Development of a Global Energy Management System for non-energy intensive multi-site industrial organisations: A methodology

DEVELOPMENT OF A GLOBAL ENERGY MANAGEMENT SYSTEM FOR NON-ENERGY INTENSIVE MULTI-SITE INDUSTRIAL ORGANISATIONS: A METHODOLOGY

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Abstract

For multi-site organisations, informed decision making on capital investment aimed closing the energy efficiency gap, cutting carbon emissions and improving network performance across a global site base is a complex problem. This paper presents the systematic development and implementation of a novel methodology to reach optimal energy efficiency in multi-site organisations across their network whilst reducing carbon footprint. The methodology, a Global Energy Management System, is based on the following strategic pillars: (1) Site Characterization (2) Performance Evaluation via key performance indicators and energy benchmarking (3) Energy Strategy (4) Shared learnings and dissemination. These pillars are underpinned by essential foundations: (a) Global energy team and communication forum, (b) Knowledge base at site and global level, and (c) Corporate Energy Policy. The methodology culminates with 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. A case study is presented for a multi-national corporation in the life sciences industry. The proposed approach increased the visibility of energy and related carbon emissions issues and triggered unprecedented levels of funding and support for energy efficiency measures, leading to entering the energy efficiency continuous improvement journey towards optimal network performance.

Keywords: Global Energy Management System, corporate social responsibility, business continuity, sustainability, decision support framework

1 INTRODUCTION

Sustainability of the world's energy resources is a major challenge for humanity today. Global energy consumption has risen to unsustainable levels over the past century due to population growth and increasing per capita energy use driven by improvements in gross domestic product in the main OECD economies [1]. This growth has been largely associated with the utilisation of finite fossil fuels (oil, coal, gas) in industrialized nations, which, at its current rate, is unsustainable. This trend is set to continue with world energy consumption predicted to rise by 56% from 553EJ in 2010 to an estimated 863EJ by 2040 [2]. 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 [3]. Since 2000, improved energy efficiency in industry has resulted in a 10% decrease in energy intensity (with further improvement using existing cost-effective energy solutions as realistic target) [4]. For non-energy intensive companies[1], where energy efficiency may not be closely related to the company's core business, energy efficiency investments and planning might be neglected [5].

Every investment in energy efficiency by the industrial sector is critical to a sustainable future, and progress has being made, particularly in the past decade [6]. Non-energy intensive multinational corporations are an interesting focus group in terms of energy management research and energy strategy formulation. First, they do not face the same environmental regulations in comparison to energy intensive industries. Second, because of their size and revenue volumes, they are subject to higher public exposure than smaller organisations through corporate sustainability rankings (i.e. RebecoSAM, Corporate Knights, Newsweek Green Rankings) that are increasingly directing investors towards top ranked corporations. Finally, industrial organisations and multinationals often fail to make positive energy efficient decision due to the lack of visibility of non-energy benefits (higher productivity, lower liability, improved public image, improved worker morale, etc.) [7], [8]. Energy efficiency measures (EEM) can also positively impact on the organisation's core business through the positive market impact achieved through an organisation's compromise with environmental sustainability [9].

The main drivers for implementing energy efficiency measures (EEM) in the manufacturing industry are primarily: legislative compliance, financial gain and, corporate social responsibility (CSR) [10]. Legislative compliance often makes implementation of EEM an imperative. Financial gain from EEM and CSR require a way to improve positive feedback in order to compete with other more directly profitable investments such as operational improvements. In improving the positive feedback for EEM, it is important to ensure that the executive leadership is aware of the intangible benefits such as positive impacts on profits (e.g. productivity enhancement) delivered from energy efficiency strategies across the organisation [11]. However, a low level of information, lack of awareness, and high investment costs without clear view of the direct and indirect benefits prevent the broad uptake of energy management practices across industry [22], [23];

This research presents a novel methodology for assessing capital projects at a global level and thus driving optimal energy efficiency in non-energy intensive industries. The methodology is being developed in partnership with a Fortune 500 global leader in the medical device sector – Boston Scientific Corporation (BSC), which will eventually serve as a robust demonstrator of the proposed approach.

2 LITERATURE REVIEW

It has been demonstrated that implementing energy management programs enables organizations to save up to 20% on their energy bill, effectively cutting operational costs and boosting competitiveness [12], [13], as long as these practices are continuously reviewed and improved [14]. In fact, current trends for energy management suggest a shifted view where energy is no longer seen as an expense but rather as an asset, at the same level of production, quality and safety [15]. Similar thinking can be applied to energy management from a global perspective whereby the implementation of energy management activities, from a global level, can result in reduction of operational costs, increased business resilience and delivering on corporate social responsibility targets. Despite an extensive body of knowledge on energy

[1] As suggested by previous literature, a company can be considered as non-energy intensive if its energy costs are less than 2% of its turnover or are less than 5% of its production costs [28], [37].

management in general, there is no clear consensus on an approach to tackling energy management and capital spend efficiencies for a multi-site organization with a global footprint.

2.1 Energy Management in practice

Energy management and its associated practices vary greatly across organisations mainly because there is no well-understood energy management model. In fact, energy management activities are not well defined in the reviewed scientific literature [16]. There are a number of definitions of 'Energy Management'. The energy management guide published by the Carbon Trust [12] defines energy management as 'the systematic use of management and technology to improve an organization's energy performance'. Bunse et al. [17] describe energy management 'as the control, monitoring and improvement activities for energy efficiency'. ISO50001 [18] 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 [19] 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'. As can be noted, 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.

For the implementation of an EnMS, standards such as ENERGY STAR™ [20], ISO50001 [18] and Superior Energy Performance (SEP)™ [21] offer the best available support to an individual site energy manager. The three standards closely follow the plan-do-check-act cycle for continuous improvement[2].

While there is currently a large body of standards around energy management in industry, Antunes et al [16], state that there is a striking gap between current literature and practical implementation of energy management practices. Current approaches to energy management systems are sufficient for individual sites but are not adequate to meet the requirements of a multi-site corporation with a diverse global presence. Furthermore, none of the energy management standards, offer a clear approach to tackling energy management and capital spend efficiencies for a multi-site organization with a global footprint.

2.2 Key components of a global energy management system

Based on an extensive review of existing literature on energy management systems, in combination with our understanding of the requirements of a multi-site EnMS, we have found that the key components of a robust global energy management system can be broken down into the following five areas:

- Communications – the ability to seamlessly communicate strategies, frameworks and data across the network, in order to enable clear and informed decision-making at both site and global level; this requires a common 'language' in terms of energy management, and a cross-network communication platform;

[2] 'recurring process which results in enhancement of energy performance and the energy management system' [18]

- Site characterisation – need to effectively identify and evaluate the key quantitative as and qualitative factors affecting each individual sites energy consumption, and baseline their current performance;

- Performance evaluation – need to develop key-performance indicators using common criteria across each site in the network, and normalise to account for elements such as building characteristics (age, function), climate and economics;

- Energy Strategy – need to develop an effective strategy to achieve corporate policy goals, while accounting for the specific needs and characteristics of individual sites in the network; need to evaluate all capital projects on the basis of their impact in terms of financial return on investment (ROI, as well as indirect benefits such as corporate social responsibility (CSR), business continuity plan (BCP) and environmental sustainability;

- Decision support framework (DSF) – ultimately, effective energy management requires strategic decision-making at both site and corporate level. To ensure these decisions are based on rational evidence-based criteria, a DSF provides a useful tool for decision-makers, aggregating and communicating the required information in a timely and effective manner.

Based on these key criteria, we have conducted a review of current practice in each of these areas, in order to identify state-of-the art standards and practices, as well as the current gaps that need to be addressed in order to develop a truly ‘global’ energy management system.

2.2.1 Communications and dissemination of knowledge

The problem to address with respect to communications can be seen from two different perspectives

- The Corporate energy manager: the person(s), within the organisation, responsible for all energy management practices across the whole network of sites;

- The Site energy manager: the person(s) responsible for energy management practices in the individual site(s).

For the corporate or global energy manager, there are a number of key issues including the complexity of multiple variables (e.g. different country regulations, mix of energy, assessment methods, etc.), improper means for accessing the information and data required to quantify the consumption and ultimately lack of guidance tools to drive an energy reduction program or policy through investment in strategic initiatives from a multi-site perspective. Key to improving any process or system is putting the correct team in place and creating a forum to allow the vested parties share the pertinent information or data and share the decision making. A review of current best practice approaches to corporate energy management suggests a silo approach between corporate policy and the individual sites [40]. Cross communication between sites is rare. However, sharing and disseminating a common view and idiosyncrasy across the corporation facilitates communication allows all involved parties to work and debate on common objectives.

For a site energy manager efficient communication is typically achievable by way of a regular face to face meeting with key stakeholders appointed to the energy team from the various departments, such as the project engineer, facilities maintenance lead and frequently a production representative. This seemingly basic step, however, can be a significant challenge for a global energy manager. Face to face communication is limited due to distance and associated cost and the team dynamic is very different to a site based energy team. The individual site energy manager, on the other hand faces the challenge of access to the network 'knowledge' to improve specific project selection and implementation efficiency's due to improper dissemination of corporate policies and approaches.

2.2.2 Site characterisation

By showing energy consumption and overall operations costs with and without an energy action plan, Whaley [39] clearly shows the positive impact of the energy plan not only the operation cost but also achieving committed sustainability targets. Traditionally, energy efficiency projects, even in large corporations, are assessed at site-level on the basis of one-off audits with no visibility on the site's position against its corporation peers. While all investments in energy efficiency are welcome, establishing the best business case for investment across the 'network' is rarely undertaken.

Creating an appropriate business case will have the effect of getting focus from upper management. However, this requires the development standardized metrics to characterise sites and assess energy projects globally by making use of the large quantities of data are generated by manufacturing sites at a global level. In addition, there is a lack of a comprehensive database for industry specific energy opportunities and associated technology solutions biased for a regional model [41].

This situation may translate into delayed or under investment due to the lack of knowledge surrounding the obvious opportunity which in turns is costly to both industry and the environment with available capital funds remaining un-invested in energy efficiencies [42].

2.2.3 Performance evaluation

Typically, we consider sites may be evaluated on the basis of either Quantitative (Numerically quantifiable indicators – e.g. kWh/m^2, \$/sq.ft etc.) or Qualitative (Descriptive information about a site – e.g. energy management maturity) criteria.

1. **Quantitative**: There are many well established key performance indicators (KPIs) that are applicable to energy management. They cater for individual site systems such as HVAC [22] or plant level metrics such as the EPA's Energy Performance Indicators [23], typically normalized for key criteria such as climate and building type. A gap exists however in the combination of local and global KPI's to produce a truly normalised cross-site comparison;

2. **Qualitative**: Introna et al. [24] 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 organization with relation to energy management and of how this maturity develops along with its dimensions'. Proper cross-site baselining of the corporation leads to unfair evaluation of energy efficiency projects between sites. Recent literature suggest a growing interest in understanding the level of maturity of an

organisation with relation to the implementation of energy management practices either by providing step-by-step guidelines for long-term implementation of energy management [25], by directly assessing the maturity level against recognised standards such as ISO 50001 [26] or as a mean to develop a qualitative baselining across a network of sites for global corporations [27].

2.2.4 Corporate policy and energy strategy

A corporate energy policy is the organisation's top management's commitment to continuously improve energy performance in the long-term and support the implementation of an EnMS [18]. Even though the existence of the policy is recognised as an essential driver for EEM implementation in industrial firms [28] [29] [30], the required characteristics of such a policy for multi-site organisations with a global network of manufacturing sites have attracted limited attention from scholars.

An EnMS is expected to identify and prioritise EEM [18]. The prioritisation is influenced by decision-making practices. In order to make fair and informed investment decisions, it should be considered that profitability is responsible only partially for the decision outcome [31], and that categorisation has a strong influence on the decision-making practices [5]. The prioritisation process depends, therefore, on multiple criteria in addition to cost-effectiveness used to evaluate EEM. These criteria will vary in nature and importance according to the organisation's characteristics and priorities. This constitutes a multi-criteria decision making problem which can be solved using available multi-criteria decision methods (MCDM) [32].

- *Funding Criteria*: A survey was completed by MAPI [Manufacturers Alliance for Productivity & Innovation]. Meckstroth & Edmonds [33] poised questions in relation to Energy policy across 24 large companies with diverse global portfolios. Only two of 24 members had unique financial rules in place to allow for lower ROI or extended payback periods related to energy investment projects. Both reported their rules have been successful in meeting their company's energy reduction/cost targets Antunes [34] recognises the internal departmental competition for funding. "Without financial backing, projects and teams are unable to implement defined measures. Management needs to define an energy budget to ensure that efforts are not reduced or made impossible by direct competition against other internal departments. Recent trends show that organizations are increasingly supporting energy related projects outside the standard 2 year return on investment and the decision to implement is influenced by setting a positive example among peers [35]. Government bodies tend to allow a longer return on investment than private industry with funding allocated to projects with pay back up to 8 years [35];

- *Corporate Social responsibility*: Mixed views exist in how corporate social responsibility and other non-energy benefits translates into value creation [36]. Industries 'do not seem to have yet acknowledge how relevant non-energy benefits are to promote energy efficiency measures adoption' [37], and 'lack of knowledge of how these [non-energy benefits] should be quantified and monetised' [38];

- *Business Continuity*: While certain energy efficiency technology solutions can improve business continuity, this in itself is rarely a driver for the adoption of any technology which implementation driver remains legislative compliance [10]. Business continuity can however become a key variable in the decision process around project implementation if assessed correctly within an energy management framework (e.g. adding financial value to down-time). There is a barrier due to the perceived risk and cost of production disruption and associated costs of obtaining the information necessary to ensure the lowest possible impact on production [28]. While certain energy efficiency technology solutions can improve **business continuity** (and therefore reduce, in the long-term, the risk of production disruption), this in itself is rarely a driver for the adoption of such technology. Business continuity can however become a key non-energy variable in the decision process around energy efficiency project implementation if assessed correctly within an energy management framework;

- *Sustainability*: From an investor perspective a company's sustainability performance is becoming an increasingly important factor. "Customers are more frequently wanting to know if Allergan has a sustainability program; what Allergan is doing to reduce energy consumption and concomitant GHG emissions; what are the GHG emissions associated with the overall business. We also find investors beginning to use sustainability data along with financial and other data to make investment decisions [39].

2.2.5 Decision support

Even in situations where individual sites are strong performers on energy, an over-arching framework is required to ensure maximum return on investment from the implementation of EEM as this is often a barrier for its implementation [43]. The lack of such a **decision support framework** may result in significant inefficiency and under funding in energy related capital projects. A strong compelling business case can be presented to the organisation's top-management by taking a strategic approach that emphasises the non-energy benefits of energy efficiency and how such measure contributes to improve competitive advantage and core business activities [31]. Knowledge is power, and as such, advertisement of non-energy benefits of energy efficiency investment can enable a more positive view from an organisation's executive leadership towards energy efficiency measures [7].

Based on the literature review, it is evident that current approaches to energy management are sufficient for informing decision making on EEM for individual sites but are not adequate to meet the requirements of a multi-site enterprise with a diverse global presence.

3 PROBLEM STATEMENT

The following table summarises the current gaps between current practice and requirements for a global energy management system, described from the perspective of the site and global energy manager:

Table 1. Site vs. Global energy manager perspective for key energy management areas.

Key areas	Site energy manager perspective	Global energy manager perspective
Communication	Typical communication is by face to face meeting with key stakeholders. Cross communication between sites is rare resulting in information silos.	Communication can represent a significant challenge as **face to face communication is limited** due to distance and associated cost. Also the team dynamic is very different to a site based energy team.
Dissemination and shared learnings	The individual site energy manager faces the challenge of a**ccess to the network 'knowledge'** to improve specific project selection and implementation efficiency's.	Developing, deploying, disseminating and communicating a global energy policy is a common challenge. This is due to the **lack** of appropriate **means** for **accessing** and **distributing** the **information**.
Site characterisation, benchmarking and performance evaluation	Individual sites **lack perspective on own energy performance in relation to network overall performance**. Usually assessment is based solely on quantitative system evaluation, without consideration of externalities outside of the control of the site or organisation.	Large quantities of energy performance data are generated by sites at a global level, but there is little clarity on how to **best exploit** such **data** for fair cross-site comparison, and what are appropriate levels on metering, monitoring and analysis of data required to enable informed decision making.
Corporate policy and energy strategy	Lack of appreciation or awareness of corporate policies which may be fundamental in driving investment decisions.	Funding criteria is based solely on direct financial return on investment criteria (e.g. payback period). Environmental issues are rarely a key decision making factor. Fuzzy long-term energy policy.
Decision making	Energy efficiency projects are often assessed less favourably in comparison to manufacturing or process improvement projects, as return on investment or yield is generally less attractive for energy efficiency projects. There is little clarity on how to **improve the value of energy efficiency projects in face of decision makers**.	Informed decision making entails a number of key issues including the **complexity** and amount of variables to be taken into account, improper means for accessing the information and data required to quantify the consumption and ultimately lack of guidance tools to drive an energy reduction program or policy through investment in strategic initiatives from a multi-site perspective.

These two views are complementary and represent the two perspectives under which energy efficiency practices are effectively perceived within a multi-site organisation. Understanding and incorporating both views in a Global Energy Management System will integrate all sites in the corporation into a common language which is also shared by top-management.

The problem to address in this paper can be stated as: *For multi-site organisations, can a framework be developed that delivers optimal network performance and enables informed decision making on energy investment projects.*

4 PROPOSED APPROACH

In order to address the barriers and needs presented in sections 2 and 3, this paper proposes a novel methodology that supports decision making towards delivering optimal network performance. The methodology can be considered as a 'Global Energy Management System' (GEMS) that complements the local site's EnMS within the corporation's global network of sites. GEMS results in a decision support framework that allows for informed decision making by analysing all the relevant information and data sources. The aggregation of the data needed for implementing such a decision support framework (DSF) is based on four 'pillars' underpinned by three 'foundations' as shown in Figure 1:

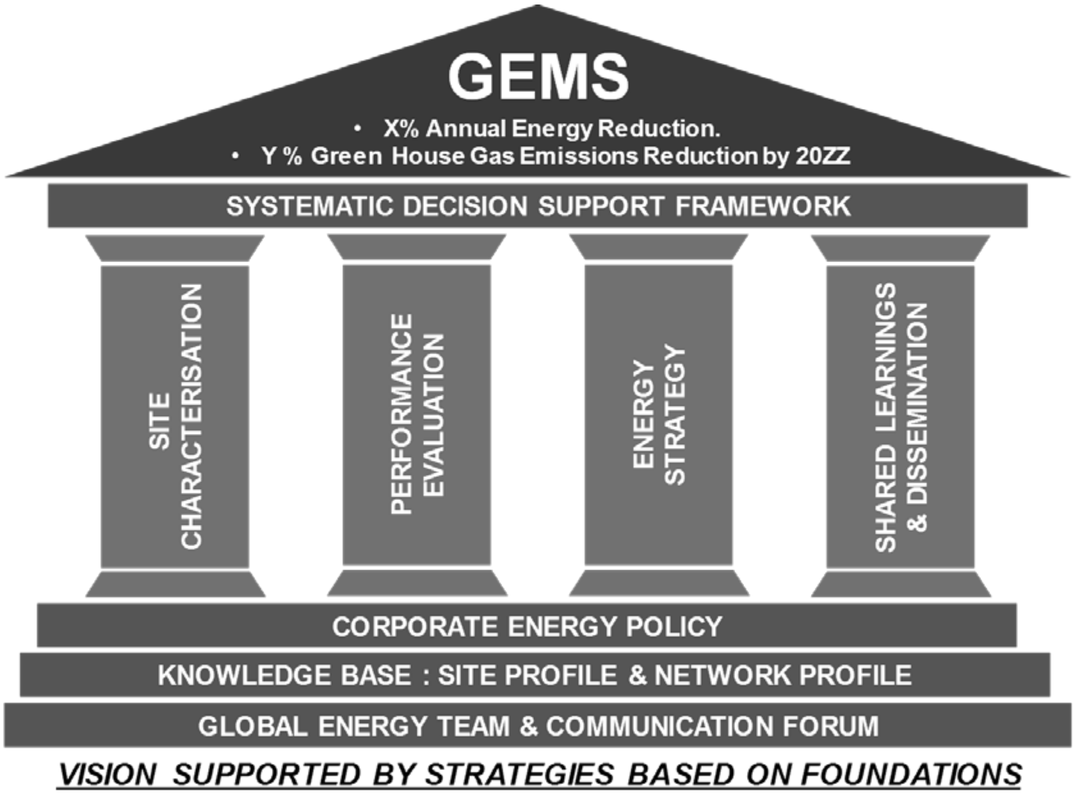


Figure 1. GEMS methodology framework.

GEMS works in parallel to a site's EnMS and is required regardless of the individual sites EnMS implementation level. In this regard, while it is recommended that each site aligns to an industrially recognised EnMS such as ISO50001 or ENERGY STAR™, this is not a pre-requisite to GEMS implementation. However, a strong site's EnMS will ensure a more efficient information gathering for GEMS. Conversely, a site starting the implementation of an EnMS will directly benefit from the GEMS structure. The following section will detail each of the components of the GEMS framework.

4.1 Foundations

For a multi-national corporation to make informed decisions on strategic investment in energy efficiency, a number of key elements or 'foundations' have been identified as necessary steps:

- Implementation of a 'Global Energy Team & Communication Forum': to enable seamless information sharing;
- Development of a 'Knowledge Base': to ensure sites and network data are known and understood;
- Definition of a 'Corporate Energy Policy': to drive the corporation towards energy sustainability.

4.1.1 Global energy team and communication forum

The global energy team is a centrally led management structure with representation from each site (Figure 2). The aims and objectives of the global energy team need to be established and the associated key deliverables outlined and tracked on a performance schedule. It is the remit of the global energy team to act as the overall governance for all aspects of energy management for the corporation.

The communication forum will ensure effective information sharing and relationship development via shared meeting technology. The forum will serve to document each site's energy profile and identify the significant energy users from a global perspective, thus forming a foundation for future decision making process. Furthermore, it will enable the communication of shared learnings and meaningful innovations within the network to improve overall network energy efficiency. Such a forum directly serves the fourth strategic pillar 'shared learnings & dissemination'.

The starting point to the implementation of a global energy team and its associated communication forum is to engage the decision makers at a corporate level, with the appointment of a *global energy manager* or *global energy management team*. Furthermore, it is necessary to ensure each site in the network can identify a resource that will become the *primary owner* for the site on the global energy forum. The primary owner is typically the facility manager or a senior engineer (who reports to the facilities manager) and is responsible for the site's energy performance. A *sponsor* should also be identified from each sites senior management team to support the primary owner. It is important to note that 'primary owners' are key in enabling the deployment of the GEMS and as such the global energy team and communication forum should be designed to positively engage and more importantly not to overburden the primary owners.

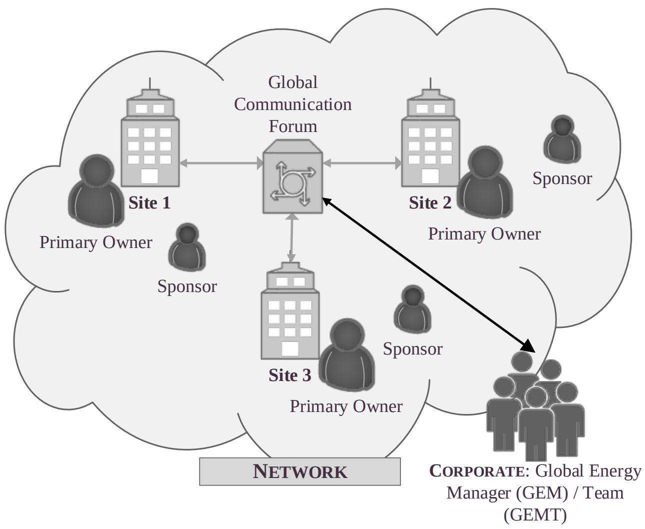


Figure 2. Global Energy Team organigram.

4.1.2 Knowledge base: Site and network profile

In simple terms, the knowledge base foundation serves to understand the:

- Externalities or uncontrollable elements for each site such as climate, economics, regulatory framework, building design and characteristics (age, product mix, local code requirements);

- Controllable factors typically prescribed in an active energy management policy such as Energy Audits, benchmarking, system efficiencies and awareness of local energy incentives among others.

In order to obtain a high-level overview of controllable and uncontrollable factors, three main requisites must be fulfilled:

- Alignment of the codes for costing different expenditures across the network. This will ensure clarity on the significance of site energy spend versus other major expenditures, such as preventive maintenance, security or janitorial. It is also important to present the data with and without factors such as depreciation, taxation, rental and salaries to ensure the 'controllable' elements are fairly represented. The cost code alignment is also a prerequisite to meaningful benchmarking at a later stage in the methodology and serves to ensure all site primary owners are aligned on concepts and able to 'speak the same language';

- A central platform for energy data collection, aggregation and analysis in order to avoid dispersion of data and the generation of 'information and knowledge silos' not accessible to the entire network. Central platforms can vary from tracking the required information on a spreadsheet to engaging a corporate level energy tracking system. The minimum data needed in this central collection platform are energy consumption by cost code (e.g. electricity, oil and natural gas) and associated costs;

- Profile sites and network by expenditure types (e.g. by pie charts) and by energy mix (e.g. renewables vs everything else).

Understanding a corporations site and network profiles leads to an initial understanding of the relevant magnitudes under GEMS scope (e.g. MWh, vs. GWh, millions of € vs billions of €). This is fundamental to creating a business case for the pilot implementation and ultimately influencing policy in the subsequent steps.

4.1.3 Corporate energy policy

The third foundation contains the organisation's commitment to continuously improve energy performance and reduce related carbon emissions. The corporate energy policy should be part of the organisation's overall corporate sustainability policy.

A chicken-and-egg situation is generated between the need for a strong corporate policy to trigger GEMS implementation, and the need for understanding the organisation's standings on energy efficiency before formulating it. This casualty dilemma arises from an initial lack of sufficient and reliable information to support the GEMS business case. To address this situation, a two-step approach is proposed. The first step is to define a business case for a pilot implementation of GEMS. The second step is to formulate a strong, long-term energy policy that ensures top management ongoing commitment to GEMS.

4.1.3.1 Business Case & Pilot Site Selection

It is expected and even desired that the implementation of GEMS in a multi-site corporation goes through the normal corporate funding approval process. This foundation step aims to build on the knowledge base already established in the previous foundation and utilizes the overall network business case to secure project funding.

Once a realistic target for reduction in energy use across the network is intially agreed (e.g. 5% annual reduction) then the overall savings, aligned with the corporation's strategic plan, can be assessed (e.g. 5 year plan). In the absence of an agreed corporate energy policy (not expected at this stage of the process), a range of 3 to 5 years as payback criteria is proposed. This allows the global energy manager to establish a min/max business case with estimated operation reductions and associated capital requirements as follows (equations (1) and (2)):

$$min\text{: (estimated savings as \% of annual spend)} \cdot \text{(strategic planning cycle in years]} \cdot \text{[3 year return]} = \text{capital required} \tag{1}$$

$$max\text{: (estimated savings as \% of annual spend)} \cdot \text{(strategic planning cycle in years]} \cdot \text{[5 year return]} = \text{capital required} \tag{2}$$

The driver for establishing the potential capital required at this stage in the GEMS process is to recognize the scale of funding that a GEMS will govern on behalf of the corporation once established. This would strengthen the business case for the cost of the GEMS implementation. The presentation of the business case for a GEMS is a vital step in the overall process and the format in which the data is presented to the executive leadership can greatly influence the outcome. Presenting the energy savings as a percentage reduction on current operation annual spend is not sufficient. The data needs to be transposed into 'Executive Committee' language and presented in parameters such as: profitability or annual revenue required to off-set the predicted savings [25].

This process will further highlight the need to establish a realistic return on investment (RoI) criteria and understand the value of non-energy benefits prior to requesting capital for projects (to be developed in detail under the third strategic pillar – Energy Strategy). Support from each individual site's upper management is vital in order to enable the associated facilities team and primary owner to engage in GEMS. In this sense, it is advisable that this communication is top-down from corporate to site management as opposed to coming from the individual site primary owners.

In order to test GEMS implementation, an initial deployment is recommended in a suitable pilot such as a single site or cluster of sites prior to full network implementation. Ideally, two or more sites within the same geographical region are preferred for pilot implementation due to climate and possible economic closeness. Sites with an established EnMS provide added value to the pilot implementation. This process will ensure the methodologies are tested on a small scale with fewer variables prior to full global implementation.

4.1.3.2 Corporate Energy Policy Formulation

In order to formulate a strong, long-term energy policy, the following key elements should be considered: (a) Organisation's long term vision in energy performance and carbon emissions; (b) Preferred roadmap to achieve corporate energy and carbon reduction goals; (c) The boundary conditions for the energy management system scope; (d) Establishment of energy performance improvement as an organisational priority and ensuring it is sufficiently resourced; (e) Alignment of all individual sites' practices on energy management to corporate organizational goals; (f) Regular revision to ensure alignment with the organisation's nature and strategic direction of the corporate sustainability policy.

4.2 Pillars

The pillars (Figure 1) serve to provide the information needed for the decision support framework of GEMS. Elements of the pillars can be progressed in parallel with the foundations; however, it is deemed more efficient to implement the foundations in advance. There is a natural progression on the pillars from 'Site Characterization' to 'Performance Evaluation' to 'Energy Strategy' to 'Shared Learnings/Dissemination'. Nevertheless, the four pillars can be established in parallel. Substantial progress on all four pillars is a prerequisite to deployment of meaningful information into the 'Decision Support Framework'. The framework should be developed in conjunction with the pillars.

4.2.1 Site characterisation

The goal of performing site characterisation is to establish an in-depth understanding of the energy drivers on each site and ultimately the whole organisation, and align with appropriate technological solutions to reduce overall energy consumption and ultimately to establish an energy baseline for each site, combining both qualitative and quantitative assessments. Site characterisation comprises two elements as follows:

- Quantitative Characterisation: understanding energy performance of the sites;

- Qualitative Characterisation: understanding maturity level in terms of energy management practices.

4.2.1.1 Quantitative Characterisation - GEMS Audit

Involves the deployment of a bespoke GEMS audit to assess the importance of controllable factors (e.g. via sensitivity/regression) driving each site's energy consumption (by default the significant energy users). It is not to be misunderstood as a standard opportunities list energy audit but rather a quantitative baseline to understand the network status. Ideally a GEMS audit should be complemented by a standard energy audit (e.g. ASHRAE Level 2 or ASHRAE Level 3) [44].

Key outputs of the GEMS audit are:

- Provide a consistent audit framework operational at all sites worldwide and conducive to the establishment of KPI's for benchmarking (Section 4.2.2.1). In the absence of data normalization, the KPI's will still provide a solid baseline for each individual site to monitor progress overtime.

- Complete a site level and corporate level metering gap analysis to support the KPI's.

4.2.1.2 Qualitative Characterisation - EM^3 baseline

The qualitative characterisation of a site involves the use of an energy maturity model (EM^3) to determine the current maturity level of the sites with relation of the implementation of energy management practices. The main purpose of the maturity model is to enable 'continuous improvement' in the organisation. GEMS EM^3 defines organisational maturity levels through a five-point Likert scale, with 'Level 5' being the highest level of maturity (Figure 3).

GEMS EM^3 is a combination of two focus areas, site and global. The site element will be based on existing industrial [18], [20], [21] and scientific models [16], [24] and adapted for GEMS requirements. The global element is a bespoke adaptation of the GEMS methodology presented in the form of a maturity model. Combined it provides a full GEMS EM^3 that is applied to all sites and the global energy management in the form of a survey questionnaire.

The qualitative nature of the EM^3 is derived from the subjective nature of the questionnaire. 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 have a final score from which compare with the network average, external peers and most importantly track internal improvements (performance evaluation pillar).

A baseline as opposed to benchmarking is the key concept to this pillar. Therefore, the EM^3 aim is to establish where in 'the energy journey' each site is in terms of the maturity of the implementation of an EnMS. Furthermore, the EM^3 will also survey the knowledge of the sites in relation to corporate energy policy which serves to understand the impact of the communication activities. Finally, it also surveys the global energy management team to establish if a gap exists between their expectations and the network's view.

EM^3 will position each site in one maturity level as follows:

- **Level 1: None or Minimal:** there is no energy policy or activity within the site;

- **Level 2: Emerging:** started the implementation of energy management by defining an energy policy and improving on-site becomes awareness on energy performance;

- **Level 3: Developing:** active energy policy and has commenced taking measures towards improving energy efficiency;

- **Level 4: Advancing:** consistently takes measures for improving energy efficiency also reaching local/national authorities and communities;

- **Level 5: Leading:** becoming a beacon for energy efficiency good practices.

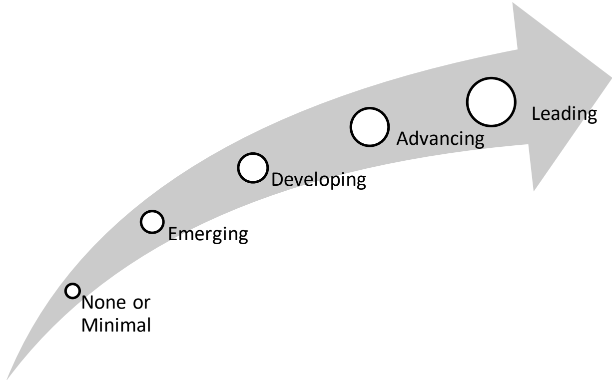


Figure 3. GEMS EM^3 maturity levels (Likert scale).

Further information about the GEMS EM^3 is described in a previous publication dealing specifically with this topic [27].

4.2.2 Performance evaluation

The 'performance evaluation' pillar builds on the data from the 'site characterization' pillar and proposes a novel benchmarking approach by combining both qualitative EM^3 and quantitative KPI results. The key is to present the data in a consistent manner and ensure that the intent of both results are clear and well defined.

GEMS benchmarking performance rating = [KPI | EM^3]

where:

- The KPI score represents the individual sites 'corporate level' KPI performance.
- The EM^3 score represents the individual sites overall EM^3 performance.

4.2.2.1 Quantitative benchmarking via KPI's

This pillar, 'performance evaluation', will establish the KPI's to track performance at both a site and corporate level. Three tiers of KPI's are defined for GEMS as follows.

- **Tier 1 KPI's**: ideally one corporate level KPI that reflects the overall site energy efficiency performance (i.e. $kWh/m^2/year$). Data normalization of controllable (technology deployed) and un-controllable (climate, economics & building type) parameters is required to ensure meaningful benchmarking (site to site & external peers);

- **Tier 2 KPI's**: also common across all sites, where feasible, but focusing on the specific significant energy users for each site. Tier 2 KPI's will directly reflect the Tier 1 performance (this is a prerequisite to selection) and will be analysed to account for Tier 1 trends;

- **Tier 3 KPI's**: these correspond to site specific bespoke KPI's that assist in supporting the analysis of Tier 2 trends and act as an early warning system.

The GEMS audit has already defined the current metering state of the facility and the required future state to support the KPI's Tier as outlined. The Tier 1 KPI's will be tracked at a corporate level. Tier 2 and Tier 3 will be tracked at the site level and are outside the scope of this paper.

4.2.2.2 Qualitative benchmarking via an EM^3

The focus of 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. For the global energy manager, the model also provides clear direction on where the corporation needs to focus central efforts. A strategy can be agreed (via the 'global communication forum') to focus on specific strategic or under-developed areas. More importantly, it is the beginning of a path of continuous improvement with a clear roadmap to progression in place.

4.2.3 Energy strategy: Enablers and drivers

The goal of the energy strategy pillar is to identify the enablers and drivers to energy improvement. It outlines the strategies that need to be in place to 'level the playing field' for investments in EEM within an organisation and achieve the goals set out in the corporate energy policy foundation.

Enablers and drivers in this strategic pillar include the following practices in energy management (but are not limited to): (a) Short-term targets in line with the corporate energy policy; (b) Funding scheme; (c) Formulation of compelling business cases by effectively communicating the link between energy improvement projects and core business activities; (d) Knowledge and monetisation of non-energy benefits, which include positive impact of operational savings, improved energy sustainability and a more resilient site infrastructure (leading to improved business continuity); (e) A fair decision-making process to drive resources towards the most strategic projects; (f) contracting of power purchase agreements with third parties; and (g) establishing accountability and links between management's remuneration and energy performance targets.

'Levelling the playing field' is achieved through the development of a prioritisation process that reduces the influence of biased opinions from decision-makers on EEM investment decisions. The prioritisation process is supported by a multi-criteria decision-making method (MCDM) that ranks the proposals for capital investment using a comprehensive set of criteria. The MCDM will also quantify not-energy related benefits and support the energy projects in competition for funding with other departments when there is no dedicated budget for this category of investments. This will ensure energy projects emerge from the local site financial review for corporate consideration.

GEMS' MCDM is a hybrid multi-criteria decision-making method that combines *Analytical Hierarchy Process* (AHP) supported by *Fuzzy Logic*, and *Technique for Order of Preference by Similarity to Ideal Solution* (TOPSIS) [45]. AHP is employed to disaggregate the decision making problem into several hierarchical levels and support the criteria weighting process. Fuzzy logic is used to allow qualitative assessments and pairwise comparisons inside the method. While TOPSIS is applied to find the best project out of a discrete number of options [32]. As shown in Figure 4, the AHP structure contains 4 first level criteria and 14 second level criteria. The first level criteria of expands the standard triple bottom line (TPL) approach of sustainability assessments [46]. The technical criteria set evaluates a project's contribution to business continuity ensuring a more holistic assessment of sustainable energy projects for organisations can be achieved [45], [47], [48].

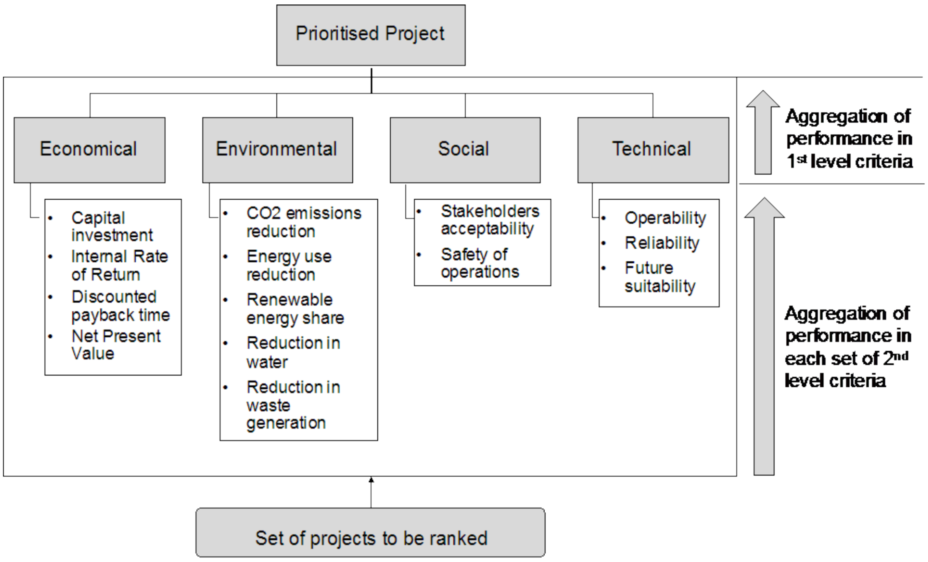


Figure 4. AHP structure and sets of criteria for assessment of energy improvement projects [49].

The ranking is based on the proposals' performance against the criteria and the priority (weight) given by the organisation to the performance in each criterion. The criteria weights are estimated using fuzzy logic to transform the linguistic pairwise comparisons carried out by experts [50], which in this methodology are top managers and experienced facilities engineers. Ultimately, the DSF uses the MCDM's output to focus the investment decisions on the group of prioritised proposals.

4.2.4 Shared learnings and dissemination

To goal of this pillar is to ensure the best methodologies, technological solutions and opportunities are proliferated throughout the network. While the 'Global energy team and communication forum' foundation is focused on the global energy management team, this pillar aims at delivering targeted information to all the people, internal and external to the corporation. The key elements to achieve effective shared learning and dissemination are:

- **Communications**: delivered with content targeted at the different stakeholders such as executive board, internal workforce and external community;
- **Collaborations**: to be engaged with a diverse range of entities such as company peers, academia, local authorities, small medium enterprises, among others;
- **Recognition and rewards**: internal reward program for energy efficiency actions and external recognition via internationally recognised standards or programmes such as ENERGY STAR™ [20] or ISO50001 [18];
- **Central approach to energy training**: energy management certification for primary owners and corporate energy training programme for workforce.

4.3 Decision support framework

Current state performance parameters are now established for each site via GEMS benchmarking performance rating (Section 4.2.2). These are combined with proposed energy projects (potentially taken from a matrix of technology solutions develop through the Global energy management team). Aligned with the corporate investment model and the MCDM results this will provide a global energy manager with a robust DSF. It will serve two mutually exclusive target audiences from the same dataset:

- Clear presentation of energy opportunities to the **executive leadership**. This informed decision making will ultimately lead to increased funding for energy efficient projects on a global scale. By presenting the information in a transparent manner strategic decision can be made with regard to investment in a site that has a low rating under 'current state performance parameters' even though the specific proposal may not rank the highest in terms of MCDM output.

- Normalized performance criteria on project proposals for the **site energy manager**. This will enable each site in the network to work towards optimal energy efficiency following a structured, informed and logical/reasonable framework. Tactically, this enables the site energy manager to run scenarios and rate potential projects ahead of site or corporate review.

The DSF will, at a minimum, detail for each proposed energy project the elements presented and detailed in Table 2:

Table 2. DSF elements detailing.

DSF element	Inputs	Outputs	Comments
Current State Performance Parameters	[KPI | EM^3]	Reflects the proposing site's quantitative and qualitative status.	Enable the executive team to assess current performance of each site and to measure the impact any proposed energy conservation project would have across the network.
Proposal Parameters	Overview of the energy conservation project under review (e.g. type of proposal such as renewable, low carbon technology, efficiency improvements, energy usage reduction and the associated high level metrics around costs, savings, sustainability impact).		
Investment Model	The proposed funding mechanism.	Capital or operational expenditure, timing and budget status.	Overview of the organisation's current strategy on the funding mechanisms (e.g. Invest own capital or use vendor capital).
MCDM Output	Corporate Policy on operational expenditure.	Financial metric score of the energy conservation project under review as defined under energy strategy.	Ranks projects across the network when evaluated on agreed corporate policy parameters.

The proposed decision support framework that will be used to assess the optimum projects from a global facilities perspective will also serve to "level" the playing field at a local level and support the energy projects in competition for funding with other departments.

5 PILOT IMPLEMENTATION

A full implementation of GEMS is an important enterprise. In this section we present the processes and learnings that were derived in the pilot implementation of GEMS in Boston

Scientific Corporation, a non-energy intensive multi-national manufacturing corporation in the life sciences industry.

5.1 Foundations

5.1.1 Global energy team and communication forum

In BSC the global energy team and communication forum is composed of a multi-site team established as shown in Figure 2:

- Global Energy Management Team: composed by the Global Energy Manager, the Global Facilities and Operation Manager and the Global Environmental and Health Manager [Corporate Level];

- Primary Owners: are the main point of contact responsible for execution of all works associated with GEMS. Typically, a facilities manager, energy manager or a senior engineer. [Site Level];

- Sponsor: Provides support for the primary owner in terms of guidance and resources. Typically, the facility manager or director for each individual site. [Site Level];

- Global Communication Forum: monthly or bi-monthly a one-hour meetings are held via web-conference. [Corporate Level].

5.1.2 Knowledge base: Site and network profiles

5.1.2.1 Cost code alignment

In BSC the project to ensure cost code alignment has taken over two years to implement as it impacts the entire payment lifecycle. A sample of the reconciled cost codes are shown in Table 3. Ensuring all cost centres are like for like across the entire network (e.g. unique ID code for electricity, gas, utilities etc.) has proven a fundamental pre-requisite to any work on a multi-site energy management system.

Table 3. BSC Cost Code Alignment sample.

GL #		Existing SAP Official Description	Description
50	**3010**	Building Maintenance	Roof, ceiling, walls, doors, windows, floor
50	**3090**	HVAC Maintenance	All HVAC Systems' Service, Maintenance & Repair
50	**3040**	Electricity	Electricity Only- Electric Utility
50	**3130**	Janitorial	Cleaning services
50	**3140**	Oil	Lube oil/gear oil- 40wt
50	**3141**	Nitrogen Gases	All process gases- Argon, N_2, CO_2, Liquid O_2,
50	**3630**	Furniture + Fixtures	Steelcase, Hayworth, desks, table, chairs & file cabs
50	**3180**	Security Guards	security guard services
50	**3210**	Utilities- Fuel	Heating fuels only - Natural Gas, Propane, Fuel Oil
50	**3215**	Water + Sewer	Water & Sewer only
50	**3240**	Waste Management	Trash/garbage, paper recycle, waste stream
50	**3260**	Facilities Exp.- Other	Site and Not directly related to building infrastructure
50	**3630**	Furniture + Fixtures	Steelcase, Hayworth, desks, table, chairs & file cabs
50	**3620**	Depreciation	Finance will provide depreciation value

5.1.2.2 Network expenditure profile

Establishing the operational spend inclusive of each site in the network (Figure 5 left) allows an initial (top down) estimate of the global energy portion in the whole corporation expenditure ahead of a more detailed review at a later stage in the process. This approach will highlight the importance and impact of energy in the corporation and it is recommended to ensure early management buy-in to the GEMS process.

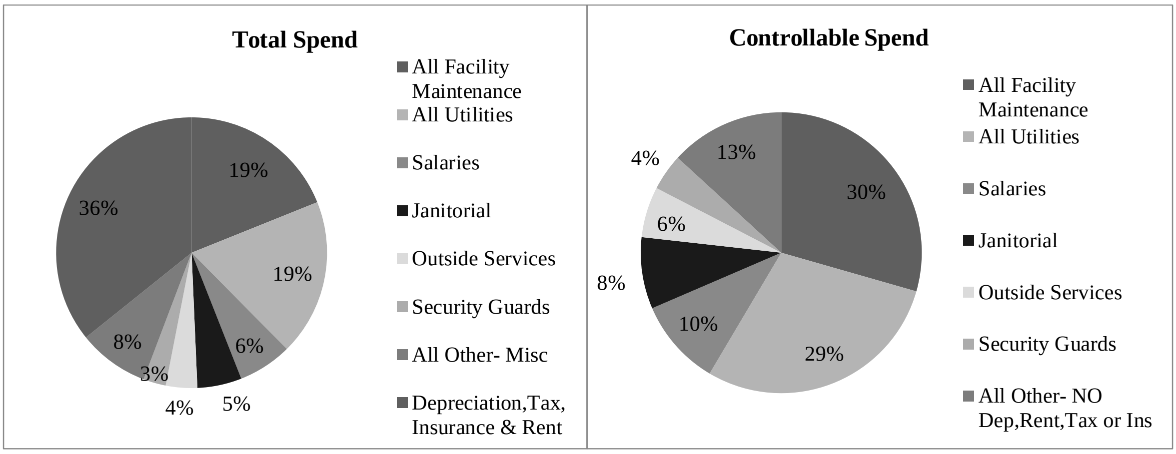
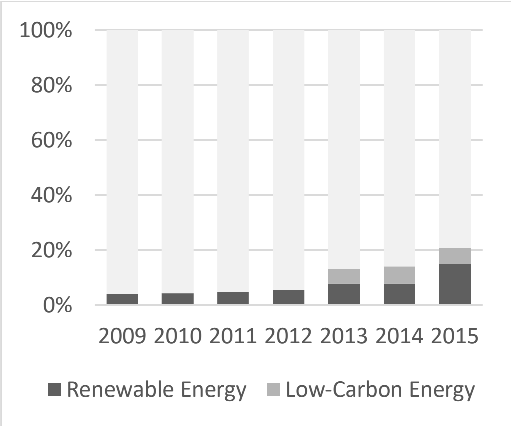


Figure 5. BSC Wheel of Spend: Total (left) and Controllable (right).

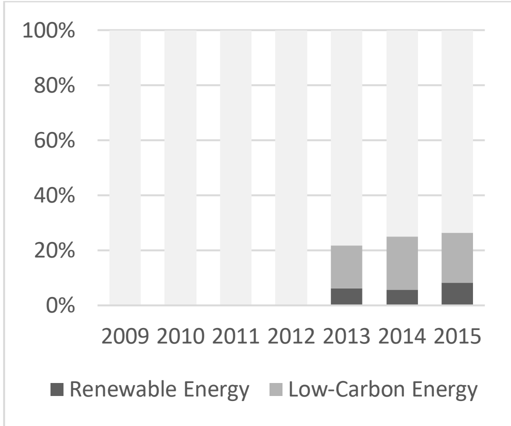
In BSC, utilities account for almost 19% of the total facilities related operation expenditure (albeit it is still less than 2% of its turn over). The figure becomes more significant when factors that are deemed 'outside of control' such as depreciation, taxation, rental and insurance are removed. Therefore, utilities account for 30% of controllable spend (Figure 5 right). Knowing that 30% of the controllable spend is under the scope of GEMS is important to define the business case (Section 5.1.3.1).

5.1.2.3 Sites and Network Energy Profile

All sites' monthly invoices are collected in a central system, this allows a platform for analysis and dissemination of energy consumption and the impact of energy efficiency measures at a later stage in the process. Understanding the sites and network profile enables an accurate tracking of the corporate energy policy objectives and also enables to understand the impact an energy efficiency measure would have in both, the individual site and the whole corporation.



a) BSC corporation.



c) One site.

Figure 6. Split of energy usage.

In Figure 6 a), the split of energy usage for BSC is shown. There is an increasing tendency towards the use of renewables and low carbon energy technologies[3]. The decision to move towards higher shares of on-site generation has two bases: the corporate social responsibility commitment by BSC to improve its environmental footprint and the need for increased resilience and independency of the energy supply for the sites which impacts business continuity. Figure 6 b), shows the split of energy use for a particular site. For this site more relevance has been given to the low carbon technology energy than to renewable energy.

Relative values are given in order to avoid distortions introduced by the addition or removal of sections to the plant or even new acquisitions or sales which would have a misleading impact on the absolute numbers.

5.1.3 Corporate energy policy

For the definition of the BSC Corporate Energy Policy, the first step was to create a business case for the implementation of GEMS. This was followed by the pilot implementation in the European sites. Finally, the energy policy definition for BSC is outlined. This process is explained in the subsequent sections.

5.1.3.1 Preparation – The business case:

Initially, BSC had targeted a 5% annual reduction on energy spend each year over its 5-year strategic plan. It has also committed a 10% reduction in carbon emissions by 2020 to the Carbon Disclosure Project [51]. This equates to approximately $1.48m in annual operational savings and a reduction of 50,000t CO_2 by 2020. With such figures, the initial GEMS business case was outlined as follows in Table 4:

[3] Low carbon technology is referred mainly to the use of combined-heat and power and tri-generation units that help reduce CO_2 emissions given its higher efficiencies when compared with traditional thermal generation plants.

Table 4. Business case for GEMS in BSC.

Programme Objective	
Develop a Global Energy Management System (GEMS) that supports decision making towards delivering optimal network performance	
Financials	
Cost of Implementation	• Expense: 50% - 2015 & 50% - 2016. • Capital: Selected Site projects driven by energy audit.
Annual reduction in global energy costs	5% equivalent to $1.5 million
Annual revenue required to offset	$11.5 million*
Increased market value of stock	$20 million*
GEMS capital governance	• Min: [$1.5 million] x [5 years] x [3 years return] = $ 22.5 million capital*** • Max: [$1.5 million] x [5 years] x [5 years return] = $ 37.5 million capital***
Schedule	
2015 European focus driven by legislation requirement. 2016-2017 World-wide focus	Two years' implementation period to deliver against 5-year financial strategic plan and 5-year BSC Global Sustainability Goals: 10% reduction in CO_2 emissions by 2020.
Dependencies	
Management commitment is a must at all levels (global and sites)	Global collaboration requires real exchange between corporate and the network of sites facilities teams via the global communication forum

* Annual Revenue Required to Offset the Energy savings =Annual Reduction in Energy / Pre-Tax Margin %
** Increase in Market Value of Stock due to Energy savings = Increase Per Share of Stock X Number of Shares Outstanding
Increase Per Share of Stock = Increase in Earnings Per Share X PE Ratio.
Increase in Earnings Per Share = Annual Reduction in Energy / Number of Shares Outstanding
*** To be invested over 5 years (Strategic plan) to enable operational savings and improved Carbon footprint.

5.1.3.2 Pilot Project Implementation

BSC's owned facilities in Europe[4] represented a unique opportunity to take the first steps of GEMS through a pilot project implementation. The selection of BSC European sites as GEMS pilot project was based on the following reasons:

- All the European sites were required to complete an energy audit by December 2015 as part of the Energy Efficiency Directive (EED), Article 8 [52]. Therefore, it was cost effective to complete the GEMS audits ahead of the EED Audit.

- All pilot sites have site level EnMs with varying levels of implementation;

- Climate is reasonably constant for the five sites making energy comparisons more fair and also all energy conservation technologies are affected in similar ways by the climate;

- On the financial side, all five sites are subject to similar same economic environment thus making it easier the cross-comparison of capital and operational investments;

- The main differences between sites (variables) are products manufactured and building profile (e.g. age, geometry, usage). In particular building profile ranges from 1998 construction to 2012 construction;

[4]Three manufacturing plants in Ireland. Warehouse in the Netherlands and reference manufacturing plant in Ireland.

5.1.3.3 Corporate Energy Policy Definition

After the pilot implementation of GEMS and the initial understanding of the characteristics of the corporation the following components of a high-level corporate energy policy has been proposed and are currently under review:

- Long term vision: Achieve significant carbon reductions aligned with global efforts to climate change, such as carbon neutrality by 2030;

- Boundary: Reduction of carbon emissions within Scopes 1 and 2 of the Green House Gas Protocol [53];

- Commitment: Establishment energy performance improvement and associated carbon emission reduction as a corporate priority across all manufacturing sites;

- Roadmap: create a dedicated fund for EEM via internal carbon pricing to: (1) cut energy use, (2) convert sources to renewables, and (3) compensate unavoidable carbon emissions via off-sets;

- Regular review: Yearly, as part of the corporation's annual operation plan.

5.2 Pillars

5.2.1 Site Characterisation and Performance Evaluation: Quantitative

In BSC the most significant energy use come from space conditioning, in particular due to the high requirements of its clean room spaces in terms of area and environmental conditions of the spaces served. Additionally, BSC sites have typical manufacturing support space such as offices, storage, data centres, etc. Due to this variety in space usage and its associated requirements it was deemed unfair to provide cross-site comparisons on energy consumption simply by area as is common practice (a site with major share of energy-intensive clean room space would be penalised against a site consisting mainly of offices). A new metric for site characterisation and performance evaluation was needed. In addressing this need a new metric was proposed supported by the fact the most energy consumption in BSC sites occurs in spaces conditioned via HVAC systems. The new approach would create an innovative energy intensity metric by dividing total site energy consumption by volume of air delivered. Table 5 shows a comparison of energy use intensity formulas.

Table 5. Energy Use Intensity Calculation

#	Energy Use Intensity Formula	Pros	Cons
1	$\frac{\boldsymbol{Total\ energy}}{\boldsymbol{Area}}$	Easy to estimate Effectively captures the size of the site in terms of floor area.	Does not typically produce accurate comparisons of large industrial or production sites due to their complex nature and varied make up. It doesn't capture floor area usage breakdown.
2	$\frac{\boldsymbol{Total\ energy}}{\sum \dot{\boldsymbol{m}}_{\boldsymbol{i}}^{*}}$ (Total Energy / Static Volume Delivered by AHUs)	Captures the floor area usage breakdown. Can be automatically computed from measurements or from building control system.	Not applicable for industrial sites with large floor areas not served by AHUs (e.g. conditioned through radiators, naturally ventilated). Not applicable for industrial sites with highly energy intensive production lines.

*Currently based on installed capacity, next step will be based on delivered volume of air during the evaluation period

Table 6 provides an overview of Energy Use Intensity for the four EU sites in BSC plus a newly state-of-the art constructed fifth site, using a variety of formulae:

Table 6. Tier 1 KPIs. Energy Use Intensities for BSC European Sites (Source: EED Audit)

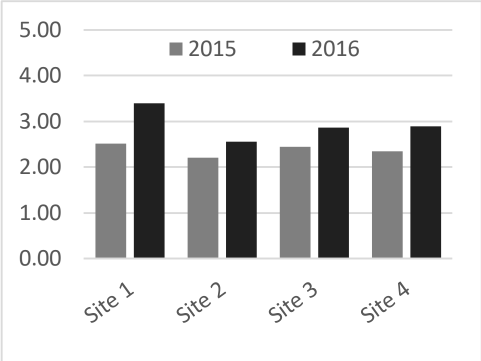
Formula #	Value/ranking	Site 1	Site 2	Site 3	Site 4	Site 5
1 (MWh/m^2)	Value	1.92	0.82	1.09	0.1	0.52
	Ranking	5º	3º	4º	1º	2º
2 (MWh/m^3/s)	Value	229	128	134	117	77
	Ranking	5º	3º	4º	2º	1º
Sites details						
Energy Consumption 2014 (MWh)		33,199	14,893	56,240	2,512	5,253
Static air volume delivered (m^3/s)		147	116	352	21	68
Floor Area (m^2)		17,484	18,194	43,138	25,000	10,126
Facility type		Production	Production	Production	Warehouse	Production

Using the traditional formula for KPI calculation led to Site 4 ranked 1st, this result doesn't reflect the fact that Site 4 is a Warehouse and therefore much less energy intensive by square meter than any production site. The proposed Tier 1 KPI corrects this issue.

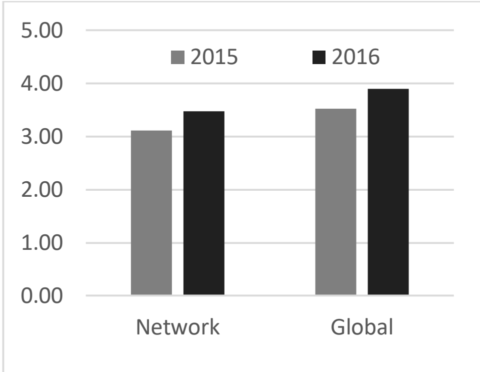
Tier 2 and 3 KPIs are site based and outside the scope of this paper as they do not provide directly relevant information for cross-comparison under the DSF.

5.2.2 Site Characterisation and Performance Evaluation: Qualitative

Qualitative characterisation and evaluation under GEMS is performed via the implementation of an EM^3. For the purposes of this paper the comparison between the EU sites is presented in Figure 7 and discussed below for the implementation of the EM^3 in 2015 and 2016.



a) Total EU Sites EM^{3}Score



b) Global versus network view of EM^3

Figure 7. EM^{3}Scores for BSC EU sites and Global scores

From Figure 7 a), it can be seen that all EU sites have managed to improve its EM^3 score which means that actions have been taken to increase the maturity level in relation to the implementation energy management practices. On the Global side of the EM^3 (Figure 7 b)), it can be seen the improvement in both, the network view and the global view, thus showing the results of the deliberate effort made be the corporation in raising awareness of all the activities its carrying out to improve energy management across the whole corporation.

5.2.3 Energy strategy: Enablers and drivers

GEMS' MCDM was applied to prioritise energy projects for five different BSC manufacturing plants as shown in Table 7. Level 1 and level 2 criteria weights were estimated using fuzzy logic to transform the linguistic response to a questionnaire by four experts within this organisation as follows in Table 8.

Table 7. Proposed projects

Project	Identifier
Tri-generation System	P1
Combined Heat & Power plant	P2
Ice Storage System	P3
Chillers' Upgrade	P4
Solar PV System	P5

Table 8. Personnel involved in defining weightings for the MCDM

Management position	Level	Criteria fields
VP of Global Real Estate, Facilities Operations, and Environment, Health & Safety.	1	Corporate Sustainability strategy (environmental, economic, social and technical)
Director for Environment, Health & Safety	2	Environmental and social
Financial expert	2	Economic
Expert in auxiliary systems operation (HVAC, heating, cooling, power)	2	Technical

The estimated resulting weights for first and second level criteria are reported in Table 9.

Table 9. Criteria weighting [49]

Description	Weight %	Description	Weight %
ECONOMIC	31	Initial Capital Investment	18
		Net Present Value	47
		Internal Return Ratio	18
		Discounted Payback Time	18
ENVIRONMENTAL	34	CO2 Emissions Reduction	29
		Energy Consumption Reduction	29
		Renewable Energy Share Increment	26
		Water Consumption Reduction	1
		Waste Generation Reduction	14
SOCIAL	9	Safety of Operation	68
		Stakeholder's Acceptability	32
TECHNICAL	26	Operability	34
		Reliability	56
		Future Suitability	10

Regarding the corporation's priorities, results shown in Table 9 indicate that the environmental performance is the first priority (34%) when ranking energy projects in this organisation. Interestingly, the economic dimension is the second priority (31%), but followed closely by the technical dimension (26%). This reveals that instead of the economic benefits, an energy project's contribution to improve the environmental footprint and business continuity is the main expectation within this organisation. The economic performance is, therefore, relevant but not decisive in the decision-making process in this multi-site corporation. This outcome is aligned with results from empirical works on investment decision for energy efficiency projects [5]. With respect to the prioritisation outcome, Figure 8 depicts that project 'P5' is the top ranked, followed by project 'P2', which offers only half of the overall performance that the best option 'P1' does. The other alternatives offer even less attractive scores.

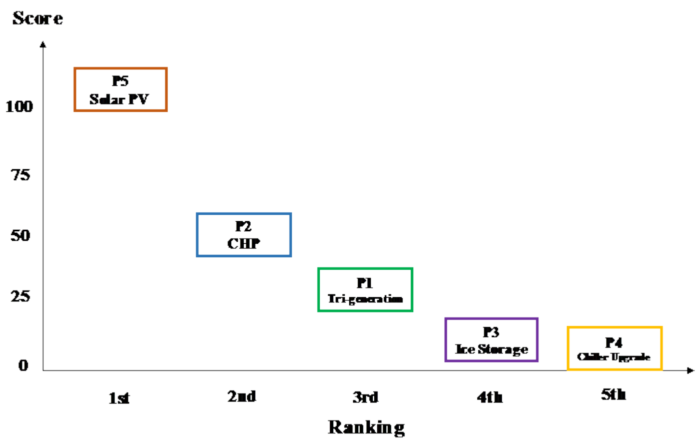


Figure 8. Case study prioritisation results

5.2.4 Shared learnings and dissemination

An online platform supported by monthly teleconference meetings is currently the approach taken to store and share relevant material for energy management across the entire global network of sites. Given the diverse locations this has been found as the most cost effective communication node however the importance of face to face meetings is recognised as key to team growth and a global summit is scheduled every 18 months, the most recent in Minneapolis in September 2015.

Initial engagements are very effective and a simple approach employed that yielded significant shared learnings was to request each site in the network to documented their best five energy projects in the previous five years (entitled ‘Top 5 in 5’). Projects were then summarized under the key headings (shared learning or meaningful innovations) and disseminated across the network. This proved a very low cost and high impact approach to create an initial energy efficiency database. It also had the added benefit of each site contributing positively to the process and effectively advancing the ‘team building’ process.

Table 10. GEMS selected two years of shared learnings.

Topic	**Date**	**Type**
Galway Facilities – 3-year Cost Reduction Planning	Jun-14	MI
GL Alignment 2105	Jul-14	MI
GFUM ISO50001 overview	Oct-14	MI
The journey to Energy Star Certification	Nov-14	SL
Overview of the GEMS proposal	May-15	SL&MI
Tri-Generation overview [Technical aspects & GFUM Capital approval process]	Jun-15	SL
Energy Management Training options overview	Jul-15	MI
Turning the EM^3 into action plans	Nov-15	SL&MI
BSC Sustainability overview [Energy Impact]	Feb-16	MI
2015 Opex Report	Mar-16	MI
GEMS Phase 2 Audit update	May-16	MI
GEMS Phase 1 KPI's	Jul-16	MI

SL: Shared Learning; MI: Meaningful innovation

From the Table 10, shared learning (SL) implies new, interesting knowledge about a specific topic that is being disseminated across the network. Meaningful innovation (MI) is the dissemination of new ‘good practices’ being implemented in BSC. It can be seen how several experiences and good practices have been appropriately shared with the whole network of sites.

The global communication forum has proven a useful tool in disseminating the ongoing work on the implementation of GEMS which can be seen from the EM^3 results (Figure 7). Additionally, as part of the shared learnings a pillar, it was requested for all primary owners to receive and obtain certification on energy management which in turns supports the implementation of the GEMs beyond the EU pilot sites.

5.2.4.1 Broader Dissemination

In order to truly make an impact inside and outside the corporation a broad dissemination strategy shall be adopted. In this case study, broad dissemination material has started to be prepared first to reach out to the whole workforce in BSC in the form of interactive screen to showcase GEMS and to be displayed in high location in all sites. This form of presentation will serve two purposes: (a) Increase dissemination and educate stakeholders on the progress accomplished by the implementation of GEMS; (b) add a physical presence that highlights the corporation’s commitment to sustainability and energy reduction.

The graphical user interface development and results fall outside the scope of this research work. However, it can be said that it includes several interactive screens showing and explaining different elements of GEMS such as the EM^3 and KPIs and how the whole corporation is progressing in sustainability. It will also display current and finished projects that contribute to the corporation’s energy policy.

5.3 Decision support framework

GEMS’ DSF will present top management, in a single placeholder, the aggregated information (coming from all the pillars) to enable informed decisions. At the current state of development, the DSF is a spreadsheet as shown in Table 11.

Table 11. GEMS DSF

Project	Invest. Model	Proposal parameters						MCDM Output	KPI	EM^3
		Total Project Cost ($)	Opex Savings p.a. ($)	Site Utility Saving %	Sustainability Impact					
						Site	Network			
P1	Capital	2,575,000	588,000	15%	1,722 tCO_2	14.7%	1.9%	3	134	2.4
P2	Capital	1,346,000	648,000	49%	1,519 tCO_2	25.0%	1.5%	2	128	2.2
P3	Capital	1,250,000	347,000	14%	0.0 tCO_2	0.0%	0.0%	4	97	2.2
P4	Capital	800,000	308,000	10%	625 tCO_2	9.0%	0.5%	5	78	2.1
P5	Power Purchase Agreement	0	175,000	6%	750 tCO_2	11.0%	0.6%	1	78	2.1

As shown in Table 11, relevant parameters are presented in concise way thus providing reader with an efficient mechanism to make informed decision making on where and how to spend capital for energy efficiency projects. From Table 11 it can be seen that the best ranked MCDM project (P5 – Solar PV) is not necessarily is the one with the highest utility savings or CO_2 emissions impact. Second in the rank was the project with the best financial and second best sustainability parameters albeit it requires capital funding.

The MCDM score does not necessary determine the order for funding. The aim of the DSF is to ensure top management have all the necessary site characteristics and performance trends from the proposed implementation sites coupled with the proposal parameters. Overall corporate policy and site production strategies (of which only top management may be informed) can determine the best location for investment.

The DSF added value lies in the systematic, repeatable and scalable approach to evaluating all energy capital projects under the same criteria and allowing a final decision with all the relevant information made available in an understandable and simplified manner.

6 CONCLUSIONS

This research work has presented the methodological approach for assessing capital expenditure projects in a multi-site organisation. Implementation steps for GEMS naturally should follow a bottom up and left to right approach (Figure 1). Additionally, several components can be developed in parallel depending on available resources and current needs without major alterations on GEMS outputs. Key conclusions to date are:

- The proposed methodology is in itself novel. It complements typical site-based EnMS and provides any corporation with a formal framework to ensure optimal energy efficiency across the network and informed decision making on capital expenditure.

- Foundations:

    - The global energy team and communication forum is a prerequisite to all other efforts and needs to be carefully planned and resourced. The meeting logistics should be centrally coordinated by the global energy leader. Engagement effort from the site coordinators needs to be kept to a minimum. This further underlines the importance of 'pooling' the efforts to ensure maximum reward for minimum efforts;

    - Establishing a split of the network's expenditure known as 'network wheel of spend' showing the impact of energy is recommended early in the process. Knowing the energy expenditure figures will help management buy-in to the GEMS process. Furthermore, if the energy expenditure is presented in a network 'wheel of spend' that does not include uncontrollable factors (e.g. depreciation, taxation, rental and insurance) the energy spend and therefore the importance of a GEMS implementation will be further emphasised;

    - Key global energy parameters need to be tracked and monitored centrally. Depending on the size and complexity of the organisation this can range from a spreadsheet saved to a shared location up to a corporate level commercial offering;

    - By using maximum and minimum parameters on the acceptable return on investment for energy projects it is possible to quantify the 'financial' magnitude that the scope GEMS will govern. This can be done ahead of any corporate agreement on energy policy and is an enabler for deployment of the GEMS;

    - From experience, the initial funding request for a GEMS deployment can prove an excellent mechanism to initiate a more detailed discussion on corporate energy policy at board level.

- Pillars:

    - Benchmarking and performance evaluation through the combination of both quantitative KPIs and qualitative EM^3 results is novel since it condenses large amounts of information into two values that can be grasped at a glance.

    - Evaluating the maturity of the corporation in terms of energy management has proven fundamental in developing the business case for GEMS full roll out and also to implement the corporate energy strategy;

    - The possibility to develop a mechanism for a yearly evaluation of the whole network has proven particularly useful in engaging with all the sites to include energy management concept in their activities;

- The development of the energy strategy pillar has allowed for an un-biased evaluation of all the energy projects seeking funding in the corporation. Traditionally this is implemented in disconnected manner without realising the potential benefits brought by the aggregation of the information and dissemination of the projects;

- The outputs of the MCDM are twofold. On the one hand, they elucidate the relative priorities given by this multi-site corporation to the environmental, economic, social and technical dimensions of energy improvement projects. On the other hand, they provide an objective prioritisation guide for resource allocation, which highlights the top ranked projects;

- Shared learning and dissemination has grown from internal global forum meetings to actively seeking for new ways and ideas to ensure GEMS is widely known across the network and possibly outside the corporation. This pillar has also allowed the corporation to look outside its boundaries to its immediate competition and understand their positioning on sustainability and energy efficiency which has then been added to the body of information available for decision making;

- The DSF enables assessing, against the predefined corporate energy policy, if the need to improve the performance of one site out-weights the importance placed on the MCDM output for each individual project. If fact, the driver for capital investment may be to bring all sites to an acceptable level of performance (impossible to establish without all the GEMS steps) and then generate a list of projects to be implemented. This enables energy to become an asset that is maintained and invested in to ensure optimum running costs across the network. With a site only approach this is non-existent.

7 FUTURE WORK

GEMS methodology will continue to be developed. Key deliverables of the future work will be:

- GEMS audit framework functional for all sites and conducive to establishment of KPI's for benchmarking. Audit reports and data entry templates to be specified;

- Corporate level metering plan to support the KPI's. Framework to automate constructed KPI's;

- A bespoke matrix of technology solutions will be developed for the corporation appropriate to its geographical locations.

- Develop standardised templates for all sites to follow when requesting corporate funding for energy conservation projects.

- A strategy for rewards and recognition;

- Best in class techniques for internal and external communications.

- DSF automation and usability improvement.

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9 REFERENCES

[1] OECD, "OECD Environmental Outlook to 2050," OECD Publishing, 2012.

[2] M. Leahy, J. L. Barden, B. T. Murphy, N. Slater-thompson, and D. Peterson, "International Energy Outlook 2013," 2013.

[3] L. Pérez-Lombard, J. Ortiz, and C. Pout, "A review on buildings energy consumption information," *Energy and Buildings*, vol. 40, no. 3, pp. 394–398, 2008.

[4] International Energy Agency, "Tracking Clean Energy Progress 2014," International Energy Agency, 2014.

[5] C. Cooremans, "Make it strategic! Financial investment logic is not enough," *Energy Efficiency*, vol. 4, no. 4, pp. 473–492, 2011.

[6] E. Worrell, L. Bernstein, J. Roy, L. Price, and J. Harnisch, "Industrial energy efficiency and climate change mitigation," *Energy Efficiency*, vol. 2, no. 2, pp. 109–123, 2009.

[7] E. Worrell, J. A. Laitner, M. Ruth, and H. Finman, "Productivity benefits of industrial energy efficiency measures," *Energy*, vol. 28, no. 11, pp. 1081–1098, 2003.

[8] T. Nehler and J. Rasmussen, "How do firms consider non-energy benefits? Empirical findings on energy-efficiency investments in Swedish industry," *Journal of Cleaner Production*, vol. 113, pp. 472–482, 2016.

[9] R. Eccles, I. Ioannou, and G. Serafeim, "The Impact of Corporate Sustainability on Organizational Processes and Performance," *NATIONAL BUREAU OF ECONOMIC RESEARCH*, vol. White Pape, 2012.

[10] D. Williamson, G. Lynch-Wood, and J. Ramsay, "Drivers of environmental behaviour in manufacturing SMEs and the implications for CSR," *Journal of Business Ethics*, vol. 67, no. 3, pp. 317–330, 2006.

[11] M. Pye and A. McKane, "Making a stronger case for industrial energy efficiency by quantifying non-energy benefits," *Resources, Conservation and Recycling*, vol. 28, no. 3–4, pp. 171–183, 2000.

[12] Carbon Trust, "Energy management—a comprehensive guide to controlling energy use," 2011.

[13] A. McKane, D. Desai, M. Matteini, W. Meffert, R. Williams, and R. Risser, "Thinking Globally: How ISO 50001-Energy Management can make industrial energy efficiency standard practice," *Lawrence Berkeley National Laboratory*, pp. 65–76, 2010.

[14] P. Therkelsen, R. Sabouni, A. McKane, and P. Scheihing, "Assessing the costs and benefits of the superior energy performance program," *ACEEE Summer Study on Energy Efficiency in Industry*, no. July, 2013.

[15] K. Vikhorev, R. Greenough, and N. Brown, "An advanced energy management framework to promote energy awareness," *Journal of Cleaner Production*, vol. 43, pp. 103–112, Mar. 2013.

[16] P. Antunes, P. Carreira, and M. Mira da Silva, "Towards an energy management

maturity model," *Energy Policy*, vol. 73, pp. 803–814, 2014.
[17] K. Bunse, M. Vodicka, P. Schönsleben, M. Brülhart, F. O. Ernst, P. Sch??nsleben, M. Br??lhart, and F. O. Ernst, "Integrating energy efficiency performance in production management - Gap analysis between industrial needs and scientific literature," *Journal of Cleaner Production*, vol. 19, no. 6–7, pp. 667–679, Apr. 2011.
[18] ISO, *ISO 50001:2011 - Energy management systems — Requirements with guidance for use*. ISO - International Organization for Standardization, 2011.
[19] V. D. Ingenieure, "VDI – Guideline 4602," *Energy*, no. October, pp. 1–66, 2007.
[20] US EPA, *ENERGY STAR Guidelines for Energy Management Overview*. U.S. Environmental Protection Agency, 2013.
[21] US Department of Energy, "Superior Energy Performance Certification Protocol," *SEP resource*, 2012.
[22] L. Pérez-Lombard, J. Ortiz, I. R. Maestre, and J. F. Coronel, "Constructing HVAC energy efficiency indicators," *Energy and Buildings*, vol. 47, pp. 619–629, Apr. 2012.
[23] G. Boyd, E. Dutrow, and W. Tunnessen, "The evolution of the ENERGY STAR Ò energy performance indicator for benchmarking industrial plant manufacturing energy use *," vol. 16, pp. 709–715, 2008.
[24] V. Introna, V. Cesarotti, M. Benedetti, S. Biagiotti, and R. Rotunno, "Energy Management Maturity Model: An organizational tool to foster the continuous reduction of energy consumption in companies," *Journal of Cleaner Production*, vol. 83, pp. 108–117, 2014.
[25] E. W. T. Ngai, D. C. K. Chau, J. K. L. Poon, and C. K. M. To, "Energy and utility management maturity model for sustainable manufacturing process," *International Journal of Production Economics*, vol. 146, pp. 453–464, 2013.
[26] B. Jovanović and J. Filipović, "ISO 50001 standard-based energy management maturity model – proposal and validation in industry," *Journal of Cleaner Production*, vol. 112, 2016.
[27] N. Finnerty, R. Sterling, D. Coakley, and M. M. Keane., "Development of a global energy management system for the life sciences industry: an energy management maturity model implementation," in *Proc. of Global Cleaner Production & Sustainable Consumption Conference*, 2015.
[28] P. Rohdin and P. Thollander, "Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden," *Energy*, vol. 31, no. 12, pp. 1836–1844, Sep. 2006.
[29] P. Rohdin, P. Thollander, and P. Solding, "Barriers to and drivers for energy efficiency in the Swedish foundry industry," *Energy Policy*, vol. 35, no. 1, pp. 672–677, Jan. 2007.
[30] P. Thollander and M. Ottosson, "An energy efficient Swedish pulp and paper industry – exploring barriers to and driving forces for cost-effective energy efficiency investments," *Energy Efficiency*, vol. 1, no. 1, pp. 21–34, Feb. 2008.
[31] C. Cooremans, "Investment in energy efficiency: do the characteristics of investments matter?," *Energy Efficiency*, vol. 5, no. 4, pp. 497–518, Nov. 2012.
[32] J.-J. Wang, Y.-Y. Jing, C.-F. Zhang, and J.-H. Zhao, "Review on multi-criteria decision analysis aid in sustainable energy decision-making," *Renewable and Sustainable Energy Reviews*, vol. 13, no. 9, pp. 2263–2278, 2009.
[33] D. Meckstroth and J. Edmonds, "Usage of Energy Service Companies," Manufacturers Alliance for Productivity and Innovation (MAPI), Arlington, VA 22209, USA, 2014.
[34] P. Antunes, P. Carreira, and M. Mira da Silva, "Towards an energy management maturity model," *Energy Policy*, vol. 73, pp. 803–814, Oct. 2014.
[35] D. Lopez-Paleo and A. Negrón, "HVAC and Luminaries Retrofit Project at The Professional College of Engineers and Land Surveyors of Puerto Rico in Hato Rey,"

Energy Engineering, vol. 111, no. 1, pp. 40–59, 2014.
[36] R. Bird, A. D. Hall, F. Momentè, and F. Reggiani, "What corporate social responsibility activities are valued by the market?," *Journal of Business Ethics*, vol. 76, no. 2, pp. 189–206, 2007.
[37] A. Trianni, E. Cagno, and S. Farné, "Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises," *Applied Energy*, vol. 162, pp. 1537–1551, Jan. 2016.
[38] T. Nehler and J. Rasmussen, "How do firms consider non-energy benefits? Empirical findings on energy-efficiency investments in Swedish industry," *Journal of Cleaner Production*, vol. 113, pp. 472–482, Feb. 2016.
[39] M. B. Whaley, "Allergan's View of the Future for Energy Management," *Strategic Planning for Energy and the Environment*, vol. 33, no. 3, pp. 41–47, Jan. 2014.
[40] ARC Advisory Group, "White Paper: A Strategic Roadmap for Sustainable Energy Management and Energy Efficiency for Industrial, Commercial, Municipal and Manufacturing Operations," 2009.
[41] T. Fleiter, E. Worrell, and W. Eichhammer, "Barriers to energy efficiency in industrial bottom-up energy demand models—A review," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 6, pp. 3099–3111, Aug. 2011.
[42] S. Sorrell, A. Mallett, and S. Nye, "Barriers to industrial energy efficiency: a literature review," *United Nations Industrial Development Organisation*, vol. Working pa, p. 98 pp., 2011.
[43] E. Sardianou, "Barriers to industrial energy efficiency investments in Greece," *Journal of Cleaner Production*, vol. 16, no. 13, pp. 1416–1423, 2008.
[44] M. Deru, J. Kelsey, and D. Pearson, *Procedures for Commercial Building Energy Audits*. Atlanta, GA 30329: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2011.
[45] J.-J. Wang, Y.-Y. Jing, C.-F. Zhang, and J.-H. Zhao, "Review on multi-criteria decision analysis aid in sustainable energy decision-making," *Renewable and Sustainable Energy Reviews*, vol. 13, no. 9, pp. 2263–2278, Dec. 2009.
[46] J. Pope, D. Annandale, and A. Morrison-saunders, "Conceptualising sustainability assessment," *Environmental Impact Assessment Review*, vol. 24, pp. 595–616, 2004.
[47] J.-J. Wang, Y.-Y. Jing, C.-F. Zhang, G.-H. Shi, and X.-T. Zhang, "A fuzzy multi-criteria decision-making model for trigeneration system," *Energy Policy*, vol. 36, no. 10, pp. 3823–3832, 2008.
[48] T. Kaya and C. Kahraman, "Expert Systems with Applications Multicriteria decision making in energy planning using a modified fuzzy TOPSIS methodology," *Expert Systems with Applications*, vol. 38, no. 6, pp. 6577–6585, 2011.
[49] S. Contreras, "A multi-criteria decision method to prioritise energy improvement projects using sustainability criteria," 2016.
[50] D.-Y. Chang, "Applications of the extent analysis method on fuzzy AHP," *European Journal of Operational Research*, vol. 95, no. 3, pp. 649–655, 1996.
[51] CDP, "Carbon Action Report 2012 - Carbon Disclosure Project," 2012.
[52] European Parliament and Council of Europe, *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)*. 2010, pp. 13–35.
[53] World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI), "A Corporate Accounting and Reporting Standard," *Greenhouse Gas Protocol*, pp. 1–116, 2004.