Energy efficiency in industry, a holistic and integrated strategy from policy to results

John O'Sullivan
Sustainable Energy Authority of Ireland

Keywords

energy management system, methodology, energy efficiency agreements, voluntary agreements, strategy, lean manufacturing, productivity, energy efficiency programmes, industrial energy saving, new tools, maturity roadmaps

Abstract

This paper outlines an approach by the Sustainable Energy Authority of Ireland (SEAI) to a holistic and integrated strategy of achieving improvements in energy efficiency in Irish industry. SEAI support programmes are split by scale of energy expenditure and by private enterprise/public sector. Just 12 % of Irish organisations account for 90 % of energy-related CO_2 emissions from Irish industry (SEAI 2007).This paper therefore focuses on the support programmes for these large businesses: the Large Industry Energy Network (LIEN) and the Energy Agreements Programme (EAP). These programmes are showing strong achievements; this paper provides insights into how these savings are achieved and also into the approach taken to continuously uncover new methodologies and opportunities in order to gain further savings.

The SEAI programmes are centred on the Energy Management Systems (EnMS) approach as the means for continuous improvement and operational control. Although this is considered best practice, various stimuli are required to accelerate special investigation activity. This is achieved through a range of proactive project initiatives. All project initiatives, resources, new tools and the derived methodologies are underpinned by the EnMS, as the enabler for effective implementation and use. A long-term strategy is to keep innovating in order to define new opportunities, to disseminate and replicate as widely as possible, and to standardise as new best practice.

The EnMS itself must also be continuously improved. SEAI has developed an Energy Management Maturity Model to facilitate this development. An organisation will mature in its use of an EnMS and learn how to be more effective; however, this progress can be cultivated through the guidance and roadmap developed by the Maturity Model.

New methods of energy diagnosis are introduced to improve the energy review process; new approaches to energy auditing are introduced; a new Energy-Efficient Design (EED) Methodology is introduced, and new testimony is provided on the synergy that can be achieved by application of Lean or Six Sigma processes. All these will not only be promoted for application by programme members, but will also be developed so they may be exploited as new business opportunities for the energy services market in Ireland.

Introduction

The aim of this paper is to introduce the reader to the approach that the Sustainable Energy Authority of Ireland (SEAI) has adopted to support the largest, most intensive energy users in Ireland. With the help of this approach, this group is achieving leading energy performance results – amounting to an improvement in energy efficiency over a 15-year period of more than 30 %.Within this timeframe, many of the easy wins are addressed, while LIEN members have become familiar with the energy-management process. Therefore, the approach by SEAI and large energy users must have a strong impetus of continual investigation in order to uncover new opportunities.

This approach is described as holistic and integrated. It is wider than the promotion of best-practice principles, utili-

Large industry specific actions under the NEEAP

Action 16. We are supporting the networking and exchange of best energy efficiency practice by the largest industrial energy users through the Large Industry Energy Network.

Action 17. We are supporting businesses in maximising their energy efficiency through adoption of IS393, the Irish Standard for Energy Management.

ties and services. It considers the role of all stakeholders in the wider energy system, and has a common thread –the use of an Energy Management System (EnMS) – for SEAI, the energy user and all market actors.

Ireland's National Energy Efficiency Action Plan (NEEAP) (DCENR, 2009), outlines the actions committed to by Ireland to achieve energy savings of 23,730 GWh of primary energy. The action plan represents 75 % of Ireland's energy-efficiency target of 20 % by 2020. A key component of NEEAP is a contribution of 8,340 GWhfrom the wider business and public sectors, of which 4,070 GWh (48 %) is to be achieved by the large-business programmes. This will represent 17 % of national energy savings delivered by the plan.

SEAI's support programmes for large businesses are the Large Industry Energy Network (LIEN) and the Energy Agreements Programme (EAP). The LIEN has been active for 15 years. It has over 150 member companies and represents up to 70 % of Ireland's total industrial primary energy requirement. Every member has an energy expenditure of more than €1 million; the full network represents €1 billion of energy spend. The EAP has been active for five years and is a subset of the LIEN, with a membership of over 80 companies. A voluntary agreements scheme, it centres on a commitment by members to implement and maintain an EnMS. In contrast with other voluntary agreement schemes, there is no specific energy-efficiency target or carbon-tax rebate connection. In addition to the EnMS, members commit to completing an average of one Special Investigation per year within the Energy Agreement timeframe.

To continually improve, special investigations that determine the viability of new opportunities must be implemented routinely. An objective of this programme is to accelerate special-investigations activity within the network. Special investigations first need to be defined. This process tends to be *ad hoc* or topical in nature, with organisations assessing the viability of best available technology or technologies driven by market suppliers. The programme aims to stimulate engagement in special investigations by combining programme supports with a focus on technologies, methodologies or sector-specific projects. Efforts are made to develop the processes or methodologies that can uncover the opportunity, regardless of the nature of the business. The network is then used to disseminate and standardise the successful actions.

Many stakeholders can benefit from the outputs of the programme, including energy users, energy-service providers, energy and general consultancy companies, engineering-design companies, enterprise-development companies, research groups and universities. All activity by the programme is underpinned by the EnMS approach.

This paper will provide an overview of each type of project, with some example cases studies to demonstrate the effectiveness of the approach. Topics include Energy-Efficient Design, Alternative (Business Improvement) Methodologies, Heating-Ventilation-Air Conditioning (HVAC) and sector-focused projects. Lessons learned will be highlighted and the next steps of development and focus will be described.

In brief, this paper will provide an overall outline so that the programme elements may be appreciated, while providing more detail where this is helpful. More detailed papers will follow, on a number of the topics and projects introduced here.

Large-business programme overview

SEAI maintains two programmes for large businesses, the LIEN and the Energy Agreements Programme (EAP). Members make commitments in return for ongoing support and a long-term relationship with SEAI.

The LIEN members benefit by networking, by sharing knowledge and experience, and by access to information. SEAI builds relationships, disseminates successes and maximises the replication of successes. The LIEN is a target group for growth of the EAP. The EAP requires a commitment to implement the EN16001 management system and one Special Investigation per year. No specific energy-saving targets are set; in theory, the combination of the EnMS, its certification and the requirement for special investigations will guarantee savings appropriate to each business. SEAI builds up experience of EN16001, pilots and develops new initiatives, engages in stronger interaction with businesses, raises performance expectations and standardises best practices.

Programme influences

INFLUENCING CHANGE

Change management is a structured process that transitions an organisation from one state to another. It is a common term in industry, particularly where new, improved business processes or other substantial organisational changed have to be managed. SEAI is introducing a change that encourages the take-up of good energy management across organisations it supports. The business-improvement process being introduced is the EN16001 management systems approach. The change model that best illustrates the SEAI approach is the *7 Seven Infrastructures for Mobilising Change* (Shiba & Walden, 2007). The model consists of seven infrastructures that can be described according to the influence that is (a) 'pushed' – a constraint or requirement imposed, or (b) 'pulled' – a stimulus or intervention that extracts or accelerates performance beyond what would occur naturally.

Table 1: Outline of programme elements.

Large Industry Energy Network (LIEN)		Energy Agreements Programme (EAP)	
Member commitment	**SEAI support**	**Member commitment**	**SEAI support**
Energy Management Programme Sets objectives and targets Undertakes annual energy review Returns data annually to SEAI	Relationship manager Energy seminars LIEN Annual Report Runs networking forum	All LIEN commitments EN16001 Certification Special Investigation per year	All LIEN supports Agreements Support Manager Annual projects initiatives Grant for Special Investigations Workshops & Training Tailored support

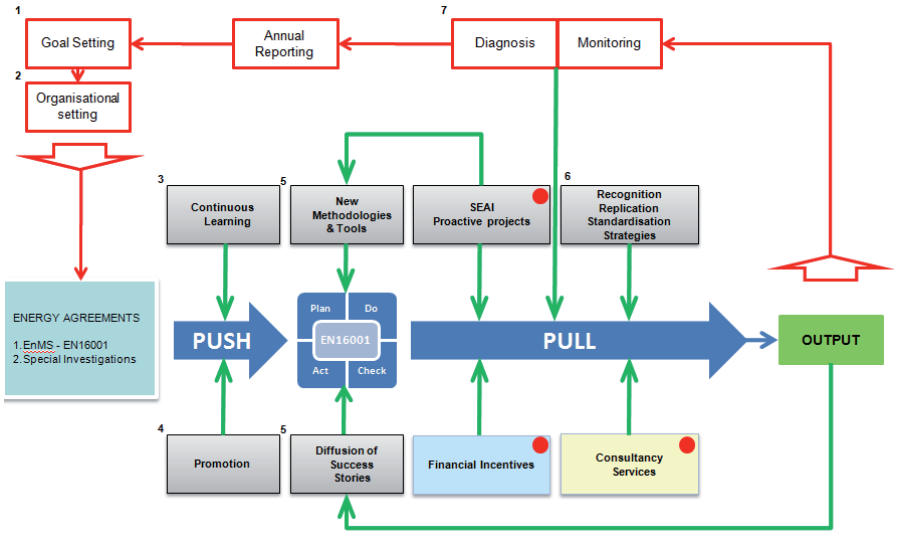

Figure 1. Programme Change Model.

DISSEMINATION OF BEST PRACTICES

The EAP focuses on the development and demonstration of best practices in energy efficiency. The process to generate and control energy savings is the EN16001 management system. The LIEN is used to replicate and standardise best practices and successes. All work is relevant to any energy users and therefore the dissemination will extend to outside the LIEN to the Small and Medium Enterprises and the Public sector.

Special project initiatives

SEAI is committed to undertaking Special Project Initiatives annually. These initiatives have an ultimate goal of stimulating further activity by Energy Agreements members, the LIEN and ultimately any relevant business or public-sector organisations.

These SEAI-led projects may take a variety of formats; the most common is a working group – referred to as a Special Working Group (SWG). Projects focus on a technology-energy user, new methodologies or a specific sector. The projects take a course of concept development, researching, testing, and the application of any new or existing methodological approaches to energy-efficiency. Through this process, a body of knowledge is developed, while the desired outcome is to replicate and standardise whatever proves successful. Project outputs may be demonstrated project solutions, new tools or methodologies, and EnMS resources.

The projects follow a process of *Piloting*, *Implementation*, *Replication* and *Standardisation* initiatives. Where best practices are established, they are proliferated or tested in demonstration projects. In many cases, new best practices are developed. The initiatives are broken into smaller, manageable projects, referred to as *Spins* (analogous with Deming's plan-do-check-act {PDCA} continuous-improvement cycle). This approach allows large projects to be split into manageable time periods in which the project team can change according to the overall objective, scope of work and the motivations. Lessons learned from each Spin are integrated into the objectives and scope of work for the next cycle.

Projects undertaken since 2007 are listed in Table 3. The Agreements Support Manager has a responsibility to continuously disseminate the output insofar as this is relevant to the company members they support.

Selected project insights

Brief summaries of selected Special Project Initiatives follow below. This paper is not intended to give a detailed synopsis of each project but rather to highlight the benefits of the process and the types of deliverables that can be produced. *Information*

Table 2: Programme model elements.

Infrastructure	Push/Pull	Relevance
1. Goal setting	Push	The Energy Agreement requires a commitment to the EnMS and to invest in continual Special Investigation activity. The programme establishes goals on savings impacts and membership for the LIEN and Energy Agreements. The Agreements Support Managers are assigned goals in line with programme objectives.
2. Organisational setting	Push	Organisational supports are put in place for the fundamental programme commitments and project initiatives, in particular the Agreements Support Manager Role.
3. Continuous learning	Push	Lessons learned through the processes are integrated into new phases of the Energy Agreement and projects.
4. Promotion	Push	Successes are promoted through a variety of methods, to confirm the efficacy of the EnMS approach.
5. Diffusion of success stories	Pull & Push	The effectiveness of new methodologies, tools and techniques are tested and adopted as new best practices within the programme. Successes by external interventions and market actors are embedded and standardised as best practices.
6. Recognition	Pull	Achievements are recognised through a variety of methods including annual report and cases studies. Recognition is also provided when replicating and standardising projects as best practice.
7. Monitoring and diagnosis	Pull	The results of the programme are monitored and diagnosed for weaknesses and new areas of focus.
Additional Stimulus		
- **SEAI proactive projects**	Pull	Special Project Initiatives that define and instigate special investigations that otherwise may not happen or not at the same pace.
- **New methodologies and tools**	Pull & Push	New methodologies and tools are developed that can be used within the programme or as additional services offered by the services market.
- **Consultancy services**	Pull	Energy and mainstream business consultancy services. New methodologies and tools developed by the programme can develop new business opportunities to be exploited.
- **Financial interventions**	Pull	*e.g.* EAP Special Investigation grant support. SEAI capital grants where available Enterprise development agency grants, where available. Renewable heat, Renewable Energy RD&D grants. Accelerated Capital Allowances (offsetting corporation taxes). Energy Efficiency Fund.

and resources developed, including case studies, are available on the SEAI website: http://www.seai.ie/Your_Business/Large_Energy_Users/ (SEAI, 2011a), (SEAI, 2011b).

HVAC SPECIAL WORKING GROUP (EXAMPLE TECHNOLOGY PROJECT)

This is a technology-based project on HVAC (Heating, Ventilation and Air Conditioning). In many industries – in particular, pharmaceutical, biotechnology, electronics and medical – HVAC may account for 20 % to 80 % of the total energy bill. The opportunity for cost saving is tremendous, but the regulatory aspects of the businesses and the substantial risks associated with changes in environmental conditions are barriers to implementing change. The HVAC Special Working Group (SWG) has moved through three Spin cycles, and at the time of writing is commencing the final phase. This phase is focused on further replication and standardisation of work completed through the LIEN and beyond. The phases of the project, with the main work content, are outlined in Figure 3.

The aim of the project is long-term HVAC savings that will be taken up by the LIEN. The direct members of the project benefited from the identification of savings through assessments, benchmarking and special investigations, which is a strong indicator of the savings potential when replicated. There is a commitment to implement 53 % of these projects; other projects require further special investigation.

The final phase of the project will focus on the proliferation of all resources and knowledge developed. One means of achieving this will be through the Agreements Support Manager function. This will include mentoring and assisting companies implementing projects that are fundamentally challenging either the energy-service requirement, process or control strategies for HVAC systems.

The Agreements Support Managers will promote special-investigation activity and will mentor EN16001 implementation, incorporating these best practices.

ENERGY-EFFICIENT DESIGN SWG (EXAMPLE METHODOLOGY PROJECT)

This methodology-based project began with an Energy-Efficient Design (EED) workshop for Irish stakeholders in 2007. The outcome was agreement to convene a SWG that would focus on EED. The SWG membership included Energy Agreements members, engineering design companies, energy consultancy companies and SEAI. An EED Methodology was developed to address the common barriers to achieving the best energy-efficient design, in projects ranging from new facility investments to smaller-scale new process designs. The EED Methodology addresses two main aspects: organisational and process. Demonstration projects were implemented using the EED Methodology. The results were very positive; energy savings of up to 50 % were achieved from baseline design. The main principle of EED is to challenge design decisions at each layer of the EED Venn Diagram (see Figure 4).

New concepts introduced here are *Design for Energy Management* (DfEM) and *Operation Optimisation Using the EED Methodology*. DfEM is a simple concept of considering the energy-management process at the design phase. This requires better integration of the facility or process owner in the design process, an understanding of Energy Performance Indicators and Energy Factors, Energy Review and other important energy-management considerations. The activity develops outputs such as energy metering plans, initiating the Register of Opportunities for which the owner will take responsibility after handover. Additionally, DfEM involves a wider discussion of

Figure 2. Target audiences of the programmes.

Table 3: SEAI Energy Agreements project initiatives.

	PROJECT INITIATIVE CATEGORY			
Year	Technology	Methodology	Sector Focus	Grant Scheme
2007	HVAC SWG Spin I Compressed Air SWG Spin I	EED Workshop & diagnosis		Industrial Best Practice Initiative
2008-2009	HVAC SWG Spin II Refrigeration SWG Spin I Benchmarking Projects Compressed Air HVAC	EED SWG Spin I Alternative Methodologies SWG Spin I		Supports for Exemplar Energy Efficiency Projects (SEEEP)
2009-2010	Special Working Groups HVAC SWG Spin III	EED SWG Spin II Alternative Methodologies SWG Spin II	Food and Dairy SWG Spin I Data Centres SWG Spin I Commercial Buildings SWG Spin I	Energy Efficiency Fund (EEF)

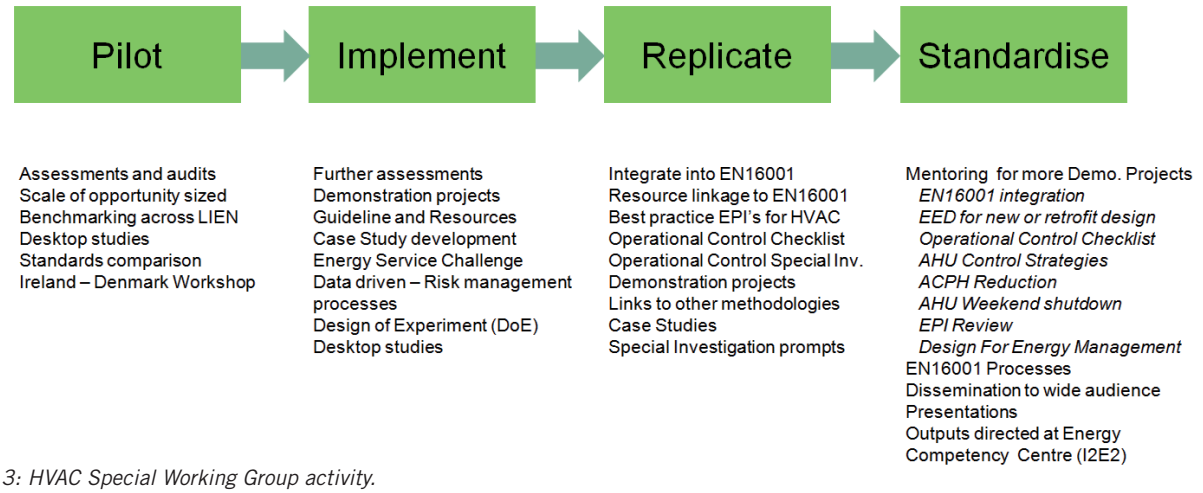

Figure 3: HVAC Special Working Group activity.

Table 4: Main outputs of the HVAC Special Working Group project.

	Key Outputs	Description
PILOT	Site-based Assessments	These ranged from general audit to special investigation. It was concluded that there was potential for an average of 16% savings of total energy usage through HVAC efficiencies.
	LIEN HVAC Benchmarking Report	A benchmarking project was undertaken on two levels: within a small subset of cGMP users within the PharmaChem sector; then a wider benchmarking project was completed across various sectors within the LIEN.
	Desktop Study – Guides and Requirements	This work contrasted the recommended HVAC settings and control strategies for cleanrooms across various standard bodies – ASHRAE, CIBSE, ISO, ISPE and others.
IMPLEMENT	Site Assessments & Demonstration Projects	This work substantiated the estimate in the earlier assessment, identifying a saving of up to 16% of total site energy.
	HVAC Systems Optimisation Methodology	A HVAC system audit guide that helps the user to identify energy-saving opportunities and provides guidance and direction to achieve these savings.
	HVAC Systems Optimisation Action Plan	A detailed action plan to optimise HVAC systems.
	Literature Review – HVAC Control Strategies	A desktop research report which directs the reader to web-based material on energy savings.
	User Requirements Specification (URS) Guideline	This document outlines the content that must be included in order to make a conventional URS effective (from an energy perspective). It also includes a specific example URS.
	HVAC Control Strategies	A control-strategy illustration which shows the importance of selecting the correct strategy and the costs associated with selecting an excessively rigid strategy.
	Case Studies	Demonstration project case studies.
REPLICATION/STANDARDISATION	Effective HVAC Energy Management Resource Guide	This guideline document provides direction on the applicability and use of SEAI-developed HVAC resources that can be used within the EN16001 EnMS.
	Effectively focused HVAC Special Investigations Guide	This guideline provides direction on the scope, boundary and definition of Special Investigation projects; in addition it provides a summary of Special Investigations completed by the HVAC SWG project.
	Use of Energy Performance Indicators (EPIs) in HVAC Systems	The report details alternative EPIs that can be used when developing metrics for continuous HVAC monitoring.
	HVAC Operational Control Checklist	An operational control checklist details potential operational 'checks' that should be carried out in order to identify potential slips in HVAC system performance.
	EED Review for HVAC systems	An Energy-Efficient Design (EED) review of HVAC systems using the SEAI EED Methodology.
	Energy Factors Factsheet	This factsheet defines energy factors for HVAC systems and describes how they should be set.
	Operations Optimisation Factsheet	This factsheet summarises an operational efficiency review for HVAC maintenance and management.
	Air Handling Unit (AHU) Weekend Shutdown Factsheet	This factsheet describes a Design of Experiment (DoE) approach to investigate opportunity for AHU shutdown during non-production hours in a risk-controlled manner.
	Waste Heat Recovery Potential for HVAC Systems	This report summarises potential waste-heat recovery options that may suit a wide variety of HVAC applications.
	Case Studies	Demonstration project case studies

Table 5: HVAC energy-saving identified within direct project members.

Spin	No. companies in SWG	Total Sites Energy		Total HVAC Energy		Total site savings from HVAC	CO_2Abatement (tCO_2)	Cost Saving (€M)
		Electrical (GWh)	**Thermal (GWh)**	**Electrical (GWh)**	**Thermal (GWh)**			
I	14	1000	726	356	322	16%	110,000	€15.8
II	13	842	521	336	249	16%	98,000	€17.9
III	9	227	219	89	142	20%	15,500	€2.44

LEO Pharma: Case Study Example

This project was a significant development for the SWG which undertook a Design of Experiment (DoE) project in collaboration with LEO Pharma, a pharmaceutical facility based in Dublin, Ireland. It had commissioned and validated a new sterile manufacturing cleanroom facility. However, production was not due to start in these conditioned areas for at least two months. LEO Pharma kindly agreed to allow SEAI to undertake a best-practice demonstration project onsite in an effort to showcase energy-efficient management of a sterile facility.

After a number of opportunities were highlighted at a DoE brainstorming workshop, it was decided to focus the DoE exercise on the reduction of air change per hour (ACPH) from what had been already validated to ISO14644, the pertinent standard for the production area, by LEO Pharma.

As a result of the DoE project, the ACPH was reduced from 63 to 30, and revalidated. The final state was limited by the physical constraints of the air-handling unit rather than a quality risk. The savings for this production area totalled €32,340 annually, giving a payback of six months on the investment. LEO Pharma is standardising this approach across the facility and this will yield total savings in excess of €250,000 annually.

This project, involving an organisation that is heavily regulated by the Irish Medicines Board, has proven to be a demonstration case in Ireland. Based on its success, many other companies are now replicating it.

general design deliverables, meter selection, mechanical requirements and cost-benefit norms.

Operation Optimisation Using the EED Methodology is developed on the principle that EED is not unique to the actual design stages; the business case may not be as attractive during the operation, but the project may still be justifiable. The process goes step-by-step, as defined by the Methodology, and complements the continuous-improvement process of an EnMS.

This method will be tested as an alternative to the traditional energy-audit process. It will have the added benefits of being a data-driven process, and one that will lead to implementation of the most appropriate findings. As the data-collection and actions are consistent with an EnMS approach, it should help small to medium-sized enterprises (SMEs) to consider further development to implement an EnMS.

ALTERNATIVE METHODOLOGIES SWG (EXAMPLE METHODOLOGY PROJECT)

This is a methodology-based project. The objective is to promote and develop capability in energy management and specifically in energy projects implemented across the functions of technical services, engineering and operations. Business improvement methodologies and diagnostic tools, which typically reside between these three functions, are enablers of deeper investigation and energy project activity. Energy efficiency is very limited when focused predominantly on the delivery of efficient utilities. The improvement methodologies that are commonplace in industry are Lean Manufacturing and Six Sigma. Lean Manufacturing typically resides within operations and Six Sigma within the engineering and quality functions.

The SEAI work explored the ability to integrate an EnMS into cultures using these methodologies, rather than each being managed independently. A particular focus was how each methodology develops and implements projects and how these processes can be 'blended' to demonstrate efficacy. A number of demonstration projects were sponsored, mentored by expert consultants. A common theme from projects was testimony from participants that they would not have developed the same project opportunities independently. Through this process, some new or enhanced concepts were developed, including an Energy Management Maturity Model, Value Stream Mapping with Energy (VSMe) and MUDAe.

Energy Management Maturity Model

The Energy Management Maturity Model has been developed to provide a roadmap for progressive energy management in large organisations. It promotes the development of energy management as a strategic goal, and complements and integrates with other activities such as corporate social responsibility and the carbon-reduction agenda. It is applicable at all levels of energy-management engagement, from organisations just starting out to those that have maintained certification to an energy-management standard for a number of years and are asking 'What's next?'The model examines the organisation as a whole and looks at how its practices not only affect its own energy performance but also that of the value chain and the wider community. The model complements EN16001 and ISO50001, and is intended to provide insights on how to improve further once good practices have been embedded.

It is envisaged that assessments would be carried out initially with support from SEAI and involve organisations' energy-management team and senior management representatives. This initial assessment would act as a baseline to help the company identify its current level of performance and to act as a reference for periodic review.

The management system maturity has five levels; their characteristics are outlined in Table 8.

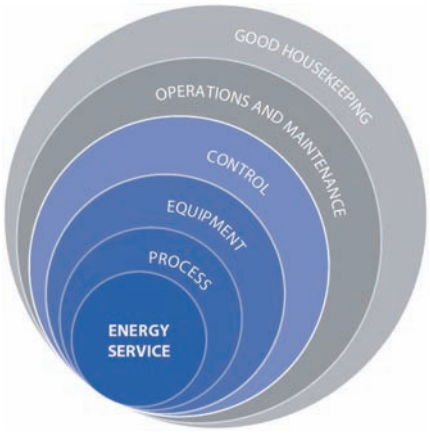

Figure 4: EED Venn diagram.

Table 6: Main outputs of the EED SWG project.

	Key Outputs	Description
PILOT	EED Methodology Rev A	A methodology that helps investors to design, construct and manage projects so that they consume the minimum quantity of energy during their subsequent operation.
	Benchmarking project - Highly purified water - Waste-water treatment plants	The benchmarking exercise used two energy uses for a small number of companies to demonstrate the degree of variation in process parameters and design. It highlighted the degree of variation for essentially the same process.
	New facility EED demonstration project 1	The EED Methodology was used by Eli Lilly for a new biotech facility in Ireland. The outcome of the project was a 22% reduction in energy cost from baseline design.
IMPLEMENT/REPLICATE/STANDARDISE	New facility EED demonstration project 2	The EED Methodology was used by Pfizer Medica (formally Wyeth Medica) for a new Pharmaceutical Development Centre in Ireland. The outcome of the project was a 51% reduction in energy cost from baseline design and an 83% reduction in CO_2emissions.
	Four process EED demonstration projects	These projects demonstrated the applicability of the Methodology for smaller process level projects.
	EED Methodology Rev 1.0	A short, more succinct version of the first EED Methodology draft. The EED Methodology includes new attributes and content (as outlined below).
	EED Methodology Synopsis Guide	Since not all stakeholders need to know the detailed Methodology, the EED Methodology Synopsis Guide provides an executive summary for stakeholders, including senior management.
	EED Methodology for Smaller Projects	The simpler version of the EED Methodology to cater for smaller design projects and for EED review projects.
	Operational Optimisation Review using the EED Methodology	This introduces a new method of optimising processes using EED principles and an EnMS. It addresses the common weakness of traditional energy auditing, which is more *ad hoc* in procuring and open-ended in its actions on findings. In addition to being action-orientated, this new method introduces and implements elements of EnMS for non-users. A means of exposing SMEs to EnMS
	Design for Energy Management Guideline	This places operational energy management on the design agenda, thus ensuring that the infrastructure required for successful operational energy management is delivered in the design phase.
	EED User Manual	This manual provides information on how to develop important elements of the Methodology, including; EED Implementation Plan, Facility Energy Balance Report, Energy Savings Register, Supplier User Requirement Specification (URS), EED Close-Out Report, and Engineering Tools for EED.
	EED Training Syllabus & Materials	These will be used for training during 2011 to disseminate the EED Methodology in industry and among other stakeholders.
	Demonstration projects	Case-study projects to demonstrate the EED Methodology and EED tools

Table 7: Main outputs of the Alternative Methodologies SWG project.

	Key Outputs	Description
PILOT	Alternative Methodologies SWG report	A report that explores the synergies between methodologies and the energy-management process. New concepts introduced with demonstration projects.
	VSMe development	An enhanced tool –the Value Stream Mapping with Energy (VSMe) paradigm is explored and tested using a demonstration case. The VSMe analysis naturally complements the Energy Review process by assessing the energy impact of operations from customer order to warehouse material supply.
	Overall Equipment Effectiveness (OEE)	OEE is explored as a method of monitoring energy efficiency. OEE is calculated by using Availability, Quality and Performance rates. It is a common method to maximise equipment use in business.
	Demonstration projects	Case studies are developed using Kaizen, VSMe, OEE and problem-solving methods.
IMPLEMENTATION	Energy Management Maturity Model	A maturity model to facilitate the assessment and roadmap development of the energy-management process. It should assist in continuously improving the EnMS process and in understanding how the EnMS can mature, leading to higher performance.
	OEE as an effective Energy Performance Indicator (EPI)	A guideline document outlining how OEE can be measured and monitored as an EPI within the EnMS.
	VSMe Guideline	A guideline document outlining how a VSMe diagram is developed and diagnosed as part of the Energy Review process of the EnMS. Concepts of *Current, Future and Ideal* states are introduced to energy management.
	MUDAe concept	The concept of MUDA applied to energy waste in non-value-adding activities. It is analogous to Operation Optimising using EED in using the Lean manufacturing concept of 7-Wastes as the prompts to diagnose wasted energy.
	Further demonstration projects	Case studies of demonstration projects for use of Alternative Methodologies.

Table 8: Energy Management Maturity Model – level descriptions.

Level	Characteristics
1. Emerging	Contemplating an EnMS. Might have elements of EnMS deployed. Unstructured or informal approach in place. Very few participating in energy management, with limited or no tools.
2. Defining	Structured system in place. Management aware of energy policy; at least one senior manager has formal responsibility. There is an energy management team in place. Management system reflects requirements of Energy Management Standard.
3. Integrating	Energy management is now mainstream across organisation. Proactive management of significant energy users. Energy considerations span functional interests, with evidence of tangible site benefits.
4. Optimising	Energy managed very effectively, leveraging all functions, processes and infrastructure. Culture of energy management embedded. Evidence of existing practices challenged and some state-of-the-art solutions deployed. Evidence of collaboration with other participants in the value chain or other corporate functions.
5. Innovating	Innovative promotion of energy-management practices. Proactive energy-management culture. External resources leveraged to develop state-of-the-art industry practices and solutions. Advocating energy management to external audiences and forming new energy-management partnerships for innovation and R&D.

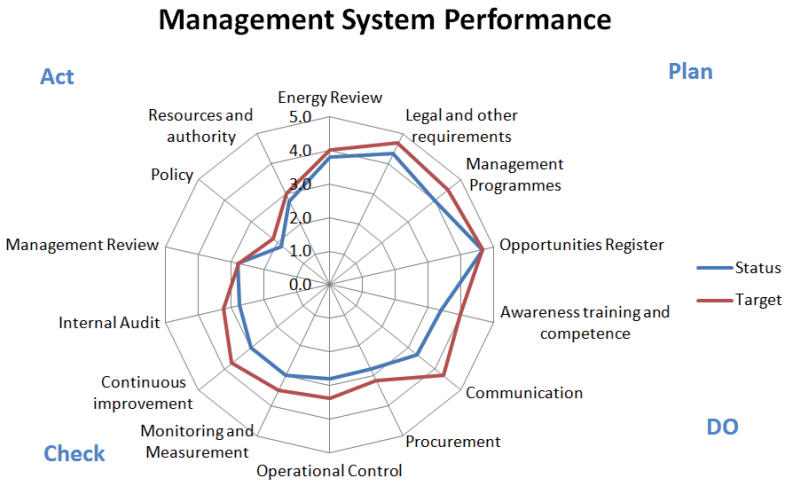

Figure 5: Energy Management Maturity Model – output example.

SECTOR-FOCUSED SPECIAL WORKING GROUPS

These sector-focused projects involved SWGs for the Food and Dairy, Data Centre, and Commercial Buildings sectors. The objective was to take the body of knowledge developed through the technology and methodology-based projects and apply it to specific sectors.

Impact and results of the LIEN and EAP

The LIEN was established in1995 and 15 years of energy and project data are now available. The energy performance of the LIEN is reported yearly. Energy Performance Indicators (EPIs) are used to highlight the individual performance of all the members. The EPI, which is set to 100 in the year of joining, is calculated each year according to baseline energy intensity (in year of joining) and the energy intensity of each subsequent reporting year. An EPI run chart is reported for each LIEN member; it includes influencing factors for the EPI result and the target set for the next year (SEAI, 2010). In addition, a series of other metrics are reported to reflect the energy performance being achieved.

The year-to-year energy saving or loss for the LIEN as a whole is reported using a *Paasche Method*, centred on the relative change of energy intensity from one year to the next. The energy saving or loss is calculated for each member; all these are added together to give an overall energy saving or loss for the LIEN. The Paasche method of calculating energy saving has some weaknesses. It calculates an energy saving or loss that captures all influences of energy usage. This would include any operational changes, e.g. where processes demand more energy with dramatic changes of production volumes or product mix. These are, however, factors that affect overall energy demand and energy efficiency and that should be incorporated into business planning, to mitigate a negative impact. As specific energy-saving projects are not transparent, energy project data is also collected. This is a 'bottom-up' measurement of energy avoided through energy projects. It is also helpful to estimate the impact of other influences by subtracting this from the 'top-down' energy avoided that is calculated using the year-to-year energy intensity change.

The author believes that, regardless of the positive or negative influences that operational variability may have on the

Table 9: Alternative Methodologies – examples of SWG member projects.

Example projects	
Astellas	**HVAC improvement in production plant.**
	Tools used were Affinity Diagram, Structured Brainstorming and DMAIC project. Consensus-building among stakeholders was critical. DoE conducted to ensure no adverse side-effects. Resultant improvements of 230,000kWh electrical and 340,000kWh thermal energy reduction –savings of approx €40,000 per annum.
Bulmers	**Reduction in energy in wastewater treatment plant.**
	Value Stream Mapping (incorporating Energy) (VSMe) and Identification of Waste Energy MUDAe tools used to identify and reduce energy used in the process. Identified Low/no cost improvements calculated to save 186,341kWh p.a.
Cadbury	**VSMe used to identify opportunities for energy reduction.**
	Identified inventory requiring controlled temperature and humidity as a significant energy user. Batch mixing time identified as a bottleneck. Team used Kaizen techniques to reduce Finished Goods inventory by 26% and to reduce Batch Mixing Cycle Time by 12%.
Connacht Gold	**OEE analysis of separators and evaporators in dairy process**.
	The development of OEE uncovered an opportunity to use OEE as an EPI for the EnMS. Savings were realised by reducing variation in separator run-times and CIP operating times, and ensuring increasing availability of evaporator, leading to *substantial* energy savings.
HJ Heinz	**Reduction in water consumption.**
	Cross-functional team performed DMAIC project to map all water flows in the facility and to determine areas for improvement – 33 improvement opportunities were identified, including temperature and flow-rate adjustments and recovery/reuse of water. Overall reduction of 7% in water usage and 10% in energy consumption for this process.
LEO Pharma	**Energy reduction in generation and use of highly purified water (HPW).**
	Blended (Energy and Lean/Six Sigma) tools used to form a detailed process map of the generation/distribution and usage of HPW. The mapping identified restrictions in capacity; correction led to capital project avoidance of €100,000. The process also uncovered another project with potential savings of 187,500kWh electrical.
Molex	**Reduction in energy used by compressed air**.
	DMAIC project to identify opportunities for improvement. Savings of €45,000 p.a. achieved. EPIs improved to reflect production variations. Units produced/kWh has demonstrated a 30% improvement since the project was completed.
Roadstone	**VSMe analysis of 'black-top' (tar macadam road surface material).**
	The VSMe diagnosis developed special-investigation opportunities: - Reduce the energy requirement in dry-and-heat processes - Reduce work-in-progress in the quarry - Reject material to be reworked

overall energy requirement, the total cost of energy used is a commercial reality. The EN16001 or equivalent EnMS should take into account all influences and energy factors, and the energy-management programme for the next period should be informed by this analysis. It may make good business sense to focus the energy programme on productivity and operational improvements, operational control or waste minimisation, either to mitigate a potential negative impact or to realise deeper energy savings from the process.

SEAI uses other methods to report national energy performance; it uses a decomposition analysis that separates the effects of structural, activity-related or intensity-related changes over a long period of time. It is felt, however, that the Paasche method is suited to reporting yearly performance changes.

2009 LIEN ENERGY PERFORMANCE

The influence of declining production volumes within the LIEN was very apparent in 2009. An energy intensity loss of 1 %, or an additional 250 GWh was reported, in comparison to 2008 (SEAI, 2010). The year 2009 was difficult for the manufacturing sector; overall production volumes fell by 9 % on average, and some sectors reduced in size by up to 12 %. The overall LIEN result in 2009 was distorted by two very large operators; the average energy avoidance for the LIEN was 2.6 %, equivalent to 600 GWh of energy saved, if these two operators are excluded.

In addition to the top-down energy saving or loss calculations, a bottom-up collection of energy-saving projects was completed. This indicated that, despite an additional energy requirement of 250 GWh over the previous year, 440 GWh or 2 % of savings is accounted for within the network from energy-saving projects. The following highlights were reported:

- Each LIEN member improved energy efficiency by 2 %, on average.
- Companies with EnMS are attributing 67 % of savings to the EnMS process.
- Analysis shows that structured EnMS is increasing the types of projects that challenge energy-service requirements and processes.
- Sectors are maintaining the efficiency gains of previous years despite reductions in production volumes; energy performance trends clearly demonstrate a strong drive to continually improve energy efficiency.

Table 10: LIEN energy performance summary – 2009.

Overall energy performance in 2009	
LIEN Total Primary Energy Requirement (TPER)	24,807 GWh
Energy Savings/Loss due to Energy Efficiency Gains/Losses	(250 GWh)
National Total Primary Energy Requirement	172,873 GWh
LIEN as Percentage of National TPER	14.3%
Total CO_2 Emissions	5,748,774 tonnes
CO_2 Avoided due to Energy Efficiency Gains	(34,761 tonnes)

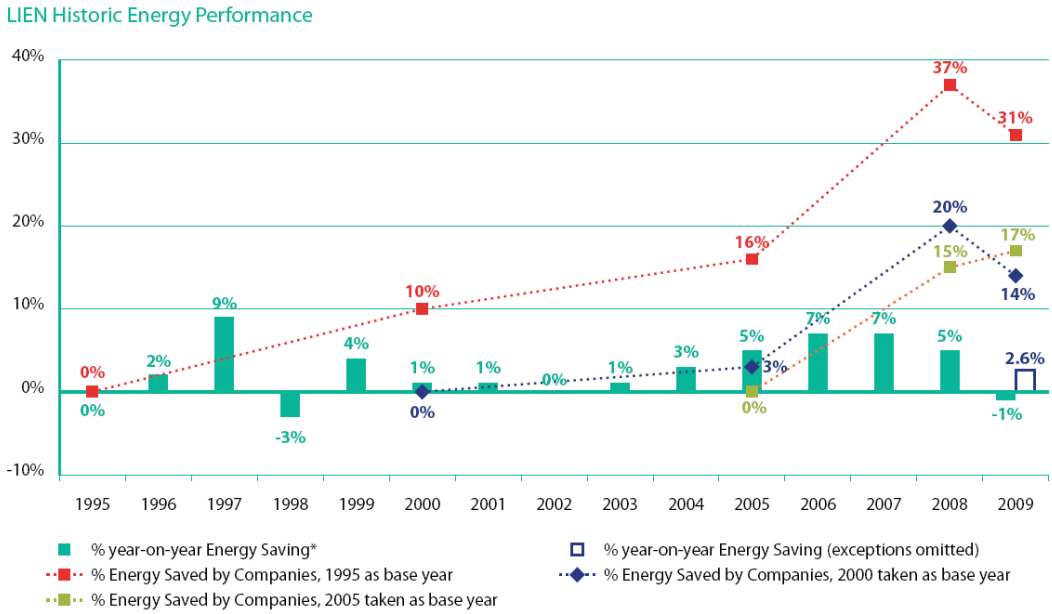

Figure 6: LIEN historical energy performance.

HISTORICAL DATA ANALYSIS

As the network is continually evolving, it is difficult to present cumulative percentage energy savings over a long period of time in a meaningful form. The performance of companies that are new to energy management and that of companies with relatively mature energy management can be very different. In addition, the companies have a natural cycle of product development. To filter this effect, in Figure 6, the energy performance trend of fixed member groups across three time periods is presented: 1995–2009, 2000–2009 and 2005–2009.

The analysis demonstrates substantial energy savings. It also shows how energy-efficiency gains are realised through operational improvements in periods of strong growth. Conversely, however, it also demonstrates how energy performance is subject to erosion during periods of reduction of production output over a short period. These savings are not necessarily lost, however; they can recovered when volume returns or through restructuring so as to regain operational improvements.

The analysis gives rise to the following conclusions:

- The LIEN members that joined in 1995 have achieved savings of 31 % in comparison to 1995 efficiency levels There was a notable drop in 2009 as a large proportion of the original members are those companies that recorded the largest drops in output. The 31 % improvement is the most accurate reflection of performance covering a 15-year period that includes periods of both strong growth and rapid decline.
- The LIEN members that were active and reported in 2000 and in 2009 have achieved savings of 14 % over that period. This group of companies includes those that recorded the largest drops in output and consequently in energy efficiency.
- The LIEN members that were active and reported in 2005 and in 2009 have achieved savings of 17 % over that period. This plot is the only series that did not report a drop in energy performance from 2008 to 2009. The EAP launched in 2006, introducing the EnMS approach. 95 % of EAP members reported, in comparison with 59 % of LIEN-only members; therefore, there is strong evidence that the EnMS approach is more effective.

Evidence of maturing EnMS and action?

Energy project activity was categorised by the companies according to the EED Venn Diagram (see Figure 4) over the past three years. It is proposed that projects that challenge the requirement for energy or that implement fundamental process changes that demand less energy are evidence of stronger action and a maturing energy programme. The data collected suggests that this trend is evident and increasing.

Table 11: Reported energy projects by category.

Project category	2007		2008		2009	
	% of savings	% of projects	% of savings	% of projects	% of savings	% of projects
Energy Service Challenge	**0%**	0%	**24%** ↑	10%	**30%** ↑↑	15%
Process Change	**0%**	0%	**1%** ↑	8%	**11%** ↑↑	5%
Equipment	14%	30%	32%	20%	20%	20%
Control	9%	15%	18%	22%	9%	21%
Operation &Maintenance	48%	37%	12%	25%	7%	13%
Housekeeping	1%	6%	3%	8%	3%	5%
Other	28%	12%	9%	7%	20%	21%

Discussion

This paper has provided insights into the approach that the SEAI is taking towards large industry in Ireland and into the energy performance improvements that have been achieved. Although this paper focuses on the strategy for large industry, the achievements are relevant to a much wider audience, since best-practice outcomes, as applicable, can be disseminated and used by all sizes and sectors.

Companies that have been LIEN members for over 15 years have improved energy intensity by over 30 % in that period. A 2 % per year average improvement is comparable with outcomes of best practice achieved through Long-Term Agreements on Energy Efficiency (SenterNovem 2008, 2010; Gudbjerg et al, 2009). While a carbon tax has been introduced in Ireland, there is no tax rebate link through the EAP. It is widely accepted that a package of measures that includes an agreements-linked tax-exemption mechanism would be more effective that a carbon tax alone. The EAP offers a strong framework on which to build the appropriate incentive, compliance and verification structures, and it could be readily adapted in the future should these be introduced.

The Energy Agreements structure was introduced in Ireland in 2006, centred on the energy-management systems approach. It appears from data collected that it has accelerated the pace of improvement in energy intensity. This is evident in the trend of energy performance improvement, particularly during a period of considerable reduction in production from 2008-2009, while users report that 67 % of energy project activity was driven by their EnMS processes. Although some benchmark comparisons can be made with the Netherlands, Sweden and Denmark and despite long-term agreements and audit-based schemes being relatively commonplace, it is difficult to make concise benchmark conclusions. This is due to the transparency of information available and no consistent measurement method.

Special Investigations are pivotal to the continuous-improvement process in that they challenge energy requirements and uncover deeper energy-efficiency opportunities. The pace of improvement will depend on the activity of special investigations within the programmes. Special investigations should be continually instigated by the energy user. SEAI plays a strong role here and is quite influential in this regard through the special project initiatives that discover new investigation opportunities. The information is available through a variety of documentation formats, then disseminated and mentored by the Agreements Support Managers. There is a requirement for members to consider applicability as an 'other' requirement under the clause *Legal and Other Requirements* of their EnMS. Established best practice can easily be standardised by the EnMS through *Operational Control* procedures.

The programme is also influential through developing information and new tools that the energy-services market could integrate as a business-service offering. The new methodologies developed by SEAI will require further demonstration to standardise.

The Energy Agreements programme is now completing its fifth year. During this time EnMS users have become much more proficient in its use and substantial savings have been achieved. The EnMS should also be continuously improved and be integrated further into an organisation's business and operations management activities. Its business case and return on investment should be continuously challenged. Some common questions asked are: *What's next now that we are certified? Can we do this work without the cost of certification? How can it be developed further?*. These are important questions. A strategy employed is the Energy Management Maturity Model; this will initially help to highlight the extent to which an EnMS can be developed. Specifically, it can be a means to develop a roadmap for development within the overall energy master planning process. As a minimum, the information that is embedded within the model can be used to impart knowledge to the users. Over time, as the maturity model is deployed, a correlation can be tested between a level of maturity and the level of sustained energy-performance improvement. It is also suggested that this may be a very useful tool to benchmark and uncover new experiences on the use of EnMSs across sectors and countries. This may prove particularly interesting with the publication of the new ISO Energy Management Standard – ISO50001.

The business case for an EnMS poses a financial barrier to its take-up within SMEs due to the scale of energy expenditure. The EnMS, however, is best practice, and as a minimum its processes should be implemented and maintained. The currently labelled *Operation Optimisation using EED Methodology*, outlined above, is very much in development stage; however, it is proposed as a countermeasure that provides an alternative to a traditional energy audit, while building the fundamental requirements of an EnMS in its implementation.

The SEAI strategy for large business uses the EnMS as best practice and it is central to all activities. SEAI is developing

the programmes that both support its EnMS development, deployment and maturity. In addition, it proactively undertakes project initiatives to stimulate the investment in special investigations that drives the continual-improvement objective. All information is shared and the energy-services market is encouraged to develop it further. For these reasons, from policy all the way to results, SEAI's approach is considered to be delivering a holistic and integrated strategy.

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Terms and definitions

Term	Definition
ASM	Agreements Support Manager – SEAI-appointed relationship manager for the EAP
DMAIC	The Six-Sigma process – Define, Measure, Analyse, Improve, Control
Energy Review	Part of EnMS clause: Review of Energy Aspects inEN16001, or Energy Planning in ISO50001
Energy Service Challenge	Challenging the requirement for an energy service or degree of energy service
Energy Service Requirement	The purpose or service provided through the delivery of energy
EnMS	Energy Management System – compliant with an Energy Management Standard. May refer to EN16001, its predecessor in Ireland, IS393, or to ISO50001, to be published in 2011.
Kaizen	A Lean methodology to continuously improve a process. A Japanese term for 'improvement', typically achieved by a process to quickly identify, test and implement improvements.
Lean Manufacturing	An improvement methodology focused on the elimination of all forms of waste through identification of value and value-adding processes. The process applies a variety of diagnostic tools, as applicable. Traditional focus on reduction in cycletime and work-in-progress.
MUDA	A Lean concept. A Japanese term for waste, it refers mainly to the seven wastes (see below).
OEE	Overall Equipment Effectiveness. The product of Availability, Quality and Performance rates. Higher rate implies higher availability, quality and performance.
Operational Control	Processes that ensure the control of energy use associated with significant users, consistent with company energy policy, objectives and targets.
PDCA	Plan-Do-Check-Act – continuous improvement cycle.
Seven wastes	Transportation, Inventory, Motion, Waiting, Over-processing, Over-production, Defects
Six Sigma	An improvement methodology that applies a DMAIC process to reduce variability within a manufacturing or business process. The process applies a variety of diagnostic tools, as applicable.
Special Investigation	A feasibility study focused on a significant energy user and integrated into the EnMS through the Register of Opportunities.
VSM	Value Stream Mapping – a Lean process. A diagnostic to understand all material processes, supporting operations and cycle-times from customer order to delivery. Three elements consist of Current State, Future State and Ideal State.