Agile Energy Modelling: A Business Centric Approach

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Abstract – **Energy management is a crucial aspect to global sustainability. Multinational Manufacturing Corporations' (MMC's) utilise a large amount of energy, making energy optimisation a priority. The ability to evaluate MMC's total energy utilisation effectively and efficiently is a challenge. This research focuses on holistically modelling the business energy systems of MMC's by adopting a business process centric approach. MMC's conduct business based on global or regional business processes depending on the function, global/regional functional enablement. The agile energy model proposed in this research integrates key knowledge areas of energy assessment, business management, business processes and system engineering, to deliver a comprehensive simulation toolset for energy quantification, evaluation and optimisation.**

Keywords – **Business process modelling, energy modelling, multinational manufacturing corporations**

I. INTRODUCTION

The manufacturing industry is critical to a country's, and global, development as manufacturing supports the growth of the local economy by providing employment and investment opportunities; however this comes with considerable energy requirements and environmental influences [1].

Traditionally, profit has been the key measure of success of a manufacturing corporation, but this has been ruthlessly challenged due to cost and security of supply of natural resources, fuels and power, increasing awareness of the impacts of industrial processes on the environment, stringent energy and environmental policies and social responsibility. This has resulted in a shift in focus of profitability as a measure of success to sustainability as a contemporary measure. Sustainability integrates the economic, environmental and social impacts of a business, to provide a holistic measure of success.

Energy is a common element influencing all three pillars of sustainability; security of supply is essential to economic development, which in turn has a cascading effect on social development and environmental management. Reference [2] reported that approximately 33% of the world's energy consumption and 36% of the carbon dioxide emissions were due to manufacturing industries.

Management of MMC's are complex as both the internal (within the corporation) and external (the local/global) environments with respect to policies, governance, environmental and labour regulations, etc. have to be addressed and integrated whilst achieving business objectives and business sustainability. MMC's have the opportunity to improve energy usage but challenges exist on the quantification side. The traditional operational energy evaluation mechanisms don't include areas such as logistics, IT, communications, maintenance and other key areas of the business. This research proposes using business processes to conduct a comprehensive MMC energy evaluation and Cleaner Production (CP) substitution. The key advantage of this approach relates to the fact that most, if not all, MMC's operations are based on business processes thus guaranteeing the comprehensiveness of the proposed research. The research details the methodology adopted in maturing a business process centric energy evaluation toolset. The agile energy model is flexible for use across all business levels, shop floor to global, and adaptable to each business type.

II. LITERATURE REVIEW

Sustainable development as defined by the United Nations Brundtland Commission is, "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3]. Reference [4] stated that, "It is a process by which companies integrate their economic, social and environmental objectives into their business strategies and optimize the balance between these three dimensions." The three pillars of sustainable manufacturing are: economic, social and environment, with each pillar having its own components as detailed by [5].

Reference [6] reported sustainability as a strategic business imperative that has to be integrated into the business. The survey also identified the following sustainability activities as commonly being practised; reduction of energy usage in operational activities, waste reduction and reputation management [6]. The benefits of sustainability includes; lowering of business risk, mitigation of waste generation and increased efficiency [4].

However, implementation of sustainable development at MMC's is challenging due to its inherent complexity. Reference [7] states that the results of the annual business sustainability ratings and GlobeScan State of Sustainable Business Survey (2013) show that, "it is the integration of sustainability into core business functions which remains the most important leadership challenge." Some of the drawbacks of multinationals, which impact on sustainability, include; market dominance, bureaucracy and inability to adapt and innovate [8, 9]. This is further affirmed by the findings of [10], which reported that, "high-performing global companies consistently scored lower than more locally focused ones on several dimensions of organizational health.”

Energy which is required by all sectors of the manufacturing industry influences all three pillars of sustainability, refer to Fig. 1. Security of supply of energy facilitates an increase in manufacturing outputs for local use and export. This promotes the growth of the local economy, which improves standard living conditions but adversely increases environmental effects, such as greenhouse gas emissions, SO_x and NO_x emissions, waste production, etc.

The manufacturing sector is accountable for 33% of the world energy consumption, with [11] finding that manufacturers can reduce production energy consumption by 20-30% [2]. Thus evaluation and optimisation of business energy systems is essential towards the achievement of sustainable development.

Energy models are one of the toolsets available for energy system evaluation and can be categorised into four groups: optimisation models, simulation models, power systems and electricity market models and qualitative and mixed method scenarios [12]. Energy model applications include; medium to long term energy planning, techno-economic analysis, policy analysis, cost analysis and reduction in greenhouse gas emissions.

An MMC by definition has business sites across various geographic regions spanning international borders. The business sites can vary from manufacturing, warehousing to corporate, thus having varying business objectives and constraints. Each MMC business site has its own specific energy profile, which is dependent on the site activities, size and availability and cost of energy. The diversity and complexity of the energy profiles of the various MMC sites negates a one fit energy optimisation solution.

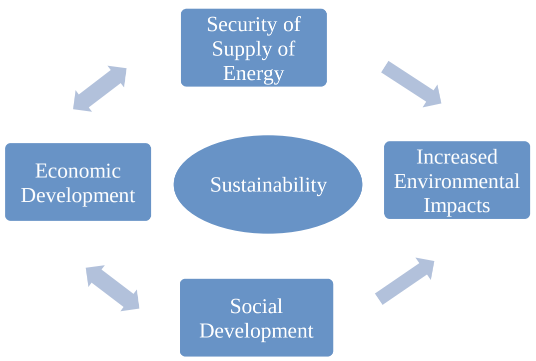

Fig. 1. Energy and sustainability

This diversity and complexity extends to management of MMC’s, which is further complicated by differences in regulations and policies with respect to trade, labour and environmental and social responsibility across international borders. Business process modelling is a universal tool for the management of MMC’s. Reference [7] defines the business model as, “a conceptual tool that contains a set of elements and their relationships and allows expressing a company's logic of earning money.” It details the execution of the business strategy via the operational activities, which is required by every MMC [7]. Business process models may be global or adapted for site specific conditions, depending on the business function. Application of business process models extends across all hierarchical business levels and disciplines; HR, IT, manufacturing, logistics, etc.

The drive for integration of sustainability into the business has resulted in traditional business models evolving into sustainable business models, but these models still have to be economically viable [13]. Reference [7] also states that, “Business models for sustainability must also add a positive social value and/or minimize environmental impacts.” The components of a sustainable business model include; resource efficiency, social relevance, localisation and engagement, longevity, ethical sourcing and work enrichment [7]. Donaldson and Preston identified six stakeholders of sustainable business models; customers, investors and shareholders, employees, suppliers and business partners, the environment and society perspective [13]. The components and stakeholders of a sustainable business model are indicative of a holistic business view. All MMC’s operate on business processes, and with the evolution of traditional business models into sustainable business models, it is a platform for business energy evaluation and optimisation.

Holistic and integrative approaches to energy and sustainable business modelling are essential to developing representative energy models of the dynamic manufacturing environment. This links closely to the concept of systems thinking, which [14] defined as, “perceives the world as a complex system and supports the understanding of its interconnectedness and interrelationships.” Key aspects of systems thinking are the identification of the levels of hierarchy within the system and the focus on the positive and negative feedback relationship of elements, which is essential in energy modelling [15]. Systems’ thinking has been applied across varying disciplines, including strategy, information systems and knowledge management, corporate social responsibility, production, project management, ecology, environment, medicine and health [15].

This research develops an agile energy model integrating key knowledge areas of energy assessment, business management, business processes and system engineering to deliver a comprehensive simulation toolset for MMC energy quantification, evaluation and optimisation.

III. MODEL CONCEPT

MMC's typically have a hierarchical structure, with the business strategy being the apex and the operational activities the base. Business processes are the links among these levels by the application of integrated IT systems such as Enterprise Resource Planning (ERP)/ Manufacturing Execution Systems (MES) and Plant Control Networks (PCN). The Manufacturing Enterprise Solutions Association (MESA) model and the hierarchical structure of MMC's formed the basis for the development of the hierarchical business energy framework. Fig. 2 shows the business energy framework, which comprises five levels [16].

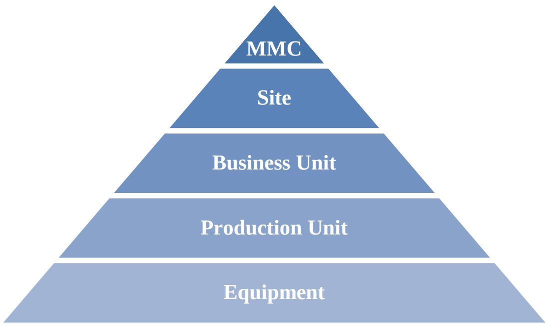

Fig. 2. Hierarchical business energy framework

Business processes are also categorised into different levels, as its requirements differ across the business structure [17]. Three levels of business processes are considered: business, functional and operational.

Key characteristics of the agile energy model include:

- Generic and reproducible, to be applied to a multitude of business enterprises.
- Ease of use, requiring minimum specialised knowledge.
- Minimum modelling and data collection time.
- Interlinking and integration of local and global influences.
- Non-linear model.

The key steps followed for this research are:

- Development of database of business processes
  A database of core business processes is developed for future use. Business processes are extracted from the database and modified to the meet the requirements of each specific MMC, as required. This modification eliminates the repetition of tasks, reduces modelling time and supports knowledge transfer for improved model outputs.

- Development of database of energy resources
  Each energy resource is classified according to design characteristics, operational mode and operational parameters, following a tiered approach. For each step of the business process the user answers limited questions specific to the energy resource/s required. The user's response directs the retrieval of the appropriate resource from the database.

- Hierarchical classification of energy resources
  The hierarchical classification of energy resources occurs simultaneously with the development of the database. It is based on the energy requirement and size of each energy resource and is classified as either low, medium or high. The classification is based on the commercial availability of the specific energy resource.

- Development of energy model for each energy resource
  The models are based on mass and energy balances, equipment efficiency, run time, maintenance, etc.

- Agile energy model
  A non-linear business energy model is developed, as a proportional change in energy consumption due to variable changes cannot be assumed. Inter-relationships and interdependencies are integrated and modelled.

- Agile energy model validation

- Application of agile energy model

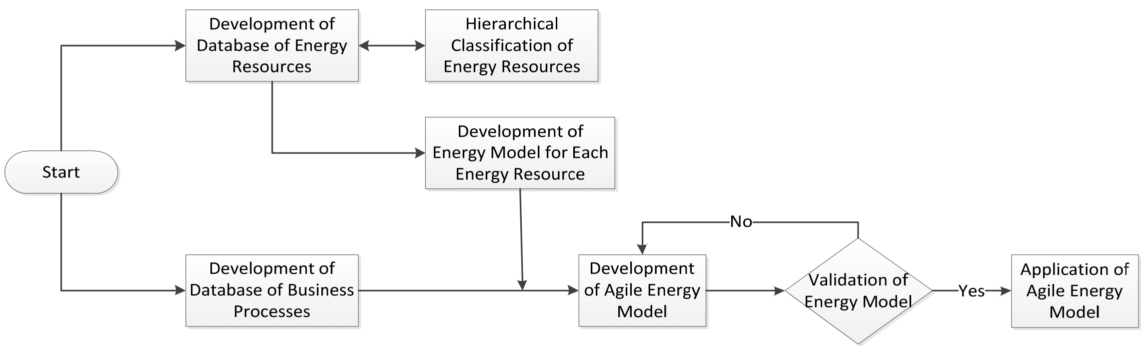

Fig. 3. Framework for agile energy model

A. *Approach to Agile Energy Model Development*

The proposed model development is systematic with a number of activities occurring concurrently. The framework for the model development is shown in Fig 3.

B. *Scenario of Model Application*

The scenario considered is the optimisation of boiler utilisation.

As the agile energy model approach is business centric, the initiation point is the selection of the business process from the database, as per the process described in Table 1. Fig 4 and Table 2 illustrates the process for energy evaluation via business processes.

The user inputs are essential operational data and easily obtainable when compared to traditional energy models, where the user requirements are data and time intensive. Fuzzy logic is applied to convert the users "fuzzy inputs" into "crisp inputs" for energy modelling accuracy and reliability. Consider the second step in the boiler utilisation business process; the user inputs for the agile energy model are steam, water and fuel rates, steam temperature and pressure, boiler power rating and air to fuel ratio. Minimal data on the design characteristics of the boiler is required, such as the number of boiler passes, boiler losses, burner characteristics, etc.

TABLE 1
PROCEDURE FOR SELECTION OF BUSINESS PROCESS

Selection of BP	User Inputs for Database	Database Link
Step 1: Select the business division	The various business divisions such as finance, logistics, manufacturing, engineering, etc., are displayed for selection. In this scenario manufacturing is selected.	Selection of the business division directs the model to extract the relevant functional areas from the database.
Step 2: Select the functional area	The various functional areas in the selected business division are displayed for selection. In the manufacturing division the functional areas include production planning, maintenance, operational, etc. For this scenario the operational functional area is selected.	Selection of the business functional area directs the model to extract the relevant operational business processes from the database.
Step 3: Select the operational business process	The various operational business processes for the selected functional area is displayed. For this scenario the boiler utilisation process is selected.	The selected operational business process is extracted from the database. The database business process is compared to the user's business process to determine if modifications are required.

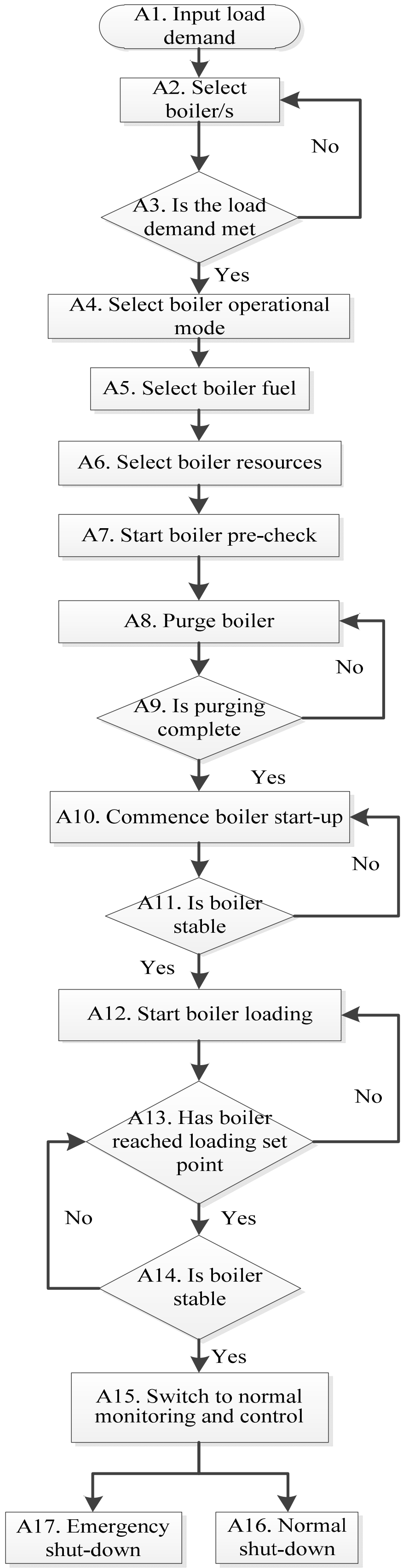

Fig. 4. Boiler utilisation process

TABLE 2
PROCESS FOR ENERGY QUANTIFICATION

Activity No.	User Inputs	Link to Database
A1	The user enters the load demand in the system to initiate the boiler utilisation process.	No link to the energy resources database.
A2	The user is required to answer questions with respect to the size and capacity of the boiler/s	The user responses are the criteria to filter and extract the potential boilers from the database. These boilers are displayed to the user for selection, with each of the selected boilers having an attached energy demand.
A3	The system checks if the selected boiler/s will achieve the load demand.	No direct link to the energy resources database.
A4	The user selects the boiler operational mode from the control system.	No direct link to the energy resources database.
A5	The available fuel categories are displayed to the user for selection, such as coal, natural gas, biomass, diesel, etc.	The available fuels within the selected category are extracted and displayed for selection. If coal is considered; the various coal types such as bituminous, sub-bituminous, lignite or anthracite are displayed, with each specific coal having a calorific range. The user selects the specific coal and may enter a calorific value, if it is available.
A6	The resources such as water, air, burner pilot fuel, etc., are selected by the user. For each of the resources the volume/ mass flow, pressure, temperature and water quality are user inputs.	As per the process above, the user responses filter the database for potential options for each of the resources for display and selection. An energy demand is attached to each resource, if applicable.
A7	The user conducts the boiler pre-check, as per the procedure detailed on the system.	No link to the energy resources database.
A8	The user follows the process described in Table 1 for the retrieval of the boiler purge process from the database.	The boiler purge process is retrieved from the business process database and the energy is quantified as per this process.
A9	The user enters a response based on the results of purging.	No link to the energy resources database.
A10	The user follows the process described in Table 1 for the retrieval of the boiler start-up process from the database.	The boiler start-up process is retrieved from the business process database and the energy is quantified as per this process.
A11	The user enters a response based on the monitoring results during start-up.	No link to the energy resources database.
A12	The user follows the instructions detailed on the system. If additional resources are required, the “select boiler resources” process step is followed.	If additional resources are required, the “select boiler resources” process step is followed. If no additional resources are required there is no link to the database.
A13	The user enters a response based on the monitoring results during boiler loading.	No link to the energy resources database.
A14	The user enters a response on the system.	No link to the energy resources database.
A15	The user answers questions with respect to the type and number of instrumentation and control equipment on the boiler.	The user responses are the criteria to filter and extract the instrumentation and control equipment from the database for display and selection. Each instrumentation and control equipment selected has an attached power demand.
A16	The user follows the process described in Table 1 for the retrieval of the normal shut-down process from the database.	The normal shut-down process for the boiler is retrieved from the business process database and the energy is quantified as per this process.
A17	The user follows the process described in Table 1 for the retrieval of the emergency shut-down process from the database.	The emergency shut-down process for the boiler is retrieved from the business process database and the energy is quantified as per this process.

Using the process described in Fig 4 and Table 2 the following data is obtained: energy demand of each energy resource, process steps and the complete process and mass/volume and size requirements of all resources. This forms the baseline energy demand, which is evaluated as per the process shown in Fig 5.

The model is intelligent with respect to identifying optimum solution/s and providing recommendations on optimisation opportunities and alternatives were possible.

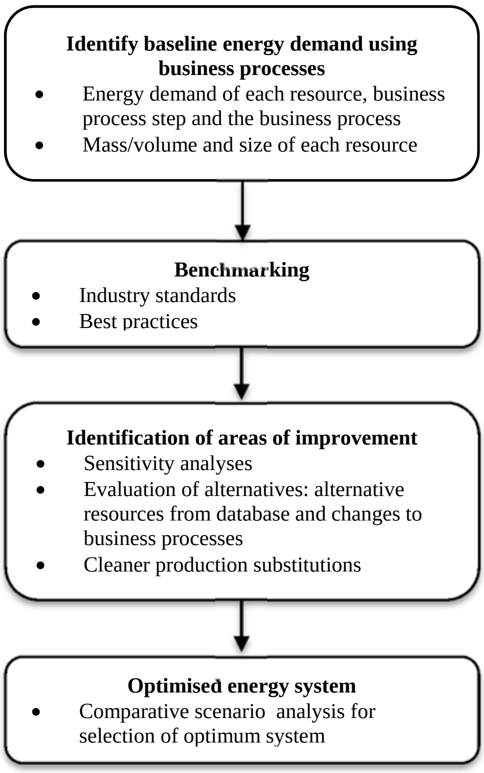

Fig. 5. Process for evaluation of energy demand

IV. CONCLUSION

The characteristic feature of the proposed agile energy model is the utilisation of business processes for energy evaluation and optimisation. Business processes are a fundamental necessity of MMC's and commonly utilised for business management, thus an appropriate platform for business energy evaluation.

The business process and energy resource databases are the building blocks of the model, as it is the primary data repository of the model. These databases support the realization of the model characteristics namely: reproducibility, ease of use and minimum modelling time.

The two databases enable the application of a simple methodology for the evaluation of complex business energy systems.

REFERENCES

[1] J. R. Duflou, et al., "Towards energy and resource efficient manufacturing: A processes and systems approach," *CIRP Annals - Manufacturing Technology*, vol. 61, no. 2, pp. 587-609, 2012.

[2] International Energy Agency, "Tracking industrial energy efficiency and CO_2 emissions," Organisation for Economic Co-operation and Development, 2007.

[3] Sustainable Development - Concept and Action, Available: www.unece.org/oes/nutshell/2004-2005/focus_sustainable_development.html [2016, April].

[4] A. Gunasekaran and A. Spalanzani, "Sustainability of manufacturing and services: Investigations for research and applications," *International Journal of Production Economics*, vol. 140, no. 1, pp. 35-47, 2012.

[5] H. I. Garbie, "Sustainability optimization in manufacturing enterprises," *Procedia CIRP*, vol. 26, pp. 504, 2015.

[6] S. Bonini and A. Bove, "Sustainability's strategic worth: McKinsey Global Survey results," *McKinsey & Company, New York*, 2014.

[7] R. Rauter, R. J. Baumgartner and J. Jonker, "Going one's own way: Drivers in developing business models for sustainability," *Journal of Cleaner Production*, 2015.

[8] M. F. Guillén, "Understanding and managing the multinational Firm," 2013.

[9] Multinational Corporations: Good or Bad, Available: http://www.economicshelp.org/blog/538/economics/multinational-corporations-good-or-bad/. [2016, January].

[10] M. Dewhurst, J. Harris, S. Heywood and K. Aquila, "The global company's challenge," *McKinsey Quarterly*, vol. 3, no. 1, pp. 76-80, 2012.

[11] S. Mohr, K. Somers, S. Swartz and H. Vanthournout, *Manufacturing resource productivity*, Mckinsey & Company, 2012.

[12] S. Pfenninger, A. Hawkes and J. Keirstead, "Energy systems modeling for twenty-first century energy challenges, "*Renewable and Sustainable Energy Reviews*, vol. 33, pp. 74-86, 2014.

[13] N. Bocken, S. Short, P. Rana and S. Evans, "A value mapping tool for sustainable business modelling," *Corporate Governance: The International Journal of Effective Board Performance*, vol. 13, no. 5, pp. 482-497, 2013.

[14] D. V. Behl and S. Ferreira, "Systems thinking: An analysis of key factors and relationships," Procedia Computer Science, vol. 36, pp. 104-109, 2014.

[15] J. Mingers and L. White, "A review of the recent contribution of systems thinking to operational research and management science," *European Journal of Operational Research*, vol. 207, no. 3, pp. 1147-1161, 2010.

[16] *MESA Model*, Available: http://www.mesa.org/en/modelstrategicinitiatives/MESAModel.asp [2016, January].

[17] SAP, Available: https://wiki.scn.sap.com/wiki/display/ModHandbook/Structuring+of+process+models [2016, May]