KES Transactions on Sustainable Design and Manufacturing II
Sustainable Design and Manufacturing 2015 : pp.450-465 : Paper sdm15-042

The application of web based Lean Manufacturing tools to support the implementation of ISO 50001: A Case Study

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Abstract

Large Manufacturing companies seem largely to fail in the integration of LEAN, sustainable and scalable certified energy management systems. Too often manufacturing companies spend time and resources focused on the systematic elements of an energy management system, and not enough on energy performance improvement. Processes such as Energy Performance indicators (EnPI) development, energy reviews and internal audits are commonly flawed in their initial set up and unwieldy in their operation. This is sometimes due to a lack of data to inform effective decision making due to a dearth of energy and associated production and scheduling information to key stakeholders, or a lack of effective tools to streamline and standardise their analysis and operation. In a survey of three large manufacturing companies, it was found that 70 – 85 days were spent implementing some of the key aspects of a structured energy management system. This paper focuses on the early stage development and use of automated tools to support the implementation of key areas of an ISO 50001 compliant energy management system with a view to reducing this resource burden.

1. Introduction

Manufacturing processes use one or more physical mechanisms to transform a material's form or shape utilising energy. The energy required for such operations is typically only partially transferred into a useful output (a machined part for example) with the remainder being transformed into product waste or residual heat during processing [1]. Based on 2014 figures, the manufacturing sector is a major consumer of energy worldwide with it accounting for circa 31% of primary energy use in total [2]. Worldwide industrial energy consumption was, in 2011, projected to grow to almost 72,000 ZW by 2030, this resulting in an average 1.4% per year increase [3]. One would assume that a manufacturing company's energy consumption is directly related to product manufacture but in fact supporting systems such as heating ventilation and air conditioning (HVAC), chilled water generation, compressed air generation and water treatment systems can consume over 50% of the energy utilised in a typical large industrial site [4]–[6].

In order to deliver energy efficiency in the manufacturing sector, three different approaches are broadly proposed; management led initiatives within companies, energy efficiency technology implementation and adherence to policies/regulations [3]. The purpose of an Energy Management System (EnMS) is to systematically integrate energy and carbon efficiency into an organisation and its implementation requires both financial and organisational resources [7]. The ISO 50001 EnMS standard was published in 2011, having been preceded by a number of national standards (e.g. Denmark: DS 2403:2001, Ireland: IS 393:2005, USA: ANSIMSE 2000:2008) as well as a European standard (EN 16001:2009) which ISO 50001 superseded and eventually replaced [7]. To date the research community has only begun to analyse the effectiveness of EnMS standards [8]–[11]. While the results of these studies indicate that an EnMS generally has a positive effect on carbon and ultimately economic performance, the effect is found to be stronger in the case of a certified energy management system [7].

1.1 Research Goal

Too often manufacturing companies spend time and resources focused on the systematic elements of an EnMS, and not enough on energy performance improvement. Processes such as Energy Performance indicators (EnPI) development, energy reviews and internal audits are flawed in their initial set up and unwieldy in their operation. This is sometimes due to a lack of data to inform effective decision making due to a dearth of energy and associated production and scheduling information to key stakeholders, or a lack of effective tools to streamline and standardise their analysis and operation. This paper hence focuses on the initial development and use of lean manufacturing based tools to support the implementation of structured energy management systems.

2. Tools to support ISO 50001 Implementation

Current research in the tool supported implementation and operation of the ISO 50001 EnMS standard seem focused on two distinct areas; the identification of the gaps to certification state of a company wishing to implement the standard and the assessment of the gap to exemplar performance of a company's existing energy management system via a maturity model assessment [12], [13]. There seems to be however a dearth of research into the tools required to help companies deliver on the specific requirements of the standard in an automated, structured and repeatable manner. From a commercial perspective, companies have at their disposal a suite of tools and ancillary systems to leverage from in order to deliver each of the clause deliverables as set out in the ISO 50001 standard. Table 1 details a non-exhaustive list of currently available commercial or academic tools which state that they can fulfil the requirements of a certified EnMS.

Commercially and academically available tools seem focused on the legislative, document management, audit management and monitoring and targeting sections of an energy

management systems operation. The more involved and bespoke to site operations elements such as the energy review and base lining, energy performance indicator development, action plan development and measurement and verification processes are largely devoid of any commercially available supporting tools. As a means of analysing if indeed it is true that in practice large manufacturing companies do not have at their disposal a suite of ISO 50001 supporting tools, three large manufacturing sector companies were surveyed by structured interview on their supporting tool use. The result of this work is detailed in the next section.

ISO 50001 Clause	ISO 50001 Deliverable	Tool Purpose	Tools Available to support development
Commitment	Policy	NA	NA
Planning	Legislative Review	Compile, notify and document a formal review of applicability of legislation to the energy use of the organisation	Envirolaw [17] Simplifi Compliance [18] Pegasus legal register[19] Acquitas Compliance[20]
	Energy Review & Base lining	Compile data on energy consumption over the past three years with a view to understanding trends in performance, identifying baselines, projecting future consumption and ensuring energy reduction action plans meet site targets	ePEP[14] IES[15] Energy Plus[16]
	Energy Performance Indicators	Identifying factors which affect the energy consumption of SEUs.. Develop EnPIs for the continuous monitoring of SEU energy use taking energy factors into consideration should a statistically significant relationship exist.	Most M&V packages claim this as part of their offering though no detail as to how it is achieved
	Measurement and verification	Development of M&V strategies to ensure that savings projected and achieved by energy action plan projects are validated	Most M&V packages claim this as part of their offering though no detail as to how it is achieved
	Objectives and Targets	NA	NA
	Opportunities & Action Plans	Development of an organisation wide energy savings ideas register, where projects deemed most beneficial in terms of company specific criteria are continually progressed to action plans	Enerit[21]
Implementation	Awareness & Communication		Manual
	Document Management	Manage EnMS documents in accordance with site procedures	Enerit[21] IBS Document Management Software[22] IQS document management[23] DocSpace[24]
	Operational Control including Procedures	Manage EnMS documents in accordance with site procedures	Manual

	and EnPIs		
	Energy Efficient Design and Procurement	Ensure new equipment and processes are designed with energy efficiency in mind	Manual
Checking	Monitoring & Measurement	Monitoring and management of SEUs in line with objectives and targets	Esight[25] EFT[26] Skyfoundry[27] Building IQ[28] Panoptix[29] Cylon Active Energy[30] ENMAT[31] Energy AnalytiX [32] ICIS Plant Energy[33] RSEnergyMetrix[34] ResourceKraft[35]
	Internal Audits	Checking and corrective action system to ensure EnMS effectiveness	Enviroaudit[36] MetricStream Internal Audit [37]
	Non-conformance tracking	Deviation tracking system	Enviroaudit[36]
Review	Management Review	NA	NA

Table 1: Commercial and Academic tools available to support the delivery of ISO 50001

3. Case Studies of tools used to implement ISO 50001

Table 1 outlines many of the tools available to assist companies in the implementation of the differing requirements of an ISO 50001 EnMS. With a view to contextualising the use of these tools in practice, the same three manufacturing sector companies were surveyed by structured face to face interview in order to determine which tools they utilised to deliver these requirements. Two of the three companies are certified to ISO 50001 (at the time of writing) while one is six months into a twelve month roadmap towards achieving certification. The results from this analysis are displayed in Table 2. Each company representative was also surveyed to quantify the time spent operating their EnMS. In order to ensure interview responses were structured in terms of the results obtained, the EnMS was broken down into eleven constituent parts (as detailed in Figure 1). Each company representative was then interviewed to determine the quantity of time (to the nearest 5 day block) that they or another responsible person within the company spent on each of the eleven tasks. This was not a simple question and answer session as in some cases the company energy manager had to be interrogated a little to understand the exact process that they followed in achieving the EnMs task. For example, if one were to quantify the time spent developing energy performance indicators, the energy manager's initial response typically only took their immediate actions into account and not the affect that that action had downstream of them in terms of the time spent by personnel reporting to them in delivering the same item.

It is clear from this work that support tools are utilised in the development of some of the key deliverables of ISO 500001 while in other areas support tools do not either exist or have been deemed ineffective when compared to the either manual or spreadsheet based work currently undertaken. As a case in point, monitoring and targeting systems and document management systems are utilised by two of the three companies analysed to fulfil the requirements of the ISO 50001 standard in terms of effective monitoring and measurement and document control. This is in stark contrast to the lack of use of a support tool in the review of energy performance and consequent base lining where none of the companies utilise a support tool, and instead use a mix of manual calculation, spreadsheet based assistance and external consultant reviews to fulfil this requirement.

Figure 1 details the estimated number of days spent in the development of processes to fill this support tool gap with a bespoke method of fulfilling the requirements of the ISO 50001 standard for that aspect of the system. Significant time is spent by company resources in the development of the energy review and base lining, EnPI's, opportunities and action plans and M&V plans. In total the companies surveyed as part of this research spend between 70 and 85 days developing bespoke, highly manual, and in many cases not either easily replicable or cross site repeatable methods of fulfilling the requirements of the standard. Some of the reasons given by company personnel for the use of these company specific and thus bespoke manual methods of data analysis were the lack of available tools to undertake the analysis, the lack of available data in an an automated manner to integrate with existing tools even if they did exist, and speed of analysis in terms of existing knowledgebase. In the opinion of the authors this bespoke method of is both time consuming and difficult to scale to other individuals in the same company or to sister sites in the same larger organisation. It is also data input heavy and thus potentially error laden due to its manual nature. An opportunity for improvement` therefore exists to collect, analyse and document data in an easily and consumable manner utilising automated tools where possible.

ISO 50001 Clause	ISO 50001 Deliverable	Dairy Processing Company	Pharmaceutical plant	Medical Device Manufacturer
Commitment	Policy	NA	NA	NA
Planning	Legislative Review	None	Envirolaw	Envirolaw
	Energy Review & Base lining	Manual in house	Consultant Report	Manual in house
	Operational Control including Procedures and EnPIs	Manual	Manual	Manual
	Measurement and verification	Manual in house	Consultant Assisted	Manual in house
	Objectives and Targets	Manual in house	Manual in house	Manual in house
	Opportunities & Action Plans			
implementation	Awareness & Communication	Manual Ad Hoc	Manual Ad Hoc	Manual Ad Hoc

	Document and Direction	MS Sharepoint	DocSpace	Adaptiv
	Operational Control including Procedures and EnPIs	Manual	Manual	Manual
	Energy Efficient Design and Procurement	Manual	Manual	Manual
Checking	Monitoring & Measurement	MS Excel	EFT	eSight
	Internal Audits	Manual	Enviroaudit	Enviroaudit
	Non-conformance tracking	Manual Spreadsheet based	Enviroaudit	Enviroaudit
Review	Management Review	MS Powerpoint	MS Powerpoint	MS Powerpoint

Table 2: Tools utilised by three large manufacturing companies to support the implementation of ISO 50001

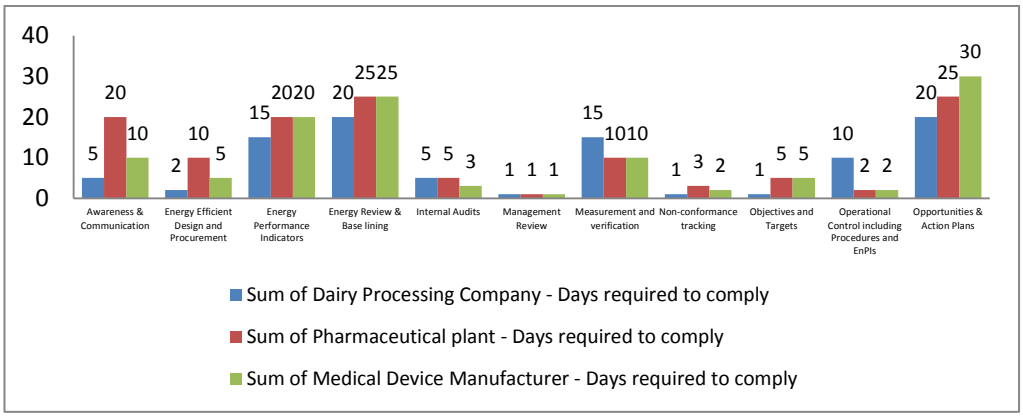

Figure 1: Survey results of three large manufacturing companies detailing the resource days required to implement ISO 50001 deliverables

4. Development of tools to support ISO 50001 implementation

Based on the results of the survey companies displayed in Figure 1, four key areas were focused upon with a view to developing tools which could assist companies in fulfilling the requirements of each deliverable, namely the energy review, action plan development, M&V and EnPi analysis. This work has sought to standardise the methods by which companies seek to demonstrate compliance in each area, while also reducing the resource burden in the process. The ISO 50001 EnMS standard requires that companies carry out an energy review. In order to demonstrate that this has been adequately completed, companies typically either carry out in depth in house manual work to draft a document which details how each aspect has been fulfilled, or procure an external consultant to undertake this work if internal resources are either unavailable or without the required skillset. The result of this work is hence bespoke. It typically houses much superfluous information which is present in other aspects of the company's operations. The authors have worked with many large companies in the development and implementation of EnMSs, and have reduced the burden of documentation with each implementation using

lean principles. Lean Production originates from the Toyota Production System (TPS); a term coined by Womack et al. in 1990 [38] and is practiced widely today among large manufacturing companies. Much research has taken place in the application of lean manufacturing techniques to environmental performance improvement with lean tools demonstrated through study to be effective in this paradigm [39]. A significant link has also been made to the effective reduction of energy and waste when lean manufacturing principles are applied [40], [41]. By utilising existing systems and processes already in use within large manufacturing companies, the authors have successfully leveraged from the A3 problem solving framework typically used by lean experts to find the root cause of variations in process operations to develop the Energy Review A3 methodology detailed in Figure 3. This one page A3 sized output covers all aspects of the energy review clause in terms of the expected deliverables and leverages from existing systems. This method of documenting an energy review has been implemented within three companies to date in Ireland, each of which has been successfully externally certified.

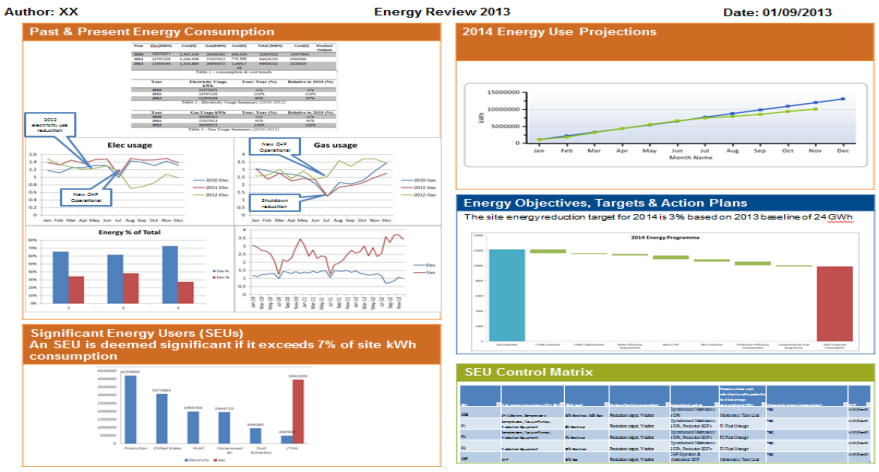

Figure 2: Energy Review A3

The authors have also developed an A3 style output (Figure 3) to guide the end user through the identification of variables affecting energy performance process. This process leverages from LEAN manufacturing techniques by utilising the Ishikawa process. This process is utilised to identify potential causes of a specific event or variation and have been used successfully in this regard by other researchers[42], [43].. The authors then drew on statistical analysis in the form of linear regression analysis to determine if high level linkages existed between the identified variables and the significant energy user under analysis. Based on this analysis, variable linked EnPIs would hence be put forward for use in the everyday operation of the energy management system.

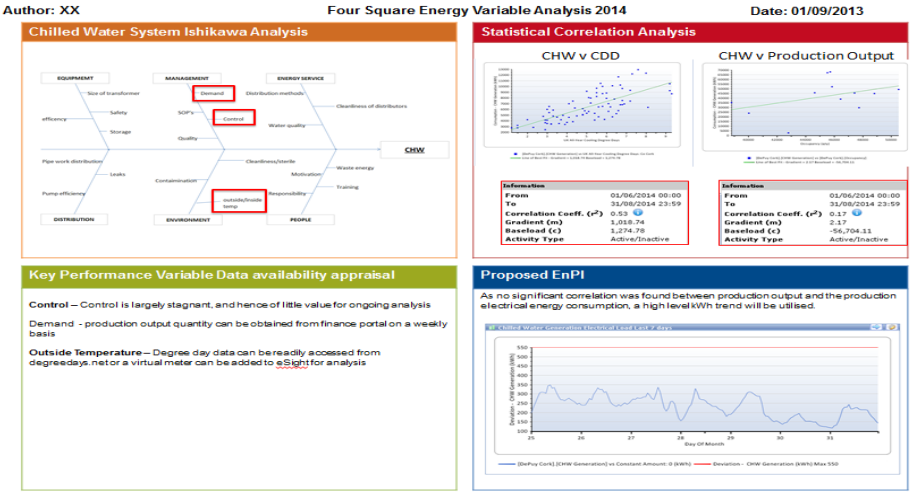

Figure 3: The Four Panel EnPI A3

The Opportunities and Action plan register

The authors have also developed an energy savings opportunities register which encompasses a rating and prioritisation method. This MS Excel based register once filtered, links directly to another worksheet within the MS Excel workbook where a programme of energy savings projects resides displayed in the form of a waterfall chart referenced against the site energy base line. This multi sheet MS excel workbook (Figure 5) has been designed to update automatically once a new project is added and rated, thus allowing its continued and dynamic use. It also encompasses an measurement and verification sheet where the use is prompted to document the Measurement & Verification techniques employed for each project as well as the evidence of the results.

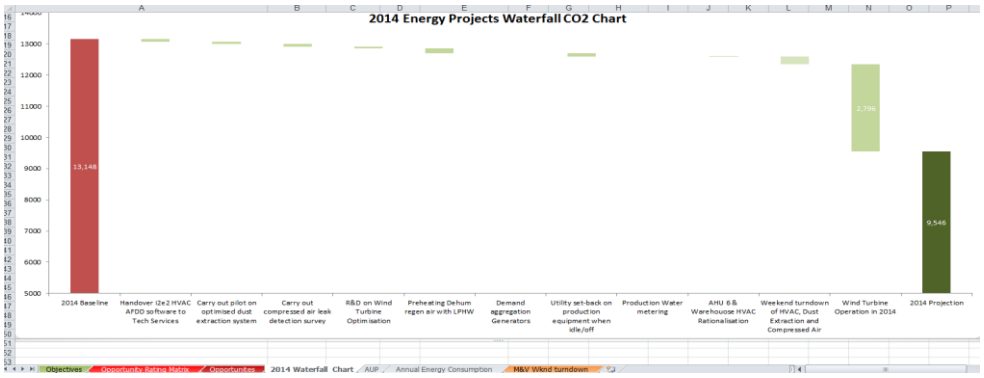

Figure 4: The Opportunities and Action plan register

The next step in streamlining these processes would be to migrate these tools to the web. Web based ISO 50001 support tools could either be directly connected to data sources or alternatively batch uploaded with the data for analysis. This would result in improvements over their current manual operation namely;

1) The time required to deliver the requirements of the standard would be significantly reduced due to the tools leveraging on existing company data
2) The analysis would be carried out by the software in a formalised and repeatable manner without the end user having to acquire knowledge to implement it
3) The web based roll out would ensure that group certification within one organisation would be consistent and auditable in an efficient manner

Based on survey feedback and with a view to developing a demonstration version of one of the tools, a data pipeline is currently under development. This will allow energy and related data to be collected for analysis and subsequently displayed via a dashboard in much the same format as illustrated in Figures 2 - 4. A data pipeline consists of sequential components, which are used to ingest, process, persist and analyse data. First, data is ingested in real-time using an appropriate connector. Second, the ingested data is passed to a cleaning and transformation process to prepare the data for aggregation. Third, the cleaned data is passed to an aggregator that produces the data views that are needed to fulfil ISO reporting and analysis requirements. Finally, the reports and accompanying analysis are automatically compiled and made available to decision-makers. In the context of ISO 50001, a data pipeline can provide an organised workflow for the transformation of disparate and heterogeneous raw data, to a meaningful and contextualised state. Figure 5 illustrates a proposed data pipeline which could potentially be used by these tools. At the top-level, a cloud-based repository is used to store site configuration and settings, such as the location and type of each data source pertaining to ISO 50001.

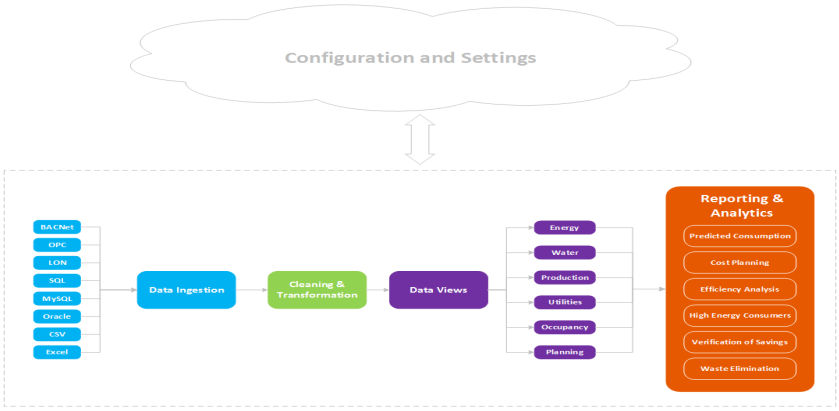

Figure 5: Data Pipeline Illustration

The proposed data pipeline provides a conceptual and modular framework that can be progressed further, and implemented using various well-known IT architectures, such as N-tier, Layer and Service-Oriented Architecture. As exhibited by this proposed data pipeline, it is necessary to consider the different concepts and workflows that are needed to develop an ISO 50001 information management system, before focusing on the implementation and low-level technology details. It is envisaged that this data pipeline will be utilised to test the operation of one of the aforementioned tools before expanding to the others. It is also planned to implement this tool as a supporting tool on one of the companies that took part in this research in parallel with their existing systems as a means to determining whether it is certification ready.

5. Conclusions and Next Steps

A significant opportunity exists to develop web based tools to support the implementation of key deliverables of the ISO 50001 standard. Companies surveyed as part of this research spend in excess of 70 resource days undertaking just four key aspects of the management system. The repetitive and data hungry nature of this work have already been templacised in MS excel and show great potential for a semi-automated web based implementation.

Acknowledgements

The authors would like to acknowledge the funding support of Science Foundation Ireland (SFI) and the Marine & Renewable Energy Ireland (MaREI) research centre, without who's support this research could not have been undertaken.

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Reviewer 1

An interesting paper, I would suggest that it is accepted however a number of comments can be found hereafter that can help. In general the paper is quite lengthy, the authors should check again the conference rules.

Title:
- no need to put ?Title:? in the title

Response to Reviewer: "Title" removed

Abstract:
- is there a reason for using capital words for Lean?

Response to Reviewer: No. Amended in line with reviewers comment.

- "it was found that 70 ? 85 resource days? over a period of a year?

Response to Reviewer: The 70 – 85 resource (man) days would be carried out by one or more employees/contractors in parallel. As such, the work could typically take 5 – 10 weeks in total over the year to complete with more than one person working full time on the tasks at hand. The word "resource" has been removed in an effort to clarify this point.

Introduction:
- well written introduction, with many relevant publications. The research gap is identified (although not explicitly stated) but the authors could have linked the research gap with their approach (the goal of the paper) a little bit more comprehensively and in detail

Response to Reviewer: Section 1.1 amended to explicitly relate the gap to the intended goal of the research and hence the paper

- the authors are suggested when presenting statistical data, to refer the year that these data were collected

Response to Reviewer: Very pertinent point. The authors have amended the introductory section to include the years in which the data was collected/projected.

- ?...can consume over 50% of the energy utilised in a typically factory, ?? a reference is needed to support this statement

Response to Reviewer: References 4-6 added. The 50% figure was based on an average across all the manufacturing support system benchmarking studies carried out over a three year period in Ireland from 2006 – 2008 by the Sustainable Energy Authority of Ireland.

Tools to support ISO 50001 Implementation:
- "Table 1 details a non-exhaustive list of currently available commercial or academic tools which state that they can fulfil the requirements of a certified EnMS? why did the authors selected the specific tools?

Response to Reviewer: The tools tabulated in Table 1 are based on the authors own knowledge of those used by companies to support ISO 50001 implementation, the results of the site interviews to ascertain which tools the case study companies utilised to support their management system work, reviews of the tools referenced in literature, and finally a desktop based review of all those tools considered viable to support the various requirements of ISO 50001.

- Table 1 caption: the authors state that the table summaries the academic and commercial tools, thus it would be suggested that these are presented in separate columns.

Response to Reviewer: Further guidance on this no doubt well founded point would be appreciated.

Case studies:
- ?...three manufacturing sector companies were surveyed by interview?? structured interviews? more information on the way the interviews were performed, the type of questions used, the way the results were analysed should be included

Response to Reviewer: The following paragraph has been added to section 3 to clarify the interview process

"Each company representative was also surveyed to quantify the time spent operating their EnMS. In order to ensure interview responses were structured in terms of the results obtained, the EnMS was broken down into eleven constituent parts (as detailed in Figure 1). Each company representative was then interviewed to determine the quantity of time (to the nearest 5 day block)

that they or another responsible person within the company spent on each of the eleven tasks. This was not a simple question and answer session as in some cases the company energy manager had to be interrogated a little to understand the exact process that they followed in achieving the EnMs task. For example, if one were to quantify the time spent developing energy performance indicators, the energy manager's initial response typically only took their immediate actions into account and not the affect that that action had downstream of them in terms of the time spent by personnel reporting to them in delivering the same item".

Developments of tools?:
- "The authors have also developed an A3 style output (Figure 4) to guide the end user through the identification of variables affecting energy performance process.? the authors possibly mean figure 3

Response to Reviewer: Thank you for identifying this internal reference error. Internal reference amended to Figure 3 as stated.

Reviewer 2

Overall a very interesting paper that makes for valuable insight to the work in three cases. The accept recommendation reflects the value of the paper, however, there are a number of issues that could/should be addressed.

First the paper is long with significant discussion. Whilst the description and subsequent discussion is valuable perhaps this is best left to a journal paper and this conference paper should be more compact and focused, if only to comply with the conference page length requirements. Related to this is sometimes 'loose' description, it is possible that some of the discussion, even individual sentences could be made a lot more compact.

Response to Reviewer: The introduction section has been tightened up in terms of language and content.

Second, this is a conference paper and 4 pages of references can be considered excessive. It is great that the authors present the rigour but perhaps it is not all needed.

Response to Reviewer: Some references have been removed. A large portion of the remaining references are in relation to the tools identified in Table 1 and as such are deemed necessary to lend context to the content.

Perhaps the data pipeline should be covered before the concluding remarks?

Response to Reviewer: This section has been moved to the previous section as requested by the reviewer.

Finally there are few minor typos (e.g. 150001).

Response to Reviewer: Paper reviewed for typos. Thank you for your feedback.

Overall the work makes interesting reading for the combination of standards, lean and energy. There is a good collection of cases. There are valuable insights into the practice implementation of the tools and insightful reflections on practical considerations.