A novel characterization based framework to incorporate industrial Energy Management Services

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Abstract:

Energy management has been widely considered as an effective means for achieving energy efficiency and sustainable competitiveness in industrial organizations. However, several barriers prevent its diffused implementation. It is thus crucial to assess and evaluate energy management and the corresponding services in the industrial context in order to further promote them. Extent literature has neither defined industrial energy management services adequately, nor developed any models that consider the characterization of energy management services to support industrial decision making. In light of this, our study aims to provide a comprehensive framework to help key industrial decision-makers and policymakers in making better informed decisions regarding the adoption of energy management activities. We accomplish this by explicitly taking into consideration the characteristics of energy management services based on 25 attributes belonging to four categories i.e., implementation, impacted area, impact on production resources and productivity. In addition, we shed further light on the practical implementation of energy management activities by also placing focus on the link between the implications of their adoption on production resources and the subsequent impact on industrial operations. The framework is validated by a sample of selected energy management experts within Australian organizations, followed by an application in an industrial context. The study concludes with suggestions for industrial decision makers and an outlook on further research avenues.

Keywords: Energy management; energy management services; industrial energy efficiency; framework; sustainability.

Nomenclature

EE	Energy efficiency	NEB	Non-energy benefits
EM	Energy management	EMP	Energy management practices
IEE	Industrial energy efficiency	CO_2	Carbon dioxide
IEM	Industrial energy management	HVAC	Heating, ventilation, and air conditioning
SEC	Specific energy consumption	TAR	Technical asset register
EEM	Energy efficiency measures	GWh	Gigawatt hours
EMS	Energy management services	USD	United States dollar
IAC	Industrial assessment center	SME	Small and mid-size enterprises
ES	Energy services	GHG	Greenhouse gas
IEA	International Energy Agency	SDG	Sustainable Development Goal

1. Introduction

Energy efficiency is increasingly being considered as a major contributor towards energy, economic and overall sustained market performance for industrial organizations [1]–[3]. Thus, being able to recognize, characterize and measure energy efficiency becomes a core capability for such organizations to hold [1]. It comes as no surprise, then, that literature has begun to place a focus in this space. For instance, Patterson [4] investigated the use of thermodynamic energy efficiency indicators encompassing physical and economic issues. Further examples include the energy efficiency index, commonly used as an indicator for measuring energy efficiency in buildings [5], and specific energy consumption (SEC), a widely used measure for energy efficiency within different industrial processes [6], [7], particularly concerning the production of commodities such as steel or cement. Nevertheless, when dealing with manufacturing processes characterized by both large differentiation in the production processes and the variety of final products, energy efficiency measurement and benchmarking may become particularly challenging. Hence, the adoption of energy efficiency measures (EEMs) could represent a valuable indicator of whether a company is effectively improving its energy efficiency [8].

The implementation rate of EEMs has been quite low in recent years [1]. In 2020, the improvement rate of energy efficiency has been much lower (0.8%) than global climate and energy goals [1], [3]. However, the rate of improvement needs to double from current levels to match the gain outlined in the IEA Net Zero Emissions by 2050 Scenario [9]. Notably, the slow rate of progress in this domain not only has implications on energy itself, but also towards the environment, consumers and businesses [10]. Previous literature [11] has highlighted that a low adoption of energy efficiency technologies and practices imply e.g. reduced lighting, higher noise level, reduced air quality, increase of waste and emissions, increased equipment wear and tear, reduce machines' reliability and availability. At broader level, considering the heavy reliance on fossil fuels for primary energy, lower rate of energy efficiency is adversely impacting the energy security and resource depletion [1], as well as leading to higher emissions of GHG, with adverse impact on climate change [12]. Indeed, as well captured by a report from IEA around capturing the multiple benefits of energy efficiency, the low adoption of energy efficiency has implications that go beyond individual level, thus with sector-wide, national and international perspectives [13]. In fact, a low rate of energy efficiency hinders the achievement of SDGs, in particular, SDG 7 (affordable and clean energy) [14] and SDG 9 (industry, innovation, and infrastructure) [15].

The low implementation rate of EEMs reveals the existence of a large "energy efficiency gap" [16], [17], demonstrating a significant potential for energy efficiency that is yet to be fully explored. However, what this gap also brings to light is the presence of a number of barriers [18], [19] that seem to be acting against their effective adoption. Thus, a deeper understanding of the barriers to industrial energy efficiency is crucial in order for organizations to adopt EM services as well as better grasp the manner in which barriers are rooted within them [20]. This has also been considered in the academic domain where, Sorrell et al. [21], for instance, investigated the occurrence of economic, behavioural, and organizational barriers. Cagno et al. [19], on the other hand, developed an approach to assess barriers to industrial energy efficiency according to seven categories including awareness, technology-related, information-related, economic, organisation, behavioural and competence-related. Indeed, literature has extensively investigated barriers to industrial energy efficiency with a wealth of empirical studies, focusing on both developed [22]–[24] and developing economies [25], [26], as well as exploring the moderating role of a number of contextual factors such as industry sectors [27]–[29] and firm size [30].

Despite a considerable focus on technical application [31], literature concerning the energy efficiency gap has also started to consider management issues [32]. In this case, theoretical and empirical contributions on themes including energy management practices and energy management services (EMSs) have begun to emerge. Authors including Trianni et al. [33], for instance, have developed a framework for benchmarking the adoption of energy management practices. Fleiter et al. [34] provided a detailed characterization of EEMs by integrating twelve features, emanating from technical, relative advantage and informational aspects, including energy management issues. In contrast, Sorrell [35] focused on energy service contracts, encompassing a customer perspective. Additionally, Benedetti et al. [36] developed a three dimension classification-based framework to highlight energy service contracts.

Considering such research interest, studies also reveal that, among other barriers, EMSs are not being adequately conveyed to industrial decision makers, often attributed to a lack of information and detail over the EMS characteristics themselves [19], [21]. It seems very little efforts are given to both describing them and providing an assessment model for facilitating better industrial decision making [29]. Thus, it appears that research should pay greater attention to comprehensively describe EMSs and understand their impact on production performance. As such, the common avenues (e.g. relationship and impact) between EM and production systems, as well as industrial decision-making procedures in this respect, remain a key issue. In particular, a comprehensive investigation of the nexus between EMSs and operational aspects in industrial organizations is not only crucial in terms of providing decision-support, though also helps to take into consideration the multi-dimensional nature of the industrial sector as a whole [37], [38]. Hence, it appears that a comprehensive identification and characterization of indicators relating to the impact of EMSs on production systems, particularly at the shopfloor, as well as their interactions with other operational features, is a fruitful endeavour for both theory and industrial decision makers.

Given the preliminary background, the present study aims at contributing to this research gap by exploring the following research objectives:

- Characterizing the EMSs in regards to industrial context.
- Developing a framework for assessing industrial EMSs in regards to production resources and productivity attributes within an operational context.

By offering the framework, we intend to highlight not only the EMSs themselves, but also the nexus between the EMSs, production resources and other production features (including production availability, resource management and utilization as well as production process time) in industrial organizations. The framework would benefit both academia and industrial decision makers related to the supply chain of energy efficiency solutions by emphasizing improvement opportunities in their EM activities. Moreover, the framework would also assist engineers operating within industrial organizations by helping highlight the improvement activities in the energy supply chain system.

The remainder of the paper is structured as follows: Section 2 comprises of the literature background. The steps and attributes that have been adopted to propose the framework are presented in Section 3. Section 4 presents the validation phase of the framework. The descriptive results of the framework and discussion are presented in Section 5. Finally, Section 6 provides some concluding remarks.

2. Literature Background

The methodology adopted to analyse existing frameworks that focus on industrial EM and EM services is summarized in Table 1. To date, it seems that theoretical and conceptual studies are commonplace when it comes to industrial EM and energy services. In fact, the idea of EM practices has indeed been addressed through comprehensive studies. However, we observed little attention to energy services and their characterization.

Table 1. Literature review criteria

Title	Remark
Research area	Energy efficiency; Industrial energy management services; Energy management; Energy service framework.
Search string	Energy management services; Energy services framework; Industrial energy management; Characterization.
Type of Publication	Academic journals, conference proceedings, and book chapters indexed in Scopus and Web of Science.
Publication language	English
Availability	Full text available online
Relevance	Articles focusing on energy management services; industrial energy efficiency proceedings at the institutional perspective
Time period	Emphasis has been given to select articles published from the year 2000 until now.

2.1 Energy Management Service Concept

Energy management is a comprehensive approach which takes into consideration a wide variety of factors including energy consumption, strategic aspects, managerial issues and people engagement [33]. When it comes to energy services, this phenomenon acts to overcome barriers as well as implement EM and energy-efficient technologies [39]. Energy service is a comparatively new term referring to contractual arrangements featuring energy efficiency at the industrial level. It also includes a financial support scheme towards the adoption of cutting edge technologies [40] and associated services to best support and intervene in industrial plants [39].

Energy service definitions observe a wide focus on themes including integrating energy consumption, commodities, economic features and many more. For example, Greening at el. [41] focused on the manufacturing side, keeping an economic perspective in order to denote energy services. On the other hand, Sorrell et al. [35] emphasized the customer perspective, specifically in the context of multidimensional services. Fell [42] referred to energy services as the activities associated towards energy for obtaining desired end services. In contrast, the definition provided by Bertoldi et al. [39] was more comprehensive, focusing on a wide range of energy services including audit, statistics, project design, implementation, management, operations and maintenance of energy performance contracts [39].

By looking at the available definitions, in this paper we refer to energy management services as the activities, featuring energy management, to save energy by applying EEMs in industrial organizations. It covers multidimensional activities including technical and non-technical measures, methodological approaches, processes, analysis and support aspects, including the financial scheme, keeping focus on industrial EEMs and objectives.

2.2 EMS model

This section presents an overall review on the existing frameworks of EM, energy services and EMSs. Table 2 presents existing frameworks in the domain of EM and its services.

Table 2. Synopsis of the existing framework focusing EM and energy services

Authors & Years	Model Narration	Remark	Reference
Sorrell (2007)	Consisted of three variables: “Scope”, “Depth”, and “Finance”.	Emphasized the customer perspective; limited to energy service contracts analysis; lack of focus on operational issues in industrial systems	[35]
Benedetti et al. (2015)	Consisted of three dimensions: “Intangibility”, “Scope”, and “Risk”.	Proposed dimensions are applicable to energy services; difficult to comprehend dimensions for all types of energy services.	[36]
Kindström & Ottosson (2016)	“Service ladder” concept is applied; service category is divided into four steps; energy efficiency potential & service complexity are the two dimensions considered.	Model emphasizes energy service type and highlights the business model; lack of focus on environmental benefits.	[43]
Trianni et al. (2019)	EM practices & services are characterized; attributes are designed based on EM practice, energy efficiency improvement type, target of EM practice, and positioning in the industrial EM settings.	Model is more focused on EM practice characterization and less towards energy services; authors acknowledge lack of attention towards SMEs within the model.	[33]
Sa et al. (2015)	Five types of strategies and programs are incorporated; features are reliability, efficiency, cost, funding, and awareness.	Characterization and classification of EMS is lacking; lack of focus on operational issues.	[44]
Fleiter et al. (2012)	Includes twelve features referring to technical, relative advantage, and informational aspects.	Energy services are not integrated comprehensively; environmental attributes are not considered; inadequate inclusion of productivity benefits featuring machine, and human resources.	[34]
Trianni et al. (2014)	Framework consists of characterization of economic, environmental, production, implementation, and interaction related.	EEMs are not conceptualized through an energy service perspective; operational performance metrics are inadequately considered.	[45]
Bertoldi et al. (2005)	Six strategies are proposed to foster the development of energy services, accreditation system, financing mechanism, contract	Study enlists energy services limited to third party financing, energy performance contract, and	[39]

	standardization, and development of third-party financing network.	project financing; lack of focus on the impact of production resources and operational performance.	
Kalt et al. (2019)	Conceptualization of energy service cascade model. Components are defined as ‘structures’, ‘functions’, ‘services’, ‘benefits’ and ‘values’.	Lack of focus on industrial energy services; inadequate focus on industrial energy management linking with operational issues (e.g. production resources, operational performance).	[46]
Katic & Trianni (2020)	Production resources and operational performances are discussed in terms of energy efficiency measures.	Attributes of production resources and operational performances are not elaborately characterized.	[47]

The literature review demonstrates that the majority of narrated models place an emphasis on business models, focusing on the customer perspective. Sorrell [35], for instance, focused on energy service contracts incorporating three variables including scope, depth, and finance. However, the model is not comprehensive and mainly focuses on energy service contracts. Benedetti et al. [36], on the other hand, focused on energy service contracts considering three dimensions. Nonetheless, it is quite difficult to understand the relevance of the proposed dimensions for all types of energy services. Kindström & Ottosson [43], in contrast, focused more on the energy service type, incorporating the concept of a “service ladder”.

Recently, a characterization-based framework has been derived by Trianni et al. [33] that features EM practices. However, the model is not specifically focused on EMSs. Similarly, Sa et al. [44] suggested strategies towards energy management. The models by Fleiter et al. [34] and Trianni et al. [45] articulated EEMs and contributed to characterizing EEMs. Though, a comprehensive characterization is lacking in either study. Meanwhile, Bertoldi et al. [39] presented strategies to foster energy service development. Nonetheless, it appears a mapping of energy services linking operational management is lacking as well.

The exploration and analysis of the existing models sheds light on several challenging and intertwined issues. Firstly, there is no clear characterization or identification of energy services, specifically industrial EMSs. Considering the significance of energy in the industrial perspective, it is important to prioritize industrial EMSs and their characterization to best support industrial decision makers and other stakeholders in the market.

Secondly, most of the models have discussed energy service contracts and its customer perspective. None of the models examined have clearly referred to the impact of energy services and their implementation in industrial organizations. Moreover, from a strategic point of view, there is very little attention paid towards energy efficiency opportunities, integrating the planning as well as control of production systems, projects and process design.

Thirdly, none of the models examined have integrated energy services with operational management features. For example, the aim of energy services (e.g. improve energy efficiency and better utilization of energy resources) should be integrated in the model with operational management. It is also important to note that the successful implementation of EMSs require integrated approaches that combine operational and strategical considerations, keeping aligned with other sustainability indicators. That being said, the organizations that plan to adopt EM should link their operational activities with their energy efficiency strategy, focusing on the long term objectives concerning sustainable competitive advantage [48]–[50]. Moreover, it is necessary to have clear benchmarking for newly adopted technical measures through an EM lens to optimize energy demand [51]. In this context, a synthesized approach towards EMSs is required, integrating the operational features linked to industrial energy efficiency [48].

Fourthly, none of the frameworks analysed in the EM and services domain have considered the technical features of Industry 4.0 (e.g. real time control and monitoring of machines, use of simulation tools during production planning and the use of Internet of Things in production systems). Researchers predict that exponential progress will be observed in achieving industrial energy efficiency through the adoption of Industry 4.0 technical features, also extensively impacting production processes [52]. Notably, EMSs have already influenced production systems in a larger context. Though, this focus must remain until we have further grasped the energy efficiency and Industry 4.0 nexus. On top of that, energy productivity investment must be associated with EM practices and services [16], [23], [53]. Energy services are acknowledged as a very basic solution; however, little effort has been paid towards characterizing them. More importantly, energy service models aimed at supporting industrial decision makers and featuring detailed actions for better EM are still lacking. Therefore, it is important to consider EMSs, keeping in mind the composite nature of industrial energy systems.

Lastly, EMSs have implications towards asset management [48], [31]. In this context, EMSs incorporate the feature of device control to optimize energy consumption. For example, manual toggling of devices based on requirements is a standard procedure of EM. In recent times, the inclusion of electro-mechanical equipment within industrial organizations brings retrofit benefits which allows for device monitoring that is linked to a specific maintenance scheme, facilitated by the adoption of EM and energy services [31]. Moreover, EM and its services improve accuracy as well response in industrial processes [52], [45]. Unfortunately, the majority of energy services-related studies have sidestepped this retrofit aspect while articulating various frameworks. In this context, attention needs to be paid towards including asset maintenance into the EMS framework.

In summary, we acknowledge that previous studies have investigated several important factors connected to EMS. However, a comprehensive characterization framework is still lacking at industrial level with some key research gaps. In this context, the paper proposes a novel framework of energy management services for key industrial decision-makers and policymakers to comprehensively evaluate the application effect of energy management services. The proposed framework, detailed in the following section, encompasses a novel characterization of industrial EMS, as well as the impact of EMS on production resources and operational features.

3. A novel framework to characterize EMS

This section presents a detailed characterization framework (see Table 4) incorporating EMSs, their impact on production resources as well as operational attributes. In order to develop a framework integrating the characterization of EMSs, a thorough collection of industrial EMSs is required. Therefore, a collection, review, and selection of EMSs, as well as the methodological steps to develop the framework, have been presented in Figure 1. The first task in building the framework involves listing the EMSs. It should be mentioned that the services are not listed in a random fashion. Rather, we carefully selected the EMSs from relevant papers which are indexed in Scopus and Web of Science. While doing this, we predominantly placed an emphasis on the industrial management perspective.

Notably, the categorization of EMSs presented in the study is inspired by the UK carbon Trust [54]. In this case, we define the framework based on an attribute value system that helps to incorporate the industrial decision makers' perspective while assessing an EMS.

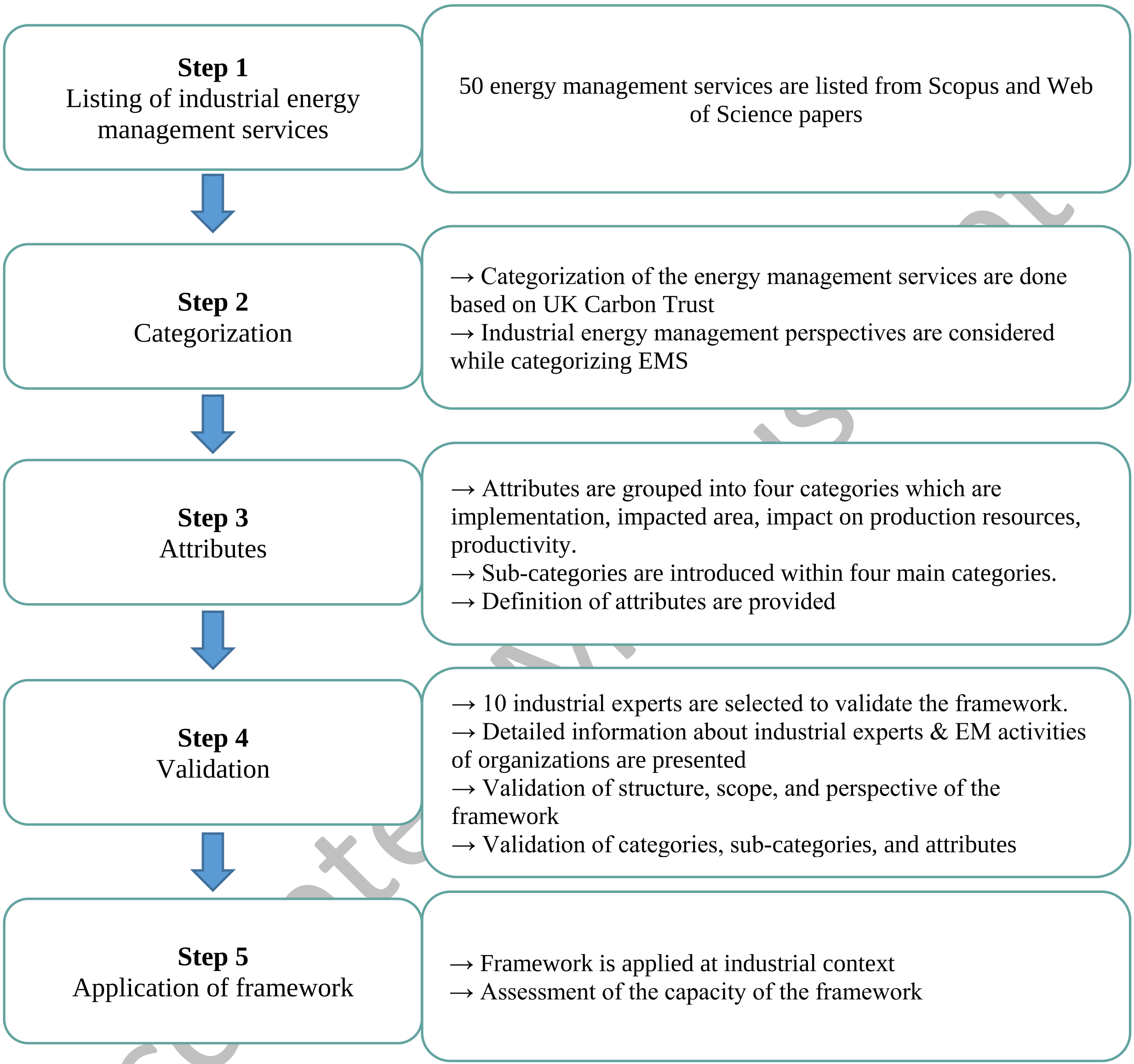

Figure 1. Flow chart of methodological steps

In our framework, the attributes are grouped into four categories: "implementation", "impacted area", "impact on production resources" and "productivity". Later, each of the categories are sub-divided. The categories are selected based on the approach of knowledge representation science [55], which carries a few assumptions. First, we considered the perspective of industrial decision makers whilst selecting the EMSs. Therefore, besides the impacted area and impact on production resources, categories like implementation and miscellaneous are integrated to adequately support the needs of industrial decision makers. Secondly, the categories were integrated by the aggregation of simple attributes which are neither short nor lengthy. Finally, and most importantly, attentions were paid to minimize the overlap among categories.

3.1 Implementation attributes

The link between implementation-related attributes and EMSs is something that remains quite nascent in extant literature. To help include implementation-related attributes into our study, we based this part of the framework on the learnings from Cagno et al. [56] and Trianni et al. [45]. This helped to facilitate more fine-grained insights concerning EMSs and their implementation-related information, given the aim of this feature is to help key industrial personnel to gain a holistic and comprehensive outlook while assessing the impacts of EMSs. That being said, by implementation we refer to activity type, applicability, ease of service and frequency of an EMS, described below:

(a) Activity type: It is important to know the EM activity type to differentiate decision maker's behaviour [57]. For example, simple repair or retrofit might be easier to implement compared to machinery purchase [58]. Therefore, based on Trianni et al. [45], it is necessary to differentiate between new, retrofitting, optimization and simple management procedures. In this framework, this feature thus differentiates if an EMS constitutes: (1) new activity; (2) optimization of an existing service; (3) retrofitting or (4) simple management procedure.

(b) Applicability: The applicability of EM activities is often discussed in the literature. Thus, taking inspiration from Fleiter et al. [34], two distinct features are considered in this framework including EMSs applicable to (1) all technologies and (2) a specific technology. The first feature is applicable industry-wide, whilst the second is applied to specific processes or technical fields. Distinguishing between these two features is useful, as it allows for a better understanding of the deployment of an EMS.

(c) Ease of service: This feature refers to the ease in which an EMS can effectively be implemented or deployed. Based on Wolfinghoff [59], by ease of service, we refer to the following categories: (1) easy: require minimal effort to implement an EMS; (2) difficult: major efforts are required and (3) dependent: interconnected with other processes and requires support from them for implementation.

(d) Frequency: The implementation of an EMS can be one-time or periodic. Therefore, based on Wolfinghoff [59], this feature can be classified as (1) one time implementation or (2) periodic implementation.

3.2 Impacted area

An identification of the impacted area in the industrial process is necessary to offer adequate support for decision makers in assessing an EMS. In order to include this aspect in our framework, we have incorporated the attributes related to impacted area based on the work of Fleiter et al. [34]. Here, we have considered the inclusion of impact on input and output processes in this framework, itself seldom observed in EMS adoption considerations. Moreover, the impact of EMSs on the input and output processes allows us to look over the industrial system, not only from a technical point of view, but also from other perspectives (e.g., administrative and supply chain).

(a) Input: In this framework, by "input" as an attribute, we are referring to not only technical aspects, but rather considering the whole industrial process. This may consist of aspects including administrative, supply chain and raw materials, among others. It is important to highlight the impact of EMSs on the overall inputs of the industrial processes, keeping in mind that a decision maker could be interested in understanding the gravity of EMS adoption beyond the technical aspects. In this context, this feature determines if an EMS has an impact on the inputs of a particular production process [60], [61].

(b) Production process: The energy efficiency characterization model by Fleiter et al. [34] incorporated the issue of EEMs linked to core technical processes and ancillary processes. By taking inspiration from Fleiter et al. [34], the production process in this framework is divided into two sub-categories i.e. (1) core technical process and (2) ancillary process. For both of the sub-categories, this feature refers to the impact of an EMS on a core technical or ancillary process.

(c) Output: This feature refers to the impact of an EMS on the output of the production process.

3.3 Attributes related to impact on production resources

Energy management has significant implications on production processes, thus requiring a more detailed illustration of their linkages [62]. The association between production features and EM is also discussed by Sa et al. [44] and Shrouf et al. [63]. Referring to the context, Trianni et al. attributed "productivity" and "operation and maintenance" as two key production features characterizing EEMs [45]. Moreover, Trianni et al. [64] studied the non-energy benefits of integrating EEMs and production resources.

The impact of production resources are categorized into seven segments i.e., machineries and devices [64], capital [65], energy [65]–[67], utilities and building [68], human resources [69], materials and resources [64], [65] and waste [64], [65]. Later on, taking inspiration from previous studies, some of the categories are divided further to show in-depth significance featuring the production resources. For instance, Finman [70] and Worrell et al. [11] suggested that wear and tear on machinery is impacted by implementing EEMs. In addition, EEMs and its impact towards engineering control are also discussed by Finman [70] and Nehler [71].

The category and sub-categories of production resources are presented in Table 3 (a), followed by a detailed description concerning the attributes of category and sub-categories in Table 3 (b).

Table 3 (a). Category and sub-categories of production resources

Category	Sub-category
Machineries and devices	Wear and tear on machinery
	Control & monitor
	Regular maintenance
	Lifetime
Capital	N/A*
Energy	Generation
	Consumption
Utilities & building	HVAC system
	Layout
Human resources	Manager
	Staff
Material & resources	Raw materials
	Natural resources
Waste	N/A*

*N/A (Not applicable)

Table 3 (b). Definition of attributes related to category & sub-categories of production resources

Attributes	Remark
Wear and tear on machinery	The damage that inevitably occurs due to continuous usage of machinery [72]. By this feature, we refer to the impact of an EMS on the wear and tear of machinery.
Control & monitor	This feature refers to the process of assessing performance as well as taking necessary steps to ensure that machines are working properly in a production plant [73]. By this feature, we refer to the impact of EMSs on the control and monitor of machines.
Regular maintenance	Refers to the impact of EMSs on scheduled maintenance work of machines and devices in a production plant [73].
Lifetime	This relates to the total time span of a machine or device in which it is in a workable state. By this feature, we differentiate the impact of an EMS on the lifetime of a machine.
Capital	This refers to the monetary resources entitled in the industrial processes [45]. In this study, it differentiates if an EMS has an impact on monetary resources.
Generation	In this study, this feature refers to the generation of electrical power from primary energy sources [74]; here it differentiates if an EMS has an impact on energy generation.
Consumption	This feature differentiates if an EMS has an impact on energy consumption.
Heating, ventilation, & air conditioning (HVAC) system	Refers to heating, ventilation and air-conditioning systems applied in the industrial premises [75]. This differentiates the impact of EMS on HVAC systems.
Layout	This refers to the physical arrangement of industrial facilities (e.g. machines and devices, equipment and service departments) [76].
Manager	By this term we refer to the person who is responsible in managing the production resources (e.g. staff, machine and raw materials) in industrial plants. This feature refers to the impact of an EMS on managerial position holders.
Staff	By this feature we refer the impact of an EMS on the staff who are working within the organization under the supervision of a manager [77].
Raw materials	By this feature we refer to the impact of an EMS on raw materials in the industrial system.
Natural resources	By this feature we refer to the impact of an EMS on the natural resources in the industrial system.
Waste	This refers to the industrial waste produced during industrial activities. This category includes hazardous, non-hazardous, and emissions as waste [52], [53]. By this feature we differentiate the impact of EMSs on waste.

3.4 Productivity attributes

In industrial systems, productivity is one of the more significant parameters to consider. This can be articulated as a relationship between output (e.g. goods, service) and input (e.g. labour, capital, energy) [70]. Improving productivity has always been the goal in industrial systems. Several studies have identified the linkage between energy efficiency and improved productivity [78], [79]. Pye and McKane

[78], for example, have discussed productivity even beyond energy efficiency, providing a link to investment decisions. However, taking inspiration from Finmann and Laitner [70] and Worrell et al. [11], we have incorporated three attributes under the umbrella of productivity i.e. availability, reliability, and process cycle.

(a) Availability: As with Brall [80], by availability we refer to the ratio of actual production time and total planned production time. By this feature, we determine the implications of EMSs on availability; classified as: (a) strongly positive; (b) positive; (c) negative or (d) not available.

(b) Resource utilization and management: Based on Sueyoshi & Goto [81], this feature points to the management of production resources and how efficiently the resources are being utilized during the various phases of industrial operations. In this study, the impact of EMSs on resource management and utilization is listed as (a) strongly positive; (b) positive; (c) negative or (d) not available.

(c) Throughput: By considering "throughput", we refer to the frequency of production within the industrial environment. Throughput is a measurement of comparative effectiveness of operational activities. It represents the output rate in the industrial context and quantifies how quickly products can be produced or developed [82]. In this framework, the impact of an EMS on throughput is classified as (a) strongly positive; (b) positive; (c) negative or (d) not available.

(d) Process cycle time: The process cycle time refers to the total time (beginning to end) in the industrial production process [83]. By this feature, we refer to the impact of an EMS on process cycle time classified as: (a) strongly positive; (b) positive; (c) negative or (d) not available.

In Table 4, considering previous studies [33], [45], we have provided an application of the novel framework to an extensive list of EMSs. This was accomplished by including values determined from literature that consider some of the features of EMSs and their corresponding impact on production resources. In this regard, we would like to acknowledge the list is not intended to be exhaustive. However, deemed broad enough for a detailed explanation of the features of the proposed framework. Of course, it is important to note that the novel framework has been designed to support industrial decision-makers in the understanding of the features of EMSs and their impact on production resources, therefore attempting to offer a set of valuable perspectives to characterize and assess them. Hence, for the specific decision-making process of adopting a particular EMS in each context, more tailored and detailed information about the considered EMS and its impact on the specific production resource is deemed necessary for accurate decision-making. Furthermore, in a specific application within a company, or with respect to a single EMS, the effective values of the impacts on operations may vary, also subject to a number of contextual factors (e.g., sector, firm size, energy intensity, etc.)

Table 4. The characterization framework incorporating the industrial EMS

Notation	Energy Management Services	Category (1)		Implementation				Impacted area				Impact on production resources														Productivity				
									Production process			Machineries					Energy		Utilities & building		Human resources		Material & resources							
			Reference	Activity type (2)	Applicability (3)	Ease of Service (4)	Frequency (5)	Input (6)	Core technical process (6)	Ancillary process (6)	Output (6)	Wear & tear on machinery (6)	Control & monitor (6)	Regular maintenance (6)	Lifetime (6)	Capital (6)	Generation (7)	Consumption (7)	HVAC system (6)	Layout (6)	Manager (6)	Staff (6)	Raw materials (6)	Natural resources (6)	Waste (6)	Availability (8)	Resource management & utilization (8)	Throughput (8)	Process cycle time (8)	Reference
EMS 1	Project Identification & appraisal	O	[22]	N	A	Dep	O	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	H	N/A	N/A	N/A	N/A	H	L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
EMS 2	Project technical design & efficiency upgrade	O	[22], [84], [85]	N	S	Dep	O/P	H	H*	H*	H	H*	L	H	H*	H	Y	Y	H	H	H	H	H	H	H	SP*	SP	SP	SP*	[87], [71] [99]
EMS 3	Project implementation & management	O	[22], [84]	N	S	Dep	O	H	H	H	H	H*	M	H	H	M	Y	Y*	H	L	H*	H*	H*	H	M*	SP	SP	P	SP	[22], [78]
EMS 4	Third-party financing	E	[22], [23], [39], [40], [87], [35], [43], [88]	N	A	Dep	O	M	N/A	N/A	M	N/A	N/A	N/A	N/A	H*	N/A	N/A	N/A	N/A	M	L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[22], [85]
EMS 5	Operation & maintenance of production equipment to reduce energy use	T	[22], [89], [90]	P	S	E	P	H	H*	H	H	H*	H*	H*	H	M	N/A	Y	H	L	H	H	H	M	H*	SP	P*	P	P*	[34], [71], [86]
EMS 6	Guarantee of performances	O/T	[22]	N	S	Dep	O	H	H	M	H	H	H	H	H	L	N/A	N/A	N/A	N/A	H	M	M	N/A	N/A	SP	SP	P	P	
EMS 7	Purchases of fuel/ electricity	E	[22]	N	A	E	P	M	H	L	N/A	N/A	N/A	N/A	N/A	M	Y	N/A	N/A	L	L	L	M	N/A	H	P	N/A	N/A	N/A	
EMS 8	Insurance coverage	E	[22]	N	S	Dep	O	L	N/A	N/A	N/A	N/A	N/A	H	H*	H	N/A	N/A	N/A	N/A	L	L	N/A	N/A	N/A	P*	SP	P	P	[11], [79], [91]
EMS 9	Energy advice	T/I	[35]	N	A	Dep	P	N/A	M	L	N/A	H	H	M	H	N/A	Y*	Y*	H	N/A	H	H	N/A	N/A	M*	P	SP	P	SP	[92]

EMS 10	Energy audits & analysis	T	[7], [15], [24], [35], [38], [43]–[45]	N	A	Dep	P	N/A	H*	M*	N/A	H	H	M	H	M*	Y	Y	H	N/A	H	M	N/A	N/A	H*	P	P*	P	SP	[95]–[97]
EMS 11	Ventilation	T	[35]	O	S	E	O	H*	M	L	M*	M	M	M	H	M*	N/A	Y	H	M*	H	H	N/A	H	N/A	P	P	P	P	[98], [56], [59]
EMS 12	Space heating	T	[99], [35], [84], [100], [101]	O	S	E	O	M	M	L	M	N/A	N/A	N/A	H	M*	N/A	Y	H	M*	H	H	N/A	H	N/A	P	P	P	P	[98]
EMS 13	Steam/hot water	T	[36]	O	S	E	O	M	L	L	L	N/A	N/A	N/A	N/A	M	N/A	Y	N/A	N/A	M	H	N/A	M	N/A	P	P	P	P	
EMS 14	Cooling	T	[35], [101], [36]	R	S	E	O	H	M	L	M	H	M	M	M	M	N/A	Y	H	M	H	H	N/A	H	N/A	P	P	P	P	
EMS 15	Industrial lighting	T	[99], [35], [84], [100], [101], [102]	R	S	E	O	L	L	L	L	N/A	N/A	N/A	N/A	M*	N/A	Y	H	H*	M	H	N/A	H	N/A	P	P	P	P	[103]
EMS 16	Energy performance contracting	O	[23], [39], [35]	N	A	Dep	O/P	H	H	M	H	M	H	M	M	H*	Y	Y*	H	N/A	H	H	H	N/A	H	P	SP	P	SP*	[71], [104]
EMS 17	Data collection about energy saving	I	[89], [90]	P	A	E	P	N/A	L	L	N/A	N/A	N/A	N/A	N/A	L	N/A	Y	N/A	N/A	H	M	N/A	N/A	N/A	P	P	P	P	
EMS 18	Data collection about carbon mitigation policies	I	[89], [90]	P	A	E	O	L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	L	N/A	N/A	N/A	N/A	H	L	N/A	N/A	N/A	P	P	P	P	
EMS 19	Establishment of EM institution with dedicated staffs	O	[89], [90]	N	A	Dep	O	M	L	L	N/A	N/A	N/A	N/A	N/A	H	N/A	N/A	N/A	N/A	H*	H*	N/A	N/A	N/A	SP	P	P	P	[55], [56]
EMS 20	Set-up organization's internal regulations	P	[89], [90]	N	A	Dep	O	H*	H	H	M	N/A	N/A	H	N/A	L*	N/A	N/A	N/A	N/A	H*	M*	H	N/A	H	SP	SP	P	SP	[105], [106]

	about energy saving & carbon reduction																													
EMS 21	Modification/adjust of current energy consumption trend by incorporating cleaner energy	T	[89], [90]	O	S	Diff	P	H	H	M	N/A	H	M	M	N/A	H	Y	Y	H	N/A	H	L	H	H	H	SP	SP	N/A	SP	
EMS 22	Investment on production facilities upgradation to ensure energy savings	E	[85], [89], [90], [107]	N	S	Diff	P	H*	H*	H*	H	H*	H*	H*	H*	H*	N/A	Y*	M	H	H	M	H	H	H*	SP*	SP*	P	SP	[19], [79], [108]
EMS 23	Investment at new production facilities for minimization of energy usage & carbon emissions	E	[85], [89], [90], [107]	N	S	Dep	O	H*	H*	H*	H	H*	H	H	H	H	N/A	Y*	M	H	H	M	H	H	H*	SP*	SP	P	SP*	[19], [79], [108]
EMS 24	Installation of monitoring devices for highly energy consuming equipment	T	[89], [90]	N	S	E	O	N/A	M	M	N/A	L	N/A	M	H	H	N/A	Y	N/A	M	H	L	N/A	M	M	P	P	P	P	
EMS 25	Eco-designing	T	[89], [90]	R	S	Diff	O	H	H	H	H	M	L	N/A	H	H	N/A	Y	M	M	M	M	H	H	H*	P	P	N/A	P	[109]
EMS 26	Modification and development of energy efficient products	T	[89], [90], [110]	R	S	Diff	O	H	H*	H*	H	H*	L	N/A	N/A	H*	N/A	Y	N/A	N/A	M	L	H	N/A	H*	SP*	SP	P	SP	[66], [97], [103], [111]
EMS 27	Training & seminar to raise energy savings awareness among employee	A	[89], [90]	P	A	Dep	P	M	H*	H*	M	N/A	N/A	M	H	M	N/A	Y	H	N/A	H*	H*	N/A	N/A	H	P	P	P	SP	[112]
EMS 28	Engage employees in energy-saving activities in daily basis (such as lighting, air-conditioner, etc.)	A	[89], [90]	P	A	Dep	P	M	L	M	L	N/A	M*	M	H*	L	N/A	Y*	H	N/A	H	H*	N/A	N/A	H*	P	P*	P	P	[56], [113], [114]

EMS 29	Energy savings pilot project	T/O	[89], [90]	N	S	E	P	H	H	H	M	H	L	M	H	M	Y	Y	M	N/A	H	H	H	N/A	H	P	P	N/A	SP	
EMS 30	Benchmarking	O	[12], [115]	P	A	E	P	H*	H*	H*	H	L	N/A	H*	H	L	N/A	Y	M	L	H	M	H	M	H	P	P*	SP	SP	[12], [63]
EMS 31	Energy policy & regulation information collection & analysis	I	[39], [43], [116]	P	A	Diff	P	M	L	L	L	N/A	N/A	N/A	N/A	L	N/A	Y*	N/A	N/A	H	L	N/A	N/A	N/A	P	P	N/A	P	[117]
EMS 32	Optimization & control of operational parameters	T	[107]	O	S	Dep	P	H	H*	H	H	H	M	H	H	H	N/A	Y	H	N/A	H	M	M	N/A	H	SP	SP	P	SP	[33]
EMS 33	Optimization of logistic services focusing energy usage reduction	T	[89], [90], [110]	O	S	E	O	M	M	M	H	N/A	N/A	M	M	H	N/A	Y*	M	N/A	H	M	M	N/A	H	P	P	N/A	SP	[33]
EMS 34	Optimization in energy procurement	E	[107]	O	S	E	O	H	L	L	M	N/A	N/A	N/A	N/A	H	Y	Y	N/A	N/A	H	L	M	N/A	M	P	P	N/A	P	
EMS 35	Energy performance monitoring and evaluation	I	[35], [38], [110]	P	A	E	P	N/A	M*	L	N/A	N/A	M*	M*	N/A	N/A	Y	Y*	N/A	N/A	H	L	N/A	N/A	M	P*	P	P	P	[35], [37], [38], [63], [118]
EMS 36	Energy efficiency capital budgeting	E	[37]	N	S	Dep	O	H	H	H	H	M	L	M	N/A	H*	Y	Y	H	N/A	H	L	H	N/A	H	SP*	SP*	P	SP	[11], [70], [79], [119]
EMS 37	Procurement of green energy	E	[44], [90], [110]	N	S	E	O	M	L	N/A	M	N/A	N/A	N/A	N/A	H	Y	N/A	N/A	N/A	L	L	H	N/A	H	P	P	N/A	P	
EMS 38	Cleaner energy	T	[85], [107]	N	S	Dep	O	M	L	N/A	M	N/A	N/A	N/A	N/A	H	Y	N/A	N/A	M	L	L	H	M	H	P	P	N/A	P	
EMS 39	Energy performance reporting	I	[120]	P	A	E	P	N/A	L	L	N/A	M	N/A	M	M	N/A	N/A	Y*	L	N/A	H*	L	N/A	N/A	L	P*	P	P	P	[32]
EMS 40	Procurement of energy efficient equipment	E	[93], [121]	N	A	E	O	H*	H	H	H*	N/A	N/A	H	H	H*	N/A	Y	H	L	M	L	M	H	M*	SP*	SP*	P	SP	[11], [70], [79],

																														[119]
EMS 41	Procurement of energy	E	[107]	N	A	E	O	M	L	L	M	N/A	N/A	N/A	N/A	H	Y	N/A	N/A	N/A	L	L	H	N/A	H	P	P	N/A	P	
EMS 42	Maintenance (preventive/predictive)	T	[84], [85]	P	A	E	P	H*	H*	H	H*	H*	L	H*	H*	M	N/A	Y	H	N/A	H*	H*	N/A	H	M	SP	SP	SP	SP	[32], [37], [63]
EMS 43	Evaluation of energy savings	I	[84], [85]	P	A	E	P	N/A	L	L	N/A	L	L	L	N/A	N/A	N/A	Y*	N/A	N/A	H	L	N/A	N/A	L	P	P	P	P	[118]
EMS 44	Property/ facility management	O	[84]	P	A	Dep	O	L	L	L	L	L	L	H*	H	L	N/A	Y	H	L	H	M	H	M	N/A	SP*	SP	P	P	[39]
EMS 45	Follow up energy efficiency projects	O	[85], [107]	P	A	E	P	L	L	L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	H	L	N/A	N/A	N/A	P	P	N/A	P	
EMS 46	Demand side management	T	[88], [107], [122]	O	A	Diff	P	H	H	H	H	H	H	H	N/A	M	Y	Y*	H*	N/A	H	H	H	M	H	P	P	N/A	SP	[63], [118], [123]
EMS 47	Project financing	E	[39], [38]	N	A	Diff	O	H	N/A	N/A	M	N/A	N/A	N/A	N/A	H*	N/A	N/A	N/A	N/A	H	L	H	N/A	N/A	P	P	P	P	
EMS 48	Production scheduling	T	[62]	O	A	E	P	H	H	H	H	H	H	H*	H	M	Y	Y*	H	N/A	H	H	H	H	M*	SP	SP	N/A	SP	[63], [124]
EMS 49	Marketing of energy efficiency actions	A/I	[38]	R	A	E	P	L	N/A	N/A	L	N/A	N/A	N/A	N/A	L	N/A	Y	N/A		H	H	N/A	N/A	N/A	P	P	N/A	N/A	
EMS 50	Measurement of emission/ GHG/CO_2	I	[44], [122]	R	A	E	P	L	L	L	L	L	L	N/A	N/A	N/A	Y	Y	N/A	N/A	M	L	N/A	N/A	H	P	P	N/A	P	

In the framework, the asterisk (*) refers to the literature backup.
(1) Organization (O); Economic (E); Technical (T); Policy (P); Information (I); Awareness (A)
(2) New activity (N); Optimization of an existing service (O); Retrofitting (R); Simple management procedure (S)
(3) All technologies in general (A); Specific technologies (S)
(4) Easy (E); Difficult (Diff); Dependent (Dep)
(5) One time implementation (O); Periodic implementation (P)
(6) High (H); Medium (M); Low (L); Not-available (N/A).
(7) Yes (Y); No (N); Not-available (N/A).
(8) Strongly positive (SP); Positive (P); Negative (N); Not-available (N/A)

4. Framework validation

The framework is validated in order to demonstrate its potential for assessing industrial EMSs. By validating the framework, we can test its ability in describing additional information about industrial EMSs to support industrial decision making. In this case, the on-field validation includes a consideration for contingency factors assuming high relevancy, not targeting comparative exploration of cases [125]. The exploratory nature of the study has called to validate the framework through a case study approach [125]. Semi-structured interviews have been conducted based on an interview protocol [126]. This approach was deemed necessary to encompass a comprehensive set of features associated with EMS adoption, an understanding of which proves particularly complex.

When it comes to sample size, previous research deemed a sample consisting of 6 to 10 participants to be acceptable for the initial validation of exploratory studies, keeping a focus on theoretical perspective rather than statistical aspects [127], [128]. In this study, 10 participants are interviewed. Our interviews have been conducted involving industrial experts within Australia. The interviewees were selected based on their relevant experience in industrial EM. More in detail, the interviewees were initially contacted via e-mail, asking for their availability and willingness to participate in the research. We also collected secondary information on their firms. Semi-structured interviews were conducted with each participant, using an interview protocol [126]. We asked to interview individuals that are able to provide valuable insights regarding the provision and implementation of EMSs into industrial companies and their potential impact on production resources [126]. The duration of each interview was approximately 45 to 50 minutes. Appendix A presents detailed information concerning the sampled interviewees. All interviewees presented an experience and working tenure within industrial energy efficiency and energy management of at least 10 years (in some cases up to almost 30 years), therefore giving sufficient confidence of the reliability of the considerations and insights provided [129]. In addition, their position within their companies (such as Chief Technical Officer, Senior Resource Management Advisor, Principal Carbon Management, etc.) places them in an ideal position to provide a broader view over EMS adoption with implications on other production resources, particularly interesting for the purposes of the study.

Interviews were aimed at collecting information regarding the participants' respective organization, including the company profile (general company description and number of employees); product and process (information about products produced, main production processes and production volume); EM (information about integrating a full-time Energy Manager, external consultation about EM, EM policy, training and energy audits) and several judgements about the framework in terms of completeness, usability and ease of use. Completeness is projected as a cluster of properties to identify whether: (i) the categorization is clear; (ii) the attributes cover all relevant performance aspects; (iii) the attributes are distinct; and (iv) attributes are sufficiently levelled. On the other hand, usability aimed to test the attributes for identifying the impact of EMS adoption; better organization of EMSs; valid help to manage the EMSs and select suitable EMSs based on organizational strategy. Finally, in the ease of usage section, we have investigated the ease in which the participants perceived the usage of the framework to be and, ultimately, its worth in application when it concerns industrial organizations.

The results of the on-field validation of the framework are presented in Table 5. Referring to completeness, it was largely confirmed in a positive manner. Notably, the interviewees marked no overlapping, referring to the categorization of the attributes. Interviewees S2, S4, S5 and S6 highlighted the relevance, particularly referring to the completeness of the attributes. Some interviewees seemed to have some prior knowledge of the attributes incorporated into the framework, but as a comprehensive opinion, the framework helped them to better shed light on what they had in their observance already.

Table 5: Results of the on-field validation

ID	Completeness		Usability			Ease of Use	
	Categorization	Attributes	Identification	Applicability	Valid & quick help	Ease of use	Worth to adopt
S1	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓
S2	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓✓
S3	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓
S4	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓
S5	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓
S6	✓✓	✓	✓✓	✓✓	✓✓	✓	✓✓
S7	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓✓
S8	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓
S9	✓✓	✓✓	✓✓	✓	✓✓	✓	✓✓
S10	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓✓

*Legend: ✓✓(Positive evaluation); ✓ (Positive evaluation, further suggestions proposed); ✗ (Negative evaluation).

On the other hand, focusing on usability, S1 recognized the attributes as a useful instrument to leverage EMSs, stating that: "*the attributes are comprehensively articulated for providing support to find out the nexus among EMS and operational aspects, precisely to the production resources*". The other interviewees, notably S3, S6, S7, S8, and S9, also highlighted the usability of the framework. In contrast, a Chief Technical Officer (S4) related the applicability perspective to the consideration of non-energy benefits, stating that "*financial issues should be incorporated in [a] quantified way to better elaborate the nexus between capital resources and EMS. This might help the industrial managers and decision makers to deeply adopt the framework*". Nonetheless, this does not reflect any flaw of the framework since the aim was not to quantify non-energy benefits, but rather to show the impact of industrial EMS adoption and their respective operational aspects. On the other hand, when it comes to ease of use of the framework, all of the interviewees provided a positive response.

In sum, all of the interviewees evaluated the framework quite positively overall. The interviewees have clearly acknowledged the usefulness towards assessing the EMS in an industrial context. In short, the model is appreciated by the interviewees in terms of approach as well as aptitude of being adopted in industrial firms.

5. Case Study

A case study is presented in this section aiming to demonstrate an on-field application of the framework. A water treatment company was selected in this context, considering the multi-dimensional as well as intensive nature of energy consumption at operational stages during water treatment. In a water treatment plant, the total energy consumption is attributed to operational energy and energy embodied in infrastructure [130]. In the recent years, researchers have started exploring EM within water treatment plants, considering the significance of the water-energy-GHG nexus [131].

The water treatment company considered in this study is located in Australia. We have carefully selected the case study ensuring the relevance of EEMs in the specific company, the presence of a number of technologies (such as industrial pumps, HVAC, lighting and electric motors) for which energy management and energy efficiency issues could be considered, as well as the knowledgeability of the respondent over industrial energy efficiency issues within the company. Therefore, in the case study considered for the framework, the firm is a large multi-site energy intensive industrial company with a number of similarities with manufacturing industries in terms of cross-cutting technologies in place. This helps to provide a level of concept generalizability and transferability, also towards production and manufacturing industries.

The plant has around 2,700 employees (with additional contractors) and an annual turnover of 2.03 billion USD. Water treatment, sewage transport and treatment, recycling of water, bio-solid and biogas generation from sludge and storm water services are the main activities of the company. The company supplies 1.34 billion litres of water to homes and businesses; recycles 70 million litres and treats 1.31 billion litres of wastewater on a daily basis. The monthly average of stationary fuel consumption in the company is 71,674 litres whilst transport fuel consumption is 2,428,691 litres. Apart from these primary energy sources, the approximate annual electricity consumption is 365 GWh.

The interviewee leads the EM activities and is responsible for energy efficiency projects, energy procurement and inclusion of sustainable energy. The interviewee has been working in the industrial EM domain for nearly 14 years and is profoundly knowledgeable within this sector. Being a part of the management team, the interviewee is involved in operational decision-making processes, which is critical for this study.

By looking at the adopted EMS, we can highlight the company's strengths and critical areas. Firstly, we observe significant commitment to EMSs, energy advice, energy procurement, operation and maintenance as well as optimization of operational parameters. Secondly, the framework highlights adequate focus on project-based services, in particular project implementation and management, energy saving pilot projects and investments on new production facilities. Lastly, the model highlights data collection on energy savings, energy efficiency capital budgeting, engaging employees when it comes to energy saving activities and regulation for energy savings as key areas where the company has scope to improve.

5.1 Energy management status

We observe that the company is primarily focusing on technical and energy performance-related EMSs. A good overall approach to EM activities is observed given the company is also aligned with ISO 50001 guidelines. Additionally, top management is involved in EM activities, whereas the mid-level employees are also a part of strategic and operational decisions. However, considering the holistic perspective of EM, the company still has scope for improvement, particularly when it comes to policy and awareness. The key points concerning energy management in the company are presented below:

- Adoption of EMSs consider administrative processes. The productivity benefits are often neglected while decisions are taken to adopt an EMS.
- The EM training appears quite limited in the company. Training on EM is offered to individuals on an as-needed basis.
- Energy audits are conducted once every four years on targeted areas.
- The EMS is mainly oriented towards the water purification and treatment process. However, the company is also engaged and connected to external stakeholders (i.e., Australian Alliance for Energy Productivity and the Water Services Association of Australia) to improve energy efficiency activities.

  The adopted EMS are both internally and externally implemented. The examples of internally adopted EMS are "investment on production facilities", "optimization", etc. In contrast, "energy advice", "energy strategy development", "energy procurement", etc. are often externally adopted.

5.2 Impacted area on production process

The impacted area due to the adoption of an EMS is generally considered in the company. In particular, the technical management team carefully adopt any EMS considering its possible impact on core technical processes. This highlights an interesting and common tendency from the management perspective to think over core technical processes due to change or adoption of any technical activity. Concerning the water purification and treatment activities, we find the core technical process and ancillary processes are impacted due to several EMSs. For example, the operation and maintenance of production equipment to reduce energy usage significantly influence the production process. Again, the optimization in energy procurement does not seem to directly impact the core technical process; however, influencing the overall input system. It is also important to note that the impact depends on the severity and activity type of the EMS.

5.3 Impact on production resources and productivity

The detailed impacts on production resources and productivity stemming from the adoption of EMSs in the company are presented in Appendix B. By looking at the detailed impact on **production resources**, we find that not all the production resources are being impacted simultaneously. Rather, the impact level is varying case by case, depending on several factors (e.g. type of activity).

The impacts of EMSs on production resources have not been considered comprehensively while adopting any EMS in the company. In fact, the impact on utilities and buildings, human resources as well as material and resources are largely overlooked. By looking at the production resources, it seems that while adopting EMSs, energy has been the only key focus.

However, a few interesting insights are observed with the application of the framework, concerning machinery in particular. For instance, electrical motors and pumps are one of the highest consuming apparatuses in a water treatment plant [131]. To increase the efficiency, experts often suggest the use of efficient motors. With efficient motors, the operational team observed a high impact on machinery, leading to better control of machinery, reduced maintenance as well as improved lifetime of the machine. Again, with another EMS, e.g. project management, the company observed increased hours of staff involvement. The company also observed an impact on capital resources due to project management. Nonetheless, the impact for such cases generally depends on several issues (e.g. project type, volume of activities and intensity of labour involvement).

"Investment on production facilities to minimize energy usage and carbon mitigation", is recently adopted on a broader scale, and the company has observed a significant impact on waste. In fact, in this case, collected sludge from the water treatment process is being used to produce biofuel, which has significantly improved not only the process cycle but also has a positive impact on materials and resources.

Some additional comments were also received during the discussion encompassing the impact on production resources. For example, in recent times the company adopted a few pilot projects related to energy savings. While implementing these projects, the company observed a positive impact on their energy consumption and productivity on a broader scale. However, what is concerning here is that often such pilot projects are not converted into larger projects due to several barriers (i.e., lack of local technical experts and other priorities). This indicates the organizational barriers to industrial EM [24], [26], [29] which remains to be discussed and addressed.

Unfortunately, it is observed that **productivity** features are also neglected while adopting the EMSs. In fact, availability and throughput have been largely overlooked. However, the interviewee acknowledged multiple productivity benefits indistinctly due to EMS adoption, as shown in Table 7.

For example, the company observed a significant amount of energy consumption reduction for the aerators by optimizing the power usage, which eventually improved the process cycle and resource utilization. The interviewee has also acknowledged the benefit of using real-time monitoring devices integrated with state-of-the-art systems in the plant. Considering the volume of data generated by different technical apparatuses, the advance database system also offers critical capabilities to look into the data [132]. By monitoring and analysing the operational data collected through the monitoring device for the electrical pump and aerator, the technical team uncovered several options to improve the operational performance, with credit to Industry 4.0 and its technical features.

Again, when it comes to production scheduling or planning, simulation technology, a technical feature of Industry 4.0, is identified as a quite significant and powerful tool in the digital manufacturing process. This stems from its capabilities in product validation, including system design and configuration by experimental methods [63]. Simulation also helps to reduce costs by optimizing product development cycles [63]. While applying the framework, the interviewee discussed the application of a simulation tool for production planning in the plant. Such a tool not only helped to save on costs prior to the implementation of any new technology, but also ensured effective resource management and utilization.

The water treatment plant has also adopted preventive maintenance (EMS 42), including condition assessment via a technical asset register system. Preventive maintenance increases the lifetime of a machine and improves the machine performance [133]. The interviewee has acknowledged that preventive maintenance has significantly improved the performance of electrical motors and pumps (e.g. reduced start-up time and defect elimination). Further, it has also reduced sudden or unplanned outage of the motors and pumps leading to increased availability of the machine. In fact, overtime cost due to additional involvement of labour is also reduced due to improved performance of the machine. In general, preventive maintenance incurs a positive impact on the production process overall due to improved performance of the electrical motor and pumps.

6. Discussion

The study presents a novel framework which allows industrial decision makers to assess EMSs based on the impact of operational features within industrial organizations. Considering the complexity in operational activities, this framework not only provides support towards energy intensive industries, but also significantly contributes to SMEs and other industries which are in the nascent stage of EM. In many cases, industrial decision makers do not consider the impact of EM on production activities and overlook its associated benefits [48], [53], [56]. By considering the framework in their decision-making processes, industrial decision makers can visualize the overall impact of EM on production resources and productivity attributes within an operational context - helping to select the appropriate services to adopt at their respective organizations.

From a theoretical standpoint, it should be acknowledged that the EMSs encompassed within the framework are independent from each other. However, in a few cases, they are performed concurrently. By observing the framework, the listing of the EMSs is not pointing to specific cross-cutting technical sectors, rather focusing comprehensively on the industrial EM domain. Another important point is that the framework mainly focused on the “soft” aspects of EM, meaning excluding co-generation, waste heat recovery and related EMSs. The reason behind such an exclusion is in enabling us to focus more on the managerial and decision-making attributes. This is particularly useful for an assessment of impacts on production resources, of which seems to be neglected in previous frameworks [33], [34].

In our framework, we have observed 22 EMSs, the act of which can be considered a novel endeavour itself. Again, 13 services are categorized as periodic; nine services are labelled as optimization types and six are listed as a retrofitting type activity. The EMS could even be exemplified in a few cases considering the concurrent features of operational performance [62]. In contrasting our findings with another characterization framework by Trianni et al. [45], we observe a high number of new activities (34). Similarly, when it comes to the applicability of the EMSs, 27 services are found to be applicable within industrial process. This indicates that the EMSs are generally applicable for all industrial sectors, also affirmed by industrial experts during the validation phase and the application of the framework. Similarly, when it comes to the ease of implementation concerning activities, 25 EMSs are categorized as easy to implement whereas 18 EMSs are categorized as dependent, referring to implementation dependency with other services and processes.

Despite the growing attention towards industrial energy efficiency, the impact of EM on production processes remains to be adequately addressed [64], [124]. Hence, our findings provide a significant contribution in the energy efficiency and sustainability field by looking at the production processes through the lens of EMSs. By looking at the framework, it can be perceived that 23 EMSs are significantly impacting industrial input processes. Again, when it comes to the impact on a core technical or ancillary process, 21 EMSs are found to have a significant impact. These findings highlight the nexus between EM and production processes in the industrial operational context [134]. When it comes to the industrial output, the majority of cases are related to the aspects of optimization, project-oriented and production based, subsequently also affirmed by industrial experts during the validation and application phase of the framework development.

One of the salient features in the framework is the inclusion of the impact of EMSs on production resources. In this case, the production resource of industrial machinery appears to be particularly intertwined with EMSs [64]. For example, 16 EMSs are found to significantly impact the wear and tear of industrial machinery. Following this, in terms of machine lifetime, there are 14 EMSs which have a significant impact on this factor. Indeed, a few of the EMSs (e.g. project technical design and efficiency upgradation, investment on production facilities upgradation as well as preventive or predictive maintenance) are not only impacting the machine lifetime, but also the regular maintenance activities. When looking at the regular maintenance of machinery, 13 EMSs are identified to have a high influence. One important point to be noted here is that the positive linkage between maintenance activities and EMSs is also supported by scientific literature in the framework [11], [78], [79]. However, considering the way EMSs are implemented, we expected to find a significant relation between control and monitoring of machinery and a few of the EMSs, particularly for maintenance activities, demand side management and production scheduling. In fact, the aforesaid EMSs are significantly impacting all the considered features in the machinery portion of the framework.

While considering economic issues through the lens of industrial energy management, researchers have largely been concerned with “implementation cost” and “payback time” [45], [135]. However, capital investment decisions in industrial organizations also depend on several circumstances (e.g. business opportunity evaluation, savings and available technologies) [31]. Considering energy management service cost, it is essential to assess the economic factors to affirm the choice of an optimum solution. Cost-benefit analysis is an accepted approach in organizations to compare economic sustainability of a probable strategy and potential actions [136], [137]. However, the proposed study aims at showing the existence of a number of implications on production resources that may be important when considering the implementation of an EMS. This is accomplished by proposing a framework to support decision-makers in highlighting them in the first place – acting as a potential first step towards their full quantification, possibly also in economic figures, supported by appropriate metrics.

The adherence of EM and economic issues, in our case the "capital", is acknowledged both in academia and industry. However, very little studies have focused on the impact of EM on monetary resources. An investigation of the nexus between capital and EMSs is a critical exercise, considering the relationship with business opportunities and expansion activities. Moreover, such an understanding can help facilitate the selection of EMSs that are worth adopting for a particular industry and business type. Indeed, the decisions linked to capital resources are dependent on various circumstances including energy price, environmental factors, subsidies and market issues. As predicted in this study, a high relationship exists for 21 EMSs with regards to capital resources. Notably, EMSs contribute to ensuring guaranteed savings or shared savings [39] in terms of energy as well as monetary value. This was, to an extent, addressed in a recent study on energy services, where Nurcahyanto et al. [138] highlighted several aspects relating to financing mechanisms. However, the specific impact on capital resources and particular EMSs was not considered in this study.

On the contrary, EMSs like data collection, engagement of employees and marketing of energy efficiency actions are identified as having a lower impact on capital. By looking at energy as a production resource from an EMS perspective, we should remember that managing energy is not just a technical challenge. Rather, the idea is to best implement the technical changes whilst maintaining minimum disruption and economic limits [31]. Therefore, the impact of EM will always have a significant impact on energy consumption within industrial organizations. For instance, in the framework we observe that there are a total of 37 EMSs available which are linked with energy consumption. Here, we should keep in mind that most industries, especially manufacturing companies, are operating in a competitive age. Therefore, a small reduction in energy consumption cost could also critically impact the whole production and value chain system. However, while looking at "energy generation", on the other hand, the framework suggests that this is not deeply affected by EMSs, with only 17 of them incurring a notable impact.

In terms of utilities and buildings, EMSs also appear to particularly related, especially to HVAC. By looking at the framework, we observe that 20 EMSs have a strong relationship with HVAC systems. For example, demand side management, production scheduling, operation and maintenance of production equipment as well as efficiency upgradation all have a clear impact on production systems. Besides HVAC factors, the physical layout of industrial organizations have an impact on energy consumption, especially at the manufacturing floor [68]. It is important for industrial organizations to have a physical layout that ensures efficient flow of material and production activities within their operational context [134]. However, when we think of offering EMSs, it does not seem to impact too much on the industrial physical layout where only four of the EMSs are observed to have a high impact. This reduced impact on plant layout by EMSs seem reasonable considering that EMSs are basically representing energy efficiency improvement activities within industrial machineries and operations. As such, production design and layout is not as severely impacted in most cases.

Concerning industrial processes and the supply chain, the role of managers cannot be understated. In fact, the paradigm of sustainability in industrial organizations and their adoption relies intensely on managerial and top management positions [31]. When looking at the framework, we observed that managers have a significant association with EMSs. To be precise, 38 EMSs are significantly impacting managers in the industrial context. However, when looking at the industrial production chain through the lens of sustainability, this association appears reasonable given managerial context and EM are both intricately linked to the strategic and operational layers in industrial processes, especially at the process layer in production plants [134]. For instance, project implementation and management, production facilities upgradation as well as setting up internal regulations about energy saving all appear significantly dependent on managerial issues and coordination. On the other hand, the level of impact concerning EMSs on line staff might not be as visible as the managerial positions. However, we highlighted 18 EMSs that have a high impact on industrial staff. Interestingly, a few of the EMSs including maintenance, establishment of an EM institution, project implementation and management are equally impacting both the managers and staff. This indicates that the impacts of EMSs on human resources depends on EMS characteristics (e.g. service complexity, strategy and organizational setup).

With respect to the relationship between EMSs and material and resources, there appears to be an inclusive impact, particularly on the raw materials. There are 20 EMSs that have a high impact relationship with raw materials. For example, while considering eco-designing as an EMS, this allows industrial managers and decision makers to rethink their industrial process, hence offering resource efficiency at the design stage [134]. Again, when it comes to energy efficiency capital budgeting, it allows industrial decision makers to consider budgetary expenditure concerning several industrial processes. Interestingly, budgetary issues have a significant impact not only on the industrial processes, but also the raw materials used in the industrial production system. On the other hand, the vast majority of EMSs do not seem to deeply impact the natural resources that are used in the industrial processes. We highlighted only 13 cases that observe a significant relationship between EMSs and natural resources used in industrial organizations.

As stated in Section 3, in this framework we have considered waste in a broader perspective and hence incorporating hazardous, non-hazardous and emissions inclusively. In this case, 23 EMSs are identified to have a significant impact on the waste stream in industrial organizations. It is important to note that when industrial firms adopt or invest in EM activities to ensure efficiency, we often observe a reduction of waste or CO_2 emissions [11]. For instance, an energy audit allows us to inspect and analyse the industrial energy consumption and highlights the energy efficiency improvement options [4] eventually leading to a reduction of waste and emissions in most cases. On the other hand, while looking at other EMSs concerning, for example, engaging employees in energy saving activities on a daily basis or optimization of logistic services to reduce energy usage; it is obvious that there is a high potential towards reduction of waste due to lesser consumption of energy for adopting such services in industrial firms.

Several studies [11], [70], [79] have pointed out the issue of industrial EEMs and productivity benefits. Indeed, this provides an avenue for opening up the Pandora's box in exploring the nexus between EM and industrial productivity. In this context, we can appreciate that the factor of "availability" is impacted by the majority of EMSs. In fact, 41 EMSs are significantly impacting this factor. This insight was facilitated by the detailed knowledge on EMSs by virtue of the developed framework. Additionally, when it comes to the nexus between production reliability and EMSs, the vast majority of EMSs seem to have an impact on production reliability.

All the production resources and productivity features considered in the framework have significant importance within the industrial production system. However, the impact on production resources and productivity attributes due to the adoption of EMSs can vary case by case. In fact, while looking at the framework theoretically as well as the case study application, we have observed that not all of the attributes are impacted simultaneously at the same level. Rather, we find that every EMS is impacting the attributes based on individual perspective, which is expected. For example, the level of impact on the attributes for EMS 2 (projects technical design and efficiency upgrade) and EMS 9 (energy advice) are different. Likewise, the impacts of EMS 26 (modification and development of energy efficient products) on production resources are dissimilar in many cases compared to EMS 23 (investment at new production facilities for minimization of energy usage and carbon emissions). This can be attributed to the fact that different levels of impact on production resources and productivity features reflect different contextual variables (e.g. energy intensity, sectors and firm size) within industrial organizations.

The same logic can also apply in the broader pursuit of minimizing the energy efficiency gap in the context of industrial organizations. Despite the notion that EM helps reduce the energy efficiency gap [16], [139], the extent to which this can be achieved also depends on several contextual phenomena (e.g. industry type, firm size and energy consumption nature). Therefore, a one- size– fits- all approach is not appropriate when it comes to energy savings or energy efficiency gap minimization. An organization might experience different proportions of energy savings, thus leading to the minimization of the so-called energy efficiency gap. However, in a recent study, Hasan et al.[50] suggested that 8-10% of energy savings could be possible with the adoption of energy management practices in industrial organizations.

Whilst looking at the barriers to industrial EM, this framework could also open a few avenues for discussion, which are modelled by previous researchers [22], [38]. For example, previous studies have highlighted various barriers that hinder an explicit consideration for supporting process-related decisions in the context of EM [18], [19]. Therefore, while looking at the implementation of EMSs, companies may broaden their decision-making perspective by integrating the impact of EEMs on the production resources. Observing such a mindset is important, considering that energy is a crucial factor for ensuring resource efficiency, sustainability and competitiveness in the market. Indeed, this introduces a significant, yet initial, finding that has emerged through the comprehensive knowledge on EEMs and production resources gained in this framework.

On a separate note, it should be mentioned here that the fourth industrial revolution, Industry 4.0, also focuses on energy efficiency to minimize the production cost in industrial organizations [140]. Therefore, the impact of EM is critical in organizations for adopting technical features associated with Industry 4.0. More importantly, EM acts as an expeditor for improved energy performance when applying optimization techniques focusing on energy productivity. Nonetheless, queries might arise on the implementation of EMSs within industries due to its multidimensional nature. From the energy productivity perspective, it is obvious that energy efficiency should be incorporated with certain technical features, and clearly, with the adoption of EMSs.

Moreover, whilst looking at Industry 4.0 through the lens of EM and production resources, we find several significant factors in the industrial context, precisely relating to real-time monitoring of the device or industrial machines. For example, in our framework, "energy" is considered as one of the production resources. When we opt for adopting an EMS (e.g. modification and development of energy efficient products, eco-designing and energy saving pilot projects), it certainly has an impact on production resources. Though, in this case the possible effect is energy consumption reduction. With the help of Industry 4.0 technologies, key decision makers can easily monitor or evaluate the impact of EMSs within the entire production system.

7. Conclusion and future research

The novel framework presented in this study aims to characterize industrial EMSs by considering their impact on industrial operational features. To the best of the author's knowledge, very little studies have focused on industrial EMSs at the same level of detail as accomplished in this framework. Furthermore, there is no prior study that has highlighted the attributes featuring an "impact on production resources" in a comprehensive manner. This is particularly critical for industrial decision makers as it highlights the nexus between production resources and operational aspects. An additional element of novelty is ascertained by having highlighted the need to analyse EMSs as per their diverse perspectives (e.g. resource management and impact on productivity). In particular, undertaking a characterization of the attributes allows to provide an inclusive view of relevant EMS perspectives and results in the consideration of a more specific mechanism underpinning the selection of the EMS to be endorsed.

When it comes to the framework itself, there are three main features that signify its novelty: firstly, the detailed reference list of EMS; second, the detailed impact of EMSs, integrating operational features; and finally, in terms of usage, the relationship matrix characterizing the attributes adopted in the framework. In addition, the validation phase of the framework includes an industrial expert's feedback, further to an application of the framework within an energy intensive industry.

In a general sense, the output of the developed framework is more inclusive than existing EM schemes or a mere appraisal of the maturity level, given the meticulous assessment of the EMSs involved in the decision-making process. By considering the framework, industrial organizations have the ability to highlight any significant factors impacting their operational performance, paving the way towards a detailed strategy for EM. It is for this reason that a comprehensive set of EMSs are developed with a defined set of attributes. Such an approach thus allows for the consideration of several important viewpoints to assess EMS adoption, specifically the capabilities and organizational perspectives, and suggest specific actions for each EMS.

The proposed framework also signifies the relevant concerns in EM supply chains within the industrial decision making and policy making process. The framework could be effectively useful in developing EM practices within industrial organizations, adapting to their specific needs. In fact, the framework could be applicable for stakeholders working in the energy efficiency value chain system and wishing to develop their approach to EM. In addition, the proposed framework could also provide support in designing policies towards more effective promotion of industrial EM by acting on a set of articulated attributes.

Despite the fact this study provides a comprehensive framework of EMS, it does consists of a few limitations. First, the validation of the framework could involve a higher sample of participants. Second, at present, quantitative metrics featuring production resources and productivity attributes have not been considered. Such metrics would provide additional support to industrial decision-makers in more objectively assessing the impact of EMSs on other production resources, therefore shedding more light on the effective contribution to the improvement of production processes and sustainability in the operations.

Considering these limitations, some interesting opportunities for future research emerge. To begin, future research should focus on how to expand cost-benefit analysis over EMS adoption by encompassing considerations over multiple impacts on operations, so to further assess their profitability and promote them within the industrial sector. Also, and partially related to the previous point, future research could better understand the role of EM in promoting industrial energy efficiency, which has received very little attention until now. In this context, future research should explore the link between EEMs and production resources at the operational level, especially regarding shop floor activities. In fact, given that the broader domain of linking industrial energy management with operational features remains little explored, both in academia and industry, future research could apply the framework in an extensive number of firms. This would help to assess the differing importance of features for EMS adoption, also pointing out the effective impact on production resources (in light of potential contextual factors such as sector, firm size, energy intensity and so on).

Finally, there is also an inherent need to link Industry 4.0 technical features with industrial EM. In this respect, it will be interesting to observe how Industry 4.0, along with industrial EEMs, can better support industrial decision makers in their pursuit towards sustainability and, ultimately, how they could improve the industrial energy system.

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Appendix A

Data of the sampled experts on industrial EM towards on field validation

ID	Interviewed designation	Main activity of interviewee	Experience of interviewee	Activities of concern organization	EM status in firm
S1	Senior Resource Management Advisor	Involved in energy efficiency programs & sustainable energy.	13 years of working experience in energy efficiency field.	Biological and physical removal processes for wastewater treatment.	Dedicated energy manager; consults EMS with external stakeholders; no standalone EM policy but follows short & long term EM goals; organize training for employees on need basis; energy audit is conducted; external contractor involved to support the audit services.
S2	Chief Technical officer	Consultation on energy procurement, bill management & reporting, operational data analysis & dash boarding, energy efficiency opportunities, energy/carbon intensity foot printing and emission reduction.	Nearly 30 years of working experience in energy field.	Technical solution provider for electricity and heat.	No dedicated energy manager; consults EMS with external stakeholders; no standalone EM policy; In-house EM.
S3	Resource Management Advisor	Involved in energy efficiency programs; especially in value chain for renewable assets from implementation to operation, optimisation and maintenance.	12+ years of working experience in energy efficiency field.	Treatment of wastewater.	Full time energy manager; short & long term EM goals; organize training for employees on need basis; energy audit is conducted.
S4	Chief Technical officer	Consultation on EM & reporting, operational data analysis, energy efficiency opportunities.	More than 17 years of working experience in energy efficiency field.	Energy advice; energy resources management and utilisation; Carbon footprint management and emission reduction; Environmental performance improvement.	Full time energy manager; short & long term EM goals; organize training for employees to raise awareness about energy; energy audit is conducted.
S5	Co-founder & energy productivity specialist	Involved in consultation activities, mainly, EM programs consisting of asset management, monitoring and analytics system.	10+ years of working experience in the field of energy efficiency.	Managing resources, specially the assets in the industrial premises using smart integrated device.	No dedicated energy manager; consults EMS with external stakeholders; no standalone EM policy; In-house EM.
S6	General Manager	Responsible for key functions to drive commercial outcomes, digital innovation & enterprise transformation in energy sector.	More than 10 years of working experience in the field of energy.	Managing of energy infrastructures; provider of gas, electricity and water.	Dedicated energy manager; consults EMS; EM policy along with short & long term EM goals; organize training for employees on need basis; energy audit is conducted.

S7	Co-founder & Managing Director	Involved in energy connectivity programs; energy advice; sustainable energy analyst.	12+ years of working experience in the field of energy.	Energy provider; fabrication services to the mining & resources, construction, agricultural & government sectors.	No dedicated energy manager; consults EMS with external stakeholders; in-house EM.
S8	Associate	Responsible for energy policy preparation; technical assessment of clean energy technologies & energy efficiency projects.	16+ years of working experience in EM field.	Consultation and financing on energy procurement, efficiency and productivity opportunities.	Dedicated energy manager; consults EMS; short & long term EM goals; organize training for employees on need basis; energy audit is conducted.
S9	Chief Executive Officer	Involved in EM projects; consultation on energy efficiency opportunities.	13+ years of experience in EM & technology field.	Energy efficient solution provider in energy sector; energy advice; policy; energy system analyzation.	No dedicated energy manager; consults EMS with external stakeholders; no standalone EM policy; In-house EM.
S10	Principal Carbon Management	Responsible for EM projects; implementation of clean energy technologies; consultation on energy efficiency scopes.	More than 13 years of experience in energy & sustainability field.	Extraction & processing of minerals, oil and gas.	Full time energy manager; consults EMS with external stakeholders; short & long term EM goals; organize training for employees on need basis; energy audit is conducted.

Appendix B

Impact on production resources and productivity attributes due to EMS in the case applied

Notation	Energy Management Services	Production resources							Productivity			
		Machine	Capital	Energy	Utilities & building	Human resources	Material & resources	Waste	Availability	Resource utilization & management	Throughput	Process cycle
EMS 2	Project technical design & efficiency upgrade	H	M							+		+
EMS 3	Project implementation & management		M			H				+		
EMS 5	Operation & maintenance of production equipment to reduce energy use	H				M			+/--	+		
EMS 9	Energy advice	L		Y						+		+
EMS 10	Energy audits & analysis			Y	M					+		
EMS 20	Set-up organization's internal regulations about energy saving & carbon reduction			Y				L		+		
EMS 21	Modification/adjust of current energy consumption trend by incorporating cleaner energy			Y			M	M		+		
EMS 23	Investment at new production facilities for minimization of energy usage & carbon emissions			Y			M	H		++	+	+
EMS 24	Installation of monitoring devices for highly energy consuming equipment	M		Y						+		+
EMS 27	Training & seminar to raise energy savings awareness among employee					L				+		
EMS 29	Energy savings pilot project			Y						+	+	
EMS 30	Benchmarking	M										+
EMS 32	Optimization & control of operational parameters	M							+			+
EMS 35	Monitoring & evaluation of energy performance									+		

EMS 36	Energy efficiency capital budgeting		M									
EMS 39	Energy performance reporting									+		
EMS 40	Procurement of energy efficient equipment		M	Y				L	++			+
EMS 41	Procurement of energy		M									
EMS 42	Maintenance (preventive/predictive)	H		Y		M			++	+		++
EMS 43	Evaluation of energy savings									+		
EMS 46	Demand side management						M					
EMS 48	Production scheduling	M							+	+		

(1) High (H); Medium (M); Low (L);
(2) Yes (Y); No (N);
(3) ++ (Strongly positive); + (Positive); -- (Negative)