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"PG2E", an innovative solution for identifying Energy Saving Potential Scope (ESPS) in municipalities : The case of Quesnoy-Sur-Deûle.

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Abstract :

Faced with the global challenges of the energy crisis and the climate targets for 2030 and 2050, municipalities play a key role in the energy transition, accounting for around 10% of their territory's energy consumption. However, for Small and Medium Municipalities (SMMs), identifying energy-intensive units remains complex, often time-consuming and costly, with processes taking between 3 and 18 months. Current systems used to identify Energy Saving Potential Scopes (ESPSs) are limited, relying on manual and time-consuming methods.

This article proposes an innovative approach with the "PG2E" tool, designed to simplify the ESPS identification process. The aim is to reduce the time and costs required to identify an ESPS dedicated to ISO 50001, without calling on technical experts. Being in an emerging field of research, we adopted a realist-critical posture to analyze the shortcomings of existing systems, based on real energy data from a municipality, and a constructivist-pragmatic approach to develop an adapted solution.

Simulations carried out with the "PG2E" solution in the municipality of Quesnoy-sur-De le revealed that traditional methods, based on existing systems, are limited in their effectiveness. The results show that "PG2E" enables the ESPS to be identified with a success rate ranging from 60% to 100%, depending on the number of energy-intensive units decided by the municipalities, based on statistical data indicator criteria such as average consumption and upper quartile. While "PG2E" is no substitute for in-depth technical analysis, it does provide an innovative approach and offers an effective, pragmatic, fast and economical alternative for SMMs.

Keywords: "Energy Saving Potential", ESPS, "ISO 50001", PG2E, Energy

Abbreviations

ADEME :	Agence De l'Environnement et de la Ma�trise de l'Energie. (French Environment and Energy Management Agency).
Cit'ergie :	A management and certification program that rewards local authorities for implementing an ambitious climate-air-energy policy.
CS :	Certification Scope
EIS :	Energy Information System
EMS :	Energy Management System
ESPS :	Energy Savings Potential Scope
EU :	European Union
GHG :	GreenHouse Gas
IPCC :	Intergovernmental Panel on Climate Change
ISO :	International Standards Organization
LMS :	Local Measurement System
PG2E :	It is an innovative solution software for identifying ESPA
PIP :	Pluriannual Investment Plan
QSD :	Quesnoy-Sur-De�le
REMP :	Real-Estate and Energy Master Plan
SMM :	Small and Medium Municipalities
TCAEP	Territorial Climate-Air-Energy Plan

1 Introduction

Energy management has become a crucial issue in the global fight against global warming. Energy systems alone account for more than two-thirds of global greenhouse gas emissions, with a heavy reliance on fossil fuels as a major source of energy (*Figure 1*). According to the Intergovernmental Panel on Climate Change (IPCC), it is imperative to drastically reduce the use of these fuels to limit global warming to 1.5°C by 2030. This transition requires concerted efforts, combining increased use of renewable energies, significant improvements in energy efficiency and the implementation of energy-saving practices [1] [2] [3].

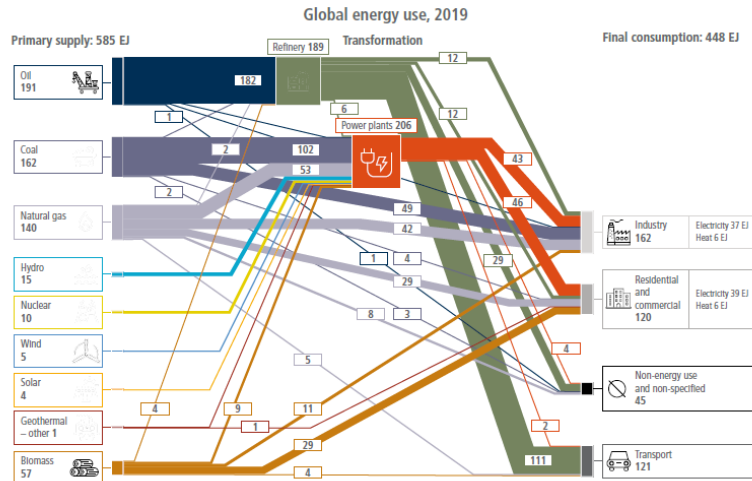


Figure 1 : Global energy flows in the 2019 global energy system (IPCC)

In this global context of energy challenges, local energy management is of crucial importance. Indeed, local authorities are in a strategic position to implement concrete, sustainable solutions, by optimizing the energy consumption of their infrastructures and encouraging the emergence of eco-responsible practices on their territory.

The policy of energy efficiency is just as important as that of sobriety, but it acts on energy consumers. For any energy consumer, this means implementing concrete actions that are characterized by a cost or investment and by the expected energy savings. The success of this energy efficiency policy depends on a number of strategic Energy Performance Indicator factors: the simultaneous implementation, coordination and correct sequencing of strategic Energy Performance Indicator implementation [4]. These are at the heart of energy management, and form part of the requirements of the ISO 50001 standard - Energy management systems adopted by private, public, industrial, tertiary and local authority organizations.

But the main factor driving the adoption of the Energy Management System (EMS) by these structures, including local authorities in countries around the world, is concern about climate change. After all, non-renewable fuels are the world's main source of energy. Thus, diminishing supply, increasing demand, rising product costs and adverse effects on the environment have led to the need to create the ISO 50001 standard to implement the Energy Management System (EMS) in order to increase energy efficiency and reduce greenhouse gas (GHG) emissions. [5].

According to the latest survey by the International Organization for Standardization in 2022, the total number of ISO 50001: 2011&2018 installations in 194 countries is 53569, including 27631 valid certificates, i.e. 52% of the total number of sites worldwide. [6] [7].

The example of the 10 countries in *Table 1* (data from the ISO survey of 2022 data) and the graph in *Figure 2*, clearly confirm the relatively high number of sites and certification of certain countries. [6] [7].

Table 1: Example of 10 countries that have installed ISO 50001 (2022 data from ISO source)

Country	Certificates	Sites
Austria	390	691
China	7 592	7 620
Denmark	75	176
France	1 010	5 307
Germany	5 523	16.452
Italy	1.656	3 496
Japan	10	12
S.Africa	20	18
UK	924	3 751
USA	68	243
TOTAL :	17.268	37 766

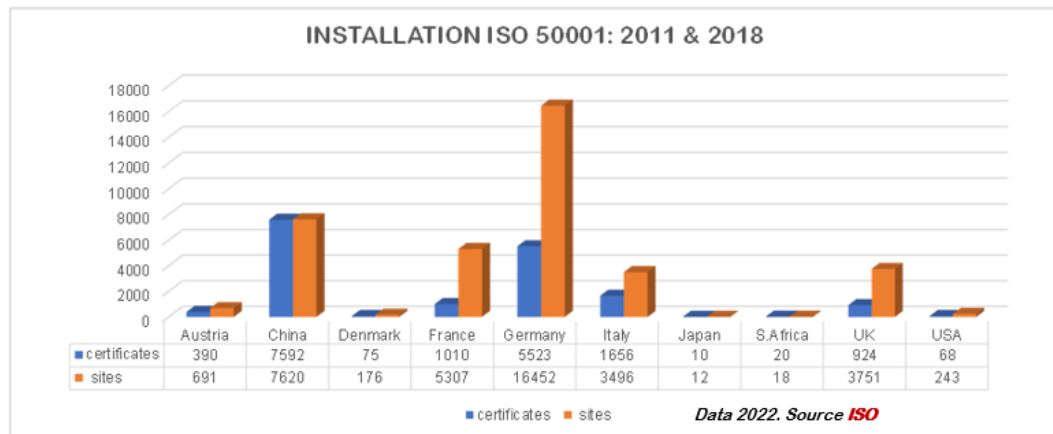


Figure 2 : EMS installation and certification to ISO 50001 in 2022

It is worth remembering that ISO standard dissemination is a process that can be influenced by environmental, economic and socio-cultural factors in each region, country and/or industry sector [5]. By way of example, the implementation of an Energy Management System in a small Latvian municipality with a population of around 6,000 has resulted in energy savings [8].

The European Union, through ambitious policies such as Directive (EU) 2023/1791, aims to reduce greenhouse gas emissions by 55% by 2030. [9]. In France, these objectives take on a particular dimension at the level of local authorities, responsible for around 10% of their territory's energy consumption [10]. They occupy a strategic position, as they are both managers of energy-intensive property assets and essential relays for promoting eco-responsible practices among the general public.

However, Small and Medium Municipalities (SMM) face specific challenges in this energy transition. Unlike larger communities, they have limited financial and human resources, which makes it difficult to adopt cutting-edge technologies or implement ISO 50001-compliant energy management systems (EMS). This essential standard provides a structured framework for optimizing energy management, reducing greenhouse gas emissions and boosting energy efficiency. But its application remains a complex process, requiring in-depth audits and the precise identification of dedicated certification Scope (CSs).

One of the major challenges lies in the identification of Energy Savings Potential Scopes (ESPS), zones or groupings of energy-intensive units where significant savings can be made. This process is often long, costly and technically demanding. Traditional methods, such as the Real-Estate and Energy Master Plan (REMP) or the Local Metering System, rely on in-depth diagnostics that can extend over several months, mobilizing considerable resources. These limitations are particularly critical for SMMs, which often lack centralized data and trained personnel to carry out these analyses [11] [12].

Despite our best efforts, current approaches have a number of limitations. Firstly, they are often based on criteria such as infrastructure obsolescence or regulatory compliance, which require in-depth technical expertise and considerable resources. Secondly, the diversity of building assets and the complexity of energy use within local authorities make it difficult to adopt a standardized approach. Finally, the absence of solutions tailored to the realities of SMMs limits their ability to participate fully in the energy transition.

Faced with these challenges, there is an urgent need to develop simplified, accessible and automated tools to enable SMMs to better manage their energy consumption. These tools must be capable of rapidly identifying the most relevant certification scopes, while respecting the technical, financial and human constraints specific to these local authorities.

Although the energy management of local authorities is the subject of a great deal of research, the specific topic of identifying Energy Savings Potential Scopes (ESPS) remains largely unexplored. Existing work focuses mainly on general energy diagnostics or approaches linked to standards such as ISO 50001 [13] [14], [15] without providing specific methodologies adapted to SMMs. In addition, academic references dedicated to the rapid and automated identification of ESPSs are rare, if not non-existent. This lack of literature highlights the need to develop new, pragmatic solutions to meet the growing needs of local authorities. This article therefore positions itself as a pioneering contribution, introducing an innovative approach to filling this gap.

This is the background to our research, which is aimed at proposing an innovative solution: the **PG2E** system (Digital solution for identifying Energy Savings Potential Scopes in municipalities). This tool, designed specifically to meet the needs of SMMs, uses a combinatorial approach based on set theory and simple statistical criteria (mean and upper quartile) to automatically and rapidly identify the most relevant ESPSs. Unlike traditional approaches, PG2E eliminates the need for time-consuming criteria such as obsolescence or regulatory compliance, and offers an accessible alternative even for municipalities with limited technical resources.

The main aim of this article is to present the operation and results of the PG2E solution, highlighting its advantages over existing methods. To illustrate its effectiveness, a case study is carried out on the municipality of

Quesnoy-sur-Deûle (QSD). The study shows how PG2E enables ESPSs to be identified rapidly, with high match rates compared with reference methods, while significantly reducing the time and cost required.

The article is structured as follows :

- The introduction sets the context and presents the issues and objectives of the study.
- The methodology details the approach adopted to analyze the limitations of existing systems and develop PG2E.
- The following section explores the concept of the Energy Savings Potential Scope (ESPS), as well as traditional methods and their limitations.
- Particular attention is paid to the specific challenges faced by SMMs.
- The innovative PG2E solution is presented in detail, followed by a case study from Quesnoy-sur-Deûle (QSD).
- Finally, the discussion and conclusion offer an analysis of the results obtained, while opening up perspectives for future research.

By combining theoretical, methodological and empirical approaches, this article aims to make a significant contribution to the field of community energy management. PG2E aims to be a pragmatic and effective solution, capable of transforming the challenges faced by SMMs into opportunities in the global energy transition.

2 Methodology

Our methodological approach falls within the framework of scientific research, aimed at exploring a new field of research linked to the identification of Energy Savings Potential Scope (ESPS). This approach is based on a combination of empirical observations, mathematical concepts and models from set theory with accessible statistical criteria, eliminating dependence on the time-consuming processes of traditional approaches, and field surveys, integrating a critical realist epistemological posture.

This approach enabled us to expose the shortcomings of existing systems, in this case the measurement system, Cit'ergie (a management and labeling program for local authorities) and the Real-Estate and Energy Master Plan (REMP) system, used in municipality energy diagnostics. With this in mind, we followed an inductive approach, starting with observation of the perceived reality of our case study. Based on this observation and empirical generalization, as well as field surveys, we developed a model based on mathematical science theory to improve existing systems.

These inductive approaches (*Figure 3*) [16] and abductive (*Figure 4*) approaches were necessary, as the development of the PG2E methodology is part of an emerging field of research, where academic references remain limited and theory concerning the inadequacy of existing systems is poorly developed or even non-existent in the scientific academic literature. In the absence of specific methodologies in the literature, this study adopted an innovative combinatorial approach, relying on set theory to generate and analyze energy-intensive sub-assemblies. In addition, the simplified criteria of average consumption and upper quartile, introduced in this research, constitute an original and accessible alternative to traditional approaches, which are often time-consuming and complex.

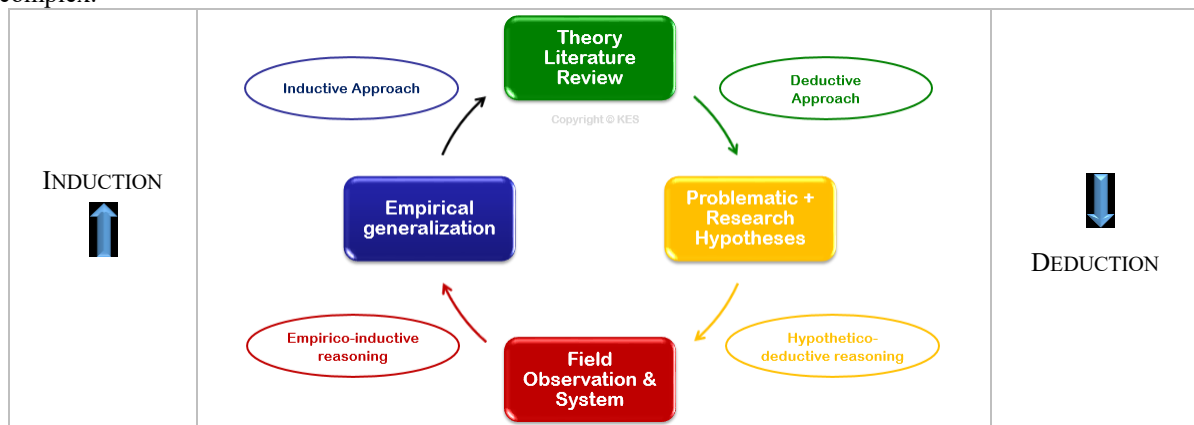


Figure 3 : The wheel of scientific knowledge inspired by Walter Wallace's wheel of scientific knowledge

ABDUCTIVE APPROACH

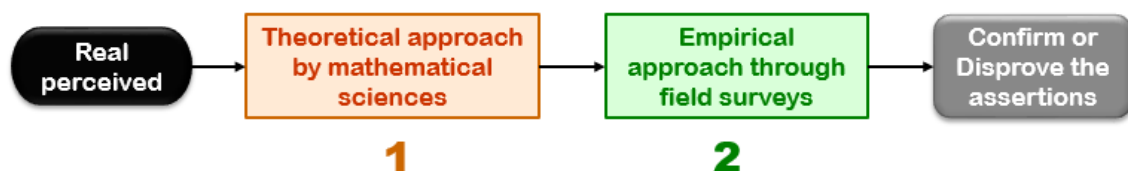


Figure 4 : The scientific abductive approach

2.1 Analysis of existing systems and identified shortcomings

Initially, we studied existing systems (Local Measurement System (LMS), Cit'ergie, Real-Estate and Energy Master Plan (REMP)) used for energy diagnostics in municipalities. This exploration identified several major problems or shortcomings :

- Heavy reliance on time-consuming criteria such as equipment obsolescence and regulatory compliance.
- The need to mobilize substantial technical and human resources, often beyond the reach of Small and Medium Municipalities (SMM).

This analysis was conducted using an inductive approach, based on empirical observations from a case study and field surveys of municipality in France and Côte d'Ivoire.

2.2 Mathematical modeling: an innovative combinatorial approach

Based on the shortcomings identified, we developed a model based on mathematical theories to improve existing systems. The main objective was to simplify and automate the identification of **ESPSs**, while guaranteeing results comparable to those of traditional methods.

2.2.1 Sub-assembly construction

The initial step in PG2E is to generate all possible subsets of a given set of energy-consuming units, with the exception of the empty set and the complete set.

Let an initial set E consist of n energy-consuming units :

$$E = \{e_1, e_2, e_3, \dots, e_n\}$$

The total number of possible subsets is given by :

$$2^n - 2$$

(This formula excludes the empty set and the complete set).

Example: for $n = 5$, the set $E = \{e_1, e_2, e_3, e_4, e_5\}$ generates 30 possible subsets.

2.2.2 Calculation of sub-assembly energy consumption

For each subset $S_i \subseteq E$, the total energy consumption $C(S_i)$ is calculated :

$$C(S_i) = \sum_{e \in S_i} C(e)$$

Where $C(e)$ is the individual consumption of the energy-consuming unit e .

2.2.3 Filtering eligible subsets

The sub-assemblies are filtered according to the threshold of 65%, recommended by ISO 50001, of the total energy consumption of the assembly E :

$$C(S_i) \geq 0,65 \times C(E)$$

Sub-areas meeting this condition are selected as *eligible Scope*.

2.2.4 Application of statistical criteria

For each eligible subset, two simplified criteria are calculated :

- Average consumption :
-

$$\bar{C}(S_i) = \frac{1}{|S_i|} \sum_{e \in S_i} C(e)$$

- Upper quartile :

The upper quartile $Q_3(S_i)$ is determined by ordering the values $C(e)$ of S_i values in ascending order, then selecting the value at the position corresponding to 75% of the workforce.

2.2.5 Selection of the best ESPS

Among the eligible subsets, the optimal scope is the one that maximizes the statistical criteria defined above :

$$S_{optimal} = \arg \max_{S_i \in \text{éligibles}} \{\bar{C}(S_i), Q_3(S_i)\}$$

This scope has been selected as the *optimal ESPS*.

2.3 Process automation

The PG2E methodology is fully automated using a combinatorial programming algorithm implemented in Python. The algorithm follows the following steps :

1. Generate all possible subsets using Python's combinatorial library (`itertools.combinations`).
2. Calculation of $C(S_i)$ for each subset.
3. Application of the filter based on the 65% threshold recommended by ISO 50001.
4. Criteria calculation $\bar{C}(S_i)$ and $Q_3(S_i)$ for eligible subsets.
5. Automatic selection of optimum Scope.

2.4 Validation and Analysis

The optimal scope identified is then compared with scopes obtained using traditional approaches (such as REMP) to assess PG2E's performance and accuracy. Match rates are calculated as follows :

$$\text{Correspondence rate} = \frac{\text{Number of common units in ESPS identified by "PG2E" and REMP}}{\text{Total number of ESPS units identified by the "PG2E" solution}} \times 100$$

The correspondence rate, a key validation indicator, will be deemed sufficient if the ratio of the number of common units in the ESPS identified by the "PG2E" tool and the REMP to the total number of units in the ESPS of the "PG2E" tool reaches a rate greater than or equal to 50% according to the REMP scenarios; this will verify the accuracy and efficiency of the "PG2E" solution.

2.5 The PG2E process

The PG2E process presents an overall summary diagram of the stages involved in the new solution (Figure 5).



Figure 5 : Stages of the innovative PG2E solution

The data collection stage is based on the extraction of monthly or annual energy consumption data for energy-consuming units, stored in the energy supplier's database. This data is then imported into an Excel file and loaded into the new "PG2E" solution. This solution, based on set theory and enumeration techniques, creates ESPSs (Energy Savings Potential Scope) and filters them according to a consumption criterion greater than or equal to 65% of the total energy consumption of energy-intensive units, in order to constitute ESPSs eligible for identifying the Certification Scope (CS) of the energy management system (EMS) according to the ISO 50001 standard (Figure 6).

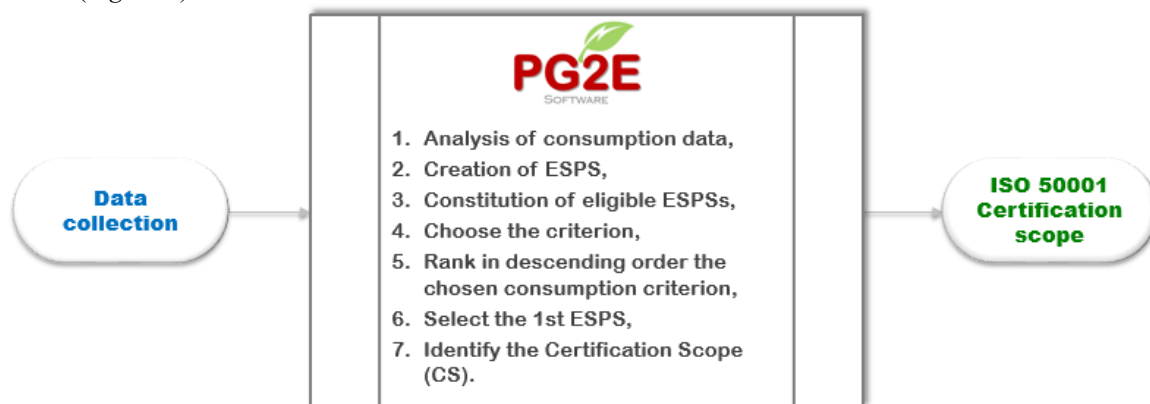


Figure 6 : PG2E process for identifying the ISO 50001 Certification Scope (CS)

2.6 Empirical survey

In addition to the modeling, a field survey was carried out with over a dozen local authorities (populations: 6,000 to 111,000). The aim was to :

- Evaluate the transportability of PG2E in various contexts.
- Confirm or refute the problems of existing systems.
- Identify local authorities' difficulties in manually managing energy-saving opportunities.

2.7 Methodological conclusion

This methodology, combining mathematical, empirical and abductive approaches, has enabled us to develop an innovative solution adapted to the realities of SMMs. By simplifying the process, PG2E reduces lead times and costs while maintaining accuracy comparable to traditional methods.

3 Energy Savings Potential Scopes (ESPS)

3.1 What is the ESPS

The Energy Savings Potential Scopes (ESPS) is defined as a set of energy-intensive units, zones or sectors where energy savings can be achieved. Figure 7 shows an example of an organization's ESPS concept, with five energy-intensive units. This involves identifying scopes where improvements can be made to reduce energy consumption while maintaining the same level of service or production. Energy-saving opportunities can be found

in various sectors, such as industry, construction, transport and agriculture. They include actions such as improving the energy efficiency of equipment, reducing energy losses, and adopting more energy-efficient behaviors [17],[18].

The process of identifying the Energy Savings Potential Scopes (ESPS) depends on the system used in the municipality. And the ISO 50001 certification scope is derived from the relevant ESPS.

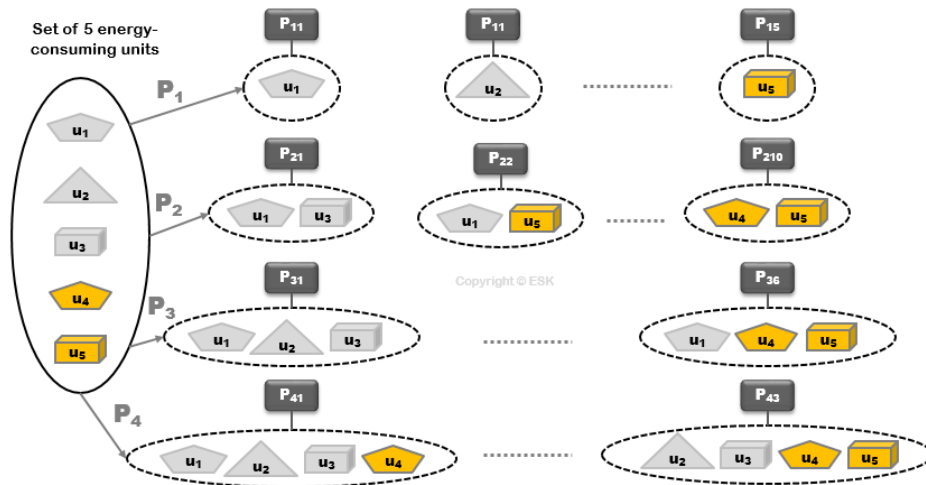


Figure 7 : Example of P5 Energy Saving Scopes with a set of 5 units

This concept is fundamental to assessing and improving energy efficiency in different contexts, and understanding it is essential to any research aimed at optimizing the management of the process of identifying energy-saving opportunities.

Based on set theory, we need to identify the subsets of a set of 5 elements, for example, excluding the empty set (\emptyset) and the full set, and calculate their count, which is $2^5 - 2 = 30$ subsets grouped by subset type characterized by its count. In our example, we obtain the following types of scope or subset :

- P₁** : Set of Energy Savings Potential Scopes with 1 energy-intensive unit 5
- P₂** : Set of Energy Savings Potential Scopes with 2 energy-intensive units 10
- P₃** : Set of Energy Savings Potential Scopes with 3 energy-intensive units 10
- P₄** : Set of Energy Savings Potential Scopes with 4 energy-intensive units 5

3.2 Current methods used to identify the ESPS

The current methodology for identifying ESPSs in local authorities is based on several existing solutions, notably the Local Measurement System (LMS), the Real-Estate and Energy Master Plan (REMP) and the Cit'ergie System, according to the field survey (Figure 8). The methodologies of the LMS, REMP and Cit'ergie systems, together with additional criteria for identifying sources of excessive energy consumption within local authorities, often represent a challenge in terms of technical, engineering, financial and time constraints, which can range from 3 to 18 months, depending on the size of the local authority's assets. This complex framework is exacerbated by the uncontrolled management of energy-intensive assets, due to a lack of resources to deal with these issues.

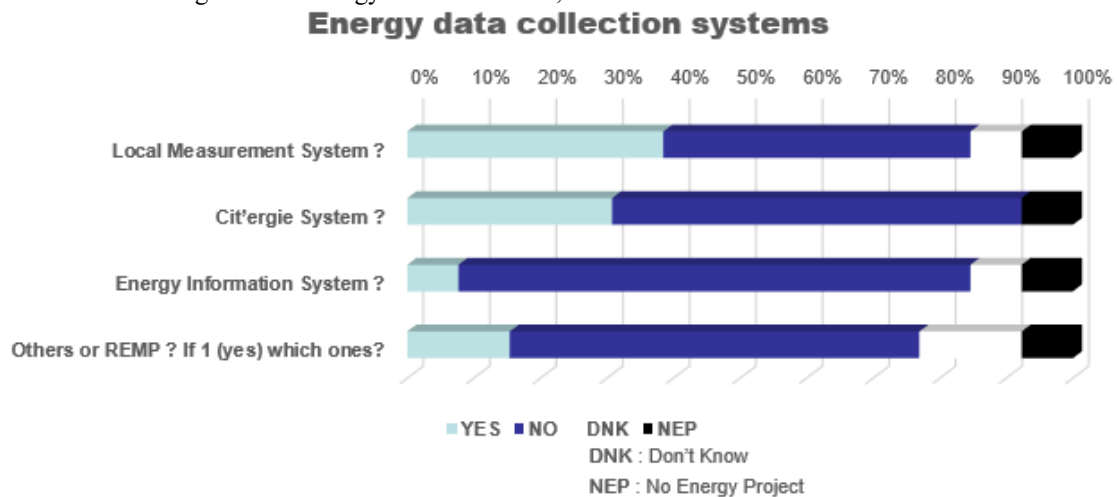


Figure 8 : Existing energy data collection systems

The survey shows that existing energy data collection systems are poorly adopted, with the exception of the local metering system, which is manual.

The energy policy of organizations or communities defines criteria among which we must use the best criteria to identify the relevant ESPS between the Energy Savings Potential Scope found to make it the Certification Scope dedicated to the ISO 50001 standard. Criteria can be, for example :

- Total energy consumption of the ESPS,
- ESPS energy consumption per square meter,
- Energy Performance Diagnostic (EPD)
- The indicator that qualifies the state of disrepair of the building, equipment and networks,
- Regulatory status,
- The cost of owning the building for the community, Etc.

The classic method of the current process used to identify Energy Savings Potential Scopes (ESPS) is as follows, as shown in *Figure 9*.



Figure 9 : Classic methods of the ESPS identification process

Walk-through audit:

- **Visual Inspection:** A rapid inspection of installations to identify energy-saving opportunities linked to equipment maintenance and operation.
- **Rapid Identification:** Quickly identify scopes with high savings potential without detailed analysis. [19]

Standard Energy Audit

- **Data Collection:** Detailed collection of energy consumption data over a significant period.
- **Consumption analysis:** Evaluation of energy consumption by use (heating, lighting, etc.) and identification of inefficiencies.
- **Recommendations :** Proposed energy efficiency improvement measures with estimated potential savings and return on investment [19].

In-depth energy audit

- **Energy Analysis:** Assessment of the quality of energy used and identification of exergy losses for specific processes.
- **Modeling and Simulation:** Using thermodynamic models to simulate energy performance and identify energy-saving opportunities [19].

The existing systems for identifying the Energy Savings Potential Scopes (ESPS) are :

- The Real-Estate and Energy Master Plan (REMP) method
- The Local Measurement System (LMS),
- The Cit'ergie system

3.3 REMP system method for identifying the ESPS

The difficulties encountered by local authorities in gathering information on a building, its history and its operation, for example, to carry out a simple energy audit, are often so insurmountable that the service provider has to do “without”. It is therefore becoming a matter of urgency for local authorities to implement a rigorous management and monitoring tool for the performance of their real estate assets, so that they can meet the energy challenges, and of course take advantage of the opportunity to meet many others: quality of use (functionality, comfort, upgradability, security, etc.), accessibility in the broadest sense (services and mobility), and controlled operating costs. According to ADEME, this tool is the Real-Estate and Energy Master Plan (REMP). It is an essential strategic tool for managing and optimizing the real estate assets of local authorities. It combines real estate and energy planning to meet current and future needs, while respecting budgetary and environmental constraints.

One of the key objectives of the REMP is to reduce energy consumption by identifying priority actions and planning investments as part of the Pluriannual Investment Plan (PIP). The REMP helps to define strategies for achieving the energy consumption reduction targets set by regulations such as the "Tertiary eco energy" decree [20] [21].

This REMP can identify the scope of energy-saving potential in several ways, following a structured methodology, as shown in *Figure 10*, and using advanced diagnostic tools.



Activities ranging from 3 to 18 months to identify a Certification Scope (CS) dedicated to the ISO 50001 standard, depending on the number of assets in a community.

Figure 10 : Steps in the REMP structured methodology

These stages are defined as follows:

1. **Asset mapping:** The first step is to carry out a detailed mapping of the building stock. This involves identifying all buildings and assessing their current condition, including energy performance, obsolescence and functional use [22]. This mapping enables us to visualize the entire portfolio and identify the buildings with the greatest potential for energy improvement.
2. **Energy Diagnosis:** An in-depth energy diagnosis is carried out for each building. This includes an analysis of energy consumption, identification of the main sources of energy loss, and assessment of the technical systems in place [20]. This diagnosis enables us to target buildings and installations where significant energy savings can be made.
3. **Multi-criteria analysis:** A multi-criteria analysis is carried out to prioritize the actions to be taken. This analysis takes into account various factors such as the cost of the work, the return on investment, the potential energy impact, and technical or regulatory constraints [20]. This helps to identify the most effective interventions and define a priority action scope.
4. **Energy strategy:** On the basis of diagnostics and analyses, an energy strategy is drawn up. This strategy includes energy improvement scenarios with clear, measurable objectives, aligned with regulatory requirements such as the "Tertiary eco energy" decree [22].
5. **Pluriannual Investment Plan (PIP) :** The REMP includes a multi-year investment plan detailing the actions to be undertaken over several years. This plan makes it possible to program the work in a coherent way and to monitor the progress of the energy savings achieved. [20].

In short, the REMP uses a combination of mapping, diagnosis, multi-criteria analysis and strategic planning to identify and exploit energy-saving potential, thus ensuring optimized, sustainable management of property assets, thanks to technical, engineering, financial and time challenges that can range from 3 to 18 months, especially for Small and Medium Municipality (SMM) that may lack the resources to deal with these issues.

3.4 Measuring system method to identify the ESPS

A metering system is a set of devices for measuring, recording and analyzing the energy performance of a site or organization. Every metering system is made up of three elementary building blocks: metering devices, reading devices and analysis devices :

- The measuring device is made up of equipment designed to be used to take measurements: voltage, current, flow, temperature, humidity, etc.
- The reading means enable data from the measuring device to be collected and centralized via an acquisition chain.
- Analysis resources are the tools used to process the data collected.

The concept of a metering system therefore encompasses the metering instruments, the energy data acquisition chain and the energy data analysis resources. [23]. The system recommended by ISO 50001 is limited by its manual or semi-automatic methodological and technological approach, mainly using Excel (Figures 11).

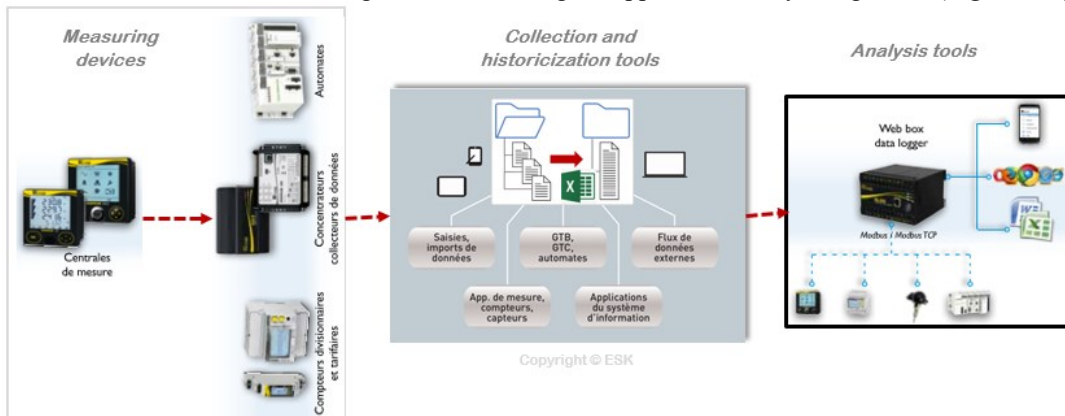


Figure 11 : The 3 building blocks of a local measurement system in detail

Thus, a local energy performance local measurement system consists of several essential elements. Firstly, it includes metering devices such as energy meters (electricity, gas, water) and temperature and pressure sensors, which measure energy data accurately and granularly [23]. Secondly, the means of reading and historizing are crucial for collecting and storing this data. This can be done by manual or automated readings, using wired or wireless data transmission networks, and gateways for data concentration [23]. Finally, analysis resources include energy management software and data analysis tools, often based on big data, which enable data visualization, calculation of Energy Performance Indicators (EPIs), and identification of energy-saving opportunities [23]. These components work together to provide continuous, optimized monitoring of energy consumption.

But how are the data collected by a local measurement system analyzed to identify energy savings?

The data collected by a local measurement system are analyzed to identify energy savings through several methodical steps according to the following *Figure 12*:

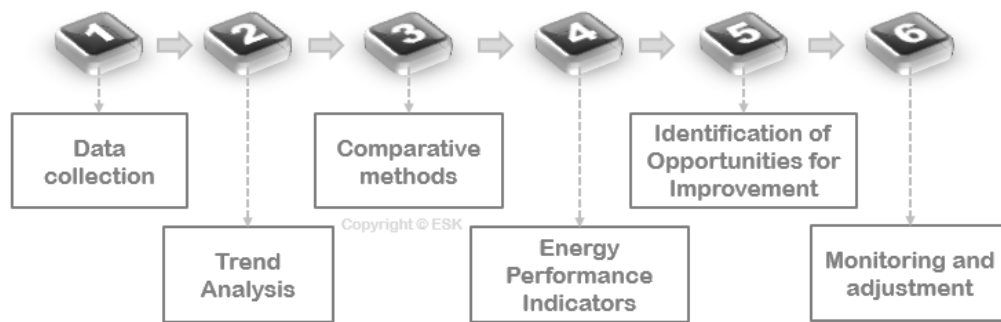


Figure 12 : Process for identifying energy savings using the Local Measurement System (LMS)

1. **Data collection** : Energy consumption data is collected from meters and sensors installed at various measuring points, such as electricity, gas and water. These data are centralized in an energy management system [24] [25]
2. **Trend Analysis** : Once collected, data is analyzed to identify trends in energy consumption. This includes examining peak periods, potential wastage, and anomalies in consumption. Specialized software is used to model energy performance and identify drifts [26] [27].
3. **Comparative methods** : Comparative methods, such as inter-site and intra-site analysis, are used to compare energy performance between different sites or within a single site. These methods make it possible to detect consumption stubs, reading errors and consumption drifts, thus facilitating the identification of corrective actions [28].
4. **Energy Performance Indicators (EPI)** : EPIs are calculated to assess energy efficiency. These indicators take into account explanatory variables, such as climatic conditions or building occupancy, to provide an accurate assessment of energy performance. [29].
5. **Identification of Opportunities for Improvement** : Based on the analysis of data and CAIs, opportunities for improvement are identified. These may include recommendations for upgrading equipment, installing automatic controls, or improving insulation. [26] [25].
6. **Monitoring and adjustment** : Energy performance is monitored on an ongoing basis to check the effectiveness of actions taken and adjust strategies where necessary. This makes it possible to quantify the energy savings generated and prioritize improvement actions. [30] [31].

By combining these steps, a local measurement system can optimize energy consumption and generate significant savings, while improving environmental sustainability.

On the other hand, setting up a local metering system in communities presents several major challenges. Firstly, technical complexity is a major obstacle, as various measuring devices, such as energy meters and sensors, need to be integrated, while ensuring their compatibility with existing building management systems [24] [23]. Data collection and management also pose challenges, requiring robust communication networks to transmit data reliably and continuously to a centralized system [24] [23]. The sheer volume of data collected requires high-performance software solutions for analysis and storage. Secondly, analyzing and exploiting the data to identify energy-saving opportunities can be complex, requiring specialized software to calculate Energy Performance Indicators (EPI) and detect anomalies. [24] [29]. Regulatory and normative compliance, particularly with standards such as ISO 50001, adds another layer of complexity, requiring system adaptation to meet legal requirements [29]. Finally, the cost and financing of system installation and maintenance can be significant, necessitating innovative financing solutions [30]. The human resources and skills needed to manage these systems represent another challenge, as it can be difficult to recruit and train qualified personnel [32].

3.5 *Cit'ergie system method for identifying the ESPS*

According to "Aides-territoires" (Territorial aids) from the "Direction Générale de l'Aménagement, du Logement et de la Nature (DGALN)" (General Directorate of Planning, Housing and Nature - GDPHN), the Cit'ergie system is a management and certification program designed to help municipalities implement ambitious climate, air and energy policies. Supported by ADEME, the program aims to reduce greenhouse gas emissions,

improve energy efficiency, cut air pollution and develop renewable energies. Cit'ergie offers technical and financial support to local authorities, enabling them to structure, monitor and evaluate their “Territorial Climate-Air-Energy Plan” (TCAEP). The Cit'ergie label, which is part of the European Energy Award (EEA), evaluates the actions of local authorities in their own scopes of competence and sphere of influence, taking into account a catalog of concrete measures for undertaking energy-climate actions on the territory. By obtaining this label, local authorities can demonstrate their commitment to the energy transition, which can also contribute to their economic development, attractiveness and quality of life for their residents [33] [34].

But in the context of energy reduction, what are the steps involved in identifying potential energy savings with a Cit'ergie system?

To identify energy-saving opportunities with a Cit'ergie system, several key steps are involved (Figure 13).

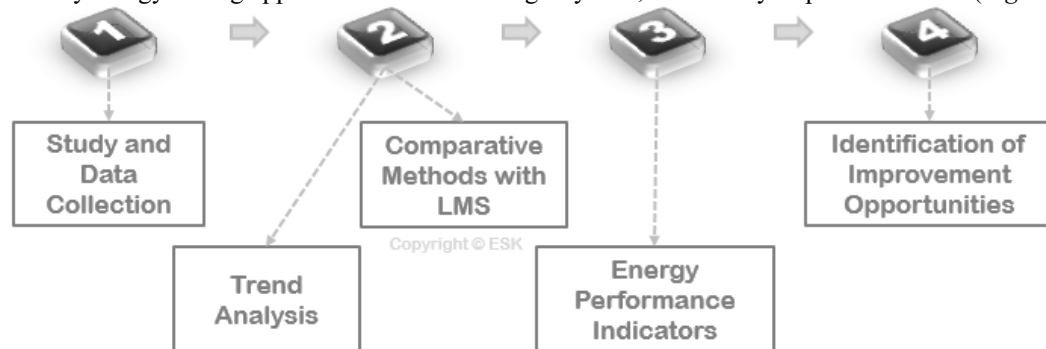


Figure 13 : Cit'ergie system process for identifying ESPS

Firstly, an energy survey is carried out to collect data on the energy consumption of the buildings or facilities concerned. This includes information on energy bills, heating, ventilation and air-conditioning systems, lighting and electrical equipment. [26]. This data is then analyzed to identify consumption trends, peak periods and potential wastage. Analysis can be carried out using specialized software that models energy performance [26].

In parallel, the use of an energy performance indicator (EPI) measurement system in Cit'ergie makes it possible to monitor energy consumption, identify opportunities for improvement, and implement strategies to reduce energy consumption and associated costs. [24]. EPIs, which are ratios between energy consumed and explanatory variables, help to understand the factors influencing consumption and predict potential savings [29]. Finally, recommendations are made for improving energy efficiency, such as upgrading equipment or installing automatic controls [26]. These steps make it possible to quantify energy savings and optimize municipality energy management.

On the other hand, the main challenges encountered when using the Cit'ergie system to identify energy-saving opportunities in municipalities include several complex aspects like other systems. Firstly, **data collection** can be difficult due to the diversity of energy infrastructures and systems in place, requiring consistent integration of various measuring devices such as energy meters and sensors [35] [24]. **Data management and analysis** also represent a challenge, as they require advanced software solutions to process large quantities of data and identify energy trends or anomalies [24]. In addition, **compliance with standards and regulations**, such as ISO 50001, requires continuous adaptation of systems to meet legal requirements [29]. Municipalities must also overcome obstacles related to **financing** the installation and maintenance of metering systems, which may require access to subsidies or specific funding [36]. Finally, **skills development** and staff training are essential to ensure effective system management, which can be a challenge in terms of available human resources [24] [36]. These challenges require a structured approach and innovative solutions if they are to be overcome effectively.

4 Results

4.1 Limits of existing systems methods

Metering-based methods for identifying Energy Savings Potential Scopes (ESPS) have a number of intrinsic limitations that can hamper their effectiveness. Firstly, traditional metering systems are often based on technologies that don't allow for sufficiently fine-grained and detailed data collection. This can lead to excessive aggregation of data, making it difficult to accurately identify sources of energy waste. When considering a large number of community assets, this limitation is exacerbated by the growing complexity of data management, analysis and, above all, the identification of Energy Savings Potential Scopes (ESPS), as shown in Figure 14: a simulation based on 10 energy-intensive units in the municipality of Quesnoy Sur Deûle (QSD).

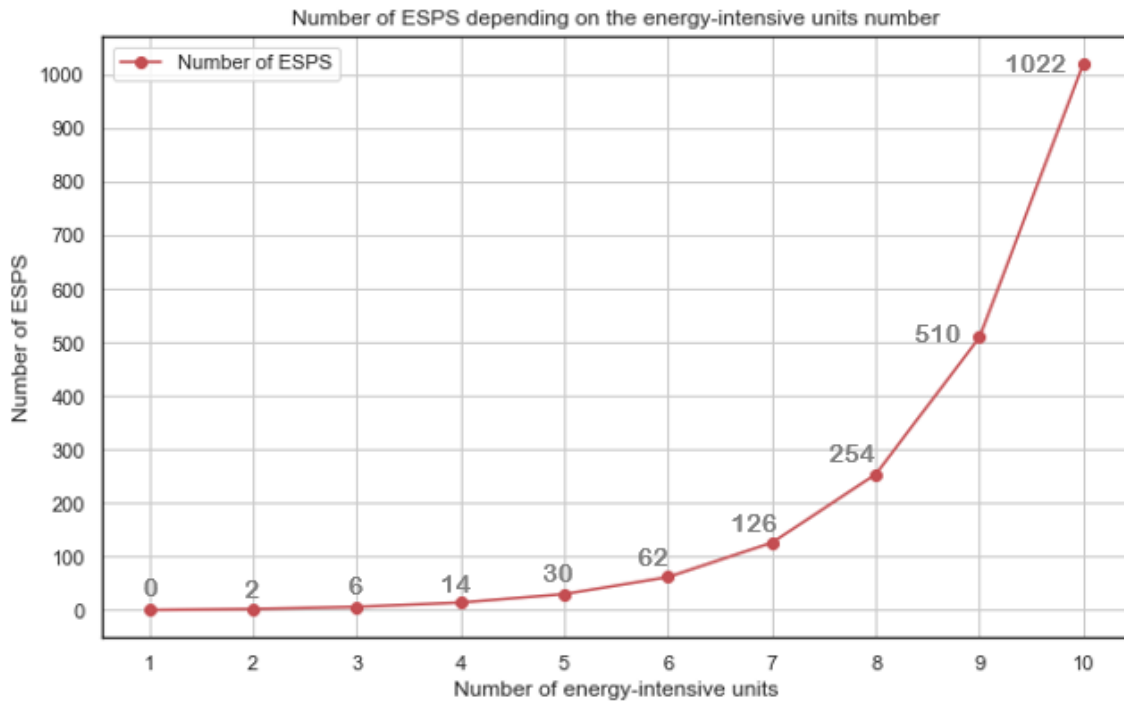


Figure 14 : Number of ESPS identified with 10 energy-intensive units in the city of QSD

With regard to the Energy Savings Potential Scopes (ESPS), our survey highlighted the systems and software solutions used by local authorities to identify the ESPS (Figure 15)

ESPS identification

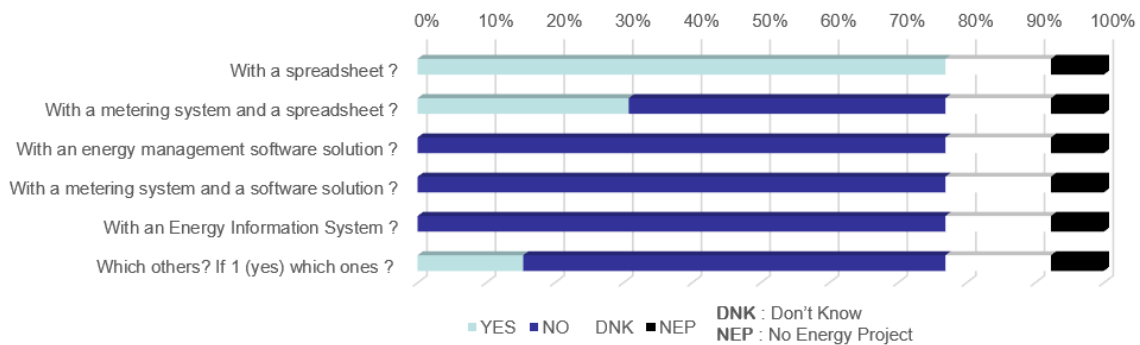


Figure 15: Survey results for solutions used by communities to identify the ESPS

The results of this survey reveal a widespread reliance on manual methods, principally the use of spreadsheets (77%), and an almost total absence of more advanced software solutions for the identification of ESPSs. Only a minority (31%) combine a metering system with a spreadsheet, and no respondent uses Energy Information Systems (EIS) or software solutions to improve the efficiency of this task. These results underline the crucial need to modernize the tools used by local authorities to optimize their energy-saving efforts.

The survey also examined the criteria used by communities to identify the ESPS. The results are shown in Figure 16.

ESPS identification criteria

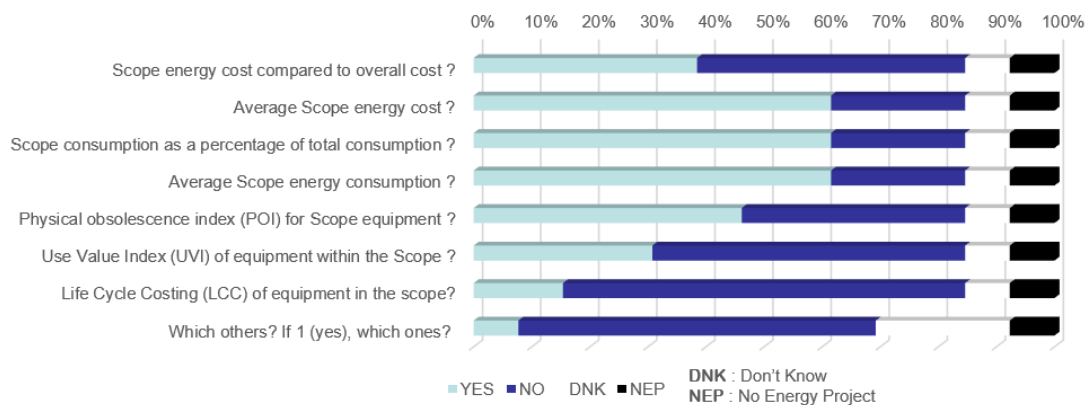


Figure 16 : Survey results on the criteria used by communities to identify the ESPS

The results of the survey show that the physical obsolescence index (PVI) of units, along with other criteria such as regulatory status used by local authorities, account for 54% of energy-hungry units.

The need to assess numerous buildings and infrastructures simultaneously means a significant increase in the time and human and material resources required. Teams need to be sufficiently trained and available to install, monitor and maintain metering devices, which can represent a high cost for communities, especially smaller ones. In addition, traditional metering systems can suffer from accuracy and reliability problems. Sensors and meters can be subject to measurement errors, failures or drift over time, compromising the quality of the data collected. These problems can lead to inaccurate assessments of potential energy savings, limiting the effectiveness of any corrective action taken. Finally, interpreting the data from these systems often requires advanced technical skills, which can represent an additional challenge for local authorities who do not have the resources to hire or train qualified personnel. In short, although metering systems are essential for the identification of ESPS, their intrinsic limitations call for technological and organizational improvements to maximize their effectiveness.

4.2 Innovative PG2E solution to identify the ESPS

The “PG2E” tool is an Innovative Solution which consists of automatically identifying the certification scope (CS) dedicated to the ISO 50001 standard from monthly or annual energy consumption data.

This solution proposes a simplified methodology, taking into account the limited human, financial and technical resources of Small and Medium Municipalities (SMM). This includes the specific steps of simplified data collection, prioritized analysis, and results-based decision-making for a solution that is less costly in terms of human and technical resources, and less time-consuming. This is because it involves activities ranging from 1 to 7 days to identify a Certification Scope dedicated to the ISO 50001 standard, depending on the number of assets owned by a Municipality. The detailed description of the PG2E process is as follows (Figure 17) :

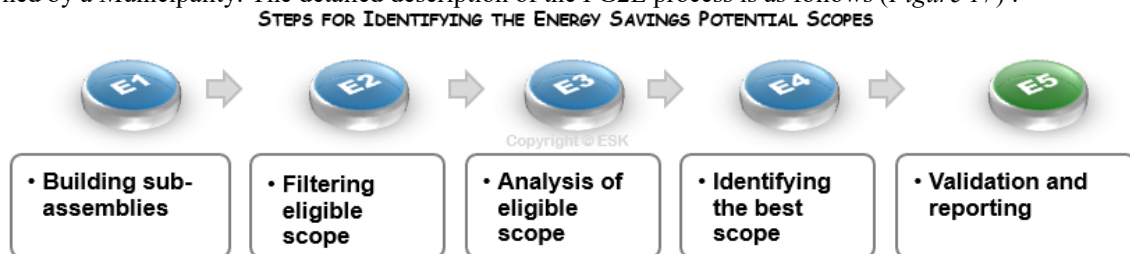


Figure 17 Steps to identify the Certification Scope with the PG2E tool

- 1. Step 1: Building sub-assemblies**
 - Given a set of energy-consuming units, PG2E automatically generates all possible subsets using combinatorial programming algorithms.
- 2. Step 2: Filtering eligible scope**
 - Sub-assemblies meeting the threshold of 65% of total energy consumption are identified using automated filters.
- 3. Step 3: Analysis of eligible scope**
 - The average consumption and upper quartile criteria are calculated for each eligible subset.
- 4. Step 4: Identifying the best scope**
 - The scope with the highest average consumption or upper quartile is selected as the best ESPS.
- 5. Step 5: Validation and reporting**
 - The selected ESPS is validated and a report is generated to guide the organization in implementing energy efficiency actions.

The CS is identified on the basis of the best ESPS obtained, ranked in descending order according to the consumption criterion among the relevant statistical data from eligible ESPSs.

This innovative solution is entirely digital, and relies solely on the energy consumption data of input energy-intensive units. It uses a calculation plan to identify eligible ESPSs, and generates statistical data which are then sorted in descending order, according to a selected indicator criterion, to determine the Certification Scope (CS) dedicated to the ISO 50001 standard (Figure 18).

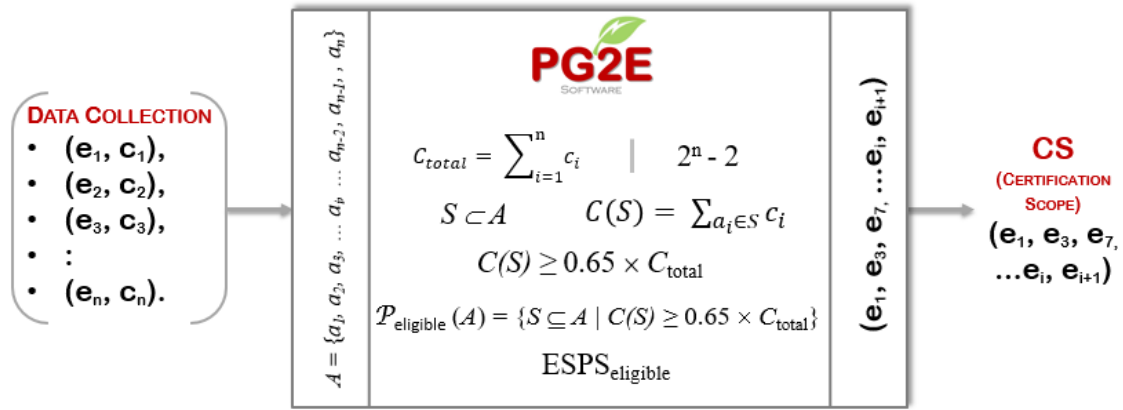


Figure 18: PG2E process and execution algorithm to identify the CS dedicated to ISO 50001

4.3 Case study : Municipality of “Quesnoy-sur-Deûle” (QSD)

4.3.1 Case study background

Quesnoy-sur-Deûle, a French municipality of 7,000 inhabitants, is an ideal setting for testing the innovative PG2E solution. This community represents a common typology of Small and Medium Municipalities (SMM), characterized by :

- A diverse range of buildings, including administrative, school and sports facilities.
- Limited technical and financial resources for energy management.
- A regulatory obligation to comply with standards such as the tertiary sector decree and ISO 50001.

In our case study, the municipality of Quesnoy-sur-Deûle observed some problems in using the REMP system to identify the ESPS; namely :

1. **Complexity** : Taking into account outdated infrastructures and regulatory compliance slowed down the process.
2. **Cost of project manager** : The in-depth energy diagnostics required an investment of €4,200.
3. **Duration** : The project to identify Energy Savings Potential Scope (ESPS) took 9 months to complete, illustrating the slowness of REMP's approach.

The main aim of this case study was to assess the effectiveness of PG2E in identifying Energy Savings Potential Scopes (ESPS), and to compare its results with those obtained using traditional methods, notably the Real-Estate and Energy Master Plan (REMP).

4.3.2 Structure and data on electricity consumption, obsolescence and regulatory status of QSD buildings

Figure 19 shows the table of data for annual electricity consumption in 2021, surface area in square meters, obsolescence and regulatory status for each building in the municipality of Quesnoy-Sur-Deûle (QSD). These data were provided by the municipality's Director of Technical Services. The structure of the data table is described as follows :

- COD_PB: building code,
- PATRIMOINE_BATIMENT: the name of the building,
- SURFACE_M2: building surface scope in square meters,
- VETUSTE: the building's obsolescence rating (out of 100),
- REGULATORY CONDITION: the rating (out of 1) of the building's regulatory condition,
- CONSO_ANNUAL: the building's annual electricity consumption (in kWh).

COD_PB	PATRIMOINE_BATIMENT	SURFACE_M2	VETUSTE	ETAT REGLEMENTAIRES	CONSO_ANNUELLE
CD02	ateliers Services Techniques	601.0	75.000000	0.142857	13279
CD03	CCAS Ange Gardien	207.0	76.250000	0.000000	10278
CD04	Centre Socio-Culturel	700.0	57.039474	0.428571	16363
CD05	Ecole Jean Macé	670.0	62.960000	0.190476	8689
CD06	Ecole Jules Ferry	1070.0	53.420000	0.285714	7513
CD07	Ecole Picasso	620.0	67.312500	0.142857	22417
CD08	Espace Deûle	798.0	52.500000	0.428571	19615
CD09	Festi'Val	2275.0	56.296053	0.285714	85228
CD11	MAIRIE	1383.2	61.710526	0.142857	31243
CD12	Maison blanche	439.0	63.273026	0.142857	12028
CD14	Restaurant scolaire [Foch]	262.0	57.039474	0.142857	11293
CD15	Restaurant scolaire [Saint-Vincent]	338.0	73.190000	0.142857	10042
CD16	Resto scolaire [Eventail]	1004.0	57.960526	0.142857	69680
CD17	Sportival	1171.0	57.500000	0.142857	76966
CD18	Complexe sportif	983.0	74.210526	0.142857	35575

Figure 19 Electricity consumption data, obsolescence and regulatory status of buildings

Data on the building's obsolescence (rated out of 100) and regulatory status (rated out of 1) have been exceptionally integrated into the table structure for correlation assessment with the criteria of average consumption and quartile 75 of the eligible ESPSs, making it possible to identify the certification scope (CS) dedicated to the Energy Management System (EMS).

Before proceeding with the identification of the ESPS by the "PG2E" solution, we analyzed the distribution of annual electricity consumption data values in relation to data on surface scope per m², obsolescence and regulatory status of QSD buildings (*Figure 20*).

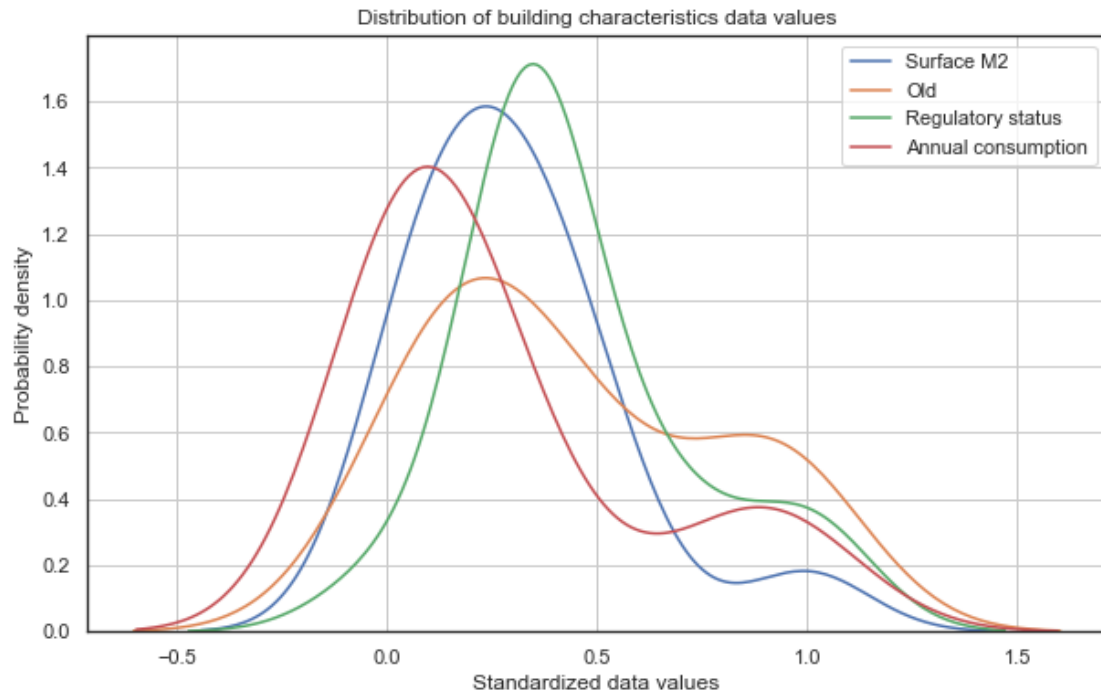


Figure 20 : Normalized data values for QSD building characteristics variables

The graphs in *Figure 20* show the **distribution of normalized values** for four variables relating to buildings in the town of Quesnoy Sur Deûle (QSD) : annual energy consumption, total surface scope, dilapidated condition and regulatory status.

Overall, we observe the following analysis:

- The graph shows that **energy consumption** (red curve) and **building surface scope** (blue curve) have different distributions, with notable deviations, suggesting that energy consumption could be influenced by factors other than simple building size, such as obsolescence or regulatory status.
- **Obsolescence** (orange curve) and **regulatory status** (green curve) appear to play an important role in the variability of energy data, with obsolescence particularly asymmetrical, indicating that a proportion of buildings are significantly older.

In conclusion, these distributions show significant variability in the different aspects of the buildings analyzed, and this underlines the need for a diversified approach to managing energy consumption. Larger, older buildings could benefit from targeted interventions to improve their energy efficiency.

4.3.3 Results obtained with REMP scenarios

In our case study, the commune of Quesnoy-sur-Deûle (QSD) has identified 3 reference ESPSs through their REMP system according to political mandates. These reference ESPSs are :

- **P₀₅ Réf.** = {CD09, CD08, CD04, CD17, CD16} : a reference scope of 5 energy-consuming units.
- **P₀₈ Réf.** = {CD09, CD08, CD04, CD17, CD16, CD06, CD11, CD14} : a reference scope of 8 energy-consuming units.
- **P₁₀ Réf.** = {CD09, CD08, CD04, CD17, CD16, CD06, CD11, CD14, CD07, CD18} : a reference scope of 10 energy-consuming units.

Our task now is to identify the best ESPS, which could correspond to the reference ESPSs, using the innovative "PG2E" solution of the new method.

4.3.4 ESPS identification with the innovative PG2E solution

The innovative "**PG2E**" solution offers a simplified methodology, taking into account the limited human, financial and technical resources of SMMs. This includes specific steps for simplified data collection, prioritized analysis, and results-based decision-making for a solution that is less costly in terms of financial, human, technical and time resources. *Figure 21* shows the flow chart of the new "PG2E" solution for identifying the certification scope (CS).

CRITÈRES

- Total scope consumption,
- Consumption per M² of the scope,
- Average scope consumption,
- Quartile 75 consumption of the scope.



Figure 21: The new solution's approach to identifying the Certification Scope

The result of a first run of the "PG2E" tool is summarized in Figures 22 and 23, using the average consumption criterion. This result shows 6,623 ESPSs eligible for the EMS certification scope (CS) according to the ISO 50001 standard. The certification scope (CS) identified by the "PG2E" tool with the criterion of average consumption of eligible ESPSs is :

Average consumption: $P_{\text{conso-m}} = \{CD09, CD11, CD16, CD17, CD18\}$

Summary of the PG2E report

ESPS summary - Energy Saving Potential Scope

Organization :	QUESNOY SUR DEULE
Heritage domain :	Building
Period year : January to December :	2021
Number of heritage elements :	15
Coefficient used to identify ESPS :	0.65
Certification scope criteria used :	Average consumption of the scope
Total energy consumption (kWh):	430 209
Average energy consumption (kWh):	28 680,60
Total number of ESPS identified :	32 766
Number of eligible ESPS :	6 623
Certification scope for ISO 50001 :	('CD09', 'CD11', 'CD16', 'CD17', 'CD18')

Figure 22 : Result of the EMC CS for Quesnoy-Sur-Deule electricity

List of the top 10 ISO 50001 Certification Scope

Scope	Average consu-kWh	Total consu-kWh
CD09, CD11, CD16, CD17, CD18	59 738,40	298 692
CD07, CD09, CD16, CD17, CD18	57 973,20	289 866
CD08, CD09, CD16, CD17, CD18	57 412,80	287 064
CD07, CD09, CD11, CD16, CD17	57 106,80	285 534
CD04, CD09, CD16, CD17, CD18	56 762,40	283 812
CD08, CD09, CD11, CD16, CD17	56 546,40	282 732
CD02, CD09, CD16, CD17, CD18	56 145,60	280 728
CD07, CD09, CD11, CD16, CD17, CD18	53 518,17	321 109
CD08, CD09, CD11, CD16, CD17, CD18	53 051,17	318 307
CD04, CD09, CD11, CD16, CD17, CD18	52 509,17	315 055

Figure 23 : List of the top 10 CS for ISO 50001 using the average consumption criterion

With the upper quartile consumption criterion, we find the same certification scope (CS) of the EMS according to ISO 50001, as with the average consumption criterion, which is as follows:

Quartile 75 consumption $P_{\text{qtr-75}} = \{\text{CD09, CD11, CD16, CD17, CD18}\}$.

4.3.5 Correlation analysis of the variables of the best ESPS (CS)

Let's now analyze the correlations of the variables of the best ESPS for the certification scope (CS) (Table 2), using Pearson's coefficients and p-values for the comparative study between reference ESPSs (from REMP) and those identified by the "PG2E" solution, to assess the relevance and effectiveness of this new method, as well as its advantages and potential for improvement.

Table 2 : Result of the values of the variables of the certification scope (CS)

ESPS / CS =		{CD09, CD11, CD16, CD17, CD18}
ESPS variable	Description	Value
CONSO_TOT	Total energy consumption of the 5 energy-intensive ESPSs units.	298 692,00
CONSO_MOY	Average energy consumption of the 5 energy-intensive ESPSs units.	59 738,40
CONSO_PAR_M2	Energy consumption per m ² of the 5 energy-intensive ESPSs units.	43,82
CONSO_QTL75	Quartile 75 of energy consumption for the 5 energy-intensive ESPSs units.	76 966,00
VETUSTE_TOT	The total obsolescence value of the 5 energy-intensive ESPSs units	307,68
VETUSTE_MOY	The average obsolescence value of the 5 energy-intensive ESPSs units	61,54
ETAT_REG_TOT	The total value of the regulatory status of the 5 energy-intensive ESPSs units	0,86
ETAT_REG_MOY	The average value of the regulatory status of the 5 energy-intensive ESPSs units	0,17

The correlation study of the variables (CONSO_MOY, CONSO_QTL75, VETUSTE_TOT and ETAT_REG_TOT) of the best ESPS for the CS should enable us to observe the level of link between them.

The results of the Pearson coefficients and the p-values between the ESPS variables are as follows:

- CONSO_MOY and VETUSTE_TOT = (-0.81, 0.0),
- CONSO_QTL75 and VETUSTE_TOT = (-0.67, 0.0),
- CONSO_MOY and ETAT_REG_TOT = (-0.65, 0.0),
- CONSO_QTL75 and ETAT_REG_TOT = (-0.55, 0.0).

The coefficients obtained reveal a negative, moderately strong and statistically significant correlation (p-value < 0.05) between the variables analyzed, although correlation does not necessarily imply a causal relationship. We observe that older or dilapidated buildings seem, counter-intuitively, to consume less on a heritage scale, which may be explained by reduced usage. Furthermore, technical "age" and compliance with regulations do not systematically translate into higher energy consumption. These observations suggest that using average consumption and the 75th percentile as statistical indicators would be a relevant choice for identifying the scope of certification (CS) of the energy management system (EMS) according to ISO 5001.

4.3.6 Comparative study of ESPS_{Référence} and ESPS_{Pg2e}

We have made several comparisons following the political mandate of the town of Quesnoy-Sur-Deûle for the construction of the Pluriannual Investment Plan (PIP). It should be noted that the "PG2E" solution is based on a threshold of 65% of total consumption to determine eligible ESPSs, and on analysis of the average and upper quartile of energy consumption for each ESPS. The results of our different scenarios are summarized in Tables 3 to 5 below :

Scenario 10: The first 10 energy-generating units :

Table 3 : Results of scenario 10 with the PG2E solution and the ESPS_{Ref}. P₁₀

P₁₀ - Électricité 2021

Political mandate	Scenarios for the Quesnoy-Sur-Deûle reference scope	Top 10 energy-generating units
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Criterion by Average Energy Consumption

Quesnoy Sur Deûle reference scope	"PG2E"	OK units	Rates	Bias
CD09, CD08, CD04, CD17, CD16, CD06, CD11, CD14, CD07, CD18	CD09, CD11, CD16, CD17, CD18	5/5	100%	0%

Criteria by Quartile 75 of Energy Consumption

Quesnoy Sur Deûle reference scope	"PG2E"	OK units	Rates	Bias
CD09, CD08, CD04, CD17, CD16, CD06, CD11, CD14, CD07, CD18	CD09, CD11, CD16, CD17, CD18	5/5	100%	0%

With a reference scope of 10 energy-intensive units identified by the town of Quesnoy sur Deûle, we observed a **100%** success rate with the "PG2E" tool, based on the average and upper quartile energy consumption of the scope identified by the solution.

Scenario 08: the first 8 energy-generating units

Table 4 : Results of scenario 08 with the "PG2E" solution and the ESPS_{Ref}. P₀₈

P₀₈ - Électricité 2021

Political mandate	Scenarios for the Quesnoy-Sur-Deûle reference scope	Top 08 energy-generating units
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Criterion by Average Energy Consumption

Quesnoy Sur Deûle reference scope	"PG2E"	OK units	Rates	Bias
CD09, CD08, CD04, CD17, CD16, CD06, CD11, CD14	CD09, CD11, CD16, CD17, CD18	5/6	83%	17%

Criteria by Quartile 75 of Energy Consumption

Quesnoy Sur Deûle reference scope	"PG2E"	OK units	Rates	Bias
CD09, CD08, CD04, CD17, CD16, CD06, CD11, CD14	CD09, CD11, CD16, CD17, CD18	5/6	83%	17%

With a reference scope of 8 energy-intensive units identified by the town of Quesnoy sur Deûle, we observed an **83%** success rate with the "PG2E" tool, based on the average and upper quartile energy consumption of the scope identified by the solution.

Scenario 05: the first 5 energy-generating units

Table 5 : Results of scenario 05 with the "PG2E" solution and the ESPS_{Ref}. P₀₅

P₀₅ - Électricité 2021

Political mandate	Scenarios for the Quesnoy-Sur-Deûle reference scope	Top 05 energy-generating units
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Criterion by Average Energy Consumption

Quesnoy Sur Deûle reference scope	"PG2E"	OK units	Rates	Bias
CD09, CD08, CD04, CD17, CD16	CD09, CD11, CD16, CD17, CD18	3/5	60%	40%

Criteria by Quartile 75 of Energy Consumption

Quesnoy Sur Deûle reference scope	"PG2E"	OK units	Rates	Bias
CD09, CD08, CD04, CD17, CD16	CD09, CD11, CD16, CD17, CD18	3/5	60%	40%

With a reference scope of 5 energy-intensive units identified by the town of Quesnoy sur Deûle, we observed a **60%** success rate with the "PG2E" tool, based on the average and upper quartile energy consumption of the scope identified by the solution.

These results confirm that PG2E offers accuracy comparable to traditional methods, while considerably reducing the time and resources required.

It should be noted that all the scenarios were carried out in a matter of seconds to identify the ISO 50001-compliant Certification Scope, using the innovative PG2E solution. This speed of execution was made possible by the prior collection of data and identification of the reference Certification Scope corresponding to each scenario.

5 Discussions

5.1 Observations and analysis of the case study

5.1.1 Case study context : Quesnoy-sur-Deûle

In this case study, the innovative PG2E solution was applied to assess its effectiveness in identifying Energy Savings Potential Scopes (ESPS) in the commune of Quesnoy-sur-Deûle. The methodology is based on a threshold of 65% of total consumption to select eligible ESPSs, using average consumption and the upper quartile as criteria for prioritizing energy-intensive ESPSs. The results were analyzed through three scenarios, comparing the ESPSs identified by PG2E with the commune's reference ESPSs.

5.1.2 Results of REMP and PG2E scenarios

1. Scenario 10 (10 energy-intensive units) :

- The reference ESPS includes **100%** of the ESPS units identified by the PG2E tool.
- This validates the relevance of PG2E criteria for large scope, where the most significant energy-consuming units are included in the scope.

2. Scenario 08 (08 energy-intensive units) :

- The reference ESPS captures **83%** of the ESPS units identified by PG2E.
- Although slightly lower than **Scenario 10**, this high rate underlines the strong compatibility between the units selected by the PG2E tool and those retained by the reference ESPS.

3. Scenario 05 (05 energy-intensive units) :

- The reference ESPS captures **60%** of the ESPS units identified by the PG2E tool.
- This reduction in capture illustrates the limits of the PG2E solution, when the scope is more restricted.

5.1.3 Analysis of results

The results show that the PG2E solution is particularly effective in identifying the most energy-intensive units, especially in scenarios with a large scope (Scenarios 10 and 08). However, in more restricted configurations, adjustments to the criteria could improve the correspondence between the units selected by PG2E and the reference ESPSs.

1. Relevance of the 65% threshold recommended by ISO 50001:

The total consumption threshold has proved to be appropriate in a context of extended scopes. However, it could be modulated to better meet the needs of smaller areas, taking into account the diversity of infrastructures.

2. Selection criteria :

The average and upper quartile criteria used by PG2E enable efficient prioritization of energy-intensive scopes. They are particularly robust for large configurations, where energy-intensive units are favored.

5.1.4 Summary

The PG2E solution is well aligned with the reference scope for extended configurations, while requiring adjustments to maximize its effectiveness in more restricted contexts. These observations reinforce PG2E's usefulness for communities seeking to quickly identify significant ESPSs, while also offering avenues for improvement to adapt it to specific situations.

5.2 Evaluation of the innovative "PG2E" solution

5.2.1 Key benefits of PG2E :

1. Simplicity and accessibility:

- The PG2E solution enables fast, automated identification of ESPSs, without requiring significant human or financial resources.
- Unlike traditional methods, which rely on complex technical audits, PG2E offers a simplified approach well suited to Small and Medium Municipalities (SMM).

2. Save time and cut costs:

- Simulations carried out with PG2E are significantly faster, taking just a few seconds, compared with several months for conventional methods such as REMP.

- This speed facilitates proactive decision-making and reduces the costs associated with energy diagnostics.

3. Flexibility and adaptability :

- Thanks to simple, configurable criteria, PG2E can adjust the identified scopes according to local priorities.
- Introduction of dynamic thresholds to better adapt to restricted scopes.

5.2.2 Identified limits :

1. Dependence on data quality :

- The effectiveness of PG2E depends on the availability and reliability of energy consumption data. An incomplete or inconsistent database can affect the accuracy of results.

2. Limited reach in large communities :

- While PG2E is well suited to SMMs, its application in larger communities with complex infrastructures requires methodological adjustments to incorporate a more detailed analysis of interactions between infrastructures.

3. Lack of comprehensive technical assessments :

- Unlike traditional methods, PG2E does not take into account factors such as infrastructure ageing, regulatory status or maintenance requirements, which could limit its scope in certain applications.

5.2.3 Prospects for improvement :

1. Criteria refinement :

- Add contextual indicators, such as building use or occupancy rates, to complete the consumption criteria.

2. Integration into broader frameworks :

- PG2E could be integrated into more complex energy management tools, such as energy information systems, comprehensive ISO 50001 management systems, or local policies such as the Intergovernmental Panel on Climate Change (IPCC).

3. Application to other contexts :

- Test PG2E in larger communities or industrial sectors to validate its adaptability and identify any necessary adjustments.

5.3 Discussion summary

The PG2E tool offers an innovative and accessible alternative for Small and Medium Municipalities (SMM), enabling them to improve their energy performance without the constraints of traditional methods. Although adjustments are needed to optimize its effectiveness in specific contexts, its advantages in terms of simplicity, cost and speed make it a promising tool for communities committed to the energy transition.

Moreover, the results obtained with PG2E also demonstrate its effectiveness as an innovative tool in a field that has yet to be scientifically explored. While traditional approaches, such as Real-Estate and Energy Master Plan (REMP), benefit from a more established literature, the proposed methodology fills an academic void by offering a solution adapted to the realities of SMMs. This work represents a first attempt at simplified automation for the identification of energy-saving scopes, paving the way for future research aimed at refining and generalizing this approach.

6 Conclusion and Outlook

The "PG2E" system is intended as an alternative to traditional methods (*Table 6*), which are often cumbersome and time-consuming to implement, or unsuited to the realities of local authorities. The case of Quesnoy-Sur-Deûle, a municipality facing energy challenges typical of Small and Medium Municipalities, was used as a basis to illustrate the simplicity and effectiveness of the "PG2E" tool. Through this case study, we have demonstrated how this solution has made it possible to overcome the technical and financial challenges associated with the identification of Energy Savings Potential Scopes. The "PG2E" approach could thus represent a significant step forward in the implementation of the ISO 50001 standard and in energy management for local authorities, by simplifying the process of identifying Energy Savings Potential Scopes and taking better account of local constraints.

Table 6 : Comparative summary of existing systems and the PG2E solution

System comparisons	Existing systems	PG2E
Need qualified personnel ?	YES	NO
Need engineering ?	YES	NO
Time-consuming ?	YES	NO
Time taken to identify the ESPS and the certification scope (CS) dedicated to ISO 50001 in municipalities.	3 to 18 months	1 to 7 days
Save time identifying a certification scope ?	NO	YES
Accelerating the definition of Pluriannual Investment Plan (PIP) for municipalities ?	NO	YES
System implementation.	Tedious	Simple
Systems based on multiple, complex criteria ?	YES	NO
In-depth analysis to identify ESPS ?	YES	NON
System offering a significant advantage for small and medium-municipalities (SMMs) ?	NO	YES
Simulations and flexibility at low system resource cost ?	NO	YES

The development of solutions such as "PG2E" meets a dual requirement: on the one hand, to optimize resources for identifying Energy Savings Potential Scopes (ESPS) at local level, and on the other, to identify Certification scope (CS) dedicated to the ISO 50001 standard. By facilitating the identification of Energy Savings Potential Scopes, the "PG2E" tool not only helps to rationalize energy management of municipalities, but also contributes to the wider objectives of energy transition and the reduction of greenhouse gas emissions.

This study makes an original contribution to the still emerging research field of rapid, automated identification of Energy Savings Potential Scopes (ESPS). By introducing a methodology based on mathematical concepts and simplified criteria, this article opens up new perspectives for the energy management of SMMs, where available resources are often limited. This work invites further research in this direction, in particular by exploring the adaptability of PG2E to other contexts and furthering its integration into local energy policies.

This article presented an in-depth analysis of the energy challenges faced by municipalities, particularly in the context of ISO 50001 implementation. It proposed a practical and innovative solution to these challenges, illustrated by the case of the town of Quesnoy-Sur-Deûle. This approach aims to encourage the adoption of more efficient energy management practices in municipalities, by offering a tool tailored to their needs and constraints.

However, prospects in the field of optimizing the process of identifying Energy Saving Potential Scopes (ESPSs), may take the form of research into improving the process of ISO 50001 implementation in communities, with the use of solutions such as "PG2E" and the Energy Information System (EIS). This topic explores how the combination of the Energy Information System (EIS) and the "PG2E" solution can improve the implementation of EMS in municipalities, and assess the effectiveness of their approach compared to existing traditional methods. The study could examine the benefits of integrating these two systems to facilitate ISO 50001 energy management system (EMS) implementation. The aim is to create an energy governance model, based on the EIS and "PG2E" pair, which supports strategic decision-making in communities for better energy performance and increased compliance with ISO standards.

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