allow sensible correlations to be established.

Once the correlation has been developed and validated, the same equation can be used to estimate KPI targets by using target values for the drivers in the equation. Thus, consistency is established. Such modeling becomes particularly important if it is wished to evaluate the relative contributions of the actual driver performance to the energy performance gap. The driver targets are set bearing in mind considerations such as safety, margin, energy, etc.

6.5.7.3. First Principles Model

The most effective, but also the most expensive, method to determine KPI targets is to use a first principles simulation model to determine both the driver and KPI targets. This step is generally not recommended for all KPIs, but should be resorted to in cases where any of the other options described previously is not tenable. Such models may already be held by the organization for other uses.

The biggest advantage of this effort is the ability to have a unified look at several competing factors that come into play while setting KPI targets. As an example, often KPI targets are driven in competing directions by considerations of energy and margin. In such a scenario, the simulation model can be used to generate an optimal KPI target that maximizes margin while minimizing energy costs.

6.5.8. Data Validation

Once the KPIs and sub-KPIs are fully identified, they should then be configured in the real-time system and tracked for consistency and robustness over a period of time.

Instrumentation issues, such as missing meters and accuracy checks, should be resolved. A recommendation would be to check all meters pertaining to EMIS calculations prior to its development, thereby, calculation of KPIs would have a sound basis. It is essential that at the end of this process robust calculations can run in real-time over a wide-range of operating scenarios. In case of insufficient data or poor data quality, flow sheet simulations can be considered.

6.6. EMIS Skills and Competencies

EMIS development and implementation requires a full cross-section of skills. These will vary depending on the phase of the project. Fundamentally, it is a change management project, although there is a need for a strong operational and process engineering input plus some supporting skills in process IT. Clearly underpinning the technical skill areas is a strong element of communicational and project management skills.

A full examination of energy management skills and competencies is given in Chapter 11.

6.7. Key EMS Applications and Processes

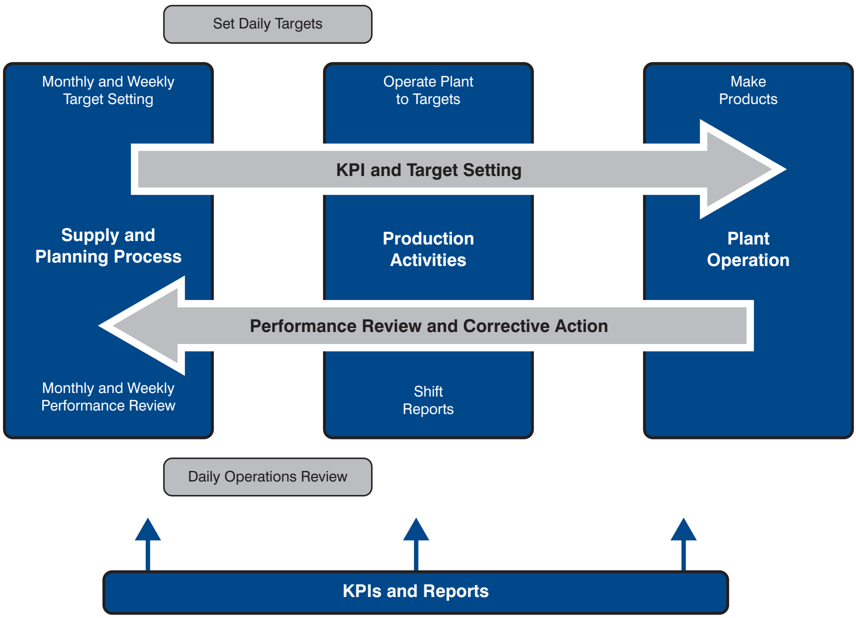
To aid the development of the documented energy management system, two key areas will be examined in more detail. Operating the plant and maintaining equipment in an energy efficient manner are fundamental to any efficiency program – this is the basis of day-to-day operation. Many factors will influence the effectiveness and success of these activities. There are often potentially conflicting aims. Given this situation, it is important that energy considerations have an appropriate place in the decision-making.

Chapter 7 and 8 discuss energy management processes for operational performance management and maintenance management respectively, and suggest some generic methods that could form the basis for developing a site's local EMS practices.

7. Energy Target Setting and Performance Review

Given the varied nature of the factors influencing energy, target setting and the performance review process become the key activity in driving efficient energy consumption. It is the opportunity to bring together the various energy-related strands into a single balanced process, at a site, area, or individual process unit level. In establishing such a concept, the following important principles need to be adhered to:

- An integrated energy database is essential, driven by process data and having easily accessed historical data that can be assembled in user-focused reports
- Consistent targets, KPIs, reports and a review process need to be established, across and appropriate to, different levels of the organization
- KPIs and performance review should be appropriate to the span of managerial influence of the review level



Two fundamental and complementary processes are developed; the energy target setting process, which develops from high level annual targets through to real-time process variables **under the control of the operator**, and the energy performance review process, which in a similar manner builds up from real-time corrective action through to management appraisal of energy performance.

7.1. The Energy Target Setting Process

The core to performance monitoring is setting of appropriate performance targets. This process starts with high level annual site targets and develops, with increasing granularity and frequency, into daily operational targets for the energy-influencing drivers on the plant.

An important consideration is that the final elements of the target setting structure at the operational level are the operational parameters **under the control of the operator**, which influence and ultimately determine the energy consumption of the unit in question. So, the whole philosophy is predicated on the need to establish optimum targets for these variables and monitor for operation away from target. These are the so-called ‘Energy Driver’ variables. They will be typically flows, temperatures, pressures, etc.

For example, it is well-known that the energy efficiency of a distillation column is improved as the column pressure is reduced. Therefore, a target for minimum column pressure is developed (consistent with product quality constraints) and the column monitored for operation at that pressure.

7.1.1. Site Energy Monitoring Targets and KPI Structure

Each site should maintain a dashboard of energy and emissions-related metrics. This will include both combined site-level KPIs and those pertaining to the principal units on-site. A site owner of the metrics and the target-setting processes supporting them (e.g. agreed frequency for target setting, approval, sign off, and up-dating) should be identified.

Targets for Key Performance Indicators (KPIs) should be determined as laid out in the following sections (annual, monthly, weekly targets setting) and performance against these KPIs reviewed as detailed in the subsequent section 7.1.2. Further details of Energy KPI structures for a site, and the different metrics that can be employed, are given in Chapter 6 covering Energy Management Information Systems. Typically, it will encompass a yearly site energy target (energy/feed) reaching down to unit energy and emissions targets (unit energy and/or loss) for individual units calculated on a monthly basis.

Metrics calculated at higher frequencies (e.g. weekly/daily) will not be part of the site dashboard, although these will be used as part of the overall performance monitoring process outlined in this manual. These metrics will need to be allocated targets consistent with the site dashboard. This forms the cascaded target setting process which links high level annual targets for site performance down to real-time plant variables directly under the operator’s control.

7.1.2. Annual Target Setting

Targets for site performance are agreed and signed off each year as part of the annual planning and budget process. This includes high level site energy targets; typically some form of energy intensity or specific energy target. The value of this target shall be determined in line with the feedstock and production premises upon which the annual plan is based, together with knowledge of any planned factors that will affect energy performance (shut-downs, changes in equipment and configuration, etc.) Ideally a seasonal breakdown, for instance into quarterly planning targets, will provide a more realistic basis for the year ahead.

7.1.3. Monthly Target Setting

Each month, the site should set targets for the energy dashboard for the forthcoming period (site KPIs and unit-level KPIs). These targets will be based on the annual targets, updated with the latest 30 day production plan (feedstock slate, product pattern, expected plant availability). These unit level targets will then be used for assessing the units' performance during the coming month and act as the foundation for more detailed energy targets within the respective units.

Energy Constraints: The production plan should be checked against energy/emissions constraints (e.g. operation at CO cap levels). In addition, based on the latest production plan, the site KPIs and month-by-month projection to year-end should be updated to reflect the latest production and availability picture for the full year.

7.1.4. Weekly Operational Targets and the Setting of Operating Instructions

Based on the production schedule for the forthcoming week (produced by the Site Planning and Scheduling Department), a detailed set of energy targets for the sub-units and equipment in the particular production area should be prepared. This will allow the effect of scheduling decisions (yields, operating modes, etc.) to be reflected in realistic energy targets at a plant level. Typically, these targets will be the operational driver variables such as flows, temperatures, column reflux rates, etc. These targets will then be finally validated and embedded as part of the daily operating instructions.

Refer to section 6.6.7 for target setting techniques.

Daily and weekly performance will be assessed on the basis of actual performance against these targets.

7.1.5. Daily and Real-Time Activities

Energy targets are included in the unit operating instructions that are passed to the operations personnel. The plant operators are tasked with maintaining operation at the target values and noting causes for variance.

7.2. The Energy Performance Review Process

Energy performance should be reviewed in a structured manner, assessing energy consumption against metrics that are appropriate to the frequency, control, and span of operations for the review process in question. Corrective and improvement actions shall be identified, documented, and close-out should be tracked. Issues that require action beyond the control or scope of the particular review shall be passed on to the next higher-level review for resolution.

7.2.1. Daily Energy Performance Review

As part of the daily operations/maintenance meeting, the energy performance of the previous 24 hour period in that area shall be reviewed. The prime aim is to keep the plant running to targets.

Inputs will include:

- The overnight shift reports
- The energy management 24 hour performance report containing details of actual performance against the energy targets for that period

Identified actions will include:

- Suggested modifications to the operating instructions for the forthcoming period
- Short term maintenance and repair actions that need attention by day staff
- Issues that need escalating to a site or production team level for further development

Where appropriate, issues should be logged into the maintenance and/or non-conformance reporting systems (if used).

7.2.2. Weekly Energy Performance Review

Within a production area the 7-day unit energy performance will be reviewed in the weekly production team meeting (or monthly if that is the meeting frequency). The intent here is to identify issues and related corrective actions for the energy performance beyond the immediate previous 24 hours. In particular, topics requiring more detailed investigation and follow-up.

Inputs will include:

- EMIS performance report for the previous period with actual performance against target
- Issues escalated from the daily area meeting
- Actions cascaded from the monthly site energy performance review meeting

Ideally, the site energy performance for the previous (7-day) period is reviewed at the site-wide production meeting (if held), with a particular perspective on cross-site energy considerations (e.g. utility and fuel supply issues).

Inputs can include:

- Issues escalated from the various daily area meetings
- Weekly/month-to-date site energy performance data
- Extraordinary energy issues arising from the forthcoming production plan (e.g. special runs, abnormal feedstocks)

Identified outputs could include:

- Common energy-related instruction to all units
- Suggested modifications to the operating instructions for the forthcoming period
- Specific instructions to a particular unit as a result of the site debate
- Utilities constraints and implications on plants for the forthcoming period

7.2.3. Monthly Site Energy Performance Review

The overall site energy performance should be reviewed on a monthly basis at the monthly site energy performance review meeting. This is an essential component in the management of energy on-site and should be attended by the nominated senior manager with energy responsibilities, and ideally, also by the Site Manager. The metrics to be examined will include site-wide energy calculations and the top level KPI for each unit based on the previous month's performance. The meeting will review the previous month's performance and also performance in the context of the yearly targets and year-to-date performance.

Inputs will include:

- Monthly performance metrics (actual) for site and main units
- The annual plan and updated targets (site and units)

Identified outputs will include:

- Identified longer term items (special studies) to be taken up through the corporate business improvement process, perhaps leading to eventual capital investment
- Energy issues for consolidation at the monthly site non-conformance meeting (e.g. training, skills, energy responsibilities, work processes)
- Improvement and corrective action issues to be cascaded (via the production unit manager) to the area production team meetings
- Updated energy plans for the rest of the year

Whatever the company incident and improvement procedures that are adopted, the key point is that energy performance monitoring should generate corrective and improvement actions. For many years, such meetings became an ‘explain away the difference’ process when targets were not met rather than a true improvement process.

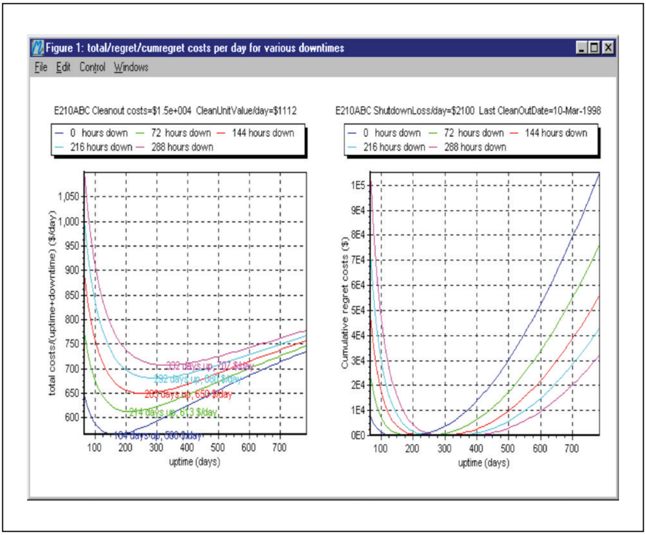
8. The Impact of Maintenance Practices on Energy Performance

The role that equipment maintenance plays in energy efficiency is often underestimated. Issues such as the optimal cleaning of heat exchangers to ensure best heat recovery, the servicing of key equipment such as steam turbines and furnace sootblowers, through to the more mundane topics of steam leaks, steam traps, and pipe lagging all play an important role in maintaining energy performance. There is evidence that maintenance contracts, often managed by departments not necessarily aligned to process optimization, have suffered in recent fixed-cost reduction exercises. Hence, the need for clear energy strategies and work processes for maintenance activities.

In developing a strategy and work processes for energy-related maintenance activities, the concept of the energy critical equipment register is presented. This is analogous to the better known ideas of safety critical equipment and quality critical equipment. In other words, equipment whose failure has a significant impact on the plant's energy efficiency is identified and appropriate maintenance measures are put in place to mitigate the risk of failure.

Modern maintenance tools and software mean this is a straightforward task and should be part of the normal maintenance planning tools. Ideally, there are two components as follows.

8.1. Statistical Risk-Based Inspection Tools

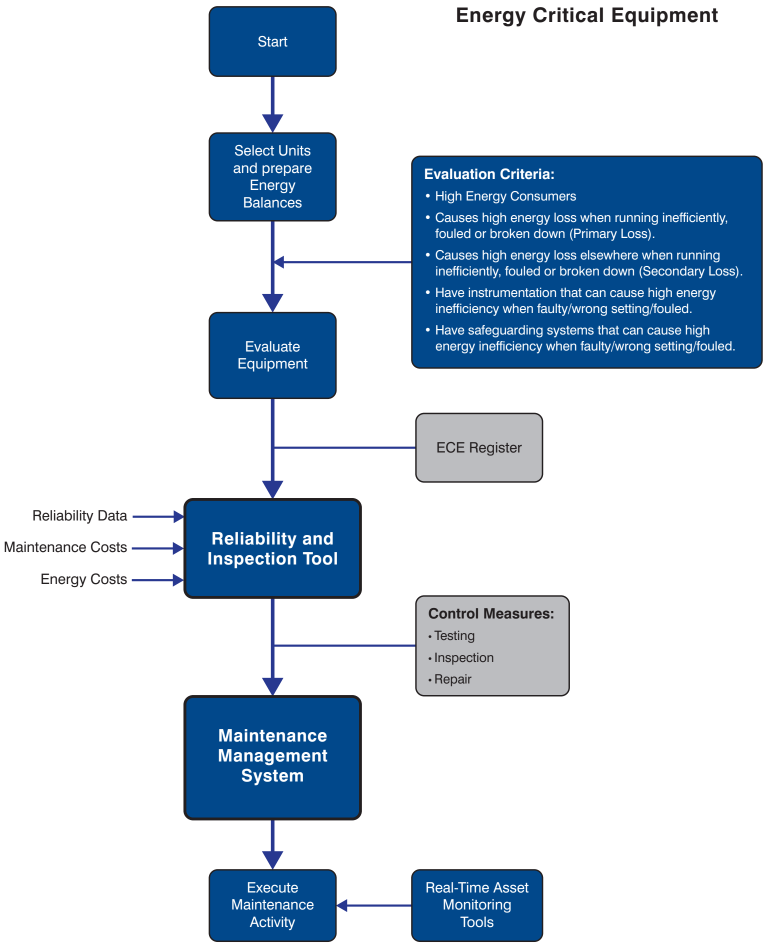


Statistical tools determine proactively and cost-effectively the optimum maintenance, inspection, testing task plan or specific requirements of equipment in its operating context. The aim is typically to maximize reliability, integrity and availability. Costs of failure, impact on energy performance and repair are combined with statistical availability and performance models to determine the most cost effective inspection, repair, and servicing schedule. This could be an optimized cleaning plan for a heat exchanger (balancing cleaning costs against performance improvement) or a preventive maintenance schedule for a key turbine generator set. A (sampled) steam trap inspection program could be another application.

8.2. Maintenance Management Systems

The maintenance management system (e.g. SAP) schedules and records the outcomes of maintenance testing, inspection and repair. This is the workhorse which drives the schedules, maintains the inspection records and is in common use these days.

These may be supplemented by on-line machine and equipment monitoring tools, typically running in association with the plant process historian, which measure and evaluate the current equipment performance. Combining these tools into an integrated process allows the development of an energy critical equipment strategy. The operational process will be laid down as part of the Energy Management System.

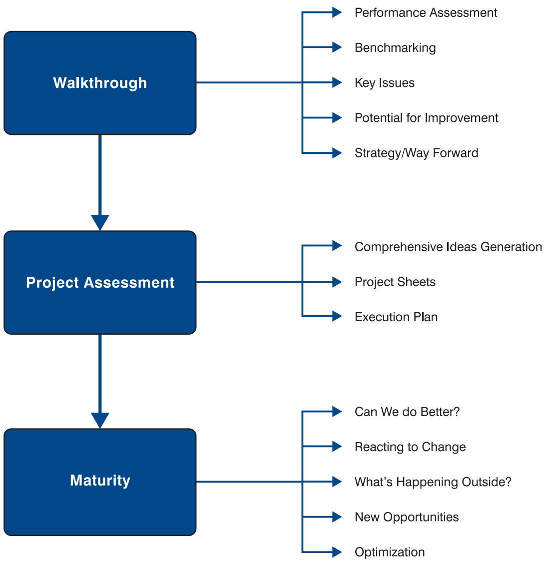


9. Making a Step-Change: Opportunities, Auditing, and Improvement Projects

The foregoing chapters have looked at building Energy Management Systems and the related information provision. These provide the foundation of culture, organization, process, and data upon which to build energy improvement projects. This chapter now considers the mechanisms for identifying specific energy improvement ideas and projects.

Inevitably there are several approaches possible and there is much scope for overlap in terms of timing and technical content. The adopted methods will inevitably reflect local conditions and priorities. The methods presented here have separate distinct aims, but could be combined or rationalized as the user wishes.

They may be carried out by local staff, corporate specialists or external consultants and suppliers as part of a more turnkey approach. Each way has its merits and downsides, in particular the balance between specialist and local knowledge.



Energy Walkthrough: A short (i.e. 1 week) assessment of the overall energy performance and scope for energy savings on a manufacturing location. Delivers energy health check, key strategic issues, outline ideas, and suggestions for improvement.

Opportunities identification and Project Assessment: Typically a 1 to 2 month exercise with in-depth analysis, identifying energy efficiency opportunities and developing a prioritized project list, which can then be used as a basis for detailed project roll-out.

Generating on-going Improvements: A mature site may have started off with a dedicated improvement plan and an initial set of energy projects, however it is to be hoped that once a certain maturity is reached then the EMS processes will continue to generate ideas for improving energy efficiency – that is a reflection of reaching a true energy improvement culture.

9.1. The Energy Walkthrough

Typically a 1-week exercise, the Energy Walkthrough aims to identify energy inefficiencies within the organization's process, storage and handling, and utilities units. It is a gap analysis, reviewing facilities against best practices and recommending opportunities to improve energy efficiency within those facilities. The result is a picture of the highs and lows of a location's current energy performance, can help shape an improvement program and set the scene for the development of the site's energy strategy.

The walkthrough is an interactive interview process. Management, process engineers, and operations personnel will be interviewed and asked to provide data.

The interviews are based around the analysis of process flow schemes. The flow schemes provide a structure to discussions on energy theme. Perhaps two or three hours discussion per unit. The flow scheme reviews start at the beginning of the process and move through the flow diagram to all end points. The aim of the interview is to identify all areas where energy enters, leaves, or is exchanged within the process, and question whether this is as efficient as it can be.

The output of the interviews is used to identify opportunities to improve energy efficiency. Simple technical, economic, and operability criteria are identified for use in screening and prioritizing opportunities for improvement. At this stage, a detailed set of worked-up project proposals is not the aim – the assessment program provides that – but the walkthrough should indicate the strengths and weaknesses of the current operation and areas of concern that need addressing.

It is worthwhile to include an energy management maturity assessment (see Appendix B) as part of the program. A particular aim of the walkthrough is to evaluate the relative standing and maturity of a site's energy operation, and lay the foundations for the longer term development of strategy and improvement activities.

A comprehensive walkthrough template and interview checklist is included in Appendix D.

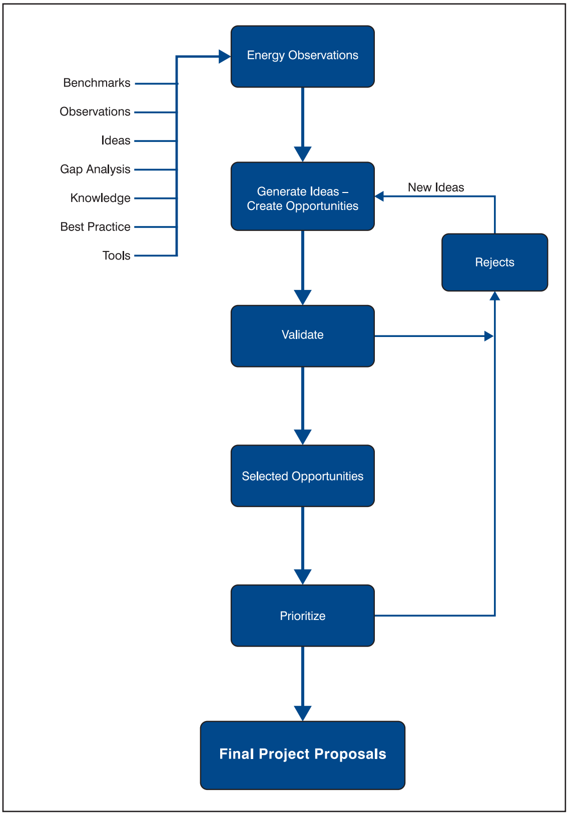
9.2. Energy Projects – Identification and Assessment

Whereas the walkthrough is very much about identifying gaps and potential, the energy project assessment is focused on generating improvement ideas. It is a more comprehensive and rigorous process which will deliver a prioritized portfolio of individual energy efficiency projects, each complete with benefits estimate and preliminary cost and feasibility assessments.

The process may take perhaps one to two months depending on the size of the location, and will involve a much more detailed line-by-line discussion of the units compared to the walkthrough. The objective is generally to identify a list of project proposals suitable for final development, authorization, and subsequent implementation. As such, it is essentially a project scoping process consisting of idea generation, validation, and project definition phases.

During the initial idea generation phase, a list of many observations concerning energy performance is documented. At this stage, they are merely observations (e.g. 'rundown temperature for stream X is 25 °C higher than design') – cause and possible action are not considered. The observations are then validated, streamlined, and used to generate a list of opportunities for improvement. These opportunities are then reviewed and validated, tested against constraints in order to generate a prioritized portfolio of projects for implementation.

Conceivably from 250 observations some 75 opportunities will be generated, which are validated to a short list of 40, and eventually a list of 15–20 realistic project proposals. These will have order of magnitude financial benefit and cost figures (say ±30%) and be scoped at sufficient detail to allow a process developer to work them up into final fully scoped and estimated project definitions, ready for management approval.



9.2.1. Team and Preparation

Clearly a much more involved process than the walkthrough, the project assessment process may involve a team of three or four engineers on-site for a couple of months, with support from specialist engineers as necessary. Indeed it may be appropriate to bring in (say) a furnace or turbine specialist for a dedicated cross-site equipment review as part of the assessment. Generally a utilities specialist is a useful full-time team member.

Apart from the usual pre-visit supply of P&IDs, process manuals, and so forth, a key preparation or early phase item is agreeing the financial and business thresholds, energy pricing, methodologies, and constraints with the site. These shape the decision-making of the process and much time will be saved if these are agreed and understood by all parties at the commencement of the assessment.

9.2.2. Assessment Process and Operational Reviews

A suggested step-by-step approach to the assessment process and the development of initial energy-related observations into final project proposal sheets is given in Appendix E.

9.2.3. Project Generation and Validation

There are many well-known methods for assessing the financial value of projects (simple payback, life cycle costing, profitability index, etc.). These are touched on in section 9.4. Most companies will have a standard project evaluation methodology and a set of criteria/investment thresholds which must be followed. It is essential that these are understood before the assessment starts.

While these calculations are a normal requirement of the final financial evaluation for the worked-up project proposals, it is useful to have a preliminary project vetting method. The following matrix system is a useful screening tool which can be used to whittle down the opportunities into a collection of potential projects. Such techniques are quite common and there are variations possible on this basic system. The break points will depend on the business, and should be agreed and calibrated with the site staff before the assessment begins. More categories can be added, and it is also possible to add weighting factors to the categories. Again, whatever is finally adopted needs upfront agreement.

	RANKING INDEX			
	1	2	3	4
Net Benefits	<$100k per yr.	$100k – $1m per yr.	$1m – $2m per yr.	>$2m per yr.
Ease of Implementation	Very Difficult	Requires Shutdown	Requires Project Work	Easy/Quick
Capex	>$2m per yr.	$1m – $2m per yr.	$100k – $1m per yr.	<$100k per yr.

Ranking Score = Net Benefits x Ease of Implementation x Capex (max score 64)

'Quick Wins' = Ease of Implementation = 4 **and** *(Benefit x Capex) score >8*

Such validation techniques are very useful and provide a quick and auditable element in the design and decision process. They are not meant to replace a rigorous financial project justification, but are simply a means of eliminating unfeasible ideas in a logical and consistent manner.

9.3. On-going Improvement – The Mature Operation

The scenario presented so far has focused on developing some form of structured improvement program, typically as part of a new initiative to address a site's energy performance. This will generate ideas and projects.

However, it is also important that once the initial project activity is over and a site is operating at a more mature level of energy efficiency, there has to be a culture of supporting processes in place to ensure the continual refreshment of energy efficiency ideas. The issues around sustainable energy performance have been discussed; the nature of the energy drivers is such that operational changes can quickly change the issues affecting energy. Two or three consecutive and unrelated processing changes could move a site's utility balance from, say, an MP steam surplus to a shortage, thus radically changing the site energy strategy. External fuel pricing considerations could do likewise. Thus the cycle of opportunity and project identification needs to continue – ideally as part of the performance review (section 7.2). It is conceivable that changing operational priorities and economics could revitalize project ideas previously rejected. So the database of opportunities, including those not so far carried out, needs to be maintained.

The performance review process will undoubtedly generate many items requiring a quick fix or short term corrective action and repair. However, the review and discussion must also keep an eye open for more structural issues requiring larger scale intervention, capital projects and so forth. Gatekeeping of external developments, new technologies, and services that may be exploited in the quest for improved energy efficiency is an important part of this activity.

It is this attitude that is absolutely essential to a long term sustainable approach to energy efficiency. A one-off set of energy projects will inevitably become out of date, fall by the wayside, and site energy performance will deteriorate.

9.4. Financial Planning and Project Economics

Project investment entails significant capital and associated costs over the economic life of the project. It is usually possible to accomplish the same result with several routes, and we need to be able to make economic investment decisions about the correct way to proceed with the project. There are many textbooks and guides providing comprehensive introductions to project economics however this brief section provides an introductory summary. In all cases, support from local company economists should be sought in the selection of discount rates, investment thresholds, etc.

9.4.1. Standard Project Economics Techniques

The principle underlying all types of investment is the net return expected from the proposed investment. This net return must be evaluated and compared with the overall investment in the project. The economic technique used to compare various design alternatives by projecting (discounting or compounding) associated costs over the economic life of the project, is known as Life Cycle Analysis (LCA).

Payback Period and Return on Investment are two methods of analysis frequently used. They are not fully consistent with the Life Cycle Cost (LCC) approach in that they do not take into account all relevant values over the entire life period and discount them to a common time basis. Despite their disadvantages, these methods can provide a first level measure of profitability that is, relatively speaking, quick, simple, and inexpensive to calculate. Therefore, they may be useful as initial screening devices for eliminating more obvious poor investments.

The four principal types of analysis that follow are fully consistent with the LCC approach;
Total life cycle cost (present value method), Net Present Value (NPV), Profitability Index or benefit/cost ratio, and Internal Rate of Return (IRR).

9.4.1.1. Simple Payback

Simple Payback determines the number of years for the invested capital to be offset by resulting benefits:

$$\text{Simple Payback Period} = \frac{\text{Gain from Investment} - \text{Cost of Investment}}{\text{Annual Benefits} - \text{Annual Operating Costs}}$$

All other things being equal, the better investment is the one with the shorter payback period.

9.4.1.2. Return on Investment (ROI)

ROI is a performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. To calculate ROI, the benefit of an investment is divided by the cost of the investment:

$$\text{ROI} = \frac{\text{Gain from Investment} - \text{Cost of Investment}}{\text{Cost of Investment}}$$

ROI analysis compares the magnitude and timing of investment gains directly with the magnitude and timing of investment costs. A high ROI means that investment gains compare favorably to investment costs. The advantages of the ROI method are that it is simple to compute and it is a familiar concept in the business community.

9.4.1.3. Net Present Value (NPV)

NPV is a Discounted Cash Flow (DCF) analysis that compares the amount invested today to the present value of the future cash receipts from the investment. In other words, the amount invested is compared to the future cash amounts after they are discounted by a specified rate of return. NPV discounts all of the cash flows of a project to a base year. These cash flows include, but are not restricted to, equipment costs, maintenance expenses, energy savings, and write-off values. The cash flows are discounted to reflect their time value. Once all of the cash flows are discounted to a base year, the cash flows are weighed on a common basis and can be added together to obtain a 'total net present value'. A positive net present value indicates an acceptable project. A negative NPV indicates that the project should not be considered.

9.4.1.4. Profitability Index (PI)

The Profitability Index, or PI, (also known as a Benefit/Cash Ratio [B/C] or Savings/Investment Ratio [SIR]) compares the present value of future cash inflows with the initial investment on a relative basis. Therefore, the PI is the ratio of the present value of cash flows (PV) to the initial investment of the project:

A PI of 0.75 means that the project returns currency in present value for each current currency invested. In this method, a project is accepted if PI $>$ 1 and rejected if PI $<$ 1.

Note that the PI method is closely related to the NPV approach. In fact, if the net present value of a project is positive, the PI will be greater than 1. In other words, if the present value of cash flows exceeds the initial investment, there is a positive net present value and a PI greater than 1, indicating that the project is acceptable.

9.4.1.5. Internal Rate of Return (IRR)

An internal rate of return is also a Discounted Cash Flow (DCF) analysis commonly used to evaluate the desirability of investments or projects. The IRR is defined as the interest rate that makes the net present value of all cash flow equal to zero. In financial analysis terms, the IRR can be defined a discount rate that that makes the present value of estimated cash flows equal to the initial investment. The higher a project's internal rate of return, the more desirable it is to undertake the project.

Assuming all other factors equal amongst the various projects, the project with the highest IRR would probably be considered the best and undertaken first. IRR should not to be confused with the ROI method which calculates the rate of return that an investment is expected to yield. IRR expresses each investment alternative in terms of rate of return, a compound interest rate.

9.4.1.6. Discount Rate

An important element of DCF analysis is the determination of the proper discount rate that should be applied to bring the cash flows back to their present value. Generally, the discount rate should be determined in accordance with several factors:

Project risk, Project Size and Life, Time Horizon, Different Cash Flows, Tax Considerations, etc.

This is a specialized area, and consultation with the site/company economist should take place in selecting an appropriate discount rate for the projects in question.

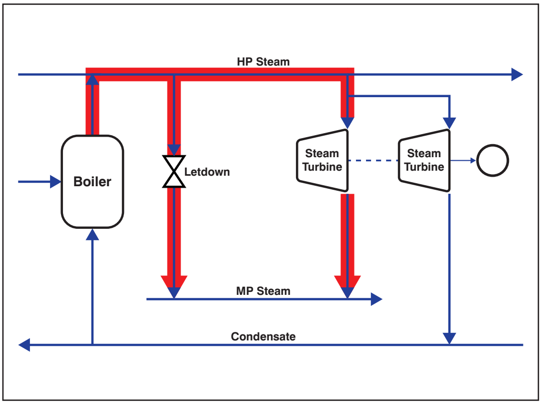
9.4.1.7. Making a Go/No-Go Project Decision

The following are 4 generic guidelines to make better investment decisions:

1. Focus on cash flows, not profits. Keep as close as possible to the economic reality of the project. Accounting profits contain many kinds of economic anomalies, flows of cash, on the other hand, are economic facts.
2. Focus on incremental cash flows. Focus on the changes in cash flows affected by the project. The analysis may require some careful thought; a project decision identified as a simple go/no-go question may hide a subtle substitution or choice among alternatives.
3. Account for time. Time is money. According to the theory of time preference, investors would rather have cash immediately (sooner than later). Use NPV as the technique to summarize the quantitative attractiveness of the project.
4. Account for risk. Not all projects present the same level or risk. One wants to be compensated with a higher return for taking more risk. The way to control for variations in risk from project to project is to use a discount rate to value a flow of cash that is consistent with the risk of that flow.

9.4.2. Utilities Marginal Pricing

Typically, a company will maintain a set of product values used for capital project estimation, perhaps including quality premiums and so forth. However utilities systems, and in particular multi-level steam networks, can provide a challenge when looking at the pricing of utilities streams for project evaluation. In most locations, there are various operational routes available (say) to generate an extra ton of steam. Historical average costs should not be used, as these do not reflect the different efficiencies of production, current constraints, and what may be available at the time.



Consider a simple two-level steam network as illustrated. There are two ways to value MP Steam. The value of MPS generated through the letdown station is essentially the value of HP steam adjusted for the enthalpy difference of HP/MP steam. However, the value of MP steam generated through the steam turbine is the value of HP steam minus the power generation. Thus the value of MP steam from both these routes are different and not the same as the average MP steam cost.

This is an important consideration and requires understanding of which constraints are active when allocating utility prices. In reality, it will be more complex than the simple example quoted here – multiple turbines with differing efficiencies, multiple steam levels, etc.

The use of marginal economics:

- Differentiates between different levels of producing steam
- Provides the necessary signals to allow optimization of the steam network
- Provides the actual value of energy saved when carrying out efficiency projects
- However, it is dynamic – as fuel prices or site demand profiles change relative to the active utilities constraints then so do the marginal costs

This nicely illustrates the potential benefit of an on-line utilities optimization system which will recognize the current constraints and what is affecting the marginal pricing, and make operational decisions on the pertinent pricing strategy.

9.4.3. Investment Thresholds for Energy Projects

Traditional investment criteria have not always served energy efficiency projects well; short term production driven investments can appear more attractive than longer term energy projects which recoup their benefits over many years. In the current difficult economic climate, where capex budgets are limited, energy efficiency projects can slip in priority against 'must do' safety or product related investments.

To mitigate these effects, companies are increasingly turning to special investment criteria for energy proposals which better reflect the longer term nature of such projects. Thus while a Profitability Index threshold of (say) 4 may be needed for normal projects, a threshold of 2 may be used for energy projects.

Such a philosophy is reflected in the Carbon Trust Energy Maturity Matrix (Appendix B) where 'positive discrimination in favor of 'green' schemes...' is rated as best practice.

Example: Company X (a large refinery/petrochemical site) had a big surplus of Low Pressure Steam (LPS) – the constraint was on Medium Pressure Steam (MPS). Hence, a traditional utilities pricing approach gave zero value to LPS – there was no apparent benefit in saving LPS. However, this was counter-intuitive to operational and engineering common sense – it implied that there was no financial benefit in repairing steam leaks. So, in conjunction with the site economist, an agreed LPS value was chosen which provided an incentive to a steam leak repair program. In parallel with this project, activities aimed at rebalancing the MPS/LPS distribution helped accommodate as much as possible of the 'saved' LPS.

10. Measurement and Control of Energy Streams

Accurate measurement of energy streams and good control of energy-influencing parameters is an absolute essential foundation for nearly all energy improvement initiatives. Indeed, it is probably one of the most effective means of improving energy efficiency.

Chapter 6 on Energy Management Information Systems discusses in some detail the role of energy information in decision-making. The foundation of this is an effective and comprehensive set of measurements. Unfortunately, at times in the past, the provision of energy measurements was often sacrificed during plant design as an economy measure. Similarly, measurement provision on package units such as turbines was left to the vendor's local package, and not fully integrated into the plant instrumentation system. Thus, it is quite common for an energy improvement project to require additional instrumentation. In this respect, the growth of wireless instrumentation in recent years has made the retrofitting of measurement points a more economical prospect. Local gauges and thermowells can now easily be brought back to the control room/DCS.

10.1. Mass and Energy Balances

Being able to construct an energy balance around the manufacturing unit in question is a basic element in the reporting and analysis of energy data. It allows an understanding of the distribution of energy consumption and loss across the unit and is the base line for identifying opportunities for improvement. The ideal measurement system enables comparison of the production of a given fluid to the sum of its downstream consumption points. For example, metering both the total steam delivered to a given header by the boilers and the individual consumers that branch off of that header. While it may not be realistic to measure every use point, there should be consumption measurements at all major users. Start with the largest branch lines and add metering as budget allows on smaller branch lines.

When monitored in real-time, the mass balance provides the basis for the calculation of energy reports, KPIs, and the consequent identification of changes in operation. High quality measurement of the energy streams (i.e. enthalpies) is essential.

In some cases, for instance the loss of energy through an air cooler, it is clearly not possible to directly measure the energy lost to atmosphere. In such cases, it will need to be calculated by difference from an energy balance around the equipment in question.

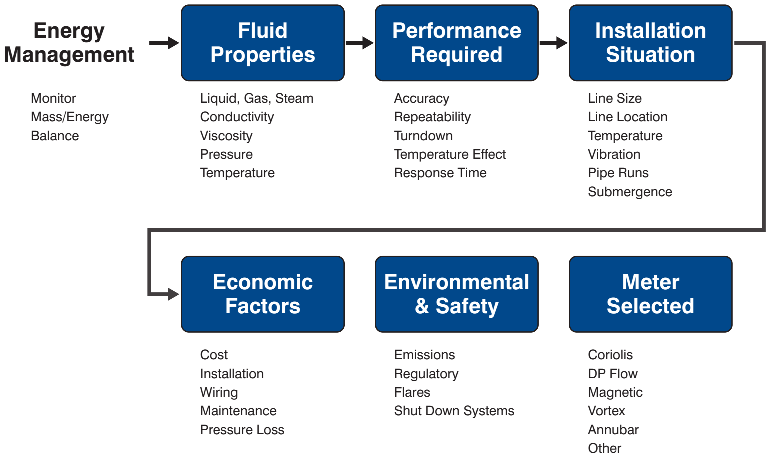
10.2. Monitoring Principles

Some general principles should be followed in implementing or expanding the utility fluid monitoring system. Start by reviewing utility bills to determine the rank of energy costs from electricity, natural gas, and other fuels. From there, combine site knowledge of the most important ways these primary sources of energy are transformed. For some sites, the majority of energy is transformed in furnaces and fired heaters. For others, steam generation represents the largest use of primary fuels; while for other sites, compressed air may be the largest use of energy.

The facility likely has many flow measurements used for the control and safe operation of the utility systems. It is a good practice to make maximum use of these existing meters in planning the layout of a monitoring system. Recent technology advances, like wireless technology, enable existing meters to maintain their role in control schemes while additionally providing data to a utility monitoring system, which may be a completely separate network.

10.3. General Considerations for All Flow Metering Points

The figure below is a flow chart summarizing the considerations for proper selection of flow metering equipment. Many technologies exist and all have particular advantages for certain applications, as well as trade-offs that need to be considered. No one meter can provide the best measurement in all utility fluid measurement applications.



The purpose of the measurement is the starting point in the selection process and influences all other meter selection criteria, including performance and economic factors. The main focus of this discussion is metering used for monitoring, as opposed to the many other uses for flow rate information. While not meant to be comprehensive, the following comments should further clarify the importance of many of the factors from the flow chart as they pertain to monitoring the flow of utility fluids.

10.3.1. Fluid versus Flow Meter Principle of Operation

Flow rate is detected via the sensitivity of a given metering technology to a particular property of flowing fluid, and is therefore limited to fluids having that property. For example, magnetic flow meters are excellent for most water flows but cannot measure gases, and differential pressure (DP) flow is a good general-purpose meter, but would not be a good choice for a very viscous fluid such as No. 6 Fuel Oil.

10.3.2. Performance Requirements

Utility flow meters are employed for usage trending and to monitor the balance between total supply and total demand of a given fluid. As such, the use of mass flow measurements is considered best practice wherever practical. Meters with higher accuracy enable detection of smaller issues than meters with lower accuracy, thus expanding the number of issues that can be identified and corrected. In many cases, published meter specifications provide an incomplete picture of the overall accuracy capability of an instrument. Installed performance, which accounts for process changes that impact fluid density, is a better performance criterion.

Proper installation of a meter is crucial to achieve performance within specification, so care should be taken to ensure sufficient straight piping is available and impulse piping (if it cannot be eliminated) is plumbed to eliminate errors. Proper sizing is essential for all meters to ensure meter performance over expected flow rates is maintained without causing potentially costly permanent pressure loss.

10.3.3. Economic Factors

The purchase price of a meter is only one portion of its total cost. In selecting a meter, the total installed cost, as well as other life-cycle costs, should be balanced with the need for accurate data on energy usage. For example, the traditional orifice-based flow measurement may have a relatively low purchase price but suffer from high installed costs (large number of components and significant labor to assemble and commission), and life cycle costs (relatively high permanent pressure loss). The impact of the Permanent Pressure Loss (PPL) of new meters in a given location should be considered, particularly if numerous new flow measurements need to be added to the plant. A major contributor to installed cost is wiring. Newer wireless devices now available can completely eliminate this cost, allowing greater coverage of a plant for a given budget. The cost of lost production in shutting down a process for meter installation may also weigh heavily in accounting for total installed cost.

10.3.4. Considerations to Specific Fluids and Energy Streams

When the above considerations are applied to a given product, energy flow or utility fluid, it is not uncommon to find several meters which may fit an application. The following comments are intended to clarify what considerations are most important for a given measurement, and what meter limitations may come into play.

10.3.4.1. Feed and Product Streams

The key is accurate and comprehensive flow measurement of all incoming and outgoing feed and product streams. When constructing energy balances, the calibration conditions for the flow measurements should be checked. In calculating stream enthalpies, the correct operating temperature should be used for the specific heat values. If there are wide variations in operating temperatures (different modes), then temperature compensation can be considered (for example, the specific heat of a typical light oil product changes from 0.625 to 0.675 kcal/kg as the temperature rises from 150 to 200° C). So, attention to such details is important. In the case of gas flow, pressure and temperature compensation may be appropriate.

10.3.4.2. Steam

The main issues around steam measurement involve the correct installation to prevent condensate problems, and (when appropriate) suitable corrections for the effect of changes in temperature and pressure. There is a host of instrumentation available for both steam (and air flows), however the two predominant technologies are Vortex and Differential Pressure (DP) derived flow using primary elements (orifice plates, pitot tubes, nozzles). Both are excellent stream meters, their application depending on line size, performance over turndown, the result of sizing calculations, and weatherization requirements.

The advancement of DP flow technology now allows for multivariable transmitters that can measure the differential pressure, static pressure and temperature, and calculate fully-compensated mass or energy flow. Thus, the instrument is able to calculate fully compensated mass flow of steam as well as the energy content of steam. When used with an Annubar (pitot tube), the permanent pressure loss is negligible and the installation costs are a fraction of in-line flow meters (requiring only one mounting nozzle to be welded in place and one entrance in to pipe medium). The cost of heat tracing should be included in the total installed cost for steam meters located outdoors. Modern ‘integrated’ DP flow greatly reduces heat tracing requirements and Vortex eliminates them.

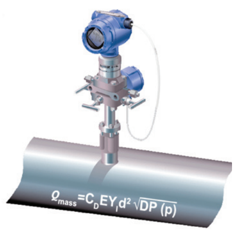
Consider accuracy over a range of flows if heating loads are seasonal or vary by steam demand from multiple units on a single delivery line. Best practice is to evaluate the performance of the meter under all expected operating conditions (minimum, normal, and maximum flow rates, start-up conditions, upsets, etc.) and make a mass measurement of steam where these condition changes warrant.

A substantial portion of steam loss occurs through steam traps. Proper steam trap maintenance is essential to minimizing these losses. Recent advances allow automation of some steam trap maintenance by instantly detecting failed steam traps so they can be addressed before energy losses become significant.

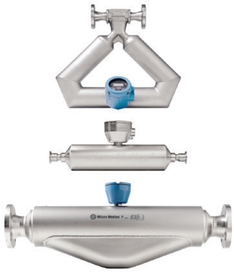
10.3.4.3. Condensate

For energy management, it is important to measure the fraction of condensate that is returned since recycling condensate through the steam system offers significant cost savings in reduced make-up water, energy, and chemical treatment. Both steam and condensate should be measured because their difference represents losses. Condensate is very near its steam flash point, so permanent pressure loss of a meter must be considered if the measurement cannot be installed downstream of a condensate pump. Magnetic flow meters are excellent for water-based fluids having sufficient conductivity. Most, but not all, condensate will be conductive enough and within the temperature limits of magnetic flow meters, so they are a good technology to consider, with DP flow and Vortex also viable choices.

10.3.4.4. Fuels



The hydrocarbon fuels burned commonly in the process industries vary considerably in their properties and therefore in the types of meters best suited for each. Metering with very high accuracy and repeatability enables optimal combustion control. As well as the obvious need for accurate flow measurement, an important factor for fuels is the calorific value of heating value of the fuel. If the fuel is of a consistent composition (e.g. externally purchased fuel oil or natural gas) then a fixed factor can be used. Internal fuel gas systems with a variety of



fuel sources and fuels generated as a by-product of a process are much more likely to be subject to swings in calorific value. In general, for similar types of gases, heating value reduces as molecular weight increases. In such cases, on-line compensation by a relative density meter on the fuel gas supply can make a significant improvement in accuracy. Direct mass flow using Coriolis maintains accuracy despite significant changes in the fuel's composition. Turndown issues should also be considered, especially if square root/DP type flow measurements are used. Double-range transmitter systems may be appropriate.

For natural gas, which has a relatively stable composition, multivariable DP flow meters are a good fit. Line size can impact meter selection if a preferred meter isn't practical in a given line size. An accurate 'check meter' on a natural gas main can help ensure proper billing by local suppliers and makes sense for large users of natural gas.

Regardless of fuel type, it is generally important to consider the impact of process changes (pressure, temperature, fluid composition) on expected meter performance. Mass meters (direct or compensated) are essential to proper metering of most common fuels.

10.3.4.5. Combustion Air

Air flow measurement around combustion processes is unique in that air is usually conveyed in thin-walled ducts instead of pipe at very low operating pressure. Annubar averaging pitot tubes provide repeatable measurements, even in areas without long straight run and in rectangular ducts.

10.3.4.6. Determination of Ideal Fuel to Air Ratio

Flue gas analysis is commonly used as an input for controlling fuel/air ratios in combustion processes at an optimum level. The zirconium oxide flue gas oxygen sensor is the most ubiquitous gas analyzer in use around the world. Every automobile manufactured utilizes one or more of these for precisely controlling fuel/air ratios and also for reducing the amount of NO_X emitted from engines. Industrial boilers and furnaces are many times larger, and have proportionally much more to gain from this fuel/air ratio optimization.

One or more oxygen analyzers should be installed directly into the flue gas duct of combustion processes to measure oxygen. An in-situ style probe is preferable to a sampling system for fuel/air control due to the speed of measurement and lower on-going maintenance requirements. The oxygen reading should be used in a control system to adjust fuel/air ratios for maximum efficiency on an on-going real-time basis.

10.3.4.7. Water Measurements

Chilled (hot) water should be measured at key cooling (heating) processes. As with all flow meter selection, a variety of factors may influence instrument selection, however, magnetic flow meters have proven a great starting point for many everyday plant water flow measurements. Other meters are suitable and might be selected based on constraints related to access, installed cost, temperature, conductivity, or need to install the meter without process shut-down. When monitoring efficiency of chillers, cooling towers, etc., good flow measurement should be combined with the best-available temperature and delta-temperature measurement devices available, as energy content of water is highly-sensitive to small changes in its temperature.

Magnetic flow meters should be considered first for line sizes about 150 mm (6 inch) and smaller due to their combination of high accuracy over wide-ranges and absence of PPL. Pressure loss in chilled water manifests as small, but important, increases in temperature and should therefore be minimized.

Combine magnetic flow meters with the most accurate delta-temperature measurement possible for monitoring chiller performance since each degree of cooling represents significant energy consumption. Annubar or Vortex may also be used if magnetic is unsuitable for some reason.

10.3.4.8. Compressed Air Measurements

In some process plants, compressed air systems represent a significant portion of overall power to electric motors in the facility. The production of compressed air is one of the most inherently inefficient processes occurring within the key utility systems. Because of this, and because compressed air is intended to directly perform work in the form of actuating other equipment, it can be important to monitor its usage throughout the plant so leaks can be identified and repaired. Flow metering should be selected to ensure very low permanent pressure loss (PPL), which would further reduce the efficiency of this system. Annubars are consequently an excellent meter to consider first due to their negligible level of PPL. Vortex also allows reduction in PPL compared to traditional orifice measurements.

10.3.4.9. Electrical Power Measurements

Most process plants control electrical motor driven assets from a Motor Control Center (MCC) via the system controls. Many are fitted with electrical power meters from which the respective electrical power consumed by the asset can be monitored and recorded. Where this provision is not in place, the use of clamp-on electrical transducers and permanent hardwired sensors can be used. There are literally hundreds of transducer sensor types available for measuring current and voltage, and hence determination of electrical power.

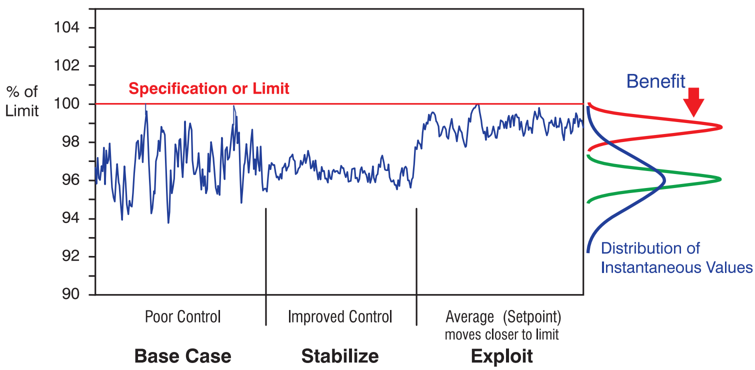
The above is a brief, general overview of considerations for proper monitoring of the usage of key utility fluids within a plant. Other measurements play a key role in maintaining the availability of utility and energy systems (i.e. boiler drum level, compressor surge measurements, vibration monitoring of pumps and compressors, and steam trap monitoring). This overview focused only on the monitoring of utility fluids as a key step in understanding where energy is used and lost to the highest degree. It is recommended to consult an expert in process industry flow measurement to ensure the best meter is selected for each potential measurement point and to assist in evaluating the meter considerations above.

11. Common Energy Tools and Techniques

A list of comprehensive energy efficiency techniques covering all industries is beyond the scope of this book. However, there are some generic best practices which do have widespread applicability across the process industries and are likely to occur in the majority of energy improvement plans. These are basic good practice and are presented here as an overview. Detailed implementation advice can be found in many standard texts and manuals.

11.1. Control of Energy Streams

As with many other considerations such as quality, yield or reliability, good control is an essential prerequisite for energy efficient operation. Being able to run a robust and stable operation close to an operational constraint is important, as is the ability to shift operation in a controlled manner as external factors change, thus always running at the energy efficient spot.



The concept of improved stability allowing a constraint to be approached more closely is illustrated. The increased stability allows the average operating point to be moved closer to an operational target or constraint without infringing the limit. And, this results in less waste and a reduction in operating costs. So, for instance, a furnace with good quality combustion air control can safely run closer to an ideal low stack oxygen target without the risk of dangerous sub-stoichiometric firing, thus saving fuel. Or, a distillation column can run closer to its ideal reboil duty and still consistently produce on-specification products without the need to over-reboil or over-reflux (more energy) to play safe.

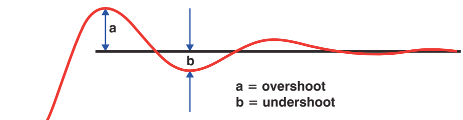
Typical generic control techniques that play a part on energy efficient operation follow.

11.1.1. Controller Tuning and Basic Set-up

The base-level control loops, typically 2 or 3-term PID controllers, are the basic manipulation handles of the plant and need to be able to operate reliably and consistently. Without them, any amount of higher level energy-saving control will not function.

All controllers should be periodically reviewed – a simple observed set-point step test is sufficient. We are looking ideally for what is known as Quarter Amplitude Damping in the response to a set-point change.

Otherwise performance will be either too sluggish or over-reactive.



Step response for sound controller settings

Controller re-tuning is a well-documented activity – methods such as Ziegler-Nichols and Cohen-Coen are well-known and will be found in many textbooks and guides. Tuning packages which run on PCs are widely available, although manual observation with a wristwatch and notebook can be as effective. Many modern DCS platforms have self-tuning packages. These can be very useful, although their use in a continual background mode must be managed.

At the same time, valve operation and instrument range should be checked – controllers running with valves consistently wide-open or almost shut will not perform well – and similarly instruments that are operating at the extreme ends of their range will not provide consistent and accurate measurements. Re-ranging transmitters and valve trims may be needed.

Finally, for master-slave systems, the master should always be tuned slower than the slave controller.

11.1.2. Feed-Forward Control

For most manufacturing processes there is proportionality between energy consumption and feedrate – the more feedstock you process the more energy is required. The precise nature of this relationship may be non-linear with significant fixed loads, but the basic proposition is generally a good starting point.

Hence, for plants where there are regular feedrate changes, feed-forward control plays an important part in keeping energy consumption down.

This is particularly important for the final process energy consumers. While on many units the utilities complex is the largest single direct energy consumer, and quite rightly receives the focus of attention, it is also important that the subsequent consumption of that utility-generated energy by the process users is tightly controlled. This is the actual energy going into the manufacturing process.

In execution, feed-forward mechanisms may vary from a simple ratio system through to a disturbance variable as part of a multivariable model-based controller at the other (see below). Dynamics do have to be considered. If the feedrate measurement that is being used to drive the system is physically far ahead in the process, then it may be appropriate to include some dynamic compensating term (typically a first order lag) to prevent ‘premature’ movement of the slave loop before the flow changes have worked their way through the process. Of course the overall loop needs to have a feedback mechanism to allow operator adjustment to adjust product quality (e.g. changing the reboil/feed ratio on a distillation column).

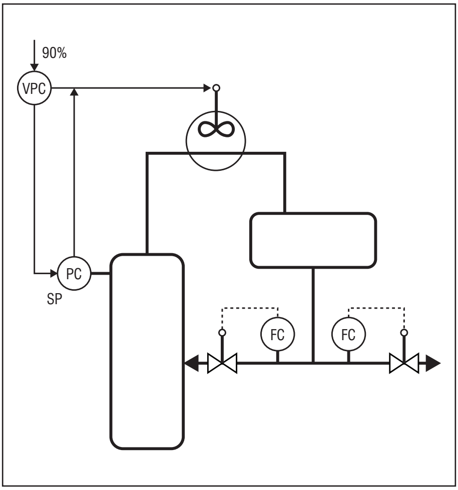
Other, less explicit, forms of feed-forward control can be considered to handle disturbances in a predictive manner. This includes use of heat duty controllers (as opposed to flow controllers) for heating systems (e.g. reboilers), which will compensate for variations in the heating medium temperature. Or, corrections for the heating value of fuel gas or steam conditions. All these allow a more accurate setting of heat input without having to allow wasteful contingency factor.

11.1.3. Constraint Pushing Control

Constraint pushing recognizes that there are often extra degrees of freedom in unit operation which can be exploited to achieve a secondary control aim over and above the basic regulatory structure. This is particularly important from an energy perspective when driving the plant towards an energy efficient position, and is a desirable outcome although not necessarily at the expense of quality or safety considerations.

It can also be used where high speed regulatory control is the first aim and then slower constraint control adapts operation to a more efficient position while maintaining primary controllability. Typical of these are valve position controllers, which are useful ways of continually pushing operation to a low energy position without losing tight control. The aim being to operate with the valves in question at about 90% open. Three examples illustrate this as follows:

Floating Pressure Control in a Distillation Column: It is well-known that, within hydraulic constraints, distillation columns require less energy to achieve the same separation as the pressure is reduced. However, at any one time, stable control of the column pressure is desirable to assist consistent product separation. The lowest pressure will generally be achieved when the overhead condenser is running at maximum duty – i.e. the output of the pressure controller which drives the condenser is at a maximum. So, a constraint controller can be added to the basic design which manipulates the pressure controller setpoint such that its output is ideally 90%. This is a slow acting controller, which will make small and gradual adjustments to reduce the pressure controller setpoint, thus allowing the pressure control to always maintain stable basic control.

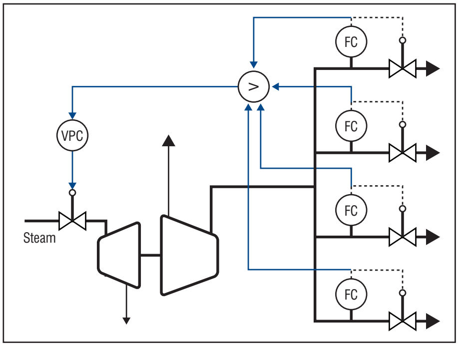


(Normally such a system will require pressure compensated temperatures and adjustment of reboil heat to match the constraint pusher and correspondingly minimize the heat input).

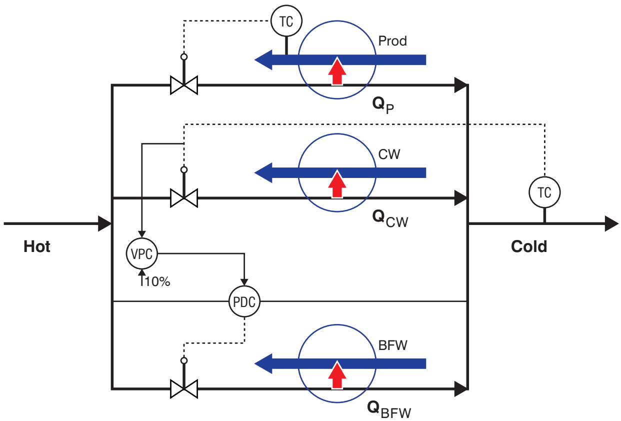
Valve Networks and Variable Speed Drives: Operating control valves at 50% open or less is wasteful, as hydraulic energy from a pump is being squandered in the high pressure drop over the valve. Consider the distribution network illustrated. A steam driven compressor supplies several consumers all on flow control. There is clearly the potential for a large turndown and spread of operation.

So again, the use of a valve position controller is suggested, which monitors the position of the control valves in a network and then slowly drives the turbine speed down such that the widest open valve is at 90%. This is an excellent means of tuning down the compressor energy consumption while maintaining good flow controllability.

Similar examples could be considered using a variable speed drive on electric pumps or controlling a common hot oil furnace which supplies several independent consumers.



Exchanger Preferential Control: In a similar manner, there may be choices in balancing heat exchanger networks as the relative duties and operation of the exchangers change in line with varying operations. Consider the illustrated situation of a process stream which is cooled against a process exchanger (Q_P), a boiler feed water heater (Q_{BFW}) and a cooling water trim cooler (Q_{CW}). High speed control of the exit temperature is provided by manipulating the valve to Q_{CW}. Flow variations through Q_P and Q_{CW} are decoupled by the pressure differential control across the exchanger bank which sets the balancing flow through Q_{BFW}.



However, it is desirable that as much heat as possible is recovered by Q_{BFW}. Thus, a valve position or constraint controller looks at the signal to the Q_{CW} valve, and manipulates the Pressure Differential Controller (PDC) setpoint so as to minimize the flow through Q_{CW}. If the Q_{CW} valve opens too much, the setpoint to the PDC will be decreased so as to divert flow through Q_{BFW}, which is economically more attractive.

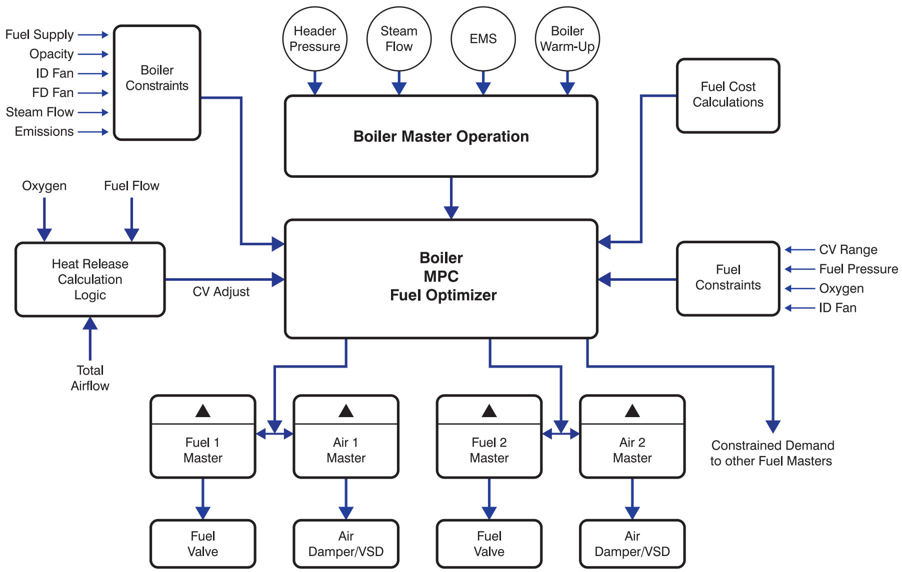
The above examples indicate the relatively simple options that can be built around this concept. The relative operation of a wide variety of equipment and processes can and will change on a continual bases, and such techniques are very useful in keeping the process in a sensible, energy efficient, area of operation.

11.1.4. Model Predictive Control (MPC)

The aforementioned techniques are all built using conventional control components, which are widely available in either pneumatic control, single loop electronic, or DCS. The basis is the 3-term PID controller.

However, all of the above can be combined in a single algorithm set. Over the last 25 years, model-based control has been increasingly used in the process industries. There are many well-known algorithms sold through a variety of system and consultancy suppliers – PredictPro, DMC, SMOC, RMPTC, etc. – all of which follow a common basic philosophy.

The controller structure envisages a set of controlled variables (plant targets – e.g. product qualities) and a set of manipulated variables (plant handles – flows, valves and other base level controllers) plus associated disturbance (i.e. feed-forward) and constraint (limiting) variables. Dynamic models (typically 1st or 2nd order) are established between the variables in a fully predictive multivariable manner. At each control cycle, a linear optimization routine calculates an optimum set of manipulated variable signals so as to meet the controlled variable set-points and honor any constraints and disturbances. It is sometimes also possible to include an economic objective function, which can move the plant towards a given goal if there are sufficient degrees of freedom available.



Initially, such applications were on a smaller scale – say a 4 x 4 controller on a single distillation column. Nowadays, much larger plant-wide matrix sizes, up to 40 x 40 variables or greater, have been built. They play a very useful role in energy efficiency as their multivariable constraint handling can better handle an energy-minimization objective or constraint than the traditional single input/single-output feedback controller.

Such controllers have proven very successful in reducing energy costs, in particular for processes such as distillation where energy savings of >5% are typically reported (in addition to yield and quality benefits). However, they require specialist skills for design, implementation, and support. It may be best to consider implementation as part of an overall quality improvement or debottlenecking project than purely for energy considerations.

11.2. Utilities Systems

Steam is probably the most common utility medium for manufacturing sites (others being tempered water and thermal fuels). Most sites will generate steam in boilers at a high pressure and then let down via compressors, pumps, turbine generators, and consumers, to generate electricity and meet process and pumping needs. Typically, sites will have a two or three level steam hierarchy. Two broad areas of attention define the focus for energy efficiency:

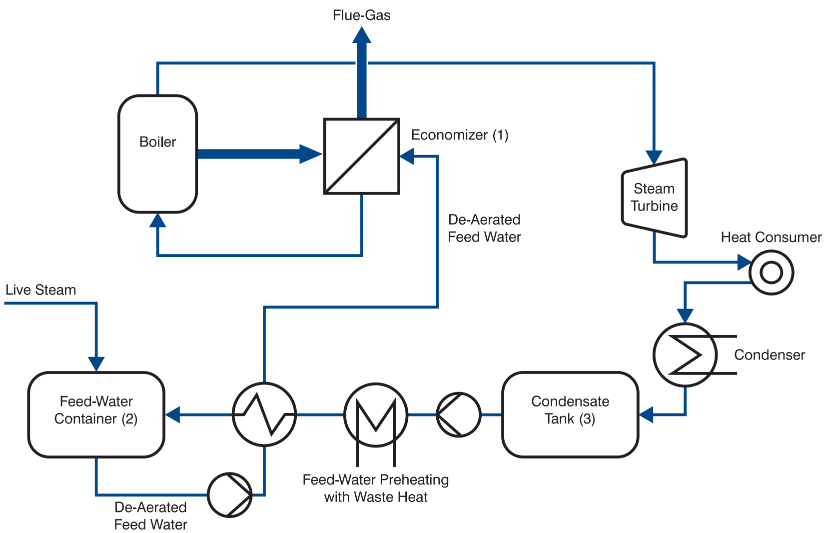
- Efficiency of generation – the boiler house
- Distribution and matching demand – the steam network

11.2.1. Steam Generation

Boiler firing will be considered as part of the general combustion discussion in section 11.3. However, given the size of many steam generating systems – providing site-wide steam at many plants – there is significant scope for optimization of the boiler operation, in particular the water-side activities. Large circulating energy streams are involved – often at relatively low temperature levels. Corrosion and water quality issues play an important part and thus provide a delicate balancing act for boiler configuration and operation.

11.2.1.1. Boiler Feed Water Preheat

The Boiler Feed Water from the de-aerator (BFW) being returned to the boiler generally has a temperature of approximately 105 °C. The water in the boiler (at a higher pressure) will be at a higher temperature. The boiler is fed with water to replace system losses and recycle condensate, etc. Heat recovery is possible by preheating the feed-water, thus reducing the steam boiler fuel requirements.



Reheating is achieved in several ways:

- **Using waste heat (e.g. from a process):**
  BFW can be preheated by available waste heat. This is an excellent way of recovering low level process heat, e.g. from product rundown streams
- **Installing an economizer (1):**
  Deliver heat exchange of boiler flue gases to BFW
- **Using de-aerated feed water:**
  The condensate can be preheated with de-aerated feedwater before reaching the feed water vessel (2). The BFW from the condensate receiver (3) has a lower temperature than the de-aerated feed water from the feed water container. Through a heat exchanger, the de-aerated feed water is cooled down further (the heat is transmitted to the feed water from the condensate tank). As a result, the de-aerated feed water forwarded through the feed water pump is cooler when it runs through the economizer. It thus increases its efficiency due to the larger difference in temperature, and reduces the flue-gas temperature and flue-gas losses. Overall, this saves live steam, as the feed water in the feed water container is warmer and therefore less live steam is necessary for its de-aeration

In practice, the possible savings from feed water preheating amount to several percent of the steam volume generated. Therefore, even in small boilers, the energy savings can be in the range of several GWh per year. For example, with a 15 MW boiler, savings of roughly 5 GWh/yr, some $100,000/yr and about 1000 ton CO/yr can be attained. Boiler flue-gases are often rejected to the stack at temperatures of more than 100 to 150°C higher than the temperature of the generated steam. Generally, boiler efficiency can be increased by 1% for every 20°C reduction in the flue-gas temperature. By recovering waste heat, an economizer can often reduce fuel requirements by 5 to 10% and pay for itself in less than 2 years.

11.2.1.2. De-aerator Operation

De-aeration protects the steam system from the effects of corrosive gases by removing dissolved gases from boiler feed water. It accomplishes this by reducing the concentration of dissolved O_2 and CO_2 to a level where corrosion is minimized. A dissolved oxygen level of 5 parts per billion (ppb) or lower is needed to prevent corrosion in most high pressure (>13.79 barg) boilers. While O_2 concentrations of up to 43 ppb may be tolerated in low pressure boilers, equipment life is extended at little or no cost by limiting the oxygen concentration to 5 ppb. Dissolved CO_2 is essentially completely removed by the de-aerator.

The design of an effective de-aeration system depends upon the amount of gases to be removed and the final gas (O_2) concentration desired. This in turn depends upon the ratio of BFW makeup to returned condensate and the operating pressure of the de-aerator. Sudden increases in free or ‘flash’ steam can cause a spike in de-aerator vessel pressure, resulting in re-oxygenation of the feed-water. A dedicated pressure regulating valve should be provided to maintain the de-aerator at a constant pressure.

Steam to the de-aerator provides physical stripping action to scrub out unwanted gases and heats the mixture of returned condensate and boiler feed-water makeup to saturation temperature. Steam flow may be parallel, cross, or counter to the water flow, bubbling through the water, both heating and agitating. Exit steam is cooled by incoming water and condensed at the vent condenser. Non-condensable gases and some steam are released through the vent. Most steam will condense, but a small fraction (usually 5–14%) must be vented to accommodate the stripping requirements. Normal design practice is to calculate the steam required for heating, and then make sure that the flow is sufficient for stripping as well. If the condensate return rate is high

(>80%) and the condensate pressure is high compared to the de-aerator pressure, then very little steam is needed for heating, and provisions may be made for condensing the surplus flash steam. Optimization of the de-aerator pressure and vent rate is an important energy-saving consideration.

The energy in the steam used for stripping may be recovered by condensing this steam and feeding it through a heat exchanger in the feed water stream entering the de-aerator.

De-aerator steam requirements should be re-examined following the retrofit of any steam distribution system, condensate return, or heat recovery energy conservation measures. Continuous dissolved oxygen monitoring devices can be installed to aid in identifying operating practices that result in poor oxygen removal.

Note: The de-aerator is designed to remove oxygen that is dissolved in the entering water, not in the entrained air. Sources of 'free air' include loose piping connections on the suction side of pumps and improper pump packing.

11.2.1.3. Minimizing Blowdown

Minimizing boiler blowdown rate can substantially reduce energy losses, as the temperature of the blowdown is directly related to that of the steam generated in the boiler.

As water vaporizes in the boiler, dissolved solids are left behind in the water, which in turn raises the concentration of dissolved solids in the boiler. The suspended solids may form sediments, which degrade heat transfer. Dissolved solids promote foaming and carryover of boiler water into the steam. In order to reduce the levels of suspended and dissolved solids (TDS) to acceptable limits, two procedures are used, automatically or manually in either case:

- Bottom blowdown is carried out to allow a good thermal exchange in the boiler, it is usually a manual procedure done for a few seconds every several hours
- Surface or skimming blowdown is designed to remove the dissolved solids that concentrate near the liquid surface and it is often a continuous process

The blowdown of salt residues to drain causes further losses, accounting for between one and three percent of the steam employed. Further costs may be incurred for cooling the blowdown residue to the temperature prescribed by regulatory authorities. The amount of energy lost by blowdown increases with higher boiler pressures.

In order to reduce the required amount of blowdown, there are several options:

- **Using waste heat (e.g. from a process):**
  BFW can be preheated by available waste heat. This is an excellent way of recovering low level process heat, e.g. from product rundown streams
- **Condensate recovery:**
  Condensate is already purified and thus does not contain any impurities concentrated inside the boiler, if half of the condensate can be recovered, the blowdown can be reduced by 50%
- **Water treatment:**
  Depending on the quality of the feed-water, water softeners, decarbonation and demineralization might be required. The level of blowdown is linked with the level of the more concentrated component present or added to the feed-water. In case of direct feed of the boiler, blowdown rates of 7 to 8% are needed. This can be reduced to 3% or less when water is pre-treated

- **Automated blowdown:**
  The installation of automated blowdown control systems can also be considered, usually by monitoring conductivity. The blowdown rate will be controlled by the most concentrated component, knowing the maximum concentration possible in the boiler
- **Flashing at lower pressure:**
  Flashing the blowdown at medium or low pressure is another way to recover the energy content of the blowdown. This solution can be more favorable than exchanging the heat in the blowdown via a heat exchanger

Pressure degasification caused by vaporization also results in further losses of between 1 and 3%. CO_2 and O_2 are removed from the fresh water in the process. This can be minimized by optimizing the de-aerator vent rate. The amount of waste water will also be reduced if blowdown frequency is reduced.

11.2.1.4. Condensate Collection and Heat Recovery

Where heat is applied to a process via a steam heat exchanger, the steam surrenders energy as latent heat as it condenses to hot water. This water is either lost or recycled to the boiler. Re-using condensate has four objectives:

- Recycle the energy contained in the hot condensate
- Saving the cost of the (raw) top-up water
- Saving the cost of boiler water treatment
- Saving the cost of waste water discharge

Condensate is collected at atmospheric and vacuum. The condensate may originate from steam in appliances at a much higher pressure. Where this condensate is returned to atmospheric pressure, flash steam is spontaneously created. This can also be recovered. De-aeration is necessary in the case of vacuum systems.

The technique is not applicable in cases where the recovered condensate is polluted or if the condensate is not recoverable because the steam has been injected into a process.

For new designs, good practice is to segregate the condensates into potentially polluted and clean condensate streams. Clean condensates are those coming from sources which, in principle, will never be polluted (for instance, reboilers where steam pressure is higher than process pressure, so that in the case of leaking tubes, steam goes into the process). Potentially polluted condensates are condensates which could be polluted in the case of an incident (e.g. tube rupture on reboilers where process-side pressure is higher than steam-side pressure). Clean condensates can be recovered without further precautions. Potentially polluted condensates can be recovered but need segmentation options in the case of pollution, which is detected by on-line monitoring (e.g. Total Organic Carbon (TOC) meter).

Condensate recovery has significant benefits and should be considered in all applications. The use of pinch analysis (see 11.8) for water systems has proven particularly effective.

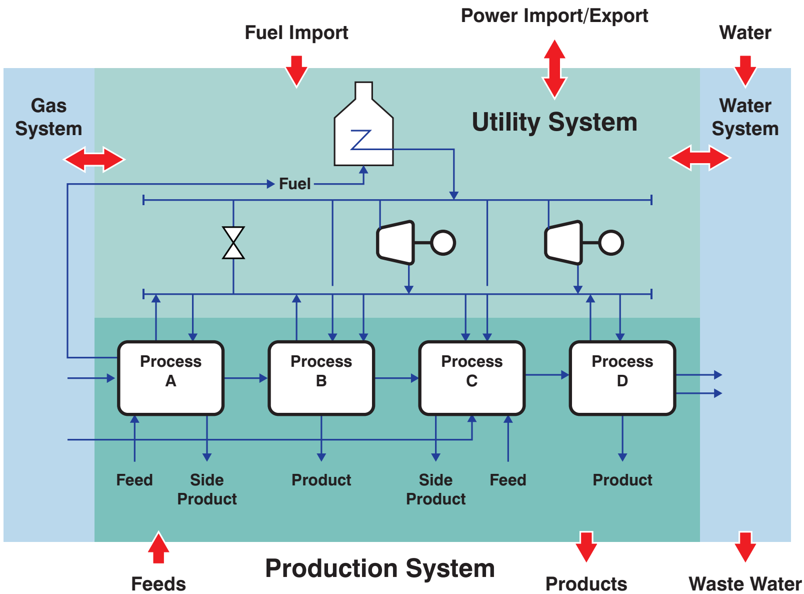
11.2.2. Steam Networks and Distribution Optimization

The successful efficient operation of a site steam network can be a major challenge, and presents significant opportunities to both waste or gain valuable energy as one attempts to balance supply and demand. Typically a manufacturing site may have two or three levels of steam networks at different pressures – a collection of boilers, turbine generators, and let-downs, in addition to the process consumers.

Some turbines may be total condensing; some may be back-pressure turbines. It is very likely that the network will have grown over the years – new equipment will have been added to relieve a particular historical constraint at a moment in time. Circumstances change and a different set of constraints will now apply. There may be different fuel options; gas, liquid, waste gas. More dynamic considerations could include time-dependent fuel and electricity tariffs (peak/off-peak).

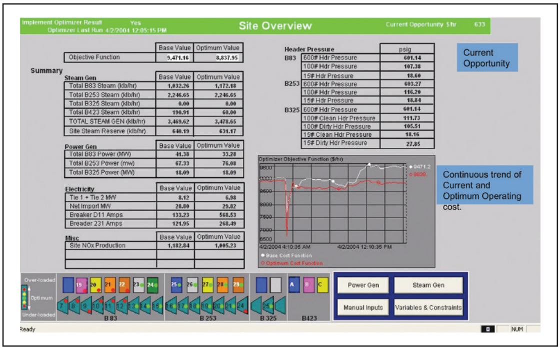
Such a scenario can all too often result in a constrained situation where typically one steam level is limited and the other is in surplus. There may be some opportunity for balancing this dynamically by control and optimization techniques; it may need some structural changes to bring the system into balance.

11.2.2.1. Utilities Optimization



For any system which has degrees of flexibility (e.g. alternate options to generate electricity, differing equipment efficiencies, varying load profiles) then a utilities optimization package can prove very useful. It may be an off-line package run in simulation mode or a fully closed-loop real-time optimizer driving the setpoints of the base level controllers around the system.

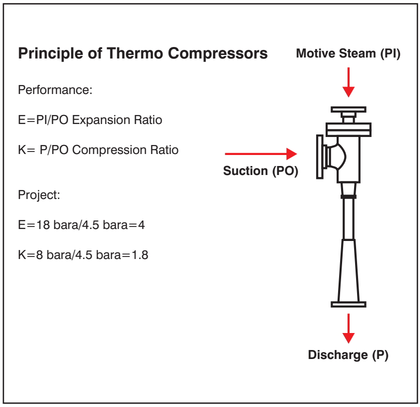
Typically, a model is built of the key utilities components – turbines, boilers, letdowns and desuperheater stations. This will be fitted to the current operational conditions and process utility requirements – making the base case or 'as is' model.



This done, the model will run in conjunction with a mathematical optimization package which will make adjustments to the fitted model (in the form of new flows, allocations between turbines, letdown streams, etc.) so as to minimize a cost function – i.e. the economic cost of delivering the required process utility consumption at that moment. Thus as operating demand, or fuel/electricity prices, or equipment performance (fouling) changes, then a more economical solution is sought. More advanced packages can handle discrete optimization steps such as pump drive changes (steam-electricity) and other step-wise changes.

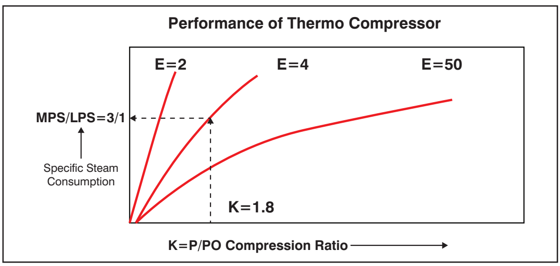
11.2.2.2. Structural Changes – Steam Blending

Significant structural imbalances in steam systems cannot always be handled by real-time control – the imbalance may be simply too large. In this case, the site has to turn to changes in the hardware and equipment configuration to bring the system nearer to balance.



Many examples are obvious – changing steam and electric drives, adding a package boiler, condensing/backpressure turbine swaps and so forth. A technique which deserves more notice is the use of steam thermo compressors to 'blend' two levels of steam to achieve an intermediate level (rather than let all the steam down from the higher pressure level).

Consider a process steam application, for instance reboil steam to a column. The process requires steam at 8 bara to meet the correct saturation temperature. The steam levels on-site are 18 bara and 4.5 bara, so normally the steam would be taken from the 18 bara system and let down to 8 bara through the normal reboiler steam control valve. The 18 bara system is limited and the 4.5 bara steam is in surplus (a common situation).



However by blending together a mixture of 18 and 4.5 bara steam in a thermo-compressor, the required 8 bara steam can be achieved using less of the (expensive) constrained 18 bara steam and making this up with surplus (cheap) 5 bara steam. In the case quoted, about one third of the total steam mass flow was shifted from 18 bara to the 4.5 bara supply.

11.3. Combustion Activities

For probably the majority of process industry sites, fired equipment represents the largest single source of energy transformation. Whether it be as direct process furnaces or as part of boiler house and utility complexes generating steam and electricity for subsequent use on-site, the effective operation and control of fired equipment plays a major role in tackling energy efficiency. As usual, there are many issues needing attention. While this User Guide does not set out to be a detailed manual on combustion engineering, the following topics may serve as reminders of the common priority areas which need to be considered as part of energy efficient operation. Furnace operation can easily slip from optimal – there are many considerations – installed equipment, operational procedures, control, setup, maintenance – all of which have a direct and interrelated impact on furnace efficiency. Furnaces are potentially highly unsafe pieces of equipment, yet also present a significant opportunity for energy saving. Thus, care and attention is needed to ensure efficient but safe operation.

11.3.1. Installed Equipment

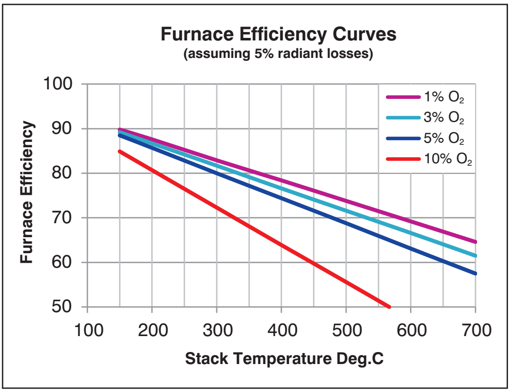
Replacing/modifying furnaces can be a major capital expense and is not undertaken lightly. However, for a large process furnace or boiler, perhaps burning 10s or 100s of tons of fuel a day, relatively small improvements in efficiency can turn into major fuel savings.

11.3.1.1. Upgrade Natural Draft to Forced Draft Operation

While most large furnaces installed in recent years will be modern forced draft units, there are still many older natural draft furnaces in operation, perhaps installed at times or in locations where energy prices were lower or as part of a package unit. The combination of relatively high stack oxygen contents and typically poor flue gas heat recovery mean that furnace efficiencies of perhaps 50–60% are typical. Thus, there is the potential to increase furnace efficiency by up to another 25%, representing major savings in fuel.

11.3.1.2. Improved Combustion Air Preheat

The recovery of waste heat from furnace flue gases, and using it to preheat combustion air, is one of the most effective ways of improving furnace efficiency. A rule of thumb – 20° C reduction in stack temperature will result in 1% improvement in furnace efficiency. Thus two questions need to be asked: is an effective air-preheater in place; and secondly, is it well maintained (e.g. regularly cleaned) to ensure maximum heat transfer?



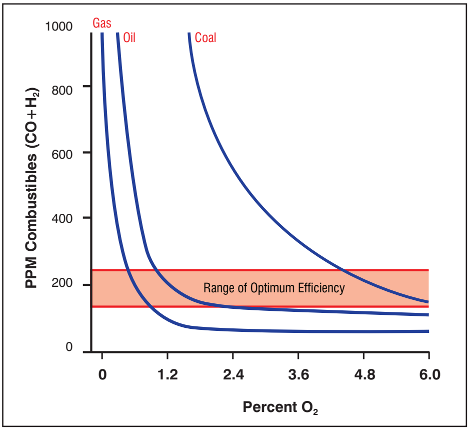
There are many forms of flue-gas recovery and air preheat. Local physical considerations (space, pressure drop) will play a large role in the final selection. Direct heat exchange or indirect exchange by pressured water (liquid coupled air preheater) is possible. Older types, such as the famous Llungstrom air preheaters, using rotating plates are not so fashionable these days and are maintenance heavy. Indeed an air-preheater upgrade may be an attractive project. Fuel-type and fouling considerations may play a major role in type-selection. There are pros and cons for most types. The main limit to operation is the constraint on how low the flue gases may be cooled. Depending on fuel type, this may be typically 150° C as below this point dew-point corrosion in the flue can be an issue. Locations burning their own fuel gas should take care here as such gases can sometimes contain other by-product compounds not found in normal natural gas, which produce undesirable combustion products.

Of course, other options to recover flue gas heat include waste heat boilers and other process or heat recovery mechanisms.

Regular cleaning of convection banks and air preheaters is essential, both as a daily operational procedure (sootblowing) and periodically through specialist cleaning (e.g. chemical, acoustic, jetting).

11.3.1.3. Burner Upgrades – Low NO_X and Turndown

Consideration may be given to the type of burner installed. Traditional pressure-atomized fuel oil burners have limited turndown (3:1) and often poor particulates performance. These constrain the operating ranges, particularly when the smoking limit is approached. A change of fuel to natural gas, installation of a steam atomized burner, or a more up-to-date design, should allow closer operation to the efficient norm. This requires simultaneous attention to control systems to provide the assurance and secure response that is needed to safely operate in these regions. Similarly, if NO_X emissions are a constraint, a modern low NO_X burner should allow more efficient furnace operation.



11.3.2. Furnace Control

Tight control of the fuel and combustion air systems is essential to safe and efficient furnace operation. The balance between fuel and combustion air, and the composition of the flue gases, is well-known. As combustion air is reduced relative to the fuel flow, furnace efficiency improves primarily due to the fact that less air has to be heated to combust with the fuel. However, the point at which incomplete combustion starts is the limit to how far this can be achieved. Beyond this, partly combusted fuels cause CO in the flue gases to rise. Operation then becomes very inefficient and the risk of furnace explosions from unburnt fuel in the furnace box or convection bank dramatically increases.

However, the point at which this happens is determined by many factors; the fuel type and composition, the quality of fuel atomization at the burner, register settings, air density, and humidity. Many of these will change over time. Disturbances are possible. Thus, high quality measurement and control of the fuel and combustion air systems plays a vital role in efficient furnace operation.

11.3.2.1. Air and Fuel Measurement

Accurate measurement of air and fuel flows is essential. Key issues for furnace measurements include:

- Quality installation of air measurement, typically a venturi, it is important that condensation affects in instrument tubing is avoided
- Turndown considerations
- Fuel calorific value – fixed, compensated, calculated?

11.3.2.2. Air-Fuel Ratio Control

The core to successful furnace operation is some form of air-fuel ratio control, preferably automatically adjusted by the stack oxygen content in a closed-loop fashion. There are many variations on the theme, and a manual could be written on this one subject. Solutions include:

- Mechanical linkage between the air damper and fuel valve (increasingly rare and limited in performance, typically found on small packaged systems)
- Straightforward ratio control which can be fuel-leading or air-leading
- Cross-limiting systems, which limit the allowed fuel rate changes depending on the actual measured air-fuel-ratio (useful in cases of slow air-damper operation which can limit the responsiveness of the furnace/boiler)
- Closed-loop O_2 control with limiting CO control
- Overall stoichiometric control based on a stoichiometric back calculation of heat input (particularly useful for high levels of unmeasured waste fuel burning)

There is no single correct solution, and as ever there is always a trade-off between complexity and benefits. It is important to consider several factors in choosing the appropriate solution:

- Degree and speed of turndown and load flexibility required (e.g. base-load vs. trim operation)
- Fuel-type and variability in composition
- Amount and variability of waste-fuel firing (if any)
- Availability of instrument/analyzer resource for maintenance and support

11.3.2.3. Waste Fuel Firing

Combustible waste fuels (gas, liquid, or solid), produced as by-products, are a common feature of many manufacturing locations. Light gases may be produced as part of a catalytic reaction or distillation by-products. Steel making produces Blast Furnace Gas (BFG) and Coke Oven Gas (COG). Black Liquor and waste wood are produced in the pulping processes of paper mills. Many other examples exist.

Gases with suitable pressure and composition (e.g. minimal inerts, no oxygen) are normally recovered in a centralized fuel gas system and burnt in a controlled manner as a distinct fuel on furnaces and boilers. The system may be topped up with (say) propane or butane to provide a fully flexible fuel utility. This fuel would be treated as a conventional fuel and included in the air-fuel ratio systems. Perhaps density compensation may be applied to account for variations in heating value.

Other gases may be unsuitable for inclusion in fuel gas recovery, for instance gas produced at very low pressure levels. Gases may have large amounts of undesirable compounds in a fuel gas network. Historically, such streams were either sent to flare or may have been piped to a local furnace for incineration. However, from an energy efficiency perspective, these streams can have a significant impact and need to be considered very carefully.

Two prime issues need to be considered; the recovery of useful energy from the waste gas and the impact of a 'wild' waste-gas stream on the controllability (and hence efficiency) of the furnace.

Small amounts of waste gas (with a potential heating value of up to approximately 5–10% of the furnace duty) can simply be piped into the furnace for incineration. Either a vented pipe or a waste gas spud burner will suffice. The waste gas should be isolated as part of the furnace instrumented safeguarding function. The variations in flow and heating value of this stream will be relatively small compared with the overall furnace duty, and will be satisfactorily trimmed by the oxygen control feedback. Perhaps a simple flow measurement added to the total fuel computation may help.

Beyond this level, however, the relative impact of the waste gas is much higher and represents both a significant potential fuel saving and also a control challenge. More advanced techniques such as the Emerson SmartProcess Boiler control strategy have been developed to tackle high levels of waste gas or other alternate fuel firing (e.g. from biomass). Here, the amount of air being consumed in the combustion process is continuously calculated from a measurement of the excess oxygen in the flue gas. Air being consumed by the waste gas fuel is determined by calculating the air being used for auxiliary fuel and subtracting it from the total. From the air calculation, a determination of calorific value of the alternate fuel is made on an on-going basis by calculating stoichiometric combustion and solving for calorific value. This is used to ratio fuel feed and other set points such that variations in the fuel are continually compensated for. Primary/secondary or undergrate/overfire air ratios are automatically controlled to set points which are set based on load, characterization curves, the excess oxygen set point, and the waste gas fuel quality calculation. The alternate fuel delivery equipment is provided a set point based on load and the fuel quality calculation.

11.3.3. Furnace Operations – Training and Competencies

Thirty or forty years ago, operator responsibilities were quite different from that found today. Manning levels were generous, there was much less multi-tasking, and local control buildings were scattered around a site (as opposed to the fully automatic and centralized control rooms of today). There was often a much greater divide between 'inside' and 'outside' operators. As a result, operators often had distinct and long-lasting roles – pump-house operator, interceptor man, and in the case of furnaces, dedicated 'firemen', who worked full-time on the furnace or boiler. These individuals built up extensive operational skills in their areas, and that of furnace operator was particularly well developed.

Furnace operation is one of the few process industry areas where there is direct physical interaction with the process – it is possible to look through the sight tubes and make physical adjustments to the burners and registers to control the quality of combustion. That is still the case. And it is still an essential activity. However, in the change to multi-tasking, centralized and flexible operational roles, there has been an eroding in some of these skills. Companies are now recognizing the need to keep operators trained in operational combustion techniques, and this has become part of many energy efficiency programs.

Furnaces are dynamic pieces of equipment – fouling from the combustion process, varying loads, fuels and ambient conditions, and the effects of high operating temperatures on machinery all conspire against stable operation. As a result, clear daily operational responsibilities need to be defined for furnace operation, and backed up with practical training. The emphasis of this should be on the operational aspects – what can an operator do to correct and improve the reliable operation of the furnaces in his charge. Typical of the topics that should be covered:

- Draft assessment, natural and forced draft – adjustment and correction
- Firing patterns – asymmetry
- Flame patterns and how to influence
- Register adjustment
- Impingement
- Safe start-up
- Burner changeover
- Leak identification
- Sootblower and shotcleaning procedures
- Control of atomizing steam
- Daily operational maintenance and checks

A good idea is to bring in an operational furnace expert for a dual exercise of furnace auditing (i.e. checking of the physical condition and the furnaces and burners) coupled with a practical hands-on operator training session. Linking his assessment of the furnace issues (and there will almost certainly be some) with the operational practices is a valuable exercise.

11.3.4. Maintaining Fired Equipment

Following on from the philosophy outlined in Chapter 8, fired equipment should certainly be on the energy critical equipment register. As we have seen, it plays a major role in a site's energy consumption, and poor maintenance can quickly lead to substandard and even dangerous operation.

As a start, the following basic maintenance activities should be determined, appropriate inspection and servicing periods defined, and the activities included in the maintenance management system:

- Servicing of sootblower/shotblasting equipment
- Periodic convection bank and air pre-heater cleaning
- Regular minimum stop checking and safeguarding system testing (flame-eye testing)
- Burner conditions (tips and plugs)
- Fuel system – lagging and steam tracing
- Instrumentation checks (e.g. zero-checking transmitters)
- Stack analyzer servicing (O_2, CO, smoke density)
- Air damper operation
- Forced draft fan machine inspection and monitoring
- Burner air-register operation and lubrication
- Furnace shell leak inspection and repairs
- Refractory condition – including burner quarls
- Lagging inspection and periodic replacement

The above items all contribute to efficient and reliable furnace operation. The list is by no means exhaustive, but simply represents the activities that are relevant to the majority of process furnaces and boilers. A rule of thumb – 2% reduction in stack oxygen content will result in 1% improvement in furnace efficiency.

11.4. Maintenance in Support of Energy Efficiency

A recent in-depth energy audit and follow-up of a major petrochemical site highlighted the impact of maintenance on energy efficiency. The site was established, mature, and had experienced staff. The audit showed that in terms of installed energy efficiency technology and practices, there was little to be gained. However, the review identified major efficiency losses due to poor equipment maintenance. A concerted improvement program identified, and realized benefits totaling 10% of the site's energy consumption simply by repairing, cleaning, and reinstalling existing facilities. The payback was less than 6 months.

Chapter 8 discusses the role of work processes supporting energy critical equipment. Such a methodology would have prevented the decline in performance illustrated above.

Typical of the generic maintenance activities/techniques that will apply to many sites are:

11.4.1. Cleaning of Heat Transfer Equipment (Including Fin-Fans)

Many, if not most, processes lay down some form of fouling on heat transfer equipment – from high temperature reaction side effects, cokes, and polymers, through to biological fouling of cooling water systems. These all result in poorer heat recovery and an increase in direct energy requirements. However, cleaning programs can be put under pressure in the pursuit of maintenance contract cost savings. Often, there is little direct relationship between the budget holders for maintenance activities and the variable energy costs associated with that equipment. This is a key reason why energy performance review needs the correct managerial structure and authority to enable cross-department decisions to be made.

Examples include:

- Feed/effluent exchangers in furnace preheat trains
- Boiler and Furnace flue gas recovery systems (convection banks, waste-heat boilers, air-preheaters)
- Furnace tube soot build-up and fouling (especially with heavy liquid fuels and incinerated waste products)
- Dust build-up on overhead fin fans (can impact downstream refrigerant systems or compression systems)
- Fouling of tempered and cooling water systems (same as above)
- Fouling of turbine blades
- Cooling tower performance

Cleaning methods are obviously many in nature, and some focus on a particular application. However, the (relatively slow) nature of the fouling process lends itself to on-line condition monitoring, which in combination with process cost models allows evaluation and prediction of the optimum (cost effective) cleaning point. This is covered in 11.7.

11.5. Steam Leak Programs

Clearly for plants with high pour-point materials, steam tracing is a necessary fact of life. And that inevitably means steam leaks. However, a focused approach to steam leak repairs can bring significant steam savings as well as consequential benefits in terms of safety (no flumes), housekeeping, and general pride in operations.

'Steam Team' Example

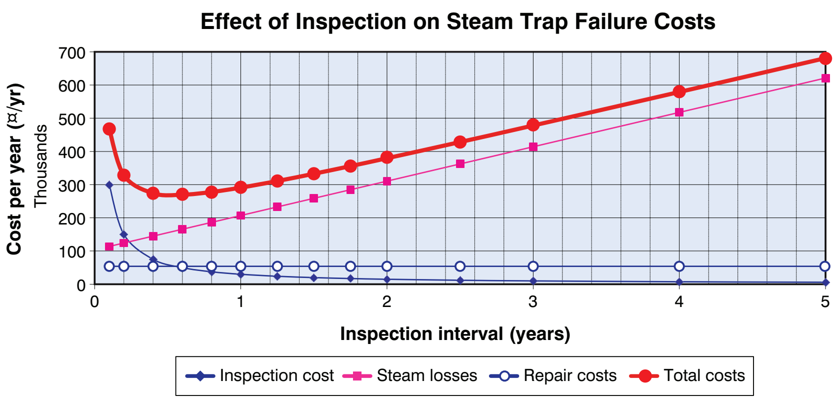
In less than 6 months a large UK petrochems site saved $2M per yr. in steam leaks from a 4-man steam team. (1 engineer, 1 foreman, 2 welders). After an initial site survey, the engineer would prioritize and select a list of leaks to be fixed each week. The Site was behind the initiative, permits to work were efficiently handled and the results well publicized. The effect was a transformation in both site attitudes, visual impact and financial benefit.

The following steps are recommended for saving energy in the steam condensate distribution system and starting an effective steam energy management program:

- Appoint a steam leak custodian with express responsibility for running the program
- Develop a standardized leak estimation methodology that you wish to use (there are many in open literature as well as from the major steam trap manufacturers), different degrees of complexity are available and different methodologies (e.g. plume size estimation vs. orifice-based), the important thing is to adopt a site standard which suits and use it consistently
- Agree a steam value pricing structure, apart from prioritizing work it is a valuable element of any awareness campaign
- Run a survey, recording all leaks, size, cost, and location
- Allocate a budget and (ideally) a dedicated 'steam-team' charged with methodically working through the prioritized leak-fixing list
- Publicize success – the weekly results

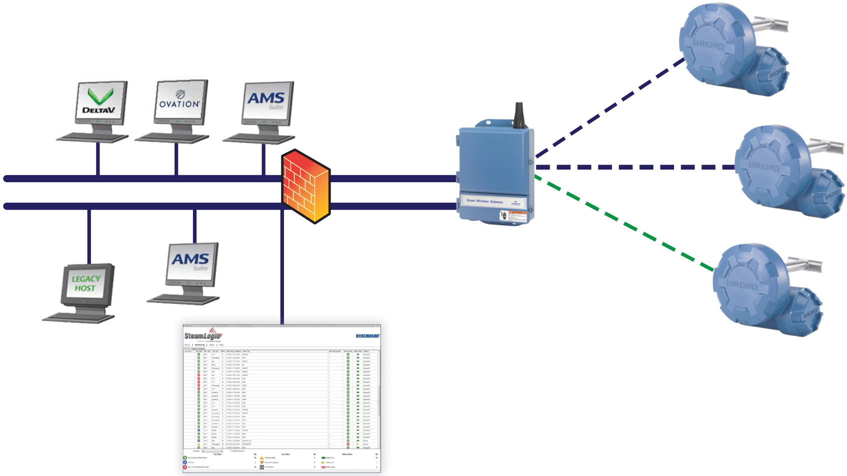
11.5.1. Steam Trap Monitoring

Along with the steam leak activities a proactive and organized approach to maintaining steam traps is required. A large process site may have tens of thousands of steam traps. Clearly a full checking program is unfeasible; however, the large population does allow a risk-based inspection approach. Modern wireless-based failure monitors allow real-time monitoring of key applications.



Key factors needed to be taken into account when designing an inspection program are:

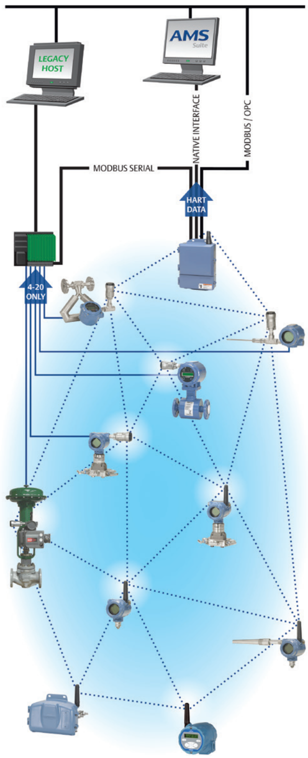
- Cost of vented steam during failure
- Cost of inspection program
- Average repair cost per trap
- Inspection rate/yr
- Average failure rate (% fail/yr)
- Average delay between failure and inspection (months)
- Population



From this, it is a relatively straightforward analysis to determine the most cost-effective inspection program, balancing inspection costs vs. lost steam costs. It also allows an understanding of the effect of failure rate, can influence the outcome, investigating the effect of trap upgrades, etc.

There are a variety of inspection techniques – ultrasonic, pyrometer, hand check, and the reader is steered towards manufacturer and service provider literature in making his assessment.

An attractive new tool on the market is the wireless monitor. Typically, a simple battery operated strap-on device, it uses acoustic technology to monitor steam trap performance. Two roles can be envisaged; monitoring of key high capacity traps (e.g. on MPS systems), and secondly for gathering statistical failure data which will allow a high quality inspection program to be constructed.

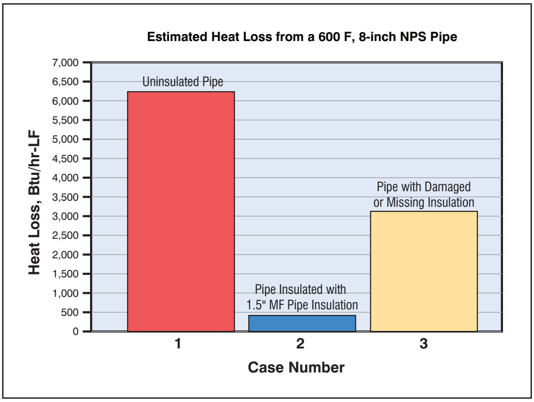


11.6. Lagging

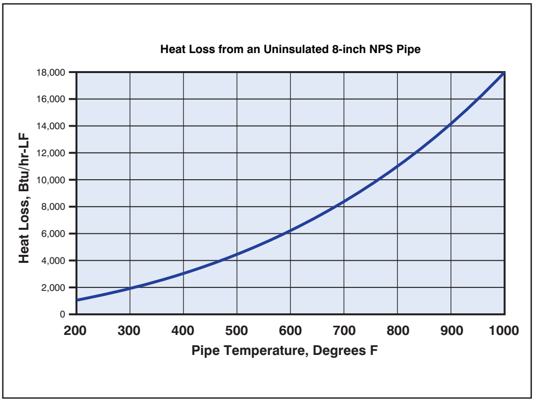
Often ignored, the effects of lagging degradation can be significant.

The Netherlands Centre for Technical Insulation has calculated the effect of damaged or missing lagging on productivity and the environment. Estimates are that 5–10% of oil refinery systems are badly insulated or not insulated at all in the European Union; for the United States, estimates are 20–25%.

One refinery with a capacity of 300,000 bbl/day was examined, and found to be losing 4,500 bbl/day due to insufficient insulation – a loss of roughly $200 million per year. Reducing the refinery's losses with proper insulation would cost approximately $25 million, with a payback of two months. This would save 500,000 t/a of CO_2 emissions.



All too often, routine maintenance involves removal and replacement of insulated items. However, insulation removed by plant personnel or by other contractors' personnel is usually not replaced unless specifically noticed. At turnarounds, replacement of insulation can get left over as the final job on the turnaround. Rain and corrosion plus minor damage can quickly lead to a loss in insulation performance.



Thus a regular program of lagging and insulation inspection is a very important element in any energy conservation program. Loss calculation methods are widely available. Infra-red scanning is a common technique. In some cases, monitoring of rundown temperatures can indicate potential performance loss over a period of time.

11.7. Use of Asset Monitoring Techniques

Equipment monitoring software, typically linked to a DCS/Process Historian, has become widely available during the last decade. Model-building and coding techniques are now within the grasp of engineers without the need for specialist math and programming skills. Modern computing power enables quick computation and convergence of the fitting and optimization routines that are core to the software. Different approaches are possible:

- Rigorous first principles modeling
- Straight statistical modeling
- 'Grey-box' modeling which combines known and scientific-based understanding of physical processes with statistical modeling – thus better able to handle measurement error, modeling inaccuracy and un-modelled effects

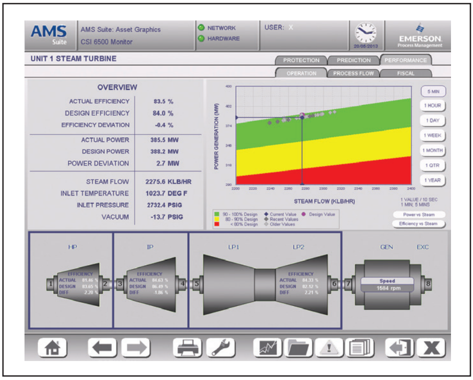
While initially aimed at fault detection these techniques can be a very useful tool in an energy-based maintenance strategy. Energy performance degradation is typically a slower process driven by factors such as fouling, and as such is a good candidate for long term monitoring.

Typically, a model will be fitted to (real-time) plant data (e.g. using hourly average data to take out short term noise). The calculated fitting parameter(s) will be an engineering quantity which has a direct relation to the energy performance issue – e.g. a heat transfer coefficient, boiler efficiency, turbine efficiency. The fitted model can be used in two ways:

1. Alarming of current condition, this could be combined with some form of SPC (Statistical Process Control) monitoring
2. The development of time-based models for the calculated model parameters, which can then be used as predictive models to investigate future operational and maintenance options, as the model is updated it becomes an up-to-date representation of the latest situation and is the best knowledge for future planning, typically, this can be combined with maintenance planning systems to determine cost-effective optimum cleaning and intervention points

Common applications include:

- Heat Exchanger fouling and performance prediction
- Turbine efficiency monitoring
- Boiler and furnace efficiency monitoring
- Gas turbine performance
- Pump curve – operation with respect to best efficiency point
- Cooling tower efficiency



Ideally, the modeling package should use the same common data as the EMIS, and its results should be fed back for data storage and reporting within the EMIS.

To get best results, the use of such packages needs formalizing – results presented and decisions made on a regular basis laid down by the EMS maintenance processes, rather than as an occasional technology hobby used by one engineer.

11.8. Pinch Analysis and Improved Heat Recovery

The techniques discussed so far have generally been supportive methodologies to improve the operational energy efficiency of a unit. The basic plant has remained the same. Major capital projects have not been discussed.

However operations do change. Different feedstock, product requirements, and so forth gradually change the operating conditions. Equipment is likely to run at different temperatures and flows from the original design. Controllability and contingency factors from the original design cases are likely to have been superseded. And, these considerations particularly apply to the process heat integration or heat recovery systems employed. Indeed, on an older unit there may be very poor heat integration with excessive energy wastage (a quick check on product rundown temperatures is a useful indication – how do they compare to storage requirements – is too much heat being sent to cooling water?).

This leads to the consideration of a more fundamental revisit of the unit heat integration and energy utilization. In recent years, the methods of process integration, and more specifically Pinch Analysis, have proven successful in addressing these issues.

11.8.1. Pinch Analysis

The technique of Pinch Analysis was first developed in 1977 by Bodo Linnhoff under the supervision of Dr. John Flower at the University of Leeds in the United Kingdom and since then has emerged as one of the most practical tools in the field of process integration, particularly for improving the efficient use of energy, water and hydrogen. It is well used in the chemicals, petrochemicals, oil refining, pulp/paper, food/drink and steel/metallurgy sectors.

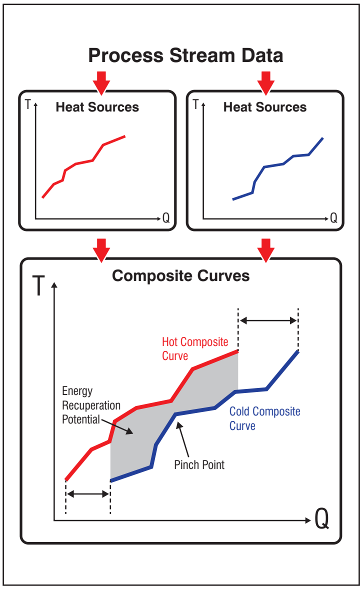
Pinch Analysis provides tools that allow the investigation of energy flows within a process and to identify the most economical ways of maximizing heat recovery and minimizing demand for external utilities. While it obviously has a place in new designs, in retrofit projects pinch analysis can be specifically aimed at maximizing the return on project investment, and allows evaluation of combinations of project ideas.

An important element to pinch analysis is the establishment of minimum energy consumption targets for a given process or plant. This information enables the identification of the maximum potential for improvement before beginning the detailed process design.

The use of specialized software is generally required. Some software applications offer tools to rapidly design heat exchanger networks. A model of the site's utility systems is generally produced as part of the pinch study. This enables process energy savings to be directly related to savings of primary energy purchases.

Typical reported savings across the sectors identified above have been in the region 10–35% (source: Pinch Analysis for the Efficient Use of Energy, etc., Natural Resources Canada).

One of the principal tools of Pinch Analysis is the graphic representation of composite curves. The process data is represented as a set of energy flows, or streams, as a function of heat load (kW) against temperature (deg C). These data are combined for all the streams in the plant to give composite curves, one for all hot streams (releasing heat) and one for all cold streams (requiring heat). The point of closest approach between the hot and cold composite curves is the pinch point, with a hot stream pinch temperature and a cold stream pinch temperature. This is where the design is most constrained.

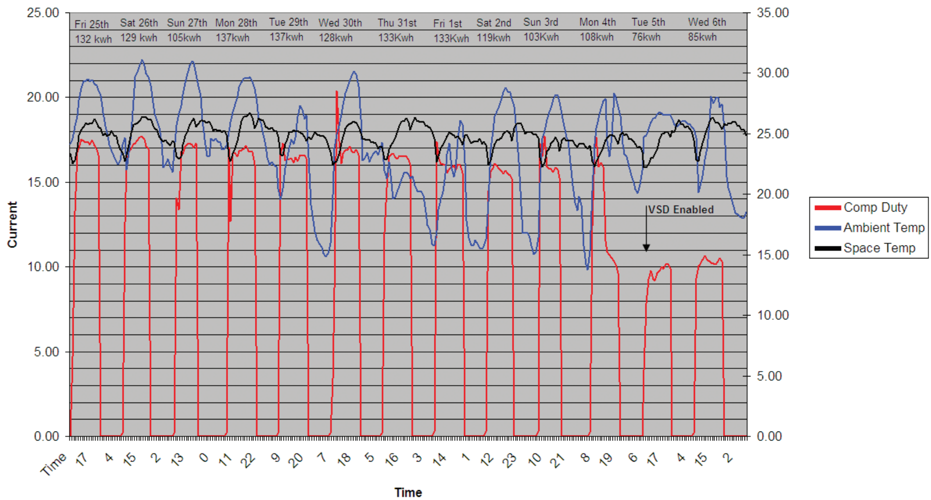


Hence, by finding this point and starting the design there, the energy targets can be achieved, recovering heat between hot and cold streams in two separate systems, one for temperatures above pinch temperatures and one for temperatures below pinch temperatures. In practice, during the pinch analysis of an existing design, often cross-pinch exchanges of heat are found between a hot stream with its temperature above the pinch and a cold stream below the pinch. Removal of those exchangers by alternative matching ensures the process reaches its energy target.

The detailed exploitation of Pinch Analysis, whether for heat exchanger networks, utility system design, or cogeneration applications, is beyond the scope of this text. Indeed specialist skills and software are needed. However, it can play an important part in reassessing and optimizing the energy and utility profiles across a unit. Suggested further reading is included in Appendix H.

11.9. Variable Speed Drives

Variable speed drives (VSDs) can deliver significant energy savings, along with better process control, less wear in the mechanical equipment, and less acoustical noise. When loads vary, VSDs can reduce electrical energy consumption particularly in centrifugal pumps, compressors, and fan applications – even up to 50%. Materials processing applications like centrifugal machines, mills, and machine tools, as well as materials handling application such as winders, conveyors, and elevators, can also benefit both in terms of energy consumption and overall performance through the use of VSDs.



The use of VSDs can provide other benefits including:

- Extending the useful operating range of the driven equipment
- Isolating motors from the line, which can reduce motor stress and inefficiency
- Accurately synchronizing multiple motors
- Improving the speed and reliability of response to changing operating conditions

While VSD technology has been around for many years, the costs tended to limit its application to high power applications. However, modern inverter electronics have reduced typical capital costs significantly and the technology is now much more suited to smaller applications.

Case study:
A refrigerant system with a small 10KW compressor, which operated under a variable load profile during the day, achieved power savings of 40% by the installation of VSD. Simple payback time was 2.4 years despite operation being limited to the period May to October each year.

Note: VSDs are not suitable for all applications, in particular where the load is constant (e.g. fluid bed air input fans, oxidation air compressors, etc.), as the VSD will lose 3–4% of the energy input (rectifying and adjusting the current phase).

12. Skills and Competencies for Energy Activities

In describing the setting up of an energy improvement program, the subject of roles and skills was briefly mentioned (Section 4.3). The forthcoming chapter looks in more detail at the competencies and skill levels required both for energy improvement programs and the development of EMS. Given the broad-range of energy factors, a correspondingly wide-range of disciplines is involved, and striking the balance between full-time and specialist resource is a fine line.

12.1. Organizational Core Competencies and Skill Areas

These skills are needed for everyday energy related activities, and should generally be available as part of the local on-site resource. In most cases, these are energy competencies being part of a broader job.

12.1.1. Site Energy Manager

This is (ideally) a dedicated position. The incumbent would typically be an experienced engineer with a strong operational overview and experience from across the site. This is not a financial or book-keeping position. Key competencies and knowledge areas:

- Operations and process engineering
- Business planning and scheduling
- Understanding of site organization and decision-making processes
- Benchmarking and data-analysis techniques
- Economics and product/utilities valuation
- Ability to track/exploit external trends and developments (technical and business)
- Facilitation/communication skills
- Understanding/appreciation of energy efficiency technologies

12.1.2. Process Engineers

All process engineers providing day-to-day operations support should have basic energy efficiency competencies:

- Thorough understanding of how process operation and operating conditions affect energy consumption on their unit
- Thorough understanding of how site fuel and utility systems impact their unit
- Standard chemical engineering skills – heat and mass balances, heat transfer, thermodynamics, separation processes, modeling, etc.
- Basic equipment operational and modeling knowledge – furnaces, turbines, heat exchangers, steam traps
- Appreciation of modern control and instrumentation techniques
- Appreciation/understanding of advanced modeling techniques (pinch analysis, steam simulations, etc.)
- Process historian report building and data analysis skills
- Process economics

12.1.3. Utilities Engineering

Very much dependent on installed utilities infrastructure, but key skills likely to include (in addition to basic process engineering skills):

- Detailed boiler operation and performance assessment
- Power distribution – operational aspects
- Steam systems and networks – balancing and optimization
- Turbine performance and troubleshooting
- Water treatment chemistry

12.1.4. Control and Instrumentation

The ability to measure and control energy-related streams is an absolutely essential requisite for efficient operation. On-site capabilities should include:

- Instrumentation design (simple loops), diagnostic, servicing skills
- DCS/process historian configuration skills (tags, calculations, displays, reports)
- Process control loop tuning
- Basic control design and configuration
- Advanced control – first line support

12.1.5. Operational Staff

The distribution of skills will depend on role-allocation within the operational (shift) teams – for instance the use of dedicated furnace operators as opposed to a fully multi-tasking rotating pattern:

- All operators should understand the basic operational drivers on their units energy efficiency (e.g. stack oxygen, equipment performance, recycle rates, stripping steam, impact of reflux and reboil, etc.) and how they can be influenced from the panel and in the field
- All operators should understand basic energy efficient equipment procedures – for instance how and when to operate sootblowers, check steam-trap operation, de-aerator operation, drain condensate, report steam leaks, pump drive selection, and so forth
- Panel operators need a sound understanding of how the process control loops affect energy consumption – heat integration, furnace controls, fuel selection, stability concepts, constraint pushing, distillation conditions
- Furnace skills (if appropriate) – flame pattern interpretation, air register manipulation, burner cleaning, burner procedures (changing tips and plugs)

12.2. Important Specialist Support Skills

The Site will need access to reliable and in-depth specialist engineers to compliment the day-to-day operation. These may be sourced from a variety of places; corporate technical center, individual specialist consultancies, integrated engineering consultancies, or EPC contractors and equipment suppliers. Adoption of an integrated approach, which enables a complimentary set of experts who work together and are aware and understand the limits and boundaries of their areas of expertise, is good practice.

Typical of the specialist skills that a process site may require:

- **Combustion design and operation:**
  Covering both furnace design as well as burner operation (setting minimum stops, flame impingent, fuel supply design and operation)
- **Heat transfer:**
  For issues such as heat exchanger design and unit configuration, (Pinch Analysis), fouling assessment and abatement
- **Power generation:**
  Turbo-alternator design and operation, generators, drives
- **Turbines and rotating equipment:**
  Compressor operation, anti-surge control, drive changes
- **Compressed air:**
  Utilization of waste compressor heat, minimization of leaks, filter monitoring, and optimization of system pressures

- **Advanced control and optimization:**
  Advanced Model Predictive Control, real-time utilities, process modeling and optimization techniques
- **Measurement:**
  Particularly for selection and design of difficult measurement situations – flow measurement techniques, on-line analyzer selection, sampling systems
- **Process and statistical modeling:**
  Developing energy base-line models, investigating non-obvious driver mechanisms, benchmarking analysis, KPI-driver correlations

12.3. EMS and EMIS Skills and Competencies

EM(I)S development and implementation requires a full cross section of skills. These will vary depending on the phase of the project. Fundamentally, it is a change management project, although there is a need for a strong operational and process engineering input plus some supporting skills in Process IT. Clearly underpinning the technical skill areas is a strong element of communicational and project management skills. Basically, EMIS is addressing the day-to-day management processes for a manufacturing site. New ways of working will be needed, existing processes may be challenged. Often, energy drivers are at odds with existing yield or production strategies. Hence, the ability to engage the site and staff to take the debate forward and resolve the issues in a positive manner is essential.

Skills needed within a team responsible for developing EMS and its associated information system:

- **Unit operations/business knowledge:**
  Understanding of process configuration, flow schemes and unit operations, plus the appropriate supporting managerial and technical processes, organizational structures, business drives, operational practices and cultures
- **Business economics:**
  Basic business economics, planning, scheduling, and marginal pricing philosophies, project economics
- **Process engineering:**
  Process engineering essentials, heat and mass transfer, thermodynamics, standard design and calculation methodologies, process modeling and flow sheeter capability
- **Data mining:**
  Ability to use statistical and mathematical modeling tools and techniques, particularly in the analysis of time-series process data
- **Process IT and instrumentation architecture:**
  Understanding of typical process IT, Instrumentation systems, and architecture, DCS and process computing and relation to business computing structures, typical applications architecture (what service, where executed), relationship with business/office computing, basic components, functionalities, and vendors
- **Process IT coding:**
  Hands on programming and configurations skills for modern process computing systems, graphics building, report generation, calculations coding, and programming
- **TQM (Total Quality Management):**
  Understanding of management systems, ISO 9001, etc.
- **Change management:**
  Knowledge of change management techniques, introduction of new approaches to working, team building, motivation, training, etc.

Clearly it is expected that an individual person will be able to handle several of the competency requirements for any given EMIS activity. The purpose of the matrix is to assist managers in building a team, and also to provide a check-list to anyone undertaking an EMS activity that they have the appropriate knowledge and skills to undertake the job.

12.4. Skill Management

Most companies these days employ some form of training and skills management system, often as part of the HR system. These allow the recording and assessment of both skill requirements for a particular position and also the abilities of the individual engineer. Thus, individual training and competency plans can be developed and progress tracked.

It is important that energy-related competencies are included in this – in particular if a registration to ISO 50001 is being considered. It is also useful to consider depth of expertise on an area. Complex categorization systems are available; however a simple two-level approach is quite feasible where a skill level is simply assessed as ‘aware’ or ‘professional’.

Awareness:

A good knowledge of what is involved in that area of expertise and its relevance to the business:

- Understanding the main elements of the area of expertise and their importance to the business
- Understanding how and where competences in the area of expertise are relevant to the task

Professional:

Being able to carry out consistently the activities of an area of expertise to the required standard:

- Able to perform satisfactorily majority of activities of the area of expertise
- Able to translate guidelines and standards for the area of expertise into practical actions
- Able to solve imaginatively common technical/operational problems in the area of expertise
- Able to guide and advise others in operational/technical aspects of the area of expertise

13. Benefits and Case Studies

Exact benefit projections for energy efficiency activities are location specific and require detailed analysis of the pre-project situation. However, there is a growing consensus and feedback of typical achieved benefits from many sources.

Worldwide energy improvement programs have been rolled out by multinational companies such as Exxon (GEMS program) and Shell (Energise program), and at conferences they consistently report energy efficiency benefits in the region of 5–10% of a site's energy consumption, with some individual sites running up to 20%.

Regional variations do occur, perhaps reflecting culture and history. US locations tend to report higher efficiency gains than European locations, possibly reflecting the greater impact of the 1970s Oil Crises in Europe which kicked off energy efficiency issues earlier. Scandinavian locations often show up well in energy benchmarking due to the greater use of district heating and other heat recovery schemes which have been driven by their society and culture. Thus, there is less scope for improvement as they are already well placed.

13.1. The Benefits from Energy Management Systems

The benefits of an EMS are more difficult to directly quantify as of course they come from the results of individual energy saving activities. Double accounting should be avoided. The issues are sustainability and driving new improvement.

An important conference organized by the Texas Technology Showcase in Galveston, December 2006 brought together many major industrial users and consultancy/system suppliers (papers available through ***http://texasiof.ces.utexas.edu/***). Both users and suppliers consistently reported problems with benefit erosion in their energy programs, and there was universal agreement that Energy Management Systems were the key element in ensuring efficiency gains were maintained.

It is also clear that an active energy management culture will drive improvement and look for new energy saving opportunities both operationally, culturally, and through capex. Some of these gains will be low cost, some will require expenditure.

Ascribing a hard value and simple payback to an EMS/EMIS implementation is not easy. It is a point where life-cycle cost analysis comes in. In the project planning economics for an energy efficiency program, it may be appropriate to apply an erosion factor (say 50% over 5 years) for programs which do not include EMS. Conversely, if an EMS is to be developed as part of the program, then the inclusion of additional annual future energy savings of perhaps 1–2% of site consumption to reflect the future impact of an EMS could be made.

13.2. Case study 1 – Performance Modeling and Measurement

A US fossil-fired power plant was experiencing large temperature swings under load change conditions. On-line modeling indicated problems with air flow measurements. After the problems were corrected and instruments recalibrated, it was possible to increase the ramp rate by 66% and reduce stack oxygen contents by one third.

This allowed the units to be turned down under automatic control and the minimum loads to be reduced by 40%. This resulted in benefits of $1.4m per annum. In addition, performance monitoring of the air-preheater on one boiler indicated poor heat transfer and thus increased fuel use. Subsequent repairs to the air preheater resulted in fuel savings of $240,000 per annum.

13.3. Case Study 2 – The Role of Maintenance and Management

A large integrated oil/petrochemical site in Europe carried out a detailed energy performance review and project (along the lines as suggested in Chapter 9). A dedicated on-site team worked for a two year period assessing performance, identifying projects, and then implementing them.

The Site was technically mature, experienced, and generally a respected operator. It had a history of competence and strong technical staffing.

The project team identified around 25 relatively low-cost energy efficiency projects which saved the company some 10% of the site's energy consumption. The total project costs were around one third of the annual energy benefits – i.e. a simple payback of a few months.

Possibly most interesting was the finding of few 'new technology' projects – this was a mature site which had a good history of keeping abreast of trends. The major part (75%) of the benefits came from equipment maintenance issues:

- Steam leaks and traps
- Convection bank cleaning
- Repairing air-preheaters
- Repairing leaking heat exchangers
- Furnace burner alignment
- Balancing steam distribution
- Getting control back in operation

It was clear that a (laudable) corporate focus on cost saving – in particular fixed cost maintenance contracts – had been at the expense of energy performance. There was no energy strategy, target setting, or monitoring, which meant that performance erosion had steadily taken place. There was no forum for debating the costs/benefit of these activities.

The project team put corrective measures in place, instituted repairs, and developed EMS procedures to ensure that the benefits were maintained.

13.4. Case Study 3 – A Pathfinder Example

An Australian Gas Plant was at maturity. Built to treat and compress sales gas, the wells were starting to decline and the use of its own sales gas as a ‘free energy source’ was no longer valid – it was burning valuable product that had originally been plentiful and ‘free’. 30 years of low-cost-energy operation had resulted in a unit where there was no culture of energy efficiency, equipment and measurements were missing, and operation was very conservative.

A three week pathfinder exercise along the lines of Appendix D was carried out by a team specializing in combustion, utilities, control and energy management. The team was able to identify 20 preliminary project ideas with outline costs benefits. The total annual benefit was estimated at AUS $10M.

Typical of the ideas that come forward were:

- Challenge to running spare rotating equipment on hot standby
- Comprehensive furnace monitoring modifications and working practice improvements
- Improved control strategies to minimize solvent usage (and hence regeneration energy) on gas treaters
- Improved anti-surge control on compressors to minimize wasteful recycle
- Challenges to utilities configuration and operating philosophies
- Introduction of energy monitoring and target setting

Fundamentally, the issues all centered around challenging a conservative operational philosophy which had used many energy-wasteful practices as a means of ‘guaranteeing’ reliable operation. A true risk/cost-benefit had not been adopted.

Supporting Appendices

Appendix A. ISO 50001

ISO 50001 (full name: ISO 50001:2011, Energy management systems – Requirements with guidance for use) is a specification created by the International Organization for Standardization (ISO) for an Energy Management System. The standard specifies the requirements for establishing, implementing, maintaining, and improving an Energy Management System, whose purpose is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy security, energy use, and consumption. The standard aims to help organizations continually reduce their energy use, and therefore their energy costs and their greenhouse gas emissions.

ISO 50001 was released by ISO in June 2011 and is suitable for any organization – whatever its size, sector, or geographical location. The system is modeled after the ISO 9001 Quality Management System and the ISO 14001 Environmental Management System (EMS).

A.1 Structure

The structure of ISO 50001 is designed according to other ISO management system standards, in particular ISO 9001 and ISO 14001. Since all three management systems are based on the PDCA cycle, ISO 50001 can be integrated easily to these systems.

There are seven major components to ISO 50001:

1. General Requirements
2. Management Responsibility
3. Energy Policy
4. Energy Action Plan
5. Implementation and Operation
6. Performance Audits
7. Management Review

(a full chapter index is provided in A.4)

A.2 Methodology

ISO 50001 provides a framework of requirements that help organizations to:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions concerning energy use and consumption
- Measure the results
- Review the effectiveness of the policy
- Continually improve energy management

ISO 50001 focuses on a continual improvement process to achieve the objectives related to the environmental performance of an organization (enterprise, service provider, administration, etc.). The process follows the Plan-Do-Check-Act, (PDCA) approach.

A.3 Implementing ISO 50001

The core essentials of any energy management system are discussed in Chapter 5, and these touch upon the key philosophies of Energy Management. It is clearly important that a site/organization understands these first, as this will make subsequent decisions as to the extent of the system easier. The process of Registration to ISO 50001 will clearly involve more structure and effort.

For a location with an existing ISO culture/system, then the building and registration process will be straightforward – many of the sub-systems and supporting processes will already be in place.

For companies without previous ISO experience the best way forward will be to approach one of local accredited agencies who are authorized to assess, audit, and register ISO systems (e.g. BSI, DNV, Lloyds, and others). In addition to registration and audit services, these organizations typically provide support, training, and system development advice to enable a company to more quickly establish its systems. Consultancy and service companies also operate in this field, providing direct system design and implementation services.

A.4 Contents of ISO 50001

Following is the adopted ISO 50001 section heading and numbering:

1	Scope
2	Normative references
3	Terms and definitions
4	Energy management system requirements
4.1	General requirements
4.2	Management responsibility
4.2.1	Top management
4.2.2	Management representative
4.3	Energy policy
4.4	Energy planning
4.4.1	General
4.4.2	Legal and other requirements
4.4.3	Energy review
4.4.4	Energy baseline
4.4.5	Energy performance indicators
4.4.6	Energy objectives, energy targets and energy management action plans
4.5	Implementation and operation
4.5.1	General
4.5.2	Competence, training and awareness
4.5.3	Communication
4.5.4	Documentation
4.5.5	Operational control
4.5.6	Design
4.5.7	Procurement of energy services, products, equipment and energy
4.6	Checking
4.6.1	Monitoring, measurement and analysis
4.6.2	Evaluation of legal requirements and other requirements
4.6.3	Internal audit of the EMS
4.6.4	Nonconformities, correction, corrective, and preventive action
4.6.5	Control of records
4.7	Management review
4.7.1	General
4.7.2	Input to management review
4.7.3	Output from management review

In addition, ISO 50001 includes informative annexes giving guidance on how to implement the above requirements, and a table comparing the requirements of ISO 50001 with other ISO management system standards.

Appendix B. Carbon Trust Energy Management Maturity Matrix

Taken from: Good Practice Guide GPG376: A Strategic Approach to Energy & Environmental Management. The Carbon Trust, ***www.carbontrust.com***

Score	Policy	Organization	Communications	Information	Planning	Audit
4	Energy Policy, action plan and regular review have commitment of top management as part of an environmental strategy.	Energy Management fully integrated into management structure. Clear delegation of responsibility for energy consumption.	Formal and Informal channels of communication regularly exploited by energy manager and energy staff at all levels.	Comprehensive system sets targets, identifies faults, quantifies savings and provides budget tracking.	Marketing the value of energy efficiency and the performance of energy management both within the organization and outside it.	Positive discrimination in favor of "green" scheme with detailed investment appraisal of all new-build and refurbishment opportunities.
3	Formal energy policy but no active commitment from top management.	Energy Manager accountable to energy committee representing all users, chaired by a member of the management board.	Energy Committee used as main channel together with direct contact with major users.	Monitoring and Targeting (M&T) reports for individual units based on sub-metering but savings not reported effectively to users.	Programme of staff awareness and regular publicity campaigns.	Same payback criteria employed as for all other investments.
2	Unadopted energy policy set by Energy manager or senior departmental manager.	Energy managers in post, reporting to ad-hoc committee, but line management and authority unclear.	Contact with major users through ad-hoc committee chaired by senior departmental manager.	(M&T) reports based on supply meter data. Energy unit has some involvement in budget setting.	Some ad-hoc staff awareness training.	Investment using short-term payback criteria only.
1	An unwritten set of guidelines.	Energy Management is par-time responsibility of someone with limited authority or influence.	Informal contacts between engineer and a few users.	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department.	Informal contacts used to promote energy efficiency.	Only low-cost measures taken.
0	No explicit policy.	No Energy Management or any formal delegation of responsibility for energy consumption.	No contact with Users.	No Information System. No accounting for energy consumption.	No promotion of energy efficiency.	No investment in increasing energy efficiency on site.

Appendix C. EMIS Objectives Checklist

The following check list can be used both to assess the capabilities of existing EMIS functions as well as in the design of new systems. A simple yes/no approach to the questions will quickly provide an indication of the EMIS maturity.

Based on original check list in the EMIS handbook published by Natural Resources Canada – see Appendix H for full reference.

YES / NO

Functionality: Does the EMIS Deliver the Following?

Early identification of poor performance.
Is excess energy use in key areas of the process identified quickly enough to allow remedial action to be taken? (Identifying performance in the past that could have been better is not enough!)

Support for decision-making.
The EMIS user should be provided with information (reports and/or software tools) to promote action when poor performance is identified.

Effective energy performance reports provided to all decision-makers:

- Executives
- Senior managers
- Operations management
- Engineering
- Operations personnel
- Planning and scheduling
- Accounts
- External bodies
- Other relevant staff

Energy performance must be reported to key decision-makers involved in the management of business and energy performance. They should include only data relevant to and designed for the individuals concerned, ideally be integrated into existing reporting systems, and must be both timely and accessible.

Audits of historical performance.
The EMIS should provide details of past performance, including breakdown of energy use, trends in key performance indicators, and comparisons of energy use and key performance indicators with robust target values.

Support for identifying savings measures.
The EMIS should quantify energy use of individual processes and the plant, and allow the quantification of the impact of changes in key process parameters on energy performance.

Provides evidence of improved energy performance.
Shows improved performance against agreed benchmarks for the entire site, individual processes, and the plant.

Supports energy budgeting and contract negotiations.
Enables the identification of relationships between influencing factors (production levels, product qualities, product mix, ambient conditions, etc.) to enable future energy demands to be predicted with confidence.

Provides energy data to other business and process IT systems.
The EMIS is the core energy data and provides relevant data and relationships to planning and scheduling systems, to management accounting and similar corporate IT systems, as well as to process and plant performance monitoring and management systems. Feeds relevant data to central data historians/warehouses.

YES / NO

Features: Does the EMIS Include the Following Key Features?

Effective storage of energy and related data.
A modern database, historian, and warehouse.

Ready access to relevant data by all relevant staff.
Energy Data should be easily accessible by all relevant staff using standard tools (spreadsheet, executive information system, enterprise resource planning, management information system, applications programs, DCS, SCADA, etc.).

- Executives
- Senior managers
- Operations management
- Engineering
- Operations personnel
- Planning and scheduling
- Accounts
- External bodies
- Other relevant staff

Calculation of effective targets from historical data or plant simulation.
The provision of modern data analysis tools to create effective targets that take account of multiple influencing factors (beyond multiple, linear regression) and/or includes first principles models of plant operations as targets.

Comparison of actual performance against targets.
A core feature. The actual values of energy use and key performance indicators and influencing factors should be compared against target values.

Historical data analysis.
Supporting tools should be available to identify patterns in historical data, ranging from simple graphics to visualization and data mining.

Graphical reporting.
Reports should include simple but effective graphics (line, scatter, bar, CUSUM, three-dimensional, etc.).

Data validation.
Raw plant data requires validation through heat and mass balances, range checks, etc.

YES / NO

System Components

Energy meters.
Energy meters in sub-areas of the site automatically read.

Measurement of influencing factors.
Measurement of influencing factors automatically read.

Measurement of key performance indicators.
KPIs automatically read or calculated.

Automated data acquisition.
Automated data collection is a key requirement of an effective EMIS.

Data historian.
A database that can store and effectively serve.

Data analysis tools.
A suite of data analysis tools from regression to data mining.

Reporting tools.
Ideally, tools are already used to report process and business performance.

Decision support tools.
Software tools or paper-based.

Interfaces.
To enterprise resource planning, management information system, DCS, SCADA, spreadsheet, etc.

YES / NO

EMIS Support

Energy Management program.
A comprehensive energy management program of which the EMIS is one element.

Management commitment.
Support and commitment for the energy management program from the CEO and senior management.

Allocated responsibilities.
Responsibility for delivering energy performance allocated to relevant production, operations and department management, not the energy manager.

Procedures.
Procedures to ensure the tasks necessary to operate the EMIS and to achieve savings are understood and adopted.

Training and support.
Technical training, training in using software, support to EMIS users.

Resources.
Financial commitment and personnel appropriate to the achievable benefits.

Regular audits.
To check system performance, adherence to procedures and benefits realized.

Appendix D. Energy Walkthrough Template

Typically a 1 week exercise, the energy walkthrough is a way of identifying energy inefficiencies within the organization. It is a gap analysis, reviewing the site facilities against best practices and recommending opportunities to improve energy efficiency. It covers a number of areas:

- Overall site operations and strategy
- Site-wide energy management background
- Individual process unit interviews (process units, storage and material handling, utilities)
- Site energy management maturity assessment

Representatives from each of these areas will be interviewed and asked to provide data. The interviews are based around the analysis of process flow schemes, which provide a structure to discussions on energy theme. The flow scheme reviews start at the beginning of the process and move through the flow diagram to all end points. The aim of the interview is to identify all areas where energy enters, leaves, or is exchanged within the process, and determine whether this is as efficient as it can be.

The output of the interviews is used to identify opportunities to improve energy efficiency. Technical, economic, and operability criteria are identified for use in screening and prioritizing opportunities for improvement. Importantly, benchmarking and external comparison data will be used to assess the relative maturity and quality of energy efficiency activities on-site.

D.1 Team Composition

The review team will include a nominated leader as well as process specialists and most probably a utilities engineer. From the location, the following key players are needed:

- **Site host**
  Works closely with the walkthrough team during the site visit and can help align persons and information needed for interviews
- **Site management sponsor**
  Can help introduce the effort, agree on deliverables and resources, and give feedback on next steps or preferences for follow-up activities
- **Site subject matter experts**
  Typically, key operations and technology representatives for the specific areas being reviewed, involvement of these individuals will be based upon the walkthrough program
- **Operations representative**
  An experience operator (e.g. Training Foreman) who can provide a grounded reality of the actual operational practices and procedures in use

D.2 Pre-Walkthrough Information to be Provided by Site

Although much of the walkthrough information comes from control system screens and engineering spreadsheets viewed during the exercise, the following pre-reading materials are helpful:

- Site block flow diagram
- Simplified flow diagrams for utility systems, process units, storage, and handling
- Any other available presentations or documents that give a concise overview of current site energy improvement efforts
- Fuel, steam, electricity, and CO pricing to be used for screening, plus any inflexion points at which these values change

D.3 Site Operational Overview

The site overview is usually a 1–2 hour meeting with senior technical staff in order to better understand:

- Plant configuration and organization
- Focus and priorities of technical and operating staff
- Procedures for making operating, maintenance, and capital changes
- Factors affecting the complexity and stability of the base case energy use
- Shutdown window for executing potential energy projects

Typical information to be discussed includes:

1. Site block flow diagram; units (with capacities), connectivity, product blending pools
2. Age of key units, dates of last revamps, which can impact energy savings potential
3. Which units are limiting plant throughput? Which units have spare capacity? Has debottlenecking been done with or without increasing furnaces or utility imports?
4. Typical shutdown/catalyst changeout frequency and grouping for major units – including the last and next planned shutdowns for each area
5. Feedstocks (including all streams to and from the site and pipelines, import gases, etc.) and main products. Are there different operating modes that impact energy use?
6. Organization of technical staff (how many engineers in daily operations support, longer term projects, advanced controls, maintenance?)
7. Capabilities and focus areas of technical staff. Do they use process simulation? Unit performance tracking sheets? Catalyst monitoring tools? Heat exchanger fouling tools? Who does 'head office' technical support? Who does engineering, procurement and construction (local engineers or an external contractor)?
8. Organization and roles of operators (how many shifts, how are they managed? How are production targets transferred? How are results and deviations communicated to management?
9. General product quality control. Use of on-line analyzers versus laboratory? Has there been a systematic effort to reduce product giveaway?
10. Briefly describe the Management of Change (MOC) process and form. How long is the approval process (for adding a new control valve, for example)? Are HAZOP or what-if analysis done? How many approvals from operations?
11. What is the capital project approval process? When is the budgeting deadline? Is there an approval committee? What accuracy of estimates is needed at what approval stage? What is the lead-time?

12. What is the hurdle rate for capital investment? What is the site's preference on financing (self or external)? Is there a lower hurdle rate for energy projects? Can it be assumed that money can be made available for all energy projects meeting the given hurdle?
13. What are the major initiatives that are expected to impact energy use in the past two years or the next few years? Ideally, please provide a 5-year capital plan.
14. What are the expectations for an energy program? Targets in terms of cost reduction or energy index?
15. Target areas or priority units or operating issues?
16. Any areas that should be avoided due to competing priorities or initiatives that may impact other consulting or supplier relationships, or may reduce the availability of site personnel?

D.4 Site-Wide Energy Management Questionnaire

The purpose of these questions is to gain a general understanding of site energy consumption and management systems, as well as an overview of specific site energy initiatives.

Typical questions include:

1. What is the average energy consumption of the site? Give total fuel consumption, including off-gases, liquids, imported natural gas, LPG, etc.
2. Indicate approximate utility prices that should be used in the analysis for fuel and power. Explain which fuel is the marginal fuel. Power should be an approximate all-in rate, and should avoid discussion of 'riders' or special arrangements with the power provider. Please explain if winter-summer seasonality or daily peaks have a major impact on utility pricing. Are there published utility prices (i.e. Platt's) that can be considered for the purpose of evaluation?
3. Indicate if there are any situations where a saving in an import utility may not yield a monetary benefit. For example, a fuel gas surplus at minimal natural gas import or a minimum take or pay on natural gas or power import. Without detailing contract terms, indicate if a saving of ≈10% import utility could be beneficial.
4. What is the energy index or external benchmarking index (e.g. Solomon EII or equivalent) for the facility?
5. An overview of the plant steam balance. What pressure levels? Own produced versus purchased steam. What is the closure of the balance at each level? Assumption on the losses?
6. Is there adequate steam turbine flexibility to satisfying plant steam users without letdowns? Explain the normal procedure for managing turbines versus letdowns? Is there any surplus or hidden vents? What is the major handle to control the pressure of each header?
7. Is there a steam trap program? Who does it and how often? Are there maintenance staff dedicated to repairing leaks and traps?
8. Are there any other consumables that can be considered part of an Energy program? Is nitrogen imported as a liquid or gas, or do you have an Air Separation Unit?
9. What is a typical plant fuel gas analysis? How much H_2? How much LPG?
10. Are there dedicated import natural gas users (furnace pilots, incinerators)? Is there a need to reduce natural gas import?
11. What is the origin of liquid fuel? What is the maximum sulfur limit? Are there issues on burner tip fouling?
12. Describe the current furnace program? Typical oxygen content in stacks? Are forced draft and induced draft systems in place? How is fouling and cleaning managed?

13. Energy management system. Who coordinates and supports? Do engineers submit energy projects? Show typical monthly report. Who is management sponsor? Are they active in this area? How are deviations addressed? Is operation staff involved or informed?
14. List energy projects.
15. Do reduced maintenance funds appear to be affecting energy use?

D.5 Typical Process Unit Interview

Below is an indicative list of questions that are usually asked in a process unit interview during an energy walkthrough. Most of these questions are typically answered by the plant process support engineer with access to process information or plant control screens. Some questions may be more suitable for an operator. Of course, specific questions about the process under review need to be included which are beyond the scope of this general document.

1. General unit configuration, ideally from a simplified process flow diagram (PFD). When was unit built?
2. When was last major revamp?
3. Unit capacity. Typical feed rate. Operating constraints. Any major operating issue?
4. Planned shut-down schedule. When was last one, when is next one? List major recent and planned projects.
5. What is the total fuel, power, steam use for the unit? List major energy equipment (furnaces, large compressors, large pumps or reboilers).
6. Feed and product overview. Sources of feed and the main feed quality concerns. Main product quality concern. Are there different operating modes? Are there slops or recycles?
7. Preheat opportunities. Layout of preheat exchangers from PFD. Are heat exchangers cleaned? How often? Are feed and product temperatures an issue? Has a pinch study been done on the unit? Has the preheat train been modified?
8. Furnace opportunities. What is the stack O_2 and stack temperature? Is minimum or maximum firing an issue? Is fouling or coking an issue? How is furnace outlet temperature adjusted? Consequence of colder or hotter furnace outlet temperature?
9. Reactor/catalyst opportunities. Does catalyst life limiting run-length (or pressure drop or annual cycle)? Is catalyst a new generation? Any additive or feed quality issue affecting catalyst life?
10. Separation/distillation opportunities. Describe the separation objectives for each column. How is pressure set? Is column capacity or flooding an issue? Any temperature limits for reboiler fouling?
11. Process compressors. Steam or electric driven? How is the flow rate controlled? Operation of reciprocating compressor unloaders? Operation of recycles for pressure control or anti-surge?
12. Any major pressure drop concerns in vapor or liquid systems?
13. Any major reliability concerns? Plans to address?
14. Advanced controls used in unit? Does the unit have an on-line optimizer? Is it well maintained and updated, with room to move? Do columns have multivariable constraint controls? Are they working?
15. Is there a working process simulation for the unit? Who runs it? For what?
16. List major projects and typical maintenance planned for next shutdown. Any maintenance done annually? Any energy projects planned?
17. Where should we focus to save energy? Suggestions on where to focus and where to avoid?

D.6 Energy Management Maturity Assessment

Refer to Appendix B for details.

D.7 Inventory and Prioritize Opportunities for Improvement

The walkthrough team will consolidate the interview information. During the interviews, all relevant interview and field observations should be recorded. At the end of each day, these should be consolidated into the energy observation list. After each interview list, perceived opportunity areas are identified with the unit staff.

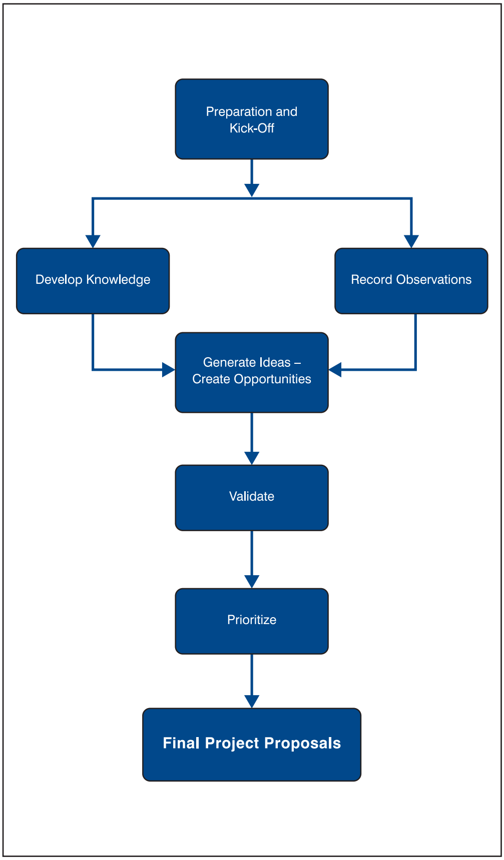
Order of magnitude benefits and implementation costs are identified. Opportunities are ranked using an agreed selection criteria – preferably something simple (e.g. traffic light approach).

This process will require input from site staff, usually to validate or explain observations and constraints, to provide data for key process variables needed to quantify perceived opportunities, and then to assist with the screening and prioritization of ideas.

Wherever possible, reference is made to benchmarks and industrial best practice as the basis for establishing performance gaps and a sound basis for recommending improvement.

Appendix E. Energy Projects – Identification and Assessment Process

The objective of the assessment program is generally to identify a list of project proposals suitable for Implementation. As such, it is essentially an idea generation, validation, and project scope definition process. During the initial idea generation phase, a list of many observations is documented. Observations are then validated and streamlined to generate a short list of opportunities. These opportunities are then reviewed and validated with the site in order to generate a portfolio of projects for implementation.



E.1 Preparation

Preparation for the assessment covers all the activities that should take place before the team goes to the site. It includes the familiarization of the team with the available background information, the preparation of an assessment plan, and completion of all necessary logistical pre-requirements.

E.1.1 Information Review

The information review should start with walkthrough documentation if that has been carried out, however some sites may start directly with the project identification. Other previous studies like margin or reliability improvement programs may give some insights into the site that will be helpful.

This information usually includes:

- Overall site configuration and logistics
- Site operational and business objectives
- Site energy utilization (overall and by unit)

A variance analysis should be done by comparing the energy use (overall site and by unit) with suitable benchmark data (Solomon EII, etc.) to highlight areas of low energy efficiency. The review should help the team be familiar with the operations on-site, highlight units with poor efficiencies for focus in ideas generation, and provide a health check at the end of definition process on consistency of the final project portfolio.

E.1.2 Plan for Assessment Period

The assessment team leader should develop an assessment period plan. This should also cover the logistic requirements such as office space and equipment, and access to IT systems, data systems, process information system and documentation, as well as the timetable for interviews and meetings.

The assessment period normally requires 4–8 weeks, depending on-site complexity, site resource availability, logistics, and site-specific constraints. Typically, one month before, the team leader should start engaging with the site energy focal point, site management sponsors, and other key site stakeholders to ensure all the program requirements are fully understood and set up the necessary preparation steps. The proposals ranking criteria should be discussed with the site and agreement and consensus on the selected criteria should be obtained.

E.1.3 Develop Understanding of Plant Configuration and Energy Use

This activity carries on in parallel to the observations and opportunities generation. In practice, knowledge creation of the site and energy utilization is an on-going process that spans through the entire program; however, there should be a conscious focus on a few key steps to enhance this process in the early stages of the assessment period.

The entire team should have a basic understanding of the plant configuration, operating and technical organization/sophistication, current energy improvement and monitoring activities, and the approximate energy usage and energy bill. This can be realized by several hours review with the host or energy coordinator. The walkthrough templates (Appendix F) can provide a suitable basis as to the information required.

The team should also have an understanding of the effective marginal fuel and power pricing mechanisms, and have identified a set of preliminary marginal prices for all utility streams. Specific elements should include the comparison of the steam prices used on-site with the calculation of HP steam costs calculated from the cost of fuel required to generate the HP steam, and the marginal MP and LP steam costs including the cost of fuel for generation and the electricity credit via steam turbines or desuperheater stations, etc.

Development of a consistent and relevant pricing set for the program will require discussions with and validation from the site economists during the assessment phase.

The plant should be divided into unit areas with a detailed analysis of the energy use per unit, preferably with a comparison against a suitable benchmark. Fuel, electricity, and steam consumptions should be inventoried for each unit. The initial marginal prices should also be added, and the utility bill for each unit estimated.

It is strongly recommended to create and analyze energy balances for the site, and to identify high energy consumption areas. Consistency of producers and consumer information should be checked. Balances should also be used to define limiting conditions in marginal energy/material quantities. Benefits which surpass these thresholds may need to be priced at different marginal value (if any).

E.1.4 Operations Reviews

The detailed operational review of the process and utilities units forms the basis for information gathering and identifying opportunities for improving energy efficiency.

This is a combination of extensive round-the-table flow sheet reviews supported by plant visits and walkthroughs. The flow sheet review will take place in a logical fashion, following the streams through the unit and at all times questioning and challenging operating conditions and facts relating to energy performance. This drives the observation gathering process E.2.1. below. The use of best practice guides with check-lists of typical operating conditions is strongly advised as a means of inviting comparison and making observations.

It is important that in addition to the conventional operational reviews, the process also covers the configuration and performance of energy equipment, i.e. fired heaters, heat exchangers (shell and tube, air coolers, special exchangers), rotating machinery (turbines, compressors, pumps), steam ejectors, electric motors, transformers and switchgears, cooling towers, etc.

E.2 Generate Observations and Opportunities

E.2.1 Observations

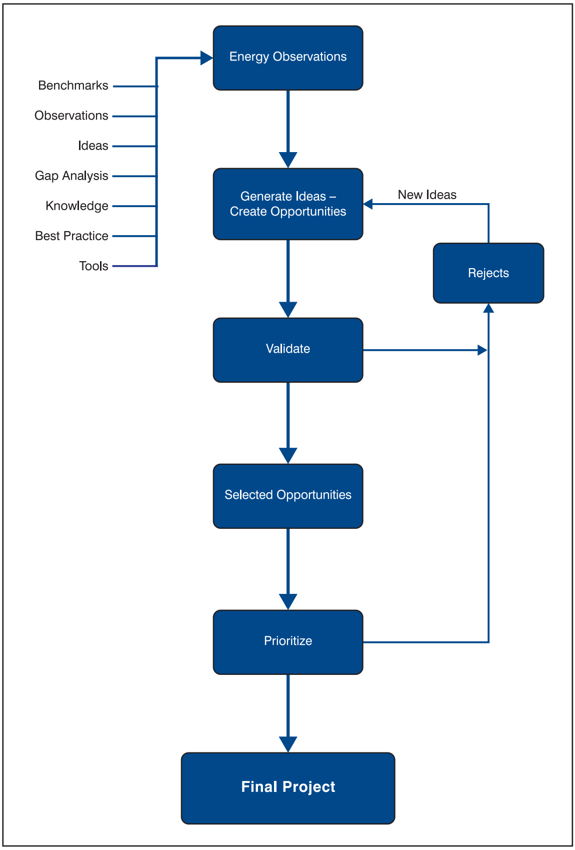
As a direct outcome of the plant review, information that is relevant to the development of value added opportunities is captured in specific observations. These can be any form of factual observation of an energy related condition or situation.

Observations can also arise from other sources, such as review of past projects, studies, and best practices, interviews with site process engineers and operators, using knowledge and tools available to the team and to the site staff. Following the capture of observations, the team goes through the observations in a systematic manner to identify items, patterns, common themes, and general ideas that can lead to the generation of opportunities. Observations are generated continuously with the different activities during the initial phase of the assessment. Care should be taken to log them in the observation list and share them within the team.

A good practice will be to maintain an observation capture spreadsheet, which is continually updated as the review meeting progresses. Observations are entered immediately, together with their potential impact. It is important not to lose the thought or idea. The final stage of the meeting is to review all the observations – allocate 'themes' (e.g. process, furnace, control, rotating equipment, scheduling, etc.) which will aid future analysis and add initial thoughts on follow-up. An example observation capture sheet is given in Appendix E.3.

E.2.2 Creating Opportunities

After the interview phase is completed, the observation list should be reviewed internally within the team in order to identify a series of preliminary opportunities for improving energy performance. The number of preliminary opportunities is significantly lower than the number of underlying observations.



Preliminary ranking criteria can be used to filter out the opportunities, based on ease of implementation, cost of capex/ opex, and benefits (refer to Chapter 9). This ranking provides a very rough indication of the overall potential for the opportunity in terms of benefits and implementation potential, and is used to decide whether to take the opportunity forward into next phase of development and benefits validation.

In a similar fashion to the observations, the opportunities are developed and logged in a list. A template example is provided in Appendix E.4. Behind this list is a common database of pricing and estimating data.

The main points to consider when developing the opportunities list are:

- Potential benefits achievable
- The actions needed to realize the benefits
- Technical feasibility and risk
- Operational feasibility and risk
- Resources requirements (man-hours, time, capital, and operating costs)

This list of preliminary opportunities is used as the basis for validation. Ideas that are not selected should remain logged in the opportunities list, stating the reasons for not pursuing for future reference.

E.2.3 Opportunities Validation

Once the list of preliminary opportunities is defined, the team proceeds internally to the first pass validation of the preliminary opportunities. It is the aim of the preliminary opportunity development effort to:

- Describe each opportunity
- Identify the main constraints, risks, and implementation requirements
- Define the indicative benefits, with breakdown of the impact on each class of energy (fuel, steam, electricity, etc.) both absolute and as a percentage of the specific unit use
- Define the indicative costs in terms of capital and operating expenditures

This process will involve several activities including:

- Site data retrieval, analysis, and review
- Trending of key parameters which relate to the opportunity
- P&ID reviews
- Field reviews
- Engineering calculations, e.g. process simulation and application of other energy tools and techniques
- Economics analysis, including preliminary benefits and cost estimates

The list of embryonic projects is now emerging from the opportunity listing. Further review involves verifying operational constraints, identifying projects and initiatives (past, present, and planned) impacting the areas under consideration, identifying stakeholders and stakeholders' position with respect to the potential opportunity under review. Site feedback on each opportunity is needed to get buy-in at a conceptual level and to identify viability, gaps, and associated development requirements.

The individual projects should also be checked against the initial 'variance analysis' to determine whether the claimed benefits are realistic and achievable.

The overall set of projects should be examined for double accounting. Multiple projects that claim on the same benefits and/or value generating mechanisms should be combined to minimize the risk of generating conflicting projects and of overestimating the achievable benefit of the overall program.

E.2.4 Opportunity Prioritization and Project Development

After the validated list of opportunities is developed, the final potential project list is then once again reviewed together with the site/business owner. This is done to prioritize the items and agree their revised relative potential benefits, resource requirements, and implementation risks in order to define a short list of potential projects to be proposed for further development towards execution.

A suggested energy improvement proposal template is provided in section E.5 as an example of a suitable form of documentation for the finalized project submissions.

E.2.5 Early Implementation (Quick-Win)

It is possible that some items could be already mature enough for execution before the completion of the assessment period (Quick-Win). It is strongly recommended to identify items with such early execution potential as soon as possible and give them the highest priority. The implementation of Quick-Win ideas will generally give a good impression to the site and be a strong advocate for the benefits of an energy efficiency program (Quick-Win assessment is discussed in Chapter 9.2.3 on project ranking).

E.3 Example of Observations-Gathering Datasheet

UNIT 1 – ENERGY USE	
Data Source	
Fuel	[amount, units]
Electricity	[amount, units]
HP Steam	[amount, units]
MP Steam	[amount, units]
LP Steam	[amount, units]
[insert other rows, CoEs as req'd]	[amount, units]

UNIT 1 – BENCHMARKING DATA	
Data Source	
Actual equivalent fuel usage/time	[fuel usage, units]
Theoretical equiv fuel usage/time	[fuel usage, units]
Cor'td Energy & Loss Index	[Index, year]
CEL Gap / Overlap	
Equiv. Distillation Capacity (EDC)	
Utilised EDC (UEDC)	
Theoretical Energy	
Energy Intensity Index (EII)	
[insert other rows, CoEs as req'd]	

UNIT 1 – MAJOR ENERGY EQUIPMENT					
Item Description	*Item Code*	*Energy Type(s)*		*Usage (units)*	*Comment*

UNIT 1 – CAPACITY & CURRENT OPERATIONAL CONSTRAINTS		
Capacity Basis, Constraint area	*Capacity (units)*	*Constraint / Comment*

UNIT 1 - RECENT, PLANNED SHUTDOWN HISTORY AND PROJECTS		
Description	*ETA*	*Comment*

UNIT 1 – MAJOR ENERGY EQUIPMENT							
Item ID	Observations	Date	Opportunity, Comments	Theme	Energy Impact	Follow-up	Link
1	Syn gas unit U7900 : the unit is running at turn down condition, 45-60 t/d with 90 t/d design capacity. Note that the design capacity is not proven over a significant period. To reduce the need of venting syn gas at low demands a plant trail is scheduled to take min. nafta feed rate down to 25 t/d.	29/02/2009	Save energy, reduce downgrading of naphtha feed in turndown mode (not too often).	PRO	PUR	Review results of plant trail.	PRO-3
2	Naphtha feed vaporiser, F5603, consumes 5 t/d fuel gas with 3.5% stack O_2, and 635 °C stack temperature. Low oxygen alarm setting at 2.5% (will clamp the fuelgas at 2.5%).	29/02/2009	Save fuel gas.	FUR	PUR	Review furnace operating condition. However, limited scope for improvement.	FUR-1
3	Steam/napthta ratio is set at 2.2 to 2.5. Two online ratios shows different number as using different flow meters. Operations want to control of this parameter, the parameter is quite conservative to absorb any fluctuations in naphtha feed rates.	29/02/2009	Save fuel gas, improve H_2/CO ratio and save MPS.	PRO	PUR	Review original proposal for ratio control of this parameter (plantchange at 2000). Consider a intermediate solution that operation can accept.	PRO-3
4	Main reformer furnace F3407 runs at 6.3% excess O_2. There may be scope to optimise/reduce the excess O_2. The convection banks do not show significant signs of fouling. Note that there are a lot of trips on this furnace. Flue gas of reformer is still at 320 °C ex convection bank.	29/02/2009	Save fuel gas.	FUR	PUR	Review furnace operations, consider excess 0_2 reduction (reduce draft via stack fan). Note that safeguarding makes this furnace operation complex.	PRO-3
5	CO_2 preheater, E6702 on main flue gas stack runs with bypass valve open. Apparently there is a constraint.	29/02/2009	Improve heat recovery.	HIS	PUR	Review temperature constraint. R3344 is filled with new catalyst that cannot operate at higher than 350 °C. No scope for improvement.	
6	Solvent circulation rate is high at 4000 t/d total. ABC Composition has shifted from the normal compostition, and re-inventorising the system is considered.	29/02/2009	Save power, LPS on solvent regeneration.	PRO	PUR	Review required solvent flow rate. Scope to reduce the flow rate after re-inventorising the system.	PRO-4
7	High heat losses observed over the HDT reaction section. Snat hot indicated a 60 °C temperature drop.	29/02/2009	Reduce heat loss.	PRO	PUR	Consider doing a IR scan of the reactor system, to review the condition of the insulation.	
8	KLM gas ratio is at 1.85 and typical range is 1.8 - 1.85. This is controlled by adjusting side stream and venting part of the produced H_2. In normal operations more hydrogen is vented then used.	29/02/2009	Energy saving, reduce H_2, off gas vent.	HIS	PUR	Review the KLMs ratio. Potential for increasing the syngas ratio is low.	PRO-3
9	MPS steam pressure of the steam generators is kept at 22.5 bara. The reason for this elevated pressure is unclear.	31/02/2009	Increase MPS production.	PRO	PUR	Review MPS pressure level, and consider pressure reduction.	UTL-2
10	Injection of oxygen scavenger into deairated water is located at suction of P2151, thus no treating of BFW to Unit 3 and Unit 4 headers.	31/02/2009	Reduce corrosion, increase reliability.	STM	PUR	Consider second oxygen scavenger injection point. (or increase deairator pressure). Will be taken up by client.	UTL-2
11	Several projects being developed to review possibility of importing cheaper feed (compared to naphtha tops from Unit 9. Alternatives would be IXU feedstream and butanes in summer.	31/02/2009	Reduce cost of feedstock.	STM	PUR	Not for Programme.	PRO-3
12	Due to lengthy compressor overhauls, sparing of critical reciprocating compressor is not always possible. Capacity control of all compressors is on spillback control and capacity can be trimmed with manual valve unloaders. To minimise compression.	31/02/2009	Reduce power consumption.	ROT	PUR	Review compression capacity vs. demand.	CON-1
13	There is continuous spillback on BFW from the BFW pumps. Spillback is via restriction orifices.	31/02/2009	Reduce power consumption.	ROT	PUR	Review spillback flow vs min. requirements of pumps.	
14	E2145 may be fouling.	31/02/2009	Increase heat recovery.	HIS	PUR	Trend OHTC based on field instruments.	
15	Steam leakage are a significant source of steam loss. Steam trap program started 2003 and situation has been improved a lot.	31/02/2009	Save MPS/LPS.	STM	PUR	Consider whether Programme can contribute.	UTL-2

E.4 Example of Opportunity Data Base

Potential Opportunities – Project Masterlist XYZ Company at Location ABC

Items		Description	Comment	Rate of energy savings - BASE PROGRAMME: Elect kWh/h 0.04 [USD]/kWh	VHP Steam tonne/h 9.92 [USD]/tonne	MP Steam tonne/h 7.64 [USD]/tonne	LP Steam tonne/h 7.64 [USD]/tonne	[RFG] tFuel/hr 130.00 [USD]/tSRF	[RFO] tFuel/hr 130.00 [USD]/tSRF	[BFW] tonne/h 0.60 [USD]/tonne	CO2 tonne/ 15.00 [USD]/tonne	Annual Energy Savings Potential - BASE PROGRAMME: HOURS ACTIVE h	OTHER BENEFIT k[USD]/Yr	TOTAL BENEFIT k[USD]/Yr	CAPEX / OPEX: 1st yr CAPEX k[USD]	1st yr OPEX k[USD]	Recur. OPEX [USD]/Y	1st year COST k[USD]	PAY OUT YEARS	TOTAL ENERGY t Fuel	Energy Index DELTA
PACKAGE	UNIT 1																				
	XYZ-UNIT1 -01	Optimise ABC circulation		75.0								8760		24	100			100	4.22	0.7	0.1
	XYZ-UNIT1 -02	Reduce hydrocarbon losses at Unit 1 plant	Note that 200 k USD of other benefits are related to ethylene recovery; additional capex 200 k USD.					0.30			0.900	8760	219	679	500			500	0.74	0.3	0.0
	XYZ-UNIT1 -03	Optimise capacity control of compressors	Based on improved controls on the compressor	100.0								8760		32	100			100	3.17	0.9	0.1
	XYZ-UNIT1 -04	Optimise ABC De-ethanisers operation	Including improved operation of the overhead compressors	40.0		0.3					0.050	8760		36				-		0.7	0.1
	XYZ-UNIT1 -05	Condensate recovery improvement						0.00		0.8	0.009	8760		9				-		0.0	0.0
	XYZ-UNIT1 -06	Optimise UNIT1 steam balance	Usages 350 t/d of MPS			0.8					0.150	8760		70	50			50	0.72	1.0	0.1
	XYZ-UNIT1 -07	Exploit UNIT1 tempered water system	Step-out project for district heating. Could be challenging to realise.									8760		-						-	-
	XYZ-UNIT1 -08	ABC heavy ends distillation optimisation						0.08			0.250	8760		128	50			50	0.39	0.1	0.0
	XYZ-UNIT1 -09	UNIT1 furnace optimisation	Cleaning of radiant section					0.1			0.188	8760		96	0	0	50	50	0.52	0.1	0.0
	XYZ-UNIT1 -10	Optimise heavy flasher operation	Mainly margin improvement; back-up item									8760		-				-		-	-
												8760		-				-		-	-
												8760		-				-		-	-
		TOTAL PACKAGE UNIT 1		215.0	0.0	1.0	0.0	0.4	0.0	0.8	1.5		219	1,072	800	0	50	850	0.79	3.8	0.3
PACKAGE	UNIT 2																				
	XYZ-UNIT2-01	Optimise MPS raising pressure E2109						0.01			0.025	8760		13				-		0.0	0.0
	XYZ-UNIT2-02	Optimise UNIT2 furnaces operation						0.1			0.188	8760		96				-		0.1	0.0
	XYZ-UNIT2-03	Rationalise UNIT2 steam tracing				0.2					0.033	8760		16				-		0.2	0.0
	XYZ-UNIT2-04	Stop MPS supply for UNIT2 reactor control				0.25					0.050	8760		23				-		0.3	0.0
	XYZ-UNIT2-05	Optimise steam/Naphtha ratio of reformer				0.25					0.050	8760		23				-		0.3	0.0
	XYZ-UNIT2-06	Reduce heat leakage reformer HDS section						0.01			0.025	8760		13		20		20	1.57	0.0	0.0
	XYZ-UNIT2-07	Reduce steam leakage and increase condensate recovery	Steam demand 300-350 t/d			1.3					0.250	8760		117				-		1.7	0.1
	XYZ-UNIT2-08	Optimise UNIT 2a distillation						0.1			0.150	8760		77				-		0.1	0.0
	XYZ-UNIT2-09	Reinstall UNIT 2b Reactor feed/effluent exchanger					0.8				0.150	8760		70	100			100	1.43	1.0	0.1
												8760		-				-		-	-
		TOTAL PACKAGE UNIT 2		0.0	0.0	1.9	0.8	0.1	0.0	0.0	0.9		0	447	100	20	0	120	0.27	3.8	0.3
PACKAGE	UNIT 3																				
	XYZ-UNIT3-01	Improve combustion UNIT3 Incinerator						0.02			0.063	8760		32	20			20	0.63	0.0	0.0
												8760		-				-		-	-
		TOTAL PACKAGE UNIT 3		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	17520	0	31.9375	20	0	0	20	0.63	0.02083	0.001736111
												8760		-				-		-	-
												8760		-				-		-	-
												8760		-				-		-	-
		TOTAL BASE PROGRAMME		215.0	0.0	2.9	0.8	0.6	0.0	1	2.5		219	1551	920	20	50	990	0.6	8	0.6

E.5 Energy Improvement Proposal Template

Company X **ENERGY IMPROVEMENT PROPOSAL no.: - XXX**

Ranking: Benefits: *give $ value pa* Ease: *description* Capital: *give $ value*	**Title:** • *Crisp description, that should relate to business area*

This item is linked to: *note any other related proposal numbers and title*

Description:

Brief description that should explain the business case.

Current Situation:

Brief description that should explain (in brief bullets) the current situation

Future Situation:

Brief description that should explain (in brief bullets) what the future situation will be and the necessary changes to achieve it.

Order of potential benefits: *benefits in M$yr*

- *provide a description how the benefits are calculated (in detail: xx extra t/day * $/t * yy days/yr = xx $/yr)*
- *refer to supporting business modeling runs as relevant.*
- *provide achievable targets or KPIs for non-financial benefits.*

Order of costs / investments: *in M$ with brief explanation / breakdown*

Capital investment : *if possible refer to engineering estimate.*
Revenue expenditure :
Development costs :

Investigations carried out so far:

- *note any key assumptions; any relevant information which underpins the proposal*
- *should provide enough (preliminary) info. to allow ranking of this proposal in terms of benefits/costs, resource requirements / ease of implementation, speed of implementation*

Barriers to success:

- *potential blockers and/or issues*

Measurement of Benefits:

- *provide clear guidelines (preferably a formula) for post-implementation determination of the benefits, indicating parameters to be measured and economic values to be used.*

Suggested approach for development:

- *High level description of implementation scope.*

Initial estimate of resources required for implementation:

- *High level estimate based on implementation scope*

E.5 Energy Improvement Proposal Template (continued)

Timing of implementation:

- *indicative: e.g. <3 mths; shutdown related + date of shutdown, etc.*

Implementation focal points:

- *Propose the name of a Site resource accountable for the implementation of this Proposal.*
- *Name of the agreed Assessment Team member who is accountable for tracking and assisting, as necessary, in the implementation of this Proposal*

	Name	Date	Signature
Site	....	....	....
Team			

	Name	Date	Signature
Site Line Manager*	....	....	....

Comments:

....
....
....

Final Approval Executive Committee:

	Name	Date	Signature
Site	....	....	....
Team			

** Person with responsibility for the area in which this Proposal is to be implemented – Manager, Superintendent, or Department Head.*

Appendix F. Emerson Process Management Tools and Techniques – Web Links

Emerson Industrial Energy
www.emersonprocess.com/IndustrialEnergy

Industrial Energy Applications

Boilers
Steam Turbine Generators
Chillers/Compressors
Utility Tie Lines
Steam Headers
Utility Energy Management Systems
Steam Traps
Energy Management Information Systems

www.emersonprocess.com/IndustrialEnergyApplications

Industrial Energy Solutions

Emissions Reduction
Fuel Cost Savings
Load Shedding
Staff Effectiveness
Energy Efficiency
Load Allocation
Reliability

www.emersonprocess.com/IndustrialEnergySolutions

Essential Asset Monitoring

Blowers
Cooling Towers
Heat Exchangers
Compressors
Fired Heaters
Pumps

www.emersonprocess.com/EAM

Refining Energy Efficiency Solutions

Heater Optimization
Distillation Optimization
Master Plan: Path To Operational Excellence
Fractionator Optimization
Process Improvement and Optimization Consulting

www.emersonprocess.com/IndustrialEnergyEfficiency

Consulting Services

Conceptual Design and Feasibility
SmartProcess® Solutions
Process Improvement and Optimization

www.emersonprocess.com/IndustrialEnergyOptimization

Emerson AMS Suite
AMS Performance Advisor
AMS Machinery Manager
AMS Asset Graphics
AMS Performance Monitor
AMS Device Manager
Improving Asset Availability

www.emersonprocess.com/AMS-Suite

Appendix G. European Union BReF Listing

The BAT Reference Documents (BReF) reflect an information exchange on Best Available Techniques (BAT) for energy management and optimization. While developed as part of programs particular to Europe, they are applicable in any part of the world. Energy Loss (through carbon emissions) is considered as a pollutant. The Energy Efficiency BReF covers generic best practice while the sector specific guides provide useful practices and benchmarks suitable for the individual industries.

The documents are freely available to download at ***http://eippcb.jrc.es/reference/***:

- Cement, Lime and Magnesium Oxide Manufacturing Industries
- Ceramic Manufacturing Industry
- Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector
- Economics and Cross-media Effects
- Emissions from Storage
- Energy Efficiency
- Ferrous Metals Processing Industry
- Food, Drink and Milk Industries
- General Principles of Monitoring
- Industrial Cooling Systems
- Iron and Steel Production
- Large Combustion Plants
- Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers Industries
- Large Volume Inorganic Chemicals – Solids and Others Industry
- Large Volume Organic Chemical Industry
- Management of Tailings and Waste-rock in Mining Activities
- Manufacture of Glass
- Manufacture of Organic Fine Chemicals
- Non-ferrous Metals Industries
- Production of Chlor-alkali
- Production of Polymers
- Production of Speciality Inorganic Chemicals
- Pulp and Paper Industry
- Refining of Mineral Oil and Gas
- Surface Treatment of Metals and Plastics
- Surface Treatment Using Organic Solvents
- Waste Incineration
- Waste Treatments Industries

Appendix H. Other Good Practice Guides and Sources of Information

1. **Energy Management – A Comprehensive Guide to Controlling Energy Use**
   The Carbon Trust, CTG054. ***http://www.carbontrust.com*** (replaces the well-known Good Practice Guide: GPG376, A Strategic Approach to Energy & Environmental Management).

2. **An Energy Star Guide for Energy and Plant Managers**
   Berkeley National Laboratory, LBNL-56183.

3. **Energy Management Information Systems – A handbook for managers, engineers and operational staff**
   Hooke/Landry/Hart, Canadian Industry Program for Energy Conservation, National Resources Canada.

4. **The website of National Resources Canada.**
   Many useful articles on energy efficiency and in particular Energy Management, ***http://canmetenergy.nrcan.gc.ca***

5. **Texas Technology Showcase**
   A useful organization based at the University of Texas at Austin with a strong emphasis on Industrial sharing and Energy Management, regular webinars, ***http://texasiof.ces.utexas.edu/***

6. **Introduction to Pinch Technology**
   Linhoff-March, 1998 (63 pages – available in multiple locations on the web)

7. **Pinch Analysis and Process Integration**
   Ian C. Kemp, second edition 2007 (390 pages, Elsevier ISBN 13: 978 0 75068 260 2)

8. **'Best Practices for Energy Management'**
   Allen Avery, ARC Advisory Group, January 2009

The Author

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David specializes in energy management and process control services for the oil, gas, and petrochemical industries and their supplier companies. As a former Shell Group Subject Matter Expert for Energy Management Systems, David developed world-wide standards and energy management work processes for Shell operating companies.

David is a highly respected engineer in the fields of energy management, process control, and operations decision support techniques. In a 32 year career with the Shell Group of companies he has held senior leadership positions in these areas and has played an influential role in the identification, development and roll-out of many of Shell's tools and technologies in these fields.

David is a Fellow of the Institution of Chemical Engineers and holds an MA in Physics from Oxford University.