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Ministère de l'Enseignement Supérieur et de la Recherche Scientifique
جــامعة أبو بـكــر بــلـــقـــايــد– تـــلمســـان –
Université Aboubakr Belkaïd– Tlemcen –
Faculté de Technologie

THESIS

Present for the **MASTER'S** degree
In: Civil Engineering
Speciality:Structure: Energy Efficiency in Building Construction
By:

- Baba Ahmed Djaoued
- Baba Ahmed Nihel Rania

Topic

THE INITIAL ASSESMENT FOR THE IMPLEMENTATION OF AN ISO 50001 COMPLIANT ENERGY MANAGEMENT SYSTEM: A CASE STUDY

Defended before the committee composed of

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

اللهم لك الحمد والشكر في الأولى ولك الحمد والشكر في الآخرة ولك الحمد والشكر من قبل ولك الحمد والشكر من بعد وآناء الليل وأطراف النهار وفي كل حين ودائماً وأبداً.

Acknowledgements

Praise be to Almighty God who has allowed us to finish this rich course with this modest search. It is with immense gratitude that we would like to thank our supervisor Dr. "BENACHENHOU Kamila Amel" as well as our co-supervisor Dr. "HAMIMED Nadia" for their valuable advice and availability throughout the realization of this work, as well as for the guidance, trust, and help they have given us.

Our sincere thanks also go to the members of the jury, especially the president Mr. "MEGNOUNIF A." and the examiner Mr. "HENAOUI M.", for the interest they have shown in our work by agreeing to examine this work.

Our sincere thanks go to all our professors in the Department of Civil Engineering of the Faculty of Technology in Tlemcen. Finally, we would also like to thank all the people who participated directly or indirectly in the realization of this work. Let us not forget Ayoub KHERBOUCHE and Hind BABA AHMED who have fruitfully enriched this work.

Dedication

I dedicate this thesis to my family, whose unconditional support and love have been sources of strength and inspiration throughout this academic journey. This work is also offered to my mother, for her wisdom, patience, and constant support. It is well dedicated to my father, for his encouragement and belief in my abilities. I would like to thanks my brothers, Walid, Nassim, and Rachid, for their support and companionship.

To my dear friends Ayoub, Soufiane, Karim, Mohamed, Nihel, and Hind, for their precious friendship and moral support. Their presence has been a source of motivation and comfort.

And above all, I dedicate this work to the heroic people of Palestine, for their courage, resilience, and relentless struggle for justice and freedom. May this dedication be a tribute to their indomitable strength and unyielding spirit.

Baba Ahmed Djaoued

Dedication

I dedicate this thesis to my parents, who have always supported me in my projects and encouraged me to pursue my dreams. Their sacrifices and unconditional love have been the inspirations behind my achievements. To my mother, whose strength, patience, and love have always supported me. Your commitment and confidence in me have given me the courage to persevere. Thank you so much. To my father, who has always believed in me and supported me at every step of this journey. Your wisdom, dedication, and advice have guided and inspired me throughout this adventure. Thank you from the bottom of my heart for everything you have done for me. To my brother Racim, whose support, encouragement, and constant presence have been essential throughout this journey.

To my cousins, who have always been there for me with their support, friendship, and encouragements. To Hind,Razane, Ghizlèneand Ines who have always been there for me. To my friends, who have been my companions, my confidants, and my sources of inspiration. Not to forget my teammate DJAWAD for his moral support, patience, and understanding throughout this project. Thank you all for your love and encouragement.

Baba Ahmed Nihel Rania

Abstract

This thesis examines Algeria's energy policy, highlighting the challenges associated with increasing energy consumption and the transition to a more sustainable approach. It examines government initiatives to promote energy efficiency and renewable energy, emphasising the importance of energy audits and compliance with standards such as ISO 50001. It also focuses on the integration of ISO 50001 to improve energy management systems, detailing the key elements of this standard and exploring how the process approach, illustrated by Crosby's turtle diagram, as well as the PDCA cycle, also called the Deming wheel, facilitates the structuring and visualisation of each phase of the energy audit. A case study of the MDC laboratory demonstrates the practical application of this methodology, identifying seasonal trends in energy consumption and enabling continuous improvement in line with the requirements of ISO 50001. In summary, this work provides a solid foundation for considering improvements and integrating recommendations to optimise the laboratory's energy conditions.

Keywords: Energy efficiency, ISO 50001, Energy audits, Energy management systems, Crosby's turtle

Résumé

Ce mémoire examine la politique énergétique de l'Algérie, mettant en lumière les défis liés à la consommation croissante d'énergie et à la transition vers une approche plus durable. Il explore les initiatives du gouvernement visant à promouvoir l'efficacité énergétique et les énergies renouvelables, soulignant l'importance des audits énergétiques et de la conformité à des normes telles que l'ISO 50001. En outre, il se concentre sur l'intégration de la norme ISO 50001 pour améliorer les systèmes de gestion de l'énergie, détaillant les éléments essentiels de cette norme et explorant comment l'approche processus, illustrée par le diagramme de la tortue de Crosby, ainsi que le cycle PDCA aussi appeler deming weel, facilite la structuration et la visualisation de chaque phase de l'audit énergétique. Une étude de cas au laboratoire MDC démontre l'application pratique de cette méthodologie, identifiant des tendances saisonnières de consommation d'énergie et permettant une amélioration continue conforme aux exigences de l'ISO 50001. En somme, ce mémoire constitue une base solide pour envisager des améliorations et intégrer les recommandations en vue d'optimiser les conditions énergétiques du laboratoire.

Mots-clés : Efficacité énergétique, ISO 50001, Audits énergétiques, Systèmes de gestion de l'énergie, Tortue de Crosby

الملخص

تتناول هذه الأطروحة سياسة الطاقة في الجزائر، مع تسليط الضوء على التحديات المرتبطة بزيادة استهلاك الطاقة والانتقال إلى نهج أكثر استدامة. ويتناول المبادرات الحكومية لتعزيز كفاءة الطاقة والطاقة المتجددة، مع التركيز على أهمية عمليات تدقيق الطاقة والامتثال لمعايير مثلISO 50001.كما يركز على تكامل ISO 50001التحسين أنظمة إدارة الطاقة، مع تفصيل العناصر الرئيسية لهذا المعيار و استكشاف كيف أن نهج العملية، الموضح في مخطط سلحفاة كروسبي،" وكذلك دورةPDCA ، التي تُسمى أيضًا عجلة ديمينغ, يسهل هيكلة وتصور كل مرحلة من مراحل تدقيق الطاقة. توضح دراسة حالة لمختبر MDC التطبيق العملي لهذه المنهجية، وتحديد الاتجاهات الموسمية في استهلاك الطاقة وتمكين التحسين المستمر بما يتماشى مع متطلباتISO 50001. وباختصار، يوفر هذا العمل أساسًا متينًا للنظر في التحسينات ودمج التوصيات لتحسين الأداء. تحسين ظروف الطاقة في المختبر.

مفاتيح الكلمات: كفاءة الطاقة,ISO 50001,تدقيقات الطاقة، أنظمة إدارة الطاقة، سلحفاة كروسبي.

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LIST OF ACRONYMSAND ABBREVIATIONS

BTU: British thermal unit.

TEP: Tons of petrol equivalents.

Mbpd: Thousand barrels per day.

LPG: Liquefied petroleum gas.

GNC: Compressed natural gas.

LPGc: Liquefied petroleum gas carrier.

CNES: National energy saving certificate.

HPE level: High energy performance**.**

BEPOS level: Positive energy building.

PNME: National electric mobility plan.

SMEn: Energy management system.

EnPI: Energy performance indicator.

EnB: Energy baseline.

EMS: Energy management system.

Cm: centimeter.

K**W**: kilowatt.

KN: kilo Newton.

V: voltmeter.

m/s: meter par second.

m: meter.

h: hour.

wh: watt hour.

bcm: billions of cubic meters.

MTJ: million terra joules.

TEP: temp equivalentpetrol.

General Introduction

Energy efficiency has become a key priority for companies and organizations looking to reduce their carbon footprint reduce their operational costs and comply with environmental regulations. ISO 50001, an international energy management standard, provides a systematic framework for integrating best energy management practices into daily operations. This case study explores the initial assessment necessary for the implementation of an ISO 50001 compliant energy management system, focusing on the energy context, energy audit, and the practical application of management tools and techniques in a laboratory project. The first chapter provides a global overview of the energy context, essential to understand the issues and opportunities related to energy management, by detailing the definition of energy, its units of measurement, energy sources, and global consumption and in Algeria, as well as energy efficiency and energy policies in Algeria. The second chapter deepens the energy audit under ISO 50001, using recognized methodologies such as the PDCA cycle and the Crosby Turtle process to optimize the audit steps. Finally, the third chapter illustrates the practical application of the concepts and methodologies discussed through a laboratory project, detailing the building materials, measuring devices, the results and their interpretation, as well as the diagnosis of the physical state of the laboratory in terms of energy management. This structure offers a comprehensive approach to evaluating and implementing an energy management system in accordance with ISO 50001, combining theoretical and practical elements for a global and specific framework.

CHAPITRE I Energy Context

I.1 Introduction

Energy consumption in Algeria has changed markedly in recent years, with a significant increase in the use of natural gas, electricity and petroleum products. Faced with this trend, the Algerian government has put in place ambitious initiatives to promote energy efficiency and the development of renewable energy in the country.

This chapter explores in detail the different aspects of Algeria's energy policy, with a focus on efforts to address the challenges related to energy consumption and the transition to a more sustainable energy future. It begins by defining the key concepts related to energy and presenting the main energy sources used worldwide. It then analyzes the trends in global energy consumption, before focusing specifically on the situation in Algeria.

The rest of the chapter looks at the initiatives put in place by Algeria to improve energy efficiency, especially in the construction sector. It also examines the ambitious renewable energy development program, which aims to diversify the country's energy mix and reduce its dependence on hydrocarbons.

Finally, the chapter focuses on the importance of energy audit in Algeria, an essential tool to identify opportunities to improve energy efficiency and reduce the costs associated with energy consumption. It explores the different stages of the audit process and the benefits it brings to companies and institutions.

I.2 Definition of Energy

Energy is a basic physical quantity that appears in different forms, such as kinetic, potential, thermal, electrical, and chemical or nuclear energy. These types of energy are also interconnected by physical laws; thus, they can move and change from one form to another in various processes and systems. For example, in the case of a mechanical system, the kinetic energy possessed by a moving object can be transformed into potential energy when this object is raised against gravity. The rules of conservation and the principles of conversion have been established and are fundamental to understanding the functioning of our universe, which has led to their extensive study in disciplines such as physics and the science of materials. [1].

In the field of environmental and sustainable development concerns, energy occupies an important place. The transition to renewable energy resources and the adoption of energy management measures, as demonstrated by the ISO 50001 relating to the energy management system standard, help to minimize the ecological costs resulting from energy consumption and to ensure a reliable power supply over the years [2].

Energy is indeed a centre of interest in global socio-economic conditions. The availability and affordable accessibility of energy resources play an important role in the economic development of countries and the quality of life of individuals. Energy policies, investments in energy infrastructure and international partnerships are important determinants in ensuring a balanced and equitable supply of energy resources [16].

I.2.1 Units of Measurement

In the contemporary world, energy is expressed using various units of measurement, each adapted to a specific field. The Joule (J), the fundamental unit of the International System (SI) for energy, represents the energy necessary to exert the force of a Newton over a distance of one meter. This universal standard is essential in physics and engineering, applying to a wide range of disciplines, from mechanics to thermodynamics [3].

To evaluate electricity consumption and production, the kilowatt-hour (kWh) is preferred, expressing the electrical energy used or produced over a given period. In the field of nutrition, calorie (cal) and kilocalorie (kcal) quantify the energy provided by food, a kilocalorie being defined as the energy needed to raise the temperature of a kilogram of water by 1°C [4].

In the United States, the British Thermal Unit (BTU) is often used to measure heating and air conditioning needs, indicating the energy required to increase the temperature of a pound of water by one degree Fahrenheit [5].

Finally, the tone of oil equivalent (TEP) is used to quantify large quantities of energy, especially in discussions on energy production and energy policies [6]. These units illustrate the diversity and complexity of modern energy management, highlighting the importance of a precise understanding to optimize the use of resources and encourage sustainability. All this information can be found in the table below.

Table I-1 Energy Measurement Units

Unit of measurement	Joules	KWH	TEP
1 Joule	1	0.00000277	0.00000000000238
1 KWH	3600000	1	0.0000857
1 TEP	4200000000	11666	1

I.3 Energy Sources

Energy resources, also referred to as primary energies, represent the natural elements exploited by humanity to produce energy in a usable way. These sources include fossil fuels such as coal, oil and natural gas, nuclear resources such as uranium, as well as renewable options such as solar, wind, hydraulic, biomass and geothermal energy, which are shown schematically in the following figure I.1 [13].

These resources are directly extracted from the environment without requiring prior processing and are immediately available for use. Nevertheless, non-renewable energy resources come from complex and prolonged transformation processes, resulting in a permanent decrease in these natural stocks during their exploitation. In addition, although renewable energy sources seem inexhaustible, excessive use can also cause problems. For example, biomass can be consumed faster than it can regenerate, or the extraction of heat from a geothermal reservoir can exceed the natural capacity to regenerate the earth's heat [15].

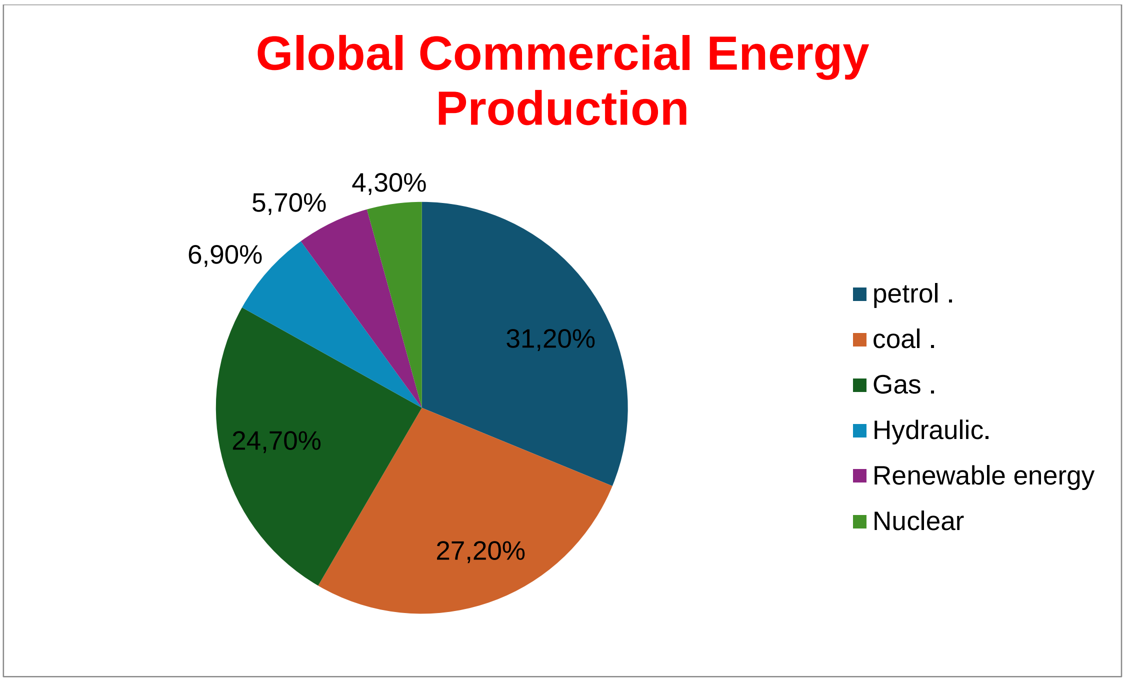

Figure I-1 Energy Marketed in the World

- **Fossil Fuels (Oil, Coal, Gas):** These energy sources represent a considerable share of the global energy supply, with oil in the lead, with a market share of 31.2%, followed by coal with 27.2% and gas with 24.7%. Fossil fuels, characterized by their non-renewable nature, are exploited to meet global energy needs, despite major environmental concerns related to their greenhouse gas emissions, thus contributing to climate change and air pollution.

- **Hydropower Representing 6.9% of the Market Share: Hydropower** is a significant source of renewable energy. It is produced from the kinetic force of water, usually exploited through dams and hydroelectric power plants. Although considered a clean source of energy, hydroelectricity is not without environmental consequences, such as the disruption of river ecosystems and the flooding of land.

- **Renewable Energy (other than hydraulics):** Other renewable energy sources, including solar, wind, biomass and geothermal energy, together account for 5.7% of the market share. These constantly expanding energy resources play a decisive role in the transition to a more sustainable energy system, because of their renewable nature and low environmental impact.

- **Nuclear Energy:** Representing 4.3% of the global market share, nuclear energy is a low-carbon energy source. However, it raises concerns related to the safety of facilities, radioactive waste management and nuclear proliferation, which limits its deployment in many countries.

This distribution highlights the proportion of each energy source in the global energy market. Notably oil, coal and natural gas occupy the first places as the main sources of commercial energy, together totalling more than 80% of the market share. In contrast, renewable energy and nuclear energy contribute to a relatively smaller share of the global energy supply.

I.4 Global Energy Consumption

The projection that global demand for fossil fuels will peak by 2030 highlights a major turning point in global energy consumption. This evolution results from a combination of factors, including stricter climate policies, improved energy efficiency and rapid growth in renewable energies. A significant transition in demand for coal is expected, with a significant decrease in its share in the global energy mix. However, natural gas and oil, although they will also grow in the coming years, should remain essential components of the energy mix, demonstrating their pivotal role in ensuring the energy security and flexibility of the global energy system.

Figure I.2 illustrates the trajectory of global demand for fossil fuels in millions of Terajoules (TJ) since 1990 with a projection until 2050. The increasing trend until 2020 demonstrates the historical dependence on these energy sources. The shaded area indicates the future projection, with demand peaking around 2030 and then gradually decreasing. This decrease is significant and represents a change of direction towards cleaner and more sustainable energy sources. It is essential to note that this figure supports the argument that, even with an expected decrease, natural gas and oil will remain important elements in the global energy balance for decades to come.

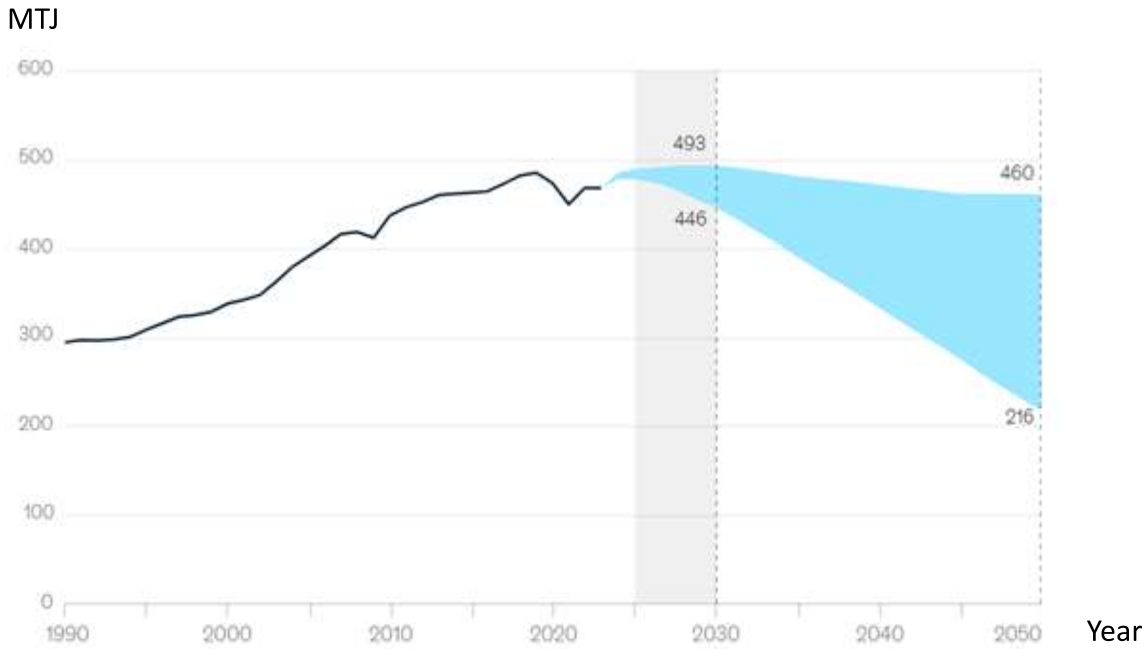

Figure I-2 Global Demand for Fossil Fuels, Million TJ

In most scenarios, demand for natural gas is expected to increase until 2040, mainly due to its crucial role in balancing renewable energy-based electricity generation. Natural gas is perceived as a transitional energy source to a low-carbon future, because of its ability to complement intermittent renewable energy sources such as solar and wind power. However, the trajectory of natural gas demand differs considerably as it approaches 2050, reflecting the variability of global energy policies and the speed of adoption of renewable and electrification technologies.

The evolution of global demand for natural gas is depicted in Figure I.3, which shows consumption in billions of cubic meters (bcm) from 1990 to 2050. The constant increase until 2020 is followed by projections showing a sustained increase until about 2040, highlighting the pivotal role of natural gas in the energy transition. However, the wide dispersion of forecasts after 2040 illustrates the growing uncertainty about the adoption of renewable technologies and the impact of energy policies. This figure not only reveals the increased importance of natural gas as a complement to renewable energies but also highlights the need for flexible energy planning to adapt to future market developments and climate imperatives [8].

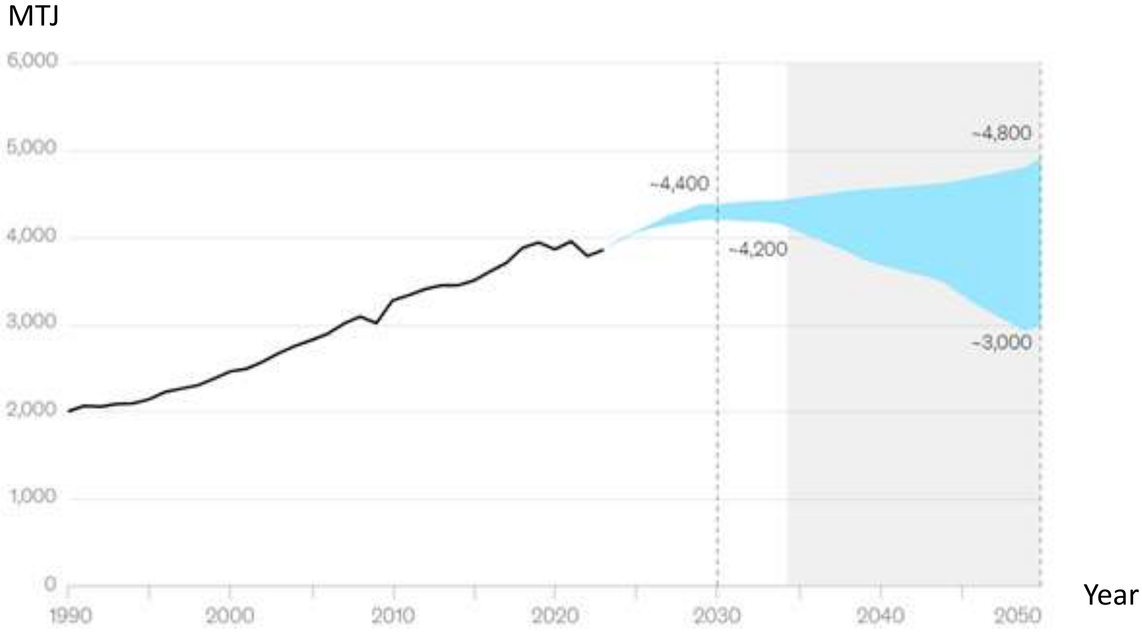

Figure I-3 Global Demand for Natural Gas, bcm (billion cubic meters)

Oil demand is expected to continue to grow during this decade before starting to decline after 2030, illustrating the challenges and opportunities in the transport sector, in particular. The evolution of oil demand will be deeply influenced by factors such as the increase in the efficiency of transport engines, the rise in transport electrification, and the development of alternative fuels. The commitments achieved scenario envisages a significant demand reduction, highlighting the potential impact of ambitious policies on the transformation of the energy sector. On the other hand, the Moment Fug ace scenario highlights the risks associated with a slower pace of decarburization and technological innovation.

Figure I.4 illustrates the expected evolution of global oil demand, expressed in millions of barrels per day (Mbpd). According to projections, this demand should continue to grow until the end of this decade before reaching a peak. Subsequently, a downward trend is anticipated, in correlation with global efforts to transition to more sustainable and less carbon-emitting modes of transport. Nevertheless, the post-2030 trajectory remains uncertain, highlighting the dependence of this development on climate policies, technological innovation and the adoption of electric vehicles and other alternatives [8].

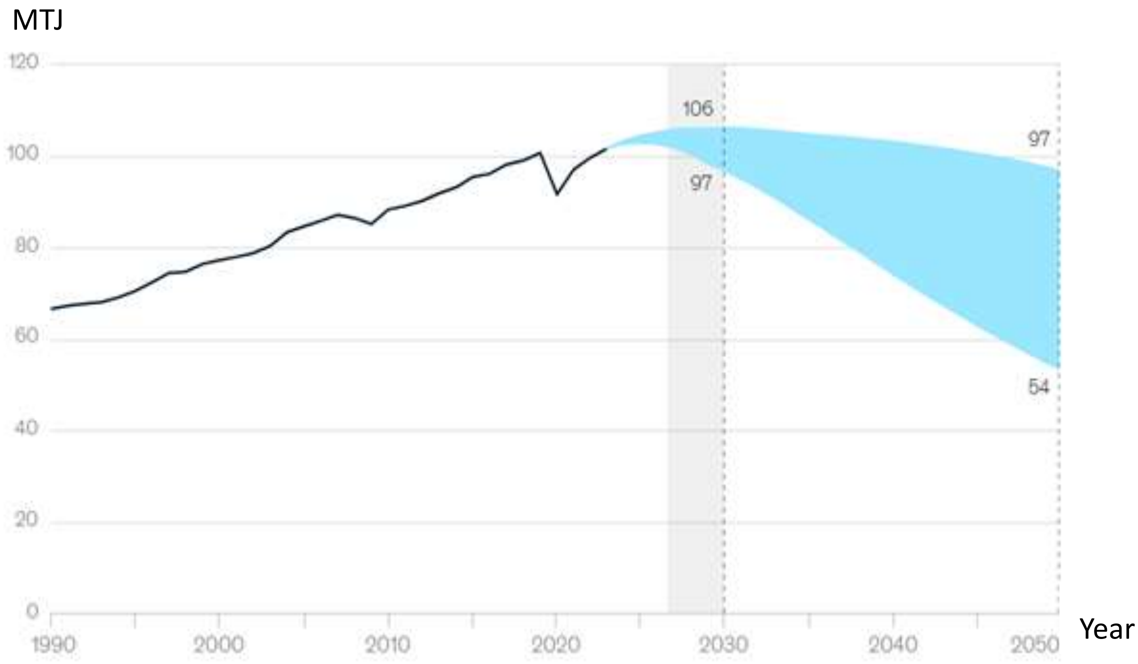

Figure I-4 Global Oil Demand, Million Barrels per Day (Mbpd)

I.5 Energy Consumption in Algeria

Energy consumption in Algeria has changed markedly in recent years, with a significant increase in energy consumption, especially in the use of natural gas, electricity and petroleum products. In 2021, national final energy consumption rebounded by 8% to 50.2 million tons of oil equivalent (TEP), after a decrease in 2020 due to various factors, including the repercussions of the COVID-19 pandemic [10]. This increase is mainly attributed to the growth of the residential sector, as well as an increase in demand in the industrial and transport sectors.

The distribution of national energy consumption did not change significantly between 2020 and 2021. Final consumption remains predominant, representing 75% of the total, followed by the consumption of energy industries (12%), non-energy industries (7%) and finally losses (6%), as indicated in the following figure I.5 [11].

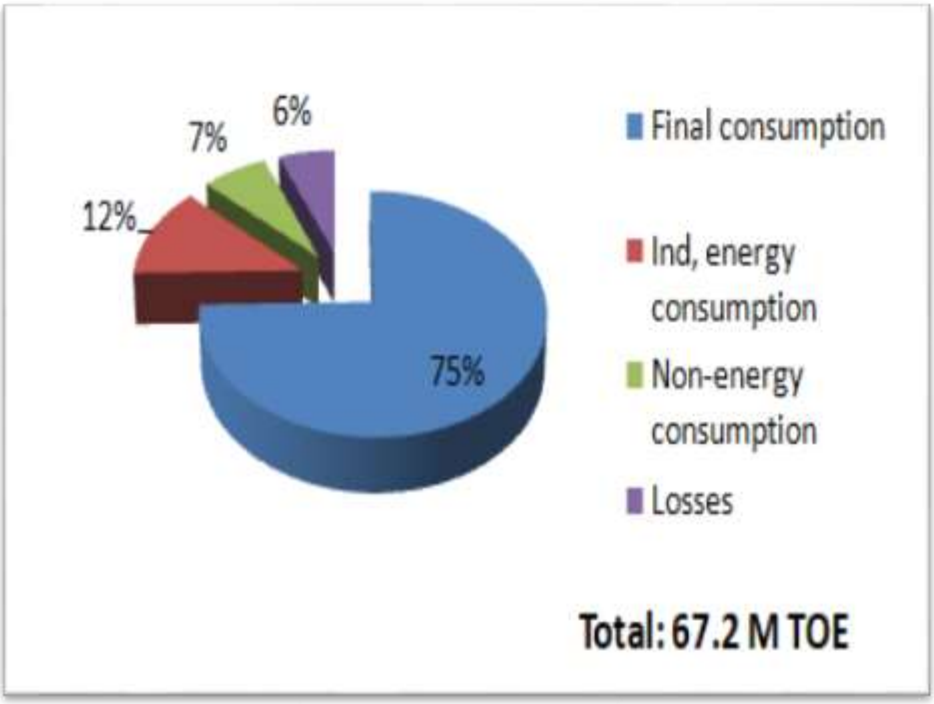

Figure I-5 Structure of National Energy Consumption

Natural gas dominates as the main source of energy consumption in Algeria, accounting for 40% of total consumption, followed by electricity at 30%, petroleum products at 22% and LPG at 5%. National demand for gas is mainly generated by households and the tertiary sector, representing 66% of total consumption.

In the decade preceding 2019, final energy consumption in Algeria increased from 31.6 million tons of oil equivalent (TEP) to 50.4 million TEP, marking an increase of 59%. This growth reflects an upward trend in consumption in all sectors, especially in the residential and tertiary sectors, followed by transport and industry.

To meet these challenges, the Algerian government has put in place a national energy efficiency program to reduce energy consumption by 9% by 2030. This initiative targets several key sectors, including transport, construction, and industry, to control the impact on energy demand while supporting the country's economic growth [9].

I.6 Energy Efficiency in Algeria

Algeria attaches strategic importance to energy efficiency to cope with the increase in energy demand and the decrease in fossil resources. The country's energy consumption has increased significantly over the last decade, from 31.6 million tons of oil equivalent (TEP) in

2010 to 50.4 million PTE in 2019, a growth of 59% over ten years [9]. To respond to this trend, initiatives have been taken, especially in the building sector where the focus is on thermal insulation to optimize energy consumption in new buildings and existing infrastructure.

This program provides for specific measures such as the introduction of energy efficiency measures, the modification of behaviours and the improvement of equipment to produce the same goods or services while using less energy.

As part of these efforts, local industry is encouraged to manufacture high-performance equipment such as solar water heaters and economic lamps, to promote energy efficiency and contribute to the diversification of the national economy. The government is also working to promote clean fuels such as LPGc (liquefied petroleum gas) and GNc(compressed natural gas) for transport, to enrich the fuel supply and reduce the share of diesel, which should allow energy savings of more than 16 million PE by 2030 [12].

I.6.1 The Construction Sector

Energy efficiency in the building sector is of crucial importance to meet contemporary challenges related to energy consumption and the reduction of greenhouse gas emissions. It is defined as the relationship between the service rendered and the energy devoted, based on a building's ability to effectively manage its energy, optimize flows and achieve a balance between production and consumption. In this context, air conditioning, encompassing heating, cooling and ventilation, represents the main energy consumption item of the building.

The European directives on the energy performance of buildings emphasize the importance of considering the building as a construction where energy is used to regulate the indoor climate. However, the use of energy in the building goes beyond the simple regulation of the indoor climate. Indeed, the building can not only consume energy but also generate it, in particular through the operation of furniture equipment. This distinction is essential to understanding the different sources of energy consumption and to promoting practices to reduce them.

To promote energy efficiency in the building sector, an ambitious program has been put in place. This program aims to encourage the adoption of innovative practices and technologies, particularly the thermal insulation of existing and new buildings. In addition, it seeks to promote the integration of high-performance equipment into the local market, such as solar water heaters and economical lamps, to improve indoor comfort while reducing energy consumption.

The creation of a local industry of thermal insulation and high-performance equipment is a key element of this strategy, making it possible to boost the sector while contributing to the reduction of the country's energy dependence [19].

I.6.2 The Renewable Energy Program in Algeria

The renewable energy program mainly aims to increase the share of clean energy in the country's energy mix. Algeria, thanks to its considerable solar and wind potential, aims to develop renewable energy projects to produce electricity. This strategy is crucial not only to meet the growth of energy demand but also to contribute to the fight against climate change.

The National Program is part of a long-term vision to diversify the country's energy sources and reduce its dependence on hydrocarbons. Algeria, with exceptional solar potential, intends to take advantage of its natural resources to develop its capacity to produce renewable energy. The goal set is ambitious: to install 22,000 MW of renewable energy by 2030. This capacity is intended to cover the country's growing electricity needs while considering export opportunities. This strategic orientation reflects Algeria's desire to be part of a sustainable development approach and to contribute to the overall effort to reduce greenhouse gas emissions as indicated in the following figure I.6[14].

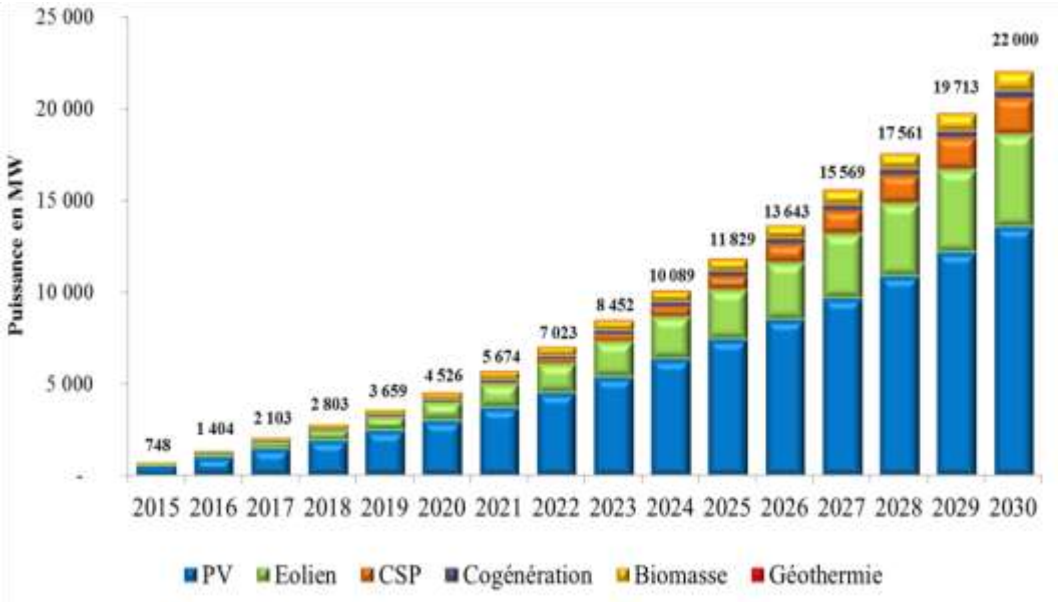

Figure I-6 Consistency of the Renewable Energy Development Program

Algeria relies on solar and wind, with a particular emphasis on photovoltaic and thermal solar, taking advantage of one of the highest sunshine durations in the world. This strategic orientation represents not only a major opportunity for clean energy production, but also for local economic development, in particular through job creation and the strengthening of local skills. The strategy adopted also includes the development of a national renewable energy production equipment industry, aimed at reducing dependence on technology imports and promoting the country's energy autonomy.

To finance this energy transition, Algeria plans to use revenues from hydrocarbons, thus demonstrating a willingness to invest in the country's sustainable energy future. However, the program faces several challenges, particularly in terms of financing, the development of the necessary infrastructure and the training of human capital. To overcome these obstacles, dedicated structures such as the High Commission for Renewable Energy and the Ministry of Energy Transition and Renewable Energies have been set up. These institutions play a crucial role in the coordination and support of renewable energy initiatives, thus contributing to the realization of national energy transition objectives [14,12].

I.7 Energy Policy in Algeria

Energy policy in Algeria is a crucial subject for the country, in particular, because of its historical dependence on hydrocarbons. According to the National Economic and Social

Council (CNES), the energy transition has become a major issue in Algeria, with a strong emphasis on renewable energies to diversify energy sources and guarantee the country's economic independence [20]. CNES has set up a working group to identify the best ways to integrate renewable energy into the national economy and to propose an energy consumption model adapted to Algerian society. The report of the Government's 2020-2024 economic recovery plan stresses that natural gas is the main source of energy in Algeria, representing 65% of the energy mix, followed by 35% oil [12]. However, the country aims to increase the share of renewable energy in its electricity production, with an initial target of 40% renewable electricity by 2030, revised downwards to 27% in 2015. Algeria is striving to achieve this objective within the deadlines set. Energy cooperation between the European Union and Algeria is also an important aspect of the country's energy policy. High-level discussions took place to strengthen cooperation in renewable energy, energy efficiency and the interconnection of electricity networks. A cooperation programworth15 million euros in 2023 has been designed to support the development of renewable energy projects, the integration of renewable energy into the energy system, electrical interconnection, the development of a green hydrogen economy, and energy efficiency in buildings and public enterprises [21]. In this context, the National Energy Management Fund (FNME), created by Law 99-09 and regulated by Decree No. 2000-116, aims to promote energy efficiency through innovative projects. Financed by energy consumption taxes, state subsidies and other contributions, it co-finances initiatives of the National Energy Management Program (PNME) and projects by public and private operators. The FNME supports awareness, training, research, and development in the field of energy, while monitoring and controlling projects funded by the Ministry of Energy or APRUE. The National Energy Management Program (Decree No. 04-149 of May 19, 2004) defines the orientations and objectives of the energy management policy[22]. It oversees the projects of economic operators and focuses on the development of energy efficiency standards, awareness, education, and energy saving, energy substitution, as well as research and development in energy efficiency

In the building sector, Algeria's energy policy, supported by the National Energy Management Fund (FNME) and the National Energy Management Program (PNME), plays a crucial role in improving energy efficiency and reducing energy consumption[22]. The FNME co-finances projects to integrate innovative energy technologies and energy efficiency standards in buildings. This includes the improvement of thermal insulation, the use of energy-efficient building materials, and the installation of more efficient heating, ventilation and air conditioning systems. In addition, awareness, training and education initiatives are put in place to inform sector actors and the general public about sustainable construction practices and energy savings. These efforts aim to reduce dependence on hydrocarbons, reduce greenhouse gas emissions, and promote sustainable development in the building sector in Algeria.

I.8 Energy Audit

Energy audits are a systematic study and analysis of energy entering and leaving a building or system to identify areas where energy efficiency measures and energy savings can be implemented to reduce energy consumption and increase energy efficiency. These audits are mainly aimed at identifying actions to save energy and costs, as well as achieving other objectives such as reducing carbon emissions, improving environmental conditions and systematically monitoring energy consumption [17]. The energy audit process generally consists of several phases, including the collection of pre-survey information, building surveys, data analysis, the formulation of energy-saving solutions and the presentation of results. The figure below represents the seven phases of energy audit [22].

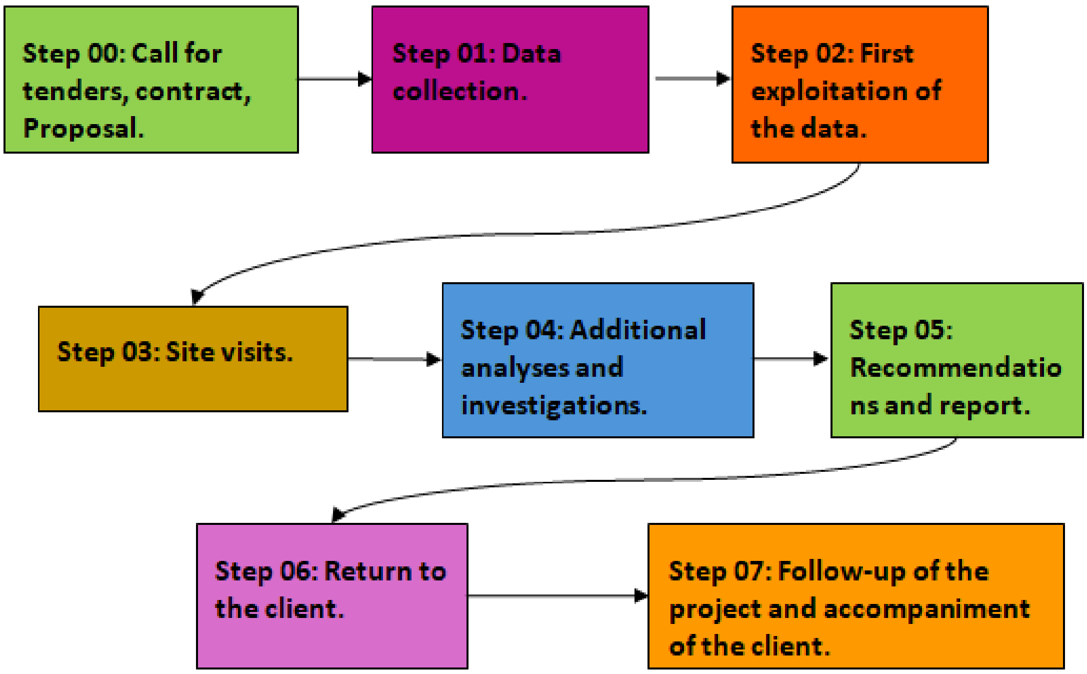

Figure I-7 The Different Phases of an Energy Audit

I.8.1 Step 1: Data Collection before the On-Site Visit

Before starting any process, it is essential to conduct rigorous data collection. This involves gathering a variety of information, including plans, invoices, control reports, and identifying resource persons (making specific request lists). This step is the necessary basis for the continuation of the operations. The information that we result:

1. Data Collection/Email/Telephone/ Fax

- Available plans, and market documents.
- Invoices over 3 years (on EXCEL file), monthly if possible.
- Invoices for successive rehabilitations.
- Statements, counts, etc.
- Measurements of PH, TH, and water quality.
- Control office reports.
- Energy uses.

I.8.2 Step 2: First Exploitation of Data

In this initial stage of data exploitation, we start the process by preparing the on-site visit, as an example, we carry out the inventory of the following data:

- Analyze consumption: first analyses by items.
- First ratios.
- Consistency of data on consumption/uses of buildings.
- Harvest the degrees real days from 3 years.
- Carry out the graphical analysis of consumption.

I.8.3 Step 3: Preparation for a Visit to the Site

Before conducting an on-site visit, careful preparation is essential to ensure effective and comprehensive data collection. By following the data below:

1. Preparation of Documents for Collection

- Establish collection sheets.
- Plans in A3.
- Questionnaires.

2. Plan the Appointments

- Decision-makers.
- Technicians (site memory).
- Uses.

3. Checklist and Necessary Measurement Tools

- Luxmeter.
- Cameras.
- Clinometers.
- Screwdriver and pliers.
- Small mirror to read in inaccessible places.

- Compass.
- Decameter, laser-meter, caliper.

4. Visits to Buildings and Equipment

- All technical rooms.
- Representative premises.
- Specific equipment.
- Inventory in each room: terminal devices, lighting, ventilation.
- Surveys and punctual measures are to be considered.

I.8.4 Step 4: Data Analysis

A data analysis would be crucial that make it possible to know:

- Re-paste data: concordance of actual data with the calculations.
- Affect the overall consumption of the different energy stations and arrive at the completeness of identifying anomalies.

if necessary, we can resort to:

- Additional measures: one-off inspections:
    - ✓ Performance measures of certain equipment.
    - ✓ Levels of instruction on the premises.
- Heavy instrumentation: energy monitoring of the building over a representative period.

I.8.5 Step 5: Recommendations and Report

For the success of this step, these different points must be respected:

1. Content of the Report:

- Summary of the audit proposals.
- Structured summary for the completeness of the AEB.
- Inventory with a setting of the initial energy image.

- Critical analysis of the existing (this phase can be an intermediate report).

2. Encourage a passage to the Act:

- Encourage rapid decision-making by looking for win-win measures.
- Scenarios established with the prospect of heritage management of an objective for example HPE level, factor level4, BEPOS level, (positive energy building), etc.

I.8.6 Step 6: Return to the Client

The success of the audit process hinges on effective communication of findings and recommendations. This step involves delivering a comprehensive presentation to the client, ensuring that all key stakeholders understand the results and are ready to make informed decisions.

- The widest possible presentation meeting (all the interlocutors involved in the chain of decisions).
- Interlocutors to be mobilized: decision-makers, payers, users, etc.
- Provide a slideshow presenting the ins and outs and encouraging rapid decision-making.

I.8.7 Step 7: Followup of the Project and Support of the Project Owner

The last step is to follow the project carefully and accompany the client, going through the following points:

- Modify his report according to the remarks of the project owner and the privileged scenario.
- Follow up until customer satisfaction.
- Be concerned about the follow-up given to the audit.
- Show availability for additional services (work mastery and follow-up of work) and restart periodically.

I.9 Mastery of Energy

Energy management in Algeria focuses on three main areas: exploiting the potential for energy efficiency, preserving national hydrocarbon resources and protecting the environment. The key objectives are to promote energy efficiency investments and create a dynamic market for energy management.

The modalities for implementing the law on energy management include:

- The introduction of energy efficiency standards and requirements
- Energy control and audits
- The development of the National Energy Management Program (PNME)
- Research and development
- Funding for initiatives
- Incentives and incentives
- Coordination of energy management actions
- Improving knowledge of the energy system
- User awareness

Algeria, through the APPRUE and other entities, implements this policy with missions defined by Decree No. 04-3 of 14 September 2004. These missions include the development and monitoring of the PNME, the creation of a national observatory for energy management, the dissemination of information, the organization of training and the promotion of energy efficiency [22].

I.10 Energy Management: the ISO 50001 Standard

The ISO 50001 standard represents a voluntary international standard developed to set up an energy management system (SMEn) to improve the energy performance of organizations. Its objective is to generate sustainable energy savings and optimize energy management by reducing the costs associated with energy consumption and reducing greenhouse gas emissions. There were two versions of the standard, the 2011 version and the current 2018 version [18].

The goals pursued by the ISO 50001 standard are as follows:

- Allow organizations to establish the systems and processes necessary to improve their energy performance, with an emphasis on energy efficiency, use and consumption.

- Lead to a reduction in greenhouse gas emissions and energy costs.
- This standard specifies specific requirements for the energy management system, thus allowing organizations to:
- Develop and implement a more efficient energy policy.
- Define objectives, targets and action plans to meet the commitments made in this policy.
- Measure the results of this energy policy based on factual data.
- Take the necessary measures to continuously improve their energy performance.

Applicable to all organizations, whether public or private, the ISO 50001 standard contributes to the achievement of the European Union's energy-saving objectives.

I.10.1 Comparison between the 2011 and 2018 Version Standard

The 2011 version of the ISO 50001 standard, as the first edition, had the main objective of providing a framework for establishing, implementing, maintaining and improving an energy management system. However, it was not yet fully aligned with other management system standards. In comparison, the 2018 version has been developed to harmonize with other management system standards, thus simplifying the integration of several management systems within the same organization. More specifically, the 2018 version aligns with the structure of the ISO 9001 quality management standard, facilitating the simultaneous management and integration of several management systems.

The 2018 version of the ISO standard introduced several important improvements to facilitate the understanding and consistent application of energy management concepts. It harmonizes terms and definitions with other ISO standards, which clarifies the concepts. It also places an increased emphasis on the commitment and responsibility of management in the implementation of the energy management system, and encourages closer integration with the organization's strategic management processes. New terms, such as "energy performance improvement", have been added to better define the expected objectives and results. The standard clarifies the types of energy included and possible exclusions, and standardizes energy performance indicators (EnPI) and basic indicators (EnB). Finally, it offers more detailed guidelines for the collection and analysis of energy data, allowing a more accurate evaluation of energy performance.For a detailed comparison between the 2011 and 2018 version, refer to the table in the Annex 1.

I.11 Certification

In Algeria, certification is of paramount importance for energy management and the reduction of energy costs. This process consists of the issuance of a certificate by an independent third-party body, attesting to the compliance of a product, service, organizational system or process with current standards and regulations. This certification is carried out by an approved organization, outside the company concerned, which guarantees compliance with the requirements specified in the relevant standards. It is subject to regular control by the third-party certifier and can be renewed after a period of validity.

Certification of compliance with the ISO 50001 standard is a rigorous process to certify that the organization in question has established an energy management system (SMEn) in line with the criteria established by the ISO 50001 standard. This process includes several crucial steps, including the initial compliance audit, the issuance of certification and regular monitoring of the effective implementation of the SMEn (energy management system).

ISO 50001's certification is a tool to help manage energy performance and makes it possible to improve energy efficiency on an ongoing basis. It applies to all organizations, regardless of their size, sector of activity or level of energy management. Certification cycles are set every 3 years, and the certification process includes two monitoring audits during this period, after the first and second years(figure I.8)[18].

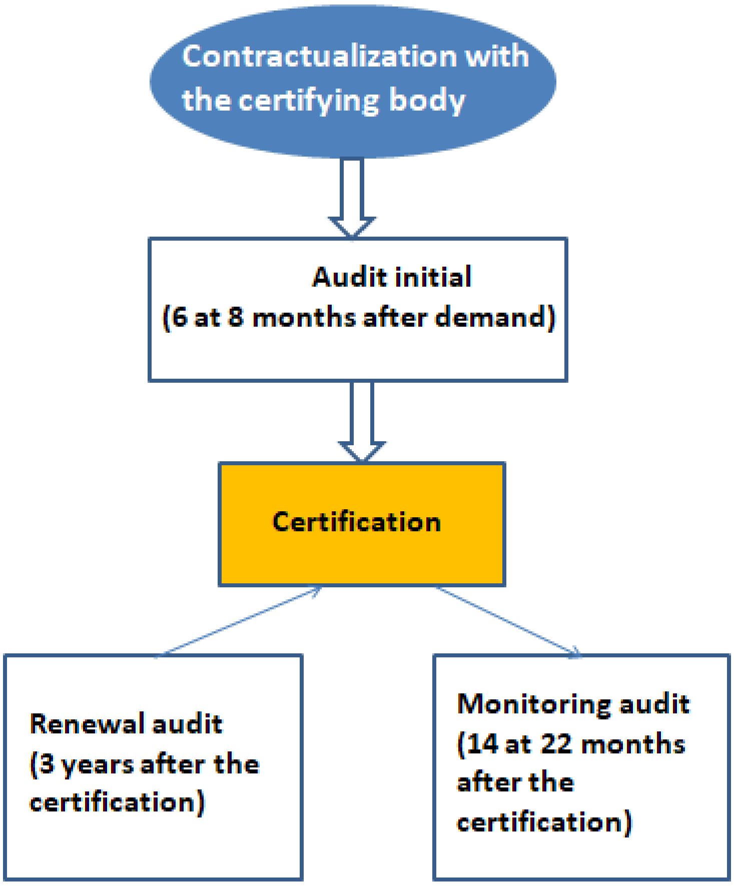

Figure I-8 The global Certification Cycle

I.12 Conclusion

In conclusion, Algeria's energy policy reflects a dynamic and multifaceted approach to addressing the challenges of increasing energy consumption and the transition to a more sustainable future. The country's reliance on natural gas, electricity, and petroleum products has spurred the government to adopt ambitious initiatives aimed at promoting energy efficiency and the development of renewable energy sources. The exploration of key concepts related to energy, the analysis of global and national energy consumption trends and the examination of Algeria's specific measures illustrate the country's commitment to improving itsenergy landscape.

The focus on energy efficiency, particularly in the construction sector, highlights the importance of optimizing energy use in buildings and infrastructure. Furthermore, the renewable energy program underscores Algeria's potential to harness its abundant solar and wind resources, which is essential for diversifying the energy mix and reducing dependence on hydrocarbons. The role of energy audits and the implementation of international standards like ISO 50001 demonstrate Algeria's efforts to systematically identify and implement energy-saving measures, enhancing both environmental and economic outcomes.

CHAPITRE II : Energy Audit: ISO50001, PDCA and Crosby turtle

II.1 Introduction

With the increasing global emphasis on sustainability and energy efficiency, the ISO 50001 standard has become an indispensable tool for organizations aiming to enhance their energy management systems (EMS). This chapter examines the structure and application of ISO 50001, focusing on its consultative and essential clauses that guide the effective implementation and continuous improvement of EMS. It begins by outlining the foundational elements of the standard, including scope, normative references, and key definitions, to establish a common understanding. The chapter then delves into the essential clauses, which specify the concrete actions organizations must take to achieve and maintain high-energy performance.

In addition, this chapter explores the integration of the PDCA (Plan-Do-Check-Act) cycle within the ISO 50001 framework, emphasizing the importance of a cyclical and iterative approach to energy management. The PDCA cycle encourages ongoing assessment and improvement, ensuring that energy management practices evolve and adapt over time. Finally, the chapter introduces the Crosby turtle model, a process representation tool that aids in visualizing and optimizing key processes within the EMS. By employing these methodologies, organizations can systematically enhance their energy performance, ensuring sustainable and efficient energy use.

II.2 The clauses of the ISO 50001 standards

The ISO 50001 standard is an essential tool for organizations wishing to set up and improve their energy management systems. As defined in paragraph I.9 of chapter 1, these clauses are specifically structured and are divided into two categories as follows in the figure II.1.

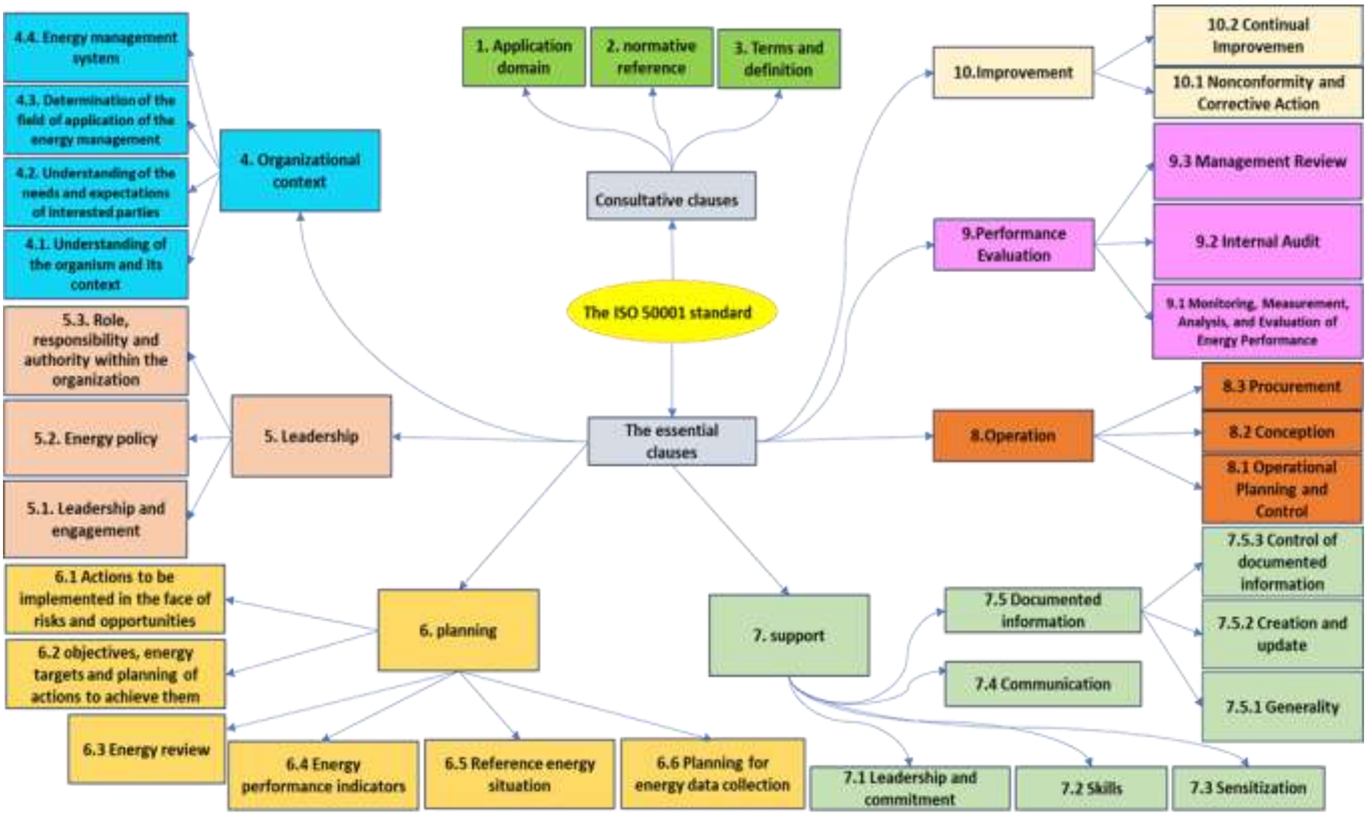

Figure II-1 Structure of ISO 50001 Clauses: Consultative and Essential

- **Consultative Clauses**

Clause 1: Scope

The first clause of ISO 50001 establishes the scope of this standard. It encompasses the requirements necessary for the planning, implementation, maintenance and updating of an Energy Management System (EMS). In addition, this clause sets out the requirements for effective communications.

Clause 2: Normative References

Clause 2 of ISO 50001 does not include any normative references

Clause 3: Terms and Definitions

The third clause of ISO 50001 provides formal definitions of the key terms used in the standard. These definitions are important to ensure a common understanding of the requirements.

These first three clauses lay the foundation by establishing a framework and providing important definitions, but they do not define specific commitments that organizations must specifically implement.

- **The Essential Clauses**

  - **Clause 4: Organizational Context**

This clause of ISO 50001 requires the organization to identify internal and external issues that may influence its energy management system (EMS), as well as the needs and expectations of the relevant stakeholders.

  - **Clause 5:Leadership**

This clause highlights management's commitment and states that the company must develop an energy policy, define clear roles and responsibilities, and allocate the necessary resources to support the Energy Management System (EMS).

  - **Clause 6: Planning**

This clause emphasizes thatfor the organization to improve its energy performance, it is necessary to plan actions aimed at improving it. This involves recognizing significant energy uses, setting measurable goals, and acting on plans once the set goals are met.

  - **Clause 7: Support**

This clause addresses the essential support for the Energy Management System (EMS), including the necessary resources, staff awareness, communication and documentation.

  - **Clause 8: Operation**

Simply put, this clause specifies what it will take to operationally implement an energy management system (EMS), such as collecting and analyzing energy data and tracking energy-related activities.

  - **Clause 9: Performance Appraisal**

This clause emphasizes the importance for the organization to continuously monitor measure, analyze and evaluate its energy performance to ensure that the Energy Management System (EMS) is effective.

- **Clause 10: Improvement**

This clause highlights the importance of continuous improvement of the energy management system (EMS) through the implementation of corrective and preventive actions, as well as periodic management reviews [7].

The essential clauses of ISO 50001 define the specific requirements that organizations must comply with to establish an effective and sustainable energy management system. They detail the concrete actions that organizations must take to continuously improve their energy performance.

II.3 The PDCA Cycle (Plan-Do-Check-Act)

The PDCA cycle encourages a continuous improvement loop, where organizations constantly review their methods, learn from their experiences, and adjust their actions accordingly. This proactive approach fosters innovation, accountability and organizational effectiveness, and is widely used in a variety of areas to promote operational excellence. It was developed by W.Edwards Deming in the 1950s and is a continuous process improvement methodology. It is broken down into four key steps (figure II.2).

Figure II-2 Diagram of the plan-Do-Check-Act cycle

Plan: This phase involves planning the activities and objectives to be achieved, as well as identifying the methods and resources needed to achieve them.

Do: Once the plan is established, this step is to implement the planned actions according to the defined specifications.

Check: In this phase, the results achieved are evaluated and compared to the objectives set in the planning phase. Data is collected and analyzed to determine whether the activities carried out have achieved the expected results.

Act: Based on the results of the assessment, corrective actions are taken to improve processes and future outcomes. Lessons learned are also incorporated into the planning process to strengthen long-term performance.

II.3.1 Analysis of Clauses in the PDCA Cycle

In the context of ISO 50001, the PDCA (Plan-Do-Check-Act) cycle is important for organizing and managing energy performance improvements. The figure above illustrates the clauses associated with each stage of the PDCA cycle:

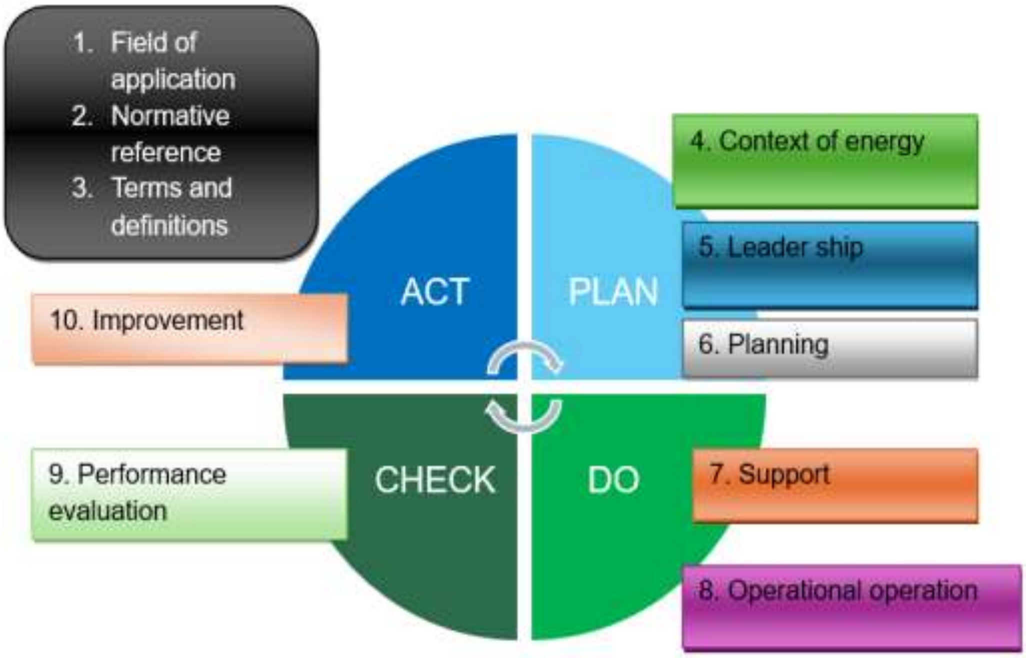

Figure II-3 Study of ISO 50001 Clauses in the PDCA cycle framework

- ***Clause 4 (Plan): Context of the Organism***

The organization must determine both external and internal issues that might affect its EnMS in accordance with clause 4. This step is analogous to the PDCA planning phase, wherein successful plan formulation requires an understanding of the context in which energy operations are conducted.

- **Clause 5 (Plan) : Leadership**

Setting the organization's energy objectives and strategy requires strong leadership. This section relates to the PDCA's planning phase when management establishes the energy strategy, related goals, roles, and duties.

- **Clause 6 (Plan): Planning of Energy**

Based on this clause, the organization must set energy goals, consider regulatory and other demands, and plan the steps required to meet these goals. It is quite similar to the PDCA plan phase, in which plans are created to achieve predetermined goals.

- **Clause 7 (Do) : Support**

The assets, expertise, knowledge, and interaction required to ensure the EnMS's efficient functioning are covered in this clause. It is equivalent to the PDCA's stage of execution, during which the created plans are carried out with sufficient assistance.

- **Clause 8 (Do) : Function**

This clause deals with putting plans and procedures into action that are required to meet the organization's energy goals. It is analogous to the PDCA stage of execution, in which prearranged activities are carried out to accomplish the predetermined goals.

- **Clause 9 (Check)**:**Evaluation of energy performance**

To make sure the goals are met, this provision mandates that the organization assess its energy performance on a regular basis. This is equivalent to the PDCA's verification phase, when findings are assessed to see if any modifications are required.

- **Clause 10 (Act) : Enhancement**

This section deals with finding ways to keep improving the EnMS going forward by using the findings of energy performance evaluations. It is comparable to the PDCA's action phase, during which proactive and reactive measures are implemented to enhance the energy management system.

II.3.2 Alignement of Energy Audit Steps with ISO 50001

It is crucial to comprehend how each audit step fits into the larger framework of the ISO 50001 standard in order to synchronize the primary phases of an energy audit with the provisions of the standard. The incorporation of ISO provisions into each audit step is seen in Table 2 below.

Table II-1Audit Steps, ISO 50001 Clauses, and Observations

Audit steps	Clauses ISO 50001	Comments
Step 00: Call for tenders, Contracts, and proposals	- Clause 4: Context of the organization. 4.1 Understanding of the organization and its context. 4.2 Understanding of needs and expectations of interested parties. - Clause 5: Leadership. - Clause 6: Energy planning.	Identification of customer requirements, analysis of the energy context, and stakeholder expectations.
Step 01: Data collection.	- Clause 6: Energy review (6.3), Data collection planning (6.6). - Clause 7: Support - Clause 8: Operation.	Collection of initial data on energy consumption, equipment, and processes.
Step 02: First exploitation of the data.	- Clause 6: Energy performance indicators (6.4), energy situation of reference (6.5). - Clause 9: Evaluation of energy performance.	Preliminary analysis of data to establish energy performance indicators and a reference situation.
Step 03: Site visits.	- Clause 7: References (7.1), competence (7.2). - Clause 8: Operation.	Inspection of facilities to verify collected data and observe operational practices.
Step 04: Additional analyses and investigations.	- Clause 8: Operational planning and control (8.1). - Clause 9: Evaluation of energy performance.	In-depth analyses to identify opportunities for improvement and energy inefficiencies.
Step 05: Recommendations and report.	- Clause 6: Objectives, energy targets, and planning of actions to achieve them (6.2). - Clause 9: Evaluation of energy performance	Writing recommendations based on analyses, including objectives and targets to improve energy performance.

Audit steps	Clauses ISO 50001	Comments
Step 06: Return to the contracting authority.	- Clause 5: Leadership. - Clause 6: Energy planning. - Clause 7: Communication (7.4).	Presentation of the results and recommendations to the client, discussion of next steps.
Step 07: Project follow-up and support of the project owner.	- Clause 9: Monitoring, measurement, analysis, and evaluation of energy performance (9.1). - Clause 10: Continuous improvement.	Monitoring the implementation of recommendations and continuous evaluation of performance.

To achieve alignment between the requirements of ISO 50001 and the practical steps of the energy audit, it is imperative to understand how these principles fit into a structured approach to the audit process. By adopting a process-based view, we can use visual tools to clearly and systematically represent each step of the energy audit, while taking into account the relevant clauses of ISO 50001.This approach will allow us to effectively visualize the flow of audit activities. With this in mind, we will explore how we can use visual tools to graphically represent the different steps of the energy audit, aligning each aspect with the requirements of ISO 50001. This will allow us to ensure optimal energy management within the organization, ensuring compliance with international standards and promoting continuous improvement of energy performance."

II.4 Crosby's Turtle Process and Usage Approach: Structured Optimization of Energy Audit Steps

The process approach provides a systematic methodology for managing activities within an organization, with an emphasis on defining, understanding and improving key processes. By adopting this approach as part of the energy audit, we can identify critical steps, interrelationships between the activities and stakeholders involved, and optimization opportunities. This allows not only better resource management and a reduction in inefficiencies, but also a continuous improvement in energy performance.Subsequently, the Crosby Turtle will be our preferred tool to visually represent the different stages of the energy audit. Inspired by the philosophy of the PDCA (Plan-Do-Check-Act), the Crosby Turtle offers a clear and logical structure to break down complex processes into more manageable elements, such as inputs, exits, resources, responsibilities and performance measures. It is mainly used in the context of quality management. This approach allows a thorough analysis and holistic understanding of each stage of the audit, thus facilitating the planning, execution and evaluation of activities.

The Crosby turtle thus facilitates the identification of checkpoints, performance measurement and continuous process improvement. By allowing a complete and detailed understanding of processes, this tool contributes to the effectiveness and efficiency of the organization.

The following figure illustrates the model of the Crosby turtle, showing the different elements that make up a process:

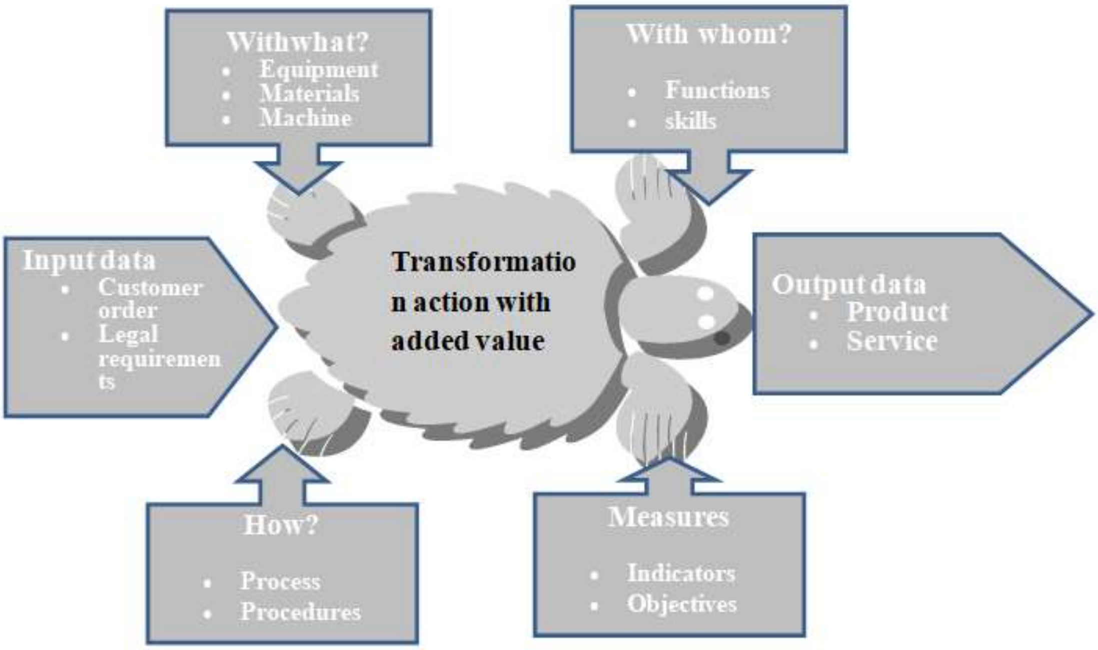

Figure II-4 Structure and Modeling of Crosby's Turtle Processes

ISO 50001:2018 provides a framework for establishing, implementing, maintaining, and improving an energy management system (EMS). To align these requirements with the practical steps of an energy audit, we will adopt a process approach that allows us to structure and visualize each phase of the audit using Crosby's tortoise.

II.4.1 Using Energy Audit Steps as Crosby's Turtle Process

In the first chapter, in paragraph l.8, it is mentioned that seven steps of the energy audit will be discussed. In this paragraph, to adopt a process approach, we will rely on the Crosby Turtle. By using the Crosby Turtle for each step of the energy audit, we will be able to clearly define the inputs and outputs of each phase, identify the necessary resources, determine responsibilities and evaluate performance measures. This approach will allow us to have a structured overview of the audit process, thus facilitating the understanding, communication and effective management of activities.

By applying Crosby's turtle to our energy processes, we will be able to better understand their components and identify potential weak points. This will help us make informed decisions to optimize these processes, with an emphasis on continuous improvement following the requirements of ISO 50001.

In addition, by integrating the clauses of ISO 50001 in each step represented by the Crosby Turtle, we will ensure compliance with international standards while pursuing our objectives of continuous improvement of energy performance (figure II.5 to figure II.12).

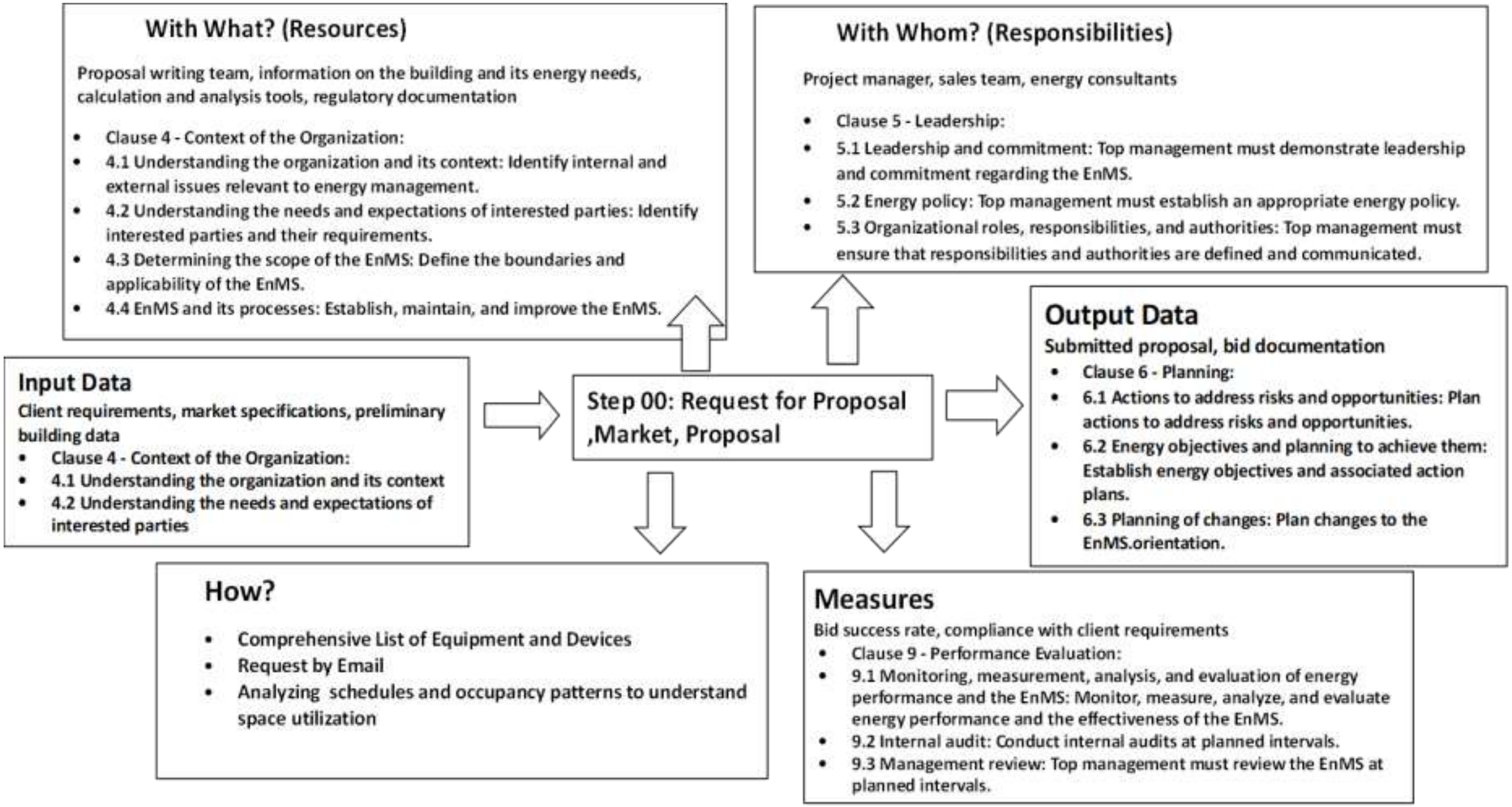

Figure II-5 Process of the Call for Tenders, Contract, Proposal Stage by Crosby's Turtle

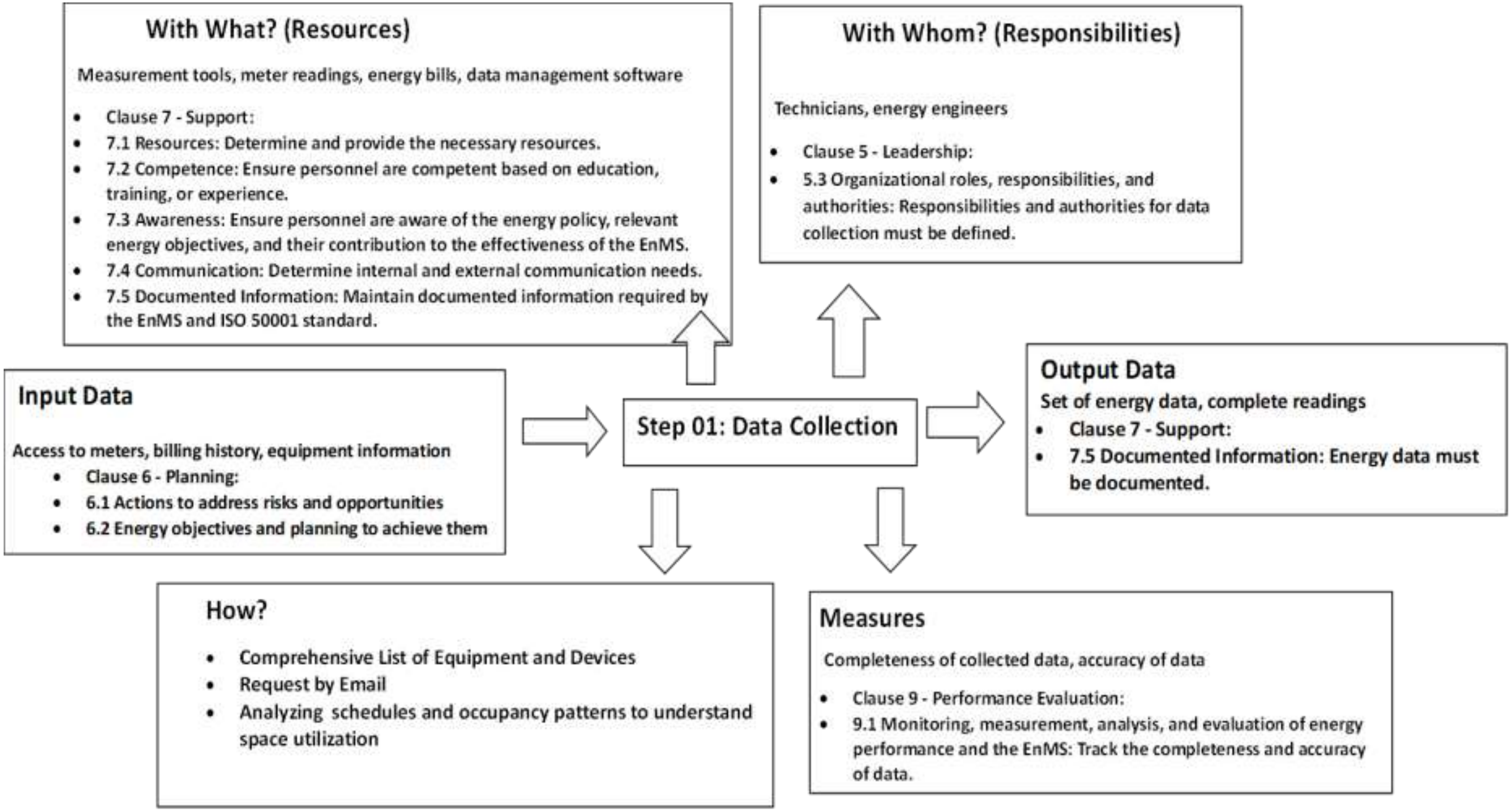

Figure II-6 Process of the Call for data collection by Crosby's Turtle Diagram

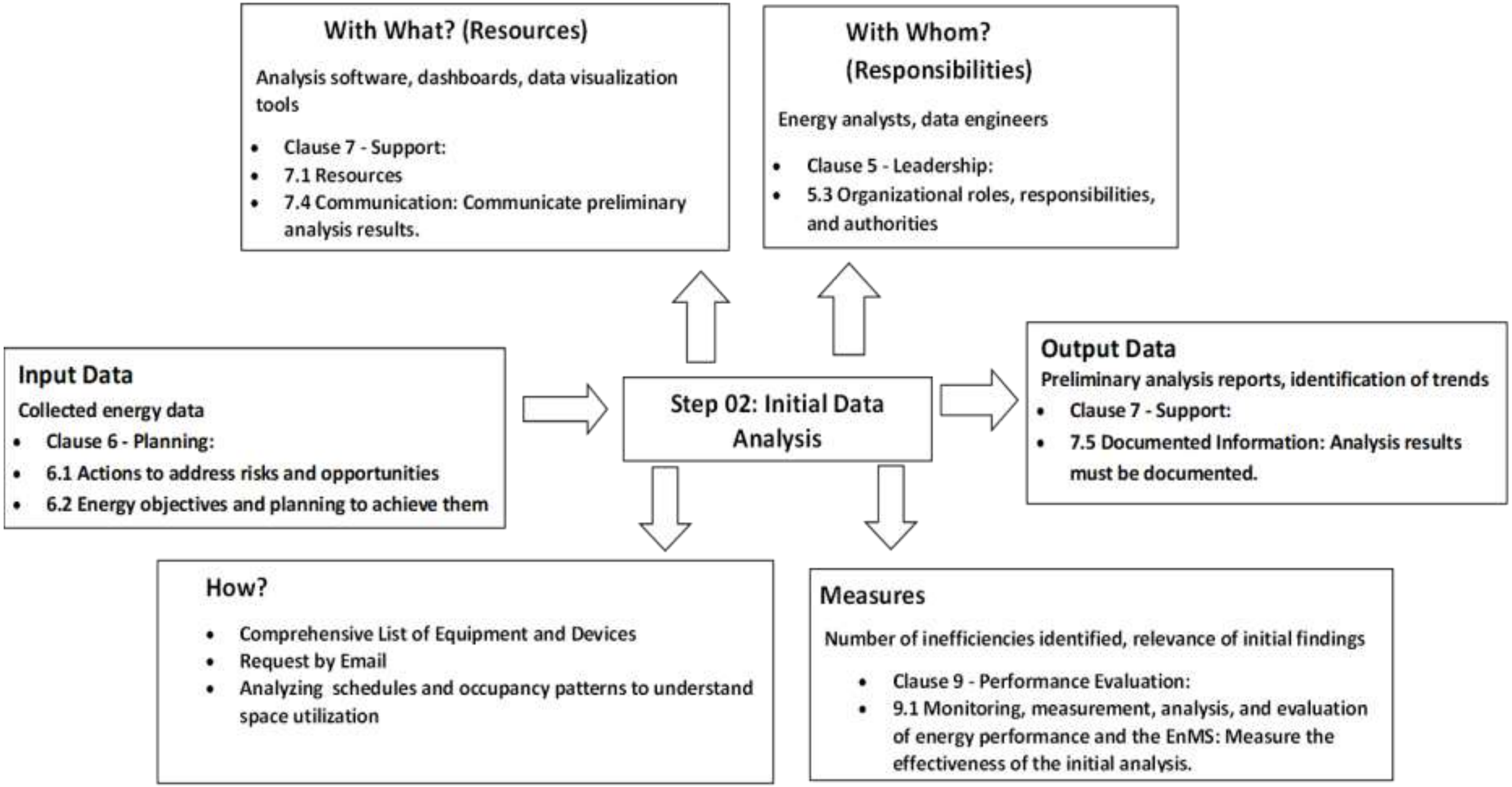

Figure II-7 Process of the Call for initial data analysis by Crosby's Turtle Diagram

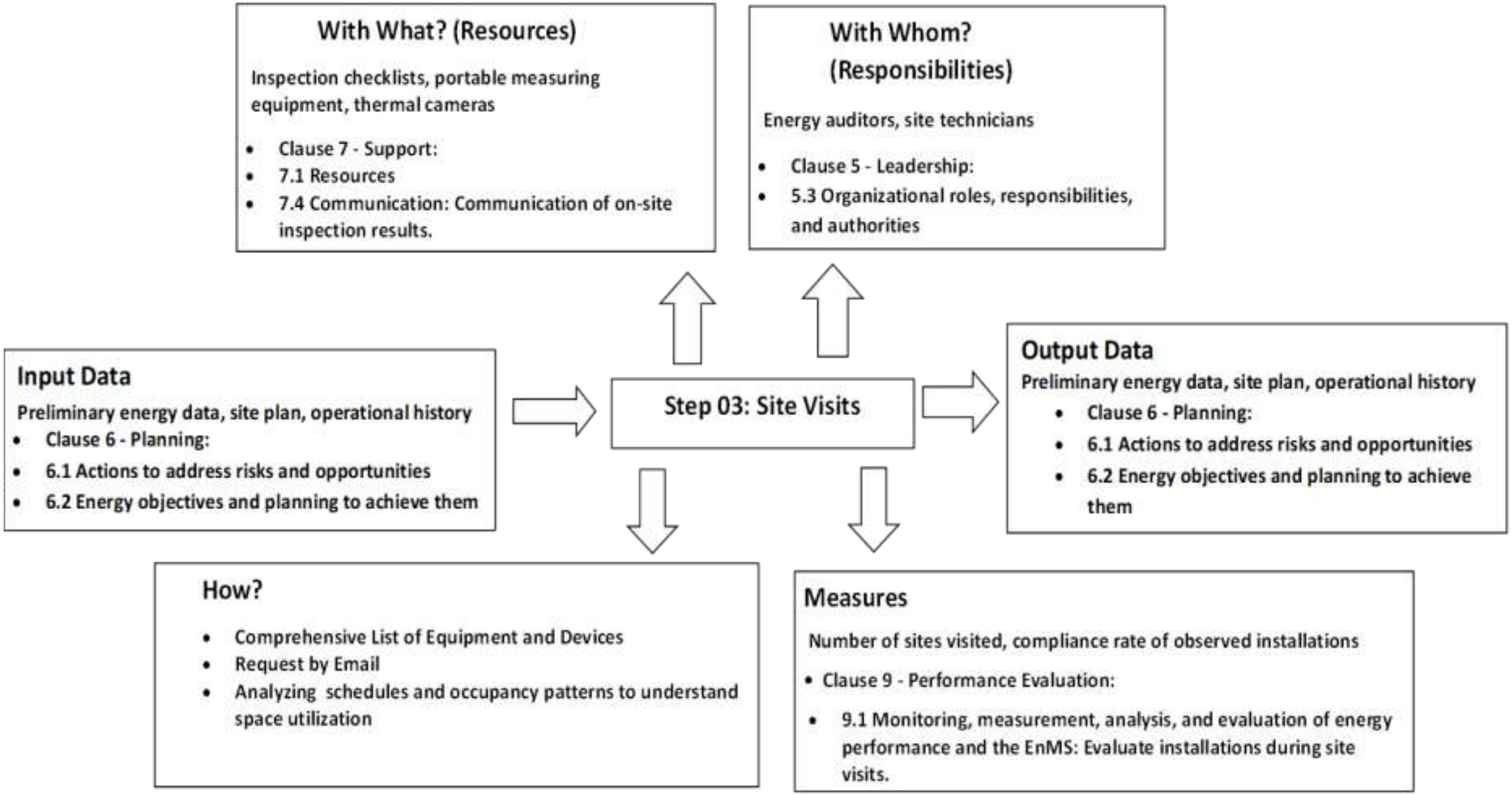

Figure II-8 Process of the Call for on-site visit by Crosby's Turtle Diagram

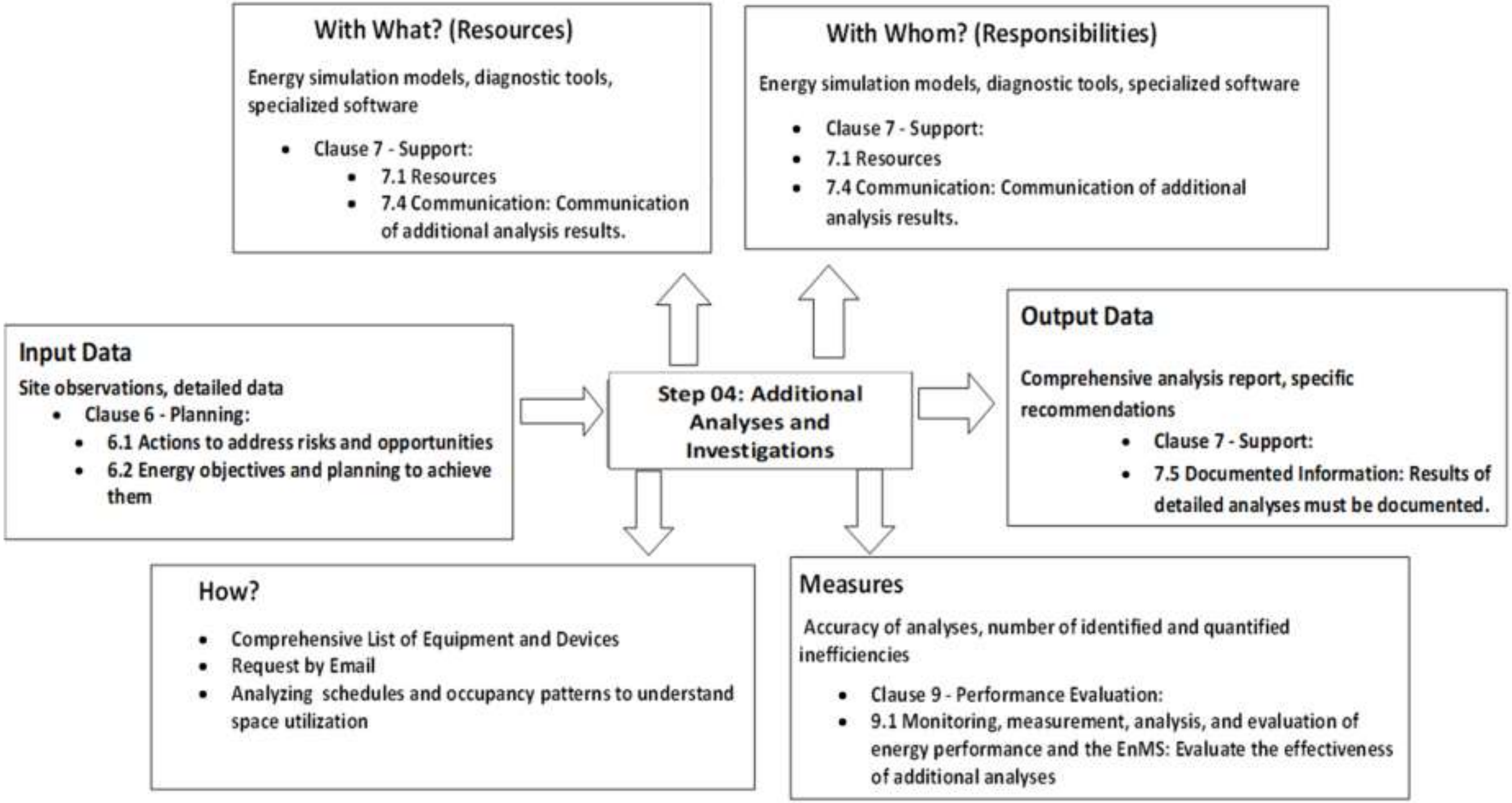

Figure II-9 Process of the Call for additional analyses and investigations by Crosby's Turtle Diagram

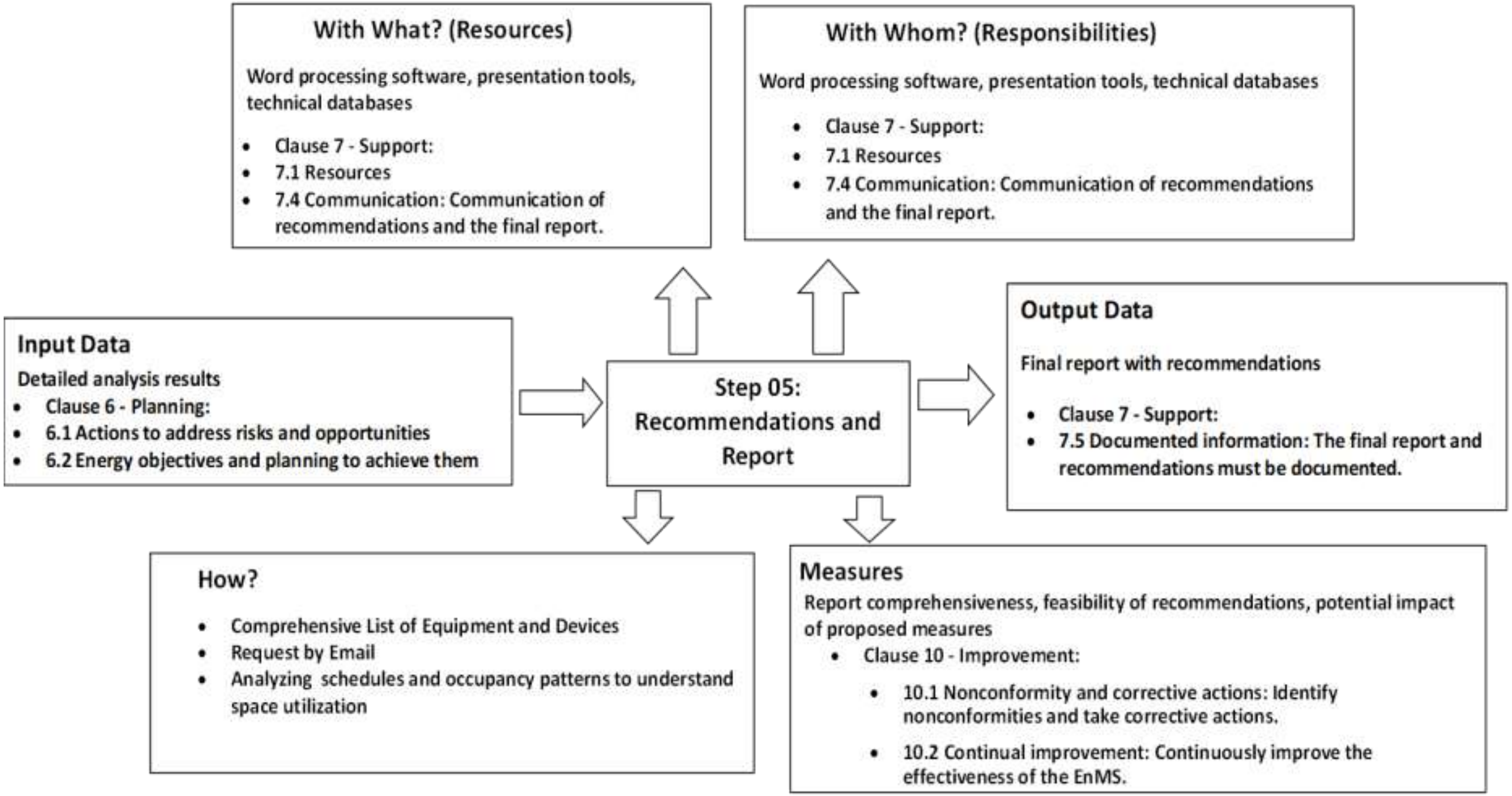

Figure II-10 Process of the Call for recommendations and report by Crosby's Turtle Diagram

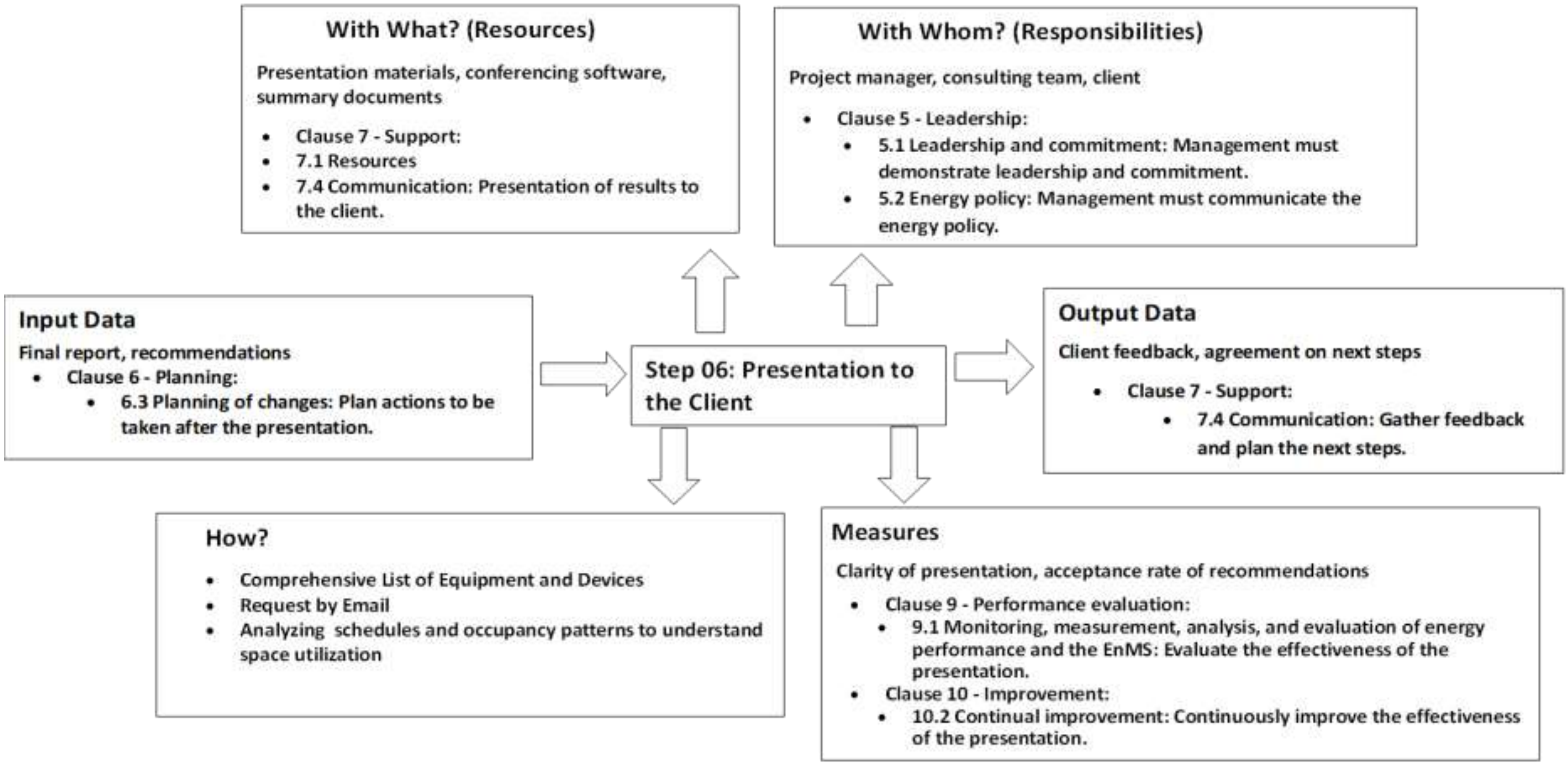

Figure II-11 Process of the Call for presentation to the project owner by Crosby's Turtle Diagram

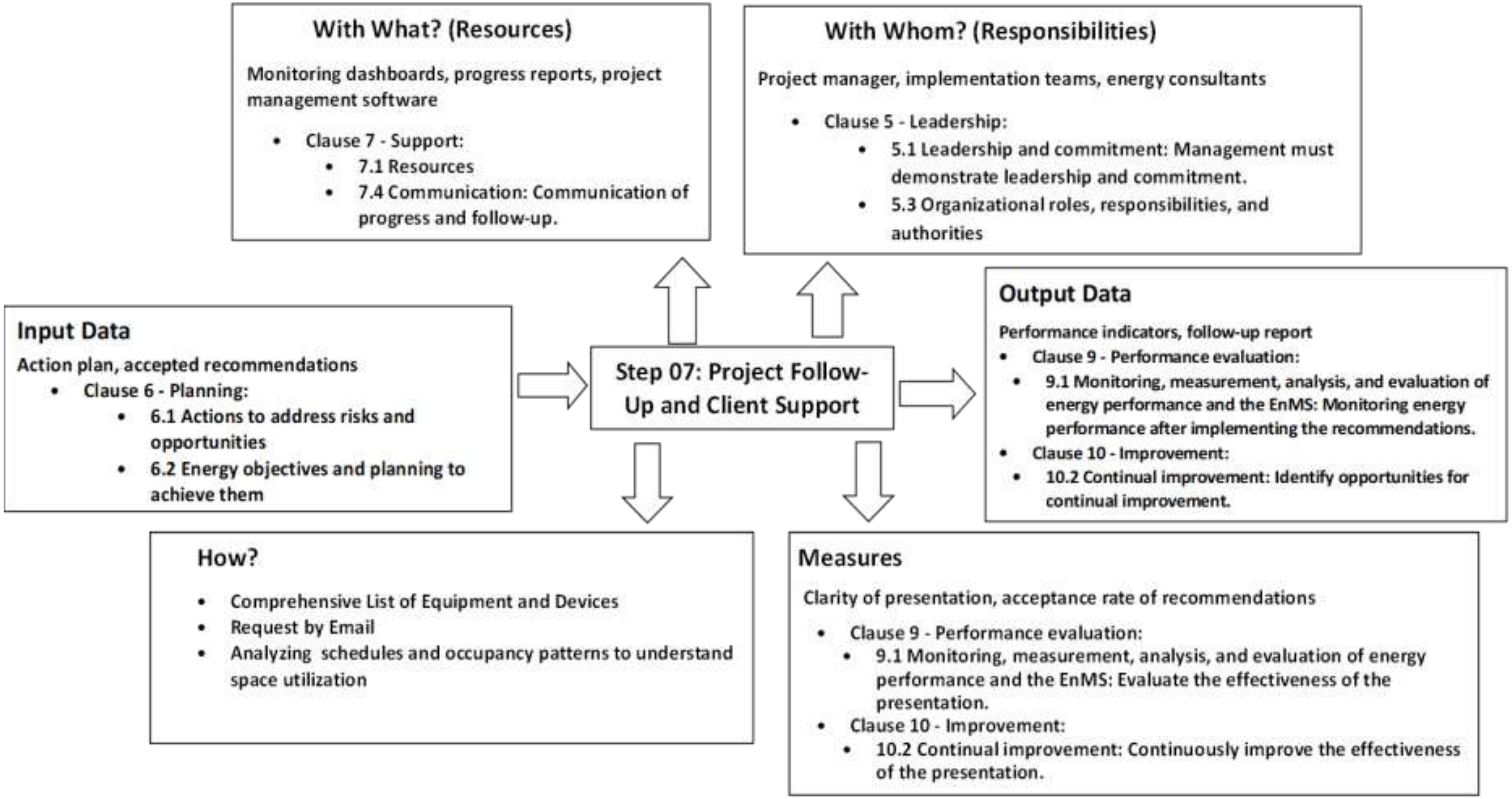

Figure II-12 Process of the Call for project follow-up and support for the Project Ownerby Crosby's Turtle Diagram

After applying Crosby's Turtle Method at each stage of the energy audit, it is essential to enrich the analysis by providing additional information to deepen understanding and maximize the efficiency of the process. To do this, we can detail the specific context and objectives to be achieved at each stage, as well as the methodology deployed, including the tools used, the analysis techniques applied and the data collected.

II.5 Conclusion

In summary, the effective implementation of ISO 50001, coupled with the PDCA cycle and the Crosby turtle model, provides a comprehensive framework for continuous improvement in energy management. Adhering to the structured approach outlined in the ISO 50001 clauses ensures that organizations can systematically plan, implement, monitor, and improve their energy performance.

This chapter has detailed the critical structure and application of ISO 50001, emphasizing its consultative and essential clauses that direct the effective implementation and continuous improvement of EMS.The integration of the PDCA (Plan-Do-Check-Act) cycle within the ISO 50001 framework is crucial for fostering a continuous improvement culture. This cyclical and iterative approach ensures that energy management practices are regularly assessed and refined, adapting to changing conditions and advancing technologies.

Furthermore, the Crosby turtle model serves as a valuable tool for visualizing and optimizing key processes within the EMS. By breaking down processes into their fundamental components, this model aids in identifying inefficiencies for improvement, thereby enhancing overall energy performance.

CHAPITRE III : Case Study: Energy Audit of the MDC Laboratory, Faculty of Technology

III.1 Introduction

In this chapter, we will thoroughly analyze the data collected during the energy audit of the Construction Materials Laboratory (MDC) at Aboubakr Belkaid University. The main objective is to conduct an internal audit and assess the laboratory's compliance with the ISO 50001 standard on energy management and to identify areas for improvement. This analysis will include an examination of energy consumption patterns, equipment performance, and a physical diagnosis of the condition of the laboratory.

We will begin by outlining the methodology used for data collection and analysis, ensuring that our approach aligns with the best practices recommended by ISO 50001. This includes the use of advanced tools like the QUALISTAR Electrical Network Analyzer and the strategies employed for monitoring energy usage. Following this, we will assess the audit results, highlighting key aspects of the laboratory's energy management practices.

Additionally, this chapter will explore the current energy policy, employee awareness of energy objectives, and how energy considerations are integrated into the design and operation of the laboratory’s facilities. By identifying gaps and proposing concrete recommendations, we aim to improve the laboratory's energy efficiency and establish a more structured and compliant energy management system. Ultimately, this chapter will provide a foundation for developing corrective measures and follow-up strategies to ensure continuous improvement in the laboratory's energy performance.

III.2 Presentation of the project

The pedagogical laboratory of Aboubakar Belkaid University in Tlemcen is mainly oriented to the south. The main entrance faces east, offering good exposure to morning light. The two secondary accesses, located on the north and south sides of the building, facilitate access from different directions of the campus. The Department of Architecture is located northwest of the Laboratory, the University Library to the southeast, the Administration to the southwest, andthe University Health Center to the south. See the following figures:

Figure III-1 Laboratory layout through Google Earth

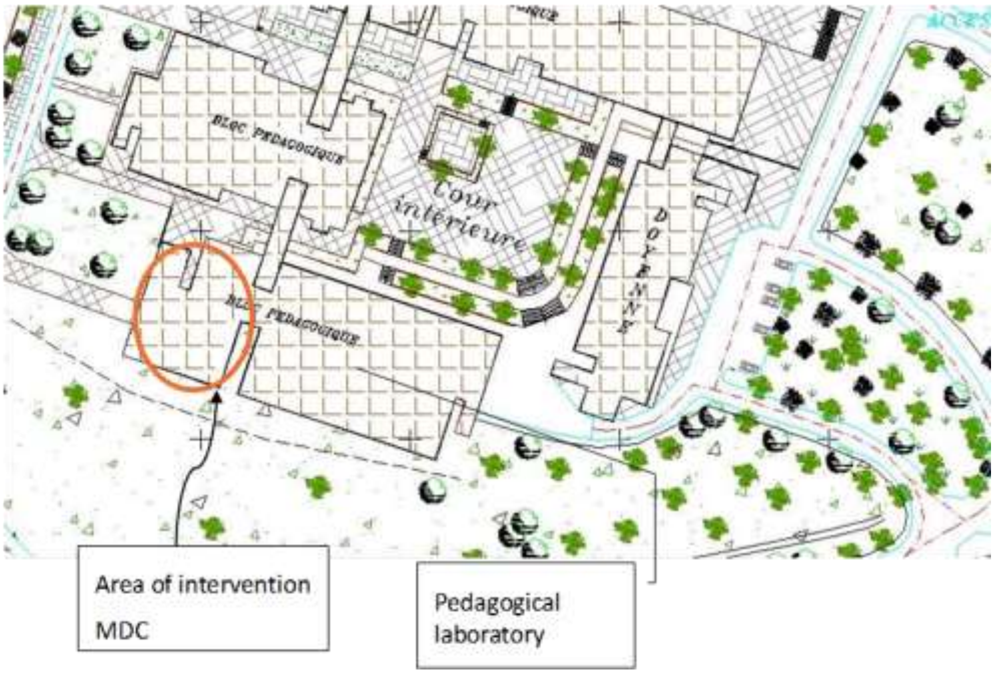

Figure III-2 Faculty Site Plan (extract from CHETOUANEPDAU)

This laboratory has two levels and three access points: one main entrance and two secondary ones. It houses various specialized sections, particularly in hydraulics, geotechnics and strength of materials. These sections are connected by a central corridor leading to the main intervention site, the Construction Materials Laboratory (MDC). The following figure presents the general plan of the laboratory on the ground floor.

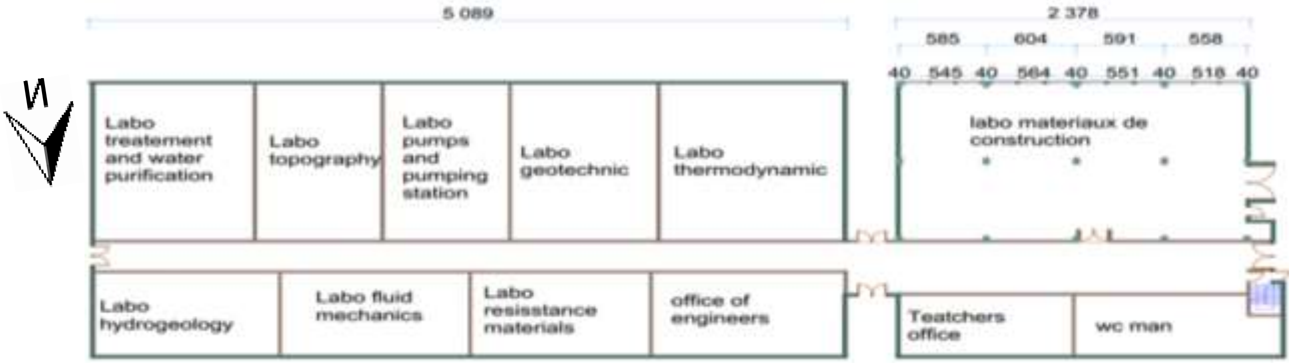

Figure III-3 Plan of the pedagogical laboratory

III.2.1 Presentation of the Construction Materials Laboratory (MDC)

Our study focused on the Construction Materials Laboratory, located at the Faculty of Technology in Tlemcen. This laboratory faces the Department of Mechanical Engineering to the west. To the north, it is bordered by a small square and the Department of Civil Engineering, while to the south, there is an open space.Covering an area of 350 square meters, the laboratory is a specialized facility for practical pedagogical work at the Bachelor's and Master's degree levels. It involves conducting experimental manipulations using various construction equipment and materials. The laboratory is managed by a team of teachers and engineers

The following figure presents the dimensions and different equipment available in the laboratory. This equipment is essential for carrying out various experimental manipulations.

Here is a description of the equipment present in the laboratory, as illustrated in the figure below.

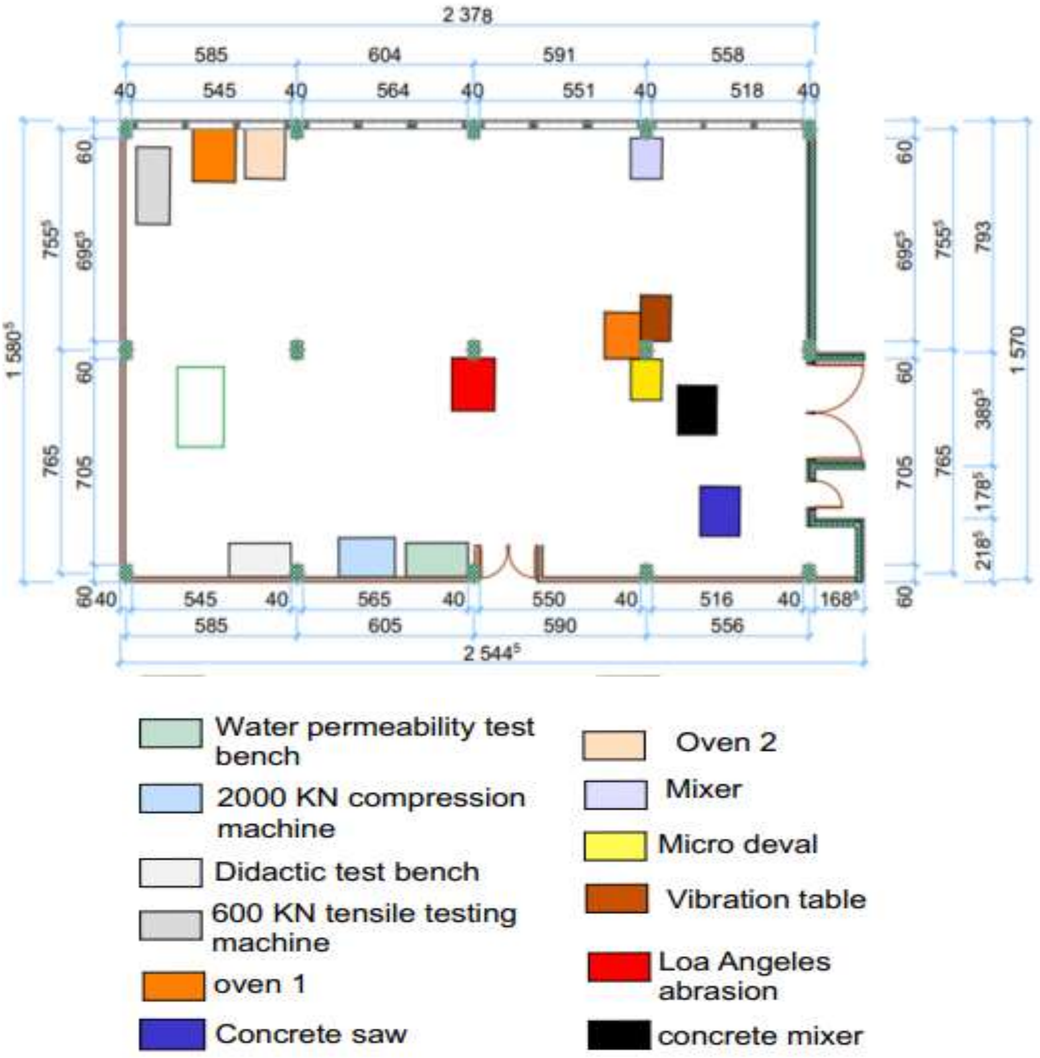

Figure III-4 Layout plan of the Construction Materials Laboratory with main equipment

The table III-1represents the figures for each piece of equipment with their consumption and use.

Table III-1 Characteristics and Uses of Laboratory Equipment

Equipment	Consumption (KW)	Use	Photo
Test bench **Permeable to water**	**1.1**	**Material Permeability Testing** (low frequency of use)	
Compression machine 2000 kN	**2.0**	**Compressive strength test** (Intermittently used material)	
Didactictest bench	**1.1**	**Pedagogical experiments** (low frequency of use)	
Tractionmachine 600 kN	**2.5**	**Tensile strength test** (low frequency of use)	

Micro Deval	**1.2**	**Wear resistance test** (low frequency of use)	
Vibration table	**0.26**	**Compaction of materials** (high frequency of use)	
Los Angeles	**0.736**	**Abrasion Resistance Test** (low frequency of use)	
Concrete Saw	**1.8**	**Cutting concrete materials** (Intermittently used material)	

Equipment	**Consumption (KW)**	**Use**	**Photo**
Concrete mixer	**0.5**	**Concrete mixing** (high frequency of use)	
Oven	**2.0**	**Drying of materials** (24-hour operation)	

III.2.2 Measurement Device Characteristics (checklist)

In our case study, we used measuring devices that allowed us to collect additional data. The following table presents the different measuring devices along with their descriptions that were used:

Table III-2 Laboratory Measurement and Analysis Equipment

Device name	Descriptive	Main applications	Precision	Measuring range	Photo
QUALISTAR Electrical Network Analyzer (CA 8336)	Power Quality Analyzer	Power System Monitoring and Analysis	High precision	10 V to 1000 V	
DAQ Box v2	Data acquisition system	Collection and recording of various data	Varies depending on the connected sensors	Varies depending on the connected sensors	
Laser Rangefinder (CT 44035)	Current sensor	Current measurement in electrical systems	High precision	0 to 100 m	
Kestrel 3000weather meter	Portable anemometer	Wind speed and weather measurement	High precision	0,6 to 40 m/s	
Infrared thermometer	Non-contact temperature measuring device	Surface temperature measurement	High precision	-50 °C to 1000 °C	

III.3 Application of Crosby's Turtle Diagram to the Energy Audit Process in Our Laboratory Project

As indicated in Chapter Two, Section II.4.2, the Crosby's turtle diagram is used as a tool to describe the audit steps, and this will be applied to our case study, which is the MDC laboratory. The application will begin with Step 1, which concerns data collection. It should be noted that Step 0, which involves the call for tenders, market analysis, and proposal preparation, does not apply to this case study since it is a master's project. We are not conducting activities related to the call for tenders, market analysis, or proposal preparation. This case study will focus on data collection, analysis, and recommendations. Similarly, Step 7, which involves project follow-up and support to the client, is not applicable. This case study is considered an attempt at an internal audit of the MDC laboratory in preparation for future ISO 50001 certification. The figures below show the different processes for the different stages of the energy audit.

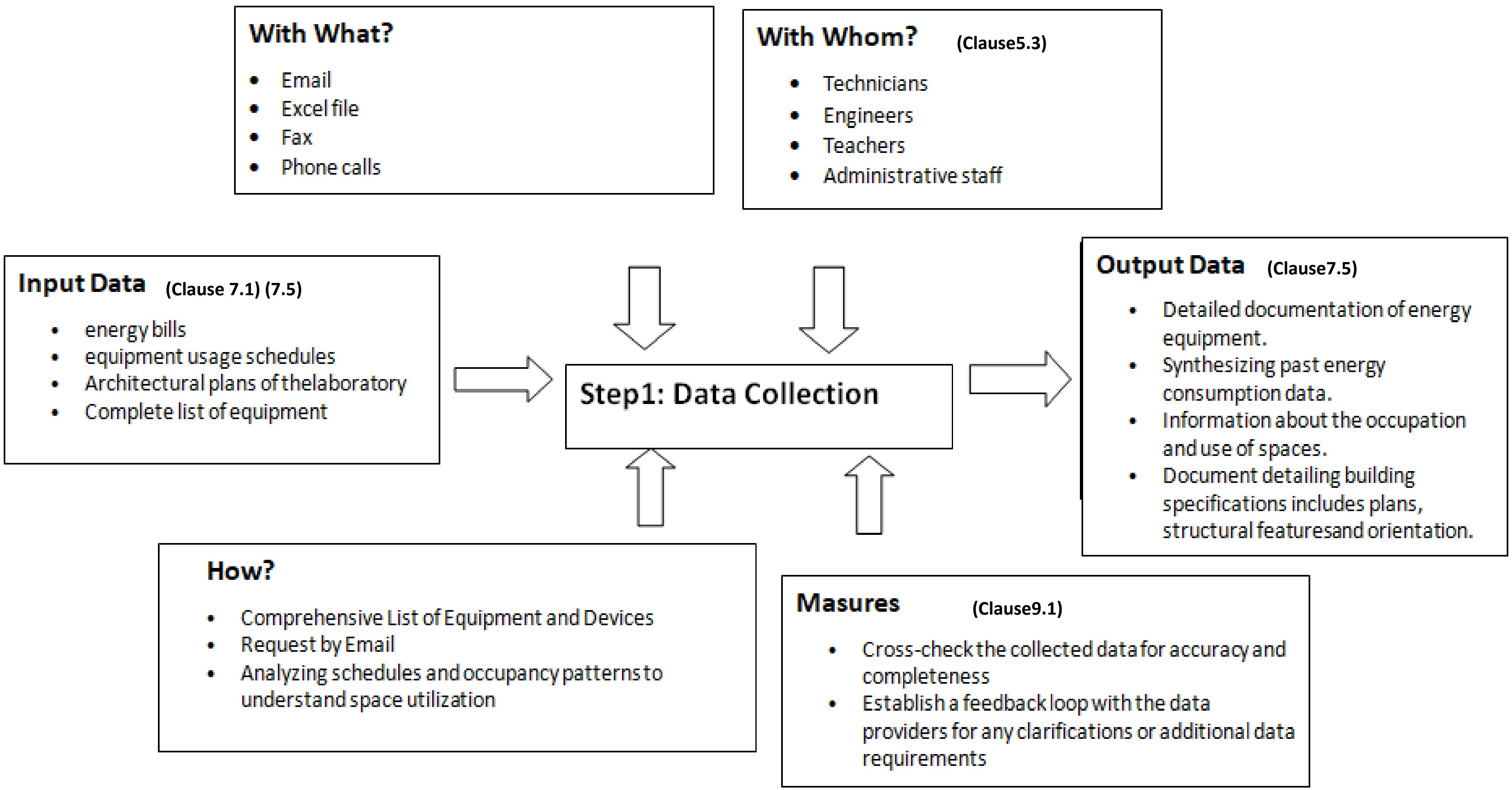

Figure III-5 Process of the Call for Initial Data Analysis by Crosby's Turtle Diagram

In the data collection process for the energy audit, the only element that initially exists in input is the detailed documentation of the energy equipment. From this documentation, we were able to generate a complete inventory of the equipment with its energy specifications.

This detailed documentation served as a crucial starting point for obtaining accurate and comprehensive information on the energy specifications of each piece of equipment in the laboratory. Through this process, we were able to transform this single input into meaningful and usable output. However, in the absence of additional data such as energy bills, equipment usage schedules, and architectural plans, we were unable to create detailed reports on neither energy consumption, nor to gain valuable insights into space occupancy and utilization. Similarly, we were unable to produce documents detailing the building's specifications, including plans, structural features and orientation.

Thus, without this complementary input, our analysis remains limited and we cannot fully identify trends, anomalies, or opportunities to improve the energy efficiency of the laboratory. For a thoroughanalysis, it is essential to collect and integrate this missing information.

To do this, we will go through the second step mentioned in paragraph II.4.2of chapter two.

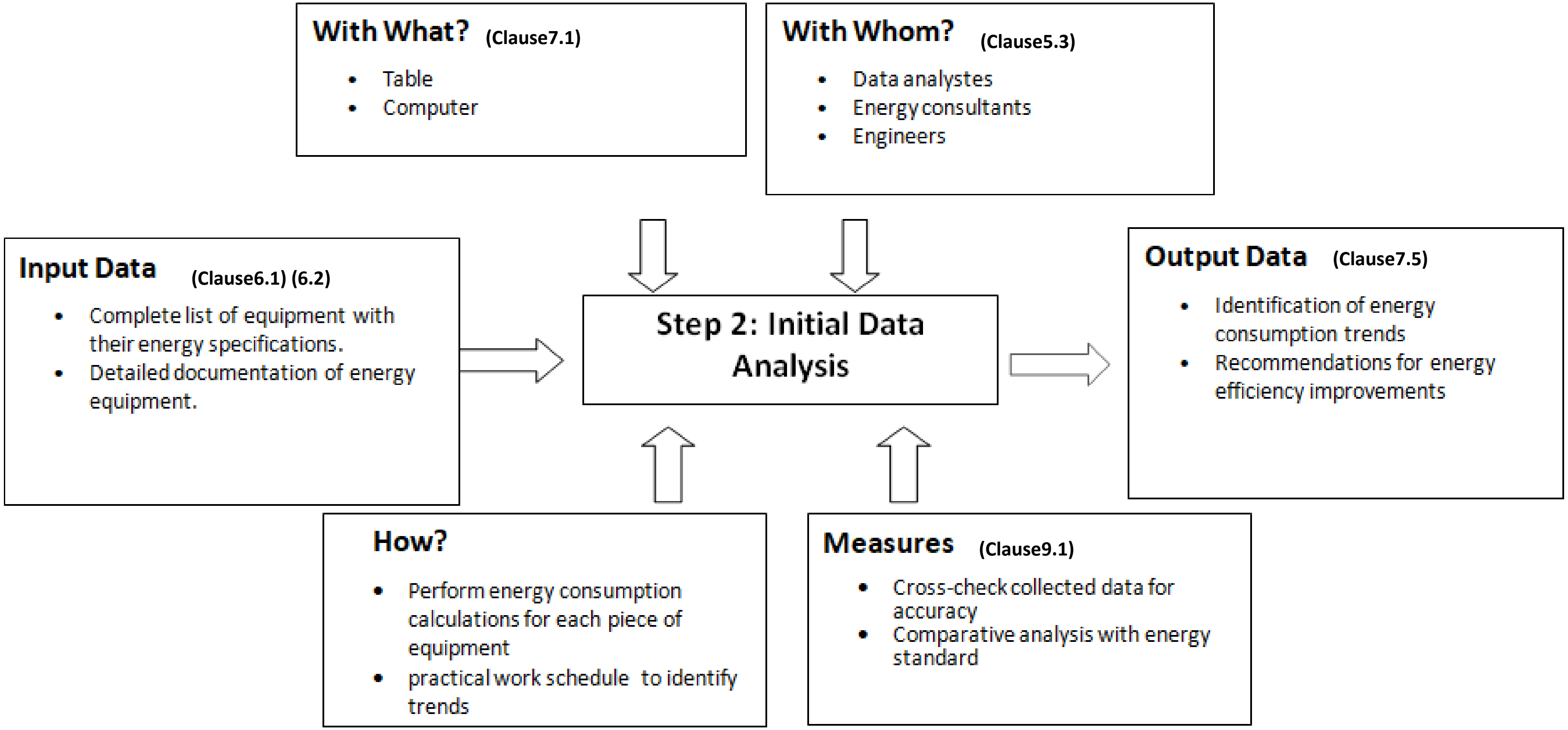

Figure III-6 Process of the Call for Initial Data Analysis by Crosby's Turtle Diagram

From the data analysis, it has been observed that the energy consumption in the laboratory begins to rise at the end of September and remains high until May. During these months, there is increased usage of equipment and appliances, likely due to academic and research activities peaking during this period. This trend indicates a higher demand for energy resources, necessitating a focus on optimizing energy usage during these months.

During the summer months, particularly from June to August, the energy consumption drops significantly and remains almost negligible. This is attributed to reduced activities in the laboratory, as students and staff may be on vacation or involved in off-site projects.

We are now going to move on to the third and fourth stages (we have combined the two stages) of the energy audit mentioned in Chapter 2, paragraph II.4.

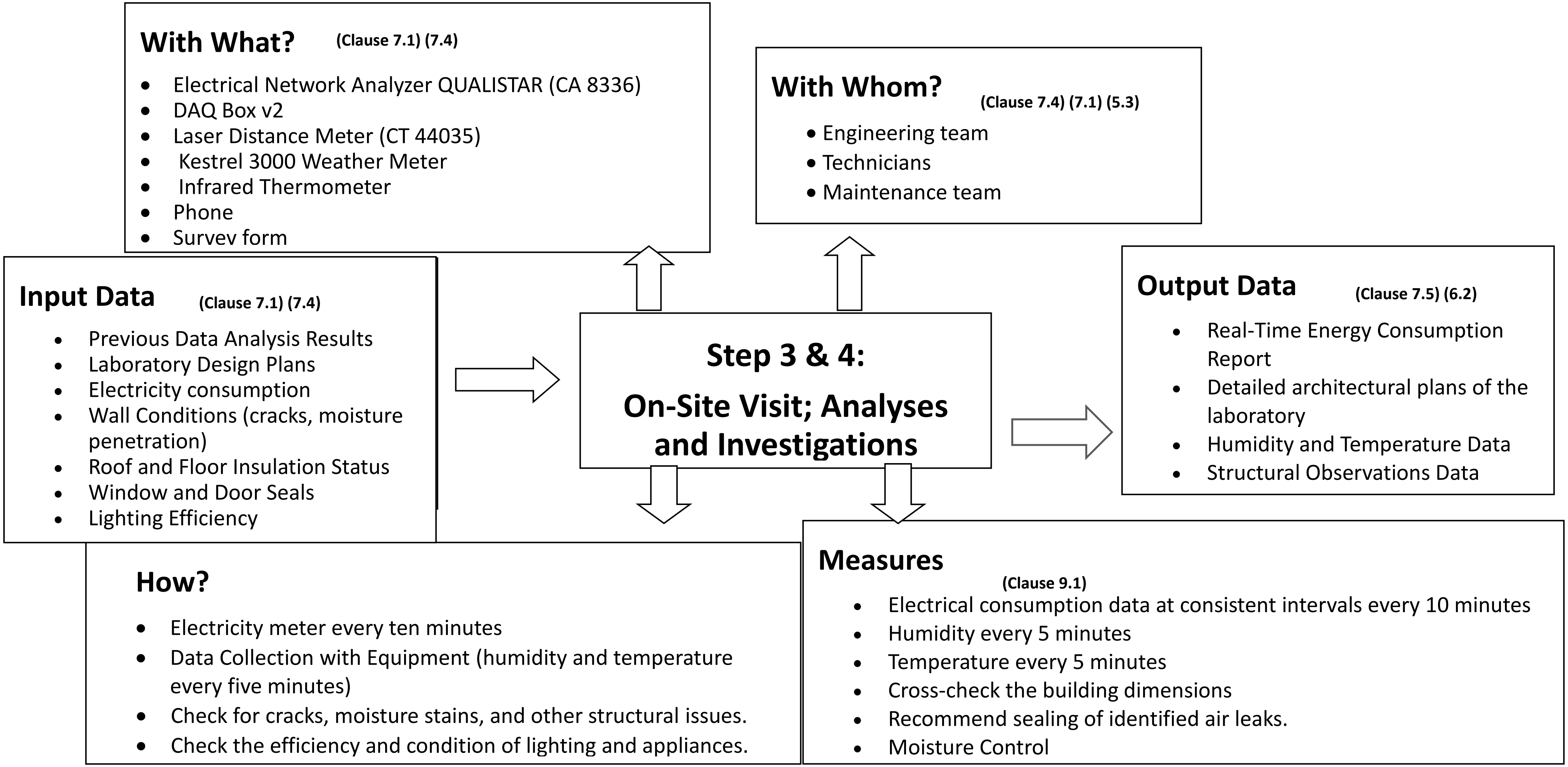

Figure III-7 Process of the Call for on-site visit, Analyses and Investigations by Crosby's Turtle Diagram

The study of energy consumption in the laboratory involved an extensive process of data collection, site visits and analysis, aimed at understanding and optimising energy use. The data collected included a site inspection checklist(Table III 3), results of previous analyses, laboratory design plans, and electricity consumption data. The measurements focused on energy, relative and absolute humidity, as well as temperature. The following figures show how the devices were placed to perform the measurements:

Figure III-8 Measuring instrument Electrical network analyzer QUALISTAR

Figure III-9 DAQ Box v2 Placement for Data Collection

The results of this study included a real-time energy consumption report as well as detailed architectural plans for the laboratory block Include in paragraph III.2 figure III-3 and the building materials laboratory Include in paragraph III.2 table III1.

The figures below represent the results of humidity and temperature with the DAQBOX.

Figure III-10 Humidity Graphs of SHT35 Sensors

Figure III-11 Temperature Graph of SHT35 Sensor

The analysis of temperature and humidity data reveals crucial information about the thermal insulation of the building. Temperature graphs show a gradual increase for all sensors (Channels 1, 3, and 10) during the monitoring period, suggesting moderately effective insulation but not entirely impermeable to heat transfer. Sensor 1, located on the east wall, shows an increase from 20.28°C to 21.72°C, likely influenced by morning light. Sensor 3, placed on the south wall, ranges from 20.16°C to 21.04°C, indicating better insulation against direct afternoon heat. Sensor 10, near an opening, exhibits the largest variation (20.66°C to

21.78°C), signaling that openings are weak points in terms of insulation. Additionally, humidity graphs show that humidity variations are also influenced by the sensor positions, with more significant fluctuations near the openings. After examining the indoor temperature and humidity variations, it is also important to analyze indoor relative humidity and outdoor temperature to gain a comprehensive understanding of the environmental conditions influencing the building. The following tables present the data collected for each wall (North, South, East, and West):

Table III-3 Relative Humidity

The time	10h	11h	12h	13h	14h	15h
Wall	Relative humidity %					
South	70 ,2	62,9	61,8	59,9	59,7	50,6
East	73,1	68,4	56,3	57,6	51,7	57,8
North	70	67,3	65,4	62,7	59,4	58
West	79,6	66,8	68,2	63,8	60	60,6

Table III-4 Dew Point

The time	10h	11h	12h	13h	14h	15h
Wall	Dew point(°C)					
South	20,2	22,4	24,8	25,7	26,4	29,4
Est	19,1	23,8	27,3	25,8	28,9	27,3
North	20	21,8	23,5	24,8	25,3	24,9
West	18,3	22,2	23,6	23,4	27,9	26

Table III-5 Outdoor Temperature

The time	10h	11h	12h	13h	14h	15h
Wall	Outdoor temperature(°C)					
South	19,8	24	24,5	26,6	27,2	28,4
Est	20,3	23,8	24,9	25,5	25,7	27,8
North	19,7	21,8	23,1	23,3	24,7	25,1
West	19,6	21,9	22	23,2	24,6	24,9

III.3.1 Results and interpretation of measurements via DAQBOX

The collected data on relative humidity, dew point, and outdoor temperature for different walls of the building (South, East, North, and West) throughout the day reveals significant insights into the thermal behaviour of the building's exterior.

The South Wall, which is in direct contact with sunlight, experiences the most considerable temperature rise from 19.8°C at 10h to 28.4°C at 15h, and the largest decrease in relative humidity from 70.2% at 10h to 50.6% at 15h. This indicates a strong solar heating effect. The dew point for the South Wall also increases significantly from 20.2°C at 10h to 29.4°C at 15h.

The East Wall shows a delayed temperature rise due to shading from other buildings in the morning, starting at 20.3°C at 10h and rising to 27.8°C at 15h, with a corresponding drop in relative humidity from 73.1% to 57.8%. The dew point for the East Wall increases from 19.1°C at 10h to 27.3°C at 15h.

The north wall, which has contact with the corridor, shows a relatively stable temperature evolution throughout the day, starting at 19.7°C at 10 a.m. and gradually increasing to 25.1°C at 3 p.m. This increase is less pronounced than that observed on the south wall, which is exposed to the sun, but comparable to that of the east and west walls. This suggests that the north wall is not as strongly affected by outdoor temperature variations as the other walls.

The West Wall, shaded by trees, exhibits a moderate temperature increase from 19.6°C at 10h to 24.9°C at 15h, resulting in a gradual change in relative humidity from 79.6% to 60.6%. The dew point for the West Wall varies from 18.3°C at 10h to 26°C at 15h.

These observations underscore the significant impact of environmental conditions and surrounding structures on the building's thermal dynamics.

III.3.2 Presentation and Interpretation of Measurements from the Electrical Network Analyzer QUALISTAR

After completing the collection of data on humidity and temperature, we will move on to collecting data on MDC laboratory consumption. The figure below provides detailed information on the voltage and current behaviour over time, which is essential for understanding energy consumption patterns:

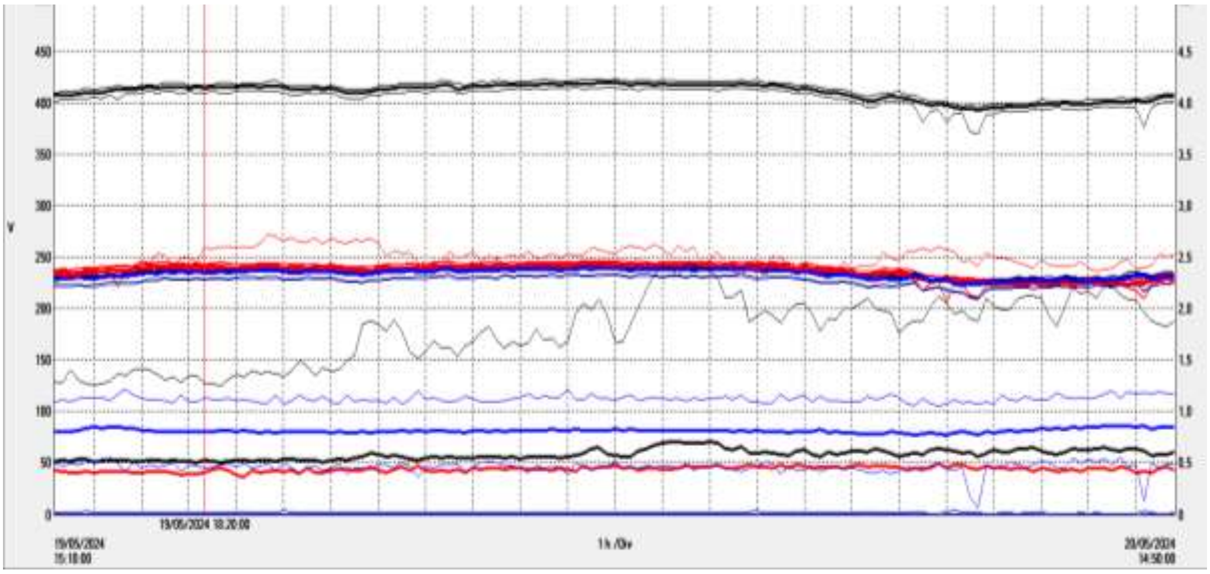

Figure III-12 Measurements of Electrical Parameters and Power Factor Over Time

Voltage stability is noted with relatively stable readings for V1 and V2, showing minor fluctuations, which suggests a consistent power supply across these phases. However, the absence of V3 implies that only two phases are active in this measurement setup. Regarding phase-to-phase voltages, while the stable high voltage U12 indicates normal operation between phases 1 and 2, the low voltage U23 suggests minimal potential difference between phases 2 and 3, hinting at potential underutilization of phase 3. Moreover, current variations (A1 rms) indicate fluctuations, indicating changes in load over time.

However, the electrical consumption is displayed in the following figure:

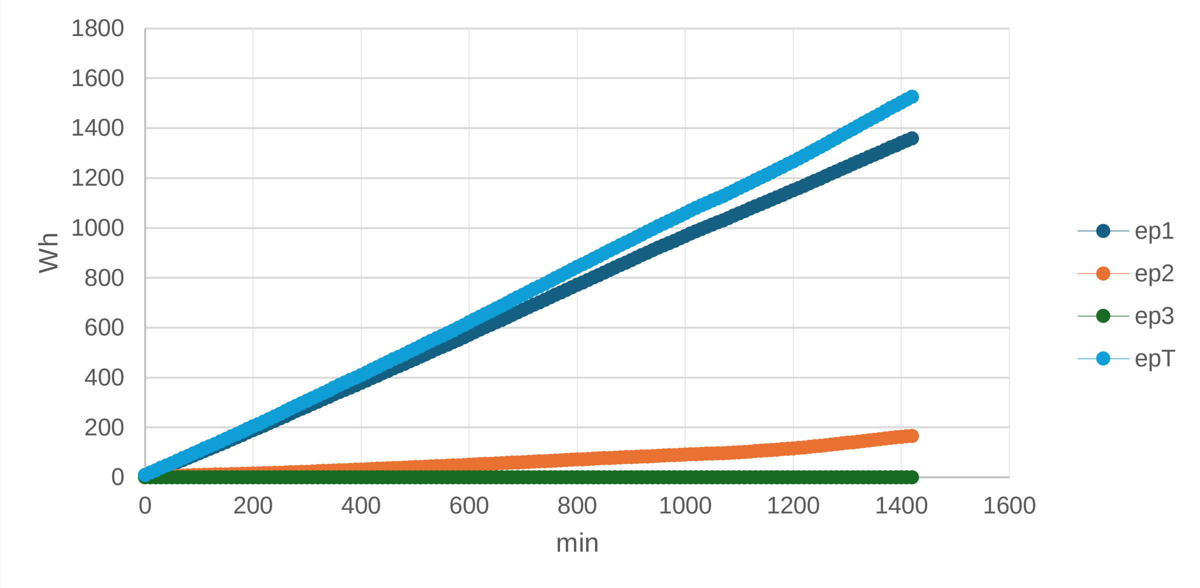

Figure III-13 Energy Consumption Over Time

The figure III-13presentsa detailed record of energy consumption in watt-hours (Wh) over time, divided into three different energy phases (Ep1, Ep2, Ep3), along with the total energy consumption (EpT). Initially, at 0 minutes, the total energy consumption is 9.7 Wh, steadily increasing to 1525.8 Wh at 1420 minutes.

Regarding the different energy phases:

- Ep1 starts at 8.9 Wh and reaches 1359.4 Wh at 1420 minutes.
- Ep2 begins at 0.8 Wh and peaks at 166.4 Wh at 1420 minutes.
- Ep3 remains at 0 Wh throughout the period, indicating no consumption in this phase.

Values increase linearly over time within each phase, suggesting a constant or regularly increasing load. The rates of energy consumption show significant differences between phasesEp1 increases by approximately 9.7 Wh every 10 minutes, while Ep2 exhibits a lower increase of about 0.9 Wh every 10 minutes. This linear trend persists throughout the recorded period, providing a detailed representation of energy consumption dynamics.

III.3.3 Diagnosis of the Physical Condition of the Laboratory

To complement our energy audit analysis, we have gathered supplementary data that are critical for assessing the overall state of the building. This data includes visual observations of physical damage to walls, floors, windows, and other structural elements. The following figures present these detailed observations:

Figure III-14 Ceiling damage

The ceiling deterioration reveals concerning signs such as peeling paint, moisture stains, and structural degradation. Potential causes include water leaks, sealing issues, and condensation due to inadequate ventilation. Despite the attempts to reseal, the leaks have not been repaired. The consequences range from health risks associated with mold to structural damage and reduced energy efficiency.

In this section, we present a photo of the cracks found on the West wall. These cracks not only allow outdoor air infiltration, thereby reducing energy efficiency, but they also facilitate moisture penetration, which can lead to mold issues.

Figure III-15 Wall Damages

The window exhibits visible signs of damage, allowing light and potentially uncontrolled airflow to enter while gaps around the window pose risks of air and water penetration. This could lead to energy inefficiency, moisture problems, and compromised security. Similarly, the garage door shows visible gaps, permitting light and air passage, indicating potential energy

Figure III-16 Building Structural Deficiencies: Impact Analysis

loss dust and insect infiltration, and security vulnerabilities. Addressing these issues promptly is crucial to maintaining comfort, energy efficiency, and security within the laboratory.

Thefigure (III.17) highlights damaged or malfunctioning lamps that are not functioning properly, resulting in inadequate lighting in the space. These defective lamps can create areas of darkness and compromise visibility, safety, and occupant comfort.

Figure III-17 Malfunctioning Lamps on Lighting Conditions

After completing the on-site visit, analysisand investigation process, we will proceed to the step five outlined in the second chapter.

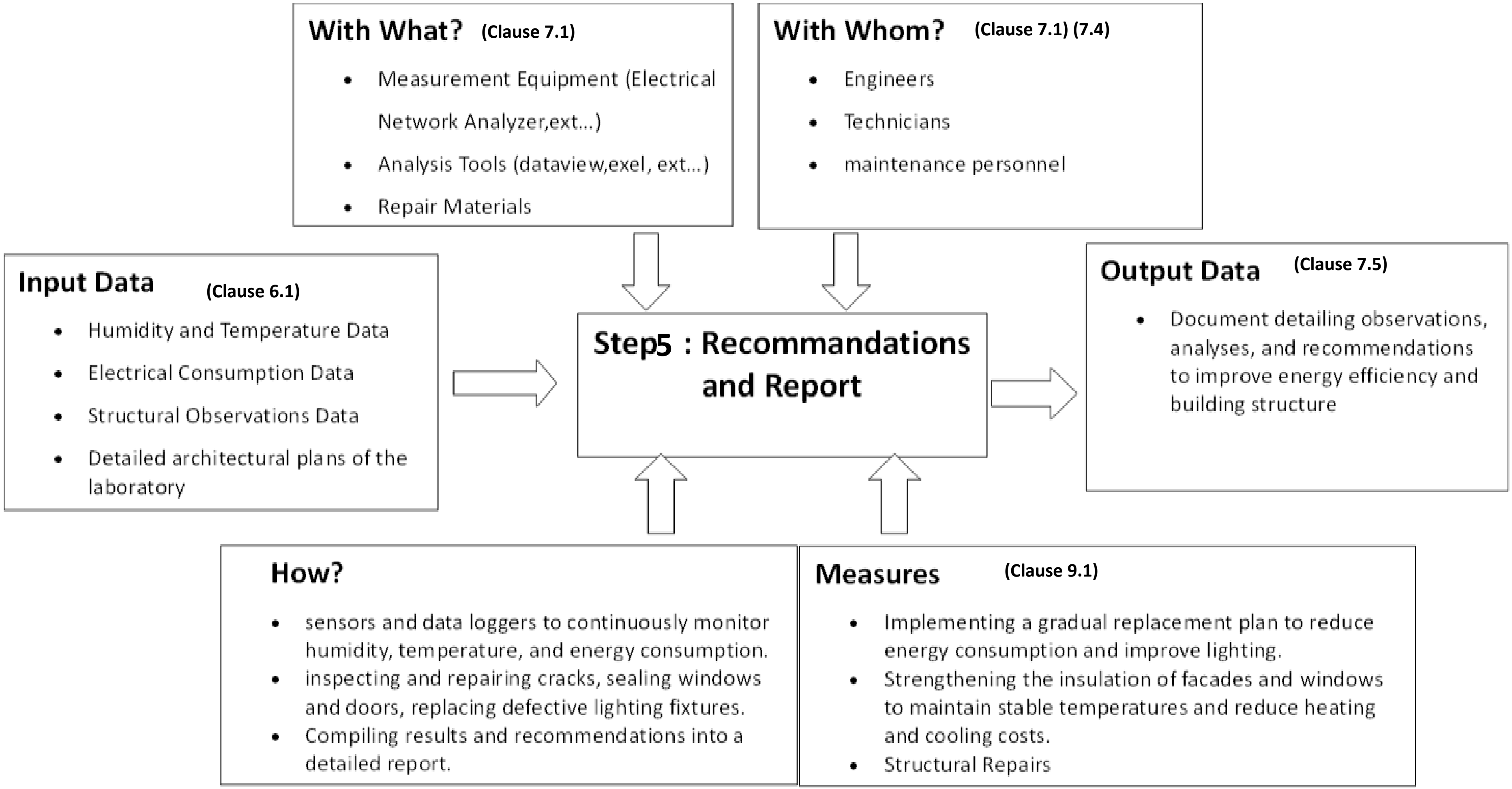

Figure III-18 Process of the Call for Recommendations and ReportingLaboratory by Crosby's Turtle Diagram

III.3.4 Final Recommendations Report

Based on our previous steps, this report presents the findings and recommendations from our comprehensive energy audit and structural assessment of the laboratory. The audit included documentation of energy-consuming equipment, on-site visits, data collection on temperature, humidity, and energy consumption, as well as visual inspections of structural elements.

- **Initial Data Collection and Analysis**

The initial phase of data collection was based on the detailed documentation of the laboratory's energy equipment. This documentation enabled us to generate a complete inventory of the equipment and its energy specifications. However, due to the absence of additional data such as energy bills, equipment usage schedules, and architectural plans, our analysis was limited. To fully understand energy consumption patterns and space usage, it is essential to collect these missing data.0

Our analysis revealed that the laboratory's energy consumption rises at the end of September and remains high until May, corresponding to increased usage during peak academic and research activities. Energy consumption drops significantly from June to August due to reduced activities.

- **Recommendations for Energy Efficiency Improvements**

1. Invest in energy-efficient equipment and appliances.
2. Install energy management systems to monitor and control energy usage in realtime.
3. Conduct energy awareness programs and training sessions for staff and students.

- **On-Site Visits and Detailed Data Collection**

The on-site visits included comprehensive data collection focusing on energy, relative and absolute humidity, and temperature measurements. The placement of the DAQ Box v2 for data collection allowed us to gather accurate data.

The analysis of temperature and humidity data revealed crucial insights into the building's thermal insulation:

- **South Wall:** Exposed to direct sunlight, experienced the most significant temperature rise and the largest decrease in relative humidity.
- **East Wall:** Showed a delayed temperature rise due to morning shading.
- **North Wall:** In contact with corridors, exhibits a relatively stable temperature evolution throughout the day and is less susceptible to fluctuations in outdoor temperature compared to the other walls
- **West Wall:** Exhibited moderated temperature increases due to shading by trees.

Electrical consumption data showed stable voltage readings for V1 and V2, but the absence of V3 suggested only two active phases. Current variations indicated fluctuating loads over time. Energy consumption data revealed significant differences between energy phases, highlighting the need for optimizing phase usage.

- **Recommendations Based on Detailed Analysis**

1. Enhance insulation around openings and exterior walls to improve thermal performance.
2. Install thermal curtains or shutters and utilize external shading devices, particularly on the South and East walls.
3. Maximize the use of three-phase energy by balancing electrical loads.
4. Use ventilation systems (VMC) to control humidity and temperature effectively.

- **Physical condition diagnosis of the laboratory**

Visual inspections revealed significant damages:

- **Ceiling:** Peeling paint, moisture stains, and structural degradation due to water leaks and inadequate ventilation.
- **West Wall:** Cracks allowing air and moisture infiltration, leading to mold issues.
- **Windows and Garage Doors:** Gaps permitting uncontrolled airflow, light, and water penetration, compromising energy efficiency, security, and comfort.
- **Lighting:** Malfunctioning lamps resulting in inadequate lighting.

Structural Repair Recommendations

1. Install new aluminum windows to improve insulation and security.
2. Repair and seal cracks in walls to prevent air and moisture infiltration.
3. Replace malfunctioning lamps with LED bulbs to enhance lighting conditions.
4. Maintain and adjust garage doors, and install seals to prevent air, dust, and insect infiltration.

To complete this project, there is one last step mentioned in paragraph II.4.2of the chapter 2: the presentation to the project owner.

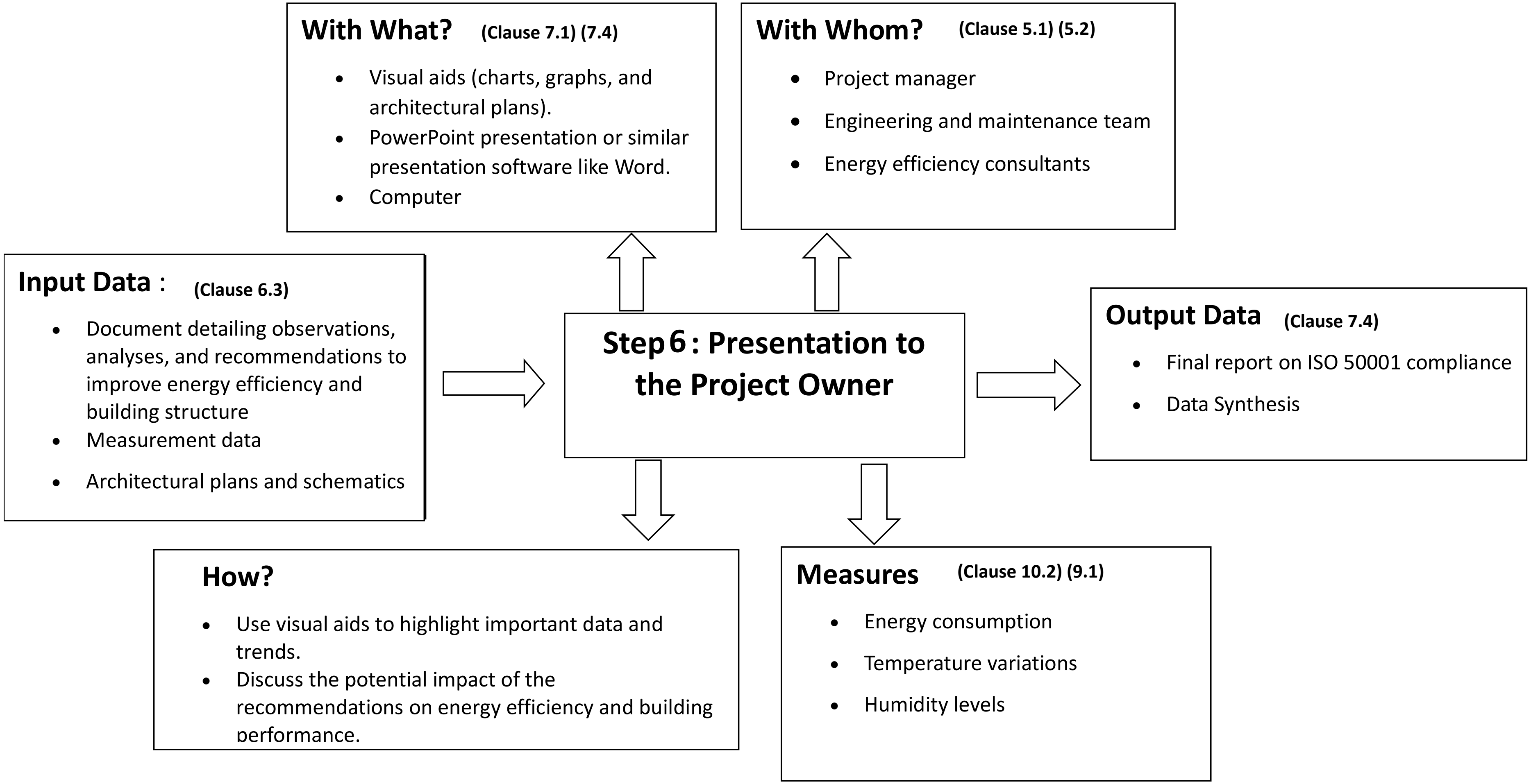

Figure III-19 Process of the Call for Presentation to the Project Owner in Laboratory by Crosby's Turtle Diagram

In this section, we will discuss the compliance of the laboratory. The following results are found in the tables below:

Table III-6 Integrating ISO 50001 Requirements and Information from the Final Report

Process	Element to Collect	ISO 50001 Requirement	Description	Tools/Techniques Used	Comments
Data Collection	ElectricityConsumption	Clause 7.1	Monthly records of electricity consumption	Electricity bills, meterreadings	Non-compliant - No meter readings
	Equipment Performance	Clause 6.6	Analysis of laboratory equipment performance	QUALISTAR Electrical Network Analyzer (CA 8336), DAQ Box v2	Non-compliant - Equipment performance is not adequately analyzed
	Building Envelope Conditions	Clause 6.1	Inspection of walls, roofs, and floors for cracks and humidity	Laser Distance Meter (CT 44035), Infrared Thermometer	Non-compliant - Recommend repairs and improvements to insulation to reduce energy loss
	ElectricalLoad Profiles	Clause 6.4	Monitoring of electrical consumption every ten minutes	QUALISTAR Electrical Network Analyzer (CA 8336)	Compliant - Load profiles are monitored continuously
	Occupant Behavior	Clause 6.2	Study of space usage habits by occupants	Questionnaires, interviews	Non-compliant - Occupant usage habits are not documented
	Environmental Conditions	Clause 6.6	Monitoring of temperature and humidity in the laboratory	SHT35 sensors for temperature and humidity	compliant - Maintain stable temperature and humidity to protect sensitive equipment
Initial Data Analysis	Energy Performance Evaluation	Clause 7.2	Comparison of current performance with performance objectives	Analysis software	Non-compliant - No objectives to compare
Site Visit	Real-time Data Collection	Clause 8.1	Collection of data on electrical consumption, humidity, and temperature	DAQ Box v2, Kestrel 3000 Weather Meter	Compliant - Real-time data is collected and analyzed correctly
Recommendations and Report	Energy Consumption Report	Clause 10.1	Compilation of data and recommendations for improving energy efficiency	Reporting software, spreadsheets	Compliant - Report is compiled and recommendations are provided

Additional Clauses (ISO 50001)

Process Step	Clause	Description	Comments
Step 0: call for tenders,contract,proposal	4.1	Context of the Organization	Non-compliant - The section is a student thesis and does not cover external and internal context requirements
	4.2	Understanding Needs and Expectations of Interested Parties	Non-compliant - The section does not identify interested parties and their requirements
	4.3	Determining the Scope and Boundaries of the EnMS	Compliant - The section clearly defines the scope of the energy management system (EnMS) within the laboratory
Step 1: Data Collection	4.4	Energy Management System	Non-compliant - The section does not present a structured, implemented, and continually improved EnMS
Step 2: First Exploitation of Data	5.1	Leadership and Commitment	Compliant - The section demonstrates management commitment through thesis supervision and set objectives
Step 1: Data Collection	5.2	Energy Policy	Non-compliant - The section does not define an appropriate energy policy
Step 3: visiton site	7.3	Awareness	Non-compliant - The section does not address employee awareness of energy objectives. Integrate training and awarenessinto the action plan
Step 4: Data Analysis	8.2	Design	Non-compliant - The section does not integrate energy considerations into the design of facilities, equipment, systems, and processes. Recommendimprovementsbased on currentenergy designs
	9.1	Monitoring, Measurement, Analysis, and Evaluation	Compliant - Establish a process for monitoring and measuring energy performance indicators (EPIs). Use tools like sensors for real-time data collection
	9.2	Internal Audit	Compliant - The section mentions the conduct of regular internal audits to assess EnMS effectiveness
Step 5: Recommendations and Report	9.3	Management Review	Non-compliant - The section does not provide for periodic management reviews to ensure the adequacy, effectiveness, and efficiency of the EnMS
	10.2	Nonconformity and Corrective Action	Non-compliant - The section does not establish a process for addressing nonconformities and taking corrective actions. Identify and correct nonconformities detected during the energy audit

III.3.5 Synthesis

The analysis of the energy audit data for the Construction Materials Laboratory (MDC) at Aboubakr Belkaid University reveals several significant non-conformities with ISO 50001 standards. One major issue is the lack of individual electricity meters, as the university uses a single meter for the entire campus. This centralized metering system complicates the direct attribution of energy consumption to the MDC laboratory, hindering compliance with Clause 7.1, which requires detailed monthly energy consumption data. Additionally, the performance analysis of equipment was found to be inadequate. Despite using advanced tools like the QUALISTAR Electrical Network Analyzer, the analysis did not fully meet the comprehensive requirements of Clause 6.6.

Furthermore, the documentation of occupant behaviour was insufficient. The study failed to adequately capture the space usage habits of staff and students, as mandated by Clause 6.2. This lack of detailed behavioural data makes it difficult to implement effective energy management strategies. The laboratory also lacked clear energy performance objectives to benchmark its current state and track improvements over time, a requirement outlined in Clause 7.2.

Other non-compliances were identified in areas such as the formulation of an energy policy, which was not appropriately defined, and the awareness and training of employees regarding energy objectives, which were not adequately addressed. The design of facilities, equipment, systems, and processes did not incorporate energy considerations, as required by Clause 8.2. These gaps highlight the need for a more structured and comprehensive implementation of the ISO 50001 energy management system.

III.4 Conclusion

The detailed analysis of the energy audit data for the Construction Materials Laboratory (MDC) at Aboubakr Belkaid University has identified several critical areas of non-compliance with the ISO 50001 energy management standard. Key issues include the lack of individual electricity meters, which complicates the precise tracking of energy consumption for the

laboratory. Additionally, the performance analysis of the equipment was found to be insufficient, preventing an accurate assessment and improvement of energy efficiency.

Furthermore, the documentation of occupant behavior was inadequate, failing to capture the space usage habits of staff and students. This lack of detailed behavioral data hinders the development of effective energy management strategies. The laboratory also lacked clear energy performance objectives, which are essential for evaluating current performance and tracking improvements over time.

Other deficiencies were noted in the laboratory's energy policy, employee awareness, and integration of energy considerations into the design and operation of facilities and systems.

General conclusion

In conclusion, Algeria's energy policy reflects a dynamic and multifaceted approach to meet the challenges posed by increasing energy consumption and the transition to a more sustainable future. The country's dependence on petroleum products and natural gas has encouraged the government to adopt ambitious initiatives to promote energy efficiency and the development of renewable energy sources.

An analysis of key concepts related to energy, energy consumption trends both globally and nationally, as well as specific measures taken by Algeria, illustrates the country's commitment to improving its energy landscape. The emphasis of energy efficiency, especially in the construction sector, underscores the importance of optimizing energy use in buildings and infrastructure. The renewable energy development program highlights Algeria's potential to exploit its abundant solar resources, which is essential for diversifying the energy mix and reducing dependence on hydrocarbons. The role of energy audits and the implementation of international standards such as ISO 50001 demonstrate Algeria's efforts to identify and implement energy-saving measures, thereby improving environmental and economic outcomes.

This thesis explored the challenges and opportunities related to energy management in Algeria, with an emphasis on improving energy efficiency and developing renewable energies. The analyses and case studies presented clearly show the importance of adopting energy management practices that comply with international standards such as ISO 50001.

The energy audit conducted at the Building Materials Laboratory (MDC) revealed strengths as well as several critical areas of non-compliance with the ISO 50001 standard. Among the main problems identified are the absence of individual electricity meters, making it difficult to accurately monitor the laboratory's energy consumption. Additionally, the performance analysis of the equipment proved to be insufficient, preventing an accurate assessment and improvement of energy efficiency. Moreover, the documentation of occupant behavior was insufficient, failing to capture the space usage habits of staff and students. This lack of detailed behavioral data impedes the development of effective energy management strategies. Additionally, the laboratory lacked clear energy performance objectives, which are essential for evaluating current performance and monitoring improvements over time.

Other shortcomings were noted in the laboratory's energy policy, employee awareness, and the integration of energy considerations into the design and operation of facilities and systems.

The recommendations provided are intended to fill these gaps and strengthen existing measures to achieve optimal energy efficiency. Continuous commitment to improving energy efficiency and sustainable energy management is essential to meet growing energy needs and combat climate change. This thesis offers a solid basis on which to consider improvements and integrate recommendations to optimize the laboratory's energy conditions.

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Annex

Annexe1 Comparison between the 2011 and 2018 Version Standard

ISO 50001: 2011	ISO 50001: 2018
Introduction	Introduction
1. Scope	1. Scope
2. Normative references	2. Normative references
3. Terms and definitions	3. Terms and definitions
	4. Organizational context
	4.1. Understanding the organization and its context
4. Energy management system requirements	
4.1 General requirements	4.3. Determination of the area of application of the energy management system 4.4. Energy management system
4.2 Management responsibility	5.1 Leadership and commitment
4.2.1 Direction	4.3 Determination of the area of application of the energy management system 5.1 Leadership and commitment 7.1 Resources
4.2.2 Management representative	5.1 Leadership and commitment 5.3 Role, responsibility and authority within the organization
4.3 Energy policy	5.2 Energy policy
4.4 Energy planning	6. Planning
4.4.1 Generality	6.1 Action to be implemented in response to risks and opportunities
4.4.2 Legal and other requirements	4.2 Understanding the needs and expectations of interested parties
4.4.3 Energy review	6.3 Energy review
	6.1 Action to be implemented in response to risks and opportunities
4.4.4 Reference consumption	6.5 Reference energy situation
4.4.5 Energy performance indicator	6.4 Energy performance indicator
4.4.6 Energy objective and target, and energy management action plan	6.2 Objectives, energy targets, and planning of actions to achieve them
4.5 Implementation and operation	7. support 8. Carrying out operational activities
4.5.1 Generality	
4.5.2 Skills, training and awareness	7.2 Skills 7.3 Sensitization
4.5.3 Communication	7.4 Communication
4.5.4 Documentation	7.5 Documented information
	7.5.1 Generality
	7.5.2 Creation and update
	7.5.3 Documented information mastery
4.5.5 Operational control	8.1 Planning and operational control
4.5.6 Conception	8.2 Conception

ISO 50001:2011	ISO 50001:2018
4.6 Verification	9. Performance evaluation
4.6.1 Monitoring, measurement and analysis	9.1 Monitoring, measurement, analysis and evaluation of energy performance and SME 6.6 Planning for energy data collection
4.6.2 Assessment of compliance with legal and other requirements	9.1.2 Assessment of compliance with legal and other requirements
4.6.3 Initial Audit of SME	9.2 Internal Audit
4.6.4 Non-compliance, corrections, corrective actions and preventive actions	10.1 Non-compliance and corrective action
4.6.5 Mastery of recordings	7.5 Documented information (see below, under documentation)
4.7 Management review	9.3 Management review
	10.2 Continuous improvement
Annex A (informative) Recommendation for implementation of this international standard	Annex A (informative) Implementationcommands
Annex B (informative) Correspondence between ISO 50001:2011, ISO 9001:2008, ISO 14001:2004 and ISO 22000:2005	Annex B (informative) Correspondence between ISO 50001:2011 and ISO 50001:2018
Bibliography	Bibliography

Annexe2Complete List of Equipment

العنوان : ص.ب230تلمسان13000
الهاتف : (043) 41 - 00 - 11/12
الفاكس : (043) 41 - 00 - 11/12

الجمهورية الجزائرية الديمقراطية الشعبية
وزارة التعليم العالي و البحث العلمي
جامعة أبي بكر بلقايد - تلمسان
كلية التكنولوجيا

Tlemcen le : 22/06/2022

Laboratoires de mécanique
Laboratoire MDC1 MDC2
Fiche D'inventaire

N°	Désignation	Quantité	N° D'inventaire	Observation
01	Bétonnière de laboratoire de 125 L	01	SN : 400555	
02	Scie à béton électrique d = 450 mm	01		Pompe à eau en panne
03	Scie à béton d = 600 mm **(Steinadler)**	01	**SN : 88076**	Au magasin Manque de pompe à eau
04	Table de secousses manuelle	01	SN : 79020351	
05	Table vibrante pour éprouvettes	01	SN : 79111451	
06	Bain thermostatique avec panneau électrique	01	SN : 80061279	
07	Bain thermostatique avec panneau électrique	01	SN : 80061276	Résistance cassée
08	Balance de capacité 30 Kg	01		
09	Machine d'essai de compression 2000KN	01	SN : T07005	**CONTROLAB**
10	Machine de compression 1100 KN RMU	01		
11	Perméamétre à béton **(Josef Freundl)**	01	**SN : 3015**	
12	Maniabilimètre à béton	01		/
13	Appareil d'étalonnage électronique avec cellules de différentes charges	01	**SN : Y06005**	
14	Machine universelle hydraulique de traction et compression 600 KN avec accessoires	01	**SN :037961**	
15	Portique didactique universel pour béton / bois et acier avec accessoires	01	**MP 34 A H 15/B 10-A 51/500**	**CONTROLAB**
16	Machine DEVAL	01	SN : 203180302	
17	Machine micro Deval	01	Mod. A78 N.3	**CONTROLAB**
18	Machine LOS ANGELES	01	**SN : 79111580**	

19	Système de mise en charge électronique pour portique univ(**DIGIMESS) M10**	01	**SN** : Y06005	
20	Carotteuse électrique à deux vitesses pour béton avec accessoires **(Cardi)**	02		**CONTROLAB**
21	Vibreur électrique **STAR**	01	**SN** : 0006085	
22	Appareil ultrasons	01	**SN** : 4062002	**CONTROLAB**
23	Balance ACS System 40 KG **TASSILI**	02		
24	Centrale de mesure modèle UPM40	01		
25	Unité multivoies de mesures extensométriques dynamique 2130	01		
26	Erudite Oscilloscope **(HAMEG)**	01 01	**SN** : 93/9678 **SN** : HM20305	
27	Appareillage équivalent de sable	01	**SN** : R05042	**CONTROLAB**
28	Etuve orange de 400 litres	02		
29	Balance électronique de portée 6 Kg **Sartorius**	01	**SN** : 13307305	**CONTROLAB**
30	Boulloire le chatelier **Controls**	01	**SN** : 10-4.008	
31	Malaxeur 5L avec cuve inox et batteur alliage léger **(HOBART)**	02		En panne
32	Appareillage de Vicat	04		
33	Perméabilimètre**(BLAINE)**	02	**SN** : 79121717 **SN** : 79121715	
34	Machine de flexion électrique 4*4*16	01	80061233	**CONTROLS**
35	Diviseur échantillonneur	04		
36	Appareil Joisel (diam 14 x 22) cm pour analyse du béton frais et détermination de la teneur en ciment sable et agrégrats	03		
37	Cône d'écoulement	02		**CONTROLAB**
38	Appreil SPEEDY	03		01 incomplète
39	Scléromètre à béton	01	17616/FT/19	/
40	Scléromètre à béton **CONTROLAB**	01	V12001	
41	Scléromètre à béton	01	N-34 120440	
42	Scléromètre à béton	01	L-9 7888	
43	Scléromètre à béton	02	C181N 9121 Mod.dep.	
44	Pachomètre	02	**SN** : 2399003 **SN** : 2399040	
45	Profomètre	01	**SN** : 014337	**CONTROLAB**
46	Déformomètre ou Réctractomètre	01		
47	Machine de fragmentation dynamique	01		
48	Appareil d'essai d'arrachement **(IBERIA)**	01		
49	Humidimétre éléctronique	01		

50	Tamiseuse électrique pour tamis diam 200 mm	02	SN : T05055 Mat :79091118	CONTROLAB
51	Mixeur de laboratoire capacité 10 L	01	SN : V09007	CONTROLAB en panne
52	Aéromètre à béton	01		CONTROLS
53	Table à choc pour mortier	01	SN : 80071508	
54	Pétrin électrique	01	15995/FT/16	CONDOR
55	Concasseur à mâchoires	01	SN : 670-01-013	CONTROLAB
56	Pont d'extensomètre portable EI 616	01	SN : 50143947	CONTROLAB
57	Pompe à vide	01		
58	Imprimante HP laser 1020	01	SN : CNCOH42968	
59	Bureau	02		
60	Armoire métallique	02	FSI/3739/03	
61	Armoire métallique vitrée	05		
62	Rayonnage	04		
63	Moule pour essai de fissurabilité	01	SN : E0067M	
64	Extincteur	01		
65	Compresseur **FIAC**	01		
66	Enclume d'étalonnage pour scléromètre	01	SN : C0184	
67	Tableau blanc 3 mètres	01		
68	Cône d'abrams	01	17617/FT/19	
69	Mark VII Strain GAGE Soldering unit	01	SN : 0001761	
70	Capteur de déplacement SDP-100C	01	SN : 629053	
71	Capteur de déplacement SDP-50C	01	SN :619742	
72	Capteur de déplacement CDP-5	01	SN :558456	
73	Capteur de déplacement CDP-25	01	SN :529013	
74	Bascule à romaine capacité 51 Kg	01		
75	Balance LUBELSKIE Cap : 15Kg	01	n°1485/95r	
76	Centrale de mesure électronique d'humidité relative et de température BARON S. A.	01		CONTROLAB
77	Appareil d'adhérence	01	7528	

ملاحظة: إن أي عملية في تغيير العتاد، نقله، أو جلبه لا تتم الا بإعلام مصلحة الجرد، وذلك لإجراء ما يلزم تغييره ضمن قائمة الجرد

Responsable | **Chargé(e) d'inventaire** | **Service des moyens et de maintenance**

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