

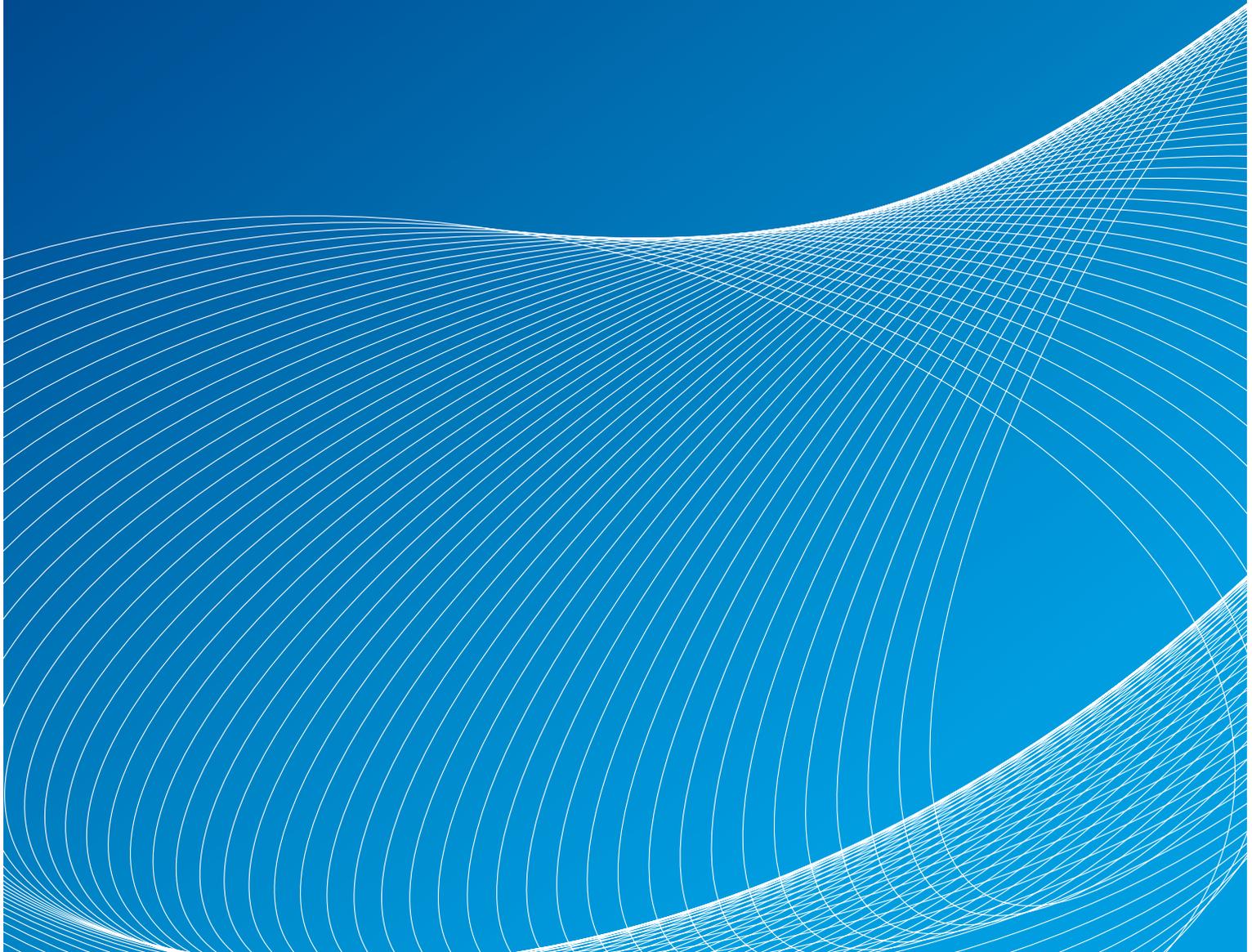
# Technical Guideline

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## I.S. EN 16001:2009

Energy management systems – Requirements with guidance for use

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## I.S. EN 16001:2009 Technical Guideline

This document has been prepared to describe technical information that organisations could present in applying for approval of their energy management systems under the Energy Management Systems Standard I.S. EN 16001:2009.

The document follows the headings in the I.S. EN 16001:2009 standard, but solely addresses sections with a 'technical' focus. These are the following:

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## Introduction

The I.S. EN 16001:2009 Energy Management Systems Standard was developed to ensure that energy management becomes integrated into organisational business structures, so that organisations save energy, save costs and improve energy and business performance. However, in itself, the standard does not establish absolute requirements for energy performance nor does it guarantee optimal energy outcomes.

I.S. EN 16001:2009 is structured and based on existing management standards such as ISO 9001 and ISO 14001. It also includes guidance on the use of the standard which primarily has its focus on the management systems aspects.

In recognition of the significant technical component necessary to maximise the benefits of I.S. EN 16001:2009, Sustainable Energy Ireland (SEI) has, in consultation with relevant stakeholders, developed this technical guideline. This guideline identifies technical stages and processes of an energy management system. It provides a range of possible methodologies and approaches which could be used in both satisfying the standard and ensuring the development and operation of an **effective** and documented Energy Management System.

The aim of the standard is to put practices in place that are effective, and result in measurable energy savings. In practice, an effective energy management system should result in:

- organisations taking action to improve energy efficiency,
- a continual improvement year-by-year and an improved performance in energy usage,
- more thorough analysis of areas with potential for energy saving being carried out, if no action on energy efficiency is being taken.

Activities related to the technical stages and processes of the system include:

- It is essential to develop an understanding – primarily through data collection – of energy use and the factors that drive it.
- The organisation should demonstrate an understanding of the energy requirements for significant energy users.
- In setting objectives and targets, the use of energy performance indicators (EPIs) at both management and operational levels is a key activity.
- A register of energy saving opportunities should be established, prioritised and fed into the energy management programme.
- With EPIs in place, information obtained from monitoring and measuring energy usage can be used to review and modify the system.
- The management review ensures that top management are responsible for assessing overall performance and recommending changes.

The management system provided for in I.S. EN 16001:2009 and associated guidance, should be considered as a support tool to assist implementation of energy management and cost reducing programmes. This technical guideline outlines methods of how to establish, operate and maintain these programmes. Organisations may then consider applying for certification to I.S. EN 16001:2009 as referred to in the following note.

## **Accreditation programme**

Accreditation is the formal recognition of a certification body's competence to conduct a specific activity such as testing or certification. This recognition is based on a specific series of International and European standards and guides.

The Energy Management Scheme requires that Certification Bodies become accredited to ISO 17021 in order to provide Irish organisations with an accredited certification to I.S. EN 16001:2009

An accredited certification means that Certification Bodies must audit companies to all scheme requirements, i.e. I.S. EN 16001:2009, the associated guidance and I.S. EN 16001:2009 Technical Guideline. The competence of the Certification Bodies to provide this certification will be assessed by accreditation programme operated by The Irish National Accreditation Board (INAB).

## 3.3 Planning

### 3.3.1 Identification and review of energy aspects

The review shall include:

**a) past and present energy consumption and energy factors based on measurement and other data.**

The annual energy consumption (fuel and electricity) from the previous three years (MWh/year) shall be presented along with corresponding energy factors (e.g., production volumes, weather data). Energy usage data collection may be based on the methods identified in I.S. EN 16001:2009 Annex A.3.1 a).

Patterns and trends in energy consumption over the previous three years should also be presented and discussed, where identifiable.

It may also be appropriate to include tariff analysis in your review of energy usage, as this can often result in the identification of cost savings.

Possible methods of presenting energy consumption information include the following:

*Options*

- Graphs and charts.
- Tables and spreadsheets.

Possible sources of data include:

- Meter readings.
- Estimations.
- Hours run.
- Name plate data.
- Compiled monthly bills.
- Monthly bill analysis for penalties/correct tariff structure.

**b) the identification of equipment having significant energy consumption, in particular of significant changes in energy use during the last period**

The main purpose of this step is to identify the areas having significant energy usage and substantiate why the energy usage is regarded as significant.

Possible technical issues to take into account when determining the significance of energy aspects, include:

*Options*

- Energy aspects that use the most energy.
- Energy aspects that determine energy use or the core energy requirement.
- Energy aspects that offer the most potential for saving.

Examples of typical areas to consider in identifying significant energy aspects, include:

*Options*

- Processes.
- Plant, equipment, fixtures, fittings.
- Buildings and building services.
- Raw materials.
- Water use (energy associated).
- Other services, such as transport.

A non-exhaustive list of possible ‘top-down’ and ‘bottom-up’ techniques that could be used in approaching this step include the following, or combinations thereof:

*Options*

<i>Top-down</i>	<i>Bottom-up</i>
<ul style="list-style-type: none"> <li>• Process maps.</li> <li>• Graphs and charts, e.g. pie charts.</li> <li>• Spreadsheets or tables.</li> <li>• Sankey diagrams.</li> <li>• Energy balances, mapping of energy use etc.</li> <li>• Energy models.</li> </ul>	<ul style="list-style-type: none"> <li>• Surveys of end-use technologies, e.g. a lighting survey.</li> <li>• Master lists of energy-using equipment, e.g. a master list of all energy using equipment on site, with their rated loads recorded. Actual loads may also be recorded. For example, organisations may begin with a master list of motors and more equipment surveys could be done over time.</li> </ul> <p>Note The following information is likely to be recorded for master lists of electrical equipment: rated power; rated efficiency; load factor; working hours p.a. and actual energy use.</p>

For other approaches, organisations may consult the Sustainable Energy Ireland EnergyMAP resource ([www.sei.ie/energymap](http://www.sei.ie/energymap)).

In practice, how organisations identify significant energy usage may involve a combination of these or other approaches. **The analysis should result in a breakdown of energy use to the extent that the**

**energy requirement and energy drivers are identified for each significant energy usage.** This will also require an identification of the system boundary of the significant energy aspect under consideration.

**c) an estimate of the expected energy consumption during the following period**

An estimate of the expected energy consumption should be an integral part of a system where the planned consumption is estimated for the following period. Tracking the energy consumption versus this estimated consumption will provide a useful energy performance indicator and will aid in the budget setting exercise.

**d) the identification and prioritisation of opportunities for improvement**

The identification of opportunities for improvement should be part of a continuous process, but may also involve periodic analysis using proven techniques. Periodic analysis will identify opportunities at a specific point in time, with the outcome then being fed into the planning process. However, continuous opportunity assessment may also be applied using certain techniques. The following paragraphs provide non-exhaustive lists of possible techniques for both approaches.

*Options*

Identification of opportunities for improvement (periodic)

- Energy requirement analysis
- Energy audits. These may be walkabouts, surveys or formal audits (see 'BREF')
- Energy models/balances/process maps and Sankey diagrams
- Value engineering
- System efficiency analysis
- Manufacturer's/Design data analysis
- Pareto Analysis
- Metering reviews
- Re-evaluation of procurement policies, contract and design specifications, procedures etc.
- Maintenance techniques, e.g. maintenance assessments, predictive maintenance, etc.
- Training needs analysis
- Review of best available techniques (BAT)
- Best practices
- Pinch analysis
- Root cause analysis

### Options

Identification of opportunities for improvement (continuous)

- Energy monitoring (may also include energy use profile analysis, regression analysis, etc.)
- Benchmarking (may include EPI analysis)
- Lean manufacturing, Six Sigma, Right first time etc.
- Cost centre control
- League tables
- Suggestion or incentive schemes
- Team meetings, brainstorming etc.
- Good housekeeping
- Awareness and culture change
- Opportunity lists and tips, e.g. top ten ways to save energy etc.

In assessing opportunities for improvement, the organisation should demonstrate an understanding of the energy requirement for the energy aspect under consideration.

### Special investigations (SI)

In the case that no opportunities for improvement are being implemented in any one year (and none have been identified), the organisation shall carry out, in that year, at least one special investigation into areas that may offer potential for energy savings, and report on its outcome.

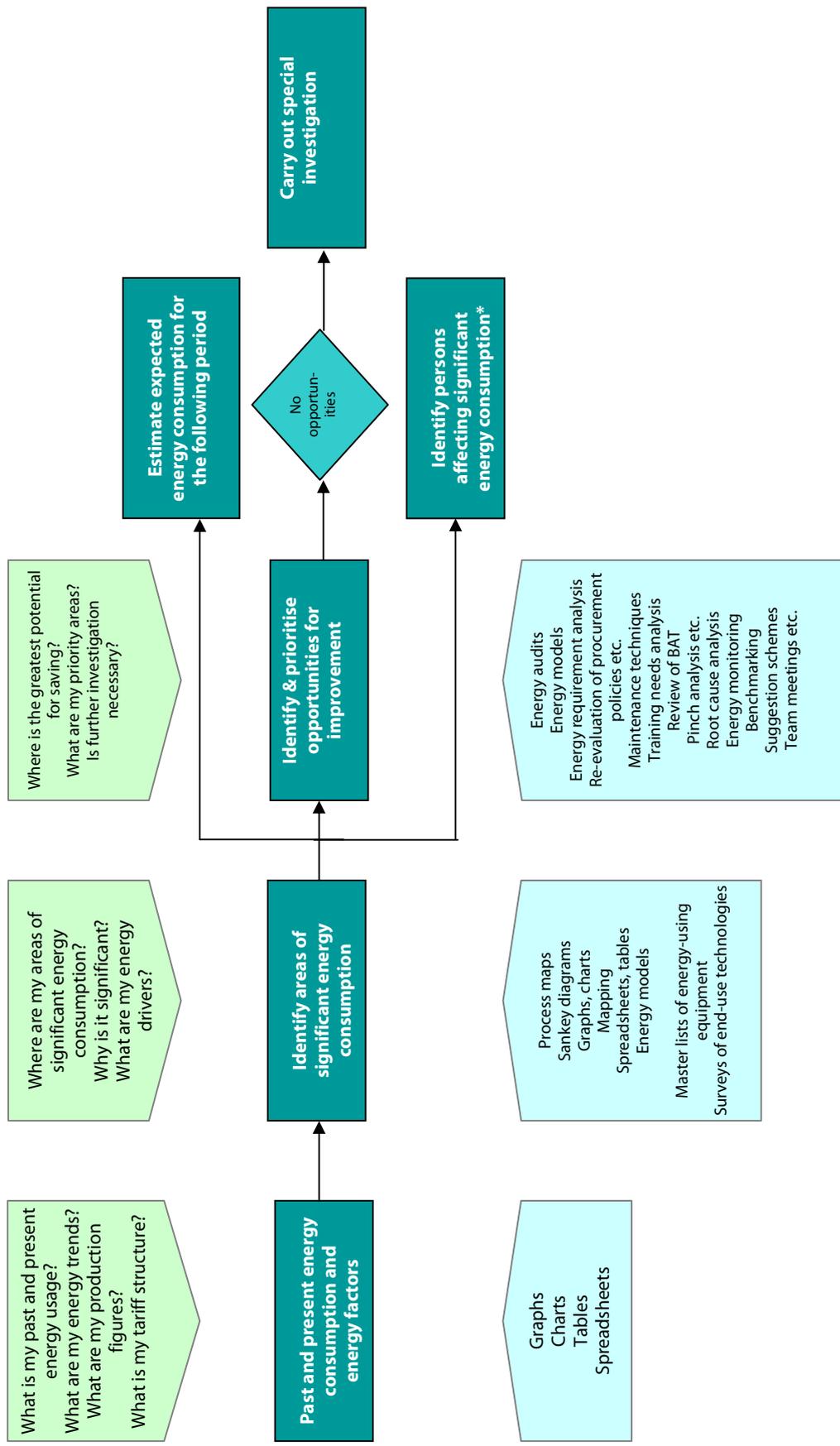
A special investigation shall be planned and described in terms of:

- Aim of project
- Expected saving potential
- Activities to be carried out
- Organization and responsibilities
- Time schedule
- Budget and resources

Where organisations have already identified opportunities, they should concentrate on implementing these. Over subsequent reviews, as opportunities for improving energy efficiency are more difficult to identify and the standard begins to infiltrate business practices and create a culture of energy efficiency, then more in-depth analysis will be required to understand where and how performance can be improved.

All opportunities identified during the opportunity identification process and any audit or special investigation shall be recorded in the Register of Opportunities for improvement.

**Figure 1: Review of energy aspects**



Note This diagram is for illustrative purposes only, and merely provides a synopsis of the guidance on the Review of energy aspects

### 3.3.3 Energy Objectives, targets and programme(s)

General approaches to setting energy consumption reduction targets include:

#### Options

- Past performance, i.e. analysing past performance and setting appropriate targets.
- Best practice, e.g. benchmarks or best practice performance of plant such as compressed air.
- Internal benchmarks, i.e. comparing performance with other similar energy aspects.
- Theoretical limit.
- Predictive maintenance techniques.

Target setting is a cyclical process and in some cases may be regarded as continuous, if short time scales are used.

Targets should be SMART (simple, measurable, achievable, realistic and time-based). See the SEI Energy MAP website for further advice on setting objectives and targets.

Possible techniques for helping set objectives and targets include the following:

#### Options

- Regression analysis.
- CUSUM analysis.
- Statistical process control (SPC).
- Base load analysis.
- Data mining.
- League tables.
- Register of opportunities.

Note Energy usage data should always be normalised to take account of influencing factors.

Each identified significant energy usage should have an associated objective or target. This may be in the form of an energy performance indicator (EPI).

EPIs for energy consumption can be set at management and operational levels. Management level EPIs will generally relate to the overall control of significant energy usage. Operational level EPIs may relate to particular items of plant, equipment etc., and focus on specific energy savings opportunities.

Examples of EPIs include:

<i>Options</i>
<i>Overall</i>
Energy intensity of a site.
<i>Management</i>
Energy performance of a production line. Energy performance per m <sup>2</sup> for buildings.
<i>Operational</i>
Operational efficiency of a chiller unit. Operational efficiency of a boiler.

The organisation should designate responsibility for the achievement of objectives and targets. Progress on objectives and targets should be monitored and measured and corrective action taken as appropriate.

The energy management programme should be based on the Register of Opportunities identified in the review. The process of prioritising and selecting the opportunities that are outlined in the energy management programme should be transparent.

When setting the energy management programmes the organisation's business plan for the period, should also be taken into account.

## 3.4 Implementation and operation

### 3.4.1 Resources, roles, responsibility and authority

The organisation should consider developing a matrix, organisation chart or similar, outlining the roles and responsibilities of individuals in relation to the energy management system.

#### *Options*

Whilst the successful implementation of the energy management system will require a commitment from relevant key personnel and awareness from all persons working for, or on behalf of the organisation, the establishment of an 'energy team' should also be considered.

As energy consumption data monitoring becomes more sophisticated through more comprehensive metering, organisations may consider devolving the responsibility for energy management across the organisation through developing:

- Cost control centres controlled by the business unit management teams,
- EPIs for specific business units, with responsibility for achieving set targets allocated to the business unit's management team.

### 3.4.6 Operational control

The following information refers to the specification, design, procurement, installation, operation and maintenance of significant energy utilising plant, facilities, equipment and raw materials.

#### **Design**

- For significant projects, an energy representative should be part of the design team, and the team should work in an integrated manner. For major projects an interdisciplinary team should be established.
- Where appropriate, energy performance targets and performance measures should be set.
- Whole-system design of the project should be addressed.
- Life-cycle costing should be applied, where appropriate.

#### **Specification and Procurement**

Procurement policy should include a requirement to take into account the energy implications of procurement decisions and all procurement decisions that affect significant energy use should start with an evaluation of needs. Procurement specifications, tender and contract documentation should include energy consumption criteria and a requirement to analyse the life-cycle costs of purchases.

Organisations should consider energy efficient products and services (including those carrying a recognised eco-label) as the first choice in all applicable procurements, unless there are reasons not to do so such as health, safety, performance, or cost considerations.

#### Options

- Staff should be aware of the investment criteria used in procurement decisions.
- Specific procurement guidelines may be established for certain items of plant, equipment or other items. For example, a motor purchasing guideline specifying that only high efficiency motors is purchased.
- The organisation may also wish to consider using energy from renewable sources.

#### Options

There are opportunities for reducing costs in purchasing electricity and fuels through competitive purchasing. Tariff analysis and load management may also lead to reductions in electricity costs. Questions to consider include:

- are you on the most appropriate tariff for your usage profile?
- are you incurring penalty charges, and if so, why?

#### **Installation**

Proper commissioning should be carried out by suitably qualified personnel for new facilities, plant, equipment, fixtures and fittings, and records maintained.

Sufficient information should be provided on the operation of the plant, facilities or equipment on completion of the installation and any necessary training delivered for operational and/or management staff.

#### **Operation and maintenance**

Each significant energy user should have an associated operation and maintenance procedure(s). For some organisations, the correct operation of significant energy using plant, equipment or other users, may account for the majority the energy saving potential. Personnel who operate such plant, equipment etc. should be competent on the basis of appropriate education, training and/or experience as specified in section 3.4.2 *Awareness, training and competence*, of the I.S. EN 16001:2009 standard.

Possible maintenance techniques include:

*Options*

- Preventive Maintenance.
- Predictive Maintenance.
- Reliability Centered Maintenance (will require equipment specific maintenance routines).
- Overall Equipment Effectiveness (OEE).
- Totally productive maintenance.
- Other principles may be applied, such as 'right first time'.

Note: Maintenance activities on equipment that is relatively unimportant in terms of energy use and facility reliability may apply a reactive maintenance approach.

## 3.5 Checking

### 3.5.1 Monitoring and measurement

Significant energy usage should be metered as appropriate and recorded in a metering plan. The addition of energy meters will depend on the feasibility and cost-effectiveness of the metering.

Factors to take into account in determining cost-effectiveness of metering, include the cost of:

- Design
- Purchase
- Installation
- Operation
- Data storage
- Analysis of the data output
- Maintenance

This must be weighed against the estimated energy cost savings. A metering strategy should be considered that identifies what needs to be metered and takes into account the factors determining cost-effectiveness. Metering can range from sophisticated permanent meters to simple low cost spot meters. Due consideration should be given to other instrumentation that is available from which energy consumption can be deduced/calculated, such as hours run meters, flow meters and temperature measurement.

An important principle of metering and its outputs is that it should be increasingly integrated into the business management process.

In justifying the relevance of the measurement frequency applied in relation to the identified energy usage, simple risk analysis may be used.

Significant energy usage should be monitored in order to identify unnecessary or wasteful energy usage. Monitoring techniques may consist of meter readings, indirect measurements, estimations etc.

It is important to establish relationships between the significant energy users and the factors that affect its consumption. It should be noted that it is not always practicable or beneficial to monitor energy consumption or energy factors due to a relatively stable and constant energy requirement. In these instances it should be demonstrated that it is not practical or beneficial to monitor the energy consumption or associated energy factor of the significant energy user.

### 3.5.3 Nonconformity, corrective action and preventive action

The organisation should be able to quickly respond to deviations in energy use and make the necessary reactive (immediate or short term) adjustments in order to correct the situation. The organisation shall evaluate the effectiveness of the long term preventative action periodically.

### 3.6 Review of the energy management system by top management

In addition to the requirements of I.S. EN 16001:2009, the review should also identify:

- the changes to the energy management system and constituent programmes, that will be necessary in the coming period;
- the activities to be carried out in the coming period;
- Status of Register of Opportunities

#### Performance statement

The organisation shall produce an energy performance statement to be reviewed by the certification body. This is effectively an 'executive summary' of the organisation's performance.

The aim of the performance statement is to provide energy performance information and evidence on the continual improvement of the energy performance of the organisation.

The statement shall contain a summary of data on the performance of the organisation against its energy objectives and targets with respect to its significant energy usage. This should identify what has been done to improve energy efficiency and the energy savings achieved. The performance statement should also include a summary of the Register of Opportunities (referred to in 3.3.1 c above) and/or an Energy Savings Register, in order to compare opportunities with achievements.

The data should allow for year-by-year comparison to assess the development of the energy performance of the organisation over time.

The organisation should use relevant energy performance indicators to demonstrate its energy performance.

Performance data can be presented in a number of ways, such as graphs, charts and tables.

The structure of the performance statement is a matter for the organisation to determine. However, it is important to include the same type of information as reported in previous years to help ensure comparability.

## References

I.S. EN 16001:2009. Energy Management Systems – requirements with guidance for use, The National Standards Authority of Ireland, 2009.

Guidance note on energy efficiency auditing, The Environmental Protection Agency, Ireland. 2003.

EnergyMAP, Sustainable Energy Ireland. <http://www.sei.ie/energymap/>

## **Annex A (informative)**

### **Examples of aspects and associated objectives, targets, programmes, indicators, operational control, and monitoring and measurement.**

The organisation may find it useful to summarise in a table, the process of linking significant energy aspects, objectives, targets, programmes, performance indicators, operational control and monitoring and measurement. For each significant energy aspect:

1. develop objectives and targets;
2. establish programme actions to achieve the objectives and targets;
3. identify specific indicators to evaluate performance;
4. establish operational controls in implementing the actions;
5. monitor and measure performance.

Examples are given in the following table.

**Table A.1 — Examples of aspects and associated objectives, targets, programmes, indicators, operational control, and monitoring and measurement.**

<b>Energy aspect</b>	<b>Objective</b>	<b>Target</b>	<b>Programme</b>	<b>Indicator(s)</b>	<b>Operational control</b>	<b>Monitoring and measurement</b>
Building heating	Reduce heating energy use in buildings.	Reduce building heating energy consumption by at least 7% on current year's level, by 2008.	Install optimum start controller for heating system. Upgrade heating distribution insulation. Install PVC strip curtains in loading bay. Draught-proof windows, roof lights and doors. Ensure thermostats are correctly set. Ensure heat emitters are unobstructed. Raise awareness.	Building heating energy consumption in kWh/m <sup>2</sup> p.a.	Specification for installing optimum start controller. Specification for installing PVC strip curtains. Procedure for upgrading heating distribution insulation. Procedure for checking thermostat settings, state of heat emitters, windows and doors.	Monthly measurement of heating fuel energy consumption. Regular monitoring of space temperatures. Periodic monitoring of heating system time and control settings.

continued...

Energy aspect	Objective	Target	Programme	Indicator(s)	Operational control	Monitoring and measurement
General wash-up in dairy processing plant	Reduce warm water usage.	Reduce warm water usage in litre/m <sup>2</sup> by 5% of current levels within 1 year.	Replace hose nozzles with more efficient models. Ensure solid waste residues on floor are swept up instead of flushed away. Ensure leaks are detected and fixed. Raise awareness.	Warm water usage in litre/m <sup>2</sup> p.a. Mean temperature of water.	Specification for fitting new nozzles. Work instruction for floor cleaning. Procedure for detecting, reporting and fixing leaks. Basic instruction in basic correct floor cleaning.	Bi-weekly monitoring of warm water usage for cleaning. Regular monitoring of water temperature. Spot checks on operators.
Heating and cooling in connection with processing of a product (food, chemicals, medical etc.).	Reduce energy used in heating (fuel based steam) and cooling (outside air ventilated through the material).	Reduce energy consumption to the minimum required to perform the aim of the processing (changing the structure and/or contents of the material processed).	Install more accurate temperature measuring equipment. Improve process management. Train those responsible for controlling the process. Install energy efficient ventilators & motors. Install frequency steering on ventilator motors. Reduce air leakage in vent. system	Use of fuel per ton processed. Use of electricity per ton processed.	Specify max. and min. temperatures in connection with heating of the processed material. Specify max. and min. temperatures in connection with cooling of the processed material.	Daily or weekly monitoring of steam or fuel usage (frequency depending on potentials). Daily or weekly monitoring of electricity used for ventilation.

## Glossary

### Best available techniques (BAT)

As defined in the integrated pollution prevention and control (IPPC) Directive 1996,

'Best' means the most effective in achieving a high general level of protection of the environment as a whole;

'Available' techniques means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technical viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

'Techniques' include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

### Base load analysis

A means of analysing the minimum amount of energy delivered or required over a given period of time at a steady rate. It generally refers to the energy load when the normal activity of the entity is not being carried out, e.g. in industry, outside of production hours. An energy data set is thus derived over a defined period of time to represent the behaviour of a particular load within a system, e.g. a building or process.

### CUSUM (Cumulative sum)

A technique for analysing energy data that uses the difference between the base line (expected or standard consumption) and the actual consumption over the base line period of time.

### Data mining

A technique for extracting patterns from a large collection of data in order to derive previously unknown and potentially useful information.

### Energy audit

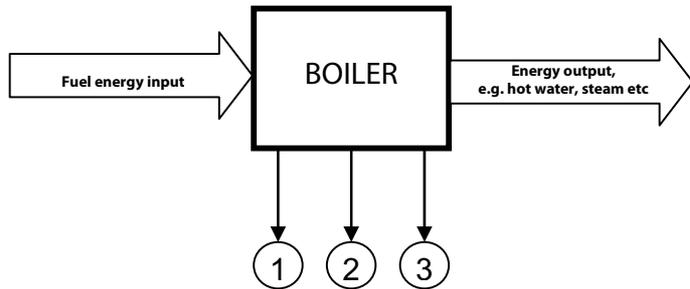
A systematic, independent and documented process for obtaining evidence on energy consumption, conservation and efficiency, and evaluating it objectively to determine the extent to which defined criteria are fulfilled.

### Energy Intensity

The ratio of energy consumption to a measure of the activity carried out by an entity, e.g., production levels, total floor space, number of employees, financial turnover etc. Energy consumption related to production levels is also referred to as 'specific consumption'.

### Energy balance

A systematic accounting of energy flows and transformations in a system. The flows include energy losses, energy supply from utility systems, internal heat generation (chemical reaction) etc. Percentages or values can be assigned to the flows identified. The diagram shows the flows in a simple boiler energy balance.



1. Heat loss in flue gases
2. Heat loss from radiation and convection
3. Heat loss from blowdown

### Energy mapping

This generally refers to a dis-aggregation of energy consumption (MWh/year) into its constituent end-uses. For example, mapping of electricity may consist of a dis-aggregation of electricity consumption into lighting, HVAC, compressed air etc. An overall dis-aggregation of annual primary fuel consumption (MWh/year) may also be presented, including conversion losses, power production and distribution losses. The pie chart shows a simple energy map of heating load in buildings.



### Energy model

A technique for summarising, in the form of a data sheet, the energy consumption in a system. This is then used to carry out an in-depth diagnoses to identify and select actions that will reduce energy consumption or cost.

### Energy requirement

The minimum amount of energy required to achieve a desired output. The concept relates to the issue of why a particular amount of energy is being used, and whether the output can be delivered in a different way that requires using less or no energy. Does the activity actually need energy? Is there another way of delivering the output? This will require energy requirement analysis.

### Lean Manufacturing

A manufacturing/production philosophy that strives to eliminate waste from all activities and operations, increase efficiency, and create value for the consumer of the finished product. Also known as Lean Production.

### Life cycle costing

The total cost associated with the purchase and operation of a product, service or other item. Such costs will include energy and maintenance costs, but exclude costs associated with disposal. Life cycle costing is sometimes referred to as the "Total Cost of Ownership" (TCO).

### Monitoring

A process intended to assess or determine the actual values and variations in energy usage, based on procedures of systematic, periodic or spot surveillance, inspection, sampling, measurement or other assessment methods, intended to provide information about energy usage.

### Normalise

A process of modifying energy data in order to deal with influencing factors. Depending on the activity, influencing factors could include, the number of machine hours for a product, product weight, external temperatures etc. Normalisation facilitates comparison, benchmarking etc.

**Overall Equipment Effectiveness (OEE)**

A framework for assessing the efficiency and effectiveness of plant, equipment or processes, through a break down into three constituent components: availability, performance and quality.

**Pinch analysis**

A process integration methodology for analysing industrial processes in terms of energy flows and savings. Also called pinch technology or pinch methodology.

**Predictive maintenance**

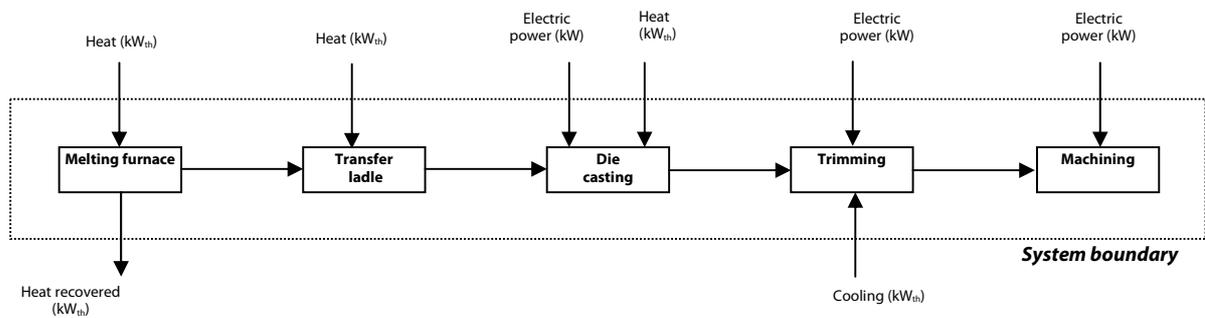
Maintenance based on analysis of the condition of an item or facility that checks if it is operating as required, and if not, corrective action is taken.

**Preventative maintenance**

Maintenance actions performed on the basis of a set time or run-time interval.

**Process map or flow chart**

A diagrammatic representation of an industrial or other process that shows the principal activities carried out in the process and the main energy inputs and outputs for the process. The diagram shows an example of a process flow chart for a die casting operation.



**Regression analysis**

A technique for analysing energy data that analyses the association between one (dependent) variable and one or more other (independent) variables.

**Reliability Centered Maintenance (RCM)**

An approach used to determine the maintenance requirements of a physical asset in its operating context. Essentially, RCM prioritises maintenance according to the importance of an item and the probability of failure and matches these with the resources available. This principle may be applied to identifying the critical items of plant with significant impact on energy use and ensuring that they are operating correctly. For example, the cleanliness of heating and refrigeration heat exchangers.

### **Right First Time**

An approach to manufacturing that strives to ensure that the desired outcome is achieved at the first attempt.

### **Root Cause Analysis**

A systematic process to find the fundamental cause of an outcome (failure, non-conformance etc.) by tracing back from the outcome to its original root cause.

### **Sankey diagram**

A diagram that summarises, in true proportion, all the energy transfers taking place in a system or process, including energy sources, losses, etc.

### **Six Sigma**

A statistically based process improvement methodology that strives to limit defects to six standard deviations from the mean.

### **System boundary**

The boundary of the system under analysis that identifies what elements are included in the system for analysis purposes.

### **Theoretical limit**

A term given to a point of perfection or perfect performance, based on current levels of technology.

### **Total Productive Maintenance**

An approach to maintenance that brings different functions together such as operations, maintenance, purchasing and other support services to develop and implement a formal structure for maintaining a building, plant, fixtures or fittings.

### **Training needs analysis**

A method of determining the existing skills and the training that is required for personnel.

### **Value engineering**

A technique for analysing the best value alternatives in terms of qualitative and quantitative costs and benefits of component parts of a proposed system.







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