PEER-REVIEWED PAPER

A strategic review of energy management systems in significant industrial sites in Ireland

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Abstract

The purpose of this research was to carry out an analysis of a selection of large Irish industrial energy users, employing 6,800 persons, across a number of sectors, (Pharmaceuticals, Medical Devices and Semiconductor), to assess the role and development of effective energy management systems (EnMS[1]) within their organisations. A comprehensive survey, completed by top management[2], was carried out with five large industry partners. It facilitated the assessment of the levels of maturity, perceived barriers to, and potential opportunities for the development of EnMS and sustainable manufacturing within their organisations. The final details relevant to each site have been validated by reviewing the results with each of the respondents. Those industries surveyed had an overall annual energy spend of €28 million, which resulted in 144,000 tonnes of carbon dioxide being emitted. The level of maturity of each EnMS was assessed, scored and compared. The lack of human and financial resources were identified as common barriers to the development of their EnMS. The most important energy performance indicators were identified and reported. All of the organisations have sustainability master plans and are interested in centralising the role of their EnMS. Each respondent reported that carbon will be a key production metric in the near future. There are certain key elements of the survey, such as the EnMS maturity matrix, which could be effectively applied across a larger number of industries. Such research would greatly enhance our knowledge of energy management systems.

Introduction

This research is funded by Enterprise Ireland and is being carried out in collaboration with Limerick Institute of Technology, University of Ulster, Innovation for Irelands Energy Efficiency Research Centre (I2E2[3]) and the International Energy Research Centre (IERC[4]) under the project Total Energy Management in Production Organisations (TEMPO[5]). The primary aim of this project is the development of a proof of concept visualisation tool that communicates the current and predicted energy use facilitating energy performance improvements for production organisations. The benefits of improved energy performance and efficiency are environmental improvement (reduction in greenhouse gases and other pollutants), energy security (reduction in Ireland's reliance on imported energy sources), reduced energy costs (both for final users and for utilities), increased economy competitiveness and job creation (Schnapp 2012).

1. Energy Management Systems (EnMS).

2. ISO, 2011. ISO 50001 International Standard. In: Energy Management Systems – Requirements with guidance for use. Top Management is defined as 'person or group of people who directs and controls an organization at the highest level'.

3. I2E2 – Innovation for Ireland's Energy Efficiency. www.i2e2.ie/

4. IERC – International Energy Research Centre. http://www.ierc.eu/

5. TEMPO – Total Energy Management in Production Operations. http://www.acornresearch.ie/Tempo.php

The research centres and industrial partners developed the study by designing a comprehensive survey aimed to identify barriers to and opportunities for the development of energy performance improvements via effective energy management systems in a number of selected, exemplar sector specific companies.

The following were further objectives of the survey:

- To establish baselines for the total energy and water usage, carbon footprint and energy efficiency of the companies.
- To identify energy efficiency and energy monitoring exemplars within the companies.
- To determine the relevant KPIs (Key Performance Indicators), automation and IT systems that support production and their potential application in energy and cost reduction programmes.
- To develop the functional requirement specification for project TEMPO (Total Energy Management in Production Operations).

Furthermore, the survey provided a platform for respondents to report on which aspect of the EnMS they felt would be most effective in reducing their energy costs. It also offered an opportunity for the respondents to report on whether greenhouse gas emissions/carbon dioxide equivalent would be a key metric for production in the short, medium and long term. Finally it provided respondents the opportunity to report on the decision making priorities and energy management strategies being employed at their organisations.

The main focus of this paper is to provide a strategic review of the respondent's energy management systems with regard to the levels of maturity of their EnMS, the key decision making priorities of top management (and how they effect the energy strategy), as well as the barriers and potential opportunities, relevant to the further development of their EnMS.

Methodology

SURVEY DESIGN

The study required the completion of a comprehensive survey, by top management, supplemented by interviews and follow up conversations which took place over a number of months. Five industry partners representing exemplars in a wide number of sectors such as ICT, healthcare and pharmaceutical were selected to participate in the study. Two companies use continuous manufacturing processes, one uses batch manufacturing processes only and two use a combination of both continuous and batch processing. The survey took the form of one hundred and seventy five questions over a range of energy topics in relation to production operations. It was divided into the following sections; the facility's physical infrastructures, energy management systems, decision making priorities, total energy inputs, energy utilisation, production energy data and energy efficiency projects. The survey was designed with both open and closed questions that provided respondents with the opportunity to supply more details, as appropriate. The final details relevant to each site have been validated by reviewing the results with each of the respondents.

The categories of primary energy sources were selected in line with those used in the annual Business Energy Use Survey (BEUS 2012[6]) which is an annual survey jointly conducted by the Central Statistics Office (CSO) and the Sustainable Energy Authority of Ireland (SEAI[7]) who collect mandatory information about energy use by business in Ireland to meet the requirements of regulation (EC) No. 1099/2008 of the European Parliament. Their 2012 Survey was based on the reported energy consumption in business for 2011 and gives a statistically significant baseline for a range of business types and sectors. The selection of the significant energy users by relevant Primary Supply was drawn from the comprehensive four yearly Manufacturing Energy Consumption Survey (MECS 2010[8]) undertaken by the US Energy Information Administration (EIA) and the categories headings were localised based on the Byrne Ó Cléirigh Report (BOC 2008[9]) on Energy End-Use in Ireland.

The rationale for some of the key elements of the survey is set out overleaf.

Energy Management

The SEAI has developed a web-based tool (SEAI EnergyMAP, 2014) which may be used by industry to assess their energy management system under five pillars of excellence which are Commitment, Identification, Plan, Take Action and Review. Each pillar is then made up of a number of steps and the tool guides the user through the actions required to complete each step. Under the EnMS section of our survey we set out the twenty steps involved in the EnergyMAP and provided a tick-box to indicate how the industry assesses their progress on each step. The responses are presented as a Maturity Matrix in the form of a spider diagram and may be compared against sectoral reports published by SEAI.

Decision Making Priorities and Energy Strategy

Questions were asked in relation to the ability and willingness of production personnel and managers to consider changes in their production schedules and operations based on the provision of accurate information on energy usage. The rationale for gaining an insight into overlapping production and energy related aspects could facilitate the development of energy management strategies such as interval-based pricing, demand side management and smoothing of demand variability to complement the integration of on-site, renewable energy technologies.

Barriers to and Opportunities for the Development & Implementation of an EnMS

The respondents were asked to list the top three barriers that they felt were obstacles to the development, implementation and maintenance of a full and effective energy management

6. The Business Energy Use Survey (BEUS) is carried out under Commission Regulation (EC) No 1099/2008 of the European Parliament and the Council of 22 October 2008 and carried out by the Irish Central Statistics Office. www.cso.ie

7. The Sustainable Energy Authority of Ireland (SEAI).

8. The Manufacturing Energy Consumption Survey (MECS 2010). http://www.eia.gov/consumption/manufacturing/index.cfm

9. Energy End-Use in Ireland, Study Summary Report, November 2008 http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Commissioned_Research/Energy%20End-Use%20in%20Ireland.pdf. Accessed 16th January, 2014.

system. Furthermore, the respondents were asked to answer questions in relation to carbon emissions, renewable energy and maintenance strategies. The promotion of energy efficiency and the use of renewable energy sources are strategic instruments that will help alleviate the environmental burden caused by production operations (Pérez-Lombard 2013).

A significant proportion of questions were designed to gather background information about current energy utilisation, which is outlined in the next section.

Findings

ENERGY UTILISATION

The survey was carried out at five large industries who have a direct and indirect headcount of 6,800 personnel. Their total energy usage, in gigawatt hours, and the different types of energy used, in the period from 2008 to 2011 is outlined in Figure 1. These data suggest that the overall energy usage is rising and there seems to be a trend towards using more natural gas and less electricity. Additionally, biomass usage was introduced in 2010 at company E and that is captured in this graph. The different types of energy used at each of the companies are summarised in Figure 2.

The energy usage and overall cost is outlined in Table 1. It indicates that biomass accounts for a very small proportion of overall energy usage. This result suggests that it is an area for potential growth given that most of the energy used is based on imported fossil fuels which could present a security of supply issue. The total energy usage by the five companies constituted 1.48 % of overall energy usage in production facilities in Ireland during 2010[10]. The natural gas and electricity tariffs, average unit prices (per kWh) and the overall cost of energy at each company was assessed.

Electrical energy usage accounts for 63.7 %, natural gas accounts for 35.9 % and biomass accounts for 0.003 %. Even though, natural gas accounts for almost 36 % of overall energy usage, it only accounts for 18 % of the overall CO_2, carbon dioxide[11] emissions (resulting from that energy usage). The following chart, Figure 3, indicates that the total CO_2 emissions of the surveyed companies was 144,322 tonnes, during 2010. The conversion factors used are those outlined in Sustainable Energy Authority of Ireland (2011).

ENERGY MANAGEMENT SYSTEM (ENMS)

The energy and environmental management systems standards and policies in operation at the respondent companies will be outlined in the next paragraph. Subsequent to that the maturity of each companies EnMS will be looked at in detail.

Energy & Environmental Management System Standards & Policies

The respondents were asked to indicate the energy and environmental standards/policies implemented and used at their organisations. All five replied to this question. A summary is outlined in Table 2.

10. Sustainable Energy Authority of Ireland, Energy in Ireland, (2011). http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_In_Ireland_1990_-2010_-_2011_report.PDF. Accessed on 8th January, 2014.

11. Carbon Dioxide – CO_2.

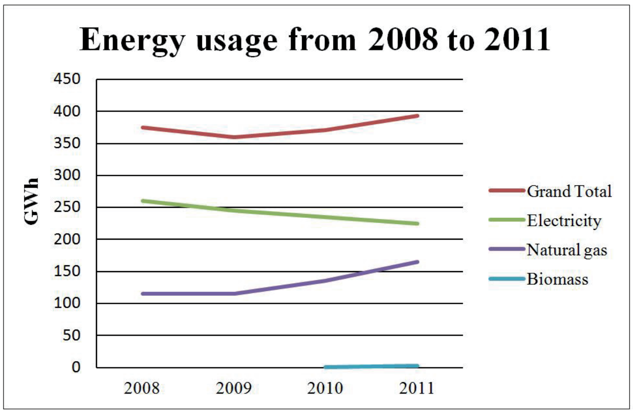

Figure 1. Energy Usage from 2008 to 2011.

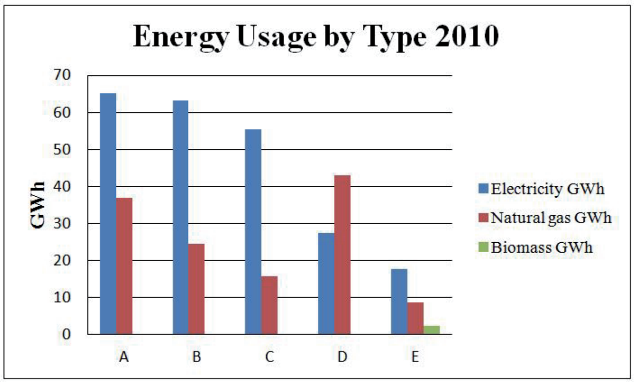

Figure 2. Energy Usage by Type during 2010.

Table 1. Overall Energy Usage and Costs, during 2010.

Electrical Energy	229 GWh
Natural Gas	129 GWh
Biomass	1 GWh
Overall Energy Usage	**359 GWh**
Total Cost	**€28m**

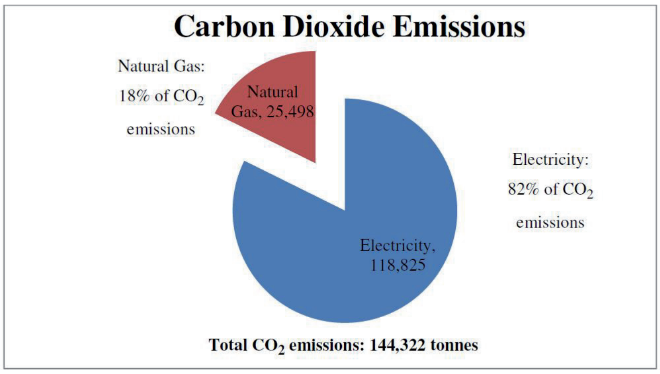

Figure 3. Total Tonnes CO_2 Emissions of all Companies, during 2010.

Table 2. Summary of the Standards & Polices being adhered to.

Company A	Company B	Company C	Company D	Company E
ISO14001, Environmental management systems standard and has a Corporate Social Responsibility Statement.	ISO14001: EMS, LEED, Leadership in energy and environmental design, and has a CSR Policy.	ISO14001: EMS, ISO50001, Energy management systems standard and has a CSR Policy.	ISO14001: EMS, ISO50001: Energy management systems standard and has a CSR Policy.	ISO14001: EMS ISO50001: Energy management systems standard and has a CSR Policy.

All five companies have implemented and operate a Certified Environmental Management System and have a Corporate Social Responsibility Statement or Policy. Three of the companies (Companies C, D & E) operate a certified energy management system that complies with the requirements of ISO 50001. Company B use LEED certification when designing new buildings.

Energy Management Maturity Matrices

An energy management maturity matrix is a set of twenty questions that reflect the key aspects of an energy management system[12]. These questions were included in full in the survey. The twenty questions are divided into five key pillars for an effective energy management system. These pillars include; commitment, identification, planning, taking action and reviewing (its performance). Due to their importance each of these pillars will be discussed individually. This discussion will include a brief explanation and a summary of the questions pertaining to each pillar in the survey.

The commitment pillar highlights the level of commitment shown by top level management of the organisation towards the implementation and running of an energy management system. Hence, a high percentage result indicates that the organisation has assigned sufficient resources to the implementation of the objectives and targets as documented in the organisation's energy policy. In the survey, the commitment element was assessed and participants were asked to comment on the level of commitment their top management team showed towards the EnMS. The participants were asked if there was a senior management sponsor, whether there was an energy manager (co-ordinator) appointed, whether there was an energy team in place, and whether the organisation had a specific energy policy in place.

The identification pillar outlines if the organisation has surveyed current energy usage and identified its significant energy users. It also shows if they have a clear understanding of the factors that influence energy consumption and energy performance indicators. Additionally, this pillar highlights if an organisation continuously identifies opportunities for improvement.

The planning pillar highlights whether the organisation has an energy programme plan in place and whether adequate resources are formally allocated to the energy management/saving activities. On the planning aspect, the participants were asked whether their organisation sets objectives and targets, whether they had or had not an energy savings programme plan and whether adequate resources were being formally allocated to the EnMS energy saving activities.

The action pillar reports on the level of implementation of the energy programme plan. It determines if an assessment of energy efficient practices and energy awareness is being carried out amongst employees. It highlights the training standards of the key personnel and the level of operation and maintenance of the significant energy users. Under the take action pillar, the organisations were asked to answer questions relating to the implementation of energy saving programme plans, the level of energy efficiency awareness and practices and whether their Significant Energy Users (SEU[13]) were designed, operated and maintained to optimise energy efficiency.

The review pillar highlights the extent to which organisations measure and assess their energy performance versus targets. It also explores whether the organisation uses corrective action procedures and if an organisation periodically reviews and updates the targets for the improvement of the energy management system and its energy performance. In relation to the review aspect, the organisations were asked whether they measure and monitor their energy performance, whether they identify and implement corrective actions and whether they periodically review their EnMS and identify improvements.

Results

An overview of the results of the maturity matrix follows, in Figure 4. Under the commitment pillar, three out of five companies produced very good scores in this section. The organisations that performed least well have a certified ISO 14001, environmental management system, and those could develop their environmental policy to include an energy specific component, appoint an energy sponsor and co-ordinator and that would help them to improve their scores under the commitment pillar. Under the identification pillar when asked if your organisation had undertaken an overview of the past and pre-

12. Sustainable Energy Authority of Ireland (SEAI), EnergyMap – Energy Management Action Programme (MAP) – Online Tool for Energy Management in Industry. http://www.seai.ie/EnergyMAP/. Accessed 4th January, 2014.

13. ISO, 2011. Significant Energy Use is defined as 'energy use accounting for substantial energy consumption and/or offering considerable potential for energy performance improvement'.

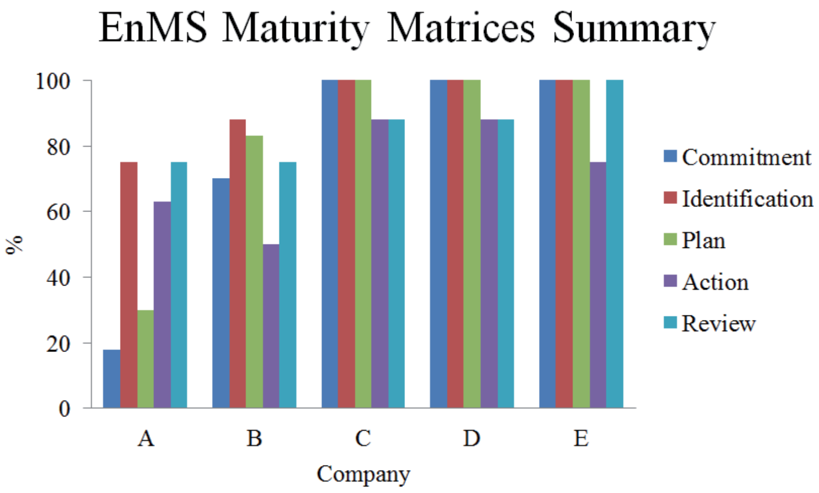

Figure 4. EnMS Maturity Matrices Summary.

sent energy consumption, most of the respondents surveyed replied that this has been carried out formally. When asked whether your organisation had surveyed current energy use and identified the SEU four out of five replied in the affirmative and they had carried out this aspect formally and had a quantified assessment. When asked whether your organisation had identified the key factors that influence energy consumption and energy performance indicators all of the respondents answered that they had formally carried out this task and had quantified energy performance indicators. Similarly, all of the respondents answered that they continuously identify the potential energy savings opportunities at site and plant level.

Under the planning pillar, three out of five companies scored very well in this aspect. The organisations that performed least well operate certified ISO 14001 systems and they could develop their environmental related objectives, targets and programme plans and integrate energy specific programme plans. Under the action pillar, all five organisations felt that they had potential to improve the effectiveness of their EnMS regarding the level of implementation of their energy programme plan. Finally, under the review pillar, all five companies have experience of using ISO management systems standards and are well versed in measuring and monitoring, using corrective action procedures and carrying out periodic reviews of their management systems. As a result, candidates performed very well in these aspects of their EnMS. However, they all reported that the most challenging part of the review process was the measurement and monitoring of energy performance and the checking of their performance against targets.

The level of maturity of each of the organisation's EnMS was discussed and summarised using spider diagrams. Two of the companies have been selected and their responses are assessed. Company A's level of maturity is summarised in Figure 5. Using the diagram as a summary of the levels of maturity, it can be established that both the identification & review pillars are 80 %. This would indicate that the company uses the identification and review aspects of its environmental management system to capture energy management related activities. An action pillar level of 60 % indicates that the organisation has a formal, although insufficient, allocation of resources to its EnMS energy saving activities, has partially implemented its Energy Programme Plan, most of its key personnel (or interested parties[14]) are trained in energy efficiency practices and its SEU are informally designed, operated and maintained to optimise energy efficiency.

Although the company has had success in identifying, reviewing and taking action, to implement and develop an EnMS, the matrix highlights less success in the planning and commitment aspects. Regarding planning, little feedback on this topic was provided by the respondent which suggests that the organisation does not have a comprehensive, formal, well communicated energy policy. This could also suggest that adequate resources are not being allocated by top management. Resources include human resources, specialised skills, technology and financial resources[15].

Company B's level of maturity is summarised in Figure 6. Using the diagram as a summary of the levels of maturity, it can be established that the company scored well in the identification and planning aspects, not so well in the commitment and review characteristics and performed poorly in the taking action part of its energy management maturity matrix. The organisation could develop and implement a complete energy policy, could carry out a training needs analysis and use the results to develop an energy training programme. Furthermore, it could continue to integrate its energy management system with its environmental management system.

The poor result in the taking action aspect would suggest that there is only partial implementation of an energy savings programme plan and that energy efficiency practices and training could be improved and carried out in a systematic and formal way.

As outlined in Table 2, Companies C, D & E operate certified ISO 50001 EnMS, reflected in each achieving 100 % in the commitment, identification and planning aspects of the maturity matrices. These companies performed least well under the action

14. ISO, 2011. Interested party is defined as 'a person or group concerned with, or effected by, the energy performance of the organisation'.

15. ISO, 2011. Resources include human resources, specialised skills, technology and financial resources.

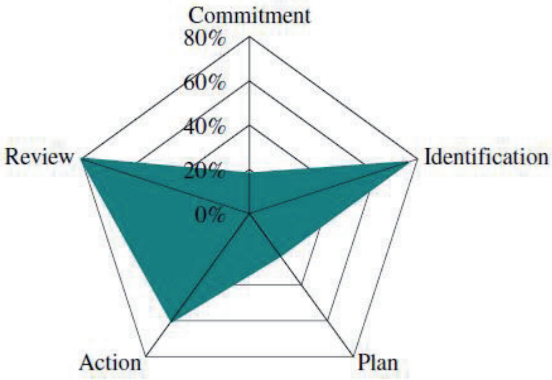

Figure 5. Five pillars of Company A's EnMS.

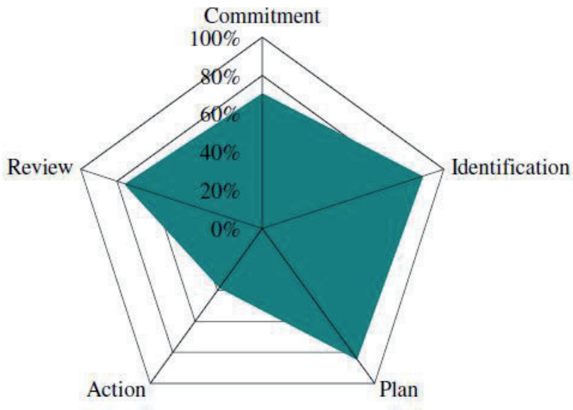

Figure 6. Five Pillars of Company B's EnMS.

and review pillars. Based on an analysis of the responses and other feedback, a few common themes emerged which was a lack of adequate human and capital resources and a difficulty in centralising the EnMS and maintaining compliance with regulatory bodies. The author suggested that the organisation's energy co-ordinator could try to ring-fence savings achieved from the implementation of energy efficiency programmes and use those savings to pay for additional resources to develop and implement targets and objectives.

DECISION MAKING PRIORITIES AND ENERGY STRATEGY

The respondents were asked to outline their decision making priorities and energy strategies, to gain a better understanding of the drivers that will influence the key, production related, decisions in the next eighteen months (short term), in the period from eighteen months to five years (medium term) and in the period greater than five years (long term). These priorities and drivers will have a very significant impact on the further development of the EnMS. For the purposes of this paper the focus is on the respondent's short term views.

Decision Making Priorities

The respondents were asked to review a list of factors that could have an impact on their decision making processes in relation to a, hypothetical, change to their production facility. Those topics were capital costs, operating costs, energy consumption, supply of utilities (e.g. water, compressed air etc.), production/automation technology, cycle time, reliability, quality, production space, environmental impacts (emissions, waste, waste water etc.), life cycle cost analysis, material handling, maintenance, supply chain, headcount, IT infrastructure (non-automation) and return on investment.

Four out of five companies responded and one of those was disqualified as they did not adhere to the guidelines. Of the three that did adhere to the guidelines, two replied that capital costs and one replied that operating costs were the significant factors that would influence their decision process. Two relied that quality and one relied that headcount would be their secondary consideration. Cycle time, operating costs and reliability was ranked in third place. Supply of utilities, supply chain and operating costs accounted for the next ranking. Energy consumption and production/automation technology were ranked fifth place in order of importance. It is notable that all three reported that operating costs and energy consumption are important factors to be considered when changing a production facility. The results are summarised in Table 3.

The respondents were then asked to carry out the ranking exercise again, taking a medium term view, and to consider the factors that would influence their production related decisions. The answers were similar to those outlined above and in addition three respondents felt that production space and maintenance would be important factors to consider, in the medium term.

Energy Strategy

Respondents were asked whether their organisations had a corporate energy strategy relating to their production. All five organisations replied 'yes' to this question. The respondents were then asked to describe the payback criteria and the monitoring and verification methods employed by the companies, and their feedback is outlined in the following two sections. This information is essential when looking at how the respondent companies measured the success, or otherwise, of energy projects completed and how it impacts on their future energy strategy.

Payback Criteria

The respondents were asked what payback measures were applicable for each new project. Companies A and E have an IRR[16] of greater than or equal to 15 %. Company B has an 18 month simple payback measure/criteria, Company C has a 2–3 year simple payback measure/criteria and Company D has a simple payback (defined as cost savings versus total project costs), but the exact criteria used to decide whether a project would be supported financially, was not outlined.

Respondents were then asked if the investment rate of return differed from a local and corporate perspective. Companies A and E stated that projects were funded using a corporate fund, Company B stated that capital budgets were controlled locally

16. IRR – Internal rate of return or economic rate of return (ERR) is a discounting cash flow technique which gives a rate of return that is earned by a project. The IRR is the discount rate at which the net present value (NPV) of costs (negative cash flow) equals the NPV of the benefits (positive cash flow) of the investment.

Table 3. Summary of Decision Making Priorities in the Short Term.

	Company B	Company D	Company E
If considering a change to your production facility rank the following topics in terms of their relative importance?			
Capital Costs		1	1
Operating Costs	1	3	4
Energy Consumption	5	6	5
Supply of Utilities (water, compressed air)	4	7	
Production/Automation Technology		5	
Cycle Time	3		
Reliability			3
Quality	2		2
Production Space [m2]			
Environment (emissions, waste, waste water)			
Life Cycle Cost Analysis			
Material Handling			
Maintenance			
Supply Chain		4	
Headcount		2	
IT Infrastructure (non-automation)			
Return on Investment			

and that a payback of eighteen months was applicable, Company C responded that they do not have a local investment rate of return and Company D did not provide an answer.

Monitoring and Verification (M&V)

The companies were asked to explain how projects were reviewed and four out of the five companies replied. Companies A and E stated that projects were reviewed by the corporate worldwide energy teams, Company B said that each project was audited against projected savings and Company C stated that they use M&V plans for all active projects. Company C have engaged with a student from a local learning institute, and they are working on developing M&V plans using the EVO[17] International Performance Measurement and Verification Protocol (IPMVP). Additionally, respondents were asked what formal processes are being used to evaluate and prioritise new projects relating to production and energy efficiency. Company A did not offer a reply and all others responded as follows:

- Company B replied that the team carries out a feasibility study on the potential project and then, depending on whether the outcome is favorable, they present the key elements to top management. Top management then make a decision on whether the project will be financed or not.
- Company C has a monitoring and verification (M&V) procedure in place. Energy opportunities are ranked using life cycle cost analysis, capital expenditure (CapEx), payback and tonnes of carbon dioxide emissions offset criteria.
- Company D has a cross-functional project priority team that meets every month. That team reviews all minor projects including energy savings projects. The respondents from Company D developed their response by adding that the major energy saving projects have to go through formal off-site approval processes before being sanctioned.
- Company E said that they receive financial and engineering approval at site level before a request is escalated and sent to corporate for approval. Corporate personnel then carry out a further engineering and financial appraisal before a decision is made. Furthermore, Company E replied that they use a software project management tool to help them with the selection and evaluation of energy related projects.

17. EVO – Efficiency Valuation Organisation.

Energy Metrics and Energy Performance Indicators

When asked whether energy consumed is being embedded into the calculation of production metrics, Companies B & C replied that this was the case in their organisation. Company D replied that it was not being embedded at present; that energy consumed is being reported at product level and that they would aspire to it being reported per batch. Company E replied that it was not being reported and Company A did not offer a reply. The companies were then asked if energy costs were allocated to the value streams and how. Company B said that costs are allocated by manually entering data onto spreadsheets, Company C replied that the costs are charged but that their method of costing energy is evolving, Company D replied that costs are being allocated as a standard cost per product and Company E stated that that costs are being allocated, but this activity is being carried out 'crudely' and that a generic value is allocated to each product.

Each of the organisations responded that they use energy performance indicators (EnPI[18]) to monitor the relative energy performance of their operations and of their plant and equip-

18. ISO, 2011. ISO 50001 Energy Performance Indicator is defined as 'quantitative value or measure of energy performance, as defined by the organisation. Note EnPIs could be expressed as a simple metric, ratio or a more complex model.'

ment. The EnPIs that are of particular interest to the production managers are the energy intensity indicators[19] and the EnPIs that relate to the performance of the plant and utilities equipment are of particular interest to the facilities managers. Managerial level EnPIs are also being used. For example, energy per square metre of treated floor area, the cost of energy and heating degree days. The energy managers are responsible for monitoring all types of EnPIs. Given that energy consumption is an increasingly important factor in production costs and all companies are actively engaged in energy management it is important to establish barriers and opportunities for the further development of EnMS.

BARRIERS TO AND OPPORTUNITIES FOR THE DEVELOPMENT & IMPLEMENTATION OF AN ENMS

Barriers

The respondents were asked to list the top three barriers to the development, implementation and maintenance of a full and effective energy management system. Companies A, B, C & D identified that a lack of human resources was a crucial barrier. Companies A & B identified that the perceived costs associated with developing and implementing an EnMS represented a barrier and Company D identified that a lack of available finance was a barrier. Companies D and E identified that maintaining compliance with regulatory bodies and the 'quality challenge' were barriers. Company C identified that having no central documentation system was a barrier to the development of their EnMS. Additionally, Companies B and E felt that there was a lack of commitment and this presented a barrier. Company E felt that employees were becoming tired of the sustainability message, reporting a 'green fatigue' and this was a barrier, and finally Company C felt that the identification of a measurable and effective energy performance indicator was a barrier. A summary of the responses is outlined in Table 4.

Opportunities

Four out of five companies felt that the EnMS aspects most effective in reducing costs were good performance management, via monitoring and targeting plans and effective energy performance indicators. These four companies were Company A, C, D & E. Companies A and C also felt that it would help to facilitate a programme of energy awareness training at their organisations. Company B felt that an EnMS would help to reduce electrical energy usage.

Additionally, it is important to identify the key personnel, such as those operating and maintaining the significant energy using equipment, and that those people are trained and motivated and fully understand their impact on the organisation's energy performance. In circumstances where staff and employees are not aware of the opportunities, and are not motivated to act, then the benefits of implementing and using an EnMS are not maximised. This can be achieved through energy awareness campaigns and training activities.

Carbon Dioxide Emissions

The management of CO_2 emissions may be perceived as an opportunity and/or a threat. For the purposes of this survey and given the sectors that the companies operate in, greenhouse gases refers to carbon dioxide emissions only. Each company was asked if they periodically calculate the weight of carbon dioxide, associated with their use of energy in their production facility, and all of the companies surveyed carry out an analysis periodically. Company C answered that their usage was 25 % below the target set under the EU's Emissions Trading Scheme (ETS)[20]. Company C is a member of the ETS, whilst Company D is a member, but the production facility being surveyed is not.

Company D measures the carbon footprint of each of their products, whilst Company C said that they would measure this parameter if it was achievable. All of the other companies do not, at present, carry out CO_2 emissions calculations per production line/value stream.

Carbon Dioxide as a Key Production Metric

Respondents were asked whether they agree or disagree that CO_2 emissions associated with their production would become a key metric in the short, medium and long term. The organisations were asked to take three timeline views and to answer each question with each timeline view in mind. Four of the five companies provided feedback. All four responded that they would either agree or strongly agree that carbon foot printing would be a key production metric in the short, medium and long term. The energy usage and associated carbon dioxide emissions can be visualised using the Sankey diagram in Figure 7.

It is worth noting that Companies C and D use similar quantities of energy, but because Company D uses proportionately more natural gas, their corresponding carbon footprint is approximately one third less.

Renewable Energy Plans

Company A has a planning application with the local authority, to install a 3 MW wind turbine at its site. Companies B and C do not have any plans to introduce renewable energy technologies at their sites in the short term. Companies D and E are in the process of installing 3 MW wind turbines at their sites and are expecting that these turbines will to be operational by the middle of 2014. Both companies anticipate that this will result in significant decreases in their electricity costs.

Shifting the Timing of Production

Respondents were asked if they agreed whether they would shift production by up to four hours, given the potential for energy savings. Four out of five companies responded. Company B replied that this question was not applicable as they ran a continuous, 24 hour 7 day, production cycle. Company C replied that cost and throughput improvements would be required to shift the timing of production. However, they did say that there is one group that use capacity planning for WIP[21] and that group does shift the timing to optimise the efficiency

19. ISO, 2011. ISO 50001 Energy intensity is defined as 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.

20. http://ec.europa.eu/clima/policies/ets/index_en.htm

21. WIP – Work in Progress.

Table 4. Table Summarising the Barriers to the Development and Implementation of an effective EnMS.

A	B	C	D	E
Human resources	Costs	Human resources	Insufficient resources (people & money)	Commitment
Costs	Human resources	No central EnMS system	Maintain compliance with regulatory bodies	Quality challenge
	Commitment	EnPIs	Competing with other priorities within plants	Green fatique

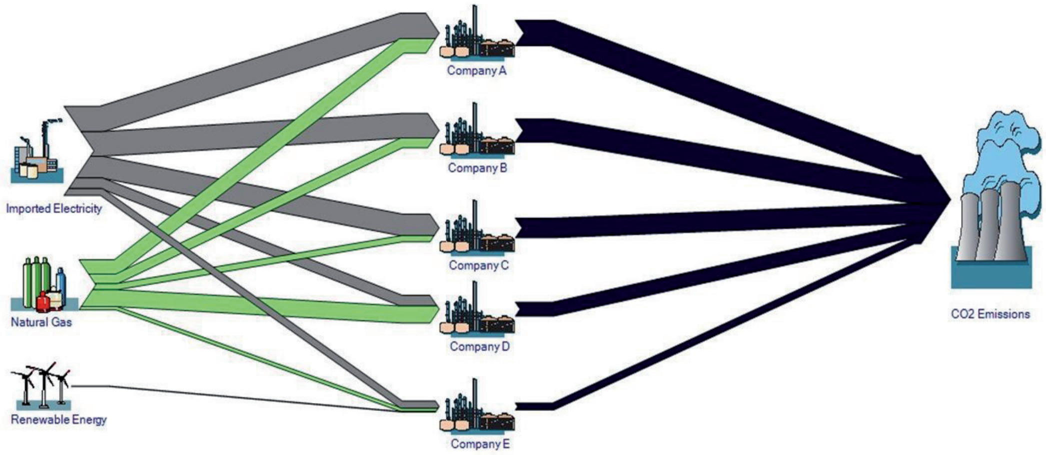

Figure 7. Visual Interpretation of Energy Usage and Associated CO_2 Emissions.

of this energy intensive process. Company D responded that they would shift the timing of production, if information relating to energy usage for each major process step, during the manufacture of a batch, was readily available and if there was the potential to save energy. They also felt that, in an ideal world, they would like to see direct and indirect differentiation of energy reported, from a utilities perspective. Company E reported that if dollar savings were apparent, then the timing and sequencing of planned production could be shifted by up to four hours.

Energy Efficient Projects

The respondents were also asked how they source ideas or opportunities for improvement in their energy performance and four out of five of the companies offered a response. Company B use independent energy audits, Company C use their Energy Team and an online tool called Greenwise, to register ideas, Company D use ISO 50001 audits, ideas from their energy team members and energy consultants and Company E use ISO 50001, ideas from their energy team members and results of internal and external audits. The organisations were asked to select top exemplar energy efficiency projects that they have carried out and to briefly describe those. In order to maintain confidentiality amongst the organisations, a random selection of projects are highlighted e.g. the production hall airflow velocity was reduced by 22 %, a nitrogen plant software upgrade was introduced resulting in a reduction in energy usage of 8.5 %, the air handling units (AHU) control software was updated resulting in savings of approximately €80 k per annum, a compressed air pressure reduction programme was introduced and the distribution pressure dropped from 8.8 barG to 6.8 barG, a heat recovery project was introduced on the foundry furnace and 80 kW of heat is being recovered and used to heat water, a new demand control ventilation system was installed and its electrical performance improved by 31 % and an automatic process equipment shutdown system was introduced. These EnMS related projects deliver both energy and maintenance cost savings. Furthermore, by adopting an EnMS, with continuous energy performance improvement targets, an organisation will continue to improve its competitiveness and reduce its environmental burden into the future.

Conclusions

The companies overall energy usage during the period from 2008 to 2011, in Figure 1, suggests that the energy usage is rising, which corresponds to an increase in production and there is a trend towards using more natural gas and less electricity. Additionally, biomass was introduced into the primary energy mix, at Company E, during 2010. The cost of primary energy, including crude oil, oil products, coal and natural gas has risen three to four fold over the past ten years (IEA – International Energy Agency, 2012). Based on international forecasts this exponential rise will continue over the next decade.

All of the companies surveyed operate either a certified energy or a certified environmental management systems standard, or both and are well versed in the plan-do-check-act continuous improvement methodology which is central to all ISO management systems standards. All have corporate social responsibility statements and one company use LEED certification when designing new buildings. Three of the companies operate certified energy management systems that comply with the requirements of ISO 50001. Companies that have a certified ISO 50001 EnMS performed exceptionally well in the maturity matrix and are better positioned to reap energy performance improvements in the medium and long term. The levels of maturity of their EnMS, were assessed under the following pillars; commitment, identification, planning, taking action and review. The assessment tool proved useful in identifying barriers to and opportunities for the development of effective energy management systems under each of the pillars. All of the companies indicated a strong desire to further improve their energy performance and four our five companies found the review aspect to be most challenging.

All are using their management systems to help to identify opportunities and projects that will improve their energy and enviromental performances. They all agreed that having information on the current status of their energy performance indicators would facilitate a continuous improvement management systems philosophy. All of the organisations identified a gap in this regard; there was no direct information technology link between the manufacturing and facilities systems. The TEMPO project is actively carrying out research in this area.

All five companies reported that they periodically calculate the weight of carbon dioxide associated with their use of energy and four responded that they would either agree or strongly agree that CO_2 emissions would become a key production metric in the short, medium and long term. At present, the companies rely on national, annual, average emissions data, that is published retrospectively. Methods to carry out advanced, up to date reporting of carbon emissions, especially in relation to electricity energy usage, should be developed.

Furthermore, respondents were asked whether they agree or disagree that their CO_2 emissions would become a key production metric in the short, medium and long term. Four of the five companies provided feedback and those that responded said that they would either agree or strongly agree that CO_2 would be a key production metric in the short, medium and long term. Three of the companies are taking immediate actions to reduce their CO_2 emissions and are planning to install renewable energy, 3 MW wind turbines on their sites, in the short to medium term. With stringent legally binding energy and green house gas emission reduction targets, such as an annual reduction of 13,117 GW (of primary energy equivalent), during 2016, as set in Statutory Instruments 542:2009 European Communities (Energy End-Use Efficiency and Energy Services) Regulations 2009 and the NEEAP 2 (Ireland's Second National Energy Efficiency Action Plan) which reaffirms the Governments commitment to reducing green house gases by 20 % by the year 2020. The stated desire to reduce CO_2 emissions and the knowledge that legislation compelling its reduction suggests that CO_2 emissions performance will become central to effective EnMS. This aspect warrants further research.

All of the respondent companies expressed a desire to further improve their energy performance. All are using ISO management systems to monitor their energy performance improvement objectives and targets. The EnMS twenty step maturity matrix proved useful in helping to identify barriers to and opportunities for the development of effective EnMS. Barriers such as, financial and human resources, which impeded upon their rate of progress with further EnMS development, and opportunities such as closer integration of environmental and energy management systems which would help to make the systems element more efficient. The energy and environmental performance indicators should be a combination of energy usage, carbon dioxide emissions and good quality production. The availability of up to date information will allow key personnel to take immediate actions that will support continual improvements to the organisation's energy, environmental and quality performances.

Glossary

AHU	Air handling units
CHP	Combined heat and power
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
CSO	Central Statistics Office
EIA	Energy Information Administration
EnPI	Energy Performance Indicators
ERR	Economic rate of return
EVO	Efficiency Valuation Organisation
GWH	Gigawatt Hours
ICT	Information, Communications & Technology
IRR	Internal rate of return
ISO	International Standards Organisation
IT	Information Technologies
KPI	Key Performance Indicators
KWh	Kilowatt Hours
LEED	Leadership in energy and environmental design; U.S. Green Building Council
NPV	Nett present value
SEAI	Sustainable Energy Authority of Ireland
TEMPO	Total Energy Management in Production Operations

References

Central Statistics Office, 2012. The Business Energy Use Survey (BEUS) is carried out annually under Commission Regulation (EC) No 1099/2008 of the European Parliament and the Council of 22 October 2008 by the Irish Central Statistics Office www.cso.ie.

European Commission, 2014. The EU Emissions Trading System (ETS). http://ec.europa.eu/clima/policies/ets/index_en.htm. Accessed 6th January, 2014.

Harrington, J., Cosgrove, J., 2013. *Total Energy Management in Production Operation's Industrial Survey Report.* (Report available on request only).

IEA – International Energy Agency, 2012. World Energy Outlook 2012 Report. http://www.worldenergyoutlook.org/ Accessed 4th September, 2013.

ISO, 2011. ISO 50001 International Standard. In: Energy Management Systems – Requirements with guidance for use.

ISO, 2004. ISO 14001 International Standard. In: Environmental Management Systems – Requirements with guidance for use.

Manufacturing Energy Consumption Survey (MECS 2010) http://www.eia.gov/consumption/manufacturing/index.cfm. Accessed on 16th January, 2014.

NEEAP 2, 2012. Ireland's Second National Energy Efficiency Action Plan. http://www.dcenr.gov.ie/NR/rdonlyres/B18E125F-66B1-4715-9B72-70F0284AEE42/0/2013_0206_NEEAP_PublishedversionforWeb.pdf

Pérez-Lombard, L. Ortiz, J., Valazquez, D. (2013), Revisiting energy efficiency fundamentals. *Energy Efficiency* (2013) 6: 239–254.

Schnapp, R. (2012), *Energy statistics for energy efficiency indicators.* Joint Rosstat-IEA Energy Statistics Workshop Moscow, February 2012.

Statutory Instruments 542:2009 European Communities (Energy End-Use Efficiency and Energy Services) Regulations 2009.

Sustainable Energy Authority of Ireland (SEAI, 2014), EnergyMap – Energy Management Action Programme (MAP) – Online Tool for Energy Management in Industry. http://www.seai.ie/EnergyMAP/. Accessed 4th January, 2014.

Sustainable Energy Authority of Ireland, 2011. Energy in Ireland 1990-2010 (2011 Report). http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_In_Ireland_1990_-2010_-_2011_report.PDF. Accessed on 8th January, 2014.

Sustainable Energy Authority of Ireland, 2008. Energy End-Use in Ireland, Study Summary Report. http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Commissioned_Research/Energy%20End-Use%20in%20Ireland.pdf Accessed 16th January, 2014.

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