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Assessing Capital Investment on Energy Improvement Projects from a Global Energy Management Perspective: A Tri-generation Case Study

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Abstract

For multi-national companies, assessment of energy improvement projects across a global site-base requires a thorough understanding of the driving factors affecting energy consumption on each site. Traditionally, assessment is performed on the basis of single site-level audits. These audits provide quantitative metrics for the implementation of energy improvement projects such as economics (capital cost, operating costs, return on investment, net present value) and energy/greenhouse gas reductions. However, audits do not typically assess, holistically for all sites, metrics concerning the three levels of abstraction namely system, facility and global. In order to improve effectiveness of capital spending in terms of corporate social responsibility (CSR), sustainability, business continuity and return on investment, it is necessary to develop standardised approaches for auditing sites across a global site-base. Within this context, Boston Scientific, a leading multinational medical device company with a diverse global presence, is currently in the process of implementing a global energy management system (GEMS) in order to improve corporate decision-making on capital energy efficiency spending. The paper will illustrate, from a site's perspective, the interactions between a typical energy project life cycle and the GEMS corporate energy management system.

Introduction

Over the last decades, the energy demand worldwide has almost doubled in a trend that is set to continue in the near future [1]. This has led to a significant rise in energy costs and increased awareness of the impact energy efficiency has not only on the world's climate but also in the sustainable competitiveness of the industrial sector. In fact, the industrial production and processing sector consumes around 25% of the EU-27 energy requirements [2]. Within the industrial sector, approximately 10 million m^2 floor space are used for energy intensive clean room activities, of which the medical device industry accounts for 6% [3].

Managing energy and carbon footprint in large organisations presents significant challenge due to the lack of appropriate methods to address energy efficiency in a way that is both practical and comprehensive, thus inherently leading to effective implementations [4]. In particular, such challenge is increased when aiming at maximising the effectiveness of capital spending on energy improvement projects in organisations with manufacturing facilities across geographically diverse locations. In such cases, it is often the case that the identification of improvement opportunities - and the request for funding to implement them - originates at site level but will ultimately require corporate level approval, particularly when significant capital investment is required. The challenge then lies in matching the corporate and site views, and integrating all the information necessary for informed decision-making. From a corporate perspective, this can include diverse variables such as climate, economics, politics, infrastructure, building type, technology availability and maturity, culture and product mix, to name a few. From a site point of view, it is important to understand the criteria upon which global investment decisions are based in order to maximise the potential for project approval, and minimise time spent analysing projects which are ultimately not viable.

In order to address this challenge, this paper proposes a novel methodology that supports a global energy manager in decision making within a 'Global Energy Management System' (GEMS) [5], complementing the local site's energy improvement project life cycle within the corporate network. GEMS is divided into foundations, pillars and decision support framework (DSF) as shown in Figure 1.

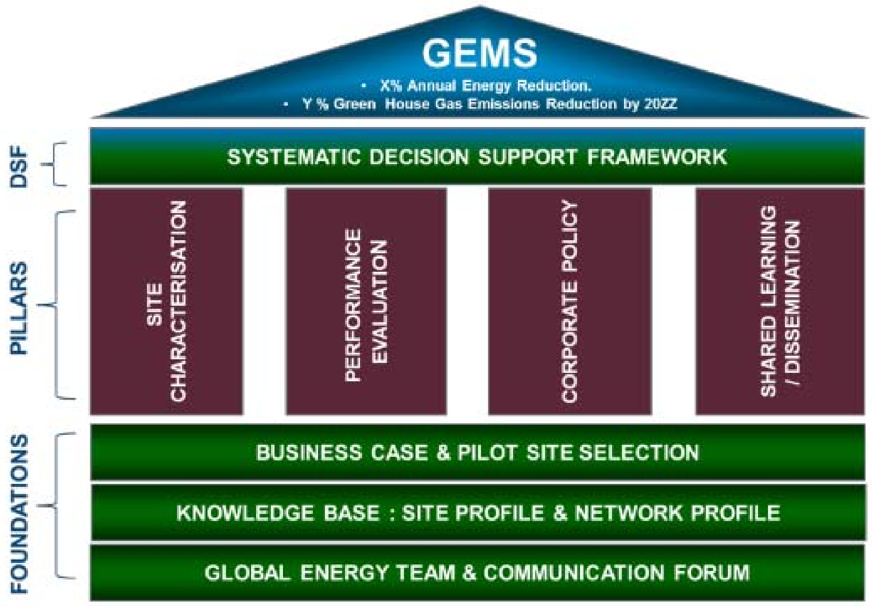

Figure 1. GEMS methodology overview.

Key infrastructural or organizational enablers represent the foundations of GEMS including:

- **Global Energy Team & Communication Forum:** This is a global energy management team with representatives from each individual site. A discussion forum (both physical and virtual) supports by information sharing between members, thus allowing for knowledge sharing and collaboration regardless of the geographical location;
- **Knowledge Base (Site and Network)**: A central platform for data collection, aggregation and analysis which enables a unified cross-site comparison of benchmarks (e.g. electricity, water, gas) as well as general network performance profiling;
- **Business Case and Pilot Site Selection**: Initial pilot case that is used to secure management buy-in and funding for the development of GEMS;

Four pillars are built upon these foundations to deliver the necessary information to the decision support framework such as:

- **Site Characterisation**: Understanding the characteristics of each site in the network, in particular establish the drivers for energy consumption, the baseline of energy consumption and the best energy efficiency technological possibilities for each geographical location;
- **Performance Evaluation**: Evaluate the performance of each site against its network peers via normalised key performance indicators
- **Corporate Policy**: Ensure awareness and alignment between corporate and individual sites management on the organisation policy towards energy improvement investments;
- **Shared Learning & Dissemination**: Create a dissemination network to share the learnings and ensure the success stories are properly communicated across the network, to the decision makers and to the general public.

Finally, the information is aggregated, analysed and processed within a decision support framework (DSF). This facility incorporates current and proposed project performance parameters (technical, economic, sustainability etc.), the corporate capital application model (own capital investment, per purchase agreement) and the outputs from a multi-criteria decision making model (MCDM) developed by GEMS (Figure 2). The methodology accounts for the combined positive impact of operational savings, improved sustainability and a more resilient site infrastructure and outputs a ranking on proposed projects.

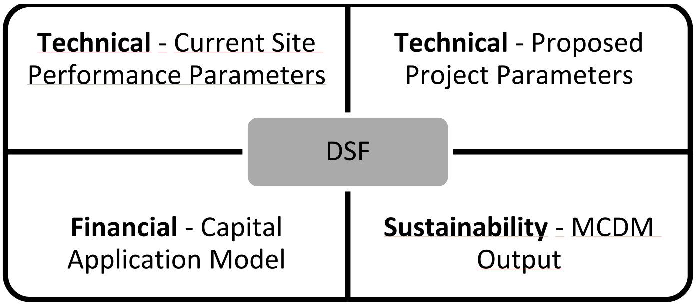

Figure 2. Decision support framework.

This paper presents the development of an energy improvement project – installation of a tri-generation plant – at one of Boston Scientific's sites. We provide a brief summary of the key stages of the tri-generation project, with particular emphasis on the interactions with GEMS. as shown in Figure 3.

Case Study

Boston Scientific Corporation (BSC) is a worldwide developer, manufacturer and marketer of medical devices, with annual revenue of approx. $8.2 billion, and global workforce of approx. 23,000. The corporation has a presence in more 40 countries, with 16 manufacturing site located in the US, Ireland, Costa Rica and Puerto Rico.

The case study will present the approval process of a tri-generation project in BSC Galway site, its interaction with GEMS and its ranking against other two projects in other BSC sites in Cork and Coyol.

- **BSC Galway** is the largest site in the global network with approximately 3,000 employees. The BSC Galway site was established in 1994 and is situated on a 24 acre site. As well as 14,800 m^2 of manufacturing space, the site accommodates an R&D facility, warehousing, laboratories and 1,900m^2 of office accommodation.
- **BSC Cork** is in existence since 1998, and has a total floor area of 19,500m^2, of which 7,200 m^2 is production space. The Cork site has approximately 900 employees and manufactures products for the Interventional Cardiology, Peripheral Intervention, Endoscopy & Urology divisions.
- **BSC Coyol,** the larger of the two BSC manufacturing sites in Costa Rica, extends to 35,000 m^2, with 12,300 m^2 of production floor area and 16,700 m^2 of office and common area. There are more than 2,000 people and the site manufactures products for the Endoscopy, Urology & Pelvic Health, Peripheral Intervention and Cardiology divisions. The site was established in 2009.

Tri-generation Project Proposal at the Galway Site

For the purposes of this paper tri-generation, refers to the simultaneous extraction of electricity, heating, and cooling from the on-site combustion of natural gas from the grid. The system, as illustrated in Figure 3, consists of the following key components:

- An **internal combustion engine** producing power via an alternator,
- A **heat recovery system** for extracting heating from the engine jacket cooling system and the exhaust gas
- An **absorption chiller** driven by the low quality heat that would otherwise be exhausted, providing the cold water required to meet the building cooling loads, principally for air conditioning.

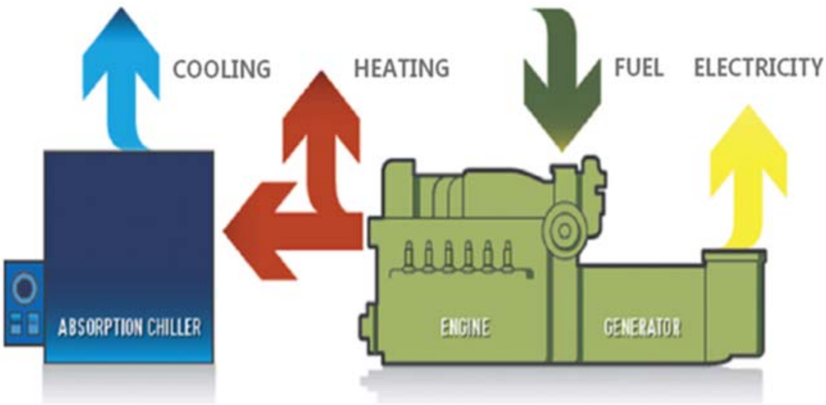

Figure 3. Tri-generation schematic.

The recovery of heat energy results in high thermodynamic efficiencies and reduced environmental impacts per unit of energy consumed. The remaining building requirements for electricity, heating, and cooling are provided by a combination of gas-fired boilers and grid power.

Technical suitability of this solution for any given building is dependent on electricity, heating and cooling load profiles, while financial feasibility will depend on the cost of installation and the thermal and electrical utility costs.

The overall timeline for the tri-generation project includes the following steps and interactions with GEMS as shown in Figure 4:

- Opportunity identification and interaction with the global energy team and communications forum;
- Opportunity assessment extracting and providing data for site characterisation and performance evaluation;
- Project approval integrating the details from the opportunity assessment with the corporate policy into the decision support framework;
- Design, planning and construction which enforces the business case and pilot site selection for GEMS being this among the first projects to use the methodology;
- Commissioning and operation which will provide details and a success story for the shared learning and broad dissemination of GEMS.

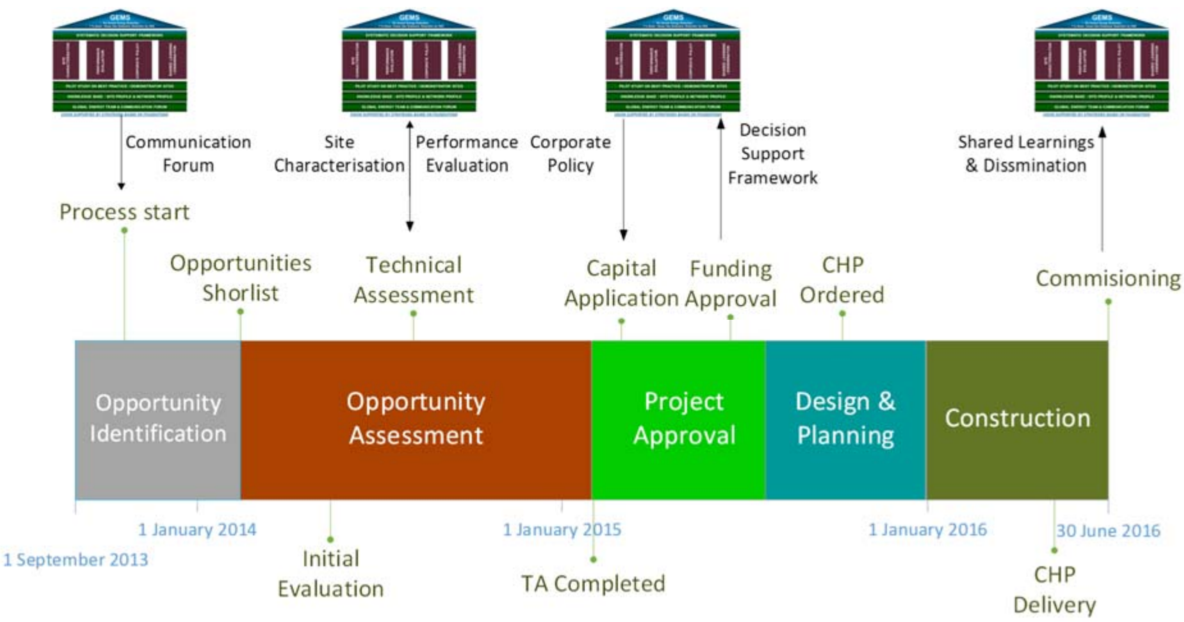

Figure 4. Tri-generation project timeline with GEMS interactions and information flows

This paper presents the work to date which represents the first three phases and a future work will detail the later ones.

Opportunity Identification

A competitive marketplace drives downward pressure on plant operating costs, including energy expenditure. In addition, a continuous improvement philosophy requires all departments to consistently review the significant areas of spend, and look for reduction opportunities. A robust plan for cost reduction, based on actual projects, is a key deliverable of the budget cycle of each year for all departments.

The BSC Galway Facilities group, supported by the outcomes from previous meetings of the global energy team and communications forum, ran an opportunity identification process in late 2013 in order to develop a comprehensive list of cost reduction or improvement opportunities. Key information for this process included a breakdown of the annual facilities overhead budget into key categories including energy, maintenance, consumables, etc. The annual energy cost and consumption had been further analysed to quantify areas of significant energy use and spend.

Through information sharing during the global energy team and communications forum, it was possible to see what utility cost reduction ideas were planned, or had already been implemented at other sites across the BSC network. This produced new ideas for possible implementations in BSC Galway. In total, approx. 312 "brainstorming" ideas were collected, and these were later consolidated into 113 cost reduction opportunities with a total value of $4 million, one of which was Tri-generation which was included in a 3 year implementation plan. Figure 5 summarises this process.

Figure 5.: Site opportunity identification process – Summary by numbers

Opportunity Assessment

Once the realistic improvement opportunities have been identified, the next step is to perform an assessment of the impact such improvement would have in the site and across the network. This assessment required two steps: an initial evaluation and a technical assessment as explained below.

Initial Evaluation

A high-level evaluation was carried out on all opportunities identified during the opportunity identification process, including gross estimations of project cost, potential savings and additional benefits and risks. In the case of the Tri-generation project, the initial assessment indicated a potential payback of approximately 6 years, with additional environmental benefits through CO_2 reduction. Crucially, the assessment also highlighted a potential source of funding for detailed technical assessment: National Energy Services Framework via Sustainable Energy Authority of Ireland. Although initial indications were that the payback criteria did not meet the BSC guidance of 2 years, the potential environmental benefits and the availability of funding for detailed technical analysis led to a decision to proceed to the next stage as it would potentially align this project with the corporate policy on sustainability.

Detailed Assessment

Technical assessment of the tri-generation proposal examined in detail the technical and economic feasibility of installing this technology solution at the BSC Galway site, and specifically addressed the key electrical, mechanical, economic and environmental issues. Thermal and electrical load profiles were assessed in detail to establish the optimum tri-generation plant capacity for the site. Several system integration options and system configurations were assessed prior arriving at a recommended solution. A financial analysis was also carried out for each of the potential system solutions considered. The optimum solution was found to be a 1,169 kW (electrical) combined heat and power (CHP) plant, with a 580 $kW_{thermal}$ absorption chiller. Figure 6 shows a 12-month profile of heating and cooling loads for the BSC Galway site and the loads that could be offset by the tri-generation plant. As can be seen from Figure 6, all the heating demand will be met by the tri-generation plant while the cooling demand will be partially met by the tri-generation plant and partially by chillers in situ. In addition the new CHP will provide a 36% of the yearly electrical energy demand. When combined with the existing CHP (2009), this will bring the total electricity demand that will be generated on-site to 72%.

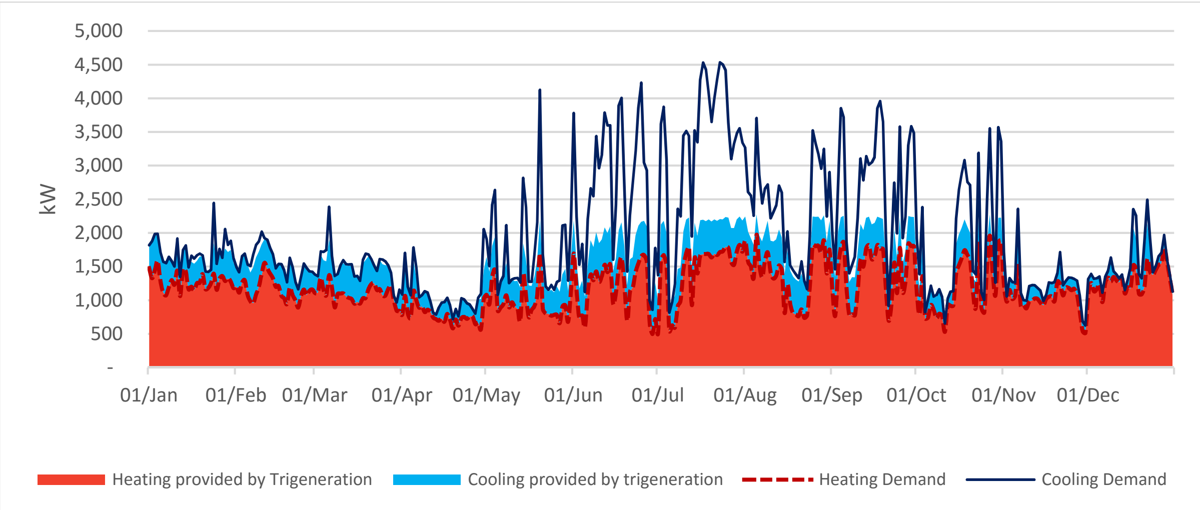

Figure 6. Tri Gen thermal utilisation analysis

Project Approval

The level of capital investment for the tri-generation project required approval beyond the BSC Galway site since corporate finance approval is required for all projects above a pre-determined value. For capital requests for large utility projects, BSC corporate facilities – Global Real Estate Facilities – are required to evaluate the proposed site-level investment and make recommendations regarding funding approval. Here the decision support framework of GEMS is utilised as follows.

Investment model

The detailed assessment formed the primary supporting documentation of the application for internal BSC project funding. As well as a calculation of primary energy savings, the technical assessment also identified some additional potential project supports and revenue streams which will constitute the investment model of the decision support framework. For the purposes of this work, the investment model investigated is that of BSC directly expending capital on the project supported by local State funding and other revenue streams. Following a process to validate the estimated energy savings, revenue streams, supports, and develop high level project cost estimates, a financial evaluation was carried to examine key cost-benefit analysis criteria, including return on investment (ROI), internal rate of return (IRR), net present value (NPV) and simple payback period (Figure 7).

Financial Valuation Results	
IRR	19.0%
Net Present Value	$ 841,053
Payback Period	3.90
Average ROIC	*26.2%*

Figure 7. Financial evaluation summary

Multi-criteria decision-making outputs

Besides the fulfilment of the technical selection criteria of BSC, any selected project must contribute to generate positive impacts in terms of economic, environmental and social criteria. For BSC it also implies that energy improvement projects must be executed where they are the most needed and can deliver their maximum contribution to achieve corporate sustainability goals. BSC uses a Multiple-criteria decision-making (MCDM) method based on fuzzy - Analytical Hierarchical Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [6]–[8] to facilitate a rational selection of energy improvement projects manufacturing sites globally. Each alternative can be evaluated using this fuzzy-AHP-TOPSIS method and ranked out of a discrete number of initiatives based on the quantitative and qualitative criteria presented in Figure 8.

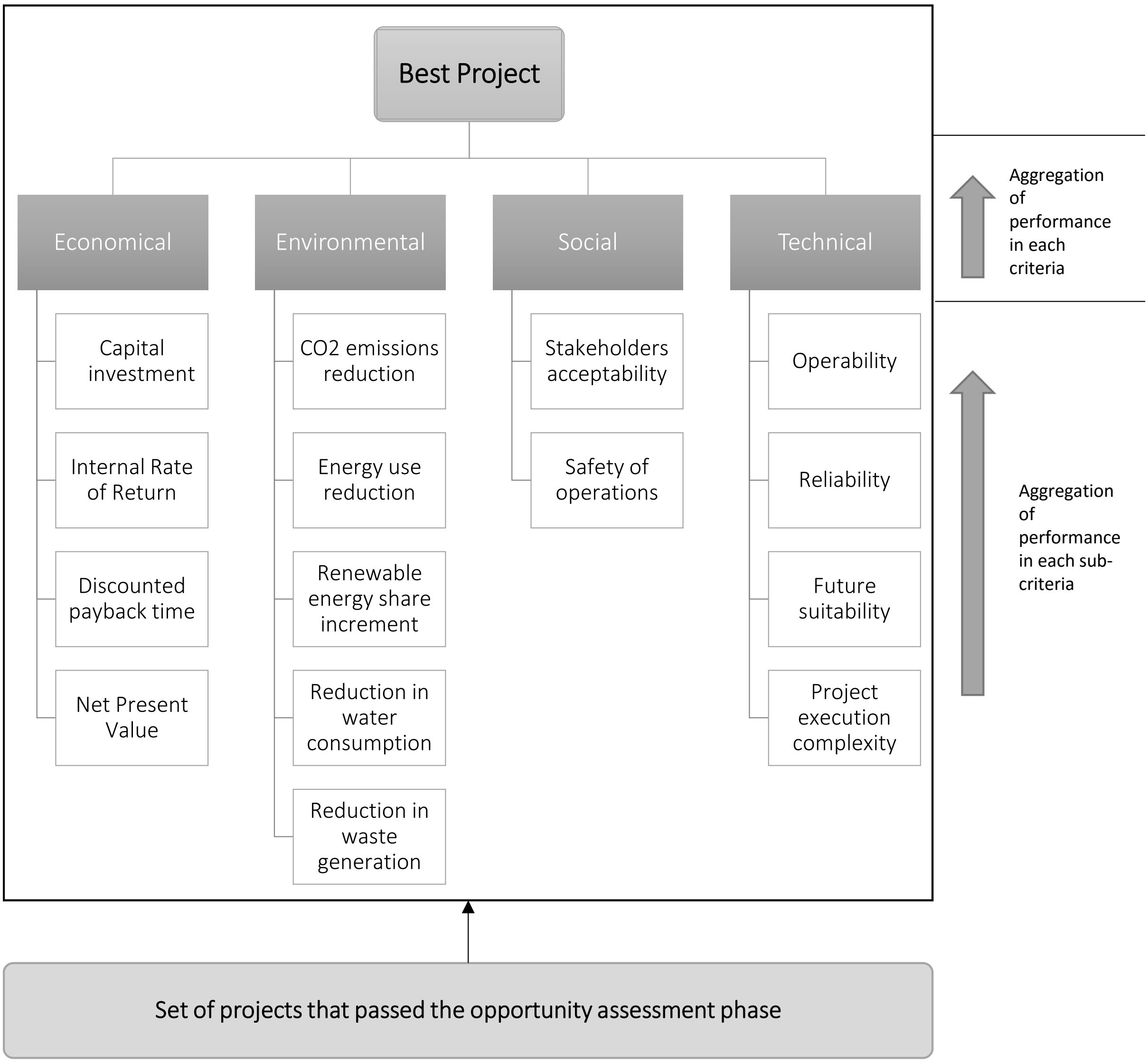

Figure 8. AHP structure and set of criteria for sustainability assessment of alternatives for BSC

For this case of study, BSC's MCDM method (under development) is applied to rank the best energy improvement project between those of Galway, Cork and Coyol using, as a first approach, the same weights for each criteria and sub-criteria from Figure 8. Figure 9 shows the performance of each project in each sub-criteria, which are divided into four main criteria groups: Financial, Environmental, Social and Technical. Information to fill these criteria was obtained through the technical assessment and capital application.

Financial criteria comes directly from the capital application as explained before. Environmental criteria information is obtained mainly through the technical assessment and represents the impact of each project, in environmental terms, for the whole corporation and thus allows to align each project with corporate goals in this regard. Performance in social and technical criteria is given in linguistic terms, which are integrated into the model using fuzzy logic.

				A1	A2	A3
Criteria	**Weight**	**Sub criteria**	**Weight**	**Galway**	**Cork**	**Coyol**
Name	**%**	**Description**	**%**	**Tri-generation**	**CHP**	**Ice Storage**
Financial	25	Capex ($)	25	$2,575,000	$1,346,000	$1,250,000
		Net present value ($)	25	$841,000	$1,900,000	$609,627
		Opex savings ($)	25	$588,000	$648,000	$347,000
		Payback time (yr.)	25	3.9	2.1	3.6
Environmental	25	CO_2 emissions reduction global (%)	34	1.9	1.5	0.0
		CO_2 emissions reduction site (%)	34	14.7	25.0	0.0
		Energy savings site (%)	33	15.0	49.0	14.0
Social	25	Safety of operations	50	High	High	High
		Stakeholders acceptability	50	High	High	Medium
Technical	25	Operability	25	High	High	High
		Reliability	25	High	High	High
		Future suitability	25	Medium	Medium	High
		Project complexity	25	Very High	Very High	Medium

Figure 9. BSC's MCDM method ranking for Galway, Cork and Coyol energy improvement projects.

The results in Table 1 show that in this case the best investment opportunity is the project for the Cork site, followed by the one for Galway, while the least attractive opportunity is given by Coyol. Between Cork and Galway, the former performs almost 40% above the later given its better contributions in terms of financial and environmental criteria. At the end of the study at corporate level, both projects were funded.

Table 1. MCDM results.

Rank	Alternative	Closeness to best %
1	Cork – CHP	0
2	Galway – Tri-generation	-60
3	Coyol – Ice Storage	-70

Conclusions

It is in the interest of every company to reduce their energy consumption and cost base. For multi-national companies, with a global production and manufacturing base, this requires the assessment of multiple variables across diverse countries, sites and individual segments of a product value-chain and life-cycle. This is currently a complex task, requiring integration and analysis of diverse data-sets. The GEMS framework provides a structured methodology for integrating these diverse data sources and support in the process of deciding the best approach for capital expenditure in energy improvement projects for a global corporation.

From the site's point of view, the key conclusions that can be drawn to date are:

- A consistent and robust approach to ranking of energy improvement projects across a global network is a critical input to a corporate-level decision support framework;
- Standardised performance improvement measures provide clarity on project outcomes for both the site and the corporation, thus simplifying and improving the project evaluation process;
- Clarity on key corporate-level project evaluation criteria enables an improved project assessment process at site-level;
- GEMS provides a critical role at site level for early opportunity identification, through network shared learning. In turn, dissemination of the tri-generation project outcomes via GEMS will enhance the network knowledge base and provide the basis of opportunity evaluation for other sites in the network;
- Of the three projects evaluated, both the Galway and Cork proposals received approval in 2015. The Coyol Ice Storage project has not been approved;
- Under the GEMS framework, sites are required to not only evaluate the financial benefits of their proposed project, but also the sustainability impacts for the site and ultimately the corporation. This not only serves the green and sustainable image of the site, but can also help increase site resilience in the case of energy supply interruptions or global price volatility;
- The GEMS system enables a corporate link at a site level which boosts the chances of project approval at the site level.

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