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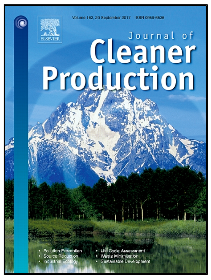

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An energy management maturity model for multi-site industrial organisations with a global presence

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Abstract

Literature reviewed suggests energy maturity models are in their infancy in the energy management sector, with little practical guidance for their implementation in multi-site organisations. In addressing this gap, this paper presents the development and implementation of an Energy Management Maturity Model for multi-site industrial organisations with a global presence, considered as a fundamental step towards continuous improvement and optimal energy efficiency. The developed maturity model provides a global view of the overall network readiness for engaging in energy efficiency by adapting and enhancing existing 'site focused' maturity models to cater for multi-site industrial an organisation. The model enables two-way communication between global and local energy management teams; not only are the individual sites benchmark but the global energy management team gets feedback and a gap analysis on their performance from the network of sites perspective. The evaluation framework created around the maturity model supports automated prioritization of elements with larger deviations. In parallel it provides the global energy management team with direction on where the organisation needs to focus central efforts to support the sites. The maturity model enables the evaluation of key not technical aspects of energy management required for continuous improvement on a multi-site and global scale.

Keywords: Energy Management Maturity Model; Performance Indicators, ISO 50001, Plan-Do-Check-Act, SWOT Analysis.

1 Introduction

Climate change and energy resource sustainability is a major challenge facing humanity today with implications for individuals, businesses and multi-national organisations [1]. Global energy consumption has continuously risen over the past century due to population growth, further industrialisation and increasing energy use per capita [2]. This growth has been largely associated with finite fossil fuels (oil, coal, gas) in industrialized nations, which, at its current rate, is unsustainable. The trend is set to continue with world energy consumption predicted to rise by 56% from 553EJ in 2010 to an estimated 863EJ by 2040 [3].

Industrial production and processing consumes a significant portion of global energy resources. In the EU-27 alone, it is estimated at 25% of the total energy requirements are associated with industry [4]. Investment in energy efficiency by the industrial sector is thus critical to a sustainable future and low carbon economy. Progress has been made, particularly in the past decade [5]. In addressing these issues, the European Environment Agency noted that between 1990 and 2009, energy efficiency in industry has on average improved by 1.8% per year, with further improvement possible using existing cost-effective energy solutions.

Energy management systems are expected to reach a market value of $35.92 Billion by 2024, representing a 13.4% compound annual growth from its value in 2009 [6]. Policy recognises that the consumption of energy and natural resources represents a major overhead for enterprises, and developing sustainable energy policies can represent a significant competitive advantage due to growing price of energy and volatility of supply [7]. Implementing sustainable energy policies in industry enables the dual benefits of increased industrial efficiency whilst allowing the transition to a sustainable, renewables-based energy future.

Energy management systems play a vital role as part of the energy efficiency measures (EEM) aimed at reducing energy consumption [8], [9]. In industry, the implementation of EEM is mainly a response to legislative demands, economics and corporate social responsibility (CSR) [10]. While legislative compliance is a strong driver since it demands implementation of EEM, they may ineffective if long-term energy management strategies and practices are not enforced to support continuous improvement [11], [12]. Implementation of energy management practices faces a series of barriers affecting companies of all sizes [12]–[19]. Low priority given to energy management has been consistently reported in literature [12], [14], [15], [17], [20], [21]. Two main drivers to overcome such barriers have been identified in literature. The first driver is the reduction of energy costs [12], [14], [16], [17]. The second driver is the existence of a long-term energy strategy [12], [15], [16], [17], [22]. The economic driver alone may not be sufficient to trigger positive decisions on energy efficiency [14], [21], especially for non-energy intensive organisations[1] where energy costs are a small portion of the production costs [12]. In such cases a strong long-term energy strategy becomes the main factor driving energy efficiency. This work is concerned with supporting multi-site organisations in establishing a long-term energy strategy by providing means to implement, evaluate and continuously improve energy management practices at both, site and global levels, through a systematic, repeatable, and scalable framework based on the maturity model's definition.

This work in engrained in a larger methodology for the development of a Global Energy Management System [23] which is briefly introduced in section 1.1.

1.1 Global Energy Management System

For multi-site organisations, informed decision making on capital investment aimed at closing the energy efficiency gap, cutting carbon emissions and improving network performance across a global site base is a complex problem. A methodology is thus needed, to enable decision making towards delivering optimal network performance, in the form of a 'Global Energy Management System' (GEMS) acting in parallel to the individual sites' energy management systems in supporting long-term energy efficiency strategies. The GEMS methodology [23] results in a simplified, understandable, systematic, repeatable and scalable **decision support framework** addressing the complexities unique to decision-making on capital investments in global multi-site organisation.

1.2 Energy Management Maturity Models in the context of GEMS

To deliver the GEMS vision and input the critical information into the decision support framework, strategies are needed to gather and evaluate all the information from the network of sites. Thus, GEMS proposes a novel benchmarking approach that combines two types of metrics in key performance indicators:

- A **quantitative** metric relating to the energy consumption, GHG emissions, financial and other aspects from the sites which can be typically expressed using key performance indicators (KPI);
- A **qualitative** metric that reflects the level of readiness and maturity of each site for effectively implementing energy management actions.

This work presents an approach to deliver the **qualitative** metrics in the form of an energy management maturity model (EM^3). The EM^3 provides an ideal framework to enable industrial multi-site organisations to enter in a continuous improvement process within their long-term energy strategy. Additionally, the EM^3 enables cross-site baselining thus creating a direct and common

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[1] In a non-energy intensive organisation energy costs are less than 2% of its turnover or less than 5% of its production costs [12], [15].

language between the different energy stakeholders in the organisation towards fair evaluation of energy projects.

The paper is organised as follows. Section 2 provides the result of a systematic literature review about energy management maturity models and energy management in practice. Section 3 describes the methodological approach for the implementation of the EM^3. Section 4 presents and discusses an implementation case study over two years for the EM^3 in a non-energy intensive manufacturing organisation in the life-sciences industry. Finally, in sections 5 and 6 the final conclusions and future work are reported.

2 Energy Management Systems

This section provides an overview of energy management systems (EnMS) in the context of global (multi-site) organisations. A detailed review of the broader area of 'energy management' is outside of the scope of this literature search, and is already covered in significantly more detail in more recent articles by Schulze et al. [24] and May et. al. [25]. Here, we provide a succinct overview of the key aspects of energy management in practice, particularly as they relate to 'maturity model' formulation.

2.1 What is energy management and energy management system?

There are several definitions of 'Energy Management'. The energy management guide published by the Carbon Trust [8] defines energy management as "*the systematic use of management and technology to improve an organisation's energy performance*". Bunse et al. [26] describe energy management "*as the control, monitoring and improvement activities for energy efficiency*". ISO 50001 [27] defines an energy management system (EnMS) as a "*set of interrelated or interacting elements to establish an energy policy and energy objectives, and processes or procedures to achieve those objectives*". The VDI – Guideline 4602 [28] released a definition which includes the economic dimension: *"Energy management is the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives*". In the reviewed academic and industrial literature, there is not a clear distinction in the definition of energy management as opposed to an energy management system. On a practical level 'Energy Management' is the control of energy related activities while an 'Energy Management System (EnMS)' outlines the strategic steps required to implement a systematic process for continually improving energy performance.

2.2 What are the advantages of implementing an energy management system?

The main drivers for implementing an energy management system (EnMS) may include, but are not limited to: legislative compliance, financial savings, competitive advantage, operational efficiency improvement, corporate sustainability and social responsibility. Legislative compliance (e.g. EU Energy Efficiency Directive [29]) often makes application of such systems an imperative. While legislation, competitive advantage and financial payback offer clear quantitative requirements for performance improvements, other impacts are less tangible and require translation to quantitative measures to ensure objective decision making (e.g. emissions reduction, sustainability and business continuity). By implementing energy management programs, organisations can save up to 20% on their energy bill, and 5%–10% of operational costs with minimal investment [8], [30], leading to increased productivity [31]. The key for making an energy management programme cost-effective lies in the continuity of the programme. In this way, instead of approaching energy use as an expense, it is managed as an asset like production, quality, and safety [32]. On the contrary, implementation of several one-off energy efficiency projects is likely to fail in delivering continuous savings [33]. Executive leadership engagement is key for ensuring continuity of an energy management programme and they need to be made aware of the non-energy benefits of EnMS associated with corporate social responsibility (CSR) corporate sustainability.

2.3 Energy management systems implementation

Literature on energy management systems implementation is vast and to ensure a meaningful review, the following boundary conditions were applied:

- The scope is limited to the physical boundary of the site(s) or organisation in question in line with Scope 1 and 2 of The Greenhouse Gas Protocol [34]. Determining the energy and greenhouse gas emissions associated with each stage of the supply chain was deemed overly complex without adding value [35].

- The scope will not include solutions or approaches to improve or reduce energy consumption at production floor level, as this is typically not under the control of a facilities department, thus difficult to influence. This consumption will however, be quantified and its results input into the decision support framework.

The literature of interest for energy management system implementation can be sub-divided into: standards, industrial guidelines and scientific literature. An overview of these categories is provided in the following paragraphs.

Standards such as ENERGY STAR™ [36], ISO 50001 [27] and SEP [37] offer the best available support to an individual site energy manager. The ENERGY STAR™ programme, established in the United States in 1992, is focused on the energy efficiency of products, homes, buildings, industrial plants and organisations. ENERGY STAR™ provides a certification based on the achievement of actual energy performance levels for a specific facility and provides guidance as per the steps to take for the development of energy management programs. ISO 50001, released by the International Standards Organisation in 2011 replaces the old EN 16001:2009 'Energy Management Systems - Requirements with guidance for use.' ISO 50001 focuses on an organisation's ability to manage their energy sources and energy use. It provides a framework that enables organisations to improve their understanding of their energy use and consumption, and subsequently improve their energy performance. Superior Energy Performance (SEP) is a certification program that verifies improvements in energy management and performance in industrial facilities. Certification requires the use of the ISO 50001 energy management standard, and, the American National Standard, ANSI/MSE 50021, which specifies energy performance criteria and additional requirements for the energy management system. All three standards closely follow the plan-do-check-act (PDCA) cycle for continuous improvement. The resources are readily available and the overall guidance provided is of a very high standard, most notably ENERGY STAR™. None of the standards, however, offer a clear approach to tackling energy management and capital spend efficiencies for a multi-site organisation with a global footprint.

Industrial guidelines have been published by several entities with a view to establishing a set of industry best practices or guidelines. Two of the leading guides are published by the Carbon Trust [8] and Sustainable Energy Authority of Ireland (SEAI) [38] respectively. Both guides are similar, following five key steps with minor differences in the approaches such as the SEAI guide that starts with commitment whereas the Carbon Trust specifies an initial review prior to management commitment. Both, the SEAI guide and the Carbon Trust guide, specify strategy, action plans and periodic report as key activities. The activities outlined in both guidelines align to the PDCA strategy but do not specify provisions for multi-site organisations.

Scientific literature in energy management systems focuses on the technological implementations of various energy efficiency measures associated with intelligent buildings [39]. These measures include improved control of the heating ventilation and air conditioning systems [40]–[42], fault detection and diagnosis [43]–[45], renewable energy sources integration [46], etc. However, there is limited scientific literature addressing implementation activities ensuring a successful implementation energy management systems for organisations of any size [47]. This lack of standardised models for energy management implementation results energy management programmes not covering the whole range of activities that are defined in the standards and guidelines [47].

The literature review revealed that current approaches to implementation of EnMS are adequate for the requirements of single-site organisation. Literature reviewed provides elements that can be directly extrapolated to multi-site organisations (e.g. initial review, action plan, energy policy definition) but other issues encountered by multi-site industrial organisations are not addressed (e.g. information exchange between site, investment decision support, definition and implementation of a global energy management team, etc. [23]). In multi-site industrial organisations, even in situations where individual sites have advanced EnMS implemented, an over-arching framework, driving an energy management programme implementation, is required to ensure maximum energy efficiency is delivered across all sites. The lack of such a framework may result in significant inefficiencies and under-funding in energy related capital projects since it would not be possible to overcome barriers to corporate energy efficiency including economic (hidden costs, risk aversion, access to capital), organisational (reduced decision making power from energy management team) and behavioural (idiosyncrasy) [48].

Extrapolating from the literature review, key enablers for the implementation of an energy management programme in multi-site organisations are:

- Understanding of the energy efficiency drivers and barriers in the organisation;
- Implementation of a framework that enables the organisation to enter a continuous improvement cycle by strengthening the drivers and addressing the barriers.

The first point would require a site by site characterization based on energy management principles [8], [27], [37]. The second point touches on the definition of Maturity Models [47], [49], [50]. Combined, it becomes clear that an Energy Management Maturity Model is necessary to tackle both points in the journey towards efficient corporate energy management.

Maturity in the energy management context is associated with the capabilities an organisation possesses to efficiently and effectively manage energy, from self-generation and procurement to distribution and utilisation. Section 3 will elaborate on the concept of 'maturity' and how it can be used, through the definition of maturity models, to provide a continuous improvement framework for the implementation in energy management practices.

3 Maturity Models

In this section, we conduct a systematic literature review, as outlined by Tranfield et al. [51] and further applied to the field of 'energy management' by Schulze et al. [24]. The purpose of this approach to is to locate relevant past publications using a pre-defined scope, and systematic identification process, thereby ensuring consistency, transparency and future replicability. This type of systematic approach reduces the scope for selection bias, and ensures a formal process for search string formulation. Furthermore, these search strings may be compiled as RSS Feeds and e-mail alerts to ensure ongoing identification of newly published material.

To ensure academic relevance, we limited our search to full-text peer-reviewed journal articles contained in three main online databases: Web of Science, EBSCO, and ScienceDirect. Since there is relatively limited published literature in this area, it was decided to use a broad search string to ensure we captured all relevant studies, including those outside of the core domain of energy management. In addition, no date restrictions or further filters were applied to the search results. We used a single search string, containing the keywords 'maturity model', to identify relevant scientific articles. The process followed during the literature review is presented in Figure 1.

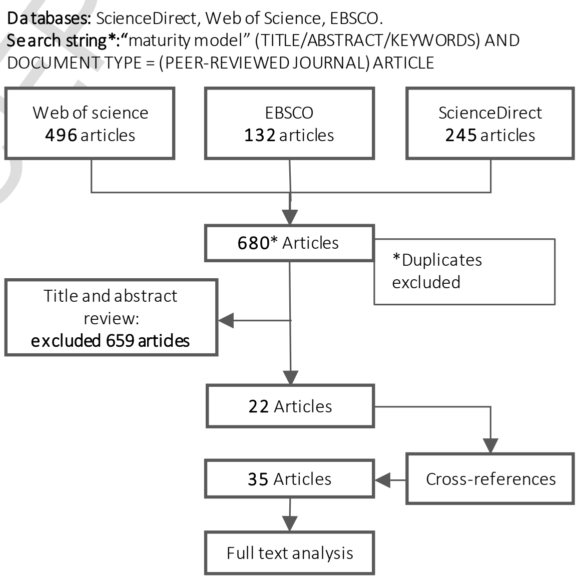

Figure 1. Systematic literature search - Process summary.

3.1 Purpose and structure of maturity models

Maturity models can be used as a tool to assess the as-is situation of a company, derive and rank improvement measures, and control implementation progress. They typically define organisational maturity levels through a five-point Likert scale, with five being the highest level of maturity [52]. Maturity models represent a theory of stage-based evolution, their basic purpose consists in describing stages and maturation paths. In practice, they are expected to include improvement measures, to disclose current and desirable maturity levels and to include respective improvement measures [53]. Maturity, in this case, can be defined as a metric to evaluate capabilities of an organisation regarding a certain discipline. Advancing through this evolution path indicates that organisations are improving their capabilities step by step [54]. Maturity models differ from energy management standards in that, rather than specifying a pre-defined threshold for acceptance or failure, they provide a scale of maturity and insights into how to advance along the maturity path [55]. As well as providing a basis for assessment and benchmarking of an organisation, they also provide a basis for '*strategic planning*' of investment to ensure continuous improvement towards corporate goals and objectives [56].

Maturity models can be differentiated according to various criteria [57]:

- *Model structure*: continuous or staged;
- *Methodology of analysis*: the way the maturity is determined;
- *Reference to international standards*;
- *Mode of assessment*: technical procedures through which the assessment is operationally conducted (including self- assessment);
- *Results of assessment*: the key elements to understand strengths and weaknesses of the organization,
- *Guide to improvement*: the more or less explicit and structured presence of specific instructions for the improvement of the organization.

With respect to the model structure, a staged representation "*(…)uses maturity levels to characterize the overall state of the organisation's processes relative to the model as a whole*" while the continuous approach *"(…)uses capability levels to characterize the state of the organisation's processes relative to an individual process area*" [58].

Additionally, the following application-specific purposes of use are distinguished [52], [53], [59]:

- *Descriptive*: applied for as-is assessments where the current capabilities of the entity under investigation are assessed with respect to given criteria.
- *Prescriptive*: indicates how to identify desirable maturity levels and provides guidelines on improvement measures.
- *Comparative*: allows for internal or external benchmarking. Given sufficient historical data from a large number of assessment participants, the maturity levels of similar business units and organizations can be compared.

3.2 Maturity Models in practice

One of the first recognised maturity models used in practice was the Capability Maturity Model (CMM), developed by the Software Engineering Institute (SEI) at Carnegie Melon University (CMU), to help organisations improve their software process [49]. Maturity model research continues to be heavily dominated by software development and software engineering disciplines [50]. Since their inception, maturity models have been applied to many different domains and industries [52], [54], including finance [60], automotive [61], software development [62], [63], business strategy [56], project management [64], e-Government [65], [66], etc. Several key examples are discussed below, highlighting the variety of interpretation and application of maturity models in a cross-section of domains.

The information process maturity model (IPMM) [56], based on the CMM framework, provides a strategic planning tool for organisations, to help understand and analyse their marketplace and customers, particularly in terms or strengths, weaknesses, opportunities and threats (SWOT analysis).

It defines five stages of process maturity: (1) Ad-hoc, (2) Rudimentary, (3) Organised and repeatable, (4) Managed and sustainable, and (5) Optimising. Each stage is characterised by activities or practices, and recommendations are provided for transitioning to the next stage along the maturity path. Finally, a summary of eight key practices (e.g. organisational structure, quality assurance, cost control etc.) is presented, alongside the typical characteristics of an organisation at each stage of IPMM maturity.

The Capability Maturity Model Integration (CMMI), developed by a group of experts from industry, government, and the Software Engineering Institute (SEI), provides guidance for developing or improving processes in three key areas: Product and service development — Development [63], Services [58], and Product/Service Acquisition [67]. The maturity of product development is divided into five levels: initial, managed, defined, quantitatively managed, and optimizing. The model can be either continuous or staged, which depends on the objective or policy of an organisation. According to the Software Engineering Institute (SEI), CMMI helps "*integrate traditionally separate organisational functions, set process improvement goals and priorities, provide guidance for quality processes, and provide a point of reference for appraising current processes*."

Based on the CMMI, Kaner and Karni [68] describe a Capability Maturity Model for organisational Decision-Making (DM-CMM) and knowledge management. It describes five levels comprising ad-hoc, planned, defined, controlled and sustained decision-making. There are also four intermediary knowledge stages, which include reception (individual knowledge capture), revised (team-based knowledge revision and organisation), retained (measure-based knowledge formulation and assessment), and reuse (reapplication of prior effective decisions). Each level is categorized through four attributes / characteristics (formality, foundation, favour, and feedback) and each stage is partitioned into four classes of activities (acquisition, arrangement, appraisal, and application. These provide a multi-dimensional view in the DM-CMM which represents "*a formal archetype of the levels and stages through which an organisation evolves as it defines, implements, measures, controls and improves its decision-making processes.*"

In 2010, the Software Engineering Institute adapted the CMMI framework for the energy industry, developing the Smart Grid Maturity Model (SGMM), a "*management tool that utilities can leverage to plan their smart grid journeys, prioritize their options, and measure their progress as they move toward the realization of a smart grid*" [69]. Along with the core six-tier maturity model matrix, the SEI provide an SGMM suite consisting of: (1) *Compass Survey:* questionnaire to support the maturity rating and performance comparison; (2) *Navigation Process*: expert-led workshops to complete the Compass Survey and inform outcomes and objectives; (3) *Training*: Navigator courses and seminars; and; (4) *Licensing*: certifications for courses and individuals.

More recently Domingues et al. [70] proposed a three-dimensional Integrated Management Systems (IMS) Maturity Model (IMS-MM©), based on a hybrid of CMMI and statistical components. It uses a six-level maturity model, considering the following axes: key process agent (KPA), externalities and excellence management. The statistical component allows the user to distinguish the variables which contribute most significantly to the latent IMS maturity variable, while the CMMI component provides an intuitive framework within which to convey results to end-users. According to the authors, the IMS-MM© is the first published initiative to normalise the results to allow the comparison between IMSs that evolved in different contexts and environments.

3.3 Energy Management Maturity Models

In Section 2, we describe how energy management systems (EnMS) can support an organisation in continuous improvement of their energy efficiency. However, there is a gap between theory and real-world implementation of best practices for energy management. In particular, most approaches fail to consider the depth and breadth of activities defined in energy management guides [27], [71], [72], such as; "*ensuring management commitment, appointing individuals or teams responsible for energy management, defining energy policies and action plans, as well as reviewing implemented measures by management, or metering of energy use.*" [55]. According to Antunes et. al. [55], an energy management maturity model for an organisation will: (i) structure and improve the understanding of energy management practices, (ii) provide a roadmap towards continuous improvement, (iii) provide an understanding of the steps required towards successful energy management, (iv) enable benchmarking the current energy practices against other organisations, and (v) guide investment efforts.

Energy management maturity models allow the assessment of the maturity level of the organisation with respect to a predefined set of parameters allowing a baselining, benchmarking and continuous improvement [73]. The adoption of an energy management maturity model intrinsically provides a progression path from the lowest to highest level of maturity, corresponding with effect of improving delivery the strategic energy objectives of the organisation [74]. O'Sullivan [75], highlights the advantages of implementing an energy management maturity model as a strategy to maximise the impact of energy efficiency measures.

Until recently, there have been relatively few published works on the adoption of maturity models for energy or sustainability. In fact, as previously reported by Antunes et. al. [55], a relatively recent survey of 237 articles on maturity models, only 3 focused on the area of sustainability [50]. In this section, we analysed the main contributions from both industry (standards, guidelines and best practice) and academia (scientific literature) to understand the current state-of-the-art for energy maturity models in practice. A summary of our findings are presented in Table 1.

Most of the energy management maturity models reviewed focus on similar key areas to evaluate an organisation. The EDF Matrix [76] and Carbon Trust Energy Matrix [77] are high-level quick assessment that don't provide a real guidance as per the improvement path. In contrast, the Carbon Trust Energy Management Assessment [77] and the SEAI [38] models are comprehensive and aligned with ISO 50001 resulting in a more detailed set of recommendations, but requiring more time and resources to perform. On the scientific literature side, all the models reviewed see the need for providing a continuous improvement path following the PDCA approach and ISO 50001. Ngai et al. [78] is limited to a series of steps as a guidance for organisation that wish to successfully implement long-term energy management practices, whereas Antunes et al. [47] and Introna et al. [79] provide fully developed maturity models and continuous improvement steps for organisation implementing energy management activities. While Antunes provides the framework and key areas evaluated in his model, Introna also provides the questionnaire and process that needs to be implemented to evaluate energy management maturity in an organisation. Jovanović [80] presents a model that is strongly linked with ISO 50001's steps, aiming at complementing the result of an ISO 50001 audit with a level of maturity within the certification. In this context, the author points out that most ISO 50001 verified organisations reach level 3 in the maturity model.

Reviewed literature suggests maturity models are in their infancy in the energy management sector, resulting in a gap between current literature and practical implementation of energy management practices coming from the lack of an appropriate incremental roadmap for implementation of energy management [47]. Similarly, Introna et al. [79] reiterate this issue, stating "*with regards to energy management, existing tools are still not well-structured and do not allow a deep analysis of the level of maturity of an organisation and of how this maturity develops along with its dimensions*". Additionally, effective implementation of an energy management maturity model relies on the ability to deliver insight on the status of each site in the network while also allowing a two-way evaluation where the view of the sites with respect to global policies and practices is also reflected. However, none of the models reviewed offer the tools to evaluate the needs and maturity levels of a multi-site organisation from a corporate perspective by providing the necessary insight both at single site level to network of sites level to corporate as whole level.

The approach proposed in this research work therefore extends existing models by including network, corporate and global dimensions that allow the user to establish gaps and action plans at site level, and provide a pathway for the entire network of sites towards more efficient energy investment and utilisation by providing a corporate view. This integration of the site and corporate perspective is what ultimately drives management-level strategic energy initiatives.

Table 1. Summary of energy management maturity models in literature.

Type	Model	Maturity Levels	Parameters / Dimensions	Comments
Industrial Guidelines	Carbon Trust Energy Management Matrix [77]	5 (0 – 4)	Energy Policy; Organising; Training; Performance Measurement; Communication; Investment	The tool aims to provide "*a quick high-level assessment of strengths and weaknesses across six areas of energy management*". In line with plan-do-check-act cycle
	Carbon Trust Energy Management Assessment [77]	0%-100%	Management Commitment; Regulatory Compliance; Procurement and Investment; Energy information system & identifying opportunities; Culture and Communications	This tools provides a detailed appraisal of energy management performance across twelve key areas grouped in 5 dimensions. In line with plan-do-check-act cycle
	Sustainable Energy Authority of Ireland [38]	Emerging Defining Integrating Optimising Innovating	Energy Review; Performance Metrics; Legal and other requirements; Opportunities register; action Plan. Monitoring, measurement and analysis; Continuous improvement; Internal audit; Competence, training and awareness; Communication; Operational control; Procurement; Design Management review; Policy; Resources and authority	This is a very comprehensive model built around the four domains of the plan-do-check-act cycle. The output of this model is a single graph which illustrates the strengths and weaknesses of each domain and each pillar within that domain, thus enabling organisations to strategize in terms of the energy management.
	EDF [76]	None Emerging Developing Leading Advancing	Engage Executives; Invest in People; Access Capital; Manage projects and data; Share results	The EDF survey targets all types of organisations regardless of size and sector. It evaluates the whole organisation at a high level without considering the multi-site organisation scenario and the associated dynamics.
Scientific Literature	Ngai et al. [78]	Initial Managed Defined Quantitatively Managed Optimised	This models defines progress between maturity levels as overall goals achieved by the organisation including: energy management practice establishment, practice standardisation, performance management and continuous improvement	This model is not a tool for analysing the maturity of an organisation, rather a description of the various phases an organisation will go through during the evolution of its energy management.
	Antunes et al. [47]	Initial Planning Implementation Monitoring Improvement	Energy Management Commitment, responsibilities and roles, Energy review, Performance benchmarking and KPIs, Energy Policy, Regulatory Compliance, Investment, Procurement, Training, Communication, M&V, Management Review	The model is based on clearly defined and understood activities, i.e. the activities reiterated through various energy management texts. The movement from one maturity level to the next follows PDCA path.

Introna et al. [79]	Initial Occasional Project Managerial Optimal	Awareness, knowledge and skills; Methodological approach; Energy performance management and information system; Organisational structure; Strategy and alignment	The model consists of a low number of questions (40), it is complementary to the implementation of ISO 50001 (aligning with PDCA) and it is envisioned for the single-site organisations.
Jovanović & Filipović [80]	Initial Managed Defined Quantitatively managed Optimized	EnMS establishment; Demonstration top management commitment for energy management; Energy manager appointment; Energy policy defining; Energy planning; Energy legal and other requirement's identification and evaluation; Energy Review; Energy baseline establishment; Defining energy performance indicators; Defining energy objectives and targets and action plans Energy plans implementation; Involving employees in energy management; Internal and external communication; Energy documentation and records management; Control of operation affecting energy performance; Energy efficiency design and renovation of facilities, equipment, systems and processes, Energy efficient procurement. Monitoring, measurement and analysis of energy indicators, Internal audit of the energy management system, Energy related corrective and preventive action's implementation. Energy management review	The model is directly linked to the ISO 50001 standard aiming at directly evaluating the level of maturity of an organisation in implementing the standard (aligning with PDCA)

4 Proposed Approach

In this section, we propose an Energy Management Maturity Model (EM^3) targeted at an industrial multi-site organisation. The approach aims to baseline (characterise) and benchmark (evaluate the performance of) each site and the whole 'network' of sites in terms of the technical and non-technical readiness to implement energy efficiency actions as follows:

- *Baseline*: the EM^3 allows understanding of how mature each site is in relation to the implementation of energy efficiency measures and provides an improvement path towards full energy efficiency maturity. The EM^3 supports a qualitative characterisation, contributing towards two elements. Firstly, a site element based on existing industrial and scientific models. Secondly, a global element which is a bespoke survey targeted to evaluate the maturity level of an organisation in implementing a long-term energy efficiency strategy across multiple sites;
- *Benchmark*: the EM^3 now expands to benchmarking by comparing each site's EM^3 results relative to the network average and by comparing the network average with external peers. In this way, each site can assess where future efforts must be focused. In parallel the same information provides the global energy management team with clear direction on where the organisation needs to focus central efforts to support the sites. A strategy can be agreed, as part of the organisation's energy policy, to focus on specific areas that have scored below an acceptable level from a network average perspective or versus the external peer performance. More importantly, it is the beginning of a path of continuous improvement with a clear roadmap to progression in place. Finally, it enables a gap analysis between the site and global energy team's perspective on corporate policy and strategy.

The EM^3 is not intended as a best-practice guide but rather as a tool for defining the continuous improvement roadmap in a synergistic manner between the individual sites and the whole network. This research work gets inspiration from several other approaches [27], [47], [79] but also includes elements gained through experience on interacting with global energy management teams in different organisations.

The EM^3 is divided into two main parts:

- *A survey* to be applied to the individual(s) responsible for energy management on each site and to the respective global energy management team;
- *An evaluation framework* and continuous improvement roadmap that can be directly and automatically populated from the results of the survey.

Before explaining the two parts, some key concepts need to be clarified, namely the different points of view targeted in the EM^3:

- *Site*: the view of the individual facility that takes the survey;
- *Network:* the combined, averaged, view of all facilities in the multi-site organisation;
- *Corporate*: the view of the global energy management team;
- *External peers*: the view of the global energy management team and the network of sites with respect to selected external organisation peers [76].

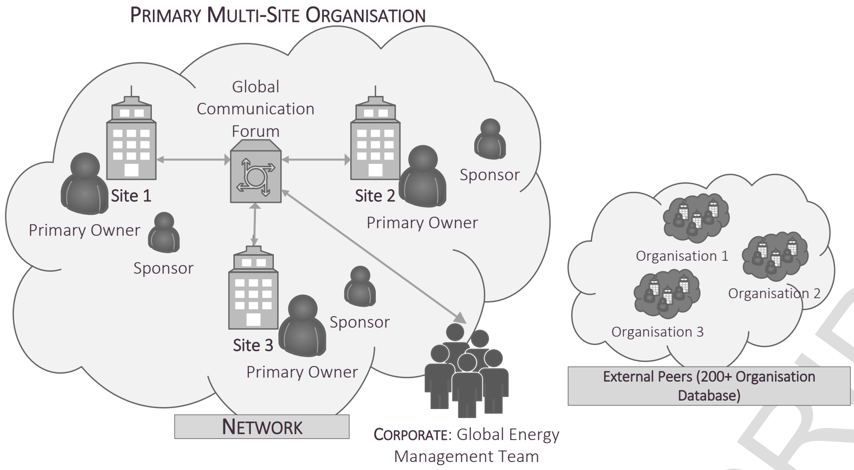

Figure 2. Points of view for the application of the EM³.

The approach's potential resides in combining these various views thus delivering insight to the status of each site in the network while also allowing a two-way evaluation of the sites' view versus the corporate position with respect to corporate policies and practices. It also positions the organisation with respect to external peers. This will in turn be the basis for a methodological development of an energy management system across site, network and corporate levels while being positively influenced by External Peers.

4.1 EM³ survey

The survey is the central piece of the EM³ as it allows extraction of all the relevant information from each site, the network and the global energy management team. The survey is aimed at delivering the most pertinent information in the most efficient time possible (through a consultation process with the responsible parties it was deemed a requirement to ensure the survey lasted no longer that 90 minutes). The survey enables a survey of the network's perception on some key aspects of corporate energy management. The survey is divided into three distinct parts as illustrated in Figure 2:

- *Part A*: is site focused and only applies to the site energy managers;
- *Part B*: a corporate view that is completed by both the site energy managers and global energy management team;
- *Part C*: surveys complementary information to enable the comparison with external peers. This section is based exclusively on a database of external peer organisations and is completed by both the site energy managers and the global energy management team.

Each part groups questions into one of the four phases of Plan-Do-Check-Act aligning with industrial standards [47]. Each PDCA phase is aligned with parameters found in reviewed literature (see Table 1) and then divided into key areas as follows:

- *Part A - Site*: is a set of nine key areas aimed at understanding where each site is in terms of an energy management maturity model.

Table 2. Site key areas under PDCA.

PDCA	Key Area	Comment
Plan	Commitment	Assesses the existence of an energy manager, an energy management team, an energy policy and the site's management commitment to energy efficiency.

	Energy planning and review	It is used to understand the site's policy towards collection, processing, communication and dissemination of energy performance data.
	Action plan	Evaluates the site's policy towards the implementation of energy performance measures, including evaluation criteria and investment levels.
Do	Implementation (people)	Gauges the importance given by the sites to personnel energy training, personnel awareness and dissemination of energy management measures.
	Implementation (processes)	Evaluates how energy efficiency measures are documented and stored. Also, how normal operation and management practices incorporate energy efficiency measures. Finally, how energy efficiency practices are applied to space designing and suppliers' choice.
Check	Measurement and verification (M&V)	Evaluates the M&V policy of the site including how data is visualised and how results are reported.
	Compliance and audits	Used to understand if energy audits are applied, who requests the application of energy audit, how are these carried out and whether there is a policy to audit the entire value chain.
Act	Management review	Measures the level of site's implementation of energy management systems.
	Recognition	Measures the levels of internal and external recognition of energy efficiency actions. It also evaluates the engagement of the site with local communities and authorities on energy efficiency.

- *Part B - Corporate*: consists of eight key areas (see Table 3) and it is aimed at using the network average score as a benchmark for how the corporate approach to energy management and its maturity level is perceived by the network. This enables a gap analysis between the network and the corporate perceptions. Thus, it allows an evaluation of the level of understanding each site has towards the corporate policy so global management can formulate the corrective actions where necessary to align site's view with corporate the position.

Table 3. Corporate key areas under PDCA.

PDCA	Key Area	Comment
Plan	Team	Evaluates the existence and engagement of a coordinated global energy team.
	Data analysis and benchmarking	Assesses the interaction between site and corporate level in relation to operational expenditure. Also, it evaluates the level of detail known on the splits of energy use and the level of harmonization of cost codes across sites.
	Best practices	Determines the indicators used for assessing energy management at corporate level.

Do	Benchmarking	Evaluates cross-site energy consumption comparison levels and data normalisation. It also evaluates how energy performance indicators are integrated into the enterprise-level energy management system.
	Skills and communication	Evaluates the existence and engagement of a corporate-level communication forum, the resources assigned to it and the corporate policy towards energy training for site level energy managers.
	Corporate assessment metrics	Determines the indicators used for assessing energy related capital expending at corporate level.
Check	Decision Support	Assesses the existence and indicators used for corporate-level decision support on energy-efficiency related capital expenditure.
Act	Performance sustainability targets	Evaluates existence and pursue of corporate level sustainability targets, their update frequency and the inclusion of business continuity into the sustainability targets.

- *Part C - External peers*: incorporates the EDF Smart Energy Diagnostic Survey [76], into the EM^3 aiming at benchmarking the multi-site organisation against industrial peers in a global scale.

Key areas are then composed by key factors to provide the basis for one or more specific questions to be asked in the survey. Each question has five possible answers to choose from, which serve to give marks to each question depending on the selected answer. The answers are posed in ascending levels of maturity. Each question addresses one factor that is then is then grouped into the key areas and averaged for scoring.

4.2 Evaluation framework and continuous improvement roadmap

The evaluation framework is underpinned by the definition of five maturity levels in line with the number of levels typically used in literature (see Figure 3). Each of the maturity levels represents an incremental step in the energy maturity journey from the previous level in the key areas under the scope of the EM^3.

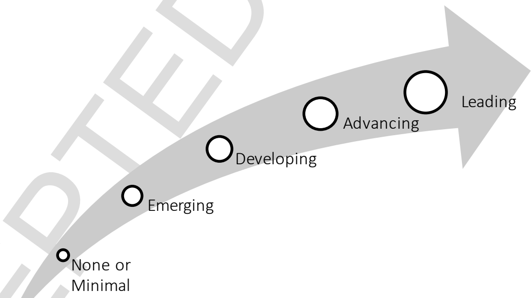

Figure 3. Maturity Levels.

The maturity levels are defined as shown in Table 4:

Table 4. Maturity level definition and associated scores.

Maturity Level	Score	Definition
None or Minimal	1	This is the first step in the energy journey and in general it corresponds with the situation where there is no energy policy within the organisation.
Emerging	2	Organisations in this level would have started the energy journey by defining an energy policy and is aware of energy performance.
Developing	3	Here the organisation is half way through the energy journey, it would have and enact an energy policy and start taking measures towards improving energy efficiency.

Advancing	4	In this level, the organisation consistently takes measures for improving energy efficiency, not only within the same organisation, but also reaching local/national authorities and communities.
Leading	5	This is the final step in the energy journey as currently conceived and corresponds with an organisation that becomes a beacon for energy efficiency good practices.

The scoring system, based on the maturity levels aims to quantify qualitative aspects related to the EM^3 and thus incentivise and enable the development of a roadmap for continuous improvement.

In the appendix, a Rubik representation of the key areas against maturity levels is provided to understand what it is considered good practices in the framework of this EM^3 implementation.

4.2.1 Site-level analysis

For each site in the network, the continuous improvement roadmap is then given by two elements:

- Development of an individualised Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis that benchmarks each site against the network (see Figure 4). Each facility is then requested to address the found weaknesses and plan contingency actions for the threats. This levels each site with regards to the network.
- The natural improvement approach given by the framework between PDCA and maturity levels. The approach requires that the less mature PDCA elements are addressed before advancing the higher-ranking ones.

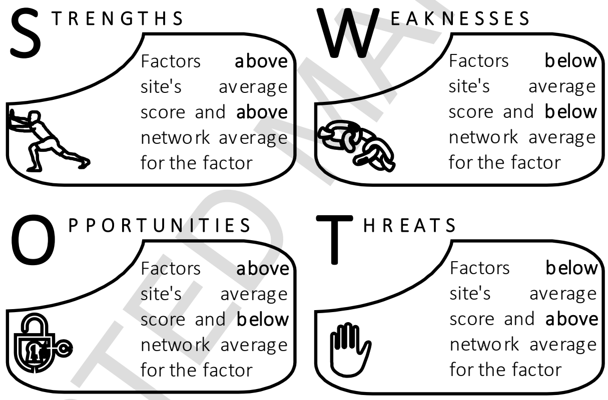

Figure 4. SWOT analysis.

This implementation of the SWOT analysis is performed from a site's point of view relative to the network:

- *Strengths*: are factors where the site <u>outperforms</u> both the **network score** for that factor and its own overall **site score**. Thus, these represent areas where a site may be able to provide leadership to other sites in the organisation;
- *Weaknesses*: are factors the site <u>underperforms</u> when compared with both the **network score** for that factor and its own overall **site score**. In this case, the factor represents a weakness locally, but the site can seek to improve through the guidance of the network;
- *Opportunities*: are factors where the site <u>outperforms</u> the **site score** but <u>underperforms</u> the **network score** for that factor. These represent areas where the site is strong locally overall but can be improved with guidance from the network on that specific factor. However, priority should normally be given to improvement of weaknesses first;
- *Threats*: are factors where the site <u>underperforms</u> the **site score** but <u>outperforms</u> the **network score** for that factor. These represent areas of weakness locally for which there is no source of improvement guidance within the internal network peer group. Therefore, these factors will likely need external guidance for improvement.

With the elements identified in the SWOT analysis and the natural evolution of maturity level, each site in the network must prepare an action plan that will enable the site to progress. The EM^3 survey is completed on an annual basis and improvements need to be associated with an action.

4.2.2 Corporate-level analysis

From a 'Corporate' or 'Global Energy Management Team' perspective the analysis is performed with a different focus depending on the section of the survey in question:

- *Part A – Site*: through the averaged network marks, the EM^3 provides clear direction on where the organisation needs to concentrate central efforts. The global energy management team needs to focus the corporate programs (via a specific corporate action plan) on the areas that will improve lowest average network scores.
- *Part B – Corporate*: this allows the global energy management team to assess how the corporate approach to energy management and maturity is perceived by the network of sites and enables a network-corporate perception gap analysis and associated remedial action plan. This is performed via a SWOT analysis like the one for the site level.
- *Part C - External peers*: this section is included for completeness. While it also enables a network-corporate perception gap analysis its objective is to indicate where the organisation is positioned relative to an external peer database. Ultimately, Part C will assist the global energy management team in creating a business case for further investment in improvements.

4.2.3 EM^3 evaluation and data comparison

In accordance with a predefined corporate energy policy, a suitable energy management evaluation framework for the organisation requires the following parameters for data comparison and evaluation:

- The condition to be above or below network average includes a dead band (in our case of ± 0.5 points chosen arbitrarily) to narrow the factors on which to focus the SWOT analysis;
- Additionally, a minimum threshold for the key areas could also be defined (in our case 2.0) to force any key area below that threshold to be improved regardless of its relative status between sites and network. The minimum threshold can be increased over time as the organisation matures;
- Finally, a weighting factor can be imposed on any of the P-D-C-A groups which helps prioritize on the groups per the status of the organisation and the policy established for continuous improvement.

This evaluation framework helps in prioritization of the elements with larger deviations or below a threshold and in accordance with a predefined corporate energy policy for continuous improvement. The framework applies to all levels of the EM^3.

5 Implementation: Case Study

In this section, a case study implementation of the EM^3 is presented and discussed. The study covers two consecutive years in a life sciences multi-site manufacturing organisation, Boston Scientific Corporation (BSC). The EM^3 model implementation followed the steps shown in Figure 5.

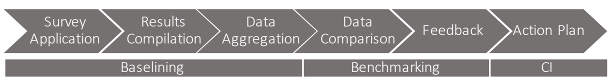

Figure 5. EM^3 Implementation Steps.

- *Survey application*: the survey is completed by each individual site and the global energy management team. Prior to the application, the survey is forwarded to the site's energy management team and during the survey, any outstanding queries are addressed. All surveys must be conducted by the same independent body to ensure consistency of reporting;
- *Result compilation*: after each survey application, the numerical results corresponding with the mark of each question are compiled in a spreadsheet or database for further analysis;

- *Data aggregation*: survey results from each site are aggregated to provide the network average, which shows the corporate position in relation to PDCA and the maturity levels;
- *Data comparison*: each individual site scores are compared against the network average. Global energy management team scores are also compared against the network average. Finally, the network and global energy management team scores are compared against an external peer data base;
- *Feedback:* feedback is provided to sites and corporate in two ways: graphical representation and SWOT analysis;
- *Action plan:* the individual sites and the global energy management team are required to prepare an action plan, including a timeline for addressing all the areas identified as requiring remediation.

5.1 Results compilation and data aggregation

After the full application of the EM[3] survey, all the data is compiled and an initial set of results is prepared. These results highlight the general status of all the sites and the network, across the PDCA sections. The aim is to identify outliers in the sites and significant differences between network and corporate scores.

5.1.1 Part A - Site

Figure 6 shows the averaged network results of the site questions applied to all 16 BSC sites.

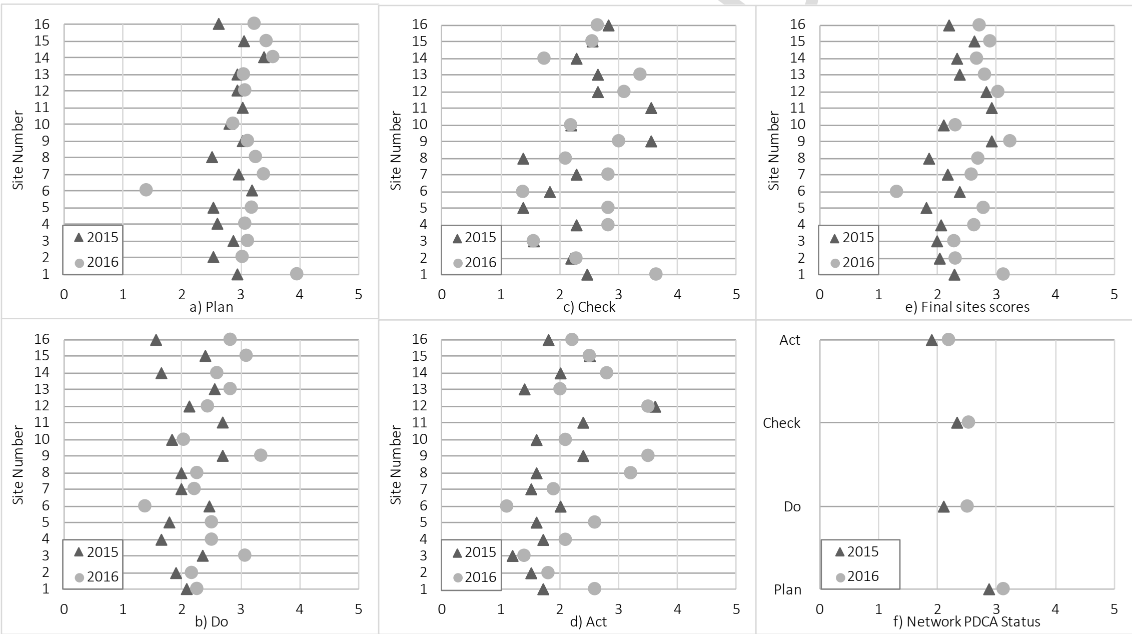

Figure 6. PDCA scores for the site-level survey applied to 16 BSC sites. a-d) P-D-C-A scores. e) Individual sites averaged PDCA scores. f) Network averaged P-D-C-A results.

Figure 6 e, shows that BSC network average is between the Emerging and Developing maturity levels (see Table 4). From Figure 6 a-d it may be observed that in 'Plan', most sites show similar results for 2015 and 2016 and for 'Do', 'Check' and 'Act', there is a growing discrepancy between sites' scores on the same year and from year to year. Worth noting from the figure is also how the scale of improvement from 2015 to 2016 is higher in 'Do', 'Check' and 'Act' than in 'Plan'. These results demonstrate the deliberate decision from the global energy management team to bring the whole network above a 'Developing' maturity level across PDCA. Such a decision impacted the focus of the action plan for 2016 whereby emphasis was made on all the key areas with a maturity level below 'Emerging' for each site. Figure 6 f, shows an overall improvement on the network average scores under PDCA albeit improvement is more accentuated for 'Do' and 'Act'.

Some particularities over the two year EM[3] implementation across the whole network of sites are:

- In 2016, site number 15 could only answer questions relating to 'Plan' and 'Do' during the period the independent body had allocated for running the survey. Hence, to ensure consistency of the results it was decided to replicate 2015 answers for 'Check' and 'Act' in the 2016 survey.
- Site number 11 was no longer in the BSC network in 2016. Nevertheless, it must be accounted for in the 2015 network average to provide a consistent basis for comparison with 2016 network average.
- In 2016 the energy manager changed for site number 6. At the time of taking the survey, the new energy manager was new to the site resulting in lower scores across all PDCA phases. This would align with how the EM^3 evaluates the level of readiness for the implementation of energy management practices, whereby reduced or lack of knowledge from an energy manager negatively impacts the ability to effectively implement energy management.

5.1.2 Parts B and C - Corporate and external peer

Figure 7 shows the scores for the corporate and external peers sections of the survey, from the perspective of the network of sites and the global energy management team.

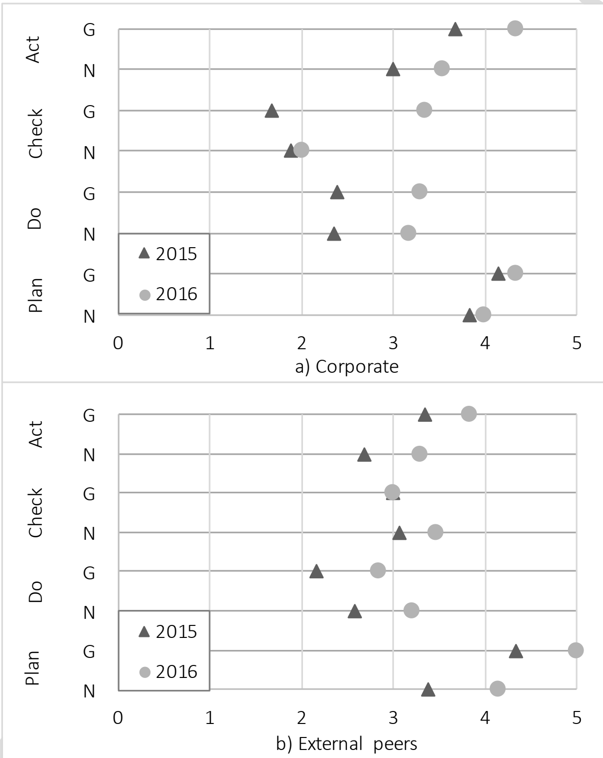

Figure 7. PDCA scores for the Corporate/External-peer survey comparing averaged answers of the 16 surveyed BSC sites and the global energy management team. G: Global. N: Network.

Before the aggregation of the site's results, this section of the survey was applied to the global energy management team to avoid bias. From Figure 7 it is interesting to note:

- For the Corporate section (Figure 7 a), 'Plan' and 'Do' results are consistent between network and global energy management team for both 2015 and 2016, while for 'Check' and 'Act' it is not the case. In such case, it is important for the global energy management team and the sites to engage and evaluate the elements that do not align. Results from the 2015 survey showed that it was important to address the maturity gap between 'Plan' (Advancing) and 'Check' (None or Minimal). The global energy management team 2016 action plan concentrated efforts on improving 'Check'. The improvement is apparent on the global responses but networks results are not aligned. The 2017 action plan must address this gap as part of the continuous improvement cycle.

- For the External peers section (Figure 7 b), the greatest discrepancies are on 'Plan' where the network perspective is below that of the global energy management team for both years albeit both elements scored high. This may point to a delay between the implementation of measures to improve the score and its communication to the network of sites. This requires an item in the 2017 action plan for the global energy management team.

For both sections, BSC is more mature in 'Plan' and 'Act' which translates in a need to concentrate 2017 efforts on 'Do' and 'Check' for reaching a level scoring. This will be influenced by corporate policy and will be addressed in the 2017 action plan.

5.2 Data comparison

Data comparison of the results from the EM^3 is performed following the same top-level split as the survey namely site-part, global-part and external-peers-part. From a global energy management team perspective, it is important to understand the average score of the network and the corporate score in the key areas of the survey. This point of view is represented in the following sections.

5.2.1 Part A – Site questions

Figure 8 shows how the 2015 and 2016 network average results in the key areas of the site survey.

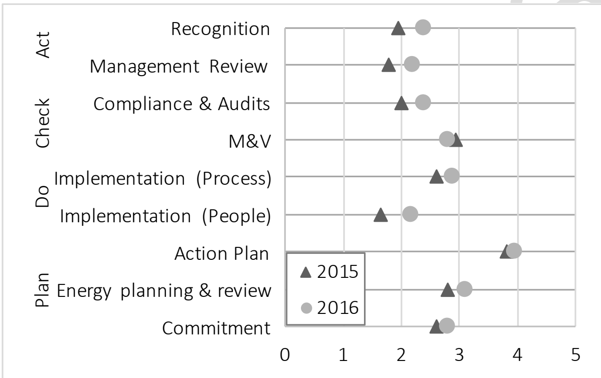

Figure 8. Network averages in key areas of site survey.

Key areas with a score of less than 2.0 in the 2015 survey were prioritized in the 2016 action plan. The impact of such corporate policy is evident in the 2016 survey results for the 'Implementation (People)', 'Management review' and 'Recognition' key areas. All key areas show improvement in the 2016 survey with exception of 'Measurement & verification', the 2017 action plan needs to address this. Though the network average has now exceeded the 2.0 global target threshold, in certain key areas individual sites are still scoring below the threshold. This will be the focus of the 2017 individual sites action plan. The global energy management team 2017 action plan can however, further the continuous improvement process by targeting the dissemination of an increase to the global threshold (now 2.0).

5.2.2 Part B – Corporate

The Corporate results give individual sites an insight into the overall performance of the organisation. This provides direction to the areas corporate policy target in the future and allows the sites to start alignment. The results also provide the global energy management team with valuable information about the network's perception in relation to the overall organisation's performance.

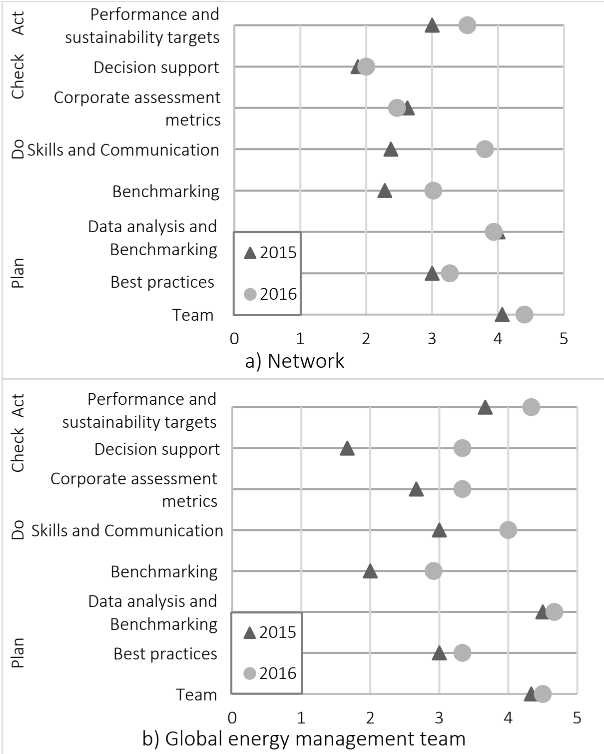

Figure 9. a) Network and b) Global energy management team averages in key areas of global survey.

At corporate level, the global energy management team 2016 action prioritized all key areas scoring below the 2.0 threshold. The outcome of the actions taken is reflected in the 'Decision support' key area for the 2016 global energy management team survey outputs (Figure 9 b). It is worth noting however, the developments in 'Decision support' were only used in those sites (20%) which requested capital for energy efficiency projects. Therefore, the improvements made are not yet broadly disseminated across the BSC network which explains the lower average score received from the network (Figure 9 a). Dissemination of developments in the 'Decision support' key area will be addressed in the 2017 global energy management team action plan.

In the results from the 2015 survey, the 'Skills & communication' key area show discrepancies between the network average results and those of the global energy management. The 2016 global energy management team action plan addressed the discrepancy by creating specific actions to:

- Improve the dissemination and sharing of learning across the network via a dedicated forum and;
- Implement an energy management training programme for the relevant personnel.

During 2016, a structured corporate energy policy and associated energy strategy is being defined by the global energy management team. Awareness of such development across the network will be addressed in the 2017 action plan.

5.2.3 Part C - External-peers

Figure 10 reflects the results of the external-peers section of the survey taken by the network of sites and the corporate energy management team.

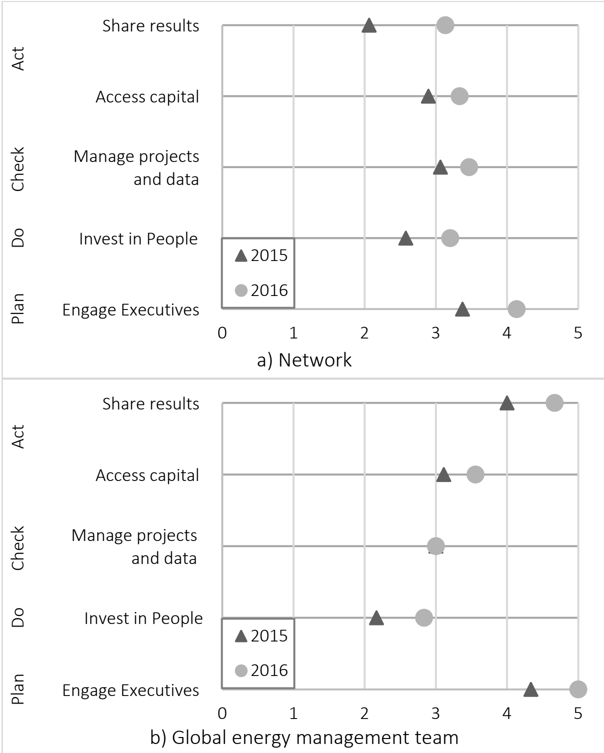

Figure 10. a) Network and b) Global energy management team averages in key areas of external peer survey.

While both, the network and the global energy management team scores have improved in 2016, as shown in Figure 10, attention is still required:

- For 'Engage executives' and 'Share results' there still exists a dissemination gap (higher than 0.5) that needs to be addressed in the 2017 action plan from the global energy management team;
- For 'Invest in people' and 'Manage projects' key areas, there is an inverse gap whereby the network of sites view on the maturity level is better than that of the global energy management team. However, as the results are within the ±0.5 threshold, addressing is not necessary under the current framework.

5.3 Feedback to sites and corporate

Feedback is provided in two ways: first, a graphical representation of the status of each sites performance against the network average and that of the organisation with respect to external peers and second, a SWOT analysis (section 4.2). Combined they provide the initial definition of the action plan and continuous improvement roadmap.

- *Graphical representation*: each site receives three comparative charts from the results of the EM^3. The first chart shows a comparison between that site's scores under PDCA compared with averages of the whole network of sites thus showing a site to network comparison. The second graph shows, under PDCA, a comparison for the corporate questions of the averaged network responses against the averaged responses of the global energy management team. The third graph is similar to the second but for the external-peer questions and adds the results from the EDF Climate Corps Surveys. The second and third graphs are the same for all sites.
- *SWOT Analysis*: for the sites, the elements of the SWOT are calculated as depicted in section 4.2 and the results are transformed into a bespoke SWOT for the site. For the corporate part, the averaged answers of the global energy management team become the baseline and the aim is to close the gap between the network's perception and the global energy management team perception.

5.4 Action plan and continuous improvement path

The sites and the global energy management team are requested to prepare an action plan including a timeline for addressing all the issues identified. This action plan will serve several purposes:

- Address all the items with score below the corporate's established threshold (e.g. <2.0);
- Address any key areas that show a decreased score from the previous year.
- Tackle the weaknesses;
- Prepare contingency measures for the threats.
- In the case of the global energy management team the action plan also need to address the gap in the different perceptions between global and network on key elements.

This plan is re-evaluated and updated periodically every time the EM^3 is re-applied to the organisation (e.g. every year). The plan needs to align with the established corporate energy strategy [23].

6 Conclusions

The implementation of the energy management maturity model proposed in this paper is a fundamental step towards aiding a global energy management team into the continuous improvement process leading to optimal network energy efficiency. In this regard, several lessons have been learned and will be presented in the following paragraphs.

While most maturity models have either one or two application-specific purposes (section 3.1: Description, Prescriptive, Comparative), the energy management maturity model presented in this paper encompasses all three purposes. It is descriptive, in that it provides criteria for the evaluation of energy management maturity and assesses the status of each site, the network and the global energy management team against those criteria. It is prescriptive through the implementation of the evaluation framework and continuous improvement path. Finally, it is comparative by incorporating a benchmarking exercise against a large database of external peers.

The combination of standard tools such a maturity models and SWOT analysis enabled the creation of an automated, scalable, repeatable and un-biased approach to assessing the maturity level in energy management within an organisation. Two side benefits where directly linked with the EM^3 implementation on the presented case study:

- A boost on the training levels on energy management in the organisation was observed;
- The creation of a common language between sites and global energy management teams enabled a more fluid communicaiton and a common ground to start working towards continuously improving witihn the long-term energy strategy;
- It became possible to evaluate part of the non-energy benefits of energy efficiency and its incorporation in the continuous improvement cycle which is promoted by several energy management standards.

Additionally, the inclusion of the global energy management team and external-peers' elements into the EM^3 present a novelty where each site, the network of sites and the corporate level can benchmark, internally and externally, the whole organisation. Critically, such two-way communication enables the global energy management team to get valuable feedback and a gap analysis on their performance from the network of sites perspective.

The qualitative nature of the EM^3 is derived from the subjective nature of the site survey. However, the Likert approach used enables the implementation of a scoring system in the EM^3. This benefits the EM^3 greatly from a practical implementation perspective and allows each site in the network to have a final score from which compare itself with the network average, external peers and most importantly track internal improvements against the established baseline (e.g. first implementation of the EM^3).

The EM^3 provides the global energy management team with a powerful benchmarking tool to complement the key performance indicators provided by the facilities with a quantification of the qualitative aspects required for successfully implementing a global energy policy. Both, site and global energy management teams are normally aware of the gaps within their remits, the EM^3 however, allows them to quantify and highlight such gaps is a systematic, structured and repeatable manner to seek and ensure top management commitment.

The EM^3 provides a tool not only to baseline (characterise) and benchmark (evaluate the performance of) all the sites in an organisation with a global presence, but it also allows for the development and application of a common language and common goals towards a unified and globally understood global energy policy. The EM^3 is expected to be proven useful in smoothing internal communication by providing such a common language which in turn results in more informed and comprehensive decision making across all stakeholders within the organisation.

As a site, orientated baseline and benchmarking tool the EM^3 is very valid towards pushing the sites to become the best they can be. Through the common language of the EM^3 the SWOT analysis brings to the surface the diverse strengths that lie within the network and which can then be efficiently disseminated. Further efficiencies lie in the central approach to closing gaps identified as threats, by utilizing the network volume to negotiate contracts.

On an implementation note, it is important that the survey is honestly answered by the person in charge of energy management since not doing so would compromise the future successful implementation of energy efficiency measures and it would show in the future reviews of the EM^3. In addition, it is recommended that the survey be conducted by an independent body and not the global energy management team. This is to avoid over inflation of the survey answers.

The combination of the application of a scoring system, a SWOT analysis and a roadmap for future actions creates incentives and an implementation path for each site to take the necessary measures to become the best it can be. Although some sites might clearly better than others, care must be taken when analysing these results as the variety of building ages, spaces uses and technologies implemented in the facilities may bias such analysis. In this sense, the EM^3 score when benchmarked against other sites may help a site that scores poorly to get additional resources, likewise the organisations score vs. external peers score may assist in getting more resources at a global or corporate management level.

7 Future Work

Several lines of future work are open thus from the development and implementation of the EM^3 presented in this research work, worth mentioning:

- Extension of the EM^3 so as the quantification of elements relating to corporate social responsibility and business continuity can be integrated into the decision support framework;
- Even if the EM^3 presented in this research work encompasses several other approaches found in literature it does not include every conceivable aspect of energy management (e.g. legal issues). Further developments and improvements might be applied to refine and/or extend the models should such unconsidered aspects reveal relevant for the application;
- An automated ranking methodology will be developed to prioritize the actions that are deemed more important (e.g. those elements farther below network average, weight factors per corporate policies, etc.). This will help in creating action plans suited for aligning all sites with corporate policy.

Acknowledgements

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Appendix A

Table 5. Site level maturity levels vs. key areas.

PDCA	Key Areas	None or Minimal	Emerging	Developing	Advancing	Leading
Plan	Commitment	No EM / EMT, no SM commitment to EE, No Energy Policy	EM exists with limited training, experience, recognition and action documentation. SM aware of energy	EM has sufficient experience and training but limited responsibilities SM is reactive towards EE. Energy Policy is incorporated and documented but with limited scope	EM has adequate training, responsibility but limited authority. EM is supported by an EMT. SM proactive towards EE. Energy Policy has broad scope including different site areas and is well known internally	EM is certified, has adequate authority. SM is involved in EE. Energy Policy communicated externally. EMT is cross functional and has continuous training
	Energy Planning and review	EPD is never collected and/or reviewed	EPD collected and occasionally reviewed through bills is the main source of information. Benchmarking performed against same site at site level. Audits on major equipment. Site level KPI. Limited goals	EPD analysed regularly and predicted with ad-hoc tools and reported. Cost analysed from bills with a split for major areas. Audits performed regularly. Benchmarking within same organisation. KPI for MEU and source. Site level goals and for MEU communicated internally.	EPD analysed with specific tools. Sub-metering for MEU in place. Site compared against other facilities in the same sector. Opportunities periodically reviewed and pursued. KPI for MEU include drivers and split by final use. System level goals defined, periodically reviewed and communicated internally	EPD automatically analysed. Energy costs reviewed frequently. Energy tariff reviewed by third party. Sub-metering includes other energy users. Site compared against different sites at different levels. EEM are continuously pursued site-wide. M&V plan used. Energy Policy defined for most areas and externally communicated. KPI defined for most energy users. KPI normalised.

	Action Plan	No planning nor investment on EEM	EEM depend on general funding and are considered only after major anomalies are detected	EEM can be proposed by ET and are assessed based on economic considerations. Moderate investment in EEM in place	SM, EM and technical personnel can propose EEM which are assessed considering also environmental factors. Funding for major EEM in place.	All personnel can propose EEM which are assessed also on CSR metrics. There is dedicated funding for EEM comparable to core business funding
Do	Implementation people	No training, awareness nor communication platform	Informal training to ET. Awareness reaches only few levels and awareness campaigns are sporadic with limited funding. No resources allocated for energy-related communication	Frequent training on energy management to ET and SM. Promoting awareness becomes site's policy. A communication platform for sharing documentation exists	A comprehensive and frequent energy training programme exists delivered also to some other personnel. Site's policy is to promote awareness at all levels and high level of resources are allocated to it. A dedicate communication manager exists to deal with energy matters. The communication platform allows tele-conference	Certified energy training is provided and available to all personnel. Awareness campaigns are a priority and engage internal personnel and general public. The energy team communicates with all areas with dedicated resources.
	Implementation process	Energy O&M only performed for business continuity. Space design, materials and suppliers are defined on aspects unrelated to energy	Energy actions internally documented. Energy O&M performed when anomalies are found. Energy is somewhat considered in space design, materials and suppliers' choice	Energy actions are documented on digital format following structured and formal approach with access to some personnel. Energy O&M performed regularly by ET. O&M team is aware of energy matters. Energy is prioritised for	Energy actions documentation accessible to personnel in all areas. Energy O&M seeks low-cost actions continuously. Space design and materials selection use modelling and simulation for performance evaluation. Equipment	Energy actions documentation accessible to all personnel. Energy O&M is comprehensive with interventions planned and communicated. At least one member of O&M team is energy certified. LCA is performed for space design, material and equipment

				space design, materials and suppliers' selection	selection is based on energy performance	selection. Energy is a major consideration in the whole supply chain
Check	Measurement and Verification (M&V)	Utility meters used. Data stored ad-hoc. M&V inly on major energy users. Analysis using ad-hoc tools	Major systems occasionally checked for identifying energy consumption. A measurement system is partially developed in-house. M&V is frequent for major energy users. A standard platform is used for analysing data	Major systems periodically checked. Fully development collection and storage system. M&V is incorporated in O&M for major energy users. Advanced visualisation used for data analysis	Most systems/areas monitored occasionally. A standard M&V protocol partially implemented. M&V has a stand-alone system for major energy users. Statistical analysis used for data analysis	Most systems and areas are periodically monitored. A standard M&V protocol is fully implemented. M&V is planned for most spaces regularly. Advanced analysis performed through data aggregation
	Compliance audits	No internal nor external audits carried out	Internal audits planned. Suppliers audit planner. External audits performed based on external request, by a third party and results communicated to SM and ET	Methodology for internal audit exists but is rarely used. Known to ET and some personnel. Only major issues addressed after audit. External audits are periodic on customer demand. Results communicated to some personnel in MEU	Audits are widespread, regular and well communicated. Most issues addressed after audit. Suppliers audited occasionally. External entities are invited to perform audits with results communicated to all personnel. In-house auditing methodology in place	Standardised auditing methodology in place. Results communicated internally and externally. All issues addressed. Suppliers audited regularly. External audits are invited and performed by some State entity, following standardised approach and with results broadly communicated
Act	Management Review	No EnMS	EnMS is being implemented. SM is planning to review EnMS	EnMS is fully implemented. SM occasionally reviews the EnMS	EnMS is implemented, actuated and certified by a third party. SM regularly reviews the EnMS	EnMS is certified and integrated with other management systems. SM

					consults with third partied for reviewing EnMS
Recognition	No incentives for EE actions. Site is not energy certified	Incentives for EE actions are being planned. Energy certification is planned. Initial contact with authorities in place. Information on energy matters is shared	Occasional incentives given to EM for EE actions. Site is energy certified but outdated. Sporadic support to local communities on energy awareness	EE actions informally rewarded. Resources allocated for selected personnel to implement EE actions. Site has been recently energy certified. The site frequently supports local communities in EE projects/campaigns. The site is used as demonstrator for awareness campaigns. Internal information on energy matters is shared	EE actions are rewarded under a formal programme. Resources for implementing EE actions are available to all personnel. Site is continuously energy certified. The site in engaged with local authorities and communities to support EE actions, share knowledge, develop policy and create awareness campaigns. The site is active in media in promoting energy efficiency

EM: Energy Manager
EMT: Energy Management Team
EP: Energy Policy
SM: Site Management
EPD: Energy Performance Data
EE: Energy Efficiency
MEU: Major Energy Users

Table 6. Corporate level maturity levels vs. key areas.

PDCA	Key Areas	None or Minimal	Emerging	Developing	Advancing	Leading
Plan	Team	Non-existent	Is unofficial with limited resources	Is official but with irregular meetings. Personnel resources are part-time. Energy is low priority	Officially exists and meets periodically. Part-time personnel resources. Energy is equal priority to other areas	Officially exits and meets regularly and with a defined structure. Full time resources and a global EM exists
	Data Analysis / Benchmarking	No knowledge. Each site tracks energy spent individually	Overall OPEX is known by site. Each site manually update GEM on OPEX	OPEX is known and split into main uses. Manual tracking through a global analytics system	Wheel of spend is established globally. Central automated tracking, analysis and payment system for most sites	Wheel of Spend is established for each site and harmonised thorough all the sites. Central automated tracking, analysis and payment for all sites
	Best practices	Forecasted ROI only	Forecasted ROI with associated sustainability impact	Forecasted ROI (based on opportunities list) with associated sustainability impact	Opportunities list reflecting the positive impact on operational savings, sustainability and business continuity	Complete business case reflecting impact on stock parameters (e.g. market value, annual revenue required for off-setting investment)
	Engage executives	No goal	regional or departmental, intensity-based goal	organisation-wide intensity goal	regional or departmental absolute goal	organisation-wide absolute goal
Do	Benchmarking	No site characterisation. No KPI used	Site's energy used split by source. Audits required on each site. Some sites have local	Energy consumption split by MEU. Each site is audited by a global partner. Sites benchmarked quantitatively.	Sites energy data normalised by climate and economics. A sensitivity analysis on energy uses is performed on each site. Benchmarking of sites is	Energy data normalised to all relevant variables. Site's audits and opportunities list are part of global database. An EM^3 is used for benchmarking. Enterprise-

			benchmarking. Site level KPIs	Site. And global-based KPIs used	quantitatively and qualitatively. Site and global KPIs combined in enterprise-level EnMS	level EnMS includes KPIs and EM[3]
	Skills and communication	No structure. No dissemination	Global forum in place for basic inter-site communication. Global and local individuals provide basic energy training	Global forum that allows presentation and dissemination of key topics. Global basic training programme in place for all energy stakeholders	Best practices based global forum for easy access and inter-site and external communication. Global intermediate training programme in place for all energy stakeholders	Enhanced technology for efficient transfer of inter-site best practices. Global advanced training programme in place for all energy stakeholders aligned with external accreditation
	Corporate assessment metrics	ROI short term	ROI short term and impact on sustainability	ROI medium term and impact on sustainability	ROI medium term combined with impact on sustainability and qualitative reference to business continuity improvement	Single financial energy metric that reflects the combined positive impact of operational savings, improved sustainability and a more resilient site infrastructure as part of a multi-criteria decision support system based
Check	Decision support framework	Each project is assessed in isolation, local site impact only.	Each project is assessed in isolation, global impact.	Each project is assessed against a global database to ascertain the optimum investments and benchmark against historical projects	Each project is assessed against a global database to ascertain the optimum investments and benchmark against historical projects. Site-level and global KPI's in conjunction with a site maturity model is considered. These are combined with a list of ECO's (and associated performance risk)	Software platform to support previous

Act	Performance sustainability targets	No global targets for energy consumption reductions or GHG emissions reduction	Targets in place but not officially approved by EC	EC approval of annual targets	EC approval of 5 year targets with annual review	EC approval of 5 year targets with annual review. Agreement on strategy for value associated with sustainability and business continuity impacts

EM: Energy Manager
EMT: Energy Management Team
EP: Energy Policy
SM: Site Management
EPD: Energy Performance Data
EE: Energy Efficiency
MEU: Major Energy Users