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NATIONAL UNIVERSITY OF IRELAND, GALWAY

DEVELOPMENT OF A GLOBAL ENERGY MANAGEMENT SYSTEM FOR NON-ENERGY INTENSIVE MULTI-SITE MANUFACTURING ORGANISATIONS

by Noel Finnerty

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Abstract

Climate change and energy resource sustainability are both major challenges facing humanity today. Due to their scale, multi-site (and/or multi-national) manufacturing organisations (MMO), are large consumers of energy, typically with industrial bases across the globe to meet market demands. Increasing evidence shows an overall positive link from corporate environmental performance to improved corporate financial performance. This symbiotic relationship needs to be harnessed.

Non-energy intensive MMO provide an interesting focus group, representing a novel sector, with the resources, motivation and capacity through corporate social responsibility reporting to positively impact climate change and become leaders in industry with other sectors following suit. To avoid ad-hoc decision-making and improve the effectiveness of capital spending in terms of corporate social responsibility whilst maximizing return on investment it is necessary to develop an approach for assessing projects in an unbiased fashion at a global level.

This thesis presents the development and implementation of a novel Global Energy Management System (GEMS) to enable non-energy intensive MMO reach optimal energy efficiency performance whilst meeting corporate energy and carbon emission reduction goals. It outlines the steps at a global level whilst complementing existing 'site based' energy management systems. In addressing further gaps identified during the literature review a novel energy management maturity model was developed, providing a global view of the overall network readiness for engaging in energy efficiency.

The thesis further contributes to closing the energy efficiency gap by addressing the formulation of a long-term energy policy and associated strategy based on best practice. It culminates with a systematic, repeatable and scalable decision support framework, underpinned by a multi-criteria decision-making methodology that uses economic, environmental, social and technical criteria. The GEMS methodology was applied to a Fortune 500 non- energy intensive MMO and global leader in the medical device sector – Boston Scientific Corporation. The results include a company commitment to carbon neutrality with unpresented levels of capital invested into energy efficiency projects. It is now the corner stone of BSC's approach to energy management both at a site level and corporate level. GEMS is well and truly engrained into the BSC culture and is front and centre to any energy related sustainability discussions within BSC and with external stakeholders.

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Declarations

This dissertation is the result of my own work, except where explicit reference is made to the work of others. It has not been submitted for another qualification to this or any other University.

Noel Finnerty

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To the GEMS team:

My research supervisors, Dr. Raymond Sterling, Dr. Daniel Coakley and Dr. Marcus Keane. I cannot thank you enough for your invaluable support and guidance throughout this project. It was Marcus who planted the seed for me to take on this research and saw the potential in GEMS to become a special industrial / academic collaboration. Dan provided much needed structure, especially in the early days of research and always with a smile. Ray was a powerhouse throughout, in his own understated fashion.

Paul Donhauser, VP of Global Real Estate and Facilities BSC, started this journey over a decade ago with the GFUM and backed me on the GEMS venture without hesitation, a visionary.

Sergio Contreras and Ronan Coffey, both true gentlemen complete the GEMS team. Sergio, a remarkable mind, was the catalyst for many a philosophical debate in room 1028. Ronan's GEMS journey continues and is now deservedly, the global energy manager for BSC.

The work ethic of this team combined with the friendships formed has made this an experience I will always cherish.

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My parents, for all they have done for me throughout the years. Sadly, Dad passed away during the GEMS journey, losing his battle to Alzheimer's disease. Ironically, he provided me with inspiration when it was most needed in the early days of literature review. Mam, always a cool head when needed and a great source of sound advice (although not always scientifically backed!). My sisters, Fiona and Joan for their support and words of encouragement always.

Dedication

To Angela

List of Abbreviations

AHP	Analytical Hierarchy Process
AHU	Air Handling Unit
ASHRAE	American Society if Heating Refrigeration Air Conditioning Engineers
BCP	Business Continuity Process
BSC	Boston Scientific Corporation
CDP	Carbon Disclosure Project
CO_2	Carbon dioxide
CO_2-eq	CO_2 equivalent
CFP	Corporate Financial Performance
CSR	Corporate Social Responsibility
DSF	Decision Support Framework
EC	European Commission
EEM	Energy Efficiency Measure
EH&S	Environmental, Health & Safety
EJ	Exajoule (1 EJ = 10^{18} joule)
EEM	Energy Efficiency Measures
EM	Energy Management
EM^3	Energy Management Maturity Model
EnMS	Energy Management Systems
EU	European Union
FL	Fuzzy Logic
GEMS	Global Energy Management System
GHG	Greenhouse Gas.
GWhrs	Giga-Watt hours
IEA	International Energy Agency

IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KPI	Key Performance Indicator
MMO	Multi-site (and/or multi-national) Manufacturing Organisation(s)
MCDM	Multi-criteria decision method
NEB	Non-Energy Benefits
OECD	Organisation for Economic Cooperation and Development
PPA	Power Purchase Agreements
REC	Renewable Energy Certificates
SEU	Significant Energy Users
TBL	Triple bottom line
TFN	Triangular Fuzzy sets
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UNFCCC	United Nations Framework Convention on Climate Change
ppm	parts per million

1 Introduction

"Opportunity is missed by most people because it is dressed in overalls and looks like work" – Thomas Edison.

Climate change is a major environmental sustainability challenge, one which will define our generation. Its outcomes will have long term implications for individuals, businesses and multi-national organisations (Stern, 2006). Climate Change is real, its ***affect*** is felt across the globe on an ever-increasing frequency through catastrophic weather events such as flooding and hurricanes, resulting in the loss of human life and causing our poorest economies to spiral into further poverty. Figure 1-1 shows the link between energy consumption and climate change.

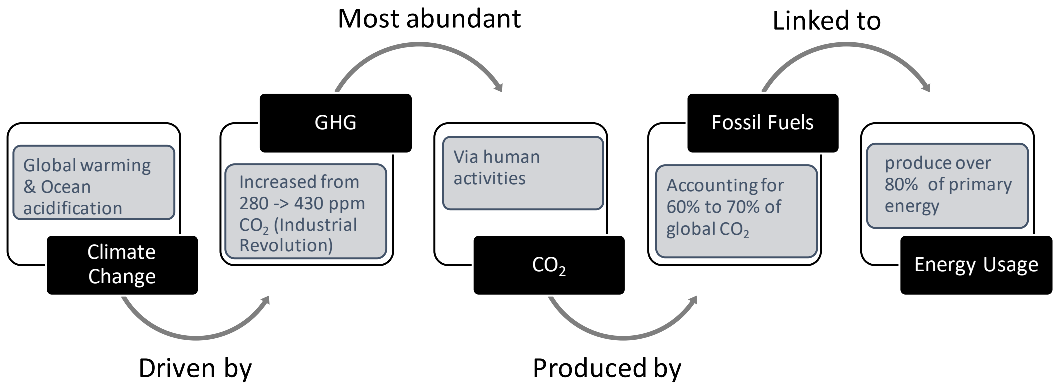

Figure 1-1. Energy usage link to Climate Change

A leading ***cause*** of Climate change is greenhouse gas (GHG) emissions. Carbon dioxide (CO_2) is classified as a greenhouse gas and while it is not the only GHG contributing to the problem, it is the most abundant GHG produced by human activities (IPCC, 2005). GHG emissions, commonly referred to as CO_2 equivalent (CO_2-eq) or even sometimes simply CO_2, is created as a by-product of consuming fossil fuels such coal, petroleum and natural gas as energy sources (Thollander, Danestig and Rohdin, 2007). The current level of greenhouse gases in the atmosphere is equivalent to around 430 parts per million (ppm) CO_2, compared with only 280ppm before the Industrial Revolution. This has been primarily attributed to increased use of fossil fuels, particularly since the industrial revolution (Figure 1-2).

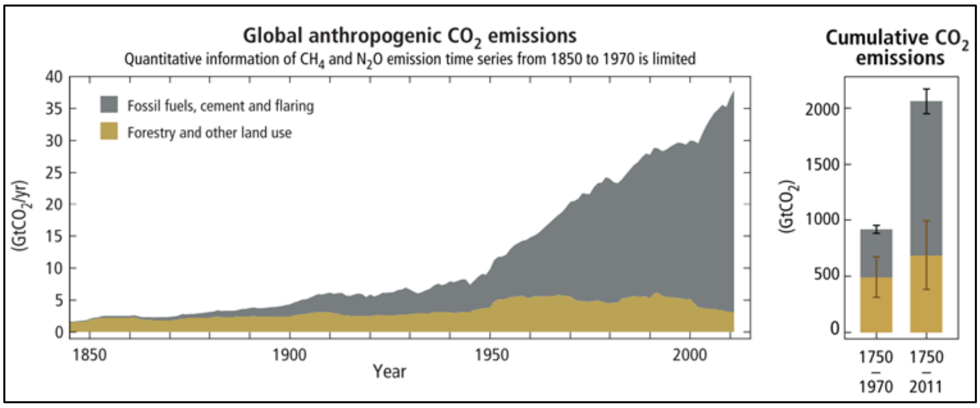

Figure 1-2. Annual global anthropogenic carbon dioxide (CO_2) emissions (gigatonne of CO_2 -eq per year, GtCO2 /yr) from fossil fuel combustion, cement production and flaring, and forestry and other land use (FOLU), 1750–2011 (IPCC, 2014)

An estimated 81%-82% of the world's total primary energy supply was derived from fossil fuels in the period from 2008 to 2013 (IEA, 2015) . This type of energy source is polluting and depletes the earth's resources (Peura, 2013). The combustion of these fossil fuels generated between 60% and 70% of global CO_2 emissions in the same period (IEA, 2015). Given the direct relationship between GHG's and global warming (IEA, 2016) (IPPC, 2014), efforts to reduce GHG's emissions merits industrial and academic focus. To mitigate global GHG emissions, reductions in the order of 50–80% are required by 2050, in comparison to year 2000 baseline (Fitzpatrick and Dooley, 2017).

Furthermore, other negative effects observed include the absorbtion of CO_2 by the world's oceans. As emissions have risen, the resultant acidification of those same oceans is leading to ecological and biological changes, while the continuously rising atmospheric concentration of CO_2 leads to global warming and thus climate change. The Arctic Sea Ice Retreat is just one example. The extent of Summer arctic sea ice declined to unprecedentedly low levels in September 2007 (Stroeve and Serreze, 2008a), as evidenced in Figure 1-3. This decline has been attributed to the progressive rise in mean air temperature over the past two centuries.

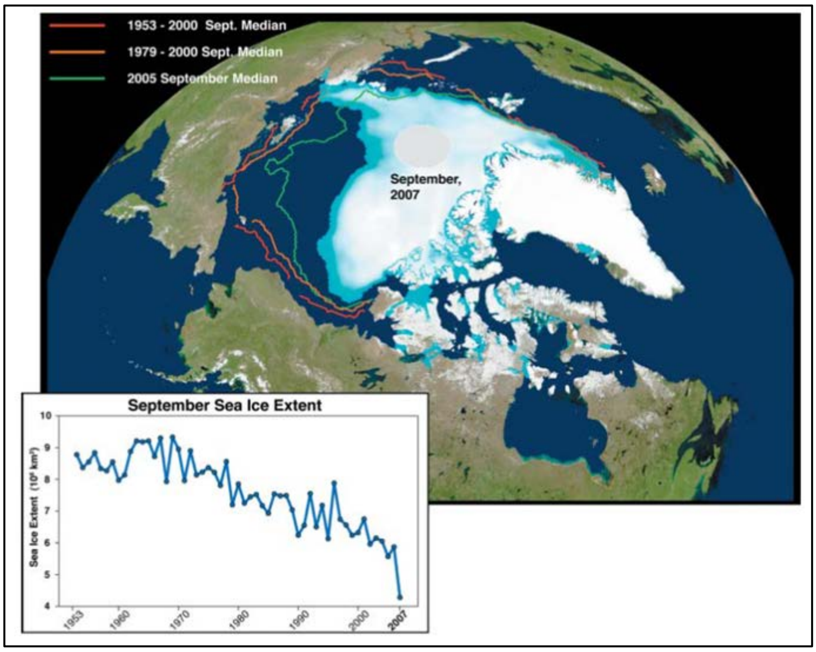

Figure 1-3. Sea ice concentration for September 2007, along with Arctic Ocean median extent ((Stroeve and Serreze, 2008b)*) September ice extent time series from 1953 to 2007 is shown at the bottom ((Intergovernmental Panel on Climate Change, 2007)*

Unfortunately, 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 (Leahy *et al.*, 2013) (Figure 1-4).

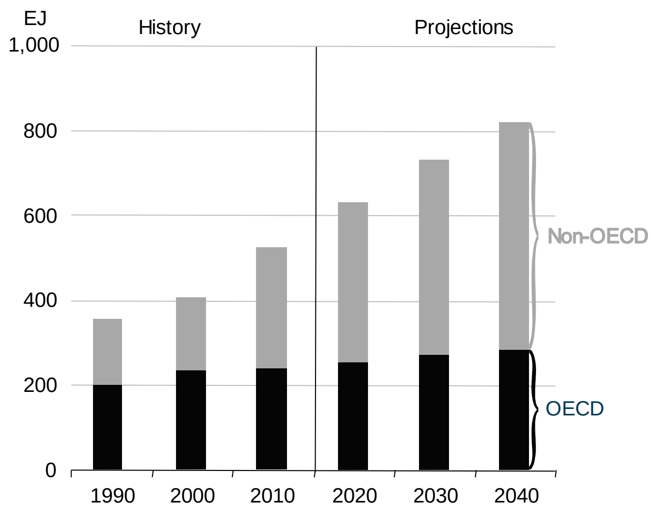

Figure 1-4. World energy consumption, 1990-2040 (EJ) (Leahy *et al.*, 2013)

There are a number of key factors contributing to this rise, such as population growth, urbanisation, further ***industrialisation*** and increasing energy use per capita (International Energy Agency, 2014). Current world population is in excess of 7 billion people and it is expected to reach 9 billion by 2048 (Figure 1-5), much of which is attributable to the growth in cites. This will naturally further strain our planet's natural resources.

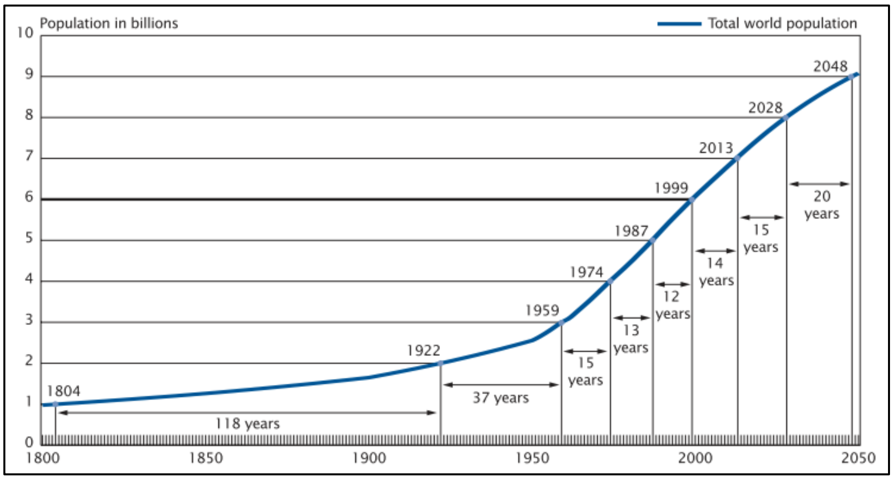

Figure 1-5. World Population Growth, 1800-2050, time to successive billions (Rowe *et al.*, 2004)

At present, over half of the world's population live in urban areas. By 2050, the population living in urban areas is projected to reach 6.3 billion (United Nations, 2011). Urbanisation has the added effect of increasing energy consumption per capita, with recorded energy use intensities for urban dwellers 10 times greater than their rural counterparts (Crompton and Wu, 2005) (Dhakal, 2009). To date this growth has been largely associated with finite fossil fuels in industrialized nations with a resultant increase of global CO_2 emissions (Figure 1-6). While renewables are growing progressively, it is uncertain if they can grow to meet the fossil fuel 'gap'.

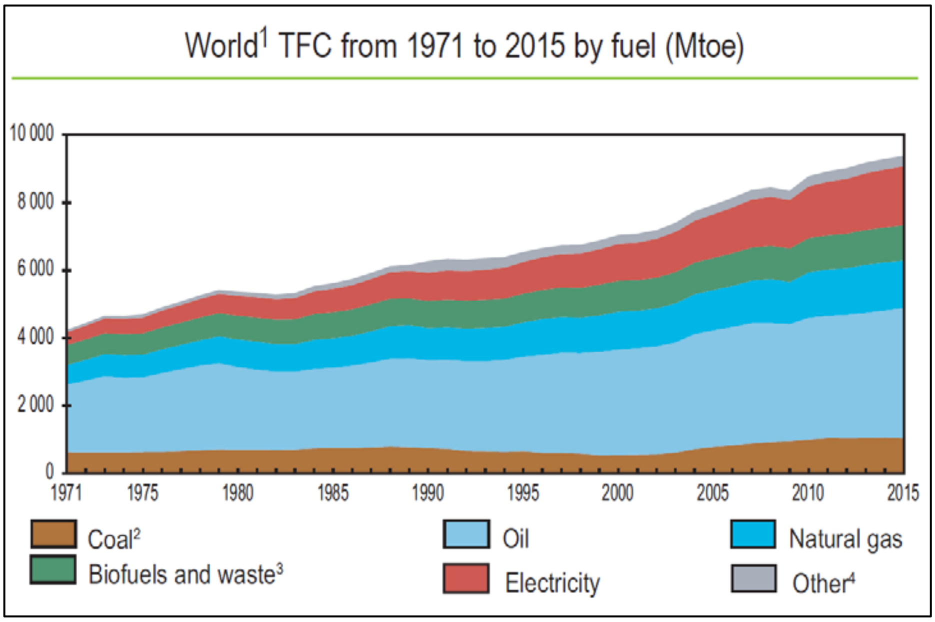

Figure 1-6. World Total Final Energy Consumption (TFC) by fuel ((International Energy Agency (IEA), 2017)) [1]

Final energy consumption is usually divided into the main sectors shown (Figure 1-7). Manufacturing alone accounts for almost a quarter of all energy consumption.

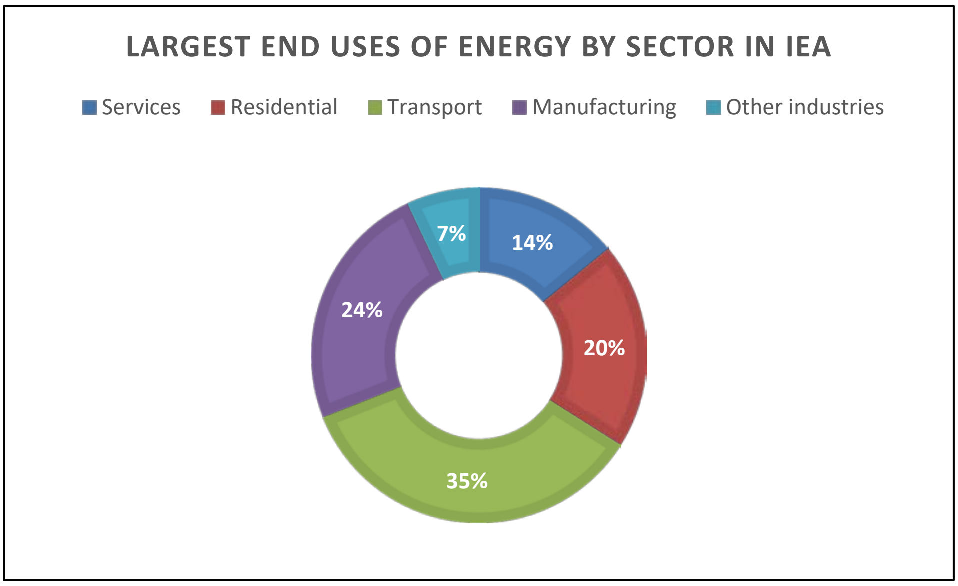

Figure 1-7. Final energy consumption by sector (International Energy Agency (IEA), 2017)

As evidence points to rising energy consumption as a primary cause of increased CO_2 production, the most effective way for industry to achieve carbon emissions reduction is through the implementation of ***Energy Management*** (EM), ***Energy Management Systems*** (EnMS)

[1] International Energy Agency data. Data from within graph: World includes international aviation and international marine bunkers[1]. In these graphs, peat and oil shale are aggregated with coal[2]. Data for biofuels and waste final consumption have been estimated for a number of countries[3]. Includes heat, solar thermal and geothermal[4].

and ultimately ***Energy Efficiency Measures*** (EEM) (Costa-Campi, García-Quevedo and Segarra, 2015). In literature, these terms are sometimes used interchangeably, thus a clear definition is beneficial at this early stage in the thesis, (Finnerty *et al.*, 2016) and Figure 1-8.

- Energy Management (EM) is the systematic monitoring and control of energy related activities (Kanneganti *et al.*, 2017);
- Energy Management System (EnMS) is the procedure or strategic steps put in place to achieve effective energy management [e.g. ISO 50001 (ISO, 2011), GEMS ((Finnerty *et al.*, 2017)];
- Energy Efficiency Measure (EEM) is the implementation of actions aimed at improving the efficient use of energy (Bunse *et al.*, 2011) [e.g. improve the ratio of useful output vs energy input (Herring, 2006)] under the governance of the EnMS and aligned with the pursuit of EM.

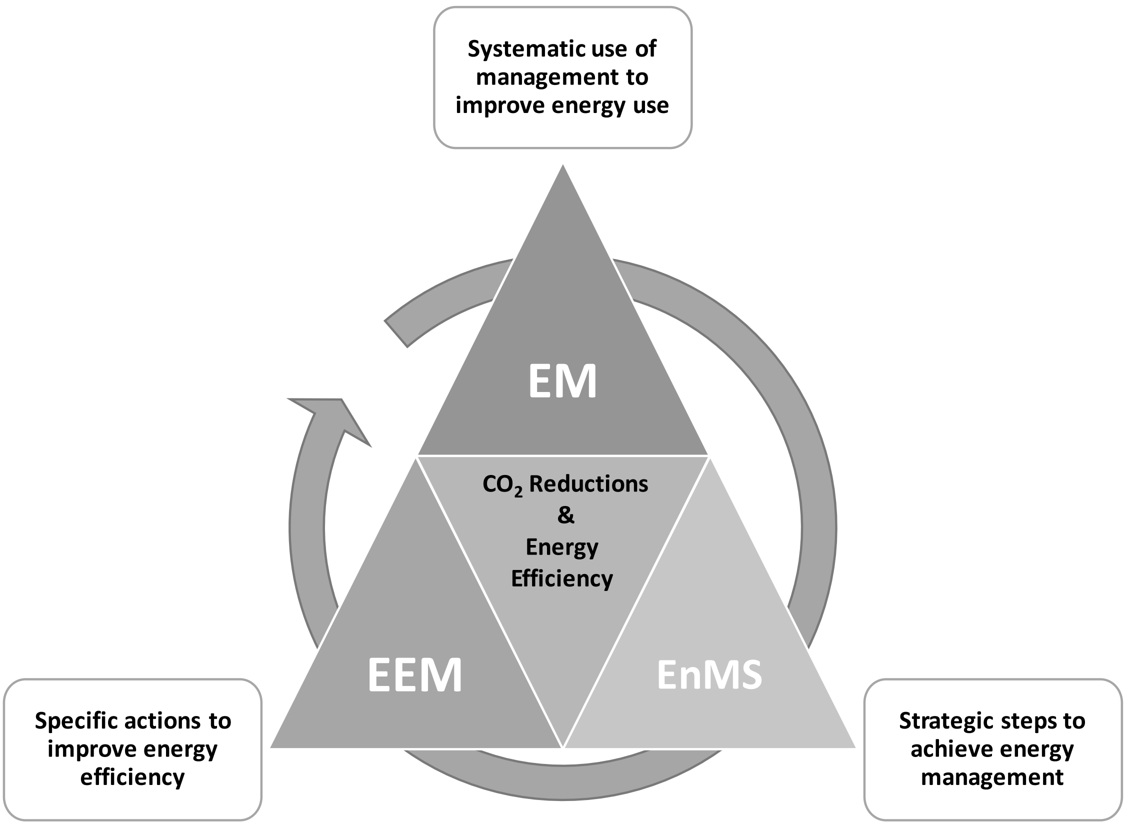

Figure 1-8. Energy management vs. energy management system vs. energy efficiency measure

EM and EnMS represent a real opportunity to improve overall energy efficiency through EEM leading to more sustainable economic growth while simultaneously minimizing environmental and social impact. Energy efficiency and its further increase, represents one of the pathways to mitigate climate change (European Commission, 2011). It is worth noting, EEM typically require capital investment. For example, the European Union (EU) decarbonisation target for 2050 alone is expected to require EUR 4.25 trillion in additional energy efficiency investments above the business-as-usual scenario (Hrovatin, Dolšak and Zorić, 2016).

The challenge we face is enormous and society will need to make critical choices that could alter the course of human history and affect the wellbeing of our planet for generations to come. The aforementioned factors such as population growth, urbanization and industrialization are certainly contributing to climate change. However, these factors are measurable, well understood and documented. Factors such as security of supply and political instability, are more volatile and potentially more impactful to the delicate balance of the complex equation that is 'Global Energy Sustainability'. The threat of economic loss due to global warming has created a driver for governments and the public to manage CO_2 emissions, conversely, rising energy consumption can be viewed as a sign of strong national economic growth and thus politically favourable. One pathway to achieve both goals is utilizing sustainable energy consumption practices to slow and ultimately eliminate environmental degradation through EM.

There is hope. As part of a global response, the United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992 to provide a framework for policy making to mitigate climate change. The Kyoto Protocol (UNFCCC Secretariat, 1997) and its successor, the Copenhagen Accord (UNFCCC Secretariat, 2009) aimed to establish an international agreement to mitigate GHG emissions, particularly amongst the highest contributors. The Paris Agreement (UNFCCC, 2016) represents a new departure in international efforts to address climate change, with an unprecedented 197 parties agreeing to pursue a course of action with the following aim: "*Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change*" (UNFCCC, 2016)

Aligned with this global trend, this research will focus on improving the EM and EnMS associated with industrial manufacturing multisite organisations with a view to reach optimal energy efficiency and associated capital spend on EEM across the organisation, whilst in parallel meeting commitments to sustainability goals.

This chapter will continue with an overview of key focus areas for the problem at hand, sections 1.1 to 1.3. The solution in the form of the knowledge gaps, research question and proposed approach are outlined in section 1.4 and 1.5. Sections 1.6 to 1.8 presents the thesis novelty, structure, case study and dissemination achieved during this research work. Figure 1-9 captures this flow.

It is important to point out these sections contain a synopsis of the key findings on the subject matter. Chapters 2 to 4 provide an in-depth review as published journal papers, whilst chapter 5 and 6 are developed from conference papers. Chapter 7 contains conclusions and future work from the thesis research as a whole.

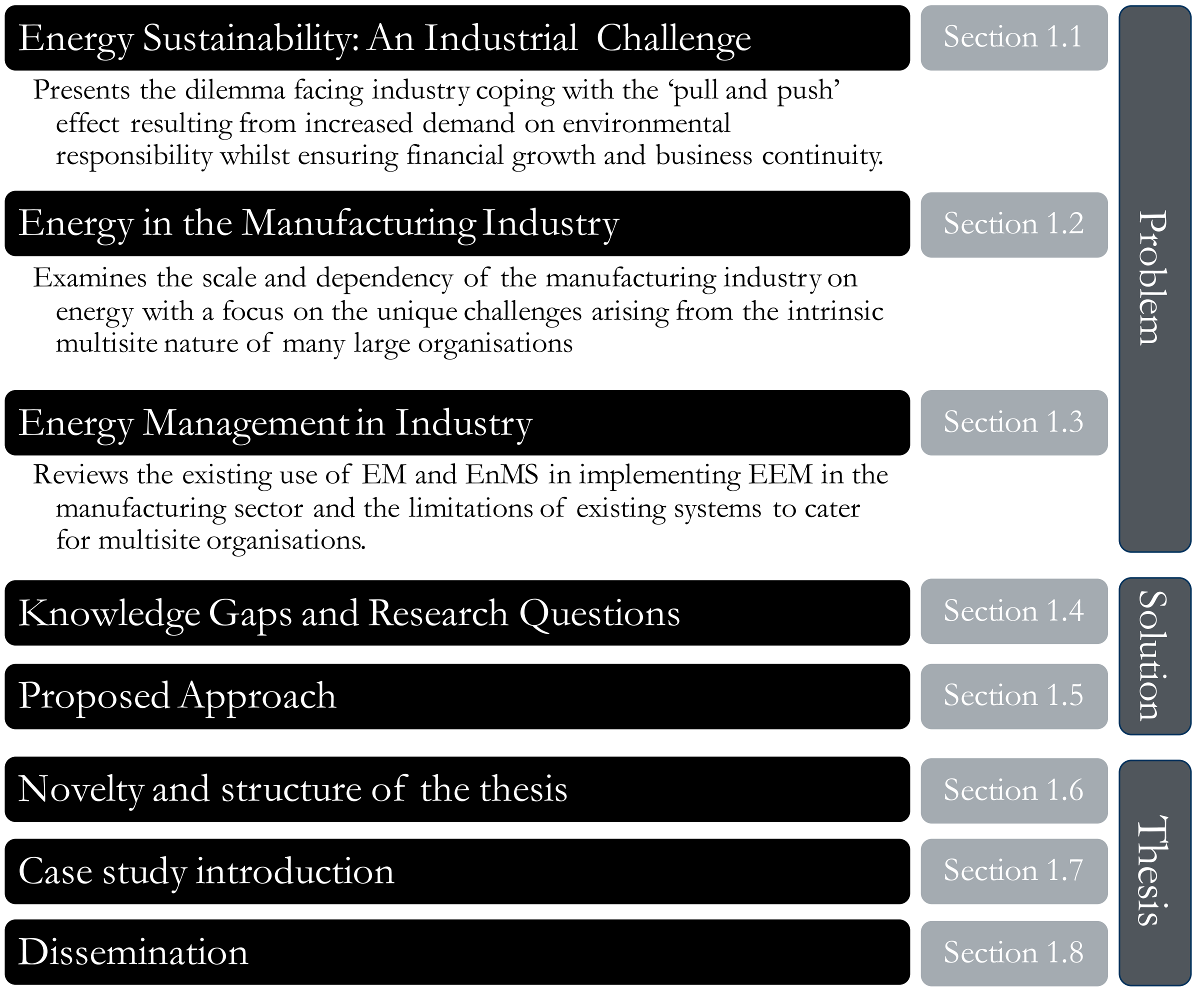

Figure 1-9. Flow Diagram - Sections Overview

1.1 Energy Sustainability – An Industrial Challenge

A primary motivation driving this research is energy sustainability and climate change mitigation. Carbon emissions reduction is primarily achieved either when imposed by a regulatory framework because of environmental concerns (Almutairi and Elhedhli, 2014), or when the economic and financial benefits associated with reduced emissions are clearly presented and understood by decision makers (Cooremans, 2012; Ouyang and Shen, 2017). This section will examine key factors that will influence industrial carbon emission reductions to enable a sustainable energy future outside the regulatory framework, such as economic factors and Corporate Social Responsibility (CSR).

From the regulatory standpoint, progress will be driven by government response to global initiatives such as the Paris Agreement (UNFCCC, 2016) and its translation into national directives. However, improvement in energy performance and reduction of CO_2 emissions across all industrial sectors is imperative to the success of such initiatives.

Due to government legislation and increasing awareness among the public (e.g. EU 2030 Energy strategy) to protect the environment, firms today cannot ignore environmental issues if they want to survive in the global market (Büyüközkan and Çifçi, 2012). The 2010 supply chain report from the Carbon Disclosure Project (CDP) states that more than half of the members surveyed said that in the future, they would cease doing business with suppliers that do not manage their carbon emissions wisely (Liou, 2015).

Improved public image is one of a number of 'Non-Energy Benefits' (NEBs) associated with implementation of EEM (May *et al.*, 2016). There is also a growing consensus among researchers that organisations pursuing systematic and continuous EM have stronger financial performance (Böttcher and Müller, 2014; Martí-Ballester, 2016; Sáez-Martínez *et al.*, 2016; Bergmann *et al.*, 2017). Environmental concerns for innovation are becoming more common as firms are more aware of the consequences of their activities and attempt to be socially responsible (Sáez-Martínez *et al.*, 2016). Although customer willingness to pay for environmental improvements tends to be low, firms are exposed to the creation of new market opportunities that arise from consumers' awareness that their choices can help reduce the environmental impact of production (De Marchi, 2012). Nevertheless, sometimes firms are not able to recognize the cost saving potential of environmental innovations in terms of energy or material savings. In those cases, environmental policy measures are needed to support firms in detecting and understanding those cost saving potentials, fostering the introduction of new cleaner production systems and other green innovations (Horbach, 2008).

Large companies are likely to respond to the environmental demands for the following reasons:

(1) Pressure from stakeholders to adopt environmental strategies because they are highly visible and thus easy to hold accountable for the environmental impact of their business activities on society (Serafeim, 2014)

(2) Available financial resources to make the investments required to implement sustainable energy systems (Martí-Ballester, 2017)

Fitzpatrick and Dooley (2017) profile the experience of a leading industrial processor, Interface Inc. (carpet tile manufacturer and sale) and their founder Ray Anderson, trying to embed sustainability within industry. Between 1996 and 2008 Interface reduced GHG emissions by 71% in absolute terms. It was mainly achieved as follows:

- 40% through improved energy efficiency, utilization of natural gas, elimination of wastes and introduction of renewables;
- 60% through verifiable offsets (funding the planting of trees remotely).

This case-study shows that Interface reduced its GHG emissions per unit of product by over 50% in a 12-year period. However, this is reduced to about 30% in absolute terms because of economic growth of about 60% during the same period. These numbers highlight the major difficulties that even a company that is highly committed to environmental sustainability has in trying to move towards zero GHG emissions as part of a program to eliminate environmental impact from its products.

Meta-studies provide evidence that corporations managing their environmental performance achieve a higher Corporate Financial Performance (CFP) than their competitors which do not (Endrikat, Guenther and Hoppe, 2014). A recently published meta-analysis includes around 2,200 studies and findings. It indicates an overall positive link from environmental, social, and governance criteria to CFP (Friede, Busch and Bassen, 2015). This leads to an overall win-win situation for corporations as well as for the natural environment. (Bergmann *et al.*, 2017). Thollander (2010) further concludes that a higher level of energy efficiency leads to improved CFP. Considering that CFP is an essential indicator of firm performance and corporate survival in the long term (Bergmann *et al.*, 2017), corporations should be quite willing to implement energy efficiency measures. Therefore, despite the legal requirements, the climatic effects and positive financial business cases, many EEM (technological or managerial) opportunities are not implemented. This results in a sub-optimal performance level, estimated to account for 25% of the energy reduction opportunity (Commission of the European Communities, 2006), referred to in literature as the ***energy efficiency gap*** (Thollander and Ottosson, 2010). It is a result of the interaction between energy efficiency barriers and drivers that negatively affect an organisation's decision-making processes in energy efficiency.

Industrial corporations often focus on other, more economically relevant issues (Sardianou, 2008a), such as reducing personnel expenses. Even when organisations are willing to improve their energy performance, they lack appropriate decision support tools that allow for positive business models. Examples include tools for evaluating energy efficiency investments (Trianni, Cagno and Farné, 2016) that account for appropriate cost-benefit analysis (Bunse *et al.*, 2011).

1.2 Energy in the Manufacturing Industry

The industrial sector uses more delivered energy[2] than any other end-use sector, consuming about 54% of the world's total delivered energy. The industrial sector can be categorized by three distinct industry types (Conti *et al.*, 2016):

- energy-intensive manufacturing;
- non-energy intensive manufacturing;
- nonmanufacturing.

In the International Energy Outlook 2016 (Conti *et al.*, 2016) reference case, worldwide industrial sector energy consumption is projected to increase by an average of 1.2%/year, from 234 EJ in 2012 to 326 EJ in 2040. In the industrial sector most of the long-term growth (for delivered energy consumption) occurs in countries outside of the Organization for Economic Cooperation and Development (OECD).

With 98% of direct industrial GHG emissions (Fischedick *et al.*, 2014) and 36% of total industrial CO_2 emissions (direct and indirect) (Bunse *et al.*, 2011) coming from the manufacturing sector alone, this merits a detailed focus for research due to obvious implications on climate change. Consequently, the progress made by the manufacturing industry in environmental sustainability will have a major bearing on how humanity as a whole progresses (Fitzpatrick and Dooley, 2017). The main drivers for implementing EEM in the manufacturing industry are: legislative compliance, financial gain and CSR (Williamson, Lynch-Wood and Ramsay, 2006).

While pressure is mounting to account for CO_2 emissions in manufacturing, firms often find that implementing effective carbon reduction programs is/can be difficult (Fernando and Hor, 2017), partly due to the complexity in determining the sources and causes of excessive carbon emissions

[2] Delivered energy is measured as the heat content of energy at the site of use. It includes the heat content of electricity but does not include conversion losses at generation plants in the electricity sector. Delivered energy also includes fuels (natural gas, coal, liquids, and renewables) used for combined heat and power facilities (cogeneration) in the industrial sector.

(Nakajima and Kimura, 2015) and partly due to the lack of visible direct financial benefits (Schaltegger and Csutora, 2012). This can be especially true for smaller firms with low energy intensity, unless conclusive evidence can prove the benefits of such a reduction for the sustainability of the firm (Côté *et al.*, 2008). Fortunately, EM is increasingly prevalent in industrial organisations with goals to reduce energy and carbon footprint while at the same time improving energy security, business continuity and financial performance (Böttcher and Müller, 2014; Martí-Ballester, 2016; Sáez-Martínez *et al.*, 2016; Bergmann *et al.*, 2017). An industry survey by Deloitte (Deloitte Center for Energy Solutions, 2017) shows an increased level of energy investment achieved by industrial organisations in recent years. While this is encouraging, much work is needed to enable industry to reach its potential in energy efficiency.

The following sections will review the scale of corporate Multi-site (and/or 'multi-national') Manufacturing Organisation(s) (MMO) within the industrial sector and take a closer look at an interesting focus group that is the non-energy intensive MMO.

1.2.1 Corporations and Multi-site Manufacturing Organisations

According to the non-governmental organization Global Justice Now, in 2016, 69 of the world's 100 top economies are corporations (Green, 2016). The value of the top 10 corporations reached $285tn, $5tn more than the value of the bottom 180 countries (Inman, 2016). Hence, corporations or MMO have more resources than many countries and their impact can be even bigger in terms of environmental sustainability given that they control the highest share of the world's resources (Fitzpatrick and Dooley, 2017).

For MMO the consumption of energy and natural resources represents a significant overhead. In addition, the increasing global competition, growing price of energy and other resources, as well as price volatility due to political instability, means that increasing resource efficiency and developing sustainable energy policies can represent a significant competitive advantage (Fedrigo-Fazio *et al.*, 2011). Implementing sustainable energy policies in industry enables the dual benefits of increased industrial efficiency whilst allowing the transition to a sustainable energy future. Customers, suppliers, and the public are increasingly demanding that businesses in general and manufacturing firms minimize any negative impact of their products and operations on the natural environment.

Many innovative MMO are already leading the way: "*Allergan's energy consumption will decrease significantly if planned tactical projects are implemented. Its GHG emissions will decrease concomitantly with energy reductions. The company will save a substantial amount of money by completing the visionary plan, and its* *reputation and competitiveness will become more robust. We believe that this is the right path for Allergan to follow and intend to achieve the visionary sustainability goals*" (Whaley, 2014).

In MMO, most research to date focus on analysing corporate energy efficiency in the energy intensive sector (Trianni, Cagno and Farné, 2016). However, the non-energy intensive sector has received less attention as outlined in the following section.

1.2.2 Non-energy intensive multi-site manufacturing organisations

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 (Rohdin and Thollander, 2006; Trianni, Cagno and Farné, 2016). In the International Energy Outlook 2016 (Conti *et al.*, 2016) reference case, real inflation-adjusted gross output is used to estimate industrial sector energy consumption by disaggregating economic activity into sectors and industries. As illustrated in Figure 1-10 the gross output (includes all economic activity) for non-energy intensive manufacturing is significant and is expected to account for 43% ($98 trillion) of global gross output by 2040.

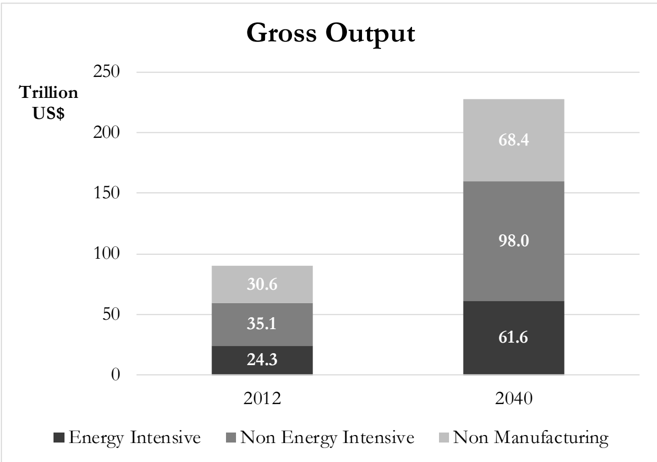

Figure 1-10. Global gross output by industrial subsector, 2012 and 2040 (trillion 2010 dollars)[3] (Conti *et al.*, 2016)

Empirical research shows that carbon reduction through energy efficiency in the manufacturing sector faces barriers that affect small, medium and large organisations alike. The impact of those barriers on non-energy intensive organisations is greater than on the energy intensive ones (Trianni, Cagno and Farné, 2016). This is because energy costs are a small fraction of the overall production costs in non-energy intensive organisations, leading to energy efficiency being given

[3] Gross output includes intermediate inputs such as energy, materials and purchased services used in production processes, providing data on all industry links that make up economic activity. In contrast, gross domestic product (GDP) and its components—which are value-added concepts—do not include intermediate inputs to industrial processes

less importance (Yeen Chan and Kantamaneni, 2015). Moreover, as energy may not be closely related to the core business activities, energy management may not be deemed strategic, leading to a lack of senior management commitment, competition for funding with other "more important" investments, limited resources and an unstructured decision-making process (Cooremans, 2011).

Non-energy intensive MMO are an interesting focus group in terms of EM and CO_2 emissions reduction targets for several reasons:

- They do not yet face the same environmental regulations in comparison to energy intensive industries;
- They may have several manufacturing sites globally, in some cases in regions with little or no legal obligations to reduce CO_2 emissions. Conversely, this presents an opportunity for MMO to look beyond site-focused EEMs and to leverage the most suitable locations across their portfolio to maximise their carbon reduction potential (e.g. conversion to renewables matching regional limitations (Fitzpatrick and Dooley, 2017), thus limiting the environmental impact associated with their production globally;
- Due to their size and revenue volumes, they are subject to higher public exposure and shareholder scrutiny than smaller organisations through corporate sustainability rankings that are increasingly directing investors towards top ranked corporations (e.g. RobecoSAM, Corporate Knights, Newsweek Green Rankings). This adds incentive for these MMO to use their financial position to improve their environmental performance as part of CSR and Corporate Sustainability programmes (Martí-Ballester, 2016).

Non-energy intensive MMO represent a novel sector, with the resources, motivation and capacity through CSR reporting to positively impact climate change and become leaders in industry with others following suit. EM and EnMS are fundamental to enabling progress as will be outlined in the following sections.

1.3 Energy Management in Industry

The International Energy Agency (IEA) recognises energy efficiency as the world's "first fuel", worth between $310 billion and $360 billion in 2012 (IEA, 2014). Investments in energy efficiency, which would help close the energy efficiency gap, are therefore seen as a "win-win" proposition (Hrovatin, Dolšak and Zorić, 2016) .

Energy use and efficiency are strongly interwoven with the issue of carbon emissions and climate change as by far the largest proportion of energy still comes from fossil. Hence, carbon emitting sources. Savings of 20% on energy consumption has been demonstrated by organisations implementing EM, effectively cutting operational costs and boosting competitiveness (McKane *et al.*, 2010; Carbon Trust, 2011a). However, these practices need to be continuously reviewed and improved (Therkelsen *et al.*, 2013).

An extensive review of existing literature on EM & EnMS, in combination with the observed requirements of a multi-site EnMS can be found in sections 2.2, 3.2 and 4.2. The following sections present an executive summary of the findings, including highlights of the key components of a robust 'Multi-Site' or 'Global' EnMS with existing gaps as identified in literature.

1.3.1 Energy Management – The Approach

EM and its associated practices vary greatly across organisations mainly because there is no well-understood energy management model. According to the International Organization for Standardization (ISO), EM stands out as one of the top five areas that require the development and promotion of international standards. In fact, EM activities are not well defined in the reviewed scientific literature (Antunes, Carreira and Mira da Silva, 2014).

A critical aspect to EM is the approach taken. Figure 1-11 displays a traditional project-based or ah-hoc approach to EM. It is not sustainable or systematic. EEM's are a 'reactive' response to a legal requirement or an increase in energy costs. In the past, piecemeal approaches to carbon and energy reduction have worked in the short term, however, these approaches have not achieved long term progress towards zero carbon manufacturing (Fernando and Hor, 2017).

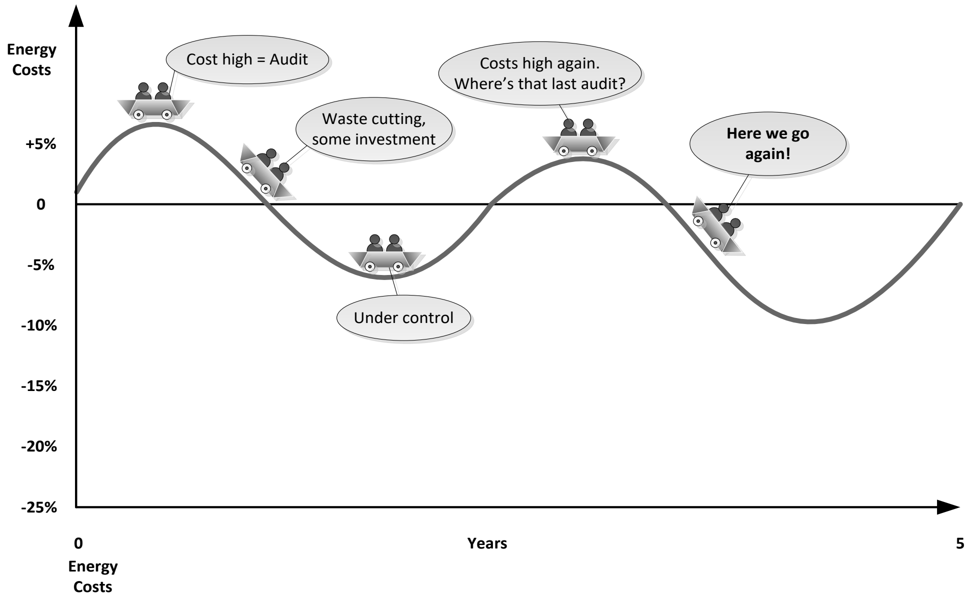

Figure 1-11. Project-only approach to energy management (Schreck, Bettina, 2011)

Figure 1-12 displays a systematic approach to continuous improvement of EM where EEM's are part of an overall organisational policy.

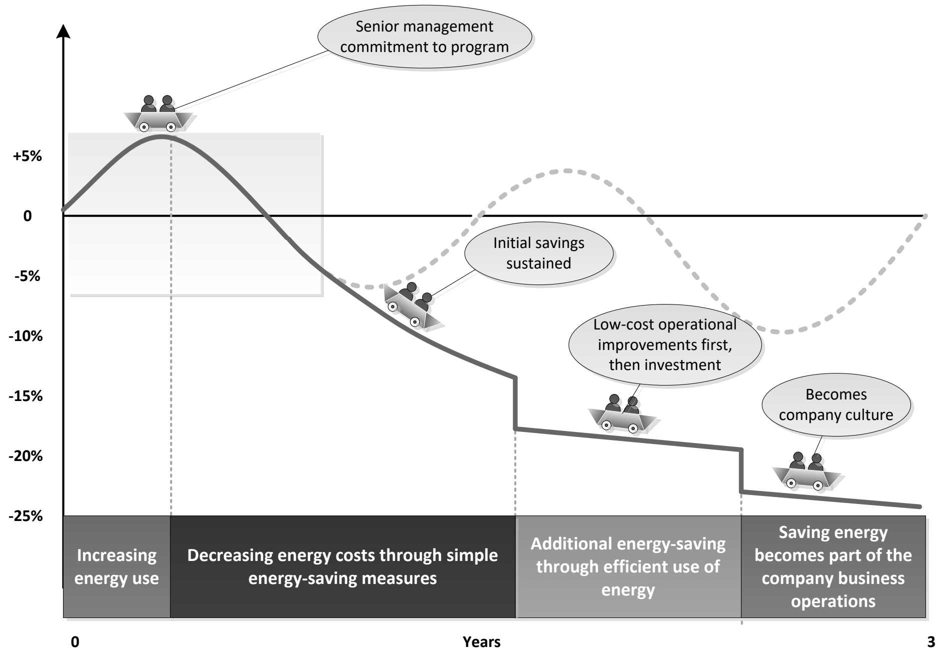

Figure 1-12. Systematic approach to energy management (Schreck, Bettina, 2011)

The key for making an EM 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 (Vikhorev, Greenough and Brown, 2013), (Sterling, 2015), (May *et al.*, 2016). On the contrary, implementation of several one-off energy efficiency projects is likely to fail in delivering continuous savings (Therkelsen *et al.*, 2013). In fact, technology is only part of the energy efficiency improvement potential, and when technologies are complemented by structured EM, the opportunity may be magnified resulting in continuous energy performance improvement over time.

A systematic EM approach is critical when implementing an EnMS aimed at reducing the energy efficiency gap as part of an overall approach to climate change.

1.3.2 Energy Management Systems

EnMS play a vital role as part of the EEM aimed at reducing energy consumption (Carbon Trust, 2011b), (Schulze *et al.*, 2016). EnMS are expected to reach a market value of $35.92 Billion by 2024 (Transparency Market Research, 2016). The adoption of a standard, such as the ISO 50001 (ISO, 2011), increases energy efficiency by more than 20% in industrial facilities (Piñero, 2009). The literature of interest for EnMS implementation can be sub-divided into: standards, industrial guidelines and scientific literature. A detailed review of these categories is provided in section 3.2.3. The literature reviewed suggests that current approaches to EnMS are adequate for a single-site organisation but not sufficient for MMO.

1.3.3 Multi-site energy management systems

A 'Multi-Site' EnMS is applicable to any industry with multiple locations within the same region/country or geographically dispersed through the world. This thesis is focused on the manufacturing sector, hence, the abbreviation MMO is used for easy representation of 'Multi-Site' and/ or 'Multi-national' 'Manufacturing' Organisation or Organisations. The following section gives an overview on the key components of an EnMS for MMO followed by an outline of the associated limitations. Chapters 1-4 cover these topics in detail.

1.3.3.1 Key components of a 'Multi-site' Energy Management System

The key components of a robust MMO EnMS can be broken down as follows;

- A corporate <u>'Energy Policy'</u> should be part of the organisation's sustainability policy or plan to improve environmental performance which in turn reflects the company's mission statement and core values. Bottcher (Böttcher and Müller, 2014) noted "to systematically improve energy and carbon efficiency, companies need to integrate energy management into their overall strategy, organisational structure and daily operations." .
- An <u>'Energy Strategy'</u> as a systematic approach and roadmap to achieve the targets set-out in the energy policy.

- The ability to seamlessly communicate strategies, frameworks and data (e.g. shared learnings) across the network of sites, enabling clear and informed decision-making at both site and global level. This requires a 'common language' in terms of EM and a cross-network communication platform. Leadership at a central level and point of contact with responsibility for EM on each site is needed, ideally personnel with EM experience.

- The need to effectively identify and characterise the key quantitative and qualitative factors affecting each individual site's energy consumption. The ability to baseline and benchmark, via Key Performance Indicators (KPI), current performance using common criteria across each site in the network, ideally in the form an energy management maturity model as part of continuous improvement cycle.

- Ultimately, effective EM requires strategic decision-making at both site and corporate level. To ensure these decisions are based on rational evidence-based criteria, a decision support framework (DSF) provides a useful tool for decision-makers, aggregating and communicating the required information in a timely, un-biased and effective manner whilst catering for all non-energy related benefits.

1.3.3.2 Limitations of existing Energy Management Systems for MMO

An overall summary on the limitations of existing EnMS with respect to MMO requirements is as follows:

- Corporate policy and energy strategy: although the existence of the policy is recognised as an essential driver for EEM implementation in industrial firms (Thollander and Ottosson, 2008), the required characteristics of such a policy for MMO with a global network of manufacturing sites lacks attention in current literature. International standards and certifications recognise that energy policy is fundamental to set the direction and drive energy performance improvement through the implementation of EnMS and converge in defining energy policy as senior management's official commitment to improve energy performance in an organisation. However, none provides a step by step guide to policy formulation and associated supporting strategies.

- Communications and dissemination of knowledge: A review of current best practice approaches to corporate EM suggests a silo approach between corporate policy and the individual sites (ARC Advisory Group, 2009). Cross communication between sites is rare.

- Site characterisation: Understanding the energy characteristics of each individual site in the network is a fundamental step in any MMO EnMs, thus creating a baseline from which to improve upon. Ensuring each site has an energy cost centre that is aligned to an 'apples' to 'apples' comparison is a prerequisite to success. However, it gets little coverage in literature. Deploying a standards based energy audit to each site in the network represents an effective method to understand the site energy drivers and enable alignment to technological solutions to reduce consumption. Existing systems, however, lack the steps required to ensure an 'enterprise level' approach to effective baselining and to enable a benchmarking framework. Traditionally, energy efficiency projects, even in large corporations, are assessed at site-level based on one-off audits with no visibility on the site's position against its network peers. While all investments in energy efficiency are welcome, establishing the best business case for investment across the 'network' is rarely undertaken.

- Performance evaluation: there are many well established KPI that cater for a *Quantitative* analysis, e.g. individual site systems such as the heating, ventilation and air conditioning system (HVAC) (Pérez-Lombard *et al.*, 2012) or plant level metrics such as the EPA's Energy Performance Indicators (Boyd, Dutrow and Tunnessen, 2008). A gap exists for *Qualitative* analysis. Introna (2014) states: "*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*". The gap is wider still for MMO, none of the models reviewed (Chapter 3) 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 and to corporate as whole. A further gap exists in the combination of *Quantitative and Qualitative* KPI's at a site and enterprise level.

- Decision Support Framework: even in situations where individual sites are strong in EnMS, an over-arching framework is required to ensure maximum return on investment from the implementation of EEM (Sardianou, 2008b). The creation of a business case that accounts for NEB and shows how such measures can contribute to improve competitive advantage and core business activities can enable a more positive view from an organisation's executive leadership towards EEM (Worrell *et al.*, 2003), (Cooremans, 2012). International standards and certifications require the implementation of EEM, however they do not provide clear guidelines to systematically evaluate energy investments. 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) (Rohdin, Thollander and Solding, 2007). This issue is further compounded by the complexities associated with MMO with a global footprint. A framework to deliver this for MMO is currently lacking.

1.4 Knowledge Gaps and Research Question

The previous sections outlined the challenge facing energy sustainability, the scale of the manufacturing sector and an overview of existing EM and EnMS. On the positive side there are several well-established protocols, standards and tools available at a site level to assist in bringing together many of the fundamental elements required to provide the Global Energy manager with a sound platform on which to build a systematic 'multi-site' or 'global energy management system'. In addition, the business case for the development of and engagement in a 'global energy management system' is very strong due to the dependency of global enterprises on energy and the associated overhead it represents. However, during this research work the following knowledge gaps were identified:

1. For MMO, informed decision making on capital investment aimed at improving energy performance and cutting carbon emissions across a global site base is a complex problem, involving multiple (multi-level) variables such as climate, economics, building type, technologies, culture and product mix, to name a few. Much of the energy management research and practice to date is 'site' focused with little practical guidance for the global energy manager. **Current approaches to energy management are sufficient for individual sites but not adequate for a multi-site enterprise with global footprint**. An overarching framework is required to cater for the needs of MMO, both from the site and global energy manager or management team's perspective.

2. 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. **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. In additional current literature lacks a KPI framework that caters for both the quantitative (energy

consumption) and qualitative (maturity model) status of energy management for the site in question, information that is needed make informed investment decisions.

3. **Research on the characteristics of long-term energy policy and associated strategies in MMO is limited**. Carbon and energy reduction goals face barriers (e.g. low capital availability), drivers (e.g. reduction of energy overhead) and decision-making factors that are influenced by policy and strategy. Other gaps exist in the quantification of non-energy benefits and the lack of step-by-step guidelines for policy formulation and associated supporting strategies. Non-energy intensive multinationals do not face the same environmental regulations required by their energy intensive counterparts, leading to missed opportunities and further widening the energy efficiency gap. This makes non-energy intensive MMO an interesting focus group

4. Energy efficiency projects are generally assessed at site-level based on energy audit findings. Research suggests that one of the most critical barriers for closing the energy efficiency gap lies in the ad-hoc approaches taken by these organisation when planning and implementing energy investments. Industrial energy management standards such as ISO require the implementation of energy efficiency measures; however, they do not provide clear step by step guidelines to systematically evaluate energy investments. This lack of systematic process leads to both under-investment and non-optimal or biased investment decisions, especially if energy investments are given a lower priority. This issue is further compounded by the complexities associated with multi-site organisations with a global footprint. It has been recognised that energy projects are more likely to be assessed favourably if a proper business case is constructed that confers the strategic nature to the investment. The business case also needs to account for the so-called 'non-energy benefits' which demonstrate how these types of projects can create a competitive advantage for the organisation. **To avoid ad-hoc decision-making practices an unbiased 'Decision Support Framework' (DSF) is needed by top management**.

The **primary research question** to be addressed in this work can thus be stated as: *For non-energy intensive multi-site manufacturing organisations, can a framework be developed that delivers optimal network performance and enables informed decision making on investment projects to meet energy and carbon reduction goals?*

1.5 Proposed Approach

Industry has a major role to play in CO_2 emissions reduction and needs to lead by example. Corporations or MMO have a unique opportunity through CSR commitments to make a difference to climate change and increase their profitability simultaneously. The best mechanism to deliver on this is through a sustainability policy that underpins the company's mission statement or core values, delivered via a comprehensive energy strategy with short, medium and long-term goals. Carbon neutrality (100% CO_2 emissions offset) is ***What*** is needed, and a policy must document the motivation or the ***Why*** to do it. ***How*** to do it is still a work in progress, with many focused minds trying to bring about change and deliver the required mechanisms. One of such mechanisms is continuous energy management and associated systems which is the focus of this research work. To tackle the overarching research question and to close the specific knowledge gaps identified above, the following are the key deliverables from this study:

1. **The systematic development and implementation of a novel 'Global Energy Management System' (GEMS) underpinned by established protocols & standards to enable non-energy intensive MMO reach optimal energy efficiency performance whilst meeting global energy and carbon emission reduction goals.** The GEMS framework will outline the steps required to support and guide the 'global' energy manager or management team whilst complementing existing 'site based' energy management systems. In effect, the impact of the network management system becomes greater than the sum of the individual sites EnMS.

   To deliver the GEMS vision and input the critical information into the decision support framework, strategies are needed to gather and evaluate all of the information from the network of sites. The ability to baseline each site in the network, with a view to longer-term performance evaluation (a benchmarking strategy - internally site to site and externally against industrial norms) is key. This should encompass both the quantitative nature of energy performance e.g. energy consumption KPIs and the qualitative nature of progress such as provided via maturity models. This ensures a level of understanding on how prepared the individual sites (buildings, systems and people) are for engagement in a multisite EnMS and associated energy efficiency improvements. Thus, GEMS proposes a novel benchmarking approach for an MMO encompassing both quantitative & qualitative aspects expressed as [KPI | EM^3], where:

- KPI represents the individual sites top level quantitative criteria relating to the energy consumption, GHG emissions, financial and other aspects from the sites which can be typically expressed using KPI's
- EM^3 represents the qualitative level of readiness and maturity of each site for effectively implementing energy management actions.

2. **The development and implementation of a novel approach to deliver the qualitative metrics in the form of an Energy Management Maturity Model (EM^3) for MMO with a global presence.** EM^3 is a fundamental step towards continuous improvement and optimal energy efficiency as part of the GEMS benchmarking framework. The maturity model should provide 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 MMO. The EM^3 model needs to enable two-way communication between global and local energy management teams and provide an evaluation framework to highlight prioritization of elements with larger deviations. In parallel EM^3 should provide the global energy management team with direction on where the organisation needs to focus central efforts to support the sites. The EM^3 should enable the evaluation of key non-technical aspects of energy management required for continuous improvement within an MMO. The proposed model will support both baselining and benchmarking activities required as part of a global EnMS.
3. **The development of a long-term energy policy and supporting strategy to close the energy efficiency gap for non-energy intensive multi-site organisations**. A comprehensive 'top down' energy policy that is engrained in the company mission or core values delivered via an energy strategy. Best practice on strategy indicates that a staged approach to reaching the vision through long term target setting is optimal. Definition of targets is suggested to follow the 'SMART' approach (Doran, 1981): Scientific based, Measurable, Attainable, Relevant and Time bound.
4. **Provide a decision support framework to assist MMO make optimal investment decisions on energy performance improvement projects to meet global energy and carbon emission reduction goals**. It is intended as a simple and repeatable approach for energy managers to promote informed, unbiased energy-related decision-making from top management. The proposed framework ensures decision-makers are presented with all the necessary (un-biased) information that allows them to understand

the full impact of the energy project. The framework should account for the non-energy benefits and present the characteristics and performance trends of the energy investment projects and their associated impact on the organisation, both financially and on sustainability ranking. This will promote the optimum business case for energy investments. The framework will be underpinned by a project prioritisation tool that uses economic, environmental, social and technical criteria.

1.5.1 Overview of GEMS Parthenon - Methodology

The GEMS Parthenon is a very effective 'tool' to capture and convey the essential components of a 'multi-site' or 'global' energy management system. It covers many complex topics simultaneously yet it is easy to navigate. The 'Vision' is the highest-level aspiration of the organisation (the goal) and is strategically placed at the top of the Parthenon. In the case of the GEMS Parthenon, the DSF takes the information from the supporting 'pillars' to enable this vision. The 'pillars' act in parallel and are also cross functional. The foundations need to be in place from the outset to ensure stability. The GEMS Parthenon is covered in detail in chapter 1, however to allow the reader have an early appreciation, an overview is provided in the following section.

The GEMS methodology is based on the following strategic pillars: (1) Site Characterisation; (2) Performance Evaluation; (3) Energy Strategy; and (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. These fundamental 'foundations' are a pre-requisite to the 'pillars', See Figure 1-13. It is important to emphasise that the GEMS focus is to assist a 'Global Energy Manager' or individual with responsibility for energy on multiple sites. The system is not intended to replace the site EnMS but rather complements it with mutual benefit to both systems.

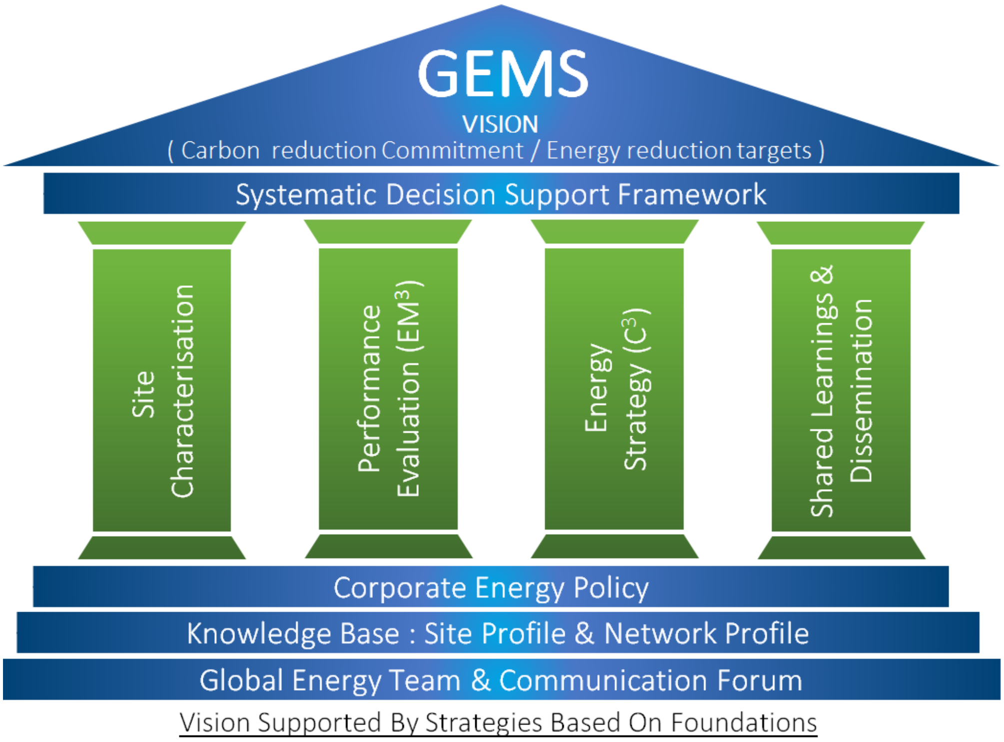

Figure 1-13. GEMS methodology framework

1.5.1.1 Foundations

Global Energy Team & Communication forum: Centrally-led team with representation from each site ensuring effective information sharing & relationship development. Sharing best practice and creating a roadmap to meet sustainability commitments are also fundamental deliverables.

Knowledge base (Site & Network Profile): Utilize a central platform for data collection, aggregation & analysis.

Corporate energy policy: Part of the organisation's sustainability policy to improve environmental performance which in turns reflects the company's mission statement and core values.

1.5.1.2 Pillars

Site Characterisation: Aims at understanding both the quantitative and qualitative energy management characteristics of each site and creating an associated **baseline.** A bespoke GEMS audit is carried out to establish the key quantifiable 'drivers' for energy consumption on each site.

Performance Evaluation: Aims at delivering a continuous benchmarking internally and externally, towards a continuous improvement cycle. It is conducted using a **novel**

benchmarking approach by a combination of both quantitative KPIs and qualitative EM[3] results.

Energy Strategy: The corporate energy strategy should define the targets, the roadmap and enablers required to meet the long-term goals that ultimately deliver the long-term vision committed to by the 'corporate energy policy' foundation.

Shared Learning and Dissemination: This pillar is aimed at avoiding the information silos that might occur in any large organisation. It will ensure the best methodologies and appropriate technological solutions are communicated and proliferated across the network.

1.5.1.3 Decision Support Framework

The decision support framework (DSF) is composed of 4 key elements, as shown Figure 1-14. For each investment, the DSF, at a minimum, needs to consider the following:

- The associated site's energy characteristics (e.g. location, overall consumption volume, cost of energy) and performance to date (e.g. energy KPIs). This can include but not be limited to the site's level of maturity i.e. the ability to engage in energy management and deliver on the project proposal.
- The proposal parameters, e.g. 1 Mega Watt Solar, with project schedule overview.
- The financial mechanism proposed, company capital or external investment (e.g. PPA).
- The output from a prioritization tool that considers financial, environmental, technical and social parameters for each proposal. How this investment contributes to the energy strategy goals (medium or long term) needs to be quantified.

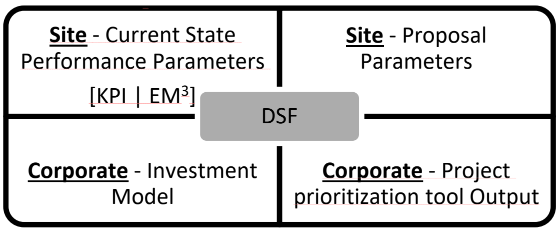

Figure 1-14. DSF overview

Top management (the decision makers) need the DSF to ensure they make informed decisions on investments. Moreover, they are privy to the long-term plans associated with the development or decommissioning of a particular site, which naturally will influence the decision outcome. In many cases, a strong policy can ensure commitment of capital to meet the sustainability goals so the main objective of the DSF is ensuring the associated capital is distributed correctly to maximise its impact on the energy and carbon reduction commitments.

1.6 Structure of Dissertation and Novelty Highlights

The following section is an outline of the thesis chapters and novelty highlights. Figure 1-15 illustrates the thesis structure and associated journal publications in addition to highlighting the sections in which key contributions to knowledge can be found. Chapters 2, 3 and 4 are by journal publication except for a brief introduction and conclusion paragraph to ensure continuity in the thesis.

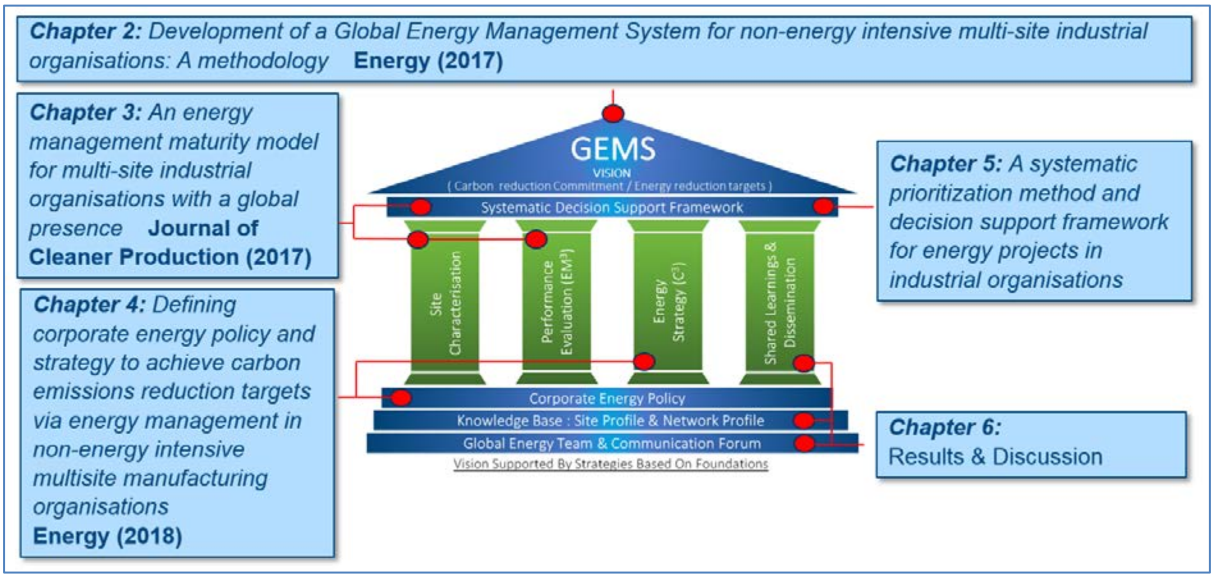

Figure 1-15. illustrates the thesis structure via the GEMS Parthenon and associated Journal publications

- Chapter 2 is a journal publication; "Development of a Global Energy Management System for non-energy intensive multi-site industrial organisations: A methodology", Energy Journal (Finnerty *et al.*, 2016) and presents the overall GEMS framework, it serves to address the primary research question poised in section 1.5. It outlines the GEMS methodology in full whilst also positioning specific topics for a deeper review in subsequent chapters. Its novelty lies in:
    - A novel framework enabling a global energy manager to follow a step by step approach to reach optimal network energy performance and informed decision making on investment projects to meet energy and carbon reduction goals whilst complementing existing 'site based' energy management systems.

- A novel benchmarking approach for an MMO encompassing both qualitative & quantitative aspects expressed as [KPI | EM^3], where:
    - KPI represents the individual sites top level quantitative criteria &
    - EM^3 represents the site level of maturity in energy management.

- Chapter 3 is a journal publication; "An energy management maturity model for multi-site industrial organisations with a global presence", Journal of Cleaner Production (Finnerty, Sterling, Coakley, *et al.*, 2018) and presents an energy management maturity model (EM^3) as a fundamental step towards aiding a global energy management team in the continuous improvement process leading to optimal network energy efficiency. Its novelty lies in:
    - Adapting and enhancing existing 'site focused' maturity models to cater for multi-site organisations & management. While most maturity models have either one or two application-specific purposes (Description, Prescriptive, Comparative), the energy management maturity model presented in this chapter encompasses all three. 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 inclusion of the global energy management team and external-peer 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 site's perspective.
    - 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.

- Chapter 4 is a journal publication; "Defining corporate energy policy and strategy to achieve carbon emissions reduction targets via energy management in non-energy intensive multisite manufacturing organizations", (Finnerty, Sterling, Contreras, *et al.*, 2018) The methodology presented in this research work contains the key components (step-by-step) of a long term corporate energy policy and strategic roadmap to address the barriers and support the drivers in the implementation of EM and EnMS in MMO. Its novelty lies in:
    - Research on the characteristics of long-term energy policy and associated strategies in multi-site manufacturing organisations is limited. To date no research has been conducted for Non-energy intensive multinationals. Other gaps exist in the quantification of non-energy benefits. Both policy and strategy proposed build on best practices identified from recognised leaders (within their industrial sector) in sustainability.
    - The energy strategy helps reduce the gaps identified in the literature around decision making practices and the non-energy benefits. The C^3 approach outlined under the energy strategy roadmap is novel: 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.
- Chapter 5 presents a systematic prioritization method and decision support framework for energy projects in industrial organisations. To avoid ad-hoc decision-making practices an unbiased 'Decision Support Framework' (DSF) is needed by decision makers. Even if each site in the network were at a highest level of energy management maturity and the global energy management and communication forum was best in class, the key research question is only complete with a bespoke decision support framework. This chapter proposes a simple and repeatable DSF underpinned by a project prioritisation to enable the quantification and structured analysis of the primary and secondary benefits from energy investment projects.
- Chapter 6 describes the **results** of the application of the GEMS methodology at each stage of the process on the demonstrator. It commences with a more in-depth review of the initial GEMS Pilot deployment outlined in Chapters 2 and subsequently discusses the

overall results associated with the GEMS program from Jan 2014 to Dec 2017 in Boston Scientific Corporation (BSC). A detailed description of the tools and processes employed to test the GEMS hypothesis at each stage of the process is included.

- Chapter 7 presents the research **Conclusions** from all aspects of this thesis as well as opportunities for future development.

1.7 Case Study Description- Boston Scientific Corporation

This section will present an overview of the selected demonstrator, Boston Scientific Corporation (BSC), a non-energy intensive multi-national manufacturing organisation in the life sciences industry, in particular:

- Company overview, including global locations.
- Energy Profile

This will ensure the reader has an appreciation for the scale and complexities of the demonstrator in question.

1.7.1 Company overview

Boston Scientific Corporation (BSC) is a non-energy intensive multi-national manufacturing organisation in the life sciences industry. It is a worldwide developer, manufacturer, and marketer of medical devices that are used in a broad range of interventional medical specialties. Its mission is to transform lives through innovative medical solutions that improve the health of patients around the world. Founded in 1979 by John E. Abele and Pete Michael Nicholas with an initial staff of 39, the company has grown to a present-day workforce of approximately 27,000 employees. BSC, headquartered Marlborough, Massachusetts, is a Fortune 500 global leader in the medical device sector with over $8Billion in annual operational sales. BSC has over 135 locations globally accounting for a total of 8.5Mft2 of owned and leased properties (2017). Manufacturing and distribution operations exist in the United States, Ireland, Costa Rica, and the Netherlands, with the company maintaining sales offices and training centers globally to support and service customers and provide education to health care professionals.

BSC will serve as a robust demonstrator of the GEMS methodology. For the purposes of this research, the focus will be on GEMS application at the key manufacturing and supply chain locations as illustrated in Figure 1-16 and Table 1-1. However, the implementation of energy initiatives extends to all locations in an effort to educate and improve the behaviours of an extensive and diverse global workforce in relation to energy conservation.

Figure 1-16. BSC Global manufacturing and supply chain locations

Table 1-1. BSC Operations - Primary function (2014)

Location	**Country**	**Primary Function**	**Zone**
Clonmel	Ireland	Manufacturing	EURO
Cork	Ireland	Manufacturing	
Galway	Ireland	Manufacturing	
Kerkrade	Netherlands	Supply Chain: Distribution	
Coventry	RI	Supply Chain: Sterilization	USA-East
Marlborough	MA	Manufacturing	
Quincy	MA	Supply Chain: Distribution	
Maple Grove	MN	Manufacturing	USA-Central
Saint Paul	MN	Manufacturing	
Spencer	IN	Manufacturing	
Fremont	CA	Manufacturing	USA-West
San Jose	CA	Manufacturing	
Valencia	CA	Manufacturing	
Coyol	Costa Rica	Manufacturing	LATIN-America
Dorado	Puerto Rica	Manufacturing	

Heredia	Costa Rica	Manufacturing	

1.7.2 Energy Profile

As illustrated in Figure 1-17 BSC consumed approximately 360 GWh of energy during 2013 at a cost of approximately $35milion. (2013 is the reference baseline for this research). The breakdown was approximately 60% for electricity and 40% for Gas.

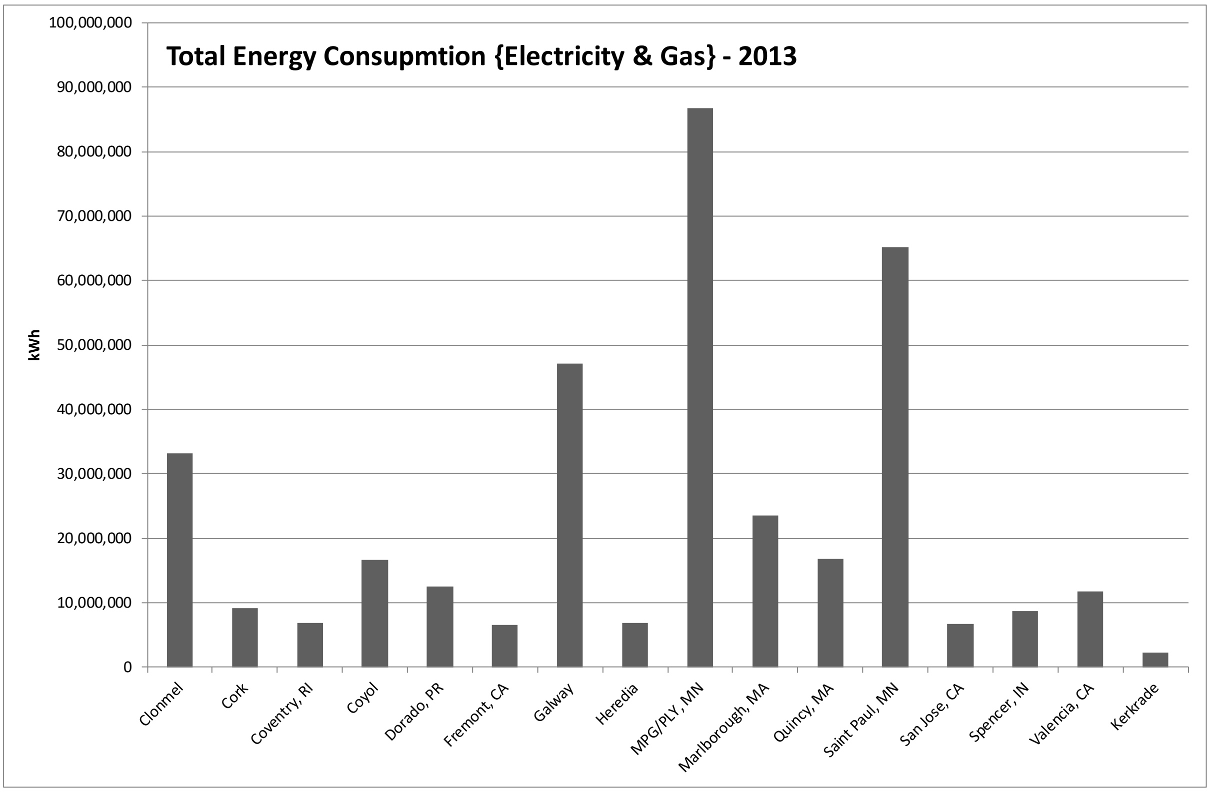

Figure 1-17. BSC locations – Total Energy consumption

BSC is deemed a non-energy intensive organisation (<0.5% of turnover). In non-energy intensive companies energy consumption or production may not be closely related to the company's core business, thus energy efficiency investments and planning may be neglected. BSC, however, has a strong culture in energy conservation and willingly engaged in this research work. Intense global competition, as well as the growing price of energy and other resources, means that an increase in energy efficiency can represent a competitive advantage by reducing the production cost base and increasing the company's corporate social responsibility profile in the market place. BSC, however, is focused on eliminating its impact on the environment. CSR is progressively gaining momentum as a priority over the associated financial impact.

1.8 Research dissemination

During this research work, several peer-reviewed journal and conference articles have been successfully published. Workshops were also used to ensure engagement and collaboration from the various parties involved in the case study.

1.8.1 Peer reviewed Journal publications

Finnerty, N., Sterling, R., Contreras, S., Coakley, D., Keane, M. *Defining corporate energy policy and strategy to achieve carbon emissions reduction targets via energy management in non-energy intensive multisite manufacturing organisations.* Energy 151 (2018) 913-929

Finnerty, N., Sterling, R., Coakley, D., Keane, M. *An energy management maturity model for multi-site industrial organisations with a global presence.* Journal of Cleaner Production 167 (2017) 1232-1250

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2 Development of a global energy management system for non-energy intensive multi-site industrial organisations: A Methodology

"All the forces in the world are not so powerful as an idea whose time has come" – Victor Hugo

Introduction

Chapter 2 serves to address the primary research question poised in section 1.4. It outlines the GEMS methodology in full whilst also positioning specific relevant topics for a deeper review in subsequent chapters. The following chapter describes in detail a novel approach that improves upon current approaches to energy management by global enterprises. The GEMS approach is rooted on a clear set of activities that emerged from the best practices found in the literature and enhanced activities to address gaps required for a global approach.

What is GEMS?
GEMS is delivering a novel methodology and decision support framework for assessing capital energy-efficiency projects for multi-site organisations whilst in parallel delivering optimal network energy efficiency performance

G E M S

Why GEMS?
While energy efficiency in the industry sector has steadily grown by over 1% annually since 2000, for multinational organisations, assessment of cost effective energy efficiency projects across a global site base is still a complex problem.

If we had €20 million CAPEX to invest in energy, where would we invest it?

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Noel Finnerty developed the methodology, collected, analysed and synthesized the data. He is the primary author of this article. Dr. Raymond Sterling, Dr. Daniel Coakley and Dr. Marcus Keane contributed to the methodology development and paper review. Sergio Contreras and Ronan Coffey contributed to the case study data collection and analysis.

The published paper detail is included in Appendix A.

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 at improving energy performance and cutting carbon emissions, across a global site base, is a complex problem. This work presents the systematic development and implementation of a novel energy management methodology for multi-site organisations to reach optimal efficiency across their network. The methodology, a Global Energy Management System, is based on the following strategic pillars: (1) Site Characterisation; (2) Performance Evaluation; (3) Energy Strategy; and (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 incorporates both quantitative performance evaluation using novel key performance indicators and benchmarking, as well as qualitative characterisation using energy management maturity models. The methodology culminates with a systematic, repeatable and scalable decision support framework, underpinned by a multi-criteria decision-making methodology. A detailed case study is presented for a multi-national corporation in the life sciences industry, which resulted in increased awareness of energy and carbon emissions, as well as related impacts on business continuity, corporate sustainability and social responsibility. This triggered increased investment in energy efficiency measures, thus promoting the conditions for continuous improvement towards optimal network performance.

Keywords: Global Energy Management System; Corporate Social Responsibility; Business Continuity; Sustainability; Decision Support Framework; Energy Management Maturity Model; Energy Performance Indicators.

2.1 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 (OECD, 2012). 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 (Leahy *et al.*, 2013). 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 (Pérez-Lombard, Ortiz and Pout, 2008). Since 2000, improved energy efficiency in industry has resulted in a 10% decrease in energy intensity, with realistic further improvements possible by using existing cost-effective energy solutions (International Energy Agency, 2014). For non-energy intensive companies[4], where energy consumption or production may not be closely related to the company's core business, energy efficiency investments and planning may be neglected (Cooremans, 2011).

Every investment in energy efficiency by the industrial sector is critical to a sustainable future, and progress has been made, particularly in the past decade (Worrell *et al.*, 2009). In coming decades, additional progress will be driven by governments and industrial organisations in response to the Paris Agreement goal of keeping a global temperature rise this century well below 2^{o} degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5^{o} degrees Celsius (UNFCCC, 2016). Delivering this objective will demand a strong improvement in energy performance and reduction of CO_2 emissions across all industrial sectors regardless of their energy intensity. Non-energy intensive multinational corporations are an interesting focus group in terms of energy management research and energy strategy formulation under this scenario. Firstly, they do not yet face the same environmental regulations in comparison to energy intensive industries. Secondly, because of their size and revenue volumes, they are subject to higher public exposure than smaller organisations through corporate sustainability rankings (e.g. 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 decisions due to the lack of visibility of non-energy benefits (higher productivity, lower liability, improved public image, improved worker morale, etc.) (Worrell *et al.*, 2003; Nehler and Rasmussen, 2016a). Energy efficiency measures (EEM) can also positively impact on the organisation's core business in the form of improved public image and market performance,

[4] 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 (Rohdin and Thollander, 2006; Trianni, Cagno and Farné, 2016).

driven by the perceived proactive commitment to environmental sustainability (Eccles, Ioannou and Serafeim, 2012).

The main drivers for implementing energy efficiency measures (EEM) in the manufacturing industry are thus primarily: legislative compliance, financial gain and, corporate social responsibility (CSR) (Williamson, Lynch-Wood and Ramsay, 2006). Legislative compliance often makes implementation of EEM an imperative. Financial gain from EEM and CSR requires a way to improve positive feedback 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 (Pye and McKane, 2000). 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 (Timilsina, Hochman and Fedets, 2016; Trianni, Cagno and Farné, 2016).

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 serves as a robust demonstrator of the proposed approach.

2.2 Literature review

It has been demonstrated that implementing energy management programs enables organisations to save up to 20% on their energy bill, effectively cutting operational costs and boosting competitiveness (McKane *et al.*, 2010; Carbon Trust, 2011), as long as these practices are continuously reviewed and improved (Therkelsen *et al.*, 2013). 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 (Vikhorev, Greenough and Brown, 2013). 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 management in general, there is no clear consensus on an approach to tackling energy management and capital spend efficiencies for a multi-site organisation with a global footprint.

2.2.1 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 (Antunes, Carreira and Mira da Silva, 2014). There are several definitions of 'Energy Management'. The energy management guide published by the Carbon Trust (Carbon Trust, 2011) defines energy management as 'the systematic use of management and technology to improve an organisation's energy performance'. Bunse et al. (Bunse *et al.*, 2011) describe energy management 'as the control, monitoring and improvement activities for energy efficiency'. ISO50001 (ISO, 2011) 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 (Ingenieure, 2007) 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™ (US EPA, 2013), ISO50001 (ISO, 2011) and Superior Energy Performance (SEP)™ (US Department of Energy, 2012) 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[5].

While there is currently a large body of standards around energy management in industry, Antunes et al (Antunes, Carreira and Mira da Silva, 2014), 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 organisation with a global footprint.

[5] 'recurring process which results in enhancement of energy performance and the energy management system' (ISO, 2011)

2.2.2 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, enabling 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;
- *Site characterisation:* the need to effectively identify and evaluate the key quantitative and qualitative factors affecting each individual site's energy consumption, and baseline their current performance;
- *Performance evaluation:* the need to develop key-performance indicators, to enable benchmarking, using common criteria across each site in the network, and normalise to account for elements such as building characteristics (age, function), climate and economics;
- *Corporate Policy & Energy Strategy:* the 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; the need to evaluate all capital projects based on 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:* 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 decision support framework (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, identifying state-of-the art standards and practices, as well as the current gaps that need to be addressed while developing a truly 'Global' Energy Management System.

2.2.2.1 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 several 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 enable 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 (ARC Advisory Group, 2009). Cross communication between sites is rare. Sharing and disseminating a common view across the corporation facilitates communication, and 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 efficiencies due to improper dissemination of corporate policies and approaches.

2.2.2.2 Site characterisation

By showing energy consumption and overall operations costs with and without an energy action plan, Whaley (Whaley, 2014) clearly shows the positive impact of the energy plan not only on the operation cost, but also achieving committed sustainability targets. Traditionally, energy efficiency projects, even in large corporations, are assessed at site-level based on one-off audits with no visibility on the site's position against its network 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 of standardized metrics to characterise sites and assess energy projects globally, by making use of the large quantities of data 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 (Fleiter, Worrell and Eichhammer, 2011).

These barriers may translate into delayed or under investment which in turn is costly to both industry and the environment, with available capital funds remaining un-invested in potential energy efficiency opportunities (Sorrell, Mallett and Nye, 2011).

2.2.2.3 Performance evaluation

Typically, we consider sites may be evaluated based on either quantitative (numerically quantifiable indicators – e.g. kWh/m^2, \$/ft^2 etc.) or qualitative (descriptive information about a site – e.g. energy management maturity) criteria.

- *Quantitative:* There are many well established key performance indicators (KPIs) that are applicable to energy management. They cater for individual site systems such as the heating, ventilation and air conditioning system (HVAC) (Pérez-Lombard *et al.*, 2012) or plant level metrics such as the EPA's Energy Performance Indicators (Boyd, Dutrow and Tunnessen, 2008), typically normalised for key criteria such as climate and building type. A gap exists however in the combination of local and global KPI to produce a truly normalised cross-site comparison;

- *Qualitative:* Introna et al. (2014) state that '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 with relation to energy management and of how this maturity develops along with its dimensions'. Improper cross-site baselining of the corporation leads to unfair evaluation of energy efficiency projects between sites. Recent literature suggests 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 (Ngai *et al.*, 2013), by directly assessing the maturity level against recognised standards such as ISO

50001 (Jovanović and Filipović, 2016) or as a means to develop a qualitative baselining across a network of sites for global corporations (Finnerty *et al.*, 2015).

2.2.2.4 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 (ISO, 2011). Even though the existence of the policy is recognised as an essential driver for EEM implementation in industrial firms (Rohdin and Thollander, 2006), (Rohdin, Thollander and Solding, 2007), (Thollander and Ottosson, 2008), the required characteristics of such a policy for multi-site organisations with a global network of manufacturing sites lacks attention in current literature.

An EnMS is expected to identify and prioritise EEM (ISO, 2011). 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 (Cooremans, 2012), and that categorisation also has a strong influence on the decision-making practices (Cooremans, 2011). 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 per 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) (Wang *et al.*, 2009a).

- *Funding Criteria:* A survey completed by Meckstroth & Edmonds (2014) posed 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 (Antunes, Carreira and Mira da Silva, 2014) 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 organisations are increasingly supporting energy related projects outside the standard two-year return on investment and the decision to implement is influenced by setting a positive example among peers (Lopez-Paleo and Negrón, 2014). Government bodies tend to allow a longer return on investment than private industry with funding allocated to projects with pay-back periods up to eight years (Lopez-Paleo and Negrón, 2014);

- *Corporate Social responsibility:* Mixed views exist in how CSR and other non-energy benefits translates into value creation (Bird *et al.*, 2007). Industries 'do not seem to have yet acknowledge how relevant non-energy benefits are to promote energy efficiency measures adoption' (Trianni, Cagno and Farné, 2016), and 'lack of knowledge of how these (non-energy benefits) should be quantified and monetised' (Nehler and Rasmussen, 2016b);

  - *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 for which the main implementation driver remains legislative compliance (Williamson, Lynch-Wood and Ramsay, 2006). 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 (Rohdin and Thollander, 2006). 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 (e.g. adding financial value to down-time) ;

  - *Sustainability:* From an investor perspective, a company's sustainability performance is becoming an increasingly important factor. A recent energy management policy paper published by a global pharmaceutical company noted: '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' (Whaley, 2014).

2.2.2.5 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 (Sardianou, 2008). The lack of such a decision support framework may result in significant inefficiency and underfunding on 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 measures contribute to improve competitive advantage and core business activities (Cooremans, 2012). 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 (Worrell *et al.*, 2003).

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.

2.3 Problem statement

Table 2-1 summarises the gaps between current practice and the requirements for a Global Energy Management System (GEMS), described from the perspective of both, the site and global energy manager.

Table 2-1. 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 access to the network 'knowledge' to improve specific project selection and implementation efficiency.	Developing, deploying and disseminating a global energy policy is a common challenge. This is due to the lack of appropriate practical means for accessing and distributing the information to/from individual sites.
Site characterisation, benchmarking and performance evaluation	Individual sites lack perspective on their own energy performance in relation to network overall performance. Usually assessment is based solely on quantitative system evaluation, without consideration of non-energy benefits or 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 with respect to capital funding approval requests.	Funding criteria is usually based solely on direct financial return on investment criteria (e.g. payback period). Non-energy benefits (e.g. CSR, Sustainability and business continuity, productivity, etc.) are rarely considered as part of the corporate

		policy, and even less frequently considered with respect to EEM investments.
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. There is little clarity on how to improve the value of energy efficiency projects for decision makers.	Informed decision making at a global level introduces several key challenges including: the complexity and number of variables to be considered; appropriate means for accessing the information and data required to assess opportunities 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 GEMS, will integrate all sites in the corporation into a common language which is also shared by top-management.

The problem to address in this work can thus 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?*

2.4 Proposed approach

In addressing the barriers and needs presented in sections 2 and 3, this work 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 2-1

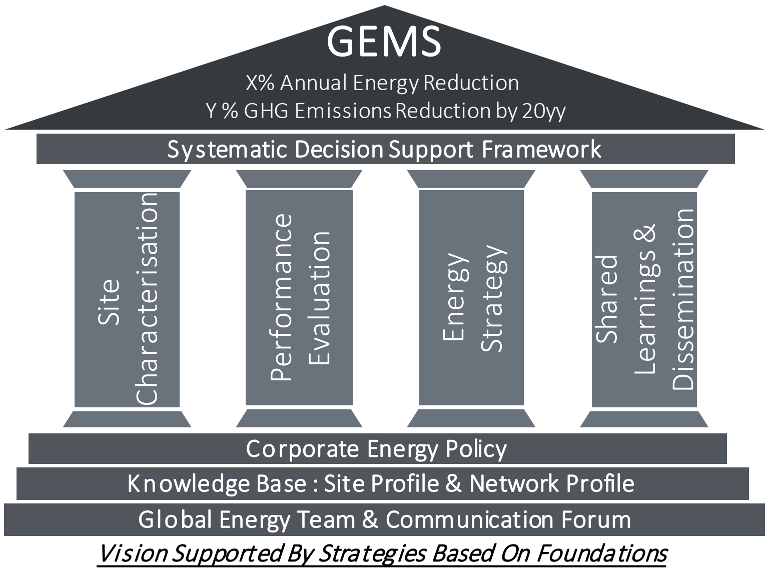

Figure 2-1. GEMS methodology framework

GEMS works in parallel to a site's EnMS and it 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 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.

2.4.1 Foundations

For a multi-national corporation to make informed decisions on strategic investment in energy efficiency, 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.

2.4.1.1 Global energy team and communication forum

The global energy team is a centrally led management structure with representation from each site (Figure 2-2). 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 manager / team (GEM/GEMT) to act as the overall governance for all aspects of energy management for the corporation.

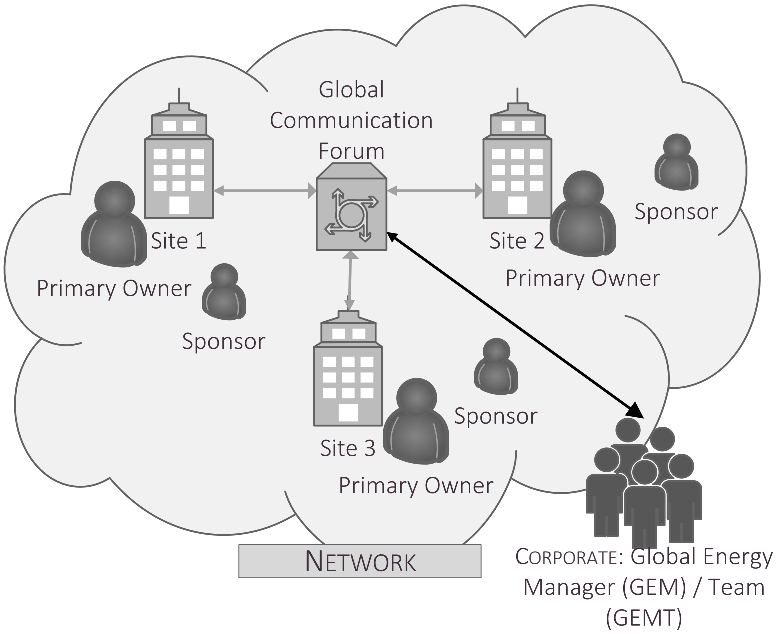

Figure 2-2. Global Energy Team organigram.

The *global communication forum* ensures effective information sharing and relationship development via shared meeting technology. The forum serves 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 processes. Furthermore, it enables 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 *GEM/GEMT*. Furthermore, it is necessary to ensure each site in the network can identify a resource that becomes 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 site's senior management team to support the primary owner. It is important to note that 'primary owners' are key in enabling the deployment of 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.

2.4.1.2 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.

In obtaining 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 ensures 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 costs and salaries ensuring 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 is essential for energy data collection, aggregation and analysis, to avoid dispersion of data and the generation of 'information and knowledge silos', which are 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. facility maintenance, rental costs) 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 of energy spend 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.

2.4.1.3 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 causality 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.

2.4.1.3.1 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 section 2.4.1.2 and utilizes the overall network business case to secure project funding.

Once a realistic target for reduction in energy use across the network is initially 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-year 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)):

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

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

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. 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 (Ryan Beesley, 2014).

This process further highlights 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 (explained in section 2.4.2.3 – Energy Strategy). Support from each individual site's upper management is vital in enabling 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.

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 similarities in uncontrollable factors such as climate, economics and regulatory environment. 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.

2.4.1.3.2 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 organisational goals; (f) Regular revision to ensure alignment with the organisation's nature and strategic direction of the corporate sustainability policy.

2.4.2 Pillars

The pillars (Figure 2-1) serve to provide the information needed for the strategic DSF 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 Characterisation' to 'Performance Evaluation' to 'Energy Strategy' to 'Shared

Learnings/Dissemination'. Nevertheless, the four pillars can be established in parallel. Substantial progress on all pillars is a prerequisite to deployment of meaningful information into the 'Decision Support Framework'.

2.4.2.1 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. This enables alignment with the 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.

2.4.2.1.1 Quantitative Characterisation - GEMS Audit

The quantitative characterisation step involves the deployment of a bespoke GEMS audit to assess the importance of controllable factors (e.g. via sensitivity/regression analysis or similar) driving each site's energy consumption (e.g. the significant energy users). The GEMS audit should not be mistaken for 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) (Deru, Kelsey and Pearson, 2011). The key outputs of the GEMS audit are:

- Provision of a consistent audit framework operational at all sites globally and conducive to the establishment of KPI for benchmarking (Section 2.4.2.2.1). In the absence of data normalization, the KPI will still provide a solid baseline for each individual site to monitor progress overtime.
- Completion of a site level and corporate level data and metering gap analysis to support calculation and continuous monitoring of the KPI for performance evaluation (explained in section 2.4.2.2.1).

2.4.2.1.2 Qualitative Characterisation - EM^3 baseline

The qualitative characterisation of a site involves the use of an energy management maturity model (EM^3) to determine the current maturity level of the sites in relation to 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 2-3).

GEMS EM^3 is a combination of two focus areas, site and global. The site element is based on existing industrial (ISO, 2011; US Department of Energy, 2012; US EPA, 2013), and scientific models (Antunes, Carreira and Mira da Silva, 2014; Introna *et al.*, 2014), and adapted for GEMS requirements. The global element is a bespoke adaptation of the GEMS methodology presented in the form of a maturity model. In combination, this provides a full GEMS EM^3 that may be applied to all sites at both site and corporate level, using a standardised 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 to have a final EM^3 score with which compare with the network average, external peers and most importantly track internal improvements over time (explained in section 2.4.2.2 - Performance Evaluation).

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 also surveys 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. The EM^3 score positions 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.

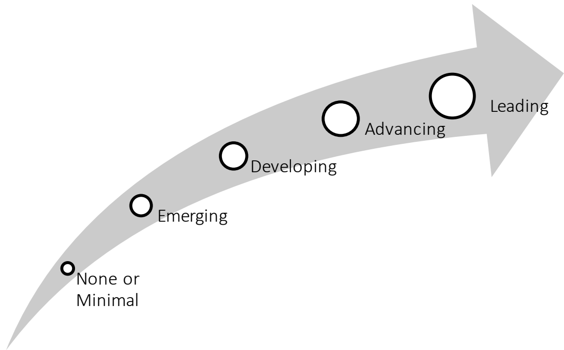

Figure 2-3. GEMS EM³ maturity levels (Likert scale).

Further information about the GEMS EM^3 is described in a previous publication dealing specifically with this topic (Finnerty *et al.*, 2015).

2.4.2.2 Performance evaluation

The ‘performance evaluation’ pillar builds on the data from the ‘site characterisation’ 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 is clear and well defined.

The final GEMS benchmarking performance rating is a combination of the Tier 1 key performance indicator score (KPI) and the final energy management maturity model score (EM3), expressed as [KPI | EM^3], where:

- The KPI score represents the individual sites ‘corporate level’ or ‘Tier 1’ KPI performance.
- The EM^3 score represents the individual sites overall EM^3 performance.

2.4.2.2.1 Quantitative benchmarking via KPI

The goal of this pillars is to establish the KPI 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 (e.g. kWh/m^2/year). Data normalization of controllable (e.g. technology deployed) and un-controllable (e.g. climate, economics & building type) parameters is required to ensure meaningful benchmarking (e.g. site vs. network vs. external peers);
- *Tier 2 KPI:* common across all sites, where feasible, but focusing on the specific significant energy users for each site. Tier 2 KPI 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:* these correspond to site specific bespoke KPI that assist in supporting the analysis of Tier 2 trends. trends. They act as a means of continuous performance tracking, and as an early warning system to alert the site energy manager where deviations occur.

The GEMS audit has already defined the current metering state of the facility and the required future state to support the KPI Tier as outlined. The Tier 1 KPI 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 work.

2.4.2.2.2 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 for progression in place.

2.4.2.3 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, but are not limited to, the following practices in energy management: (a) Short-term targets in line with the corporate energy policy; (b) Funding mechanism; (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 Figure 2-4. The MCDM also quantifies 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) (Wang *et al.*, 2009b). 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 (Wang *et al.*, 2009a). As shown in Figure 2-4, the AHP structure contains four first level criteria and 14 second level criteria. The first level criteria of expands the standard triple bottom line (TBL) approach of sustainability assessments (Pope, Annandale and Morrison-saunders, 2004). The technical criteria set evaluates a project's contribution to business continuity ensuring that a more holistic assessment of sustainable energy projects for organisations can be achieved (Wang *et al.*, 2008, 2009b; Kaya and Kahraman, 2011).

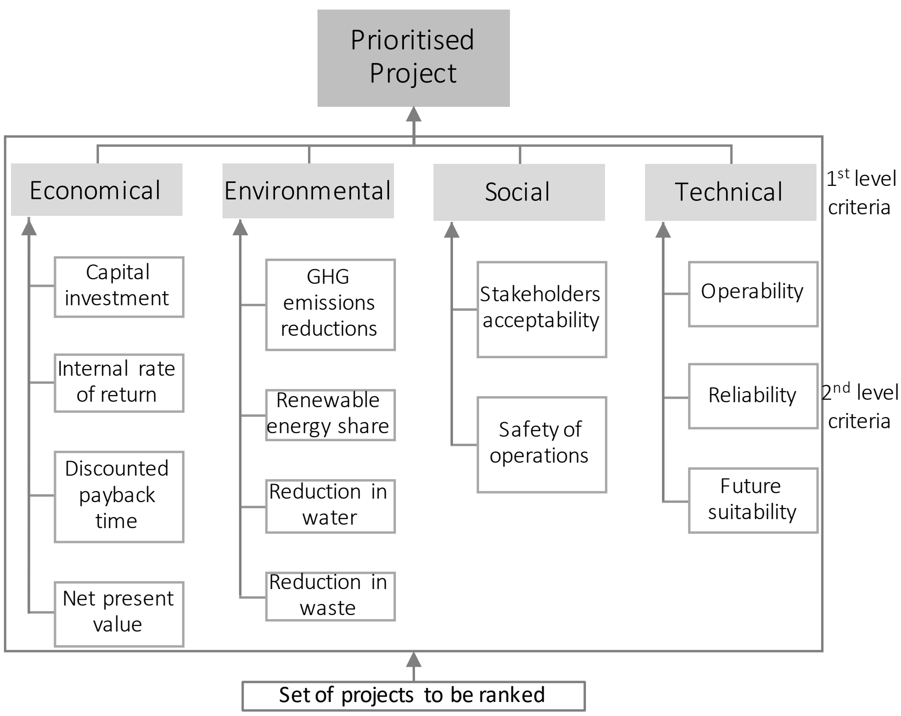

Figure 2-4. MCDM: AHP structure and sets of criteria for assessment of energy improvement projects (Contreras, 2016).

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 (Chang, 1996), 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.

2.4.2.4 Shared learnings and dissemination

The 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 stakeholders, both, internal and external to the corporation. The key elements to achieve effective shared learning and dissemination are:

- *Communications:* delivery of audience-appropriate content targeted at the different stakeholders, such as executive board, internal workforce and external community;
- *Collaborations:* engagement 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™ (US EPA, 2013) or ISO50001 (ISO, 2011);
- *Central approach to energy training:* energy management certification for primary owners and, standardised corporate energy training programme for workforce.

2.4.3 Decision support framework

The DSF requires that all sites have been evaluated using the GEMS benchmarking performance rating (section 2.4.2.2). These ratings are combined with proposed energy projects (as submitted by each site's primary owner, or as proposed by the GEM from a pre-selected matrix of high-impact EEM). 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 decisions can be made regarding investment in EEM (e.g. invest 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, thus prioritising the improvement of its performance parameters).

- Normalised 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 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, outline for each proposed energy project the elements presented and detailed in Table 2-2.

Table 2-2. DSF elements detailing.

DSF element	Inputs	Outputs	Comments
Current State Performance Parameters	[KPI | EM3]	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.
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.	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.
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).		

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.

2.5 Case Study

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.

2.5.1 Foundations

2.5.1.1 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 2-2:

- *Global Energy Management Team (Corporate Level):* the 'core' team is composed of the Global Energy Manager, the Global Facilities Operations Manager and the VP of Global Real Estate and Facilities. The Global Environmental, Health and Safety Director is an 'extended' team member;
- *Primary Owners (Site Level):* the main contact point responsible for execution of all works associated with GEMS. Typically, a facilities manager, energy manager or a senior engineer;
- *Sponsor (Site Level):* provides support for the primary owner in terms of guidance and resources. Typically, the facility manager or director for each individual site;
- *Global Communication Forum (Network Level):* central communication and knowledge exchange platform. Monthly or bi-monthly one-hour meetings are held via web-conference.

2.5.1.2 Knowledge base: Site and network profiles

2.5.1.2.1 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 2-3. Ensuring all cost centres are consistent 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 2-3. BSC Cost Code Alignment sample.

Unique identifier		Software system description	Description
50	3010	Building Maintenance	Roof, ceiling, walls, doors, windows, floor
50	3090	HVAC Maintenance	Service and maintenance
50	3040	Electricity	Electricity only- Electric utility
50	3130	Janitorial	Cleaning services
50	3140	Oil	Lube oil/gear oil

50	3141	Gases	Process gas
50	3630	Furniture + Fixtures	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	3620	Depreciation	Finance will provide depreciation value

2.5.1.2.2 Network expenditure profile

Establishing the operational spend inclusive of each site in the network (Figure 2-5 a) 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.

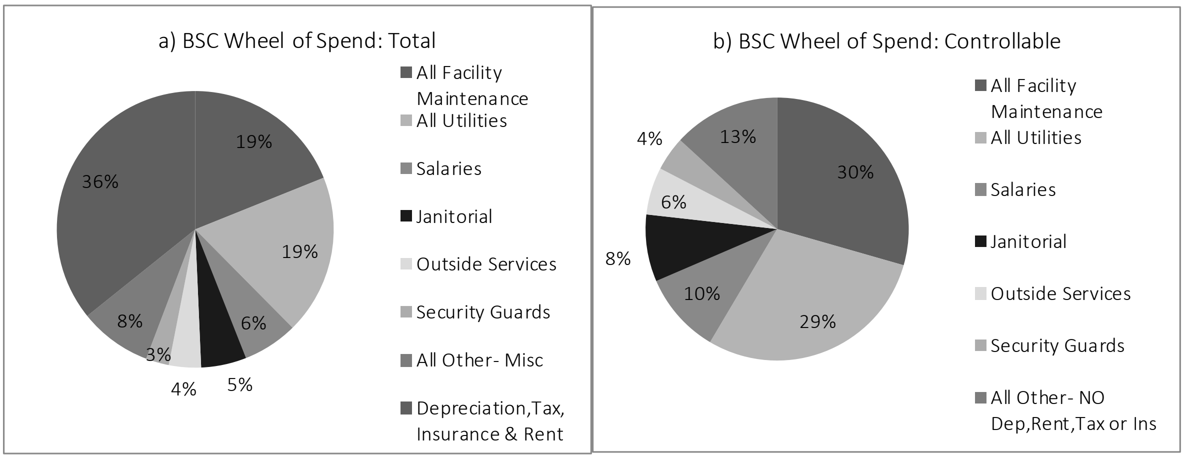

Figure 2-5. BSC Wheel of Spend.

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 2-5 b). The fact that 30% of the controllable spend is under the scope of GEMS is important to help define the business case (section 2.5.1.3.1).

2.5.1.2.3 Sites and Network Energy Profile

All sites' monthly invoices are collected in a central system, creating a platform for analysis and dissemination of energy consumption and the impact of EEM at a later stage in the process.

Understanding the sites and network profile enables an accurate tracking of the corporate energy policy objectives. It also enables an understanding of the impact an EEM would have on both the individual site and the whole corporation.

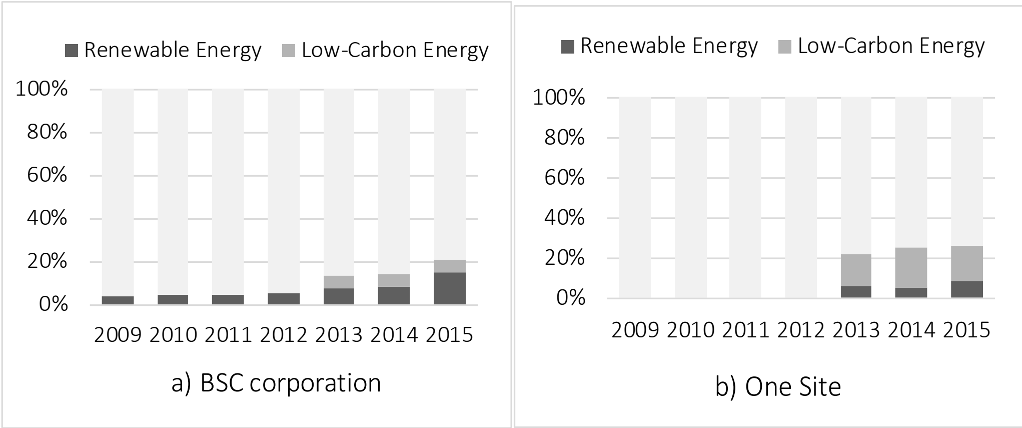

Figure 2-6. Split of energy usage.

In Figure 2-6 a), the split of energy supply sources for BSC is shown. There is an increasing tendency towards the use of renewables and low carbon energy technologies[6]. The decision to move towards higher shares of on-site generation (Low-Carbon Energy) is driven by two primary factors: (1) the corporate social responsibility commitment by BSC to improve its environmental footprint and, (2) the need for increased resilience and independence with respect to energy supply, particularly for those sites where energy is a key component of business continuity. Figure 2-6 b), shows the split of energy use for a site. For this site, more relevance has been given to the low carbon technology energy than to renewable energy.

In Figure 2-6 relative values are given 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.

2.5.1.3 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.

[6] 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.

2.5.1.3.1 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 under the Carbon Disclosure Project (CDP, 2012). This equates to approximately \$1.48m in annual operational savings and a reduction of 50,000t CO_2 by 2020. Key to this 'business case' step is to inform top management on the potential capital to be governed by GEMS. With such figures, the initial GEMS business case was outlined as shown in Table 2-4.

Table 2-4. 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 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 CO2 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. *** Potential investment over 'Strategic Plan' based on 3 or 5-year return of investment to enable savings and improved carbon footprint. Critically it is an early indication to top management on the scale of capital to be governed by GEMS.	

2.5.1.3.2 Pilot Project Implementation

- BSC's owned facilities in Europe[7] 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 (European Parliament and Council of Europe, 2010). Therefore, it was cost effective to complete the GEMS audits ahead of the EED Audit.

[7] Three manufacturing plants in Ireland (Sites 1-3). Warehouse in the Netherlands (Site 4). Reference manufacturing plant in Ireland (Site 5).

- All pilot sites have site level EnMS with varying levels of implementation;
- Climate is reasonably similar for the five sites making energy comparisons fairer. Also, all energy conservation technologies are affected in similar ways by the local climate;
- On the financial side, all five sites are subject to similar economic environment thus allowing for more balanced cross-comparison of capital and operational investments;
- The main differences between sites (variables) are products manufactured and building profile (e.g. age, geometry, usage). Building age profiles range from 1998 construction to 2012 construction;

2.5.1.3.3 Corporate Energy Policy Definition

The pilot implementation of GEMS (on all levels from foundations through to pillars & DSF) delivered an initial and integral understanding of the key characteristics of the corporation, enabling commencement of the energy policy formulation. The following components of a high-level corporate energy policy have 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 a specific date;
- *Boundary:* reduction of carbon emissions within Scopes 1 and 2 of the Green House Gas Protocol (World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI), 2004);
- *Commitment:* establish energy performance improvement and associated carbon emission reduction as a corporate priority across all manufacturing sites;
- *Roadmap (C^3):* 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.

2.5.2 Pillars

2.5.2.1 Site Characterisation and Performance Evaluation: Quantitative

In BSC the most significant energy use comes from space conditioning, due to the high requirements of its clean room spaces in terms of area and environmental conditions for 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[3] to provide cross-site comparisons on energy consumption simply by area as is common practice. In such cases, a site with a major share of energy-intensive clean room space would be penalised when compared with 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 mechanical HVAC systems. The new approach would create an innovative energy intensity metric by dividing total site energy consumption by volume of air delivered. Table 2-5 shows a comparison of energy use intensity formulas.

Table 2-5. Energy Use Intensity Calculation.

Energy Use Intensity Formula	Pros	Cons
1 $\frac{\textbf{Total energy}}{\textbf{Area}}$	• 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 $\frac{\textbf{Total energy}}{\sum \dot{m}_i^{\,*}}$ (Total Energy -kWh- / Static Volume Delivered by AHUs -m^3-)	• 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.
***Mainly based on measure date from Test & Balance reports, next step will be based on delivered volume of air during the evaluation period**		

Table 2-6 provides an overview of energy use intensity for the four EU sites (Sites 1-4) in BSC plus a newly constructed state-of-the art fifth site (Site 5), using a variety of formulae.

Table 2-6. 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	Producti on	Productio n	Productio n	Warehou se	Productio n

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 consequently much less energy intensive per square meter than any production site. The proposed volumetric airflow based Tier 1 KPI accounts for this issue.

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

2.5.2.2 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 work, the comparison between the EU sites is presented in Figure 2-7 and discussed below for the implementation of the EM^3 in 2015 and 2016.

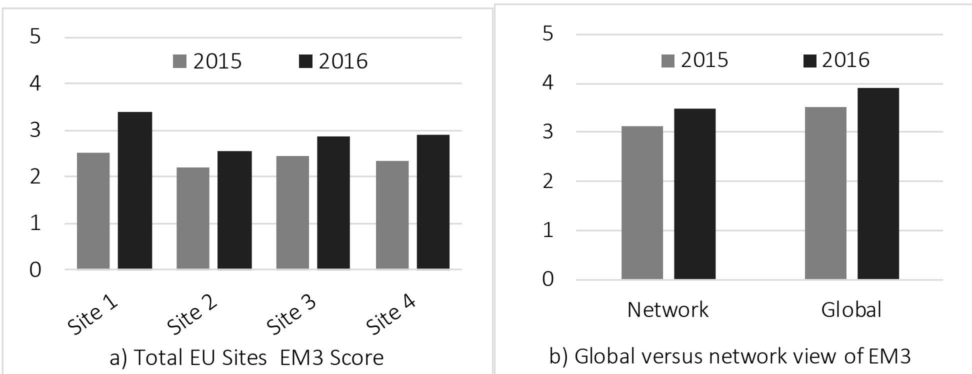

Figure 2-7. EM^3 Scores for BSC EU sites and Global scores.

From Figure 2-7 a), all EU sites have managed to improve their EM^3 score which means that actions have been taken to increase the maturity level in relation to the implementation of energy management practices. On the Global side of the EM^3, Figure 2-7 b), improvements are evident from both the Global and network perspectives. This reflects positively on the deliberate efforts made by the corporation to raise awareness on all aspects of energy management activities.

2.5.2.3 Energy strategy: Enablers and drivers

GEMS' MCDM was applied to prioritise energy projects related to five different BSC manufacturing plants as shown in Table 2-7. Level 1 and level 2 criteria (Figure 2-4) weights were estimated using fuzzy logic to transform the linguistic responses from four experts within the organisation (Table 2-8) to a qualitative questionnaire designed to assess the relative importance they placed on each of the criteria.

Table 2-7. 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 2-8. 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 2-9.

Table 2-9. Criteria weighting (Contreras, 2016).

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, the results shown in Table 2-9 indicate that the environmental performance is the main priority (34%) when ranking energy projects in this organisation. Interestingly, the economic dimension is the second priority (31%), but it is 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-making for energy efficiency projects (Cooremans, 2011). With respect to the prioritisation, Figure 2-8 shows the results of the MCDM ranking of the five projects presented in Table 2-7, resulting in the Solar PV project (P5) achieving the top ranking, followed by the CHP project (P2) in second place, achieving roughly half the overall performance of the P5.

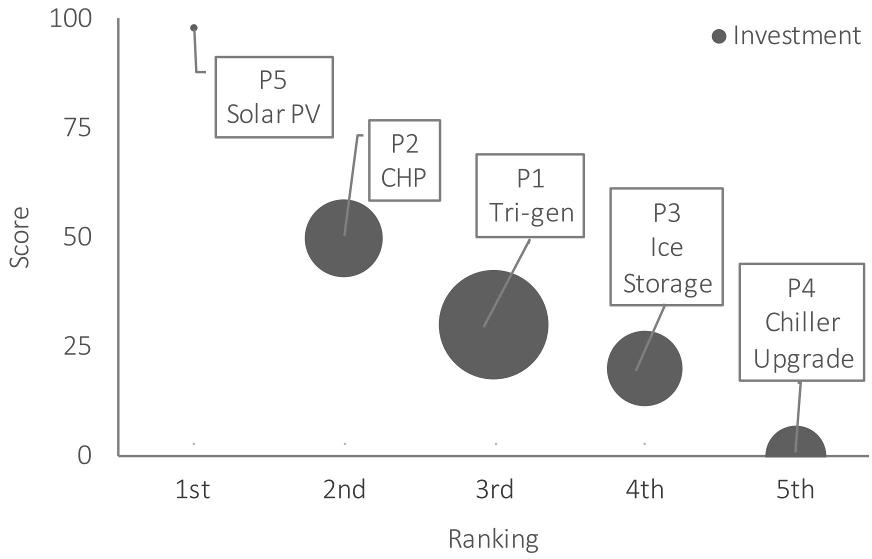

Figure 2-8. Case study prioritisation results.

2.5.2.4 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 of the global site base, this has been found as the most cost effective communication platform. 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 (USA) 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 document their top-five energy projects in the previous five years (entitled 'Top 5 in 5'). Projects were then summarised under the key headings: shared learnings (SL) or meaningful innovations (MI), 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 2-10. GEMS selected two years of shared learnings and meaningful innovation.

Topic	Date	Type
Site 3 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 Table 2-10, SL implies new, interesting knowledge about a specific topic that is being disseminated across the network. 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 2-7). Additionally, as part of the shared learnings pillar, it was requested for all primary owners to receive and obtain certification on energy management (coordinated by GEMT). This in turn, supports the implementation of the GEMS beyond the EU pilot sites.

2.5.2.4.1 Broader Dissemination

To truly make an impact inside and outside the corporation, a broad dissemination strategy shall be adopted. In this case study, the first step of this approach is under development in the form of an interactive screen, which will be installed at prominent locations on each site, to showcase GEMS and associated projects to the BSC workforce and community at large. The 'Green Screen' provides an overview and explanation of the various elements of GEMS, such as the EM^3, the Tier 1 KPIs, as well as an indication with respect to corporate progress on sustainability. It also highlights current and completed projects that contribute to the corporation's energy policy. 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.

2.5.3 Decision support framework

GEMS' DSF will present top management, in a central environment, the aggregated information (coming from all the pillars) to enable informed decision-making. At present, the DSF information is collated using a central spreadsheet (Table 2-11), but future work will focus on the development of a web-based DSF for data acquisition, management and collaborative input for decision-making.

Table 2-11. GEMS DSF (Excerpt).

Project	**Investment Model**	**Proposal parameters**					**MCDM Output**	**KPI**	**EM[3]**
		Total Project Cost ($)	**Opex Savings p.a. ($)**	**Site Utility Saving %**	**GHG Reduction**				
					Site	Network			
P1	Capital	2,575,000	588,000	15%	14.7 %	1.9%	3	134	2.4
P2	Capital	1,346,000	648,000	49%	25.0 %	1.5%	2	128	2.2
P3	Capital	1,250,000	347,000	14%	0.0%	0.0%	4	97	2.2
P4	Capital	800,000	308,000	10%	9.0%	0.5%	5	78	2.1
P5	PPA*	0	175,000	6%	11.0 %	0.6%	1	78	2.1

***Power Purchase Agreement**

As shown in Table 2-11, relevant parameters are presented in concise way, thus providing the reader with an efficient mechanism to make informed decisions on where and how to spend capital for energy efficiency projects. From Table 2-11 the best ranked MCDM project (P5 – Solar PV) is not necessarily the one with the highest utility savings or CO_2 emissions impact.

Second in the ranking was the project with the best financial and second best sustainability parameters, albeit it requires own capital funding (P2 – CHP).

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.

2.6 Conclusions

This research work has presented the methodological approach for assessing capital expenditure projects in a multi-site organisation. Implementation steps for GEMS should naturally follow a bottom up and left to right approach (Figure 2-1). Additionally, several components can be developed in parallel depending on available resources and current needs without major alterations on GEMS outputs.

The proposed novel methodology complements typical site-based EnMS and provides any multi-site corporation with a formal framework to ensure optimal energy efficiency across the network and informed decision making on capital expenditure. Key conclusions can be drawn from the implementation of the pilot study, with respect to each of the components of the proposed GEMS framework, which are summarised in the following sections.

2.6.1 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 achieve 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 expenditure and consequential 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 an enterprise energy management solution.

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 pilot.

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

2.6.2 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 easily calculated, tracked and understood.

Evaluating the maturity of the corporation in terms of energy management has proven fundamental in developing the business case for GEMS full network roll out and 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 a disconnected manner without realising the potential benefits brought by the aggregation of the information and dissemination of the projects.

The outputs of the MCDM approach to project prioritisation 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 in an un-biased manner.

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 peers to understand their positioning on sustainability and energy efficiency, which has then been added to the body of information available for decision making.

2.6.3 Decision Support Framework

The DSF enables consistent project assessment against the predefined corporate energy policy (foundation) and energy strategy (pillar). It should be noted that the role of the DSF is not to eradicate the need for expert knowledge in project selection, but rather to present all the information required for decision-making in a clear and concise manner. For example, the global energy manager may decide that the strategic need to improve the performance of one site out-weights the importance placed on the MCDM output for each individual project. In fact, the driver for capital investment may be to bring all sites to an acceptable level of performance and subsequently 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.

2.7 Future work

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

- Development of a 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 for both site and corporate-level personnel;
- Best in class techniques for internal and external communications.
- DSF automation and usability improvement.

- Further develop the 'Policy' foundation and the 'Energy Strategy' pillar methodologies.

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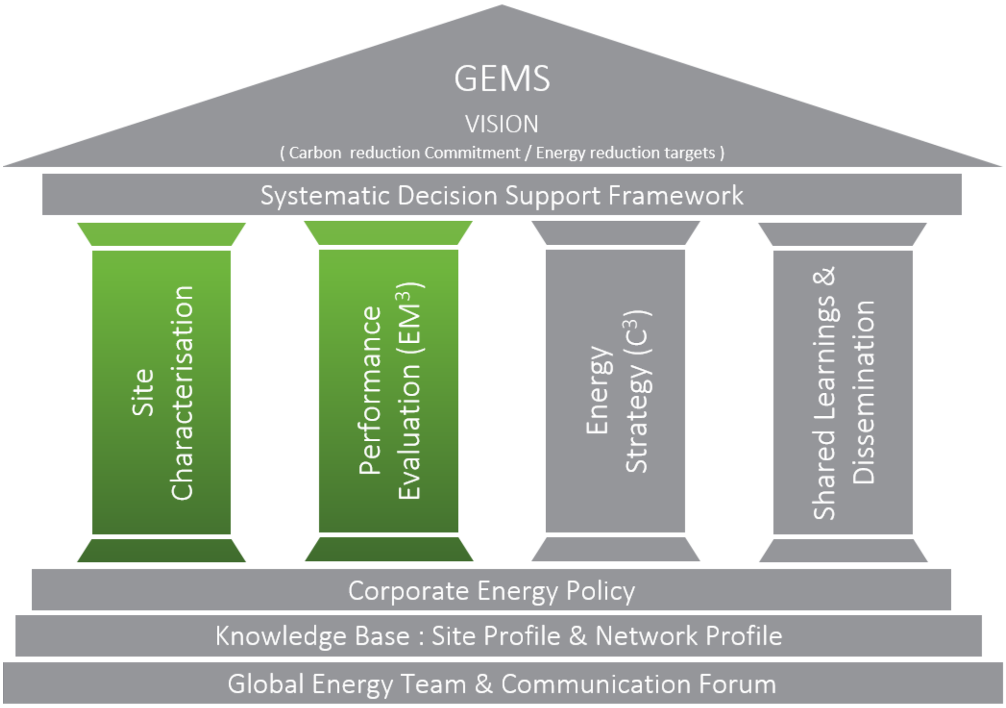
3 An energy management maturity model for multi-site industrial organisations with a global presence

"The only reason for time is that everything doesn't happen at once" – Albert Einstein.

Introduction

Chapter 3 serves to address the gap identified in section 1.4 regarding the development of maturity models in the energy field, especially in MMO. The paper can be reviewed as a standalone piece of research or in unison with the overall GEMS methodology. It is worth noting that while the Site Characterisation and Performance Evaluation Pillars serve to deliver the EM^3 as part of the GEMS framework the EM^3 assessment covers all aspects of the GEMS life cycle. It is underpinned by the Plan-Do-Check-Act cycle of continuous improvement.



Vision Supported By Strategies Based On Foundations

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Noel Finnerty developed the methodology, he collected, analysed and synthesized the data. He is the primary author of this article. Dr. Raymond Sterling contributed to the methodology development (specifically the SWOT analysis) and paper writing. Dr. Daniel Coakley contributed to the paper writing. Dr. Marcus Keane assisted with the paper review.

The published paper detail is included in Appendix A.

AN ENERGY MANAGEMENT MATURITY MODEL FOR MULTI-SITE INDUSTRIALORGANISATIONS 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 a multi-site industrial organisation. The model enables two-way communication between global and local energy management teams; not only are the individual sites benchmarked but the global energy management team receives 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 from the site and network median score. In parallel, it provides the global energy management team with direction on where the organisation needs to focus central efforts to support the individual sites. The maturity model enables the evaluation of key non-technical aspects of energy management required for continuous improvement on a multi-site and global scale.

3.1 Introduction

Climate change and energy resource sustainability is a major challenge facing humanity today with implications for individuals, businesses and multi-national organisations (Stern, 2006). Global energy consumption has continuously risen over the past century due to population growth, industrialisation and increasing energy use per capita (International Energy Agency, 2014). This growth has been largely associated with consumption of 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 553 EJ in 2010 to an estimated 863 EJ by 2040 (Leahy *et al.*, 2013).

Industrial production and processing consumes a significant portion of global energy resources. In the EU-27 alone, it is estimated that 25% of the total energy requirements are associated with industry (Pérez-Lombard, Ortiz and Pout, 2008). 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 (Worrell *et al.*, 2009). 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 (EEA, 2013). 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 (Transparency Market Research, 2016). 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 (Fedrigo-Fazio *et al.*, 2011). 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 (Carbon Trust, 2011b; Schulze *et al.*, 2016). In industry, the implementation of EEM is mainly a response to legislative demands, economics and corporate social responsibility (CSR) (Williamson, Lynch-Wood and Ramsay, 2006). While legislative compliance is a strong driver since it demands implementation of EEM, such measures may prove ineffective if long-term energy management strategies and practices are not enforced to support continuous improvement (Thollander and Ottosson, 2010; Trianni, Cagno and Farné, 2016). Implementation of energy management practices faces a series of barriers affecting companies of all sizes (Harris, Anderson and Shafron, 2000; de Groot, Verhoef and Nijkamp, 2001; Rohdin and Thollander, 2006; Thollander and Ottosson, 2008; Hasanbeigi, Menke and du Pont, 2010; Cagno *et al.*, 2014; Timilsina, Hochman and Fedets, 2016; Trianni, Cagno and Farné, 2016). Low priority given to energy management has been consistently reported in literature (Trianni, Cagno and Farné, 2016), (de Groot, Verhoef and Nijkamp, 2001), (Rohdin and Thollander, 2006), (Hasanbeigi, Menke and du Pont, 2010), (Cagno and Trianni, 2014), (Cooremans, 2012). Two main drivers to overcome such barriers have been identified in the literature. The first driver is the reduction of energy costs (Trianni, Cagno and Farné, 2016), (de Groot, Verhoef and Nijkamp, 2001), (Thollander and Ottosson, 2008), (Hasanbeigi, Menke and du Pont, 2010). The second driver is the existence of a long-term energy strategy (Trianni, Cagno and Farné, 2016), (Rohdin and Thollander, 2006), (Thollander and Ottosson, 2008), (Hasanbeigi, Menke and du Pont, 2010), (Rohdin, Thollander and Solding, 2007a). The economic driver alone may not be sufficient to trigger positive decisions on energy efficiency (de Groot, Verhoef and Nijkamp, 2001), (Cooremans, 2012), especially for non-energy intensive organisations[8], where energy costs are a small portion of the production costs (Trianni, Cagno and Farné, 2016). 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 the 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' definition. This work in engrained in a larger methodology for the development of a Global Energy Management System (Finnerty *et al.*, 2016), which is briefly introduced in section 3.1.1.

3.1.1 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 (Finnerty *et al.*, 2016) results in a simplified, understandable, systematic, repeatable and scalable **decision support framework** addressing the complexities unique to decision-making relating to capital investments in global multi-site organisation.

3.1.2 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:

[8] In a non-energy intensive organisation energy costs are less than 2% of its turnover or less than 5% of its production costs (Rohdin and Thollander, 2006; Trianni, Cagno and Farné, 2016).

- 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 language between the different energy stakeholders in the organisation towards fair evaluation of energy projects. The paper is organised as follows. Section 3.2 provides the result of a systematic literature review regarding energy management maturity models and energy management in practice. Section 3.3 describes the methodological approach for the implementation of the EM^3. Section 3.4 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 3.5 and 3.6 the final conclusions and future work are reported.

3.2 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 review, and is already covered in significantly more detail in recent articles (Schulze *et al.*, 2016). Here, we provide a succinct overview of the key aspects of energy management in practice, particularly as they relate to 'maturity model' formulation.

3.2.1 What is energy management and energy management system?

There are several definitions of 'Energy Management'. The energy management guide published by the Carbon Trust (Carbon Trust, 2011b) defines energy management as "*the systematic use of management and technology to improve an organisation's energy performance*". Bunseet al. (2011) describe energy management "*as the control, monitoring and improvement activities for energy efficiency*". ISO 50001 (ISO, 2011) 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 (Ingenieure, 2007) released a definition which includes the economic dimension: "*Energy management is the proactive, organised 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 no 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.

3.2.2 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 (European Parliament, 2006)] 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% to 10% of operational costs with minimal investment (Piñero, 2009; Carbon Trust, 2011b), leading to increased productivity (McKane *et al.*, 2010). 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 (Vikhorev, Greenough and Brown, 2013). On the contrary, implementation of several one-off energy efficiency projects is likely to fail in delivering continuous savings (Therkelsen *et al.*, 2013). 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, and business continuity.

3.2.3 Energy management systems implementation

There is a large body of literature on energy management system implementation, so 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 (WBCSD; WRI, 2004).

Determining the energy and greenhouse gas emissions associated with each stage of the supply chain was deemed overly complex without adding value (Whaley, 2014).

- 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 below. Standards such as ENERGY STAR™ (US EPA, 2013), ISO 50001 (ISO, 2011) and SEP (US Department of Energy, 2012) offer the best available support to an individual site energy manager. The ENERGYSTAR™ 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 in 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 of 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 (Carbon Trust, 2011b) and Sustainable Energy Authority of Ireland (SEAI) (O'Sullivan, 2011b), 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 (Levermore, 2000). These measures include improved control of the heating ventilation and air conditioning systems (Huang, Zaheeruddin and Cho, 2006; Mossolly, Ghali and Ghaddar, 2009; Soyguder and Alli, 2009), fault detection and diagnosis (Bruton *et al.*, 2012; Sterling *et al.*, 2014; Yu, Woradechjumroen and Yu, 2014), renewable energy sources integration (Kolokotsa *et al.*, 2011), etc. However, there is limited scientific literature addressing implementation activities that ensure a successful implementation of energy management systems for organisations of any size (Antunes, Carreira and Mira da Silva, 2014). This lack of standardised models for energy management implementation results in energy management programmes that not cover the whole range of activities that are defined in the standards and guidelines (Antunes, Carreira and Mira da Silva, 2014). The literature review revealed that current approaches to implement 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. in-formation exchange between site, investment decision support, definition and implementation of a global energy management team, etc (Finnerty *et al.*, 2016)). 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) (Rohdin, Thollander and Solding, 2007b). 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 characterisation based on energy management principles (Carbon Trust, 2011b; ISO, 2011; US Department of Energy, 2012). The second point touches on the definition of Maturity Models (Paulk *et al.*, 1993; Wendler, 2012; Antunes, Carreira and Mira da Silva, 2014). 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 3.3 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.

3.3 Maturity models

In this section, we conduct a systematic literature review, as outlined by Tranfield et al. (2003) and further applied to the field of 'energy management' by Schulze et al. (2016). 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 that 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 3-1.

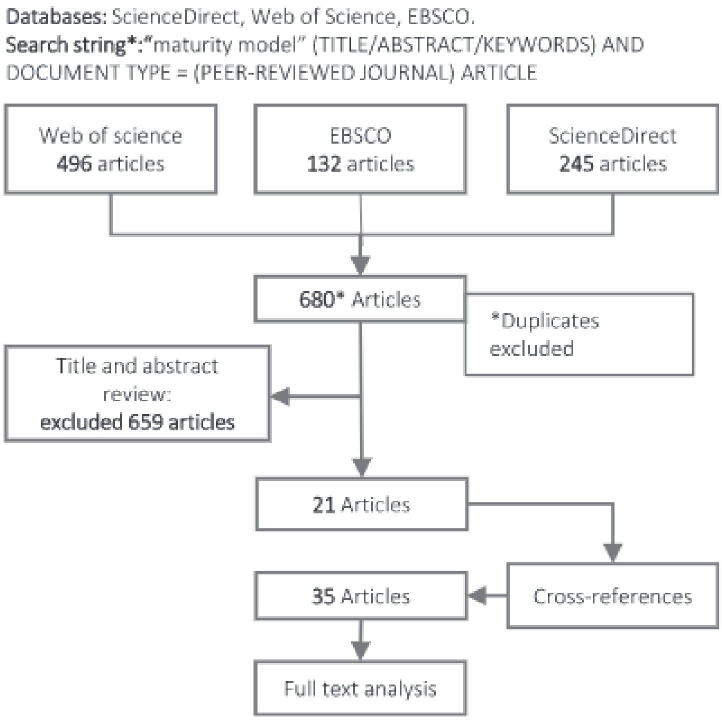

Figure 3-1. Systematic literature search - Process summary

Purpose and structure of 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 (De Bruin *et al.*, 2005). 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 (Pöppelbuß and Röglinger, 2011). 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 (Becker *et al.*, 2010). 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 (Antunes, Carreira and Mira da Silva, 2014). 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 (Hackos, 1997).

Maturity models can be differentiated according to various criteria (Introna *et al.*, 2014a):

- *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 organisation,
- *Guide to improvement*: the more or less explicit and structured presence of specific instructions for the improvement of the organisation.

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*" (Carnegie-Mellon-SEI, 2010c).

Additionally, the following application-specific purposes of use are distinguished (De Bruin *et al.*, 2005; Becker, Knackstedt and Pöppelbuß, 2009; Pöppelbuß and Röglinger, 2011):

- *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 organisations can be compared.

3.3.1 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 (Paulk *et al.*, 1993). Maturity model research continues to be heavily dominated by software development and software engineering disciplines (Wendler, 2012). Since their inception, maturity models have been applied to many different domains and industries (De Bruin *et al.*, 2005; Becker *et al.*, 2010), including finance (Lederman, 2012), automotive (Lie-Chien, Tzu-Su and Kiang, 2009), software development

(Bicego and Kuvaja, 1996; Carnegie-Mellon-SEI, 2010b), industrial data analytics, business strategy (Hackos, 1997), project management (Crawford, 2006), e-Government (Andersen and Henriksen, 2006; Valdés *et al.*, 2011), 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) (Hackos, 1997), based on the CMM framework, provides a strategic planning tool for organisations, to help understand and analyse their market-place 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 (Carnegie-Mellon-SEI, 2010b), Services (Carnegie-Mellon-SEI, 2010c), and Product/Service Acquisition (Carnegie-Mellon-SEI, 2010a). The maturity of product development is divided into five levels: initial, managed, defined, quantitatively managed, and optimising. 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 (2004) 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* (Carnegie-Mellon-SEI, 2010d). 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 out-comes and objectives; (3)Training: Navigator courses and seminars; and; (4)Licensing: certifications for courses and individuals.

More recently Domingues et al. (2016) 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.

3.3.2 Energy management maturity models

In Section 3.2, 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 (Carbon Trust, 2011a; ISO, 2011), (ANSI, 2008), 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*" (Antunes, Carreira and Mira da Silva, 2014). According to Antunes et. al. (2014), 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 (Neuhauser, 2004). 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 (Demir and Kocabaş, 2010). O'Sullivan (2011a) 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. (2014), a relatively recent survey of 237 articles on maturity models, only three focused on the area of sustainability (Wendler, 2012). 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 3-1.

Most of the energy management maturity models reviewed focus on similar key areas to evaluate an organisation. The EDF Matrix (EDF Climate Corps, no date) and Carbon Trust Energy Matrix (Carbon Trust, 2015) 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 (Carbon Trust, 2015) and the SEAI (O'Sullivan, 2011b) 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 of the models reviewed see the need for providing a continuous improvement path following the PDCA approach and ISO 50001. Ngai et al. (2013) 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. (2014) and Introna et al. (2014b) provide fully developed maturity models and continuous improvement steps for an 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. Jovanovic and Filipovic (2016) present a model that is strongly linked with ISO 50001's steps, aimed at complementing the result of an ISO50001 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 (Antunes, Carreira and Mira da Silva, 2014). Similarly, Introna et al. (2014b) 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 3-1.Summary of energy management maturity models in literature

Type	Model	Maturity Levels	Parameters / Dimensions	Comments
Industrial Guidelines	Carbon Trust Energy Management Matrix (Carbon Trust, 2015)	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 (Carbon Trust, 2015)	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 (O'Sullivan, 2011b)	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	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.

			Management review; Policy; Resources and authority	
	EDF (EDF Climate Corps, no date)	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. (Ngai *et al.*, 2013)	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. (Antunes, Carreira and Mira da Silva, 2014)	Initial Planning Implementation Monitoring	Energy Management Commitment, responsibilities and roles, Energy review, Performance benchmarking and KPIs, Energy Policy, Regulatory Compliance, Investment,	The model is based on clearly defined and understood activities, i.e. the activities reiterated through various energy management texts. The movement from one

	Improvement	Procurement, Training, Communication, M&V, Management Review	maturity level to the next follows PDCA path.
Introna et al. (Introna *et al.*, 2014b)	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 (Jovanović and Filipović, 2016)	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	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)

	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

3.4 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 (characterize) 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*: 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 EM3 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*: 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 (ISO, 2011; Antunes, Carreira and Mira da Silva, 2014; Introna *et al.*, 2014b) 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 EM3:

- *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 (EDF Climate Corps, 2015).

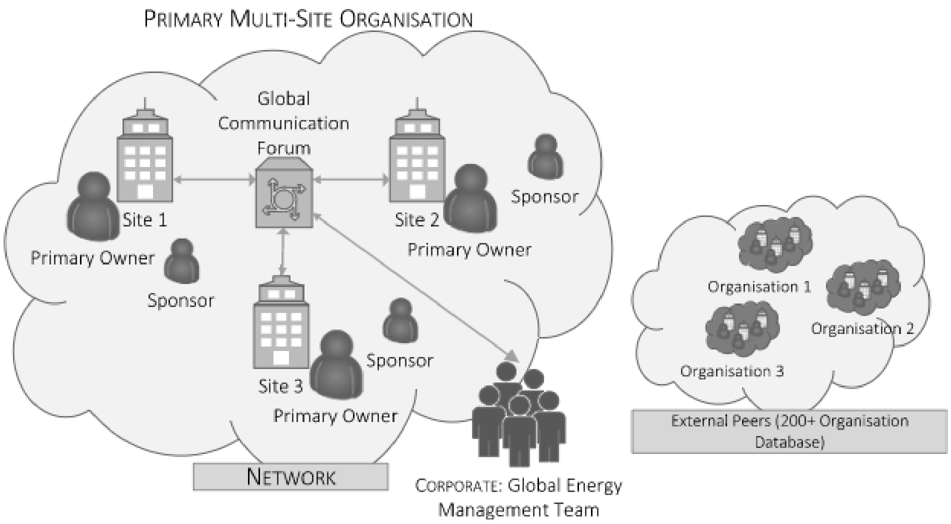

Figure 3-2. Points of view for the application of the EM³

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.

3.4.1 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 ninety min). 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 3-2:

- *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 (PDCA) aligning with industrial standards (Antunes, Carreira and Mira da Silva, 2014). Each PDCA phase is aligned with parameters found in reviewed literature (Table 3-1) and then divided into key areas as follows:

- *Part A - Site*: is a set of nine key areas (Table 3-2) aimed at understanding where each site is in terms of an energy management maturity model.

Table 3-2. 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 (Table 3-3). 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 3-3. 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 (EDF Climate Corps, 2015), into the EM^3 aimed 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.

3.4.2 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 (Figure 3-3). 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.

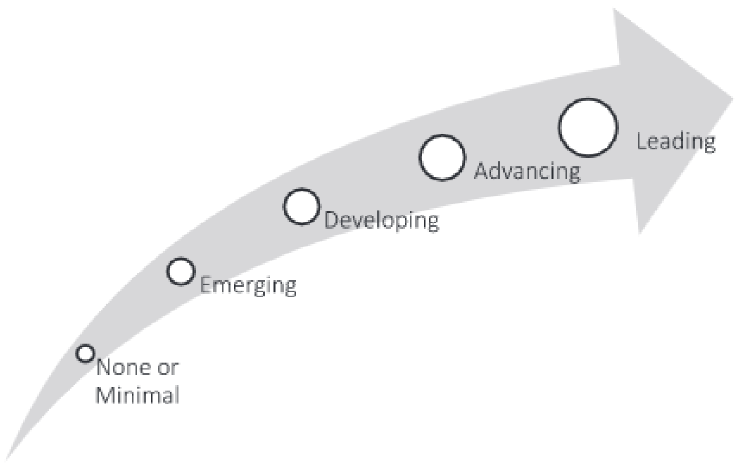

Figure 3-3. Maturity levels

The maturity levels are defined as shown in Table 3-4:

Table 3-4. 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 3.10, 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.

3.4.3 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 (Figure 3-4). Each facility is then requested to address the weaknesses found and plan contingency actions for the threats. This measures the performance of 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.

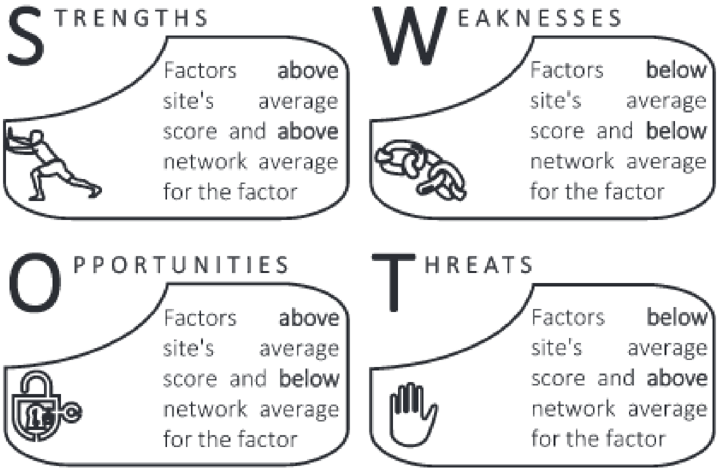

Figure 3-4. SWOT analysis

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.

3.4.4 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 the 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.

3.4.5 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 be-tween 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.

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 3-5.

Figure 3-5. 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 in-dependent 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.

3.5.1 Results compilation and data aggregation

After the full application of the EM^3 survey, all the data are 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.

3.5.1.1 Part A – site

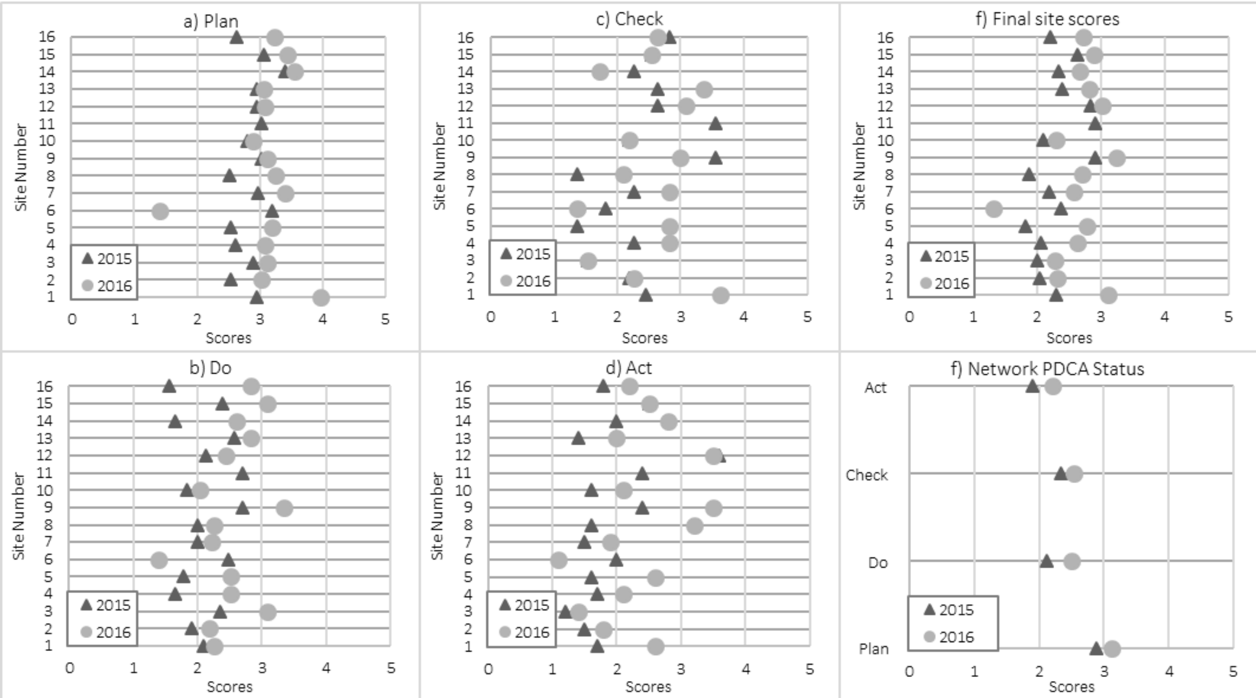

Figure 3-6. PDCA scores for the site-level survey applied to 16 BSC sites. a-d) P-D-C-A scores. e) Individual sites averaged PDCA scores. f) Network averaged P-D-C-A results.

Figure 3-6 e, shows that BSC network average is between the Emerging and Developing maturity levels (Table 3-4). From Figure 3-6 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 where-by emphasis was made on all the key areas with a maturity level below 'Emerging' for each site. Figure 3-6 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 2-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.

3.5.1.2 Parts B and C - corporate and external peers

Figure 3-7 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.

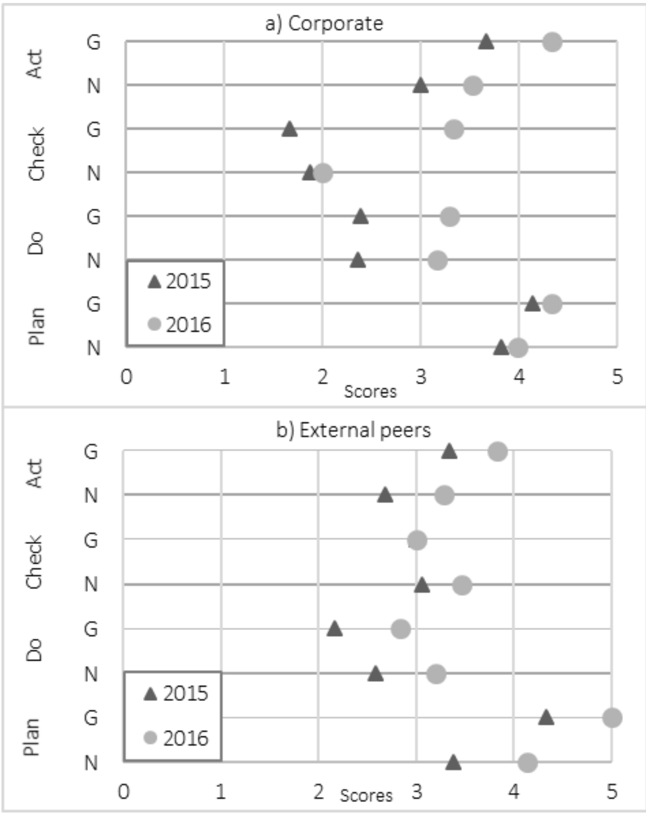

Figure 3-7. PDCA scores for the Corporate/External-peer survey comparing averaged answers of the 16 surveyed BSC sites and the global energy management team. G: Global. N: Network.

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 3-7 it is interesting to note:

- For the Corporate section (Figure 3-7 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 3-7 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.

3.5.2 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. (Figure 3-8)

Figure 3-8. Network averages in key areas of site survey

3.5.2.1 Part A - site questions

Figure 3-8 shows how the 2015 and 2016 network average results in the key areas of the 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 team2017 action plan can however, further the continuous improvement process by targeting the dissemination of an increase to the global threshold (now 2.0).

3.5.2.2 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.

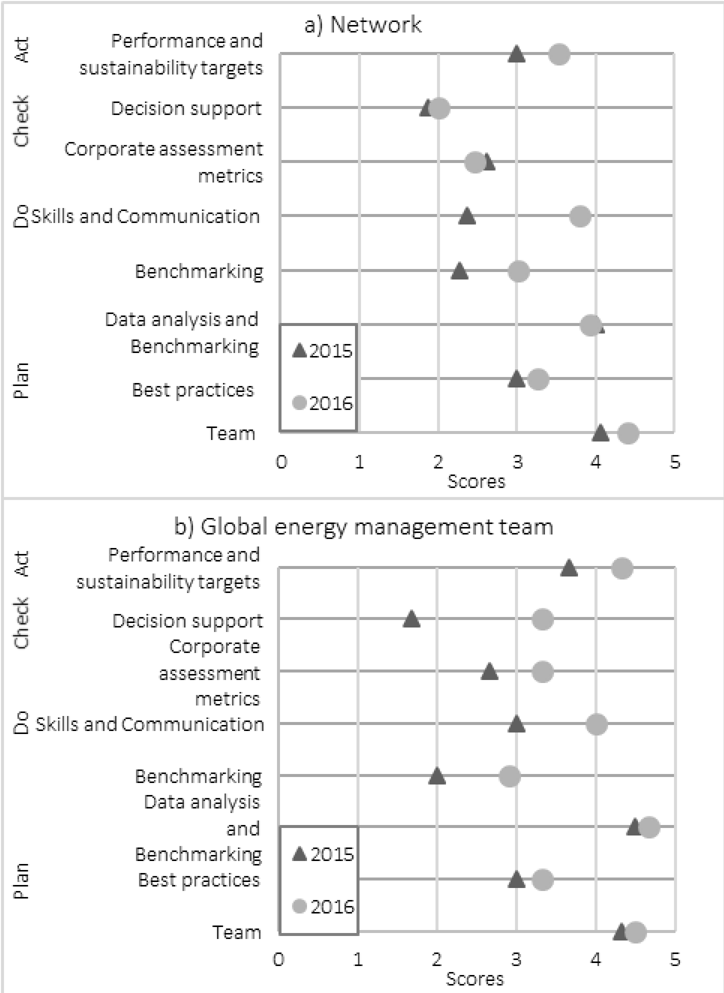

Figure 3-9. a) Network and b) Global energy management team averages in key areas of global survey

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 3-9 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 3-9 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.

3.5.2.3 Part C - external-peers

Figure 3-10 reflects the results of the external-peers section of the survey taken by the network of sites and the corporate energy management team.

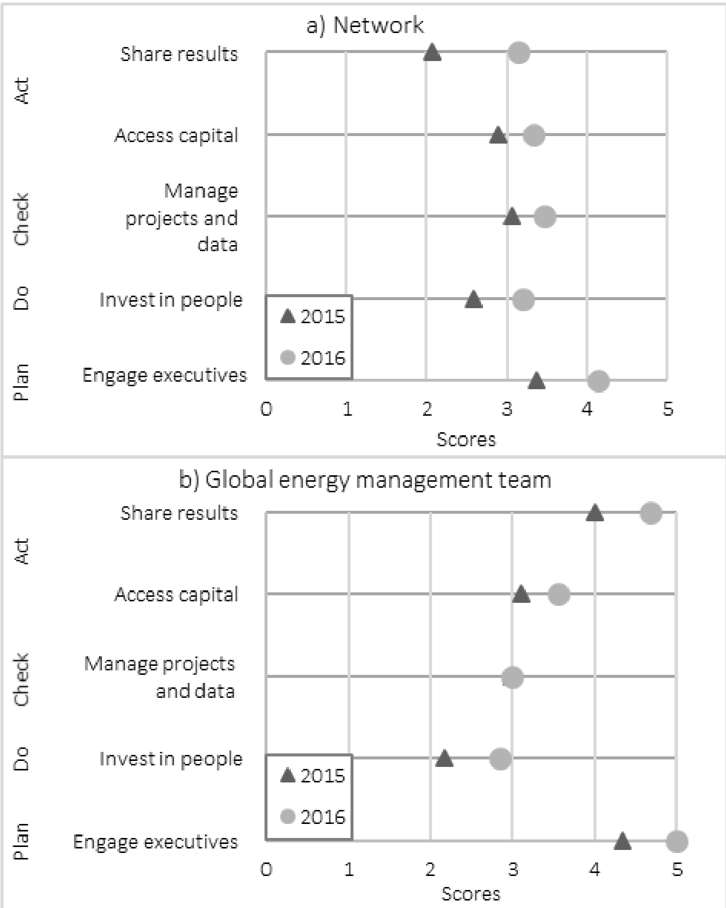

Figure 3-10. a) Network and b) Global energy management team averages in key areas of external peer survey

While both, the network and the global energy management team scores have improved in 2016, as shown in Figure 3-10, 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.

3.5.3 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 3.4.2). 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 3.4.2 and the results are trans-formed 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.

3.5.4 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 (Finnerty *et al.*, 2016).

3.6 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 3.3.1: 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 EM3implementation 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 communication and a common ground to start working towards continuously improving within 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 theEM^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 (characterize) 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.

3.7 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 EM3presented in this research work encompasses several other approaches found in literature it does not include every conceivable aspect of energy management (e.g. legal is-sues). Further developments and improvements might be applied to refine and/or extend the models should such un-considered 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.

3.8 Acknowledgements

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3.10 Appendix

Table 3-5. 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.	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	EPD analysed with specific tools. Sub-metering for MEU in place. Site compared against other facilities in the same sector. Opportunities periodically reviewed	EPD automatically analysed. Energy costs reviewed frequently. Energy tariff reviewed by third party. Sub-metering includes other energy users. Site compared against

			Site level KPI. Limited goals	organisation. KPI for MEU and source. Site level goals and for MEU communicated internally.	and pursued. KPI for MEU include drivers and split by final use. System level goals defined, periodically reviewed and communicated internally	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	Informal training to ET. Awareness reaches only few levels and	Frequent training on energy management to ET and SM. Promoting	A comprehensive and frequent energy training programme exists	Certified energy training is provided and available to all personnel.

	communication platform	awareness campaigns are sporadic with limited funding. No resources allocated for energy-related communication	awareness becomes site's policy. A communication platform for sharing documentation 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	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	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	Energy actions documentation accessible to personnel in all areas. Energy O&M seeks low-cost actions continuously. Space design and materials selection use	Energy actions documentation accessible to all personnel. Energy O&M is comprehensive with interventions planned and communicated. At least one member of

			design, materials and suppliers' choice	team is aware of energy matters. Energy is prioritised for space design, materials and suppliers' selection	modelling and simulation for performance evaluation. Equipment selection is based on energy performance	O&M team is energy certified. LCA is performed for space design, material and equipment 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	SM: Site Management	EE: Energy Efficiency
EMT: Energy Management Team	EPD: Energy Performance Data	MEU: Major Energy Users

EP: Energy Policy

Table 3-6. 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	Forecasted ROI (based on opportunities list)	Opportunities list reflecting the positive impact on	Complete business case reflecting impact on stock

			sustainability impact	with associated sustainability impact	operational savings, sustainability and business continuity	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 benchmarking. Site level KPIs	Energy consumption split by MEU. Each site is audited by a global partner. Sites benchmarked quantitatively. Site. And global-based KPIs used	Sites energy data normalised by climate and economics. A sensitivity analysis on energy uses is performed on each site. Benchmarking of sites is quantitatively and qualitatively. Site and global KPIs combined in enterprise-level EnMS	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-level EnMS includes KPIs and EM^3
	Skills and communication	No structure. No dissemination	Global forum in place for basic inter-site communication.	Global forum that allows presentation and dissemination of key topics. Global basic	Best practices based global forum for easy access and inter-site and external communication. Global	Enhanced technology for efficient transfer of inter-site best practices. Global advanced training programme

			Global and local individuals provide basic energy training	training programme in place for all energy stakeholders	intermediate training programme in place for all energy stakeholders	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	Software platform to support previous

					list of ECO's (and associated performance risk)	
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

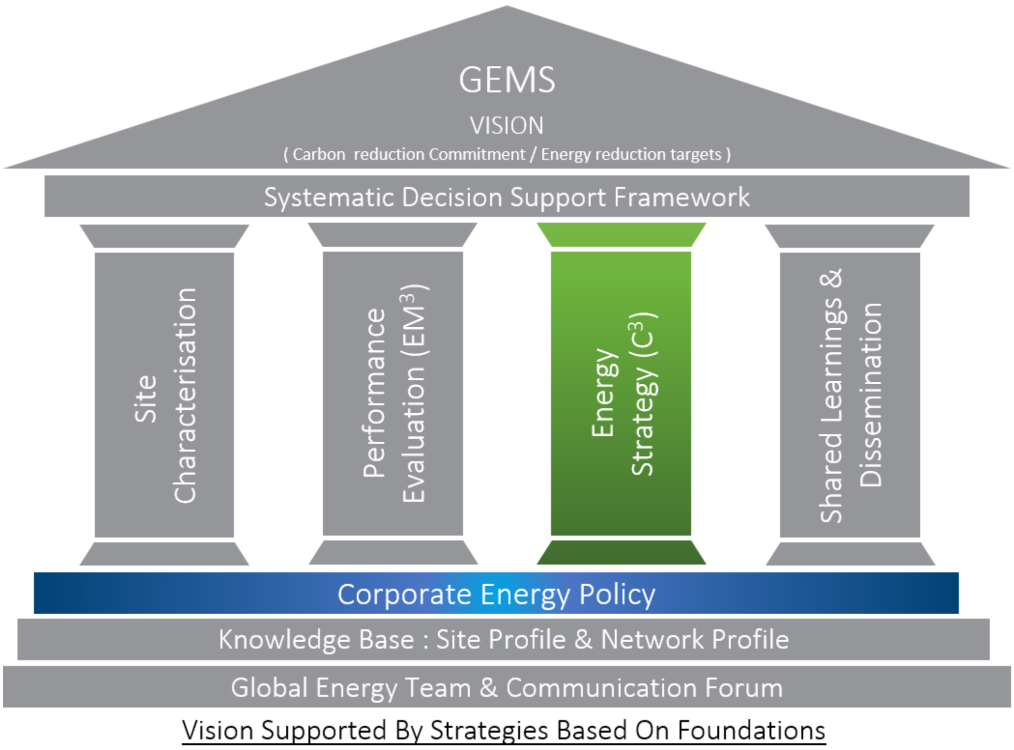
MEU: Major Energy Users

4 Defining corporate energy policy and strategy to achieve carbon emissions reduction targets via energy management in non-energy intensive multisite manufacturing organisations

"Fair play is good sport" – Paddy Finnerty.

Introduction

Chapter 4 serves to address the gap identified in section 1.4 regarding the lack of research on the characteristics of long-term energy policy and associated strategies in MMO, in addition to the gap that exists in the quantification of non-energy benefits. The paper can be reviewed as a standalone piece of research or in unison with the overall GEMS methodology. The energy strategy is organized taking into account the Plan-Do-Check-Act cycle of continuous improvement - the underlying basis for the majority of credible energy management systems.



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Noel Finnerty developed the methodology, he collected, analysed and synthesized the data. He is the primary author of this article. Dr. Raymond Sterling and Sergio Contreras contributed to the methodology development and paper writing. Dr. Daniel Coakley & Dr. Marcus Keane assisted with the paper review.

The published paper detail is included in Appendix A.

DEFINING CORPORATE ENERGY POLICY AND STRATEGY TO ACHIEVE CARBON EMISSIONS REDUCTION TARGETS VIA ENERGY MANAGEMENT IN NON-ENERGY INTENSIVE MULTI-SITE MANUFACTURING ORGANISATIONS

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Abstract

Research on the characteristics of long-term energy policy and associated strategies in multi-site manufacturing organisations is limited. Non-energy intensive multinationals do not face the environmental regulations required by their energy intensive counterparts, leading to missed opportunities and further widening the energy efficiency gap. This work investigates the development of a long-term energy policy and supporting strategy to close the energy efficiency gap focused on the inherent barriers found for non-energy intensive multi-site organisations. A systematic literature review identifies the essential components and the associated barriers/drivers to energy management. Highlights include (i) a review of energy policy guidelines and standards, (ii) an analysis of the decision-making practices, (iii) the influence of the non-energy benefits of energy-related investments and (iv) a study of six leading sustainable global organisations to identify best energy management practices. Subsequently, this work proposes a methodology to formulate a 'corporate energy policy and an associated strategy' in support of non-energy intensive multi-national manufacturing organisations by focusing on their specific characteristics and barriers. A case study is presented with findings on initial deployment in a Fortune 500 multinational corporation. Finally, conclusions are drawn and future work is proposed.

4.1 Introduction

4.1.1 Carbon emissions and energy management in industry

Carbon emissions reduction is primarily achieved either when imposed by a regulatory framework because of environmental concerns (Almutairi and Elhedhli, 2014), or when the economic and financial benefits associated with reduced emissions are clearly presented and understood by decision makers (Cooremans, 2012; Ouyang and Shen, 2017). Garrone et al.

(2017) point out how stakeholders' and public's opinion can better relate to the positive effects of carbon emission reductions as opposed to an equivalent impact from resource efficiency. In any case, the most effective way for industry to achieve carbon emissions reduction, is through the implementation of energy efficiency measures, energy management and energy management systems (Costa-Campi, García-Quevedo and Segarra, 2015). In literature, these terms are sometimes used interchangeably, thus a clear definition is provided as follows (Finnerty *et al.*, 2016) (Figure 4-1):

- Energy Management (EM) is the systematic monitoring and control of energy related activities (Kanneganti *et al.*, 2017);
- Energy Management System (EnMS) is the procedure or strategic steps put in place to achieve effective energy management (e.g. ISO 50001 (ISO, 2011), GEMS((Finnerty, Sterling, Coakley, Contreras, *et al.*, 2017);
- Energy Efficiency Measure (EEM) is the implementation of actions aimed at improving the efficient use of energy [8] (e.g. improve the ratio of useful output vs energy input [9]) under the governance of the EnMS and aligned with the pursuit of EM.

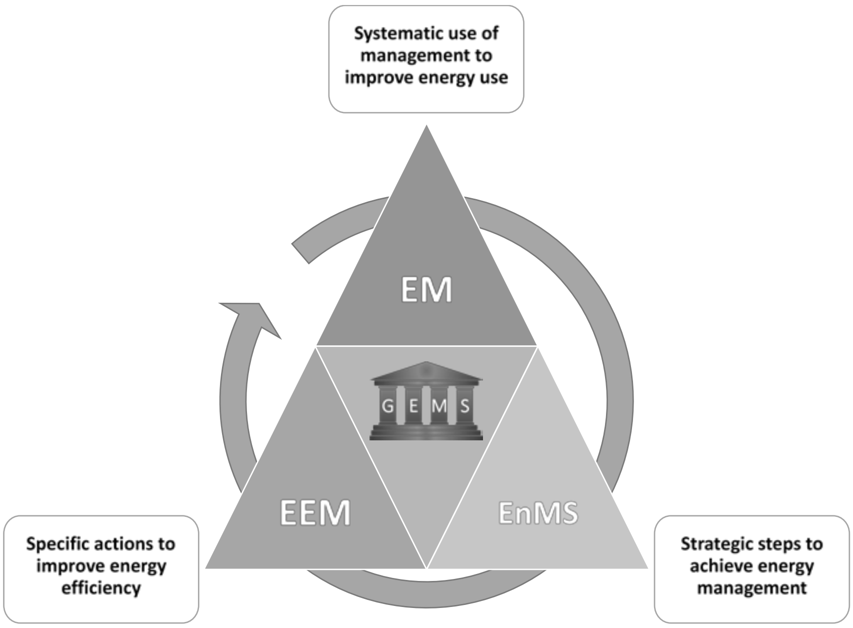

Figure 4-1. Energy management vs. energy management system vs. energy efficiency measure

Recognizing energy as an asset that is managed rather than a utility that is paid for, is key to the successful implementation of systematic energy management (Sterling, 2015), (May *et al.*, 2016) leading to carbon emissions reductions and improving energy security and financial performance (Böttcher and Müller, 2014; Martí-Ballester, 2016; May, Stahl and Taisch, 2016; Sáez-Martínez *et al.*, 2016; Bergmann *et al.*, 2017). However, even with the recognition in industry that better carbon and energy performance are linked to better financial performance, organisations still struggle to make positive investment decisions on energy efficiency measures. This remains a reality even when such measures are financially viable, contribute to lessen their impact on the environment and provide additional non-energy benefits (Contreras *et al.*, 2017). This sub-optimal performance level is referred to in literature as the “energy efficiency gap” (Thollander and Ottosson, 2010). It is a result of the interaction between energy efficiency barriers and drivers that affect an organisation's decision-making processes.

4.1.2 Energy management in the manufacturing sector

The manufacturing sector alone accounts for more than 98% of direct industrial greenhouse gases emissions (Fischedick *et al.*, 2014) and 36% of total industrial CO_2 emissions (direct and indirect) (Bunse *et al.*, 2011). Empirical research shows that carbon reduction through energy efficiency in the manufacturing sector faces barriers that affect small, medium and large organisations alike. The impact of those barriers on nonenergy intensive[9] organisations is greater than on the energy intensive ones (Trianni, Cagno and Farné, 2016). This is because energy costs are a small fraction of the overall production costs in non-energy intensive organisations, leading to energy efficiency being given less importance (Yeen Chan and Kantamaneni, 2015). Moreover, as energy may not be closely related to the core business activities, energy management may not be deemed strategic, leading to a lack of senior management commitment, competition for funding with other “more important” investments, limited resources and an unstructured decision making process (Cooremans, 2011). In implementing effective EM in organisations, international standards (e.g. ISO 50001) require the implementation of an energy policy and associated energy strategy, which may be defined as:

- Energy Policy is the documentation of the organisation's long-term vision, justification and commitment to improve its environmental performance through EM;
- Energy Strategy is the systematic approach and roadmap to achieve the targets set-out in the energy policy. The standards, however, do not provide a clear indication on how to implement an energy strategy or policy in multi-site organisations (Finnerty, Sterling, Coakley, Contreras, *et al.*, 2017).

[9] In non-energy intensive organisation, energy costs are < 2% of the turnover or <5% of production costs (Rohdin and Thollander, 2006; Trianni, Cagno and Farné, 2016).

4.1.3 Energy management in non-energy intensive multi-site manufacturing organisations

For this research work, non-energy intensive multi-site (and/or multi-national) manufacturing organisations (MMO) are an interesting focus group in terms of pursuing carbon reductions through energy management because:

1. Non-energy intensive MMO rarely face the same carbon emissions environmental regulations in comparison to energy intensive industries (which have frameworks or guidelines to which organisations must align to for compliance) (Faure and Peeters, 2008). Nonenergy intensive multi-nationals typically have several manufacturing sites spread across different countries in which they operate, and may have no legal obligations or targets to reduce CO2 emissions;
2. Carbon emissions, in non-energy intensive MMO, are produced primarily by burning fossil fuels to generate the energy required for production (Almutairi and Elhedhli, 2014). However, given the non-strategic nature of energy in these organisations, achieving significant carbon emissions reductions through EEMs requires the focus to be outside of the production area and on the facilities infrastructure;
3. There is an opportunity for MMO to look beyond site-focused EEM and to leverage the most suitable locations across their portfolio to maximise their carbon reduction potential (e.g. conversion to renewables matching regional limitations (Fitzpatrick and Dooley, 2017)), thus limiting the environmental impact associated with their production globally[10];
4. Due to the size and revenue volumes[11] of MMO, they are subject to higher public exposure than small to medium enterprises through corporate sustainability rankings (i.e. DowJones Sustainability Index, Corporate Knights). These ratings are increasingly directing investors towards high ranked organisations. This adds incentive for these organisations to use their financial position to improve their environmental performance (i.e. reduce energy intensity, offset or emit less carbon dioxide) as part of Corporate Social Responsibility and Corporate Sustainability programmes (Martí-Ballester, 2016).

[10] In fact, several multi-nationals have already pledged their commitment to the Paris Agreement on Climate Change (UNFCCC, 2016) (Tabuchi and Fountain, 2017).

[11] According to the NGO Global Justice Now, in 2016, 69 of the world's 100 top economies are corporations (Green, 2016). The value of the top 10 corporations reached $285tn, $5tn more than the value of the bottom 180 countries (Inman, 2016). Hence, corporations (like MMO) do have more resources than most countries and their impact can be even bigger in terms of environmental sustainability given that they control the highest share of world's resources (Fitzpatrick and Dooley, 2017).

5. Multi-nationals, through corporate governance, can more efficiently achieve carbon emissions reductions when compared to geographical clusters of companies. The latter face barriers such as not having a common 'energy' language (Finnerty, Sterling, Coakley and Keane, 2017) and passive participation. These barriers prevent the generation of a common problem statement (Palm and Backman, 2017) thus failing to implement effective policies.

4.1.4 Overview of the paper

This paper identifies the essential components of a corporate energy policy and proposes an approach to formulate the supporting energy strategies that enable non-energy intensive MMO meet global energy and carbon reduction goals. This work will contribute to further diminish the energy efficiency gap in a sustainable way as part of an overall approach to energy management, without compromising core-business operations. The paper is structured as follows. The literature review focuses on identifying the main barriers and drivers for implementing energy management in MMO and how they are impacted by the decision-making processes. It analyses key aspects affecting nonenergy intensive organisations such as, the need for highlighting non-energy benefits and the support from international standards. The literature review concludes with a summary of the gaps identified which leads to a systematic process to implement an energy policy and associated energy strategy to achieve carbon emissions reductions. The paper then proceeds to detail a methodology for the definition, implementation and continuous improvement of the energy policy and strategy. A case study is presented for a MMO. Finally, conclusions are drawn, and future work is proposed.

4.2 Literature review

A systematic approach to the literature review has been adopted to ensure results are consistent, transparent, un-biased and replicable[12] (Tranfield, Denyer and Smart, 2003), (Schulze *et al.*, 2016). The process has been detailed in Appendix (see section 4-10) Peer reviewed literature on corporate energy policy and supporting energy strategies to achieve carbon emissions reductions in MMO proved scarce, especially for interventions *not involving production area*. Thus, our literature review focused on:

[12] Databases: ScienceDirect (Elsevier), Web of Science (Elsevier, Springer, Wiley), EBSCO. Search string: TITLE(energy OR sustainability OR carbon) AND TITLE-ABSTRKEY((strategy OR strategic OR management OR policy) AND (industry OR industrial OR manufacturing OR corporate OR corporation OR firm OR enterprise) AND (efficiency OR conservation OR reduction) AND (factors OR barriers OR drivers)).

1. Previous empirical research on barriers, drivers and decision making procedures that affect how MMO invest in energy management. This provides a context and background that helps tackle the main reasons for the energy efficiency gap;
2. Non-energy related benefits that need to be included in the decision-making process to create a business case around achieving carbon reductions from energy management. Since energy may not be strategic for non-energy intensive MMO, it was deemed necessary to understand how a business case can be built around energy management to engage senior management;
3. International standards and corporate literature. Guidelines given by international standards on energy management such as ISO 500001 (ISO, 2011), Energy Star™ (US EPA, 2013) and Superior Energy Performance (SEP) (US Department of Energy, 2012) are reviewed. *Corporate literature* (including best practices) about energy policies and/or strategies already in place in a sample of manufacturing organisations revealed that in many cases, energy management is part of environmental sustainability and corporations are beginning to become aware of the need to reduce carbon emissions which is then disseminated to the public in their *sustainability reports*. Understanding the different ways that industrial leaders deal with energy management and implement international standards serves to identify the main strengths and weaknesses of the different models for achieving carbon emissions reductions.

4.2.1 Barriers, drivers and decision making for carbon reductions through energy management

The topic of barriers and drivers to energy management in industry has started to receive attention from the research community in recent years and a comprehensive review of papers have been published (Lee, 2015; May *et al.*, 2016; Schulze *et al.*, 2016). The focus of this research work is on identifying the key aspects that may influence MMO. Main findings are summarized below.

4.2.1.1 Main barriers to energy management implementation

A barrier in this context is defined as "*a postulated mechanism that inhibits investments in technologies that are both energy efficient and (apparently) economically efficient*" (Rohdin and Thollander, 2006).We have visited the main studies since 2000 on barriers for energy efficiency in the manufacturing sector (energy intensive and non-energy intensive). A summary of the barriers found in literature can be seen in Appendix (see section 4-10). From this literature review some patterns in the barriers arise:

- Low capital availability is a recurring and relevant economic obstacle for energy efficiency investments. In large organisations (e.g. MMO), however, this low availability is mainly due to the low priority of energy efficiency. This low priority reveals organisation's strategic view on energy efficiency (Cooremans, 2012). In fact, while access to external funding and lack of own capital are reported as causes for this barrier in SME's (Cagno and Trianni, 2014)(Trianni *et al.*, 2013), opportunity costs and allocation of capital to other non-energy projects might be the reason in large enterprises (Timilsina, Hochman and Fedets, 2016).

- Risk of production disruptions are regarded as a critical barrier in both non-energy intensive (Rohdin and Thollander, 2006) (Hasanbeigi, Menke and du Pont, 2010) and energy intensive organisations (Thollander and Ottosson, 2008)

- Lack of awareness, lack of governmental initiatives (e.g. policies or financial incentives) and time to implement energy efficiency are also identified barriers (Hasanbeigi, Menke and du Pont, 2010), (Trianni, Cagno and Farné, 2016), (Cagno and Trianni, 2014), (Timilsina, Hochman and Fedets, 2016).

The way in which barriers are perceived is determined by the characteristics of the organisations, especially size (number of employees) and energy intensity. For instance, small enterprises perceive barriers more strongly than medium and large enterprises (Trianni, Cagno and Farné, 2016), because the latter tend to allocate financial and human resources more easily to energy management and energy efficiency issues (Trianni *et al.*, 2013). With respect to the energy intensity of the company, in general non-energy intensive SME and large enterprise experience higher barriers than energy intensive counterparts (de Groot, Verhoef and Nijkamp, 2001; Trianni, Cagno and Farné, 2016). This is attributable to the higher ratio of energy costs to overall production costs in energy intensive production processes, which may lead to a higher priority of energy efficiency issues in the energy intensive organisations when compared to non-energy intensive industries. For organisations that have overcome the identified barriers and operate with maximum energy efficiency, achieving further carbon emissions reductions, or even carbon neutrality, becomes the next strategic goal. However, different barriers arise which are linked to "*the broader regional and global society, in particular the dominant neo-classical economic system*" (Fitzpatrick and Dooley, 2017). In effect, once the energy efficiency is optimized on site, further advances on CO_2 reductions is dependent on external factors and barriers outside the organisation's direct control e.g. fuel used to produce grid electricity or the availability of renewable sources of energy.

With regards to specific barriers for energy efficiency in MMO, there is a research gap in the literature reviewed where no empirical study focused on this type of company.

4.2.1.2 Main drivers to energy management implementation

Drivers are internal or external mechanisms that stimulate organisations to invest in energy efficiency. Drivers vary according to size and energy intensity of the company. As with the barriers we have studied the main research in the area since 2000. Drivers to energy management implementation found in literature are summarized in Appendix (see section 4-10).

Internal drivers are repeatedly identified in literature:

- Reduction of energy costs is perceived as the most important driver for energy efficiency. However, if energy is given a low priority within the organisation, energy cost reduction alone may not provide sufficient motivation to adopt energy conservation measures (Cooremans, 2012), (de Groot, Verhoef and Nijkamp, 2001). An appropriate business case or alignment of the energy efficiency measure with the core business of the organisation will achieve better perception from senior management (Bergmann *et al.*, 2017; Sa, Thollander and Cagno, 2017) resulting in implementation of the measure and ultimately leading to increased financial performance (Martí-Ballester, 2016);
- The existence of a long-term energy strategy and ambitious people within an organisation is one of the key drivers for adoption of energy efficiency measures (Rohdin and Thollander, 2006), (Thollander and Ottosson, 2008), (Rohdin, Thollander and Solding, 2007). Ambitious people driving change in energy behaviour within the organisation (albeit little researched so far) can be considered a cornerstone in successfully implementing long-term energy strategies strategies strategies (Andrews and Johnson, 2016);
- Awareness of the non-energy benefits (see description in section 2.2) related to an energy efficiency investment and including them in the evaluation can lead to more favourable assessments (Worrell *et al.*, 2003).Energy efficiency projects can be successfully sold to management if, rather than the usual financial approach, a strategic approach is taken (Cooremans, 2012) by using non-energy benefits to emphasise energy's contribution to enhance a company's competitive advantage.

External factors to the organisation were identified in literature:

- Energy prices and regulatory stringency are the most significant drivers as concluded by Garrone et al. (2017). Interestingly, the environmental alertness of society (apart from a market pull) was not yet deemed to have a significant effect according to Garrone's study;

- The demand for eco-friendly products (market pull) is a societal driver to implementing energy efficiency (Sáez-Martínez *et al.*, 2016).
- Availability of cheap, cleaner technology (technology push, e.g., cheaper renewable energy sources) is also one important external factor for environmental sustainability in the manufacturing industry (Sáez-Martínez *et al.*, 2016) (Horbach, Rammer and Rennings, 2012) (Rennings and Rammer, 2011).

Drivers and barriers are closely interlinked, and it is often the decision-making process and the accounting of non-energy benefits that defines whether an element can be a barrier or a driver. The next section highlights the findings in the literature about the typical decision-making practices in organisations.

4.2.1.3 Decision-making practices in manufacturing organisations

A decision-making process is the series of steps that enables organisations to determine whether to proceed with a given investment proposal. This process starts "*once the need for an investment in energy efficiency is identified*" (Nehler and Rasmussen, 2016) and finishes with decision. The investment decision process plays a definitive role in the selection and implementation of energy efficiency measures in manufacturing organisations (Contreras *et al.*, 2017), (Cooremans, 2012), (Trianni, Cagno and Farné, 2016), however, "*profitability plays an important but not decisive role in investment decision-making*" (Timilsina, Hochman and Fedets, 2016). Decision-making practices are also influenced by diverse **internal factors** such as (i) the evaluation process (e.g. criteria selection), (ii) the financial assessment (e.g. fiscal rules on payback period and methods used) and (iii) the investment parameters (e.g. categorisation, strategic nature, size and complexity). In addition, **external and idiosyncratic factors** including (i) company culture, (ii) knowledge of non-energy benefits and (iii) lack of awareness (e.g. third-party contracts with suppliers) shape the decision-making processes.

Currently, a gap exists with the lack of a systematic decision-making framework and the variety/dispersion of information sources that influence it. Addressing this gap, within an effective energy strategy, embedded within the organisations policy, will lead to an increased acceptance of energy-related improvement measures.

4.2.2 Non-energy benefits of energy management

Non-energy benefits can be related to positive impacts on productivity (e.g. lower maintenance costs), improved public image and business continuity (May *et al.*, 2016). The list of non-energy benefits encountered in literature can be found in Appendix (see section 4-10)

Recent research (Contreras *et al.*, 2017), is now making a strong case for understanding how non-energy benefits may drive energy management implementation as industry "*do not seem to have yet acknowledged how relevant non-energy* benefits *are to promote energy efficiency measures adoption*" (Trianni, Cagno and Farné, 2016), and "*lack of knowledge of how these [non-energy benefits] should be quantified and monetised*" (Nehler and Rasmussen, 2016) if the manufacturing sector is going to effectively contribute to global carbon reduction targets. Benefits such as reduced labour and maintenance costs can be monetised to construct compelling business cases with higher savings and better financial metrics than those accounting for lower energy consumption alone (Pye and McKane, 2000). Non-energy benefits can also impact financial metrics of energy investments such as the average payback period which can be significantly reduced when the contribution of productivity related benefits is monetised (Worrell *et al.*, 2003). Non-energy benefits are considered as essential components to the business case and profitability of energy efficiency investments. Two main reasons are identified. First, improving a company's competitive advantage by connecting non-energy benefits and their contribution to core business (Cooremans, 2012), (Worrell *et al.*, 2003). Second, the potential of non-energy benefits to increase the profitability of energy efficiency projects (Worrell *et al.*, 2003), (Pye and McKane, 2000). Both lead to making energy investments strategic. In fact, a consensus is emerging among researchers that organisations pursuing systematic and continuous EM have stronger financial performance. Saez-Martínez et al. (2016) conclude that establishing a corporate energy policy allows organisations to realise the full economic potential by identifying "*cost saving potentials, fostering the introduction of new cleaner production systems and other green innovations* (Horbach, 2008)". Martí-Ballester (2016) highlights how organisations implementing policies to systematically reduce carbon emissions develop new knowledge and resources that give them a competitive advantage thus opening new markets and attracting new customers which translate into short- and long term financial performance improvements. Bergman et al. (2017) highlights the productivity boost achieved from the implementation of energy efficiency investments which is directly associated with monetary benefits. Bottcher and Muller (2014) goes one step further by stating that there is "*no trade-off between carbon and economic performance, but that improved carbon performance leads to improved economic performance*" and that such improvements are stronger in organisations with a certified management system in place. Despite the consensus, quantification of non-energy benefits is not a simple task. Worrell et al. (2003) highlight three main difficulties:

1. Uncertainty on the monetary value due to difficulties in evaluating non-energy benefits, especially for benefits not directly related to productivity enhancements (e.g. improving public image);
2. Lack of data at a facility level to estimate potential productivity impacts because of energy efficiency measures;
3. The existence of negative impacts related to energy efficiency projects which may be similarly difficult to quantify and could exceed the estimated benefits (i.e. production interruption during implementation).

In helping to create a business case for carbon reductions through energy management a more systematic and strategic approach to help decision makers reach positive decisions on energy efficiency measures is needed. Examples of this are given by Fleiter et al. (2012) and by Contreras *et al* (2017). While Fleiter proposes a qualitative approach that lacks a link to the impact on the core business of non-energy benefits, Contreras proposes a quantitative decision support framework for multi-site organisations. It is intended as a systematic tool to provide senior management with all relevant data to complete informed decisions.

4.2.3 International standards and corporate literature

4.2.3.1 Energy policy guidelines from international standards

For the implementation of an EnMS, standards such as ENERGY STAR™ (US EPA, 2013), ISO50001 (ISO, 2011) and SEP (US Department of Energy, 2012) offer the best available support to an individual site energy manager. The three standards closely follow the plan-do-check-act (PDCA) cycle for continuous improvement. A comparative table on how energy policy and strategy is addressed in the standards can be found in Appendix 4-10.

The standards recognise that energy policy is fundamental to set the direction and drive energy performance improvement through the implementation of energy management systems. These standards converge in defining energy policy as senior management's official commitment to improve energy performance in an organisation. Since SEP™ is built around ISO 50001, the energy policy requirements included in these two standards are similar. In addition, SEP™ and ISO 50001 requirements are more detailed than those provided by ENERGY STAR™. However, as such, standards present only a generic process for dealing with energy management across a broad range of industries but guidance on implementation of different aspects (e.g.

energy policy and associated strategy) for certain sectors such as the non-energy intensive multinational manufacturing organisations This is a gap that this research fills.

4.2.3.2 Industry best practices on corporate energy policy and strategies

Multi-national organisations now consider climate change as part of normal management practices. According to the Carbon Disclosure Project (CDP), whilst integrating climate change issues into management activities was a leading behaviour in 2010, it is now a standard practice (CDP, 2015). Measurement and reduction of environmental footprint is presently a priority for the majority of senior managers in large organisations (PwC, 2016). Organisations address climate change as part of corporate sustainability and, according to specialised consultants, motivational drivers are reduction of energy use, improved reputation for sustainability and alignment with corporate goals and values (Bonini and Görner, 2011). Other motivations include customer reaction, investors' attraction, access to corporate insurances and securing positions in supply chains (PwC, 2016).

Organisations voluntarily participate in sustainability ranking processes via surveys (Corporate Knights, 2014; CDP, 2015; RobecoSAM, 2016a) aimed at recognition as leading performers in sustainability. The outcome of these rankings is followed by investors that direct resources towards top ranked enterprises (Corporate Knights, 2014; Newsweek, 2016; RobecoSAM, 2016b). Top ranked sustainable organisations are a source of best practices in energy performance improvement since part of the ranking criteria relate to energy performance and carbon emissions. Six non-energy intensive corporations were studied as part of the current work. They are recognised leaders in sustainability within their industrial sector and include: Unilever plc.; Roche Holding AG; Biogen Idec Inc.; Abbott Laboratories; Agilent Technologies Inc.; Johnson & Johnson. An analysis of the energy policy practices that are being applied by the afore mentioned corporations, including information found in the Carbon Disclosure Project, is used to identify best practices on energy policy. Findings include (for dull details please refer to Appendix (see section 4.9)

- **Hierarchy within the organisation**: Embedded into or dependent on the Corporate Sustainability Policy.
- **Justification**: Alignment to relevant climate change efforts (e.g. Paris Agreement (UNFCCC, 2016));
- **Carbon emission scope covered by energy policy:** Scopes 1, 2 or 3 of the Green House Gas Protocol (WBCSD; WRI, 2004);

- **Duration**: Two main deadlines identified: 100% renewable energy sources (RES) for electricity by 2020; 80%e to 100% emissions reduction by 2050;
- **Targets**: Separate energy from CO2 targets:
  - Energy: Source all electricity from RES (medium term) and all energy from RES (long term);
  - Carbon: Carbon positive or Carbon neutral;
- **Target setting methods**: 'Scientific based'.
- **Common strategies for achieving targets**: Promotion of energy efficient manufacturing; Use of renewable energy; Dedicated budget for energy and carbon reduction projects; Monetary reward for managers linked to targets' achievement; and Membership to industry advocacy initiatives.
- **Other strategies**: ISO 50001 implementation, favourable ROI requirement for energy/carbon reduction projects, operation in 'green' certified buildings, new facilities aligned to high energy efficiency standards.

At the time this review was completed, none of the six top ranked corporations used an internal price for carbon to drive investments in energy performance improvements that reduce carbon emissions. Other leading organisations in sustainability outside the MMO sector such as Walt Disney (Carbon Disclosure Project, 2016) and Microsoft (Microsoft Corporation, 2013), do use an internal carbon pricing to provide a monetary value on the impact of carbon reductions associated with energy management. In addition, only one corporation uses carbon offsets to compensate its global carbon emissions and another has set a goal to reach a carbon positive state.

4.2.4 Summary of gaps for energy policy and associated strategy implementation in non-energy intensive manufacturing organisations

According to Cooremans (2011), it is expected that an energy strategy helps to create, maintain, or develop a company's competitive advantage by increasing value, reducing costs and reducing risks associated with energy issues. However, research about essential components and characteristics of such a corporate strategy are rare. For Thollander and Ottosson (2010) an energy strategy establishes senior management's direction regarding energy issues in the long term and emphasizes senior management's support to energy management. It contains goals such as reduction of energy use and energy costs, in addition to the implementation of energy management systems. Furthermore, these authors surveyed the duration of long-term energy strategies in Sweden's biggest industrial energy users. They found that most of the studied organisations either did not have an energy strategy or had a short-term one (less than 3 years), even though those organisations were energy intensive. Brunke (2014) analysed energy management practices in the Swedish iron and steel industry and found that large organisations are more likely to have long-term energy strategies (>3 years). From Cheung (2017) a parallel can be drawn between the country's leader and its government with that of a company's chief executive officer and senior management team whereby leadership (e.g. people's ambitions), political stance (e.g. climate change ideology), clear targets and policies, political stability (e.g. agreement regardless of change of governance body), and economic conditions (e.g. capital availability) determine the country's/organisation's approach to greenhouse gases emissions reductions.

None of the works reviewed so far, however, provide a clear indication on how to implement an energy strategy or policy. The literature review presented in this research work has highlighted some clear issues or gaps that need to be addressed for organisations to fully benefit from implementing carbon reduction measures. Table 4-1 summarises such gaps and indicates how they will be addressed through the methodology presented in Section 4.3 (via an Energy Policy, an Energy Strategy or both, see section 4.1.2 for definition).

4.3 Methodology

The literature review has established that 'greener' organisations have improved economic performance (Why do it), leading to an increased demand for improved energy related carbon performance (What to do). This section proposes a methodology (How to do it) for the definition of a corporate energy policy and the development of an associated corporate energy strategy to achieve improved carbon and economic performance. The methodology emphasizes the appropriate environment for communicating, disseminating and creating awareness of all the benefits from energy management. It can be a catalyst for organisations to become proactive and even leaders in energy management rather than reactive to regulations or public pressure.

The methodology here presented does not intend to replace the application of single-site efforts but to rather complement it with structured support from top management. The methodology, albeit theoretically applicable to any type of organisations of any size, highlights and tackles the specific barriers for non-energy intensive and multisite organisations as presented in Table 4-1. The most important issues that this methodology addresses, which are typically not evident in single-site energy intensive manufacturing organisations, are:

- Lack of clearly defined decision-making process for energy investments: in energy intensive organisations, energy investment is at the same level as core-business investment and would have a structured decision making;
- Identification, quantification and evaluation of non-energy benefits: in energy intensive organisations, the non-energy benefits would have a much lower weight in presenting the business case for energy efficiency measures.

Table 4-1. Summary of issues or gaps to be addressed by the methodology

Type	**Issues or gaps identified**	**Addressed by**	
		Policy	**Strategies**
Barrier	Low capital availability	•	•
	Low priority of energy efficiency	•	•
	Risk of production disruptions		•
	Lack of awareness	•	•
Driver	Reduction of energy costs		•
	Ambitious people	•	
	Identification of non-energy benefits		•
Decision making practice	Lack of a systematic approach to decision making		•
Non-energy benefits	Difficult quantification of non-energy benefits		•
	Lack of approach for leveraging non-energy benefits		•
International Standards Industry best practices	Generic guidelines for policy formulation and associated supporting strategies	•	•

4.3.1 Corporate energy policy

Bottcher and Muller (2014) noted "*To systematically improve energy and carbon efficiency, companies need to integrate energy management into their overall strategy, organisational structure and daily operations.*" A policy document addresses this need. In fact, the corporate energy policy should be part of the organisation's sustainability policy or plan to improve environmental performance which in turns reflects the company's mission statement and core values. An energy policy establishes senior management's direction regarding energy issues in the long-term, emphasizes senior management's support to energy management and contains goals such as reduction of energy usage and implementation of energy management systems (Thollander and Ottosson, 2010).

The energy policy will document the justification (Why do it) for pursuing performance improvements and will ensure organisation's top-level commitment to achieve carbon emissions reduction targets. The policy should remove the barriers and build on the drivers identified in Section 4.2.1.

Based on the identified best-practices (Section 4.2.3.2), Figure 4-2 summarises the process for developing and implementing a corporate energy policy.

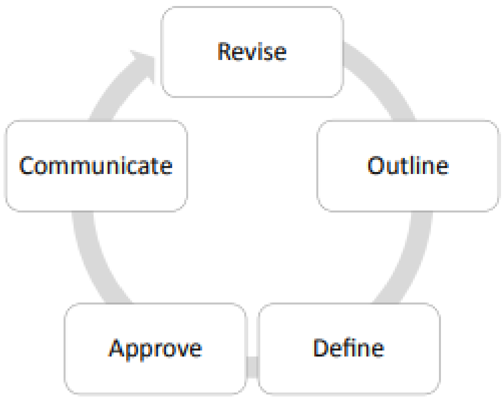

Figure 4-2. Energy policy process

- **Outline**: a single, easy to read yet comprehensive statement is needed to outline the corporate energy policy. This statement is the first commitment of the organisation towards improving its performance and is also a key communication piece for disseminating the policy. The statement must at least show a clear performance improvement goal and deadline for achievement (e.g. carbon neutrality by 2030).
- **Define**: the next step is to define the constitutive elements of the corporate energy policy. The corporate energy policy must meet the following requirements (minimum):
    - Be aligned with the organisation's nature and strategic direction of the corporate sustainability plan;

- Reflect the organisation's long-term vision in energy performance and carbon emissions (e.g. Alignment with global climate change efforts such as the Paris Agreement (UNFCCC, 2016));
- Clearly define what is within the scope of the performance targets set as defined by the Greenhouse Gas Protocol (WBCSD; WRI, 2004);
- Engage and commit senior management to the implementation of the vision;
- Commit to the development of a roadmap to achieve the long-term vision (Corporate Energy Strategy Section 4.3.2);
- Establish performance improvement as a priority and align individual sites to it;
- Reflect the commitment to provide the necessary resources to achieve the vision;
- Be documented;
- Commit to internal and external communication of its goals and achievements;
- Enact a periodic review and update process;

- **Approve**: since the energy policy presents a clear and sometimes aggressive commitment to achieving improved performances, it is paramount that it is approved, endorsed and (if possible) championed by senior management.
- **Communicate**: the energy policy must articulate and disseminate, through a common language, its commitment to employees, shareholders, the community and (internal/external) stakeholders.
- **Revise**: revise the energy policy document periodically to ensure its alignment with the corporate sustainability plan and updated global performance improvement efforts.

4.3.2 Corporate energy strategy

The corporate energy strategy should define the objectives, roadmap and enablers required deliver the long-term vision committed by the policy. In this sense, the development and implementation of a corporate energy strategy can follow the PDCA (plan-do-check-act) continuous improvement cycle. The energy strategy needs to:

1. **Plan**: define the targets to be achieved in the medium and long term;

2. **Do**: implement the roadmap and define the appropriate enablers to achieve the targets;
3. **Check**: implement metrics and continuous monitoring to verify the progress of the energy strategy implementation is aligned with the timeframe set in the plan phase;
4. **Act**: raise awareness and disseminate the strategy to involve all the organisation's stakeholders (internal and external) to provide the full support in the implementation of the strategy.

These four steps are presented in Figure 4-3 and defined in the following sections.

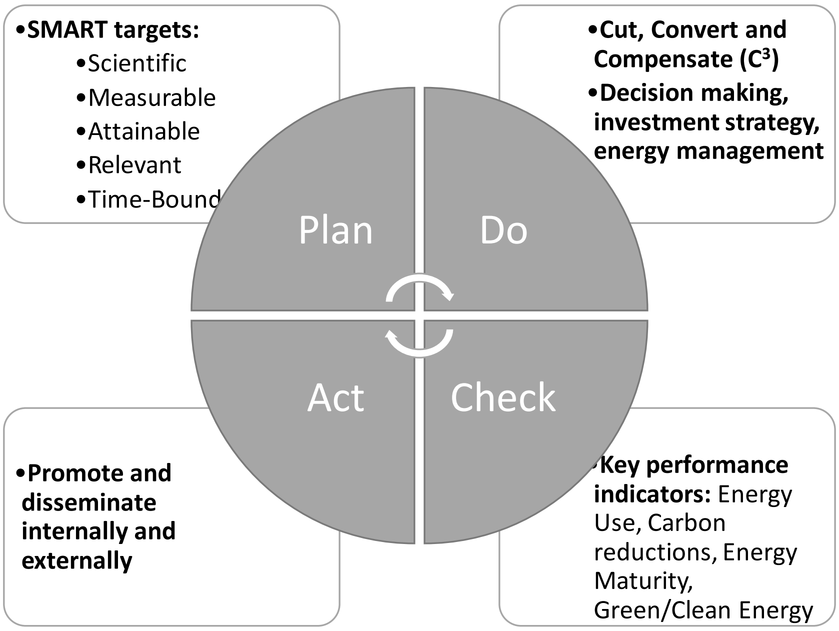

Figure 4-3. Implementing the energy strategy via PDCA approach

4.3.2.1 Plan - set 'SMART' targets

While the policy defines the long-term vision and associated boundary conditions (e.g. GHG protocol), best practice indicates that a staged approach to reaching the vision through long term target setting is optimal. Definition of targets is suggested to follow the 'SMART' approach (Doran, 1981): **S**cientific based, **M**easurable, **A**ttainable, **R**elevant and **T**ime bound. It is recommended to separate energy and carbon targets as follows:

- Target % renewable electricity in the medium-term;
- Target % renewable energy in the long-term;
- Target % CO2-eq reduction in the medium-term;
- Carbon neutral/positive in the long-term.

It is important that exact dates are defined for the 'medium term' and 'long-term' periods since this may then be used during the decision-making process for energy-related carbon reduction projects (Contreras *et al.*, 2017).

4.3.2.2 Do - energy strategy roadmap

The proposed roadmap is referred to as C^3. It stands for Cut, Convert and Compensate. It is aligned to the long-term target performance requirements.

- **Cut** energy use (Bergmann *et al.*, 2017): a continuous pursuit of increased energy efficiency at a site level through EEM (Energy Efficiency Measures). An energy audit to ASHRAE Level 2 or 3 is recommended.
- **Convert** to renewables (Fitzpatrick and Dooley, 2017):
    - Pursue on-site generation projects where possible, owned or partnership (e.g. PPA) with Renewable Energy Certificates (RECs)5 directly owned, negotiated into the contract or purchased elsewhere. There is the added benefit of 'engagement' from employees and local community when site based;
    - Consider a larger-scale off-site project to cover multiple sites, e.g. large wind-turbine project. This caters for energy use where on-site is less feasible, or where the scale of on-site generation is too small;
    - Deploy a procurement strategy for acquiring/retiring Renewable Energy Certificates to make up any difference. Strategy will depend on amount needed and geographic distribution. RECs[13] can only be used for Scope 2 emissions.
- **Compensate** unavoidable CO^2 emissions (to fully harvest nonenergy benefits (Sáez-Martínez *et al.*, 2016): purchase 'Carbon offsets' (voluntary market that required 3rd party verifiers). Examples include community projects, reforestation and forest protection. 'In country or in region' projects can help with employee and local community engagement. Carbon Offsets can be used for Scope 1 or Scope 2 emissions.

It is worth noting whilst all three strands of the roadmap can be developed in parallel, it is envisaged that the implementation of 'Compensate' commences when the 'Cut' & 'Convert'

[13] 1 REC ¼ environmental attributes of 1MWh of renewable energy generation, also known as Environmental Attribute Certificates (EACs) or Guarantees of Origin (GOs).

initiatives are mature. This is done to maximise the direct environmental impact of energy strategy implementation.

4.3.2.3 Do - energy strategy enablers

To advance the C^3 roadmap and meet the targets outlined ultimately requires investment. The literature review highlights the gaps that currently exist in the ad-hoc decision-making practices, chiefly the lack of awareness on the full range of benefits from energy efficiency measures. To ensure optimal investment in energy efficiency, a 'Decision Support Framework' implementation (Contreras *et al.*, 2017), will allow senior management unbiased visibility to all potential EEM from any site (Finnerty *et al.*, 2016). The C^3 roadmap is underpinned by several enablers that provide critical inputs from management teams. The following paragraphs outline the key areas supported by enablers;

- **Decision making process**: requires defining the project selection criteria to use (e.g. financial, sustainability and business continuity criteria) and the appropriate mechanism to quantify (monetise if possible) all associated non-energy related benefits. The strategic input is from senior management and it is fed into the decision support framework. Assigning a value to 'non-energy related benefits' needs to include the impact to the sustainability targets (e.g. using carbon pricing) as well as those related to improved business reliability and reduced maintenance. Such approach helps formulate a compelling business cases by effectively communicating the link between energy improvement projects and core business activities. This is a vital stage in the process of 'levelling the playing field' between energy and other company investments. Firstly, as defining the selection criteria enables energy projects to compete independently from other business-related projects. Secondly, if there is no dedicated energy budget it is imperative that all non-energy benefits are accounted to optimise the business case. Further research on the topic of decision making for industry can be found at Contreras et al (2017).

- **Investment Strategy**: senior management and the finance department are key players. Ideally a dedicated budget is set-aside for C^3 implementation. Even if this is not always feasible, an investment roadmap is required to deliver the strategy and policy targets. Direction is needed on the preferred company funding mechanism (e.g. own company capital vs. power purchase agreements) and on financial rules relating to payback parameters such as net present value, internal rate of return, and return on investment. The strategy needs to recognise the special features that typical energy projects exhibit (e.g. long payback times). It is recommended to fix future energy forecasting based on a set period of past performance for each site in the network. Agreement on the financial equivalent of a production disruption period (recommended 1 h) is required to monetise the potential impact or improvement on business continuity associated with an EEM. Establishing accountability and links between management remuneration and energy performance targets is also recommended to incentivise individuals.

- **Energy management system support**: The presence of an overarching energy management system that includes support for strategic initiatives is critical to achieving unbiased energy management decisions. Examples of strategic initiatives include: energy audit frequency and intensity level, energy management maturity models and yearly progression targets, alignment to independent certification bodies (e.g. LEED and ISO 50001) to ensure best practices, alignment to industry advocacy initiatives (e.g. CDP and RE100) for recognition of progress/ achievements and communication of strategies (internal and external).

4.3.2.4 Check - verify: metrics and monitoring

Key performance indicators are required to track performance at an individual site and organisation level to meet policy targets. These indicators are designed to capture both quantitative (e.g. energy usage) and qualitative (e.g. energy management maturity) metrics.

4.3.2.5 Act - promote and disseminate the strategy

Investment in EEM is improved by effectively communicating the link between EEM and core business activities. Alignment of policy and strategy reporting to the 'Global Reporting Initiatives' (Global Reporting Initiative (GRI), 2006) is recommended to facilitate benchmarking and sustainability mapping from organisation's sustainability reports.

4.4 Case study

GEMS (Global Energy Management System) (Finnerty *et al.*, 2016) is a joint industrial and academic collaboration between Boston Scientific Corporation (BSC) and the National University of Ireland, Galway (NUIG) aimed to develop a methodology that guides multi-site industrial organisations meet energy and CO^2 reduction targets. GEMS has been deployed in BSC's global network of sites and complements each individual site's energy management system. The GEMS methodology featured in Boston Scientific's 2016 Corporate Sustainability and Social Responsibility Report (Boston Scientific Corporation, 2016). BSC is a non-energy intensive multi-national manufacturing corporation in the life sciences industry.

4.4.1 GEMS introduction

Over the last decade, Boston Scientific has met or exceeded established sustainability goals. The 1st set of goals were developed in 2009 and subsequently updated in 2014. In this time BSC had delivered 32% reduction in GHG emissions (Boston Scientific Corporation, 2016).. Through GEMS, BSC now recognises the need to become a global leader in sustainability for non-energy intensive multi-national corporations. The GEMS methodology (Finnerty *et al.*, 2016) results in a simplified, understandable, systematic, repeatable and scalable decision support framework that delivers optimum network performance whilst addressing the complexities unique to decision-making on capital investments in global multi-site organisations.

The GEMS methodology is based on three foundation elements and four pillars as outlined in Figure 4-4. It is ideally positioned to implement a corporate energy policy (foundation) and associated energy strategy (pillar) as outlined in section 4.3. In 2017, BSC became a climate change leader for the medical device industry by committing to carbon neutral manufacturing operations, with a goal to achieve it by 2030 underpinned by the GEMS Methodology. The announcement coincided with climate week (18-24/09/2017) and was launched at the Climate Action Group Conference in New York[14].

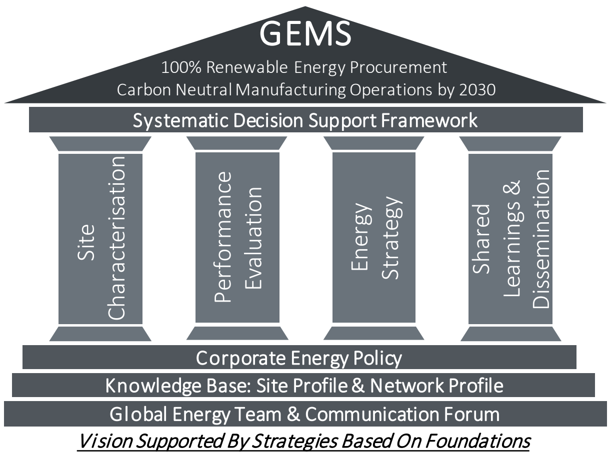

Figure 4-4. GEMS overview

4.4.2 GEMS energy policy foundation

BSC (GEMS) energy policy represents senior management's commitment to drive and fund optimal network energy performance and reduce carbon emissions across all its sites in support of global efforts aligned to the Paris Agreement on climate change (UNFCCC, 2016). The policy was outlined and defined by the global energy manager and has been approved by senior

[14] https://www.theclimategroup.org/ClimateWeekNYC

management. The policy document was created following the methodology outlined in Figure 4-2.

- **Outline**: single page, easy to read and understand. Clear goal and timelines defined as: Boston Scientific believes that leading environmental, health and safety performance contributes to our competitive strength and benefits our communities, customers, shareholders and employees as well as the environment. Boston Scientific is a climate change leader for the medical device industry by committing to carbon neutral manufacturing operations; it is our goal to achieve it by 2030 through the GEMS Methodology.
- **Define**: the policy document meets all the criteria outlined in the methodology stating that, to achieve this goal the company will:
    - Embed the Energy Policy into the organisation's corporate sustainability plan;
    - Align with the United Nations Framework Convention on Climate Change (UNFCCC) COP21 also known as the Paris agreement on climate change.
    - Agree the boundary conditions for carbon neutrality performance targets to be Scope 1 and Scope 2 emissions as defined by the Greenhouse Gas Protocol;
    - Engage and commit senior management to the implementation of the vision;
    - Commit to the development of an energy strategy with a roadmap;
    - Establish performance improvement as a priority and align individual sites to it;
    - Provide the necessary resources.
- **Approve**: the policy document was reviewed, approved, endorsed and championed by Vice President Global Real Estate, Facilities & EHS.
- **Communicate**: the policy document is clear and concise. It is suitable for dissemination to employees, shareholders, the community and (internal/external) stakeholders. The key elements of the policy will feature on targeted communications such as social media, company web site and individual site premises at strategic locations.

- **Revise**: the policy will be reviewed annually and updated as necessary to ensure its alignment with the corporate sustainability plan and global performance improvement efforts.

Through the policy formulation on carbon neutrality commitments BSC identified 3 main targeted stakeholders;

- **Internal**: aimed to boost employee engagement, talent acquisition and pride in the company:
- **External**: to respond to investors & customers who consider sustainability in decision-making;
- **Industry**: BSC will be a climate change leader for the medical device industry, its commitment will encourage others to follow.

4.4.3 GEMS energy strategy pillar

4.4.3.1 Plan - 'SMART' targets

BSC has set the following target:

- 50% renewable electricity by 2021 (short term);
- 100% renewable electricity by 2024 (medium term);
- 90% renewable energy by 2027 (long term);
- Carbon neutral manufacturing operations by 2030 (long term).

As outlined in the policy document the boundary conditions for Carbon neutrality performance targets relate to Scope 1 and Scope 2 emissions as defined by the Greenhouse Gas Protocol (WBCSD; WRI, 2004). In the 2017 Carbon Disclosure Project report, BSC recorded the following emissions as a baseline for the new targets:

- 30704 $tCO_{2\text{-eq}}$ Scope 1 emissions;
- 77990 $tCO_{2\text{-eq}}$ Scope 2 emissions.

4.4.3.2 Do - energy strategy roadmap

Using GEMS as the framework, the 'Energy Strategy' pillar navigates the roadmap to carbon neutrality using the C^3 approach.

- **Cut** energy use: under the governance of GEMS, in 2016 alone BSC invested over US$5 million into strategic energy infrastructure yielding US$2.25 million in long term operational annual savings and reducing CO_2 emissions by over 4% (3,866t of $CO_{2\text{-eq}}$ emissions avoided).

- **Convert** to renewables: 2.5 GWh of solar energy generated on site via installations in Marlborough and Quincy, Massachusetts. Further solar projects are under review in two separate locations. Kerkrade facility (Netherlands) sources all electrical power from European wind farms via REC's, resulting in net zero carbon. In addition, BSC is currently reviewing all existing energy provider contracts to assess potential for supply from renewable sources.
- **Compensate** unavoidable CO_2: BSC will review implementation of Carbon off-set projects when the 'Cut' and 'Convert' initiatives are mature.

For energy intensive organisations the business case for improving energy efficiency is obvious and directly relates to core business and revenues. For non-energy intensive organisations such as BSC, this is not the case since the direct impact of EEM is of less magnitude which reduces the possibilities to creating a compelling business case unless non-energy benefits are accounted for. Here is where C^3 is necessary. We transform energy efficiency issues into carbon related issues and propose an approach to reduce and quantify carbon emissions reductions via EEM that do not require any intervention in the core business but still deliver the desired effect.

4.4.3.3 Do - energy strategy enablers

- **Decision-making process**: under GEMS, BSC implemented a decision support framework as the cornerstone of the decision making strategy where operation savings, sustainability targets and business continuity are part of the assessment criteria (Contreras, 2016). It is worth noting the NPV on a high impact EEM (Tri Generation plant) increased by 40% when all the non-energy benefits were accounted for. These included cost avoidance of CO_2 emissions, reduced running costs (including maintenance) of exiting HVAC equipment and business continuity improvements. The impact of a specific EEM on the overall company and site sustainability target is listed in the decision support framework results, despite being already implicit in the financial outputs; such is the qualitative nature of the carbon emissions performance.
- **Investment strategy**: BSC has proposed a dedicated fund to support their long-term goals (calculated as internal carbon pricing times their carbon emissions times multiple year payback periods). This creates good practice and aligns to the 'Cut' phase of the C^3 roadmap. In addition, individual sites have the added incentive to aggressively reduce carbon footprint as after 2024 they will be charged for carbon allocation costs

(via internal carbon pricing). Company capital and PPA are both used in their strategy, with PPA model typically used for longer term returns. NPV and IRR are fundamental financial metrics for project assessment. Future energy forecasting is based on the associated sites previous 5-year historical trends (unless exceptional circumstances apply). Production disruption period of 1 h is agreed on a site by site basis proportional to the overall value of the site value of production.

- **Energy management system Support**: The GEMS methodology provides the overarching energy management support to enable the energy strategy implementation:
  - Audits & Maturity Model: The GEMS energy audit and energy maturity level parameters (Finnerty, Sterling, Coakley and Keane, 2017) are set by the Global Energy Management Team.
  - Independent Certifications: BSC has eleven LEED certified buildings including platinum for their global headquarters. BSC main distribution centre in Quincy, US, is ENERGY STAR certified. In 2016, the 'Newsweek Green Ranking' listed BSC in 21st position in the US, an improvement of eight places from 2015.
  - Advocacy Initiatives: BSC is aligned to the CDP and is currently reviewing membership of RE100 to support its renewable electricity targets.

4.4.3.4 Check - verify: metrics and monitoring

GEMS utilises six enterprise level key performance indicators to track yearly performance (at an individual site and corporate level) and to disseminate the progress of the Energy Policy implementation (Table 4-2)) (Boston Scientific Corporation, 2016).

4.4.3.5 Act - promote and disseminate the strategy

GEMS utilises a dedicated pillar to perform all aspects of 'shared learning and dissemination' (Figure 2-4) including the communicating the energy strategy. Investment in EEM is improved by effectively communicating the link between EEM and core business activities. The communication strategy is divided in internal and external communications.

- **Internal communications** include a company-wide department newsletter annually and display screens at strategic location such as the main lobbies, which show site and global information such as the six performance indicators described in Section 4.4.3.4.
- **External communications** include social media, conferences and alignment of strategy to the 'Global Reporting Initiatives' (Global Reporting Initiative (GRI), 2006)

to facilitate benchmarking and sustainability mapping from organisation's sustainability reports. Under the governance of GEMS, BSC submitted its first CDP Climate Change survey in 2017, aligned with the announcement of Carbon Neutrality by 2030, during Climate Week. These activities lead to inclusion in corporate sustainability rankings which in turn boosts the nonenergy benefits from the implementation of energy-related carbon improvement measures by ensuring proper awareness of BSC climate related initiatives to the investment community.

4.5 Discussion

Table 4-2. BSC Six enterprise level key performance indicators for 2016 (comparison against 2015 benchmark)

Indicator	**Definition**	**Value**
Energy Use	Tracks the total energy consumed annually to manufacture products.	367 GWh
Energy Management Maturity	An energy management maturity model to establish where in the "energy journey" each manufacturing site resides (Finnerty, Sterling, Coakley and Keane, 2017).	+11%
Green Real Estate	Real estate that is independently certified for energy efficiency by industry-leading bodies.	+28%
Carbon Footprint	Total amount of scope one and scope two greenhouse gas emissions that are emitted into the atmosphere.	108,000 $tCO_{2\text{-eq}}$
Green Energy	A subset of renewable energy sources and technologies that provide the highest environmental benefit such as hydro, solar or wind	+18%
Cleaner Energy	Energy produced from fossil fuels, but based on high-efficiency technologies such as combined heat and power (CHP).	+7%

As shown in the previous sections, the methodology is currently under a pilot study in a non-energy intensive MMO. Since the implementation and the value of EEM is not obvious (lack of awareness) for non-energy intensive MMO, these organisations might feel lost in implementing

EEM. We complement energy management standards like ISO50001 with the step-by-step guide (which can also be perfectly followed by all types of organisations) that creates a business model around carbon reductions brought by the EEM and highlights the need to account for the non-energy benefits and to structure the decision-making process. Initial results show the positive impact of coordinating energy-related carbon reduction efforts within an EM framework (GEMS) that is underpinned by policy and strategy. These include:

- Increased awareness of all the benefits associated with an EEM (especially including non-energy benefits) leads to a better business case, especially for projects that would normally not be considered given their long pay-back period and apparent low connection with core business;
- Through the systematic decision support framework and continuous improvement process it was demonstrated that energy-related projects reduce the risk of production disruptions by increasing energy security and forcing periodic assessment of the systems involved (Coffey *et al.*, 2016). This comprises another non-energy benefit;
- The presence of ambitious people in key positions within the organisation, who are committed to contributing to sustainability and climate change but that are also aware of the nonenergy benefits of the energy-related carbon reduction measures was key;
- Definition of metrics for a proper measurement and verification process to take place for improving the tracking of corporate and site targets;
- Enterprise-level performance indicators allow the corporation and the individual sites to understand the real impact of the energy efficiency actions and how it relates to the company's ethos;
- Making the energy strategy easy to understand to all stakeholders within and outside the company is fundamental for the successful support of everyone involved in achieving the long-term goals such as Carbon Neutrality (e.g. C3);
- Once the commitment to become Carbon Neutral is in place it becomes strategic at corporate and individual site level. This enables the allocation of appropriate resources to meet the medium and long-term targets (e.g. the creation of a fund to finance projects that have significant impact on GHG emissions);

- The successful implementation of GEMS within BSC transformed energy into an organisation-wide priority in a corporation that otherwise would not have deemed it strategic.

4.6 Conclusions

There is a general trend of organisations willing to become more environmentally sustainable. However, despite this growing interest and efforts to increase businesses' responsibility, most organisations fail to effectively impact energy use and global warming. Literature has begun to emerge on how business organisations are dealing with energy related issues. There is a growing body of knowledge that supports the positive link between increased carbon performance and a company's corporate financial performance (Böttcher and Müller, 2014; Martí-Ballester, 2016; Sáez-Martínez *et al.*, 2016; Bergmann *et al.*, 2017). This is expected to greatly improve the penetration of research and help focus the efforts required to reduce the energy efficiency gap in the long term. As stated by Bergman et al. (2017): "*This win-win situation also entails even more energy and non-energy related benefits and is further known as a form of low-hanging fruit*". Nevertheless, more research is still needed in this area, especially around policy initiatives that actually support organisations as opposed to produce lock-down effects (Andrews and Johnson, 2016). A variety of different drivers stimulate enterprises to find and execute investments in energy efficiency. These drivers can be internal or external to the company and include reduction of production costs, compliance with environmental regulations on energy efficiency and CO^2 emissions or an improved sustainability record (Williamson, Lynch-Wood and Ramsay, 2006). One of the main barriers for MMO is the lack of clear structured energy-related decision-making process that allows for an objective approach that avoids the influence of cultural or idiosyncratic factors in energy-related issues. In non-energy intensive MMO, addressing this barrier requires the creation of a link between core production and energy. This is achieved in the methodology presented in this research work, by highlighting the so called nonenergy benefits of energy improvements which include reduction of maintenance costs, improved indoor air quality conditions, improved worked morale, improved worker safety, enhanced business continuity, etc. Drivers are ineffective to overcome drivers unless MMO practice continuous energy management and have the appropriate energy management systems (Thollander and Ottosson, 2010; Trianni, Cagno and Farné, 2016) for the un-biased implementation of EEM aimed to reduced carbon emissions (Böttcher and Müller, 2014). For MMO, EM standards fail to provide clear indication on how to successfully implement EM, resulting in ad-hoc approaches typically used up to now. This leads to reduced environmental performance for MMO due to the lack of systematic approaches (e.g. decision-making processes) that efficiently articulate the organisation's efforts to become more environmentally sustainable. The methodology presented in this research work addresses this issue since it contains the key components of a long term corporate energy policy and strategic roadmap to address the barriers and support the drivers in the implementation of EM and EnMS in MMO. The energy strategy helps reduce the gaps identified in the literature around decision making practices and the non-energy benefits. Both policy and strategy build on best practices identified from recognised leaders (within their industrial sector) in sustainability. A potential limitation in the methodology presented in this research work lies in the generic approach taken where we suggest what should be done but not how to do it. This could stop implementation of energy policies and associated strategies from organisations due to the lack of a 'recipe' for implementation. An example is that we suggest a carbon pricing is established but not what such pricing should be. An approach to quantify non-energy benefits is presented in (Contreras *et al.*, 2017).

4.7 Future work

Future work will focus on analysing the long-term impact of the current pilot study under the GEMS framework. Additionally, it is foreseen to evolve the methodology to enable deployment in other MMO. The systematic decision support framework that supports the energy policy and strategy is on-going (Contreras *et al.*, 2017) and will concentrate the short-term efforts of this research work.

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4.10 Appendix

4.10.1 Literature review process

A systematic approach to the literature review has been adopted to ensure results are consistent, transparent, un-biased and replicable (Tranfield, Denyer and Smart, 2003), (Schulze *et al.*, 2016). The process followed during the literature review is presented in Figure 4-5.

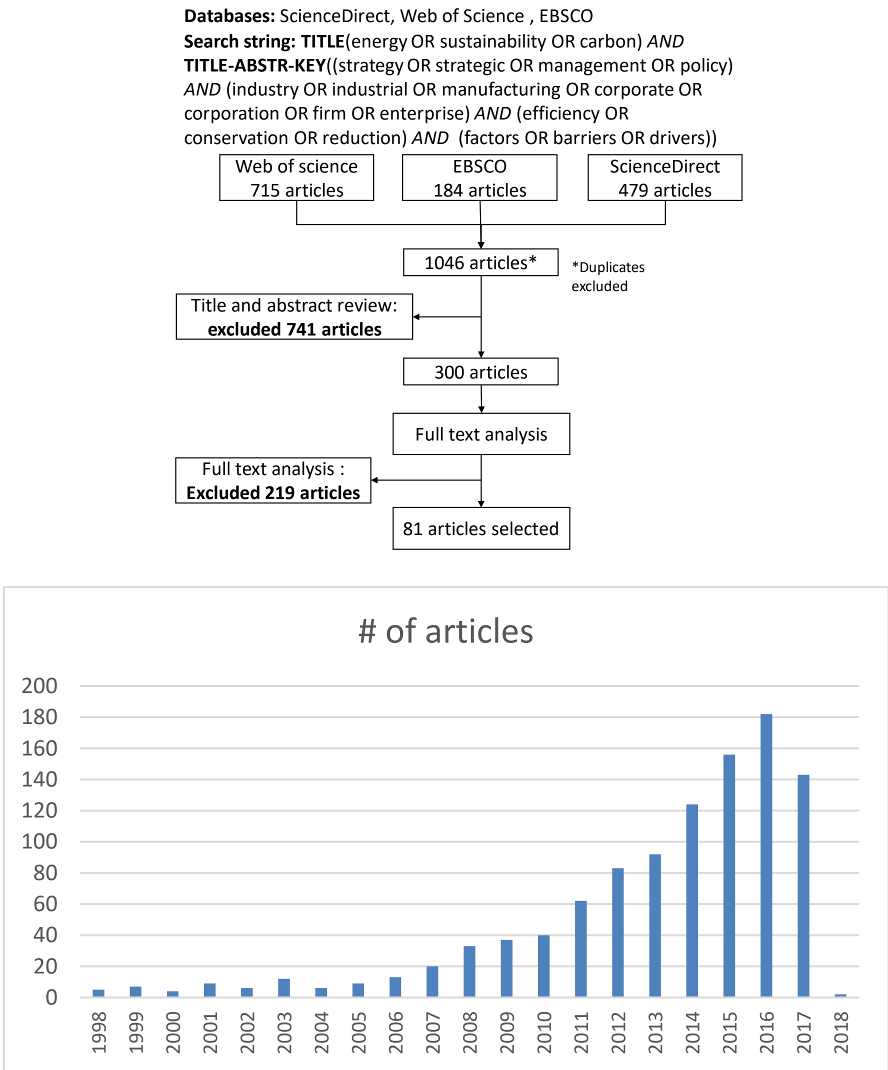


Figure 4-5. Systematic literature search - Process summary and number of articles per year

4.10.2 Barriers

Since 1998, empirical studies have provided evidence about the barriers that prevent cost-effective energy efficiency projects from being executed in manufacturing organisations. Previous research revealed that barriers vary according to both the characteristics of the organisation (e.g. size, energy intensity and sector) and the energy efficiency measure (e.g. risk of production disruption, implementation and technical requirements). Table 4-3 highlights the empirical and country-specific studies which mainly focus on energy intensive manufacturing SME and LE (e.g. foundries, pulp and paper), with some exploring non-energy intensive manufacturing organisations (e.g. electronics, textiles).

Table 4-3. Summary of barriers to energy efficiency projects in manufacturing organisations

Sample Size	Organisation Type and Country	Year	Principal barriers	Ref
15	Manufacturing of all sizes - Sweden	2017	Access to capital; time and expertise; awareness and uncertainty; practice characteristics; risks; complexity	(Sa, Thollander and Cagno, 2017)
509	Energy intensive Industrial ME and LE & commercial ME - Ukraine	2016	Lack of government policies, high upfront investment, higher cost of capital and higher opportunity costs for energy efficiency projects, need of government permits to deploy energy efficiency.	(Timilsina, Hochman and Fedets, 2016)
222	Manufacturing all sizes - Italy	2016	High investments costs; hidden costs; low ROI; lack of information; lack of awareness; other priorities	(Trianni, Cagno and Farné, 2016)
n/a	Energy intensive metalworking SE - Italy	2014	Other priorities; Implementing the intervention; Lack of time; Low capital availability	(Cagno and Trianni, 2014)
35	Manufacturing and commercial, all sizes - Switzerland	2006/ 2007	Other priorities ("more important investments")	(Cooremans, 2012)
16	Manufacturing SME - Thailand	2008	Other priorities; High investment costs; Cost of production disruption; Lack of government incentives	(Hasanbeigi, Menke and du Pont, 2010)

Sample Size	Organisation Type and Country	Year	Principal barriers	Ref
40	Energy intensive manufacturing SME - Sweden	2007	Risks and costs of production disruptions; Lack of time, Other priorities; High investment costs	(Thollander and Ottosson, 2008)
8	Non-energy intensive manufacturing all sizes - Sweden	2006	Risks and costs of production disruptions; Cost of obtaining information, Other priorities; High investment costs	(Rohdin and Thollander, 2006)
135	Manufacturing and horticultural all sizes – The Netherlands	1998	Other investments more important; Technology can only be implemented after existing technology has been replaced; Energy costs are not sufficiently important; Energy efficiency has low priority	(de Groot, Verhoef and Nijkamp, 2001)
100	Industrial all sizes - Austria	1997	Low ROI; Long payback periods; Auditors assessment inaccurate; Energy Efficiency often overlooked	(Harris, Anderson and Shafron, 2000)

4.10.3 Drivers

Drivers vary according to size and energy intensity of the company. Table 4-4 contains a summary of the principal drivers identified in the reviewed literature.

Table 4-4. Summary of drivers to energy efficiency projects in manufacturing organisations

Sample Size	Organisation type - Country	Year	Principal drivers	Ref
256	Industry in general - EU	2017	External factors: regulations; high energy prices; societal awareness	(Garrone, Grilli and Mrkajic, 2017)

Sample Size	Organisation type - Country	Year	Principal drivers	Ref
222	Manufacturing SME and LE - Italy	2016	Economic external: Public subsidies, private financing; Economic internal: Energy cost reductions, information about real costs; Regulatory internal: Long-term energy strategy; Informative internal: Knowledge on non-energy benefits	(Trianni, Cagno and Farné, 2016)
16	Manufacturing SME - Thailand	2008	Reducing energy costs; Long-term strategy for energy efficiency; Improving compliance with regulations; Improving product quality;	(Hasanbeigi, Menke and du Pont, 2010)
40	Energy intensive manufacturing SME - Sweden	2007	Reducing energy costs; People with real ambition, Long-term strategy for energy efficiency.	(Thollander and Ottosson, 2008)
8	Non-energy intensive manufacturing ME and LE - Sweden	2006	Long-term energy strategy; Increasing energy prices; People with real ambition	(Rohdin and Thollander, 2006)
135	Manufacturing and horticultural ME and LE – Netherlands	1998	Green image for the company	(de Groot, Verhoef and Nijkamp, 2001)

4.10.4 Non-energy benefits

Table 4-5 provides a summary of non-energy benefits that have been reported in literature.

Table 4-5. Summary of examples of non-energy benefits of energy efficiency investments

Non-energy benefits and categories	Ref
Waste: Use of waste fuels, heat, gas; Reduced product waste; Reduced waste water; Reduced hazardous waste; Materials reduction; Costs of environmental compliance; **Emissions:** Reduced dust emissions; Reduced CO, CO_2, NO_x, SO_x emissions; **Operation & Maintenance:** Reduced need for engineering controls; Lowered cooling requirements; Increased facility reliability; Reduced wear and tear on equipment/machinery; Reductions in labour requirements; **Production:** Increased product output/yields; Improved equipment performance; Shorter process cycle times; Improved product quality/purity; Increased reliability in production; worker safety; **Working environment:** Reduced need for personal protective equipment; Improved lighting; Reduced noise levels; Improved temperature control; Improved air quality; **Other:** Decreased liability; Improved public image; Delaying or Reducing capital expenditures; Additional space; Improved worker morale.	(Worrell *et al.*, 2003) (Pye and McKane, 2000) (Nehler and Rasmussen, 2016)

4.10.5 International standards and corporate literature

4.10.5.1 International standards

The ENERGY STAR™ programme was established in the United States in 1992 by EPA. It 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 ISO in 2011 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 and reduce carbon emissions. SEP™ e Superior Energy Performance®- is a certification program established by DOE in

2007. SEP™ promotes and verifies superior improvements in energy management and performance in industrial facilities that have already achieved ISO 50001 certification.

Table 4-6. Comparison of energy policy guidelines in ISO 50001, ENERGY STAR™, and SEP™

ENERGY POLICY	**ISO 50001**	**ENERGY STAR™**	**SEP™**
Description	- An energy policy is the organisation's commitment to achieve energy performance improvement. - It is a driver for implementing and improving an EnMS and energy performance within the scope and boundaries of the organisation.	- An energy policy formalises senior management's support for the organisation's commitment to energy efficiency. - It provides the foundation for setting performance goals and integrating energy management. - It articulates the organisation's commitment to energy efficiency for employees, shareholders, the community and other stakeholders.	- An energy policy is senior management's statement of management's intentions with respect to an organisation's energy performance. - It sets the direction for energy management activities and provide the framework for using energy objectives and targets to achieve energy performance improvements.
Organisational level responsible for approval	Senior management	- CEO or head of the organisation	Senior management
Steps for implementation	- Not provided	- (1) Drafting by Energy Director - (2) Approval	-(1) Drafting -(2) Approval

ENERGY POLICY	**ISO 50001**	**ENERGY STAR™**	**SEP™**
			-(3) Communication of the energy policy
Requirements	- (1) Alignment with company's nature. - (2) Commitment to continual improvement in energy performance. - (3) Commitment to provide the information and resources required to achieve targets. - (4) Compliance with legislation and regulations on energy efficiency and energy use. - (5) Framework for setting and reviewing objectives and targets. - (6) Support for purchase of energy efficient products and services, and design for energy performance	- (1) **State an objective:** Have a clear, measurable objective that reflects the organisation's commitment, culture and priorities. - (2) **Establish accountability:** Institute a chain-of-command, define roles in the organisation, and provide the authority for personnel to implement the energy management plan. - (3) **Ensure continuous improvement**: Include provisions for evaluating and updating the policy to reflect changing needs and priorities. - (4) **Promote**	- (1) The energy policy must state senior management's commitments to: • achieving continual improvement in energy performance • ensuring the information and resources needed to meet energy objectives and targets • compliance with applicable legal requirements and other energy-related requirements subscribed to by an organisation - (2) The energy policy must support: • the purchasing of energy efficient products and services, and • energy performance improvement in design activities. - (3) The energy policy must appropriate to the nature and extent of the organisation's energy use and consumption - (4) Senior management must take ownership of the energy policy and:

ENERGY POLICY	ISO 50001	ENERGY STAR™	SEP™
	improvement. - (7) Documentation and communication of the policy at all levels within the organisation. - (8) Regular revision & update.	**goals**: Provide a context for setting performance goals by linking energy goals to overall financial and environmental goals of the organisation.	• assure the policy is aligned with the strategic direction of the organisation. • approve the policy via signature or recorded meeting decision. • communicate the energy policy to establish energy as an organisational priority. • regularly review and update the policy if necessary.

4.10.5.2 Corporate literature

Top ranked sustainable organisations are a source of best practices in energy performance improvement. Since part of the ranking criteria relate to energy performance, their sustainability assessments cover energy related issues (see Table 4-7). Six non energy intensive corporations were studied as part of the present work. They are recognised leaders in sustainability within their industrial sector. Table 4-8 presents the MMO investigated with the main findings from corporate sustainability reports issued in 2016.

Table 4-7. Criteria used in corporate sustainability rankings that relate to energy performance

Ranking	Criteria	Weight on the overall ranking
Newsweek's Green Ranking (Newsweek, 2016)	Combined Energy Productivity	15%
	Combined GHG Productivity (Scope 1 &2)	15%
RobecoSAM (RobecoSAM, 2016b)	Environmental dimension (Operational eco-efficiency, Environmental Policy and Management Systems and others)	10%*

Corporate Knights (Corporate Knights, 2014)	Energy Productivity	8%
	Carbon Productivity (Scope 1 &2)	8%

* For Healthcare industries (Life Science, Healthcare equipment, Biotechnology, Pharmaceuticals)

Table 4-8. Summary of industrial best practices for non-energy intensive sustainability leading organisations

Company		**Unilever plc.**	**Roche Holding AG**	**Biogen Idec Inc.**	**Abbott Laboratories**	**Agilent Technologies Inc.**	**Johnson & Johnson**
Sector		Personal care / food	Health care	Health care	Health care	Health care	Health care
No. sites worldwide		261	20	4	Not available	16	256
Sustainability Ranking	*DJSI 2016*	Leader Food products	Leader Pharma	Leader Biotechnology	Leader Health Care Equipment	Leader Life Sciences Tools & Services	Health care yearbook
	CNs 2016	22	Not ranked	1	Not ranked	53	18
	NGR 2016	7	25	11	284	Not ranked	19
Organization Energy policy hierarchy		Part of CS Policy			Aligned with CS	Part of CS Policy	Aligned with CS
Energy Policy justification	*Alignment to COP21*	●					●
	Climate change	●	●	●	●	●	●
	Regulations	●	●			●	●
Carbon emission scope		Scope 1 & 2					
Target setting method				Scientific Based			Scientific Based
Energy related targets	*100% renewables*	Electricity by 2020; Energy by 2030		Electricity by 2020			Energy by 2050
	Reduction of energy consumption		15% by 2025 below 2015			10% by 2024 below 2014 level	

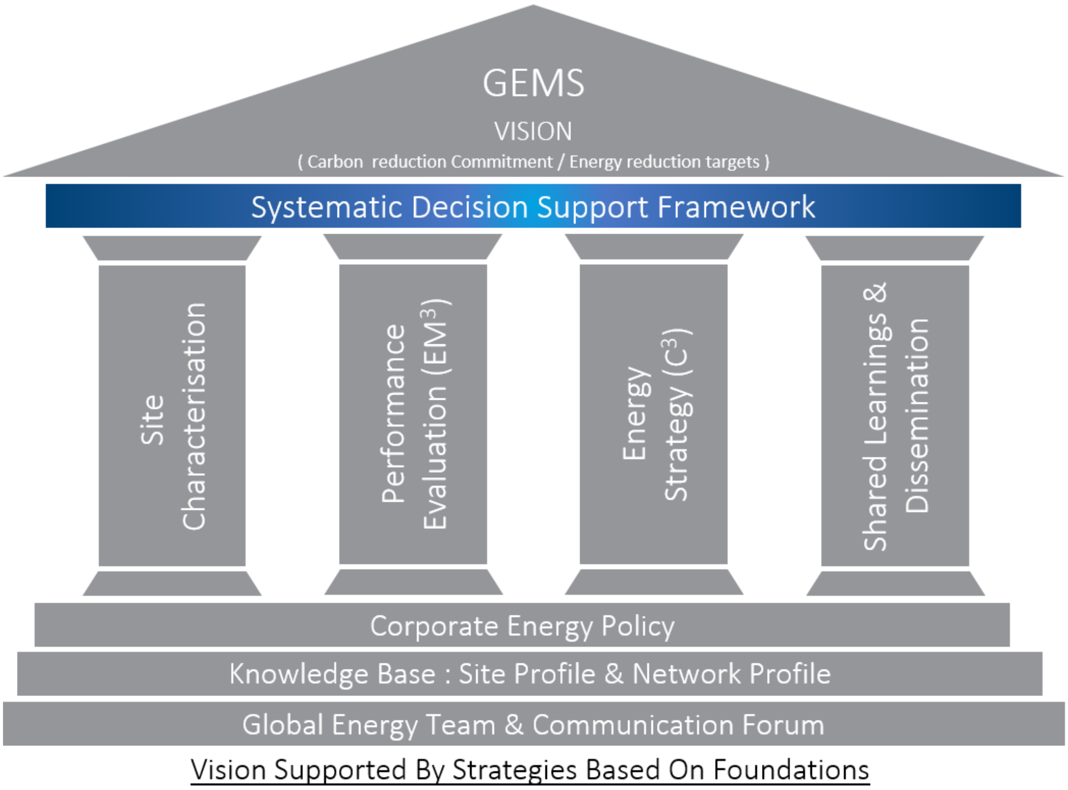
Carbon related targets	*Reduction of carbon emissions*	Carbon positive by 2030	15% by 2025 below 2015	80% by 2020 below 2006 level	40% by 2020 below 2010 level	10% by 2024 below 2014 level	20% by 2020 & 80% by 2050 below 2010
Strategies	*Use of clean energy*	●	●		●	●	●
	ISO 500001 EnMS			●	●		●
	Energy efficient new facilities	●		●			●
	LEED certification			●			●
	Dedicated budget for energy/carbon projects	●			●	●	●
	Lower ROI for energy/carbon projects		●		●		●
	Use of internal price for carbon / carbon offsets	Implicit (no offsets)	None	None (carbon offsets)	None	None	None
	Monetary reward for targets' achievement	Top management & relevant managers	all employees	Relevant managers	Senior Management	Environmental Managers	Top management & relevant managers
	Initiatives Membership	RE100; CDP	CDP	CDP	CDP	CDP	RE100; CDP

5 A systematic prioritization method and decision support framework for energy projects in industrial organisations

"In God we trust; all others bring data" – W. Edwards Deming (1900 - 1993).

Introduction

Chapter 5 serves to address the gap identified in section 1.4 regarding the lack of a systematic process within organisations when planning and implementing energy investments. The Chapter can be reviewed as a standalone piece of research or in unison with the overall GEMS methodology. The proposed systematic Decision Support Framework (DSF) ensures decision-makers are presented with all the necessary, un-biased information including non-energy benefits. It is underpinned by a project prioritisation tool.



The contents of this chapter have been initially published in proceedings of the 10th International Conference on Sustainable Energy & Environmental Protection (SEEP), 27-30 June 2017, Bled, Slovenia. Here presented is the extended version of the research work.

Noel Finnerty developed the DSF methodology, he collected, analysed and synthesized the data. The framework is underpinned by a novel project prioritisation tool (a hybrid multi-criteria decision method) developed by Sergio Contreras as a research masters which Noel Finnerty assisted as supervisor. Dr. Raymond Sterling contributed to the methodology development and paper writing. Dr. Daniel Coakley & Dr. Marcus Keane assisted with the paper review.

A SYSTEMATIC PRIORITIZATION METHODAND DECISION SUPPORT FRAMEWORK FOR ENERGY PROJECTSIN INDUSTRIAL ORGANISATIONS

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Abstract

This paper describes a decision support framework to assist industrial organisations make optimal investment decisions on energy performance improvement projects to meet global energy and carbon emission reduction goals. Itis intended as a simple and repeatable approach for energy managers to promote informed, un biased energy-related decision-making from top management. The framework is underpinned by a project prioritisation tool that uses economic, environmental, social and technical criteria. This tool is a hybrid multi-criteria decision method that combines Analytical Hierarchy Process, Fuzzy Logic and Technique for Order of Preference by Similarity to Ideal Solution. The proposed methodology is applied in a case study concerning energy projects in a Fortune 500 manufacturing corporation in the life sciences industry. One of the main outputs of this work is the realisation of the weight the non-energy benefits may have in the decision making when they are properly accounted.

Keywords: Energy, energy management, project prioritisation, decision-making method.

5.1 Introduction

Energy management can be described as the systematic monitoring and control of energy related activities (Kanneganti et al., 2017). It is now common practice in industrial organisations aiming to reduce industry's energy and carbon footprint while at the same time improving energy security, business continuity and financial performance (Böttcher and Müller, 2014; Martí-Ballester, 2016; May, Stahl and Taisch, 2016; Sáez-Martínez et al., 2016; Bergmann et al., 2017). This is reflected in the increased level of energy investment achieved by industrial organisations in recent years according to industry surveys (Deloitte Center for Energy Solutions, 2017). Despite the increased levels of energy investment and the implementation of energy management programmes, the energy efficiency gap remains. Research suggests that one of the most critical barriers for closing this gap lies in the ad-hoc approaches taken by these organisation when planning and implementing energy investments (Thollander and Ottosson, 2010). These ad-hoc approaches result in cycling energy consumption costs, in contrast to a systematic process where the benefits from energy efficiency measures can be maintained over time (United Nations industrial Development Organization, 2013).

Industrial energy management standards such as ISO 50001 (ISO, 2011), ENERGY STAR™ (US EPA, 2013) or SEP™ (US Department of Energy, 2012), require the implementation of energy efficiency measures, however, they do not provide clear guidelines to systematically evaluate energy investments. This lack of systematic process leads to both under-investment (Cagno and Trianni, 2014)(Trianni *et al.*, 2013)(Timilsina, Hochman and Fedets, 2016) and non-optimal or biased investment decisions, especially if energy investments are given a lower priority (Cooremans, 2012) (Thollander and Ottosson, 2010). This issue is further compounded by the complexities associated with multi-site organisations and a global footprint (Finnerty *et al.*, 2016).

It has been recognised that energy projects are more likely to be assessed favourably if a proper business case is constructed that confers the strategic nature to the investment (Cooremans, 2012). The business case also needs to account for the so-called 'non-energy benefits' which demonstrate how these type of projects can create a competitive advantage for the organisation (Nehler and Rasmussen, 2016).

In helping organisations overcome the limitations outlined, a practical, repeatable approach to present top-management with a factual business case (including all non-energy benefits) supported by structured, unbiased and informed decision-making support framework is needed.

This research work proposes a framework aimed at optimising the decision-making process for energy investments. The proposed framework ensures decision-makers are presented with all the necessary, un-biased information that allows them to understand the full impact of the energy project. The framework accounts for the non-energy benefits and presents the characteristics and performance trends of the energy investment projects and their associated impact on the organisation. This promotes the optimum business case for energy investments.

The framework is underpinned by a project prioritisation tool which is a hybrid multi-criteria decision method (MCDM). The MCDM combines different decision-making methodologies: Analytical Hierarchy Process (AHP), Fuzzy Logic (FL) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). In this approach, the novelty lies on how the organisation's priorities are translated into criteria weights (i.e. technical, environmental, financial and social) via qualitative assessment by top management. The result is an un-biased ranking of energy projects aligned to the core priorities of the organisation.

5.2 Background

Energy related projects are rarely seen as a priority in industrial organisations (Cagno and Trianni, 2014). This leads to a lack of top management involvement, competition for funding with other investments considered as "more important", limited financial resources and unstructured decision making processes (Cooremans, 2011).

Understanding of the investment decision processes in industrial organisations plays a key role in ensuring the execution of energy projects. The decision-making process for energy projects begins with the identification of the need to implement an energy efficiency measure (Nehler and Rasmussen, 2016) and finishes with the approval or refusal to implement the measure. Such decision-making processes are composed by a sequential and dynamic set of decision events, represented by decision-making models, such the one shown in Table 5-1.

Table 5-1. Decision-making model (Cooremans, 2012).

Phase	Description	Steps
I	Identification	1 - Initial idea / need
		2 - Diagnosis
II	Idea development	3 - Solutions build-up
III	Selection	**4 - Evaluation of different solutions and choice**
		5 - Implementation

In the model presented in Table 5-1, step 4 is key for the decision-making activity and corresponds to the prioritisation of energy improvement investments required by standards such as ISO 50001 (ISO, 2011). During step 4, proposals are evaluated against a set of business expectations. In the case of energy projects, it has been recognised that "profitability plays an important but not decisive role in investment decision-making" (Timilsina, Hochman and Fedets, 2016) and final decisions depend on other factors including organisation's size, complexity, internal and external culture, and especially, investment categorisation (Nehler and Rasmussen, 2016)(Cooremans, 2012)(Trianni, Cagno and Farné, 2016).

Organisations without a defined category for energy investments may create an unbalanced competition between energy projects and other investments considered more strategic. The result is typically a negative outcome for the energy project during the evaluation and selection step of the decision-making process (Cooremans, 2011).

For energy-intensive organisations, the connection between energy consumption and the core business activity makes any investment on energy efficiency strategic (Trianni, Cagno and Farné, 2016). A different scenario is presented for non-energy intensive[15] organisations, where energy costs are small when compared with the overall production costs, leading to energy efficiency investments not being considered strategic since they are not related to the core-business activities (Yeen Chan and Kantamaneni, 2015). For this type of organisation, this results in lack of decision-maker involvement and proper categorisation for energy investments, which are further impacted by limited resources and an unstructured decision making process (Cooremans, 2011). For multi-site organisations, decision-making faces further bias stemming from geographical, managerial and technological complexities (Finnerty *et al.*, 2016).

An option to overcome this limitation is to provide decision-makers with compelling business cases. These should highlight the strategic nature of an energy investment via non-energy benefits (NEB) and their connection to the organisation's core business (Cooremans, 2012)(Finnerty, Sterling, Contreras, *et al.*, 2017). According to May (May *et al.*, 2016) NEBs can be related to positive impacts on productivity (e.g. lower maintenance costs), improved public image and enhanced business continuity. NEBs are a vital component in ensuring that energy efficiency measures are represented in a holistic manner and assist to improving their position when competing for funding with other strategic initiatives within an organisation.

However, industry "do not seem to have yet acknowledged how relevant non-energy benefits are to promote energy efficiency measures adoption" (Trianni, Cagno and Farné, 2016). In fact, energy managers struggle to bring NEBs into practice due to a "lack of knowledge of how these [non-energy benefits] should be quantified and monetised" (Nehler and Rasmussen, 2016) and lack of a systematic decision-making process (Deloitte Center for Energy Solutions, 2017).

This reveals a gap both in the ad-hoc nature of existing decision-making practices and the misrepresentation of the energy efficiency measure business case without inclusion of all NEBs. Addressing such a gap requires the implementation of a systematic decision support framework with characteristics that encourage its use by the decision makers such as simplicity, repeatability

The role of the DSF is not to eradicate the need for expert knowledge in decision-making, but to present facts in a clear and concise manner that avoids bias (Finnerty *et al.*, 2016). When faced with multiple energy investment projects, the DSF must provide an indication on the impact the different options will have on the organisation. One approach to achieve this is by ranking the

[15]In non-energy intensive organisation, energy costs are < 2% of the turnover or <5% of production costs (Rohdin and Thollander, 2006; Trianni, Cagno and Farné, 2016).

project according a predefined set of criteria aligned with the organisation's core interests. The next section provides a short overview of systematic techniques used for assisting in decision-making via multi-criteria methods.

5.2.1 Multi-criteria systematic decision making for energy projects

In implementing a systematic decision-making process, several issues are faced such as ensuring all criteria are accounted for, being able to make the process repeatable (by assigning a consisting importance to each criterion) and understanding the link between the organisation's core business and the different criteria.

Accounting for all representative criteria for evaluating energy projects: To support the evaluation and selection of energy projects, multi-criteria decision methods (MCDM) can be useful for industrial organisations. According to Ibáñez-Forés, Bovea and Pérez-Belis (2014), about 70% of decision-making methodologies are a based on MCDM methods. MCDM are techniques that aim at facilitating a rational ranking of alternatives to select the best (e.g. decision support) and are especially advantageous when using conflicting criteria (Wang *et al.*, 2009), as for example, capital cost of energy generation technologies versus their contribution to reduce CO_2 emissions in the organisation.

Examples of the use of sustainability criteria and MCDM to rank energy projects are available in the literature. Authors have identified financial, environmental, social and technical criteria as the preferred set for ranking energy projects (Wang *et al.*, 2009). These findings align with the standard triple bottom line (TBL) approach for sustainability assessments (economic, environment, society) (Pope, Annandale and Morrison-saunders, 2004), complementing it with the technical side of the energy project if needed. Table 5-2 contains a list of criteria that are frequently used in sustainable energy oriented MCDM.

Table 5-2. List of evaluation criteria (Wang *et al.*, 2009)*(Wang et al., 2008; Kaya and Kahraman, 2011).*

Criteria	Sub-Criteria
Economical	Investment cost – CAPEX
	Payback period (Simply / discounted)
	Annual O&M cost – OPEX
	Equivalent annual cost
	Net present value-NPV

	Internal rate of return – IRR
	Fuel Cost or Electricity cost
	Fuel availability, Service life
Environment	NOx emissions, CO emissions
	CO_2 emissions, SO_2 emissions
	Particles emissions
	Renewable energy fraction
	Volatile hydrocarbons emissions
	Land use, Noise
Social	Social (stakeholders) acceptability
	Job creation, Future suitability
	Effect for energy security
	Benefited communities/ persons
	Safety, Safeguards
Technical	Efficiency, Exergy efficiency
	Automation grade
	Primary energy ratio
	Operability, Reliability
	Technology maturity
	Technology innovation

Categorising the different criteria: Analytical Hierarchy Process (AHP) is one of the preferred methods for criteria categorisation (Ibáñez-Forés, Bovea and Pérez-Belis, 2014). AHP is based on disaggregation of a problem into several levels to construct a hierarchy that eases problem solving (see Figure 5-5). When applied to sustainability problems, an AHP model with two levels aligns with the TBL approach. The first level includes the environmental, economic and social criteria. The second level sub-criteria are those included in Table 5-2.

Translating organisation's priorities into criteria: Fuzzy Logic is a theory that supports MCDM in dealing with human uncertainty of decision-makers. This theory facilitates MCDM to use qualitative criteria, for which performance is to be given in linguistic terms rather than numbers (i.e. low or high performance). It also facilitates the estimation of criteria weights, especially when combined with AHP (Kaya and Kahraman, 2011). FL translates linguistic evaluations into numerical values (Kahraman, Ertay and Büyüközkan, 2006).

The prioritization mechanism: the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a decision-making technique broadly used due to its simplicity and easy programmable computation process (Kaya and Kahraman, 2011). It is based on the concept that the best alternative shall be the closest to a positive ideal solution, and the farthest to a negative ideal solution (Wang *et al.*, 2009; Cavallaro, 2010).
By combining AHP with TOPSIS and FL, the resulting hybrid-MCDM are appropriate for use in complex multi-criteria assessments involving qualitative criteria, human judgments and uncertainty (Wang et al., 2008; Kaya and Kahraman, 2011).

5.3 Methodology

Industrial guidelines (i.e. ISO 50001) and recent literature for energy management require organisations to define the targets, roadmap and enablers required to meet the long-term environmental objectives under the framework of an energy policy (Finnerty, Sterling, Contreras, et al., 2017). Meeting the targets and reducing the energy efficiency gap requires investment in multiple energy efficiency measures. However, as can be concluded from Section 5.2, an investment plan to fund the optimal projects is typically faced with an unstructured and biased decision-making process. Such barriers are further magnified in multi-site organisations. This results in sub-optimal investment levels and poor performance. This section presents a framework to aid in the decision-making process allowing for unbiased visibility on the full impact of the energy efficiency measures on the organisation.

5.3.1 Global Energy Management System Introduction

The Global Energy Management System (GEMS) methodology (Finnerty *et al.*, 2016) provides a simplified, understandable, systematic, repeatable and scalable decision support framework (DSF) addressing the complexities unique to decision-making on capital investments in global multi-site organisation. The GEMS methodology is based on three foundation elements and four pillars as outlined in Figure 5-1. The foundations and pillars provide (directly or indirectly) the pertinent information required to make the DSF informative.

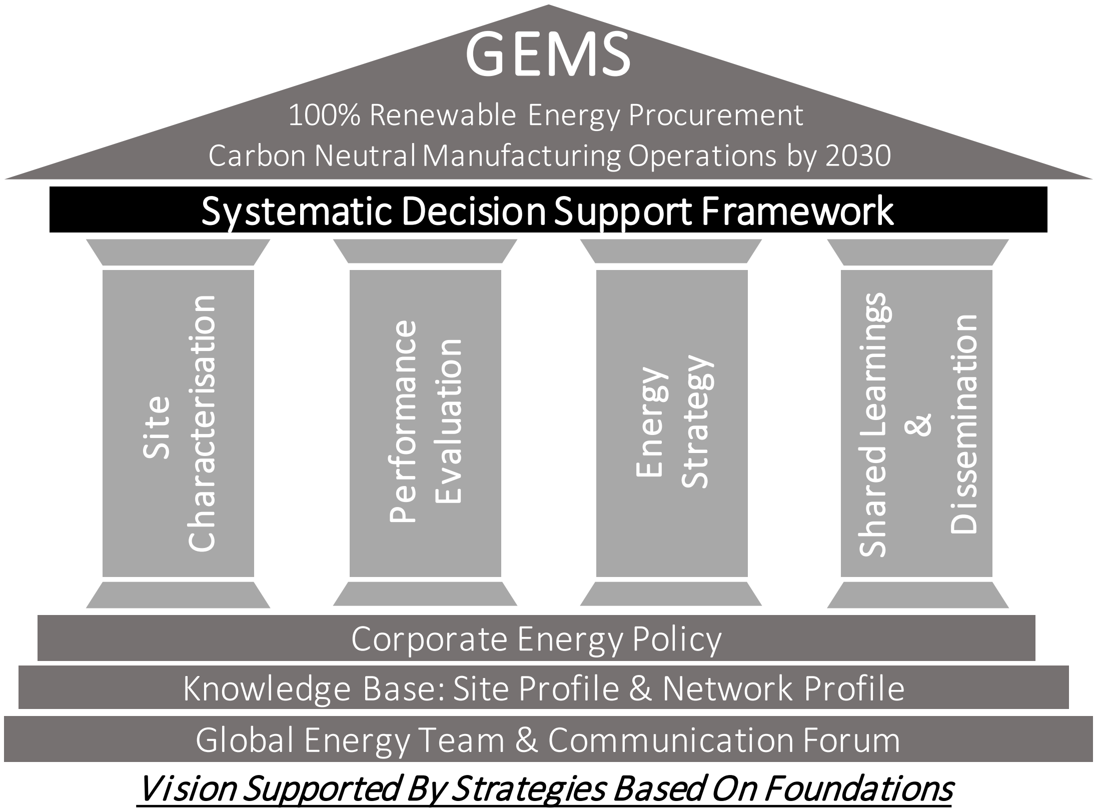

Figure 5-1. GEMS overview

5.3.2 GEMS Systematic Decision Support Framework

The purpose of the DSF is, therefore, to support the organisation during the evaluation and choice´s step of the decision-making process (see Table 5-1) by allowing decision-makers unbiased visibility to all potential energy investment project within the organisation (Finnerty *et al.*, 2016). Figure 5-2 presents the components of GEMS decision support framework.

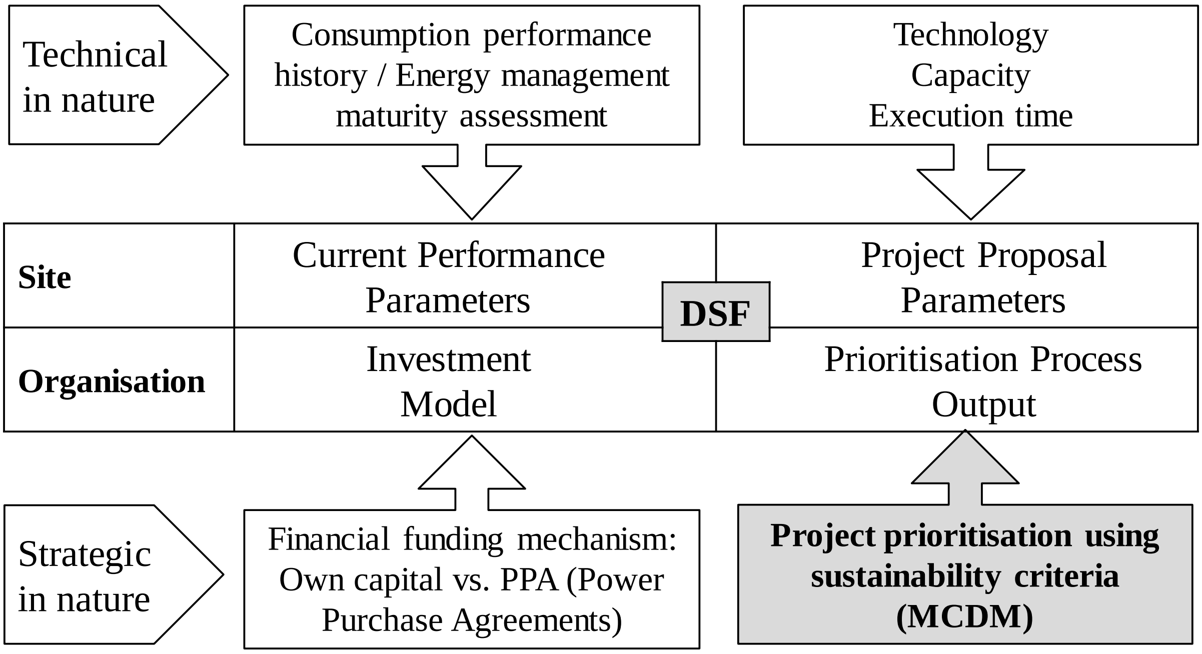

Figure 5-2. DSF - Minimal Dataset.

A minimal DSF dataset requires information from both site and corporate level.

Site level data (top-row Figure 5-2) is tactical in nature and provides two key components:

- The proposed EEM parameters (i.e. 1MW photovoltaic panels);
- The site energy performance metrics. This helps top management to assess the performance of the individual site from which the EEM is proposed in both a qualitative (energy management maturity score) and quantitative (energy use intensity) fashion. The energy and maturity indicators are outside the scope of this paper, the interested reader is referred to (Finnerty *et al.*, 2016; Finnerty, Sterling, Coakley, *et al.*, 2017)).

Organisation level data (bottom-row Figure 5-2) is strategic in nature and includes the preferred financial funding mechanism (i.e. own capital vs. Power Purchase Agreements –PPA) and the *critical output from a project prioritisation tool* showing where the proposed EEM ranks relative to other EEMs. Such a prioritisation tool is outlined in Figure 5-3 and it is fully described in the following sections.

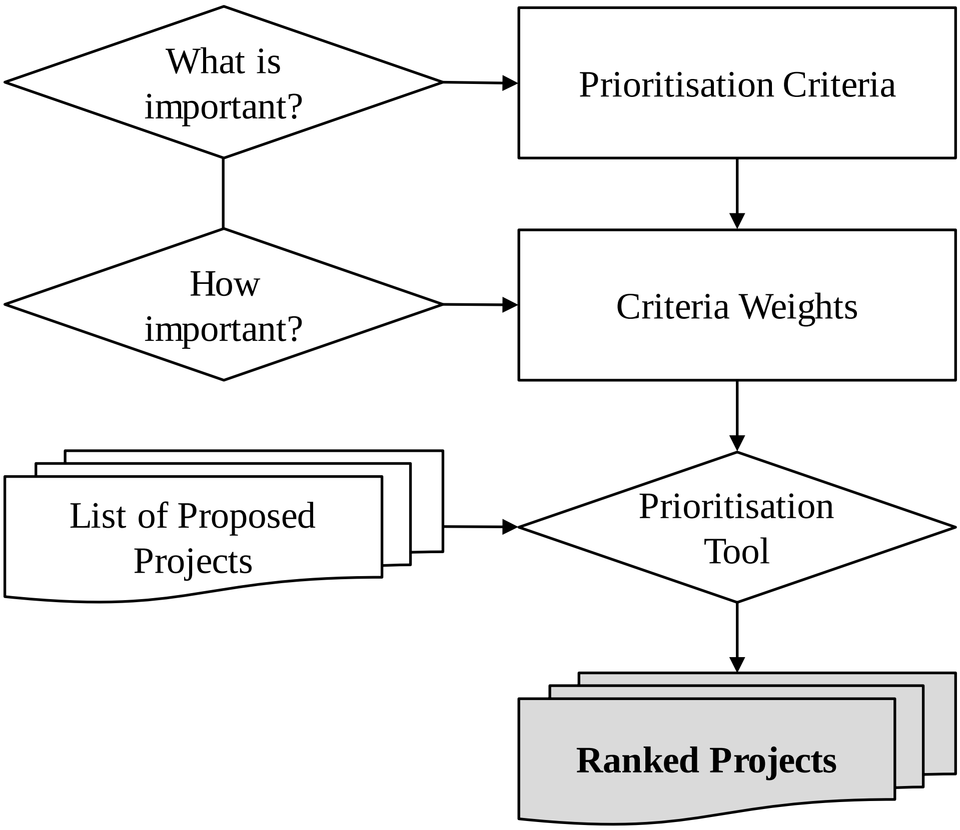

Figure 5-3. Prioritisation tool.

5.3.3 GEMS Multi-criteria decision method

GEMS prioritisation tool is an MCDM as presented in Figure 5-4. It is a hybrid approach that combines FL, AHP and TOPSIS (Contreras, 2016). It is based on previous MCDM (Wang *et al.*, 2008; Kaya and Kahraman, 2011). This is a vital stage in the process of 'levelling the playing field' between energy and other company investments, firstly as defining the selection criteria enables energy projects to compete independently from other business-related projects and secondly, if there is not a dedicated energy budget it is imperative all non-energy benefits are accounted for to optimise the business case.

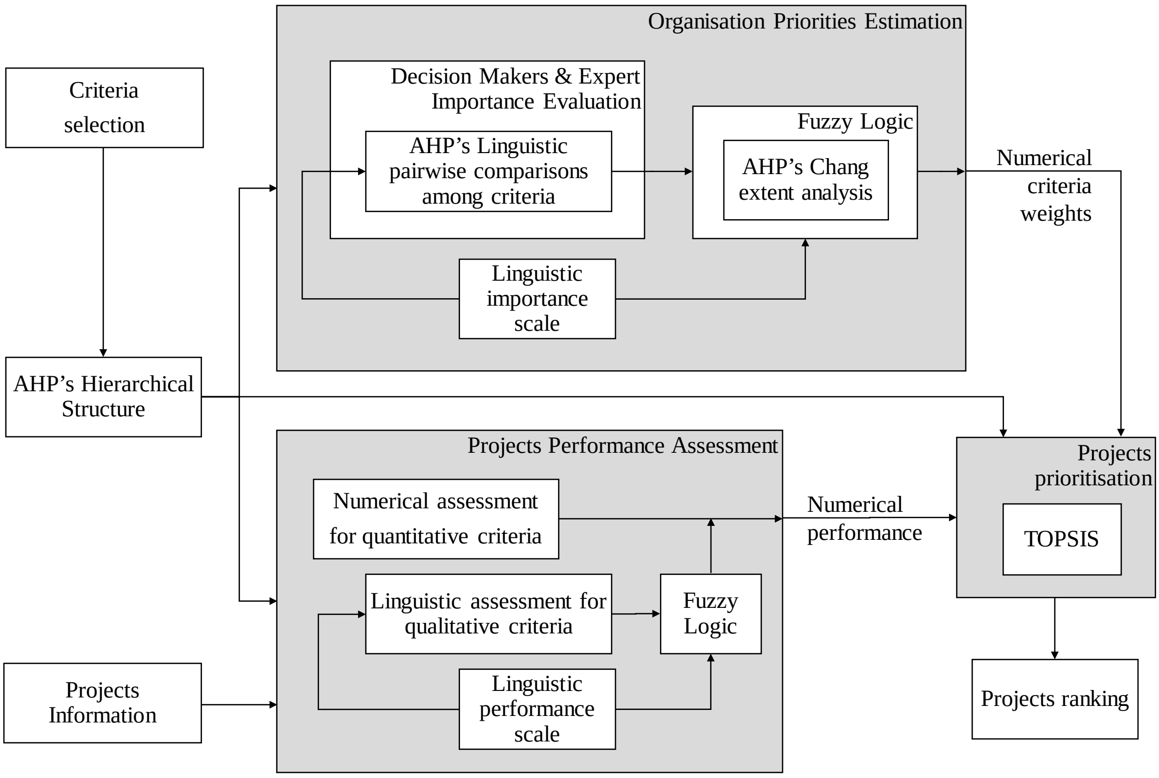

Figure 5-4. MCDM flowchart

The MCDM has the following general characteristics, which are described further in the following sections:

- It accounts for the non-energy benefits as described in section 5.3.3.1;
- A set of criteria for evaluating energy investment projects (i.e. as presented in Table 5-2 and section 5.3.3.2);
- A module for estimating the organisation's priorities (section 5.3.3.3);
- A module to assess projects performance against the set of criteria and the organisation's priorities (section 5.3.3.4);
- A project prioritisation module that uses TOPSIS and FL to establish the best solution (section 5.3.3.5).

5.3.3.1 Accounting for the non-energy benefits of energy projects

To fully address the gaps outlined in Section 5.2, it was clear that accounting for the so called non-energy benefits would provide an advantage for energy investment projects when competing with other investments. The NEB associated with each EEM need to be included in the project prioritisation tool (both quantitative and qualitative) and aligned with AHP criteria. Improved business cases result by taking a strategic approach that emphasises the non-energy benefits of EEMs and how such measures contribute to improve competitive advantage and core business activities.

It is envisaged that the energy manager presents the benefits associated with the EEM in two main categories:

- Primary 'energy' benefits: Typically, the direct cost savings associated with reduced energy usage that is reflected at the energy meter.
- Secondary 'non-energy benefits': This includes all aspects of the project that leads to both financial (ongoing operation savings, cost avoidance or one-time grants) and 'other' benefits not 'metered' via consumption of energy. These benefits can be further subdivided into several (non-exhaustive) lists, such as:
    - Environmental: Impact on long term environmental goals and company image. In addition, it is possible to associate reduced CO2 emissions with a monetary value either through internal carbon pricing or using the market rate for Renewable Energy Certificates (REC).
    - Technical – operability: reduced maintenance associated with displacement and/or replacement of 'older' equipment and technologies.
    - Technical – reliability: increased utility resilience or business continuity: associated with newly installed equipment and extended life time of backup equipment.
    - Economic: Tariff's or Capacity benefits, government grants and incentives associated with the proposed technology.

Many of these NEB's require the energy manager to investigate all aspects of the project that may be unique to the technology or locations proposed e.g. specific government grants or incentives. Where practical a financial value should be associated with the NEB's (for example carbon pricing for CO_2 or agreed 'hourly' cost associated with production disruptions) otherwise the framework enables qualitative elements to be accounted for (such as the importance of company environmental image via criteria weightings).

It is the responsibility of the energy manager to ensure that the relevant primary and secondary NEB are accounted for and aligned to the MCDM criteria (i.e. as in Table 5-2).

5.3.3.2 Identifying the organisation's criteria and hierarchical structure

Following an Analytical Hierarchical Process (AHP), a hierarchical structure with two levels is suggested. The first level comprises the top economic, environmental, social and technical criteria. The second level comprises fourteen sub-criteria as shown in Figure 5-5.

The Economic and environmental criteria include quantitative sub-criteria which can directly be evaluated numerically. The social and technical criteria comprise qualitative sub-criteria, thus requiring a further step to translate the qualitative estimation in numerical values that can be used for ranking. Such process is explained in the following sections.

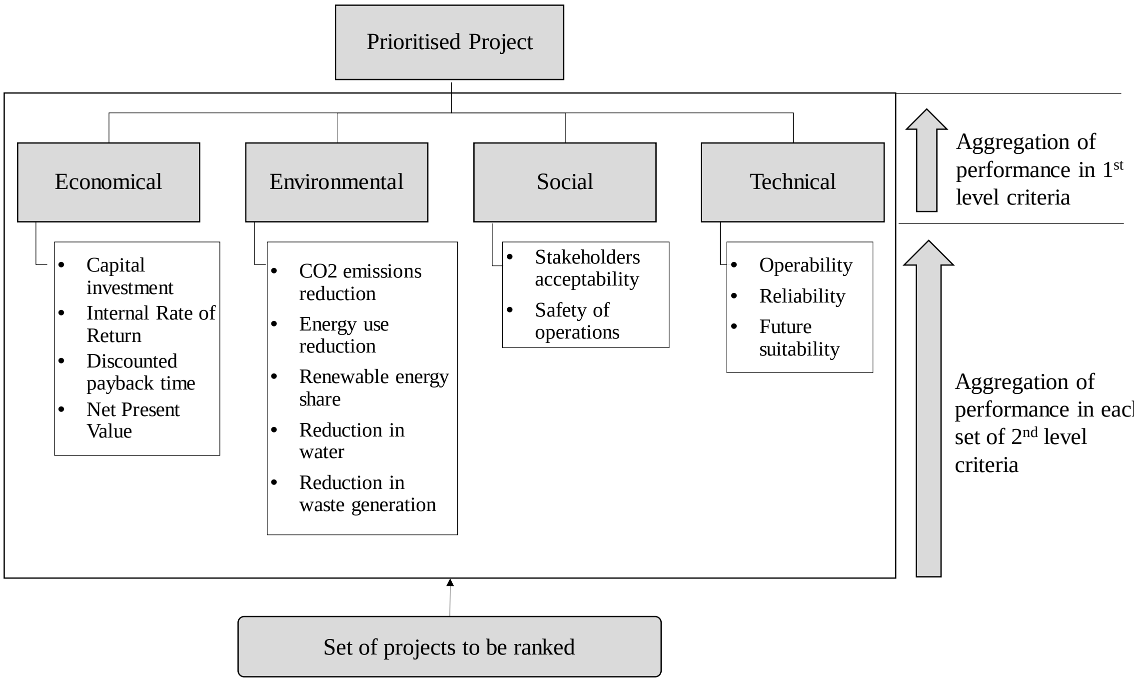

Figure 5-5. AHP structure and sets of criteria.

5.3.3.3 Estimating the organisation's priorities

An organisation's priorities estimation module based on AHP linguistic pair-wise comparisons, FL and extent analysis (Chang, 1996) is used to provide quantitative importance weights to each qualitative criteria. The organisation's priorities estimation is carried out by AHP pairwise comparisons and this step aims to elucidate the priorities when appraising energy projects. As indicated in Figure 5-4, opinions from the organisation's decision-makers and experts are used to understand those priorities and translate them into criteria weights. Nonetheless, inherent ambiguity is expected in this process due to the subjective nature of some of the questions. To deal with that uncertainty, the novel MCDM proposed in this research work, requires managers and experts to complete two tasks:

1. To judge whether criteria X (i.e. environmental) is more important than criteria Y (i.e. economical) within their organisation.
2. To use a linguistic importance scale to grade the relative importance of the more important criteria over the another (i.e. strongly more important). The linguistic importance scale is provided in Figure 5-6.

By combining the results of both tasks we can improve the confidence in the ranking of the organisation's priorities.

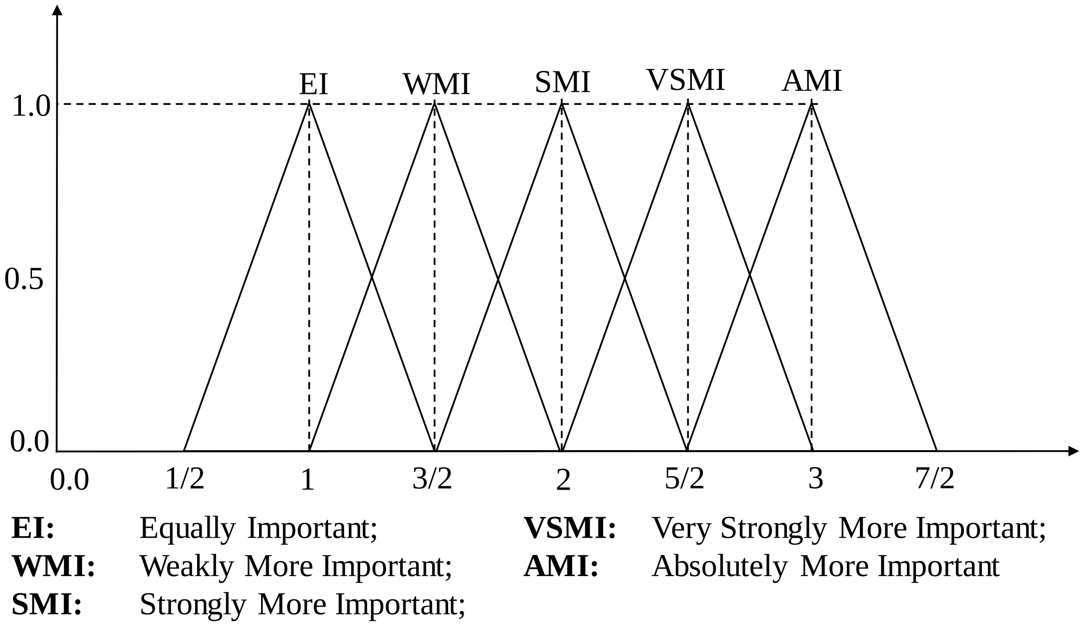

Figure 5-6. Linguistic importance scale and associated TFN sets (Kahraman, Ertay and Büyüközkan, 2006).

Estimation of the numerical criteria weights is carried out using Chang's Extent Analysis for fuzzy-AHP [5] and the TFN shown in Figure 5-6. Once the priorities weights have been established they can be used for multiple project selection scenarios until a time when decision-makers deem necessary to alter the weighting criteria (e.g. after a change in the external conditions such as organisation's policy or significant change in internal circumstances). If a judgment says that Environmental is more important than Financial, then there should be a scale of importance. Human judgement contains vagueness, an overlap between upper and lower judgement, the idea is to convert it into a numerical data point.

5.3.3.4 Evaluating projects

The project performance assessment modules compiles the quantitative criteria and uses a combination of linguistic assessment and FL for the qualitative criteria. For each project, quantitative performance is expressed 'as is' while qualitative performance assessments are based on subjective opinions about characteristics of energy projects and the technologies involved. This provides the link between the organisations core values and the strategic nature of the energy investment. Evaluators are provided with the following linguistic performance scale: very low, low, medium, high, very high. The evaluations are then translated into numerical assessments using FL for triangular fuzzy sets (TFN), see Figure 5-7.

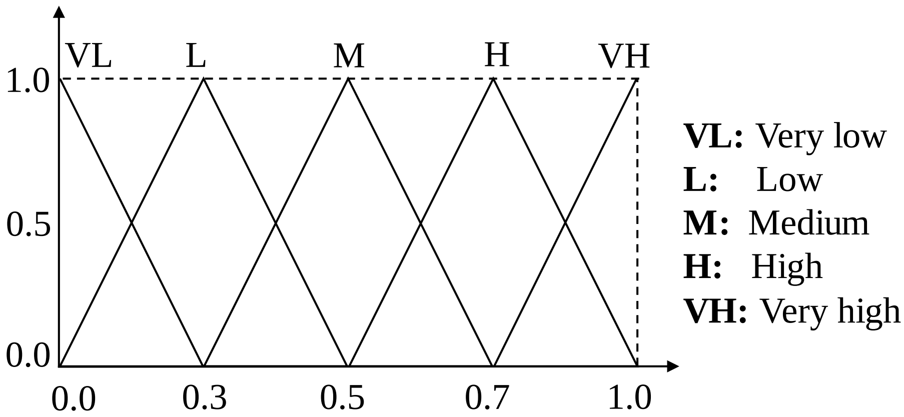

Figure 5-7. Linguistic performance scale and associated TFN sets (Wang et al., 2008; Kaya and Kahraman, 2011)

5.3.3.5 Projects ranking

Final project prioritisation is carried out by the TOPSIS component of the MCDM. It employs the numerical performances (quantitate and the transformation of the qualitative) of all projects and aggregates them in accordance with the AHP structure and criteria weights. TOPSIS ranks the set of projects based on their geometric distances from the Positive Ideal Solution and the Negative Ideal Solution of the decision-making problem. The MCDM assigns a score of 100% to the top ranked project, because it is the closest project to the ideal solution. The rest of the projects are assigned proportional scores depending on their closeness to the best project. For instance, the score for the bottom ranked project is 0%.

5.4 Case study

GEMS (Finnerty *et al.*, 2016) is a joint industrial and academic collaboration between Boston Scientific Corporation (BSC) and the National University of Ireland, Galway (NUIG). Its aim is to develop a methodology that guides multi-site organisations to optimal energy efficiency and meet energy/CO_2 reduction targets. GEMS is deployed in BSC's global network of sites and complements each individual site's energy management system. BSC is a non-energy intensive multi-national manufacturing corporation.

As part of the development and deployment of a global energy management system (Finnerty *et al.*, 2016), the DSF and associated MCDM described in Section 5.3 have been implemented to assist the investment decisions for energy projects across BSC's manufacturing sites.

5.4.1 GEMS MCDM application

This section presents GEMS MCDM application to prioritise energy projects in two case studies. Case 1 deals with five different energy projects in a single site. Case 2 deals with five projects from different sites (geographically dispersed). This study shows how the proposed MCDM can be used by single- or multi-site organisations to select their best project.

5.4.1.1 Criteria weighing

The criteria weights were estimated using FL to transform the linguistic pairwise comparisons carried out by the appropriate top managers and experts in each discipline within the organisation. The estimated weights for first and second level criteria are reported in Table 5-3. The 1st level weightings were completed by top management within the organisation, whilst the 2nd level criteria were set by the top management / subject matter experts within the applicable department.

Table 5-3. Criteria weights for BSC.

First Level Description	Weight %	Second Level Description	Weight %
Economic	31	Initial Capital Investment	18
		Net Present Value	**46**
		Internal Return Ratio	18
		Discounted Payback Time	18
Environmental	34	CO_2 Emissions Reduction	29
		Energy Consumption Reduction	29
		Renewable Energy Share	26
		Water Consumption Reduction	1
		Waste Generation Reduction	15
Social	9	**Safety of Operation**	**68**
		Stakeholder's Acceptability	32
Technical	26	Operability	34
		Reliability	56
		Future Suitability	10

Table 5-3 indicates that for the first level criteria, the environmental performance is the priority when ranking energy projects at BSC while the economic criteria are the second priority, followed closely by the technical criteria. On the second level, safety of operations is the most important criteria with NPV being the second. In combination this reflects the core ethos of the organisation.

5.4.1.2 *Case 1: Site-level MCDM application*

Projects: Five energy projects were proposed at Site 1 and were generated by the facilities engineering team as part of a site-wide exercise on opportunities identification for energy performance improvement.

The evaluation matrix: As part of the decision-making process, the performance of each project against the criteria presented in Table 5-3 was estimated by project owners and confirmed by the site's energy manager. In this case, the energy manager ensures the inclusion of both primary and secondary energy benefits. The information collected for the five projects for Site 1 is presented in the evaluation matrix Table 5-4. Performances for quantitative and qualitative criteria are numerically and linguistically expressed respectively.

Table 5-4. Decision-making matrix for Case 1.

First Level Criteria	**Second Level Criteria**	**A1**	**A2**	**A3**	**A4**	**A5**
		Lighting efficiency upgrades	**Fume hood energy reduction**	**Tri-generation system**	**Air handling unit free cooling**	**Calorifiers improvement**
Economic	Initial Capital Investment ($)	$10,334	$7,500	$2,575,000	$8,500	$45,000
	Net Present Value ($)	$1,363	$33,500	$841,000	$17,000	$94,400
	Internal Return Ratio (%)	11	100	19	68	70.0
	Discounted Payback Time (yr.)	4.2	0.8	3.9	1.4	1.3
Environmental	CO_2 Emissions Reduction on site (%)	0.1	0.3	15.0	0.5	1.1
	Energy Consumption Reduction on site (%)	0.1	0.3	15.0	0.5	1.1
	Renewable Energy Share Increment on site (%)	0.0	0.0	0.0	0.0	0.0
	Water Consumption Reduction on site (%)	0.0	0.0	0.0	0.0	0.0
	Waste Generation Reduction on site (%)	0.0	0.0	0.0	0.0	0.0
Social	Safety of Operation	High	High	High	High	High
	Stakeholder's Acceptability	Very High	Medium	Very High	High	High

Technical	Operability	High	High	High	High	Medium
	Reliability	High	High	High	High	High
	Future Suitability	Very High	Very High	Medium	Medium	High

Project prioritisation: The prioritisation outcome for the projects evaluated in Case 1 is obtained by applying the GEMS MCDM with the criteria and weights presented in Table 5-3. Figure 5-8 depicts project 'A3 – Tri-generation' as the top ranked at a site level, followed by project 'A1 – Lighting upgrade', which offers only a quarter of the rating than A3. The superior result of the latter is mainly attributed to its contribution to improve the environmental and economic performance of the site.

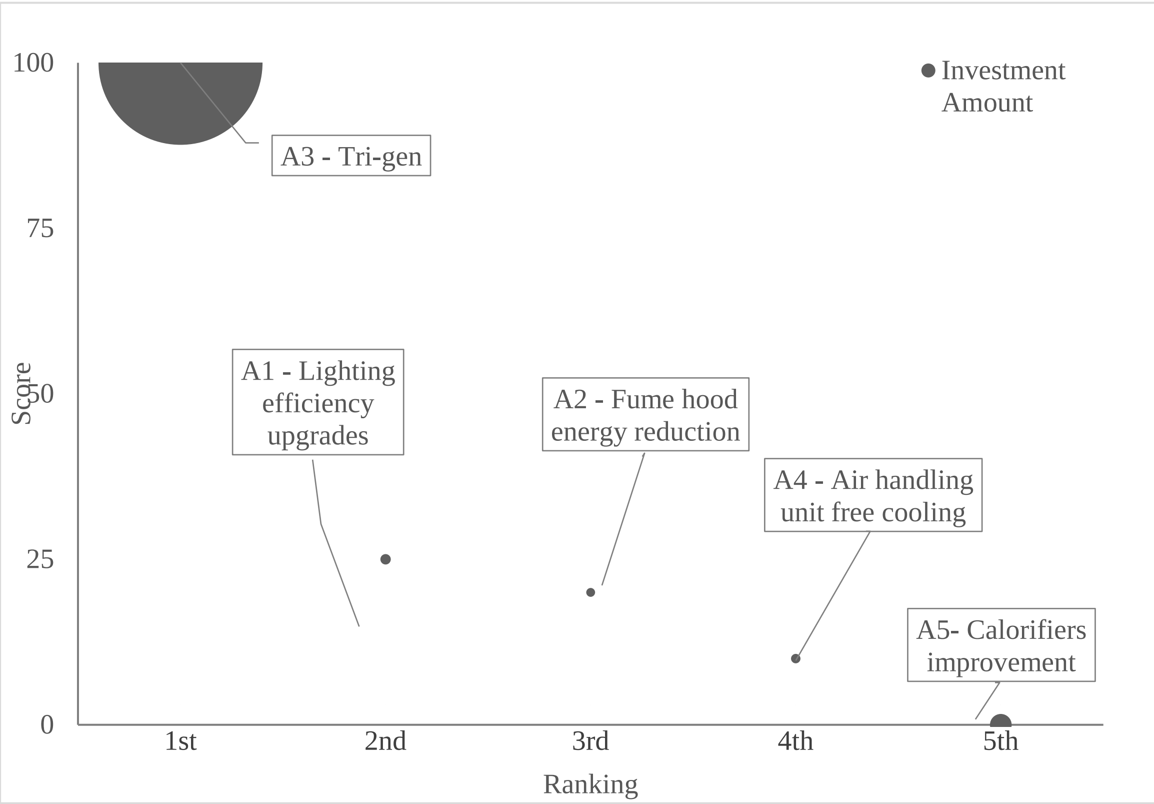

Figure 5-8. MCDM Output for Case 1 – Site Level (size of the circles represent investment level).

The output of the MCDM provides an unbiased ranking of the projects for the site´s energy manager as the selection process is aligned now with the priorities defined by the organisation for energy projects. On the other hand, they can now define an investment plan for the site based on the ranking from the MCDM. In this case, for such plan to be feasible, central corporate funding was required due to the size of project A3 – Tri-Generation system, which was the best performing project. The rest of the projects could be funded directly by the site. Case 2 in the following section presents this project in competition for funding against projects from other sites.

5.4.1.3 *Case 2: Multi-site MCDM application*

Case 2 presents the application of GEMS MCDM at a global level. In this case, the MCDM was applied to provide the global energy manager with an objective order of investment to feed into the DSF.

Projects: five projects are assessed using the MCDM, all of which were escalated from geographically disperse sites to compete for central funding.

The evaluation matrix: Project performance information is provided by site energy managers. Information for the five projects against the MCDM criteria listed in Table 5-3 is presented in the evaluation matrix Table 5-5.

Table 5-5. Decision-making matrix for Case 2.

First Level Criteria	Second Level Criteria	P1	P2	P3	P4	P5
		Site 1 - Tri-generation System	**Site 2 - CHP**	**Site 3 - Ice Storage System**	**Site 4 - Chillers' Upgrade**	**Site 5 - Solar PV System**
Economic	Initial Capital Investment ($)	$2,575,000	$1,346,000	$1,250,000	$800,000	$0
	Net Present Value (S)	$841,000	$1,900,000	$609,627	$996,000	$900,000
	Internal Return Ratio (%)	19	45	23	40.0	100
	Discounted Payback Time (yr.)	3.9	2.1	3.6	2.7	0.0
Environmental	CO_2 Emissions Reduction - global (%)	1.9	1.5	0.0	0.5	0.6
	Energy Consumption Reduction - global (%)	1.9	1.3	0.6	0.4	0.2
	Renewable Energy Share Increment - global (%)	0.0	0.0	0.0	0.0	37.0
	Water Consumption Reduction - global (%)	0.0	0.0	0.0	0.0	0.0
	Waste Generation Reduction - global (%)	0.0	0.0	0.0	0.0	0.0
Social	Safety of Operation	High	High	High	High	Very High
	Stakeholder's Acceptability	Very High	Very High	Medium	High	Very High
Technical	Operability	High	High	High	High	Very High
	Reliability	High	High	High	High	High

	Future Suitability	Medium	Medium	Very High	Medium	Very High

Project prioritisation: The prioritisation outcome for the 5 projects evaluated is shown in Figure 5-9. It was obtained using the same criteria and weights of Case 1. It depicts the project ‘P5 – Solar PV System’ as the top ranked, followed by project ‘P2 – Combine Heat & power, which offers only half the rating compared with ‘P5’. Project P1, which was the best from Site 1 in Case study #1, ranked as the third best at a global level. Projects P5 and P2 contribute more than P1 to improve the sustainability performance of the organisation from a global perspective.

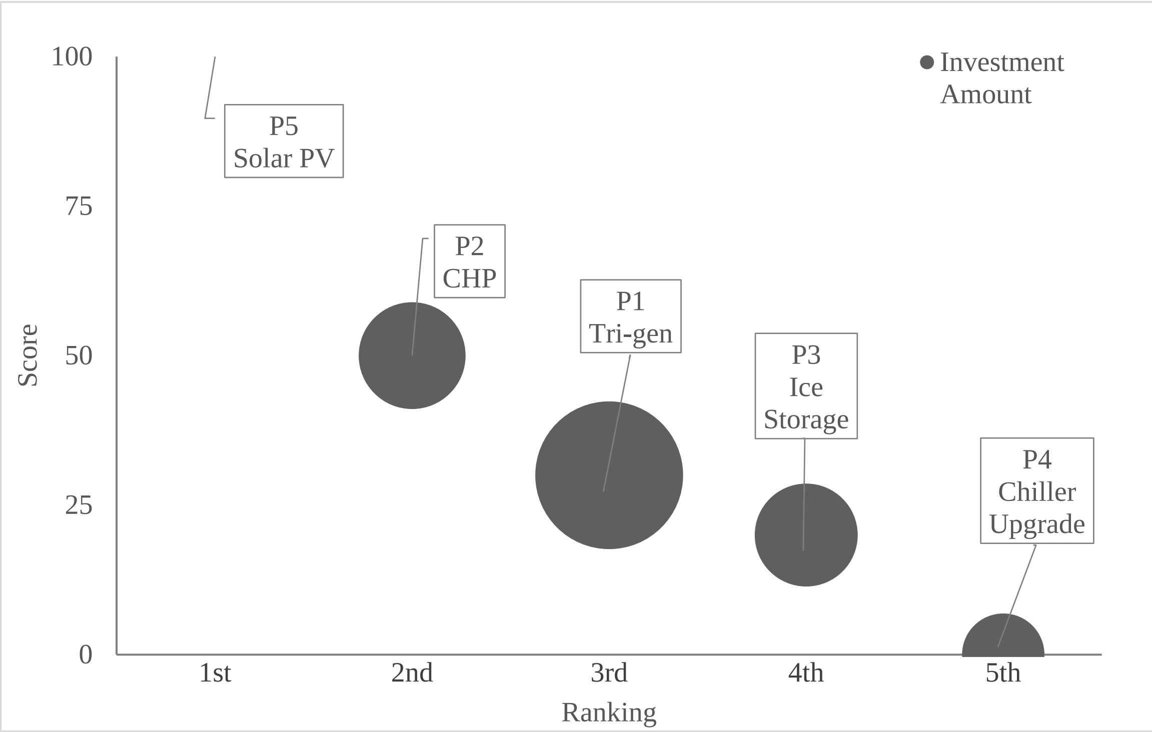

Figure 5-9. MCDM Output for Case 2 – Organisation Level (size of the circles represent investment level).

The output of the MCDM provides the global energy manager with an unbiased ranking of the investment opportunities based on the priorities defined by the organisation via criteria weighting. The outcome of the MCDM at multi-site level is fed into the DSF. This ranking, however, is not necessarily the final order in which the available corporate fund for energy projects is to be allocated. The application of the DSF is presented in the following section.

5.4.1.4 Decision support framework presentation to decision-makers

The DSF application results are shown in Table 5-6. Decision-makers were presented with the DSF results and positive, informed investment decisions were made on four of the projects proposed in 2016. This is attributable, among other elements, to the improved decision-making process for energy projects enabled by the DSF (specifically the unbiased result of the prioritisation tool), the visibility to the complete picture of savings (primary and secondary benefits) and the strategic nature of the key performance indicators.

Table 5-6. DSF dataset[16].

Project	Investment model	Prioritisation Output (MCDM)	Performance Parameters[16]		Proposal Parameters
			Energy Indicator (MWh/m³/s)	Maturity indicator (Scale 1-5)	
P1	Own capital	3 (30%)	134	2.4	\$2,575,000
P2	Own capital	2 (50%)	128	2.2	\$1,346,000
P3	Own capital	4 (20%)	97	2.2	\$1,250,000
P4	Own capital	5 (0%)	78	2.1	\$800,000
P5	PPA	1 (100%)	78	2.1	\$0

5.4.2 Discussion

A key component of the MCDM is the criteria and their weights since they reflect the priorities against which projects must be assessed across all sites. Perhaps most importantly, it enables top management to engrain the organisations core business priorities into the energy investment process. By using the same criteria and weights, energy projects are evaluated in a consistent manner company wide. In this paper, the concept is applied for both Case 1 and 2. For BSC, Table 5-3 reveals that a project's contribution to improve the environmental footprint has higher priority than financial benefits. It is interesting to note how the reliability criterion of a project (business continuity) has the same impact as the net present value (most important economic criterion) for BSC.

For all projects presented in the case studies, the benefits can be broadly broken down into those that result from the savings associated with reduction in actual energy consumption at the meter, 'primary energy benefits'. All 'other' benefits fall under 'secondary non-energy benefits' whose importance is highlighted in Table 5-7 specifically for project P1/A3.

Table 5-7. Primary and secondary benefits for the P1 project.

Savings (in thousands of \$)		2016	2017	2018	2019	2020	2021	2022
Primary benefits	Energy cost reduction	406	416	433	444	456	467	479

[16] The energy and maturity indicators are outside the scope of this paper, the interested reader is referred to (Finnerty *et al.*, 2016) and to (Finnerty, Sterling, Coakley, *et al.*, 2017).

Secondary benefits	Gas tariff reduction	64	66	68	69	70	72	73
	Capacity charges	55	55	55	55	55	55	55
	Demand side units	21	21	21	21	21	21	21
	Reduced maintenance	27	27	27	27	27	27	27
	Improved business continuity	34	34	34	34	34	34	34
	Natural Gas Carbon Tax rebate	46	46	46	46	46	46	46
	Government grant		540					
Total		**247**	**789**	**251**	**252**	**253**	**255**	**256**

In this case, the secondary NEBs account for over 40% of the overall financial savings. These include one-off government grants and ongoing government incentives associated with the technology, deferred and reduced maintenance costs, and cost avoidance through enhanced system resilience. Compounded to this are the qualitative effects from the NEB that further impact the decision-making process via the enhanced MCDM score (social and technical attributes).
If the secondary NEB were not considered for this project, the NPV would be reduced by 55%, the IRR by 75% and the payback period would double. In addition, the project would rank last - not third- against the other four projects that were competing for funding at global level.
This clearly highlights the need to include all NEB's into any EEM business case and further highlights the ability of the DSF and MCDM to collate these pertinent criteria and ensure the EEM are on a level playing field with other strategic company investments.

Finally, it is important to note that a site level there is no need for the use of the DSF, as this tool is intended to support informed decisions by senior managers by conveying not only the outcome of the MCDM, but also the investment strategy (own capital vs. third party's), the proposal and the performance parameters.

5.5 Conclusions

To avoid ad-hoc decision-making practices, an unbiased DSF is needed by decision makers. This research proposes a simple and repeatable DSF underpinned by a project prioritisation tool that uses economic, environmental, social and technical criteria. The novelty of this work lies in the novel combination of AHP, Fuzzy Logic and TOPSIS to enable the quantification and structured analysis of the primary and secondary benefits from energy investment projects.

The added value of the proposed methodology resides in the use of the same criteria and weighting to evaluate all projects and the flexibility of the methodology to work for both single and multi-site organisations. Ultimately, the role of the DSF is not to eradicate the need for expert knowledge in project selection, but to present decision-makers with an easy to understand yet comprehensive data-set of necessary, unbiased, information regarding proposed energy conservation measures. From the energy manager perspective, the DSF is a condensed, repeatable, and effective template to request approval for funding, while for the executive leadership, it constitutes an understandable, fact-based approach to reach informed decisions. There are two fundamental elements required to make the DSF successful:

- Ensuring the decision makers (top management) are part of the process when setting criteria and associated weighting and that they are aware of all the positive impacts of EEM and how EEMs cascade into meeting short and long-term energy goals. This in turn impacts the organisations sustainability policy or plan to improve environmental performance. As the sustainability policy reflects the company's mission statements and core values, this is an effective way to make EEMs strategic and part of the company's core business;
- Ensuring the MCDM captures all the possible benefits (primary and secondary) associated with energy investment project proposal, leading to maximum opportunity for success when competing for funding (especially important if there is not a dedicated fund for EEMs and interdepartmental competition for funds from all aspects of the organization). The MCDM enables all aspects of NEB to be considered either through monetarisation (where possible) or through a qualitative impact *via the 'pair wise' comparison.* However, this is not an exact formula and the NEB presented here is a non-exhaustive list that requires investigation of all aspects of the project that may be unique to the technology or locations proposed i.e. specific government grants or incentives.

The MCDM ranking does not necessarily determine the order for funding, it only ensures that the criteria with the most importance to the organization gets the highest weight. For example, in multisite organisations, the decision may conclude that the strategic need to improve the performance of one site out-weights the importance placed on the MCDM output for each individual project. This is why the broader DSF is required to show the broader picture and the MCDM output is just one key DSF input. In fact, the driver for capital investment may be to bring all sites to an acceptable level of performance and subsequently 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.

It is also worth noting that in the case studies, the clear presentation of the data via the DSF and MCDM led to an unprecedented level of investment in energy efficiency measures in BSC in 2016.

5.6 Future Work

Future work will focus on further understanding and quantifying the impact of secondary non-energy benefits for energy efficiency investments in non-energy intensive multi-site organisations. The automation of the process and the improvement of the usability of the tool, including the development of standardised templates for collecting the relevant data will focus developments in the short-term while in the long term the validation of the methodology in different types of organisations will be pursued.

5.7 Acknowledgements

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6 Results & Discussion

"Sunshine is a form of energy and the winds and the tides are manifestations of energy. Do we use them? Oh, no; we burn up wood and coal, as renter's burn up the front fence for fuel. We live like squatters, not as if we owned the property." – Thomas Edison.

6.1 Introduction

This chapter will assess how the knowledge gaps outlined in section 1.4 were addressed and how the overall Research Question was answered.

Research Question: "*For non-energy intensive multi-site manufacturing organisations, can a framework be developed that delivers optimal network performance and enables informed decision making on investment projects to meet energy and carbon reduction goals?"*

This thesis advanced the body of research in Global Energy Management systems. More specifically in non-energy intensive MMO, which was deemed a niche but highly impactful sector with the capacity to influence the much wider manufacturing and industrial sector. To achieve this the following key deliverable was identified:

- Development and case study implementation of a novel systematic 'Global Energy Management System' (GEMS) to enable an MMO reach optimal energy efficiency performance and capital spend whilst meeting global energy and carbon emission reduction goals.

In addition, the following deliverables were identified as critical to supporting a GEMS in non-energy intensive MMO:

- Development and implementation of a novel approach to deliver qualitative metrics in the form of an 'Energy Management Maturity Model' (EM^3).
- Development of a long-term energy policy and supporting strategy to close the energy efficiency gap for non-energy intensive MMO (C^3).
- Development and implementation of a decision support framework to assist MMO make optimal investment decisions on energy performance improvement projects, in support of the vision to meet global energy and carbon emission reduction goals.

This chapter will present the key results from the application of GEMS in BSC as assessed from the baseline year of 2013 through to its carbon neutrality commitment at the end of 2017. It will discuss content not already documented in previous chapters. It will discuss the overall advancement of GEMS since the journal and conference publications through its BSC partnership and tell the story from the Global Energy Manager (GEM) perspective as part of an overall macro view of the BSC GEMS implementation (2013 to 2017) (Figure 6-1) of the BSC GEMS Parthenon. This will help the reader get an appreciation of how GEMS evolved during its implementation.

The chapter is structured as follows:

- BSC GEMS Implementation overview: from the initial 'pilot' project to full deployment in an US$8B, Fortune 500 non-energy intensive MMO. This section will also reflect on the human influences and the performance of GEMS in terms of addressing the various research gaps identified as the methodology became engrained into the BSC company culture.
- Macro Trends: A review of the enterprise level KPIs developed with a specific focus on communications to enhance CSR ratings and the resultant recognitions.
- Tools and Processes; an overview of the key outputs as developed through GEMS - a joint academic and industrial collaboration.
- Summary of results.

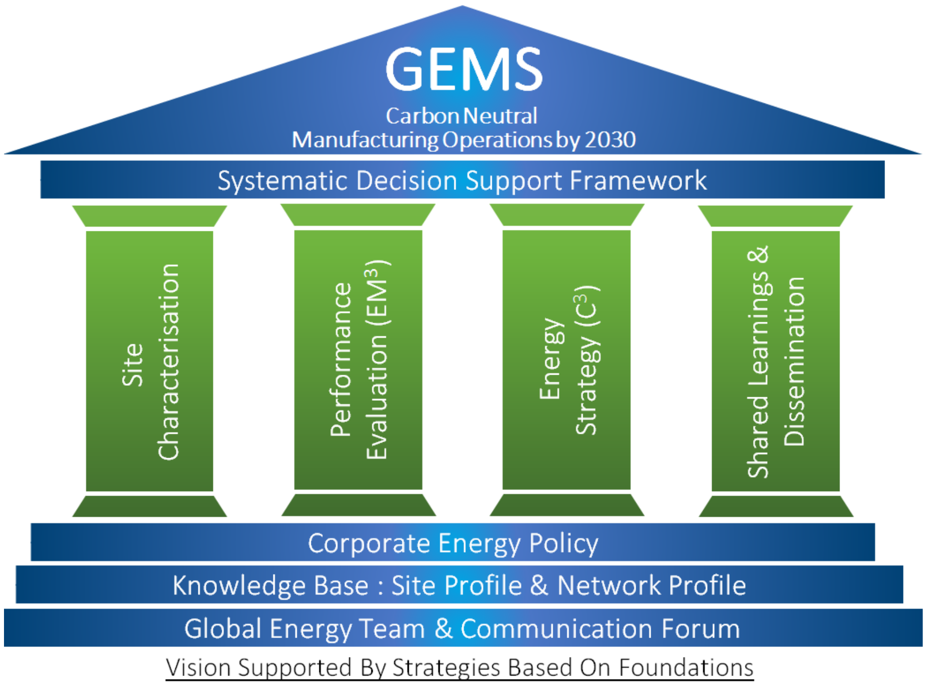


Figure 6-1. BSC GEMS Parthenon

The contents of this chapter were initially published in proceedings of the 11th International Conference on Sustainable Energy & Environmental Protection (SEEP), May 11-14, 2018, Glasgow, UK. Here presented is the extended version of the research work.

6.2 BSC GEMS Implementation – The Global Energy Manager perspective

The research and development of GEMS began in 2012; however, the first major milestone on the journey of GEMS implementation in BSC commenced in 2014 with approval for a 'pilot' deployment in Europe. The success of this pilot, coupled with the advancement of the GEMS tools and processes in parallel, enabled its world-wide BSC deployment by the end of 2015. In 2016 the GEMS DSF was responsible for the allocation of over US$4.7M in Capital funds, an unprecedented level of investment in EEM for BSC, resulting in US$2.25 million in long term operational annual savings and reducing CO_2 emissions by over 4% (3.9t of CO_2-eq emissions avoided). In June 2017 the GEMS framework featured in the BSC's annual CSR report as a joint academic and industrial collaboration ensuring BSC delivers on it energy and environmental commitments. By Sept 2017, BSC announced its commitment to carbon neutrality for all its manufacturing operations by 2030 at the New York City (NYC) Climate action week conference. In 2018 GEMS has proved to be the corner stone of BSC communications to our key customers and the investment community as they disseminate thier sustainability program. The following sections will endeavour not to repeat the case study work already outlined in chapters two through five but re-evaluate the Parthenon application holistically from the perspective of the global energy manager (responsible for its implementation). How GEMS application helps address the research question and knowledge gaps identified will also be discussed.

6.2.1 BSC GEMS Pilot

This section will discuss the findings from the early work associated with the BSC GEMS pilot. This step was essential to the senior management approval of the world-wide BSC GEMS application and is not covered in previous chapters or publications.

Section 2.4.1.3 outlines the methodology for GEMS with respect to formulating the corporate energy policy foundation. It describes the logic behind having an initial pilot site selection and how to approach it. Section 2.5.1.3 and Table 2-4 (business case for GEMS), details the initial deployment parameters for the GEMS pilot in BSC. It noted a commitment to 10% reduction in CO_2 emissions by 2020.

Conveying the 'potential' business case associated with a GEMS application enabled funding approval for the pilot. This in turn led to a full deployment of GEMS which ultimately secured significant funding for EEM. Figure 6-2 shows the GEMS Parthenon used during the initial pilot deployment, highlighting the 'Pilot Study on best practice / Demonstrator sites' foundation. The bespoke 'GEMS' Audit evolved as part of the pilot implementation.

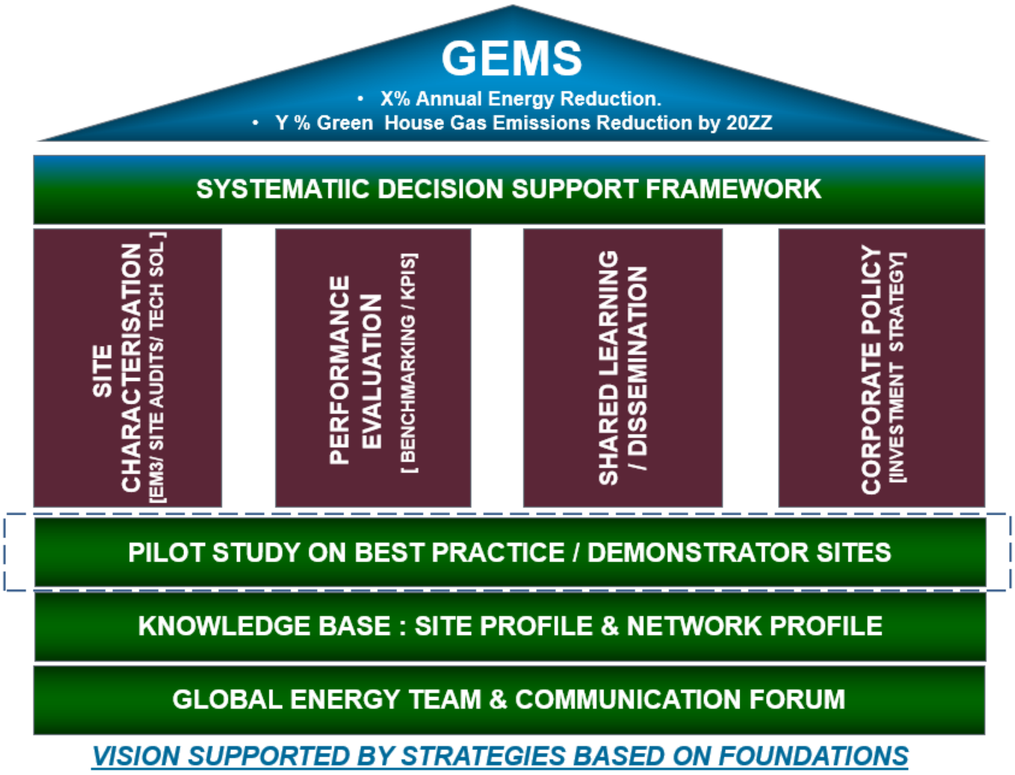


Figure 6-2. Pilot phase - GEMS Parthenon

BSC's facilities in Europe represented a unique opportunity to take the first steps of GEMS through a pilot project implementation. This consisted mainly of completing an onsite data gathering exercise (both qualitative and quantitative) and a subsequent energy audit. The selection of the BSC European sites was heavily influenced by the legal requirement for an energy audit as part of the European Energy Efficiency Directive (EED) to be completed by December 2015. BSC has three manufacturing sites in Ireland (Galway, Cork & Clonmel) and its European distribution centre is in the Netherlands (Kerkrade). All four locations had site level EnMs with varying levels of maturity. The Galway site was the initial deployment site, followed by Cork, Clonmel and Kerkrade. The approach enabled continuous improvement via shared learnings as the pilot advanced, with increasing levels of complexity assessed regarding the variables that impact energy efficiency, (Figure 6-3)

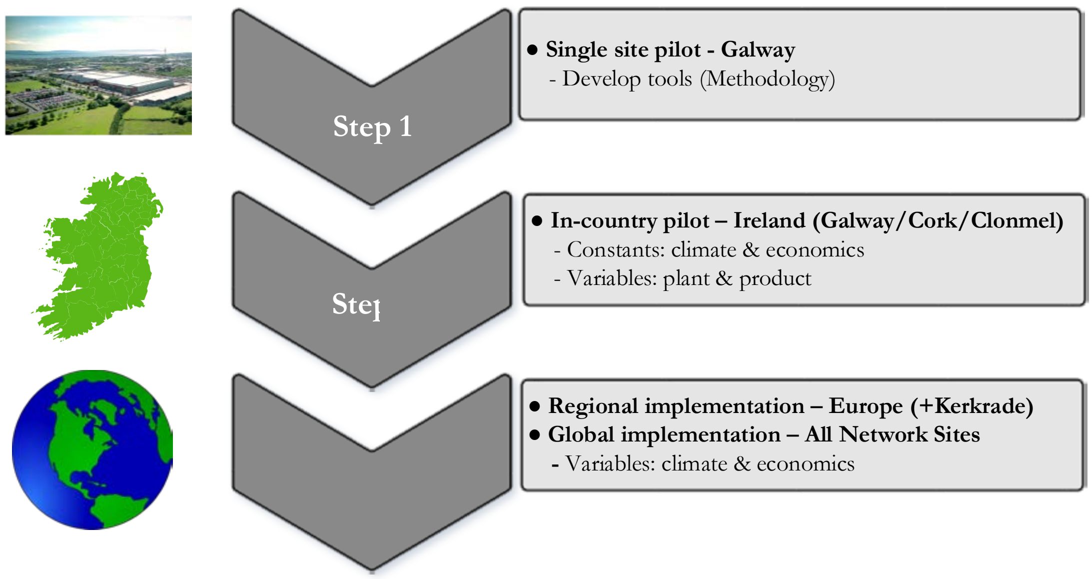


Figure 6-3. BSC GEMS Pilot - Implementation approach

In conjunction with an energy audit (per EN 16247 1-3), the objective of the GEMS pilot audit was to identify areas where energy consumption could be reduced or trends of use altered, to provide financial savings for BSC. In parallel, it was imperative the pilot would convey the business case to enable a global deployment of GEMS methodology. A comprehensive table of energy saving opportunities was compiled for each site, see examples, Figure 6-4 and Table 6-1.

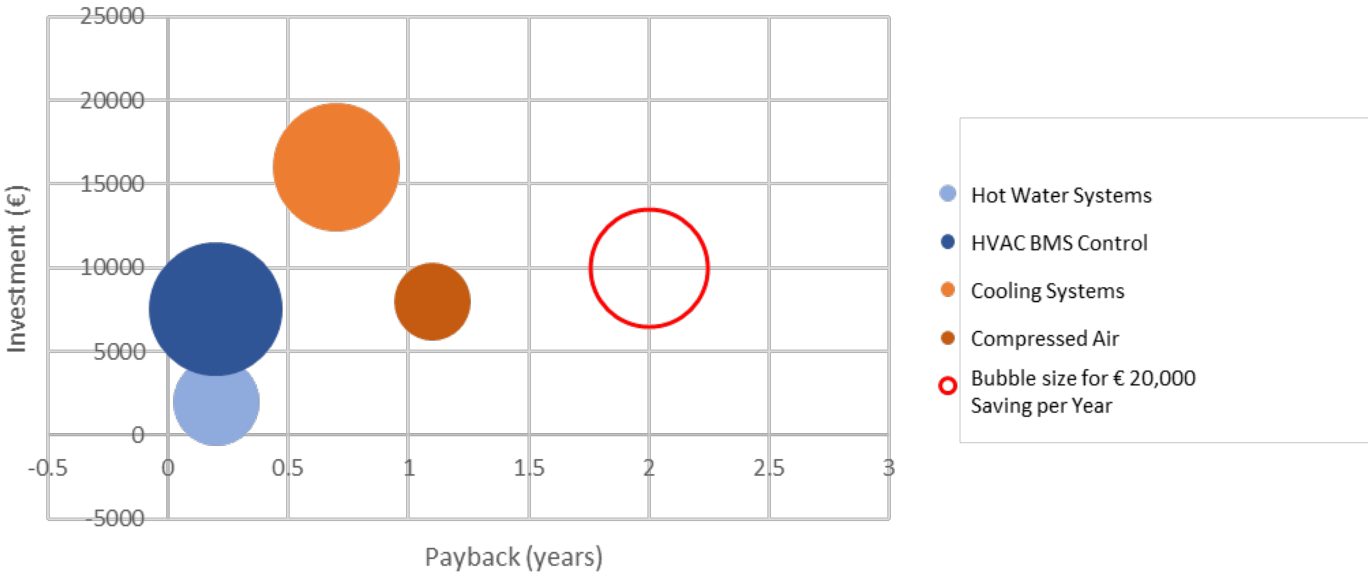


Figure 6-4. BSC GEMS pilot – Kerkrade audit report extract example (Bubble Chart of Energy savings < 3 year payback)

Table 6-1. BSC GEMS pilot – Kerkrade audit report extract example (site summary of recommendations)

Action Ref.	Recommendation	Estimated annual savings				Est. cost (€)		Payback period (years)
		(€)	($)	CO_2 (tonnes)	(kWh)	(€)	($)	
4-1	Isolate two split air conditioning cassettes in compressed air plant room unless under personnel completing maintenance, incorporating thermostatically controlled extractor fan (already present) to exhaust heat to atmosphere through external wall.	€4,075	$4,441	19	41,610	€2,000	$2,180	0.5
4.2	Implement heat recovery from compressor plant room allowing waste heat to be transferred into immediately adjacent warehouse area during winter months, incorporating thermostatic control with heat exhausted to atmosphere in summer.	€2,007	$2,188	9.4	20,498	€5,000	$5,450	2.5
4-3	Reduce operating pressure of compressors under trial conditions , at increments of 0.1 bar, from Maximum of 8.1 bar to 7.0 bar and consider evening and weekend isolation out of hours (or further pressure reduction).	€1,115	$1,216	5.2	11,388	€800	$872	0.7
5-1	Dynamically operate Trane Chiller in terms of time schedule and chilled water temperature to reduce operational hours, benefit from lower night rate electricity charges and utilise thermal capacity available from connection to underground 700,000 Litre Sprinkler Water Tank (*implemented on trial basis*)	€21,459	$23,390	76.1	166,440	€500	$545	0
5.2	Install variable speed control drives to improve control of three fixed speed Chilled Water pumps (for Trane System in Bunker) to operate in line with cooling demand.	€3,294	$3,590	15.4	33,638	€3,800	$4,142	1.2
5-3	Improve temperature control of localised cooling systems comprising 10 split air conditioning cassettes, as per improvements itemised in report Section 5.3	€1,300	$1,417	6.1	13,271	€0	$0	0
5-4	Install Dry Air Cooler to work in conjunction with Trane Chiller and benefit from free cooling potential < 10oC ambient temperature (or whenever ambient < Sprinkler Tank temperature)	€4,210	$4,589	19.6	42,995	€14,000	$15,260	3.3
6.1	Consider complete isolation of summer LPHW boilers between June to September or as a minimum rationalise summer operations and reconfigure boiler control to ensure that boilers do not operate until Warehouse temperature drops below ~17oC during peak summer months.	€7,829	$8,533	31.1	125,904	€1,000	$1,090	0.1
6-2	Install Timers on all electric hot water heaters (i.e. GYM 2.5 kW electrically heated tank element on 24/7 thermostatic control at present)	€1,287	$1,403	6	13,140	€800	$872	0.6
7-1	Introduce wider temperature control dead band between heating and cooling set points for all areas of the site, with successful trial in Warehouse area already implemented in winter (i.e. widened dead band from 0.5 to 2oC by adjusting Warehouse cooling set point from on at 21.5 to on at 23oC), deploy in line with seasonal ambient conditions.	€20,579	$22,431	83.7	313,919	€2,500	$2,725	0.1
7-2	Optimise BMS Controls i.e: • Dynamic Demand control of Trane Chilled Water System pumps (1.1 kW, 1.5 kW and 5.5 kW) • Dynamically control Trane chiller to reduce operational hours in line with ambient conditions and aim to avoid peak summer demand by dropping chilled water temperature immediately prior and storing thermal cooling energy in Sprinkler Tank . • Reduce speed of office return fan based on ratio against supply • Implement higher/lower summer and winter respective temperature set points on a seasonal basis • Avoid cyclical heating and cooling • Consider isolation of electrical elements in Gym AHU as room served with central heating (LPHW) radiators • Improve time schedule of 3kW office CHW pump and potentially improve demand control as running at 80-90% during height of winter, expand to all CHW and LPHW pumps • Reconfigure weather compensated temperature set points applied to the operation of the LPHW boilers and specific areas	€12,957	$14,123	104.5	184,203	€5,000	$5,450	0.4
	Total	**€80,111**	**$87,321**	**376**	**967,007**	**€35,400**	**$38,586**	**0.4**

In the case of Kerkrade savings of US$87k were identified with an estimated implementation cost of just under US$39k, resulting in a very attractive payback of less than 5 months, many of the proposed projects were successfully implemented during 2016 and 2017.

An executive summary of the financial opportunity for all pilot sites is shown in Table 6-2. The table uses the macro data from the pilot sites and extrapolates to the global network to underline the opportunity that lies in GEMS audit implementation (either partially or fully). Implementation of only 1/3 of the potential measures can result in significant energy savings (US$1.7M p.a.) and an associated 5% CO_2 reduction, with full implementation leading to 15% CO_2 reduction. The savings identified in the pilot audit have an average of 1-year payback which is very attractive and indicates that good opportunities are available in the network.

Table 6-2. BSC GEMS pilot - Audit report extract (2015), executive summary of finding

[BSC GEMS Audit]

Site / City	Est. Annual Savings ($k)	Est. Annual Savings T CO_2	Est. Annual Savings [MWh]	Est. Cost ($k)	Payback Period [Years]
Clonmel	142	520	1124	190	1.3
Cork	182	738	2112	82	0.4
Galway	743	2,671	7,804	1,020	1.4
Kerkrade	87	376	967	38	0.4
Total	1,154	4,305	12,007	1,330	1

Total for European Sites				
	MWh	86,358	~ 25% of Total Network	370
	T CO_2	25,011	~ 20% of Total Network	118,327

Extrapolated for Network (i.e. x4)	($k)	T CO_2	[MWh]	($k)	[MWh]	T CO_2
Full IMPLEMENTATION	4,617	17,220	48,028	5,320	13%	15%
1 / 3 IMPLEMENTATION	1,539	5,740	16,009	1,773	4%	5%
2 / 3 IMPLEMENTATION	3,078	11,480	32,019	3,547	9%	10%

There were many very valuable lessons learnt during the pilot implementation that helped shape the subsequent development of the GEMS methodology. Most significantly the pilot delivered its main objective and proved the catalyst for the full deployment of GEMS in the BSC network. The scale (> US$1M p.a.) and variety of opportunities (both EEMs and procedural optimization) uncovered by the pilot, many with attractive (<2 year) payback periods, highlighted the need for a GEMS audit in all sites.

The pilot study provided the following further benefits:

- The GEMS pilot process was central to invoking the discussion and subsequent strategy around GEMS carbon reduction targets both within the BSC Global energy team and with the top management. Previously, BSC had focused on a 'projects based' approach driven by financial fundamentals with the resultant CO_2 reduction viewed as a nice bonus. The pilot underlined the need for a DSF supported by a MCDA that catered for financial and CSR concerns. It brought to the surface a much-needed debate on CSR and how energy efficiency can contribute to BSC core business.

- By stepping through the process, the full magnitude of the funding that would be governed by the GEMS was realised. Ensuring top management understanding of the scale of capital and the potential impact the associated EEMs can have on operational running costs was fundamental to getting support for full GEMS deployment.

- It facilitated a number of sites (within Europe) to come together and share best practice. They realised they were working on common problems in a silo approach leading to inefficiencies e.g. ISO50001 implementation or EEMs. Transfer of information both technical and procedural was addressed. This outcome was shared with the overall network via the global communication forum and became a corner stone for the subsequent development of the GEMS 'Shared Learning & Dissemination' pillar.

- It allowed a benchmarking exercise between the three manufacturing sites within the same geography, in this case Ireland. The constants within the Irish study are climate and economics. The facilities are all ISO 14644-1 Class 8 in operation, this enabled a 'soft start'. The variables include (but not limited to) products manufactured and building profile. This proved a good starting point for the development of the 'Site Characterisation' pillar.

- The pilot commenced BSC's journey away from a 'projects-based' EnMs approach towards a 'systematic approach' and led to a detailed review of recognised EnMs such as ISO50001, SEP and Energy Star.

- Finally, and most significantly, it was through the pilot 'energy audits' (ASHRAE level 2) that the bespoke 'GEMS Audit' approach and the associated '*site level KPI energy performance framework'* was developed. This will be further evaluated in section 6.2.3.1.

On the negative side many of the opportunities identified by the audits in 2015 were not acted upon despite the attractive business case, further highlighting the need for a site and global EnMs to ensure a cycle of continuous improvement through management support and review. The longer that period extends the less likely it is for implementation as other external factors can alter the initial business case.

6.2.2 Positive Energy: The People Factor

As outlined in Chapter 1, current best practice approach to global energy management suggests a silo approach (site to site and corporate to site), where communication between sites is rare. The GEMS approach is innovative due to the structure of the management forum which enables an open communication flow between the sites and global and from site to site. The approach also critically has an embedded feedback loop which further fosters efficiencies through shared learning's between sites, thus ensuring the 'collective effort is greater than the sum of the parts'. The thesis scope focused on the key deliverables required to close the knowledge gaps as identified in the literature review. The global energy team foundation and the 'shared learning and dissemination pillar' were not deemed as scientifically significant or critical as the other gaps identified. Through the implementation of GEMS, however, a set of communication tools have evolved that enable decision making within and across industrial stakeholders regarding EEM investments. These will be reviewed in the subsequent sections. It is an unexpected output that resulted from the joint academic and industrial partnership that is GEMS. It reflects the significant industrial knowledge, expertise and resources combined with an academic approach. Future research work should map the approach according on both a scientific and industrial basis (see 7.4 Future work).

This section reflects on the human factors associated with the implementation of an enterprise wide program and how it is 'people' that determine its success. In BSC, strong corporate leadership was key to the success of GEMS. It was individuals within the global energy team that ensured top executive management understanding of the business case and its alignment to the company vision. This was critical to success. The Parthenon structure itself proved a key tool or model to act as the human interface. It covers a multitude of complex variables, yet it is easy to follow, both to an energy professional or a layperson. The Parthenon enabled the foundations to link to the DSF via the pillars and ultimately deliver the desired vision. Key strategies such as the GEMS Audits, the EM^3 and C^3 all contributed to making GEMS part of the day to day culture on BSC, transforming energy management from a 'project only' approach to a 'systematic' approach. The foundation and pillar predominately 'customer facing' are the 'Global Energy Team & Communication forum' and the 'Shared Learnings & Dissemination' respectively, see Figure 6-5 below.

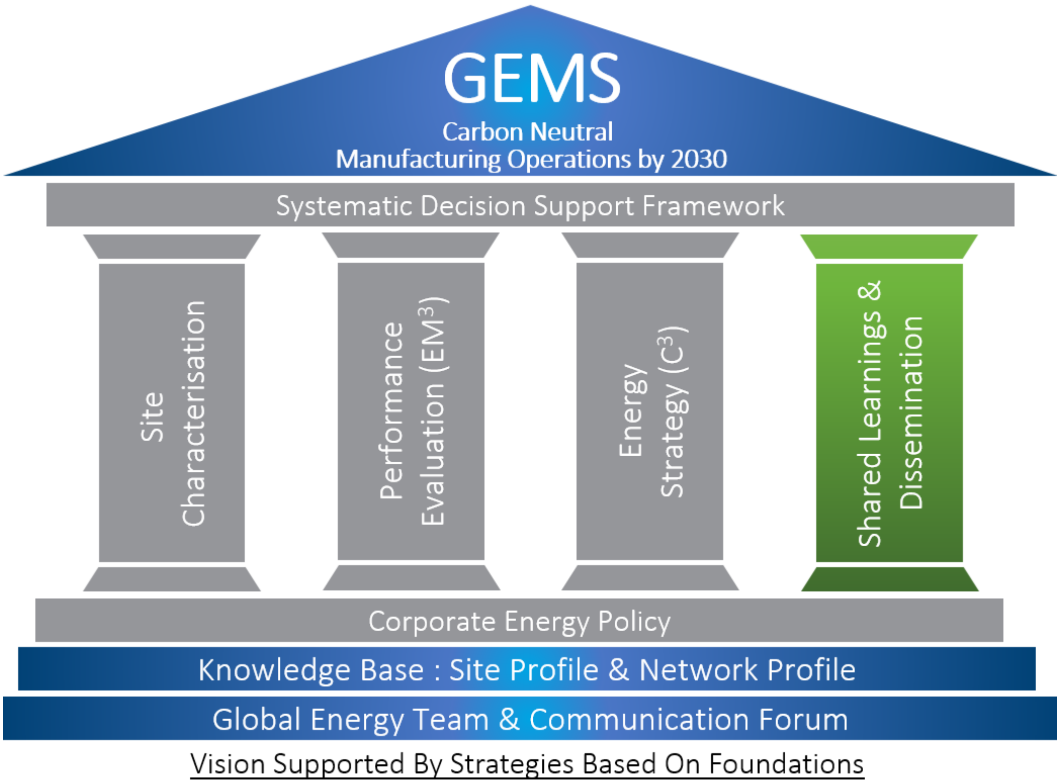


Figure 6-5. GEMS Parthenon – customer facing elements

6.2.2.1 Global Facilities Utility Management

At its very foundation is the forum to bring the people together, in BSC the 'GFUM' (Global Facilities Utility Management), is the name given to the global energy team and associated communication forum. It comprises a 'global energy manager' (GEM), 'primary' owners and 'sponsors' as outlined in Chapter 2. The GEM role became a full-time position in 2018, a direct result of the increased commitment BSC has made to carbon neutrality in 2017. Each month a one-hour meeting is held via web-conference. The GEM sets the agenda, chairs the meeting and issues the subsequent meeting minutes. A 'Share-Point' site is established as an effective platform to share and archive relevant information.

During the GEMS implementation, each month a topic aligned to the GEMS Vision was presented under the 'Meaningful innovation' heading. The other fundamental agenda item was 'Shared Learnings'. A simple but very effective approach taken was to create a rota for each site in the network to present their site profile and energy initiatives (Figure 6-6). It was also decided that each 'region' would present in sequence to further highlight any potential best practices with regional significance. By the end of 2017, all the individual sites had presented at the GFUM and the database of information (both qualitative and quantitative) proved a valuable input into the GEMS pillars as it allowed key information to be registered ahead of the GEMS audit deployment. Thus closing some of the gaps identified in the literature review with regard to existing ‘silo’ approaches.

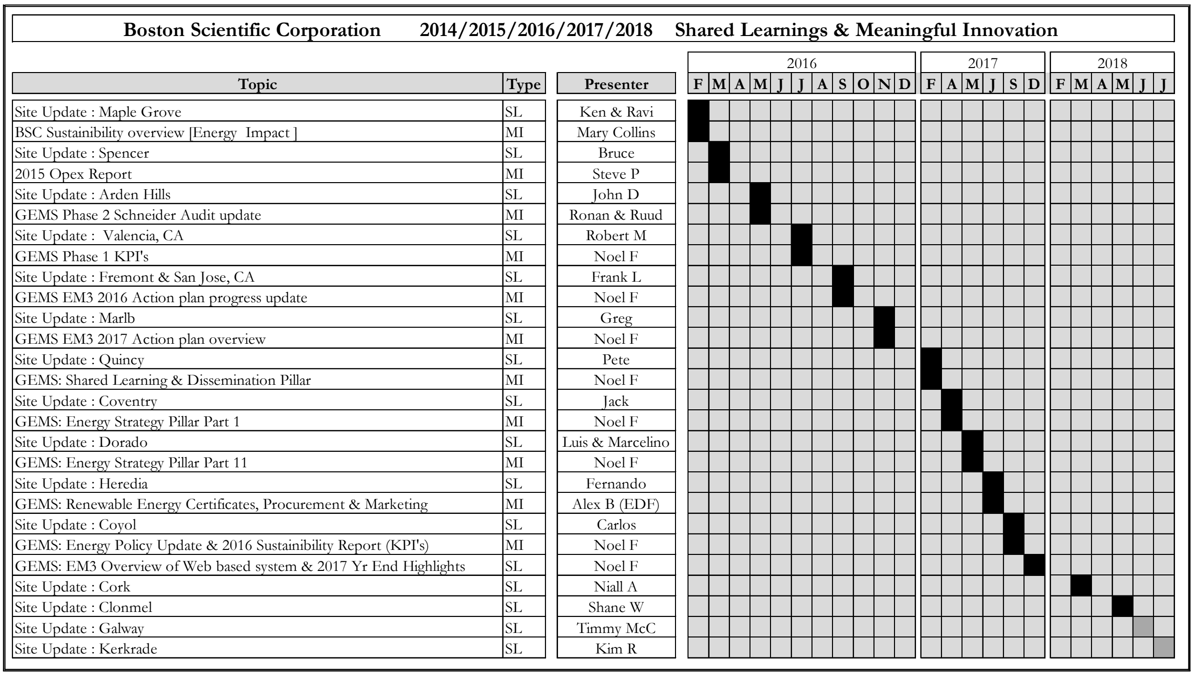


Figure 6-6. BSC GFUM – presentations rota example 2016-2018

In 2018 BSC officially opened a new manufacturing facility in Malaysia. The potential of the GFUM and shared learnings was evident in 2016, when all sites completed and shared with the Malaysia design team a list containing the top five energy initiatives completed on their site in the past five years. The initiative was call the *‘Top 5 of 5’*. While many were not feasible due to economics and local conditions it ensured a robust design review on a new BSC facility.

The deployment of this key foundation required a considerable effort in BSC and it took several months to gain the momentum required to get the forum functional. BSC had the advantage that a GFUM council had been in place for a number of years in the past and this legacy improved its successful re-launch. It is critical to scope the forum to ensure that the meeting logistics are completed centrally by the global energy leader and the work load from the sites is kept to a minimum. The role of ‘primary owner’ is a ‘part-time’ job with no site having a dedicated full-time position. This further underlines the importance of having a GEM and ‘pooling’ the efforts from the network to ensure maximum reward for minimum efforts.

Without the GFUM in place, the subsequent foundation step 'Knowledge base: Site and network profile*'* and its associated deliverables such as *'cost code alignment'* could not have been successfully completed. Cost code alignment was critical to GEMS success in BSC, as it ensured an 'apples to apples' comparison on energy spend across the network. In BSC, the central platform to track key energy parameters such as electricity & gas consumption is an enterprise system provided by Schneider Electric. All site's monthly invoices are pulled into a central system; this allows a platform for analysis and dissemination. It is worth noting that all the main network sites in BSC were already ISO9001 & ISO140001 certified, ensuring a strong starting point to data collection effort. The global 'wheel of spend' enables visibility and tracking of the controllable energy spend and is a key step to ensure energy management moves from the 'boiler house' to 'the boardroom'.

6.2.2.2 Global Collaboration and Communications

The goal of this pillar is to ensure the best methodologies, technological solutions and opportunities are proliferated throughout the network. In BSC the 4th Pillar 'Shared learning & Dissemination' (SL&D) serves as a '*global collaboration & communications'* forum. It delivers internal communications within the GFUM (global energy team) and to the broader employee base within the company itself. It also manages the external communications such as CDP, sustainability reporting and media. It enables technical, legal and financial information to be transposed into a format that is meaningful to all stakeholders, e.g. Policy and strategy; explaining the 'What', 'Why' & 'How' in a bespoke way to the audience being served (investors, board of directors, corporate leadership, employees and communities). As the 'face' of GEMS, it is 'always on' unlike the rest of the GEMS critical areas that have discrete functions and deliverables (e.g. GEMS Audits, EM^3 survey and action plans etc.).

The SL&D pillar also provides the conduit for information flow from the foundations to the DSF. The DSF had many 'hard' data sources such as the energy performance KPIs coupled with the project proposal and aligned to Policy & Strategy. It is via the SL&D pillar, however, that the 'mood' of the company and market place (shareholder sentiment) can be gauged by top management. This 'soft' information is key to ensuring the top executives are in touch with the needs of its employees and stakeholders.

Communications are typically internally and externally focused:

- *Internal* communications include companywide intranet updates on significant milestones ranging from high level items such as the 'Carbon Neutrality' announcement to site success stories on completion of an impactful EEM. In addition, BSC global facilities department has an annual newsletter. Finally, GEMS information can be displayed in the reception lobby of all major sites.

- *External* communications are managed between the GEM and the BSC communications department. They include but are not limited to press releases and the corporate sustainability report (section 6.3.3).

It is also worth documenting the significance of the *collaborations* that evolved during the development of GEMS.

- *Internally,* within BSC the engagement between the communications department and the GEMS team both through internal and external communications initiatives has paid major dividends in term of changing the existing mind sets on Carbon Neutrality and CSR. BSC's announcement on Carbon Neutrality in September 2017 clearly underlines this with pride and alignment on this ambitious goal exists right across the entire organisation. The collaborative relationship is now formed and the 'drum beat' of targeted communications continues to drive BSC to meeting its ambitious goal by 2030. This is in stark contrast to the original goal of 10% carbon emission reduction by 2020 (from 2015 baseline).

- *Externally,* the joint industrial academic partnership BSC and NUIG has evolved and matured with the development of GEMS. It was key to the successful deployment of GEMS in BSC and involved industrial engagement with IDA, SEAI, many other Irish and international companies such as ZuTec, Project Management Group (PMG) and Schneider. Academically, the SEEP conference proved an excellent platform to review and develop the GEMS methodology, with four separate conference papers presented at three separate conferences from 2015 to 2018, with two subsequent journal publications.

Through GEMS, NUIG and BSC also worked closely with the EDF Climate Corp in supporting their intern development program, which despite a short duration (approximately 12 weeks), their contribution was significant, especially in support of the EM^3 and energy training program deployment.

6.2.2.3 Corporate Energy Management training program;

In BSC, a central approach was devised for energy training to cater for the GFUM members. An independent review was undertaken in conjunction with the EDF Climate Corp fellow to assess what approach represented the best option, see Table 6-3.

Table 6-3. BSC Energy Training Review (2015)

No.	Course/ Institution Name	Fee	Format	Content	Comments
1	BOMI Intl. Independent Institute for Property & Facilities Mgmt. Education	$1300 per course	Class room and online options available	Boilers, Building Design & Maintenance, Facilities Mgmt., Energy Mgmt., Facilities Planning & Project Mgmt., etc.	•Travel & logistics are expensive and inconvenient
2	Chartered Institution of Building Services Engineers (CIBSE)	$500 per course	Class room - One full day for each course	Energy Strategy, Lighting & Energy Efficiency, Energy Surveys, Implementing EMS, Energy Monitoring, etc.	•None of them are globally recognized
3	Building Operator Certification	$1695	74 hours - 56 hours class room based; 18 hours online	Energy Efficiency in HVAC systems, Environmental quality, Measuring & Benchmarking energy performance, etc.	•Fee is extremely high
4	Natural Resources Canada - Clean Energy Project Analysis Software	Free	Software and Online	Clean energy project analysis, heating/cooling, power, cogeneration, clean energy policy toolkit, etc.	•Courses geared towards using their own tools
5	ENERGY STAR - Environmental Protection Agency (EPA) Program	Free	Online	Designing to earn ENERGY STAR, Using & reporting on portfolio manager, Sustainable buildings checklist, etc.	•Software and tools complex to use and irrelevant for BSC
6	Association of Energy Engineers - Certified Energy Manager (CEM)	$1995 for 5-day training $400 exam + certificate	Class room based	Wide range of topics with prime focus on Energy audits	•Expensive •Training travel, date and timings inconvenient
7	Institute of Energy Professionals - Schneider Electric Energy University	$400 for certificate (Free course content)	Online	Energy Efficiency Fundamentals, Energy Audits, Energy Rate Structures, Financial Analysis of Energy Efficiency Projects, Strategic Energy Planning, Cogeneration, HVAC Systems, Fan Systems, etc.	**Recommended Solution**

The 'Institute of Energy Professionals - Schneider Electric Energy University' partnership offered Professional Energy Manager (PEM) Certification. Through the GFUM, using a survey of all primary and secondary owners a Level 1 and Level 2 course content was created.

- Level 1: Basic Energy Management courses, duration 3-4 hours. Target Audience is all GFUM members.
- Level 2: Advanced Energy Management courses, duration 10-12 hours of webinars, Level 1 is a pre-requisite. Target Audience is all GFUM primary owners.

Modules in Level 1:

Energy Efficiency Fundamentals, Energy Audits, Energy Rate Structures I: Concepts and Unit Pricing, Energy Rate Structures II: Understanding Your Bill, Financial Analysis of Energy, Efficiency Projects I, Strategic Energy Planning.

Modules in Level 2:

Active Energy Efficiency Using Speed Control, Boiler Types and Opportunities for Energy Efficiency, Building Controls I: An Introduction to Building Controls, Combined Heat and Power, Commissioning for Energy Efficiency, Compressed Air Systems I: An Introduction, Demand Response and Smart Grid, Distributed Generation, Electrical Concepts, Energy Procurement I: Options in Regulated and Deregulated Markets, Fan Systems I: Introduction to Fan Performance, Financial Analysis of Energy Efficiency Projects II, HVAC Systems I: Introduction to HVAC Systems, HVAC Systems II: All-Air Systems and Temperature Control, HVAC Systems III: Air-and-Water and All-Water Systems, Industrial Insulation I: Materials and Systems, Lighting I: Lighting Your Way, Maintenance and Best Practices for Energy Efficiency Facilities, Motors: A Performance Opportunity Roadmap, Pumping Systems I: Pump Types and Performance, Steam Systems I: Advantages and Basics of Steam, Waste Heat Recovery.

The GFUM member logs into the system via Resource Advisor using an individual user name and password and then tags the BSC bespoke courses via a unique identifier. The 'Schneider University' tracks the progress and awards a certification upon completion. The completion is also tracked on the BSC e-learning system.

Once the required courses are successfully completed for the various levels it is recorded on the Schneider University system and a certificate is issued. This certificate is subsequently used to get accreditation from the BSC internal training system call *e-learning*.

6.2.3 BSC application – Closing the Gaps!

6.2.3.1 What sets the GEMS framework apart from existing approaches?

Firstly, GEMS is not in competition with existing site based EnMS, in fact the opposite is the case. GEMS complements site based EnMS and offers a framework to bring all the individual site EnMS into systematic and structured Global EnMS to serve the needs of a global energy management team in MMO. The more mature the individual site EnMS are the easier it is to populate the GEMS framework. However, GEMS will cater for all sites simultaneously, regardless of maturity level. The variance in the network creates opportunity at a corporate level that can be beneficial for GEMS via the 'Shared learning and dissemination' pillar by leaning on the stronger sites success to bring all sites to a minimum maturity level with minimum input of resources.

Secondly, as existing EnMS are site focused, a clear gap exists in current approaches available to support MMO. The GEMS framework closes this gap as demonstrated in BSC. Section 6.3 further underlines its successful application in BSC.

Finally, GEMS implementation is a journey, the framework will guide the organisation through the fundamental steps required along the way; however, success will be determined by the support and mindset of top management to deliver on the vision outlined in the GEMS Policy. GEMS allows the global energy manager to get alignment and support from the very top of the organisation. GEMS does this by presenting a clear and inclusive business case to top management to get initial support and ensuring that momentum is sustained throughout the journey via the Parthenon structure. Ultimately engraining GEMS into the BSE culture.

The following sections will take a closer look at the BSC application with respect to the key deliverables identified to support the overall GEMS framework, namely;

- A novel approach to benchmarking for MMO, catering for both quantitative (energy consumption) and qualitative (maturity model) characteristics.
- A policy supported by energy strategy.
- A decision support framework.

6.2.3.2 Site Characterization & Performance Evaluation

Chapter 2 covers in detail the *Quantitative* and *Qualitative* aspects associated with *Site Characterisation* to support *baselining* (section 2.4.2.1) and *Performance Evaluation* to support *benchmarking* (section 2.4.2.2) as part of the overall GEMS methodology, Figure 6-7.

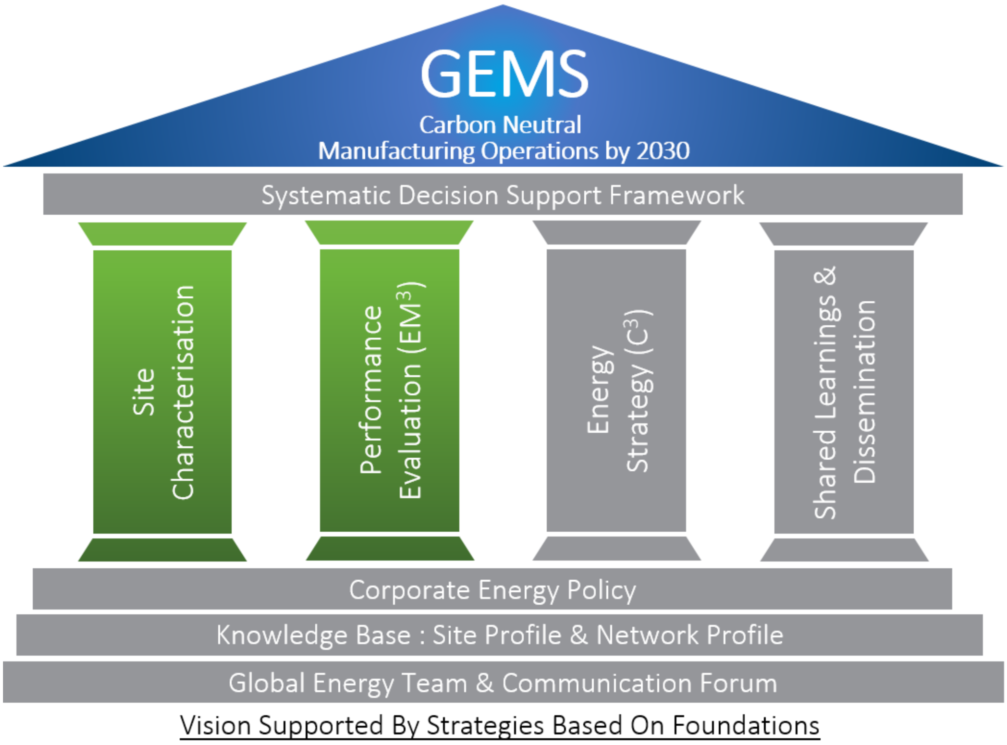


Figure 6-7. BSC GEMS Parthenon – Site Characterization & Performance Evaluation

In this section we will discuss how the implementation of the GEMS Audits in BSC led to the development of the *site level KPI energy performance framework* and how this serves the enterprise level KPI on *Energy usage*. The deployment of the *EM³* survey and how the model has evolved through its application in BSC will be reviewed. We will also review how the combination of the *Quantitative* KPI on energy usage with the *Qualitative* EM³ KPI score offers a highly insightful cross-site comparison that can be easily incorporated into the DSF to give the intended audience the 'pulse' of the site in question.

The ***GEMS audit report*** combines an 'Energy Audit' report (per EN162471-3) with a front-end interface (ideally the 'executive summary' or 'introduction' chapter) that acknowledges and addresses the unique challenges faced by MMO in relation to benchmarking KPIs at an enterprise and site level, Figure 6-8. A key deliverable of the GEMS audit is to establish the *quantitative* elements that provide the *'site characterization'* and *'performance evaluation'* pillars with the information required to support the *baselining* and *benchmarking* activities respectively.

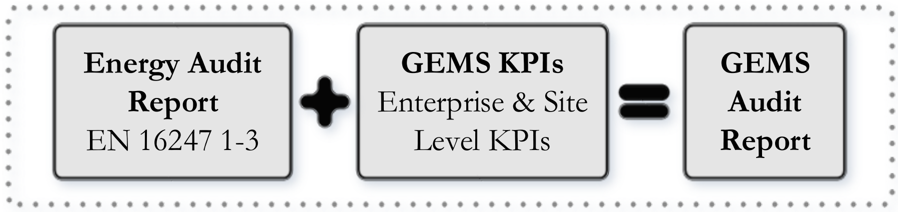


Figure 6-8. BSC GEMS Audit Report Structure

The objective of the GEMS Audit is to provide a consistent audit framework for all sites in the MMO and to enable site-to-site benchmarking via KPI's relevant to site performance. Key aspects include:

- Documenting site information that forms part of the 'Site Characterization' Pillar e.g. Energy costs and space utilization. In BSC's case it was recorded into 'resource advisor' via the data entry module.
- Understanding the key energy drivers via regression analysis and subsequently the significant energy users (SEU's), again forms part of the 'Site Characterization' pillar.
- Utilizing the *site level KPI energy performance framework* (Tier 1, 2, 3) consistently to support 'Performance Evaluation' pillar and completing a metering assessment gap analysis to support the suggested KPI framework.

The development of the *site level KPI energy performance framework* commenced as part of the initial GEMS pilot in BSC Europe in conjunction with Schneider. It resulted in a methodology for a KPI based energy performance (benchmarking) framework centred around total energy use (electricity and heat energy) and the sites SEU's. This framework was designed to allow BSC track the energy performance of each site individually (local level) and comparatively on a global basis (enterprise level). Individual KPI's make up a 3-tier energy performance framework starting at site-wide level before drilling down into more granular KPI measurements focussed on the sites SEU's. Table 6-4 summarises the proposed 3-Tier [*site level KPI energy performance framework*] from the initial pilot work at BSC.

Table 6-4. BSC GEMS Audit – Site Level KPI energy performance framework

		No. of KPI Metrics per Tier		
		Tier I	Tier II	Tier III
Site Wide (20)		3		17
SEU Categories	**HVAC / NON-HVAC**			
Mechanical Cooling (10)	HVAC		1	9
Compressed Air Generation (8)	NON-HVAC		1	7
Aiur Handling Units (AHU's) (6)	HVAC		1	5
Chilled Water Pumps (6)	HVAC		1	8
Heating Pumps (9)	HVAC		1	8
Heating Systems (2)	HVAC		1	1
Combined Heat & Power / Dumped Heat (4)	HVAC		1	2
Humidification (4)	HVAC		1	2
Production (3)	NON-HVAC		1	2
All HVAC Energy (1)			1	0
Total		**3**	**11**	**61**

The definitions of the three Tiers are covered in section 2.4.2.2.1. However, it is worth recapping in the context of the site level KPI energy performance framework vs the Enterprise level KPI framework.

- The Tier I KPIs consist of individual KPI's for electricity and gas plus a combination of both for total site energy usage. The combined KPI on total site energy usage is then used as the site's 'Enterprise level' KPI on energy usage that forms part of the six GEMS enterprise level KPI framework (section 6.3.1).
- Tier II KPIs are built around the SEU's and if correctly selected will offer a real-time insight into any shift in the Tier I KPI performance. Ideally the Tier II are common across all sites in the network to enable site-to-site level benchmarking on SEU's.
- Tier III KPIs are bespoke for the site and should act as an early warning system for any changes to Tier II.

The final sections of the GEMS Audit report provide a metering gap analysis to identify any gaps in existing sub-metering capability to bring each site up to the standard required to fully operate the *site level KPI energy performance framework*.

In the context of benchmarking the key outputs form the GEMS Audits were:

- A KPI framework to cater for 'individual site' and 'site to site' requirements associated with baselining & benchmarking.

- The GEMS pilot Audits in BSC focused heavily on establishing the significant energy users in each site and the associated driver for that use (e.g. Cleanroom HVAC controls, Climatic condition). HVAC energy proved dominant at production sites in Galway, Cork and Clonmel, with up to 75% of site energy usage consumed by HVAC equipment. Production energy usage was also influential although on a far smaller scale to HVAC, typically 10-20% of total site energy.
- Volume of air delivered presents an opportunity to normalise total site HVAC energy usage versus traditional methods of simply dividing by the site area. This Enterprise level KPI on energy usage is discussed in section 7.4(Future work) on ways to improve its relevance in terms of benchmarking by normalizing via the 'Energy Use Intensity', (see 2.5.2.1) Table 2-5 and Table 2-6.

The GEMS audit is currently being rolled out to all BSC sites. The GEMS audit report is based on an 'Energy Audit' report (per EN162471-3) but with a bespoke section on the GEMS *site level KPI energy performance framework* under 1.0 Executive Summary.

The **GEMS EM^3** incorporates both internal (site-to-site) and external (multi-site organisational level) benchmarking. External is against industrial peers on a global scale via the EDF Smart Energy Diagnostic Survey (EDF Climate Corps, 2015). BSC has a partnership with the EDF Climate Corp which involves a 12-week placement for an intern in BSC each Summer (typically at the HQ in Marlborough). The interns are highly qualified in energy management and typically are undertaking a business masters. One of the key deliverables from the placement is to conduct the ***EM^3 survey***. This has proven very successful on several levels. Firstly, it allows an independent (un-biased) evaluation of the individual sites each year from a subject matter expert. Secondly, and perhaps more significantly, it creates an environment that allows each primary owner to answer the survey in an open and candid manner. It helps the primary owner not to be tempted to over play their current progress, which could be the case if the survey was conducted by the GEM or other personnel from the BSC corporate management team. How the survey is performed has evolved each year, initially (2105) it was a very manual process conducted over a teleconference with the template shared ahead of time. The process now utilizes a database that can be completed on- line with the EDF intern on hand to assist the primary owner as needed during its completion. From a process perspective, the survey now requires the primary owner to include a comment if the answer shows a regression from the previous year or an advancement greater than one positional improvement, this ensures the changes are valid and documented. These data are readily available once the survey is complete and the scorecard reports are available shortly afterwards. This enables the primary owners to prepare their action plan for the following year in good time to allow the necessary resources to be allocated. The ability to automatically generate the site scorecard or action plans in pdf is available, an example is included in Appendix B. All the EM^3 information is available via a web application, see Figure 6-9, which is designed to display information based on the log in details, e.g. the GEM has full access but the primary owner can only access site specific information.

Figure 6-9. BSC EM^3: Web application

The EM^3 progress in BSC at a site and global level over the three years of the survey is evident from the EM^3 Enterprise Level KPI shown in Figure 6-23, section 6.3.1. Figure 6-10 shows the site breakdown in the key areas of PDCA over the 3 years. In BSC, the focus is now shifting from Plan and Do into Check and Act as the company moves from *developing* into *advancing*. The difference in score between internal scorecards (Figure 6-10) and external (Figure 6-23,) is due to a higher weighting on the 'plan' phase, which was an internal decision and deemed not appropriate for external reporting. It is worth noting that an individual site progress year upon year is far more significant than how it compares to its sister sites. GEMS strives to enable each site to be the best they can be. The EM^3 SWOT analysis facilitates the stronger sites to help the weaker ones.

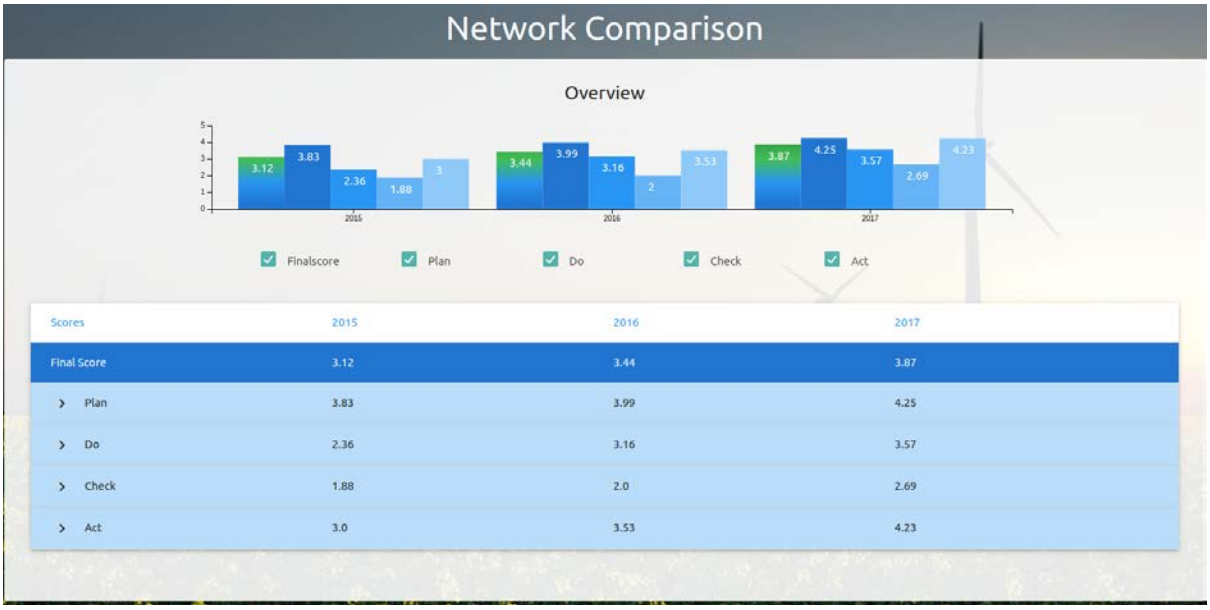


Figure 6-10. BSC EM³: Overall network PDCA performance - 2015 to 2017

The GEMS Audit and the EM³ provide KPIs, both of which are leading indicators in the 6 Enterprise level KPIs (section 6.3.1). It is in the combination of these two 'parent' KPIs, however, that a novel benchmarking tool is generated that covers both quantitative (energy consumption) and qualitative (maturity model) status of energy management for the site in question.

GEMS Enterprise benchmarking performance rating = [Energy Usage (Quantitative) | EM³ (Qualitative)]

In addition to offering a cross site comparison, the data points can be easily incorporated into the DSF to give the intended audience a perspective on the site proposing the investment.

6.2.3.3 Policy & Strategy

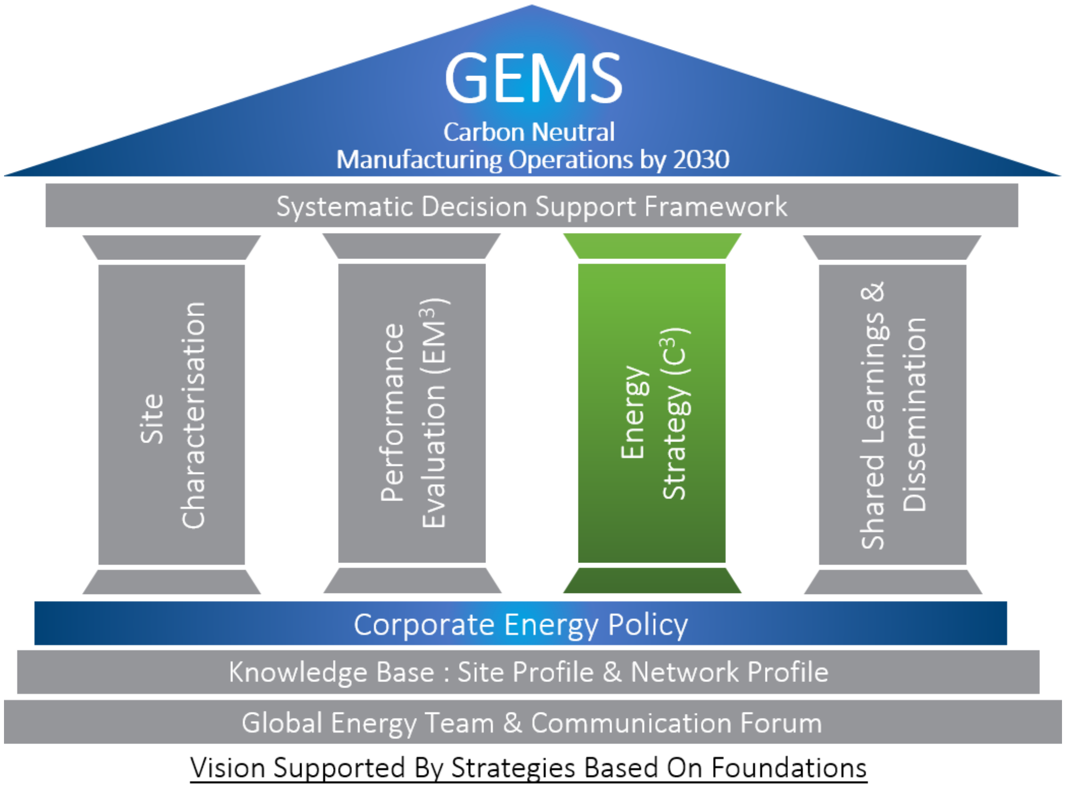


Figure 6-11. BSC GEMS Parthenon – Energy Policy & Strategy

While the Vision details *'What'* the desired achievement should be, the policy needs to articulate the motivations on *'Why'* to do it and the strategy should outline the steps on *'How'* to do it. This is well documented in Chapter 4 via the literature review, methodology and initial deployment into BSC. The following sections further reflect on the BSC implementation, Figure 6-11.

Policy: In section 6.2.1 the evolution of the GEMS Parthenon with respect to the pilot implementation and the policy development was discussed. It was during the pilot the importance of moving the policy from a pillar to a foundation became clear. In simple terms, without a strong policy as detailed in chapter 4 the pillars cannot be efficiently developed and built. The policy mandates the commitment and resources needed to meet the Vision.

During the last decade, Boston Scientific has met or exceeded established sustainability goals. The 1st set of goals (5yr) were developed in 2009 and updated in 2014 (5yr). During this period the EH&S policy document included an energy commitment:

"Optimizing energy and resource use with a goal of reducing greenhouse gas emissions;"

Through GEMS BSC now recognises the need to become a global leader in sustainability for non-energy intensive multi-national corporations. A dedicated 'Policy document' was deemed necessary and was implemented via the GEMS methodology. The BSC policy doc is shown in Figure 6-12.

Boston Scientific

Boston Scientific Global Energy Management System (GEMS) Policy

I Commit to Protecting
our Planet, People, Property and
all things Boston Scientific

Boston Scientific believes that leading environmental, health and safety performance contributes to our competitive strength and benefits our communities, customers, shareholders and employees as well as the environment. Boston Scientific was the first medical device company to commit to carbon neutral manufacturing; it is our goal to achieve it by 2030 through our GEMS Methodology.

To achieve this goal, the company will:

- Embed our Energy Policy into the organization's corporate sustainability plan;
- Align with the United Nation's framework Convention on Climate Change (UNFCCC) COP21 also known as the Paris Agreement on Climate Change
- Agree the boundary conditions on carbon neutrality conditions performance targets to be Scope 1 and Scope 2 emissions as defined by the Greenhouse Gas Protocol.
- Engage and commit top-management to the implementation of the vision;
- Commit to the development of an energy strategy with a roadmap;
- Establish performance improvement as a priority and align individual sites to it;
- Provide necessary resources;

This policy will be reviewed annually and updated as necessary to ensure its alignment with the corporate sustainability plan and global performance improvement efforts. It shall be made available within the organization and to certain interested parties.

Signed: ___________________________

Vice President Global Real Estate, Facilities & EHS

Date:

Figure 6-12. BSC GEMS Policy document

It was through the Policy document that top management commitment was established and documented. It is aligned to the overall company sustainability programme. BSC recognizes the need to ensure that the manufacture of their products does not have a negative impact on the environment. The goal was set for Carbon Neutrality on all Scope 1 and Scope 2 emission by

2030. The initial focus and strategy is based around the manufacturing and distribution plants which BSC typically own and can influence, hence the inclusion of *"carbon neutral manufacturing "*. This is in line with the approach taken by the majority of the MMO leaders in sustainability (as detailed in Table 4-8) and can be considered a best practice. The policy can easily be extended to commercial operations over time, which are typically leased facilities (over 100 locations). The Scope 3 emissions are not considered at this point but will be reviewed in line with best practice.

Strategy: *"The GEMS approach guides our work to deliver optimal network energy performance and informs decision-making on energy investment projects across our diverse global footprint. The system focuses on cutting energy use, converting to renewable energy sources instead of fossil fuels, and compensating with carbon offset projects where needed."* This statement was issued by BSC in its 2016 and 2017 sustainability report and outlines the C^3 methodology which underpins execution of the SMART targets. Figure 6-13 shows the BSC boundary conditions (2016 scope 1 and scope 2 CO_2 emissions) and SMART targets leading to the carbon neutrality 2030 Vision.

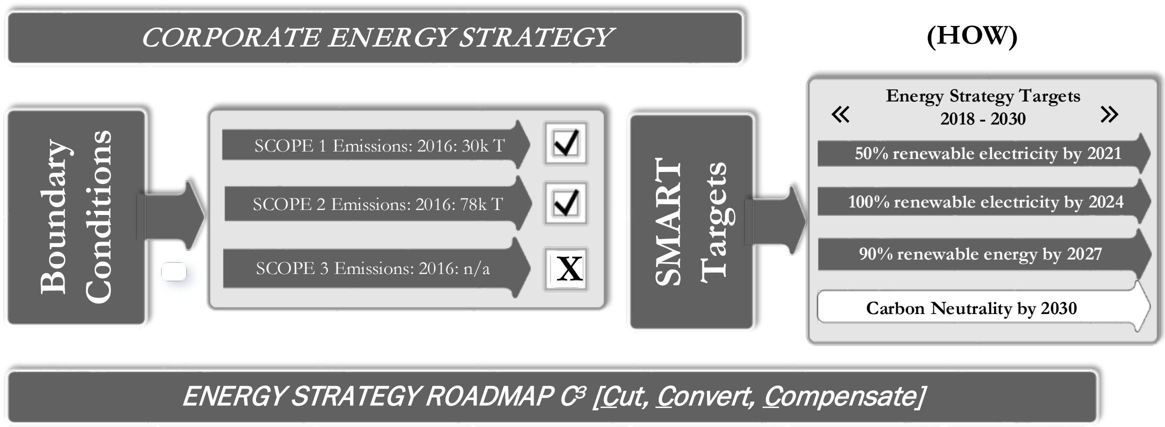


Figure 6-13. BSC GEMS Strategy – Boundary Conditions & SMART Targets

Using GEMS as the framework, the 'Energy Strategy' pillar navigates the roadmap to carbon neutrality using the C^3 approach. Examples of practical implementation are presented as follows:

- **Cut:** Dorado (Puerto Rico) replaced all its Chiller plant for high energy efficiency machines resulting in a 40% reduction in plant operations, Figure 6-14.

Figure 6-14. BSC GEMS Strategy – Cut: New high efficiency chiller plant in Dorado

- **Convert** to renewables: 2.5GWh of solar energy is generated on site in BSC via installations in Marlborough and Quincy, Massachusetts, Figure 6-15, with solar assessments underway in Dorado and Cost Rica. The Kerkrade facility (Netherlands) sources all electrical power from European wind farms via REC's, resulting in net zero carbon. In addition, BSC is currently reviewing all existing energy provider contracts to assess potential for supply from renewable sources.

Figure 6-15. BSC GEMS Strategy – Convert: Solar Projects in Marlborough (left) and Quincy (right), M.A.

- **Compensate** unavoidable CO_2: To date BSC has not implemented any measures.

BSC's approach will endeavour to exhaust the *Cut* and *Convert* opportunities before entering a major program for *Compensate*. This is based on the belief that a 'kWh' cut is the optimum solution both financially and environmentally, the next best option is to convert the kWh to a renewable source which can still yield savings along with the improved environmental impact. BSC's approach to *Convert* will be driven by the 100% renewable electricity target for 2024. On site and off site renewable capex energy projects are currently under investigation, in parallel with extensive reviews on PPA and VPPA contracts. Ideally BSC will preference on-site renewable generation. However, for most sites this will be limited by space constraints. This is followed by larger scale off-site projects. Finally, RECs will be reviewed as part of a PPA or VPPA partnership. A key factor for PPA/VPPA is ensuring 'additionality'. It is worth differentiating between a *REC* and *Offsets*, Figure 6-16. While a REC is one component under the '*Convert*' approach, offsets are used to *'Compensate'* for any remaining unavoidable CO_2.

Difference between REC & Offset		
	REC	Offset
What it conveys	Represents attributes from energy generation (e.g. tons CO_2/MWh)	Represents tons avoided emissions
Purpose	For suppliers and consumers to characterise their energy consumption	Qualify avoided or reduced emissions from a project
Market	Country-specific or regional	Global
Scope application	Only applicable to electricity emissions (Scope 2)	Can be used to offset emissions from any scope
Additionality	Not required but companies often aim to use certificates from new RE projects that they helped happen	Required

Figure 6-16. BSC GEMS- REC's vs Offsets.

Carbon offsets operate in a voluntary market where suppliers offer projects to the offset consumers (like BSC) at a market value. The offsets are independently verified by a 3rd party. Project examples can range from community water projects to reforestation, forest protection or renewable energy projects.

BSC funding will be made available for major infrastructure investments required to meet the 2030 targets. The MCDA will enable an un-biased prioritization. An interesting approach taken by BSC to create a business case for investment funds was to calculate the equivalent operational cost that would be required were BSC to take a soft approach to Carbon Neutrality and simply go straight to *Compensate* offsets, e.g. \$15/tonne x 108k Tonnes Co2 = \$1.62M p.a. x 12 years = \$19.4M (2018 – 2030). This 'Carbon fund' is then allocated to site projects with 3-6 yr ROI. Projects with an ROI <3yrs will follow a standard funding approach in competition with other departments.

It is in each individual site's interest to deliver on *Cut* and *Convert* in the short term as from 2024 they will be responsible for their portion of the BSC 'Carbon footprint', see Figure 6-17. Using a cost allocation model BSC will cross-charge the equivalent market value for the CO_2 emissions based on a *Compensate* program. This will help prepare BSC for the *Compensate* element of the C^3 strategy post 2030. In addition, the charge will be used to fund further *Cut* and *Convert* projects. With this approach the cost of *offsets* are avoided for a defined period (12 yrs) and instead the equivalent funds are used to invest into projects which in turn further reduce the CO_2 footprint ahead of the 2030 timeline. In section 6.3.2 CSR ranking will be discussed in detail, however it is worth noting that this approach yields the CSR benefits via the initial announcement and is a very simple approach to what is effectively 'internal carbon pricing' versus some of the models studied which require a breakdown of carbon usage and pricing for each department or user within the site structure e.g. Microsoft or Walt Disney.

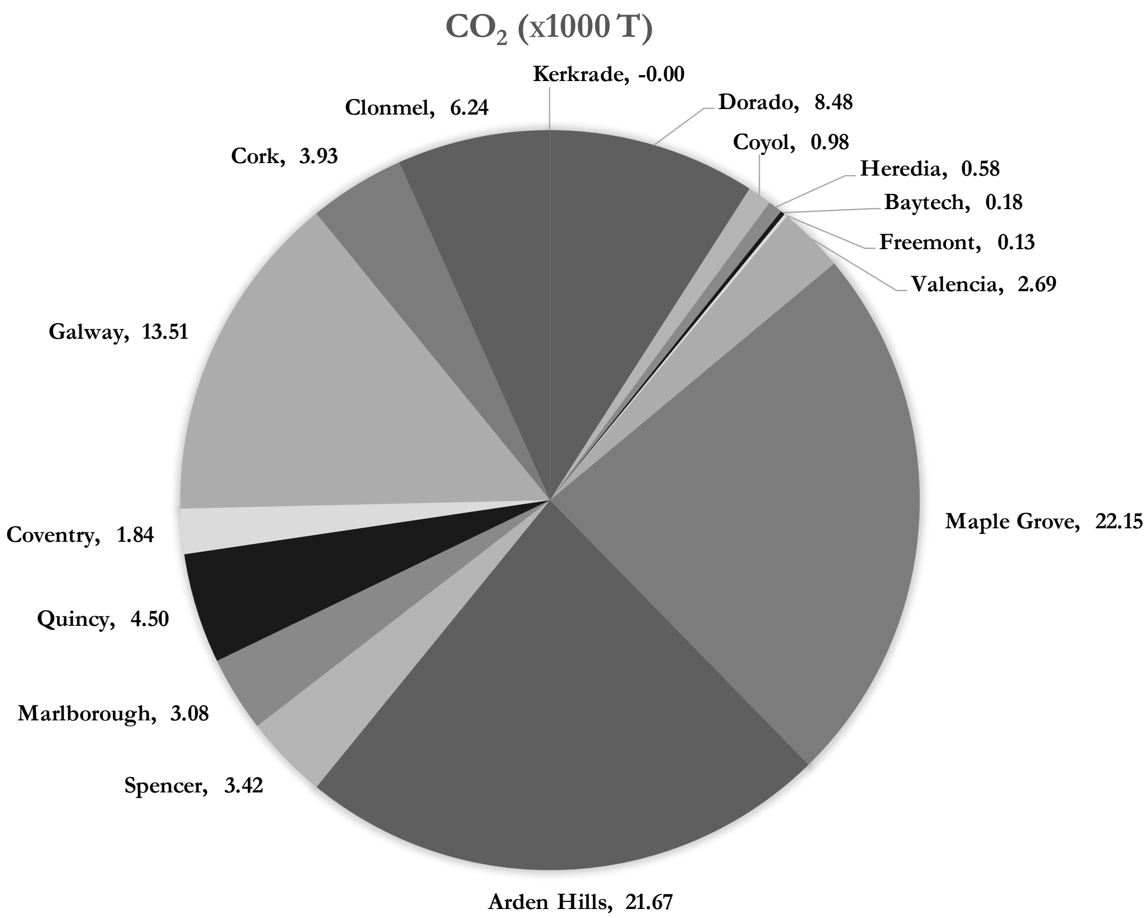


Figure 6-17. BSC GEMS- Site carbon footprint breakdown 2017

The policy and strategy approach outlined in Chapter 4 has been successfully deployed in BSC. The corporate energy strategy should define the targets, the roadmap and enablers required to meet the long-term goals that ultimately deliver the long-term vision committed by the 'corporate energy policy' foundation. As part of an overall GEM framework, the BSC implementation has demonstrated the positive impact that a logical, easy to understand policy and energy strategy can have on a major corporation as demonstrated by the increased funding for EEM. It contributes to closing the knowledge gap outlined in Chapter 2 regarding the lack of research on the characteristics of long-term energy policy and associated strategies in MMO.

6.2.3.4 Decision Support Framework

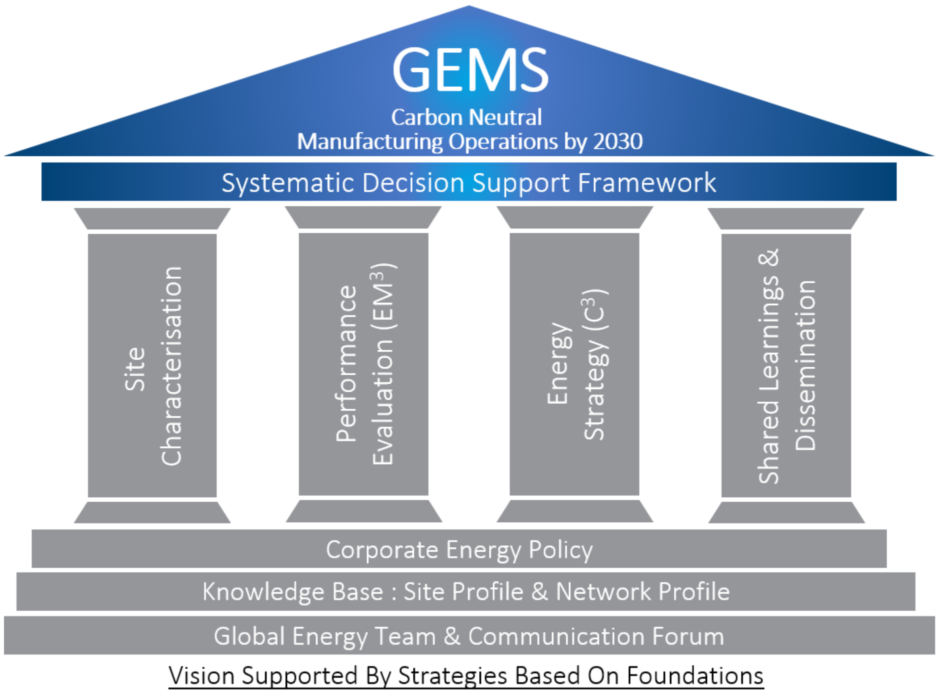


Figure 6-18. BSC GEMS Parthenon – DSF

In 2016, under the governance of GEMS DSF, BSC **invested $4.7M** into strategic energy infrastructure in its operations network [CHP (Cork), Tri Gen (Galway), Chillers (Dorado)], yielding **$2.25M p.a**. in long term Operational **saving**s & reducing CO_2 by 4% (**3,900 tCO_2-eq** removed from the environment). This represented an investment multiple times that of any previous years before GEMS. The DSF, see Figure 6-18, was the main driver in securing, selecting and managing such an investment. Chapter 5 covers the mechanics of the DSF and MCDM in detail. This section further reviews the BSC experience and the impact of the DSF:

- The DSF, through the various GEMS structures (GFUM, site characterization and shared learning), ensured the best projects in the network were under review. Primary owners understood the framework and could take site management through the process. It allowed each site to test several projects for suitability prior to elevating for funding at the corporate level. In addition, they could compare the proposed project against previously funded projects which gave a practical benchmark. This led to a pool of the best projects in each site being positioned for analysis via the MCDM/DSF. This (in itself) was a major confidence boost to top management in BSC when considering an investment. Human nature tends to be less committed to investments if the feeling is the best one is around the corner and not yet under review. The DSF avoids this situation.

- The DSF presents the information in a very simple and structured fashion. This is despite a broad range of project proposals in terms of financing (0-$3M, PPA or BSC Capital), scale (0-2MW), technologies (Solar, CHP, Ice banks, Chiller replacements) and locations (Europe, US, Latin America). The MCDM enables a condensed ranking and ensures all the key criteria (plus weightings), as agreed by management are considered. Most importantly it facilitates and encourages the primary owner to account for the non-energy benefits.
- The DSF considers not only the individual project parameters through the MCDM but also the broader context of the proposal site. This includes both quantitative (energy consumption) and qualitative (maturity model) status of energy management i.e. *[Energy Usage (Quantitative) | EM^3 (Qualitative)]*. Top management are privy to the future of the site development in terms of business planning and can then take this into consideration when selecting projects.
- Aligning to BSC core business and making CSR tangible with a solid C^3 roadmap further enhances the DSF.

Combining these elements ensured support from BSC top management for GEMS and the DSF approach, enabling significant funding allocations. In BSC, the DSF is spreadsheet based, this is sufficient in the short term but a future consideration is to develop a web based system. This would further facilitate the primary owners to utilize the DSF for project scenario planning. The MCDM weightings are critical to ensuring the correct parameters are applied to each project in question. This should be revised annually and documented. This is yet to be revisited in BSC since 2016. Changes to the MCDM weighting and how this will affect the historical benchmarking is not yet considered. While populating the MCDA, considering all the NEB's associated with the project proposals is critical to the implementation of a GEMS program. The

Tri Generation project in BSC Galway is an excellent case study and is outlined in Chapter 5. By considering the secondary 'non-energy benefits' the business case was considerably improved. In fact, the NEB's accounted for 43% of the overall savings when all aspects were monetized, see Figure 6-19. While the GEMS DSF methodology outlined in chapter 5 recognizes this, more work is needed to ensure it is not so subjective and heavily dependent on the knowledge and experience of the primary owner in question.

7-Year Savings Calculations in $k	2016	2017	2018	2019	2020	2021	2022	TOTAL
Primary energy savings	374	384	399	410	420	431	443	
CHW enchancements	32	33	34	34	35	36	37	
Primary energy savings	406	416	433	444	456	467	479	**$3,101**
Gas tariff reduction	64	66	68	69	70	72	73	
Demand Side Units	55	55	55	55	55	55	55	
Capacity Charges	21	21	21	21	21	21	21	
Maintenance cost reduction	27	27	27	27	27	27	27	
Business continuity savings	34	34	34	34	34	34	34	
Nat Gas Carbon Tax savings	46	46	46	46	46	46	46	
External capital grant		540						
Supplementary savings	247	788	250	252	253	255	256	**$2,302**

Figure 6-19. BSC GFUM 2017 Year End highlights – NEB's: Galway Tri-Generation business case outline

Finally, a further consideration for improvements will be how PPA proposals are presented and reviewed. Given the zero-capex requirement they will inevitably score favorably in the MCDM economic criteria, this does not however consider the long term legal and financial commitment required to partner with an external body if placing an asset such as a solar project on site. VPPA (Virtual power purchase agreements) need to be considered in the DSF as the C^3 approach matures.

The knowledge gap in DSF associated with current practice was outlined in chapter 2, research suggests that one of the most critical barriers to reducing the 'energy efficiency gap' is the current ad-hoc approaches to planning and implementing energy investments. *"If an MMO has $20M to invest in EEM where should it invest it?"* A structured, un-biased DSF, that considers non-energy benefits and enables top management to make optimal energy efficiency investments to meet carbon and energy reduction goals was required. The GEMS DSF helps close this gap considerably as demonstrated in the BSC application.

6.3 Macro Trends

This section shows the main highlights from the implementation of GEMS in BSC. Figure 6-20 shows the trends associated with energy consumption and carbon footprint from 2013 to 2017, while Figure 6-21 gives a deep dive on 2017 data broken down by regions and sites.

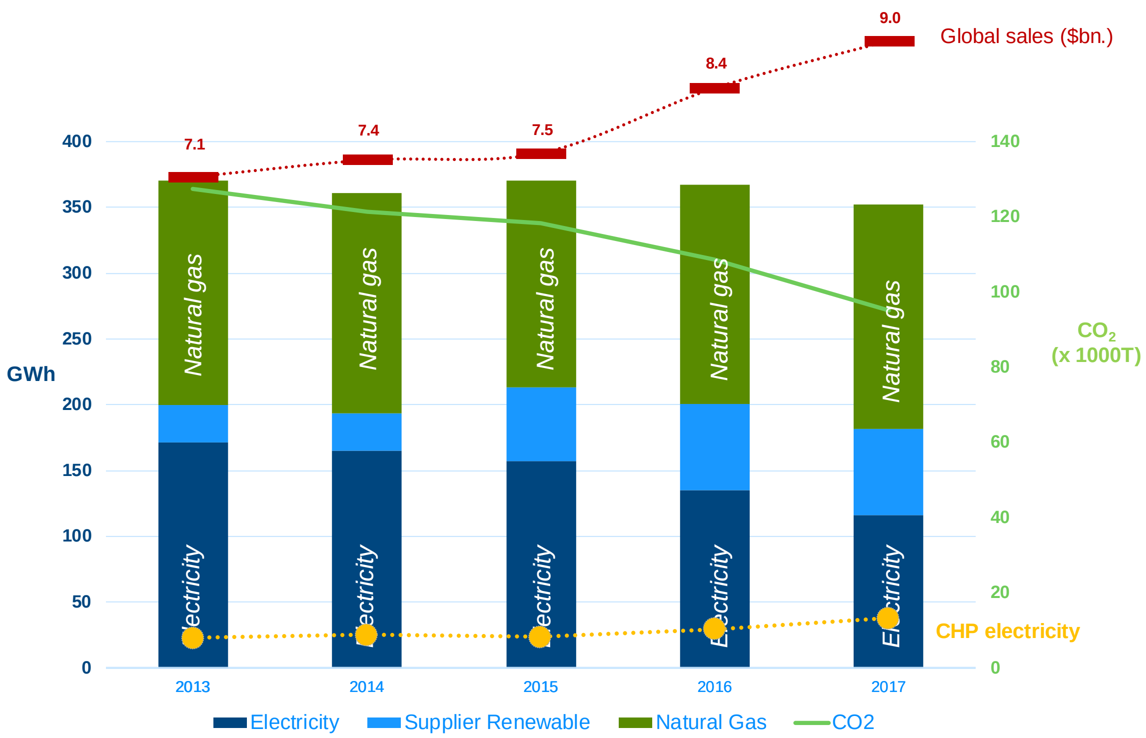
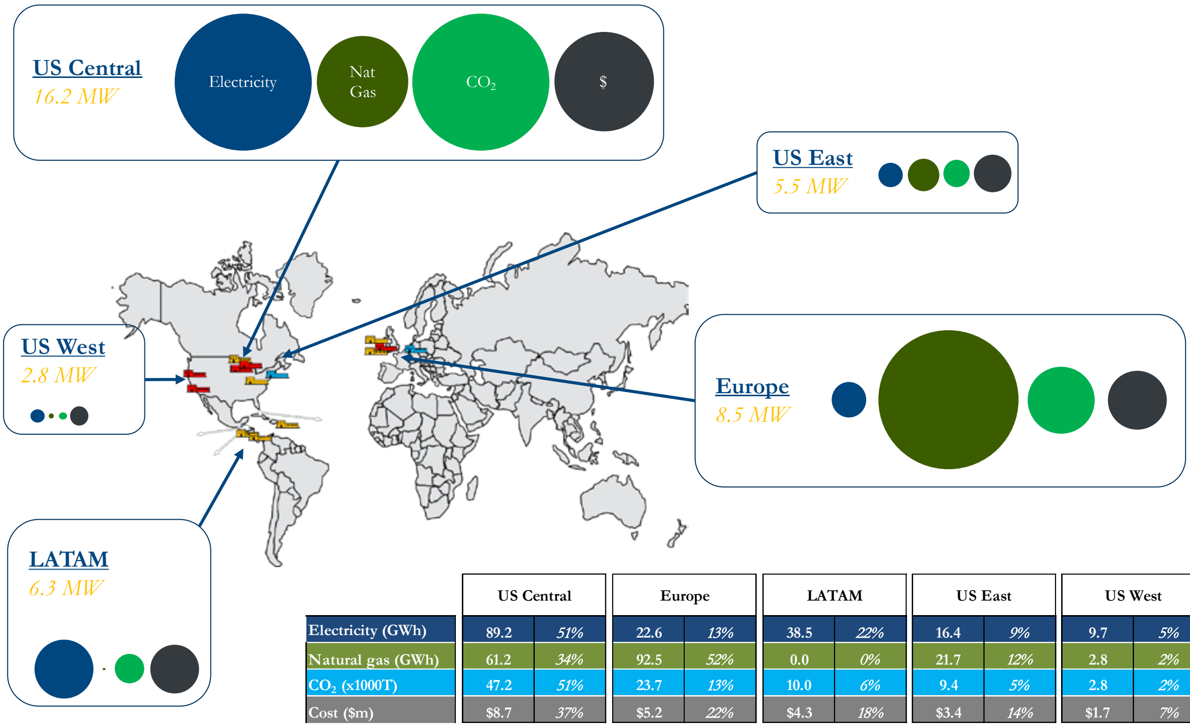


Figure 6-20. BSC GEMS Implementation - $C0_2$ & Energy: 2013 – 2017



	US Central		Europe		LATAM		US East		US West	
Electricity (GWh)	89.2	*51%*	22.6	*13%*	38.5	*22%*	16.4	*9%*	9.7	*5%*
Natural gas (GWh)	61.2	*34%*	92.5	*52%*	0.0	*0%*	21.7	*12%*	2.8	*2%*
CO_2 (x1000T)	47.2	*51%*	23.7	*13%*	10.0	*6%*	9.4	*5%*	2.8	*2%*
Cost ($m)	$8.7	*37%*	$5.2	*22%*	$4.3	*18%*	$3.4	*14%*	$1.7	*7%*

	US Central			Europe				LATAM			US East			US West		
	Maple Grove	Arden Hills	Spencer	Galway	Cork	Clonmel	Kerkrade	Dorado	Coyol	Heredia	Marlb.	Quincy	Coventry	Baytech	Freemont	Valencia
Use (GWh)	40.1	41.3	7.8	11.5	3.0	6.5	1.6	11.8	16.5	10.3	5.7	8.1	2.6	1.0	0.5	9.2
Demand (MW)	7.1	7.6	1.4	4.5	1.7	1.9	0.5	2.0	2.7	1.6	2.7	2.1	0.7	0.4	0.4	2.0
Natural Gas (GWh)	33.30	27.90	0.0	47.60	14.50	19.30	0.10	0.0	0.0	0.0	6.50	9.80	5.50	0.10	0.20	2.70
CO_2 (x1000T)	22.1	21.7	3.4	13.5	3.9	6.2	0.0	8.5	1.0	0.6	3.1	4.5	1.8	0.2	0.1	2.7
Cost ($m)	$4.0	$4.0	$0.7	$3.0	$0.7	$1.5	$0.0	$1.1	$2.1	$1.1	$1.5	$1.4	$0.5	$0.2	$0.3	$1.2

Figure 6-21. BSC GEMS Implementation - C02 & Energy: 2017 Breakdown

Since the deployment of GEMS in BSC the 'Macro' trends are compelling, with the energy consumption and CO_2 emissions showing consistent year on year improvements, from 2013 to 2017 energy consumption has dropped by 5.2% and CO_2 by 25.5%, against a backdrop of 25% revenue growth and acquisitions. The performance against the 6 KPI's, developed through the GEMS deployment in BSC, will be reviewed in more detail in the following section. The cycle of continuous improvement continues, during 2017 the GFUM identified energy saving projects with a combined value (run rate and one-off) of $4.5M (15M kWhrs / 11k tCO_2-eq), see Figure 6-22. This will ensure a pipeline of projects to impact on performance in 2018 and beyond.

Boston Scientific Corporation 2017 GFUM Highlights

Site / City	Total $ Annual savings	Total KW savings	Total CO2 Reductions (tCO2-eq).	Short Summary of Highlights	KPI's
Clonmel	$ 223,152	1,185,236	686	**LED** Lighting Upgrades, AHU 11 Hudmidifiers Upgrade & CHP Upgraded with a newer engine.	3 / 6
Cork	$ 582,176	4,279,982	790	CHP Full year operation, Non production Lighting **LED** Upgrade, CE4A T5 Sensor Lighting , AHU-20 IE3 Motors, Upgrade on kitchen Equipment	3 / 6
Coventry, RI	$ 54,200	433,600	-	CHP, 75 kW of electric and 100% process hot water. Retrofit 100% **LED** site lighting. W/H ventilation deadband	
Coyol	$ 153,006	1,275	15	ISO 50001 IMPLEMENTATION- CERTIFICATION. **LED** substitution - PPA . AIR CONDITIONING REPLACEMENT AT DATA CENTER - Eliminate F12 units.HEAT RECOVER PHASE 2	5 / 6
Dorado, PR	$ 295,000	1,292,343	971	6 Electric Boilers (replaced for a 40 HP LPB Boiler)	2 / 6
Fre& SJ, CA	-	-	-	The Baytech Site in San Jose is presently being developed to consolidate operations in Fremont and other Bay Area facilities. This new site is designed to the most modern energy efficiency standards and building codes.	-
Galway	$ 974,350	639,400	1,005	Energy improvement grant supports ($570k), **LED** upgrades, Fresh air reduction, Controls upgrades	5 / 6
Heredia	$ 173,000	456,000	789	CERs **LED** Ligths VIP 62246 y 51646, Evaporcool system VIP 57210, Solar Water Heater VIP 57457, HAN 19 sustitution VIP 57792, Energy recovery dishwasher VIP 58177, Cooking Rational Oven full size VIP 68115	5 / 6
Maple Grove, MN	$ 71,000	816,323	586	Replaced all lights in Building 1 with **LED** lights, (VSD) Chiller 750 Tons & compressors in the MCT room, Installed two electric car charging stations in parking lot	4 / 6
Marlborough, MA	$ 452,057	1,082,310	2,581	VFD's, Fumehood Auto Sash, PV Generation, CCHP, CFLs with LED replacements, Evolve -ECM Motors & **LED** Lighting Upgrades	4 / 6
Quincy, MA	$ 760,000	1,000,000	500	Warehouse **LED** Retrofit (over 1,500 fluorescent fixtures swapped for LED). North Building sale reduced our footprint by ~475K SF (innefficient space)... QUI 2.0 construction -Maintaining LEED Silver	4 / 6
Arden Hills, MN	$ 623,310	2,041,000	1,518	Move East Project Rebate through Xcel Energy Consolidation Project ($507k). High efficiency boilers, **LED's**, Connected building 10 to run off of central plant hot and chilled water.	4 / 6
Spencer, IN	$ 37,100	315,187	235	Painted metal roof White , 2017 **LED** Light Fixture Conversions, Café LED Lighting Retrofit	2 / 6
Valencia, CA	$ 80,567	553,901	1,005	**LED** lighting upgrade & CAV to VAV box conversion.	
Kerkrade	$ 68,999	922,736	466	Purchase of Green Energy and Gas, LEED Certification: Silver Award , Lean and Green Awards, Schneider GEMS Audit action points, Energy reduction by integrating the Maastrict office in to Kerkrade	6 / 6
Malaysia	-	-	-	Opened in 2017. Lessons Lernt from 10yrs of GFUM incorporated. LEED Certification underway.	-
	$ 4,547,916	15,019,294	11,145	CN2030	

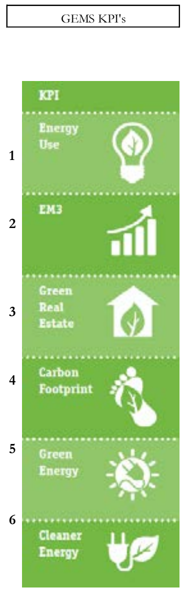


Figure 6-22. BSC GFUM 2017 Year End highlights – extract showing the network savings summary

6.3.1 Enterprise Level KPIs

The 'Energy Usage' and 'Energy maturity level' KPIs are discussed in depth in Chapter 1. Combined, they enabled a novel performance benchmarking from both a quantitative (kWh) and qualitative (EM^3) perspective. Tracking 'Carbon Footprint' was also deemed critical from the outset, especially given the overall 'Vision' with respect to carbon neutrality goals. Through the deployment of GEMS in BSC however, the need to track progress on other 'enterprise level' KPIs was also identified. The six KPIs that are used to drive continuous improvement in energy performance are described in Figure 6-23. These 'enterprise level' KPIs are built up from the performance of each site in the network.

KPI	DEFINITION	2017	2016	2015
Energy Use	Tracks the total energy Boston Scientific consumes annually to manufacture our products.	352M KILOWATT HOURS	367M kilowatt hours	370M kilowatt hours
EM3	An energy management maturity model to establish where in the "energy journey" each manufacturing site resides on a scale from one (minimal) to five (leading).	3.6 AVERAGE FOR ALL SITES	3.2	2.7
Green Real Estate	Percentage of Boston Scientific real estate that is independently certified for energy efficiency by industry-leading bodies such as LEED for design and Energy Star or ISO 50001 for building operations.	32%	28%	27%
Carbon Footprint	Total amount of scope one and scope two greenhouse gas emissions that are emitted into the atmosphere from manufacturing and distribution sites. Measured in tons of carbon equivalent (tCO2-eq).	95,000 TONS	108,000 tons	118,000 tons
Green Energy	Percentage of energy that is generated from renewable energy sources and technologies on-site or purchased from our suppliers.	19%	18%	15%
Cleaner Energy	Energy produced from fossil fuels, based on high-efficiency technologies such as combined heat and power (CHP) in comparison to conventional power generation (gas, oil or coal-fired power stations).	10%	7%	6%

Figure 6-23. BSC GEMS Enterprise level KPI's (Boston Scientific Corporation, 2017)

By tracking all 6 it ensured engagement and enhanced motivation from the various sites to focus on the implementing technological solutions and management systems to drive towards the ultimate vision of 'Carbon Neutrality'. The KPIs form an integral part of the 'Energy strategy' pillar (PDCA cycle), under 'Check': *Verify metrics and monitoring*. It is worth noting that the Green Energy, Cleaner Energy and Green Real Estate KPIs ultimately influence the performance of the other three 'parent' KPIs. Examples of implementation in BSC are shown below.

Green Energy: *A subset of renewable energy sources and technologies that provide the highest environmental benefit such as hydro, solar or wind.* Solar projects in Marlboro (2015) and Quincy (2015) account for 2.6GWh of renewable energy generated on site in BSC. In 2017 a PPA was agreed for a 3rd BSC solar installation, this time a 1.0MW installation in Dorado, Puerto Rico.

Cleaner Energy: *Energy produced from fossil fuels, but based on high-efficiency technologies such as combined heat and power (CHP) in comparison to conventional power generation (gas, oil or coal-fired power stations.* In 2017 the Galway site deployed it 2nd CHP, this time with Tri Generation technology, utilizing waste engine heat for 'heating' and 'cooling' the building, Figure 6-24. CHP technology is now deployed in Galway (2014: CHP & 2016: Tri Generation), Clonmel (2014), Marlboro (2014), Cork (2016) and Coventry (2016). This accounts for 26GWh of high efficiency Cleaner Energy.

Figure 6-24. Cleaner Energy – BSC Tri-Generations in Galway , Ireland

Green Real Estate: *Boston Scientific real estate that is independently certified for energy efficiency by industry-leading bodies such as LEED for design and Energy Star or ISO 50001 for building operations.* Examples include Quincy EPA Energy Star Certification (2014), LEED Gold in Marlborough Global HQ (2015), Figure 6-25 and ISO50001 certification in Costa Rica, (Heredia and Coyol) sites in 2017.

Figure 6-25. Green Real Estate – BSC Marlboro M.A, LEED Gold

6.3.2 CSR Reporting

All leading EnMs recognise the importance of management commitment, ISO50001 recommends not proceeding without it. Fundamental to the success of GEMS in BSC was ensuring management understood the impact of EEM on carbon emission reductions and in the broader context its knock-on impact on CSR. In conjunction with the internal and external communications / collaborations outlined in section 6.2.2.2 a number of areas merit further review as detailed in the following sections.

6.3.2.1 *BSC Sustainability reports*

Sustainability reports from 2016 and 2017 proved key to dissemination and understanding of the link between EEM and CSR. Key extracts are shown in Figure 6-26(2016) and Figure 6-27(2017) respectively. The 2017 BSC sustainability report was combined with the financial report, a first for BSC.

OUR PLANET

GEMS

GEMS is a joint academic and industrial global collaboration between the National University of Ireland, Galway, and Boston Scientific. Since 2013, we have invested in open-access research on energy management with a goal to develop a world-class energy management system focused on the needs of non-energy intensive multi-site industrial organizations.

G E M S

OUR GLOBAL ENERGY MANAGEMENT SYSTEM

At Boston Scientific, we use a global energy management system (GEMS) to help ensure we meet energy reduction and GHG targets. This GEMS approach guides our work to deliver optimal network energy performance and enable informed decision making on energy investment projects across our diverse global footprint.

GEMS, supported by our EHS policy, complements each manufacturing site's energy management efforts. The global energy team, which helps implement GEMS, is made up of representatives from each of our manufacturing sites.

GEMS focuses on the following areas:

- Site characterization: understanding site energy characteristics, creating a baseline and identifying energy efficiency opportunities
- Performance evaluation: delivering continuous improvement by reducing energy usage and benchmarking
- Energy strategy: developing processes for delivering on our energy targets
- Shared learning and dissemination: sharing best practices across our global manufacturing sites

Energy Strategy

Boston Scientific recognizes the need to ensure that the manufacturing of our products does not have a negative impact on our environment. We are developing a road map to carbon neutrality via GEMS that will detail initiatives, including cutting down the use of on-site and purchased energy, converting to renewable energy where possible and compensating for unavoidable carbon emissions. The performance of our energy strategy roadmap will be tracked by six key performance indicators (see page 7).

IN 2016

$5M

INVESTED

IN STRATEGIC ENERGY INFRASTRUCTURE

ACHIEVED

$2.26M

ANNUALLY IN LONG-TERM OPERATIONAL SAVINGS

REDUCED

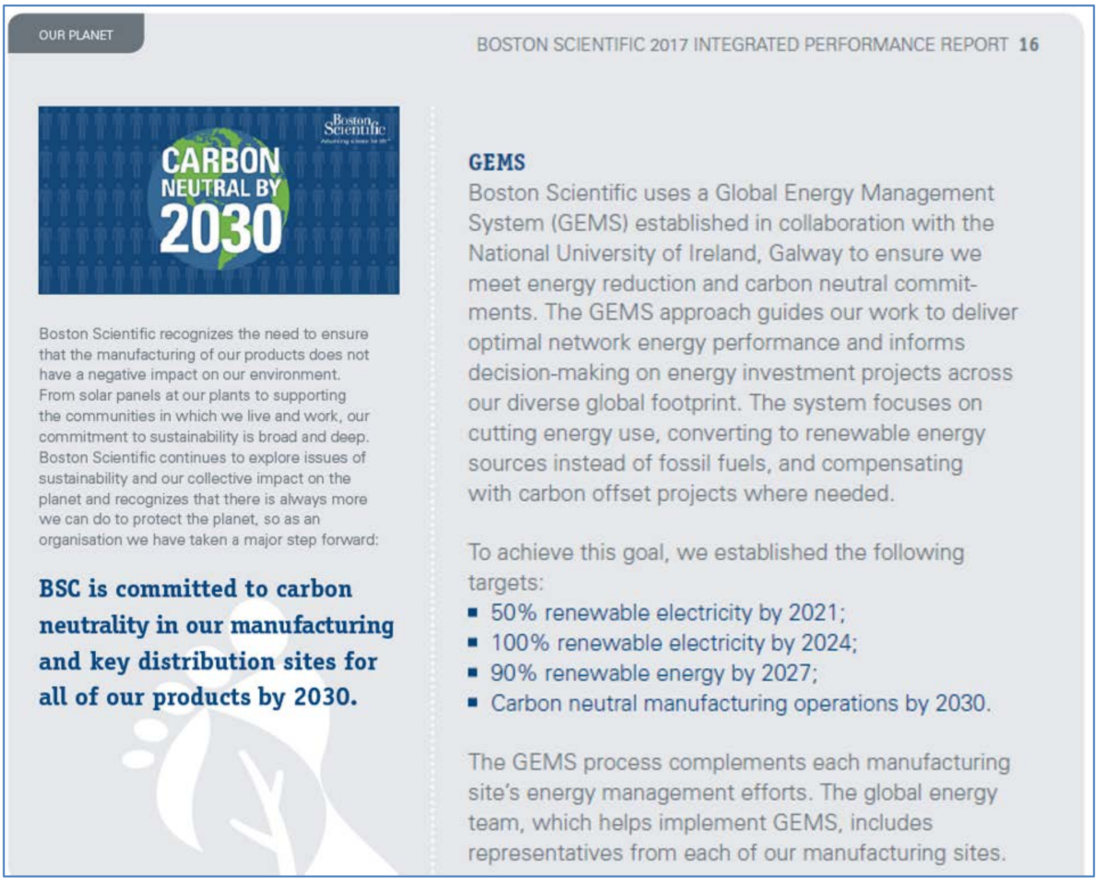
CO_2 EMISSIONS BY

9%

FROM 2015

2016 CORPORATE SUSTAINABILITY AND SOCIAL RESPONSIBILITY REPORT 6

Figure 6-26. BSC 2016 Corporate sustainability& social responsibility report – GEMS Extract



OUR PLANET

BOSTON SCIENTIFIC 2017 INTEGRATED PERFORMANCE REPORT **16**

Boston Scientific recognizes the need to ensure that the manufacturing of our products does not have a negative impact on our environment. From solar panels at our plants to supporting the communities in which we live and work, our commitment to sustainability is broad and deep. Boston Scientific continues to explore issues of sustainability and our collective impact on the planet and recognizes that there is always more we can do to protect the planet, so as an organisation we have taken a major step forward:

BSC is committed to carbon neutrality in our manufacturing and key distribution sites for all of our products by 2030.

GEMS

Boston Scientific uses a Global Energy Management System (GEMS) established in collaboration with the National University of Ireland, Galway to ensure we meet energy reduction and carbon neutral commitments. The GEMS approach guides our work to deliver optimal network energy performance and informs decision-making on energy investment projects across our diverse global footprint. The system focuses on cutting energy use, converting to renewable energy sources instead of fossil fuels, and compensating with carbon offset projects where needed.

To achieve this goal, we established the following targets:

- 50% renewable electricity by 2021;
- 100% renewable electricity by 2024;
- 90% renewable energy by 2027;
- Carbon neutral manufacturing operations by 2030.

The GEMS process complements each manufacturing site's energy management efforts. The global energy team, which helps implement GEMS, includes representatives from each of our manufacturing sites.

Figure 6-27. BSC 2017 Intergrated performance report – GEMS Extract

6.3.2.2 Climate week New York City September 2017 – BSC Carbon Neutrality commitment by 2030

In September 2017, Boston Scientific attended Climate Week, in New York City and announced its commitment to carbon neutrality by 2030. BSC joined hundreds of other businesses, non-profits, and government organizations to explore issues of sustainability and our collective impact on the planet.

6.3.2.3 Enhancing CSR ranking

In 2017 BSC engaged with CDP (formally the carbon disclosure project) to further its CSR profile and rankings. CDP have pioneered the world's only global natural carbon disclosure system, through which more than 4,500 companies (from more than 80 countries and 207 cities) report, manage and share vital environmental information.

- **What:** Annual environmental disclosure survey
- **Who:** Investors representing over $100 trillion in managed assets
- **Why:** CDP is the leading platform used by investors to access information on companies' environmental performance

- **Data:** GHG emissions, energy efficiency projects, climate-related risk assessment, environmental governance

It is incumbent on the Global Energy Manager to ensure the executive leadership are aware of the non-energy benefits associated with the CSR program. In the case of BSC there is now a strong 'pull' on CSR data and achievements from the sales and marketing teams that utilize it as part of their sales messaging.

6.3.3 Rewards and Recognitions

In line with its GEMS Vision to reach carbon neutrality by 2030, BSC has recognised the importance of receiving independent external rewards and recognitions to achieving this goal.

6.3.3.1 LEED

Leadership in Energy and Environmental Design (LEED) is an internationally recognized green building certification program, which supports the *'Green Real Estate Enterprise KPI'*. LEED certification was pursued by BSC prior to GEMS deployment. Boston Scientific global facilities include 11 LEED certifications covering over 250k m^2 of real estate. Under GEMS the following certifications were achieved; LEED Silver in Singapore (2015), LEED Gold in Beijing and Marlborough (2015) and most recently the Kerkrade facility attained LEED Silver under the office renovation category (2017). Plans are in place for LEED certification in its new manufacturing facility in Malaysia. Developing green facilities through environmentally responsible construction is a critical part of the BSC global sustainability plan.

6.3.3.2 Energy Star

In 2014, the Quincy site has earned the EPA's (Environmental Protection Agency) ENERGY STAR Certification. This was a first for BSC and the GEMS program. This achievement demonstrates the site's dedication to energy efficiency and sustainability. The certification signifies that the facility performs in the top 25 percent of similar facilities nationwide for energy efficiency and meets strict energy efficiency performance levels set by the EPA. On average, Energy Star Certified Facilities consume 35 percent less energy and contribute 35 percent fewer greenhouse gas emissions than their peers. This was a great win for BSC and the Quincy site in particular.

6.3.3.3 ISO50001 Certification

In Q4 2017, the final stage of the ISO 50001 external audit was completed in Coyol and Heredia with zero non-conformances and a recommendation for certification. This was a first in the BSC network. ISO50001 represents the highest award in Energy Management from an operations perspective and it aligns with the Green Real Estate Enterprise KPI.

6.3.3.4 Newsweek U.S. Green Rankings

The U.S. Green Rankings, one of the most globally recognized environmental performance assessments, assess the top 500 companies by revenue and rank their sustainability performance based on key performance indicators such as energy, carbon, water and waste productivity. Newsweek published its 2017 Green Rankings, naming BSC #16 of the 500 largest publicly traded companies in the U.S. BSC has moved up in the rankings from #21 in 2016 and #29 in 2015 as they continue to deliver on their commitment to corporate social responsibility via GEMS. The 2017 rankings were based on data published through December 31, 2016. See Table 6-5.

Table 6-5. Newsweek U.S Rankings – BSC

2014 #244	based on data published through December 31, 2013
2015 #29	based on data published through December 31, 2014
2016 #21	based on data published through December 31, 2015
2017 #16	based on data published through December 31, 2016

6.4 Summary of Results

Table 6-6 presents a summary of the results from the GEMS application in BSC. Prior to GEMS deployment in BSC there was no cohesive global energy management system.

Table 6-6. Summary of Industrial Impact

Key areas	Pre-GEMS deployment in BSC	Post GEMS Deployment in BSC
Communication	A global team, the GFUM, was started in 2007 but had disbanded by 2012.	Global Energy Team re-established with meeting cadence and agenda driven by Parthenon Vision. Centrally lead with defined membership roles and responsibilities. GEM role now a full-time position post Carbon Neutrality commitment.
Knowledge base	Some individual sites tracked energy usage and cost. No global visibility.	Enterprise system tracking and analysing usage and cost. Underpinned by cost code alignment. Clear visibility to global consumption and SEU's. Enables enterprise efforts to support C[3]

		through supplier agreements and on site / off site scaling for renewables.
Shared learnings and Dissemination	Limited and ad-hoc through informal site links (mainly driven by adjacency or common product mix). Individual sites had no visibility or exposure to corporate or global employee base. Developing, deploying and disseminating critical initiatives a major challenge and impractical (e.g. a global energy policy).	Defined and structured via global energy team and communication form. Enables technical, legal and financial information to be transposed into a format that is meaningful to all stakeholders Critical for both policy and strategy dissemination. In addition, formal links established with corporate communications team for both internal and external dissemination. Full visibility and exposure for individual sites to corporate and global employee base. GEMS as the main driver for climate change featured in the 2016 & 2017 BSC CSR reports. Strategic collaborations (academic and industrial) fostered. Formal Training approach in place.
Site Characterization & Performance evaluation.	Majority of sites lack a baseline. Benchmarking is non-existent, individual sites lack perspective on their own energy performance in relation to the network performance. Individual site assessment (where in existence) are solely based on quantitative system evaluation, without consideration of any qualitative attributes.	Through the GEMS Audit approach and EM^3 all sites now have a baseline (site characterization) from which to improve upon and the ability benchmark (performance evaluation) against peer sites and external database. Both site level and enterprise level KPI frameworks developed. *GEMS Enterprise benchmarking performance rating = [Energy Usage (Quantitative) | EM^3 (Qualitative)]* 2013 – 2017: • Energy usage: -5.2% • Carbon Footprint: -25.5% *2015-2017: • Energy usage: -5% • Carbon Footprint: -19% • EM^3 score: + 33% • Green Real Estate: + 5% • Green Energy: + 4% • Cleaner Energy: + 4% *Tracking system develop via GEMS and deployed in 2015.
Energy policy and strategy	No defined Energy Policy, a reference to energy usage did exist as part of the EH&S policy. No	A clear Vision detailing 'What' the desired achievement is (a top management point of view), a policy

	defined energy strategy either at a site or global level. Funding criteria based solely on direct financial return on investment criteria (e.g. payback period). Non-energy benefits (e.g. CSR, Sustainability and business continuity, productivity, etc.) are rarely considered, leading to a less favourably business case for EEM in comparison to manufacturing or process improvement projects. EM is not deemed 'core' to the business and EEM's are not linked to a greater company goal, thus not considered strategic.	document that articulates the motivations on 'Why' to do it and a strategy outlining the steps on 'How' to do it. Through C^3 BSC Commitments are: • 50% renewable electricity by 2021 (short term); • 100% renewable electricity by 2024 (medium term); • 90% renewable energy by 2027 (long term); • Carbon neutral manufacturing operations by 2030 (long term). EM is now 'Core' to the BSC business. EEM are now strategic. Increasingly BSC's sustainability program is requested by vendors and investors. GEMS is a key component. BSC now recognises the need to become a global leader in sustainability for non-energy intensive MMO and the financial benefits that will bring.
Investment decisions on EEM	Project based approach to EM and ad-hoc approach to EEM investment. Max EEM investment < $1M p.a. Lack of guidance tools to drive an energy reduction program or policy through investment in strategic initiatives from a multi-site perspective. No visibility to EEM cadence within the network at a corporate level. No structured approach for comparison of proposed EEM. No formal review process or pre-screening in place for EEM, same forum as all other company departments requesting funding.	Systematic approach to EM and DSF to support EEM Investment. 2016 EEM investment > $4.5M p.a The DSF enabled the site energy managers to assess potential projects prior to formal submission for funding. It ensured the key decision makers had visibility to all the potential EEM in the network, increasing investor confidence. Most significantly it demonstrated the power of 'levelling the playing field' against other core business investment by quantifying all the energy related and non-energy related benefits when presenting a business case. e.g. Trigeneration project in Galway.
Rewards and Recognitions	LEED certification was pursued by BSC prior to GEMS deployment	Under GEMS the following certifications were achieved; LEED Silver Singapore (2015), LEED Gold in Beijing and Marlborough (2015) and most recently the Kerkrade facility attained LEED Silver (2017).

		Plans are in place for LEED certification in a new manufacturing facility in Malaysia. BSC now has 11 LEED certifications (over 2.8 million ft2). Since the deployment of GEMS BSC has received to following independently certified awards for the first time: Energy Star: Quincy (2014); ISO50001: Coyol and Heredia (2017) Finally, 'Newsweek' recently published its 2017 U.S. Green Rankings, naming BSC #16 of the 500 largest publicly traded companies in the U.S. BSC has moved up in the rankings from #21 in 2016 and #29 in 2015 as we continue to deliver on our commitment to corporate social responsibility via GEMS. As a reference in 2014, BSC ranked #244 (based on data up to December 31, 2013). The U.S. Green Rankings, is one of the most globally recognized environmental performance assessments.
Company Vision	No overall company vision for carbon. Communicated goal to reduce carbon emissions by 10% bo 2020 from 2015 baseline.	Carbon Neutrality for all Manufacturing operations (Scope 1&2) by 2030.

The outputs clearly demonstrate the industrial validation of the GEMS academic approach. It shows the approach has worked in BSC and is recognised at a site and corporate level as well as externally.

Table 6-7 presents a summary of the key advancements to research for global energy management systems.

Table 6-7. Summary of Academic Contribution

Key areas	Pre-GEMS Research	Post GEMS Research
Global EnMS	Research indicated existing EnMS are site focused, a clear gap exists in current approaches available to support MMO.	Developed a novel systematic 'Global Energy Management System' (GEMS) to enable an MMO reach optimal energy efficiency performance and capital spend whilst meeting global energy and carbon emission reduction goals. GEMS is not in competition with existing site based EnMS, in fact the

		opposite is the case. GEMS complements site based EnMS and offers a framework to bring all the individual site EnMS into systematic and structured Global EnMS to serve the needs of a global energy management team in MMO. *Journal: Energy 151 (2018) 913-929*
EM3	Reviewed literature suggests maturity models are in their infancy in the energy management sector. In additional current literature lacks a KPI framework that caters for both the quantitative (energy consumption) and qualitative (maturity model) status of energy management for the site in question.	The EM^3 advanced existing site focused models and developed a novel approach to deliver qualitative metrics catering for individual site, multi-site and external peer requirements. The model enables a two-way communication from site to corporate through its common language. It gives visibility to the global team on optimal allocation of resources to improve the site and network scores. Finally, it allows evaluation of the non-technical aspects of EM required to ensure continuous improvement in an MMO. *Journal: Journal of Cleaner Production 167 (2017) 1232-1250*
Energy policy and strategy	Research on the characteristics of long-term energy policy and associated strategies in MMO was limited. Carbon and energy reduction goals face barriers (e.g. low capital availability), drivers (e.g. reduction of energy overhead) and decision-making factors that are influenced by policy and strategy. Other gaps exist in the quantification of non-energy benefits and the lack of step-by-step guidelines for policy formulation and associated supporting strategies.	This research contributed to closing the knowledge gap found in literature by delivering a set of minimum requirements that a non-energy intensive MMO should consider when developing an energy policy and supporting strategy. The strategy includes guidance on the creation of a business case that includes non-energy benefits and a roadmap underpinned by the novel C^3 approach. *Journal: Energy 136 (2017) 16-31*
DSF	Research suggests that one of the most critical barriers for closing the energy efficiency gap lies in the ad-hoc approaches taken by organisation when planning and implementing EEM. Industrial EM standards such as ISO require the implementation EEM, however, they do not provide clear step by step guidelines to systematically evaluate energy investments. This	The developed DSF represents a simple and repeatable approach for energy managers to promote informed, unbiased energy-related decision-making from top management. The framework ensures decision-makers are presented with all the necessary (un-biased) information that allows them to understand the full impact of the energy project. It accounts for the non-energy benefits and presents the characteristics and performance trends

	lack of systematic process leads to both under-investment and non-optimal or biased investment decisions, especially if energy investments are given a lower priority. This issue is further compounded by the complexities associated with MMO.	of the energy investment projects and their associated impact on the organisation. The DSF is underpinned by a project prioritisation tool that uses economic, environmental, social and technical criteria. *Conference Paper: Proceedings of the 10th International Conference on Sustainable Energy & Environmental Protection (SEEP), 27-30 June 2017, Bled, Slovenia.*

The development of GEMS and its deployment in BSC resulted in many impactful tools and process as summarized in Figure 6-28.

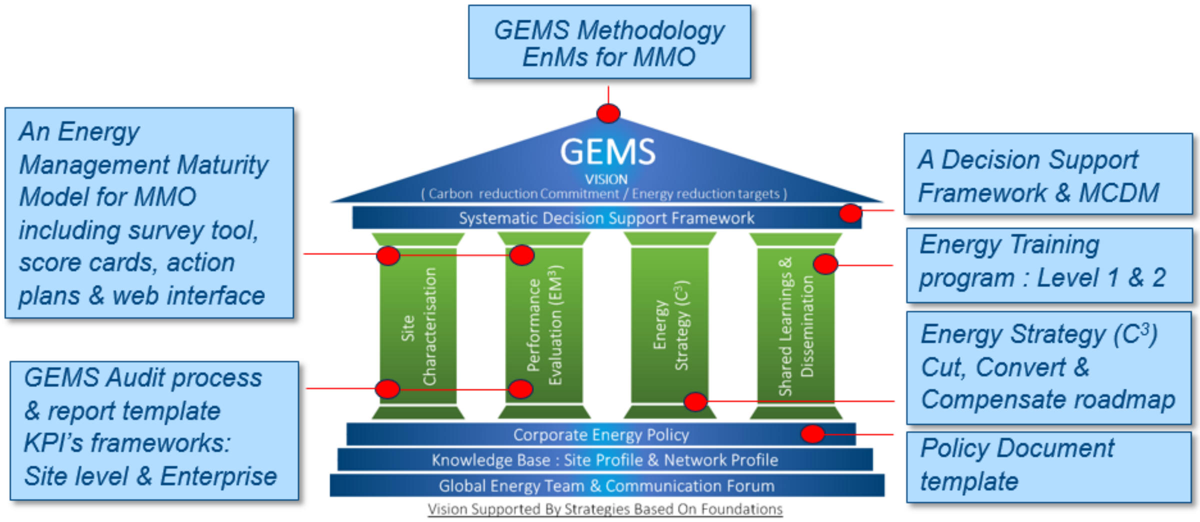


Figure 6-28. GEMS: Tool & process

The details of each are included in the various published papers and a summary listed here for convenience.

6.5 References

Boston Scientific Corporation (2017) 'Boston Scientific Performance Report 2017'. Available at: https://www.bostonscientific.com/content/dam/bostonscientific/corporate/citizenship/sustainability/Boston_Scientific_Performance_Report_2017.pdf.

EDF Climate Corps (2015) 'EDF Smart Energy Diagnostic Survey', *EDF Climate Corps*. Available at: http://edfclimatecorps.org/edf-smart-energy-diagnostic-survey (Accessed: 1 January 2015).

7 Conclusions & Future work

'Dost thou love life? Then do not squander time, for that's the stuff life is made of' – Benjamin Franklin.

7.1 Overview and context

This chapter presents the main conclusions from this thesis work regarding the overall GEMS framework. Conclusions based on implementation of the specific GEMS deliverables and their associated case studies are also presented, along with recommendations for further applications. The final section presents potential future work based on the findings of this thesis.

Garrone, Grilli and Mrkajic (2017) point out how corporate stakeholders and the public can better relate to the positive affects of carbon emission reductions as opposed to an equivalent impact from resource efficiency. This is an important observation in relation to the approach needed to combat climate change and influenced the direction taken when developing GEMS. It should not be a case of economic and social progress at the expense of Mother Nature. Conversely, it is naïve to depend on a political intervention to save the planet if the impact is to stagnate or reverse global development. Government and industry need to work in tandem, which is why the Paris Agreement represents a significant step forward. The role of policy and strategy in industrial corporations through CSR can be a catalyst for impactful contribution and change. One pathway to achieve both goals is utilizing sustainable energy consumption practices that either slow or eliminate environmental degradation, so that the earth's natural carbon sinks have the chance to re-absorb some of the CO_2 emissions in the atmosphere.

In any business, investment is with-a-view to a financial return or to meet compliance. The economic driver alone may not be sufficient to trigger positive decisions on energy especially for non-energy intensive organisations, where energy costs are a small portion of the production costs. In such cases, a strong long-term energy strategy becomes the main factor driving energy efficiency. The motivation for a long-term strategy is influenced by financial and CSR considerations. Given the financial resources of corporations and the increased stakeholder emphasis on sustainability, MMO are an attractive target group to lead the way in reaching this environmental sustainability. In addition, MMO, through their large employee base can influence both private and professional networks across many regions and countries, bringing a simple message on energy conversation and CO_2 reduction into their homes and communities.

Boston Scientific proved an effective partner for the initial GEMS implementation, not just in terms of engagement and resources but strategically as a representative of the Medical Device (MD) industry and an MMO. There are approximately 22,500 medical technology companies in the European Union with collective annual sales of approximately €95 billion. In Ireland alone 250 medical technology companies are currently in operation, accounting for 8.5% of Ireland's total merchandise exports, which have a value of approximately €8 billion per year (Irish

Medical Device Association (IMDA), 2015). MD companies typically (BSC as a good example) have the relevant mix of building use (office, warehouse, laboratory's and cleanrooms) and fall under the non-energy intensive criteria due to the high profitability of the industry. It is also representative of the broader life sciences sector and scalable to the manufacturing industry in general. MD companies can provide leadership in the CSR and global EnMS field. Manufacturing firms will strongly emphasise energy management practices when they see and hear the success story of their competitors in achieving organizational goals. This 'mimetic' driver is because a firm tries to replicate successful competitors. An excellent example of this in Ireland occurred in the 1990s. In this instance, in the field of construction safety when Intel Corporation set the standards in its Leixlip facility. This proved a catalyst for improved safety standards across the entire construction industry in Ireland. This can be a significant factor in the deployment of GEMS via its successful application in BSC.

The GEMS methodology brings to the table another instrument to address energy efficiency and carbon reductions. It promotes efficiency through the adoption of several energy management activities, with implications in any organization that wishes to improve its energy performance. It contributes to energy maturity models, energy benchmarking, energy policy and decision support on investment in EEM through guidelines and templates. Finally, this work could also be a stepping stone to further academic research as the analysis of several topics regarding energy management of larger organisation. This, in turn, could guide further efforts in global or multi-site energy management.

7.2 Conclusions

The GEMS deployment in BSC continues to have a positive impact in supporting the company in reaching its sustainability commitments. Academically, its deployment has demonstrated how a systematic approach (such as GEMS) to multi-site energy management can help an MMO reduce the energy efficiency gap. All aspects of the methodology were implemented at BSC, including; the EM^3, a focused policy document, an energy strategy roadmap and a DSF for capital investment decisions. Its output addresses the research question and closes the knowledge gaps identified.

Chapters 2 to 5 can be reviewed as standalone pieces of research or in unison with the overall GEMS framework. Each chapter has a methodology, case study and detailed conclusion section. The following sections will endeavour not to repeat the details of those conclusion sections but rather give the reader an overview of the key conclusions with some discussion from the viewpoint of the global energy manager for BSC during its implementation, highlighting what went well, what could be improved upon and the important lessons learnt.

The main conclusions are:

- ***GEMS Framework:*** GEMS provides a novel framework to enable non-energy intensive MMO meet their energy and carbon reduction goals, whilst in parallel optimizing their energy efficiency performance and associated investments. The GEMS framework complements existing site-based EnMs and guides the MMO through their journey to meet the company vision and goals. The approach ensures top management are aware of how energy can be turned into an asset that benefits the organisation through financial optimization and CSR.

  Global Energy Manager perspective:

  - The implementation of the GEMS methodology in BSC led to its announcement on Carbon Neutrality. It drove significant improvements at a corporate level on energy management as measured by the 6-enterprise level KPIs. Along with key initiatives such as the global energy team, cost code alignment, GEMS Audit, EM^3 and C^3 , the GEMS implementation has engrained a company culture to ensure a structured approach to energy management into the future.

  - The pilot study was integral to both gaining initial management support and to achieving a robust global deployment of GEMS. Due to the geographical, cultural and energy profile diversity, intrinsic to any MMO, ensuring all sites understood the methodology was critical and required a high level of communication and open exchange at the GFUM forum on a continuous basis.

  - A recap on the 'GEMS Parthenon' is recommended at least annually. Changing personnel (both primary owners and sponsors) also drove this need for continuous communications. The appointment of a dedicated GEM will be beneficial in this context. However, the need to pool site level resources and maximise productivity through shared learning will always be needed.

  - The collaboration between BSC and NUIG was a major highlight from the research thesis, exemplified by the GEMS articles in the BSC CSR reports and the publications in leading academic journals. The approach taken and its structures should be used as a lesson learnt in future industrial / academic collaborations.

- ***EM³:*** The Energy Management Maturity Model advanced existing site focused models and developed a novel approach to deliver qualitative metrics catering for individual site, multi-site and external peer requirements. It possesses three application-specific 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 of sites 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 both internal and external benchmarking.

  Global Energy Manager perspective:

  - EM^3 implementation in BSC has established a common language between site and global teams, enabling a more fluid communication. Despite the qualitative nature of the EM^3, via the Likert approach a scoring system is possible allowing a site comparison with the network average, external peers and most importantly tracking internal improvements against the established baseline.

  - The combination of a scoring system, a SWOT analysis and a roadmap for future actions incentivises each site to take the necessary measures to become the best it can be.

  - The model hinges on the quality of the survey and while the web-based application has checks in place, it is inherently dependent upon honest and accurate feedback. A further frailty comes from each site manager's interpretation of the questions and associated progress. This is compounded with a change of personnel within the sites. Conducting the survey via an external body is highly recommended as it facilitates a more neutral setting. While it also assists in level setting, a more robust solution will be established once the Global Energy Manager can visit each site and calibrate on the baseline scores.

  - Initial engagement from the sites to complete their 'Action plan' was poor and the quality of the plans varied. The subsequent development of the '6 Enterprise level KPI framework' allowed the site energy manager's to tie their proposed actions to an appropriate KPI and the resultant 'Action Plans' improved.

  - As the energy management maturity model concept is mostly unknown, efforts are needed to disseminate it and ensure understanding across the corporation.

Featuring EM^3 as one of the six enterprise-level KPIs, published in the sustainability reports, serves to close this knowledge gap.

- Finally, the EM^3 score, when combined with the energy usage intensity factor provides insightful information on the site in question in addition to serving the DSF.

▪ *Corporate Energy Policy and Strategy*: Ensuring cross functional engagement from all the internal stakeholders to deliver on corporate sustainability requires formal commitment from top management. A prerequisite to this support is a strategic plan to deliver on the sustainability goals. The GEMS framework outlines the three key elements to deliver on the above. The *policy* documents the justification ('*Why*' do it) for setting company goals on carbon and energy reduction targets to achieve the sustainability *vision* ('*What*' to do). The *strategy* details the roadmap to deliver on these goals ('*How*' to do it). This research contributed to closing the knowledge gap found in literature by delivering a set of minimum requirements that an MMO should consider when developing an energy policy and supporting strategy.

Global Energy Manager perspective:

- Prior to GEMS, BSC did not have a dedicated energy policy document covering sustainability or carbon neutrality. Initial work on energy efficiency was focused on the financial outputs from the EEM on a case by case basis. The first step on the journey that led to the carbon neutrality vision, began with the initial approval for a pilot GEMS implementation in Europe. This in turn highlighted the need to develop an inclusive business case that would *'level the playing field'* for energy investments against other core business requirements. To do this it became obvious that the financial benefits alone would not be sufficient. A business case was needed that accounted for all non-energy benefits and clearly articulated the impact sustainability can have on the company's finances and reputation.

- The business case is underpinned by a strategy or roadmap to convey how these targets or ambitions can be achieved. Over time, the successful implementation of EEM combined with the evolving business case led to the commitment and signature of the policy document from top management. This proved to be the catalyst for increasing the commitment from a % CO_2 reduction target to Carbon Neutrality by 2030. Both the policy document and the strategic roadmap need to be reviewed and updated as required to meet the company vision.

- The presence of ambitious people in key positions within the organization, who are committed to contributing to sustainability and climate change was key to the systematic development of the GEMS policy and strategy. Once the commitment to Carbon Neutral is in place, it becomes strategic at corporate and individual site level. This enables the allocation of appropriate resources to meet the medium and long-term targets.

- In terms of lessons learnt, making the energy strategy roadmap easy to understand within and outside the company was key to achieving stakeholder engagement. In GEMS, the C^3 is readily branded, its implementation sequence is logical and it represents the core of the energy strategy.

- The 'compensate' step is yet to be adequately tested in BSC. Nevertheless, once the *Cut* and *Convert* steps are exhausted, the *Compensate* step is inevitable and it will be subject to the market value of carbon offsets. This step should be carefully managed, marketed and disseminated to ensure a positive impact to the overall program.

- When implementing GEMS policy and strategy it became evident that more prescriptive detail is needed to allow the individual sites enhance and quantify their contribution to the Carbon Neutrality vision.

- The development of a policy and strategy, brought the 'sustainability' debate into the mainstream from a top management perspective and as a result featured heavily in the BSC sustainability reports.

- Finally, the energy policy allowed BSC to demonstrate its clear commitment with the increasing demand from the market and customers to display our sustainability credentials. BSC has engaged with its investor relations department to ensure the GEMS efforts are appropriately disseminated to the investor community and BSC customers alike.

▪ ***Decision Support Framework / MCDM***: To avoid typical ad-hoc decision-making practices an unbiased approach was needed for MMO. This will assist their decision makers on optimal investment decisions for EEM. GEMS DSF, underpinned by the MCDM, provided a condensed, repeatable and effective template to request approval for funding. For the executive leadership, it resulted in an understandable, fact-based approach to reach consistent informed decisions. In this sense, the MCDM captures all the possible energy (primary) and non-energy (secondary) benefits while the DSF presents all the quantitative and qualitative key performance metrics that enable the un-biased decision making.

Global Energy Manager perspective:

- It is imperative that the decision makers (top management) are part of the process in creating the DSF and associated criteria. Ultimately, they decide on investment. The DSF role is solely to present the pertinent information in a clear, concise and un-biased manner, that can then facilitate effective decision making within the company culture.
- Since its deployment, BSC has had an unprecedented level of investment in EEM. Clear presentation of data, a knowledge that the process is fair and encompassing all opportunities in the network has attributed to this success in terms of energy investment.
- The MCDM part of the DSF provides a ranking system. It does not necessarily determine the order for funding, but it ensures that the criteria with the most importance to the organization recieves the highest weight. A weakness of the MCDM is the subjective nature on the allocation of weightings (especially if determined by a single individual) and how this can be altered with a change in personnel. While the MCDM weightings should be reviewed periodically, this may have the consequence of hampering historical cross-comparison of projects due to the potential different weightings. This affect can be minimized if historical weightings are recorded and utilized when comparing projects from different eras. Good practice would suggest revisions are documented with associated drivers for that change.
- The MCDM in its current form does not cater for the risks associated with the various financial models (e.g. Capex Vs PPA). Another limitation of the MCDM to date is the small number of projects that can be analysed simultaneously. However, on a positive note, it can be used as an effective tool at both a site (in preparation and scenario planning) and global level.
- Finally, it is worth noting that DSF currently lacks the ability to present some of the less tangible information that is present in the 'shared learning and dissemination pillar' such as the 'mood' of the company and the market place,

ensuring the top executive are in touch with the employee base and stakeholder requirements.

7.3 Changing Culture

The impact of GEMS in BSC is well illustrated in the following quotes from key personnel.

"*Over the past five years the GEMS methodology has steadily embedded itself into the day to day running of our Sustainability program. It is now the corner stone of our approach to energy management both at a site level and corporate level, with the maturity model providing a common language to enable this. Key steps along the way included understanding the scale and impact of the program, gaining top management commitment from the outset, communicating key wins along the way (both internally and external), engaging and collaborating with our internal sites and with influential external bodies. Having the methodology itself and strategic components such as EM^3, Policy and the DSF validated by the by the academic community through peer reviewed journals has further elevated GEMS high status within BSC and gained the trust and respect of top management. The rigour and structured approach to the DSF (in particular) has led to unpresented level of investment on energy efficiency in recent years from BSC. We are experiencing more and more requests from our key customers and the investment community to disseminate our sustainability program. I can safely say GEMS is now well and truly engrained into the BSC culture and is front and centre to any energy related sustainability discussions within BSC and with our external stakeholders."* Paul Donhauser, VP Global Real Estate, Facilities, EH&S. Boston Scientific.

"*GEMS provides a co-ordinated program of energy management activities that did not exist before 2015. It offers a platform for shared learnings & dissemination of key energy related information with other sites in the BSC network, and through EM3 it developed a means to comparatively asses the strengths and weaknesses of your site's energy management performance with other BSC plants. GEMS created a common language to describe BSC's energy management initiatives, and through the DSF it offers a clear path for energy investment approvals that did not previously exist. In addition, the development of GEMS has firmly established climate action through energy improvement as a priority for BSC, demonstrated in the commitment to carbon neutrality by 2030. This goal was adopted into the Galway SQP (Strategic Quality Process) for 2018.*" Primary Owner, Galway site, Boston Scientific.

"*GEMS sets out a clear methodology to address BSC's global energy use, and its associated environmental impacts. With the embedding of the GEMS methodology into BSC's sustainability program, a clear mandate for implementation is provided to the energy manager. This is aided by the common language GEMS provides around energy management initiatives – from senior company management to on-site energy leads.*" Ronan Coffey, Global Energy Manager, Boston Scientific.

"It is expected that any high-performing organization will have an established system for documenting and reviewing overall energy usage. Boston Scientific sets itself apart with its Global Energy Management System, a framework that uses key performance indicators to track energy performance and drive sustainability at individual sites and across its global network. These distinct indicators allow GEMS users to benchmark their performance, identify opportunities, and develop comprehensive strategies to improve energy management. This is all made possible by high-quality, granular data generated from on-site metering and a qualitative survey." Charles Vinsonhaler, EDF Climate Corp (Environmental Defense Fund).

Table 7-1 displays a selection of question and results from the EM^3 over the past three years that exemplify how the culture is changing in BSC as viewed by the various primary owners from each site.

Table 7-1. Trends from EM3 reflecting Culture change in BSC

	Trend (2015-2017)	% change (2015-2017)
Global Energy Management Team: existence and forum		6%
Resource level to support the global energy management team		17%
Understanding Global operational spend Vs Energy Expenditure		9%
Multi-site level of data collection and analysis		2%
Assessment metrics of global energy management		26%
Energy consumption breakdown		35%
Energy auditing level		71%
Energy benchmarking		45%
KPIs existance and usage		56%
Inter-Site communication and associated resources		41%
Energy training levels		174%
Metrics for assessing CapEX in Energy projects		8%
Decision support framework to support investment decisions		44%
Global energy performance and sustainability targets review frequency		41%
Average		**31%**

GEMS continues to provide the platform for BSC's structured approach to energy management and is now part of the core business culture.

7.4 Future work

During this research a number of impactful topics were evaluated that were deemed not fundamentally critical to the initial development of GEMS. However, considered significant for future development. These topics are outlined in the following section and will further streamline the framework and help to increase its adoption and reliability in MMO, see Figure 7-1.

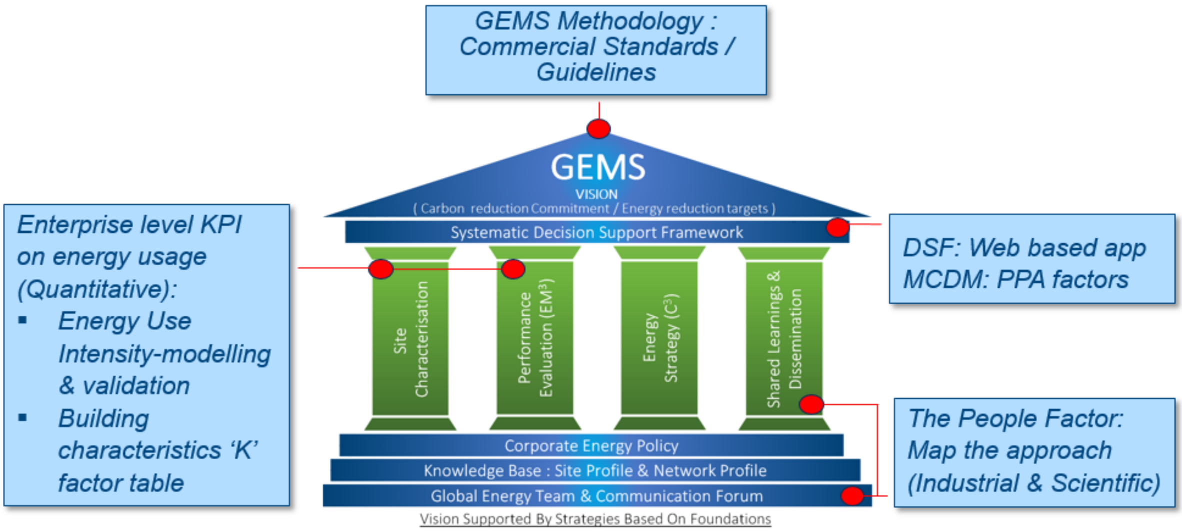


Figure 7-1. GEMS: Future work

- ***Enterprise level KPI on Energy usage (Quantitative):*** There are many well established KPI's for assessing building energy performance such as Energy Utilization Index (kWh/m^2/year) or Cost Index (\$/m^2/year). Standard KPI's are usually developed with an individual building/facility energy performance in mind. The ability to compare sites in both a performance-based, and normalized fashion will allow the global energy manager to complete a gap analysis on each site. This will help ascertain the key contributing factors between actual performance versus design performance and / or industrial norms. Once the gap is understood appropriate technical solutions can be characterised based on applicability for each region and building type. In chapter 2 the concept of the 'Energy Use Intensity' KPI was introduced (see Table 2-5 and Table 2-6) and further evaluated in the GEMS pilot study (Chapter 6). The breakdown of different types of floor space will invariably impact energy performance, as different processes will have different energy intensites. Therefore, in terms of energy consumption per unit of area; a site with a high percentage of office space will naturally have an apparently superior performance, compared to a site with a high percentage of cleanroom floor space. This is the crux of the issue that must be addressed; the normalization of energy performance data across a geographically diverse plant network. Using the 'Volume of air delivered' presents an opportunity to normalise total site energy usage in a meaningful way versus traditional methods of simply dividing by the site area. A gap still exists in validating this concept scientifically and represents a significant scope for future work. Figure 7-2 shows the steps proposed in data normalization techniques with specific focus on space breakdown and building profiles leading to a meaningful benchmarking approach.

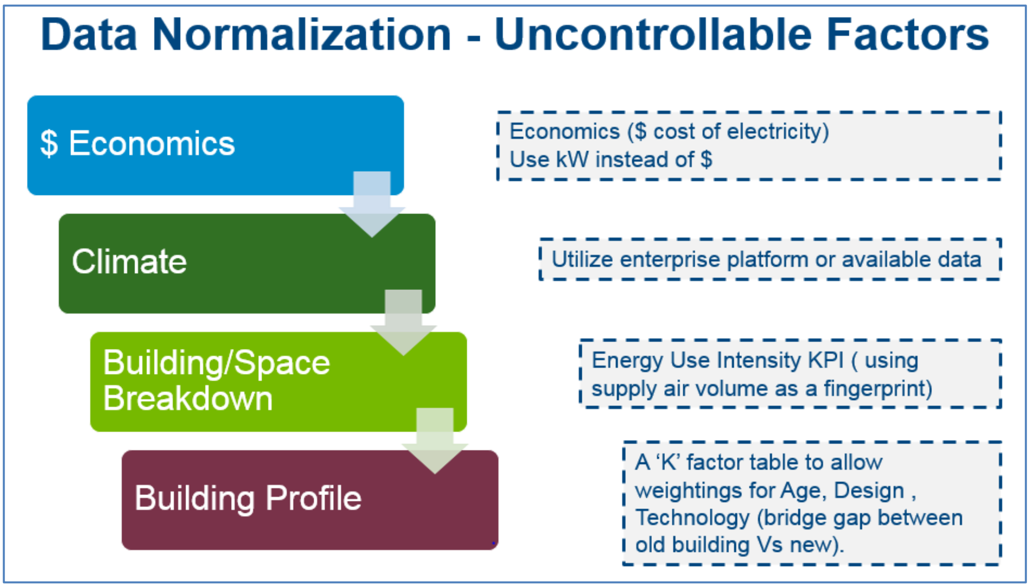


Figure 7-2. Future Work: Data normalisation

- *DSF / MCDM:* A future consideration is to develop a web-based system enabling primary owners to further utilize the DSF for project scenario planning. A further consideration for improvement is the analysis of 'if and how' the financial risks should be accounted for in the MCDM. Future work should also focus on understanding and quantifying the impact of secondary non-energy benefits for energy efficiency investments in non-energy intensive multi-site organisations, more work is needed to ensure it is not so subjective and heavily dependent on the knowledge and experience of the primary owner in question.

- *The People Factor*: While the GEMS methodology (Chapter 2) researched the current practices in relation to communication and dissemination, the global energy team foundation and the SL&D pillar were not deemed as scientifically significant or critical as the other gaps identified. It was during the implementation in BSC however, that its importance to the success of GEMS became apparent. The communication tools that have evolved are best in class (both internal and external) and enable decision making within and across industrial stakeholders regarding EEM investments. Future research work should provide a scientific basis to the shared learning and dissemination pillar, thus providing relevant tools for effective engagement and accounting of the social aspects of GEMS. A strategy for rewards and recognition at both site and corporate-level will be developed in the future work.

- *GEMS Commercial Standards / Guidelines*: The framework should be further evolved into a white paper that serves as a basis for GEMS inclusion in ongoing discussion of the relevant technical committees on current and future national and / or international standards such as ISO50001 development.

Whilst GEMS was developed for non-energy intensive MMO the framework is also adaptable to energy intensive MMO or indeed a campus with multiple buildings, serving a varied purpose, such as a University campus. This, however, would need further evaluation and development.

7.5 References

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Irish Medical Device Association (IMDA) (2015) *About Irish Medical Device Association*, *Irish Medical Devices Association*. Available at: http://www.imda.ie/Sectors/IMDA/IMDA.nsf/vPages/About_us~about-the-association!OpenDocument.

Appendix A:
Published Papers

Finnerty, N., Sterling, R., Contreras, S., Coakley, D., Keane, M. *Defining corporate energy policy and strategy to achieve carbon emissions reduction targets via energy management in non-energy intensive multisite manufacturing organisations.* Energy 151 (2018) 913-929

https://doi.org/10.1016/j.energy.2018.03.070 {*IF 4.968*}

Energy 151 (2018) 913–929

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Defining corporate energy policy and strategy to achieve carbon emissions reduction targets via energy management in non-energy intensive multi-site manufacturing organisations

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Finnerty, N., Sterling, R., Coakley, D., Keane, M. *An energy management maturity model for multi-site industrial organisations with a global presence.* Journal of Cleaner Production 167 (2017) 1232-1250

http://dx.doi.org/10.1016/j.jclepro.2017.07.192 {*IF 5.651*}

Journal of Cleaner Production 167 (2017) 1232–1250

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

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[c] *Boston Scientific Corporation, Ballybrit Business Park, Galway, Ireland*

Finnerty, N., Sterling, R., Coakley, D., Contreras, S., Coffey, R., Keane, M. *Development of a Global Energy Management System for non-energy intensive multi-site industrial organisations: A methodology.* Energy 136 (2017) 16-31

http://dx.doi.org/10.1016/j.energy.2016.10.049 {*IF 4.968*}

Energy 136 (2017) 16–31

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/energy

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

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Appendix B:
EM^3 Score Cards

EM^3

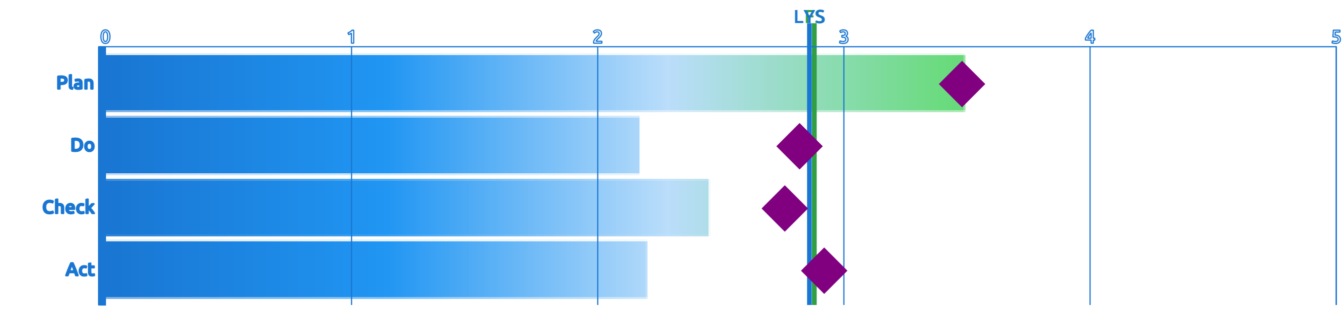
Energy Management Maturity Modelling

Galway

2017 - Report Card

GEMS EM^3 Status: Site

Below are your site's results from the GEMS Survey and Maturity Model. The graph displays your scores in the four main headings: Plan, Do, Check and Act. The scoring system ranges from 1.0 to 5.0 and positions each of the evaluated aspects in one of the five maturity levels: None (or) Minimal, Emerging, Developing, Advancing and Leading. Also displayed on the graph are the average for Boston Scientific Global Network Sites.For details on how each score was calculated, see the text beneath the graph for the main measured areas. To learn more click BSC GEMS EM3.



None (or) Minimal | Emerging | Developing | Advancing | Leading

Average BSC Network Sites

(LYS) Last Years Final Score: 2.88

(FS) Final Score: 2.86

	SITE	NETWORK
Plan	**3.49**	**3.48**
Commitment	**3.17**	**3.21**
Managment Responsibility	4.33	3.92
Energy Policy	2.33	2.61
Energy Team	3.0	3.14
Energy Review/Planning	**3.5**	**3.45**
Data Analysis & Energy Baseline	3.86	3.51
Benchmarking	2.5	3.65
Energy Opportunities Audit	3.75	3.58
Key Performance Indicators	2.5	3.0
Energy Goals	3.67	3.28
Action Plan	**4.2**	**4.26**
Project Assesment & Planning	4.0	4.33
Resources	5.0	4.0
Do	2.17	**2.82**
Implementation	2.17	**2.82**
Training	1.0	2.35
Awareness	2.25	2.46
Communication	2.33	2.85
Documentation & Control	2.67	3.26
Operation and Maintenance	3.25	3.58
Design	2.0	2.92
Procurment	2.0	2.38
Check	**2.45**	**2.76**
M&V	**3.0**	**2.79**
Monitoring, Measurement & Analysis	3.0	2.79
Compliance & Audits	2.14	**2.75**
Internal Audits	1.0	2.5
External Audits	3.67	3.08
Act	2.2	**2.92**
Management Review	2.0	**2.92**
Management Review & Recognition	2.0	2.92
Recognition	2.25	**2.93**
Internal Recognition	1.0	2.92
External Recognition	3.0	2.92

(FS) Final Score:
((3*Plan) + Do + Check + Act)/6

Grey indicates: site score < 2.0 or site score < network average - 0.5

Red indicates: Site score < 1.0 or network score < 2.0

EM^3

Energy Management Maturity Modelling

Galway

2017 - Report Card

SWOT Analysis

Strengths

Galway is above threshold for all categories of Global and EDF questions

There is generally good awareness and involvement with BSC energy management at the global level

Energy goals are included in the site's quarterly environmental review, so there is a regular process for reviewing these goals

Weaknesses

The site has no systematic tracking of KPIs or a set list of KPIs that are routinely tracked

Site energy policy is still informal, and there is no standard approach to training

Opportunities

Standardize a list of KPIs and establish a measurement process to begin tracking these KPIs systematically at a site level

Alignment with the KPIs from the 2016 sustainability report may be helpful to align with global strategy

Develop a more formalized site energy policy

Threats

Galway is below threshold in "Do" and "Act" at the site level

This is mostly due to the lack of an organized training program for the energy team, and the overall awareness and communication of energy initiatives and goals across the site

Action Plan

Title	Savings	KW	Reductions	Category	Dates	kpis
Exeed cleanroom energy use optinmisation pilot	$			Plan	01/18 - 08/18	
Chilled water system controls improvement	$			Do	02/18 - 05/18	
Fume hood extraction review	$			Do	01/17 - 08/17	

EM^3

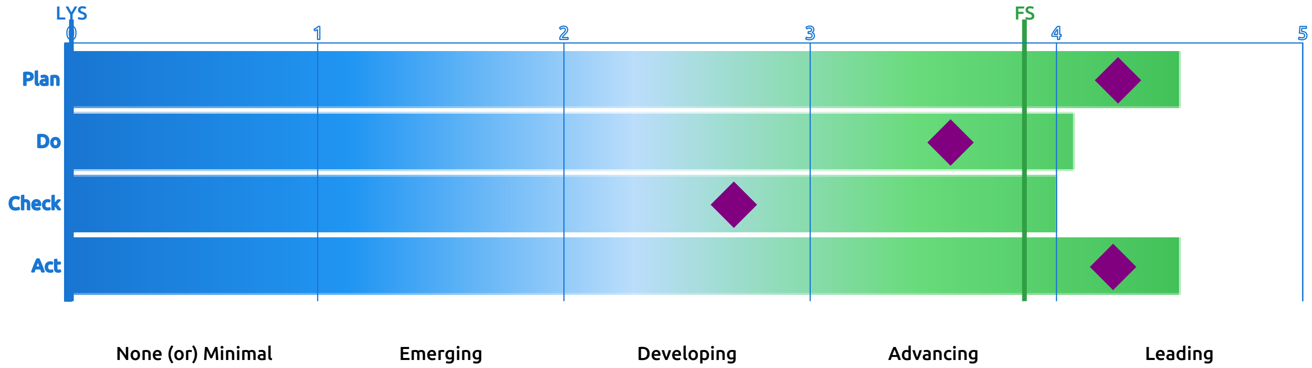
Energy Management Maturity Modelling

Galway

2017 - Report Card

GEMS EM^3 Status: Network

This score card displays, in the four main headings: Plan, Do, Check and Act; the comparative results from an energy management prescence. Two points of view are presented in the graph, the averaged perspective of all the sites in the global network and the global energy management team. The scoring system ranges from 1.0 to 5.0 and the graph positions each of the evaluated aspects in one of the five maturity levels: None (or) Minimal, Emerging, Developing, Advancing and Leading. For details on how each score was calculated, see the text beneath the graph for the main measured areas. To learn more click BSC GEMS EM3.



Average BSC Network Sites:

(FS) Final Network Score: 3.87

	G.E.M.T.	NETWORK
Plan	**4.5**	**4.25**
GFUM	**4.5**	**4.5**
Existence	5.0	4.69
Resources assigned	4.0	4.31
Site Profile & Network Profile	**4.5**	**4.23**
Energy Share of OPEX	5.0	4.69
Data Collection and Analysis	4.0	3.77
Best Practices/Demonstrator Sites	4.5	**3.77**
Information Level	4.5	3.77
Do	**4.07**	**3.57**
Site Characterisation	**3.67**	**3.33**
Energy Breakdown	2.5	3.46
Energy Audits	3.5	2.46
Energy Benchmarking	5.0	4.08
Performance Evaluation	5.0	**3.62**
EnPI	5.0	3.62
Shared Learning/Dissemination	**4.0**	**4.27**
Information Sharing	5.0	4.77
Energy Training	3.0	3.77
Corporate Policy	4.5	**2.85**
Investment Assessments	4.5	2.85
Check	4.0	**2.69**
Systemaric DSS	4.0	**2.69**
DSS	4.0	2.69
Act	**4.5**	**4.23**
Management Evaluation & CI	**4.5**	**4.23**
Sustainability Targets	4.5	4.23

(FS) Final Score: ((3*Plan) + Do + Check + Act)/6

Grey indicates: G.E.M.T score > network average + 0.5

Red indicates: score < 2.0

EM^3

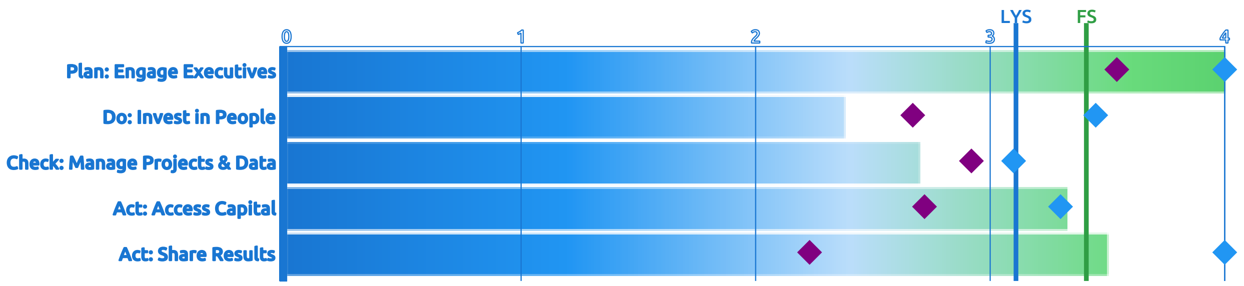
Energy Management Maturity Modelling

Galway

2017 - Report Card

GEMS EM^3 Status: EDF

Below are the results from the EDF Smart Energy Diagnostic. The graph displays both, the global energy management teams scores and the network average scores in five key capacities, with the highest score possible being a 4.0. Also displayed on the graph are the 90th percenter-alignile scores for the EDF Climate Corps organizations who completed the Smart Energy Diagnostic in 2014 (over 300 companies). For details on how your score was calculated, see the text beneath the graph, and if you'd like to learn more about the practices EDF Climate Corps has identified as leading, please view the complete EDF Smart Energy Diagnostic Rubric.



Average BSC Network Sites

2014 Climate Corps Cohort, 90th percentile

(LYS) Last Years Final Score: 3.11

(FS) Final Score: 3.41

	G.E.M.T.	NETWORK
Plan	4.0	3.54
Engage Exectutives	4.0	3.54
Ambition and goals	4.0	3.54
Do	2.38	2.67
Invest in People	2.38	2.67
Accountability	3.0	2.69
Expertise	2.5	2.92
Collaboration	3.0	2.92
Engagement	1.0	2.15
Check	2.7	2.92
Manage Projects & Data	2.7	2.92
Identifying Projects	3.5	3.23
Implementing Projects	4.0	3.08
Data Collection	1.5	2.62
Measuring Savings	2.0	3.15
Decisions	2.5	2.54
Act	3.38	2.6
Access Capital	3.33	2.72
Funding	3.0	2.31
Dependability	3.5	3.23
Accessibility	3.5	2.62
Share Results	3.5	2.23
Reporting	3.5	2.23

(FS) Final Score:
((3*Plan) + Do + Check + Act)/6

Grey indicates: network score < G.E.M.T score - 0.5

Red indicates: Score < 2.0