

Identifying essential data to evaluate and monitor energy performance

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Dissertation accepted in fulfilment of the requirements for
the degree *Master of Engineering with Development and
Management Engineering* at the North West University

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Graduation: June 2021

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ABSTRACT

Title: Identify essential data to evaluate and monitor energy performance
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Keywords: Monitoring and reporting, energy management and monitoring, identifying essential data, monitoring efficiency, tracing energy

The quantification of energy efficiency projects on a company's energy footprint are important. Energy management projects previously monitored energy consumption by using a ring-fenced approach. Though energy management projects are experiencing a shift towards group-level monitoring.

Efficient energy monitoring is imperative for energy management. The use of technology is vital in energy management. Energy consumption meters are used to measure the usage of energy. The energy consumption data measured, is stored in a database. Energy meters do, however, introduce certain challenges. An increase in the availability of data leads to an increase in the volume of data that needs to be evaluated. These big datasets then creates a resource- and time-intensive energy analysis process.

Based on these challenges, the three main focus areas of the study are (1) monitoring and reporting, (2) traceability, and (3) monitoring efficiency. This enables energy management by efficiently tracing energy initiatives over various boundaries. The objective of this study is to formulate techniques for establishing which energy consumption meters are the important meters when monitoring the energy usage of a facility.

Energy metering structures consist of a Point-of-Distribution (POD), built-up of a grouping of incomer meters. Each incomer meter also consists of a grouping of feeder meters. It is essential that energy monitoring and management are based on quality data. To determine the data quality, various datasets should be compared for validation and verification.

If these datasets match-up, an analysis to determine whether energy usage is accounted for throughout the entire facility, should be performed. This energy balance is utilised to understand the energy flow of a system and it also functions as a data quality test.

Key performance indicators (KPIs) are created and allocated to each available feeder meter. These KPIs are known as the Absolute Impact KPI and the Volatility KPI. A combination of the two KPI's are used to rank the energy meters. The number of meters that were established to

monitor at least 80% of the facility's energy consumption is then counted down in this ranked list. These highlighted feeders are then known as the essential meters.

The methodology was applied to two case studies. The first case study (Case Study A) functions in the mining sector and consists of 12 PODs, 37 incomers, and 180 feeders. The identified ("essential") meters constitute 21% of Case Study A's available feeder meters. These significant meters are used to calculate and monitor the energy consumption of the entire facility on a regular basis. When comparing the total estimated energy consumption based on the essential meters, of the current month with the following month a 4% increase is noted at Case Study A.

Through this study, ways to determine the essential meters were researched and developed. It was established that only the essential meters can be used to monitor the facility's energy consumption, indicating that the study objective was met. It is recommended that this study be expanded to be able to function alongside real-time energy management software.

ACKNOWLEDGEMENT

I would like to dedicate this degree to Simeon Nel, as you will never have the privilege of finishing your degree. May you rest in peace, Simeon.

To my Oupa Peet van der Merwe, I know you would have loved to celebrate this degree with me.

I would like to express my sincere gratitude towards Prof. Edward Mathews, Prof. Marius Kleingeld and Dr. Johann van Rensburg for the invaluable opportunity and resources to conduct this research. Thank you to Enermanage (Pty) Ltd and its sister companies for financial support to complete this study.

The success of this study rides on the back of one person, Dr. Andries Gous. Andries, I will never be able to thank you for your constant support, belief and calmness throughout this study. Thank you for your guidance, your way to take my passionate ideas for the study and ensure that they still link-up with the bigger picture. Also all the hours you spent to read through my work and making suggestions, even though you have a family. I am so blessed.

Dr. Walter Booysen, thank you for believing in me.

Thank you Andra Bester, for your respected recommendations.

A thank you to my parents, my sister, grandparents and “heart” friends for the support and prayers you provided while I wrote this dissertation. Thank you for understanding when I had to work on this instead of spending more time with you. Thank you that I could also always come to you for a hug and sympathy during this journey.

The Nel family should receive a special thanks: thank you that I could use your safe haven for my studies.

However, the most important Person, the One who made this opportunity, who helped me survive this road and who gave me the knowledge: Thank you my loving Father, the Lord above all.

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LIST OF ABBREVIATIONS

<i>Abbreviation</i>	<i>Description</i>
M&V	Measurement and Verification
KPI	Key Performance Indicator
POD	Point-of-Distribution
ECM	Energy Conservation Measure

NOMENCLATURE

<i>Terminology</i>	<i>Description</i>
POD	(Point-of-Distribution) This energy consumption value should be equal to an Utility bill. The POD is the sum of a grouping of incomer meters.
Incomer meter	The incomer meter is the sum of a grouping of feeder meters. The incomer meters measure the energy consumption of sections of a system.
Feeder meter	Feeder meters measure a subsection of an energy consumption system.
Ring-fenced boundary	An energy management boundary focusing on evaluating and monitoring the individual, isolated energy savings project.
Group-level boundary	An energy management boundary focusing on evaluating and monitoring the impact of an energy savings project(s) on the full / whole facility. Thus, the impact of energy savings projects should be identified on the Utility bill(s).
Eskom bill	An Eskom bill represents a <u>Utility bill</u> for South African energy users.

CHAPTER 1 - INTRODUCTION

1 Introduction

1.1 Preamble

Effective energy management has become increasingly vital over the past years [1]. This is due to ongoing attempts to decrease company expenses, for example, electricity costs¹. Whilst prioritising a company's social responsibility to reduce their carbon footprint (which is directly linked to energy consumption)¹.

At the same time, South Africa is experiencing a shortage of electricity-generation capacity [1]. Public requests to reduce electricity demand have increased and are maintained by rolling blackouts (otherwise known as load shedding), frequently experienced throughout the country² [1].

It is important to measure the energy consumption before it can be reduced or managed. However, it has become difficult to manage energy usage [2]. This is due to volumes of available data growing immensely and making it resource intensive to filter and handle the data³.

Certain consequences stem from the increasing importance of energy management and the difficulty in data handling. Consequences like valuable and strategic decision-making of a company's energy usage, based on informative data-analysis, becomes a complex necessity.

This chapter will give the background on the importance and the concepts related to energy management (*Section 1.2* and *1.3*). This will be followed by a literature analysis of Measurement and Verification (M&V) to find possible assistance for energy management (*Section 1.4*). M&V is an established tool by which energy management can be quantified and monitored [3]. *Section 1.5* will explore the data required to do M&V calculations, as well as tests to ensure quality data is used for these calculations. The tools to efficiently monitor the energy consumption of a facility are then analysed (*Section 1.6*). Afterwards, a broad summary of the literature review was done, to recap on the important deductions (*Section 1.7*).

¹ A. Mehta, "Why energy management is important." [Online]. Available: <https://www.albireoenergy.com/why-energy-management-is-important/>, 2016. [Accessed: 16-Aug-2020].

² Eskom, "What is load shedding." [Online]. Available: <https://loadshedding.eskom.co.za/LoadShedding/Description>. [Accessed: 23-Aug-2020].

³ I. Mund, "The top 5 data management challenges and how to overcome them." [Online]. Available: <https://www.bba.org.uk/news/insight/the-top-5-data-management-challenges-and-how-to-overcome-them/>. [Accessed: 16-Aug-2020].

Taking all of these sections into account, a need and scope for the study is determined (Section 1.8 and 1.9). Lastly, the outline of the document is given in Section 1.10.

1.2 Energy management

Energy usage in the global environment

Energy usage has become a global concern^{4, 5} [4] since the generation of electricity is mostly dependent on fossil fuels, which has the possibility to become a depleted resource^{4, 5} [4]. At the same time these traditional energy generation processes harm the planet by releasing air pollution, such as greenhouse gases^{4, 5 and 6}. Thus managing energy usage is essential^{4, 5} [4].

Energy management can be defined as the procedure to optimally use energy by minimising energy wastage^{7, 8}. This directly lessens electricity expenditure, which in effect augment profits^{7, 8}. Energy management also refers to condensing and reporting on the energy pollution associated with energy usage^{7, 8}.

Energy usage in South Africa

Eskom is South Africa's main power supplier⁹. According to an article by Reuters, Eskom provides 90% of South Africa's power and 40% of the energy on the African continent⁹. However, Eskom has been experiencing challenges in their ability to generate power^{9, 10 and 11}. First, by neglecting maintenance on existing power plants^{9, 10 and 11}. Secondly, during the construction of new power plants Eskom did not adequately manage the expenditures⁹ and encountered delays in the construction process⁹. This mismanagement and delays cumulated to an inability for Eskom to generate enough power to satisfy the demand^{9, 10 and 11}.

⁴ S. M. Audsley, "Why Study Energy Management." [Online]. Available:

<https://www.masterstudies.com/article/why-study-energy-management/>, 2019. [Accessed: 23-Aug-2020].

⁵ MITSDE, "Importance of Energy management." [Online]. Available: <https://blog.mitsde.com/importance-of-energy-management/>, 2018. [Accessed: 23-Aug-2020].

⁶ United States Environmental Protection Agency, "Learn about Energy and its Impact on the Environment." [Online]. Available: <https://www.epa.gov/energy/learn-about-energy-and-its-impact-environment>. 2019. [Accessed: 24-Sep-2020].

⁷ C. Nikhila, "Energy management: Meaning, Steps and Objectives." [Online]. Available: <https://www.businessmanagementideas.com/energy-management/energy-management-meaning-steps-and-objectives/>. [Accessed: 14-May-2020].

⁸ C. Heinz, "Three Reasons to Manage Your Energy." [Online]. Available: <https://blog.energycap.com/three-reasons-to-manage-your-energy>, 2013. [Accessed: 23-Aug-2020].

⁹ E. Sithole-Matarise, "Factbox: South Africa's power crisis - overhauling state utility Eskom." Reuters, Oct. 2019 [Online]. Available: <https://www.reuters.com/article/us-safrica-eskom-factbox>. [Accessed: 16-Aug-2020].

¹⁰ Eskom, "Load shedding FAQs." [Online]. Available: <http://www.eskom.co.za/documents/LoadSheddingFAQ.pdf>. [Accessed: 16-Aug-2020].

¹¹ M. Cohen and R. Vollgraaff, "Eskom crisis, jobs top ANC's priority list, Ramaphosa vows." [Online]. Available: <https://www.news24.com/fin24/news/eskom-crisis-jobs-top-ancs-priority-list-ramaphosa-vows-20200111>, 2020. [Accessed: 16-Aug-2020].

This incapability leads to radical rolling blackouts commencing since 2007 until the present day^{9, 10 and 11}. In an attempt to hinder a nation-wide breakdown (blackout) of the electricity network^{10, 11}, load shedding was implemented and this can take days to be reinstated.

On the other hand, the South African Government has implemented policies and programmes to pro-actively attempt to grow the generation capacity [5]. One of these policies is prescribed in the Electricity Regulation Act 4 of 2006 (ERA) [5], stating that the National Energy Regulator of South Africa (NERSA) is responsible to define the rules to execute the Integrated Resource Plan (IRP) [5].

The IRP's energy capacity plan [5], [6], [7] reveals the predicted power demand, the way the demand should be met, and the associated expenses [5], [6] [7]. The IRP is aiming to meet the projected energy demand and grow the generation capacity, by detecting affordable investment opportunities in the energy sector of South Africa [7], [8].

At the same time, South African Government policies and programmes were implemented to encourage sensible and sparing energy usage by citizens and companies [9]. One of which is the National Energy Efficiency Strategy (NEES) of South Africa, approved in March 2005 [9], [10]. The vision of the NEES is to reduce the country's energy intensity through energy efficiency [9], [10].

A campaign promoting NEES commenced during the winter months of 2014, known as The National Electricity Efficiency Program [1]. This initiative encourages the reduction of energy usage on the national electricity grid by all South Africans[1], [11], with the focus on developing an ethos of energy saving [1].

Energy usage of South African companies

The Energy Efficiency Target Monitoring System was implemented by the Department of Energy to monitor the advancement towards meeting the energy efficiency objectives stipulated in the NEES [12], [13]. For this tracking to realise, South African companies are required to report on their energy management procedures and progress [12], [14]. According to the Regulations on the Mandatory Provision of Energy Data, which came into operation on 1 March 2012, companies are also required to report on their energy consumption [12], [13], [15].

At the same time, energy costs have escalated with 446% from 2007 till 2019^{12,13} [16]. Whereas inflation has only increased by 98% for the same period¹². Figure 1-1 graphically compares the cost of energy in South Africa with the inflation rate¹².

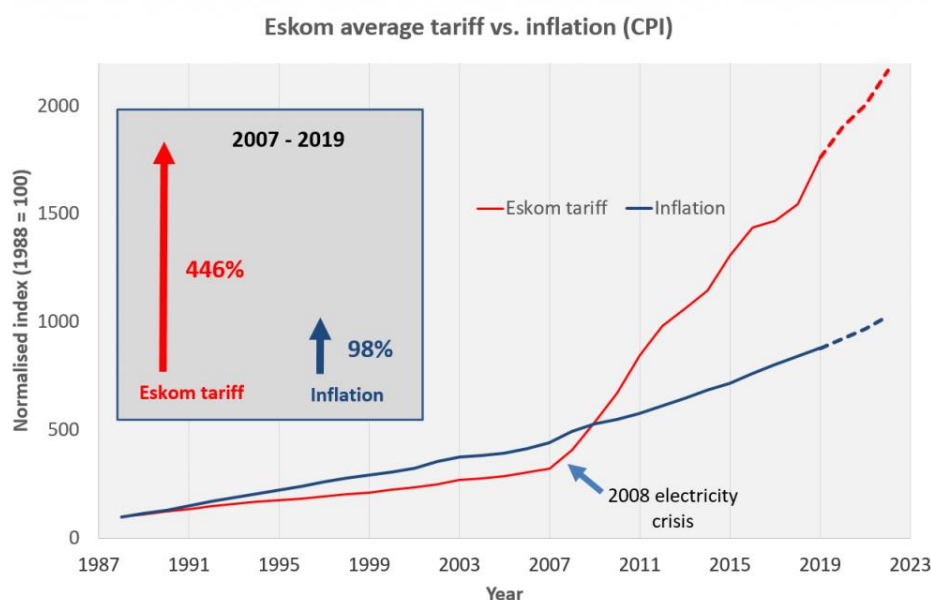


Figure 1-1 Comparison between the cost of energy in South Africa versus inflation

In Figure 1-1 it is clear that since the 2008 electricity crisis, the cost associated with energy increased more drastically than the inflation rate in South Africa¹². Further price escalation is also expected up to at least 2022¹². Implying that the financial pressure associated with electricity usage is not likely to subside.

Figure 1-1 also suggests that energy costs currently grow 4.5 times faster than the inflation rate¹². This indicates that electricity has become a large expense for companies and thus even just based on this fact alone, should be sensibly managed.

All South African citizens and companies have a responsibility to use energy sparingly and report on energy consumption as well as on energy efficiency. Together with the major electricity cost spike, energy management has become an important aspect for companies¹.

¹² S. Moolman, "2019 update: Eskom tariff increases vs inflation since 1988 (with projections to 2022)." Power Optimal, Oct. 2019. [Online]. Available: <https://www.poweroptimal.com/2019-update-eskom-tariff-increases-vs-inflation-since-1988-with-projections-to-2022/>. [Accessed: 12-Sep-2020].

¹³ Businesstech, "Expect big electricity price hikes in South Africa." Feb. 2020. [Online]. Available: <https://businesstech.co.za/news/energy/370700/expect-big-electricity-price-hikes-in-south-africa/>. [Accessed: 14-May-2020].

The term "energy management" refers to saving energy, with "energy-saving" meaning to monitor, regulate and conserve energy¹⁴ [17]. Saving energy includes opportunities such as identifying energy wastage, as well as substituting equipment with energy-efficient alternatives¹⁴.

When attempting to manage energy savings, the associated steps are to ensure energy meters are available and then obtaining this data¹⁴. Analysing the data to identify an energy savings opportunity and implementing the opportunity¹⁴. Lastly, to quantify (by comparing the energy consumption data before the implementation with the energy data after implementation) and keep a record of the energy savings obtained, Measurement and Verification (M&V) is used¹⁴ [18].

To effectively use M&V, energy efficiency initiatives (also known as energy savings projects) should be measured and monitored on an ongoing basis. The information obtained through this continuous observation should be reported to the relevant parties, for strategic decision-making [19]. This process of continuously observing and reporting on energy consumption and energy savings initiatives, is known as monitoring and reporting [19].

1.3 Concepts for energy management

Over the years, energy management has developed to present results with significant confidence. This confidence is founded on the underlying concepts that support energy management. These energy management concepts are:

- a) Continuously monitoring and reporting on the energy consumption and energy savings initiatives [19];
- b) Comprehensive disclosure of energy initiative impacts [20];
- c) Structured quality data should be used to calculate the energy initiative impacts [21];
- d) Transparency and traceability requirements^{15, 16}; and
- e) Efficiency in monitoring¹⁷.

¹⁴ BizEE, "The What, Why, and How of Energy Management." 2020. [Online]. Available: <https://www.energylens.com/articles/energy-management>. [Accessed: 12-Sep-2020].

¹⁵ Transparency and traceability of the progress of a company's energy management and -footprint.

¹⁶ L. Alton, "How transparency became a top priority for businesses, and why you should care," Entrepreneur South Africa, Jun. 2017. [Online]. Available: <https://www.entrepreneur.com/article/295739>. [Accessed: 24-Sep-2019].

¹⁷ Control Any, "Smart energy monitoring system," 2020. [Online]. Available: <https://www.controlany.com/solution/energy-monitoring-system/>. [Accessed: 04-May-2020].

(a) Monitoring and Reporting

Essential foundations for effective energy management is monitoring and reporting. Where monitoring and reporting can also provide feedback to the relevant parties with regards to energy savings initiatives [35], [22].

When regarding energy monitoring on its own, it allows tracking, documenting, and graphical representation of the energy consumed by the company [19]. Energy consumption monitoring is defined as the process of determining the cost of energy usage of a company and then managing the energy consumption accordingly [22]. Whereas energy consumption and energy efficiency initiative reporting are requirements for companies as stated by law (previously discussed in *Section 1.2*).

Substantial energy consumption cutbacks are a characteristic of healthy monitoring and reporting¹⁸ [22], due to being able to continuously identify energy wastage and energy savings opportunities (as noted in *Section 1.2*) [22]. Monitoring and reporting also adds traceability to the reduction in energy consumption, through a paper trail [22]. More advantages are the ability to understand how much energy is consumed by a company and the ratio in which the different areas of business consume energy¹⁹.

(b) Comprehensive disclosures of the energy initiative impact

One of the necessities for responsible energy management is to comprehensively disclose the impact of the energy initiatives [20], indicating that the direct and indirect impact of an energy efficiency project should be identified and calculated, according to the IPMVP [23]. Where “direct and indirect impact” refers to any and all energy efficiency changes which occurred due to the implementation of this initiative. The project is also not just identifying the “obvious” impacts, but thoroughly analysing the entire scope of the energy efficiency impact and declaring all of these changes.

This comprehensive disclosure is important and adds a function of knowledge about the energy initiatives and the related impacts, as well as an awareness for all stakeholders

¹⁸ Energy Manager Magazine, “The Importance of Metering and Monitoring Energy Consumption.” Feb. 2018 [Online]. Available: <https://www.energymanagermagazine.co.uk/the-importance-of-metering-and-monitoring-energy-consumption/>. [Accessed: 04-May-2020]

¹⁹ Energy.net, “Energy monitoring and reporting.” 2020. [Online]. Available: <http://www.energynet.it/en/our-services/energy-monitoring-and-reporting>. [Accessed: 14-May-2020].

involved as to the extent of the impact of these energy efficiency initiatives²⁰. A layer of accountability is added to the energy efficiency impact, due to the comprehensive disclosure of the impacts²⁰. The disclosure does not only motivate stakeholders to maintain the energy efficiency initiative, but might even encourage more energy efficiency initiatives to be implemented.

(c) Structured quality data

In order to ensure credibility in the energy efficiency impact and in effect the energy management performance, quality data should be used [20], [21]. This quality data should be utilised to calculate and monitor the impact of the energy efficiency initiative, as well as monitoring the energy consumption of a facility [20], [21]. This credibility is needed, to ensure that all stakeholders have assurance in the calculations and monitoring of not only the energy efficiency initiative, but also the energy consumption of a facility [20].

It is however, still important to note that the quality of the data should be balanced between a precision level and the cost needed to obtain this accurate data [20], [24]. This balance should be determined by the stakeholders [20], [24].

(d) Traceability of impacts

If stakeholders choose that the impact of the energy efficiency initiative should be analysed on the total company level, it in essence implies that the influence of the energy initiative should be traced to the level of an Eskom bill [25]. Unfortunately, the impact of the energy initiatives that should be analysed on total company level, needs to be greater than 10% in order to view the influence on the Eskom bill [23]. This is to ensure that the energy savings are greater than the energy consumption fluctuations, which are known as the changes seen in energy consumption not associated with the energy efficiency initiative.

If however, the impact of the energy efficiency initiative only needs to be determined at the energy efficiency implementation points (a.k.a. the individual isolated savings project), the energy savings do however, need to be isolated [25]. This separates the energy efficiency impact from any unrelated operation's energy consumption. This level of analysis (otherwise

²⁰ C40 Cities Climate Leadership Group, "How to use reporting and disclosure to drive building energy efficiency." Apr. 2019. [Online]. Available: <https://www.c40knowledgehub.org/s/article/How-to-use-reporting-and-disclosure-to-drive-building-energy-efficiency>. [Accessed: 24-Sep-2019].

known as a boundary) is determined by the stakeholders involved in the energy efficiency initiative [23].

(e) Efficiency in monitoring impacts

Although it is important to be able to identify the influence of energy initiatives on the predetermined evaluation and monitoring boundary of choice, it is also imperative to obtain this information within an acceptable time frame.

The smaller the time lapse between the energy consumption occurrence and the answers obtained through the energy consumption analysis, the more efficient the energy monitoring process.

It is essential that efficient energy monitoring should be performed, to identify anomalies of energy consumption as soon as possible¹⁷. Another advantage of efficient energy monitoring for companies, is to be able to frequently form energy management strategies according to the ascertained present-day energy consumption¹⁸.

Challenges observed when utilising the concepts of energy management

As these concepts form the foundation of energy management, certain challenges are prevalent. One of which is the constant changes experienced in the industry²¹. An example of this is energy management boundaries that may change from evaluating and monitoring the individual isolated savings project (ring-fenced boundary) to evaluating and monitoring the energy savings impact on the full facility (group-level boundary) [25]. This challenge does not only influence the monitoring and reporting concept, but also the traceability of impacts concept, as it makes it more difficult to trace the energy initiative's impact through having to change the monitoring and reporting boundary from the ring-fenced boundary to the group-level boundary.

Another challenge encountered is the fact that data availability has grown, leaving the energy management industry with large datasets [26], [27], [28], for example, having more than 200 data sources, which are available in half-hourly intervals. This excessive volume of data increases the difficulty to identify only the essential energy data, required for monitoring. Therefore, to acquire useful data from the big datasets might become a resource- and time-

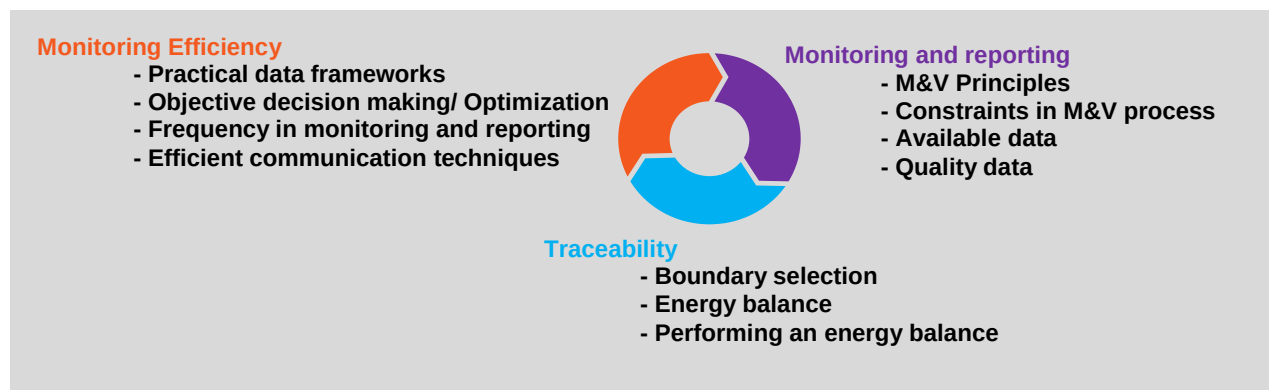
²¹ B. Marr, "What is Industry 4.0?." Forbes, Sep. 2018. [Online]. Available: <https://www.forbes.com/sites/bernardmarr/2018/09/02/what-is-industry-4-0-heres-a-super-easy-explanation-for-anyone/>. [Accessed: 24-Sep-2019].

intensive assignment (which in turn increases the difficulty in efficient energy management) [29].

To be able to efficiently monitor the energy usage, essential energy data will need to be identified within big datasets within a reasonable time frame. This is to have the ability to efficiently monitor and report on energy savings projects, as well as identifying energy consumption anomalies within an acceptable time frame. This challenge influences the monitoring and reporting concept and the efficiency in monitoring concept. This is because the large datasets, in effect causes the efficiency in monitoring these impacts to decrease and makes it difficult to continuously monitor and report on the associated energy consumption.

Knowing the importance of energy management and the challenges encountered in this field, the main focus areas of this study will be the three energy management concepts affected by these challenges. These concepts are (a) monitoring and reporting; (d) traceability of impacts; and (e) efficiency in monitoring impacts.

Take note that for the remainder of this study the symbol below will be used to indicate which concept is being addressed in the segment following the symbol. The concepts which will not be addressed and the subsections previously addressed will be greyed out, only indicating the subsections which have been addressed up to that specific point.



To “monitor”, “manage” and even “report” on energy consumption or energy efficiency savings projects, M&V should be used (as mentioned in *Section 1.2*) because M&V is the process of quantifying energy savings.

1.4 Measurement and Verification

As noted in *Section 1.2*, M&V is the process to quantify and confirm the savings attained through the intentional modifications of energy consumption [18]. Another way of looking at the M&V process is quantifying the absence of energy consumption and referring to this as the impact of energy saving initiatives²². This calculation of determining the absence of energy consumed is done by determining how much energy would have been consumed if no energy saving initiatives were implemented, and then subtracting the actual energy consumed²².

M&V guidelines and standards

Official international guidelines have been developed to assist in the M&V process [2], [30]. The International Performance Measurement and Verification Protocol (IPMVP) has been released in 2012 and reflects industry best practices for M&V [2], [23], [30]. A conceptual framework for measuring, quantifying, and reporting energy savings is revealed in the IPMVP [2], [23]. The IPMVP offers four M&V options (A – D) [2], [23], [30]. These options represent the different energy management boundaries available to measure the impact of the energy efficiency projects, ranging from specific parameter based evaluations to whole-facility evaluations [23], [30].

The Federal Energy Management Program (FEMP) reveals guidelines and techniques to calculate energy savings²³ [2]. The FEMP guidelines were created to enhance the IPMVP, as specific procedures were created and presented, to apply to concepts noted in the IPMVP²³ [2].

Another guideline associated with M&V is the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Guideline 14, *Measurement of Energy and Demand Savings*²⁴ [2]. The ASHRAE functions as a guideline to quantify energy- and demand savings as well as forming a guideline for metering- and data management²⁴ [2]. This guideline offers three methods that closely associate with Options B – D of the IPMVP, however, no method exists for Option A²⁴ [2].

In combination with these guidelines, specific standards exist, which can also be used to shepherd M&V calculations. The International Organisation for Standardisation (ISO) released

²² Efficiency Valuation Organization, "What is M&V." 2020. [Online]. Available: <https://evo-world.org/en/m-v/what-is-m-v>. [Accessed: 04-May-2020].

²³ U.S. Department of Energy, "Federal Energy Management Program." 2020. [Online]. Available: <https://www.energy.gov/eere/femp/about-federal-energy-management-program>. [Accessed: 13-Sep-2020].

²⁴ Energy Watch, "Measurement of Energy, Demand, and Water Savings." 2020. [Online]. Available: <https://energywatch-inc.com/ashrae-guideline-14/>. [Accessed: 13-Sep-2020].

the ISO 50 001 (2) and the South African National Standard (SANS), the SANS 50 010 (1), was created [25], [31], [32], both of which commenced in 2011 [25], [31].

ISO 50 001 (2) encourages continually improving energy management and measuring these results [32]. The SANS 50 010 is necessary and first act as an instrument to lessen the uncertainty which coexists with energy efficiency savings calculations, for all stakeholders [25], [31], [32]. Secondly, this standard ensures more trustworthy energy efficiency calculations [25], [31], [32].

The ISO 50 001 (2) is an international standard and it has been created to assist companies in establishing management systems needed to improve energy efficiency [31], [32]. The SANS 50 010 (1), on the other hand, is a standard specifically created for M&V in South Africa [25], [31]. The purpose of the SANS 50 010 (1) is to guarantee a transparent and consistent approach to calculating energy efficiency savings [25], [31].

According to the IPMVP, tasks associated with M&V are²² [33]:

1. Calibrating and maintaining energy consumption meters;
2. Obtaining and cleaning the data;
3. Construct appropriate and fair evaluation procedures;
4. Calculate the savings; and
5. Provide feedback, review calculations, and ensure that third parties review the calculations.

All these tasks are based on foundations crucial for M&V. These foundations are known as first principles.

M&V principles

The IPMVP states that the first principles of M&V are [34]:

- Precision;
- Comprehensiveness;
- Conservativeness;
- Repeatability;
- Relevance; and
- Transparency.

Precision refers to the level of uncertainty linked to the energy consumption savings, stating that the most conservative energy savings method should be selected, and which the M&V budget can afford [25].

Comprehensiveness indicates that the entire impact of an energy efficiency project should be revealed. However, only the sections of the impact which prove to be substantial should be calculated.

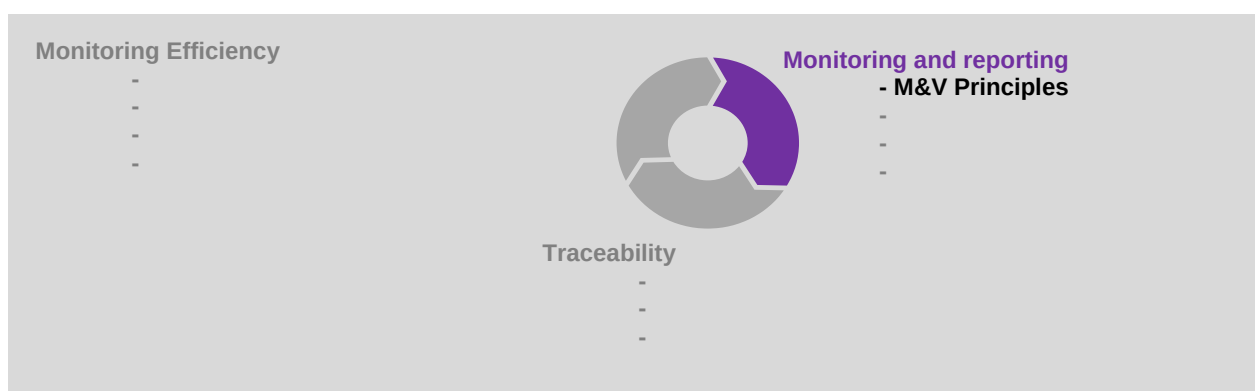
Whenever calculations are based on uncertain quantities, the most conservative choices should be made. The focus should be on these conservative choices, understating the savings obtained through the energy savings projects.

For the M&V process to be classified as repeatable, the energy efficiency calculations should reveal similar energy savings. The savings should thus not be highly dependable on the specific time the project was implemented, or the specific individuals implementing the project.

Relevance indicates that only the noteworthy sections of the impact should be quantified. Still, according to the comprehensiveness principle, the entire impact of the energy efficiency project should be stated.

Lastly, according to the principle of transparency, all the activities associated with the M&V energy efficiency calculations should be revealed. This principle includes that the energy efficiency savings report should also be fully disclosed.

Even though the specific steps to calculate the energy efficiency savings might need to be adapted per energy savings project, the M&V principles should always be present in the energy efficiency calculations. The foundations associated with calculating the energy efficiency savings will however, remain the same.



To add credibility to the monitoring and reporting of energy consumption of the facility or energy savings initiatives, the M&V process should be utilised. The principles of M&V are thus important to incorporate into the monitoring and reporting of a facility's energy consumption.

Foundations of energy efficiency calculations

Energy savings are calculated by²⁵ [35]:

1. Determining the pre-energy efficiency initiative implementation dates (also known as the baseline period) of energy consumption;
2. Perform an energy efficiency initiative;
3. Measuring the energy usage after the initiative;
4. If the operating conditions have changed since the energy efficiency project has been implemented, adjustments to the baseline energy consumption will be required; and
5. The difference between the baseline energy usage (or, if applicable, the adjusted baseline energy usage) and the post-initiative energy usage, is known as the energy savings.

These steps can be represented by the following equation [35]:

$$Energy\ usage_{saving} = Energy\ usage_{baseline} - Energy\ usage_{post-initiative} \pm Energy\ usage_{adjustments}$$

Where [35]:

$Energy\ usage_{saving}$ = is known as the energy saved (in kWh) by implementing the energy efficiency initiative. This is also seen as the impact of the energy efficiency initiative.

$Energy\ usage_{baseline}$ = is known as the energy consumed (in kWh) prior to implementing the energy efficiency initiative. This can also be known as the baseline energy consumption. To be able to create an energy consumption baseline for M&V purposes, historical data will be required [36]. The historical data should date back for at least one full cycle of operation, according to M&V regulations [20], [36]. It might even deem sensible to have the historical data date back for a year, to reveal the effect of seasonality on the data [37], [36].

²⁵ Office of Energy Efficiency & Renewable Energy, "Measurement and Verification Activities Required in the Energy Savings Performance Contract Process." [Online]. Available: <https://www.energy.gov/eere/femp/measurement-and-verification-activities-required-energy-savings-performance-contract>. [Accessed: 31-Dec-2019].

$Energy\ usage_{post-initiative}$ = is known as the energy consumed (in kWh) after implementing the energy efficiency initiative. Which might be known as the actual energy consumed or even the evaluation period energy usage.

$Energy\ usage_{adjustments}$ = is known as the energy consumption adjustments required (in kWh) to normalise the baseline energy, for fair energy savings evaluations. This is only necessary whenever operational changes have occurred since the implementation date of the energy efficiency project, influencing the energy consumption. This might include accounting for production changes, or whenever new equipment has been added to the facility.

Figure 1-2 is a graphical representation of the energy efficiency calculations²⁶ [35]. However, the baseline only needs adjustment if any of the operating conditions have changed since implementing the energy initiative [35].

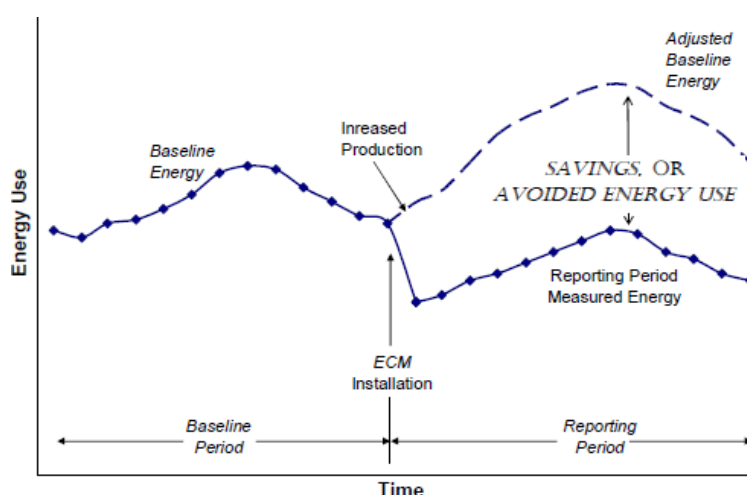


Figure 1-2: Energy efficiency calculation graphical representation²⁶

As can be interpreted from Figure 1-2 the difference between the adjusted baseline and the reporting period energy is known as the energy initiative savings, or rather the energy consumption avoided due to implementing the energy efficiency project.

This energy efficiency graphical representation might only represent the energy meters linked to the energy efficiency project. The graph might also include more energy meters, depending on the selected energy efficiency measurement boundary.

²⁶ Energy Watch, "Measuring and Verifying (M&V) Efficiency Projects." 2020. [Online]. Available: <https://energywatch-inc.com/measuring-verifying-mv-efficiency-projects/>. [Accessed: 16-Sep-2020].

Boundary selection

One of the starting points of using M&V is to determine the energy efficiency evaluation boundary [38]. The IPMVP notes that a selection of established boundaries is available to choose from. These boundaries are [2], [18], [25], [29], [35], [38]:

- a) Ring-fencing
 - a. Key-parameter
 - b. All-parameter
- b) Group-level / Full facility
- c) Calibrated simulation

When selecting the key-parameter ring-fencing boundary, only the crucial energy consumption aspects, linked to the specific endeavour, are reported on. Whereas with the all-parameter ring-fencing boundary all the energy consumption aspects, linked to the specific endeavour, are reported on. If group-level evaluation is selected it indicates that the entire facility would need to be analysed to dissect the impact of the energy efficiency initiative on the whole facility. To calibrate a simulation refers to creating a separate system to test a variety of scenarios and in effect reveal the energy which would have been consumed. The calibrated simulation is particularly handy in circumstances with missing data.

The Guidelines for Verification of Greenhouse Gas Emissions (GHG) state that it will become obligatory for particular companies to provide feedback on their GHG emissions [39], [40]. This movement noticed in government regulations, confirms the need to be able to monitor energy consumption and the influence of energy savings initiatives on the full-facility boundary. Due to movements like the GHG feedback, it can be seen that there is a present-day phenomenon experienced by the industry, of moving from ring-fenced energy efficiency evaluation, toward a full-facility boundary energy efficiency evaluation [25], [39], [40].

It should be noted that energy savings will only be visible on the full-facility level, once the savings surpass 10% of the pre-initiative energy consumption [23]. This is due to normal fluctuations in energy consumption (a.k.a. “noise”) adding challenges in identifying pure energy savings.

This challenge is however not the only challenge in the M&V process. Each of these challenges is caused by a specific constraint linked to the M&V process.

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Monitoring and reporting - M&V Principles

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When stakeholders select the boundary for monitoring and reporting purposes, it determines to what degree the energy efficiency savings should be isolated. However, this is done while still ensuring that by selecting any boundary, the energy efficiency's impact is traceable and measurable.

Constraints related to energy efficiency projects and the associated M&V process

Some of the hurdles encountered when performing the M&V process are:

- The persistent changes in the energy reporting obligations [14], [29];
- Severe administrative commitments to legislation [29];
- Transparency and comprehensiveness of the business-related activities and decisions, as well as the entire M&V process, leads to a tedious energy reporting write-up process [14];
- Energy-related data is known to be incomplete, difficult to obtain and rarely all-inclusive [14];
- Any model used to quantify energy-related savings, contains a level of uncertainty [29];
- Energy changes might occur at the facility, making non-routine baseline adjustments necessary [2];
- Reports based on energy, are seldom consistent and comparable [14];
- These energy associated reports are often regarded as “not-important” and irresponsibly created [14];
- The impact of energy efficiency initiatives should be traced (“noticeable”) to reflect the influence on the entire business [14]; and
- Having to quantify the financial impact of an energy efficiency project to the energy-related data to indicate the financial impact of this data [2].

These constraints have to be managed responsibly. However, specific constraints related to energy metering exist, as well as the associated energy management software.

One of the consequences for companies not utilising up to date and comprehensive energy management software for monitoring purposes, is the lengthy time intervals between energy measurements [29], [41]. This means that energy efficiency opportunities might go by unnoticed [29], [41].

To counter the limited available energy data, modern energy management software is accessible. As a result of this modern and comprehensive software, excessive amounts of data are prevalent [2], [29], [35]. This excessive amount of data needs to be filtered to be able to identify the important data, which might become a resource- and time-intensive process³ [29].

Another concern of implementing modern energy management software is the large infrastructure expenses and the possibility of idling operations [41]. To implement modern energy management software, is however, a decision for company management.

Lastly, the scale known as the M&V intensity, should also be considered by the stakeholders involved in the energy efficiency project [29]. The time and amount of resources dedicated to the M&V project are directly associated to this scale [29], [42]. At the same time, the costs linked to the amount of time and resources spent on calculating the impact of the energy efficiency project, on the facility, is also an important factor to consider [29], [42]. In the end, a balance between the M&V intensity and the level of uncertainty, associated with the energy efficiency calculations, should be obtained [29], [42].

Knowing that energy data is required to perform M&V calculations for energy efficiency projects, it is important to determine what data is available and necessary for energy savings calculations. At the same time, the quality of the data needed for M&V calculations, must be determined.

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Monitoring and reporting should utilise the M&V process to calculate the impact of energy efficiency savings and the energy consumption of a facility. Therefore, the constraints associated with the M&V process in effect will influence the monitoring and reporting concept of energy management.

1.5 Data used for M&V

Available data

M&V calculations are meant to quantify the savings obtained through energy initiative projects²² [18], thus enumerating the effects of the energy changes and then converting this energy change into an equivalent cost impact²² [18]. To be able to compute the savings using M&V calculations, energy consumption data is necessary [43]. Secondly, the associated tariff structure is essential to calculate the cost of the energy saving [43].

The SANS 50010 states that energy bills can be used for energy consumption data [2], [25]. This is since these bills reflect what was paid for the energy consumed and these readings need to adhere to industry accuracy rules [23]. Energy consumption meters may also be used to measure the energy initiative savings [25], [29].

When using energy bills as a source of energy consumption data, a few challenges might arise. As the Eskom bills do not necessarily have to produce frequent meter readings, this data might not be sufficient for M&V use [23], [43]. Eskom bills might also reflect projected energy consumption data, which will only be corrected after a certain period [23]. Consequently, no legitimate data exists for the period reflected on those projected energy consumption bills [23].

Lastly, companies might use a variety of energy sources [23], [43] and therefore Eskom bills will not reflect the entire available energy that was consumed [23], [43]. In these cases, a

down-stream meter, or even a difference in inventory levels of energy sources (for example fuel) added on top of the Eskom bills, might emulate the full-facility energy consumption [23], [43].

If energy meters are the source of the energy consumption data, it is necessary to ensure sub-meters are installed to measure and monitor the energy consumption of the specific areas of interest [23], [43], [44]. If the ring-fenced M&V boundary is selected for the M&V calculations, it is best to calculate energy savings per energy meter linked to the energy initiatives, as far as possible [23], [44].

Whenever energy meters obtain their energy data readings on separate days, these meters need to be evaluated independently for energy savings [23]. The total savings should only be combined after evaluating each energy meter separately [23]. It should be noted that energy meters, measuring data of regions without energy savings initiatives, may be disregarded in savings calculations [23], [44].

Lastly, if ever data gaps exist in energy metering data, the data can be filled using a mathematical model [23], [44], as long as it is noted as savings obtained with “missing data” [23].

Knowing the types of data available, it is necessary to determine the frequency of energy data points which are available to choose from, as well as how to determine what type of data is needed for each type of M&V evaluation.



Due to the fact that the M&V process should be used to monitor and report the energy consumption of a facility, the data required for M&V calculations should be used to calculate the energy consumption of a facility.

Data frequency and selecting a data source

The frequency of energy consumption data regarded as necessary will belong to one of the following categories [20]:

1. Spot evaluation;
2. Continuous evaluation; or
3. Utility bill evaluations.

The spot evaluation is ideal to evaluate minor energy initiative projects, for example, to measure lighting efficiencies [20]. This is to take once-off measurements to reveal energy savings, thus comparing an energy consumption reading prior to the energy initiative with an energy consumption after the energy initiative was implemented.

For large energy initiative projects, it would be wise to use continuous evaluation measurements. As well as energy data in the smallest frequency available, otherwise known as energy metering software data [20]. This is to monitor the impact of the energy initiative and also to evaluate the influence of this initiative over a period of time to ensure the change in the energy consumption was not just a once-off phenomenon. However, this frequency method is most beneficial for facilities where energy consumption projects can be isolated [20]. This is to guarantee that energy consumption “noise” is not being confused with energy savings due to the energy initiative [23].

If the energy savings impact is greater than 10% of the Eskom bill (otherwise known as the full-facility level), the energy efficiency impact will be noticed on the full-facility level [23]. This is due to the energy consumption “noise” influencing the energy savings on the Eskom bill and making it difficult to identify the entire impact of the energy initiative on the facility [23]. Eskom bills are also ideal whenever the energy initiative savings can be grouped to a full-facility level [20]. Implying that energy savings initiatives occurs throughout the entire facility and all of these energy savings may be evaluated together.

Another aspect to take into account when deciding on the form and the frequency of the energy consumption data, is the Eskom time-of-use (TOU) tariffs [45]. TOU refers to Eskom's

partitioning of a 24-hour day and associating a different cost tariff with each section [45].

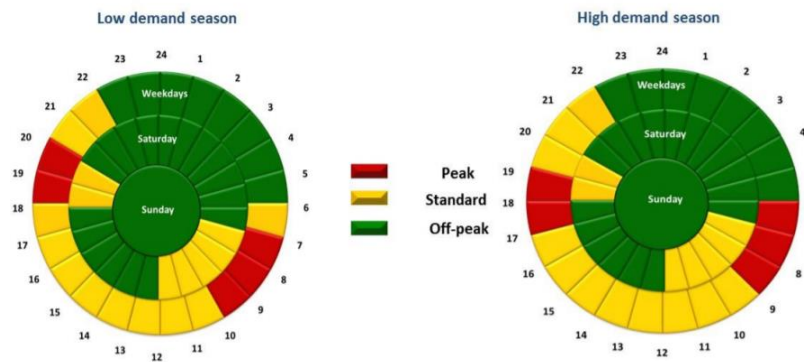


Figure 1-3 is an example of Eskom's TOU periods [45]. The outer circle, revealing the partitioning of a weekday, the middle circle revealing the partitioning of a Saturday and in the middle, a Sunday [45]. The high demand season refers to winter months (June, July and August) and the low demand season refers to the remaining months [45]. Lastly, the green blocks indicate the cheapest tariff period, also seen as the low demand period [45]. The red blocks reveal the most-expensive tariff period and is also known as the high demand period [45]. Whereas the yellow blocks refer to the medium demand period [45].

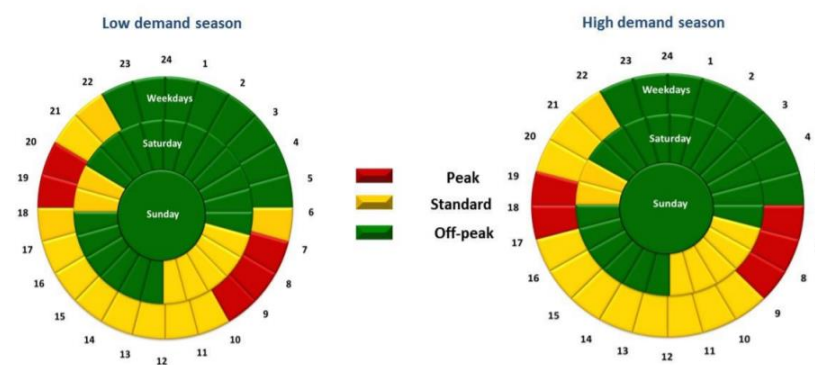


Figure 1-3: Eskom Time-of-Use graph

Whenever a company is striving to obtain cost savings benefits from this tariff variations, it is important to monitor the energy consumption data at a small enough frequency [41], [45]. This will assist with more effective energy management.

Yet, even though a main data source with a specific frequency may be used, a variety of data sources may be used and compared for M&V calculations [35], [41]. For example, the energy invoices as well as the energy consumption metering system can be used and compared. If these aids then match with a reasonable error, this will add to the reliability of the energy

consumption data. Other ways do however, exist, to classify what the quality of the used data is.

Quality of the data

The quality of data can be defined by a combination of four categories [29], [37]. These categories are based on what data-consumers expect of quality data [37]. (1) Intrinsic data encompasses the objectivity and accuracy of the data [20], [29], [37]. The data should be relevant and complete to be classified as good contextual data quality (2) [20], [29], [37]. For representational data quality (3) interpretability and concise representation is required [20], [29], [37]. Lastly, for accessible data quality, ease of accessibility to the data is a necessity, as well as having a cost-standard, associated with obtaining quality data, suitable to all interested parties (4) [20], [37].

One of the consequences of not using quality data is bad or uninformed decision-making [29], [46]. Whereas the advantages of quality data are applicable, comprehensive, small-error prone, and representative data, used for strategic decision-making [29].

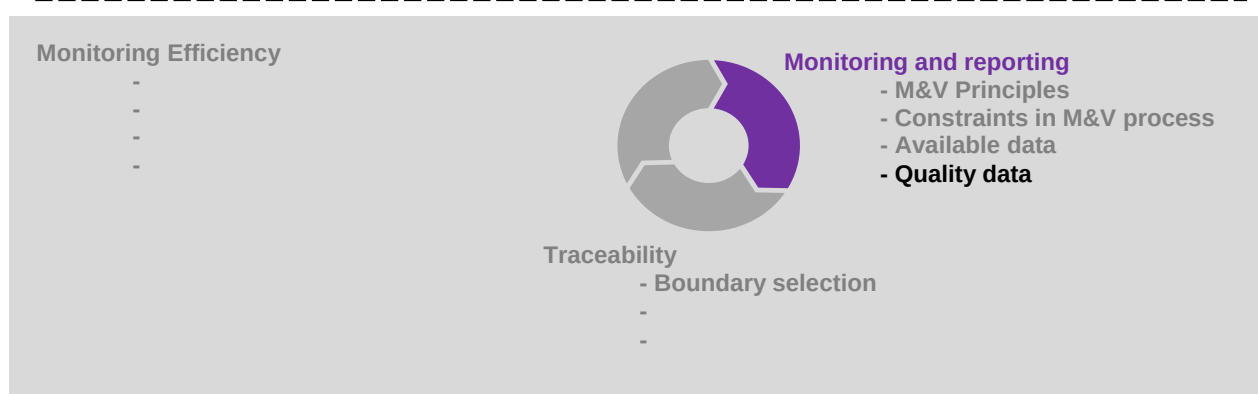
Unfortunately, there will always be a degree of uncertainty associated with energy consumption data [29], [46]. Some of the reasons for the inaccuracies are: Energy consumption metering equipment may have calibration errors, as well as the modelling method selected to calculate the energy savings might not always fully entertain the fluctuations in energy usage [20]. Nonetheless, these uncertainties should be identified and managed.

Ways exist to test the accuracy of the data and determine the uncertainties of the data, one of which the energy balance calculations for the entire facility can be performed [29]. An energy balance is a technique to determine and account for all the energy flow throughout the entire organisation²⁷ [14], [29], [47]. Another test can be performed, such as a measurement test along the path of energy flow and compared to the energy consumption dataset to determine the relevance of the dataset [29]. If any unexplained deviations during the comparison of the energy consumption dataset and the measured energy consumption occur, it will lead to uncertainty of the data [29]. Lastly, analysing the documents confirming the calibration of the energy meters, may lead to greater confidence in the quality of the data.

²⁷ M Tribedi, "Essay on Material and Energy Balance in Industries - Energy Management," Engineering Notes, 2016. [Online]. Available: <http://www.engineeringenotes.com/essay/energy-management/essay-on-material-and-energy-balance-in-industries-energy-management/18746>. [Accessed: 31-Dec-2019].

The precision of the data can still be improved and managed, but these improvements might be costly (for example installing new energy meters) [20]. It might be beneficial to implement a tool known as “data-cleaning” in order to find a balance between data-uncertainty and cost implications, which will be accepted by all stakeholders [29], [48]. Data-cleaning is to ensure outliers are removed and only relevant data is used in M&V calculations, rather than buying-, replacing- or calibrating energy meters [29].

However, to be able to clean data and test the quality of the data, the data needs to be usable. Thus, a data framework in a practical format still reflecting the details linked to the data, should be beneficial.



The last subsection allocated to monitoring and reporting, is quality data. This is again due to the fact that monitoring and reporting will utilise the M&V process by in effect using the data required for M&V calculations. The use of quality data for the calculations will add a layer of credibility.

Practical data frameworks

A data framework is a tool used to assist in storing, scrutinizing and processing data²⁸. Storing refers to keeping the data in an accessible format for the use of M&V calculations, whilst still keeping the detailed information of the data. Scrutinizing is also known as analysing the data, which states that the quality of the data needs to be determined and the data should be cleaned. Finally, to process the data means to use the data for the M&V calculations.

²⁸ S. Andrieiev, “What is big data framework?.” 2019. [Online]. Available: <https://www.quora.com/What-is-big-data-framework-1>. [Accessed: 20-Sep-2020].

There are two stages when using the data framework tool [29]. Stage one is to select the measurement boundary and obtain the data needed to evaluate this measurement boundary, where stage two assesses and scrutinizes the acquired datasets [29].

During stage one of the data framework tool, it is important to describe the obtained data in such a way that it can be categorised [20], [35], [49], [50]. These descriptions are known as “meta-data”, for example noting that the specific data reading is obtained on this date and time, originating from the energy metering software, specifically the fifth energy meter [20], [48], [50], [51]. This contributes to the traceability of the data.

When moving on to stage two, the data is analysed and “cleaned” by removing outliers [29]. However, after “cleaning”, trends should be identified in the data [29]. If abnormalities are noticed in the energy data trends and no explanation can be assigned, the dataset will be classified as either unrelated or low quality data [29]. Which will add to the level of uncertainty and unreliability linked to the M&V calculations. Another test associated with this stage of the data framework, is known as performing an energy balance. This will determine if all the data is accounted for, as well as the specific flow of the energy throughout the system.

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Monitoring and reporting

- M&V Principles
- Constraints in M&V process
- Available data
- Quality data

Traceability

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As part of the M&V process requirement to store the data used for the M&V calculations, a method to categorise the data should be implemented. This is to ensure efficient “drilling down” and pin-pointing to the impact of the energy efficiency initiative, also ensuring that the data is cleaned and stored for quick referencing.

Energy balance

Energy balance is a technique available to track the energy flow throughout the entire organisation²⁷ [14], [47]. It focusses on noticing the magnitude of the flow to ensure that energy does not go unaccounted for²⁷ [14].

Some of the available forms of energy balances are unit balance and distribution balance [14]. A unit balance is based on the scientific rule of all the energy “in” should be equal to all the energy “out”²⁷ [14], [46], [47], [52], [53]. Distribution balance is the summation that all the individual energy flows should be equal to the total energy flow²⁷ [14], [46], [47]. Figure 1-4 demonstrates the unit- and distribution balance principles [14].

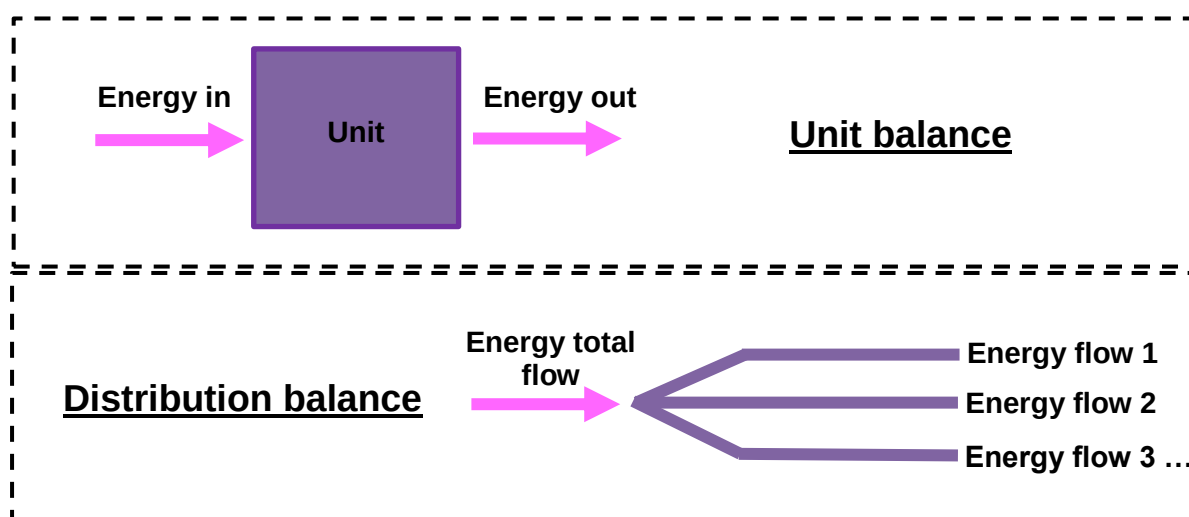


Figure 1-4: Types of energy balances

There are a variety of reasons and advantages for performing an energy balance²⁷ [52], [54]. An energy balance can assist in reconciling energy data, as an energy balance is based on the principle that energy into a system should be equal to the energy out of the system²⁷ [52], [54]. An energy balance helps to “fine-tune” the energy data if, for example, calibration errors occur.

By performing an energy balance the entire energy flow of the system can be analysed, better understood and audited, to ensure energy flow does not go by unnoticed²⁷ [52], [54], [55]. As companies do not necessarily measure each individual energy flow in a facility, by utilising the “energy in equals the energy out” principle of an energy balance, it assists in determining the missing energy flows’ magnitudes. Also, by adding reasons behind the energy balance analysis, opportunities can be identified for either smarter energy usage or a decrease in energy consumption (also known as energy wastage) [55].

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Monitoring and reporting

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- Available data
- Quality data

Energy balances can be used not only as a data quality test, but also to trace the impact of energy efficiency initiatives over the various boundaries of the facility.

Performing an energy balance

To perform an energy balance all the energy data, associated with the selected M&V measurement boundary, should be obtained, where after the data should be “cleaned”²⁷. Secondly, the overall, main energy flow should be drafted, followed by breaking the main energy flow system up into smaller subsystems²⁷.

Perform an energy balance by alternating the unit balance and the distribution balance throughout the whole facility’s energy consumption dataset²⁷ [14]. Due to a lack of reliable and comprehensive data, assumptions will be prevalent [14]. If data is missing, it may also be filled utilising scientific methods²⁷.

As the energy balances are performed error percentages will be established²⁷ [14]. Indicating how well the various unit- and distribution balances matched-up throughout the facility [14]. Data reconciliation should follow, where after the balances must be recalculated²⁷ [14]. This process should continue until an error of zero percent is evident²⁷ [14].

Up until this stage it has been determined what data to use for monitoring and reporting, as well as the quality of the associated data. Afterwards, energy efficiency initiatives are traced throughout the entire facility’s energy consumption.

Next, to ensure efficient monitoring and reporting, techniques are available to identify the important energy meters and efficiently communicate the energy consumption “state” of the facility with management.

Monitoring Efficiency

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**Traceability**

- Boundary selection

Monitoring and reporting

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- Constraints in M&V process
- Available data
- Quality data

Due to the energy balance subsection being associated with the traceability concept of energy management, the requirements to perform an energy balance should be allocated under traceability, because energy efficiency initiatives have to be traced over the various boundaries.

1.6 Efficiently monitoring energy consumption techniques

In this section, techniques to efficiently monitor energy consumption will be highlighted. These techniques do not only include ways to optimally and objectively identify important energy meters, but also how frequently these important meters need to be revised. The discussion ends with techniques to efficiently communicate the energy consumption information with the stakeholders involved.

Objective decision making/ Optimisation

According to the Business Dictionary, the definition of objective decision making is to base a decision purely on facts²⁹. In which case the most important energy meters will be identified using objective decision making tools. Using only the identified important meters, optimisation of the energy monitoring and reporting process occurs. Optimisation refers to changing a data set in order to make it work more efficiently, according to the Oxford Learner's Dictionary³⁰.

An effective measurement technique is known as key performance indicators (KPI) [22], [56], [57]. Where KPIs refer to a measurable value that measures and monitors the performance of a specific energy meter [22], [56], [57]. Some of the advantages associated with KPIs are to regulate energy use by comparing it to previous energy usage; to identifying trends in the

²⁹ J. Glen, "Objective vs. Subjective." 2013. [Online]. Available: <http://www.businessdictionary.com/article/966/objective-vs-subjective-d1113/>. [Accessed: 24-Sep-2020].

³⁰ Oxford Learner's Dictionary, "Optimize." 2020. [Online]. Available: <https://www.oxfordlearnersdictionaries.com/definition/english/optimize>. [Accessed: 24-Sep-2020].

energy data and more efficiently recognizing energy consumption wastage [22]. These indicators are utilised to assist the user in decision-making [58].

According to the ISO 50001 the Plan-Do-Check-Act (PDCA) cycle should be followed when setting-up KPIs [58]. KPIs usually takes on the form of a statistical value and is the level of agreement of the specific benchmark [58]. It forms a platform to be able to relate a variety of processes or units with each other and see which is more energy-efficient [58]. However, KPIs can also reflect an economic value or status [26].

Another technique available for objective decision making is a sensitivity analysis which identifies the most volatile inputs of a model [59]. This directly echoes the uncertainty and volatility pertained by the energy metering data [59]. When optimising decision-making it is important to take note of the sensitivity of energy consumption meters. These meters should be identified and closely monitored, to eliminate pointless energy usage and having these meters unnecessarily be identified as an important meter.

Using both KPIs and sensitivity analysis will assist in identifying the rank of importance between the energy meters. From then onwards a Pareto analysis (otherwise known as the 80/20 rule) can be utilised to base the concept of only monitoring the important energy meters, rather than monitoring the entire facility's energy meters³¹. The 80/20 rule is based on the concept of having 80% of the results reflected by using 20% of the data³¹. This implies that it might be worthwhile to identify the important 20% energy consumption meters, rather than analysing and monitoring the entire facility's energy meters.

However, the most important meters might change from time-to-time. Therefore, it is imperative to determine when to re-identify the important energy meters.

Monitoring Efficiency

- Practical data frameworks
- **Objective decision making/ Optimization**
-
-



Monitoring and reporting

- M&V Principles
- Constraints in M&V process
- Available data
- Quality data

Traceability

- Boundary selection
- Energy balance
- Performing an energy balance

³¹ Kevin Kruse, "The 80/20 Rule And How It Can Change Your Life," Forbes, 2016. [Online]. Available: <https://www.forbes.com/sites/kevinkruse/2016/03/07/80-20-rule/>. [Accessed: 24-Sep-2019].

Due to the fact that the monitoring and reporting process should work toward efficiently monitoring the energy consumption of a facility, techniques to optimize the monitoring and reporting process are required. However, due to the fact that large datasets are a challenge, ways to objectively identify the important data are required. These objective tools will assist in ensuring a more efficient process.

Frequency of monitoring and reporting

As mentioned in *Objective decision making/Optimisation* ISO 50001 the Plan-Do-Check-Act are to be followed when setting-up KPIs [58]. This means that KPIs should be generated during the planning phase and afterwards revised on a regular basis [58].

Due to the comprehensive and modern energy management software (as noted in *Available data*) real-time^{32, 33} energy monitoring is a possibility [26], [27]. In which case KPIs will be of great importance [26]. As the KPI will assist in pro-actively identifying operations (otherwise known as energy meters) moving from unimportant energy meters to important energy meters, or vice versa, rather than just passively observing the energy consumption data²⁵ [22], [26], [27]. This will contribute to a decrease in unnecessary energy expenses [26].

Monitoring Efficiency

- Practical data frameworks
- Objective decision making/ Optimization
- Frequency in monitoring and reporting
-



Monitoring and reporting

- M&V Principles
- Constraints in M&V process
- Available data
- Quality data

Traceability

- Boundary selection
- Energy balance
- Performing an energy balance

Even though these objective techniques to identify the important data will be utilised, these energy data meters will however not always be classified as important. Due to the constant changes in operations and growth of a company, the objective identification of the important meters should frequently be re-evaluated. This process should still ensure efficient identification of the important meters.

³² Defined by the Cambridge dictionary, as presented at the same time as the actual occurrence of the incident.

³³ Cambridge dictionary, "Real-time." [Online]. Available: <https://dictionary.cambridge.org/dictionary/english/real-time>. [Accessed: 08-May-2020].

Efficient communication techniques

Finally, providing regular feedback on the energy consumption of a facility has certain advantages, such as inspiring energy reduction initiatives³⁴ [22]. Providing frequent feedback on implemented energy efficiency initiatives will benefit management's decision-making. Regulating costs are associated with energy consumption and finally, ensuring the constant performance of cost reductions.

One of the methods to communicate and monitor energy data and –trends is by pairing graphs and numerical results³⁴ [49], [60]. Advantages of graphical evaluations are [50], [60]:

1. To obtain a broad and comprehensive “feel” for the data.
2. To be able to view and analyse the more detailed events noticed in the data.
3. It is simpler to investigate and digest a graph when confronted with large datasets.
4. If “meta-data³⁵” is used, graphs be categorised and more effectively assessed and compared.

Monitoring Efficiency

- Practical data frameworks
- Objective decision making/ Optimization
- Frequency in monitoring and reporting
- **Efficient communication techniques**



Monitoring and reporting

- M&V Principles
- Constraints in M&V process
- Available data
- Quality data

Traceability

- Boundary selection
- Energy balance
- Performing an energy balance

The final subsection is about the use of techniques to efficiently communicate the energy consumption “state” of the company using only the important meters. These tools should assist management to efficiently make decisions regarding the information obtained from this energy consumption “state” report.

³⁴ BizEE, “Energy Monitoring Charts and Tables Created by Energy Lens,” 2019. [Online]. Available: <https://www.energylens.com/outputs>. [Accessed: 31-Dec-2019].

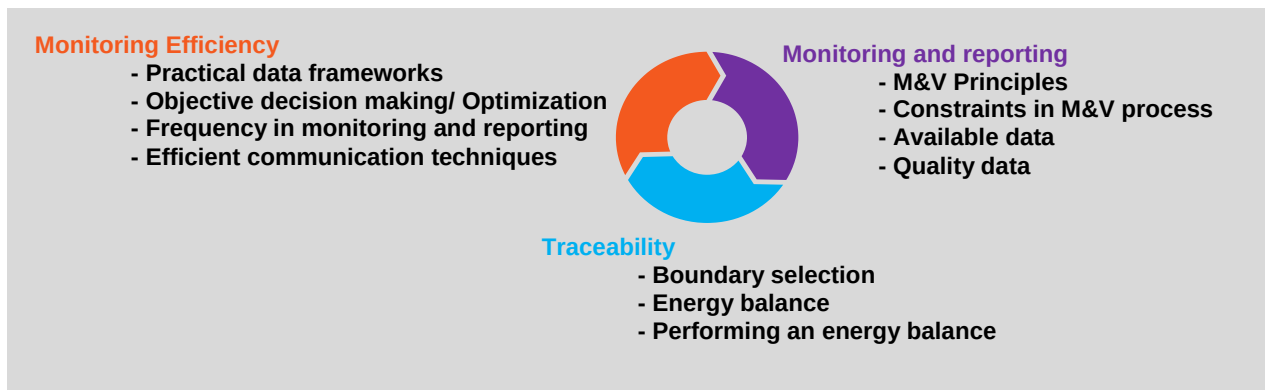
³⁵ As discussed in *Practical data frameworks* it is adding descriptions to data. Doing this with the goal to categorise data.

1.7 Broad summary

As previously established in *Section 1.3 (Concepts of energy management)* the three aspects of prominence for this study, are:

1. Monitoring and reporting;
2. Traceability; and
3. Monitoring efficiency.

Throughout the chapter the symbol below was used to identify when each concept was addressed. These concepts were attended through twelve different attributes. These attributes are subdivided towards which concept they contribute.



M&V principles is used to monitor the energy consumption of a facility and energy efficiency initiatives. The constraints in the M&V process, such as large datasets adding to the time intensity of determining the overall energy consumption of the facility, is addressed through the monitoring efficiency concept of the study.

Seeing what data is available for the M&V process and how to determine the associated quality of the data, add credibility to the monitoring and reporting of the energy consumption of the facility.

Adding a data framework ensures that the details associated with the energy consumption are captured and this contribute to the need to efficiently monitor the energy efficiency impacts. This is due to the fact that the detailed information allocated to the data should assist in categorising the data as well as tracing the energy efficiency impacts over the various boundaries.

Finally, to ensure efficient monitoring of the energy consumption of a facility, objective decision making methods are available, such as allocating KPIs to each energy meter and thereby determining the most important meters. Re-evaluating the energy consumption is done frequently by means of reassessing the KPIs and identifying the important meters. The last step is to use these important meters to effectively communicate the overall energy consumption “state” of a facility.

Table 1-1: Summary of the M&V landscape

[illegible]

SOURCE	MONITORING AND REPORTING				TRACEABILITY			MONITORING EFFICIENCY			
	M&V Principles	Constraints in M&V process	Available data	Quality data	Boundary selection	Energy balance	Performing an energy balance	Practical data frameworks	Objective decision making/Optimization	Frequency in monitoring/reporting	Efficient communication

When observing the table, it is seen that only three studies occur in both the monitoring and reporting concept, as well as the monitoring efficiency concept. Only two studies occur in both the traceability concept and the monitoring efficiency concept. Lastly, only 16% of the traceability concept studies touch on the monitoring and reporting concept. When seeing these figures it can be concluded that little overlapping occurs between these energy management concepts. The need to combine these three concepts consequently arise.

1.8 Aim of study

Monitoring and reporting

To effectively monitor energy efficiency projects, M&V can be performed. Regular changes in the M&V requirements are some of the challenges associated with effective M&V, monitoring and reporting. This causes a sense of uncertainty and might even slow down the M&V process.

By now it is a well-established fact that data of a high-quality is critical to be able to effectively monitor and report on energy consumption. Data quality tests exist and are beneficial to determine the confidence level associated with the dataset.

Data availability has also drastically grown over the past years, to where working with “large datasets” is now a common occurrence. These datasets usually consist of real-time energy consumption data.

Traceability

A current phenomenon in the industry is the move from ring-fenced energy monitoring and evaluating, to group-level (or otherwise known as whole-facility) energy monitoring and evaluating.

This, however, causes strain on the process of being able to identify and determine the impact of energy initiatives on the entire facility. Due to the energy consumption volatility of an organisation.

A technique to study and analyse the energy flow throughout the entire facility is known as an energy balance. Energy balances can also assist with reconciling data on different levels of the company.

Monitoring efficiency

KPIs and energy benchmarking are some of the tools to help identify essential data meters and unusual occurrences.

Effective visualisation techniques are available to communicate the information obtained through the KPI identified energy consumption meters. Using graphs to communicate the energy consumption information assists in efficient analysis and decision-making.

Broad-outline

It is a necessity to perform frequent energy monitoring with high-quality data, while ensuring the ability to trace the impacts of energy initiatives over multiple boundaries. Lastly, to efficiently monitor these energy initiatives, it is critical to identify essential data.

This establishes the need for the study:

Identify essential data to trace the impacts of energy initiatives over different boundaries efficiently.

This need will specifically be addressed through the following objectives:

- Frequently monitoring of energy consumption, using high-quality data;
- Tracing energy impacts over various boundaries; and
- Identifying essential data to monitor energy consumption.

1.9 Scope of study

Calculate and monitor the energy consumption of a facility only by using the identified and essential electrical meters.

Different tools will be created to identify the essential electrical energy usage meters of a facility. These meters will then be used to approximate the electrical energy consumption of the organisation. Energy monitoring by using these identified meters will also be possible.

In the future this study can be extended to include other energy carriers (e.g. diesel, coal etc.). If ever the methodology is used on a facility with a variety of energy carriers, the same principles of the study should be applicable. However, it is important that all of the energy carries are regarded and that these energy carrier's energy consumption values are converted to the same unit and then compared. Hence, firstly ensuring that all of the energy is accounted for and then fairly comparable. The main reason for not including it in this study, was due to a shortage of data.

This study is not to be confused with official M&V savings calculations.

This study will only focus on identifying the necessary meters to obtain a “feel” and the general status of the energy consumption position of an organisation. Therefore, this study cannot be utilised to calculate actual and official M&V energy efficiency savings calculations. Not all of the meters will be taken into account and this is therefore not based on the absolute precision necessary for M&V calculations.

A general energy consumption status is obtainable through this study.

The method will focus on identifying the essential meters, which will lead to establishing only a general condition of the facility's energy usage. To acquire accurate- and true circumstances all the energy meters need to be considered.

This study will be focussed on the South African mining industry

The method established in this study can be performed in any industry with the need to identify important energy meters within a group of energy data. However, this study chose to only perform the techniques in the South African mining industry due to the availability of data.

The study will only be used to identify the important energy meters within a group of energy meters.

Even though this study chose to identify the important energy meters/data within a group of meters, the techniques obtained through this study can be performed on any type of dataset. For example, the study can help identify the most important and profit-worthy products within a shop which might help management to focus their investments even more on the production of these identified products.

1.10 Document overview

Chapter 1: Introduction

Chapter 1 focusses on describing the background and general landscape for this study. By critically analysing this environment, a need for the study is determined. Alongside the need for the study, specific objectives are established.

Chapter 2: Method to identify essential data

Through studying relevant literature methods, tools and techniques are determined to structure the data, allocate a level of importance to each data meter, filter through all the available meters and then determining which meters are worth monitoring.

The frequency of re-evaluating and re-determining the important meters are determined; and lastly, how to effectively visualise and report the energy consumption of the facility by using only the important meters.

These methods, tools, and techniques are combined and visually summarised to create an all-inclusive methodology. This methodology is verified by the use of basic examples.

Chapter 3: Results and discussion

The methodology created in *Chapter 2* is performed on actual case studies. First, the case study's energy metering structure is described after which KPIs are calculated and allocated to the various energy meters. The essential meters are identified by utilising these KPIs.

Using essential identified meters, the estimated energy consumption of the full-facility is monitored and reported on. Lastly, by means of analysing the results obtained from the case study, the methodology is validated.

Chapter 4: Conclusions & Recommendations

This last chapter reflects and summarises the conclusions of this study. It refers to the objectives of the study (*Chapter 1*) to prove that they were met throughout the completion of this study. Finally, recommendations are suggested for further studies.

CHAPTER 2 - METHOD TO IDENTIFY ESSENTIAL DATA

2 Method to identify essential data

2.1 Preamble

It is important to efficiently monitor the energy consumption of a company and consequently make strategic decisions. To reach this point essential data needs to be identified. This will be used to estimate the energy consumption of the full-facility.

Chapter 2 will show the various steps required to identify the essential meters of a facility. First, the energy data will need to be determined and structured for storing purposes. It is necessary to ensure quality data is used to monitor the energy consumption, implying that the data should be cleaned and compared to other data sources (*Section 2.2*). Developing an energy balance does not only show the flow of the energy streams throughout the facility but also serves as an additional data quality test (*Section 2.3*). *Section 2.4* uses the Pareto analysis to determine the number of energy meters which will be needed to monitor at least 80% of the facility's energy consumption.

Next, the Absolute Impact KPI and the Volatility KPI are established for each energy meter (*Section 2.5*). These KPIs are then combined and afterwards ranked from the largest to the smallest. By using Pareto analysis, the essential energy meters are identified (*Section 2.6*). These essential meters are then used to calculate the estimated energy consumption of a facility (*Section 2.7*). Finally, this derived total energy consumption should be reported to management (*Section 2.8*). *Section 2.9* gives a general overview of the methodology.

Please note that the methodology, created in *Chapter 2*, was not validated or verified during this chapter. The validation and verification can be seen in *Chapter 3*, using actual case studies. Examples of data were used in this chapter to assist in demonstrating the methodology.

2.2 Energy consumption data

Availability of Data

As noted in *Chapter 1, Section 1.5 (Data used for M&V – Available data)*, a variety of energy data sources are available. It was also established that it is ideal to use at least two different energy data sources for M&V calculations [35], [41]. The reasoning for this is by comparing different datasets with one another, it functions as a data quality test and adds a level of credibility to the data [35], [41].

One of the sources of energy consumption data is an Eskom bill [2], [36], [41]. Where Eskom bills are a monthly summation of the energy usage of the entire facility [2], [36], [41]. These bills also reflect the costs related to the energy consumption [2], [36], [41]. According to the SANS 50010, the data reflected on the Eskom bill can be regarded as credible as these bills need to obey industry accuracy rules [2], [23], [25]. Thus, the energy consumption data on an Eskom bill should function as a yardstick for other energy data sources.

Another energy consumption data source is energy meters linked to energy management software [2], [46]. The frequency of available energy data will depend on the energy management software that is used [20], [36]. Some software can reflect “real-time” data, as defined in *Section 1.6 (Efficiently monitoring energy consumption techniques)* [29], [37]. The smaller the time difference between the measurements, the greater the energy monitoring advantage that allows the identification of energy consumption anomalies and wastages more readily. The measurements ensure that the created energy efficiency opportunities do not go by unnoticed. Hence this energy management data source should function as the main energy data source.

An additional reason for utilising the energy meters and energy metering software as the main energy data source, is the ability (by use of installed sub-meters) to measure more isolated sections of the facility [23], [43], [44], instead of just monitoring the total energy consumption of the facility [23], [43], [44]. This is ideal to monitor specific operations or even energy efficiency project’s energy consumption, without being influenced by energy consumption “noise” [23].

Since the energy metering is used as the main data source, a data framework should be used to efficiently store the energy data. The energy measurements should be stored with a date-and-timestamp, as well as a detailed naming convention to ensure effective grouping of the different subsections of the facility. Table 2-1 illustrates the method to store energy consumption data, using a naming convention.

Table 2-1: Practical data framework

Type of meter	Energy meter number	Sub-meter number	Unit of measurement
Energy meter:	Meter1		_ kWh
Sub-meter:	Meter1	_Sub-meter1	_ kWh

Table 2-1 indicates that for an energy meter, the data should be stored by numbering the meter and adding the unit of measurement. It also indicates that, for a sub-meter, the main energy meter's number should be indicated, as well as the sub-meters' number, and finally adding the unit of measurement. This will assist in tracing the impact of energy efficiency initiatives, as well as understanding the flow of the energy consumption throughout the facility.

Methodology of the study – Step 1

The functionality of this chapter is to construct a methodology to identify the essential energy meters. With the objective to monitor the energy consumption of the facility, using only these identified meters. Therefore, determining the available datasets and storing the data, should be the first step of the methodology.

The diagram Figure 2-1 will be used as the process chart for this study where the steps, which were addressed up to each stage, are highlighted.



Figure 2-1: The methodology of the study – Step 1

In the process chart (Figure 2-1) the steps which were addressed, were to identify the available energy data. This energy data was also stored using a date-and-timestamp for each measurement and a detailed naming convention for each energy meter.

At this stage the main energy data source is established, accompanied with the associated Eskom bill. The quality of these datasets need to be determined next.

Data Quality

There is always a degree of uncertainty linked to energy consumption data, which for example might be due to calibration errors of the metering equipment [20], [29], [46]. However, even though there is this inherent degree of uncertainty in the data, the M&V process still requires quality data for energy consumption monitoring and calculations [34].

To ensure that quality data is used when utilising the energy meter data, the energy dataset needs to be inspected and adjusted accordingly [36]. First the main dataset needs to be scrutinized and checked for any type of dataset error or data loss. These dataset errors may include outliers or duplicate values³⁶.

Once dataset errors or data loss has been identified, an assortment of approaches are available, to correct these values and in effect adjust the quality of the data [36]. The graphs depicted in Figure 2-2, reveals and illustrates some possibilities in terms of rectifying data loss and data discrepancies.

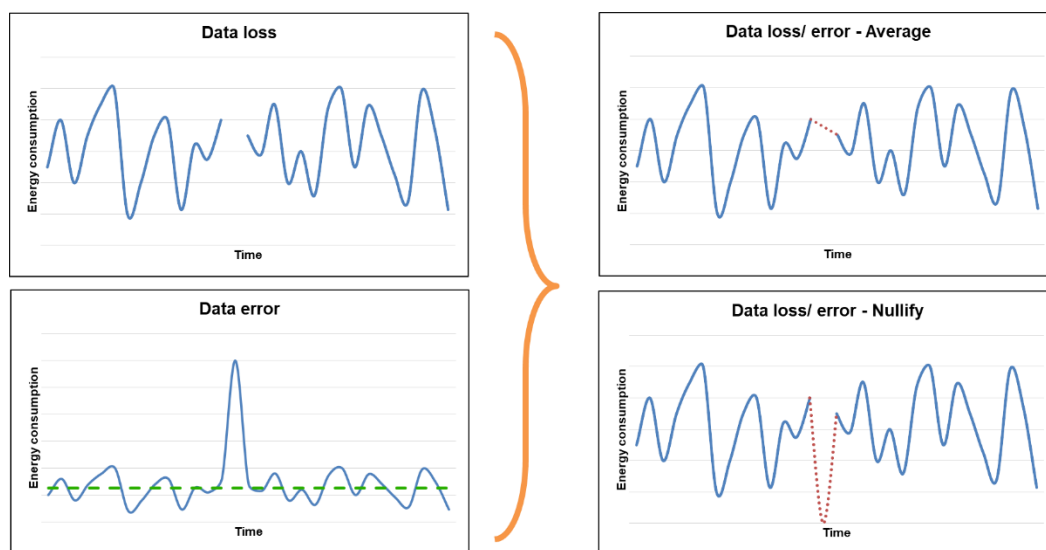


Figure 2-2: Data loss & -error rectifications

Figure 2-2 demonstrates that whenever data loss or data errors occur, the data periods can either be filled or replaced by using the averages of the data surrounding the data loss or-error period, or nullifying the data loss or-error period [29], [33], [48], [49]. For the sake of

³⁶ A. Mamun, "How do you normally find errors in a large dataset," 2016. [Online]. Available: <https://www.quora.com/How-do-you-normally-find-errors-in-a-large-dataset>. [Accessed: 25-Sep-2020].

performing a conservative M&V calculation (according to the first principles of M&V), both the data loss and data error periods are nullified, during this study [34].

Each time adjustments are made to the dataset, it is crucial to document these changes [29], [36], [37], in order to contribute to the transparency of the M&V process.

After the dataset errors and data loss has been identified and “cleaned”, comparisons can be made between different energy data sources. Even though it is still beneficial to use the energy meters as the main source of energy data, the Eskom bills should be used to compare the data. Therefore, by adding-up the total monthly energy consumption of the energy meter, measuring the entire facility’s energy consumption, and comparing this with the Eskom bill’s energy consumption, the inherent assurance associated with the data will be revealed. Table 2-2 uses an example to illustrate the calculations associated with comparing datasets.

Table 2-2: Dataset comparison

Date & Time	Energy management software’s total facility energy consumption (kWh)	Eskom Bill (kWh)	% Error between the datasets
2019-04-01 00:00	0.1	-	-
...	+	-	-
2019-04:30 23:30	2	-	-
Monthly total for April 2019	9	10	$\left \frac{(10-9)}{10} \right \times 100\% = 10\%$

Table 2-2 indicates the specific date and time at which the energy management software took the energy consumption measurement of the energy meter, associated with the total energy consumption of the facility. Next, these energy measurements should be added together until the same time period noted on the Eskom bill is replicated. In this case, the energy measurement points for the entire month of April 2019, should be added together. The Eskom bill column is only a monthly value and hence only the total energy consumption for the month is required. Finally, the absolute percentage difference between these two monthly energy consumption totals is calculated.

The acceptable range for the percentage difference, should be determined by management. However, it should be noted that the smaller the error percentage the more accurate the datasets can be considered.

Methodology of the study – Step 2

Figure 2-3 indicates that by testing and cleaning the data quality, it can be categorised as data verification. This forms the next step of the methodology.

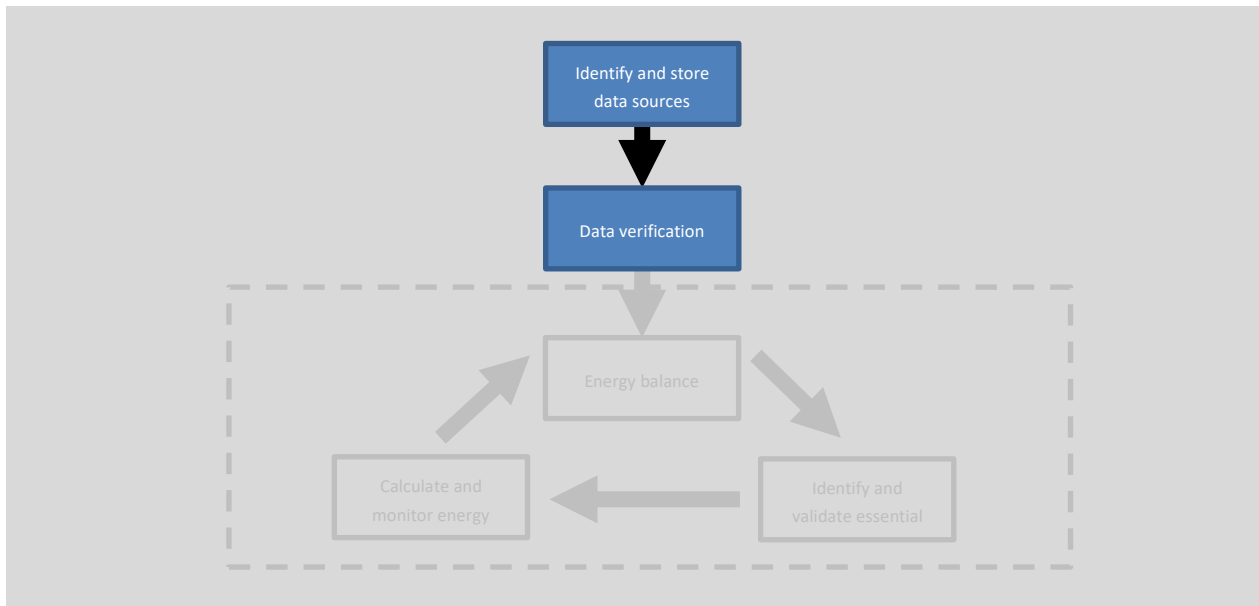


Figure 2-3: Methodology of the study – Step 2

Step 2 is to analyse the dataset and determine if data errors and data loss is present in the dataset. Afterwards, comparisons between different data sources were made, which functions as another data quality test.

However, now that the data is acceptable for use, the structure of energy metering should be understood. This will provide an understanding of the format in which the data can be presented.

2.3 Traceability

Metering structure

The total energy consumption is expected to be equal to the sum of the individual energy usage sections as well as the sum of the subsections²⁷ [54], [55], [61]. For the remainder of the study the naming convention of these energy consumption meters are:

1. Point-of-Distribution (POD);
2. Incomer meter; and
3. Feeder meter.

The POD energy consumption is measured at the same point as the Eskom bill. This indicates that the POD should be equal to the energy usage reflected on the Eskom bill. In other words, a POD reflects the total energy consumption of a system.

A POD should equal the sum of the incomer meters where an incomer meter represents the energy consumption of a specific section. An incomer meter can also be equal to the sum of the relevant feeder meters. However, this will depend on the number of installed feeders that measure the energy coming from the incomers. Feeder meters represent the energy meters measuring the energy consumption of subsections of the facility or even just specific operations of the facility.

Now that the energy metering structure is determined an energy balance can be performed to analyse and measure the different energy streams throughout a facility. Energy balances also serve as a data quality check by ensuring that all the energy usage streams are accounted for.

Energy balance

An energy balance is known as a technique to firstly examine the flow of energy and secondly to perform a data quality check [52]. The energy balance is focussed on the energy conservation law, which states: energy into a system should equal the energy out of a system²⁷ [52], [61], [62]. Therefore this technique traces the path of all the various energy flows throughout a system [52].

To perform an energy balance, it is essential to use energy consumption data over the same time period and with the same measurement unit. The various incomer meter's energy usage data can then be added together and compared with the POD's energy consumption. Afterwards the various feeder meters' energy usage data should be added together and compared with the relevant incomer meter's energy usage data. Figure 2-4 demonstrates the flow of energy throughout the various energy consumption levels of a facility.

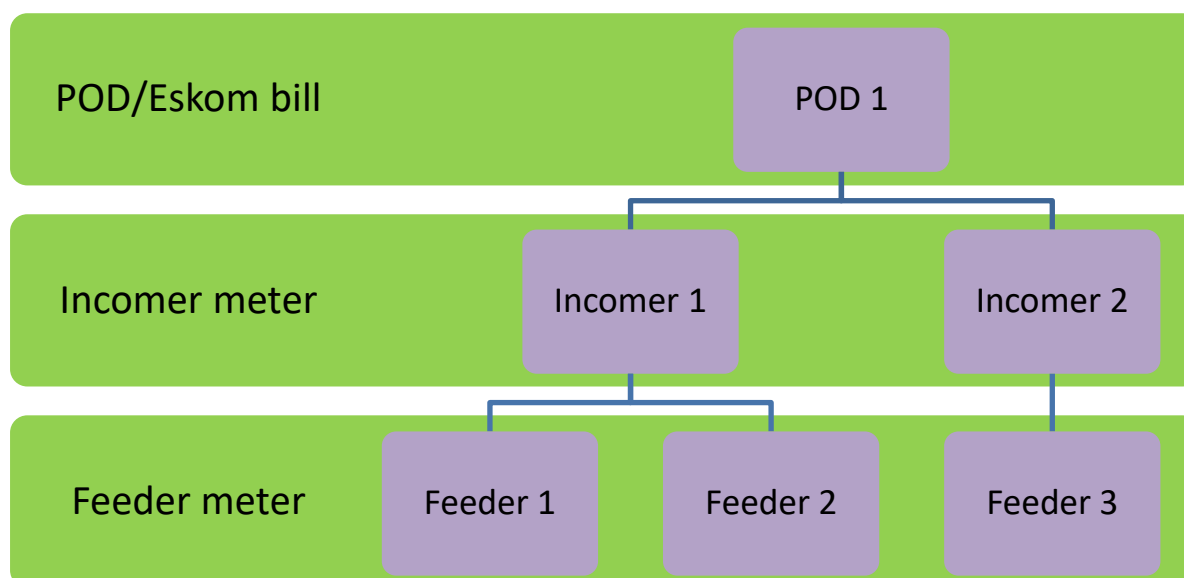


Figure 2-4: Energy balance representing a data quality test

Figure 2-4 illustrates the flow of energy streams throughout a facility, showing how the POD is the sum of the incomers, and an incomer is a result of the sum of the feeders.

Theoretically both the POD-Incomer comparison, as well as the Incomer-Feeder comparison, should match up. However, due to the fact that an inherent uncertainty is associated with energy meter's data, these datasets will not necessarily match-up 100%. On the other hand, if the error percentage between these datasets are reasonable (between 1-2%), the energy balance can still be regarded as satisfactory [63]. This is known as a data quality test [52].

There are however cases where energy balances might not match-up 100%, as well as not having an error percentage that is reasonable. In these cases not all of the energy consumption is measured throughout the facility. For example, the feeder meters do not measure the entire facility's energy consumption, in which case the difference between the incomer meters and the feeder meters should be calculated. This is then added on top of the total feeder meter's energy consumption, when monitoring the facility's energy usage.

Methodology of the study – Step 3

To perform an energy balance, not only as a data quality test, but also as an analysis of the flow of the energy streams in an organisation, it is stated as step 3 in the process diagram.

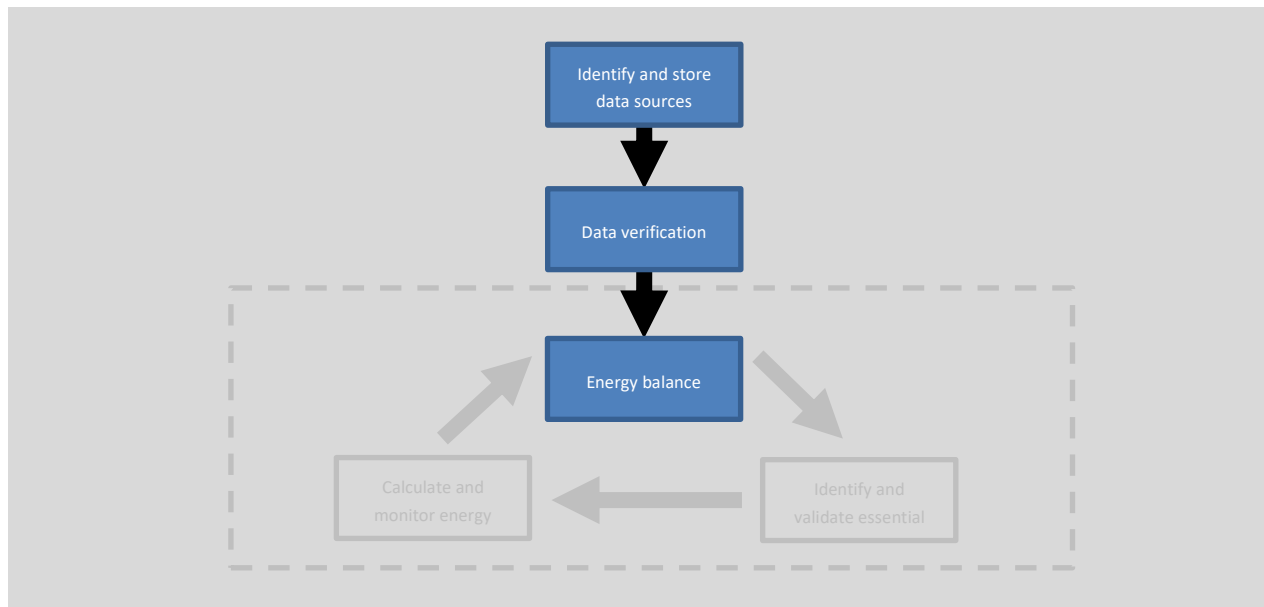


Figure 2-5: Methodology of the study – Step 3

This data quality test adds to the precision of the dataset, as well as the traceability of energy consumption flows throughout the organisation. Therefore, this energy balance step will be highlighted as the step which satisfies the traceability concept of energy management.

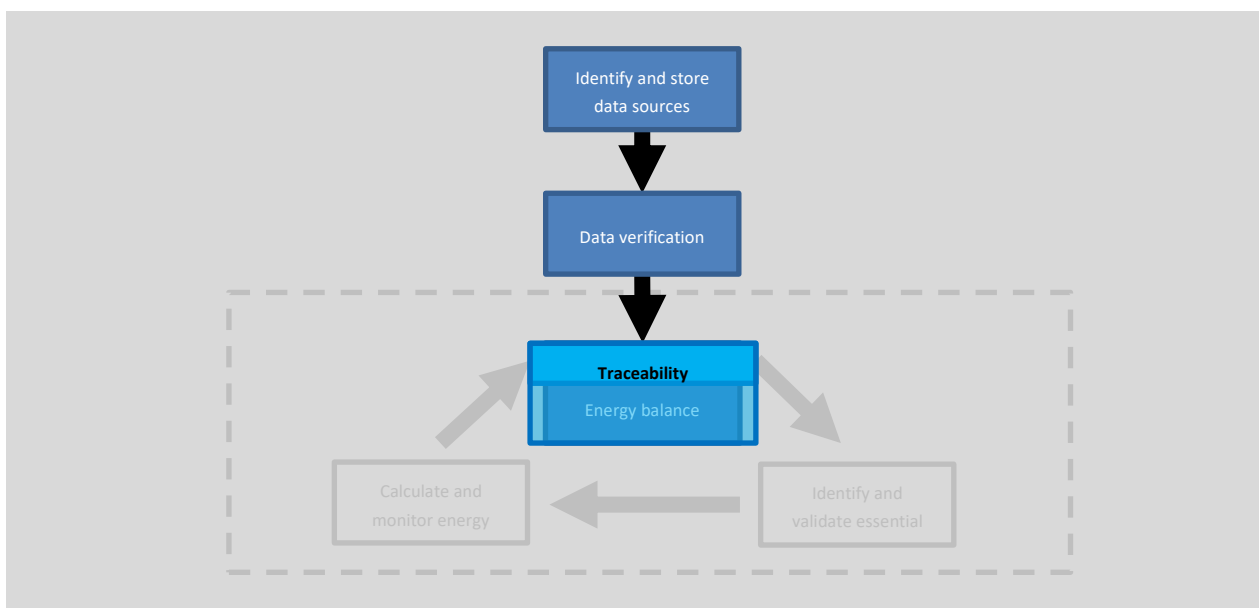


Figure 2-6: Methodology of the study – Step 3 Traceability

After this step the data is obtained, stored and “cleaned”. The energy consumption flow is understood and it is ensured that all of the data is accounted for, throughout the facility. Hence, the important sections of the data can now be determined.

2.4 Number of important meters

Before each meter is evaluated separately to determine whether it qualifies as an important meter, it is necessary to define how many energy consumption meters should be regarded as important.

A technique, known as the Pareto analysis (a.k.a. the 80/20 rule), states that 20% of data points will represent 80% of the data³¹. Vice versa the 80/20 rule declares that the remaining 80% of the data points embodies 20% of the data³¹. Essentially affirming that companies only have to focus on 20% of their metering, to monitor 80% of their energy data³¹. Furthermore, companies only need to monitor 20% of their data points, to reveal the overall energy consumption “status” of 80% of their company³¹. However, it is important to note that the Pareto analysis will not always be based on an 80/20 ratio, it is only a rough indication for the usual data distribution³⁷. This ratio can be for example 80/30, implying that 30% of the energy meters can be used to monitor 80% of the energy consumption of the facility.

Knowing this, it is therefore important to determine the ratio of distribution for each dataset. In this study, the aim will be to determine the number of energy meters needed to monitor at least 80% of the energy consumption of a facility.

Observing the energy consumption of a facility will be most beneficial on a deeper level/sub-section energy meter level of the energy system (a.k.a. feeder meters). This assists in specifically identifying the operation with the most energy consumed. However, the level of monitoring should be based on meters that form part of a selected boundary. Only these meters, which form part of the boundary, should be used to determine the number of energy meters required to monitor at least 80% of the energy consumption.

Now to determine the number of feeder meters required to monitor 80% of the energy consumption of a facility, the total monthly energy consumption per energy meter should be calculated. These energy meters should thereafter be sorted from the energy meters consuming the most energy to the least. Lastly, calculating the total energy consumption of all of the feeders. These steps are displayed in Table 2-3.

³⁷ C. Newton, “Pareto’s Principle - The 80/20 Rule,” 2020. [Online]. Available: <http://www.clairnewton.co.za/my-articles/paretos-principle-the-80-20-rule.html>. [Accessed: 25-Sep-2020].

Table 2-3: Total monthly energy consumption per feeder meter

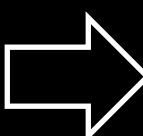
Feeder meters	Total monthly energy consumption (kWh)		Feeder meters - sorted in a descending order	Total monthly energy consumption (kWh)
Feeder 1	1 000		Feeder 6	500 000
Feeder 2	10 000		Feeder 10	200 500
Feeder 3	5		Feeder 2	10 000
Feeder 4	0		Feeder 5	1 200
Feeder 5	1 200		Feeder 1	1 000
Feeder 6	500 000		Feeder 7	200
Feeder 7	200		Feeder 8	65
Feeder 8	65		Feeder 3	5
Feeder 9	0		Feeder 4	0
Feeder 10	200 500		Feeder 9	0
Total	712 970		Total	712 970

Table 2-3 indicates that Feeder 6 is regarded as the energy meter consuming the most energy, followed by Feeder 10. After establishing, by use of the energy balance (*in Section 2.3*), that the various levels of energy consumption in the facility is equal (or only differ by 1-2%), it can be concluded that the important meters can be determined from these feeders.

The following calculation can be performed next by using the list of feeder meters which were sorted by descending order. This calculation will determine the number of important meters to determine at least 80% of the energy consumed by a facility.

$$x_1 = \frac{(\text{Feeder 6})}{(\text{Total of the Feeders})} \times 100\% \quad (2.1)$$

$$\text{if } (x_1 \geq 80\%) \rightarrow \text{Number of important meters per dataset} = 1 \quad (2.2)$$

$$\text{BUT if } (x_1 < 80\%) \rightarrow x_2 = \frac{(\text{Feeder 6} + \text{Feeder 10})}{(\text{Total of the Feeders})} \times 100\% \quad (2.3)$$

$$\text{if } (x_2 \geq 80\%) \rightarrow \text{Number of important meters per dataset} = 2 \quad (2.4)$$

$$\text{BUT if } (x_2 < 80\%) \rightarrow \text{Repeat till } x_n \geq 80\% \quad (2.5)$$

Where:

- x_n is the percentage energy consumption of the total facility represented by the summation of the one to the n^{th} top ranked energy consumption feeders;
- x_1 is the percentage energy consumption of the total facility represented by top ranked energy consumption feeder; and
- x_2 is the percentage energy consumption of the total facility represented by the top two ranked energy consumption feeders.

This calculation indicates that the energy consumption of the feeder consuming the most energy should be divided by the total energy consumption. This ratio is then converted to obtain a percentage contribution of the specific feeder's energy consumption towards the total energy consumption. If this percentage contribution is equal to or exceeds 80%, the number of important meters required to indicate 80% of the energy consumption of the facility, is one. However, if this one feeder meter does not contribute 80% of the energy consumption of a company, the calculation should be repeated. This time, taking not only the feeder consuming the most energy into account, but adding the feeder contributing the second most energy in a facility. This calculation should be repeated until the percentage contribution of the number of feeders towards the total energy consumption is either equal to or greater than 80%.

By taking the example as noted in Table 2-3 and performing the calculation, to determine the number of important meters per dataset, the following can be observed:

$$x_1 = \frac{(\text{Feeder 6})}{(\text{Total of the Feeders})} \times 100\% \quad (2.6)$$

$$x_1 = \frac{(500\,000)}{(712\,970)} \times 100\% \quad (2.7)$$

$$x_1 = 70\% \quad (2.8)$$

$$(x_1 < 80\%) \rightarrow x_2 = \frac{(\text{Feeder 6} + \text{Feeder 10})}{(\text{Total of the Feeders})} \times 100\% \quad (2.9)$$

$$x_2 = \frac{(500\,000 + 200\,500)}{(712\,970)} \times 100\% \quad (2.10)$$

$$x_2 = 98\% \quad (2.11)$$

$$\therefore x_2 \geq 80\% \rightarrow \text{Number of important meters per dataset} = 2 \quad (2.12)$$

Therefore, the example in Table 2-3 revealed when Feeder 6 was used to calculate the percentage contribution towards the total energy consumption, the percentage contribution was only 70%. As the minimum requirement for the percentage contribution is 80%, this calculation needed to be repeated with Feeder 6 and Feeder 10, the two highest ranked feeder meters according to Table 2-3. After repeating the calculation with Feeder 6 and Feeder 10, it was determined that the percentage contribution of these feeder meters towards the total energy consumption is 98%. This is greater than 80% and therefore it can be concluded that the number of important meters for the current dataset is two. Implying that by using 20% of the feeder meters, 98% of the energy consumption data is represented.

In some cases the granularity of the feeder meters can become a concern. For example, one feeder might measure 80% of the entire facility's energy consumption and as this study is focused on monitoring energy usage of a facility, this might be problematic. Due to the fact that the changes in energy consumption can't necessarily be pinpointed to an exact area of usage. In these cases, it is suggested to replace the single feeder meter with a feeder meter per every operation or –section, or even points of interest. However this is only required if the management of the facility wants a specific pinpoint of the energy usage, if this is not necessary the methodology can continue, with monitoring only one feeder meter.

Knowing the number of meters required to be regarded as important for the current dataset, the feeders can now be evaluated individually to determine which of these meters are the most important meters.

2.5 KPI Identification

Whenever the potential of KPIs are fully realised and utilised, it becomes a powerful tool for companies. Not only does it have the ability to reveal the areas for growth or enhancement, but it can also compare KPI values with previous KPI values, with similar circumstances^{38, 39}. The main function of a KPI is to measure, track, and manage the energy consumption and energy cost³⁹ [64]. Some common KPIs are measured, such as the absolute energy usage,

³⁸ S3C, "Guideline: KPIs for energy consumption effects." [Online]. Available: https://www.smartgrid-engagement-toolkit.eu/fileadmin/s3c/toolkit/user/guidelines/GUIDELINE_KPIS_FOR_ENERGY_CONSUMPTION_EFFECTS.pdf. [Accessed: 31-Dec-2019].

³⁹ S. Stiner, "Energy Benchmarking: What Is It And Why Does Your Business Need It?," 2018. [Online]. Available: <https://www.forbes.com/sites/forbestechcouncil/2018/06/21/energy-benchmarking-what-is-it-and-why-does-your-business-need-it/>. [Accessed: 31-Dec-2019].

the energy intensity of these energy meters and the number of times the energy usage has exceeded a certain set point [64].

It is imperative to define what qualifies an energy meter as important. In the case of this study, the need arose to decrease energy consumed by industries. Naturally, it is instinct to have a KPI which focusses on identifying the meters using the most energy [64]. For the remainder of this study, this KPI will be referred to as the Absolute Impact KPI.

In some cases, the energy meter might consume a great amount of energy, but the operations linked to this energy meter might only have been active for a few minutes. In such a case these energy meters should be disregarded as important, as these meters do not reveal a steady opportunity for energy savings. Hence, it would also be beneficial to determine which energy meters consistently consume the most energy [64]. During the rest of the study this KPI will be referred to as the Volatility KPI.

It is also important to note that, as the energy consumption of a facility is constantly changing, which makes it necessary to determine the important meters over an acceptable period of time. This is to ensure that the most regular important meters are identified. Henceforth, the important meters will be identified using a month's data.

Absolute Impact KPI

To calculate the absolute impact of each feeder, the monthly total energy consumption per feeder is calculated. This constitutes the weight of importance per feeder on a monthly basis. Table 2-4 illustrates an example of monthly feeder data obtained from an energy management software providing half-hourly energy consumption measurements. In this example, 10 feeder meters exist, with each feeder's measurement unit being kWh. Take note that this table proceeds with the example used in Table 2-3.

Table 2-4: Example to determine the Absolute Impact KPI per feeder

Date & Time	Energy management software's energy consumption for feeder 1 (kWh)	Energy management software's energy consumption for feeder 2 (kWh)	Energy management software's energy consumption for feeder 10 (kWh)
2019-04-01 00:00	100 +	100 +	1 000 +
...	...	...	...
2019-04:30 23:30	50 =	1 100 =	0.2 =
Monthly total for April 2019	1 000	10 000	20 500
∴ Absolute Impact KPI per feeder	= 1 000	= 10 000	= 20 500

Table 2-4 thus adds all of the half hourly energy consumption measurements per feeder meter, providing a total monthly energy consumption kWh value. This total monthly energy consumption kWh value equates to the Absolute Impact KPI value per feeder. Implying the weight that each feeder carries, with regards to its importance. Hence, obtaining the Absolute Impact KPI value per feeder, results in a list of values. Where each value in this list reflects the Absolute Impact KPI weight of the corresponding feeder meter. In other words, the first value in the list, will reveal the absolute impact weight of Feeder meter 1 and so forth. For the duration of the study, this list will be known as the Absolute Impact list.

Volatility KPI

Now that the absolute impact was determined per feeder, it is however important to note that these energy consumption measurements per feeder may drastically differ throughout a month. For example, an operation, associated with a feeder, might be switched on for a short period of time. This operation may use a great amount of energy to operate, however, it is not an operation which consistently consumes a great amount of energy, as it is switched off afterwards.

Therefore, a weight should be associated with each feeder meter, indicating the number of times (throughout a month) a feeder meter is noted as using a great amount of energy. First, it should be determined when a meter is regarded as important. If the same example are used as in *Section 2.4*, it can be seen that for this dataset two feeder meters were needed to monitor

at least 80% of the total energy consumption. In other words, the two feeder meters contributing the most energy consumed, qualify as the important meters.

Hence, the energy consumption per feeder should be calculated, on a daily basis, for the duration of a month. The daily energy consumed according to each feeder are then ranked from the feeder meters consuming the most energy, to the feeders consuming the least. Then proceed to count the number of times (per feeder) each feeder was regarded as the feeder either consuming the most, or the second most energy. The number of times these meters were regarded as the important meters (one of the two meters consuming the most energy), forms the Volatility KPI. Implying that the larger the number associated with the feeder, the more consistent the feeder consumes a great amount of energy throughout a month. Table 2-5 indicates how to calculate the volatility of each feeder, using the same example as seen in *Section 2.4*.

Table 2-5: Example to determine the volatility of each feeder meter

Action performed	Date	Energy management software's energy consumption for feeder 1 (kWh)	Energy management software's energy consumption for feeder 2 (kWh)	Energy management software's energy consumption for feeder 10 (kWh)
Daily energy consumption per feeder	2019-04-01	119	1 000	2 000
	...	...	...	...
	2019-04-30	60	200	1
Daily energy consumption per feeder, ranked	2019-04-01	7	5	1
	...	...	...	...
	2019-04-30	8	6	9
Number of times in a month a feeder was identified as important (or rather part of the top 2 meters consuming the most energy) ∴ Volatility KPI		5	10	15

Table 2-5 indicates that on 2019-04-01 Feeder 10 consumed the most energy. When the energy consumption per feeder was ranked on a daily basis, it can be seen that the energy which was consumed by Feeder 10 on 2019-04-01, resulted in the feeder being ranked as the top energy consumer for the day. Finally, the number of times the feeders were regarded as the top two energy consumers of the day, were counted per feeder. This leaves Feeder 10 with being identified 15 times, as one of the top two most important energy meters, throughout the month.

The Volatility KPI values per feeder form a list, with the first value in the list indicating the Volatility KPI value of Feeder 1, the second value reveals the Volatility KPI value of Feeder 2 and so forth.

To verify the impact of the Volatility KPI on identifying the most important meters were analysed in Appendix F. To test this KPI Case study A (as referred to in Chapter 3) was used. However, due to the general flow of the study, this verification was mentioned in this chapter. The test consisted of utilising standard deviation to identify the volatility of each feeder and then determining if the feeder would have been identified as important to monitor energy consumption. The identified meters are then compared to the important feeders identified through the volatility KPI created in this study to determine the percentage similarity.

The results of the verification test indicate that there is a similarity of 75% in the feeders which were identified using either method. Hence, using the study's proposed Volatility KPI 75% of the feeders would have still been identified as if the standard deviation method would have been used. This implies that the Volatility KPI will be sufficient in identifying the important feeder meters.

Absolute Impact and Volatility KPIs assisting tools

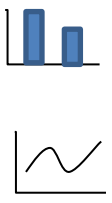
Certain graphs can assist in understanding and identifying the meters with the greatest effect on the total energy consumption, as well as visualising the energy meters consistently consuming the most energy [60]. Graphs contributing to effective identification of important energy consumption meters are listed in Table 2-6^{34, 40, 41, 42} [59], [65], [66].

⁴⁰ Community Colleges of Spokane, "Characteristics of Good Graphs." [Online]. Available: <https://faculty.sfcc.spokane.edu/inetshare/autowebs/asab/goodgraphs.pdf>. [Accessed: 24-May-2020].

⁴¹ C. Dalton, "What Constitutes a Good Tornado Diagram?." 2015. [Online]. Available: <https://www.syncopation.com/blog/what-constitutes-good-tornado-diagram>. [Accessed: 31-Dec-2019].

⁴² Samantha Lile, "44 Types of Graphs Perfect for Every Top Industry." 2019. [Online]. Available: <https://visme.co/blog/types-of-graphs/>. [Accessed: 31-Dec-2019].

Table 2-6: Analysis of graphs to assist in identifying important meters

Type of graph	Graph visualization	Description	Qualified to assist (1 = No, 2 = Partly, 3 = Yes)
Column graph/Line graph/Stacked bar graph/Histograms		This graph will reveal the absolute value of an energy meter. And/or even the daily change in energy consumption for an energy meter. However, this graph will become overpowering with the amount of information being displayed.	2
Pie chart		The pie chart might reveal the weight of contribution for each energy meter, percentages or recurring data. However, this graph is impractical as it can be overwhelming to have a large number of meters and their weight reflected on one circle.	1
Population pyramids/ Tornado diagrams/Sensitivity analysis		A Tornado diagram can function as a powerful tool to compare energy consumption of meters changing from one time period to the next. This graph reveals not only the absolute value of the meters, but also the sensitivity of these meters. (A.k.a. the volatility). This is because the energy consumption meters, moving from insignificant in size to significant, can be identified.	3
Waterfall diagram		Waterfall charts reflect the collective effect of contributions to a start and end value. It gives a	3

Type of graph	Graph visualization	Description	Qualified to assist (1 = No, 2 = Partly, 3 = Yes)
		sense of the volatility of the energy meters between one time period and the next.	

Table 2-6 concludes that the Tornado diagram is useful for this study, to determine whether the energy consumption associated with a feeder meter can be regarded as significant. In other words, if the feeder meter contributes a great amount to the total energy consumed by the facility. This graph can also indicate whether or not a feeder meter's energy consumption is volatile. Implying that whenever the energy meter moves from measuring a significant amount of energy to an insignificant amount, or vice versa, this meter is not necessarily a consistent significant energy meter.

Table 2-6 also indicates that the Waterfall diagram reflects the volatility of each feeder. With the weight in the difference of energy consumption per feeder, revealed. Hence if the energy consumption value for a feeder stays consistent and at the same time, if the feeder regularly consumes a large amount of energy, the Volatility KPI value will most probably be a large value (compared to the other feeders). At the same time the block associated with the change in the energy consumption on the Waterfall diagram, for the same feeder, will be small. Implying little change in the energy consumption for the feeder.

Thus to assist in establishing the important energy meters using both the Absolute Impact and the Volatility KPIs are the Tornado diagram and the Waterfall diagram. These graphs will objectively reveal the absolute energy consumption and the volatility of these energy meters. Which should objectively confirm the feeders identified as important through the use of the calculations. Figure 2-7 displays Waterfall diagrams analysing the incomers and then the feeders.

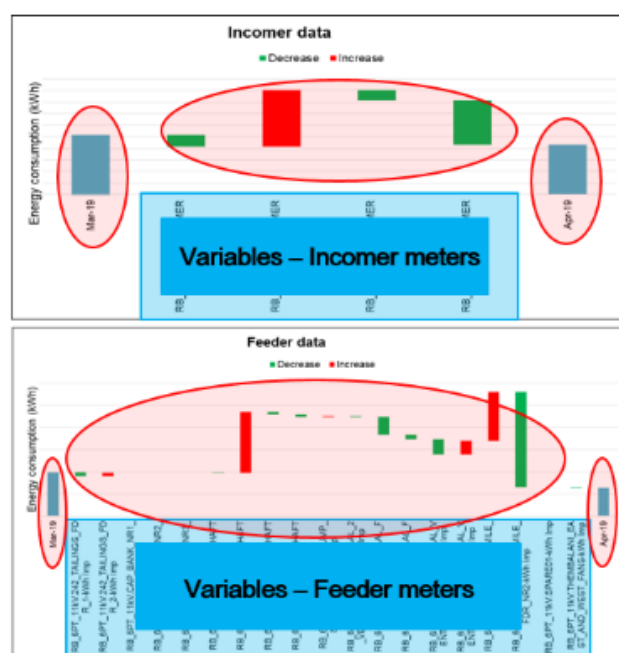


Figure 2-7: Waterfall diagrams analysis

In Figure 2-7 it can be seen that the red columns indicate an increase in energy consumption for the incomer/feeder and the green columns indicate a decrease in energy consumption. If an energy saving initiative was implemented during the month, theoretically it should indicate a green column on the corresponding incomer and feeder.

Figure 2-8 displays the tornado diagram used to compare different months' energy consumption for different meters.

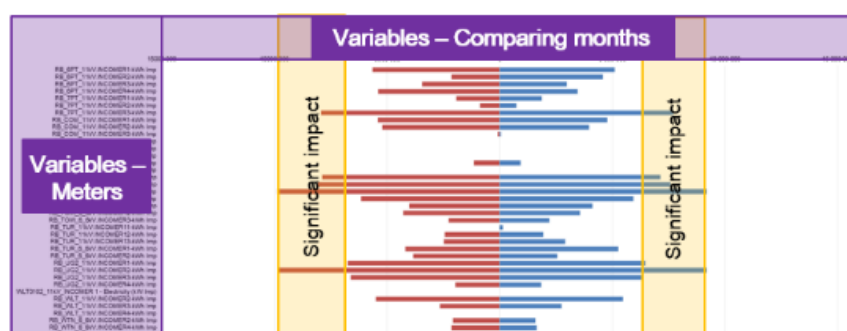


Figure 2-8: Monthly energy consumption comparison

This will help to identify the energy meters with significant impact and will help to identify whether or not a significant meter, changed to be an insignificant meter, or vice-versa. Which will give cause for an investigation, to determine the reasoning behind this occurrence.

Both the KPI calculations and the graphs will help to objectively and proficiently identify the important meters and possible areas for future energy savings initiatives. At this stage the different graphs and KPIs are established to rank the energy consumption meters according

to their individual importance and the corresponding number of times these meters were identified as significant energy consumers. However, the Absolute Impact KPI values and the Volatility KPI values per feeder, need to be consolidated to be able to identify the overall important energy meters of the dataset.

2.6 Decision making of KPIs

In *Section 2.4*, KPIs were developed to identify the important meters of an industry, focussing on the absolute impact and the volatility of the energy meters as the determining factors of qualifying as a significant meter.

However, these two traits/KPIs need to be analysed in combination with one another. As an energy consumption meter might consume a great amount of energy, after which the operations related to the specific feeder, might be switched-off. Edifying that the energy consumption meter is effectively not as important (not possessing enough of an opportunity for a consistent energy initiative saving).

To be able to assess these KPI results in conjunction, a scatterplot can be used where both of the axis represent a dataset⁴². The energy meters are then plotted according to their traits/KPIs and weight using both axis⁴². Mirroring the relationship between the actual impact of the energy meter and that of the volatility of the same energy meter⁴². Figure 2-9 illustrates an example of a scatter plot of the Absolute Impact versus the Volatility of energy meters, for a month. This example is based on the example used in *Section 2.4*.

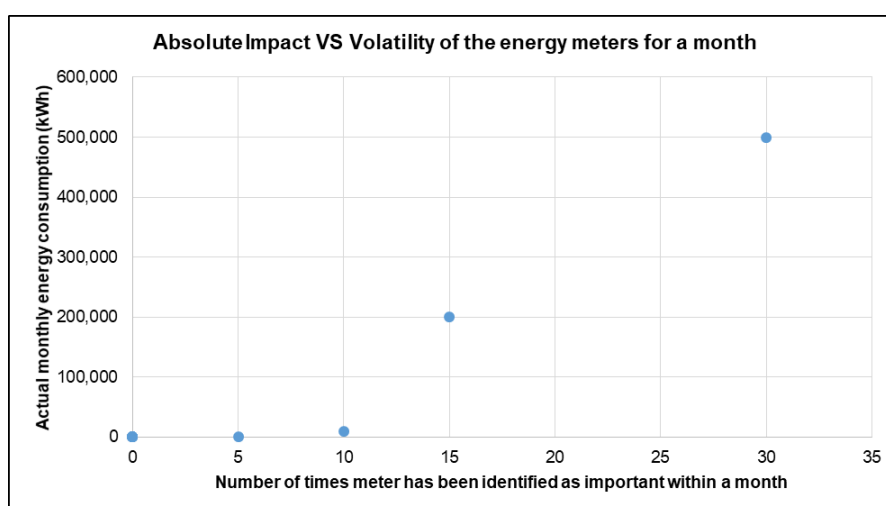


Figure 2-9: Absolute Impact VS Volatility of energy meters for a month

Figure 2-9 illustrates ten energy meters and their associated Absolute Impact and Volatility values. Indicating that one of the feeders was consuming 500 000 kWh, as well as being identified as an important energy meter 30 times throughout the month. Thus this energy meter

will most probably be identified as an overall essential energy meter. Six of the energy meters are all located on the (0;0) point on the scatter diagram. This is as these six meters consumed so little energy throughout the month, as well as not being identified once as an important energy meter, during the month.

When referring back to *Section 2.5* two KPI values were specified for each feeder meter. These KPI values were the Absolute Impact KPI value and the Volatility KPI value. However, these KPI values should be combined. Figure 2-10 explains the process.

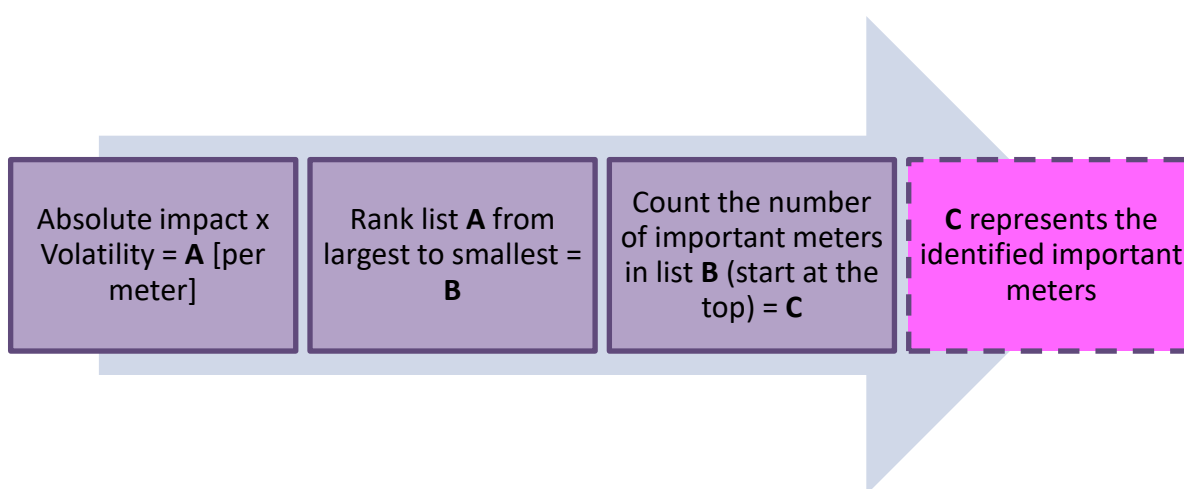


Figure 2-10: The process to determine the important meters

By multiplying these two KPI values with one another, these two KPI values are combined. After uniting these two KPIs, these new joint KPI values per feeder meter should be ranked from the meters with the highest value, to the lowest. Finally, by implementing the Pareto analysis, as discussed in *Section 2.4*, the number of important meters associated with a dataset should be counted. Take note to start counting from the highest ranked value. These energy meters reveal the overall essential feeder meters of the facility. Table 2-7 uses an example (used in *Section 2.4*) to illustrate the process to determine the essential meters.

Table 2-7: Example of process to identify essential meters

Feeder meters	Total monthly energy consumption (kWh) ∴ Absolute Impact KPI	Number of times feeder was identified as important during the month ∴ Volatility KPI	Combined KPIs ∴ Absolute Impact KPI x Volatility KPI	Ranked the combined KPIs in descending order
Feeder 1	1 000	5	5 000	4
Feeder 2	10 000	10	100 000	3
Feeder 3	5	0	0	5
Feeder 4	0	0	0	5
Feeder 5	1 200	0	0	5
Feeder 6	500 000	30	15 000 000	1
Feeder 7	200	0	0	5
Feeder 8	65	0	0	5
Feeder 9	0	0	0	5
Feeder 10	200 500	15	3 007 500	2

It can be seen in Table 2-7 that Feeder 6 was ranked as the most important meter in the dataset, after combining the Absolute Impact and Volatility KPI. The second most important meter was Feeder 10. The Pareto analysis in *Section 2.4* concluded that two meters were required to monitor more than 80% of the energy consumption of the facility. This is why the top two ranked energy meters, Feeder 6 and Feeder 10, are identified as the essential energy meters and therefore highlighted in purple.

Proceeding to illustrate these important feeder meters on the scatter diagram as illustrated in Figure 2-9, the same scatter diagram is used. However, in Figure 2-11 the essential energy meters are highlighted with red circles.

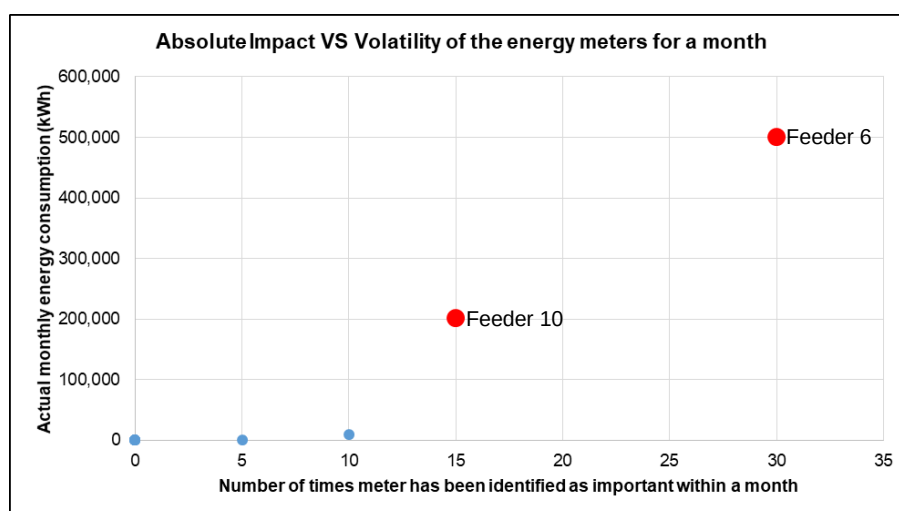


Figure 2-11: Absolute Impact VS Volatility of the energy meters

Figure 2-11 illustrates the two essential meters are Feeder 6 and Feeder 10, revealing that they both had a large amount of monthly energy consumption, as well as the fact that they were identified as the important meters for a sufficient number of times throughout a period of a month.

Methodology of the study – Step 4

By allocating KPIs to the various energy meters, multiplying these KPIs and then ranking the answers from largest to smallest. The Pareto analysis can then be used to identify the essential energy meter. This is known as the next step in the process chart.

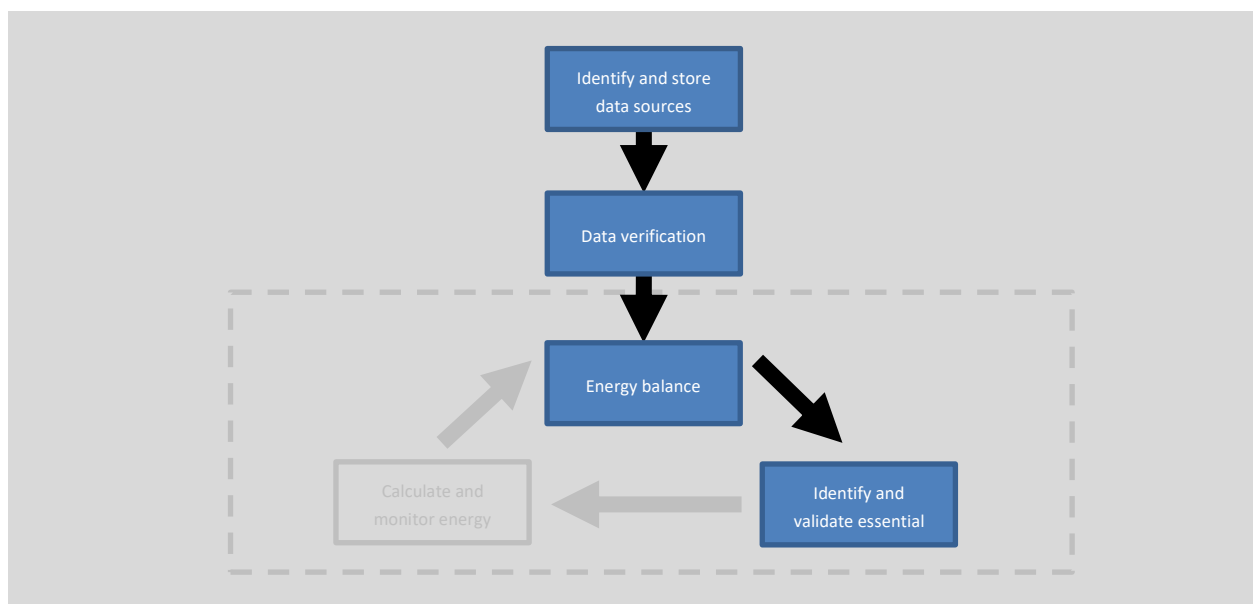


Figure 2-12: Methodology of the study – Step 4

Due to this tool of identifying the essential meters, it addresses the monitoring efficiency concept of energy management.

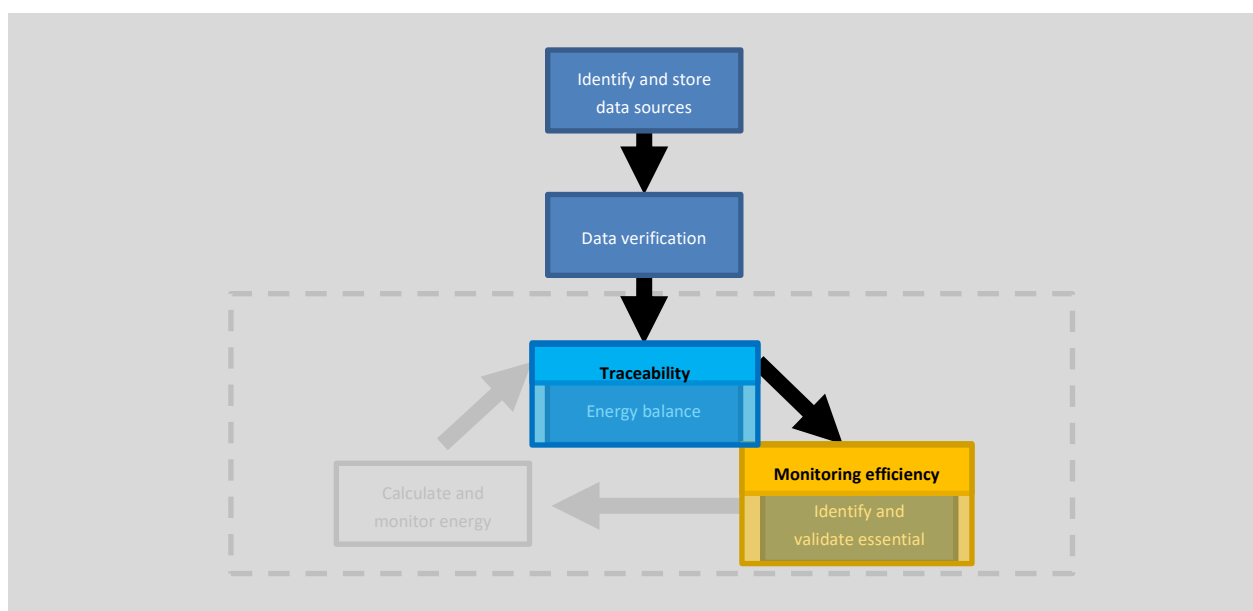


Figure 2-13: Methodology of the study – Step 4 Monitoring efficiency

Now that these essential meters have been identified, these meters should be used to further monitor the entire energy consumption of a facility. This assists in efficiently monitoring the energy consumption of a facility throughout a month.

2.7 Monitoring efficiency

Now that the essential meters have been identified, the process of monitoring and reporting on the energy consumption of the facility should be optimized, by using only the essential meters to calculate the estimated energy consumption of the full facility.

Optimizing refers to initially setting up a process in which the important meters were identified and afterwards using only the essential energy meters to monitor energy consumption⁴³ [53], [56], [67]. By doing this, “barriers” (such as the fact that it is time consuming to identify the important meters) are effectively removed and in effect the time to monitor the energy consumption of a facility should decrease significantly⁴³ [53], [56]. Removing barriers on the essential sections of the data is a prominent instrument used for optimizing traffic flow⁴³ [56]. Traffic intersection optimization effectively also allocates different weights to certain roads

⁴³ S. Bur, "How to Fix Nightmare Double Roundabouts." Cities Skylines - Town Planner Plays, Mar. 2019. [Online]. Available: <https://www.youtube.com/watch?v=z4OzNX8aVHU>. [Accessed: 31-Dec-2019].

(based on the flow of cars, etc.) and consequently removes the barriers observed on these essential roads [53]. Ensuring efficient flow of traffic⁴³ [53], [56].

The traffic optimization principle, of removing the barriers, is used to efficiently monitor the energy consumption of a facility. This is done by using the current month's identified essential meters, to monitor the following month's energy consumption. The example used in *Section 2.4* is continued in Table 2-8, as the energy consumption monitoring is most ideal when monitored frequently. The frequency of monitoring can even be on daily intervals. However Table 2-8 demonstrates the following month's energy consumption, which is monitored by using the essential meters of the current month. This is to indicate the overall monthly effect of monitoring the energy consumption of these essential meters.

Table 2-8: Essential meters to monitor energy consumption

Feeder meters	Actual energy consumption (kWh) of the following month (May 2019)
Feeder 1	1 200
Feeder 2	9 890
Feeder 3	4
Feeder 4	0
Feeder 5	1 350
Feeder 6	500 020
Feeder 7	212
Feeder 8	0
Feeder 9	0
Feeder 10	190 650
Total energy consumption for May 2019	703 326
Total derived energy consumption for May 2019 (using only the essential meters)	690 670
Percentage contribution to the total energy consumption, using only the current month's essential meters	98%

Table 2-8 reveals that the total energy consumption of the facility for May 2019 is 703 326 kWh. But when only using the current month's identified essential meters (Feeder 6 and Feeder 10) the energy consumption for the following month is 690 670 kWh. This indicates that the energy consumption of the essential meters contributes to 98% of that specific month's energy consumption.

Figure 2-14 illustrates the estimated energy consumption for April 2019 versus the estimated energy consumption for May 2019. This estimated energy consumption is based on the energy consumption of Feeder 6 and Feeder 10. Both the current and the following months' estimated energy consumption is 98% of the total energy consumption.

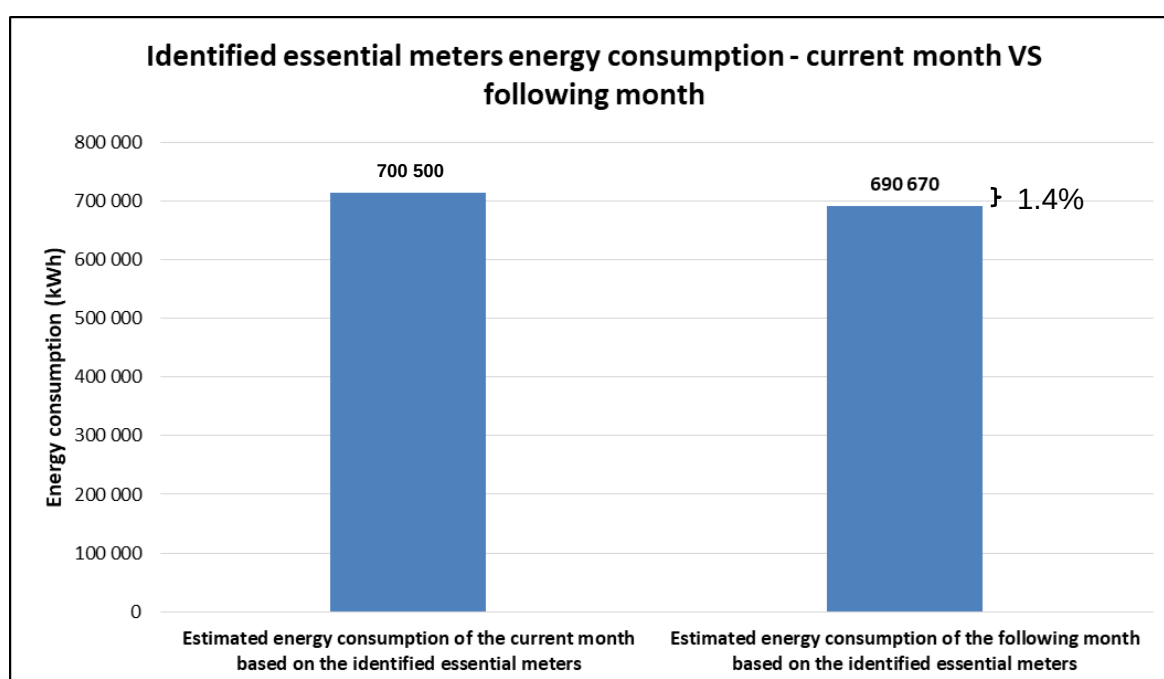


Figure 2-14: Estimated energy consumption comparison

Figure 2-14 reveals that by utilising the current month's identified essential meters that the following month's energy consumption, being monitored, remained 98% of the total energy consumption. However, it is also revealed that the overall energy consumption of the mine decreased with 1.4%. This information is communicated with management. Hence it can be seen that the essential meters will therefore be ideal to effectively monitor the overall "status" of the energy consumption of the facility.

2.8 KPI re-evaluation and reporting on energy consumption

KPI re-evaluation

Consider re-evaluating the essential data meters after a month or whenever major changes occur at the facility²⁵ [22], [58]. These major changes refer to any changes which might affect the energy consumption of a facility [22].

However, when energy initiatives have been implemented on the facility, do not recalculate the essential meters immediately [22]. Wait for a minimum of three days as data needs to build-up to determine actual influence of the step change on the energy consumption, after which the new essential energy meters should be identified [22]. This identification will use the previous three day's energy consumption as the Absolute Impact KPI and determining the new Volatility KPI values, based on these three days. For the duration of the month, these new identified energy meters should be used to monitor the energy consumption of the facility.

In some instances, major changes will occur in the energy consumption which causes new essential feeder meters to be identified. The data required to then evaluate the following month's important meters, should be based on the energy consumption after the major change.

Reporting on the energy consumption

Monitoring the derived (based on the essential energy meters) energy consumption should occur on a regular basis, such as a daily basis [22]. The main focus of this feedback is to provide the estimated energy consumption of the facility, based on these identified essential meters, to management [22]. With this information strategic decisions can be made, based on the energy consumption of the facility.

Methodology of the study – Step 5

Using the identified essential energy meters to monitor the energy consumption and then reporting back to company management on this energy consumption, serves as the final step in this process.

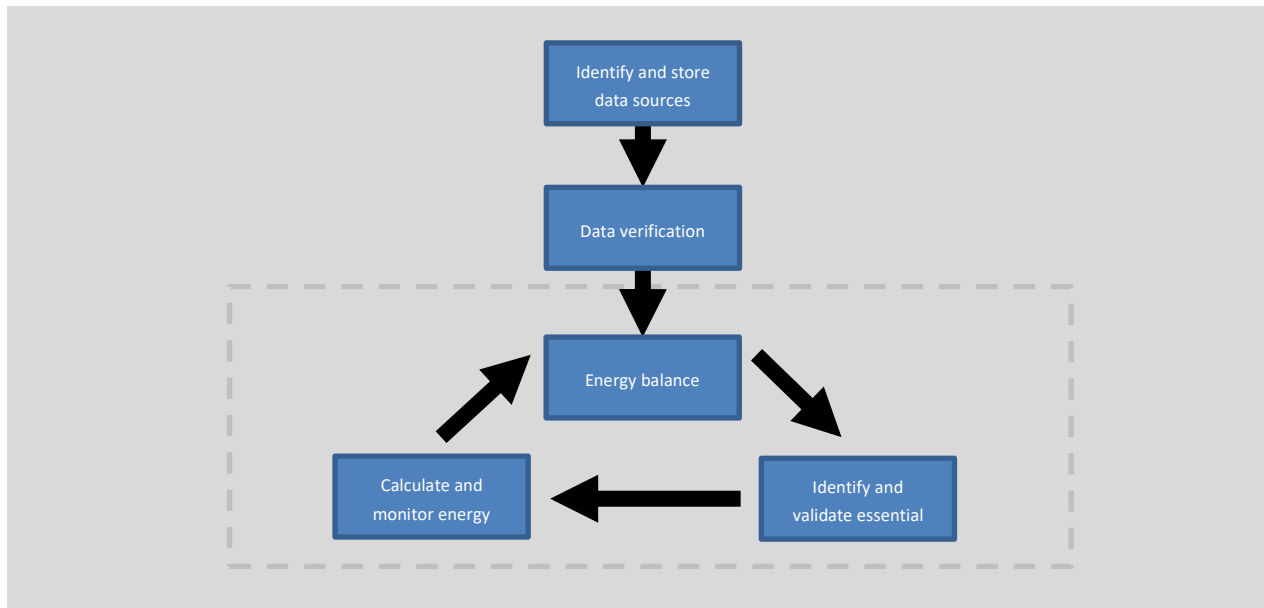


Figure 2-15: Methodology of the study – Step 5

This step is modelled to satisfy the energy management concept of monitoring and reporting.

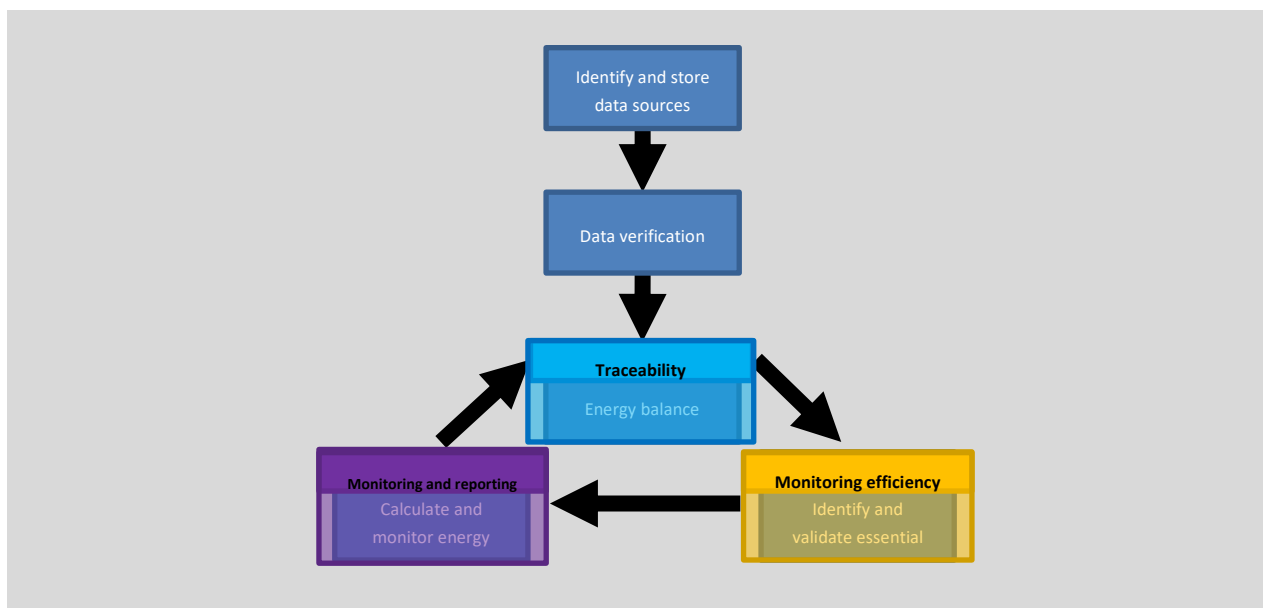


Figure 2-16: Methodology of the study – Step 5 Monitoring and reporting

2.9 General overview

To be able to address the need for the study, data should be obtained by firstly determining the data sources. Data sources include physical sources, for example, Eskom bills, as well as a digital energy management software program. This program provides data with frequent time-intervals. To validate and verify these data sources, the energy metering data and the Eskom bills should be compared. The dataset should be stored with a time stamp and a descriptive name, which can be used to categorise the energy meters (which assists with tracing the flow of energy throughout a system).

An energy balance should be used as a data quality test where an energy balance is based on the law of energy conservation. This test unveils the fact that different levels in an energy system should be equal to one another. An energy balance will also address the need to be able to trace energy initiatives through multiple boundaries. Knowing that all the data is accounted for, which was established through the energy balance, the feeder's energy consumption data is used to determine how many meters are required to monitor at least 80% of the facility's energy consumption.

After drawing up an energy balance, essential energy meters and data sources can be identified and validated, using the "Absolute Impact KPI" and the "Volatility KPI". Both the Absolute Impact KPI and the Volatility KPI should be combined, by multiplying both values with one another, per feeder meter. These multiplied values are then ranked from the largest to the smallest. The ranked-and-combined KPI values are used to count the top number of feeders required to monitor at least 80% of the energy consumption of a facility, which identifies the essential energy meters of the dataset. A scatter diagram can also be used to assist in identifying the combined essential energy meters.

Lastly, to address the need for monitoring and reporting, the following month's energy should be calculated and monitored using these essential meters. This estimated energy consumption of the full-facility, should be reported to management for strategic decision making.

Figure 2-17 illustrates the methodology created in *Chapter 2* which assists in identifying the essential data for monitoring purposes. The black dashed line represents the part of the methodology that should be repeated on a monthly basis. Referring to the fact that the latest essential meters should be identified once a month.

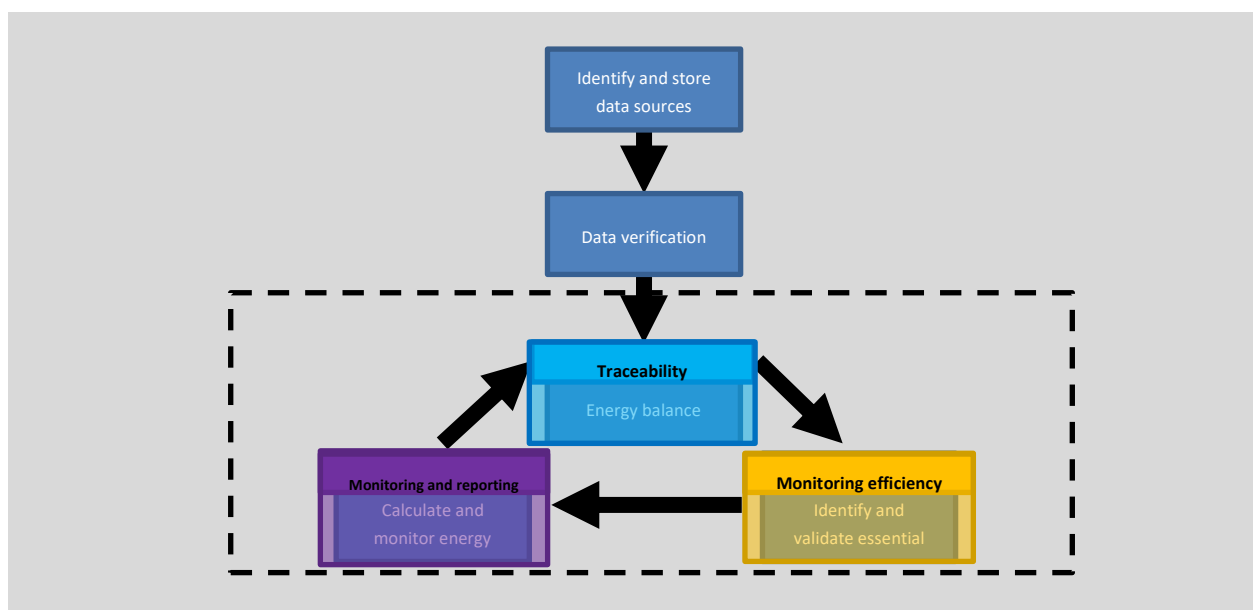
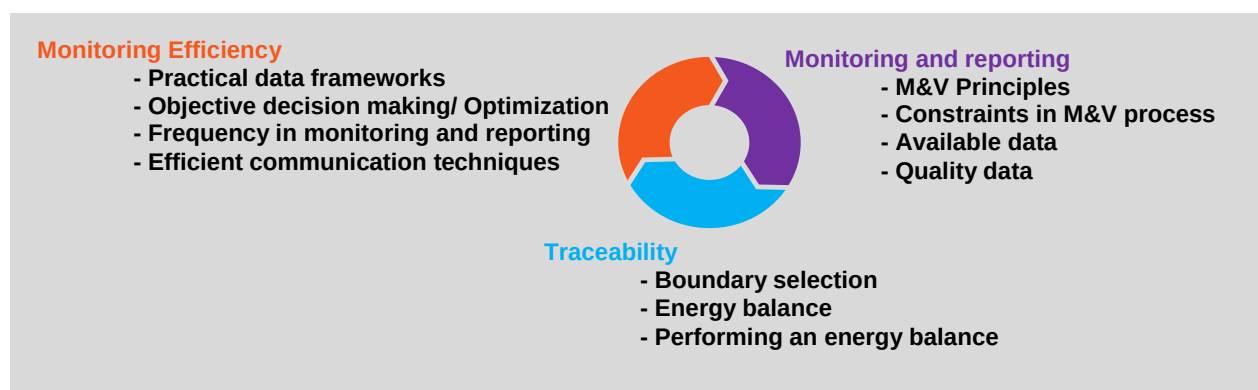


Figure 2-17: Methodology to identify essential meters

Finally, it is necessary to determine whether or not the methodology addresses the various aspects on which the study is based. These aspects were established in *Chapter 1* and aims to satisfy the need of the study. The various aspects are visualised in the following symbol and is used throughout the study.



Regarding the symbol, parallels will be drawn to indicate which steps of the study addresses each specific aspect of the study. By identifying the data, using a practical data framework, the monitoring and reporting concept's available data is addressed. Afterwards the data is stored, using not only a descriptive naming convention but also with a date-and-time stamp, which is based on the monitoring efficiency concept's practical data frameworks.

The following step is to perform data verification, which is mainly to ensure that quality data is used for the energy consumption monitoring. During this step, the data is cleaned from outliers and data loss. The main dataset is also compared to Eskom bills, to ensure that this data does in fact match-up. This step, therefore, is grounded on the monitoring and reporting concept's Quality data.

By executing an energy balance, the flow of the energy consumption is understood throughout a company. However, an energy balance also acts as a way to ensure quality data is used. This is achieved by ensuring that all of the energy consumption flows are accounted for throughout the facility, while addressing the traceability concept's energy balance and performing an energy balance aspect.

Moving on to identifying and validating the essential meters, first it is determined that the feeder meters are most ideally based on the energy consumption monitoring of the study. Which in effect addresses the boundary selection point allocated to traceability. Afterwards the number of meters needed to monitor at least 80% of the energy consumption of the facility is determined. Which contributes to the aspect of optimizing the process of monitoring the energy meters, allocated to the monitoring efficiency concept. Next, KPI values are allocated to each feeder meter and through combining the KPI values, a weight can be allocated to these energy meters which ensures that the energy meters can be ranked. At the same time graphs are used to visually communicate the weight allocated to these energy meters, according to the KPI values. Grouping these steps, it can be seen that the objective decision making/optimization aspect and the efficient communication techniques of the monitoring efficiency concept were addressed. However, it was also determined how often these essential meters should be re-evaluated. Hence, addressing the frequency in monitoring and reporting of the monitoring efficiency concept.

Finally ending off with calculating and monitoring the energy consumption of the facility, using only these essential meters, is not only based on the principles associated with M&V, but also addressing the constraints associated with M&V. These are aspects of monitoring and reporting.

Taking all of these steps into account, the fact that each aspect of the study (as noted in the symbol) is addressed, through the methodology. However, note that the methodology was not verified or validated during this chapter. It will only be verified and validated in *Chapter 3*, through the utilisation of case studies. All of the examples used in *Chapter 2*, was only to illustrate the process being developed.

CHAPTER 3 - RESULTS AND DISCUSSION

3 Results and discussion

3.1 Preamble

The methodology (as developed in *Chapter 2*) was tested, verified and validated by applying it to case studies. These case studies are based within the mining environment.

Firstly, the background regarding the case study and the associated energy metering structure is discussed (*Section 3.2*). Followed with the explanation of the available datasets, the associated practical data storing frameworks and the various data quality tests. One of which is the energy balance, which doubles as a technique to understand the energy consumption flow throughout the entire organisation (*Section 3.3*). *Section 3.4* utilises the Pareto analysis to determine how many meters are needed to monitor at least 80% of the energy consumption.

Section 3.5 and *Section 3.6*, focus on allocating a KPI value for both the Absolute Impact KPI and the Volatility KPI to each feeder. These KPI values are then combined and ranked. The Pareto analysis then identifies the top energy feeders as the essential energy meters. *Section 3.7* uses these identified essential meters to calculate the estimated daily energy consumption of the mine for the following month, where after the essential energy meter identification process reinitiates.

The verification and validation are discussed in *Section 3.8*. Whereas *Section 3.9* reveals the separate benefits, which arose out of the study. Finally, the chapter is concluded with a short summary (*Section 3.10*).

3.2 Case study background

To test, verify and validate the methodology generated in *Chapter 2* of this study, two case studies were used. Both of these case studies are organisations functioning in the mining industry.

Detailed results from Case Study A will be discussed in this chapter. The final step of the methodology, as performed on Case Study B, will also be presented and evaluated along with those from Case Study A. Details on the second case study's (Case Study B) results will be given in Appendix A.

Both of the case studies consist of operational units known as shafts, plants and care-and-maintenance (C&M) shafts. Shafts refer to the underground zones where ore is extracted and

in layman's terms it is known as production shafts⁴⁴. Whereas plants, also referred to as processing plants, are the parts of the mine where the ore is processed, or in other words, where the waste rock is separated from the valuable minerals⁴⁵. The C&M shafts are shafts which are currently not used for production, but which are still being maintained as no final decision has been made to permanently close that part of the mine [68].

The mining complex in Case Study A consists of six production shafts, five plants and seven C&M shafts. The mine receives 13 different Eskom bills per month, as specific groupings of their operations are combined. Showing that each Eskom bill does not represent a shaft, or plant or C&M shaft, but rather groupings of these operations. To understand and determine this Eskom bill layout, the Eskom bill- to-operational units' layout was obtained from the mine. This was used to attain an overall background of the operations occurring at the mine.

Metering structure

At the same time there is an energy metering structure established at the mine, with an accompanying online energy metering software. The metering structure of this Case Study A is illustrated in Figure 3-1.

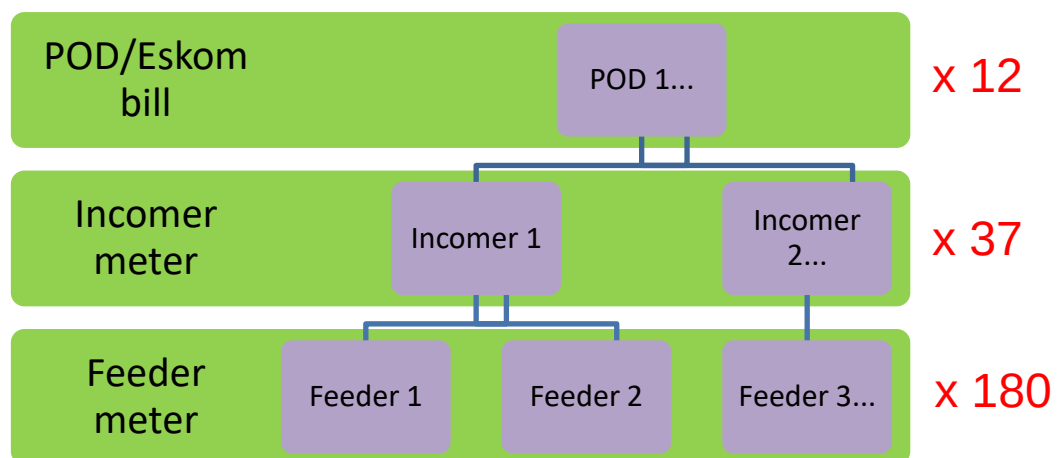


Figure 3-1: Case Study A's metering structure

⁴⁴ J. Daviau, "The Components of a Mine Shaft: Mine Skips and Cages." [Online]. Available: <http://www.wabcorp.com/components-mine-shaft-mine-skips-cages/#:~:text=A mine shaft is a up and down the shaft.> [Accessed: 28-Sep-2020].

⁴⁵ C. H. Lorig, "Mineral processing," 2020. [Online]. Available: <https://www.britannica.com/technology/mineral-processing>. [Accessed: 28-Sep-2020].

Figure 3-1 notes that there are 12 different PODs (with each POD representing an Eskom bill), all of these PODs grouped together reflect the total energy consumption of the mine. Each POD is built-up of a combination of incomer meters, which represents a section of the total energy stream. In Case Study A there are 37 incomers in total. Which can further be broken down between 180 feeder meters. Combinations of these 180 feeder meters are equivalent to an incomer meter. Currently all 217 (37 incomer meters + 180 feeder meters) energy meters are being monitored on a monthly basis (see Figure 3-2 below). To determine the total energy consumption and to establish the energy flow throughout the mine.

Figure 3-2: Total monthly energy consumption monitoring

Figure 3-2 reveals that the feeder meters do not measure the entire energy consumption of the facility. It disregards 12% of the total energy consumption of a month. Yet, the feeder meters do however still measure a large portion of the mine's energy consumption. Therefore, monitoring these feeder meters will likely still suffice to identify any energy wastages, as well as obtaining an overall feel of the "energy consumption status" of the facility.

This study aims to identify the essential meters to proceed with monitoring most of the facility's energy consumption, whilst decreasing the number of energy meters which are monitored in detail.

The feeder meters will be used to identify the essential meters; in other words, the 180 feeder meters will form the range out of which the essential meters will be selected. This allows the "break-down" of the energy consumption to the lowest level and thus gaining a better understanding of the energy savings opportunities on the mine.

3.3 Case study data

Acquire data, practical data framework, and data quality test

The case study uses energy metering software, providing energy consumption data points for each half-hour. The software can provide up to three years of historical data. With the software functioning as a product and a service provided by a third-party. The service-provider ensures that the data quality is acceptable, and that data loss and data errors are filled with averages. However, these data quality tests should still be performed to ensure that quality data is used.

Thus to determine if data loss was present, all of the incomer meters and feeder meters were evaluated. This evaluation was done by counting any half-hour, during the month, which presented no energy consumption reading per energy meter. Followed by converting it to a percentage of the total available energy consumption half-hourly values available in a month. Note that the energy meters' (both the incomer and the feeder meters) data loss were grouped under the associated POD in Table 3-1.

Table 3-1: Case Study A - Percentage data loss of month per POD

POD name	POD 1	POD 2	POD 3	POD 4	POD 5	POD 6	POD 7	POD 8	POD 9	POD 10	POD 11	POD 12
% Data loss	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 3-1 reveals that no data loss is present in the data, during this specific month, for all the incomer and feeder meters. Figure 3-3 displays the total monthly energy consumption of the sum of the mine's feeder meters per half-hour. This graph is to determine whether or not outliers are present in the data.

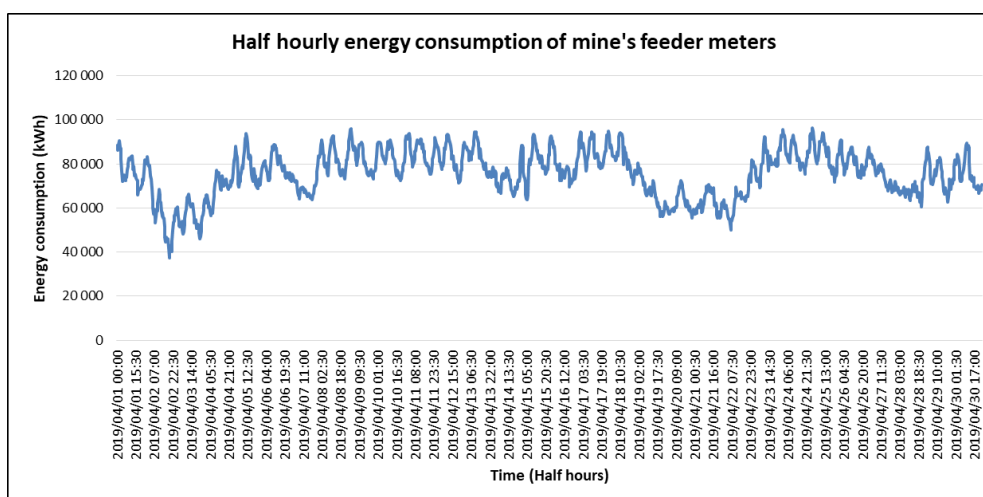


Figure 3-3: Energy consumption of total mine per half hour

Figure 3-3 uncovers that no energy consumption outliers have occurred. This is as the data seems to follow a pattern and at the same time does not occur to move out of a specific range of energy consumption.

Thus it can be concluded that no data loss and no data outliers are present in the monthly energy consumption data. Hence, it can be determined that the data has already been "cleaned" by the energy management software provider. Therefore, the execution of Step 1 and Step 2 of the methodology was already performed in Case Study A and the next step can thus continue.

Each data point is stored with a date-and-time stamp and is accessible on the energy management software. The data point is also stored with a detailed energy meter naming convention. Table 3-2 serves as an explanation of the practical data framework that the energy metering data of Case Study A is stored with.

Table 3-2: Case Study A - practical data framework

	A	B	C	D	E
	Abbreviation of mine name	Name of POD under which energy meter is allocated	Description of operation the meter measures	Type of meter	Unit of meter and "Imp"
Incomer	e.g. CSA_	POD 1_	Compressor GHH_	INCOMER1_	kWh Imp
Feeder	e.g. CSA_	POD 1_		FDR_	kWh Imp

In Table 3-2: each column represents a different section of the naming convention, where:

- A = 'CSA' is an abbreviation for Case Study A.
- B = 'POD 1' represents the name of the POD.
- C = A description is not required for the incomer, however, it adds a layer of traceability to the feeder meters.
- D = This can either be an "INCOMER" or a feeder, where the abbreviation used for a feeder meter is 'FDR'. When referring to the incomer meters, the incomer meters should be numbered, to indicate that this meter is for example the first incomer associated with this specific POD. However, when naming the following POD's incomer meters another 'INCOMER1' will exist however with the corresponding 'POD 2' naming convention, as indicated in column B.
- E = The measurements are in kWh. The 'Imp', which is an abbreviation of import, refers to the measurement point of the energy meter. Noting that the energy meter measures the energy stream at the point where the energy flows into the meter or rather from the point of generation to the current feeder⁴⁶.

Refer to Appendix B for a list of all the energy consumption meters (incomer and feeder meters) available in Case Study A. Take note that due to ensuring that the mine's identity is protected, the feeder meters were not described as mentioned in Table 3-2's Column C. The feeders were given a generic description such as Feeder1.1, indicating that this is the first feeder in POD 1. An example of a feeder meter name is CSA_POD 1_Feeder1.1. kWh Imp, based on the practical data framework for Case Study A.

Now that it has been determined that the data is "clean" and stored using a practical data framework, further data quality checks are required. This entails comparing the energy management software dataset with Eskom bills. Thus, Eskom bills are compared with the dataset as an extra data quality check.

Figure 3-4 demonstrates the percentage difference between the total of the Eskom bills' energy consumption and that of all the POD's energy consumption, for a month. The percentage difference, per month, is indicated on the graph.

⁴⁶ S. Jhalora, "Import and export of electrical energy." [Online]. Available: https://www.securemeters.com/files/5113/7291/7734/imp_exp_elec_energy17.pdf#:~:text=When the angle between the,active energy is being consumed. [Accessed: 29-Sep-2020].

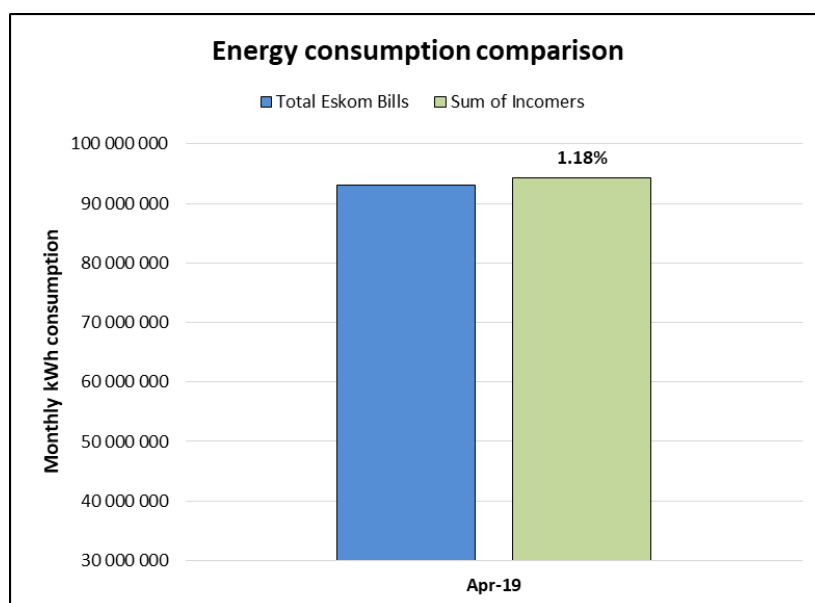


Figure 3-4: Eskom bill VS energy management software comparison

Figure 3-4 displays the total monthly energy consumption obtained from the management software, by adding all the incomer meters together, as well as the total monthly energy consumption obtained from all the Eskom bills associated with the mine. The percentage difference between these data sets is 1.18%.

In an agreement between the mine and the energy management software company, percentage differences between the Eskom bills and the PODs of the energy management software should be less than 3%. This is still a satisfactory level of data quality for the mine. However, if this percentage difference is greater than 3%, the energy management software company will be required to correct the energy metering software data. However, in Figure 3-4 the percentage difference is less than 3%, indicating that the quality of the data is of a satisfactory level.

Now that data of a satisfactory level is established, it is time to refer back to the methodology of the study, to obtain a birds-eye view of the progress of the study. Figure 3-5 demonstrates the methodology, as created in *Chapter 2*, with the first two steps marked as completed.

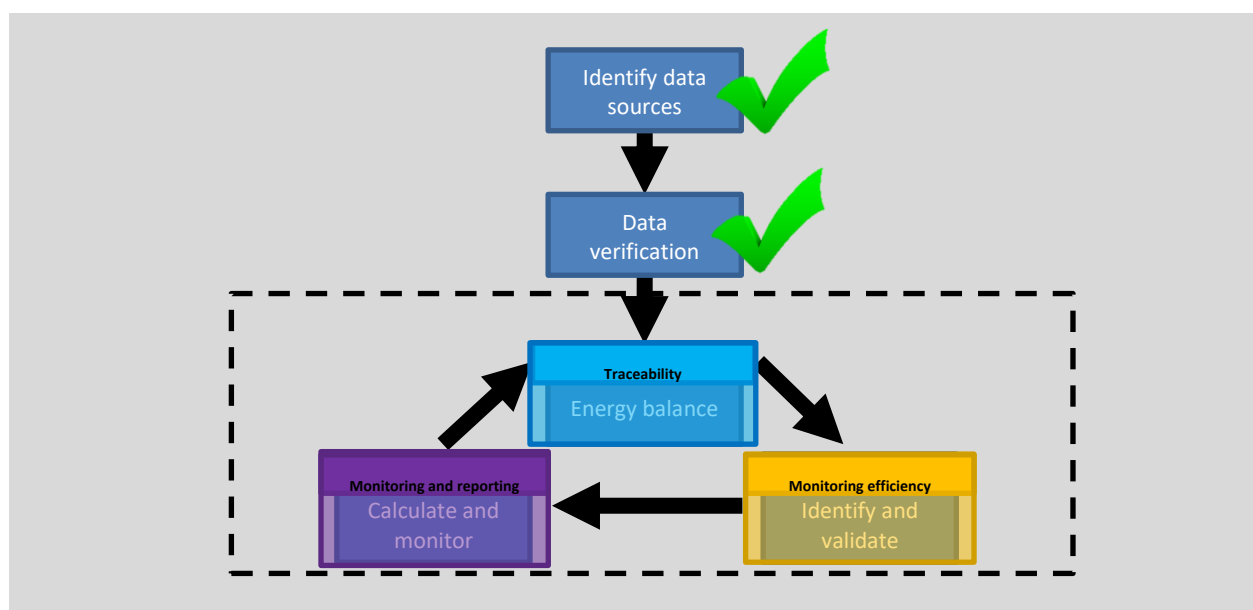


Figure 3-5: Methodology of the study – Step 1 & 2

At this stage in the methodology the data sources have been identified. Basic data quality cleaning, such as nullifying data loss gaps and data outliers, have also been performed and checked. After the data was determined as quality data, the data is stored using a practical metering naming convention. Each energy consumption measurement point is also allocated to a specific date-and-time stamp. Finally, the energy consumption software data set was compared to Eskom bills as another data quality test.

Using this data, the next step is to understand and trace the flow of energy throughout the organisation. Therefore, an energy balance is required.

Energy balance

As previously stated, (Section 3.2 – Metering structure) Case Study A consists of 12 PODs, with a summation of specific incomers forming the energy consumption of a POD. Therefore, there will be no difference between the energy consumption of a POD and the energy consumption of the corresponding incomers.

Case Study A is comprised of 37 incomer meters and 180 feeder meters. A grouping of specific feeder meters' energy consumption theoretically should be equal to the energy consumption of the corresponding incomer meter. However, the Case Study A mine has chosen not to measure all of the energy flow on the feeder meter level. Therefore, the sum of the feeder meters will not match the sum of the incomer meters.

In Appendix C a table indicating the structure of the energy meters as well as each meter's associated energy consumption percentage towards the total energy consumption. However, as a visual summary of the information displayed in Appendix C, a Sankey diagram was used (Figure 3-6) [14]. Starting with the total mine's energy consumption, followed by the 12 PODs linked to the mine. Next, the 37 incomer meters are displayed and finally the 180 feeder meters are displayed.

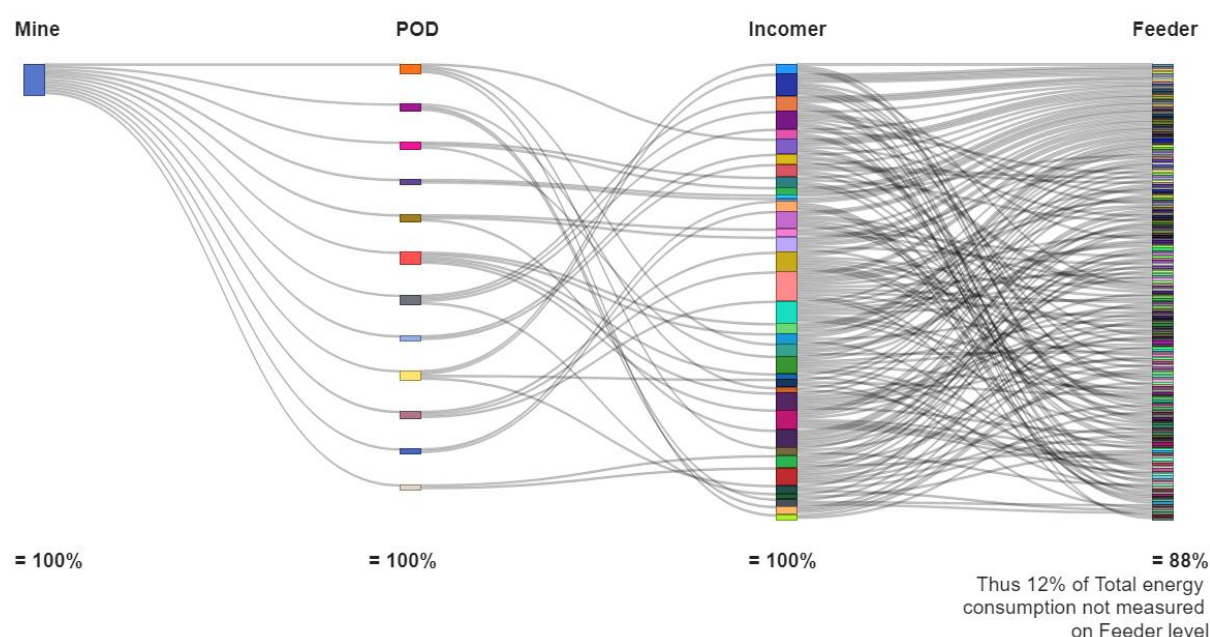


Figure 3-6: Case Study A - energy balance using a Sankey diagram

In Figure 3-6 the percentage energy consumption was revealed to being monitored completely (100%) for the entire mine, the PODs and the incomers. However, when examining the energy consumption of the feeder meters, only 88% of the total energy flow is monitored by energy meters. Indicating that 12% of the total energy consumption is not measured by the feeder meters.

Energy balance challenge and solution

The challenge associated with this study is the fact that the energy balance might not always match-up. It depends on the company's preferences. This is due to the fact that the third party energy management software provider might not measure all the energy consumption on feeder meter level. As per mine management's request for a cost-sensitive measuring software, only certain points on a feeder level are measured.

However, the solution to this challenge is to calculate the difference between the incomer meters and the feeder meters. Then adding that difference to the total of the feeder meters' energy consumption when monitoring total energy consumption of the facility. Referring to this as the difference between the incomer and the feeder meters.

Now that the energy balance was done as the final data quality check, the methodology (*Chapter 2*) should be updated to indicate that the energy balance has been completed. *Chapter 2* notes that the energy balance contributes to the traceability concept of the energy management of the study. Therefore, Figure 3-7 demonstrates that the traceability step in the methodology has been “ticked-off”.

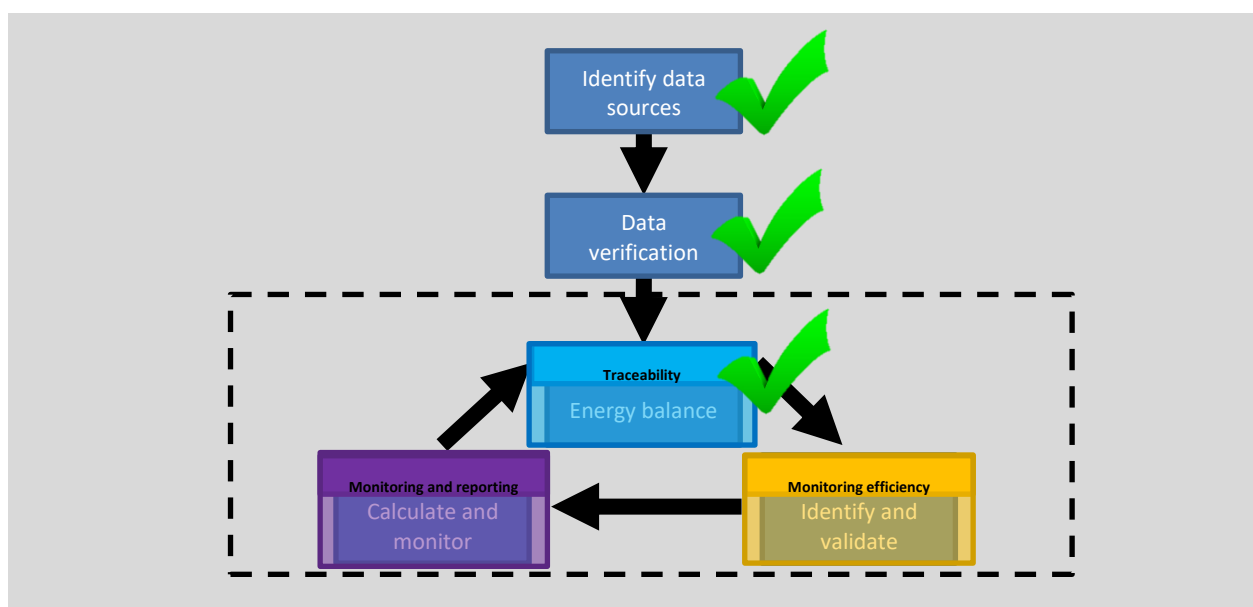


Figure 3-7: Methodology of the study – Step 3

At this stage in the methodology, an energy balance has been performed. Indicating the energy flow of the total energy consumption throughout the entire mine. As well as ensuring that the energy consumption is balanced throughout the entire organisation. This data can then be used to determine the essential energy meters throughout the facility, by use of KPIs.

3.4 Number of important meters

Now that it was determined that all of the data is accounted for and can be seen as quality data, the number of meters needed to monitor at least 80% of the energy consumption can be determined. This concept is based on the Pareto principle. Figure 3-8 visualises the total monthly energy consumption of the feeder meters plus the difference between the incomer and the feeder meters, sorted from the largest to the smallest.

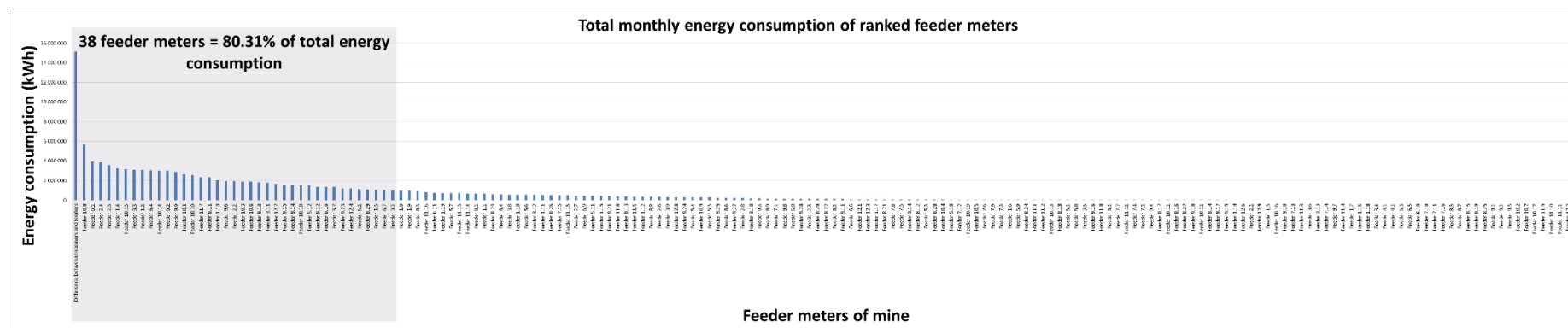


Figure 3-8: Total monthly energy consumption per feeder meter

In Figure 3-8 it is illustrated that the top 38 feeder meters, along with the difference between the incomer and the feeder meters monitors 80.31% of the total energy consumption. Thus for Case Study A 38 feeder meters will need to be identified to monitor at least 80% of the energy consumption of the facility.

3.5 Essential KPIs

The two KPIs which were established in *Chapter 2* where the Absolute Impact KPI and the Volatility KPI. With the Absolute Impact KPI taking the total amount of energy consumed (per month) by the operations linked to the specific meter, into account. Secondly, the Volatility KPI measures the number of times the energy meter is regarded as an important meter, within a period of a month. An energy meter is regarded as important if the daily Absolute Impact of the energy meter is within the top 38 feeder meters (as determined in *Section 3.4*) of the meters contributing the most to the total energy consumption.

As mentioned in *Section 3.2* this study will focus on identifying the important energy meters on the feeder meter energy level. This is since feeder meters are the lowest level of the energy consumption measurements available. This allows the “break-down” of the energy consumption and to effectively pin-point the energy efficiency opportunities.

The important energy meters can be established by using the Absolute Impact KPI, as well as the Volatility KPI. The Absolute Impact KPI was established by determining the total monthly energy consumption per feeder meter. Thus the KPI value has a unit of kWh.

Next, the Volatility KPI is determined by calculating the total daily energy consumption per feeder meter for the month's data. Then by ranking these energy meters according to the energy meters consuming the most energy, to the least, for each day's energy consumption. Finally counting the number of times each feeder was classified as the top 38 (as determined in *Section 3.4*) feeder meters contributing the most to the total energy consumption. In other words, counting the number of times the meter was regarded as important throughout the month.

To view the detailed Absolute KPI values and Volatility KPI values for each feeder meter, refer to Appendix D. However, Figure 3-9 is a graphical summary of the information displayed in Appendix D. This scatter diagram plots the total monthly energy consumption of a feeder meter versus the number of times the feeder meter was identified as important during a month.

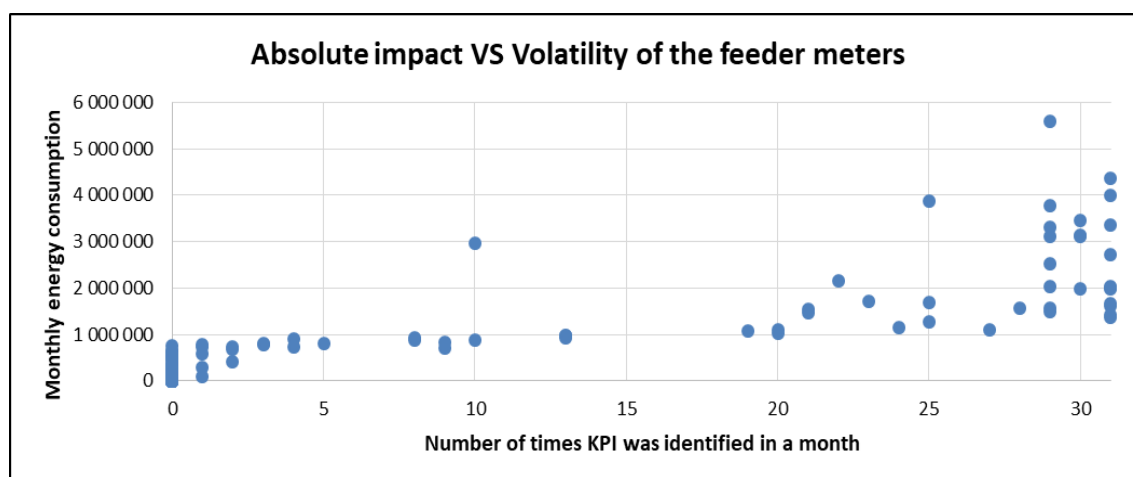


Figure 3-9: Scatter diagram of Absolute Impact VS Volatility KPI

In Figure 3-9 it can be seen that some of the feeder meters are located on the zero mark of the x-axis. Indicating that they have not once been identified as an important meter, during the month, even though they might have consumed energy. It is also clear to see that some of the feeders were identified as an important meter each day during the month (31 days, thus the 31 mark on the x-axis).

It is anticipated that the feeder meters with the greatest energy consumption and the feeders with the highest Volatility KPI values will be regarded as the essential feeder meters. Hence, by looking at Figure 3-9 it can be anticipated that the feeder meters located in the upper-right corner of the diagram will be highlighted as the essential meters.

At the same time graphs were used to assist in identifying the essential energy meters, by highlighting the Absolute Impact KPI, as well as the Volatility KPI characteristics of the energy meter.

To trace the energy consumption changes which occurred throughout a month, a Waterfall diagram was used that analysed the feeders allocated to each POD. The diagram starts with the previous month's energy consumption (or otherwise known as March 2019's energy consumption), followed with the change in energy consumption of each feeder and ends off with the energy consumption at the end of April 2019 (Figure 3-10).

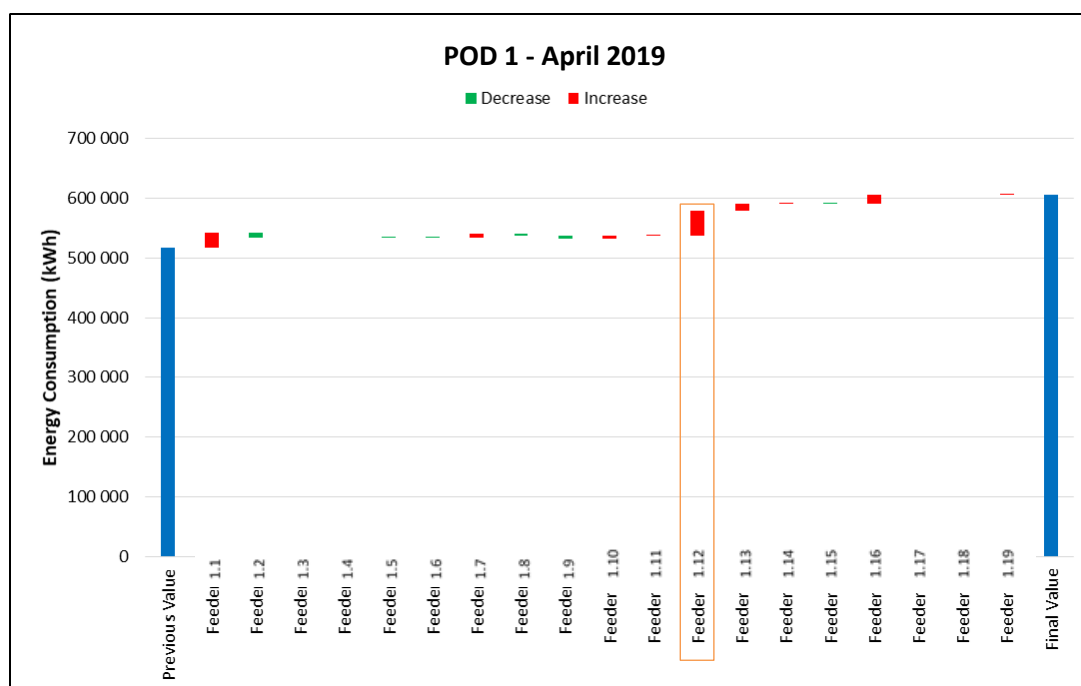


Figure 3-10: Waterfall diagram for POD 1

Evaluation of the Waterfall diagram (Figure 3-10) reveals that Feeder 1.12 (indicated as the orange block) located on POD 1 appeared to consume significantly more energy throughout the month of April 2019 versus the previous month. This was due to the facility expanding and hence using more energy to ventilate the facility.

Another graphical tool to determine the Absolute Impact of a feeder, as well as the Volatility of the feeders, is known as a Tornado diagram. This graph functions as a sensitivity analysis, as any type of comparison can be performed. Such as plotting the total energy consumption of two months next to each other, or even two days. Figure 3-11 illustrates a Tornado diagram of the feeder meters of Case Study A. Comparing March 2019 with April 2019. The red block located in Figure 3-11 highlights Feeder 1.12 as identified on the Waterfall diagram.

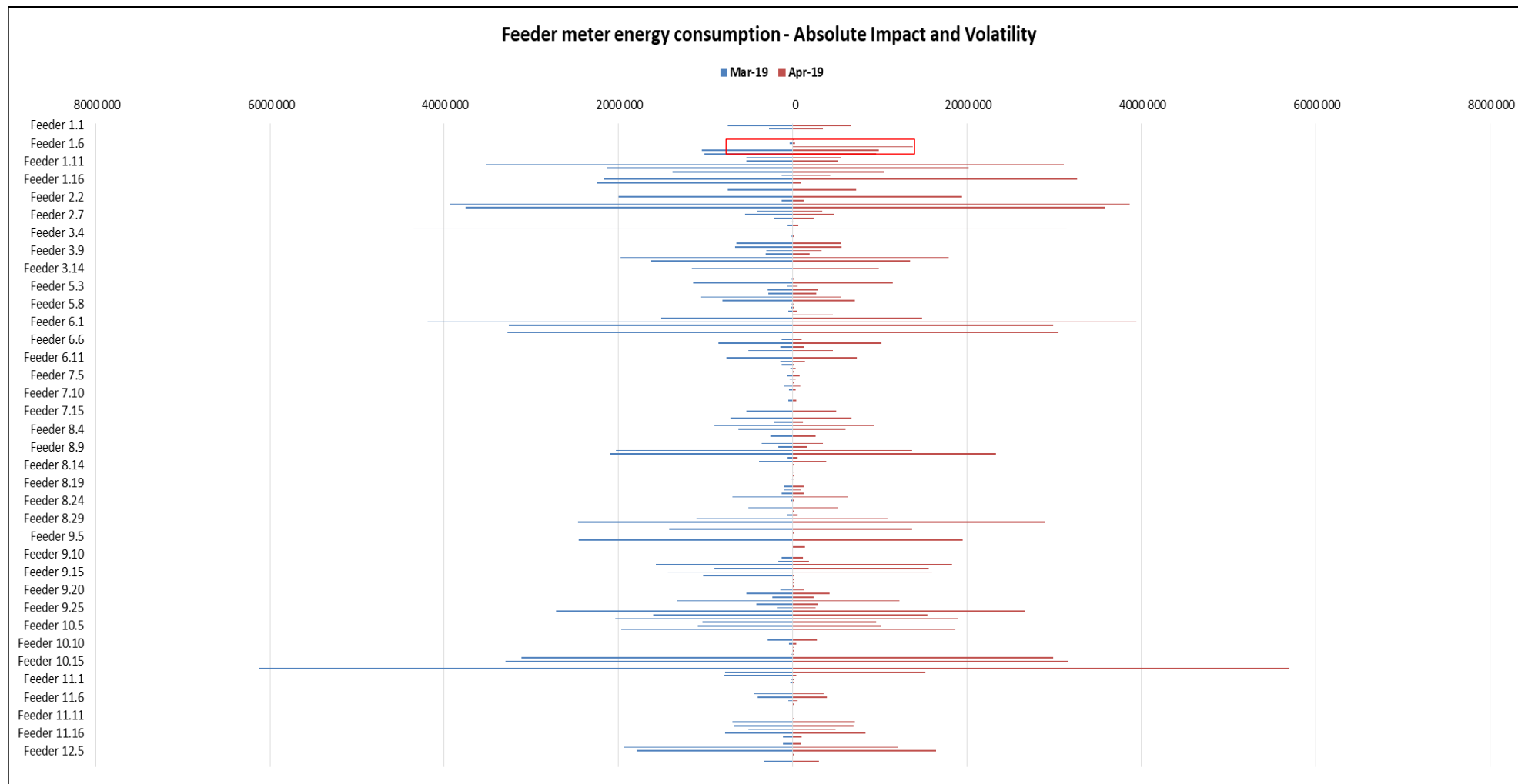


Figure 3-11: Tornado diagram comparing consecutive months

Figure 3-11 indicates that Feeder 1.12 was highlighted as a feeder with an increase in energy usage. Though relative to the other feeder meters, this feeder's energy consumption remains insignificant, which verifies and validate the use of not only the graphs but also the KPIs. Indicating that both methods reflect the same information.

Now two KPI values per feeder (which needs to be combined) and two graphs exist to assist in revealing the essential meters.

3.6 Identify the essential meters

In *Section 3.5* two separate KPI values were allocated to each feeder meters. These KPI values were the Absolute Impact KPI and the Volatility KPI. As a result of having two separate values, these values needed to be combined to obtain the overall essential meters.

The combined essential feeder values were obtained through multiplying the two KPI values with one another. Afterwards these multiplied values were ranked from largest to smallest. Counting the top 38 meters (determined in *Section 3.4*). These 38 meters represent the essential meters.

By adding the difference between the incomers' and the feeders' energy consumption data for the month to the energy consumption of the top 38 energy meters, a derived energy consumption for the total mine is available for the month.

Table 3-3 is a summary of the results obtained in Table E-1. Refer to Appendix E to view the calculations to identify the essential energy meters. Table 3-3 takes the 38 essential energy meters and compares this to the total monthly energy consumption of the feeders. The energy consumption of these 38 essential meters, as well as the difference between the incomer and the feeder meters' energy consumption was added to calculate the estimated energy consumption.

Table 3-3: Case Study A - Energy consumption comparison

Description	Monthly energy consumption (kWh)
kWh Difference between Incomers and Feeders	15 158 791
Total estimated monthly energy consumption based on the essential meters & kWh difference between Incomers and Feeders	99 645 713
Actual total monthly energy consumption of feeders & kWh difference between incomers and feeders	124 108 775
% of the total monthly energy consumption using only the essential meters (and the difference between the incomers and the feeders)	80%
% identified essential meters	21%

By comparing this derived value with the total monthly energy consumption, it can be concluded that 80% of the mine's energy consumption data is represented by these 38 feeder meters ($21\% = 38/180 \times 100\%$). This verifies and validates that the Pareto analysis can be performed on the dataset, to help identify the essential energy meters. As well as shows that a combination between the Absolute Impact KPI and the Volatility KPI effectively ensures that the important energy meters can be identified.

Afterwards the answers obtained through the calculations (*Appendix E*) were used to reflect only the essential meters (Figure 3-12).

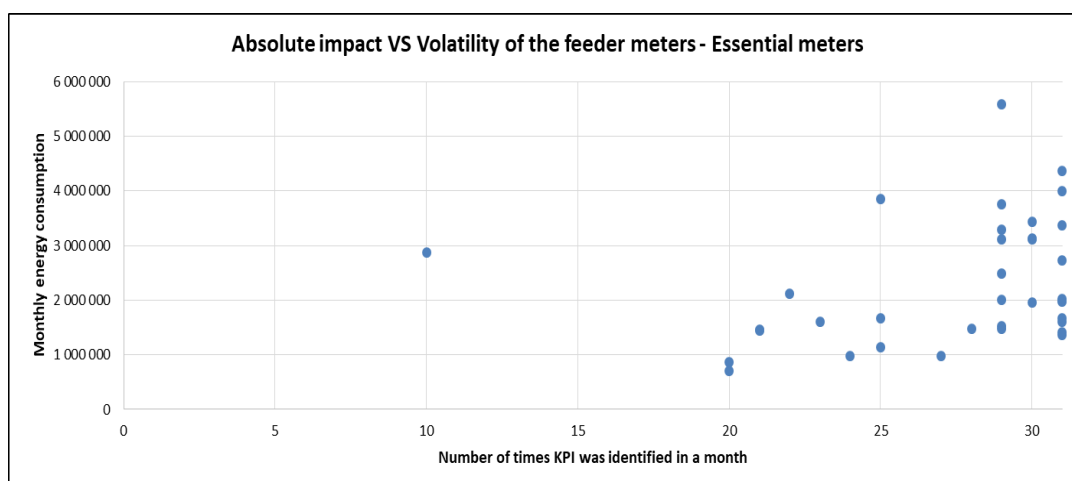


Figure 3-12: Absolute Impact VS Volatility of the 36 essential meters

When examining Figure 3-12 originally (in Figure 3-9) it was anticipated that the feeder meters located in the top right corner of the Scatter diagram will be regarded as the essential energy meters. This was reflected in reality by looking at Figure 3-12.

As it can be concluded that the essential energy meters have been identified, the methodology as established in *Chapter 2* can be updated. The fact that the essential energy meters were identified adds to the ability of this study to efficiently monitor the energy consumption of a facility. Figure 3-13 shows that the next step in the methodology was achieved.

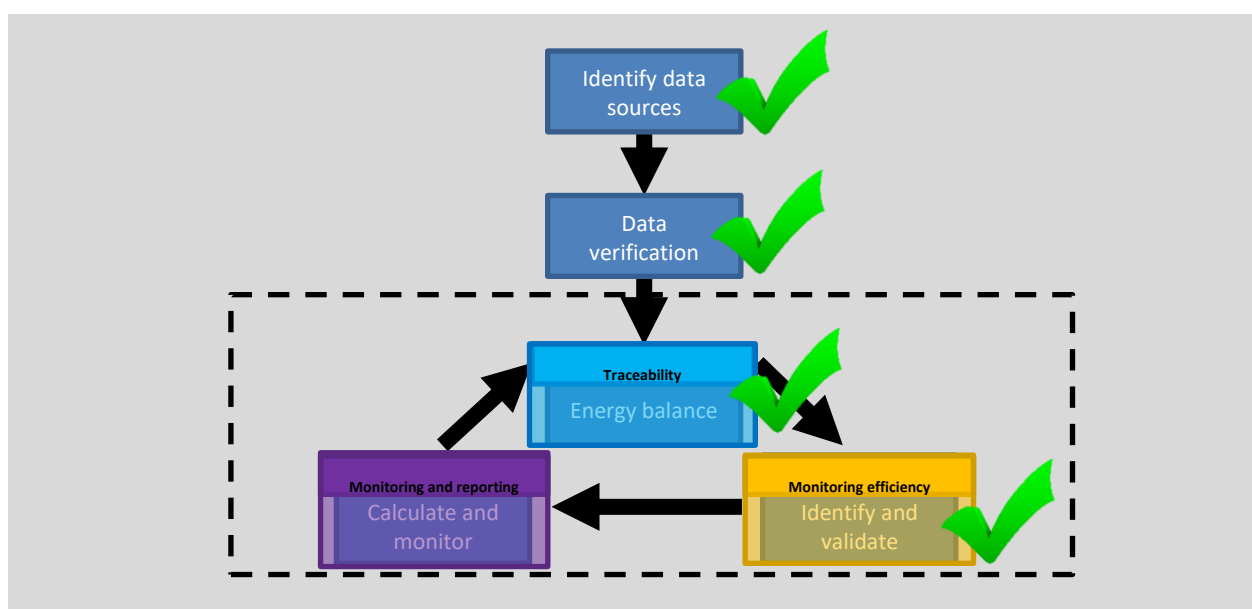


Figure 3-13: Methodology of the study – Step 4

Figure 3-13 illustrates that the essential energy meters were identified during this step. This contributes to the monitoring efficiency concept of energy management, by ensuring that the essential energy meters are identified to calculate a derived energy consumption of the mine.

These essential meters should be used in the following month, to monitor the derived energy consumption of the mine.

3.7 Monitoring and reporting

Case Study A

The final step is to monitor and report on the energy consumption, using the essential energy meters. This energy consumption monitoring and reporting to management should occur on a daily basis.

The essential meters as identified was used as the essential meters for the following month. Using only these essential meters' daily energy consumption to estimate the energy consumption of the entire mine. Yet, still adding 12% of the total energy consumption of the total mine's energy consumption (as determined by Figure 3-6 and Table C-1), to compensate for the difference between the incomer meters and the feeder meters. Thus by accounting for the energy consumption of the essential meters and the 12% difference between the incomers and the feeders, will leave an estimated energy consumption of the total mine.

Figure 3-14 serves as the energy consumption comparison for the current month versus the following month's energy consumption using only the essential energy meters. The 12% difference between the incomer meters and the feeder meters is added to the comparison. This is compared to the current month's estimated energy consumption. The section of the data columns indicating the energy consumption based on the essential energy meters are light blue. The darker blue section of the data columns refers to the 12% difference between the incomer and the feeder meter's energy consumption.

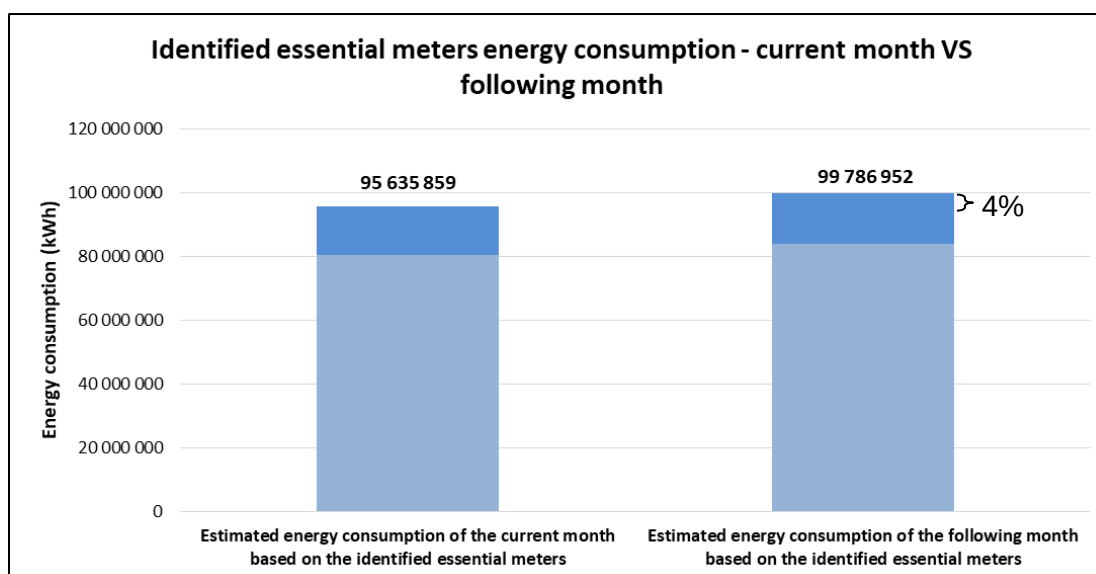


Figure 3-14: Case Study A - The essential energy meter's consumption comparison

By analysing Figure 3-14 it can be seen when comparing both the estimated energy consumptions for the current month and the following month, that there is a 4% increase. The increase indicates that by monitoring only the 38 feeder meters ($21\% = 38/180 \times 100\%$) it could be seen that there has in fact been a 4% increase in the overall energy consumption of the facility from the previous month. This can be very helpful to management to make strategic decisions on a daily basis with regards to the energy consumption of the essential feeder meters.

Case Study B

As mentioned previously, Case Study B also functions in the mining environment. Refer to Appendix A to view the results associated to performing the methodology on Case Study B. However, the final step of the methodology performed on Case Study B can be seen in Figure 3-15. Where the light blue box on the graph indicates the energy consumption of the essential meters per month. Following this is a small blue box, indicating the 6% difference between the incomer and feeder.

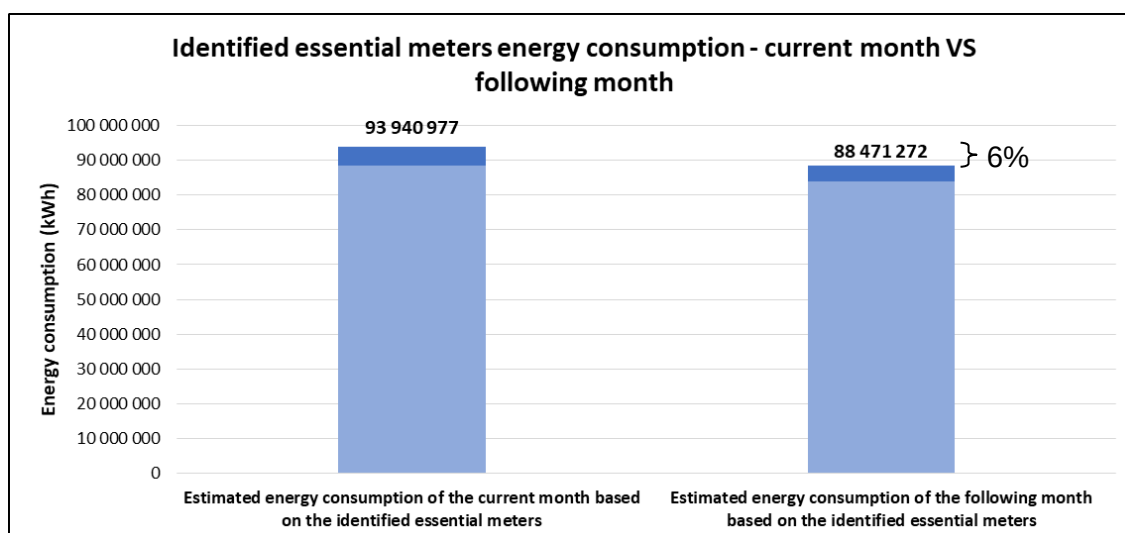


Figure 3-15: Case Study B - The essential energy meter's consumption comparison

Figure 3-15 reveals that by comparing both the estimated energy consumptions for the current and the following month, that there is a 6% decrease. Thus by monitoring 30% of the feeders (83 essential feeders / 277 available feeders x 100%) it can be determined that there has been a 6% decrease in the energy consumption usage between the two months. Though at the same time using the 30% of the feeder meters, 80% of the facility's energy consumption is being monitored. Which is beneficial, due to the fact that with 30% of the effort (monitoring 30% of the available feeder meters) the "state" of the energy consumption of the facility can be determined and management can make effective and strategic decisions to pursue energy efficiency initiatives.

Final thoughts of monitoring and reporting the energy consumption of the essential meters

It is important to mention the energy balance assisted in visualising the flow of energy consumption of energy initiatives throughout the facility. But at the same time, if ever an essential meter also classifies as an energy efficiency initiative meter the energy consumption of this meter will be monitored on a daily basis. In effect the impact of this energy initiative will be traced throughout the entire facility if the energy efficiency initiative is located on an essential meter. Thus a hidden advantage of this methodology is the fact that essential energy meters are identified and these energy meters carry great and consistent potential for energy savings.

However, these essential meters should not be accepted as the important meters indefinitely, instead at the end of each month (at the end of the following month), the same evaluation which was performed in current month, should be performed to ensure that the identified meters are still classified as essential meters. Drastic changes on these essential meters

(occurring during the month) should be investigated and communicated to management, where after these changes should be monitored. Another result of drastic changes is that it forms an exception to re-evaluate the essential meters, during the course of a month. For the remainder of the month the new essential energy meters should be utilised.

This was the final step of the methodology as noted in *Chapter 2*. Figure 3-16 is an updated version of the methodology, indicating that the last step has been completed.

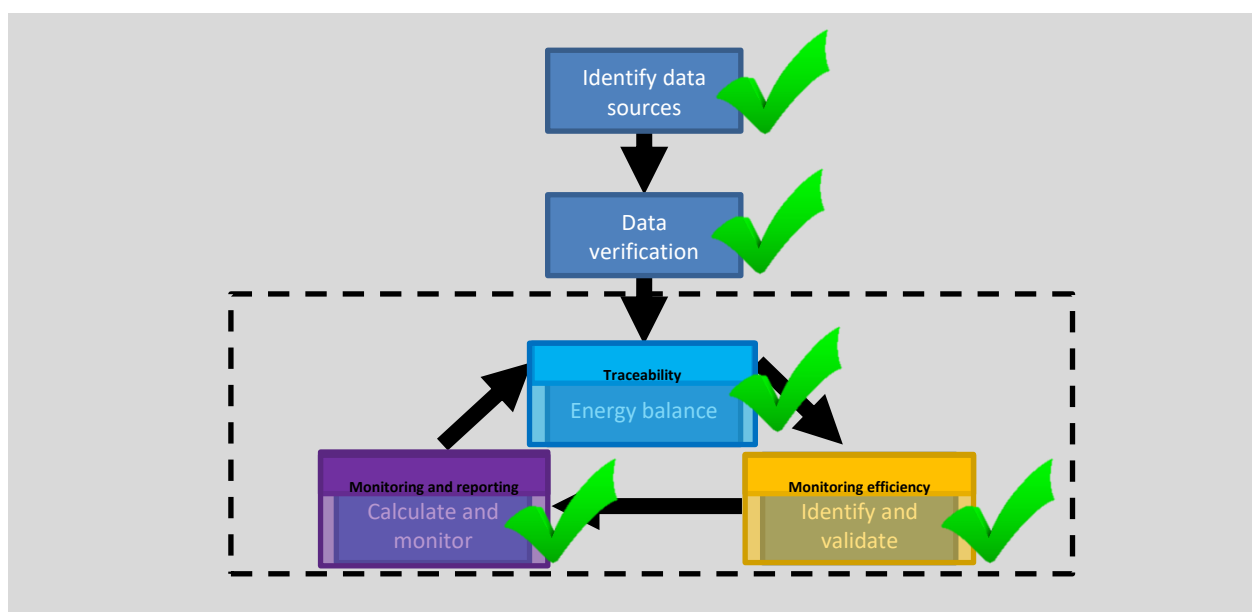


Figure 3-16: Methodology of the study – Step 5

Figure 3-16 indicates that the entire methodology was performed on Case Study A, including Case Study B (refer to Appendix A). As well as noting that the energy management concept, monitoring and reporting, was executed during this final step. This was achieved by using only the essential energy consumption meters as established in the previous step and then calculating the following month's energy consumption.

Now that the methodology was executed, it is necessary to verify and validate the study.

3.8 Verification and validation

To verify and validate the methodology the identified meters should reflect the reality of the changes in the full facility's energy consumption. In other words if the energy consumption of the full facility increases from one month to the next, the estimated energy consumption based on the essential meters should also reflect an increase.

To test this, Case Study A will be used. Previously, it was seen in Figure 3-14 that a 4% increase in energy consumption occurred from the current month to the following month. In

Figure 3-17 the total energy consumption of the facility is compared from the current month to the following month.

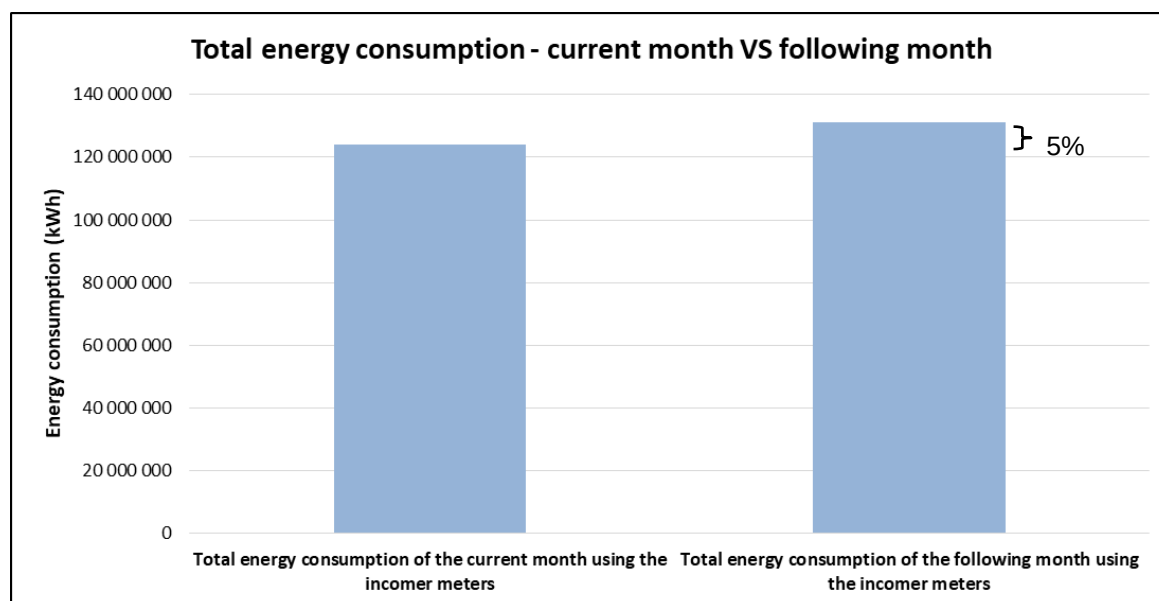


Figure 3-17: Case Study A – The full facility’s energy consumption comparison

On the full facility level it can be seen that a 5% increase in energy consumption from the current month to the following month is reflected. The fact that both the full facility’s energy consumption and the estimated energy consumption based on the important meters increased in energy consumption, indicates that the methodology does reflect the same tendencies in the full facility’s energy consumption.

To further verify and validate the study, it should be determined if the need for the study was addressed. As well as if the corresponding objectives were achieved.

As noted in Section 1.8 the need for the study was to: “Identify essential data to trace the impacts of energy initiatives over different boundaries efficiently”, with the objectives of this study, stemming from the need of the study, to:

- Frequently monitor energy consumption, using quality data;
- Trace energy impacts over various boundaries; and
- Identify essential data to monitor energy consumption.

By analysing the methodology and the symbol created for the literature of this study, it can be determined if the need and the associated objectives were addressed and satisfied.

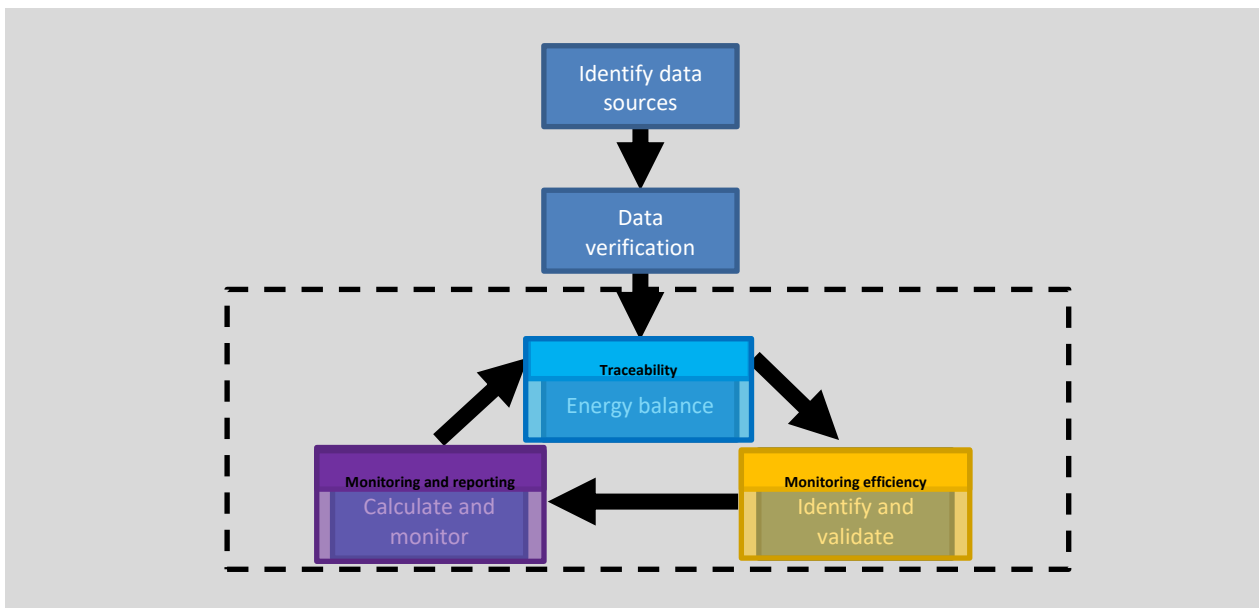
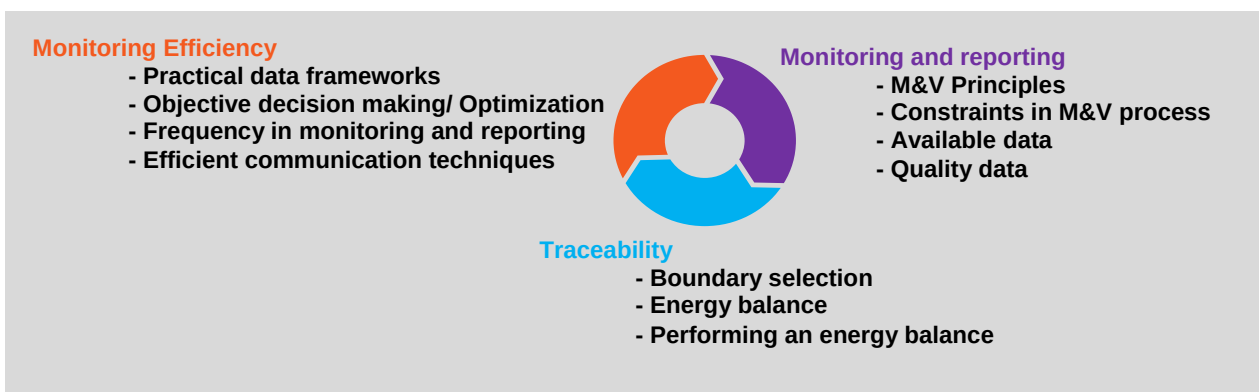


Figure 3-18: Methodology of the study



Objectives

First examine the methodology and the literature with the perspective of: “Does the methodology and the literature address and satisfy the objectives of the study?”

- Frequently monitoring of energy consumption, using quality data:

As can be seen, the methodology is grounded in the use of quality data. This is revealed by the fact that multiple data sources are obtained to compare the datasets with one another, as well as the fact that the data is examined to see if it is “clean” from outliers and data loss. Finally, an energy balance is performed to compare the various sections of energy consumption data in a facility and thus ensuring all the data is accounted for.

The energy consumption of the facility is also monitored on a daily basis. Thus the energy consumption is monitored “frequently”, using M&V principles such as using quality data.

Consequently, this objective was achieved not only through the fact that quality data is used, but also through the act of frequently monitoring energy consumption.

- Tracing energy impacts over various boundaries:

The energy balance and practical data storing framework assists in ensuring that the energy consumption can be traced throughout the entire facility. The energy balance promotes the understanding of the flow of the energy consumption throughout the entire facility. Thus an energy balance of the entire facility ensures that an energy initiative’s impact can be traced throughout the entire facility.

However, it is important to note that the energy initiative impacts which are not implemented on operations linked to the essential energy meters, will thus not be monitored. Hence, an energy initiative will only be monitored if the project is located on an essential/significant meter. Nonetheless, this will thus help management to strategically decide to implement energy initiative projects on energy meters with great energy consumption potential.

This objective was met through the use of the energy balance, ensuring that the flow of the energy consumption can be traced throughout the entire facility. If the energy initiatives do however occur on an essential meter, this objective will also be met with the fact that the initiative is monitored over various boundaries on a daily basis.

- Identifying essential data to monitor energy consumption:

The final objective is met by utilising the essential feeder meters which were identified. These essential meters were characterised as meters with great absolute impact and with high volatility. The high Volatility KPI values indicated that these energy meters consistently consumed the most energy throughout the month. These data meters are then used to measure the energy consumption of the estimated full-facility on a daily basis.

The essential energy meters, established on the current month’s data, was used to calculate the energy consumption using only these energy meters for the following month. On top of calculating the energy consumption of the mine using these energy meters, the difference between the incomer and feeder meters were added. Therefore, when comparing the current month’s essential meters energy consumption with the following, a 4% increase is noticed between the two years (see Figure 3-14). The energy consumption monitoring reveals the

general “state” of the energy consumption of the mine. Hence the objective of the study was satisfied.

Need for the study

Finally, by analysing the need for the study and determining if it was satisfied, it can be concluded whether or not the methodology was verified and validated.

- Identify essential data to trace the impacts of energy initiatives over different boundaries efficiently:

“Identify essential data” - As can be seen in both Figure 3-18 and the symbol used in this study, the essential energy meters were identified, using specific KPIs and then selecting the top essential energy meters. These essential energy meters are then utilised to calculate the estimated total energy consumption of the facility on a daily basis.

“(T)o trace ... over different boundaries efficiently” - Due to the use of energy balances the energy consumption flow was determined throughout the entire facility. Ensuring that the flow of energy efficiency initiatives is traceable throughout the entire mine and the associated boundaries.

“(T)he impacts of energy initiatives” - However, as only 21% of the energy meters are utilised in Case Study A, it still monitors 80% of the facility. Hence, if the energy meters, on which the energy initiatives occurred, consume energy of great significance, it will be monitored.

Even though the study objectives and need has been met and satisfied, a few separate benefits became apparent throughout the execution of the study.

3.9 Benefits and shortcomings of method

This study is helpful and beneficial based on the following reasons:

1. Initially the mine had to monitor all the energy meters to determine the state of the mine’s energy consumption. Now, the mine only needs to monitor the essential feeder meters, to obtain the broad state of the mine’s energy consumption.
2. Through the help of energy balances, a better understanding of the energy flow of the mine is acquired.
3. Energy balances also reveal the path of energy flow for energy initiatives, adding a layer of traceability for energy efficiency initiatives.

4. Effectively the energy meters with the greatest amount of energy consumption and the most consistent usage of this energy consumption, is highlighted through this study, and can be seen as an area/operation of opportunity to decrease the mine's energy consumption.

The study also has the following shortcomings:

1. This methodology is based on historical data and only predicts future energy usages. Hence, it is a drawback for not using real-time data. As with real-time data energy wastages can be identified and handled much faster.
2. By re-evaluating the important feeders once a month, major energy changes/events might be missed.
3. The fact that there are scenarios where not all of the energy consumption is measured by the feeder meters, adds to the shortcoming that energy usage changes can not be pinpointed to specific operations.

3.10 Summary

Throughout *Chapter 3* the methodology (as developed in *Chapter 2*) was tested on two case studies. These case studies exist in the mining sector and monitor several energy meters on a daily basis.

The data that was used and stored was made available by an energy management software to obtain the half-hourly energy consumption data. This data was analysed to see if it was “cleaned” (if data outliers and data loss have been removed) by a third-party. At the same time Eskom bills were gathered and used for data quality tests, by comparing the different datasets with one another. Energy balances are performed on the energy management software data to understand the energy flow of the facility and to serve as another data quality check. These energy balances assist in tracing energy streams across various boundaries of a facility. This was followed by determining how many feeder meters were required to monitor at least 80% of the energy consumption of a facility.

Next, the Absolute Impact KPI and the Volatility KPI values were multiplied and ranked from the largest to the smallest. Then counting the top meters, which will help to monitor at least 80% of the total energy consumption. These meters are then known as the essential energy meters.

Only the identified essential energy meters' consumption is used to monitor the entire facility's energy consumption. Account is made for the difference in the incomer and feeders' energy

consumption when monitoring the energy consumption of the facility. This estimated energy consumption of the mine is monitored and reported to management, on a daily basis. At the end of each month, the methodology to identify the essential meters should be performed, this is as the energy consumption of a facility is an ever changing process. Therefore, the essential energy meters should consistently be re-identified.

This technique is beneficial to efficiently monitor the estimated energy consumption of an entire facility, with only the essential feeder meters. The fact that these techniques and tools can be performed in any environment and using any type of dataset, also contributes towards saving energy. As the goal of this tool is to have the ability to identify the essential data within a data series.

CHAPTER 4 - CONCLUSION & RECOMMENDATIONS

4 Conclusion & recommendations

4.1 Summary

Throughout the course of the study, energy management was established as important for companies. This is due to increasing energy costs and the fact that South African companies are requested to lessen their energy usage, to decrease the pressure on the national electricity grid.

The three main energy management concepts which the study aimed to address, are monitoring and reporting, traceability, and lastly monitoring efficiency. The subsections allocated to each of the energy management concepts and which were focussed on during the study are as noted in the symbol below.

Monitoring Efficiency

- Practical data frameworks
- Objective decision making/ Optimization
- Frequency in monitoring and reporting
- Efficient communication techniques



Monitoring and reporting

- M&V Principles
- Constraints in M&V process
- Available data
- Quality data

Traceability

- Boundary selection
- Energy balance
- Performing an energy balance

Indicating that due to the attention on decreasing energy consumption of an organisation, it is important to use M&V principles to base calculations on. M&V functions as the method to determine the effect of energy efficiency projects on an organisation. There are, however, certain constraints that are experienced during the M&V process. These constraints include the fact that modern energy management software read energy measurements in small increments, causing large and overpowering datasets. This produces a time-intensive process to monitor the energy consumption of an organisation. This challenge is however addressed through the monitoring efficiency concept.

The starting point to monitor the energy consumption is to obtain the appropriate datasets. Where after these datasets are “cleaned” of data outliers and data loss. Ensuring that credible data is used for the monitoring of the energy consumption, as well as the M&V calculations. By storing the data using a specific naming convention and a date and time stamp, this forms a data framework. The data framework assists in efficiently tracing the energy impact of an

initiative throughout the facility. Another tool to trace energy efficiency impacts over various boundaries is energy balances, which also doubles as a data quality test.

The number of meters required to monitor the overall “state” of the energy consumption of the facility, is determined next. This is done by utilising the Pareto principle and thus determining what minimum number of meters which are necessary to monitor at least 80% of the facility’s energy consumption.

Afterwards each energy meter is allocated with two separate KPI values, such as an Absolute Impact KPI and a Volatility KPI. A combination of these two KPIs helps to rank the energy meters in the facility to determine each meter’s overall importance. Lastly using the number of important energy meters determined through the Pareto analysis, the most essential meters are counted and selected. These meters are then used to calculate the estimated energy consumption of the facility, which should be reported to management.

However, due to the ever-changing nature of the energy consumption of a facility, these ranked meters (based on a combination of both KPIs) should be re-determined each month. This is to ensure that the latest and relevant essential meters are used to monitor the energy consumption.

Nonetheless, the study should be evaluated against the need and the objective of the study, to determine if the study achieved what it set out to do. The objectives of the study:

1. Frequently monitoring of energy consumption, using high-quality data.

Through data quality tests, such as energy balances and data loss/error identification and – handling, as well as dataset comparisons, quality data was obtained. This quality data was used to monitor the energy consumption.

The estimated energy consumption of the mine was also calculated on a daily basis, using only the essential energy meters.

2. Tracing energy impacts over various boundaries.

By utilising energy balances the flow of energy consumption is understood throughout the entire system. Secondly, energy balances help trace the impact of energy initiatives over various boundaries. Using the Waterfall diagram and the sensitivity analysis, energy efficiency impacts are also noticed and monitored with the effect traced throughout the entire facility.

3. Identifying essential data to monitor energy consumption.

Through using the Pareto principle, the first step was to establish how many meters are required to monitor at least 80% of the energy consumption of a facility.

Afterwards a combination of the Absolute Impact KPI and the Volatility KPI was used to determine the essential data meters. To combine these KPIs, Scatter diagrams and the ranking of feeders according to these KPIs, were used.

Finally, based on the previous established Pareto principle's number of meters, the essential meters are counted down on the ranked-combined KPI feeders. These feeders are then known as the essential meters. Thus by identifying the essential feeder meters to monitor at least 80% of the energy consumption of a facility, indicates that this objective was met.

Regarding the fact that each objective was met separately, it in effect implies that the need was satisfied and addressed through this study.

Even though the need and the objectives of this study are met, separate benefits and implications also arose throughout the study, which are worth mentioning. One of the implications and benefits of this study is the ability to efficiently monitor the entire mine's energy consumption, by only using a minimum number of the data points. This helps with efficiently having the data available for management to make strategic decisions. Another benefit is the fact that this technique of identifying the important data within a series of data, can be replicated and used in any environment, and for any type of dataset.

4.2 Recommendations

There are a few recommendations to further develop this study and improve the techniques. The first recommendation is to consider linking the techniques developed in this study to real-time energy management software. By doing this energy consumption can be monitored and strategic decisions regarding the energy consumption can be made in real-time. Another advantage of linking the study to real-time energy management software, is that energy consumption changes can be identified in real-time, which will lead to a significant impact of decreasing unnecessary energy consumption (otherwise known as energy wastages).

The second recommendation is to consider adding an alert system to the technique of identifying important meters, whereby an alarm should be triggered once noteworthy changes occur within the different KPI lists.

Finally, this study focuses on emphasizing the essential energy meters. However, by using this information as the starting point, it can be determined which operations do not require energy on a regular basis and this energy consumption data should then be classified as energy wastage and eliminated accordingly. In other words, by identifying which operations are crucial and rather ensuring that the energy meters linked to these crucial operations use most of the energy, whilst the rest of the operations are switched off (or utilised less).

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APPENDIX A – CASE STUDY B

Appendix A - Case Study B

This appendix is mainly to perform the methodology of the study on Case Study B. Where the background of the case study is discussed. The data of the case study is analysed and verified. The amount of feeder meters needed to monitor at least 80% of the energy consumption of the facility is determined. Afterwards the KPI's are allocated to each feeder and used to identify the essential feeder meters of the organisation.

Case study background

Similar to Case Study A, Case Study B is a mining company. Case Study B comprises of five shafts, two plants and two C&M shafts. The energy metering structure of Case Study B is illustrated in Figure A-1.

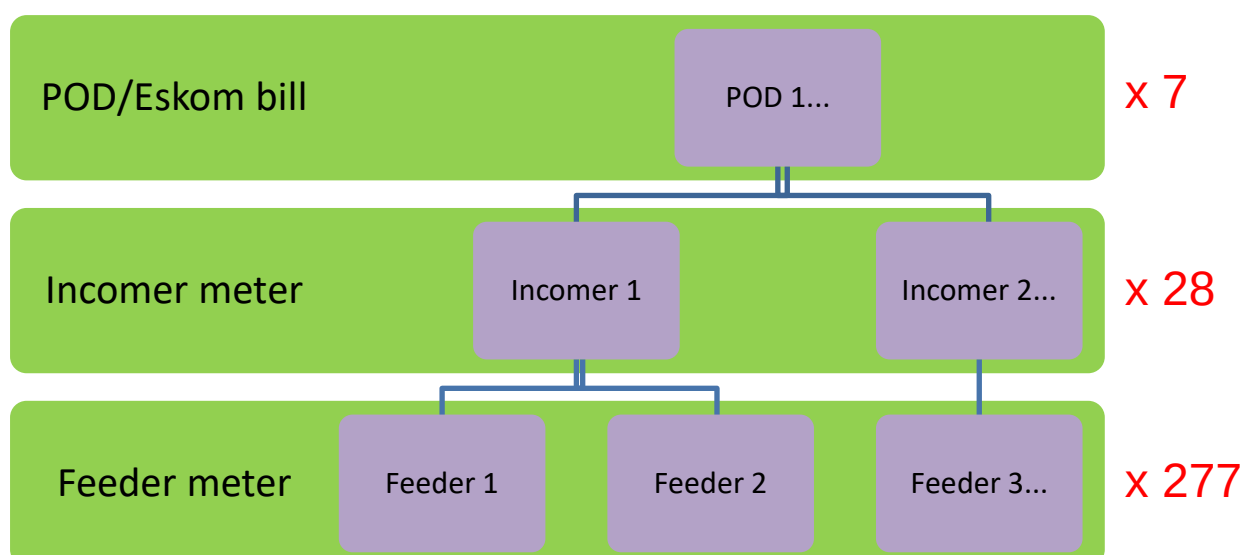


Figure A-1: Case Study B's metering structure

Figure A-1 notes that there are 7 different PODs (with each POD representing an Eskom bill). Each POD is built-up of a combination of incomer meters, which represents a section of the total energy stream. In Case Study B there are 28 incomers in total. Lastly, 277 feeder meters are available to monitor energy consumption. Groupings of these 277 feeder meters is equivalent to an incomer meter, with the feeder meters measuring a sub-section of the total energy flow.

Case Study data

Case Study B has the same energy management software provider used by Case Study A. Hence, similar to Case Study A, Case Study B's energy consumption data is available in half-hourly increments. The software provider also manages data loss and data outliers. However, it is still necessary to evaluate the datasets and ensure quality data is used.

To determine the percentage data loss, both the incomer and feeder meters are evaluated. To calculate this any half hour, during the month, which presented that no energy consumption reading is counted. This counted value is converted to a percentage of the total available half hours in each month. These percentage values are grouped under the relevant POD in Table A-1.

Table A-1: Case Study B - Percentage data loss of the month per POD

POD name	POD 1	POD 2	POD 3	POD 4	POD 5	POD 6	POD 7
% Data loss	0%	0%	0%	0%	0%	0%	0%

Table A-1 indicates no data loss, during this specific month, occurred for all the incomer and feeder meters. Next, examine the data for outliers. Figure A-2 is used to establish whether outliers are present in the data. This is done by visually displaying the energy consumption in half hourly format of the total mine.

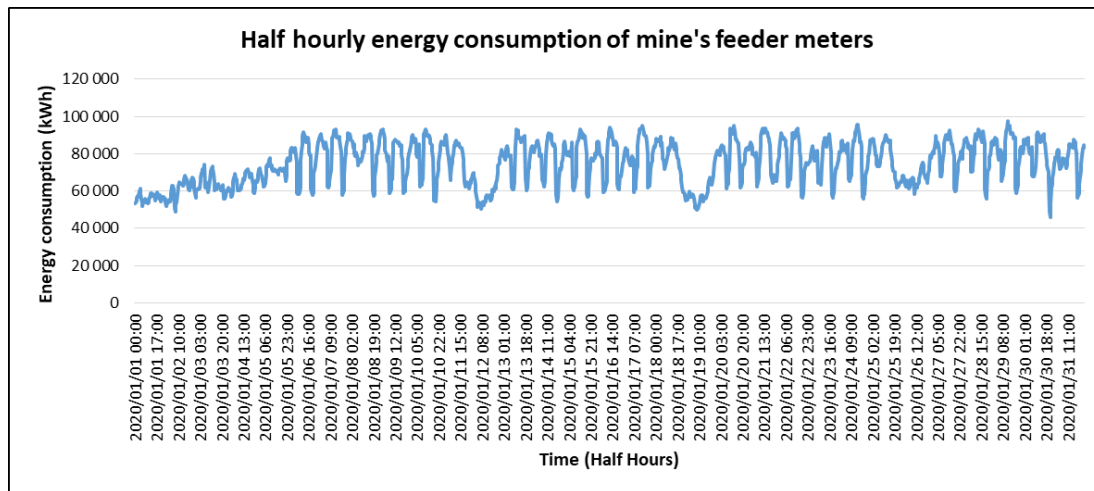


Figure A-2: Case Study B - Total energy consumption per half hour

Looking at Figure A-2 it can be seen that no data outliers are present. This is because no data readings exceeded or dropped lower than the usual energy consumption. Hence, it can be concluded that both the data loss and data outliers were “cleaned” by the energy management software provider.

The following step is to store the data using the practical data framework. First, the data measurements are stored with a date-and-time stamp and is accessible to retrieve on the energy management software. Secondly, it is determined that each energy meter is also stored with a detailed energy meter naming convention. Case Study B’s practical data framework is explained using Table A-2.

Table A-2: Case Study B - practical data framework

	A	B	C	D	E
	Abbreviation of mine name	Name of POD under which energy meter is allocated	Description of operation the meter measures	Type of meter	Meter description
Incomer	e.g. CSB_	POD 1_		INC NO 1_	Pimp
Feeder	e.g. CSB_	POD 1_	Compressor GHH_		P Net

In Table A-2: each column represents a different section of the naming convention, where:

- A = 'CSB' is an abbreviation for Case Study B.
- B = 'POD 1' represents the name of the POD.
- C = A description is not required for the incomer, however, it adds a layer of traceability to the feeder meters.
- D = "INC NO 1" is an abbreviation for Incomer number 1. The numbering is associated with each POD. Thus with each POD a new Incomer number 1 will occur.
- E = The 'Pimp', which is an abbreviation of Power import, refers to the measurement point of the energy meter. Noting that the energy meter measures the energy stream at the point where the energy flows into the meter or rather from the point of generation to the current feeder⁴⁶. With "P Net", it refers to net power. Indicating that if power were to be generated by the mine itself, that only the power coming from Eskom or the municipality will be billed and measured⁴⁷.

Table A-3 reveals the energy incomers and –feeders with the specific naming convention used by Case Study B. Take note that due to ensuring that the mine's identity is protected, the feeder meters were not described as mentioned in Table A-2's column C. The feeders were given a generic description such as Feeder 1, indicating that this is the first feeder in POD 1.

Table A-3: Case Study B - Practical data framework

Type of meter	Meter name
Incomer meters	CSB_POD 1_INC NO 1_Pimp
	CSB_POD 1_INC NO 2_Pimp
	CSB_POD 1_INC NO 3_Pimp
	CSB_POD 1_INC NO 4_Pimp
	CSB_POD 1_INC NO 5_Pimp
	CSB_POD 1_INC NO 6_Pimp
	CSB_POD 1_INC NO 7_Pimp
	CSB_POD 2_INC NO 1_Pimp

⁴⁷ Pacific Gas and Electric Company, "Understand Net Energy Metering and your bill," 2020. [Online]. Available: https://www.pge.com/en_US/residential/solar-and-vehicles/green-energy-incentives/solar-and-renewable-metering-and-billing/net-energy-metering-program-tracking/understand-net-energy-metering.page. [Accessed: 16-Oct-2020].

Type of meter	Meter name
	CSB_POD 2_INC NO 2_Pimp
	CSB_POD 2_INC NO 3_Pimp
	CSB_POD 2_INC NO 4_Pimp
	CSB_POD 3_INC NO 1_Pimp
	CSB_POD 3_INC NO 2_Pimp
	CSB_POD 3_INC NO 3_Pimp
	CSB_POD 3_INC NO 4_Pimp
	CSB_POD 3_INC NO 5_Pimp
	CSB_POD 4_INC NO 1_Pimp
	CSB_POD 4_INC NO 2_Pimp
	CSB_POD 4_INC NO 3_Pimp
	CSB_POD 4_INC NO 4_Pimp
	CSB_POD 4_INC NO 5_Pimp
	CSB_POD 5_INC NO 1_Pimp
	CSB_POD 5_INC NO 2_Pimp
	CSB_POD 5_INC NO 3_Pimp
	CSB_POD 6_INC NO 1_Pimp
	CSB_POD 6_INC NO 2_Pimp
	CSB_POD 7_INC NO 1_Pimp
	CSB_POD 7_INC NO 2_Pimp
Feeder meters	CSB_POD 1_Feeder 1_P Net
	CSB_POD 1_Feeder 2_P Net
	CSB_POD 1_Feeder 3_P Net
	CSB_POD 1_Feeder 4_P Net
	CSB_POD 1_Feeder 5_P Net
	CSB_POD 1_Feeder 6_P Net
	CSB_POD 1_Feeder 7_P Net
	CSB_POD 1_Feeder 8_P Net
	CSB_POD 1_Feeder 9_P Net
	CSB_POD 1_Feeder 10_P Net
	CSB_POD 1_Feeder 11_P Net

Type of meter	Meter name
	CSB_POD 1_Feeder 12_P Net
	CSB_POD 1_Feeder 13_P Net
	CSB_POD 1_Feeder 14_P Net
	CSB_POD 1_Feeder 15_P Net
	CSB_POD 1_Feeder 16_P Net
	CSB_POD 1_Feeder 17_P Net
	CSB_POD 1_Feeder 18_P Net
	CSB_POD 1_Feeder 19_P Net
	CSB_POD 1_Feeder 20_P Net
	CSB_POD 1_Feeder 21_P Net
	CSB_POD 1_Feeder 22_P Net
	CSB_POD 1_Feeder 23_P Net
	CSB_POD 1_Feeder 24_P Net
	CSB_POD 1_Feeder 25_P Net
	CSB_POD 1_Feeder 26_P Net
	CSB_POD 1_Feeder 27_P Net
	CSB_POD 1_Feeder 28_P Net
	CSB_POD 1_Feeder 29_P Net
	CSB_POD 1_Feeder 30_P Net
	CSB_POD 1_Feeder 31_P Net
	CSB_POD 1_Feeder 32_P Net
	CSB_POD 1_Feeder 33_P Net
	CSB_POD 1_Feeder 34_P Net
	CSB_POD 1_Feeder 35_P Net
	CSB_POD 1_Feeder 36_P Net
	CSB_POD 1_Feeder 37_P Net
	CSB_POD 1_Feeder 38_P Net
	CSB_POD 1_Feeder 39_P Net
	CSB_POD 1_Feeder 40_P Net
	CSB_POD 1_Feeder 41_P Net
	CSB_POD 1_Feeder 42_P Net

Type of meter	Meter name
	CSB_POD 1_Feeder 43_P Net
	CSB_POD 1_Feeder 44_P Net
	CSB_POD 1_Feeder 45_P Net
	CSB_POD 1_Feeder 46_P Net
	CSB_POD 1_Feeder 47_P Net
	CSB_POD 1_Feeder 48_P Net
	CSB_POD 1_Feeder 49_P Net
	CSB_POD 1_Feeder 50_P Net
	CSB_POD 1_Feeder 51_P Net
	CSB_POD 1_Feeder 52_P Net
	CSB_POD 1_Feeder 53_P Net
	CSB_POD 1_Feeder 54_P Net
	CSB_POD 1_Feeder 55_P Net
	CSB_POD 1_Feeder 56_P Net
	CSB_POD 1_Feeder 57_P Net
	CSB_POD 1_Feeder 58_P Net
	CSB_POD 1_Feeder 59_P Net
	CSB_POD 1_Feeder 60_P Net
	CSB_POD 1_Feeder 61_P Net
	CSB_POD 1_Feeder 62_P Net
	CSB_POD 1_Feeder 63_P Net
	CSB_POD 1_Feeder 64_P Net
	CSB_POD 1_Feeder 65_P Net
	CSB_POD 1_Feeder 66_P Net
	CSB_POD 1_Feeder 67_P Net
	CSB_POD 1_Feeder 68_P Net
	CSB_POD 1_Feeder 69_P Net
	CSB_POD 1_Feeder 70_P Net
	CSB_POD 1_Feeder 71_P Net
	CSB_POD 1_Feeder 72_P Net
	CSB_POD 1_Feeder 73_P Net

Type of meter	Meter name
	CSB_POD 1_Feeder 74_P Net
	CSB_POD 2_Feeder 1_P Net
	CSB_POD 2_Feeder 2_P Net
	CSB_POD 2_Feeder 3_P Net
	CSB_POD 2_Feeder 4_P Net
	CSB_POD 2_Feeder 5_P Net
	CSB_POD 2_Feeder 6_P Net
	CSB_POD 2_Feeder 7_P Net
	CSB_POD 2_Feeder 8_P Net
	CSB_POD 2_Feeder 9_P Net
	CSB_POD 2_Feeder 10_P Net
	CSB_POD 2_Feeder 11_P Net
	CSB_POD 2_Feeder 12_P Net
	CSB_POD 2_Feeder 13_P Net
	CSB_POD 2_Feeder 14_P Net
	CSB_POD 2_Feeder 15_P Net
	CSB_POD 2_Feeder 16_P Net
	CSB_POD 2_Feeder 17_P Net
	CSB_POD 2_Feeder 18_P Net
	CSB_POD 2_Feeder 19_P Net
	CSB_POD 2_Feeder 20_P Net
	CSB_POD 2_Feeder 21_P Net
	CSB_POD 2_Feeder 22_P Net
	CSB_POD 2_Feeder 23_P Net
	CSB_POD 2_Feeder 24_P Net
	CSB_POD 2_Feeder 25_P Net
	CSB_POD 2_Feeder 26_P Net
	CSB_POD 2_Feeder 27_P Net
	CSB_POD 2_Feeder 28_P Net
	CSB_POD 2_Feeder 29_P Net
	CSB_POD 2_Feeder 30_P Net

Type of meter	Meter name
	CSB_POD 2_Feeder 31_P Net
	CSB_POD 2_Feeder 32_P Net
	CSB_POD 2_Feeder 33_P Net
	CSB_POD 2_Feeder 34_P Net
	CSB_POD 2_Feeder 35_P Net
	CSB_POD 2_Feeder 36_P Net
	CSB_POD 2_Feeder 37_P Net
	CSB_POD 2_Feeder 38_P Net
	CSB_POD 2_Feeder 39_P Net
	CSB_POD 2_Feeder 40_P Net
	CSB_POD 2_Feeder 41_P Net
	CSB_POD 2_Feeder 42_P Net
	CSB_POD 2_Feeder 43_P Net
	CSB_POD 2_Feeder 44_P Net
	CSB_POD 3_Feeder 1_P Net
	CSB_POD 3_Feeder 2_P Net
	CSB_POD 3_Feeder 3_P Net
	CSB_POD 3_Feeder 4_P Net
	CSB_POD 3_Feeder 5_P Net
	CSB_POD 3_Feeder 6_P Net
	CSB_POD 3_Feeder 7_P Net
	CSB_POD 3_Feeder 8_P Net
	CSB_POD 3_Feeder 9_P Net
	CSB_POD 3_Feeder 10_P Net
	CSB_POD 3_Feeder 11_P Net
	CSB_POD 3_Feeder 12_P Net
	CSB_POD 3_Feeder 13_P Net
	CSB_POD 3_Feeder 14_P Net
	CSB_POD 3_Feeder 15_P Net
	CSB_POD 3_Feeder 16_P Net
	CSB_POD 3_Feeder 17_P Net

Type of meter	Meter name
	CSB_POD 3_Feeder 18_P Net
	CSB_POD 3_Feeder 19_P Net
	CSB_POD 3_Feeder 20_P Net
	CSB_POD 3_Feeder 21_P Net
	CSB_POD 3_Feeder 22_P Net
	CSB_POD 3_Feeder 23_P Net
	CSB_POD 3_Feeder 24_P Net
	CSB_POD 3_Feeder 25_P Net
	CSB_POD 3_Feeder 26_P Net
	CSB_POD 3_Feeder 27_P Net
	CSB_POD 3_Feeder 28_P Net
	CSB_POD 3_Feeder 29_P Net
	CSB_POD 3_Feeder 30_P Net
	CSB_POD 3_Feeder 31_P Net
	CSB_POD 3_Feeder 32_P Net
	CSB_POD 3_Feeder 33_P Net
	CSB_POD 3_Feeder 34_P Net
	CSB_POD 3_Feeder 35_P Net
	CSB_POD 3_Feeder 36_P Net
	CSB_POD 3_Feeder 37_P Net
	CSB_POD 3_Feeder 38_P Net
	CSB_POD 3_Feeder 39_P Net
	CSB_POD 3_Feeder 40_P Net
	CSB_POD 3_Feeder 41_P Net
	CSB_POD 3_Feeder 42_P Net
	CSB_POD 3_Feeder 43_P Net
	CSB_POD 3_Feeder 44_P Net
	CSB_POD 3_Feeder 45_P Net
	CSB_POD 3_Feeder 46_P Net
	CSB_POD 3_Feeder 47_P Net
	CSB_POD 3_Feeder 48_P Net

Type of meter	Meter name
	CSB_POD 3_Feeder 49_P Net
	CSB_POD 3_Feeder 50_P Net
	CSB_POD 3_Feeder 51_P Net
	CSB_POD 3_Feeder 52_P Net
	CSB_POD 3_Feeder 53_P Net
	CSB_POD 3_Feeder 54_P Net
	CSB_POD 3_Feeder 55_P Net
	CSB_POD 3_Feeder 56_P Net
	CSB_POD 4_Feeder 1_P Net
	CSB_POD 4_Feeder 2_P Net
	CSB_POD 4_Feeder 3_P Net
	CSB_POD 4_Feeder 4_P Net
	CSB_POD 4_Feeder 5_P Net
	CSB_POD 4_Feeder 6_P Net
	CSB_POD 4_Feeder 7_P Net
	CSB_POD 4_Feeder 8_P Net
	CSB_POD 4_Feeder 9_P Net
	CSB_POD 4_Feeder 10_P Net
	CSB_POD 4_Feeder 11_P Net
	CSB_POD 4_Feeder 12_P Net
	CSB_POD 4_Feeder 13_P Net
	CSB_POD 4_Feeder 14_P Net
	CSB_POD 4_Feeder 15_P Net
	CSB_POD 4_Feeder 16_P Net
	CSB_POD 4_Feeder 17_P Net
	CSB_POD 4_Feeder 18_P Net
	CSB_POD 4_Feeder 19_P Net
	CSB_POD 4_Feeder 20_P Net
	CSB_POD 4_Feeder 21_P Net
	CSB_POD 4_Feeder 22_P Net
	CSB_POD 4_Feeder 23_P Net

Type of meter	Meter name
	CSB_POD 4_Feeder 24_P Net
	CSB_POD 4_Feeder 25_P Net
	CSB_POD 4_Feeder 26_P Net
	CSB_POD 4_Feeder 27_P Net
	CSB_POD 4_Feeder 28_P Net
	CSB_POD 4_Feeder 29_P Net
	CSB_POD 4_Feeder 30_P Net
	CSB_POD 4_Feeder 31_P Net
	CSB_POD 4_Feeder 32_P Net
	CSB_POD 4_Feeder 33_P Net
	CSB_POD 4_Feeder 34_P Net
	CSB_POD 4_Feeder 35_P Net
	CSB_POD 4_Feeder 36_P Net
	CSB_POD 4_Feeder 37_P Net
	CSB_POD 4_Feeder 38_P Net
	CSB_POD 4_Feeder 39_P Net
	CSB_POD 4_Feeder 40_P Net
	CSB_POD 4_Feeder 41_P Net
	CSB_POD 4_Feeder 42_P Net
	CSB_POD 4_Feeder 43_P Net
	CSB_POD 4_Feeder 44_P Net
	CSB_POD 4_Feeder 45_P Net
	CSB_POD 4_Feeder 46_P Net
	CSB_POD 4_Feeder 47_P Net
	CSB_POD 4_Feeder 48_P Net
	CSB_POD 4_Feeder 49_P Net
	CSB_POD 4_Feeder 50_P Net
	CSB_POD 4_Feeder 51_P Net
	CSB_POD 4_Feeder 52_P Net
	CSB_POD 4_Feeder 53_P Net
	CSB_POD 4_Feeder 54_P Net

Type of meter	Meter name
	CSB_POD 5_Feeder 1_P Net
	CSB_POD 5_Feeder 2_P Net
	CSB_POD 5_Feeder 3_P Net
	CSB_POD 5_Feeder 4_P Net
	CSB_POD 5_Feeder 5_P Net
	CSB_POD 5_Feeder 6_P Net
	CSB_POD 5_Feeder 7_P Net
	CSB_POD 5_Feeder 8_P Net
	CSB_POD 5_Feeder 9_P Net
	CSB_POD 5_Feeder 10_P Net
	CSB_POD 5_Feeder 11_P Net
	CSB_POD 5_Feeder 12_P Net
	CSB_POD 5_Feeder 13_P Net
	CSB_POD 5_Feeder 14_P Net
	CSB_POD 5_Feeder 15_P Net
	CSB_POD 5_Feeder 16_P Net
	CSB_POD 5_Feeder 17_P Net
	CSB_POD 5_Feeder 18_P Net
	CSB_POD 5_Feeder 19_P Net
	CSB_POD 5_Feeder 20_P Net
	CSB_POD 5_Feeder 21_P Net
	CSB_POD 5_Feeder 22_P Net
	CSB_POD 5_Feeder 23_P Net
	CSB_POD 5_Feeder 24_P Net
	CSB_POD 6_Feeder 1_P Net
	CSB_POD 6_Feeder 2_P Net
	CSB_POD 6_Feeder 3_P Net
	CSB_POD 6_Feeder 4_P Net
	CSB_POD 6_Feeder 5_P Net
	CSB_POD 6_Feeder 6_P Net
	CSB_POD 6_Feeder 7_P Net

Type of meter	Meter name
	CSB_POD 7_Feeder 1_P Net
	CSB_POD 7_Feeder 2_P Net
	CSB_POD 7_Feeder 3_P Net
	CSB_POD 7_Feeder 4_P Net
	CSB_POD 7_Feeder 5_P Net
	CSB_POD 7_Feeder 6_P Net
	CSB_POD 7_Feeder 7_P Net
	CSB_POD 7_Feeder 8_P Net
	CSB_POD 7_Feeder 9_P Net
	CSB_POD 7_Feeder 10_P Net
	CSB_POD 7_Feeder 11_P Net
	CSB_POD 7_Feeder 12_P Net
	CSB_POD 7_Feeder 13_P Net
	CSB_POD 7_Feeder 14_P Net
	CSB_POD 7_Feeder 15_P Net
	CSB_POD 7_Feeder 16_P Net
	CSB_POD 7_Feeder 17_P Net
	CSB_POD 7_Feeder 18_P Net

As it has been determined that the data is stored and “clean”, the energy consumption data should be compared to the Eskom bills, acting as another quality check. Figure A-3 indicates the total mine’s monthly energy consumption of both the Eskom bills and the energy management software. The percentage difference is also indicated on the graph.

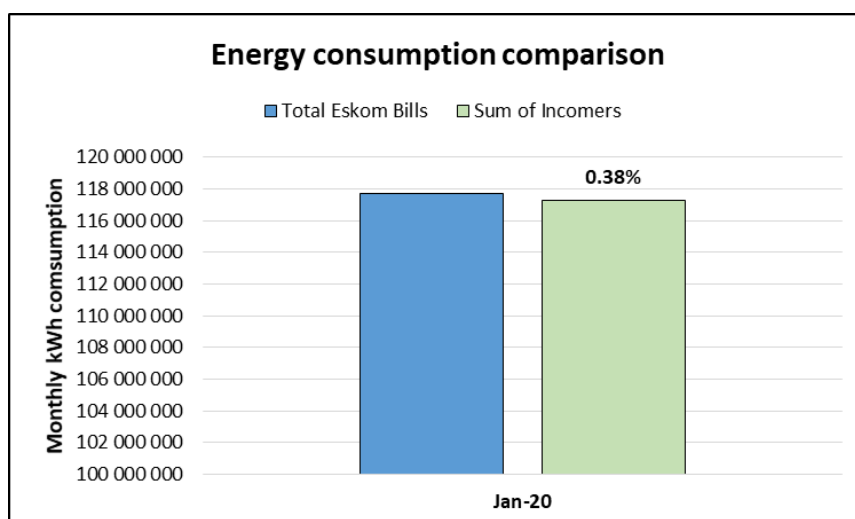


Figure A-3: Case Study B - Eskom bill VS energy management software comparison

Figure A-3 illustrates the total monthly energy consumption obtained from the management software, by adding all of the incomer meters together. As well as the total monthly energy consumption obtained from all the Eskom bills associated with the mine. The percentage difference between these data sets are 0.38%.

The mine and the energy management software provider made an agreement that the percentage difference between these two datasets may differ, at most, with 3%. The percentage difference of Figure A-3 is less than 3%, thus the quality of the data is satisfactory. Up to this point the first two steps of the methodology has been performed.

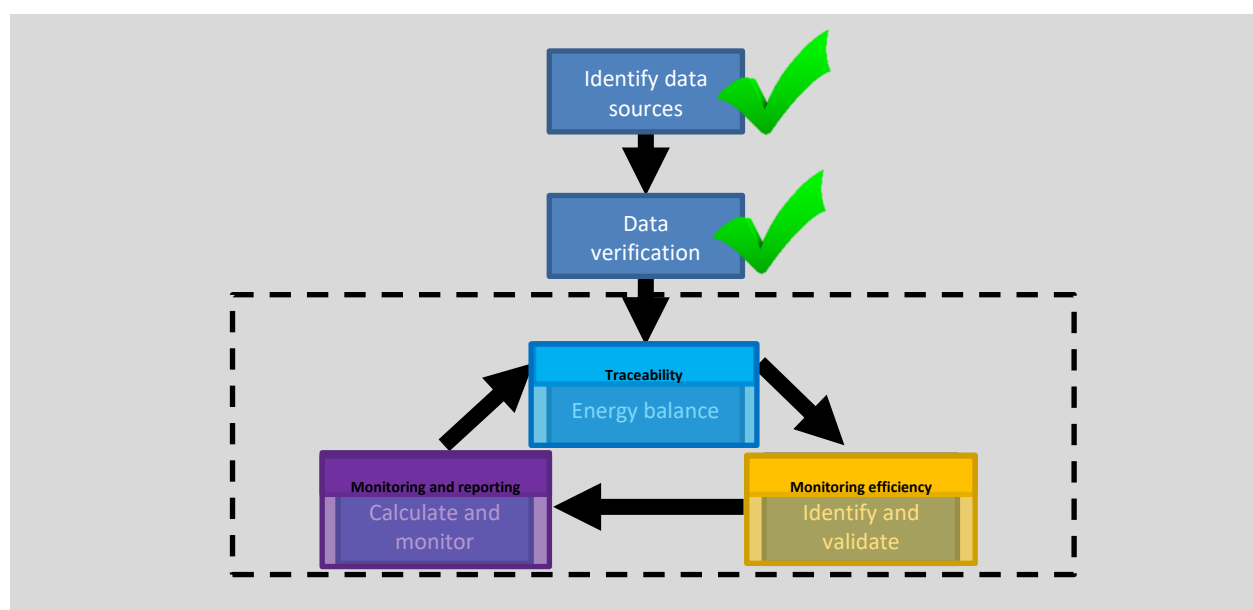


Figure A-4: Case Study B - Methodology of the study Step 1 & 2

Figure A-4 notes that the data has been identified and is clean. This data is also stored and has been compared to other datasets. The next step is to perform an energy balance.

Case Study B consists of 28 incomer meters and 277 feeder meters. A grouping of specific feeder meters' energy consumption theoretically should be equal to the energy consumption of the corresponding incomer meter. However, the Case Study B mine has chosen (similar to Case Study A) not to measure all of the energy flow on the feeder meter level. Therefore, the sum of the feeder meters will not match the sum of the incomer meters.

A Sankey diagram (Figure A-5) was used to visualise the energy consumption flow throughout the organisation. It was also used to indicate the associated energy consumption percentage towards the total energy consumption. Starting with the total mine's energy consumption, followed by the 7 PODs linked to the mine. Next, the 28 incomer meters are displayed and finally the 277 feeder meters are displayed.

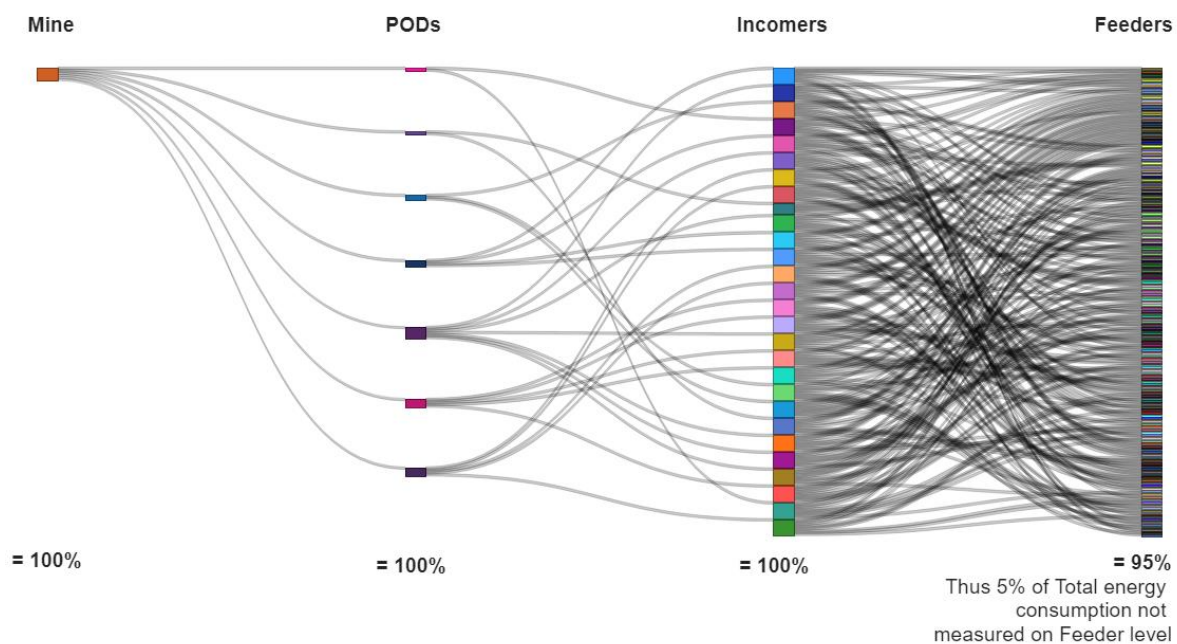


Figure A-5: Case Study B – energy balance using a Sankey diagram

Figure A-5 reveals that the percentage energy consumption being monitored is 100% of the total mine-, the PODs', and also the incomers' energy consumption. However, when examining the energy consumption of the feeder meters, only 95% of the total energy flow is monitored by these energy meters. Indicating that 5% of the total energy consumption is not measured by the feeder meters.

To perform an energy balance is to not only understand the overall energy flow throughout the facility, but also determine if all the data is accounted for, which serves as another data quality check. Figure A-6 updated the methodology to indicate that the energy balance has been performed on Case Study B.

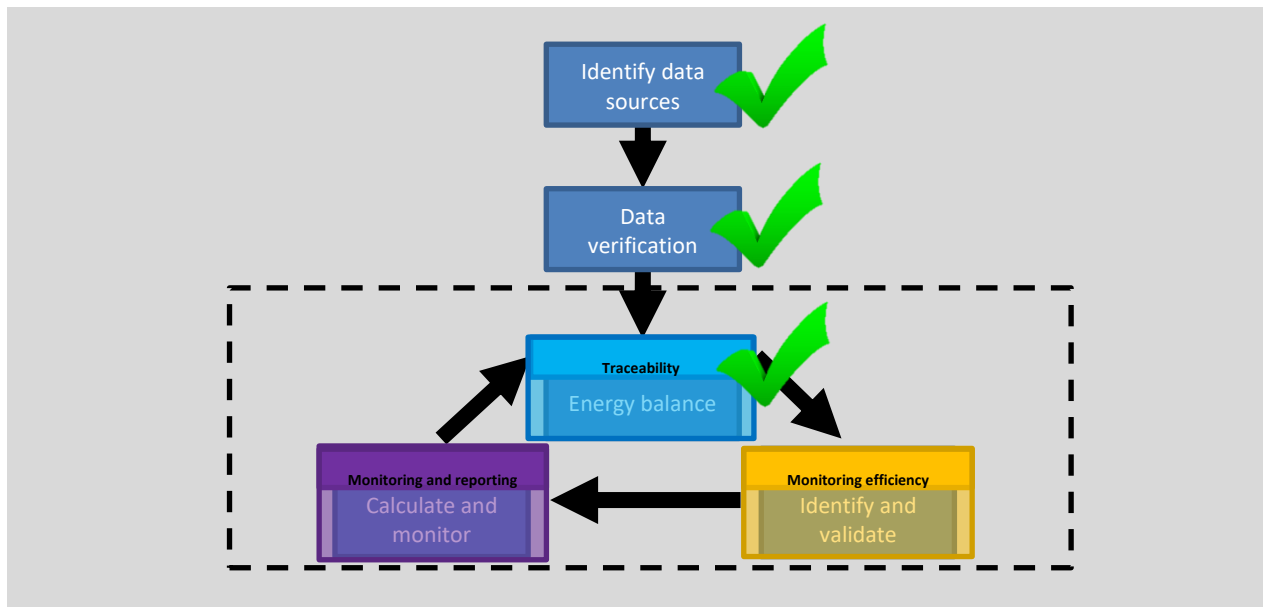


Figure A-6: Case Study B - Methodology of study Step 3

Figure A-6 indicates that quality data is now available for use and hence the data can be analysed further. Next, the data will be examined to see how many data meters are necessary to monitor at least 80% of the total energy consumption.

Number of important meters

Figure A-7 is a visual representation of the feeder meters, which are ranked by their total monthly energy consumption. This graph reveals how many energy meters are needed to monitor at least 80% of the energy consumption of the mine.

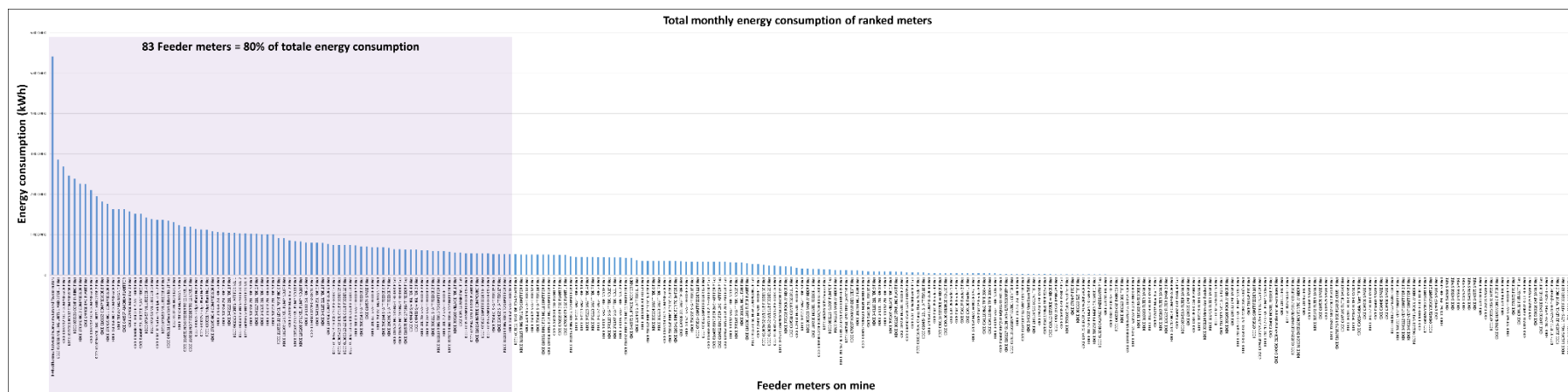


Figure A-7: Total monthly energy consumption per feeder

Figure A-7 reveals that Case Study B uses 83 feeder meters to monitor 80% of the energy consumption of the facility. Hence, to monitor at least 80% of the total energy consumption, 83 feeder meters should be identified.

Essential KPIs

Table A-4 reveals the associated Absolute Impact KPI values and the Volatility KPI values per feeder meter for a month. These values are based on the values obtained in Case Study B.

Table A-4: Case Study B - KPI values for a month

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 1_Feeder 1_P Net	7 362	0
CSB_POD 1_Feeder 2_P Net	514 263	19
CSB_POD 1_Feeder 3_P Net	22 216	0
CSB_POD 1_Feeder 4_P Net	516 151	21
CSB_POD 1_Feeder 5_P Net	509 963	17
CSB_POD 1_Feeder 6_P Net	464 412	8
CSB_POD 1_Feeder 7_P Net	32 535	0
CSB_POD 1_Feeder 8_P Net	593 737	27
CSB_POD 1_Feeder 9_P Net	571 806	26
CSB_POD 1_Feeder 10_P Net	0	0
CSB_POD 1_Feeder 11_P Net	0	0
CSB_POD 1_Feeder 12_P Net	27 426	0
CSB_POD 1_Feeder 13_P Net	16 956	0
CSB_POD 1_Feeder 14_P Net	34 194	0
CSB_POD 1_Feeder 15_P Net	3 520	0
CSB_POD 1_Feeder 16_P Net	0	0
CSB_POD 1_Feeder 17_P Net	1 949 700	31
CSB_POD 1_Feeder 18_P Net	2 856 341	31
CSB_POD 1_Feeder 19_P Net	274 935	0
CSB_POD 1_Feeder 20_P Net	539 282	21
CSB_POD 1_Feeder 21_P Net	16 788	0
CSB_POD 1_Feeder 22_P Net	16 615	0
CSB_POD 1_Feeder 23_P Net	10 727	0
CSB_POD 1_Feeder 24_P Net	353 311	1
CSB_POD 1_Feeder 25_P Net	351 995	0
CSB_POD 1_Feeder 26_P Net	355 046	1
CSB_POD 1_Feeder 27_P Net	1 240 329	31

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 1_Feeder 28_P Net	4	0
CSB_POD 1_Feeder 29_P Net	16 090	0
CSB_POD 1_Feeder 30_P Net	9 563	0
CSB_POD 1_Feeder 31_P Net	507 239	16
CSB_POD 1_Feeder 32_P Net	508 106	19
CSB_POD 1_Feeder 33_P Net	431 783	2
CSB_POD 1_Feeder 34_P Net	1 815 889	30
CSB_POD 1_Feeder 35_P Net	0	0
CSB_POD 1_Feeder 36_P Net	772 297	21
CSB_POD 1_Feeder 37_P Net	1 627 936	31
CSB_POD 1_Feeder 38_P Net	805 423	22
CSB_POD 1_Feeder 39_P Net	0	0
CSB_POD 1_Feeder 40_P Net	322 826	0
CSB_POD 1_Feeder 41_P Net	322 826	0
CSB_POD 1_Feeder 42_P Net	322 703	0
CSB_POD 1_Feeder 43_P Net	327 116	0
CSB_POD 1_Feeder 44_P Net	125 797	0
CSB_POD 1_Feeder 45_P Net	0	0
CSB_POD 1_Feeder 46_P Net	0	0
CSB_POD 1_Feeder 47_P Net	0	0
CSB_POD 1_Feeder 48_P Net	639 843	28
CSB_POD 1_Feeder 49_P Net	705 607	30
CSB_POD 1_Feeder 50_P Net	0	0
CSB_POD 1_Feeder 51_P Net	638 518	28
CSB_POD 1_Feeder 52_P Net	636 523	27
CSB_POD 1_Feeder 53_P Net	0	0
CSB_POD 1_Feeder 54_P Net	207 640	4
CSB_POD 1_Feeder 55_P Net	11 611	0
CSB_POD 1_Feeder 56_P Net	285 376	0
CSB_POD 1_Feeder 57_P Net	0	0
CSB_POD 1_Feeder 58_P Net	236 743	0
CSB_POD 1_Feeder 59_P Net	237 113	0
CSB_POD 1_Feeder 60_P Net	255 432	0

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 1_Feeder 61_P Net	739 416	28
CSB_POD 1_Feeder 62_P Net	742 371	28
CSB_POD 1_Feeder 63_P Net	742 143	28
CSB_POD 1_Feeder 64_P Net	744 112	28
CSB_POD 1_Feeder 65_P Net	11 542	0
CSB_POD 1_Feeder 66_P Net	1 622	0
CSB_POD 1_Feeder 67_P Net	1 306 268	27
CSB_POD 1_Feeder 68_P Net	0	0
CSB_POD 1_Feeder 69_P Net	32 342	0
CSB_POD 1_Feeder 70_P Net	0	0
CSB_POD 1_Feeder 71_P Net	2 470 957	31
CSB_POD 1_Feeder 72_P Net	2 684 949	31
CSB_POD 1_Feeder 73_P Net	2 111 286	31
CSB_POD 1_Feeder 74_P Net	354 226	9
CSB_POD 2_Feeder 1_P Net	0	0
CSB_POD 2_Feeder 2_P Net	19 914	0
CSB_POD 2_Feeder 3_P Net	0	0
CSB_POD 2_Feeder 4_P Net	4 321	0
CSB_POD 2_Feeder 5_P Net	0	0
CSB_POD 2_Feeder 6_P Net	0	0
CSB_POD 2_Feeder 7_P Net	0	0
CSB_POD 2_Feeder 8_P Net	1 076	0
CSB_POD 2_Feeder 9_P Net	551 912	17
CSB_POD 2_Feeder 10_P Net	0	0
CSB_POD 2_Feeder 11_P Net	3 175	0
CSB_POD 2_Feeder 12_P Net	61 101	0
CSB_POD 2_Feeder 13_P Net	23 230	0
CSB_POD 2_Feeder 14_P Net	44 948	0
CSB_POD 2_Feeder 15_P Net	44 080	0
CSB_POD 2_Feeder 16_P Net	1 126 148	30
CSB_POD 2_Feeder 17_P Net	1 144 691	30
CSB_POD 2_Feeder 18_P Net	1 131 508	30
CSB_POD 2_Feeder 19_P Net	0	0

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 2_Feeder 20_P Net	0	0
CSB_POD 2_Feeder 21_P Net	0	0
CSB_POD 2_Feeder 22_P Net	684 570	31
CSB_POD 2_Feeder 23_P Net	6 793	0
CSB_POD 2_Feeder 24_P Net	354 952	3
CSB_POD 2_Feeder 25_P Net	355 036	3
CSB_POD 2_Feeder 26_P Net	2 387 866	31
CSB_POD 2_Feeder 27_P Net	340 963	2
CSB_POD 2_Feeder 28_P Net	335 561	1
CSB_POD 2_Feeder 29_P Net	35 127	0
CSB_POD 2_Feeder 30_P Net	373 568	9
CSB_POD 2_Feeder 31_P Net	509 411	18
CSB_POD 2_Feeder 32_P Net	508 739	17
CSB_POD 2_Feeder 33_P Net	508 179	15
CSB_POD 2_Feeder 34_P Net	0	0
CSB_POD 2_Feeder 35_P Net	0	0
CSB_POD 2_Feeder 36_P Net	0	0
CSB_POD 2_Feeder 37_P Net	517 919	22
CSB_POD 2_Feeder 38_P Net	515 294	19
CSB_POD 2_Feeder 39_P Net	516 165	21
CSB_POD 2_Feeder 40_P Net	58 537	0
CSB_POD 2_Feeder 41_P Net	2 940	0
CSB_POD 2_Feeder 42_P Net	1 638 302	25
CSB_POD 2_Feeder 43_P Net	104 452	0
CSB_POD 2_Feeder 44_P Net	5 329	0
CSB_POD 3_Feeder 1_P Net	1 344 459	31
CSB_POD 3_Feeder 2_P Net	1 372 943	31
CSB_POD 3_Feeder 3_P Net	0	0
CSB_POD 3_Feeder 4_P Net	93 909	0
CSB_POD 3_Feeder 5_P Net	93 777	0
CSB_POD 3_Feeder 6_P Net	92 948	0
CSB_POD 3_Feeder 7_P Net	92 366	0
CSB_POD 3_Feeder 8_P Net	810 695	31

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 3_Feeder 9_P Net	801 313	31
CSB_POD 3_Feeder 10_P Net	795 850	31
CSB_POD 3_Feeder 11_P Net	3 319	0
CSB_POD 3_Feeder 12_P Net	32 396	1
CSB_POD 3_Feeder 13_P Net	0	0
CSB_POD 3_Feeder 14_P Net	0	0
CSB_POD 3_Feeder 15_P Net	0	0
CSB_POD 3_Feeder 16_P Net	128 813	0
CSB_POD 3_Feeder 17_P Net	1 043 947	31
CSB_POD 3_Feeder 18_P Net	1 020 424	31
CSB_POD 3_Feeder 19_P Net	1 006 198	31
CSB_POD 3_Feeder 20_P Net	8 131	0
CSB_POD 3_Feeder 21_P Net	28 239	0
CSB_POD 3_Feeder 22_P Net	1 055 408	31
CSB_POD 3_Feeder 23_P Net	1 016 804	31
CSB_POD 3_Feeder 24_P Net	1 022 518	31
CSB_POD 3_Feeder 25_P Net	0	0
CSB_POD 3_Feeder 26_P Net	1 062 756	31
CSB_POD 3_Feeder 27_P Net	149 147	0
CSB_POD 3_Feeder 28_P Net	121 268	0
CSB_POD 3_Feeder 29_P Net	67 478	0
CSB_POD 3_Feeder 30_P Net	1 014 325	31
CSB_POD 3_Feeder 31_P Net	20 805	0
CSB_POD 3_Feeder 32_P Net	0	0
CSB_POD 3_Feeder 33_P Net	1 523 662	31
CSB_POD 3_Feeder 34_P Net	1 521 822	31
CSB_POD 3_Feeder 35_P Net	0	0
CSB_POD 3_Feeder 36_P Net	0	0
CSB_POD 3_Feeder 37_P Net	0	0
CSB_POD 3_Feeder 38_P Net	5 913	0
CSB_POD 3_Feeder 39_P Net	51 022	2
CSB_POD 3_Feeder 40_P Net	142 857	0
CSB_POD 3_Feeder 41_P Net	0	0

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 3_Feeder 42_P Net	2 259 126	31
CSB_POD 3_Feeder 43_P Net	632 103	25
CSB_POD 3_Feeder 44_P Net	635 196	26
CSB_POD 3_Feeder 45_P Net	0	0
CSB_POD 3_Feeder 46_P Net	1 041 887	31
CSB_POD 3_Feeder 47_P Net	1 038 273	31
CSB_POD 3_Feeder 48_P Net	1 037 149	31
CSB_POD 3_Feeder 49_P Net	0	0
CSB_POD 3_Feeder 50_P Net	1 626 129	31
CSB_POD 3_Feeder 51_P Net	0	0
CSB_POD 3_Feeder 52_P Net	0	0
CSB_POD 3_Feeder 53_P Net	423 386	10
CSB_POD 3_Feeder 54_P Net	0	0
CSB_POD 3_Feeder 55_P Net	0	0
CSB_POD 3_Feeder 56_P Net	0	0
CSB_POD 4_Feeder 1_P Net	62 579	0
CSB_POD 4_Feeder 2_P Net	0	0
CSB_POD 4_Feeder 3_P Net	1 090 436	21
CSB_POD 4_Feeder 4_P Net	434 773	2
CSB_POD 4_Feeder 5_P Net	436 325	3
CSB_POD 4_Feeder 6_P Net	314 243	0
CSB_POD 4_Feeder 7_P Net	436 886	3
CSB_POD 4_Feeder 8_P Net	444 367	6
CSB_POD 4_Feeder 9_P Net	320 992	1
CSB_POD 4_Feeder 10_P Net	43 434	0
CSB_POD 4_Feeder 11_P Net	16 063	0
CSB_POD 4_Feeder 12_P Net	643	0
CSB_POD 4_Feeder 13_P Net	6 214	0
CSB_POD 4_Feeder 14_P Net	8 112	0
CSB_POD 4_Feeder 15_P Net	451 407	5
CSB_POD 4_Feeder 16_P Net	451 936	5
CSB_POD 4_Feeder 17_P Net	446 517	3
CSB_POD 4_Feeder 18_P Net	449 949	6

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 4_Feeder 19_P Net	0	0
CSB_POD 4_Feeder 20_P Net	450 776	6
CSB_POD 4_Feeder 21_P Net	167 608	4
CSB_POD 4_Feeder 22_P Net	498 132	18
CSB_POD 4_Feeder 23_P Net	497 396	18
CSB_POD 4_Feeder 24_P Net	496 109	18
CSB_POD 4_Feeder 25_P Net	82	0
CSB_POD 4_Feeder 26_P Net	0	0
CSB_POD 4_Feeder 27_P Net	114 807	0
CSB_POD 4_Feeder 28_P Net	220 471	0
CSB_POD 4_Feeder 29_P Net	2 264 042	31
CSB_POD 4_Feeder 30_P Net	11 647	0
CSB_POD 4_Feeder 31_P Net	0	0
CSB_POD 4_Feeder 32_P Net	853 790	16
CSB_POD 4_Feeder 33_P Net	539 341	21
CSB_POD 4_Feeder 34_P Net	18 884	0
CSB_POD 4_Feeder 35_P Net	0	0
CSB_POD 4_Feeder 36_P Net	183 459	0
CSB_POD 4_Feeder 37_P Net	266 711	0
CSB_POD 4_Feeder 38_P Net	47 691	0
CSB_POD 4_Feeder 39_P Net	1 757 158	24
CSB_POD 4_Feeder 40_P Net	1 579 274	28
CSB_POD 4_Feeder 41_P Net	1 421 057	31
CSB_POD 4_Feeder 42_P Net	1 386 049	31
CSB_POD 4_Feeder 43_P Net	1 368 253	31
CSB_POD 4_Feeder 44_P Net	0	0
CSB_POD 4_Feeder 45_P Net	329 633	2
CSB_POD 4_Feeder 46_P Net	330 717	2
CSB_POD 4_Feeder 47_P Net	536 130	22
CSB_POD 4_Feeder 48_P Net	0	0
CSB_POD 4_Feeder 49_P Net	536 497	23
CSB_POD 4_Feeder 50_P Net	0	0
CSB_POD 4_Feeder 51_P Net	541 521	24

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 4_Feeder 52_P Net	336 836	2
CSB_POD 4_Feeder 53_P Net	0	0
CSB_POD 4_Feeder 54_P Net	223 055	0
CSB_POD 5_Feeder 1_P Net	309 639	3
CSB_POD 5_Feeder 2_P Net	0	0
CSB_POD 5_Feeder 3_P Net	14 776	0
CSB_POD 5_Feeder 4_P Net	355 937	3
CSB_POD 5_Feeder 5_P Net	49 163	0
CSB_POD 5_Feeder 6_P Net	4 163	0
CSB_POD 5_Feeder 7_P Net	49 270	0
CSB_POD 5_Feeder 8_P Net	1 361	0
CSB_POD 5_Feeder 9_P Net	112 043	0
CSB_POD 5_Feeder 10_P Net	136 096	0
CSB_POD 5_Feeder 11_P Net	0	0
CSB_POD 5_Feeder 12_P Net	89 474	0
CSB_POD 5_Feeder 13_P Net	616 664	28
CSB_POD 5_Feeder 14_P Net	594 031	27
CSB_POD 5_Feeder 15_P Net	588 287	26
CSB_POD 5_Feeder 16_P Net	0	0
CSB_POD 5_Feeder 17_P Net	4 562	0
CSB_POD 5_Feeder 18_P Net	0	0
CSB_POD 5_Feeder 19_P Net	734 640	31
CSB_POD 5_Feeder 20_P Net	12 782	0
CSB_POD 5_Feeder 21_P Net	18 696	0
CSB_POD 5_Feeder 22_P Net	688 941	31
CSB_POD 5_Feeder 23_P Net	710 997	31
CSB_POD 5_Feeder 24_P Net	159 962	0
CSB_POD 6_Feeder 1_P Net	26 460	0
CSB_POD 6_Feeder 2_P Net	560 487	21
CSB_POD 6_Feeder 3_P Net	680 556	30
CSB_POD 6_Feeder 4_P Net	676 559	30
CSB_POD 6_Feeder 5_P Net	608 953	25
CSB_POD 6_Feeder 6_P Net	1 477	0

Feeder	Absolute Impact KPI	Volatility KPI
CSB_POD 6_Feeder 7_P Net	91 201	0
CSB_POD 7_Feeder 1_P Net	1 195 429	31
CSB_POD 7_Feeder 2_P Net	1 198 293	31
CSB_POD 7_Feeder 3_P Net	0	0
CSB_POD 7_Feeder 4_P Net	80 036	0
CSB_POD 7_Feeder 5_P Net	152 230	0
CSB_POD 7_Feeder 6_P Net	0	0
CSB_POD 7_Feeder 7_P Net	832 185	28
CSB_POD 7_Feeder 8_P Net	834 982	28
CSB_POD 7_Feeder 9_P Net	0	0
CSB_POD 7_Feeder 10_P Net	0	0
CSB_POD 7_Feeder 11_P Net	908 913	26
CSB_POD 7_Feeder 12_P Net	909 662	26
CSB_POD 7_Feeder 13_P Net	0	0
CSB_POD 7_Feeder 14_P Net	558	0
CSB_POD 7_Feeder 15_P Net	0	0
CSB_POD 7_Feeder 16_P Net	0	0
CSB_POD 7_Feeder 17_P Net	0	0
CSB_POD 7_Feeder 18_P Net	0	0

Table A-4 reveals the KPI values of the energy consumption feeder meters of Case Study B for a month. These however, need to be combined to determine the overall essential meters.

Identify the essential meters

Table A-5 expands on Table A-4. Table A-5 combines the Absolute Impact KPI and the Volatility KPI by multiplying them. After this the feeders are ranked from the largest to the smallest and finally the number of important meters (which was established in *Number of important meters*) are counted down. These are referred to as the essential energy meters.

Table A-5: Case Study B - Combine and rank meters

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 1_Feeder 1_P Net	7 362	0	0	201	
CSB_POD 1_Feeder 2_P Net	514 263	19	9 770 992	83	514 263
CSB_POD 1_Feeder 3_P Net	22 216	0	0	201	
CSB_POD 1_Feeder 4_P Net	516 151	21	10 839 168	81	516 151
CSB_POD 1_Feeder 5_P Net	509 963	17	8 669 374	90	
CSB_POD 1_Feeder 6_P Net	464 412	8	3 715 292	95	
CSB_POD 1_Feeder 7_P Net	32 535	0	0	201	
CSB_POD 1_Feeder 8_P Net	593 737	27	16 030 893	67	593 737
CSB_POD 1_Feeder 9_P Net	571 806	26	14 866 948	71	571 806
CSB_POD 1_Feeder 10_P Net	0	0	0	201	
CSB_POD 1_Feeder 11_P Net	0	0	0	201	
CSB_POD 1_Feeder 12_P Net	27 426	0	0	201	
CSB_POD 1_Feeder 13_P Net	16 956	0	0	201	
CSB_POD 1_Feeder 14_P Net	34 194	0	0	201	
CSB_POD 1_Feeder 15_P Net	3 520	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 1_Feeder 16_P Net	0	0	0	201	
CSB_POD 1_Feeder 17_P Net	1 949 700	31	60 440 703	8	1 949 700
CSB_POD 1_Feeder 18_P Net	2 856 341	31	88 546 563	1	2 856 341
CSB_POD 1_Feeder 19_P Net	274 935	0	0	201	
CSB_POD 1_Feeder 20_P Net	539 282	21	11 324 914	79	539 282
CSB_POD 1_Feeder 21_P Net	16 788	0	0	201	
CSB_POD 1_Feeder 22_P Net	16 615	0	0	201	
CSB_POD 1_Feeder 23_P Net	10 727	0	0	201	
CSB_POD 1_Feeder 24_P Net	353 311	1	353 311	119	
CSB_POD 1_Feeder 25_P Net	351 995	0	0	201	
CSB_POD 1_Feeder 26_P Net	355 046	1	355 046	118	
CSB_POD 1_Feeder 27_P Net	1 240 329	31	38 450 202	22	1 240 329
CSB_POD 1_Feeder 28_P Net	4	0	0	201	
CSB_POD 1_Feeder 29_P Net	16 090	0	0	201	
CSB_POD 1_Feeder 30_P Net	9 563	0	0	201	
CSB_POD 1_Feeder 31_P Net	507 239	16	8 115 819	92	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 1_Feeder 32_P Net	508 106	19	9 654 015	84	
CSB_POD 1_Feeder 33_P Net	431 783	2	863 566	111	
CSB_POD 1_Feeder 34_P Net	1 815 889	30	54 476 668	9	1 815 889
CSB_POD 1_Feeder 35_P Net	0	0	0	201	
CSB_POD 1_Feeder 36_P Net	772 297	21	16 218 244	65	772 297
CSB_POD 1_Feeder 37_P Net	1 627 936	31	50 466 007	10	1 627 936
CSB_POD 1_Feeder 38_P Net	805 423	22	17 719 311	61	805 423
CSB_POD 1_Feeder 39_P Net	0	0	0	201	
CSB_POD 1_Feeder 40_P Net	322 826	0	0	201	
CSB_POD 1_Feeder 41_P Net	322 826	0	0	201	
CSB_POD 1_Feeder 42_P Net	322 703	0	0	201	
CSB_POD 1_Feeder 43_P Net	327 116	0	0	201	
CSB_POD 1_Feeder 44_P Net	125 797	0	0	201	
CSB_POD 1_Feeder 45_P Net	0	0	0	201	
CSB_POD 1_Feeder 46_P Net	0	0	0	201	
CSB_POD 1_Feeder 47_P Net	0	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 1_Feeder 48_P Net	639 843	28	17 915 611	59	639 843
CSB_POD 1_Feeder 49_P Net	705 607	30	21 168 217	52	705 607
CSB_POD 1_Feeder 50_P Net	0	0	0	201	
CSB_POD 1_Feeder 51_P Net	638 518	28	17 878 498	60	638 518
CSB_POD 1_Feeder 52_P Net	636 523	27	17 186 121	63	636 523
CSB_POD 1_Feeder 53_P Net	0	0	0	201	
CSB_POD 1_Feeder 54_P Net	207 640	4	830 559	112	
CSB_POD 1_Feeder 55_P Net	11 611	0	0	201	
CSB_POD 1_Feeder 56_P Net	285 376	0	0	201	
CSB_POD 1_Feeder 57_P Net	0	0	0	201	
CSB_POD 1_Feeder 58_P Net	236 743	0	0	201	
CSB_POD 1_Feeder 59_P Net	237 113	0	0	201	
CSB_POD 1_Feeder 60_P Net	255 432	0	0	201	
CSB_POD 1_Feeder 61_P Net	739 416	28	20 703 644	56	739 416
CSB_POD 1_Feeder 62_P Net	742 371	28	20 786 379	54	742 371
CSB_POD 1_Feeder 63_P Net	742 143	28	20 779 996	55	742 143

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 1_Feeder 64_P Net	744 112	28	20 835 145	53	744 112
CSB_POD 1_Feeder 65_P Net	11 542	0	0	201	
CSB_POD 1_Feeder 66_P Net	1 622	0	0	201	
CSB_POD 1_Feeder 67_P Net	1 306 268	27	35 269 231	25	1 306 268
CSB_POD 1_Feeder 68_P Net	0	0	0	201	
CSB_POD 1_Feeder 69_P Net	32 342	0	0	201	
CSB_POD 1_Feeder 70_P Net	0	0	0	201	
CSB_POD 1_Feeder 71_P Net	2 470 957	31	76 599 662	3	2 470 957
CSB_POD 1_Feeder 72_P Net	2 684 949	31	83 233 432	2	2 684 949
CSB_POD 1_Feeder 73_P Net	2 111 286	31	65 449 880	7	2 111 286
CSB_POD 1_Feeder 74_P Net	354 226	9	3 188 030	97	
CSB_POD 2_Feeder 1_P Net	0	0	0	201	
CSB_POD 2_Feeder 2_P Net	19 914	0	0	201	
CSB_POD 2_Feeder 3_P Net	0	0	0	201	
CSB_POD 2_Feeder 4_P Net	4 321	0	0	201	
CSB_POD 2_Feeder 5_P Net	0	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 2_Feeder 6_P Net	0	0	0	201	
CSB_POD 2_Feeder 7_P Net	0	0	0	201	
CSB_POD 2_Feeder 8_P Net	1 076	0	0	201	
CSB_POD 2_Feeder 9_P Net	551 912	17	9 382 497	85	
CSB_POD 2_Feeder 10_P Net	0	0	0	201	
CSB_POD 2_Feeder 11_P Net	3 175	0	0	201	
CSB_POD 2_Feeder 12_P Net	61 101	0	0	201	
CSB_POD 2_Feeder 13_P Net	23 230	0	0	201	
CSB_POD 2_Feeder 14_P Net	44 948	0	0	201	
CSB_POD 2_Feeder 15_P Net	44 080	0	0	201	
CSB_POD 2_Feeder 16_P Net	1 126 148	30	33 784 431	28	1 126 148
CSB_POD 2_Feeder 17_P Net	1 144 691	30	34 340 733	26	1 144 691
CSB_POD 2_Feeder 18_P Net	1 131 508	30	33 945 251	27	1 131 508
CSB_POD 2_Feeder 19_P Net	0	0	0	201	
CSB_POD 2_Feeder 20_P Net	0	0	0	201	
CSB_POD 2_Feeder 21_P Net	0	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 2_Feeder 22_P Net	684 570	31	21 221 679	51	684 570
CSB_POD 2_Feeder 23_P Net	6 793	0	0	201	
CSB_POD 2_Feeder 24_P Net	354 952	3	1 064 857	108	
CSB_POD 2_Feeder 25_P Net	355 036	3	1 065 108	107	
CSB_POD 2_Feeder 26_P Net	2 387 866	31	74 023 854	4	2 387 866
CSB_POD 2_Feeder 27_P Net	340 963	2	681 927	113	
CSB_POD 2_Feeder 28_P Net	335 561	1	335 561	120	
CSB_POD 2_Feeder 29_P Net	35 127	0	0	201	
CSB_POD 2_Feeder 30_P Net	373 568	9	3 362 108	96	
CSB_POD 2_Feeder 31_P Net	509 411	18	9 169 391	86	
CSB_POD 2_Feeder 32_P Net	508 739	17	8 648 565	91	
CSB_POD 2_Feeder 33_P Net	508 179	15	7 622 690	93	
CSB_POD 2_Feeder 34_P Net	0	0	0	201	
CSB_POD 2_Feeder 35_P Net	0	0	0	201	
CSB_POD 2_Feeder 36_P Net	0	0	0	201	
CSB_POD 2_Feeder 37_P Net	517 919	22	11 394 226	77	517 919

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 2_Feeder 38_P Net	515 294	19	9 790 595	82	515 294
CSB_POD 2_Feeder 39_P Net	516 165	21	10 839 475	80	516 165
CSB_POD 2_Feeder 40_P Net	58 537	0	0	201	
CSB_POD 2_Feeder 41_P Net	2 940	0	0	201	
CSB_POD 2_Feeder 42_P Net	1 638 302	25	40 957 541	21	1 638 302
CSB_POD 2_Feeder 43_P Net	104 452	0	0	201	
CSB_POD 2_Feeder 44_P Net	5 329	0	0	201	
CSB_POD 3_Feeder 1_P Net	1 344 459	31	41 678 221	20	1 344 459
CSB_POD 3_Feeder 2_P Net	1 372 943	31	42 561 244	17	1 372 943
CSB_POD 3_Feeder 3_P Net	0	0	0	201	
CSB_POD 3_Feeder 4_P Net	93 909	0	0	201	
CSB_POD 3_Feeder 5_P Net	93 777	0	0	201	
CSB_POD 3_Feeder 6_P Net	92 948	0	0	201	
CSB_POD 3_Feeder 7_P Net	92 366	0	0	201	
CSB_POD 3_Feeder 8_P Net	810 695	31	25 131 558	40	810 695
CSB_POD 3_Feeder 9_P Net	801 313	31	24 840 694	41	801 313

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 3_Feeder 10_P Net	795 850	31	24 671 364	42	795 850
CSB_POD 3_Feeder 11_P Net	3 319	0	0	201	
CSB_POD 3_Feeder 12_P Net	32 396	1	32 396	123	
CSB_POD 3_Feeder 13_P Net	0	0	0	201	
CSB_POD 3_Feeder 14_P Net	0	0	0	201	
CSB_POD 3_Feeder 15_P Net	0	0	0	201	
CSB_POD 3_Feeder 16_P Net	128 813	0	0	201	
CSB_POD 3_Feeder 17_P Net	1 043 947	31	32 362 358	31	1 043 947
CSB_POD 3_Feeder 18_P Net	1 020 424	31	31 633 137	36	1 020 424
CSB_POD 3_Feeder 19_P Net	1 006 198	31	31 192 150	39	1 006 198
CSB_POD 3_Feeder 20_P Net	8 131	0	0	201	
CSB_POD 3_Feeder 21_P Net	28 239	0	0	201	
CSB_POD 3_Feeder 22_P Net	1 055 408	31	32 717 651	30	1 055 408
CSB_POD 3_Feeder 23_P Net	1 016 804	31	31 520 910	37	1 016 804
CSB_POD 3_Feeder 24_P Net	1 022 518	31	31 698 068	35	1 022 518
CSB_POD 3_Feeder 25_P Net	0	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 3_Feeder 26_P Net	1 062 756	31	32 945 450	29	1 062 756
CSB_POD 3_Feeder 27_P Net	149 147	0	0	201	
CSB_POD 3_Feeder 28_P Net	121 268	0	0	201	
CSB_POD 3_Feeder 29_P Net	67 478	0	0	201	
CSB_POD 3_Feeder 30_P Net	1 014 325	31	31 444 070	38	1 014 325
CSB_POD 3_Feeder 31_P Net	20 805	0	0	201	
CSB_POD 3_Feeder 32_P Net	0	0	0	201	
CSB_POD 3_Feeder 33_P Net	1 523 662	31	47 233 525	12	1 523 662
CSB_POD 3_Feeder 34_P Net	1 521 822	31	47 176 470	13	1 521 822
CSB_POD 3_Feeder 35_P Net	0	0	0	201	
CSB_POD 3_Feeder 36_P Net	0	0	0	201	
CSB_POD 3_Feeder 37_P Net	0	0	0	201	
CSB_POD 3_Feeder 38_P Net	5 913	0	0	201	
CSB_POD 3_Feeder 39_P Net	51 022	2	102 045	122	
CSB_POD 3_Feeder 40_P Net	142 857	0	0	201	
CSB_POD 3_Feeder 41_P Net	0	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 3_Feeder 42_P Net	2 259 126	31	70 032 904	6	2 259 126
CSB_POD 3_Feeder 43_P Net	632 103	25	15 802 585	68	632 103
CSB_POD 3_Feeder 44_P Net	635 196	26	16 515 094	64	635 196
CSB_POD 3_Feeder 45_P Net	0	0	0	201	
CSB_POD 3_Feeder 46_P Net	1 041 887	31	32 298 497	32	1 041 887
CSB_POD 3_Feeder 47_P Net	1 038 273	31	32 186 463	33	1 038 273
CSB_POD 3_Feeder 48_P Net	1 037 149	31	32 151 619	34	1 037 149
CSB_POD 3_Feeder 49_P Net	0	0	0	201	
CSB_POD 3_Feeder 50_P Net	1 626 129	31	50 409 999	11	1 626 129
CSB_POD 3_Feeder 51_P Net	0	0	0	201	
CSB_POD 3_Feeder 52_P Net	0	0	0	201	
CSB_POD 3_Feeder 53_P Net	423 386	10	4 233 860	94	
CSB_POD 3_Feeder 54_P Net	0	0	0	201	
CSB_POD 3_Feeder 55_P Net	0	0	0	201	
CSB_POD 3_Feeder 56_P Net	0	0	0	201	
CSB_POD 4_Feeder 1_P Net	62 579	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 4_Feeder 2_P Net	0	0	0	201	
CSB_POD 4_Feeder 3_P Net	1 090 436	21	22 899 158	47	1 090 436
CSB_POD 4_Feeder 4_P Net	434 773	2	869 547	110	
CSB_POD 4_Feeder 5_P Net	436 325	3	1 308 976	105	
CSB_POD 4_Feeder 6_P Net	314 243	0	0	201	
CSB_POD 4_Feeder 7_P Net	436 886	3	1 310 658	104	
CSB_POD 4_Feeder 8_P Net	444 367	6	2 666 203	100	
CSB_POD 4_Feeder 9_P Net	320 992	1	320 992	121	
CSB_POD 4_Feeder 10_P Net	43 434	0	0	201	
CSB_POD 4_Feeder 11_P Net	16 063	0	0	201	
CSB_POD 4_Feeder 12_P Net	643	0	0	201	
CSB_POD 4_Feeder 13_P Net	6 214	0	0	201	
CSB_POD 4_Feeder 14_P Net	8 112	0	0	201	
CSB_POD 4_Feeder 15_P Net	451 407	5	2 257 036	102	
CSB_POD 4_Feeder 16_P Net	451 936	5	2 259 678	101	
CSB_POD 4_Feeder 17_P Net	446 517	3	1 339 550	103	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 4_Feeder 18_P Net	449 949	6	2 699 694	99	
CSB_POD 4_Feeder 19_P Net	0	0	0	201	
CSB_POD 4_Feeder 20_P Net	450 776	6	2 704 657	98	
CSB_POD 4_Feeder 21_P Net	167 608	4	670 433	115	
CSB_POD 4_Feeder 22_P Net	498 132	18	8 966 377	87	
CSB_POD 4_Feeder 23_P Net	497 396	18	8 953 130	88	
CSB_POD 4_Feeder 24_P Net	496 109	18	8 929 962	89	
CSB_POD 4_Feeder 25_P Net	82	0	0	201	
CSB_POD 4_Feeder 26_P Net	0	0	0	201	
CSB_POD 4_Feeder 27_P Net	114 807	0	0	201	
CSB_POD 4_Feeder 28_P Net	220 471	0	0	201	
CSB_POD 4_Feeder 29_P Net	2 264 042	31	70 185 312	5	2 264 042
CSB_POD 4_Feeder 30_P Net	11 647	0	0	201	
CSB_POD 4_Feeder 31_P Net	0	0	0	201	
CSB_POD 4_Feeder 32_P Net	853 790	16	13 660 644	72	853 790
CSB_POD 4_Feeder 33_P Net	539 341	21	11 326 170	78	539 341

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 4_Feeder 34_P Net	18 884	0	0	201	
CSB_POD 4_Feeder 35_P Net	0	0	0	201	
CSB_POD 4_Feeder 36_P Net	183 459	0	0	201	
CSB_POD 4_Feeder 37_P Net	266 711	0	0	201	
CSB_POD 4_Feeder 38_P Net	47 691	0	0	201	
CSB_POD 4_Feeder 39_P Net	1 757 158	24	42 171 799	19	1 757 158
CSB_POD 4_Feeder 40_P Net	1 579 274	28	44 219 672	14	1 579 274
CSB_POD 4_Feeder 41_P Net	1 421 057	31	44 052 777	15	1 421 057
CSB_POD 4_Feeder 42_P Net	1 386 049	31	42 967 532	16	1 386 049
CSB_POD 4_Feeder 43_P Net	1 368 253	31	42 415 847	18	1 368 253
CSB_POD 4_Feeder 44_P Net	0	0	0	201	
CSB_POD 4_Feeder 45_P Net	329 633	2	659 267	117	
CSB_POD 4_Feeder 46_P Net	330 717	2	661 434	116	
CSB_POD 4_Feeder 47_P Net	536 130	22	11 794 866	75	536 130
CSB_POD 4_Feeder 48_P Net	0	0	0	201	
CSB_POD 4_Feeder 49_P Net	536 497	23	12 339 420	74	536 497

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 4_Feeder 50_P Net	0	0	0	201	
CSB_POD 4_Feeder 51_P Net	541 521	24	12 996 501	73	541 521
CSB_POD 4_Feeder 52_P Net	336 836	2	673 671	114	
CSB_POD 4_Feeder 53_P Net	0	0	0	201	
CSB_POD 4_Feeder 54_P Net	223 055	0	0	201	
CSB_POD 5_Feeder 1_P Net	309 639	3	928 918	109	
CSB_POD 5_Feeder 2_P Net	0	0	0	201	
CSB_POD 5_Feeder 3_P Net	14 776	0	0	201	
CSB_POD 5_Feeder 4_P Net	355 937	3	1 067 810	106	
CSB_POD 5_Feeder 5_P Net	49 163	0	0	201	
CSB_POD 5_Feeder 6_P Net	4 163	0	0	201	
CSB_POD 5_Feeder 7_P Net	49 270	0	0	201	
CSB_POD 5_Feeder 8_P Net	1 361	0	0	201	
CSB_POD 5_Feeder 9_P Net	112 043	0	0	201	
CSB_POD 5_Feeder 10_P Net	136 096	0	0	201	
CSB_POD 5_Feeder 11_P Net	0	0	0	201	

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 5_Feeder 12_P Net	89 474	0	0	201	
CSB_POD 5_Feeder 13_P Net	616 664	28	17 266 581	62	616 664
CSB_POD 5_Feeder 14_P Net	594 031	27	16 038 828	66	594 031
CSB_POD 5_Feeder 15_P Net	588 287	26	15 295 462	69	588 287
CSB_POD 5_Feeder 16_P Net	0	0	0	201	
CSB_POD 5_Feeder 17_P Net	4 562	0	0	201	
CSB_POD 5_Feeder 18_P Net	0	0	0	201	
CSB_POD 5_Feeder 19_P Net	734 640	31	22 773 830	48	734 640
CSB_POD 5_Feeder 20_P Net	12 782	0	0	201	
CSB_POD 5_Feeder 21_P Net	18 696	0	0	201	
CSB_POD 5_Feeder 22_P Net	688 941	31	21 357 175	50	688 941
CSB_POD 5_Feeder 23_P Net	710 997	31	22 040 908	49	710 997
CSB_POD 5_Feeder 24_P Net	159 962	0	0	201	
CSB_POD 6_Feeder 1_P Net	26 460	0	0	201	
CSB_POD 6_Feeder 2_P Net	560 487	21	11 770 237	76	560 487
CSB_POD 6_Feeder 3_P Net	680 556	30	20 416 676	57	680 556

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 6_Feeder 4_P Net	676 559	30	20 296 757	58	676 559
CSB_POD 6_Feeder 5_P Net	608 953	25	15 223 817	70	608 953
CSB_POD 6_Feeder 6_P Net	1 477	0	0	201	
CSB_POD 6_Feeder 7_P Net	91 201	0	0	201	
CSB_POD 7_Feeder 1_P Net	1 195 429	31	37 058 287	24	1 195 429
CSB_POD 7_Feeder 2_P Net	1 198 293	31	37 147 092	23	1 198 293
CSB_POD 7_Feeder 3_P Net	0	0	0	201	
CSB_POD 7_Feeder 4_P Net	80 036	0	0	201	
CSB_POD 7_Feeder 5_P Net	152 230	0	0	201	
CSB_POD 7_Feeder 6_P Net	0	0	0	201	
CSB_POD 7_Feeder 7_P Net	832 185	28	23 301 182	46	832 185
CSB_POD 7_Feeder 8_P Net	834 982	28	23 379 495	45	834 982
CSB_POD 7_Feeder 9_P Net	0	0	0	201	
CSB_POD 7_Feeder 10_P Net	0	0	0	201	
CSB_POD 7_Feeder 11_P Net	908 913	26	23 631 748	44	908 913
CSB_POD 7_Feeder 12_P Net	909 662	26	23 651 206	43	909 662

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
CSB_POD 7_Feeder 13_P Net	0	0	0	201	
CSB_POD 7_Feeder 14_P Net	558	0	0	201	
CSB_POD 7_Feeder 15_P Net	0	0	0	201	
CSB_POD 7_Feeder 16_P Net	0	0	0	201	
CSB_POD 7_Feeder 17_P Net	0	0	0	201	
CSB_POD 7_Feeder 18_P Net	0	0	0	201	
kWh Difference between Incomers and Feeders	5 417 250	-	-	-	5 417 250
Total estimated monthly energy consumption, using only the identified essential meters	-	-	-	-	93 940 977
Actual total monthly energy consumption	117 278 744	-	-	-	117 278 744
% of the total monthly energy consumption using only the essential meters (and the difference between the Incomers and the Feeders)	-	-	-	-	80%

Feeder	Absolute Impact KPI	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
% identified essential meters	-	-	-	-	30%

Table A-5 indicates that the essential energy meters were identified and these energy meters have the ability to monitor 80% of the total energy consumption. The number of essential meters used to monitor 80% of the total energy consumption is 83 feeder meters. These 83 feeder meters equates to 30% (83 essential meters / 277 available feeder meters x 100%) of the total available feeder meters. This was known as step 4 of the methodology. Thus Figure A-8 is updated to indicate that there is only one step left for Case Study B.

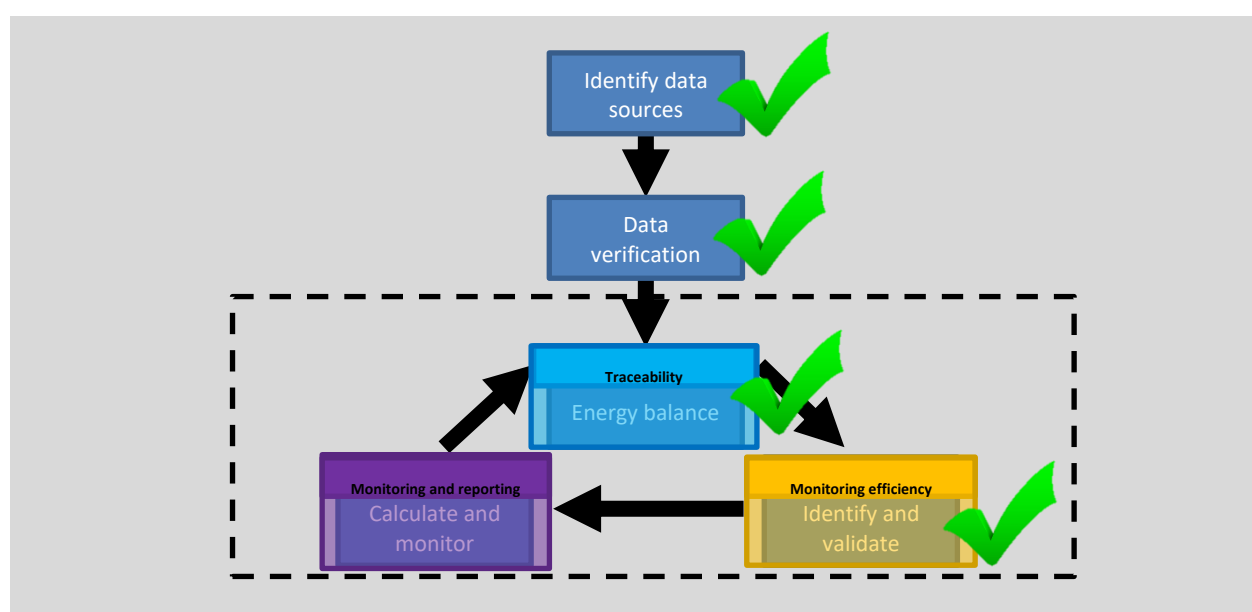


Figure A-8: Case Study B - Methodology of the study Step 4

Figure A-8 has updated the methodology to indicate that the essential meters have been identified for Case Study B. However, for the discussion of the final step of the methodology (performed on Case Study B) refer to *Chapter 3's Section 3.7*.

APPENDIX B – CASE STUDY A NAMING CONVENTION

Appendix B – Case study A naming convention

Table B-1 illustrates the naming convention of the energy meters located at Case Study A. The first section is the names of the incomer meters, followed by the names of the feeder meters. Take note that due to the confidentiality of the mine's information, that no specific details were exposed in the names of these meters.

Table B-1: Case Study A - Practical data framework

Type of meter	Meter name
Incomer meters	CSA_POD 1_INCOMER1_kWh Imp
	CSA_POD 1_INCOMER2_kWh Imp
	CSA_POD 1_INCOMER3_kWh Imp
	CSA_POD 1_INCOMER4_kWh Imp
	CSA_POD 2_INCOMER1_kWh Imp
	CSA_POD 2_INCOMER2_kWh Imp
	CSA_POD 2_INCOMER3_kWh Imp
	CSA_POD 3_INCOMER1_kWh Imp
	CSA_POD 3_INCOMER2_kWh Imp
	CSA_POD 3_INCOMER3_kWh Imp
	CSA_POD 4_INCOMER1_kWh Imp
	CSA_POD 4_INCOMER2_kWh Imp
	CSA_POD 5_INCOMER1_kWh Imp
	CSA_POD 5_INCOMER2_kWh Imp
	CSA_POD 6_INCOMER1_kWh Imp
	CSA_POD 6_INCOMER2_kWh Imp
	CSA_POD 7_INCOMER1_kWh Imp
	CSA_POD 7_INCOMER2_kWh Imp
	CSA_POD 7_INCOMER3_kWh Imp
	CSA_POD 8_INCOMER1_kWh Imp
	CSA_POD 8_INCOMER2_kWh Imp
	CSA_POD 8_INCOMER3_kWh Imp
	CSA_POD 9_INCOMER1_kWh Imp

Type of meter	Meter name
	CSA_POD 9_INCOMER2_kWh Imp
	CSA_POD 9_INCOMER3_kWh Imp
	CSA_POD 9_INCOMER4_kWh Imp
	CSA_POD 9_INCOMER5_kWh Imp
	CSA_POD 10_INCOMER1_kWh Imp
	CSA_POD 10_INCOMER2_kWh Imp
	CSA_POD 10_INCOMER3_kWh Imp
	CSA_POD 10_INCOMER4_kWh Imp
	CSA_POD 11_INCOMER1_kWh Imp
	CSA_POD 11_INCOMER2_kWh Imp
	CSA_POD 11_INCOMER3_kWh Imp
	CSA_POD 11_INCOMER4_kWh Imp
	CSA_POD 12_INCOMER1_kWh Imp
	CSA_POD 12_INCOMER2_kWh Imp
Feeder meters	CSA_POD 1_Feeder 1.1_FDR_kWh Imp
	CSA_POD 1_Feeder 1.2_FDR_kWh Imp
	CSA_POD 1_Feeder 1.3_FDR_kWh Imp
	CSA_POD 1_Feeder 1.4_FDR_kWh Imp
	CSA_POD 1_Feeder 1.5_FDR_kWh Imp
	CSA_POD 1_Feeder 1.6_FDR_kWh Imp
	CSA_POD 1_Feeder 1.7_FDR_kWh Imp
	CSA_POD 1_Feeder 1.8_FDR_kWh Imp
	CSA_POD 1_Feeder 1.9_FDR_kWh Imp
	CSA_POD 1_Feeder 1.10_FDR_kWh Imp
	CSA_POD 1_Feeder 1.11_FDR_kWh Imp
	CSA_POD 1_Feeder 1.12_FDR_kWh Imp
	CSA_POD 1_Feeder 1.13_FDR_kWh Imp
	CSA_POD 1_Feeder 1.14_FDR_kWh Imp
	CSA_POD 1_Feeder 1.15_FDR_kWh Imp
	CSA_POD 1_Feeder 1.16_FDR_kWh Imp
	CSA_POD 1_Feeder 1.17_FDR_kWh Imp

Type of meter	Meter name
	CSA_POD 1_Feeder 1.18_FDR_kWh Imp
	CSA_POD 1_Feeder 1.19_FDR_kWh Imp
	CSA_POD 2_Feeder 2.1_FDR_kWh Imp
	CSA_POD 2_Feeder 2.2_FDR_kWh Imp
	CSA_POD 2_Feeder 2.3_FDR_kWh Imp
	CSA_POD 2_Feeder 2.4_FDR_kWh Imp
	CSA_POD 2_Feeder 2.5_FDR_kWh Imp
	CSA_POD 2_Feeder 2.6_FDR_kWh Imp
	CSA_POD 2_Feeder 2.7_FDR_kWh Imp
	CSA_POD 2_Feeder 2.8_FDR_kWh Imp
	CSA_POD 3_Feeder 3.1_FDR_kWh Imp
	CSA_POD 3_Feeder 3.2_FDR_kWh Imp
	CSA_POD 3_Feeder 3.3_FDR_kWh Imp
	CSA_POD 3_Feeder 3.4_FDR_kWh Imp
	CSA_POD 3_Feeder 3.5_FDR_kWh Imp
	CSA_POD 3_Feeder 3.6_FDR_kWh Imp
	CSA_POD 3_Feeder 3.7_FDR_kWh Imp
	CSA_POD 3_Feeder 3.8_FDR_kWh Imp
	CSA_POD 3_Feeder 3.9_FDR_kWh Imp
	CSA_POD 3_Feeder 3.10_FDR_kWh Imp
	CSA_POD 3_Feeder 3.11_FDR_kWh Imp
	CSA_POD 3_Feeder 3.12_FDR_kWh Imp
	CSA_POD 3_Feeder 3.13_FDR_kWh Imp
	CSA_POD 3_Feeder 3.14_FDR_kWh Imp
	CSA_POD 4_Feeder 4.1_FDR_kWh Imp
	CSA_POD 4_Feeder 4.2_FDR_kWh Imp
	CSA_POD 5_Feeder 5.1_FDR_kWh Imp
	CSA_POD 5_Feeder 5.2_FDR_kWh Imp
	CSA_POD 5_Feeder 5.3_FDR_kWh Imp
	CSA_POD 5_Feeder 5.4_FDR_kWh Imp
	CSA_POD 5_Feeder 5.5_FDR_kWh Imp

Type of meter	Meter name
	CSA_POD 5_Feeder 5.6_FDR_kWh Imp
	CSA_POD 5_Feeder 5.7_FDR_kWh Imp
	CSA_POD 5_Feeder 5.8_FDR_kWh Imp
	CSA_POD 5_Feeder 5.9_FDR_kWh Imp
	CSA_POD 5_Feeder 5.10_FDR_kWh Imp
	CSA_POD 5_Feeder 5.11_FDR_kWh Imp
	CSA_POD 5_Feeder 5.12_FDR_kWh Imp
	CSA_POD 6_Feeder 6.1_FDR_kWh Imp
	CSA_POD 6_Feeder 6.2_FDR_kWh Imp
	CSA_POD 6_Feeder 6.3_FDR_kWh Imp
	CSA_POD 6_Feeder 6.4_FDR_kWh Imp
	CSA_POD 6_Feeder 6.5_FDR_kWh Imp
	CSA_POD 6_Feeder 6.6_FDR_kWh Imp
	CSA_POD 6_Feeder 6.7_FDR_kWh Imp
	CSA_POD 6_Feeder 6.8_FDR_kWh Imp
	CSA_POD 6_Feeder 6.9_FDR_kWh Imp
	CSA_POD 6_Feeder 6.10_FDR_kWh Imp
	CSA_POD 6_Feeder 6.11_FDR_kWh Imp
	CSA_POD 7_Feeder 7.1_FDR_kWh Imp
	CSA_POD 7_Feeder 7.2_FDR_kWh Imp
	CSA_POD 7_Feeder 7.3_FDR_kWh Imp
	CSA_POD 7_Feeder 7.4_FDR_kWh Imp
	CSA_POD 7_Feeder 7.5_FDR_kWh Imp
	CSA_POD 7_Feeder 7.6_FDR_kWh Imp
	CSA_POD 7_Feeder 7.7_FDR_kWh Imp
	CSA_POD 7_Feeder 7.8_FDR_kWh Imp
	CSA_POD 7_Feeder 7.9_FDR_kWh Imp
	CSA_POD 7_Feeder 7.10_FDR_kWh Imp
	CSA_POD 7_Feeder 7.11_FDR_kWh Imp
	CSA_POD 7_Feeder 7.12_FDR_kWh Imp
	CSA_POD 7_Feeder 7.13_FDR_kWh Imp

Type of meter	Meter name
	CSA_POD 7_Feeder 7.14_FDR_kWh Imp
	CSA_POD 7_Feeder 7.15_FDR_kWh Imp
	CSA_POD 7_Feeder 7.16_FDR_kWh Imp
	CSA_POD 8_Feeder 8.1_FDR_kWh Imp
	CSA_POD 8_Feeder 8.2_FDR_kWh Imp
	CSA_POD 8_Feeder 8.3_FDR_kWh Imp
	CSA_POD 8_Feeder 8.4_FDR_kWh Imp
	CSA_POD 8_Feeder 8.5_FDR_kWh Imp
	CSA_POD 8_Feeder 8.6_FDR_kWh Imp
	CSA_POD 8_Feeder 8.7_FDR_kWh Imp
	CSA_POD 8_Feeder 8.8_FDR_kWh Imp
	CSA_POD 8_Feeder 8.9_FDR_kWh Imp
	CSA_POD 8_Feeder 8.10_FDR_kWh Imp
	CSA_POD 8_Feeder 8.11_FDR_kWh Imp
	CSA_POD 8_Feeder 8.12_FDR_kWh Imp
	CSA_POD 8_Feeder 8.13_FDR_kWh Imp
	CSA_POD 8_Feeder 8.14_FDR_kWh Imp
	CSA_POD 8_Feeder 8.15_FDR_kWh Imp
	CSA_POD 8_Feeder 8.16_FDR_kWh Imp
	CSA_POD 8_Feeder 8.17_FDR_kWh Imp
	CSA_POD 8_Feeder 8.18_FDR_kWh Imp
	CSA_POD 8_Feeder 8.19_FDR_kWh Imp
	CSA_POD 8_Feeder 8.20_FDR_kWh Imp
	CSA_POD 8_Feeder 8.21_FDR_kWh Imp
	CSA_POD 8_Feeder 8.22_FDR_kWh Imp
	CSA_POD 8_Feeder 8.23_FDR_kWh Imp
	CSA_POD 8_Feeder 8.24_FDR_kWh Imp
	CSA_POD 8_Feeder 8.25_FDR_kWh Imp
	CSA_POD 8_Feeder 8.26_FDR_kWh Imp
	CSA_POD 8_Feeder 8.27_FDR_kWh Imp
	CSA_POD 8_Feeder 8.28_FDR_kWh Imp

Type of meter	Meter name
	CSA_POD 8_Feeder 8.29_FDR_kWh Imp
	CSA_POD 9_Feeder 9.1_FDR_kWh Imp
	CSA_POD 9_Feeder 9.2_FDR_kWh Imp
	CSA_POD 9_Feeder 9.3_FDR_kWh Imp
	CSA_POD 9_Feeder 9.4_FDR_kWh Imp
	CSA_POD 9_Feeder 9.5_FDR_kWh Imp
	CSA_POD 9_Feeder 9.6_FDR_kWh Imp
	CSA_POD 9_Feeder 9.7_FDR_kWh Imp
	CSA_POD 9_Feeder 9.8_FDR_kWh Imp
	CSA_POD 9_Feeder 9.9_FDR_kWh Imp
	CSA_POD 9_Feeder 9.10_FDR_kWh Imp
	CSA_POD 9_Feeder 9.11_FDR_kWh Imp
	CSA_POD 9_Feeder 9.12_FDR_kWh Imp
	CSA_POD 9_Feeder 9.13_FDR_kWh Imp
	CSA_POD 9_Feeder 9.14_FDR_kWh Imp
	CSA_POD 9_Feeder 9.15_FDR_kWh Imp
	CSA_POD 9_Feeder 9.16_FDR_kWh Imp
	CSA_POD 9_Feeder 9.17_FDR_kWh Imp
	CSA_POD 9_Feeder 9.18_FDR_kWh Imp
	CSA_POD 9_Feeder 9.19_FDR_kWh Imp
	CSA_POD 9_Feeder 9.20_FDR_kWh Imp
	CSA_POD 9_Feeder 9.21_FDR_kWh Imp
	CSA_POD 9_Feeder 9.22_FDR_kWh Imp
	CSA_POD 9_Feeder 9.23_FDR_kWh Imp
	CSA_POD 9_Feeder 9.24_FDR_kWh Imp
	CSA_POD 9_Feeder 9.25_FDR_kWh Imp
	CSA_POD 10_Feeder 10.1_FDR_kWh Imp
	CSA_POD 10_Feeder 10.2_FDR_kWh Imp
	CSA_POD 10_Feeder 10.3_FDR_kWh Imp
	CSA_POD 10_Feeder 10.4_FDR_kWh Imp
	CSA_POD 10_Feeder 10.5_FDR_kWh Imp

Type of meter	Meter name
	CSA_POD 10_Feeder 10.6_FDR_kWh Imp
	CSA_POD 10_Feeder 10.7_FDR_kWh Imp
	CSA_POD 10_Feeder 10.8_FDR_kWh Imp
	CSA_POD 10_Feeder 10.9_FDR_kWh Imp
	CSA_POD 10_Feeder 10.10_FDR_kWh Imp
	CSA_POD 10_Feeder 10.11_FDR_kWh Imp
	CSA_POD 10_Feeder 10.12_FDR_kWh Imp
	CSA_POD 10_Feeder 10.13_FDR_kWh Imp
	CSA_POD 10_Feeder 10.14_FDR_kWh Imp
	CSA_POD 10_Feeder 10.15_FDR_kWh Imp
	CSA_POD 10_Feeder 10.16_FDR_kWh Imp
	CSA_POD 10_Feeder 10.17_FDR_kWh Imp
	CSA_POD 10_Feeder 10.18_FDR_kWh Imp
	CSA_POD 10_Feeder 10.19_FDR_kWh Imp
	CSA_POD 11_Feeder 11.1_FDR_kWh Imp
	CSA_POD 11_Feeder 11.2_FDR_kWh Imp
	CSA_POD 11_Feeder 11.3_FDR_kWh Imp
	CSA_POD 11_Feeder 11.4_FDR_kWh Imp
	CSA_POD 11_Feeder 11.5_FDR_kWh Imp
	CSA_POD 11_Feeder 11.6_FDR_kWh Imp
	CSA_POD 11_Feeder 11.7_FDR_kWh Imp
	CSA_POD 11_Feeder 11.8_FDR_kWh Imp
	CSA_POD 11_Feeder 11.9_FDR_kWh Imp
	CSA_POD 11_Feeder 11.10_FDR_kWh Imp
	CSA_POD 11_Feeder 11.11_FDR_kWh Imp
	CSA_POD 11_Feeder 11.12_FDR_kWh Imp
	CSA_POD 11_Feeder 11.13_FDR_kWh Imp
	CSA_POD 11_Feeder 11.14_FDR_kWh Imp
	CSA_POD 11_Feeder 11.15_FDR_kWh Imp
	CSA_POD 11_Feeder 11.16_FDR_kWh Imp
	CSA_POD 12_Feeder 12.1_FDR_kWh Imp

Type of meter	Meter name
	CSA_POD 12_Feeder 12.2_FDR_kWh Imp
	CSA_POD 12_Feeder 12.3_FDR_kWh Imp
	CSA_POD 12_Feeder 12.4_FDR_kWh Imp
	CSA_POD 12_Feeder 12.5_FDR_kWh Imp
	CSA_POD 12_Feeder 12.6_FDR_kWh Imp
	CSA_POD 12_Feeder 12.7_FDR_kWh Imp
	CSA_POD 12_Feeder 12.8_FDR_kWh Imp
	CSA_POD 12_Feeder 12.9_FDR_kWh Imp

APPENDIX C – CASE STUDY A ENERGY BALANCE

Appendix C – Case study A energy balance

Table C-1 shows the total monthly percentage energy consumption flow throughout the entire facility, for Case Study A. It is important to be aware that the feeder meters do not measure the entire facility's energy consumption. In Table C-1 it is revealed that 12% of the entire facility's energy consumption is not measured on the feeder meter section.

Table C-1: Case Study A - Energy balance

Mine		POD		Incomer		Feeder	
Total Mine	100%	POD 1	13%	Incomer 1.1	4%	Feeder 1.1	1%
						Feeder 1.2	3%
						Feeder 1.3	0%
				Incomer 1.2	4%	Feeder 1.4	3%
						Feeder 1.5	1%
						Feeder 1.6	0%
				Incomer 1.3	2%	Feeder 1.7	0%
						Feeder 1.8	1%
						Feeder 1.9	1%
						Feeder 1.10	0%
		POD 2	8%	Incomer 1.4	3%	Feeder 1.11	0%
						Feeder 1.12	0%
						Feeder 1.13	2%
						Feeder 1.14	0%
						Feeder 1.15	0%
						Feeder 1.16	0%
						Feeder 1.17	0%
						Feeder 1.18	0%
						Feeder 1.19	1%
				Incomer 2.1	2%	Feeder 2.1	0%
				Incomer 2.2	6%	Feeder 2.2	2%
						Feeder 2.3	0%
						Feeder 2.4	3%
				Incomer 2.3	0%	Feeder 2.5	3%
						Feeder 2.6	0%

Mine		POD		Incomer		Feeder	
						Feeder 2.7	0%
						Feeder 2.8	0%
		POD 3	7%	Incomer 3.1	4%	Feeder 3.1	0%
						Feeder 3.2	1%
						Feeder 3.3	3%
						Feeder 3.4	0%
				Incomer 3.2	3%	Feeder 3.5	0%
						Feeder 3.6	0%
						Feeder 3.7	1%
						Feeder 3.8	0%
						Feeder 3.9	0%
						Feeder 3.10	0%
						Feeder 3.11	1%
				Incomer 3.3	0%	Feeder 3.12	0%
						Feeder 3.13	0%
						Feeder 3.14	0%
		POD 4	0%	Incomer 4.1	0%	Feeder 4.1	0%
				Incomer 4.2	0%	Feeder 4.2	0%
		POD 5	12%	Incomer 5.1	6%	Feeder 5.1	0%
						Feeder 5.2	1%
						Feeder 5.3	0%
						Feeder 5.4	0%
						Feeder 5.5	0%
						Feeder 5.6	0%
						Feeder 5.7	1%
				Incomer 5.2	6%	Feeder 5.8	0%
						Feeder 5.9	0%
						Feeder 5.10	0%
						Feeder 5.11	0%
						Feeder 5.12	1%
		POD 6	12%	Incomer 6.1	7%	Feeder 6.1	3%
						Feeder 6.2	2%
						Feeder 6.3	0%

Mine		POD		Incomer		Feeder	
						Feeder 6.4	2%
				Incomer 6.2	5%	Feeder 6.5	0%
						Feeder 6.6	0%
						Feeder 6.7	1%
						Feeder 6.8	0%
						Feeder 6.9	0%
						Feeder 6.10	0%
						Feeder 6.11	1%
		POD 7	1%	Incomer 7.1	0%	Feeder 7.1	0%
						Feeder 7.2	0%
						Feeder 7.3	0%
						Feeder 7.4	0%
						Feeder 7.5	0%
						Feeder 7.6	0%
						Feeder 7.7	0%
				Incomer 7.2	1%	Feeder 7.8	0%
						Feeder 7.9	0%
						Feeder 7.10	0%
				Incomer 7.3	0%	Feeder 7.11	0%
						Feeder 7.12	0%
						Feeder 7.13	0%
						Feeder 7.14	0%
						Feeder 7.15	0%
						Feeder 7.16	0%
		POD 8	8%	Incomer 8.1	3%	Feeder 8.1	1%
						Feeder 8.2	0%
						Feeder 8.3	1%
						Feeder 8.4	0%
						Feeder 8.5	0%
						Feeder 8.6	0%
						Feeder 8.7	0%
						Feeder 8.8	0%
				Incomer 8.2	3%	Feeder 8.9	0%

Mine		POD		Incomer		Feeder	
						Feeder 8.10	1%
						Feeder 8.11	2%
						Feeder 8.12	0%
						Feeder 8.13	0%
						Feeder 8.14	0%
						Feeder 8.15	0%
						Feeder 8.16	0%
						Feeder 8.17	0%
						Feeder 8.18	0%
						Feeder 8.19	0%
						Feeder 8.20	0%
				Incomer 8.3	2%	Feeder 8.21	0%
						Feeder 8.22	0%
						Feeder 8.23	1%
						Feeder 8.24	0%
						Feeder 8.25	0%
						Feeder 8.26	0%
						Feeder 8.27	0%
						Feeder 8.28	0%
						Feeder 8.29	1%
		POD 9	10%	Incomer 9.1	0%	Feeder 9.1	0%
						Feeder 9.2	0%
						Feeder 9.3	0%
						Feeder 9.4	0%
				Incomer 9.2	2%	Feeder 9.5	0%
						Feeder 9.6	2%
						Feeder 9.7	0%
						Feeder 9.8	0%
				Incomer 9.3	2%	Feeder 9.9	2%
						Feeder 9.10	0%
				Incomer 9.4	4%	Feeder 9.11	0%
						Feeder 9.12	1%
						Feeder 9.13	1%

Mine		POD		Incomer		Feeder	
						Feeder 9.14	1%
						Feeder 9.15	1%
						Feeder 9.16	0%
						Feeder 9.17	0%
						Feeder 9.18	0%
				Incomer 9.5	2%	Feeder 9.19	0%
						Feeder 9.20	0%
						Feeder 9.21	0%
						Feeder 9.22	0%
						Feeder 9.23	1%
						Feeder 9.24	0%
						Feeder 9.25	0%
		POD 10	19%	Incomer 10.1	6%	Feeder 10.1	2%
						Feeder 10.2	0%
						Feeder 10.3	2%
						Feeder 10.4	0%
						Feeder 10.5	0%
						Feeder 10.6	2%
				Incomer 10.2	7%	Feeder 10.7	0%
						Feeder 10.8	5%
						Feeder 10.9	0%
						Feeder 10.10	2%
						Feeder 10.11	0%
						Feeder 10.12	0%
						Feeder 10.13	0%
				Incomer 10.3	5%	Feeder 10.14	2%
						Feeder 10.15	3%
						Feeder 10.16	0%
						Feeder 10.17	0%
				Incomer 10.4	1%	Feeder 10.18	1%
						Feeder 10.19	0%
		POD 11	7%	Incomer 11.1	0%	Feeder 11.1	0%
						Feeder 11.2	0%

Mine		POD		Incomer		Feeder	
						Feeder 11.3	0%
						Feeder 11.4	0%
						Feeder 11.5	0%
				Incomer 11.2	4%	Feeder 11.6	0%
						Feeder 11.7	2%
						Feeder 11.8	0%
				Incomer 11.3	2%	Feeder 11.9	0%
						Feeder 11.10	0%
						Feeder 11.11	0%
						Feeder 11.12	0%
						Feeder 11.13	1%
						Feeder 11.14	1%
				Incomer 11.4	1%	Feeder 11.15	0%
						Feeder 11.16	1%
		POD 12	3%	Incomer 12.1	2%	Feeder 12.1	0%
						Feeder 12.2	0%
						Feeder 12.3	0%
						Feeder 12.4	1%
				Incomer 12.2	1%	Feeder 12.5	0%
						Feeder 12.6	0%
						Feeder 12.7	1%
						Feeder 12.8	0%
						Feeder 12.9	0%
				% of Feeders not measured			

APPENDIX D – CASE STUDY A KPI VALUES

Appendix D – Case study A KPI values

Case Study A's KPI values are indicated in Table D-1. Each feeder meter is associated with two KPI values, the Absolute Impact KPI and the Volatility KPI. Where the Absolute Impact KPI is the total monthly energy consumption of the specific feeder. On the other hand, the Volatility KPI is the number of times a feeder meter was identified as consuming a large amount of energy, during a month.

Table D-1: Case Study A - KPI values

Feeder	Absolute Impact KPI (kWh)	Volatility KPI
Feeder 1.1	664 306	1
Feeder 1.2	3 111 692	30
Feeder 1.3	0	0
Feeder 1.4	3 261 837	28
Feeder 1.5	1 046 683	16
Feeder 1.6	27 758	0
Feeder 1.7	0	0
Feeder 1.8	990 514	16
Feeder 1.9	957 301	12
Feeder 1.10	552 950	0
Feeder 1.11	519 078	0
Feeder 1.12	347 994	0
Feeder 1.13	2 021 580	30
Feeder 1.14	2	0
Feeder 1.15	432 690	0
Feeder 1.16	0	0
Feeder 1.17	92 873	1
Feeder 1.18	0	0
Feeder 1.19	731 341	1
Feeder 2.1	0	0
Feeder 2.2	1 941 668	30
Feeder 2.3	126 741	0
Feeder 2.4	3 865 430	30

Feeder	Absolute Impact KPI (kWh)	Volatility KPI
Feeder 2.5	3 582 225	30
Feeder 2.6	342 006	0
Feeder 2.7	472 573	1
Feeder 2.8	237 857	0
Feeder 3.1	6 423	0
Feeder 3.2	990 627	19
Feeder 3.3	3 138 746	20
Feeder 3.4	0	0
Feeder 3.5	9 243	0
Feeder 3.6	0	0
Feeder 3.7	1 345 477	19
Feeder 3.8	563 924	0
Feeder 3.9	328 767	0
Feeder 3.10	194 919	0
Feeder 3.11	1 791 503	30
Feeder 3.12	550 163	0
Feeder 3.13	0	0
Feeder 3.14	67 688	0
Feeder 4.1	0	0
Feeder 4.2	0	0
Feeder 5.1	10 886	0
Feeder 5.2	1 146 822	24
Feeder 5.3	58 304	0
Feeder 5.4	281 868	0
Feeder 5.5	273 060	0
Feeder 5.6	551 868	7
Feeder 5.7	714 013	7
Feeder 5.8	9 566	0
Feeder 5.9	19 957	0
Feeder 5.10	46 232	0
Feeder 5.11	461 027	6
Feeder 5.12	1 486 062	21

Feeder	Absolute Impact KPI (kWh)	Volatility KPI
Feeder 6.1	3 941 415	30
Feeder 6.2	2 986 034	28
Feeder 6.3	0	0
Feeder 6.4	3 053 795	28
Feeder 6.5	0	0
Feeder 6.6	105 638	0
Feeder 6.7	1 019 071	13
Feeder 6.8	132 315	0
Feeder 6.9	461 347	0
Feeder 6.10	0	0
Feeder 6.11	738 851	1
Feeder 7.1	139 813	0
Feeder 7.2	3 729	0
Feeder 7.3	33 388	0
Feeder 7.4	4 379	0
Feeder 7.5	75 957	0
Feeder 7.6	34 226	0
Feeder 7.7	6 417	0
Feeder 7.8	86 476	0
Feeder 7.9	34 115	0
Feeder 7.10	0	0
Feeder 7.11	0	0
Feeder 7.12	41 724	0
Feeder 7.13	0	0
Feeder 7.14	0	0
Feeder 7.15	496 208	2
Feeder 7.16	0	0
Feeder 8.1	674 995	2
Feeder 8.2	115 995	0
Feeder 8.3	935 949	8
Feeder 8.4	608 191	0
Feeder 8.5	0	0

Feeder	Absolute Impact KPI (kWh)	Volatility KPI
Feeder 8.6	261 629	0
Feeder 8.7	0	0
Feeder 8.8	347 801	0
Feeder 8.9	162 957	0
Feeder 8.10	1 369 645	19
Feeder 8.11	2 328 920	28
Feeder 8.12	58 739	0
Feeder 8.13	385 644	0
Feeder 8.14	445	0
Feeder 8.15	0	0
Feeder 8.16	1 974	0
Feeder 8.17	2 712	0
Feeder 8.18	12 601	0
Feeder 8.19	0	0
Feeder 8.20	126 467	0
Feeder 8.21	90 937	0
Feeder 8.22	122 117	0
Feeder 8.23	638 679	3
Feeder 8.24	18 812	0
Feeder 8.25	0	0
Feeder 8.26	512 432	0
Feeder 8.27	1 387	0
Feeder 8.28	56 983	0
Feeder 8.29	1 087 931	20
Feeder 9.1	0	0
Feeder 9.2	0	0
Feeder 9.3	188 469	0
Feeder 9.4	3 130	0
Feeder 9.5	0	0
Feeder 9.6	1 952 815	29
Feeder 9.7	0	0
Feeder 9.8	138 607	0

Feeder	Absolute Impact KPI (kWh)	Volatility KPI
Feeder 9.9	2 894 837	11
Feeder 9.10	0	0
Feeder 9.11	115 849	0
Feeder 9.12	1 370 283	30
Feeder 9.13	1 829 197	23
Feeder 9.14	1 561 224	29
Feeder 9.15	1 600 550	30
Feeder 9.16	8 882	0
Feeder 9.17	72	0
Feeder 9.18	1 323	0
Feeder 9.19	8	0
Feeder 9.20	130 574	0
Feeder 9.21	425 813	0
Feeder 9.22	239 947	0
Feeder 9.23	1 223 675	26
Feeder 9.24	295 351	0
Feeder 9.25	261 709	0
Feeder 10.1	2 667 320	30
Feeder 10.2	0	0
Feeder 10.3	1 899 614	30
Feeder 10.4	53 833	0
Feeder 10.5	38 483	0
Feeder 10.6	1 867 730	28
Feeder 10.7	0	0
Feeder 10.8	5 702 284	29
Feeder 10.9	277 800	0
Feeder 10.10	2 556 858	44
Feeder 10.11	2 317	0
Feeder 10.12	616	0
Feeder 10.13	12 700	0
Feeder 10.14	2 987 674	29
Feeder 10.15	3 167 648	29

Feeder	Absolute Impact KPI (kWh)	Volatility KPI
Feeder 10.16	0	0
Feeder 10.17	0	0
Feeder 10.18	1 522 558	27
Feeder 10.19	41 222	0
Feeder 11.1	14 332	0
Feeder 11.2	14 039	0
Feeder 11.3	0	0
Feeder 11.4	0	0
Feeder 11.5	351 571	6
Feeder 11.6	393 808	0
Feeder 11.7	2 333 961	39
Feeder 11.8	7 257	0
Feeder 11.9	0	0
Feeder 11.10	0	0
Feeder 11.11	0	0
Feeder 11.12	5 463	0
Feeder 11.13	712 054	4
Feeder 11.14	697 139	3
Feeder 11.15	493 552	0
Feeder 11.16	834 017	6
Feeder 12.1	101 267	0
Feeder 12.2	0	0
Feeder 12.3	93 713	0
Feeder 12.4	1 212 822	15
Feeder 12.5	0	0
Feeder 12.6	1	0
Feeder 12.7	1 647 267	22
Feeder 12.8	303 665	0
Feeder 12.9	0	0

APPENDIX E – CASE STUDY A IDENTIFIED METERS

Appendix E – Case study A identified meters

Table E-1 combines the two KPI values per feeder meter, by multiplying these KPIs with one another. Afterwards the feeder meters are ranked from the largest to the smallest. Finally ending off with only regarding the feeder meters, which were ranked as the top 38 feeder meters, as the essential identified meters.

The total monthly energy consumption of these essential meters is added to the difference between the incomer meters and the feeder meters' energy consumption. This is then compared to the total monthly energy consumption of the entire facility, leaving a percentage contribution of 80% of the total energy consumption, which is being monitored by the essential energy meters. The percentage of energy meters that is used to monitor 80% of the energy consumption of the facility, equals 21% of the available feeder meters.

Table E-1: Case Study A - KPI values combined

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
Feeder 1.1	664 306	1	664 306	54	
Feeder 1.2	3 111 692	30	93 350 768	6	3 111 692
Feeder 1.3	0	0	0	119	
Feeder 1.4	3 261 837	28	91 331 432	8	3 261 837
Feeder 1.5	1 046 683	16	16 746 926	37	1 046 683
Feeder 1.6	27 758	0	0	119	
Feeder 1.7	0	0	0	119	
Feeder 1.8	990 514	16	15 848 227	38	990 514
Feeder 1.9	957 301	12	11 487 608	40	
Feeder 1.10	552 950	0	0	119	
Feeder 1.11	519 078	0	0	119	
Feeder 1.12	347 994	0	0	119	
Feeder 1.13	2 021 580	30	60 647 401	16	2 021 580
Feeder 1.14	2	0	0	119	
Feeder 1.15	432 690	0	0	119	
Feeder 1.16	0	0	0	119	

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
Feeder 1.17	92 873	1	92 873	56	
Feeder 1.18	0	0	0	119	
Feeder 1.19	731 341	1	731 341	53	
Feeder 2.1	0	0	0	119	
Feeder 2.2	1 941 668	30	58 250 025	17	1 941 668
Feeder 2.3	126 741	0	0	119	
Feeder 2.4	3 865 430	30	115 962 897	3	3 865 430
Feeder 2.5	3 582 225	30	107 466 758	5	3 582 225
Feeder 2.6	342 006	0	0	119	
Feeder 2.7	472 573	1	472 573	55	
Feeder 2.8	237 857	0	0	119	
Feeder 3.1	6 423	0	0	119	
Feeder 3.2	990 627	19	18 821 919	35	990 627
Feeder 3.3	3 138 746	20	62 774 922	15	3 138 746
Feeder 3.4	0	0	0	119	
Feeder 3.5	9 243	0	0	119	
Feeder 3.6	0	0	0	119	
Feeder 3.7	1 345 477	19	25 564 055	33	1 345 477
Feeder 3.8	563 924	0	0	119	
Feeder 3.9	328 767	0	0	119	
Feeder 3.10	194 919	0	0	119	
Feeder 3.11	1 791 503	30	53 745 079	20	1 791 503
Feeder 3.12	550 163	0	0	119	
Feeder 3.13	0	0	0	119	
Feeder 3.14	67 688	0	0	119	
Feeder 4.1	0	0	0	119	
Feeder 4.2	0	0	0	119	
Feeder 5.1	10 886	0	0	119	

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
Feeder 5.2	1 146 822	24	27 523 728	31	1 146 822
Feeder 5.3	58 304	0	0	119	
Feeder 5.4	281 868	0	0	119	
Feeder 5.5	273 060	0	0	119	
Feeder 5.6	551 868	7	3 863 076	44	
Feeder 5.7	714 013	7	4 998 091	43	
Feeder 5.8	9 566	0	0	119	
Feeder 5.9	19 957	0	0	119	
Feeder 5.10	46 232	0	0	119	
Feeder 5.11	461 027	6	2 766 162	46	
Feeder 5.12	1 486 062	21	31 207 302	30	1 486 062
Feeder 6.1	3 941 415	30	118 242 450	2	3 941 415
Feeder 6.2	2 986 034	28	83 608 952	12	2 986 034
Feeder 6.3	0	0	0	119	
Feeder 6.4	3 053 795	28	85 506 260	11	3 053 795
Feeder 6.5	0	0	0	119	
Feeder 6.6	105 638	0	0	119	
Feeder 6.7	1 019 071	13	13 247 923	39	
Feeder 6.8	132 315	0	0	119	
Feeder 6.9	461 347	0	0	119	
Feeder 6.10	0	0	0	119	
Feeder 6.11	738 851	1	738 851	52	
Feeder 7.1	139 813	0	0	119	
Feeder 7.2	3 729	0	0	119	
Feeder 7.3	33 388	0	0	119	
Feeder 7.4	4 379	0	0	119	
Feeder 7.5	75 957	0	0	119	
Feeder 7.6	34 226	0	0	119	
Feeder 7.7	6 417	0	0	119	

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
Feeder 7.8	86 476	0	0	119	
Feeder 7.9	34 115	0	0	119	
Feeder 7.10	0	0	0	119	
Feeder 7.11	0	0	0	119	
Feeder 7.12	41 724	0	0	119	
Feeder 7.13	0	0	0	119	
Feeder 7.14	0	0	0	119	
Feeder 7.15	496 208	2	992 416	51	
Feeder 7.16	0	0	0	119	
Feeder 8.1	674 995	2	1 349 990	50	
Feeder 8.2	115 995	0	0	119	
Feeder 8.3	935 949	8	7 487 592	41	
Feeder 8.4	608 191	0	0	119	
Feeder 8.5	0	0	0	119	
Feeder 8.6	261 629	0	0	119	
Feeder 8.7	0	0	0	119	
Feeder 8.8	347 801	0	0	119	
Feeder 8.9	162 957	0	0	119	
Feeder 8.10	1 369 645	19	26 023 261	32	1 369 645
Feeder 8.11	2 328 920	28	65 209 753	14	2 328 920
Feeder 8.12	58 739	0	0	119	
Feeder 8.13	385 644	0	0	119	
Feeder 8.14	445	0	0	119	
Feeder 8.15	0	0	0	119	
Feeder 8.16	1 974	0	0	119	
Feeder 8.17	2 712	0	0	119	
Feeder 8.18	12 601	0	0	119	
Feeder 8.19	0	0	0	119	
Feeder 8.20	126 467	0	0	119	
Feeder 8.21	90 937	0	0	119	

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
Feeder 8.22	122 117	0	0	119	
Feeder 8.23	638 679	3	1 916 036	49	
Feeder 8.24	18 812	0	0	119	
Feeder 8.25	0	0	0	119	
Feeder 8.26	512 432	0	0	119	
Feeder 8.27	1 387	0	0	119	
Feeder 8.28	56 983	0	0	119	
Feeder 8.29	1 087 931	20	21 758 610	34	1 087 931
Feeder 9.1	0	0	0	119	
Feeder 9.2	0	0	0	119	
Feeder 9.3	188 469	0	0	119	
Feeder 9.4	3 130	0	0	119	
Feeder 9.5	0	0	0	119	
Feeder 9.6	1 952 815	29	56 631 627	19	1 952 815
Feeder 9.7	0	0	0	119	
Feeder 9.8	138 607	0	0	119	
Feeder 9.9	2 894 837	11	31 843 211	28	2 894 837
Feeder 9.10	0	0	0	119	
Feeder 9.11	115 849	0	0	119	
Feeder 9.12	1 370 283	30	41 108 481	26	1 370 283
Feeder 9.13	1 829 197	23	42 071 542	24	1 829 197
Feeder 9.14	1 561 224	29	45 275 485	23	1 561 224
Feeder 9.15	1 600 550	30	48 016 486	22	1 600 550
Feeder 9.16	8 882	0	0	119	
Feeder 9.17	72	0	0	119	
Feeder 9.18	1 323	0	0	119	
Feeder 9.19	8	0	0	119	
Feeder 9.20	130 574	0	0	119	
Feeder 9.21	425 813	0	0	119	
Feeder 9.22	239 947	0	0	119	

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
Feeder 9.23	1 223 675	26	31 815 550	29	1 223 675
Feeder 9.24	295 351	0	0	119	
Feeder 9.25	261 709	0	0	119	
Feeder 10.1	2 667 320	30	80 019 588	13	2 667 320
Feeder 10.2	0	0	0	119	
Feeder 10.3	1 899 614	30	56 988 422	18	1 899 614
Feeder 10.4	53 833	0	0	119	
Feeder 10.5	38 483	0	0	119	
Feeder 10.6	1 867 730	28	52 296 445	21	1 867 730
Feeder 10.7	0	0	0	119	
Feeder 10.8	5 702 284	29	165 366 250	1	5 702 284
Feeder 10.9	277 800	0	0	119	
Feeder 10.10	2 556 858	44	112 501 736	4	2 556 858
Feeder 10.11	2 317	0	0	119	
Feeder 10.12	616	0	0	119	
Feeder 10.13	12 700	0	0	119	
Feeder 10.14	2 987 674	29	86 642 558	10	2 987 674
Feeder 10.15	3 167 648	29	91 861 802	7	3 167 648
Feeder 10.16	0	0	0	119	
Feeder 10.17	0	0	0	119	
Feeder 10.18	1 522 558	27	41 109 079	25	1 522 558
Feeder 10.19	41 222	0	0	119	
Feeder 11.1	14 332	0	0	119	
Feeder 11.2	14 039	0	0	119	
Feeder 11.3	0	0	0	119	
Feeder 11.4	0	0	0	119	
Feeder 11.5	351 571	6	2 109 426	47	
Feeder 11.6	393 808	0	0	119	

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
Feeder 11.7	2 333 961	39	91 024 487	9	2 333 961
Feeder 11.8	7 257	0	0	119	
Feeder 11.9	0	0	0	119	
Feeder 11.10	0	0	0	119	
Feeder 11.11	0	0	0	119	
Feeder 11.12	5 463	0	0	119	
Feeder 11.13	712 054	4	2 848 216	45	
Feeder 11.14	697 139	3	2 091 417	48	
Feeder 11.15	493 552	0	0	119	
Feeder 11.16	834 017	6	5 004 101	42	
Feeder 12.1	101 267	0	0	119	
Feeder 12.2	0	0	0	119	
Feeder 12.3	93 713	0	0	119	
Feeder 12.4	1 212 822	15	18 192 332	36	1 212 822
Feeder 12.5	0	0	0	119	
Feeder 12.6	1	0	0	119	
Feeder 12.7	1 647 267	22	36 239 871	27	1 647 267
Feeder 12.8	303 665	0	0	119	
Feeder 12.9	0	0	0	119	
kWh Difference between Incomers and Feeders	15 158 791	-	-	-	15 158 791
Total derived monthly energy consumption	-	-	-	-	99 645 713
Actual total monthly energy consumption	124 108 775	-	-	-	124 108 775

Feeder	Absolute Impact KPI (kWh)	Volatility KPI	Multiply both KPIs	Rank meters	Essential meter's monthly energy
% of the total monthly energy consumption using only the essential meters (and the difference between the Incomers and the Feeders)	-	-	-	-	80%
% identified essential meters	-	-	-	-	21%

APPENDIX F – VOLATILITY KPI VERIFICATION

Appendix F – Volatility KPI Verification

This appendix is mainly to verify the Volatility KPI created in this study. Each feeder is awarded a Volatility KPI value when utilising the methodology of the study. This value is compared to a standard deviation value awarded for each feeder. Case Study A's data was used to verify the Volatility KPI.

The verification occurred by calculating the standard deviation and average energy consumption of each feeder. By dividing the standard deviation by the average energy consumption a percentage is obtained. Multiplying this percentage with the Absolute Impact KPI, the KPI's were combined. Finally, ranking the multiplied values, to determine the importance of the meters. Table F-1 illustrates the methodology followed to determine the importance of the feeder meters using standard deviation.

Table F-1: Volatility KPI Verification

Feeder	Standard Deviation (kWh)	Average (kWh)	% Standard Deviation	Absolute Impact (kWh)	Multiply both KPI's	Rank
Feeder 1.1	8 042	22 144	36%	664 306	241 274	43
Feeder 1.2	4 729	11 600	41%	347 994	141 860	56
Feeder 1.3	0	0	474%	0	0	144
Feeder 1.4	0	0	396%	0	0	150
Feeder 1.5	0	0	37%	2	1	141
Feeder 1.6	86	925	9%	27 758	2 576	123
Feeder 1.7	15 287	45 818	33%	1 374 548	458 614	22
Feeder 1.8	11 591	33 017	35%	990 514	347 729	32
Feeder 1.9	11 763	31 910	37%	957 301	352 903	31
Feeder 1.10	3 441	18 432	19%	552 950	103 231	63
Feeder 1.11	1 335	17 303	8%	519 078	40 043	77
Feeder 1.12	38 005	103 723	37%	3 111 692	1 140 143	5
Feeder 1.13	14 686	67 386	22%	2 021 580	440 578	25
Feeder 1.14	10 695	34 889	31%	1 046 683	320 846	34
Feeder 1.15	9 532	14 423	66%	432 690	285 964	38
Feeder 1.16	27 925	108 728	26%	3 261 837	837 749	14
Feeder 1.17	14 112	3 096	456%	92 873	423 364	26

Feeder	Standard Deviation (kWh)	Average (kWh)	% Standard Deviation	Absolute Impact (kWh)	Multiply both KPI's	Rank
Feeder 1.18	0	0	0%	0	0	169
Feeder 1.19	1 701	24 378	7%	731 341	51 034	72
Feeder 2.1	0	0	441%	0	0	143
Feeder 2.2	6 568	64 722	10%	1 941 668	197 037	49
Feeder 2.3	232	4 225	6%	126 741	6 973	108
Feeder 2.4	13 123	128 848	10%	3 865 430	393 681	30
Feeder 2.5	17 994	119 408	15%	3 582 225	539 830	19
Feeder 2.6	9 196	11 400	81%	342 006	275 879	39
Feeder 2.7	9 189	15 752	58%	472 573	275 672	40
Feeder 2.8	514	7 929	6%	237 857	15 423	101
Feeder 3.1	2	214	1%	6 423	50	137
Feeder 3.2	277	2 256	12%	67 688	8 297	107
Feeder 3.3	80 212	104 625	77%	3 138 746	2 406 350	2
Feeder 3.4	0	0	0%	0	0	169
Feeder 3.5	8	308	3%	9 243	235	131
Feeder 3.6	0	0	374%	0	0	152
Feeder 3.7	8 317	18 339	45%	550 163	249 498	42
Feeder 3.8	8 782	18 797	47%	563 924	263 453	41
Feeder 3.9	5 389	10 959	49%	328 767	161 656	52
Feeder 3.10	3 420	6 497	53%	194 919	102 604	64
Feeder 3.11	14 075	59 717	24%	1 791 503	422 242	27
Feeder 3.12	31 817	44 849	71%	1 345 477	954 524	8
Feeder 3.13	0	0	539%	0	0	157
Feeder 3.14	10 573	33 021	32%	990 627	317 188	36
Feeder 4.1	0	0	0%	0	0	169
Feeder 4.2	0	0	0%	0	0	169
Feeder 5.1	105	363	29%	10 886	3 139	120
Feeder 5.2	13 975	38 227	37%	1 146 822	419 237	28
Feeder 5.3	199	1 943	10%	58 304	5 976	110
Feeder 5.4	3 280	9 396	35%	281 868	98 398	65
Feeder 5.5	3 122	9 102	34%	273 060	93 646	66

Feeder	Standard Deviation (kWh)	Average (kWh)	% Standard Deviation	Absolute Impact (kWh)	Multiply both KPI's	Rank
Feeder 5.6	16 497	18 396	90%	551 868	494 905	20
Feeder 5.7	10 613	23 800	45%	714 013	318 383	35
Feeder 5.8	150	319	47%	9 566	4 493	116
Feeder 5.9	347	665	52%	19 957	10 401	104
Feeder 5.10	652	1 541	42%	46 232	19 568	91
Feeder 5.11	25 617	15 368	167%	461 027	768 506	16
Feeder 5.12	31 048	49 535	63%	1 486 062	931 440	9
Feeder 6.1	14 924	131 381	11%	3 941 415	447 717	24
Feeder 6.2	30 237	99 534	30%	2 986 034	907 115	11
Feeder 6.3	0	0	0%	0	0	169
Feeder 6.4	28 195	101 793	28%	3 053 795	845 850	12
Feeder 6.5	0	0	0%	0	0	169
Feeder 6.6	1 078	3 521	31%	105 638	32 355	82
Feeder 6.7	9 682	33 969	29%	1 019 071	290 448	37
Feeder 6.8	920	4 411	21%	132 315	27 613	88
Feeder 6.9	5 293	15 378	34%	461 347	158 801	53
Feeder 6.10	0	0	0%	0	0	169
Feeder 6.11	558	24 628	2%	738 851	16 725	95
Feeder 7.1	445	4 660	10%	139 813	13 348	102
Feeder 7.2	312	124	251%	3 729	9 353	105
Feeder 7.3	25	1 113	2%	33 388	739	127
Feeder 7.4	7	146	5%	4 379	206	133
Feeder 7.5	169	2 532	7%	75 957	5 071	114
Feeder 7.6	43	1 141	4%	34 226	1 286	125
Feeder 7.7	3	214	1%	6 417	77	136
Feeder 7.8	549	2 883	19%	86 476	16 480	98
Feeder 7.9	136	1 137	12%	34 115	4 076	118
Feeder 7.10	0	0	0%	0	0	169
Feeder 7.11	0	0	0%	0	0	169
Feeder 7.12	173	1 391	12%	41 724	5 178	112
Feeder 7.13	0	0	224%	0	0	151

Feeder	Standard Deviation (kWh)	Average (kWh)	% Standard Deviation	Absolute Impact (kWh)	Multiply both KPI's	Rank
Feeder 7.14	0	0	539%	0	0	155
Feeder 7.15	5 755	16 540	35%	496 208	172 650	51
Feeder 7.16	0	0	0%	0	0	169
Feeder 8.1	2 686	22 500	12%	674 995	80 579	67
Feeder 8.2	1 098	3 867	28%	115 995	32 926	81
Feeder 8.3	4 574	31 198	15%	935 949	137 227	58
Feeder 8.4	304	20 273	2%	608 191	9 123	106
Feeder 8.5	0	0	0%	0	0	169
Feeder 8.6	522	8 721	6%	261 629	15 674	99
Feeder 8.7	0	0	0%	0	0	169
Feeder 8.8	1 322	11 593	11%	347 801	39 662	79
Feeder 8.9	943	5 432	17%	162 957	28 278	87
Feeder 8.10	30 961	45 655	68%	1 369 645	928 835	10
Feeder 8.11	22 438	77 631	29%	2 328 920	673 143	17
Feeder 8.12	973	1 958	50%	58 739	29 196	85
Feeder 8.13	172	12 855	1%	385 644	5 168	113
Feeder 8.14	5	15	32%	445	142	134
Feeder 8.15	0	0	0%	0	0	169
Feeder 8.16	89	66	135%	1 974	2 659	122
Feeder 8.17	21	90	23%	2 712	629	128
Feeder 8.18	160	420	38%	12 601	4 797	115
Feeder 8.19	0	0	0%	0	0	169
Feeder 8.20	752	4 216	18%	126 467	22 567	89
Feeder 8.21	405	3 031	13%	90 937	12 141	103
Feeder 8.22	1 075	4 071	26%	122 117	32 249	83
Feeder 8.23	11 546	21 289	54%	638 679	346 377	33
Feeder 8.24	94	627	15%	18 812	2 829	121
Feeder 8.25	0	0	0%	0	0	169
Feeder 8.26	1 503	17 081	9%	512 432	45 092	73
Feeder 8.27	2	46	3%	1 387	46	138
Feeder 8.28	555	1 899	29%	56 983	16 662	96

Feeder	Standard Deviation (kWh)	Average (kWh)	% Standard Deviation	Absolute Impact (kWh)	Multiply both KPI's	Rank
Feeder 8.29	613	36 264	2%	1 087 931	18 388	92
Feeder 9.1	126 214	96 495	131%	2 894 837	3 786 434	1
Feeder 9.2	0	0	0%	0	0	169
Feeder 9.3	133	45 676	0%	1 370 283	3 986	119
Feeder 9.4	562	104	539%	3 130	16 856	94
Feeder 9.5	0	0	0%	0	0	169
Feeder 9.6	16 312	65 094	25%	1 952 815	489 371	21
Feeder 9.7	0	0	539%	0	0	156
Feeder 9.8	521	4 620	11%	138 607	15 623	100
Feeder 9.9	0	0	0%	0	0	169
Feeder 9.10	0	0	494%	0	0	147
Feeder 9.11	553	3 862	14%	115 849	16 604	97
Feeder 9.12	1 074	6 282	17%	188 469	32 211	84
Feeder 9.13	39 801	60 973	65%	1 829 197	1 194 038	4
Feeder 9.14	6 639	52 041	13%	1 561 224	199 156	48
Feeder 9.15	149	53 352	0%	1 600 550	4 468	117
Feeder 9.16	1 446	296	488%	8 882	43 373	74
Feeder 9.17	1	2	32%	72	23	139
Feeder 9.18	4	44	8%	1 323	107	135
Feeder 9.19	0	0	149%	8	11	140
Feeder 9.20	1 341	4 352	31%	130 574	40 227	76
Feeder 9.21	7 987	14 194	56%	425 813	239 607	44
Feeder 9.22	1 919	7 998	24%	239 947	57 572	71
Feeder 9.23	5 229	40 789	13%	1 223 675	156 874	54
Feeder 9.24	2 572	9 845	26%	295 351	77 156	69
Feeder 9.25	2 464	8 724	28%	261 709	73 915	70
Feeder 10.1	7 834	88 911	9%	2 667 320	235 020	46
Feeder 10.2	4 161	51 454	8%	1 543 614	124 840	61
Feeder 10.3	5 146	63 320	8%	1 899 614	154 390	55
Feeder 10.4	7 666	31 980	24%	959 414	229 982	47
Feeder 10.5	7 914	33 775	23%	1 013 243	237 417	45

Feeder	Standard Deviation (kWh)	Average (kWh)	% Standard Deviation	Absolute Impact (kWh)	Multiply both KPI's	Rank
Feeder 10.6	14 941	62 258	24%	1 867 730	448 221	23
Feeder 10.7	0	0	0%	0	0	169
Feeder 10.8	0	0	374%	0	0	153
Feeder 10.9	1 399	9 260	15%	277 800	41 960	75
Feeder 10.10	191	1 283	15%	38 483	5 717	111
Feeder 10.11	17	77	22%	2 317	507	129
Feeder 10.12	7	21	35%	616	217	132
Feeder 10.13	9	423	2%	12 700	279	130
Feeder 10.14	26 712	99 589	27%	2 987 674	801 352	15
Feeder 10.15	28 194	105 588	27%	3 167 648	845 820	13
Feeder 10.16	0	0	151%	0	0	148
Feeder 10.17	50 444	190 076	27%	5 702 284	1 513 332	3
Feeder 10.18	13 682	50 752	27%	1 522 558	410 459	29
Feeder 10.19	4 721	1 374	344%	41 222	141 626	57
Feeder 11.1	75	478	16%	14 332	2 257	124
Feeder 11.2	1 124	468	240%	14 039	33 734	80
Feeder 11.3	0	0	440%	0	0	149
Feeder 11.4	0	0	539%	0	0	154
Feeder 11.5	21 726	11 719	185%	351 571	651 769	18
Feeder 11.6	2 604	13 127	20%	393 808	78 131	68
Feeder 11.7	230	1 794	13%	53 833	6 901	109
Feeder 11.8	607	242	251%	7 257	18 222	93
Feeder 11.9	0	0	0%	0	0	169
Feeder 11.10	0	0	0%	0	0	169
Feeder 11.11	0	0	0%	0	0	169
Feeder 11.12	39	182	22%	5 463	1 175	126
Feeder 11.13	4 393	23 735	19%	712 054	131 801	59
Feeder 11.14	4 343	23 238	19%	697 139	130 290	60
Feeder 11.15	3 609	16 452	22%	493 552	108 268	62
Feeder 11.16	6 145	27 801	22%	834 017	184 356	50
Feeder 12.1	706	3 376	21%	101 267	21 194	90

Feeder	Standard Deviation (kWh)	Average (kWh)	% Standard Deviation	Absolute Impact (kWh)	Multiply both KPI's	Rank
Feeder 12.2	0	0	0%	0	0	169
Feeder 12.3	957	3 124	31%	93 713	28 698	86
Feeder 12.4	37 049	40 427	92%	1 212 822	1 111 467	6
Feeder 12.5	33 676	54 909	61%	1 647 267	1 010 283	7
Feeder 12.6	0	0	45%	1	1	142
Feeder 12.7	0	0	84%	0	0	146
Feeder 12.8	1 323	10 122	13%	303 665	39 690	78
Feeder 12.9	0	0	114%	0	0	145

After the feeder meters were ranked according to importance, based on utilising standard deviation, the 36 essential meters were identified. Table F-2 compares these meters with the important meters, as identified using the Volatility KPI.

Table F-2: Standard deviation versus Volatility KPI

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 1.1	0	0	0
Feeder 1.2	0	0	0
Feeder 1.3	0	0	0
Feeder 1.4	0	0	0
Feeder 1.5	0	0	0
Feeder 1.6	0	0	0
Feeder 1.7	1 374 548	1 374 548	1
Feeder 1.8	990 514	0	0
Feeder 1.9	957 301	0	0
Feeder 1.10	0	0	0
Feeder 1.11	0	0	0

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 1.12	3 111 692	3 111 692	1
Feeder 1.13	2 021 580	2 021 580	1
Feeder 1.14	1 046 683	0	0
Feeder 1.15	0	0	0
Feeder 1.16	3 261 837	3 261 837	1
Feeder 1.17	92 873	0	0
Feeder 1.18	0	0	0
Feeder 1.19	0	0	0
Feeder 2.1	0	0	0
Feeder 2.2	0	1 941 668	0
Feeder 2.3	0	0	0
Feeder 2.4	3 865 430	3 865 430	1
Feeder 2.5	3 582 225	3 582 225	1
Feeder 2.6	0	0	0
Feeder 2.7	0	0	0
Feeder 2.8	0	0	0
Feeder 3.1	0	0	0
Feeder 3.2	0	0	0
Feeder 3.3	3 138 746	3 138 746	1
Feeder 3.4	0	0	0
Feeder 3.5	0	0	0
Feeder 3.6	0	0	0
Feeder 3.7	0	0	0
Feeder 3.8	0	0	0
Feeder 3.9	0	0	0
Feeder 3.10	0	0	0
Feeder 3.11	1 791 503	1 791 503	1
Feeder 3.12	1 345 477	1 345 477	1

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 3.13	0	0	0
Feeder 3.14	990 627	990 627	1
Feeder 4.1	0	0	0
Feeder 4.2	0	0	0
Feeder 5.1	0	0	0
Feeder 5.2	1 146 822	1 146 822	1
Feeder 5.3	0	0	0
Feeder 5.4	0	0	0
Feeder 5.5	0	0	0
Feeder 5.6	551 868	0	0
Feeder 5.7	714 013	0	0
Feeder 5.8	0	0	0
Feeder 5.9	0	0	0
Feeder 5.10	0	0	0
Feeder 5.11	461 027	0	0
Feeder 5.12	1 486 062	1 486 062	1
Feeder 6.1	3 941 415	3 941 415	1
Feeder 6.2	2 986 034	2 986 034	1
Feeder 6.3	0	0	0
Feeder 6.4	3 053 795	3 053 795	1
Feeder 6.5	0	0	0
Feeder 6.6	0	0	0
Feeder 6.7	0	0	0
Feeder 6.8	0	0	0
Feeder 6.9	0	0	0
Feeder 6.10	0	0	0
Feeder 6.11	0	0	0
Feeder 7.1	0	0	0

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 7.2	0	0	0
Feeder 7.3	0	0	0
Feeder 7.4	0	0	0
Feeder 7.5	0	0	0
Feeder 7.6	0	0	0
Feeder 7.7	0	0	0
Feeder 7.8	0	0	0
Feeder 7.9	0	0	0
Feeder 7.10	0	0	0
Feeder 7.11	0	0	0
Feeder 7.12	0	0	0
Feeder 7.13	0	0	0
Feeder 7.14	0	0	0
Feeder 7.15	0	0	0
Feeder 7.16	0	0	0
Feeder 8.1	0	0	0
Feeder 8.2	0	0	0
Feeder 8.3	0	0	0
Feeder 8.4	0	0	0
Feeder 8.5	0	0	0
Feeder 8.6	0	0	0
Feeder 8.7	0	0	0
Feeder 8.8	0	0	0
Feeder 8.9	0	0	0
Feeder 8.10	1 369 645	1 369 645	1
Feeder 8.11	2 328 920	2 328 920	1
Feeder 8.12	0	0	0
Feeder 8.13	0	0	0

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 8.14	0	0	0
Feeder 8.15	0	0	0
Feeder 8.16	0	0	0
Feeder 8.17	0	0	0
Feeder 8.18	0	0	0
Feeder 8.19	0	0	0
Feeder 8.20	0	0	0
Feeder 8.21	0	0	0
Feeder 8.22	0	0	0
Feeder 8.23	638 679	0	0
Feeder 8.24	0	0	0
Feeder 8.25	0	0	0
Feeder 8.26	0	0	0
Feeder 8.27	0	0	0
Feeder 8.28	0	0	0
Feeder 8.29	0	1 087 931	0
Feeder 9.1	2 894 837	2 894 837	1
Feeder 9.2	0	0	0
Feeder 9.3	0	1 370 283	0
Feeder 9.4	0	0	0
Feeder 9.5	0	0	0
Feeder 9.6	1 952 815	1 952 815	1
Feeder 9.7	0	0	0
Feeder 9.8	0	0	0
Feeder 9.9	0	0	0
Feeder 9.10	0	0	0
Feeder 9.11	0	0	0
Feeder 9.12	0	0	0

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 9.13	1 829 197	1 829 197	1
Feeder 9.14	0	1 561 224	0
Feeder 9.15	0	1 600 550	0
Feeder 9.16	0	0	0
Feeder 9.17	0	0	0
Feeder 9.18	0	0	0
Feeder 9.19	0	0	0
Feeder 9.20	0	0	0
Feeder 9.21	0	0	0
Feeder 9.22	0	0	0
Feeder 9.23	0	1 223 675	0
Feeder 9.24	0	0	0
Feeder 9.25	0	0	0
Feeder 10.1	0	2 667 320	0
Feeder 10.2	0	1 543 614	0
Feeder 10.3	0	1 899 614	0
Feeder 10.4	0	0	0
Feeder 10.5	0	0	0
Feeder 10.6	1 867 730	1 867 730	1
Feeder 10.7	0	0	0
Feeder 10.8	0	0	0
Feeder 10.9	0	0	0
Feeder 10.10	0	0	0
Feeder 10.11	0	0	0
Feeder 10.12	0	0	0
Feeder 10.13	0	0	0
Feeder 10.14	2 987 674	2 987 674	1
Feeder 10.15	3 167 648	3 167 648	1

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 10.16	0	0	0
Feeder 10.17	5 702 284	5 702 284	1
Feeder 10.18	1 522 558	1 522 558	1
Feeder 10.19	0	0	0
Feeder 11.1	0	0	0
Feeder 11.2	0	0	0
Feeder 11.3	0	0	0
Feeder 11.4	0	0	0
Feeder 11.5	351 571	0	0
Feeder 11.6	0	0	0
Feeder 11.7	0	0	0
Feeder 11.8	0	0	0
Feeder 11.9	0	0	0
Feeder 11.10	0	0	0
Feeder 11.11	0	0	0
Feeder 11.12	0	0	0
Feeder 11.13	0	0	0
Feeder 11.14	0	0	0
Feeder 11.15	0	0	0
Feeder 11.16	0	0	0
Feeder 12.1	0	0	0
Feeder 12.2	0	0	0
Feeder 12.3	0	0	0
Feeder 12.4	1 212 822	1 212 822	1
Feeder 12.5	1 647 267	1 647 267	1
Feeder 12.6	0	0	0
Feeder 12.7	0	0	0
Feeder 12.8	0	0	0

Feeder	Essential meter's monthly energy [Standard Deviation]	Essential meter's monthly energy [Volatility KPI]	Match? [1 = Yes; 0 = No]
Feeder 12.9	0	0	0
Count the number of feeders that agree in both methods			27
% feeders that agree using both methods			75%

Table F-2 indicates that of 36 important meters which were identified using the Volatility KPI, 75% (27 matching feeder meters / 36 essential feeder meters) of the meters agreed using standard deviation. This implies that the Volatility KPI can be used to a satisfactory level to identify important meters, with a 75% confidence level.