A methodology to select energy-related key performance indicators (e-KPIs) for improving energy management in manufacturing industries: A case study in the paper industry

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Abstract

In a competitive world, effective use of performance indicators and more meticulous monitoring and control of energy consumption are essential for achieving improved energy efficiency performance. However, a recent report exhibits that nowadays only 2% of the companies meet or exceeds their strategy sustainability programs. The primary cause is pointed to be the misalignment between energy-related indicators and the other company's indicators. The existing methods and norms on how to select energy-related performance indicators are not able to address this and other literature gaps, such as the underdevelopment of the conceptual frameworks for selection and use of indicators, and the rudimentary of the energy-related decision-making tool. Therefore, the present dissertation proposes the use of a novel methodology to choose the energy-related indicators considering the company's overall strategy as well as the energy strategy. For that purpose, best practices tools from other fields were adapted to be in accordance with the energy management reality. The tools adjusted were the Balanced Scorecard and Strategy Maps. To test the methodology, it has been applied in the most significant European Kraft mill leading to a new energy-related indicators network that considers the current indicators and proposes new ones that could significantly improve the decision-making process.

Keywords: Business Strategy, Energy Management, e-KPIs, KPIs

Introduction

Energy resources are directly linked to well-being and prosperity across the globe [1]. Access to energy is considered as one of the critical factors for the development of organisations and human beings [2].
Even though the importance of energy in the society, a recent report [3] exhibit that more energy is wasted than consumed, approximately per 1 unit of energy consumed 0.58 units are wasted. However, the rise of energy's prices, environmental laws and more demanding purchasing behaviours towards environmentally friendly products are forcing organisations to search for energy management systems that can improve the efficiency and effectiveness on how the energy is consumed [4].
To keep its competitiveness and satisfied the consumer, organisations around the world began to implement sustainability programs for managing their energy consumption and fulfil the law [5]. However, a recent report released by Bain & Company [6] states that only 2 per cent of those programs achieves or exceed their goals. The primary cause indicated is the disconnection between business objectives and sustainability objectives. Also, the same study [6] specifies that the factors that are critical for achieving the company's sustainability goals are: the commitment of the top management, the employee's engagement, and clear goals and metrics.

Nowadays, the literature [7-8] calls the most important metrics for assessing the achievements of the objectives in an organisation as KPIs. KPIs can be defined as the most significant parameters in an organisation that help to assess how far a company is from achieving its objectives.
For energy management are norms and methods [7,9,10,11,12] to state Energy-Related Key Performance Indicators (e-KPIs); however, none of them gives guideline on how connect them with the company's strategy, which could be one of the reason for the five gaps that the e-KPIs were not being able to address in the literature [5,12]: (i) Few of the proposed KPIs are suited for energy management; (ii) The benchmarketing between organisations it's not always possible; (iii) The e-KPIs do not report how the energy is being used; (iv) Conceptual frameworks for selection and use of KPIs underdeveloped; (v) Decision supporting tools for e-KPIs are rudimental.

It was found that in other fields there were well-established tools that could help to attach the KPIs to the company's strategy [13] and help in the selection process [14-15]; nevertheless, during the research process, no study was found that proposed them as a medium for an organisation to develop its energy strategy management or as a guide for obtaining and managing e-KPIs. Therefore, to overcome the preceding stated limitations and to consider the gaps identified by May G, this work proposes adaptations to Balanced Scorecard (BSC) and Strategy Map (SM) frameworks [14,15]]to create a sophisticated tool to develop an energy management system for selecting and control e-KPIs

Taking into consideration the above-mentioned, it is expected that the present dissertation contributes to:

- Find a method to select (energy related Key Performance Indicators) e-KPIs.
- Document the characterization of the e-KPIs
- Construction of a KPI network, in a real environment, paper & pulp industry

Literature Review

As referred, KPIs assess the accomplishment of objectives. Therefore, it is fundamental to state the goals that the company desires to achieve [13]. Commonly, for that purpose, companies deploy the Hoshin Kanri methodology, which utilises two main methods [16,17], Plan–Do–Check–Act (PDCA) and Catchball process, as a medium to indicate and align the company's objectives across the different hierarchical levels. Even though Hoshin Kanri outlines the importance of attaching metrics to measure the goal, it does not give guidelines on how to communicate the objectives and monitor its achievement [3]. Therefore, generally, after applying it [18,19], organisations employ the BSC framework to help in strategic communication and metrics selection process. The BSC framework [14] categorised the objectives by the most significant organisation's areas and stipulated that for each goal stated one metrics should be attributed to it. Besides the metric selection, it ensures the range of value target for that metric and initiatives to achieve it.
The initial efforts to use the BSC alone appeared to either propel organisations to success or burden them [20]. The crucial step was in the outline of the relationship between objectives and metrics with the company's mission, i.e., if there were no overlap of goals and metrics and if all were connected to the company's mission [20].
The authors of the BSC proposes the use of a Strategy Map (SM) framework [21] to visualise how the organisation's goals and metrics are correlated. An SM is a framework that places objective as well as its KPI according to a category inside a perspective of the BSC framework, highlighting the interconnection between them through arrows.
Once the metrics are stated is necessary to document them [7,8]; for that purpose, some ISO norms and rules can aid. Regarding energy management, there is the ISO 22400 [9], which says that for a metric being consider an e-KPI needs to fulfil specific criteria of content and context

Methodology Development

The methodology developed for the selection, display and exploration of e-KPIs for energy management is explained and discussed in this section. To ease its explanation, Figure 1 exhibits the proposed implementation workflow of the methodology.

Figure 1 - Methodology implementation scheme

It's important to remark that even though the first step of the scheme is the definition of company's mission and goals, the present methodology assumes that that process already happened in the organisation; therefore, Hoshin Kanri will be out of the scope.

Hierarchical division

As proposed in the KPIs guidelines [7, 10], the methodology recommends the outline of the hierarchical organisational divisions and the information requirements in each level. Even though there are no clear guidelines on when this should happen, this methodology places it at the beginning, because with the information it is possible to have an idea of what types KPIs are required in each level for the decision-making process. Usually, the strategic decisions should be of the responsibility of the top management, while the tactical and operational decisions are of the responsibility of middle and operational management. Depending on the company, the information requirements can change at each level.

Balanced Scorecard for energy management

With the objectives and information requirements outlined, it's possible to correctly use the BSC framework to communicate the goals and select a metric to measure them. For the BSC framework be suited for energy management some adaptations were proposed. To ease its implementation, all the adaptations considered the structure of the original one.

As Figure 2 exhibits, the first substantial modification was the placement of the customer perspective as the foundation of the energy strategy; this adaptation is significant because it was not found in the literature. The reasoning behind the rearrangement of the perspectives was that in any organisation the energy is consumed with the goal of generating a service or a product; therefore, the specification of the service or product should be the foundation of the strategy. Then, to guarantee them, the energy requirements are managed by the agents of the organisation, such as the employees, the technology and the corporate culture. Next, these agents will apply the energy through an internal process that needed to be financially viable. Finally, the strategic energy mission should respect all the requirements of the perspectives and their connections. Consider the beforementioned, the rearrangement ensures the connection between the e-KPIs and the company KPIs, addressing one of the critical factors to achieve the sustainability goals.

Perspective	Company's Strategic Objectives	Sustainability Objective	E-KPI	Target	Responsible Person	Initiative
Financial						
Internal Business Process						
Learn & Growth						
Customer						

Figure 2 - Adapted Balanced Scorecard for energy management

To assure the alignment of the company's strategy with the sustainability strategy, it was added the column company's strategic objectives. This column gives the reader an idea of what the energy strategy must achieve. It's important to notice, that the objectives are not in a one to one relationship with the company's sustainability goals. They are there to remind that the user what the sustainability goals must ensure.

It is intended that the BSC for energy management works as a tool to outline the company's energy goals in different organisation's perspective, as well as a channel to ease the selection of the metrics that measure and monitor those goals. Thus, the original column measurement was renamed to e-KPIs instead of metric, this medication has the purpose of reminding the user that the metric is related to energy management and its role in the organisation.

Another significant alteration made to the framework was the addition of the column responsibilities, this addition considered the guidelines of B. Marrs and the norm IS022400 [9], which stated that for each organisational KPI there must be a responsible person for it.

In order to save time and preventing organisation to due redundant work, R. Kaplan [20] advice that after stating the goals and metrics and before filling the rest of the columns of the framework, it is crucial to ensure the cause-effect relationship between goals and KPIs.

To address that purpose, there is a proven tool in the literature that helps to visualise the relationship between the different objectives and their e-KPI, it is called SM and was also proposed by Kaplan and D. Norton [20,21] when they notice that organisation found difficult to made the connection.

Strategy Map for energy management

As in the BSC, the original SM needed adaptation, because it is considered that the categories identified, where the objectives of each should be placed, did not follow the energy management needs. The above Figure 3 exhibits the new SM framework, the yellow blocks represent the adaptations made, and the greys represent the parts kept from the original frame. The coloured blocks are the requirements of the product or service that the consumption of energy must guarantee.

At the top of the SM framework, the intended organisation's mission should be stated. The initial perspective that the mission is connected to is the financial perspective because, usually, this is the perspective that has more weigh in an organisation. The original divide the perspective into two groups, one that considers the growth of revenue by increasing the sales and another one that considers the cut of expenses when producing the product. In the new framework, the same group logic was kept; however, they were renamed to be more energy-related, the energy revenue growth efficiency and energy productivity strategy.

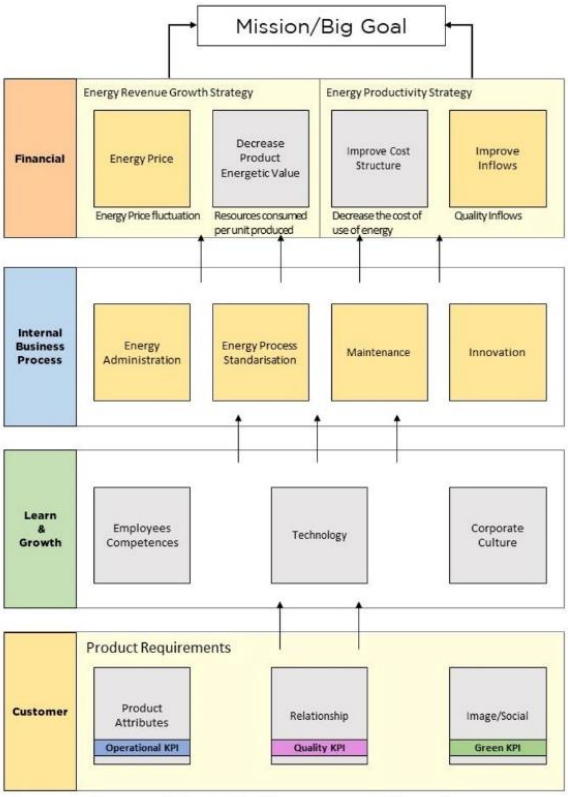

Figure 3 - Adapted Strategy Map for energy management

The energy revenue growth efficiency group considers objectives that impact financially how the energy is consumed in the organisation. As in the original framework, this group is subdivided into two categories.

- Energy price: objectives link to the cost of the energy, i.e., the ones that lead the company to buy the energy at the best price possible or make the organisation less susceptible to price fluctuations.
- Decrease energetic product value: objectives that affect the work unit/equipment performance to decrease the energetic product value.

While the energy productivity strategy group considers objectives that could lead to new opportunities for improving financially through the application of new elements or reuse of energy within the system, the production efficiency is also sectioned in two categories as in the original framework.

- Improvement cost structure: objectives that reformulate the process of purchasing energy from the grid, for example, the decision of an organisation acquire solar panels to produce solar energy primarily depends on the comparison between the price of energy from the grid and the one from the panel, i.e., the financial cost structure of both.
- Improvements of the inflows: objectives that improve the quality of the inputs in the system having in mind long terms paybacks, i.e., the quality of the inflow impacts the equipment efficiency and also have influenced its maintenance. Here, objectives that relate to emission pollutants can be placed. For example, if the company is trying to reduce its carbon emission that objectives should be here.

Since the financial perspective is directly connected to process energy consumption, the following perspective is the internal and business process. In comparison to the original SM, this perspective was the one that suffered more adaptation, all the categories were renamed; however, the number of categories were kept and the logic behind it too. The new categories were named we based on the types of process energy consumption defined in the literature and with the experience of the mentors of this dissertation:

- Energy administration: Objectives that increase the control of energy management inside the process. For example: improve energy monitorization.
- Standardisation: objectives that attempt to define a baseline for the energy consumption of the process or a baseline for the emission of pollutants.
- Maintenance: Objectives that decrease the non-working time or that intend to make the work unit/ equipment to work at their design conditions.
- Innovation: Objectives that enable the organisation to improve their energy consumption or reduce the emission of pollutants through inclusion in the process of new elements or technology.

All the business processes are executed by agents of the organisation to produce a product or a service. Therefore, the next perspective in the framework is the learn and growth perspective. All the categories of the classical SM were kept since they accurately summarise all the agents present in an organisation. The objectives of this category should be connected to the operational objectives. If the objectives cannot be linked, they should be replaced with ones that can.

Finally, the foundation is reached; in the new framework, the base is the customer perspective. All the categories identified by R. Kaplan were kept product, such as, attributes, relationship, and image/social. Nevertheless, they were reframed to be under the typical requirements that a service or a product most guarantee. Each of the categories represents a product specification. As a result of this modification, the operational, quality, and green KPIs of the product or services will be the foundation of the strategy, i.e., they will be the first thing to be respected in the organisation.

Finally, after ensuring that there is a continuous connection between the company's objectives to the company's mission, the rest of the BSC framework should be filled, i.e., a responsible person should be connected to each e-KPI, then a target for each metric should be stated as well as initiatives to achieve the target.

ISO 22400 KPI framework

After ensuring that all goals and metrics are interrelated, it is necessary to document the metric and attached to a responsible person. For ease the documentation process the ISO 22400 KPI [9] already purpose the use of characterization framework as a medium to accurately guarantee that each metrics assure the e-KPI criteria. Therefore, this dissertation proposes to use the of the framework for the documentation process. Nevertheless, a minor adaptation was made to the ISO 22400 framework so it will be in accordance with B. Marr guidelines [8], the row audience was renamed to responsible person.

It is important to remark that the row effect model diagram is of extreme importance for the development of the KOI network because highlight the variables that have a direct and indirect influence on the e- KPI.

KPI Description	
Content	
Name	
ID	
Description	
Scope	
Formula	
Unit of Measure	
Range	
Trend	
Context	
Timing	
Responsible person	
Production methodology	
Effect model diagram	
Notes	

Figure 4 - ISO 22400 KPI framework

Communication through the hierarchical division

Once all the e-KPIs are documented it's necessary to communicate to elaborate a network that exhibit how they are articulated in a manner that the decision-maker can appreciate it. Following the guidelines of B. Marrs and D. Parameter [8,10], one way to do it is by the type of decision that it is possibly make according to the hierarchical levels.

Field Work

In order to test the proposed methodology and expose its flaws and opportunities, it was applied in a real organisation with the goal of KPI network for an industrial complex pulp mill. For that purpose, a 2-month internship in the pulp mill was performed to understand the pulping process, the needs of the decision makers, and outline the energy strategy goals. During this period, it was possible to outline the hierarchical division of the puling factory, considering the largest energy consumers and the physical divisions.

Balanced Scorecard for energy management

Perspective	Company's Strategic Objectives	Sustainability Objective	E-KPI
Financial	• Increase in the pulp production rate until 2021 • Decrease the number of non-planning stops • Introduction of social and environmental sustainability elements the business model • Increase the motivation levels among employees • All departments should be guided by principles of transparency, ethics and respect when dealing with each other and with other • Increase the contribution of employees in the innovation process	Reduce the cost of energy	€/KWh
		Improve the energy efficiency of the equipment	KWh/tAD
		Increase the energy from new sources	%E
		Increase the profitability of the inflows	$M_{woodchip}/Tad$
Internal Business Process		Reduce process energy waste	E_{useful}/E_{total}
		Standardize the minimum energy consumption	$\%E_{save\ due\ to\ improv.}$
		Increase the monitorization and control of energy in the process	Score
		Modernize the pulp making process	Time to approval
Learn & Growth		Enhancement employee energy management knowledge	Return to Investment
		Take maximum advantage of the energy management tools	Frequency of use of E-tools
		Build a strong awareness towards energy consumption	Survey
Customer		Excellent Pulp	Operational and Quality KPIs
		Environmentally friendly pulp	Green KPIs

Figure 5 - Balanced Scoredcard for energy management

The objectives were stated with the help of the energy manager; thus, the metrics attributed to each objective considered the information needs of strategical management. These metrics were chosen by the energy manager while considering the KPI available in the literature [19], Figure 5 summarize the result. The process selection worked as follows: for every objective, three possible metrics were identified, then the one that outlined the information that the pulp mill manager considered to be the most relevant for the decision-making process was kept in the framework.

The first perspective filled was the customers. Here, the objectives follow the requirements that the outcome pulp must guarantee; these requirements are achieved through the accomplishment of the operational, quality, and green KPIs target values, imposed by the final customer – another factory section or an external customer. Since the product can change depending on the costumer, there were not specified in Figure 5.

The second perspective filled was the learn and growth perspective. The perspective's objectives and metrics were stated considering the human resource policies of the organisation and the company's new investment in energy management tools.

The third perspective filled was the internal and business process. The goals and metrics in this perspective intend to assess how energy is consumed in the pulping process, for example: The first goal, increase the monitorization and control of energy in the process, intends to evaluate the monitorisation and control capacity of the process; therefore, the metric chosen was the software sustainability index, which evaluates through a score process how much a structure is adequate for energy management.

The last perspective filled was the financial one. In this perspective, the objectives consider the process' financial viability and the amount of energy consumed. The first goal, reduce the cost of energy, tries to assess the energy cost of the process; the metric chosen was the price of a KWh.

After selecting the metric for each objective and before stating targets for the metrics, the SM framework for energy management was filled with the objectives and metrics identified to ensure their interconnection. displays the completed framework.

Strategy Map for energy management

After placing the objectives and metrics according to their category inside a perspective in the SM framework, the cause-effect links were with support and knowledge of the energy mill manager, starting

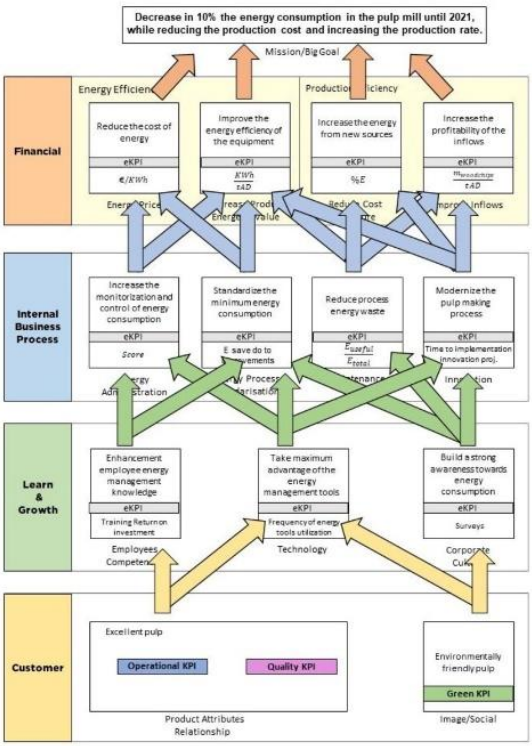

Figure 6 - Strategy Map for energy management

from the bottom. For example, in the customer's perspective, the operational and quality KPIs are linked to the employee's competence and company's technology because those are the primary agents that secure them, then inside the learn and growth perspective, the increment of the employee's knowledge, has a direct impact on how the energy is monitored and managed as well as how the energy is used in the process, this it is connected to the monitorization and control that has a direct impact on how the energy is consumed in the process and the company's energy bill; thus is connected to

the first goal, reduce the cost of energy, guides the organisation to achieve the financial viability of the energy mission. The second goal, improve the energy efficiency of the equipment, is directly connected to the consumption reduction part of the organisation's mission. The third goal, increase the energy from new sources, enables the company to reduce the grid consumption, and finds new ways to feed the process. Lastly, increase the profitability of the inflows, helps the organisation achieve its mission by increasing the earns from the inputs, making the process more efficient.

Documentation of the e-KPIs through the ISO22400 framework

After ensuring that all the objectives and metrics were interconnected, the ISO 22400 framework for stating the e-KPIs was used for each of the proposed metrics. Figure 20 displays an example of one of the selected metrics. The example above considers the metric for the objective of the financial perspective - improve the energy efficiency of the equipment. The next step is to create an effect diagram that presents the parameters that affect the metric; Figure 21 exhibits the effect diagram for the specific energy consumption, and it is possible to see that the metric is an aggregated result of the same parameter in sub-hierarchical levels. Therefore, the same metric will be considered as an e-KPI in the lower levels. The effect diagram is crucial for finding e-KPI in the lower hierarchical levels of the organisation. It is important to remark that only after each of the metrics is exhibited under the ISO2240 framework are they labelled e-KPIs because the framework ensures that the metrics fill all the required criteria to be considered e-KPIs.

E-KPI Description	
Content	
Name	Specific Energy Consumption
ID	1002
Description	Specific energy consumption is the ratio between all the energy consumed in a production cycle and the produced quantity (PQ)
Scope	Pulp Mill
Formula	e = E/PQ e: unit energy consumption of an equipment E: Total energy consume in a production cycle
Unit of Measure	KWh/TaD
Range	Min: 0 Kwh/tAD Max: product specific
Trend	The lower,the better
Context	
Timing	Weekly
Responsible person	Pulp Manager
Production methodology	Continuous
Effect model diagram	See Figure 18
Notes	Energy consumption is an important factor impacting the production costs and company profits. National

Figure 7 - ISO 22400 framework filled with an example

Proposed Network vs Actual Network

Since the Navigator company already has an e-KPI network that it is being use for a long time and has proven to be useful for managing and assessing the energy strategy of the company, the proposed e-KPI network was compared to the actual one in order to ensure that it keep the advantages of previous one and bridge its downsides.

	Actual Network	Proposed Network
Hierarchical Levels	3	3
Total nº of KPIs	6	37
Type of information	Aggregated	Aggregated and Disaggregated
Decision making capability assessment	Tactical	Strategic, tactical and operational
KPI assesment areas	Energy	Operational, Quality, Green and Energy
Frequency of measurement	Per hierarchical level	per e-KPI

Figure 8 - Actual Network vs Proposed Network

The comparison considered the networks structures as well as three significant factors that affect the implementation and the usage of KPIs outlined by the literature. The resulting information is presented and summarised in Figure 8. As it is possible to see the skeleton of both networks is the same, i.e., the hierarchical level division is identical.

One of the weakness of the original network was that it only provides aggregated information. According to R. Parmenter and B. Marrs [8,10], the origin of the situation could dwell in the fact that the network only uses one type of KPI and does not have enough e-KPI per each hierarchical level. Using the methodology, 37 KPIs were identified, 10 per hierarchical level instead of 2, which allow the network to provide more information.

The type of information given by each network is different. The current KPI network only measures aggregated values; thus, the type of decision that could be made are tactical decisions While, the proposed network gives aggregated and disaggregated values. Therefore, the user of the new network to assess strategic, tactical and operational decisions.

Another factor that affects the usage of the network is the type of e-KPI used by each of them. The actual network only uses e-KPI while the proposed network includes KPIs from different taxonomies, such as operational, quality, green and energy KPIs. This inclusion expected to lead to a better alignment between the operational strategy and the energy strategy of the organisation.

The latest comparison made between the network was the frequency of measurement of the KPIs. The actual network attributes the measurement of the KPIs is by hierarchical level, namely: weekly, \daily, or once per turn. This approach was found useful because all the e-KPIs are from the same type. Nevertheless, since the proposed network suggests the usage of a broad type range of e-KPIs, the frequency of measurement is tailored accordingly to the type of decision that can be made by assessing that e-KPI.

Conclusions

The proposed methodology intended to development a KPI network for a pulp mill. For that purpose, the current state of the art of KPIs was analysed focusing on what is their usefulness and the guidelines on how to select them. From the state of the art is possible to conclude that independently of the type of KPI, it is indispensable to connect the metrics to a well-established strategy and objectives. However, from the literature review conducted by May G [5], it was possible conclude that when it comes to e-KPIs, the methods and tools are not mature. One case is that contrary to the business KPIs, the current frameworks do not clearly tie the KPI to the company's objectives and mission. Therefore, the present methodology proposes key adaptations to some of the best-practices framework as a medium to develop an e-KPI network.
The methodology was applied the largest Kraft European pulp mill. To gather the information needed for the implementation, a two-months internship was made to understand the company culture and recognized the key elements in the decision-making process. The outcome of the methodology was a functional e-KPI network to deploy and manage the organisational energy strategy considering only the fiber department. Therefore, since I was obtained a functional e-KPI network, it can be said that the present methodology can be an alternative for an organisation state and obtain the key elements, goals and e-KPIs, influences the accomplishment of the sustainability objectives.

Taking into consideration the above-mentioned, it is expected that the purposed methodology contribute to:

- Express the organisation's sustainability strategy through the use of e-KPIs
- Growth the importance of the e-KPIs in organisations
- Attach the e-KPI to other company's metrics.
- Develop the procedures that help to select e-KPIs

Future work

Even though it was obtained capable network to manage the energy of a pulp mill, due to timing and work extension reasons, it was not possible to gather information about the outcome of its implementation. Due to the absence of these data, it is not feasible to conclude the most accurate way for the framework being spread and applied in organisations. For example, it is significant to conclude if the methodology is static or flexible, depending on if the frameworks can be arranged and modified, according to the company's necessities.

The outcome of the methodology was a broad spectrum of KPIs' types; some of them are not usually seen as being related to energy management. However, it is not possible to conclude if the inclusion of them makes the network richer or lose focus. Therefore, it is necessary to further research Additionally, the present methodology was very focused on energy management, but as previously seen, it can be easily applied for pollutants management.

Lastly, the present methodology admits that the organisations already know how to state a chose their sustainability mission. However, the identified problem - only two per cent of organisations achieve their sustainability programs - can dwell in the fact of the fact that organisations are not prepared to state sustainability missions and goals.

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