IEA – DSM TASK XXI: Standardization of Energy Savings Calculations

Task I: State-of-the-art

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1. EXECUTIVE SUMMARY

1.1 Introduction

The International Energy Agency plays a key role as an intergovernmental organization acting as energy policy advisor to its 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. The IEA Demand-Side Management Programme (IEA-DSM) is one of more than 40 co-operative energy technology programmes sponsored by this organization, working to develop and promote tools and information on demand-side management and energy efficiency.

In this sense, the IEA-DSM Task XXI responds to the lack of common standards on Energy Efficiency Savings Calculations. The Operating Agent, in this case The Netherlands, is the responsible for the task planning and for the integration of its vision in cooperation with the other partners.

1.1.1 General background

The Energy Savings Directive 2006/32/EC, also called ESD, can be defined as the first European Directive concerning energy efficiency. It provides the possibility of using energy efficiency and demand-side management as alternatives to new supply and for environmental protection.

To achieve its objectives, member states have launched action plans in energy efficiency. These action plans are designed to mobilize the general public, the policy makers and the market players, and transform the internal market of energy to provide for the citizens of the European Union the infrastructures (including buildings), the products (appliances and automobiles, etc), the processes and the most efficient energy systems in the world. The final aim of the action plans is to control and reduce energy demand and act selectively in relation to consumption and energy supply in order to achieve savings on annual primary energy consumption.
1.1.2 Task XXI objectives

IEA-DSM Task XXI is structured in four subtasks, the first concerned with the analysis of the current standards on energy savings calculation (ESC) concerning the following objectives:

- To identify national and regional existing energy saving calculation (ESC) standards and standards under development
- To identify and assess the most relevant evaluation and monitoring reports for ESC
- To identify basic concepts, calculation rules and systems.
- To identify the key elements to nominate and describe Demand Response products

1.2 Methodology

The methodology applied during the development of this subtask I have followed three parallel work lines, one for analysis of the current state-of-the art of international M&V protocols, other for the determination of a list of most relevant ECMs and finally one for the evaluation of success cases of demand response products:
1.3 **International standards for measuring energy efficiency**

The main industry standard for M&V, internationally used, is the International Performance Measurement and Verification Protocol (IPMVP). There are other standards and M&V guidelines published by several organizations, but most of these guidelines are based on IPMVP. To give an overview of the most common international M&V protocols applied worldwide, in this study the following have been described and compared to IPMVP:

1. EVO IPMVP
2. ASHRAE 14
3. DOE
4. ESMG

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1.3.1 Basic concepts

Most M&V guidelines have several points in common, hence some definitions and basic concepts that must be described before entering to detail:

- **Energy Performance Contracts (EPCs)**, also called Energy Savings Performance Contracts (ESPCs) are the documents where the contractor (normally ESCO\(^1\)) provides and arranges financing and implementation of energy improvements and is repaid over the contract term from the cost savings generated by the improvements.

- **Baseline and reporting period**: one way of calculate this savings is by the comparison of the situation once the ECM is implemented with the situation before its implementation. Baseline period corresponds to the initial situation, before the ECM; reporting period corresponds with the period of time where the ECM is active.

- **Measurement period selection**: where it must be considered the baseline period length, the reporting period length and the possibility of using adjacent measurement periods.

- **Measurement boundary**: determining whether savings are going to be evaluated for an entire facility or for a part of it.

- **Savings calculation**: understood as the diminution of energy consumption after the implementation of an ECM.

1.3.2 EVO IPMVP

The International Performance Measurement and Verification Protocol (IPMVP) is a guidance document describing common practice in measuring, computing and

\(^1\) ESCO: Energy Services Company

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reporting savings achieved by energy or water efficiency projects at end user facilities. The IPMVP presents a framework and four measurement and verification Options (A, B, C and D) for transparently, reliably and consistently reporting of project’s savings. M&V activities include site surveys, metering of energy or water flows, monitoring of independent variables, calculation, and reporting.

The IPMVP is intended to be used by professionals as a basis for preparing savings reports. Each user must establish its own specific M&V Plan that addresses the unique characteristics of the project. The IPMVP is not a standard and thus there is no formal compliance mechanism for this. Adherence with the IPMVP requires preparation of a project specific M&V Plan consistent with IPMVP terminology.

As other M&V protocols, IPMVP defines measurement options that must fulfill the different situations of measuring energy savings. In order to create standard measurement options taking into account the different techniques described before, IPMVP proposes four measurement options:

- **Option A: Retrofit isolation. Key parameter measurement:** Savings are determined by field measurement of the key performance parameters which define the energy use of the ECM’s affected systems and/or the success of the project
- **Option B: Retrofit Isolation. All parameter measurement:** Savings are determined by field measurement of the energy use of the ECM-affected system
- **Option C: Whole facility:** Savings are determined by measuring energy use at the whole facility or sub-facility level
- **Option D: Calibrated simulation:** Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility
1.3.3 ASHRAE 14-2002

ASHARE 14-2002 is a guideline published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), aimed to the calculation of energy savings derived by the application of energy efficiency initiatives in a facility.

The procedures included in the ASHRAE Guideline 14-2002 take in all forms of energy (electricity, gas, oil, district heating/cooling) and cover residential, commercial and industrial buildings. However, these procedures do not include sampling methodologies that can be used in large-scale demand-side management programs, metering standards or major industrial process loads.

Guideline 14-2002 contains minimum compliance requirements to assure a fair level of confidence in the savings determination. These requirements can be fulfilled with the three engineering approaches proposed by ASHRAE, equivalent to the four IPMVP measurement options:

a) **Whole-building metering**: also named as Main Meter approach; it consists in the verification of the performance of the retrofit for those projects where whole-building, pre-retrofit and post-retrofit data are available to determine the savings. This measurement may include consumption and demand values taken from sub-meters, where those meters represent a significant portion of the building or group of subsystems in the building that are being retrofitted. This option is appropriate when the total building performance is being calculated, for this purpose ASHRAE-14 proposes two different paths:

- **Prescriptive path**: appropriate for projects where savings are expected to be greater than 10% of the energy consumed. Requires continuous and complete data, furthermore all relevant data must be included in the baseline model and the post-retrofit model
- **Performance path**: appropriate when it is not possible to comply with the requirements of prescriptive path. This path allows for data gaps and other irregularities on data collection, only requiring the user to show that the
b) **Retrofit isolation metering:** intended for retrofits where the end use energy consumption can be completely measured both during the baseline period and post-installation period. The measurement can be continuous or for a limited period of time; in most cases energy consumption is calculated by developing statistically representative models of the energy use.

c) **Whole-building calibrated simulation:** only applicable for whole-building measurement, involves the use of a commercially available hourly computer simulation program to create a model of energy use and demand of the facility or installation. This model must be calibrated or checked against actual measured data like current energy use, weather data and other relevant operating data. Once the model is calibrated, it is used to predict energy use with the retrofit conditions. Energy savings are calculated by the comparison of the modeled results under the two sets of conditions (pre-retrofit and post-retrofit), or by the comparison of modeled data against actual metered results.

### 1.3.4 DOE-FEMP


The DOE-FEMP guide it is a handbook based on the International Performance Measurement and Verification Protocol\(^2\) (IPMVP). Its main purpose is to facilitate procedures and guidelines for quantifying the savings resulting from energy efficiency.

\(^2\) The DOE-FEMP guide is based on IPMVP Volume 1: Concepts and Options for Determining Energy and Water Savings, published in April 2007
equipment, water conservation, improved operation and maintenance, renewable energy, and cogeneration projects implemented under DOE’s ESPC contract mechanisms in the US. The document is specifically intended for federal energy managers, federal procurement officers, and contractors implementing performance contracts at federal facilities\(^3\), however, its principles, advices and procedures may be applied to other kind of energy savings projects through all geographic regions.

Since FEMP Guidelines are an application of the IPMVP, measurement options are the same IPMVP Options: A, B, C, and D. FEMP emphasizes that M&V approaches can be divided into two general types: retrofit isolation (Options A&B) and whole-facility (Options C&D).

- Retrofit isolation methods look only at the affected equipment or system independent of the rest of the facility
- Whole-facility methods consider the total energy use not focusing on specific equipment performance

### 1.3.5 ESMG

The Department of Resources, Energy and Tourism of the Australian Government published in 2008 the Energy Savings Measurement Guide (ESMG), a best practices guide aimed to assist companies in the estimation, measurement, evaluation and tracking energy savings, quantifiable costs and benefits created as a result of implementing energy efficiency opportunities. The guide was published within the Energy Efficiency Opportunities Program, administered by the Australian Government Department of Resources, Energy and Tourism and sits under the National Framework for Energy Efficiency.

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\(^3\) The FEMP guideline includes a contractual requirement for ESCOs to comply with the guide in planning and carrying out M&V activities for federal agency customers in the US

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ESMG defines four measurement options for the verification of the actual savings derived from implemented opportunities:

- Option 1: Partially measured isolated project
- Option 2: Fully measured isolated project
- Option 3: Whole facility
- Option 4: Calibrated simulation

These four schemes, designed to cover all possible situations, are really close to the IPMVP measurement options (A, B, C & D). Methods 1 and 2 examine only the equipment or system affected by a specific energy opportunity. Savings are determined for each opportunity individually as the measurement boundary is around the equipment or system associated with the saving opportunity. Method 3 considers total energy use for the whole facility where savings are determined and not for each individual saving opportunity. Method 4 can be used at facility, site, process or sub-process level. Methods 3 and 4 are used when it is not practical or feasible to isolate the effects for each ECM usually due to interactions between them.

1.3.6 Comparison between international protocols

After revising the most common international measurement and verification protocols, it can be appreciated the great similarities among all of them. To some degree, all protocols have IPMVP as a common ancestor, thus, they all share the same approach to energy savings determination, differing in the scope of application or being more developed from the mathematical and engineering aspects of the work. Both ASHRAE 14-2002 and FEMP guide are clearly based on IPMVP; on the other hand ESMG does not emphasize the strong similarities with IPMVP but proposes four measurement schemes really close to the IPMVP measurement options.
It is interesting to make an overall comparison of each one of the protocols with IPMVP, taking into account that this one is the common ancestor for all the others:

- **IPMVP vs. ASHRAE 14-2002**: an obvious difference comes at first sight, there are three measurement options instead of four having condensed options A and B of the IPMVP into one, although the possibility of a partial measurement, remains. Where ASHRAE 14-2002 stands apart is in its thoroughness and level of detail when analyzing the different metrological and statistical aspects of M&V Planning. Thus it is closer to an engineering handbook than to a conventional guide, although the principles that guide it are underlying in the IPMVP, and, in most cases, the application of both protocols by different engineers will throw the same results.

- **IPMVP vs. FEMP**: this can be considered as a development of IPMVP for the Federal Super ESPC projects, detailing very clearly all the steps and procedures to develop and apply the M&V Plan. This approach is necessary.
in Federal Projects, where the Building Manager often does not have a technical background, nor has the resources to develop the project; thus, an easy to apply, standardized method of contracting is necessary, as well as a guarantee of transparency

- **IPMVP vs. ESMG**: this last one is a development of IPMVP with focus in estimating energy savings before the actual application of the measures. There are no methodological differences of note in both protocols regarding how to determine the actual savings.

The worldwide usage level of each M&V guide is closely related with the purpose the guide was created for. As it seems logical, IPMVP is the guide preferred by most of the professionals, since offers a global and complete solution to tackle different situations that can appear while developing an energy efficiency project.

Nowadays, IPMVP has become a standard in almost all energy efficiency projects. Originally created for the US market, currently is available in English, French, Spanish, Portuguese and Polish, and it is getting an important penetration in Europe through its adoption in countries like Belgium, France and Spain. Major players in the European energy market, like EDF, EUBAC and Gas Natural-Union Fenosa are now supporting strongly EVO in its mission to promote the use of IPMVP. Its

On the other side, the usage of ASHRAE 14-2002 is not as extended worldwide as IPMVP. ASHRAE 14-2002 provides more detail in statistical estimations and metrology, the implementation of projects following this guide normally acquires more complexity.

FEMP M&V guide and ESMG are documents designed specifically for governmental projects, thus, normally the application of these guides is subject to the success and application of these projects.

Regarding the methodology proposed by each M&V guide, each one divides the methodology in different steps, but the general content of all of them is very similar. It can be stated that there are three common parts in which all the methodologies are divided:

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1. Before project implementation
2. During project implementation
3. After project implementation

In chapter 5.6 of this document individual methodologies for each protocol are deeply analyzed, focusing on the methodological aspects that distinguish one protocol to another, and also proposing a common methodology involving the main steps of each one.

1.4 Usage of these standards in Spain

1.4.1 Spanish market situation

Regulation plays a key role in the development of Spanish energy efficiency market, and hence, in the promotion of energy services companies. Spain has incorporated European policies by the transposition of these Directives into the Spanish regulation, mainly through the National Action Plan for Energy Savings and Energy Efficiency PAE4 2004-2012 and PAE4+ 2008-2011.

Associated with the promotion of policies regarding energy efficiency, it has been a development of a new industry around energy efficiency projects, lead by the creation of new Energy Service Companies in Spain. However, the situation is still in stark contrast to the great developed market in North America and many countries of the EU, like France and Germany.

There are still some barriers that have been hindering the development of the energy services market in our country, most of them related with the uncertainty of project’s results:

- Absence of standardized methods for measuring and verification of energy savings, making difficult the evaluation of the results achieved
- Lack of awareness and confidence in energy services provided by companies, mainly due to deficiency in information
- High risk perception by customers, both technical and economical

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- Resistance to outsource energy management
- Difficulties to access to necessary funds and financial methods

Public administration plays a key role in the abolition of these barriers, by the implementation of mechanisms that help customers to trust in energy services companies and also providing the necessary funds and financial solutions. This has facilitated that several international energy companies have begun to offer energy services in Spain, like Dalkia and Suez Energy Services. Spanish big corporations, mainly building and facility service companies, have also make profit of this new market niche. Companies like Acciona, SyV Group, Ferrovial and ACS have created a dedicated business line for energy services. Also is considerable the number of small engineering companies offering this service and new companies recently created exclusively for this purpose.

1.4.2 Importance of the standards for market development

Despite the advance of the Spanish ESCO market since 2008, the non existence of a broadly accepted M&V standard restrains the future development of this market for the next years. M&V standards are fundamental to the development of an energy efficiency market because their application in a project is guarantee of its success.

The lack of a common standard in the Spanish ESCO market is replaced by the application of own engineering or “ad hoc” measurement methods. Other ESCOs are currently applying international M&V guides, but even for the adoption of these standards there are still a number of significant barriers obstructing their successful implementation:

- Limited technical knowledge of the guides and lack of formative processes
- Lack of endorsement and guidance by the public sector
- Lack of a real background in the Spanish ESCO industry, which means that many projects are developed without a clear methodology
• Non-adequate funding in the early phases of a project, which is when the M&V Plan is at its most critical phase
• Language barrier to the spread of the existent guides, even though the IPMVP has been translated, only one of its volumes it is available in Spanish

To overcome these barriers, the answers lie in:

• Training and formation for the ESCO professionals
• Development of a local standard, of compulsory application in the public sector contracts
• Endorsement of this standard by the key players of the market
• Financing entities becoming aware of this business model and how the appliance of standardization can reduce the risk involved in it

What is an absolute certainty is that any of the future solutions adopted regarding M&V standards for the Spanish market will be based in the experiences of more developed and mature markets, such as those of EU countries and USA.

In this context, the trend in the short term seems to be the implementation of the IPMVP, followed in the foreseeable future by the development of a recognized and broadly accepted standard, strongly based in the IPMVP and ASHRAE 14-2002. The success or failure of such a standard will depend largely on its endorsement in public contracts; it still remains an open question if the public EPC projects will endorse the IPMVP, a locally developed standard, or will apply and “ad hoc” approach.

1.4.3 International M&V methodologies used by Spanish ESCOs

Given the lack of official consensus in Spain, there are still a big number of energy service companies that use its own M&V methods for the evaluation of energy savings. These methods normally involve engineering calculations and estimations to determine the baseline period necessary to compare with the post-ECM situation. Most simple methods may include only utility bills reading, before and after ECM, without taking into account some factors that modify the conditions (weather,
occupancy, production load, etc). The omission of these relevant factors may distort the real savings achieved, decreasing the accuracy of project’s results and allowing the ESCO to make up them at its convenience. It ends up in a lack of confidence by customers, who do not see guaranteed results coming from their investments.

On the other hand, among companies applying international M&V guides, the more well-established is IPMVP to a large extent. There are several reasons that justify this choice; the main one is the international spread of this protocol around the world as it is promoted by an international non-profit professional’s organization. Furthermore, some ESCOs recently introduced in the Spanish market are subsidiaries of international companies, already users of IPMVP. This fact makes other ESCOs to use the same methods as their competitors, in order to offer similar energy services with comparable results. Big Spanish utilities offering energy services, like Gas Natural Group, use and promote IPMVP in their energy efficiency projects. In fact, Gas Natural Group is one of the current primary subscribers of EVO, participating actively in the development of new versions of the international M&V guide. Another of the reasons that reinforce the penetration of IPMVP in Spain is the opportunities that EVO gives to ESCOs and energy professionals through their training courses, like the Certified Measurement and Verification Program (CMVP).

Other international M&V guides like FEMP and ESMG have less diffusion in Spain, since they are adaptations of IPMVP for specific energy saving programs. ASHRAE-14 2002 is normally well-known among energy efficiency professionals; nevertheless, its use is not as extended as IPMVP because of its higher complexity and accuracy in calculations.

Besides the M&V techniques for the evaluation of energy savings, there are some other mechanisms introduced by recent Spanish regulation that are aimed to the application of energy efficiency initiatives in buildings. These methods can be considered a “standard” somehow, as far is clearly defined the cases where the application of these initiatives is mandatory, and also in terms there is a developed methodology for their application and for the measurement of their performance:
• **Spanish Technical Building Code (CTE).** This code, on its last version approved in March 2006, introduced for the first time one dedicated section to energy saving in buildings, specifying rules and procedures allowing to fulfill the basic needs of energy efficiency in buildings

• **Spanish Royal Decree 47/2007** of 19 January, which introduced the obligation of certificating energy efficiency in buildings of new construction. Since the approval of this Royal Decree, every facility built after June 2007 must have a certification showing the degree of efficiency in energy consumption, using an energy efficiency scale similar to the one used for electric devices. In order to carry out this certification process, the use of the free software tool CALENER is promoted and recommended

### 1.5 Energy efficiency initiatives

Initially, for this task, a list of over 80 energy conservation measures were proposed, including ECMs for household, commercial and industrial sectors. Each one of these ECM have been evaluated in terms of useful potential, savings potential and load curve impact potential:

1. **Useful potential:** qualitative measure of the current penetration of an initiative in the Spanish market, also taking into account the perspectives for the next years and other criteria as profitability, complexity, barriers, etc

2. **Savings potential:** qualitative measure of the savings (both monetary and energy savings) reached by the implementation of this ECM, based on previous experiences and success cases

3. **Load curve impact potential:** qualitative measure of the impact of that ECM on the global energy demand curve, specially on those cases when the application of this measure can contribute to reduce energy demand on maximum peaks. This is not a common feature in energy conservation measures; however, in this section have been introduced due to its high usefulness for this subtask’s objectives
As a result, from the initial list, a selective process has been conducted with the intention of obtaining a list of 25 prioritized techniques taking into account these factors. To these selected techniques, all four IPMVP options have been explored, identifying for each one the most proper IPMVP option:

![Image](https://via.placeholder.com/150)

**Figure 3: List of the 25 selected ECMs**

This list of 25 prioritized techniques represents the selected ECMs for the IEA-DSM Task XXI. The sample list is composed by 10 initiatives for household sector, 5 for commercial sector, 5 for industrial processes, 1 for public sector and 4 new additional measures.

To understand the process needed to carry out the application of IPMVP M&V plan to the selected ECMs, a series of practical examples have been developed for each one of the four IPMVP measurement options, which are described in section 7.3 of this document.

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1.6 Energy efficiency and Demand response

Although the concept of demand response (DR) is broadly used to refer to a multitude of issues related to energy efficiency, it can be concluded that demand response refers to all those policies and concrete measures which purpose is to influence the final consumer in their energy behavior, often making smarter use of resources. Demand Response (DR) can be considered as a particular set of DSM policies, where the final customer receives whether economic incentives or penalties according with the changes in energy behavior reached.

The success of such initiatives must be based on achieving a series of clear and stable profits for all actors involved, so that all of them find motivation to give continuity to the efforts made.

Demand Response must be seen as a tool for public institutions and utilities, which allows articulating its relationship with the user of the network, serving as a catalyst for changing habits consumption. This allows making the energy use more efficient and rational.

Involve the customer on energy efficiency is not always easy; improvement actions usually imply financial investments or modification of habits, which could generate some resistance. The end user should see clearly the benefits associated with efficiency initiatives.

Demand response programs help the client to act more efficiently, without implying a decrease in their perception of the service, as the possible inconvenient associated with the measures implemented should be compensated by the decrease of the electricity bill and the improve of the supply continuity.

1.6.1 International references in demand response products

There is a clear relationship between energy efficiency and demand response programs. During the selection and development of the initiatives which will be
included in these programs, there is the possibility to introduce ECMs not only oriented to general energy savings, but more oriented to control the intraday energy consumption and hence the load curve on the system.

The viability of demand response programs in the present and future depend largely on public initiative. On one hand, public initiative has an underlying interest in improving the country's energy efficiency (greater business competitiveness, less energy dependence, lower CO₂ emissions, etc.). On the other hand, there is a great need for regulatory framework that not only allows, but encourages the implementation of these types of energy efficiency measures.

In this study, some international references on demand response programs, whose aim is to influence into the end consumer habits in order to rationalize the use of energy resources, have been analyzed:

- **In-Home Displays (IHDs):** also called Real-Time Monitors (RTM), are small household devices that provide real-time energy consumption and costs information to customers. The IHDs can revolutionize the way utilities provide information to customers, faster and more effective than traditional bills, turning into a vehicle for consumers to change their electricity consumption behaviors.

- **Dynamic pricing in the mass market:** These mechanisms allow utility companies to dynamically change energy pricings in order to encourage customers to reduce energy consumption on peaks. Consumers, through the use of Advance Metering Infrastructures (AMI) and IHDs, can be aware of the energy price in every moment of the day, adapting their consumption and moving non critical loads from expensive (peak) hours to cheaper (valley) hours (load shifting), so that the daily load curve becomes more flat.

- **Direct load control and time-of-use rates:** In contrast to dynamic pricing options, DLC programs can be implemented utilizing the existing metering infrastructure by simply installing a switch on the most consuming selected appliances, which is operated via a radio signal. DLC programs provide utilities with a high degree of control over load reductions. In the same way
as DLC, TOU rates do not require AMI for implementation. TOU customers are typically metered using a special device which separately captures their total consumption during the peak and off-peak periods.

- **Active Demand Management research programme (GAD)**: this research programme has been considered for this study because of its interest in terms of demand response. The project is formed by a consortium of 15 Spanish entities and research centers, aimed at optimize the energy consumption in low and medium tension, through the application of new mechanisms of active demand side management.

## 1.6.2 Interaction between demand response and M&V

One of the aspects to be taken more into account when designing a demand response program is the way the results are going to be measured. This is a key issue to the success of the initiative because it identifies and quantifies the benefits obtained.

It should be clear that the information requirements of demand response programs are not always equally demanding than those of other energy efficiency initiatives discussed in this document. In a classical improving energy efficiency action (equipment replacement, improvement of installations, etc.), sponsoring company (ESCO) agrees to specific outcomes that justify their fees, in this case, the M&V becomes the main process project. In case of DR programs, while the M&V is still important, motivation for its use varies substantially.

On one hand, promoters of demand response initiatives must be able to assess the results, not only to justify the investment but also to evolve the program, identify

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4 GAD in Spanish stands for Gestión Activa de la Demanda, which direct translation is Active Demand Management.
improvements, and propose new DR initiatives. In this regard, those responsible will be interested to know the overall results, comparisons of total consumption before and after implementation of the initiatives, the feedback from users about the initiatives, etc., ignoring the detail of each individual’s energy performance.

Additionally, in most DR services, the M&V is also necessary to settle financial commitments to each customer (billing at different energy prices, service interruption, etc.). For this task, more related to the operation of the program, it is necessary to monitor the behavior of each individual client, not to evaluate the results but as a part of the DR process.

Generally, when demand response products are related to a group of initiatives but not to a specific one, bottom-up calculation methods like international M&V guides are not applicable, hindering the individual measurement of the results achieved. In these cases, top-down approaches can be more suitable, measuring the initiative results directly on the electrical network. This measurement can be made at different levels, from the measurement of the load curve on a single home or small sample group of homes in a neighborhood, to the measurement of this curve in a whole district area. As the sample selected is bigger, it can be seen how the different demand response products are contributing to change the general load curve, and how the global effect on the electric mains is the sum of the different individual results achieved.
2. INTRODUCTION

2.1 General background: IEA-DSM and Task XXI

Nowadays the importance of energy efficient policies is growing fast. Some studies, like the November 2007 report of the United States (US) National Action Plan for Energy Efficiency Leadership group, reveal that energy efficiency will be a key factor to mitigate the effects of climate change if energy consumption is cut by 20% by 2020. Furthermore, better use of resources means lower cost of service and a more secure and reliable energy supply. From an economic point of view, an expansion of productivity with less energy consumption is a bolster for future business.

In this sense, the International Energy Agency plays a key role as an intergovernmental organization acting as energy policy advisor to its 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. The IEA Demand-Side Management Programme (IEA-DSM) is one of more than 40 co-operative energy technology programmes sponsored by this organization, working to develop and promote tools and information on demand-side management and energy efficiency.

As a result of this collaborative work between countries in Asia, Europe and North America, the programme has created a ‘tool box’ of resources and information for governments, utilities and energy companies to help them incorporate DSM measures in their energy policies and activities. The work is carried out through the development of Tasks regarding the main topics, within it include the Task purpose of this document.

The IEA-DSM Task XXI responds to the lack of common standards on Energy Efficiency Savings Calculations. The EXCO (Executive Committee) delegates discussed first time the IEA-DSM Task XXI in October 2006 in Maastricht, the work begun in October 2008. They asked an Operating Agent, in this case The Netherlands, to prepare a plan for the task and to integrate its vision in cooperation with the other partners.

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In order to help achieving these objectives, the International Partnership for Energy Efficiency Cooperation (IPEEC) was created on June 2008 by the G8 countries, China, India, South Korea and the European Community in collaboration with the IEA. The aim of this organization is to promote energy efficiency in two different fields: supporting the work of the participant countries and relevant organizations, and impulse improvements in energy efficiency.

2.2 Task XXI objectives

As stated before, there is no agreement between countries about how policies and measures in energy savings impact on the quantitative evaluation and what are the most important elements affected. Also its necessary a broader agreement on the basic concepts, rules and system borders on Energy Efficiency in IEA member states.

To measure the success of the energy efficiency programs, an essential role is played by the Evaluation process. There are three different types of evaluation that depend on the period of time in which the evaluation is performed:

- **Ex-ante analysis of the energy efficiency policy options**: should help selecting the most appropriate policy
- **Evaluation during policy implementation**: enables policy makers to solve problems along the way and redirect the policy if necessary
- **Ex-post analysis of energy efficiency policies**: allowing making a balance of the benefits and costs of the measure so that its effectiveness can be determined. The main advantage of this type of evaluation is that it allows learning from past measures

In order to make possible standardization in the evaluation process and energy savings calculation, the first step is that all energy experts use the same common definitions and terms to achieve a common understanding. The agreement on basic
concepts is a must for a set of standards. Hence, the objectives for the Task XXI can be summarized as:

- To identify national and regional energy saving calculations (ESC) protocols, the concepts, calculation rules and systems used in ESC protocols and guides and how and why these documents are used in energy efficiency projects
- To develop a methodology to describe the Demand Response products
- To determine the organizations that are responsible for the maintenance and future development of these standards and what conditions should they satisfy
- To give these organizations the necessary resources to make an international comparison of standards, policies and measures
- To explore how these standards can be used in savings calculation

The work is being carried out by a combination of country experts\(^5\), the Operation Agent and some experts that have worked for other relevant IEA DSM Tasks. The TASK XXI work is divided in four subtasks with different objectives and periods to be implemented:

- Subtask 1: Existing energy savings calculation (ESC) standards and standards under development, and use of most relevant reports for ESC
- Subtask 2: Basic concept, rules and systems for ESC standards
- Subtask 3: Potential for use and continue development and maintenance of ESC standards
- Subtask 4: Communication and information

\(^5\) Countries collaborating in Task XXI are: The Netherlands, Austria, France, Korea, Norway, Spain, Switzerland and USA

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The aim of the present document is to give a response for the first subtask related to the state-of-the-art on energy saving calculations, summarized into these four objectives:

- To identify national and regional existing energy saving calculation (ESC) standards and standards under development
- To identify and assess the most relevant evaluation and monitoring reports for ESC
- To identify basic concepts, calculation rules and systems.
- To identify the key elements to nominate and describe Demand Response products
3. METHODOLOGY APPLIED TO THE PROJECT DEVELOPMENT

The methodology applied during the development of this subtask I have followed three parallel work lines. In the main one, there has been an identification process of the current state-of-the art of international M&V protocols followed by a deep analysis of them and their application in Spain. On the other side, starting from the initial list of ECMs, an evaluation and selection process has been conducted in order to determine a list of most relevant ECMs in the Spanish market, with the aim of evaluate the application of M&V methods to these energy efficiency initiatives. Parallel with this analysis, some success cases of demand response products have been also analyzed:

**Figure 4: General methodology for this project**

Each one of the four general methodology phases can be described with more detail:
1. **ESC methods and M&V procedures identification**: in this phase, the most used M&V standards have been indentified, the detailed activities conducted are:
   - Identification of international M&V protocols
   - Identification of organizations promoting this protocols and energy savings methods: general background, current situation in Europe and international organizations involved

2. **Analysis of international M&V protocols**, including the next activities:
   - Analysis of the four most used international M&V protocols
   - Comparison between international M&V: points in common, mean features of each one, development of a common application methodology, etc.
   - Detection and evaluation of other energy savings calculation standardization projects: current work done, best practices, etc.

3. **Application of M&V procedures in Spain**, focusing on the situation of M&V energy saving in Spain
   - Current situation if international M&V standards application of in Spain
   - Evaluation of other M&V procedures applied: engineering methods, ad hoc solutions, etc.

4. **Report elaboration**
   - Composition of draft final report
   - Validation
   - Final report submission

Additionally, for the analysis of interaction between energy efficiency and demand response, the methodology has been structured into three steps:

   i. Demand Respond as a tool for energy efficiency
   ii. Demand response management products
   iii. Interaction between Demand Respond and M&V

The results of each one of these steps have been ended up in the last phase of the general methodology (report elaboration).

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Finally, to conduct the selection process of ECMs, the methodology has followed three steps:

i. Analysis of proposed ECMs for this study: preliminary analysis of the initial ECM list

ii. Selection of 25 ECMs for this study: evaluation and selection of a list of energy efficiency techniques with high potential in Spain

iii. Application of these M&V standards to selected ECMs: applicability of international M&V procedures to the selected ECMs in this study, including practical examples of its application in Spain

The results of each one of these steps have also been ended up in the last phase of the general methodology (report elaboration).
4. GENERAL BACKGROUND

4.1 Energy Savings Directive 2006/32/EC


Although the ESD can be defined as the first European Directive concerning energy efficiency, there are two previous directives that can be settled as a precedent:

- **Directive 2002/91/EC on energy performance of buildings**: energy consumption in buildings represents around one third of final energy consumption\(^6\) in the Community, in this situation was necessary a plan on energy efficiency in the building sector so that the European community could comply with the Kyoto Protocol. The Directive 2002/91/EC on energy performance of buildings establishes a common methodology to design buildings and their heating, ventilation and air conditioning (HVAC) installations for energy savings taking into account outdoor climatic and local conditions, as well as indoor climate requirements

- **Directive 2005/32/EC on energy using products (EuP)**: on the other hand, energy-using products (EuPs) account for a big large proportion of the consumption of natural resources and energy in the Community, also having

\(^6\) Source: Directive 2002/91/EC
a number of other important environmental impacts. In this context, energy using products Directive 2005/32/EC aims to apply improvements in energy efficiency, and also harmonize national laws to eliminate barriers to trade and competition in the Community.

The main purpose of the Directive 2006/32/EC is to make the end use of energy more economic and efficient by:

- Establishing indicative targets, incentives and the institutional, financial and legal frameworks needed to eliminate market barriers and imperfections which prevent efficient end use of energy.
- Creating the conditions for the development and promotion of a market for energy services and for the delivery of energy-saving programs and other measures aimed at improving end-use energy efficiency.

The Directive applies to the distribution and retail sale of energy, the delivery of measures to improve end-use energy efficiency, with the exception of activities included in the greenhouse gas emissions trading scheme, and, to a certain extent, the armed forces. It targets the retail sale, supply and distribution of extensive grid-based energy carriers, such as electricity and natural gas as well as other types of energy such as district heating, heating oil, coal and lignite, forestry and agricultural energy products and transport fuels.

To achieve the objectives defined in the ESD, member states have launched action plans in energy efficiency. These action plans are designed to mobilize the general public, the policy makers and the market players, and transform the internal market of energy to provide for the citizens of the European Union the infrastructures (including buildings), the products (appliances and automobiles, etc), the processes and the most efficient energy systems in the world. The final aim of the action plans is to control and reduce energy demand and act selectively in relation to consumption and energy supply in order to achieve savings on annual primary energy consumption.

The first necessary action to perform a significant and sustainable energy saving is develop techniques, products and efficient services from de energy point of view. On
the other hand, it is very important to change the behaviors, making the consumers use less energy and conserve, at the same time, an equal quality of life.

To secure the full financial benefits of energy efficiency products and services, common measurement and verification (M&V) protocols are essential. The Energy Savings Directive is the first European Directive requiring Member States to report for energy savings. Member States already have their own experiences and skills in this field, but it should not be expected that all Member States will be able to use state-of-the-art evaluation methods right away. And the Commission will also have to set up its own evaluation system to comment the National Energy Efficiency Action Plans (NEEAPs) reported by the Member States. Therefore, the first Energy Savings Directive interim implementation phase (i.e., 2008-2010, to be reported in the second NEEAPs in 2011) should be used as a formative process for all stakeholders to issues raised when evaluating energy savings.

The general goal of the ESD methodology requirements is to provide a unified definition and method for savings calculation. Some countries have their own evaluation system for energy efficiency, and they have applied it for so long. These countries could continue applying their evaluation system in spite of the development of “Harmonizes methods”.

Subsequently, other commission’s communications have reinforced the plans for energy efficiency in the scheme of the Directive 2006/32/EC:

- Commission Communication of 19 October 2006 Action Plan for Energy Efficiency: Realizing the Potential

- Commission Communication of 23 January 2008 on a first assessment of national energy efficiency action plans as required by Directive 2006/32/EC on


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energy end-use efficiency and energy services - Moving forward together on energy efficiency

Finally, the Directive 2009/28/EC on Renewable Energy Sources, recently published, must be also considered. Its general scope is the opportunities for growth and employment that investment in regional and local production of energy from renewable sources brings about in the Member States and their regions. The development of energy from renewable sources, together with the application of energy efficiency initiatives, play a key role in order to reduce greenhouse gas emissions within the Community and reduce its dependence on energy imports.

The achievement of these objectives will be reached with a 20% target for the overall share of energy from renewable sources and a 10% target for energy from renewable sources in transport. The Community 20 % target must be translated into individual targets for each Member State, taking account of Member States’ different starting points and potentials.

Most of these directives have been transposed to Spanish legislation; in section 6.2 the Spanish regulatory framework will be deeply analyzed.

<table>
<thead>
<tr>
<th>European regulatory framework</th>
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<tbody>
<tr>
<td>The Energy Savings Directive 2006/32/EC (ESD) can be defined as the first European Directive concerning energy efficiency</td>
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4.2 Measuring and verification of energy savings

Measuring and verification (M&V), sometimes also called monitoring and verification, is the capability to track the performance of a piece of equipment, a mechanical system, or an entire building where one or more energy efficiency initiatives or energy conservation measures (ECM)\(^9\) have been implemented. Ideally, this tracking allows for adjustments that reduce resource use and operating costs. M&V is most often used to track energy consumption, but can also be applied to water use, indoor environmental quality, and a range of other metrics. M&V simply allows a user to compare the performance of a particular system or building to the performance of the same system or building at an earlier time, to the performance predicted by a simulation, or to the performance of other systems or buildings.

The M&V industry came about in the early 1970’s when high energy prices favored the creation of the first energy service companies (ESCOs) that offered to design, implement, and finance energy-efficiency improvements to existing buildings. ESCOs generally guarantee specific results and operate on performance-based contracts, so M&V emerged as a mechanism to determine whether the predicted savings had been achieved and, in turn, to reduce the building owner’s financial risk of investing in efficiency improvements. As a result of this origin, the M&V industry has historically focused on measuring the effects of replacing individual energy-system components in existing buildings.

In addition to its role in verifying savings, M&V can also be employed as a more direct means of reducing energy use. Monitoring energy systems can identify problems that might otherwise have gone unnoticed as well as opportunities for greater efficiency even when systems are operating as intended. It allows for relatively easy reductions in energy use, and it allows those reductions to be more

\(^9\) Energy Conservation Measures (ECM) are also called Energy Efficiency Measures (EEM)
consistent and persistent. Among other purposes, measurement techniques can be used to:

- **Increase Energy Savings**: giving valuable feedback on the development of conservation measures. This feedback helps to adjust ECM design or operations to improve savings, achieve greater persistence of savings over time.

- **Document financing transactions**: for some projects, the energy efficiency savings are the basis for performance-based financial payments and/or a guarantee in a performance contract.

- **Enhance financing for efficiency projects**: the M&V plan increases the transparency and credibility of reports on the outcome of efficiency investments, increasing the confidence of project’s investors and sponsors.

- **Improve engineering design and facility operations and maintenance**: the preparation of a good M&V plan encourages comprehensive project design by including all M&V costs in the project’s budget.

- **Manage energy budgets**: even where savings are not planned, M&V techniques are used to adjust for changing facility operating conditions in order to set proper budgets and account for budget variances.

Unlike energy consumption, energy savings can usually not directly be measured. However, they can be indirectly measured or estimated in relation to a reference situation. Such a reference situation will, therefore, always be needed to calculate energy savings.

In order to measure these savings, two different approaches can be made:

a) **Top down calculation method**: meaning that the amount of energy savings is calculated using the national or larger-scale aggregated sectoral levels of energy savings as the starting point. This approach uses statistical figures at an aggregated level, like energy consumption and production in sub-sectors of industry or hot water use and related energy use in households.
b) **Bottom up calculation method:** meaning that energy savings obtained through the implementation of a specific energy efficiency initiative are measured and added to energy savings resulting from other specific measures. This approach uses more detailed data, focusing on one or more end-user actions, often as a result of specific facilitating measures, like the implementation of high efficiency boilers in dwellings due to a subsidy scheme or various end-user actions due to an audit scheme.

Top-down evaluations are not the aim of this study, for the evaluation of the results of top-down initiatives is necessary to use econometric modeling for determining energy savings from taxes or other measures that influence prices, or to analyze various aggregated sector or national indicators, as for example tracking the average national specific energy demand for space heating per square meter and year.

In this work, the protocols described and analyzed are oriented to calculate energy savings derived from the application of bottom-up initiatives.

<table>
<thead>
<tr>
<th><strong>M&amp;V energy savings</strong></th>
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<tbody>
<tr>
<td>Energy savings can usually not directly be measured. However, they can be indirectly measured or estimated in relation to a reference situation</td>
</tr>
<tr>
<td>There are two common approaches for M&amp;V energy savings: Top down and bottom up calculation methods</td>
</tr>
<tr>
<td>In top down calculation methods the amount of energy savings is calculated using the national or larger-scale aggregated sectoral levels of energy savings as the starting point</td>
</tr>
<tr>
<td>In bottom-up calculation methods energy savings obtained through the implementation of a specific energy efficiency initiative are measured and added to energy savings resulting from other specific measures</td>
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</table>
4.3 Current projects

Besides the work carried out by Task XXI of the IEA-DSM, there are other international projects related with the standardizations of energy savings calculation. The most relevant are also the more related with Task XXI are:

- Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services (EMEEES), consortium of 21 institutes assisting the European Commission in developing harmonized top-down and bottom-up evaluation methods.

- International Partnership for Energy Efficiency Cooperation (IPEEC): methodologies of energy measurement, auditing and verification procedures, certification protocols and other tools to achieve optimal energy efficiency performance over the lifetime of building and industrial processes, relevant products, appliances and equipment.

- European Committee for Standardization (CEN): is working on standardization for energy efficiency and savings calculations. This resulted in the CWA 27 report, an advice for energy savings lifetime, and a project plan for the Taskforce 190 “Energy efficiency and savings calculation.

4.4 Energy savings guides

In order to help in the implementation of energy conservation measures, some institutions, governments and associations have launched guides and publications detailing the methodologies and process for the application of these ECMs within business, homes or industries.

These guides do not explain specifically the process to calculate or estimate the energy savings, however, they deserve special attention due to their usefulness helping and giving interesting ideas in energy efficiency projects. Considering the specifics of the Spanish market, some of the most used energy savings guides are:
• **IDAE Energy Savings Guides**: published by the Spanish Diversification and Energy Savings Institute (IDAE). These guides are a compilation of tips and examples of application of ECMs about lighting, HVAC\(^{10}\), and energy use at home. Their aim is to show consumer the benefits of the application of ECMs through examples and best practices

• **Energysavers**: the US Department of energy provides guides and on-line energy savings calculators where consumers can estimate their energy savings by the implementation of ECMs or simply by changing habits at home and businesses. Also provides several tips and guidelines trying to make aware consumers about energy consumption and benefits that can report

• **Energy Star**: is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy, helping consumers to save money and protect the environment through energy efficient products and practices. They offer a proven strategy for superior energy management with tools and resources assisting organizations in improving its energy and financial performance while distinguishing these organizations as environmental leaders

Besides these guides, there are other publications and handbooks published by local governments or energy administrations on each country. An important part within the implementation of ECMs described in any of these guides is the process for determinate ‘how much energy’ is being saved during the development of the project. As much of these guides do not precise this issue, necessary methods for energy savings calculation are needed; these will be described in the next section.

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\(^{10}\) Heat, Ventilation and Air Conditioning

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5. INTERNATIONAL STANDARDS FOR MEASURING ENERGY EFFICIENCY

Interest in energy efficiency, as an investment opportunity or as necessary public policy, has never been greater. Hence, there is a continuing need for standard methods to quantify the results of energy efficiency investments.

The main industry standard for M&V, internationally used, is the International Performance Measurement and Verification Protocol (IPMVP). There are other standards and M&V guidelines published by several organizations, but most of these guidelines are based on IPMVP. Among them are the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE); the U.S. Department of Energy’s Federal Energy Management Program (FEMP); the Energy Savings Measurement Guide published by the Australian Government; the U.S. Green Building Council (USGBC) LEED Rating System and some US utilities and states that fund energy-efficiency projects, like North Carolina Utilities Commission.\(^{11}\)

To give an overview of the most common international M&V protocols applied worldwide, in this chapter the following will be described:

5. EVO IPMVP
6. ASHRAE 14
7. DOE
8. ESMG

For each one of the protocols, the next main aspects will be discussed:

- Basic principles, including history and motivation for the publication of this protocol/guide.

\(^{11}\) In 2007 North Carolina became the first state in the US Southeast to adopt a Renewable Energy and Energy Efficiency Portfolio Standard (REPS)
- Savings calculation, including the M&V design and general savings equation.
- Measurement options for each protocol, including common applications and examples.
- Determination of the proper M&V option, detailing the methodology and criteria for the selection of the best measurement option.
- Methodology for project implementation, detailing the process followed from the beginning to the end of the project.

Before entering to the analysis of each protocol, as most M&V guidelines have several points in common, some definitions and basic concepts that apply to all of them will be described.

### 5.1 Basic concepts

#### 5.1.1 Energy performance contracts

Energy Performance Contracts (EPCs), also called Energy Savings Performance Contracts (ESPCs) are the documents where the contractor (normally ESCO) provides and arranges financing and implementation of energy improvements and is repaid over the contract term from the cost savings generated by the improvements.

The primary purpose of the EPC varies in the context of which is intended. In the context of building, an EPC presents the actual monetary performance of a retrofit project. In the context of industrial customers the main purpose of the EPC is to demonstrate the short-term performance of a retrofit project; following such demonstration the plant management takes over responsibility for operation and usually does not seek an ongoing relationship with the ESCO.

In both cases, the M&V Plan becomes part of the EPC’s terms and defines the measurements and computations to determine payments or demonstrate compliance with a guaranteed level of performance.
5.1.2 Baseline and reporting period

Since energy savings are defined as the absence of energy consumption, one way of calculate this savings is by the comparison of the situation once the ECM are implemented with the situation before its implementation:

- **Baseline period**: corresponds to the initial situation, before the ECM.
- **Reporting period**: corresponds with the period of time where the ECM is active.

There are several methods for the calculation and estimation of the baseline consumption, like reading utility bills, placing energy meters, or simulating the baseline consumption on the facility.

Nevertheless, besides the current energy use, there are some physical facts that must be considered in the baseline definition, making the necessary adjustments. There can be two types of adjustments:

- **Routine adjustments**: for those factors expected to change routinely during the reporting period (i.e. external conditions, production changes, etc.). There are several techniques to define the adjustment methodology: adding constant values (no adjustment) or using multiple parameter non-linear equations correlating energy with one or more independent variables.
- **Non-routine adjustments**: for those factors which are not usually expected to change (i.e. size of facility, normal occupancy, etc.). These static factors must be monitored for change throughout the reporting period.

Furthermore these adjustments, there are some other physical factors called interactive effects that must be taken into account next to baseline and reporting period. Some typical interactive effects are changes in temperature, luminosity or

12 These effects are also called leakages
other interactions caused by the application of an ECM. If the impact of these effects is relevant for the reporting period, they should be taken into account in the saving equations, otherwise can be ignored.

### 5.1.3 Measurement period selection

Another key factor for the measurement scheme is the selection of the length for the baseline and reporting period, and the possibility of use adjacent measurement periods:

- **Baseline period length**: defined as the period of time when baseline consumption is measured. It must represent all operating modes of the facility, covering from maximum energy use to minimum.
- **Reporting period length**: the length of the reporting period must be at least one normal operating cycle of the equipment or facility analyzed. This length depends on the type of initiative considered.
- **Adjacent measurement periods**: in case the initiative can be activated or deactivated easily, the baseline and reporting periods selected can be put adjacent to each other in time. That allows to measure with the initiative activated, and immediately with the initiative deactivated, comparing both results in a short period of time. The adjacent periods used for the on/off test should be long enough to represent stable operation.

### 5.1.4 Measurement boundary

One of the main determinants in M&V is defining whether savings are going to be evaluated for an entire facility or for a part of it. That defines the measurement boundary:

- a) For measuring isolated equipment affected by a saving program, the measuring boundaries must be drawn around that equipment
b) For measuring total energy performance on a facility, the measuring boundaries covers the whole facility

In case there is no available baseline or previous data, energy data must be obtained from a calibrated simulation, for full or a part of the facility, which determines the measurement boundary.

All the effects derived from the energy efficiency initiative must be taken into account. Even if these effects fall outside a practical measurement boundary (interactive effects) must be taken into account estimating their impact. Only in the case that interactive effects are so small as to be derisory, can be ignored.

5.1.5 Savings calculation

Energy savings, understood as the diminution of energy consumption after the implementation of an ECM, can be calculated as the comparison of these two scenarios. Although each measurement and verification protocol defines its own savings formula with the necessary adjustments for each measurement option and project situation, the general savings equation can be expressed as:

\[
\text{energy savings} = \text{energy use before ECM} - \text{energy use after ECM} \pm \text{adjustments}
\]

The next figure summarizes the process that must be carried out for the energy savings calculation:
When evaluating energy savings, there is a commitment between project costs and metering accuracy. In most cases when it is necessary to measure parameters, level of uncertainty is determined by the accuracy of the measure, which is normally related with the project budget.

### Common M&V concepts

Energy performance contracts (EPCs) are the documents where the contractor (ESCO) settles its energy improvements derived from the energy conservation measures (ECMs)

Savings are generally calculated by the comparison of the situation once the ECM is implemented (reporting Period) and before the ECM implementation (baseline period) taking into account necessary adjustments

Energy savings have to consider the trade-off between costs and accuracy

### 5.2 EVO IPMVP

#### 5.2.1 Introduction

The International Performance Measurement and Verification Protocol (IPMVP) is a guidance document describing common practice in measuring, computing and reporting savings achieved by energy or water efficiency projects at end user
facilities. The IPMVP presents a framework and four measurement and verification Options (A, B, C and D) for transparently, reliably and consistently reporting of project’s savings. M&V activities include site surveys, metering of energy or water flows, monitoring of independent variables, calculation, and reporting.

IPMVP guideline consists of three volumes:

- Volume I defines terminology and establishes procedures for determining the savings resulting from retrofits
- Volume II focuses on maintaining or improving indoor environmental quality during and following the implementation of energy-conservation measures
- Volume III provides guidance on specific M&V issues, including applying M&V to renewable-energy systems and to new construction

The IPMVP is intended to be used by professionals as a basis for preparing savings reports. Each user must establish its own specific M&V Plan that addresses the unique characteristics of the project. The IPMVP is not a standard and thus there is no formal compliance mechanism for this. Adherence with the IPMVP requires preparation of a project specific M&V Plan consistent with IPMVP terminology.

The IPMVP is sponsored by the Efficiency Valuation Organization (EVO), a non-profit private corporation whose mission is to develop and promote standardized methods to quantify and manage the risks and benefits associated with business transactions on end-use energy efficiency, renewable energy, and water efficiency. EVO is a subscriber-based organization with supporters around the world.

EVO, besides the International Performance Measurement and Verification Protocol, has published the International Energy Efficiency Financing Protocol (IEEFP), which provides guidelines for local financing institutions around the world to evaluate and finance energy efficiency and savings-based renewable projects.

Together with the publications of M&V guidelines, EVO through its partners around the world have launched training programs in measurement and verification, which train professionals on methods and recent developments in M&V and can end up in
the Certified Measurement and Verification Program (CMVP), aimed for those professionals that demonstrate their knowledge experience and training in IPMVP.

5.2.1.1 Brief history and previous publications
The first edition of IPMVP, entitled the North American Energy Measurement and Verification Protocol, was published in March 1996. It was modified in December 1997 and then renamed the International Performance Measurement and Verification Protocol. Some measurement options were changed substantially when IPMVP was re-published in 2001 and minor editorial changes were added in a 2002 edition. Volume II on Indoor Environmental Quality was published in 2002. Energy professionals committees, sponsored by the United States’ Department of Energy (DOE) wrote and edited these documents.

In 2002, IPMVP Inc. was incorporated as an independent non-profit corporation in order to include the international community and relieve the U.S. Department of Energy of its responsibilities as the organizer. IPMVP Inc. raised its own funds, created a website, and published the new Volume III Parts on New Construction and Renewables in 2003. In 2004, IPMVP Inc. was renamed Efficiency Valuation Organization as it expanded its focus.

EVO IPMVP is related to other M&V guides as ASHRAE 14-2002 (which has many of the same original authors as IPMVP), and Greenhouse Gas Protocol for Project Accounting 2005 (where IPMVP Technical Committee was represented on the advisory committee for this document).

5.2.1.2 Measurement and verification principles
The IPMVP is based on six basics principles, which describe good use of the protocol and features that the savings report must fulfill:
### 5.2.2 Savings calculation

IPMVP defines six steps for savings determination involved within any energy management endeavor:

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurate</td>
<td>The level of accuracy is determined by the M&amp;V budget, as more accuracy level might imply more M&amp;V cost</td>
</tr>
<tr>
<td>Complete</td>
<td>Considering all possible effects in energy consumption in the final report, those significant must be measured in a quantitative way, others that cannot be measured should be estimated</td>
</tr>
<tr>
<td>Conservative</td>
<td>Where judgments are made about uncertain quantities, M&amp;V procedures should be designed to under-estimate savings</td>
</tr>
<tr>
<td>Consistent</td>
<td>Certain level of consistency must be guaranteed between different types of energy efficiency projects, energy management professionals for any project, periods of time for the same project and consistent between energy efficiency projects and new energy supply projects</td>
</tr>
<tr>
<td>Relevant</td>
<td>Performance parameters must be well determined, other less critical can be estimated</td>
</tr>
<tr>
<td>Transparent</td>
<td>On the savings report all activities conducted and all results must be clearly presented and described</td>
</tr>
</tbody>
</table>

Figure 6: IPMVP principles
The description of each step and main activities conducted are:

1. **M&V plan development**: advance planning ensures that all data needed for savings determination will be available after the implementation of the ECM within an acceptable budget. An M&V plan should be adapted while the project itself is being developed and should also be included as a part of the overall project budget. The M&V plan includes the user's needs evaluation, determination of suitable measurement option and gathering relevant information from baseline period for future comparison.

2. **ECM installation verification**: it is necessary to inspect and verify the installed equipment after the ECM implementation, ensuring they conform the design intended.

3. **Reporting period data gathering**: during the reporting period, energy and operating data are gathered as defined in the M&V plan.

4. **Savings computation**: according to the M&V plan, savings must be computed in energy and monetary units.
5. **Savings report**: results must be reported according to what is established in the M&V plan.

6. **Savings review**: savings reports must be reviewed by energy managers, this review may reveal useful information about how the facility is using energy and can help to the adoption of new ECMs.

For the savings calculation, IPMVP defines a general equation considering the baseline energy, the measured consumption with the initiatives and the necessary adjustments:

$$\text{savings} = (\text{BE} - \text{RPE}) \pm \text{routine adj.} \pm \text{nonroutine adj.}$$

Where

- \( \text{BE} \) is the Baseline energy, that is the initial energy consumption.
- \( \text{RPE} \) is the Report Period energy, that is the energy consumption after ECM.
- **Routine and non-routine adjustments** are the necessary adjustments to equal the conditionings between the two periods (before and after ECM).

These savings can be reported on the basis of the reporting period conditions or there can be normalized to some other fixed set of conditions, so IPMVP defines two approaches for the general savings equation:

a) **Reporting period basis**, also known as avoided energy use, or avoided cost. It quantifies savings in the reporting period relative to what energy use would have been without the application of the initiative. In this case, baseline-period energy needs to be adjusted to reporting-period conditions:

$$\text{savings(avoided energy use)} = [\text{adjusted BE} - \text{RPE}] \pm [\text{adjustments}]$$

Where

- **Adjusted BE** is the modified base energy consumption
- **RPE** is the Report Period energy, that is the energy consumption after ECM

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- **Adjustments** are the non-routine adjustments of baseline energy to reporting periods conditions

Adjusted-baseline energy is defined as the baseline energy plus any routine adjustments needed to adjust it to the conditions of the reporting period.

b) **Fixed conditions basis**, also known as normalized savings, where conditions are those of the baseline period, some other arbitrary period or a typical average or normal set of conditions. In this scheme, energy of the reporting period and possibly of the baseline period, are adjusted from their actual conditions to the common fixed or normal set of conditions selected

\[
\text{Normalized savings} = [BE \pm \text{adjustments.}] - [RPE \pm \text{adjustments}]
\]

Where

- BE is the Baseline energy, that is the initial energy consumption
- RPE is the Report Period energy, that is the energy consumption after ECM
- Adjustments are the routine and non-routine necessary adjustments to fixed conditions

The calculation routine-adjustments for the reporting period usually involves the development of a mathematical model that correlates reporting-period energy with the independent variables of the reporting period. This model is then used to adjust reporting-period energy to the chosen fixed conditions. Further, if the fixed set of conditions is not from the baseline period, a mathematical model of baseline energy is also used to adjust baseline energy to the chosen fixed conditions.

### 5.2.3 Measurement schemes

As other M&V protocols, IPMVP defines measurement options that must fulfill the different situations of measuring energy savings.

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5.2.3.1 General overview

Energy consumption and hence energy savings as diminution of energy used, can be measured using different techniques:

- Reading general utility meters or services invoices
- Placing special meters where the energy efficiency initiatives are set
- Measuring parameters used in computing energy use (i.e. electrical load, operating hours), and multiplying together to compute the equipment’s energy use
- Measuring proven proxies of energy use, as direct indicators of energy consumption (i.e. amount of light produced by lighting system)
- Simulating the energy consumption with a computer program

There are two situations where energy consumption measurement is not needed:

a. When the energy value is already known (i.e. by technical specifications, etc)

b. When it cannot be determined in an easily reasonable way, in this situation the measurement can be estimated

In order to create standard measurement options taking into account the different techniques described before, IPMVP proposes four measurement options:

- **Option A: Retrofit isolation. Key parameter measurement**: Savings are determined by field measurement of the key performance parameters which define the energy use of the ECM’s affected systems and/or the success of the project

- **Option B: Retrofit Isolation. All parameter measurement**: Savings are determined by field measurement of the energy use of the ECM-affected system

- **Option C: Whole facility**: Savings are determined by measuring energy use at the whole facility or sub-facility level
• **Option D: Calibrated simulation:** Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility.

The choice of one option or another involves many previous considerations, such as location of the measurement boundary, frequency of the measures, parameters selected, etc.

In the next paragraphs each measurement option will be described, detailing the features, main uses and principles considered.

### 5.2.3.2 Option A: Retrofit isolation. Key parameter measurement

When savings measurement is focused only on the energy efficiency initiative (not the entire facility), isolation meters must be placed where it is possible to measure the energy use of the systems affected by the initiative, separate from the energy use of the rest of the facility. Meters location must be established to include as many of the significant energy impacts of the ECM. Energy impacts that are not measured (interactive effects) must be estimated.

Energy savings are determined by field measurement of the key performance parameters that determines the energy use of the ECM’s affected system or facility. The frequency of measurement varies widely, depending on the expected variations in the measured parameter, and the length of the reporting period. Parameters not selected for measurement are estimated, based on historical data, manufacturer’s specifications or engineering assumptions.

Savings are determined by engineering calculation of baseline and reporting period energy, from short term or continuous measurement of key operating parameters and estimated values. In the common situation of no changes occurring in operating conditions between the baseline and reporting periods (no adjustments required), the savings equation can be written as:

\[
\text{Savings (option A)} = EV \times (BE - RPE)
\]
Where

- \( EV \) is the estimated value
- \( BE \) is the baseline period measured energy parameter
- \( RPE \) is the reporting period measured energy parameter

One example of measuring savings with option A is the replacement of lighting systems in a building: the wattage of the new lamps is known, but the wattage of the old lamps varies considerably due to previous replacement during the past years. In this case, the key parameter is lighting power, and measurements are made on the power consumption before and after the installation of the new lamps. One interactive effect is the heat produced by the old bulb lamps, so additional heat production would be needed in some zones of the building. In this example the energy requirements for the extra heat are estimated, and energy savings are calculated taking into account this energy consumption.

**5.2.3.3 Option B: Retrofit isolation. All Parameter Measurement**

Option B is similar to Option A because it draws a measurement boundary around the ECM, smaller than the entire facility. The main difference with Option A is that Option B requires either measurement of all ECM parameters used to compute energy, or measurement of energy global use itself.

Energy savings are determined by field measurement of energy use in the ECM-affected system. Measurement frequency ranges from short term to continuous, depending on the expected variations on the savings and the length of the reporting period selected.

Energy savings are calculated by short term or continuous measurements of baseline and reporting period energy, complemented by engineering calculation using proxies of energy use if it is needed. In case there are no changes in the operating conditions between the baseline and reporting periods, the savings equation can be written as:

\[
\text{Savings (option B)} = BE - RPE
\]
Where

- $BE$ is the baseline period measured energy parameter.
- $RPE$ is the reporting period measured energy parameter.

If the operating conditions change between baseline and reporting period, it is necessary to introduce adjustments to the measurements in order to have the same set of baseline conditions.

As an example of the application of Option B, considering the same example for Option A, savings can be reported measuring all operating periods and the load change. The operating periods can be measured by lighting loggers inserted in randomly selected fixtures. The lighting system energy use is then calculated by multiplying the measured load change by the measured operating periods of the reporting period. Another possibility, when available, is measure directly the lighting consumption with electrical energy meters. In both situations, all full measurements should be made for the baseline and reporting periods.

5.2.3.4 Option C: Whole facility

This measurement option involves the use of utility meters, whole facility meters or sub-meters to assess the energy performance of a total facility or installation. The measurement boundary encompasses either the whole facility or a major section. This option determines the collective savings of all ECMs applied to the part of the facility monitored by each energy meter. Since whole facility meters are used, savings reported under this option include the positive or negative effects of any change on the facility, even those not due to the ECMs.

Energy savings identification is easy when the expected savings are much higher than random or unexplained energy variations. Furthermore, the longer the period of savings analysis after the ECMs installation, the less significant is the impact of short term unexplained variations.
Energy savings are calculated by the analysis of whole facility baseline and reporting period meter, so the equation can be written as:

\[
\text{Savings (option C)} = [\text{Adjusted BE} - \text{RPE}] \pm \text{adjustments}
\]

- *Adjusted BE* is the modified base energy consumption
- *RPE* is the reporting period measured energy
- *Adjustments* are the non-routine adjustments of baseline energy to reporting period conditions

Adjusted baseline energy typically comes from analysis of the baseline data to determine a relationship between energy use and independent variables (i.e. outdoor temperature or any other conditions variable during the reporting period, etc.). This relationship is used to re-state the baseline energy data under the conditions of the reporting period, and may involve techniques such as regression analysis, and enables adjustment for external variables, such as weather or any others that vary routinely.

In the savings equation, non-routine adjustments have been taking into account. Since the measure is over all the installation, there is a high probability of finding interactive factors that change between the baseline and reporting periods.

As an example of a measure using Option C, let’s suppose an office building where a number of ECMs are implemented, for lighting, mechanical cooling and heating, combining with operator training and occupant energy awareness campaigns. The electrical data (power and consumption) can be taken from the utility bills, and the cooling degree days from an external weather station. The energy demand data can be correlated with the weather data, evaluating the existence of correlation between energy consumption and weather. The level of correlation defines the suitable formula for the baseline model. The comparison of the reported period energy with the adjusted baseline determines the energy savings, taking into account the non-routine adjustments (i.e. abnormal occupancy of the building) if there are relevant.
5.2.3.5 Option D: Calibrated simulation

With this measurement option, savings are determined through computer simulation of the energy use of the whole facility or a part of it, so no measurement devices are required.

Simulation routines normally model actual energy performance measured in the facility adequately; this option usually requires high experienced teams with strong skills in simulation.

Energy savings are calculated by energy use simulation, calibrated with hourly or monthly utility billing data. Savings equation can be written as:

\[ \text{Savings (option D)} = SBE - SRPE \pm CE \]

- \( SBE \) is the simulated baseline energy, that is, the baseline energy from the calibrated model (without ECMs)
- \( SRPE \) is the simulated report period energy, that is, the actual reporting or calibration period energy (with ECMs)
- \( CE \) is the calibration error in the corresponding calibration reading

The prediction of energy use in a facility under a known set of conditions can be made by simulation software. The simulation is adjusted to come as close to the calibration data as possible; calibration error is understood as the set of differences between the modeled and calibration actual data points.

One example of the application of this scheme is a new building designed to use less energy than required by local building code. In this example, computer simulation is used extensively throughout the building design process to guarantee a target of less energy use than originally expected. When the building is complete and fully operative the first year, year one’s energy and operational data will become the baseline for an Option C approach to reporting ongoing performance. A year after commissioning and full occupancy, the original design simulation’s input can be updated to reflect the as-built equipment and the current occupancy. A weather data file helps to adjust year’s one consumption with actual monthly heating and cooling
degree days. The utility consumption data from year one can be compared to the simulation model, testing the suitability of the calibrated simulation, called as-built model. The input data for the as-built model now is changed to describe a building with the same occupancy and location but which simply meets the building code standard, this is called the standard model. The standard model’s monthly predicted energy use must be adjusted by the monthly calibration errors (previously established) to yield the corrected standard model. Actual metered data for year one is then subtracted from the corrected standard model to yield the monthly savings.

5.2.3.6 Best option applications

On the next figures there is a brief description of each measurement option including a list of situations where each option is the best applicable and key features that must be taken into account:

<table>
<thead>
<tr>
<th>Option A: Retrofit isolation: key parameter measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metering:</strong></td>
</tr>
<tr>
<td><strong>Adjustments:</strong></td>
</tr>
<tr>
<td><strong>Best application</strong></td>
</tr>
<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
options D or C.

- Long term testing is not warranted.
- No need to directly settle savings reports with changes in payments to energy suppliers.
- Estimation of key parameters may avoid possibly difficult non-routine adjustments when future changes happen.
- The uncertainty created by estimation is acceptable.
- The continued effectiveness of the ECM can be assessed by simple routine inspection.
- A key parameter used in computing savings is well known.

Figure 8: Best application of IPMVP Option A

<table>
<thead>
<tr>
<th>Option B: Retrofit isolation: all parameter measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metering:</strong></td>
</tr>
<tr>
<td>All parameter where the ECM is applied.</td>
</tr>
<tr>
<td><strong>Adjustments:</strong></td>
</tr>
<tr>
<td>Only needed if changes during operation conditions are relevant.</td>
</tr>
<tr>
<td><strong>Best application</strong></td>
</tr>
<tr>
<td>Only the performance of the systems affected by the ECM is of concern.</td>
</tr>
<tr>
<td>Interactive effects of the ECM can be reasonably estimated, or assumed to be insignificant.</td>
</tr>
<tr>
<td>Difficult to identify changes beyond the measurement boundary.</td>
</tr>
<tr>
<td>Independent variables affecting energy use are not difficult to monitor or measure.</td>
</tr>
<tr>
<td>Sub-meters already exists to isolate energy use of systems.</td>
</tr>
<tr>
<td>Meters added at the measurement boundary can be used for other purposes.</td>
</tr>
<tr>
<td>Parameters measurement and estimation is less costly than</td>
</tr>
</tbody>
</table>
option D or C.
- Long term testing is not warranted.
- No need to directly settle savings reports with changes in payments to energy suppliers.

Figure 9 Best application of IPMVP Option B

<table>
<thead>
<tr>
<th>Option C:</th>
<th>Whole facility measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metering:</strong></td>
<td>Whole facility</td>
</tr>
<tr>
<td><strong>Adjustments:</strong></td>
<td>Needed to reduce the effects of static factors that may change between baseline and reporting periods.</td>
</tr>
</tbody>
</table>
| **Best application** | - When energy performance will be assessed for the whole facility, not only where the ECM is applied.  
- Different types of ECMs in the facility.  
- Difficult to measure ECMs independently.  
- Expected savings are larger than the variation in the baseline data during the reporting period.  
- Interactions between ECMs make Option A and B too much complex.  
- Major future changes on the facility are not expected during the reporting period.  
- Reasonable correlation between energy use and independent variables is considered. |

Figure 10: Best application of IPMVP Option C

<table>
<thead>
<tr>
<th>Option D:</th>
<th>Calibrated simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metering:</strong></td>
<td>Needed for calibrate the simulation</td>
</tr>
<tr>
<td><strong>Adjustments:</strong></td>
<td>Calibration error: set of differences between the modeled and</td>
</tr>
</tbody>
</table>
calibration actual data points.

| Best application | • When no other option is feasible. |
|                 | • Either baseline energy data or reporting period energy data (but not both) are unavailable or unreliable, i.e. when only central metering is available. In this case, Option D can be use to model baseline data. |
|                 | • There are too many ECMs to assess using Options A or B. |
|                 | • The ECMs involves diffuse activities, which cannot be easily isolated. |
|                 | • The performance of each ECM can be estimated individually within a multiple-ECM project, but the costs of Options B and C are excessive. |
|                 | • Interactions between ECMs are complex, isolation analysis is complicated. |
|                 | • Major future changes to the facility are expected during the reporting period. |
|                 | • ECM and facility can be both well documented by simulation software. |
|                 | • Only one year’s performance is measured, immediately following installation and commissioning of the energy management program. |

**Figure 11: Best application of IPMVP Option D**

### 5.2.4 Determining the proper M&V scheme

There are some parameters like projects conditions, previous analyses, budget available and criteria of the designer of the M&V program that determine which measurement option is the best suitable for each project. One of these parameters is complexity of installed systems, which IPMVP classifies into two types:
- **Simple**: characterized by constant load and constant operating hours. Simple systems also include static measures, such as lighting, some motors, windows and insulation
- **Complex**: characterized by variable load or variable operating hours, such as lighting schedule controls, steam traps, variable speed drives, variable air volume retrofits, boiler or chiller replacement, packaged rooftop replacement and outdoor air control. The recommended M&V rigor increases as the installed systems become more complex

Nevertheless, even considering those aspects, it is impossible to generalize on the Best Option for any type of situation given. IPMVP gives some ideas and advices for the selection of the proper measurement option, some of the features and conditions for each option scheme have been yet explained in the figures before. The next figure summarizes the main ECM project characteristics and suggested the best option:

<table>
<thead>
<tr>
<th>ECM Project Characteristic</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need to assess ECMS individually</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Need to assess only total facility performance</td>
<td></td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Expected savings less than 10% of utility meter</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple ECMS</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Significance of some energy driving variables is unclear</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interactive effects of ECM are significant or un-measurable</td>
<td></td>
<td></td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Many future changes expected within measurement boundary</td>
<td>√</td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Long term performance assessment needed</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.2.5 Methodology for the application of this protocol

The M&V design and reporting process parallels the ECM design and implementation process. Proper M&V project development should involve the following steps:

1. User’s needs consideration
2. IPMVP Option selection
3. Data gathering: Baseline period
4. M&V Plan preparation
5. Measurement equipment installation
6. Installed equipment inspection
7. Data gathering: Reporting period
8. Savings computation
9. Savings report

The nine steps of the IPMVP methodology cover all M&V Project, since the identification of user’s needs to the elaboration of the savings report and the necessary documentation:

1. **User’s needs consideration on the planned M&V report:** contents the description of the ECM, its intended result, and the commissioning procedures that will be used to verify successful implementation of each ECM.

2. **IPMVP Option selection:** in this step the project responsible specifies which IPMVP Option will be used to determinate savings. It has to be consistent...
with the scope of the ECMs, the needs for accuracy and the budget for M&V. It must include the date of publication of the IMVP edition being followed and the measurement boundary of the savings determination in order to describe its possible effects.

3. **Baseline period energy data gathering**: all the baseline documentation needed in the M&V plan is provided by an energy audit, surveys, inspections and/or short term metering activities. This baseline documentation should include the following steps:
   - Identification of the baseline period.
   - All available baseline energy consumption data.
   - All independent variable data coinciding with the energy data (e.g. production rate, ambient temperature).
   - All static factors coinciding with energy data. (For example in a building, it is important to consider light level, space temperature humidity and ventilation levels).

4. **M&V Plan preparation**: advance planning ensures that all data needed for savings determination will be available after implementation of the ECMs, within an acceptable budget. It is important to record data from the baseline for future reference in case conditions change or ECMs fail. Documentation should be easy to find and easy to understand by verifiers and others, because years may pass before these data are needed.

5. **Design installation, calibration and Commissioning of any special measurement equipment**: specifies the characteristics of the measurement equipment, the procedure and periods for reading obtained results and a method to deal with lost data.

6. **Installed equipment inspection**: revision of operating procedures guarantying the conformation with the objectives of the ECM. Usually, all energy measurements must be adjusted to the set of conditions of the reporting period.
7. **Reporting period energy data gathering:** specify how results will be reported and documented. Results must include an explanation of the change in conditions since the baseline period and all observed facts and assumptions.

8. **Savings computation in energy and monetary units:** determine the savings calculation using the mathematical model assumed in the M&V Plan.

9. **Savings report in accordance with the M&V plan:** analyze the development of the whole process and verify that it has reached the expected accuracy to determinate savings and a high level of quality assurance of procedures.

---

**IPMVP main features**

<table>
<thead>
<tr>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPMVP was the first M&amp;V guideline published, for the first time in March 1996. It settled the basis to determine energy savings in projects. Other protocols are based on IPMVP</td>
</tr>
<tr>
<td>This M&amp;V guide is sponsored by the Efficiency Valuation Organization (EVO)</td>
</tr>
<tr>
<td>IPMVP presents four M&amp;V options (A, B, C and D), also providing the criteria and methodology for the selection of the Best Measurement Option in each case</td>
</tr>
<tr>
<td>It is the most extended protocol, both worldwide and in Europe</td>
</tr>
</tbody>
</table>

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**5.3 ASHRAE 14-2002**

**5.3.1 Introduction**

ASHARE 14-2002 is a guideline published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), aimed to the calculation of energy savings derived by the application of energy efficiency initiatives in a facility.

Guideline 14-2002 was created by a committee of ASHRAE members who represented future guideline users, producers of products that would be affected by the guideline (i.e., software, hardware or services), and ASHRAE members with a general interest in the guideline. This guide may be used for transactions between energy services companies (ESCOs) and their customers and between ESCOs and...
utilities. The purpose is to provide savings results sufficiently well specified and reasonably accurate due to building energy management projects.

In order to calculate energy and demand savings, the main billings determinants (e.g. kWh, kW, MFC, etc) must be quantified using measured pre-retrofit and post-retrofit data.

The procedures included in the ASHRAE Guideline 14-2002 take in all forms of energy (electricity, gas, oil, district heating/cooling) and cover residential, commercial and industrial buildings. However, these procedures do not include sampling methodologies that can be used in large-scale demand-side management programs, metering standards or major industrial process loads.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers was founded in 1984, nowadays is an international organization of 51,000 persons. ASHRAE is a professional's organization that actively conducts research, standards writing, publishing and continuing education.

Guideline 14-2002 was developed by ASHRAE to fill a need for a standardized set of energy and demand savings calculation procedures. The guide was edited in June 2002, up to date is the only version published. This guide refers to the IPMVP Volume I for further information about some topics (i.e. performance contracts), as it was designed as a complementary guide providing detail on implementing M&V plans with the framework.

Guideline 14-2002 contains minimum compliance requirements to assure a fair level of confidence in the savings determination. These requirements can be fulfilled with the three engineering approaches proposed by ASHRAE, equivalent to the four IPMVP measurement options:

- **d)** Whole-building metering
- **e)** Retrofit isolation metering
- **f)** Whole-building calibrated simulation
These three approaches are provided to balance the accuracy of the chosen approach against the cost of implementation. Compliance of each approach requires that the overall uncertainty of the savings estimates is below prescribed thresholds.

As it can be seen, the three approaches presented are closely related to and support the options provided in IPMVP. In terms of nomenclature and measurement principles, ASHRAE defines ‘retrofit’ as the application of an energy efficiency initiative or energy conservation measure (ECM), specifically the term post-retrofit is used for the measurement after the implementation of the initiative. Other concepts like baseline period and reporting period maintain the same nomenclature as in IPMVP.

5.3.2 Savings calculation

Energy savings cannot be measured in a direct way as the instruments available cannot measure the absence of energy use or demand. However, a comparison between the energy use before and after the implementation of an energy conservation measure (ECM) gives us a measure of the savings. It also has to include the impacts of the ECM and other factors, for example, weather or occupancy.

The basic method used in this guideline forecasts energy use or demand patterns of the pre-retrofit (baseline) period into the post-retrofit period in order to calculate savings, comparing the actual use of energy with an estimation of what energy use would have been in the absence of the ECM:

\[
Savings = (BPE) - (PRE)
\]

Where

- \( BPE \) is the Baseline energy use or demand projected to Post-retrofit conditions
- \( PRE \) is the Post-retrofit energy use or demand
The estimation of what energy use would have been in the absence of the ECM requires data analysis and assumptions of the relationships between the factors that affect energy use.

There are two types of factors that affect energy use or demand:

- Flexible factors that usually change since the baseline period such as weather and occupancy
- Fixed factors that do not change often such as building dimension

In the savings measurement is only necessary to remove the influence of flexible factors.

Absolute certainty is not achievable because there are numerous sources of uncertainty, for example, instrumentation or measurement error, normalization or model error, sampling error, and errors of assumptions. The importance of certainty should be balanced with measurements costs and with the earnings that these measures will produce.

The achievement of a higher degree of certainty could be reached by using more sophisticated measurement equipment, analysis methods, sample sizes and assumptions. Nevertheless there are some factors that could not be measured in a quantitative way like human error or the incorrect placement of sensors.

ASHRAE 14-2002 guideline assets a procedure to calculate quantifiable uncertainties and fixes a maximum acceptable for each saving calculation.

In order to guarantee success in calculating savings efficiently is important to specify a planning of the process that includes all relevant data and the requirements of the process that can be obtained with an acceptable budget.

There are three possible basic objectives for the savings calculation when one or more ECMs are implemented:

- **Determining Payments Under an Energy Service**: in many energy savings contracts, savings are used to determine the required payments, so here a
critical parameter would be the importance that any uncertainty in the savings has to the total payments

- **Controlling Energy-Using Systems**: in some energy savings contracts, savings are used to control operation of the energy-using systems and improve overall performance. The key factor here is timelines. If the savings reports are frequent, uncertainty will be of lesser importance because it will be possible the correction of errors so that use excesses do not occur

- **Justify Retrofit Investments**: saving contracts also could be used to justify that investments in energy savings made good economic sense

To ensure a fair level of confidence in the calculation of savings there are some compliance requirements. The general rule, as explained before, is the necessary balance between the accuracy of the approach against the costs of the implementation.

The three basic approaches developed in ASHRAE 14-2002 guidelines have to follow some minimum requirements or a general approach. The general methodology should be developed in these steps:

1. Prepare M&V plan showing compliance path
2. Measure baseline energy use and record governing conditions
3. Measuring post-retrofit energy use and record governing conditions
4. Project baseline and cost-retrofit energy use to a common set of conditions (usually post-retrofit conditions)
5. Calculate the savings using the formula explained before
6. Report savings

In addition, for the three approaches the level of uncertainty must not be greater than 50% of the annual reported savings (at the 68% confidence level\textsuperscript{13}).

\textsuperscript{13} This minimum level of uncertainty is established in the ASHARE 14-2002 guideline

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5.3.3 Measurement schemes

5.3.3.1 General overview

The three engineering approaches defined by ASHARE correspond with three measurement options, trying to cover all possible situations to measure energy savings after the implementation of an ECM:

a) Whole-building metering
b) Retrofit isolation metering
c) Whole-building calibrated simulation

In the next pages, each measurement option will be described, showing the basic principles, savings formula and best case applications.

5.3.3.2 Whole building approach

ASHRAE-14 also names this option as Main Meter approach; it consists in the verification of the performance of the retrofit for those projects where whole-building, pre-retrofit and post-retrofit data are available to determine the savings.

This measurement may include consumption and demand values taken from sub-meters, where those meters represent a significant portion of the building or group of subsystems in the building that are being retrofitted.

This option is appropriate when the total building performance is being calculated, for this purpose ASHRAE-14 proposes two different paths:

- **Prescriptive path**: appropriate for projects where savings are expected to be greater than 10% of the energy consumed. Requires continuous and complete data, furthermore all relevant data must be included in the baseline model and the post-retrofit model
- **Performance path**: appropriate when it is not possible to comply with the requirements of prescriptive path. This path allows for data gaps and other irregularities on data collection, only requiring the user to show that the
calculated uncertainty in the cumulative savings is less than 50% of the total savings reported for the post retrofit period.

The whole building approach is fed by periodic utility data stored or directly measured, like bills, readings of coal, gas, etc. This data must fulfill some degree of periodicity, necessary for savings calculation that includes time of use charges, time of day or real time electricity pricing. Sometimes regression models\textsuperscript{14} based on daily data provide the best statistical accuracy; hourly data can also provide more accurate insight into the building’s energy use characteristics, which can be useful in determining why a building’s post-retrofit operation may be performing below expectations. The use of interval data also requires the collection and storage of data of weather conditions from a reliable source.

The energy use applying the whole building approach can be modeled with a linear multiple variable equation:

\[ E = C + B_1 V_1 + B_2 V_2 + B_3 V_3 + A_1 V_n + \ldots \]

Where:

- \( E \) is the energy use estimated by the equation
- \( C \) is the constant term in energy units per day
- \( B_n \) is the coefficient of independent variable \( V_n \) in energy units/driving variable units/day
- \( A_1 \) is the coefficient of the independent variable for any adjustment
- \( V_n \) is the independent driving variable

Depending on the number of independent driving variables and adjustments needed the savings equation can be simplified.

\textsuperscript{14} ASHARE 14-2002 guidelines provides one dedicated section to regression techniques, detailing the necessary calculations and methodologies.
Typically, this approach is applied on big facilities or buildings like college campuses, hospitals or commercial buildings. Models that have been recognized as the most appropriate for modeling monthly and daily energy use in these facilities include:

- Constant or mean models
- Day adjusted models
- Two-parameter linear models
- Variable-based degree day models
- Three to five-parameter change-point linear models
- Variable-based degree day models
- Multivariate linear and change-point linear models

For each one of these models with whole building approach, ASHRAE guideline defines a particular savings equation taking into account the parameters and variables involved.

### 5.3.3.3 Retrofit isolation approach

This approach is intended for retrofits where the end use energy consumption can be completely measured both during the baseline period and post-installation period. The measurement can be continuous or for a limited period of time; in most cases energy consumption is calculated by developing statistically representative models of the energy use.

This measurement option is used when the whole-building approach is not suitable (for example when savings are relatively small), and when savings can be easily determined by measurements taken at a specific equipment item or subsystem.

Guideline 14-2002 relies heavily on previously developed standards for the laboratory measurement of temperature, pressure, airflow, liquid flow, power, etc., Also is based on previous work that have been developed on in-situ measurement techniques for various energy consuming devices, including lighting systems, pumps, blowers, thermal storage, etc.
Retrofit isolation approach can be classified according to whether the load is fixed or variable, or whether the use is constant or variable. This classification of constant or varying loads versus constant or varying uses creates four scenarios:

a) Constant load – constant use  
b) Constant load – variable use  
c) Variable load – constant use  
d) Variable load – variable use

The methodology and calculation steps for the possible situations are:

a) **Constant load – constant use**: consist of systems where the energy used by the system is constant\(^{15}\) (i.e. varies by less than 5%) and the use of the system is constant (i.e. varies also by less than 5%) through both the baseline and post-retrofit period. The savings from an ECM can be determined using:
   • One-time, end-use baseline energy use measurement and one-time, end-use post-retrofit energy use measurement: savings are calculated by comparing the difference of the one-time, end-use baseline versus post-retrofit energy use measurement times the hours of operation in the post-retrofit period
   • One-time, end-use baseline energy use measurement and continuous end-use energy use measurement: savings are calculated by comparing the difference of the one-time, end-use baseline time the hours of operation versus post-retrofit energy use measurement
   • Continuous, before-after end-use energy use measurement: savings are calculated by comparing the difference of the continuous end-use baseline versus continuous post-retrofit energy use measurement

---

\(^{15}\) This assumption of constant systems where variation is less than 5% can be applied to the four possible situations

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b) **Constant load - variable use**: consist of systems where the energy used by the system is constant but the use of the system is variable\(^\text{16}\) (i.e. varies by more than 5%) through either the baseline or post-retrofit period. In these systems savings can be determined by:

- One-time, end-use baseline energy use measurement and continuous end-use energy use measurement, calculating savings in the same way as described above
- Continuous, before-after end-use energy use measurement, calculating savings in the same way as described above

c) **Variable load - constant use**: consist of systems where the energy used by the system is variable but the use of the system is constant, through either the baseline or post-retrofit period. Savings can be determined by:

- Continuous, before-after end-use energy use measurement, calculating savings in the same way as described above
- Continuous before-after end-use energy use measurement where a statistical model is created of the baseline use and is used to forecast the baseline into the post-retrofit period. Energy use is then calculated by comparing the forecast baseline us against the actual post-retrofit end-use energy use

d) **Variable load – variable use**: consist of systems where the energy used by the system is variable, and also the use of the system. Savings from an ECM can be measured using:

- Continuous, before-after end-use energy use measurement as defined above, for those cases where the variation in the use is due to unpredictable scheduled effects

---

\(^\text{16}\) This assumption of variable systems where variation is more than 5% can be applied to the four possible situations

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Continuous before-after end-use energy use measurement where a statistical model is created of the baseline use and is issued to forecast the baseline use into the post-retrofit period. Energy can be calculated by the comparison of forecasted baseline and actual post-retrofit end use energy

The kind of retrofit isolation is characterized by the kind of load and schedule for the load before the retrofit and effect that the retrofit has on the load and schedule. The load is either constant or variable and the schedule is either a known or an unknown variable schedule. The retrofit may change the magnitude of the load and change it to a constant load from variable load or vice versa; the retrofit may also change the schedule. The next table summarizes the different possible situations that determine the required metering:

<table>
<thead>
<tr>
<th>Pre-retrofit</th>
<th>Retrofit changes</th>
<th>Required pre-retrofit metering</th>
<th>Required post-retrofit metering</th>
</tr>
</thead>
<tbody>
<tr>
<td>CL/TS</td>
<td>Load but still CL</td>
<td>One time load measurement</td>
<td>One time load measurement</td>
</tr>
<tr>
<td>CL/TS</td>
<td>Load to VL</td>
<td>One time load measurement</td>
<td>One time load measurement</td>
</tr>
<tr>
<td>CL/TS</td>
<td>Schedule but still TS</td>
<td>One time load measurement (either pre- or post-retrofit)</td>
<td>One time load measurement</td>
</tr>
<tr>
<td>CL/TS</td>
<td>Schedule to VS</td>
<td>One time load measurement (either pre- or post-retrofit)</td>
<td>Sufficient measurement of runtime</td>
</tr>
<tr>
<td>CL/TS</td>
<td>Load but still CL and schedule but still TS</td>
<td>One time load measurement</td>
<td>One time load measurement</td>
</tr>
<tr>
<td>CL/TS</td>
<td>Load to VL and schedule but still TS</td>
<td>One time load measurement</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td>CL/TS</td>
<td>Load but still CL and schedule to VS</td>
<td>One time load measurement</td>
<td>One time load measurement and sufficient measurement of runtime</td>
</tr>
<tr>
<td>CL/TS</td>
<td>Load to VL and schedule to VS</td>
<td>One time load measurement</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td>CL/VS</td>
<td>Load but still CL</td>
<td>One time load measurement and sufficient measurement of runtime</td>
<td>One time load measurement and sufficient measurement of runtime</td>
</tr>
<tr>
<td>CL/VS</td>
<td>Load to VL</td>
<td>One time load measurement and sufficient measurement of runtime</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td>CL/VS</td>
<td>Schedule to TS</td>
<td>One time load measurement (either pre- or post-retrofit) and sufficient measurement of runtime</td>
<td></td>
</tr>
<tr>
<td>CL/VS</td>
<td>Schedule but still VS</td>
<td>One time load measurement (either pre- or post-retrofit) and sufficient measurement of runtime</td>
<td>Sufficient measurement of runtime</td>
</tr>
<tr>
<td>CL/VS</td>
<td>Load but still CL and schedule to TS</td>
<td>One time load measurement and sufficient measurement of runtime</td>
<td>One time load measurement</td>
</tr>
<tr>
<td>CL/VS</td>
<td>Load to VL and schedule but</td>
<td>One time load measurement and sufficient measurement of runtime</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Characterize Load</td>
<td>Measurement</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>CL/VS</td>
<td>Load but still CL and schedule to VS</td>
<td>One time load measurement and sufficient measurement of runtime</td>
<td>Still TS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL/VS</td>
<td>Load to VL and schedule but still VS</td>
<td>One time load measurement and sufficient measurement of runtime</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Load to CL</td>
<td>Sufficient load measurements to characterize load</td>
<td>One time load measurement and sufficient measurement of runtime</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Load but still VL</td>
<td>Sufficient load measurements to characterize load</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Schedule still or to TS</td>
<td>Sufficient load measurements to characterize load</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Schedule to or still VS</td>
<td>Sufficient load measurements to characterize load</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Load to CL and schedule still or to TS</td>
<td>Sufficient load measurements to characterize load</td>
<td>One time load measurement</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Load but still VL and schedule still or to TS</td>
<td>Sufficient load measurements to characterize load</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Load to CL and schedule to or still VS</td>
<td>Sufficient load measurements to characterize load</td>
<td>One time load measurement and sufficient measurement of runtime</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL/TS or VS</td>
<td>Load but still VL and schedule to or still VS</td>
<td>Sufficient load measurements to characterize load</td>
<td>Sufficient load measurements to characterize load</td>
</tr>
</tbody>
</table>

**CL = constant load**

**TS = timed (known)schedule**

**VL = variable load**

**VS = variable (unkwonw)schedule**

**Figure 14: Combination of pre-retrofit conditions and retrofit changes for the establishment of required metering**

Furthermore this guide-table for the determination of the type of metering, ASHRAE 14-2002 also provides user additional advice for the application of retrofit isolation depending on the area of improvement (pumps, fans, chillers, boilers, lighting, etc.)

**5.3.3.4 Calibrated simulated approach**

This last option in the ASHRAE 14-2002 guideline, only applicable for whole-building measurement, involves the use of a commercially available hourly computer simulation program to create a model of energy use and demand of the facility or
installation. This model must be calibrated or checked against actual measured data like current energy use, weather data and other relevant operating data. Once the model is calibrated, it is used to predict energy use with the retrofit conditions.

Energy savings are calculated by the comparison of the modeled results under the two sets of conditions (pre-retrofit and post-retrofit), or by the comparison of modeled data against actual metered results.

The whole-building calibrated simulation approach is suitable for a set of conditions and facility situations; however, there are some cases where this measurement scheme cannot be applied. The next table summarizes the situation where the calibrated simulation is the most suitable option and also where this option cannot be applied:

<table>
<thead>
<tr>
<th>Applicable cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where baseline shifts may be encountered and where future energy impacts may</td>
</tr>
<tr>
<td>be adjusted.</td>
</tr>
<tr>
<td>2. When either pre-retrofit or post-retrofit metered data are not available,</td>
</tr>
<tr>
<td>simulation is the only option to determine these data.</td>
</tr>
<tr>
<td>3. When the initiatives interact with other building systems and the impact of</td>
</tr>
<tr>
<td>this interaction is relevant.</td>
</tr>
<tr>
<td>4. When savings from individual retrofits are needed but only whole-building</td>
</tr>
<tr>
<td>data are available.</td>
</tr>
<tr>
<td>5. When savings cannot be easily determined using before-after measurements.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-applicable cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. When evaluating measures cannot be simulated, for example buildings with</td>
</tr>
<tr>
<td>large spaces where temperature varies significantly and depends on several</td>
</tr>
</tbody>
</table>
| external factors difficult to
2. When the retrofits cannot be simulated, for example certain HVAC control changes

3. When project resources are no sufficient to support calibrated simulation: the evaluation of retrofits are so complex and expensive that exceed the budget established

The application of the whole-building calibrated simulation scheme follows a methodology establish by ASHRAE in the guideline 14-2002, which consists of 8 progressive steps:
5.3.3.5 Approach specific requirements

The three ASHRAE 14-2002 approaches constitute four compliance paths, as the whole building approach can be divided into prescriptive and performance path. So the four compliance paths can be summarized as:

1. Whole building prescriptive path.
2. Whole building performance path.
3. Retrofit isolation performance path.

Each path has its own requirements that are summarized in the next table:

<table>
<thead>
<tr>
<th>Measured data available from</th>
<th>Whole building Prescriptive</th>
<th>Whole building Performance</th>
<th>Retrofit isolation</th>
<th>Whole building calibrated simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline and post-retrofit</td>
<td>Baseline and post-retrofit</td>
<td>Baseline and post-retrofit</td>
<td>Baseline and post-retrofit</td>
<td>Baseline and/or post-retrofit. Report</td>
</tr>
</tbody>
</table>

Figure 17: Methodology for the application of ASHARE calibrated simulation option
<table>
<thead>
<tr>
<th>Energy use measurement type</th>
<th>Continuous</th>
<th>Continuous</th>
<th>Continuous</th>
<th>Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum period spanned by baseline data</td>
<td>12 months</td>
<td>Full range</td>
<td>Full range</td>
<td>12 months</td>
</tr>
<tr>
<td>Minimum number of valid data points</td>
<td>9</td>
<td>(*) 18</td>
<td>(*)</td>
<td>12</td>
</tr>
<tr>
<td>Allow elimination data?</td>
<td>No</td>
<td>Justified up to 25%</td>
<td>Justified</td>
<td></td>
</tr>
<tr>
<td>Algorithm for savings determination</td>
<td>Net determination bias &lt;0.0005%</td>
<td>Net determination bias &lt;0.0005%</td>
<td>Net determination bias &lt;0.0005%</td>
<td>Not necessary</td>
</tr>
<tr>
<td>Baseline model uncertainty</td>
<td>Variable with post-retrofit savings reporting period length: For &lt;12 month, max 20% of energy use For 12-60 month, max 25% of energy use For &gt;60 month, max 30% of energy use</td>
<td>(*)</td>
<td>(*)</td>
<td>For monthly calibration data 15% For hourly calibration data 30%</td>
</tr>
<tr>
<td>Expected savings</td>
<td>&gt;10%</td>
<td>Not defined</td>
<td>Not defined</td>
<td>Not defined</td>
</tr>
<tr>
<td>Uncertainty analysis</td>
<td>Not required</td>
<td>Required</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td>Number and type of ECM</td>
<td>&gt;1 or complex</td>
<td>&gt;1 or complex</td>
<td>1</td>
<td>&gt;1 or complex</td>
</tr>
<tr>
<td>ECM interaction with energy use of the rest of the building</td>
<td>Can be significant</td>
<td>Can be significant</td>
<td>None</td>
<td>Can be adequately simulated</td>
</tr>
<tr>
<td>Special skills of personnel</td>
<td>(*) 19</td>
<td>(*)</td>
<td>(*)</td>
<td>Simulation experience</td>
</tr>
<tr>
<td>Maximum level of uncertainty</td>
<td>Not defined</td>
<td>50% of annual reported savings at 68% confidence</td>
<td>50% of annual reported savings at 68% confidence</td>
<td>50% of annual reported savings at 68% confidence</td>
</tr>
<tr>
<td>Use of sampling</td>
<td>Not allowed</td>
<td>Multiple similar facilities, providing</td>
<td>Multiple similar system at one</td>
<td>Not allowed</td>
</tr>
</tbody>
</table>

18 Not specified
19 Not specified
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These requirements for each compliance path and consequently for each approach give the first idea about which approach can be the most suitable on each situation.

### 5.3.4 Determining the proper M&V scheme

Every project must find a balance in the trade-off between costs and uncertainty. The optimal approach results from increasing improvements in accuracy relative to the increase in measurement cost. Unlike IPMVP or other M&V guides, ASHARE 14-2002 does not provide a specific methodology for the selection of the suitable approach, however, gives some key considerations to help energy efficiency professionals in the process of selecting the best compliance path according to the project requirements. These considerations are summarized in the table below:

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Whole building</th>
<th>Retrofit isolation</th>
<th>Whole building calibrated simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to determine savings of individual ECMs</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Nature of possible future baseline adjustments</td>
<td>Minor, can be estimated adequately</td>
<td>Minor, can be estimated adequately</td>
<td>Complex to measure, but effect on ECM performance may be simple to estimate adequately</td>
</tr>
</tbody>
</table>

Figure 18: ASHRAE specific requirements for each approach

<table>
<thead>
<tr>
<th>Minimum data interval</th>
<th>Sampling error is included in savings uncertainty calculation</th>
<th>Facility, providing sampling error is included in savings uncertainty calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day (*)</td>
<td>(*)</td>
<td>(<em>) Simulation, public domain or commercially available (</em>)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modeling tool</th>
<th>Not necessary</th>
<th>Not necessary</th>
<th>Not necessary</th>
<th>Simulation, public domain or commercially available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allow estimate of post-retrofit data</td>
<td>No</td>
<td>From data spanning missing data</td>
<td>From data spanning missing data</td>
<td>From data spanning missing data</td>
</tr>
</tbody>
</table>

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Because of the trade-off between cost and uncertainty, the optimal approach for a specific project usually results from an iterative approach, where incremental improvements in accuracy are assessed relative to the increase in measurement cost.

### 5.3.5 Methodology for the application of this protocol

ASHRAE 14-2002 guidelines describe a general methodology for the implementation of an energy savings calculation project. This methodology, common for every measurement option, includes six steps:

1. **Measurement and verification plan preparation**: it must reflect the compliance path, metering schemes, analysis procedures and expected cost
of the implementation. The Measurement and Verification Plan shall document the following:

- The selected measurement approach and compliance path.
- Baseline period data
- Energy use and demands. Actual meter reading dates or times should be recorded
- All independent variables selected for use in analyses may be considered. Measurements in meters for monthly quantities should be made on the same day and for daily quantities on the same hour.
- Baseline conditions
- The methodology to be used for all sets of post-retrofit conditions and how to deal with each type of anomaly when developing the baseline model
- The procedure to apply to any measurement option, not only utility meters
- Quality control procedures
- The savings reporting frequency and format

2. **Previous energy use measurement**: analysis of the Energy consumption before the retrofits are applied (baseline determination), taking into account record factors and conditions that govern energy use.

3. **Post energy measurement**: measurement of the energy use after the retrofits application (post-retrofit period), also taking into account record factors and conditions that govern energy use.

4. **Baseline projection**: convey the baseline and post-retrofit period energy use and demand measurements to a common set of conditions. These conditions are normally those of the post-retrofit period, so only baseline period energy use and demand needs to be projected.

5. **Savings calculation**: by the subtraction of the projected post-retrofit period use from the projected baseline period use.
6. **Uncertainty determination:** this requires the determination and reporting of the level of uncertainty in the cumulative savings computed to date. ASHRAE defines that generally the level of uncertainty in reported savings should not be greater than 50% of the total savings in the post-retrofit reporting period. In case the measurement involves the whole facility, uncertainty calculations are replaced by prescribed requirements, like baseline data characteristics or other features.

<table>
<thead>
<tr>
<th>ASHRAE 14-2002 main features</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHRAE 14-2002 guideline was edited in June 2002 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)</td>
</tr>
<tr>
<td>It is designed as a complementary guide for IPMVP, providing more detail in implementing M&amp;V plans</td>
</tr>
<tr>
<td>This guide proposes three measurement options: whole building metering, retrofit isolation metering and whole building calibrated simulation</td>
</tr>
<tr>
<td>Its usage is not as extended worldwide as IPMVP, ASHRAE 14-2002 provides more detail in statistical estimations and metrology, the implementation of projects become more complex and expensive</td>
</tr>
</tbody>
</table>

### 5.4 DOE- FEMP

#### 5.4.1 Introduction

The US Department of Energy (DOE) has published its own M&V guide called Measurement and Verification for Federal Energy Projects (FEMP) providing guidelines and methods for measuring and verifying energy, water and cost savings
associated with federal Energy Savings Performance Contracts (ESPCs, also called Super Energy Savings Performance Contracts).

The DOE-FEMP guide is a handbook based on the International Performance Measurement and Verification Protocol\textsuperscript{20} (IPMVP). Its main purpose is to facilitate procedures and guidelines for quantifying the savings resulting from energy efficiency equipment, water conservation, improved operation and maintenance, renewable energy, and cogeneration projects implemented under DOE’s ESPC contract mechanisms in the US. The document is specifically intended for federal energy managers, federal procurement officers, and contractors implementing performance contracts at federal facilities\textsuperscript{21}, however, its principles, advices and procedures may be applied to other kind of energy savings projects through all geographic regions.

The federal use of ESPCs was authorized in the 1986 amendments to the National Energy Conservation Policy Act of 1978 (NECPA), which gave federal agencies the authority to enter into shared-energy-savings contracts with private-sector energy service companies (ESCOs). The Energy Policy Act of 1992 (EPACT\textsuperscript{22}) authorized federal agencies to execute guaranteed-savings ESPCs. EPACT also directed DOE to develop an ESPC regulation through a formal rule-making process. The final ESPC rule was published in 1995 and implemented the DOE ESPC regulation. The Ronald W. Reagan National Defense Authorization Act for 2005 revised the definition of energy savings in federal ESPCs to include water conservation measures, and the National Energy Independence and Security Act of 2007 extended the federal ESPC authority indefinitely.

\textsuperscript{20} The DOE-FEMP guide is based on IPMVP Volume 1: Concepts and Options for Determining Energy and Water Savings, published in April 2007

\textsuperscript{21} The FEMP guideline includes a contractual requirement for ESCOs to comply with the guide in planning and carrying out M&V activities for federal agency customers in the US

\textsuperscript{22} Further amended NECPA

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Current federal energy goals were defined in Executive Order 13423, released in January 2007, which strongly supports the use of alternative financing methods, including ESPCs, to achieve them.

Nowadays the most recent document available is version 3.0 from April 2008, which incorporates update definitions for most recent ESPCs and for savings and adjustments of IPMVP 2007. Most relevant previous publications are guideline 2.2 in September 2000 and 2.0 in 1996.

The main purpose of the FEMP is to provide guidelines and methods for M&V energy savings with federal Super Energy Savings Performance Contracts. In an ESPC, the ESCO provides the energy surveys, engineering, design, construction management, labor, equipment, and sometimes maintenance to reduce energy and water use and costs, as well as related costs such as operations and maintenance (O&M) of energy systems. In federal ESPCs, the ESCO is required to guarantee a specific level of cost savings that will be sufficient to pay for the improvements over the term of the contract. Savings must exceed payments in every year of the contract. The federal ESPC authority requires the contractor to undertake measurement and verification (M&V) activities and provide documentation to demonstrate that the guarantee has been met.

As the measurement options in the FEMP guide are the same as IPMVP, the measurement and verification principles applicable are those described in section 5.2.1.2 and summarized below:
5.4.2 Savings calculation

Facility energy savings cannot be measured, since they represent the absence of energy use. Instead, savings are determined by comparing the energy use before and after the installation of conservation measures, making appropriate adjustments for changes in conditions.

FEMP uses the same definitions in IPMVP for the pre-measured energy (baseline) and the post installation measured energy (performance period). Proper determination of savings includes adjusting for changes that affect energy use, but that are not caused by the conservation measures (interactive effects). Such adjustments may account for changes in weather, occupancy, or other factors between the baseline and performance periods. Taking into account these adjustments, the general saving equation can be written as:
savings = (BE − PIE) ± adjustments

Where:

- **BE** is the Baseline Energy, that is the initial energy consumption
- **PIE** is the Post Installation Energy that is the energy consumption after ECM
- **The adjustments** are the changes made to the baseline and/or the performance period energy use to account for changes

Baseline and performance period energy use can be determined by using the methods associated with several different M&V approaches classified by the types of measurements performed. FEMP M&V guide define four measurement options, adopted from the IPMVP, using the same terminology:

- Option A: Retrofit Isolation with Key Parameter Measurement
- Option B: Retrofit Isolation with All Parameter Measurement
- Option C: Whole Building
- Option D: Calibrated Simulation

### 5.4.3 Measurement schemes

#### 5.4.3.1 General overview

As it was stated before, the FEMP Guidelines are an application of the IPMVP, so FEMP measurement options are the same IPMVP Options: A, B, C, and D. The options are generic M&V approaches for energy and water saving projects.

FEMP emphasizes that M&V approaches can be divided into two general types: retrofit isolation (Options A&B) and whole-facility (Options C&D).

- Retrofit isolation methods look only at the affected equipment or system independent of the rest of the facility
- Whole-facility methods consider the total energy use not focusing on specific equipment performance
The main aspect that differences these two general types of measurement scheme is where the boundary of the energy conservation measure (ECM) is drawn:

![Diagram showing options A, B and C, D for FEMP measurement options](image)

**Figure 22: General overview of FEMP measurement options**
Source: DOE-FEMP

### 5.4.3.2 Measurement options

As the measurement options for FEMP are the IPMVP options, explained in previous chapters, in this section only a brief description of each option will be given:

- **Option A: Retrofit isolation with key parameter measurement.** Based on a combination of measured and estimated factors when variations in them are not expected. Measurements are spot or short-term, and are taken at the component or system level, both in the baseline and post-installation cases. Measurements should include the key performance parameters which define the energy use of the ECM. Estimated factors are supported by historical or manufacturer’s data. Savings are determined by means of engineering calculations of baseline and post-installation energy use based on measured and estimated values. Adjustments to models are not typically required.

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23 For complete description of IPMPV options A, B, C and D see chapter 5.2.3

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- **Option B: Retrofit isolation with all parameter measurement.** This option is based on periodic or continuous measurements of energy use taken at the component or system level when variations in factors are expected. Energy or proxies of energy use are measured continuously. Periodic spot or short-term measurements may suffice when variations in factors are not expected. Savings are determined from analysis of baseline and reporting period energy use or proxies of energy use. Adjustments to models may be required.

- **Option C: utility data analysis.** This option is based on long-term, continuous, whole-building utility meter, facility level, or sub-meter energy data. Savings are determined from analysis of baseline and reporting period energy data. Typically, regression analysis is conducted to correlate with and adjust energy use to independent variables such as weather, but simple comparisons may also be used. Adjustments to models are typically required.

- **Option D: Calibrated computer simulation.** Computer simulation software is used to model energy performance of a whole-facility or sub-facility. Models must be calibrated with actual hourly or monthly billing data from the facility. Implementation of simulation modeling requires engineering expertise. Inputs to the model include facility characteristics; performance specifications of new and existing equipment or systems; engineering estimates, spot-term, short-term, or long-term measurements of system components; and long-term whole-building utility meter data. After the model has been calibrated, savings are determined by comparing a simulation of the baseline with either a simulation of the performance period or actual utility data. Adjustments to models are always required.

### 5.4.3.3 Best option applications

As the measurement options described in the FEMP guides are the same as IPMVP, the best option applications are consequently the same described in section 5.2.3.6.
5.4.4 Determining the proper M&V scheme

Since the primary purpose of M&V is to validate payments or performance guarantees, FEMP guidelines establishes that the cost of M&V should be less than the payment amount or guarantee that is at risk. Consequently, the objective of M&V should not necessarily be to derive a precise energy savings number, but rather to ensure that energy services companies (ESCOs) properly complete their projects and that the resulting energy savings are reasonably close to the savings claimed.

FEMP guidelines list a series of key issues that must be taking into account when selecting the appropriate M&V approach:

- **Value of the ECM in terms of projected savings and project costs**: the M&V effort should be scaled to the value of the project so that the accuracy of the information provided by the M&V activity is appropriate to the value of the ECM and the project itself.

- **Complexity of ECM or system**: in general, the complexity of isolating the savings is the critical factor. When defining the appropriate M&V requirements for a given project, it is helpful to evaluate the complexity of ECMs in terms constant versus variable key parameters like load, operating hours, pattern, etc.

- **Number of interrelated ECMs at a single facility**: when multiple ECMs are being installed at a single site, the savings from each measure may have an influence on the savings resulting from other measures or other non-ECM activities at the facility. This may make whole-building approach the most suitable option.

- **Risk of achieving savings**: the importance of the M&V activities is often tied to the confidence associated with the estimated energy or cost savings. A simple method of estimating payment risk can be based on the estimated project value, technical uncertainty, and project sponsor experience.
Responsibility allocation between the ESCO and the federal agency: as stated before, at least, the ESCO and the federal agency must verify yearly that the installed equipment or systems have been properly maintained, continue to operate correctly, and continue to have the potential to generate the predicted savings.

Considering this five key issues, FEMP guideline proposes its own rule-of-thumb for the determination of the most appropriate IPMVP approach for an application:

<table>
<thead>
<tr>
<th>Conditions and situation</th>
<th>Suitable option</th>
</tr>
</thead>
<tbody>
<tr>
<td>- When the most critical M&amp;V issue is identifying the potential to generate savings</td>
<td>Option A</td>
</tr>
<tr>
<td>- When the magnitude of savings is low for the entire project or a portion of the project to which Option A can be applied</td>
<td></td>
</tr>
<tr>
<td>- When the risk of not achieving savings is low or ESCO payments do not need to be directly tied to actual savings</td>
<td></td>
</tr>
<tr>
<td>- For simple equipment replacement projects with energy savings that are less than 20% of total facility energy use, as recorded by the relevant utility meter or sub-meter</td>
<td>Option B</td>
</tr>
<tr>
<td>- When energy savings values per individual measure are desired</td>
<td></td>
</tr>
<tr>
<td>- When interactive effects are to be ignored or are calculated using estimating methods that do not involve long-term measurements</td>
<td></td>
</tr>
<tr>
<td>- When the independent variables that affect energy use are not complex and excessively difficult or expensive to monitor</td>
<td></td>
</tr>
<tr>
<td>- When sub-meters already exist that record the energy use of subsystems under consideration (e.g., a 277 V lighting circuit, a separate sub-meter for HVAC systems)</td>
<td></td>
</tr>
<tr>
<td>- For complex equipment replacement and controls projects</td>
<td>Option C</td>
</tr>
<tr>
<td>- When predicted savings are larger than about 10% to 20% of the overall consumption measured by the utility or sub-meter</td>
<td></td>
</tr>
<tr>
<td>- When energy savings values per individual measure are not desired</td>
<td></td>
</tr>
<tr>
<td>- When interactive effects are to be included</td>
<td></td>
</tr>
<tr>
<td>- When the independent variables that affect energy use are complex and excessively difficult or expensive to monitor</td>
<td></td>
</tr>
<tr>
<td>- When new construction projects are involved</td>
<td>Option D</td>
</tr>
<tr>
<td>- When energy savings values per measure are desired</td>
<td></td>
</tr>
<tr>
<td>- When Option C tools cannot cost-effectively evaluate particular measures or their interactions with the building when complex baseline adjustments are anticipated</td>
<td></td>
</tr>
</tbody>
</table>

Figure 23: Conditions and situations for the application of the best FEMP measurement option
Apart from these tips for the best option determination, FEMP guideline includes its own M&V planning tool to assist in the development of custom M&V approaches for individual projects:

![Figure 24: FEMP M&V planning tool](image)

The application of this iterative process assures with certain guarantee that the M&V plan meets the requirements in terms of proper M&V option selected, risk level and estimated costs.

### 5.4.5 Methodology for the application of this protocol

In general, determining actual savings achieved can be difficult and costly. In many performance contracts, it is more important to verify the potential of the ECM to generate the predicted savings. Verifying this potential requires confirming the accuracy in the baseline definition and the proper performance of the installed equipment. Regardless to the M&V applied, FEMP establishes a common methodology for the savings determinations, structured on six steps:

1. List ECM and project objectives and constrains
2. Evaluate Project and ECM level Objectives & Constraints to identify candidate M&V options
3. Evaluate savings risk for the M&V option
4. Estimate cost for the M&V option. Is acceptable?
5. Write M&V Plan.
6. If all the M&V requirements are met and the savings risk justify the M&V expenses, proceed with the development of the M&V plan for the project
**Step 1: Allocate Project Responsibilities.** The basis of any project-specific M&V Plan is determined by the allocation of key project responsibilities between the ESCO and the federal agency involved. On an ESPC project, a number of typical financial, operational, and performance issues must be considered when allocating risks and responsibilities. The distribution of responsibilities will depend on the agency’s resources and preferences, and the ESCO’s ability to control certain factors. For example ESCOs often have no control over savings fluctuate depending on weather, the number of hours in which equipment is used, user intervention, and equipment loads.

**Step 2: Develop a Project-Specific M&V Plan.** The plan defines how savings will be calculated and specifies any ongoing activities that will occur during the contract term. The measurement option should be selected prior to the start of the Investment Grade Audit (IGA)\(^{24}\), considering that this choice will determine to a large extent what activities will be conducted during the audit, and therefore the cost of the project.

**Step 3: Define the baseline.** As part of the Investment Grade Audit, the ESCO must define the baseline energy consumption, either through surveys,

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\(^{24}\) *Investment Grade Audit (IGA)*: FEMP M&V guide defines this audit as a comprehensive assessment of a facility’s energy and water usage characteristics, identifying and analyzing energy conservation measures.
inspections, spot measurements, short-term metering activities or utility bills. The baseline has to be defined suitably; once the ECM is implemented it is not possible to change the baseline conditions since they no longer exist.

- **Step 4: Install and Commission Equipment and Systems.** Commissioning ensures that systems are designed, installed and functionally tested in all modes of operation, and are capable of being operated and maintained in conformity with the design intent (appropriate lighting levels, cooling capacity, comfortable temperatures, etc.). Commissioning activities include inspections and functional testing. Normally they are completed by the ESCO and witnessed by the agency, however, in some cases may be contracted out to a third party.

- **Step 5: Conduct Post-Installation Verification Activities.** Post-installation M&V activities are conducted by both the ESCO and the federal agency to ensure that proper equipment/systems were installed, are operating correctly, and have the potential to generate the predicted savings. Verification methods include surveys, inspections, spot measurements, and short-term metering. The post-installation report must include project description, a detailed list of installed equipment and changes between the final proposal and as-built conditions, and documentation of all post-installation verification activities, performance verification, construction-period savings and expected savings for the first year.

- **Step 6: Perform Regular-Interval Verification Activities.** FEMP guideline establishes that at least once a year, the ESCO and the federal agency must audit the project. This includes, at a minimum, verifying that the installed equipment/systems have been properly maintained, continue to operate correctly, and continue to have the potential to generate the predicted savings. The ESCO must report the annual M&V activities and guarantee savings for the year, including the comparison of verified savings with the guaranteed amounts, details of all analysis and savings calculation, summary of operations and maintenance activities conducted and details of any
performance or issue that might require attention. Although the report is only obligatory annually, in many cases more frequent verification activities are appropriate depending on the type and features of the project.

<table>
<thead>
<tr>
<th>FEMP guide main features</th>
</tr>
</thead>
<tbody>
<tr>
<td>The US Department of Energy (DOE) publishes this guide, last version available is April 2008</td>
</tr>
<tr>
<td>DOE-FEMP guide is based on the IPMVP and is specially intended to carry out Measurement and Verification for Federal Energy Projects</td>
</tr>
<tr>
<td>Its measurement options are the same than in IPMVP (Options A, B, C and D)</td>
</tr>
<tr>
<td>This guide is specifically designed for governmental projects in the US so its use is not extended worldwide as the IPMVP</td>
</tr>
</tbody>
</table>

### 5.5 ESMG: Energy Savings Measurement Guide

#### 5.5.1 Introduction

The Department of Resources, Energy and Tourism of the Australian Government published in 2008 the Energy Savings Measurement Guide (ESMG), a best practices guide aimed to assist companies in the estimation, measurement, evaluation and tracking energy savings, quantifiable costs and benefits created as a result of implementing energy efficiency opportunities.

The guide was published within the Energy Efficiency Opportunities Program, administered by the Australian Government Department of Resources, Energy and Tourism and sits under the National Framework for Energy Efficiency. This program
encourages Australian companies that use more than 138.889 MWh of energy per annum to improve their energy efficiency.

The ESMG is conceived as the key document helping these companies to meet the key assessments and reporting requirements of the Energy Efficiency Opportunities Program by assisting to accurately estimate and measure energy savings to enable accurate reporting of energy efficiency opportunities with a payback of four years or less. Nevertheless, the ESMG is suitable to be applied in companies and organizations worldwide, helping business in the development and implementation of energy efficiency initiatives, and therefore, in the calculation of energy savings.

This guideline was first published in 2008 in its version 1.0. Previously, the Australian Government published in 2006 the Energy efficiency Opportunities Act 2006 and the Energy Efficiency Opportunities Regulations and Energy Efficiency Opportunities Industry Guidelines. These two documents are complementary to the ESMG.

The main intention of the Energy Savings Measurement Guide is to assist companies to estimate, measure, evaluate and track energy savings, quantifiable costs and benefits created as a result of implementing energy efficiency opportunities. The ESMG aims to help companies to:

a) Improve their understanding of how to forecast and measure energy savings.
b) Realize energy savings by accurately quantifying the whole of business costs, benefits and payback of energy efficiency opportunities.
c) Determine the economic value of an energy efficiency opportunity so that investment quality information is provided to company decision makers.
d) Quantify the accuracy range for each stage of the energy savings analysis.

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25 Equivalent to 500.000 Giga Joules (GJ)

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The ESMG gives a practical overview of the implementation of energy efficiency projects. Besides, contains some examples of ECM application industry sectors like mineral processing, manufacturing, commercial buildings and transport.

The guide is structured in sections that can be read and applied as a whole or in specific parts, depending on the characteristics or objectives of the project. The ESMG contains these five sections that are also the key steps proposed for the development of the complete M&V plan:

1. **Develop** an energy baseline.
2. **Estimate** the energy savings from a potential energy efficiency opportunity.
3. **Evaluate** the full costs and benefits for each energy efficiency opportunity.
4. **Measure** energy use and energy savings.
5. **Track** the progress and performance of implement opportunities.

ESMG classifies energy savings in terms of energy efficiency opportunities, which can be characterized on three different types:

- **People-based energy savings:** it consists on changing human practices. Energy savings opportunities from this category typically require acute awareness of the energy usage profile, which is a benefit obtained from having high resolution metering data.

- **Process-based energy savings:** are those that can be achieved by changes to operational practices, for example, by altering power usage and temperature settings of a particular process. Process-based savings also generally cost little to implement and there is usually small or no capital expenditure.

- **Investment-Based Energy Savings:** may involve significant capital costs. However, the capital improvements often have a higher degree of persistence than people-based or process-based savings which can be lost through changes in behavior, procedures or working team.
5.5.2 Savings calculation

General savings formula in ESMG establishes energy savings as the difference between the energy consumption that would have been measured if an opportunity had not been implemented (also call in this guide as the “Business-As-Usual” or BAU case), and the actual consumption measured post implementation:

\[ \text{savings} = \text{energy use before implementation} - \text{energy use after implementation} \]

Furthermore, it is necessary to take into account the necessary adjustments in the energy consumption caused by other factors such as weather, occupancy and production levels. Calculated energy savings can then be reconciled against the expected savings to determine the success of the project.

General process for the determination of energy savings described in ESMG covers these four steps:

1. Select a measurement methodology
2. Collect the actual measurement and non-energy data for the pre and post implementation period
3. Calculate the energy savings as per the measurement methodology
4. Report on the savings outcomes for the performance period

5.5.3 Measurement schemes

5.5.3.1 General overview

ESMG defines four measurement options for the verification of the actual savings derived from implemented opportunities:

- Option 1: Partially measured isolated project
- Option 2: Fully measured isolated project
- Option 3: Whole facility
- Option 4: Calibrated simulation
These four schemes, designed to cover all possible situations, are really close to the IPMVP measurement options (A, B, C & D).

Methods 1 and 2 examine only the equipment or system affected by a specific energy opportunity. Savings are determined for each opportunity individually as the measurement boundary is around the equipment or system associated with the saving opportunity.

Method 3 considers total energy use for the whole facility where savings are determined and not for each individual saving opportunity. Method 4 can be used at facility, site, process or sub-process level. Methods 3 and 4 are used when it is not practical or feasible to isolate the effects for each ECM usually due to interactions between them.

5.5.3.2 Option 1. Partially measured isolated opportunity

In this method, energy use is measured by engineering calculations using short term or continuous post-implementation measurements, plus the estimation of the other factors determining energy use. This method is best used when the key drivers responsible for energy savings suppose changes in performance (i.e. efficiency, capacity, usage demand, etc.). It is aimed to projects in which the potential to generate savings must be verified, but actual savings can be determined from short term data collection, engineering calculations and stipulated factors (utility bills, meter readings, etc.).

The use of assumptions is typically the least accurate method and contributes the greatest uncertainty to the savings estimate; however assumed factors are usually easier and less expensive to estimate.

Generally, the accuracy of this option is inversely proportional to the complexity of the energy project, so greater certainty can be obtained for relatively simple projects. Where greater accuracy is required, the other methods outlined below should be also considered. The decision of what parameters to measure and which to stipulate
should take into account the significance of the stipulations on the overall reported savings. Using stipulations is especially appropriate when:

- The energy opportunity contributes a small percentage to the overall project savings
- The site or contractor has extensive experience with the implementation of similar opportunities
- Cost of measurement is not justified by the value of the reduced accuracy, or cannot be justified for other uses

### 5.5.3.3 Option 2. Fully measured isolated project

There is a great similarity between this method and the previously described partially measured isolated opportunity. The only difference is that with this approach, no stipulations are made, only uses engineering calculations by short-term or continuous measurements. So, it is intended for saving opportunities where performance and operational factors can be measured, being possible to use short term metering data where variations in operations are not expected. However, continuous measurement can provide long term data on energy performance, which can be used for ongoing monitoring, management and identification of further energy efficiency opportunities.

It is also possible to use measurement data from a sample of the total population when this sample is considered representative.

ESMG recommends using this method in the next situations:

- For simple equipment replacement projects with savings less than 20% of the total facility energy use
- When energy savings per individual energy efficiency opportunity are required
- Where variables that affect energy use are not complex or difficult to monitor
- When sub-meters already exist to record energy use as per the defined boundary of the opportunity
Where interactions between multiple identified opportunities can be ignored

5.5.3.4 Option 3. Whole facility

This method is based on the analysis of whole facility or building metered or sub metered energy use, available continuously, using techniques such as regression analysis for post-implementation baseline adjustments. The baseline model is developed for the base year period by performing a multivariate regression analysis of the base year energy use and selected energy influencing variables. The values of the regression variables in the post implementation period are used to estimate the post-implementation energy consumption that would have occurred if no energy efficiency opportunities had been implemented (predicted consumption). The energy savings are calculated as the difference between the actual consumption and the predicted consumption.

This method is intended for projects where direct savings are expected to be much larger than savings caused by unexplained variation in energy consumption (typically where savings are expected to be greater than twice the standard error of the baseline energy consumption). In some cases there may be a need to make a non-routine adjustment to either the predicted energy consumption or the actual measured consumption.

5.5.3.5 Option 4. Calibrated simulation

The last option proposed by ESMG is the use of simulation software to predict facility energy consumption for the baseline year. This simulation can be used to assess the performance of the whole building or of an individual piece of equipment or sub system within a facility. It is intended for use where no base year data exists, typically for new installations where energy efficiency opportunities are incorporated into the new design or in the situation where sub-metering does not exist until the opportunity is implemented.
Other cases where simulation should also be used is where the impact of non-energy factors cannot be quantified with sufficient accuracy, or where the expected savings are not large enough to be separated from unexplained variation in the utility meter data.

This option is not used often as calibrated simulations are complex to produce and require the expertise of energy simulation specialists.

5.5.4 Determining the proper M&V scheme

As the ESMG options are closely related with the IPMVP options, the IPMVP key factors for the selection of the suitable measurement option can be also applied for the ESMG:

<table>
<thead>
<tr>
<th>Factors in selecting measurement methodology</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need to assess ECMs individually</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Need to assess only total facility performance</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Expected savings less than 10% of utility meter</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Multiple ECMs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Significance of some energy driving variables is unclear</td>
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<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Interactive effects of ECM are significant or un-measurable</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Many future changes expected within measurement boundary</td>
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</tr>
<tr>
<td>Long term performance assessment needed</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Baseline data not available</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Non-technical persons must understand reports</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Metering skill available</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
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</tbody>
</table>
5.5.5 Methodology for the application of this protocol

The general methodology for the development of an energy efficiency project under the Energy Savings Measurement Guide covers all steps from the establishment of the energy balance to the energy performance monitorization. Briefly, the ESMG methodology can be represented as:
Each section of the ESMG covers with strong detail level each step of the methodology, giving the necessary definitions and methods for the application of every concept.

1. **Establishing your energy baseline**

The energy baseline, understood as the current level of energy consumption of a process, needs to be well understood as future energy savings will be referenced to this starting point. The majority of energy savings cannot be measured directly, but
are calculated from a comparison of the baseline (historical) energy consumption with the post ECM implementation energy consumption. To accurately report energy savings, the baseline energy consumption needs to be based on reliable data that has been analyzed appropriately. Mainly, this can be determined using three different techniques:

- **Regression Analysis**: determination of independent variables affecting energy consumption form historical energy data using statistical methods
- **Modeling / Simulation**: determination of energy consumption pattern using known variables, manufacturer’s data and engineering calculations
- **Short Term Metering**: spot or short term metering of process and sub-processes to determine energy use patterns

2. **Completing an energy mass balance**

An Energy Mass Balance (EMB) is an analysis of the energy and mass flows in a business or system. Mass and energy flows are co-related, EMB can be two types:

   a) **Differential balance**: taken at a specific instant in time. It is generally applied to a continuous process, and generally constant

   b) **Integral balance**: taken at two specific instants in time. It describes what has happened over the time period between the two points. An integral balance is generally applied to the beginning and the end of a batch process. It can be applied to discrete or continuous processes where an average value is admitted

3. **Measuring, metering and capturing energy data**

A strategy for obtaining accurate energy data by utilizing and improving existing metering and data capture systems is needed to sustain the estimation, evaluation, measurement and tracking of energy efficiency opportunities. Accurate energy data

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will provide business decision makers with investment quality information on energy use to permit informed decision making on energy efficiency opportunities and enable ongoing and accurate public reporting of energy use and energy savings.

Developing a measurement system under the principles of ESMG involves eight steps:

1. Define each process and its boundaries
2. Collect all relevant and available data
3. Establish the extent of current data capture capability
4. Determine the critical metering locations and data capture frequency
5. Plan metering and measurement
6. Built capability to manage and store energy data
7. Regulate the quality of energy data
8. Review and revisit metering methodology

Furthermore the steps for the development of the measurement system, ESMG also gives advice on metering hardware, data capture frequencies, and communication of metering data for typical projects.

4. **Estimating the energy savings from an opportunity**

Estimating the potential energy savings of an opportunity involves forecasting or projecting the future energy consumption of a system, process or sub-process relative to baseline energy use. The accuracy of the estimated energy savings is highly dependent upon the accuracy of the baseline energy use and the accuracy of data used to forecast future energy consumption.

ESMG considers three types on energy savings, in terms of the origin of the energy efficiency opportunity:

- People based energy savings: best practices, new habits
- Process based energy savings: changing key parameters on a process (power usage, temperature, etc)
• Investment-based energy savings: investing money on new solutions

The long range impact of energy savings must be estimated and forecasted. The boundaries that define the energy saving opportunity will determine whether the energy baseline and savings are measured at equipment, process, plant or site level. To achieve meaningful energy savings projections, ESMG provides several different methodologies aimed to forecast energy savings:

1. Calculated savings: engineering calculations (estimated from baseline)
2. Pilot scheme: example of the equipment being considered
3. Modeling simulation: extension of baseline energy consumption model
4. Bench test using a small scale facility
5. Replication of savings opportunity: extrapolate from another site which has implemented the energy efficiency opportunity
6. Supplier promoted opportunities: work with suppliers and/or experienced installers

5. Accuracy in energy savings analysis

ESMG establishes the level of accuracy in energy savings measurement in ±30% of the derivation of the payback. This means that the sum of all costs divided by the sum of all benefits used to calculate the payback requires a combined accuracy in the range of ±30%. Larger energy efficiency opportunities which require significant capital investment would need a higher degree of accuracy ±10%.

All estimations and measurements have a level of uncertainty associated with them. Increasing the accuracy of estimated and measured energy flows usually increases the cost of the measurements. To be useful, the uncertainty of the analysis needs to be reasonable in relation to the level of the proposed investment, taking into account some critical aspects:
Defining uncertainty: expected savings must be expressed in conjunction with their confidence and precision levels. Confidence level is the probability that the savings will fall within the precision range.

Accuracy in modeling: one of the methods for determining your energy baseline and estimating and measuring energy savings is modeling the energy system. This can take the form of a statistical regression analysis, computer process simulations or any other method that uses theoretical calculations to establish relationships between independent variables and energy consumption.

Accuracy in sampling: sampling techniques are used to estimate the properties of a population, for example the mean energy use, by analyzing a sample of that population.

Accuracy in measurement: as with other forms of measurement, metering accuracy must be stated in terms of precision and confidence level. Most manufacturers quote accuracy for their meters, and for those that do not include a confidence level, it is likely to be 95%.

6. Evaluating an energy efficiency opportunity

The application of an energy efficiency initiative produces savings in energy that are translated into economical savings. The financial analysis of a potential energy efficiency opportunity involves determining its payback period. This evaluation must include whole of business costs and benefits.

ESMG determines the financial payback period by dividing the projects costs by project benefits:

- Project costs are evaluated in the financial analysis and include all costs associated with implementation of the opportunity, such as capital costs and loss of production.
Project benefits include the annual energy savings which are determined using the energy savings forecast methods, and converting these energy savings into monetary savings using accepted energy prices. It also includes determining the other whole of business benefits flowing from the project.

7. **Measuring and tracking your implemented opportunities**

Once an energy efficiency opportunity has been implemented, it is necessary to measure the resultant energy savings to determine the success of the opportunity. For this purpose, the ESMG uses four generic approaches:

1. Partially measured, isolated project: engineering calculations using short term or continuous post-implementation measurements, plus estimates of the other factors determining energy use
2. Fully measured, isolated project: engineering calculations using short-term or continuous measurements
3. Baseline measurement–whole of facility/multiple project measurement: analysis of whole facility or building metered energy use, or sub meter data, available continuously, using techniques such as regression analysis for post-implementation baseline adjustments
4. Modeling: adjusted base-year energy use and demand are generated by a simulation model

As was stated in previous sections, the four ESMG approaches are close related with the four IPMVP measurement options.

8. **Energy monitoring and reporting**

The implementation of energy projects involves the engagement of different types of energy saving opportunities, including investment based energy saving initiatives which typically have permanent, built-in energy savings. Other initiatives, such as people and process based opportunities, rely on the constant monitoring to maintain

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performance, and the application of new procedures, technology and innovative thinking to achieve energy savings. To ensure that this occurs, there is a need to monitor performance and report progress on a regular and ongoing basis.

ESMG defines four key principles for successful energy monitoring:

1. Monitoring actual performance versus expected performance
2. Monitoring energy efficiency using Key Performance Indicators
3. Developing energy goals using Key Performance Indicators
4. Detecting exceptions, trends and anomalies in performance

Through the process of evaluating and measuring energy savings for energy efficiency opportunities it is possible to have in place measurement and data collection systems that will provide the information necessary for continuous energy status reporting.

---

**ESMG main features**

<table>
<thead>
<tr>
<th>The Energy Savings Measurement Guide (ESMG) was published in 2008 by The Department of Resources, Energy and Tourism of the Australian Government</th>
</tr>
</thead>
<tbody>
<tr>
<td>This guide is the only one without strong similarities with the IPMVP and other guides</td>
</tr>
<tr>
<td>It defines four measurement options (option 1: partially measured isolated project, option 2: fully measured isolated project, option 3: whole facility, option 4: calibrated simulation)</td>
</tr>
<tr>
<td>It is specifically designed for Australian governmental projects, so its level of usage in Europe is lower compared with the other guides</td>
</tr>
</tbody>
</table>
5.6 Common concepts and methodologies for these standards: comparison between international M&V protocols

After revising the most common international measurement and verification protocols, it can be appreciated the great similarities among all of them. To some degree, all protocols have IPMVP as a common ancestor, thus, they all share the same approach to energy savings determination, differing in the scope of application or being more developed from the mathematical and engineering aspects of the work. Both ASHRAE 14-2002 and FEMP guide are clearly based on IPMVP; on the other hand ESMG does not emphasize the strong similarities with IPMVP but proposes four measurement schemes really close to the IPMVP measurement options.

The next table summarizes the main characteristics of this four M&V guides:

<table>
<thead>
<tr>
<th>Protocol/guide</th>
<th>Organization</th>
<th>Last release date</th>
<th>Measurement options</th>
<th>Usage level in Europe</th>
<th>Comments</th>
</tr>
</thead>
</table>
• Option B. Retrofit isolation. All parameter measurement  
• Option C. Whole facility  
• Option D. Calibrated simulation | High | Is the most extended protocol, other protocols are based on IPMVP |
| ASHRAE 14-2002 | American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) | June 2002 | • Whole building approach  
• Retrofit isolation approach  
• Calibrated simulated approach | Medium | Develops with more detail the statistical estimations and metrology |
| FEMP - Federal Energy Management Program | US Department of Energy | Version 3.0 April 2008 | Same IPMVP options | Medium | Recommend by DOE for the implementation of energy efficiency in federal buildings projets under ESPC |
• Option 2. Retrofit isolation with all parameter measurement  
• Option 3. utility data analysis  
• Option 4. Calibrated computer simulation | Low | Main focus on the evaluation of energy efficiency opportunities, more detailed development of IPMVP methodology |

**Figure 28: General comparison among different M&V guides**

In this section, a comparative analysis of these protocols will be conducted; comparing individually each one of the protocols with IPMVP, identifying the
differences and similarities among them and highlighting the specific features of each one that makes it different respect others.

5.6.1 Individual comparison with IPMVP

Before entering to the comparison of specific features of each M&V guide, it is interesting to make an overall comparison of each one of the protocols with IPMVP, taking into account that this one is the common ancestor for all the others.

5.6.1.1 IPMVP vs. ASHRAE 14-2002

When analyzing the ASHRAE 14-2002, an obvious difference comes at first sight, there are three measurement options instead of four having condensed options A and B of the IPMVP into one, although the possibility of a partial measurement, remains.

Where ASHRAE 14-2002 stands apart is in its thoroughness and level of detail when analyzing the different metrological and statistical aspects of M&V Planning. Thus it is closer to an engineering handbook than to a conventional guide, although the principles that guide it are underlying in the IPMVP, and, in most cases, the application of both protocols by different engineers will throw the same results.

5.6.1.2 IPMVP vs. FEMP

The FEMP can be considered as a development of IPMVP for the Federal Super ESPC projects, detailing very clearly all the steps and procedures to develop and apply the M&V Plan.

This approach is necessary in Federal Projects, where the Building Manager often does not have a technical background, nor has the resources to develop the project; thus, an easy to apply, standardized method of contracting is necessary, as well as a guarantee of transparency.
5.6.1.3 IPMVP vs. ESMG

The ESMG, as stated before in this document, is a development of IPMVP with focus in estimating energy savings before the actual application of the measures.

There are no methodological differences of note in both protocols regarding how to determine the actual savings.

5.6.2 Guides purpose and first publication date

IPMVP was the first M&V guideline published. In 1994 were settled the first basis in international consensus on methods to determine energy/water efficiency savings in energy efficiency projects. This initiative pulled together energy efficiency experts from North America in the beginning and later from all over the world, that ended in the publication of the first edition of IPMVP in 1996. After that, other energy departments and organizations began to develop their own M&V guides based on IPMVP, as ASHRAE 14-2002, FEMP M&V guide and recently ESMG.

The general purpose of these guides is to help ESCOS, energy & facility managers, business or even consumers, in the development of energy efficiency projects, providing guidelines, tips and advices on measuring and verification of the energy savings achieved by the application of energy conservation measures.

As IPMVP has been developed by the Efficiency Valuation Organization, its main purpose is to help in the implementation of energy efficiency projects for any kind of facility, organization, company or institutions. Its principles and measurement options can be applied to every kind of project. ASHRAE 14-2002 takes the main concepts of IPMVP providing more detail on implementing M&V plans, and is also applicable to every kind of project or final customer.

Different situation is the one of FEMP M&V guide and ESMG, as these guides were especially design for a specific kind of projects. FEMP M&V is an adaptation of IPMVP for the implementation of energy efficiency projects in US Federal Buildings.
under the Federal Energy Management Program, focusing in the agreements reached in the Energy Savings Performance Contract signed between the ESCO and the facility. ESMG have been recently published by the Department of Resources, Energy and Tourism of the Australian Government in order to help Australian companies to meet the key assessments and reporting requirements of the Energy Efficiency Opportunities Program, by assisting to accurately estimate and measure energy savings in order to enable accurate reporting of energy efficiency opportunities with a payback of four years or less.

<table>
<thead>
<tr>
<th>Protocol/guide</th>
<th>Organization</th>
<th>Main purpose and applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPMVP</td>
<td>Efficiency Valuation Organization (EVO)</td>
<td>Help in the implementation of energy efficiency projects for any kind of facility, organization, company or institutions</td>
</tr>
<tr>
<td>ASHRAE 14-2002</td>
<td>American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)</td>
<td>Complement IPMVP work providing detail on implementing M&amp;V plans for the project</td>
</tr>
<tr>
<td>ESMG</td>
<td>Department of Resources, Energy and Tourism of the Australian Government</td>
<td>Help Australian companies to meet the key assessments and reporting requirements of the Energy Efficiency Opportunities program</td>
</tr>
</tbody>
</table>

Figure 29: Purpose of M&V guides

5.6.3 Usage level

The worldwide usage level of each M&V guide is closely related with the purpose the guide was created for. As it seems logical, IPMVP is the guide preferred by most of the professionals, since offers a global and complete solution to tackle different situations that can appear while developing an energy efficiency project.

Nowadays, use of IPMVP has become a standard in almost all energy efficiency projects where payments to the contractors are based on the energy savings that will result from the implementation of a variety of ECMs. The International Measurement and Verification Protocol is the leading international standard in M&V for energy efficiency projects. Originally created for the US market, currently is available in English, French, Spanish, Portuguese and Polish, and it is getting an important
penetration in Europe through its adoption in countries like Belgium, France and Spain. Major players in the European energy market, like EDF, EUBAC and Gas Natural-Union Fenosa are now supporting strongly EVO in its mission to promote the use of IPMVP. Its M&V flexible framework has proven successful in all types of programs and projects and its use has grown as a consequence. Since the first drafts of this protocol, more than 300 professionals from 100 U.S. and international organizations have contributed voluntarily to update and continuously revise IPMVP.

On the other side, the usage of ASHRAE 14-2002 is not as extended worldwide as IPMVP. ASHRAE 14-2002 provides more detail in statistical estimations and metrology, the implementation of projects following this guide normally acquires more complexity. It implies that the accuracy in the measures increases, but also might increment the project costs. Origins of ASHRAE 14-2002 are also the US market, but its international spread have not been as huge as IPMVP. One of the causes is that ASHRAE guideline is not a free resource and it is necessary to purchase the guideline from its website.

FEMP M&V guide and ESMG are documents designed specifically for governmental projects, thus, normally the application of these guides is subject to the success and application of these projects. Although these guides are applicable for every type of project apart from these described, generally for normal projects IPMVP and ASHRAE 14-2002 are the most common protocols applied.

5.6.4 Measurement options

Every M&V proposes its own measurement options, aimed to cover all possible situations when evaluating energy savings after the implementation of an energy conservation measure. As the first and more extended protocol is IPMVP, it can be stated that the rest of measurement schemes are based on the four IPMVP measurement options:
Analyzing in depth the different IPMVP measurement options and the way they cover all situations, the similarities between these and other protocol’s options can be better understood. Notice that this comparison is only with ASHRAE and ESMG, since FEMP M&V guide uses IPMVP options:

- **IPMVP Option A: Retrofit isolation. Key parameter measurement.** Savings are determined by partial field measurements of the energy use of the system to which an ECM was applied, separate from the energy use of the rest of the facility. These measurements may be either short-term or continuous, and some but not all parameters may be stipulated. This measurement situation is covered by ASHRAE option “Retrofit isolation approach”, designed for measuring energy use of the subsystem affected by the ECM. ESMG defines Option 1 for this approach.

- **IPMVP Option B: Retrofit isolation. All parameter measurement.** Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period. ASHRAE uses same option “Retrofit isolation approach”, but taken into account the conditionings of measuring all parameters. ESMG defines Option 2 for this approach.
• **IPMVP Option C: Whole facility.** Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period. This option corresponds exactly with ASHRAE “Whole building approach” and ESMG option 3.

• **IPMVP Option D: Calibrated simulation.** Savings are determined through simulation of the energy use of components or for the whole facility. ASHRAE has “Whole building calibrated simulation approach” option to cover this situation, excepting that ASHRAE defines the simulation for the whole application, not for a part of it. ESMG has option 4, which exactly corresponds with option D.

The next table summarizes how every protocol covers the same options defined in IPMVP:

<table>
<thead>
<tr>
<th>Option</th>
<th>IPMVP</th>
<th>ASHRAE 14-2002</th>
<th>FEMP M&amp;V guide</th>
<th>ESMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrofit isolation. Key parameter measurement</td>
<td>Option A</td>
<td>Retrofit isolation approach</td>
<td>Option A</td>
<td>Option 1</td>
</tr>
<tr>
<td>Retrofit Isolation. All parameter measurement</td>
<td>Option B</td>
<td>Retrofit isolation approach</td>
<td>Option B</td>
<td>Option 2</td>
</tr>
<tr>
<td>Whole facility</td>
<td>Option C</td>
<td>Whole building approach</td>
<td>Option C</td>
<td>Option 3</td>
</tr>
<tr>
<td>Calibrated simulation</td>
<td>Option D</td>
<td>Calibrated simulated approach</td>
<td>Option D</td>
<td>Option 4</td>
</tr>
</tbody>
</table>

**Figure 31: Comparison of different measurement options**

### 5.6.5 Depth of analysis

Since each M&V guide has its own purpose, the depth of which every aspect and analysis is conducted varies widely among these guides. Some of the M&V protocols are more oriented to advice and help energy managers in the application of energy efficiency initiatives without deepen too much in engineering or statistical
calculations, while others develop a series of formulas and proceedings for the calculation of baselines with strong degree of accuracy.

Generally, the depth of analysis is related with the complexity of the application of the protocol. However, in some cases M&V guides that are more open and do not deepen on some aspects make the energy manager or ESCO look for other sources to achieve the objectives.

The next table summarizes the depth of analysis and main aspects where each guide focuses:

<table>
<thead>
<tr>
<th>Protocol/guide</th>
<th>General depth of analysis</th>
<th>Main aspects developed</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPMVP</td>
<td>Medium</td>
<td>Give general definitions and broad approaches</td>
<td>The level of accuracy is variable, open to the installer’s criterion</td>
</tr>
<tr>
<td>ASHRAE 14-2002</td>
<td>High</td>
<td>Strong focus on metrology, develops several statistical methods</td>
<td>Complete the IPMVP definitions of ways to quantify uncertainty so that M&amp;V design decisions can consider costs in light of the best available methods for quantifying uncertainty</td>
</tr>
<tr>
<td>FEMP M&amp;V guide</td>
<td>Medium</td>
<td>Focus on the ESPC. Furthermore FEMP provides a more detailed guidance on the application of different M&amp;V options for specific energy conservation measures</td>
<td>FEMP M&amp;V Guide, for some ECMs, allows M&amp;V Option A approach without any metering</td>
</tr>
<tr>
<td>ESMG</td>
<td>High</td>
<td>Special attention to the evaluation of energy efficiency opportunities</td>
<td>Dedicated section to the completion of the Energy Mass Balance (EMB)</td>
</tr>
</tbody>
</table>

Figure 32: Depth of analysis of different protocols

EVO-IMPV guide provides a general framework in measuring energy consumption, but does not provide details for specific measures or technologies.

ASHRAE 14 focuses part of the process in determining uncertainty conditions. It fixes a limit of uncertainty on each project; if that limit exceeds the results obtained, the project has not the enough accuracy. Also this guide establishes how to calculate uncertainty, simplifying the work for its application.

The DOE-FEMP recommends fixing an obligatory audit by extern experts for the project at least once a year. In addition, it highlights the technology applications, settling a guide for the application of M&V methods to a variety of common
conservation measures. It provides high details for five areas of improvement: lighting efficiency, motor efficiency improvements, chiller replacement projects, water conservation projects and renewable energy projects.

ESMG has some special points that demonstrate its high level of accuracy. This guide is the only one including an analysis of the Energy Mass Balance (EMB); also makes special focus in the evaluation of the energy efficiency initiatives applied in terms of business costs and benefits, determining whether that energy initiative is convenient or not. Furthermore it contains a complete section of “worked examples for Industry”, specifying the application of the protocol for each type of industry, the manufacturing industry, the commercial building industry, the mining industry, the transport industry and the mineral processing industry.

5.6.6 Differences between methodologies

In this section, the methodology for the application of each protocol is deeply analyzed in order to determine the similarities and differences among them.

Each protocol divides the methodology in different steps, but the general content of all of them is very similar. It can be stated that there are three common parts in which all the methodologies are divided as it is represented in the table below:
## METHODOLOGY FOR SAVINGS CALCULATION

<table>
<thead>
<tr>
<th>EVO IPMVP</th>
<th>ASHRAE 14-2002</th>
<th>DOE-FEMP</th>
<th>ESMG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BEFORE PROJECT IMPLEMENTATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. User’s need consideration on the planned M&amp;V report</td>
<td>1. Measurement and verification plan preparation</td>
<td>1. Allocate Project Responsibilities</td>
<td>1. Establishing your energy baseline (step 2 can be integrated in define the baseline)</td>
</tr>
<tr>
<td>2. IPMVP Option selection</td>
<td>2. Previous energy use measurement</td>
<td>2. Develop a Project-Specific M&amp;V Plan (step 1 can be integrated in this step)</td>
<td>2. Completing an energy mass balance</td>
</tr>
<tr>
<td>3. Baseline period energy data gathering</td>
<td>3. Define the baseline</td>
<td>3. Measuring, metering and capturing energy data</td>
<td></td>
</tr>
<tr>
<td>4. M&amp;V Plan preparation (step 1 and 2 can be integrated in the M&amp;V plan preparation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DURING PROJECT IMPLEMENTATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Design installation, calibration and Commissioning of any special measurement equipment</td>
<td>3. Post energy measurement Baseline projection (this step only appears in this methodology)</td>
<td>4. Install and Commission Equipment and Systems</td>
<td>4. Estimating the energy savings from an opportunity</td>
</tr>
<tr>
<td>6. Installed equipment inspection Reporting period energy data gathering</td>
<td>4.</td>
<td>5. Conduct Post-Installation Verification Activities</td>
<td>5. Accuracy in energy savings analysis</td>
</tr>
<tr>
<td></td>
<td>5.</td>
<td></td>
<td>6. Evaluating an energy efficiency opportunity</td>
</tr>
<tr>
<td><strong>AFTER PROJECT IMPLEMENTATION</strong></td>
<td>5. Savings calculation Uncertainty determination (This step only appears in this methodology)</td>
<td>6. Perform Regular-Interval Verification Activities</td>
<td>7. Measuring and tracking your implemented opportunities</td>
</tr>
<tr>
<td>8. Savings computation in energy and monetary units</td>
<td>6.</td>
<td></td>
<td>8. Energy monitoring and reporting</td>
</tr>
<tr>
<td>9. Savings report in accordance with the M&amp;V plan</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 33: Comparison of different methodologies*
The table above compares the methodology for the application of savings calculation between the different protocols. As it is seen, the methodology for each protocol can be divided in three steps taking into account the stage of project implementation:

a) Before project implementation
b) During project implementation
c) After project implementation

As it has been exposed previously, different savings calculation methods follow some common guidelines:

- EVO-IPMVP, ASHRAE 14 and DOE- FEMP follow basically a common methodology structure. ESMG is the protocol which follows a methodology structure different from the others, in spite of its global content is very similar

- ASHRAE 14 adds two new steps that do not appear in the other M&V guides. The first new step is the *baseline projection*, in which the baseline period energy use and demand measurements are projected to the set of conditions of the post-retrofit period. This process is necessary to determinate the savings calculation, so all the protocols include it, but ASHRAE guide is the only one in which it appears in a separated and clarified step. The second new step is *Uncertainty determination*, which contains the necessary resources to calculate uncertainty under different conditions. This step also appears in the ESMG, but not separately. In this way the ASHRAE 14 has bigger step detail

- ESMG dedicates a separate step to calculate the *Energy Mass Balance* (EMB), analysis that is not included in the other M&V guides. An EMB is an analysis of the energy and mass flows in a business or system, that will help in order to identify the most valuable energy efficiency opportunities

- All the protocols except ASHRAE 14 have a few steps dedicated to installation, calibration and commissioning of the measurement equipment and the activities that should be done in order to its verification and inspection. This last guide also does not focus on the report of the savings in
order to verify that the M&V plan has reached its objective, neither on the points in which is possible to do any improvement of the savings reached

5.6.7 Common methodology for savings calculation

After the revision of the particular methodologies for each protocol, it is possible to outline a common methodology including the common points and best practices from each one. This common methodology should be clear, well-organized and practical so that the implementation of the ECM is easy and rapid. It should be applied to all the possible cases so is necessary a high level of accuracy in all its parts.

The common methodology for savings calculation that harmonizes these four M&V guides can be divided in eight sections, as is shown in the table below. Inside each section is included the number and the content of the steps of each protocol to which corresponds:
<table>
<thead>
<tr>
<th><strong>COMMON METHODOLOGY FOR SAVINGS CALCULATION</strong></th>
<th><strong>EVO IPMVP</strong></th>
<th><strong>ASHRAE 14-2002</strong></th>
<th><strong>DOE-FEMP</strong></th>
<th><strong>ESMG</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Define the baseline</td>
<td>3. Baseline period energy data gathering</td>
<td>2. Previous energy use measurement</td>
<td>3. Define the baseline</td>
<td>1. Establishing your energy baseline (step 2 can be integrated in define the baseline) 2. Completing an energy mass balance</td>
</tr>
<tr>
<td>3. Reporting period energy data gathering</td>
<td>7. Reporting period energy data gathering</td>
<td>3. Post energy measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Installation, calibration and commissioning of the measurement equipment</td>
<td>5. Design installation, calibration and Commissioning of any special measurement equipment</td>
<td>4. Install and Commission Equipment and Systems</td>
<td>5. Accuracy in energy savings analysis</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 34: Common M&V methodology*
The following paragraphs include a further development of the sections included in the table:

1. **M&V Plan preparation**: measurement and verification plan should document the following:
   - Allocate risks and responsibilities between the agency and the ESCO. This depends on the agency’s resources and preferences, and the ESCO’s ability to control certain factors
   - Describe the ECM, its intended result and the expected cost of the implementation
   - Description of selected measurement approach and compliance path
   - Baseline period data: energy use and demands and all independent variables selected for use in analyses
   - The methodology to be used for all sets of post-retrofit conditions and define ongoing activities that will occur when developing the baseline model, including how to deal with each type of anomaly
   - Metering scheme, as the procedure to apply to any measurement option, not only utility meters
   - Define how savings will be calculated, its frequency and format
   - Quality control procedures to verify successful implementation of each ECM

2. **Define the baseline**: Define the energy baseline consumption (before the application of ECM) as future energy savings will be referred to this starting point. This information will be provided by energy audits, surveys, inspections or short term metering data. Baseline energy consumption needs to be based on reliable data that has been analyzed appropriately, taking into account all independent variables coinciding with energy data (i.e. production rate,
ambient temperature) and static factors coinciding with energy data. As it is explained in the ESMG this step should contain the calculation of the Energy Mass Balance (EMB)

3. **Reporting period energy data gathering:** Gather energy and operating data from the reporting period (post-retrofit measurements)

4. **Baseline projection:** Project the baseline period energy use and demand needs to a common set of conditions that are those of the post-retrofit period

5. **Installation, calibration and commissioning of the measurement equipment:** ensuring that the measurement equipment is properly designed, installed and functionally tested in all modes of operation, so as to the achievement of the design intent is assured. It also has to determine the specific features of the measurement equipment, the procedure and periods for reading the results, and a method to deal with lost data

6. **Installed equipment inspection:** Verification methods are done through surveys, inspections, spot measurements, and short-term metering. The general objective is to ensure that proper equipment/systems were installed, are operating correctly, and have the potential to generate the predicted savings. It could be appropriate to evaluate the energy efficiency initiative in terms of business costs and benefits. It should be also convenient to fix an obligatory audit for the project at least once a year done by extern experts

7. **Savings calculation:** Compute savings in energy and monetary units

8. **Savings report in accordance with the M&V plan:** To conclude the process there are two more aspects that should be considered. The first one is to analyze the accuracy to determinate savings and the quality of the whole process. A final review will help to include improvements in the future. The second one has to be with the determination of uncertainty. All estimates and measurements have a level of uncertainty associated with them. The development of the guidelines to calculate uncertainty and the fixation of its
limit to apply an ECM with success is necessary to obtain the expected results.

<table>
<thead>
<tr>
<th>Comparison of main M&amp;V guides' features</th>
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<tbody>
<tr>
<td><strong>EVO-IPMV</strong></td>
</tr>
<tr>
<td>- EVO-IMPV guide provides a general framework in measuring energy consumption, but does not provide details for specific measures or technologies</td>
</tr>
<tr>
<td>- The accuracy of the implementation of the project depends on the installer</td>
</tr>
<tr>
<td><strong>ASHRAE</strong></td>
</tr>
<tr>
<td>- ASHRAE 14-2002 guide provides strong focus on metrology, and develops several statistical methods to complete the IPMVP definitions</td>
</tr>
<tr>
<td>- This guide focuses part of the process in determining uncertainty conditions. It fixes a limit of uncertainty on each project; if that limit exceeds the results obtained, the project has not the enough accuracy</td>
</tr>
<tr>
<td><strong>DOE-FEMP</strong></td>
</tr>
<tr>
<td>- DOE-FEMP focuses on the ESPC</td>
</tr>
<tr>
<td>- This guide provides a more detailed guidance on the application of different M&amp;V options for specific energy conservation measures</td>
</tr>
<tr>
<td>- It recommends fixing an obligatory audit by extern experts for the project at least once a year</td>
</tr>
<tr>
<td><strong>ESMG</strong></td>
</tr>
<tr>
<td>- ESMG has a dedicated section to the completion of the Energy Mass Balance (EMB)</td>
</tr>
<tr>
<td>- This guide makes special focus on the evaluation of energy efficiency opportunities in terms of business costs and benefits.</td>
</tr>
</tbody>
</table>
6. USAGE OF THESE STANDARDS IN SPAIN

6.1 Introduction

Since the end of the last century there has been an increase of energy use in Spain according to the growth of the Spanish economy. However, the energy intensity\textsuperscript{26} ratio remained almost constant with light increases between 1990 and 2004, on the contrary to the OCDE average\textsuperscript{27}, where this ratio decreased around 12%.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure35.png}
\caption{Evolution of energy intensity in Spain versus OCDE}
\label{fig:energy_intensity}
\end{figure}

There are several factors that may have caused this situation, one of the mains is that in this period in Spain the economical growth was bigger than in other European countries, and the effort to cover basic energy needs was also bigger than in other

---

\textsuperscript{26} The Energy intensity ratio shows the Energy consumption per GDP

\textsuperscript{27} Source: Centro de Eficiencia Energética, Unión Fenosa
countries with more developed industries and infrastructures. These circumstances were added to the fact that big part of the economic growth was due to the boom of building industry, with larger energy consumption than other mature industries.

In the midst of the 2000 decade, the rising tendency of energy intensity use began to change aimed with the efforts of public administration to aware citizens about energy efficiency and its relation with climate change and environmental policies. Since then, social conscience about making rational use of energy have changed, also boosted by the increase of the installation of renewable energy sources both at large scale and at homes and industries. 2006 was the first year in which the primary energy consumption decreased respecting to the previous year:

![Figure 36: Evolution of energy consumption in Spain, in ktep](Source: Spanish Ministry of Industry, Tourism and Commerce)

However, one of the factors that have restrained the reduction in energy consumption is energy prices in Spain, still much lower than in other European countries. This have caused that although the social awareness about saving energy is quite high, the lack of short term monetary savings associated with energy savings restricts the energy efficiency investments, making regulatory policies and government intervention necessary to develop energy efficiency initiatives. This factor, besides the absence of standardized measuring and verification, have contributed to hinder
the development of the market of energy services companies, at levels comparable to the market developed in other EU countries.

6.2 Regulatory framework

Regulation plays a key role in the development of Spanish energy efficiency market, and hence, in the promotion of energy services companies.

The Energy Savings Directive laid down the basis of the European strategy on energy efficiency for the next years. In 2008, the European Energy and Climate Change Pack (Pack 20 20 20) facilitated the establishment of objectives and coordination among the measures previously proposed. The 20-20-20 EU policy requires the achievement of the next goals by 2020:

- 20 % reduction in greenhouse gas (GHG) emissions compared with 1990 levels
- 20 % cut in energy consumption through improved energy efficiency
- 20 % increase in the use of renewable energy

Recently, the European directive 2009/28/CE regarding the promotion of renewable energy use reinforces these objectives, by the introduction of compulsory performance a 20% of energy consumption from renewable sources, and 10% of renewable energy in the transport sector by 2020.

Spain has incorporated European policies by the transposition of these Directives into the Spanish regulation, mainly through the National Action Plan for Energy Savings and Energy Efficiency PAE4 2004-2012 and PAE4+ 2008-2011. In 2008, to encourage the energy efficiency market, the Energy Saving Plan was launch with 31 short-term initiatives aimed to the reduction of energy consumption, among them was included the promotion of energy services companies by the public administration.

Currently, the energy efficiency market is involved in a complex regulatory framework. In the last years there have been several improvements in this area, albeit regulatory framework is constantly evolving due to the transposition of
European Directives and the need of reviewing plans' objectives with the real market situation achieved.

<table>
<thead>
<tr>
<th>Spanish energy efficiency regulatory framework</th>
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<tbody>
<tr>
<td>Since energy prices are still much lower than in other EU countries, regulation plays a key role in the promotion of Spanish energy efficiency market</td>
</tr>
<tr>
<td>European policies have been incorporated into Spanish regulation through the National Action Plan for Energy Savings and Energy Efficiency PAE4 2004-2012 and PAE4+ 2008-2011</td>
</tr>
<tr>
<td>In 2008 the Energy Saving Plan was launch with 31 short-term initiatives aimed to the reduction of energy consumption, including the promotion of energy services companies</td>
</tr>
</tbody>
</table>

### 6.3 Spanish ESCOs: Current situation and future perspectives

Associated with the promotion of policies regarding energy efficiency, it has been a development of a new industry around energy efficiency projects, lead by the creation of new Energy Service Companies in Spain. However, the situation is still in stark contrast to the great developed market in North America and many countries of the EU, like France and Germany.

The main instrument to promote the ESCO market in Spain is the National Action Plan for Energy Efficiency 2008-2011, which guarantees its regulatory protection, destining special funds for the creation of new ESCOs and giving preferences in public contracts for companies with energy efficiency certification. The idea is to take best practices of ESCOs' market in other countries where this type of companies are more expanded, like USA, France, UK and Germany. This impulse to the ESCO model from the Spanish Administration is sight also as an opportunity to reduce national dependence of foreign energy, reduce carbon footprint of the economy and increase competitiveness and dynamism of the country economic system.

Spain has a great energy savings potential; as stated before there is still a long distance between energy intensity ratio in Spain and the European average. However, there are also some barriers that have been hindering the development of
the energy services market in our country, most of them related with the uncertainty of project’s results:

- Absence of standardized methods for measuring and verification of energy savings, making difficult the evaluation of the results achieved
- Lack of awareness and confidence in energy services provided by companies, mainly due to deficiency in information
- High risk perception by customers, both technical and economical
- Resistance to outsource energy management
- Difficulties to access to necessary funds and financial methods

Public administration plays a key role in the abolition of these barriers, by the implementation of mechanisms that help customers to trust in energy services companies and also providing the necessary funds and financial solutions. In this sense, recently in December 2009 the government approved a special plan for ESCOs activation in Spain, which first initiative is to conduct energy audits in 330 public buildings, aimed to save around 20% of energy in these facilities. This plan, worth with 2.350 million euros, includes subventions for the offers preparation, contract models and training programs for the companies involved.

On the other hand, in the last five years several international energy companies have begun to offer energy services in Spain, like Dalkia and Suez Energy Services. Spanish big corporations, mainly building and facility service companies, have also make profit of this new market niche. Companies like Acciona, SyV Group, Ferrovial and ACS have created a dedicated business line for energy services. Also is considerable the number of small engineering companies offering this service and new companies recently created exclusively for this purpose.

### 6.4 Importance of the standards in energy efficiency development

Despite the advance of the Spanish ESCO market since 2008, the non existence of a broadly accepted M&V standard restrains the future development of this market for
the next years. M&V standards are fundamental to the development of an energy efficiency market because their application in a project is guarantee of its success.

The lack of a common standard in the Spanish ESCO market is replaced by the application of own engineering or “ad hoc” measurement methods. Other ESCOs are currently applying international M&V guides, but even for the adoption of these standards there are still a number of significant barriers obstructing their successful implementation:

- Limited technical knowledge of the guides and lack of formative processes
- Lack of endorsement and guidance by the public sector
- Lack of a real background in the Spanish ESCO industry, which means that many projects are developed without a clear methodology
- Non-adequate funding in the early phases of a project, which is when the M&V Plan is at its most critical phase
- Language barrier to the spread of the existent guides, even though the IPMVP has been translated, only one of its volumes it is available in Spanish

To overcome these barriers, the answers lie in:

- Training and formation for the ESCO professionals
- Development of a local standard, of compulsory application in the public sector contracts
- Endorsement of this standard by the key players of the market
- Financing entities becoming aware of this business model and how the appliance of standardization can reduce the risk involved in it

What is an absolute certainty is that any of the future solutions adopted regarding M&V standards for the Spanish market will be based in the experiences of more developed and mature markets, such as those of EU countries and USA.

In this context, the trend in the short term seems to be the implementation of the IPMVP, followed in the foreseeable future by the development of a recognized and broadly accepted standard, strongly based in the IPMVP and ASHRAE 14-2002. The
success or failure of such a standard will depend largely on its endorsement in public contracts; it still remains an open question if the public EPC projects will endorse the IPMVP, a locally developed standard, or will apply and “ad hoc” approach.

6.4.1 International M&V methodologies used by Spanish ESCOs

Given the lack of official consensus in Spain, ESCOs are either relying in their own savings and measurements methods or on foreign and well proven M&V protocols to develop their projects.

There are still a big number of energy service companies that use its own M&V methods for the evaluation of energy savings. These methods normally involve engineering calculations and estimations to determine the baseline period necessary to compare with the post-ECM situation. Most simple methods may include only utility bills reading, before and after ECM, without taking into account some factors that modify the conditions (weather, occupancy, production load, etc). The omission of these relevant factors may distort the real savings achieved, decreasing the accuracy of project’s results and allowing the ESCO to make up them at its convenience. It ends up in a lack of confidence by customers, who do not see guaranteed results coming from their investments.

On the other hand, among companies applying international M&V guides, the more well-established is IPMVP to a large extent. There are several reasons that justify this choice; the main one is the international spread of this protocol around the world as it is promoted by an international non-profit professional’s organization. Furthermore, some ESCOs recently introduced in the Spanish market are subsidiaries of international companies, already users of IPMVP. This fact makes other ESCOs to use the same methods as their competitors, in order to offer similar energy services with comparable results. Big Spanish utilities offering energy services, like Gas Natural Group, use and promote IPMVP in their energy efficiency projects. In fact, Gas Natural Group is one of the current primary subscribers of EVO, participating actively in the development of new versions of the international M&V guide.
Another of the reasons that reinforce the penetration of IPMVP in Spain is the opportunities that EVO gives to ESCOs and energy professionals through their training courses, like the Certified Measurement and Verification Program (CMVP). These formative sessions, in 2010 available in Spain for the first time, allows attendees to train in current methods of measuring and verifying savings, specifically reviewing recent changes in the IPMVP; obtaining the CMVP diploma after passing the final exam. Currently there are around 100 professionals certified in Spain, and this number probably will increase by the end of this year. This certification is seen by potential customers as a guarantee of the proper conduction of the energy savings project.

Other international M&V guides like FEMP and ESMG have less diffusion in Spain, since they are adaptations of IPMVP for specific energy saving programs. ASHRAE-14 2002 is normally well-known among energy efficiency professionals; nevertheless, its use is not as extended as IPMVP because of its higher complexity and accuracy in calculations.

6.4.2 Other Spanish energy efficiency certifications

Besides the M&V techniques for the evaluation of energy savings, there are some other mechanisms introduced by recent Spanish regulation that are aimed to the application of energy efficiency initiatives in buildings. These methods can be considered a “standard” somehow, as far is clearly defined the cases where the application of these initiatives is mandatory, and also in terms there is a developed methodology for their application and for the measurement of their performance.

The main regulation affecting energy efficiency in buildings is the Spanish Technical Building Code (CTE). This code, on its last version approved in March 2006,
introduced for the first time one dedicated section to energy saving in buildings, since their energy consumption has a great savings potential, in some cases up to 25% of current energy consumption\(^2\). The CTE energy section establishes rules and procedures allowing fulfilling the basic needs of energy efficiency in buildings, and it is structured in five parts, according to five areas of improvement:

1. Limitation of energy demand
2. Thermal installation performance
3. Energy efficiency on lighting systems
4. Minimum contribution of DHW by solar heating
5. Minimum contribution of electricity by solar power

Generally, the specifications of the Technical Building Code only apply for new buildings or for those affected by significant alterations. In every section is established the particular conditionings of application, methodology of calculation, verification procedures and facilities excluded.

The purpose of the CTE is not the application of energy efficiency initiatives. However, establishes basic procedures for the evaluation of the performance of solutions applied regarding optimal energy use in the building. In every chapter the methods for the evaluation of the results are clearly defined. Since the application of these methods is mandatory for every new building, the evaluation process can be considered a M&V standard for energy use in buildings.

Following the success on energy savings derived from the application of the initiatives in new CTE, a few months later its publication, the Spanish Royal Decree 47/2007 of 19 January introduced the obligation of certificating energy efficiency in buildings of new construction, also following the European Directive 2002/91/CE of energy efficiency in buildings. Since the approval of this Royal Decree, every facility

\(^2\) Source: Institute for Diversification and Saving of Energy (IDAE)

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built after June 2007 must have a certification showing the degree of efficiency in energy consumption, using an energy efficiency scale similar to the one used for electric devices. In this Royal Decree is also considered the future application of this energy labeling system for existing public buildings under certain conditions, which will be foreseeable mandatory in the next years.

The Ministry of Industry, Tourism and Commerce and the Ministry of Housing promote the use of the free software tool CALENER to carry out this certification process. The use of CALENER is not compulsory but recommended, since the use of other software tools should have been approved by the commission that advised for the certification of energy efficiency. In practice, the use of CALENER has become the standard methodology for the energy certification process in existing and refurbished buildings.

The technical specifications for the energy use calculation methodology in new buildings are regulated by this Royal Decree, where the conditionings, requirements, approach and features of simulation software are specified. The application of this methodology ends up in the energy use rating of the building:
Buildings can be rated from more energy efficient (A) to less energy efficient (G), depending on the results of the energy use evaluation process. The value of the energy use rate from A to G depends on the value of two calculated parameters related with the energy consumption in building, its placement and the purposes the building is designed for. Since the energy label is mandatory for every facility built after June 2007, the application of these labeling systems can be also considered a standard in the measurement of energy efficiency in Spanish buildings. The labeling process is described in the Royal Decree RD 47/2007 of 19 January.
system allows somehow comparing the energy performance between buildings with similar features, and also comparing the energy use in an existing building before and after the application of ECMs, and therefore, the energy savings caused by these ECMs.

### M&V methods in Spain

<table>
<thead>
<tr>
<th>Description</th>
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<tbody>
<tr>
<td>The non existence of a broadly accepted M&amp;V standard restrains the development of the Spanish ESCO market</td>
</tr>
<tr>
<td>The lack of a common standard is replaced by the application of own engineering or “ad hoc” measurement methods or international M&amp;V guides</td>
</tr>
<tr>
<td>Own methods normally involve engineering calculations and simple estimations to determine the baseline period necessary to compare with the post-ECM situation</td>
</tr>
<tr>
<td>IPMVP is the most applied international M&amp;V guide, due to its worldwide spread and the possibilities EVO gives through its training courses</td>
</tr>
<tr>
<td>Recent regulation have introduced some methods that can be considered as standards for energy efficiency, such as the energy efficiency labeling system for buildings</td>
</tr>
</tbody>
</table>

### 6.5 Spanish energy efficiency key players

The Spanish energy efficiency market is rather complex, made up by different types of companies operating successfully among private companies, public administration, utilities and international multiservice companies.

In comparison with other European countries like France and Germany, Spanish market presents a limited development. Recently, international utilities and multiservice companies (i.e. Dalkia, Siemens, Honeywell, etc.) have begun to offer energy services in Spain. These companies were previously installed in Spain offering different services, in view of the new market situation and new opportunities they opened this new business service. Other Spanish companies operating in
different sectors, like those related with industry services or construction, begun to develop energy service divisions (i.e. Acciona, Repsol, Applus, etc.). The growth of opportunities in renewable energies has also enlarged the development of energy efficiency market in the past years, since most of companies involved offer services in both markets.

As stated before, public administration has been responsible in the recent years for the great impulse to the creation of energy service companies in accordance to the new European legislation in energy efficiency, implementation of renewable energies and emission of CO₂. In this sense the public Spanish entities have a key role in the success of this market. The efforts carried out by the Ministry of Industry, Tourism and Trade, added by the efforts of different regional energy agencies have positioned Spanish public administration as one of the most relevant key players in energy efficiency. Several institutions and research departments in the field of energy efficiency are supported by public administration, which also sponsors different types of associations formed by manufacturers, installers, promoters, etc.

As a summary, Spanish energy efficiency key players can be classified into two groups:

a) Companies, such as energy service companies, manufacturers, installers, renewable energy promoters and other energy efficiency related companies

b) Associations, working groups, research centers, institutions, public administration and other entities related with energy efficiency

The next tables summarize the main key players classified into these two groups:

| ESCOs, manufacturers, installers and energy efficiency related companies |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Acciona                         | Altran                          | Applus                          | Balmart                         |
| Besel                           | Bureau Veritas                  | Canal Eficiencia                | Centrica                         |
| Cofely                          | Creara                          | CVS                             | DOMOTICA                        |
| Dalía                           | DEPAES                          | Diagnostica                     | Domotiks                         |
| Efenic                          | Research                        | Effrenova                       | Eifaron                          |
| Elecnor                         | Electrodomésticos               | Fagor                           | Ferroser                         |
| Eteres                          | Euroquality                     | Fricain                         | Gás Natural                      |
| Euxinor                         | exeteria                        | Gas Natural                     | Fenosa                           |
| Ebrodería                       | Electrodomósticos               | Geotex                          | Green Power                      |
| Grupo Agbar                     | Grupo Ente                      | Grupo IG                        | Grupo REPSOL                     |
| Grupo ENSA                      | Grupo Euro                      | HCEnergía                       | INGENIERIA TECNICA Y CLIMATICA   |
| Grupo ENSA                      | Grupo Euro                      | Honeywell                       | Integralsa                       |
| Grupo ENSA                      | Grupo Euro                      | Iberdrola                       | Iposom                           |
| Grupo ENSA                      | Grupo Euro                      | Ingeniería Termica y Climática  | Johnson Controls Manufacturing   |
| Grupo ENSA                      | Grupo Euro                      | Kroonsbröder                    | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Manar Consulting Nexus energía   | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Orbis                           | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Philips Alumbrado               | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Prosoila                        | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Red Eléctrica de España         | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Remica                          | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Sal cricket                     | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | San José Energía y Medio Ambiente| KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Saycalen                        | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Schneider Electric              | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Self Energy                     | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Siemens                         | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | SinCeO2                         | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Soler & Palau                   | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | SOUINTEL                        | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Tecnálula                       | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Telvent                         | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Viesman                         | KAWARNA                          |
| Grupo ENSA                      | Grupo Euro                      | Zigar                           | KAWARNA                          |
Besides these players, there are others operating locally since there are a lot of small engineering companies, previously only dedicated to engineering and building related services and now more oriented to energy efficiency services and renewable energy. Furthermore it is needed to emphasize the efforts made by regional and local councils and administrations, by the incentives given to the development of energy efficiency projects and the promotion of the energy services market in their areas.

For future development of standards regarding methods and procedures to conduct energy efficiency projects, the active participation of the most relevant key player is a guarantee of success in the implantation of these new solutions. The collaboration and compromise of public administration with private companies and professionals associations must help to facilitate the transition to a new energy efficiency standardized market.
7. ENERGY EFFICIENCY INITIATIVES

7.1 First approach

Initially, for the IEA-DSM Task XXI, a list of over 80 energy conservation measures were proposed, including ECMs for household, commercial and industrial sectors. Each one of these ECM was evaluated in terms of useful potential, savings potential and load curve impact potential:

4. **Useful potential**: qualitative measure of the current penetration of an initiative in the Spanish market, also taking into account the perspectives for the next years and other criteria as profitability, complexity, barriers, etc.

5. **Savings potential**: qualitative measure of the savings (both monetary and energy savings) reached by the implementation of this ECM, based on previous experiences and success cases.

6. **Load curve impact potential**: qualitative measure of the impact of that ECM on the global energy demand curve, specially on those cases when the application of this measure can contribute to reduce energy demand on maximum peaks.

The load curve impact potential is not a common feature in energy conservation measures; however, in this section its valuation for every ECM was specially introduced due to its high usefulness for this subtask’s objectives.

The choice of these three criteria (useful, savings and load curve impact potential) and the valuation given to each one was based on practical experience, and also on the analysis of success cases on the implementation of these initiatives in Spain. These specific factors of the Spanish energy market were specially taken into account to the valuation of the ECMs:
a) **By sectors**, there are big differences in terms of quantity of energy used and savings potential:\(^{30}\):

- **The household sector**, responsible of around 17% of total consumption, has a savings potential close to 10%.

- **Commercial and industrial sectors**, both two represent more than 40% of total energy consumption in Spain; the savings potential can reach up to 18% depending on the activity.

b) **By improvement areas**, heating systems, commercial lighting and industrial equipments are the areas with larger savings potential:

- **Improvement of heating systems** has high savings potential\(^{31}\) on household sector, because more than 40% of total energy consumption on a home is used on heating. The investments needed on this area have commonly a short payback, furthermore there are subventions to change heating systems.

- **The lighting systems** savings potentials\(^{32}\) can reach up to 50%, especially in workspaces and commercial areas where lighting consumption has an important weight in total energy consumption.

- **On industrial equipment**, the extra cost of the reactive energy can be removed by the use of capacitor banks; variable speed drives can also help to reduce outstandingly the energy bill.

\(^{30}\) Source: Study “Indicadores de la Eficiencia Energética”, Unión Fenosa, 2008

\(^{31}\) Source: IDAE, Guía Práctica de la Energía, 2nd Edition 2007

\(^{32}\) Source: Energy Savers. US Department of Energy

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c) **In terms of network impact**, there are several initiatives that can contribute to reduce the peaks on consumption curve, either reducing global energy demand or moving the demand to valley zone.

In order to parameterize the initiatives, a quantitative valuation of every factor (Useful potential, Savings potential and Load Curve Impact potential) were given to every attribute, applying this criterion:

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<td>![Low]</td>
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<td>![Medium]</td>
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<td>![Medium - high]</td>
<td>Medium – high</td>
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<tr>
<td>![Very high]</td>
<td>Very high</td>
</tr>
</tbody>
</table>

*Figure 39: Valuation criteria for each ECM feature*

Furthermore, to obtain a global valuation of each initiative taking into account the valuation in terms of useful potential, savings potential and load curve impact potential; each one of the attributes has received a different relative weight, as follows:

*Figure 40: Relative weight for every ECM feature*
But, in order to have a complete sample of ECMs, additionally to the criteria of useful potential, savings potential and load curve impact potential, some other relevant features of the Spanish energy market and premises for every ECM and sector have been considered:

- **Insulation building envelope**: Due to legislative restrictions (Spanish Technical Building Code) there is reduced savings potential in new constructions. In legacy housing exists some potential, where glazing is the most critical aspect especially in office buildings

- **Hot water heating equipment**: Domestic Hot Water (DHW) is one of the main consumptions in the residential sector. There is great potential to reduce energy consumption at a reduced cost, however DHW demand is generally lower in office and public buildings

- **Heating**: Heating is one of the main energy consumption in the Spanish residential sector, and there are synergies with DHW production. For commercial uses usually heating is lower than cooling demand, nonetheless, there is enough potential to warrant attention

- **Cooling**: Not as important in energy volume as heating, but it has big effect in the electrical system. Cooling is a critical aspect of energy consumption in commercial sector, with big savings potential

- **Ventilation**: Due to current regulatory issues there is not a big potential in most cases

- **Electrical appliances**: energy savings potential in household sector is reduced. For commercial uses, except in data center installations, there is not a big field of application as an energy efficiency product

- **Lighting**: One of the most easily applied and measured energy efficiency products, with better payback periods and with great potential to be integrated in Demand Response Control schemes
- **Power Generation:** strategic group, with the potential to greatly increase the overall efficiency of energy usage, combined with mature technology. On industrial environment, these measures are highly effective.

- **Energy Management:** Energy Management systems are critical in the implementation of energy efficiency measures, as well as a measure to save energy itself, with great profitability.

- **Energy efficient industrial equipment:** Depending on the specifics of the industrial process involved, a mix of these measures delivers maximum efficiency.

- **Steam:** Steam production and usage is a key aspect of energy efficiency in the industrial sector.

- **Public lighting:** Is the main energy consumption in municipalities, easy to integrate in demand response control systems.

As a result, in the next figures there are summarized the initial list of ECMs, the quantitative valuation for each ECM feature and the global valuation for each ECM considering the criteria and the premises described before:
Notice that the household sector’s ECMs with high relation with load curve impact are highlighted in bold green. In the next tables are listed the initial ECMs for commercial and public buildings sector:

### Figure 41: Initial list of ECMs for household sector

<table>
<thead>
<tr>
<th>Household sector</th>
<th>Useful potential</th>
<th>Savings potential</th>
<th>Load curve impact potential</th>
<th>Global Valuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Insulation building envelope</td>
<td>![icon]</td>
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<td>![icon]</td>
<td>![icon]</td>
</tr>
<tr>
<td>1.1 Wall insulation</td>
<td>![icon]</td>
<td>![icon]</td>
<td>![icon]</td>
<td>![icon]</td>
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<tr>
<td>1.2 Roof insulation</td>
<td>![icon]</td>
<td>![icon]</td>
<td>![icon]</td>
<td>![icon]</td>
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<tr>
<td>1.3 Windows / glazing</td>
<td>![icon]</td>
<td>![icon]</td>
<td>![icon]</td>
<td>![icon]</td>
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<tr>
<td>1.4 Floor</td>
<td>![icon]</td>
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<td>![icon]</td>
</tr>
<tr>
<td>1.5 Draught proofing, increase the air-tightness of buildings</td>
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<tr>
<td>2. Hot water heating equipment</td>
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<tr>
<td>2.3 Insulation hot water pipes</td>
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<td>3. Heating</td>
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<tr>
<td>3.1.1 Boiler</td>
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<tr>
<td>3.1.2 Heat pump</td>
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<td>3.1.3 District heating</td>
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<td>3.2.1 Timing devices</td>
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<td>3.3 Reflecting radiator panels</td>
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<td>4. Cooling</td>
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<td>4.1 Energy efficient cooler or room air-conditioner</td>
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<td>5. Electrical appliances</td>
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<tr>
<td>5.3.3 Settop box, decoder</td>
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<td>5.3.4 Home computer</td>
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<td>6.1 Energy efficient compact fluorescent light bulbs</td>
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<td>6.2 LED’s</td>
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<tr>
<td>7. Power Generation</td>
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<td>7.1 Micro-CHP</td>
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<td>7.2 Photovoltaic solar panels</td>
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### Commercial, industrial and public buildings

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<tr>
<th>Useful potential</th>
<th>Savings potential</th>
<th>Load curve impact potential</th>
<th>Global Valuation</th>
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<tbody>
<tr>
<td>8. Insulation building envelope</td>
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<tr>
<td>8.1 Wall insulation</td>
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<tr>
<td>8.2 Roof insulation</td>
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<tr>
<td>8.3 Windows/glazing</td>
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<tr>
<td>8.4 Floor</td>
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<tr>
<td>8.5 Draught proofing, increase the air tightness of buildings</td>
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<tr>
<td>9. Ventilation</td>
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<tr>
<td>9.1 Efficient ventilation system (mechanically controlled)</td>
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<td>10. Hot water</td>
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<tr>
<td>10.1 Boiler</td>
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<tr>
<td>11. Heating</td>
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<tr>
<td>11.1.1 Boiler</td>
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<tr>
<td>11.1.2 Heat pump</td>
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<tr>
<td>11.1.3 District heating</td>
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<tr>
<td>12. Cooling</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>12.1 Energy efficient cooler or room air-conditioner</td>
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<tr>
<td>12.2 Integral air-conditioning system</td>
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<tr>
<td>12.3 Passive cooling (blinds, etc.)</td>
<td></td>
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<tr>
<td>13. Appliances</td>
<td></td>
<td></td>
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<tr>
<td>13.1 Office equipment</td>
<td></td>
<td></td>
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<tr>
<td>13.1.1 Computers</td>
<td></td>
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<td>13.1.2 Printers</td>
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<td>13.1.3 Copiers</td>
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<td>13.1.4 Fax machines</td>
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<tr>
<td>14. Lighting</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>14.1 High efficiency lighting systems</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>14.2 Motion detection light switches</td>
<td></td>
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<tr>
<td>15. Energy Management</td>
<td></td>
<td></td>
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<tr>
<td>15.1 Consumption management</td>
<td></td>
<td></td>
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<tr>
<td>20. Public lighting</td>
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<tr>
<td>20.1 Energy efficient lighting systems for public spaces (e.g. roads)</td>
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</tbody>
</table>

**Figure 42: Initial list of ECMs for commercial and public buildings sector**

### Industrial sector

<table>
<thead>
<tr>
<th>Useful potential</th>
<th>Savings potential</th>
<th>Load curve impact potential</th>
<th>Global Valuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Power Generation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.1 CHP</td>
<td></td>
<td></td>
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<tr>
<td>16.2 Windmills</td>
<td></td>
<td></td>
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<tr>
<td>16.3 Efficient generators</td>
<td></td>
<td></td>
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<tr>
<td>17. Energy Management System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.1 Monitoring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.2 Waste heat recovery system and recirculation of heat</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>18. Energy efficient industrial equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.1 Electric motors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.2 Variable speed drive</td>
<td></td>
<td></td>
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<tr>
<td>18.3 Compressed air system</td>
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<tr>
<td>18.4 Pumping systems in industrial processes</td>
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<tr>
<td>19. Steam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.1.1 Boiler monitoring system</td>
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<tr>
<td>19.1.2 Boiler load management</td>
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<tr>
<td>19.1.3 Boiler condensate return</td>
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<td></td>
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<tr>
<td>19.3 Distribution system</td>
<td></td>
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</tr>
</tbody>
</table>

**Figure 43: Initial list of ECMs for industrial sector**
Additionally, this initial list have been completed with other ECMs considered of interest for this project, due to the close relation with load curve impact or its high application potential in Spain. The additional ECMs proposed are:

<table>
<thead>
<tr>
<th>Additional measures</th>
<th>Useful potential</th>
<th>Savings potential</th>
<th>Load curve impact potential</th>
<th>Global Valuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.1 Individual monitoring and control system for public lighting</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>21.2 High performance UPS in Data Centers</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>21.3 Capacitor bank</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>21.4 Free cooling in Data Center</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
<td>☑</td>
</tr>
</tbody>
</table>

Figure 44: Additional ECMs proposed for this study

In all these tables the ECMs highly related with load curve impact are highlighted in bold green because of its high interest for this project.

### 7.2 Selection of a sample of energy efficiency initiatives

After the valuation of every ECM criteria and the global valuation of each initiative, a selective process has been conducted with the intention of obtaining a list of 25 prioritized techniques.

With the aim of having a better understanding of the process followed, all the ECMs have been drawn in a matrix taking into account the useful potential, savings potential and load curve impact potential:
Figure 45: Positioning matrix with the initial ECMs
The horizontal axis in this matrix represents the savings potential (both energy savings and monetary savings) of each ECM, while in the vertical axes is shown the useful potential of each ECM taking into account the current situation of the Spanish market and the future perspectives. Load curve impact potential is represented by the size of the ball, considering the impact that the application of every initiative could have in the electrical mains.

By making a selection of the most relevant ECMs in terms of the three criteria described before, it is possible to obtain the list of the 25 prioritized techniques for this study, as it can be shown in the next matrix:
As it can be observed in the previous figure, the selected ECMs are those with higher useful and savings potential, taking especially into account the load curve impact. The next table summarizes the 25 selected ECMs classified by sectors, their qualitative valuation and comments for each one:
<table>
<thead>
<tr>
<th>Id.</th>
<th>Household sector</th>
<th>Useful potential</th>
<th>Savings potential</th>
<th>Load curve impact</th>
<th>Global Valuation</th>
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<td>2.1</td>
<td>Boiler</td>
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<tr>
<td>2.1.1</td>
<td>Hot water heating equipment</td>
<td>High efficiency boilers, combined with small thermal energy accumulation vessels</td>
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<tr>
<td>2.1.2</td>
<td>Solar thermal collectors</td>
<td>Solar energy for Domestic Hot Water (DHW)</td>
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<tr>
<td>2.2</td>
<td>Hot water storage tank</td>
<td>Hot water accumulation, improves the performance of production system</td>
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<tr>
<td>3.1</td>
<td>Heating</td>
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<tr>
<td>3.1.1</td>
<td>Boiler</td>
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<tr>
<td>3.1.1.1</td>
<td>Condensation and low-temperature boilers</td>
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<td>3.1.2</td>
<td>District heating</td>
<td></td>
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<tr>
<td>3.1.2.1</td>
<td>Centralized hot water production: reduces the unitary costs and improves efficiency, as well as reduce the net impact caused by electric heating devices on peaks</td>
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<tr>
<td>3.2</td>
<td>Heating</td>
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<tr>
<td>3.2.1</td>
<td>Timing devices</td>
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<tr>
<td>3.2.2</td>
<td>Thermostats and radiator valve thermostatic controls</td>
<td>Control 2-way valves in terminal units, thus reducing electrical and fuel consumption</td>
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<tr>
<td>5.1</td>
<td>Electrical appliances</td>
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<td>5.1.1</td>
<td>Refrigerators</td>
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<tr>
<td>7.1</td>
<td>Micro-CHP</td>
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<tr>
<td>8.3</td>
<td>Windows / glazing</td>
<td>Thin film to reduce solar loads, complete overhaul of glazing systems, including low-E and high reflection layers</td>
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<tr>
<td>11.1</td>
<td>Heating</td>
<td></td>
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<tr>
<td>11.1.2</td>
<td>Heat pump</td>
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<tr>
<td>11.1.2.1</td>
<td>Depending on the climate zone, the heat pump represents a significant energy save over boilers, specially where DHW consumption is minimal or null</td>
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<td>12.2</td>
<td>Heating</td>
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<tr>
<td>12.2.2</td>
<td>Integral airconditioning system</td>
<td>Centralized system has lower cost and better efficiency</td>
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<td>14.1</td>
<td>Lighting</td>
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<tr>
<td>14.1.1</td>
<td>High efficiency lighting systems</td>
<td>Low consumption lightings, T5 fluorescent, high pressure sodium, LED, motion detection lightswitches, etc.</td>
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<tr>
<td>15.1</td>
<td>Energy Management</td>
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<tr>
<td>16.1</td>
<td>Power Generation</td>
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<tr>
<td>16.1.1</td>
<td>Chp</td>
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<tr>
<td>17.1</td>
<td>Energy Management System</td>
<td>Combined Heat and Power production in industrial scale, helps to manage de demand response (distributed generation)</td>
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<td>17.1.1</td>
<td>Monitoring</td>
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<tr>
<td>17.1.2</td>
<td>Waste heat recovery system and recirculation of heat</td>
<td>Real-time energy consumption measurement, recording and control, and load control on the energy distribution system</td>
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<td>18.2</td>
<td>Energy efficient industrial equipment</td>
<td>Decrease the speed drive (and the energy consumption) based on the current needs</td>
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<td>18.4</td>
<td>Variable speed drive</td>
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<td>18.4.1</td>
<td>Pumping systems in industrial processes</td>
<td>Variable flow hot water pumping systems</td>
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<td>21.1</td>
<td>Public lighting</td>
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<tr>
<td>21.1.1</td>
<td>Energy efficient lighting systems for public spaces (e.g. roads)</td>
<td>High efficiency lamps, LED streetlights, automatic intensity regulation, etc.</td>
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<tr>
<td>21.2</td>
<td>Individual monitoring and control system for public lighting</td>
<td>Remote control of public lighting: data bus connection or wireless networks with integrated “intelligent” systems</td>
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<tr>
<td>21.3</td>
<td>Capacitor bank</td>
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<tr>
<td>21.4</td>
<td>Free Cooling on Data Centers</td>
<td>Rejection of heat generated by the CPO to the ambient without usage of compressors, when low external temperatures allow to</td>
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</tbody>
</table>

**Figure 47:** List of the 25 selected ECMs
This list of 25 prioritized techniques represents the selected ECMs for the IEA-DSM Task XXI. The sample list is composed by 10 initiatives for household sector, 5 for commercial sector, 5 for industrial processes, 1 for public sector and 4 new additional measures.

### Selection of ECMs for this study

<table>
<thead>
<tr>
<th>To the selection of 25 ECMs, useful potential and savings potential have been evaluated, considering also the load curve impact due to its high importance for this project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additionally, other considerations regarding sector and application in Spain have been considered, in order to have a complete sample of initiatives</td>
</tr>
<tr>
<td>Besides the initial list of ECMs, some other highly related with demand response have been considered and added to the final sample of initiatives because of its high relation with the objectives of this project</td>
</tr>
</tbody>
</table>

#### 7.3 M&V standards applied to the selected ECMs in this study

For the selected initiatives in this document, the IPMPV Guide shall be applied, as this is the most general and used standard in the Spanish market. In this section, for every selected ECM, all four IPMVP options have been explored. Based on the experience and market criteria, for each ECM it has been identified the most proper IPMVP option:
<table>
<thead>
<tr>
<th>Id.</th>
<th>Household sector</th>
<th>IPMVP Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Hot water heating equipment</td>
<td></td>
</tr>
<tr>
<td>2.1.1</td>
<td>Boiler</td>
<td>B/C</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Solar thermal collectors</td>
<td>B</td>
</tr>
<tr>
<td>2.2</td>
<td>Hot water storage tank</td>
<td>B</td>
</tr>
<tr>
<td>3.</td>
<td>Heating</td>
<td></td>
</tr>
<tr>
<td>3.1.1</td>
<td>Boiler</td>
<td>B</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Heat pump</td>
<td>B</td>
</tr>
<tr>
<td>3.1.3</td>
<td>District heating</td>
<td>B/C</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Timing devices</td>
<td>B</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Thermostats and radiator valve thermostatic controls</td>
<td>A</td>
</tr>
<tr>
<td>5.</td>
<td>Electrical appliances</td>
<td></td>
</tr>
<tr>
<td>5.1.1</td>
<td>Refrigerators</td>
<td>A</td>
</tr>
<tr>
<td>7.</td>
<td>Power Generation</td>
<td></td>
</tr>
<tr>
<td>7.1</td>
<td>Micro-CHP</td>
<td>B</td>
</tr>
<tr>
<td><strong>Commercial, industrial and public buildings</strong></td>
<td>IPMVP Scheme</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Insulation building envelope</td>
<td></td>
</tr>
<tr>
<td>8.3</td>
<td>Windows / glazing</td>
<td>D</td>
</tr>
<tr>
<td>11.</td>
<td>Heating</td>
<td></td>
</tr>
<tr>
<td>11.1.2</td>
<td>Heat pump</td>
<td>B/C</td>
</tr>
<tr>
<td>12.</td>
<td>Cooling</td>
<td></td>
</tr>
<tr>
<td>12.2</td>
<td>Integral airconditioning system</td>
<td>B/C/D</td>
</tr>
<tr>
<td>14.</td>
<td>Lighting</td>
<td></td>
</tr>
<tr>
<td>14.1</td>
<td>High efficiency lighting systems</td>
<td>A/C</td>
</tr>
<tr>
<td>15.</td>
<td>Energy Management</td>
<td></td>
</tr>
<tr>
<td>15.1</td>
<td>Consumption management</td>
<td>B/C</td>
</tr>
<tr>
<td><strong>Industrial sector</strong></td>
<td>IPMVP Scheme</td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Power Generation</td>
<td></td>
</tr>
<tr>
<td>16.1</td>
<td>CHP</td>
<td>B</td>
</tr>
<tr>
<td>17.</td>
<td>Energy Management System</td>
<td></td>
</tr>
<tr>
<td>17.1</td>
<td>Monitoring</td>
<td>B/C</td>
</tr>
<tr>
<td>17.2</td>
<td>Waste heat recovery system and recirculation of heat</td>
<td>B/C/D</td>
</tr>
<tr>
<td>18.</td>
<td>Energy efficient industrial equipment</td>
<td></td>
</tr>
<tr>
<td>18.2</td>
<td>Variable speed drive</td>
<td>B</td>
</tr>
<tr>
<td>18.4</td>
<td>Pumping systems in industrial processes</td>
<td>B</td>
</tr>
<tr>
<td><strong>Public sector</strong></td>
<td>IPMVP Scheme</td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>Public lighting</td>
<td></td>
</tr>
<tr>
<td>20.1</td>
<td>Energy efficient lighting systems for public spaces (e.g. roads)</td>
<td>A/B</td>
</tr>
<tr>
<td><strong>Additional measures</strong></td>
<td>IPMVP Scheme</td>
<td></td>
</tr>
<tr>
<td>21.1</td>
<td>Individual monitoring and control system for public lighting</td>
<td>B</td>
</tr>
<tr>
<td>21.2</td>
<td>High performance UPS in Data Centers</td>
<td>A</td>
</tr>
<tr>
<td>21.3</td>
<td>Capacitor bank</td>
<td>A</td>
</tr>
<tr>
<td>21.4</td>
<td>Free Cooling on Data Centers</td>
<td>B/D</td>
</tr>
</tbody>
</table>

Figure 48: IPMVP option applicable for each ECM proposed
In order to understand the process needed to carry out the application of IPMVP M&V plan to the selected ECMs, a series of practical examples have been developed. In this section, for each one of the four IPMVP measurement options, an example exercise for one of the selected ECMs will be described, including all the necessary steps in the project:

1. **Background**: describing the initial situation, facility features and working elements
2. **Interactive effects**: taking into account the effects that may impact in the measure, and the criteria for their inclusion or not
3. **M&V option**: detailing the Option selected and its justification
4. **Measurement equipment and process**: describing the necessary equipment and the process followed
5. **Baseline consumption**: detailing the path selected for its determination
6. **Energy savings calculus**: describing how the energy savings will be evaluated

### 7.3.1 Option A. Retrofit Isolation, partial measurement

IPMVP Option A is applicable for the measurement of savings from retrofit isolations. It can be applied to the following selected ECMs:\(^{33}\):

<table>
<thead>
<tr>
<th>Id.</th>
<th>Household sector</th>
<th>IPMVP Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.2</td>
<td>Thermostats and radiator valve thermostatic controls</td>
<td>A</td>
</tr>
<tr>
<td>5.1.1</td>
<td>Refrigerators</td>
<td>A</td>
</tr>
<tr>
<td>14.1</td>
<td>High efficiency lighting systems</td>
<td>A/C</td>
</tr>
<tr>
<td>20.1</td>
<td>Energy efficient lighting systems for public spaces (e.g. roads)</td>
<td>A/B</td>
</tr>
<tr>
<td>21.2</td>
<td>High performance UPS in Data Centers</td>
<td>A</td>
</tr>
<tr>
<td>21.3</td>
<td>Capacitor bank</td>
<td>A</td>
</tr>
</tbody>
</table>

\(^{33}\) Notice that for each ECM, one or more IPMVP options are applicable.

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As an example of IPMVP Option A application, the improvement of lighting system in an office (selected ECM “High efficiency lighting systems”) will be described.

7.3.1.1 Background

The measure to apply is the retrofitting of lighting in a public office. The data for the case are as follows:

- Office building
- Number of lamps: 2000
- Power per lamp before retrofitting: 50 W
- Power per lamp after retrofitting: 20 W
- Working time: from 8:00 to 20:00, Monday to Friday

7.3.1.2 Interactive effects

There is an important interaction with the HVAC\(^34\) system, nonetheless, for this particular building it has been estimated that the savings in the cooling load offset the greater heating load, and thus, are not included in the analysis.

7.3.1.3 M&V Option

Option A, has been determined as the best option for this case, due to lower expected CAPEX\(^35\) and OPEX\(^36\) cost, and a sufficient degree of accuracy, since the interaction effects have been determined as not significant.

\(^34\) Heat, Ventilation and Air Conditioning

\(^35\) CAPEX: Capital expenditures, are the funds used by a company to acquire or upgrade physical assets such as property, industrial buildings or equipment

\(^36\) OPEX: Operational expenditures, are the ongoing costs for running a product, business, or system

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The variable to be measured is the real power consumption of randomly chosen lamps, before and after the retrofitting.

### 7.3.1.4 Measurement equipment and process

The actual measurements shall be performed with a RMS\(^{37}\) portable wattmeter, with an accuracy of 2% in the measurement range.

The number of samples taken shall ensure a degree of uncertainty of less than 10% in the older lamps and less than 2% after retrofitting, each day during a week period, in each case. Furthermore, the number of burnt lamps will be registered, and taken into account in the analysis.

The overall accuracy of the post retrofit savings measurement is determined by using statistical analysis, and is expected to be slightly over 10%.

The illumination level shall be measured to ensure that it is maintained after the retrofitting.

### 7.3.1.5 Baseline consumption

The baseline instantaneous energy consumption shall be determined as follows:

\[
P(W) = M_p \cdot N_l - M_p \cdot N_{lb}
\]

Where:

- \(P\) is the total power, in watts
- \(M_p\) is the mean power consumption per lamp before retrofitting
- \(N_l\) is the number of lamps

---

\(^{37}\) RMS: root mean square wattage measure

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• \(Nlb\) is the mean number of burnt lamps at any given time before retrofitting

It has been agreed with the client that there are no other influence variables, as long as the operational aspects of the building do not change. In case the operating hours change, the new figure shall be introduced in the savings determination.

### 7.3.1.6 Energy savings calculation

The energy savings per period (monthly) is determined as follows:

\[
Es(kWh) = \frac{Nh}{1000} \times [(Mp \times Nl - Mp \times Nlb) - (M'p \times Nl - M'p \times N'lb)]
\]

Where:

• \(Es\) is the period energy savings in kilowatt per hour
• \(Nh\) is the number of operating hours of the period
• \(Mp\) is the mean power consumption per lamp before retrofitting
• \(Nl\) is the number of lamps
• \(Nlb\) is the mean number of burnt lamps at any given time before retrofitting
• \(M'p\) is the mean power consumption per lamp after retrofitting
• \(Nl\) is the number of lamps
• \(N'lb\) is the mean number of burnt lamps at any given time after retrofitting

Thus for example in a typical month of 22 work days, the savings will be:

\[
Es(kWh) = \frac{264}{1000} \times [(50 \times 2000 - 50 \times 100) - (20 \times 2000 - 20 \times 50)]
\]

That is, 14.784 kWh.
7.3.2 Option B. Retrofit Isolation, all parameters measurement

Option B is applicable to the next selected ECMs\(^{38}\):

<table>
<thead>
<tr>
<th>Id.</th>
<th>Household sector</th>
<th>IPMVP Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1.1</td>
<td>Boiler</td>
<td>B/C</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Solar thermal collectors</td>
<td>B</td>
</tr>
<tr>
<td>2.2</td>
<td>Hot water storage tank</td>
<td>B</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Boiler</td>
<td>B</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Heat pump</td>
<td>B</td>
</tr>
<tr>
<td>3.1.3</td>
<td>District heating</td>
<td>B/C</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Timing devices</td>
<td>B</td>
</tr>
<tr>
<td>7.1</td>
<td>Micro-CHP</td>
<td>B</td>
</tr>
<tr>
<td>11.1.2</td>
<td>Heat pump</td>
<td>B/C</td>
</tr>
<tr>
<td>12.2</td>
<td>Integral airconditioning system</td>
<td>B/C/D</td>
</tr>
<tr>
<td>15.1</td>
<td>Consumption management</td>
<td>B/C</td>
</tr>
<tr>
<td>16.1</td>
<td>CHP</td>
<td>B</td>
</tr>
<tr>
<td>17.1</td>
<td>Monitoring</td>
<td>B/C</td>
</tr>
<tr>
<td>17.2</td>
<td>Waste heat recovery system and recirculation of heat</td>
<td>B/C/D</td>
</tr>
<tr>
<td>18.2</td>
<td>Variable speed drive</td>
<td>B</td>
</tr>
<tr>
<td>18.4</td>
<td>Pumping systems in industrial processes</td>
<td>B</td>
</tr>
<tr>
<td>20.1</td>
<td>Energy efficient lighting systems for public spaces (e.g. roads)</td>
<td>A/B</td>
</tr>
<tr>
<td>21.1</td>
<td>Individual monitoring and control system for public lighting</td>
<td>B</td>
</tr>
<tr>
<td>21.4</td>
<td>Free Cooling on Data Centers</td>
<td>B/D</td>
</tr>
</tbody>
</table>

As an example of IPMVP Option B application has been considered the decommissioning of an electrical heating system (Joule effect) and its substitution by a new, more efficient air to air heat pump, in a moderately cold climate (selected ECM “Heat pump”).

\(^{38}\) Notice that for each ECM, one or more IPMVP options are applicable.

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7.3.2.1 Background

The location of the site where the ECM is to be applied is critical in this case, since the heating demand and the performance of the heat pump are dependent on outside air temperature. Below is a table with the weather data for the city where the installation is located. \( T \) is the monthly average temperature, while \( TM \) and \( Tm \) are the monthly average temperature maximum and minimum.

<table>
<thead>
<tr>
<th>Month</th>
<th>( T )</th>
<th>( TM )</th>
<th>( Tm )</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>10.7</td>
<td>15.9</td>
<td>5.4</td>
</tr>
<tr>
<td>February</td>
<td>12.0</td>
<td>17.5</td>
<td>6.6</td>
</tr>
<tr>
<td>March</td>
<td>14.0</td>
<td>20.2</td>
<td>7.7</td>
</tr>
<tr>
<td>April</td>
<td>15.4</td>
<td>21.5</td>
<td>9.4</td>
</tr>
<tr>
<td>May</td>
<td>18.4</td>
<td>24.6</td>
<td>12.1</td>
</tr>
<tr>
<td>June</td>
<td>22.0</td>
<td>28.8</td>
<td>15.3</td>
</tr>
<tr>
<td>July</td>
<td>25.5</td>
<td>33.0</td>
<td>18.0</td>
</tr>
<tr>
<td>August</td>
<td>25.7</td>
<td>33.1</td>
<td>18.4</td>
</tr>
<tr>
<td>September</td>
<td>23.5</td>
<td>30.2</td>
<td>16.8</td>
</tr>
<tr>
<td>October</td>
<td>19.1</td>
<td>25.0</td>
<td>13.3</td>
</tr>
<tr>
<td>November</td>
<td>14.7</td>
<td>20.1</td>
<td>9.2</td>
</tr>
<tr>
<td>December</td>
<td>11.9</td>
<td>16.8</td>
<td>7.1</td>
</tr>
<tr>
<td>Year</td>
<td>17.7</td>
<td>23.9</td>
<td>11.6</td>
</tr>
</tbody>
</table>

![Figure 51: Monthly outside air temperatures](source: exeleria)

We shall assume that the heat pump is used only for heating, since in cooling there is no actual system, and thus, no savings to be obtained.

The technical data for the retrofit measure are as follows:

- Retrofit site: 150 sqm detached house.
- Heating demand: 17.2 kWh/sqm and year.
- Actual system: electric heater, 7 kW power, efficiency close to 1.
- Proposed system: air to air heat pump, 3 kW max. electrical consumption, thermal power in standard conditions, 10 kW, COP=2.8
7.3.2.2 Interactive effects

There are no interactive effects of this ECM with the other consumptions of the house, unless more measures are implemented.

7.3.2.3 M&V Option

For this measure, there are various options, as the level of savings expected is more than 20% of the annual consumption, option B can be adopted.

As the only independent variable to be expected in the system is outside temperature, the statistical model developed can be fairly simple.

The baseline will be developed by measuring for six months (heating campaign) the electrical consumption of the actual system and the outside air temperature. With these data, a model that relates heating demand and outside air temperature will be developed, which shall be used as the equation to evaluate the baseline demand.

The electrical consumption of the new system will be measured continuously and compared with the baseline to obtain the savings.

7.3.2.4 Measurement equipment and process

For the measurement of electrical consumptions a three phase power meter with capacity to register up to 32,000 measurement points shall be used, the accuracy of the power meter is equal or better. The data will be collected each six months with an hourly frequency of acquisition. The outside air temperature shall be acquired from a nearby meteorological station.

With the data of hourly electrical consumption and outside temperature, and assuming a constant temperature inside the house of 21 ºC (due to the specifications of the client), the next equation is obtained:

\[ H_i(T) = A + B \times (T - T_o) \]
Where the parameters $A$ and $B$ are to be obtained by linear least squares regression.

- $Hi$ is the daily heating load
- $T$ is the daily average temperature
- $To$ is the inside air temperature of 21 °C

Obviously, the $A$ parameter should be equal to zero, and if positive or negative, it can mean that something anomalous is occurring in the system, or an analysis error.

The $B$ parameter is equal to the global heat transfer coefficient for the house.

To ensure an appropriate level of confidence, an $R^2$ of at least 0.8 is assumed as necessary and a standard error no greater than 0.15.

The sum of the $n$ $Hi$ loads in a month adds to the monthly load, which, with the existing system is approximately equal to the consumption.

### 7.3.2.5 Baseline consumption

The baseline monthly energy consumption shall be determined as follows:

$$Eb[kWh] = \sum_{i=1}^{n} Hi$$

Where:

- $Eb$ is the monthly energy consumption in kWh
- $Hi$ is the daily heating load, calculated previously

It has been agreed with the client that there are no other influence variables, as long as the operational aspects of the building do not change.

### 7.3.2.6 Energy savings calculation

The energy savings per period (monthly) are determined as follows:

$$Es[kWh] = Eb - Em$$

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Where:

- $E_s$ is the period energy savings in kilowatt per hour
- $E_b$ is the baseline energy
- $E_m$ is the energy consumption measured in the new system

The standard error in the evaluation would be as follows:

$$S = \sqrt{S_{m}^2 + S_{r}^2}$$

Where:

- $S_{m}$ is the standard error in the measurement
- $S_{r}$ is the standard error in the regression

### 7.3.3 Option C. Whole building

IPMVP Option C is applicable for the next list of selected ECMs\textsuperscript{39}:

<table>
<thead>
<tr>
<th>Id.</th>
<th>Household sector</th>
<th>IPMVP Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1.1</td>
<td>Boiler</td>
<td>B/C</td>
</tr>
<tr>
<td>3.1.3</td>
<td>District heating</td>
<td>B/C</td>
</tr>
<tr>
<td>11.1.2</td>
<td>Heat pump</td>
<td>B/C</td>
</tr>
<tr>
<td>12.2</td>
<td>Integral airconditioning system</td>
<td>B/C/D</td>
</tr>
<tr>
<td>14.1</td>
<td>High efficiency lighting systems</td>
<td>A/C</td>
</tr>
<tr>
<td>15.1</td>
<td>Consumption management</td>
<td>B/C</td>
</tr>
<tr>
<td>17.1</td>
<td>Monitoring</td>
<td>B/C</td>
</tr>
<tr>
<td>17.2</td>
<td>Waste heat recovery system and recirculation of heat</td>
<td>B/C/D</td>
</tr>
</tbody>
</table>

---

As an example of IPMVP Option C has been considered an office building where it has been installed a new control and monitoring system (selected ECM “Consumption management”).

\textsuperscript{39} Notice that for each ECM, one or more IPMVP options are applicable.

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7.3.3.1 Background

In this example it is assumed that the location is an office building in which, through the installation of a new control and monitoring system, a number of control strategies are implemented such as:

- Optimization of the start up and shut down of the HVAC system
- Reduction in the number of hours of usage of the lighting system
- Increase in the water temperature in the outlet of the chiller

The chiller is assumed to be air condensed and of screw compressor, while the power consumption of the lighting system is constant.

7.3.3.2 Interactive effects

There are strong interactive effects between these three measures, the lighting shall affect both the heating and cooling load in the HVAC system, while the effect of the measures implemented in the chiller will affect the comfort temperature.

7.3.3.3 M&V Option

Due to this interactive effects, and the fact that it is not desired to exceed the 5% limit of the savings in the M&V Plan, an Option C approach has been adopted. As part of the M&V Plan a regression model of three variables, outside temperature, functioning hours of the lighting system and outlet temperature in the chiller will be developed.

7.3.3.4 Measurement equipment and process

To model the energy usage, it will be measured the consumption for a period of 12 months prior to the implementation of any Energy Conservation Measure, with a frequency of 15 minutes. The outside air temperature and outlet water temperature in the chiller will be recorded with the same frequency.
After the implementation of the ECM the three parameters will be measured, and savings will be determined as the difference between the measured consumption and the baseline modified according to the measured hours of lighting and mean outside air temperature. The temperature of a sample of zones in the building will be controlled, to ensure that it falls within accepted limits when the start up and shut down of the system is modified.

### 7.3.3.5 Baseline consumption

The proposed equation which describes the daily baseline consumption will have this form:

\[
E_{bi}[kWh] = A + B \times H_l + C \times (T - T_w) + D \times (T - T_w)^2
\]

- Where the parameters \(A, B, C\) and \(D\) are determined by linear least squares regression.

In this case it is not reasonable to expect \(A\) to be equal to zero, since the measurement of electrical consumption is made at building level, and there are consumptions which are not explained by the independent variables chosen (but are assumed to be constant).

The variables \(T\) and \(T_w\) represent the daily mean of the outside air temperature and outlet water for each day.

It is expected that the model will fit with at least an \(R^2\) of 0.8 and a standard error no greater than 0.15.

### 7.3.3.6 Energy savings calculation

After the modeling has been completed, the changes are implemented, so that the number of hours of operation of the lighting system is reduced to match the actual occupancy of the building, and the outlet water temperature in the chiller is increased.
(which has the effect of raising the efficiency of the chiller for a given load and air temperature, at the cost of reducing its cooling power).

There will be an adjustment period in which the measures will be fine tuned, considering its effect in air temperature in the building zones, thus the objective is to minimize energy consumption without affecting the comfort of the building occupants. It can be pointed out that with a more complex model which would include the air temperature within the building as an independent variable, the problem is susceptible of being solved mathematically with an iterative method.

Thus, the equation used to compute the monthly savings will be as follows:

\[ Es[kWh] = \sum_{i=1}^{n} [Ebi] - Em \]

Expanding the equation we obtain:

\[ Es[kWh] = \sum_{i=1}^{n} [(A + B \times Hi + C \times (T - Tw) + D \times (Ti - Twi)^2)]i - Em \]

Where:

- \( Es \) is the savings per month in kWh

The standard error will be obtained as in the previous example and will be obtained by the standard error of the different measurements and that of the regression model with the following formula:

The standard error in the evaluation would be as follows:

\[ S = \sqrt{Smi^2 + Sr^2} \]

Where:

- \( Smi \) is the standard error in each of the measurements (air temperature, water temperature, hours and electrical consumption)
- \( Sr \) is the standard error in the regression
7.3.4 Option D. Calibrated simulation

IPMVP Option D can be applied to these selected ECMs:\(^{40}\):

<table>
<thead>
<tr>
<th>Id.</th>
<th>Household sector</th>
<th>IPMVP Scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.3</td>
<td>Windows / glazing</td>
<td>D</td>
</tr>
<tr>
<td>12.2</td>
<td>Integral airconditioning system</td>
<td>B/C/D</td>
</tr>
<tr>
<td>17.2</td>
<td>Waste heat recovery system and recirculation of heat</td>
<td>B/C/D</td>
</tr>
<tr>
<td>21.4</td>
<td>Free Cooling on Data Centers</td>
<td>B/D</td>
</tr>
</tbody>
</table>

Figure 53: Selected ECMs where Option D is applicable

As an example of Option D application, it will be analyzed an office building with multiple dwellers, where a VRV\(^{41}\) system is to be replaced by centralized, water condensed chillers (related with selected ECM "Integral air conditioning system").

7.3.4.1 Background

In this office building, with multiple dwellers, a VRV\(^{42}\) system is going to be replaced by centralized, water condensed chillers. Due to number of machines in the building it is difficult and expensive to measure the consumption of each VRV outside unit. Due to the multiple hourly profiles and loads, to sample the measurements is considered to be unsuitable.

Thus, option D is considered to be the best approach in this case, simulating the performance of the building and its actual HVAC\(^{43}\) system. With the data gathered in the annual simulation a relationship between outside air temperature and electrical

\(^{40}\) Notice that for each ECM, one or more IPMVP options are applicable.

\(^{41}\) VRV: Variable Refrigeration Volume systems allow independent temperature control of several indoor units with simultaneous heating and cooling from one outdoor unit

\(^{42}\) VRV: Variable Refrigeration Volume systems allow independent temperature control of several indoor units with simultaneous heating and cooling from one outdoor unit

\(^{43}\) Heat, Ventilation and Air Conditioning system

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consumption shall be developed, and the rest of significant parameters (occupation, lighting, and temperature set points) shall be assumed to be constant.

7.3.4.2 Interactive effects
The refitting of the HVAC system shall have a significant effect in the comfort temperature of the building. The water system is expected to have more stable comfort temperature than the existing one, as well as reduce the water and electricity consumption in the humidifiers of the ventilation system due to the higher temperatures in the heat exchangers of the terminal units.

7.3.4.3 M&V Option
As has been explained, D option is considered to be most adequate for this particular problem. The output of the simulation will be calibrated by using the billing data from the utility to refine the data obtained.

7.3.4.4 Measurement equipment and process
The building and the actual HVAC system will be modeled using a simulation suite among one of the available in the market. The weather data used in the simulation will not be the typical meteorological year of the location, but the actual real data corresponding to the last year available of billing data from the utility.

A whole year will be simulated obtaining the total hourly consumption of the building. The simulated data will be compared with the monthly billing data from the utility, obtaining the Medium Bias Error, and the Standard Error for the simulation which shall be of less than 10% and 15% respectively to be considered adequate.

With the hourly data consumption, a regression shall be performed to obtain an equation that relates electrical consumption and outside air temperature.
During the reporting period both the electrical consumption of the whole building and the outside air temperature will be registered, for the electrical consumption, monthly data are adequate, while the temperature will be registered hourly.

### 7.3.4.5 Baseline consumption

The baseline consumption is determined with the regression equation obtained before, which will give as output the hourly consumption for a given outside temperature. The monthly consumption will be the sum of hourly consumptions for a given month. Thus:

$$Ebi[kWh] = A + B \cdot (T - To) + C \cdot (T - To)^2$$

$$Eb[kWh] = \sum_{i=1}^{n} Ebi$$

Where:

- $Ebi$ is the hourly energy consumption
- $Eb$ is the monthly sum
- $T$ is the outside air temperature
- $To$ is the air temperature inside the building (assumed to be constant)
- $A$, $B$ and $C$ are constant parameters

It is expected that the model will fit with at least an $R^2$ of 0.8 and a standard error no greater than 0.15.

### 7.3.4.6 Energy savings calculation

After the installation, commissioning and adjustment of the new system, the savings will be calculated comparing the baseline adjusted with the registered hourly temperature with the actual monthly consumption.

Thus, the equation used to compute the monthly savings will be as follows:
Expanding the equation we obtain:

\[ Es[kWh] = \sum_{i=1}^{n} [E_{bi}] - E_m \]

Where:

- \( Es \) is the savings per month in kWh
- \( n \) is the number of days per month

The standard error will be obtained as in the earlier example and will be obtained by the standard error of the temperature measurement, the simulation and the regression model:

The standard error in the evaluation would be as follows:

\[ S = \sqrt{S_{mi}^2 + S_s^2 + S_r^2} \]

Where:

- \( S_{mi} \) is the standard error in each of the measurements (air temperature and electrical consumption)
- \( S_r \) is the standard error in the regression
- \( S_s \) is the standard error in the simulation
8. ENERGY EFFICIENCY AND DEMAND RESPONSE

8.1 Demand Response as a tool for Energy Efficiency

Although the concept of demand response (DR) is broadly used to refer to a multitude of issues related to energy efficiency, it can be concluded that demand response refers to all those policies and concrete measures which purpose is to influent the final consumer in their energy behavior, often making smarter use of resources. Demand Response (DR) can be considered as a particular set of DSM policies, where the final customer receives whether economic incentives or penalties according with the changes in energy behavior reached.

The success of such initiatives must be based on achieving a series of clear and stable profits for all actors involved, so that all of them find motivation to give continuity to the efforts made.

The following table represents a generic list of benefits common to all initiatives for demand response:

<table>
<thead>
<tr>
<th>Customer benefits</th>
<th>Societal benefits</th>
<th>Utility benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfy electricity demands</td>
<td>Reduce environmental degradation</td>
<td>Lower cost of service</td>
</tr>
<tr>
<td>Reduce/stabilize costs (bills)</td>
<td>Conserve resources</td>
<td>Improve operating efficiency, flexibility</td>
</tr>
<tr>
<td>Improve value of service</td>
<td>Protect global environment</td>
<td>Reduce capital needs</td>
</tr>
<tr>
<td>Maintain/improve lifestyle and productivity</td>
<td>Maximize customer welfare</td>
<td>Improve customer service</td>
</tr>
</tbody>
</table>

Figure 54: Demand response benefits

As it can be seen in the previous table, demand response programs must be based on the assumption that the level of service (residential customer comfort and productivity in industry) is not substantially modified, so that based on the temporal flexibility of consumption, or the ability of making them more efficient, obtaining for this effort a financial compensation.

The utility has new tools for system operation, while it sees how it reduces the net demand of its customers, resulting in a reduction and delay of investment in expansion of the network. Finally, society and environment as a whole will be benefited by more efficient use of the energy resources available.

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The implementation of these programs is a complex and often costly process, which have to deal with a number of potential risks and barriers, so it is necessary a good implementation methodology:

Figure 55: Methodology for the implantation of demand response initiatives

Source: everis

1. **Load research.** It is necessary to study the behavior of demand on which to work, analyzing the purchasing power, the level of equipment, environmental awareness, etc.

2. **Define load-shape objectives.** Determine the ultimate purpose of program management. That is, what kind of modifications is intended to produce on the general curve of consumption

3. **Assess program implementation strategy.** Generate the business plan associated with the DR program, outlining the costs associated with the implementation and the expected benefits

4. **Implementation.** To carry out the program effectively. Development of the necessary infrastructure and associated communication campaigns

5. **Monitoring and evaluation.** For proper tracking and feedback of the program, it is necessary to have an adequate monitoring system, which is able to effectively measure the benefits obtained. Measuring demand response products performance can present a high degree of complexity; the last section of this chapter will tackle this issue in deep
As noted in step 2 of the previous figure (Define load-shape objectives), there are a multitude of possible interests when implementing a demand response program. The figure below shows the most important ones:

### Figure 56: Typical load curve transformations with demand response
Source: Tata Power

- **Peak clipping.** Aims at reducing the load, primarily on periods of peak demand
- **Valley filling.** Increasing the load during the hours of minor utilization of the system.
- **Load shifting.** Redistribution of the daily system load, moving part of the consumption in peak hours to valley hours
- **Conservation.** Reducing the load homogeneously over all hours of the day
- **Load building.** Increasing the load homogeneously over all hours of the day
- **Flexible load shape.** These are programs that seek to provide tools to the utilities to modify the load curve in real time

Demand Response must be seen as a tool for public institutions and utilities, which allows articulating its relationship with the user of the network, serving as a catalyst
for changing habits consumption. This allows making the energy use more efficient and rational.

Involve the customer on energy efficiency is not always easy; improvement actions usually imply financial investments or modification of habits, which could generate some resistance. The end user should see clearly the benefits associated with efficiency initiatives.

Demand response programs help the client to act more efficiently, without implying a decrease in their perception of the service, as the possible inconvenient associated with the measures implemented should be compensated by the decrease of the electricity bill and the improve of the supply continuity.

<table>
<thead>
<tr>
<th>Demand response as a tool for energy efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy efficiency can be related with demand response, as some ECMs can contribute to grade the load curve on the system</td>
</tr>
<tr>
<td>Utilities and electrical network operators can use demand response policies as a tool for system operation</td>
</tr>
<tr>
<td>There are a multitude of possible interests when implementing a demand response program, but all oriented to grade the load curve and reduce peaks on demand</td>
</tr>
<tr>
<td>The implementation of DR programs is a complex and often costly process, which have to deal with a number of potential risks and barriers</td>
</tr>
<tr>
<td>In order to achieve the objectives on demand response, it is necessary a significant involvement by clients, who should notice the results in the electricity bill</td>
</tr>
</tbody>
</table>

8.2 International references in demand response products

There is a clear relationship between energy efficiency and demand response programs. During the selection and development of the initiatives which will be included in these programs, there is the possibility to introduce ECMs not only oriented to general energy savings, but more oriented to control the intraday energy consumption and hence the load curve on the system.
The viability of demand response programs in the present and future depend largely on public initiative. On one hand, public initiative has an underlying interest in improving the country’s energy efficiency (greater business competitiveness, less energy dependence, lower CO₂ emissions, etc.). On the other hand, there is a great need for regulatory framework that not only allows, but encourages the implementation of these types of energy efficiency measures.

In the following subsections will be shown some international references on demand response programs, whose aim is to influence into the end consumer habits in order to rationalize the use of energy resources. Energy savings are calculated here by the comparison of the energy consume before and after the implementation of the ECM. These international examples are pilot programs carried out by utilities companies over a sample of users; during a period of time have been tested the customers’ response through the change of their habits in energy consumption.

### 8.2.1 In-Home Displays (IHDs)

In-Home Displays (IHDs), also called Real-Time Monitors (RTM), are small household devices that provide real-time energy consumption and costs information to customers. The IHDs can revolutionize the way utilities provide information to customers, faster and more effective than traditional bills, turning into a vehicle for consumers to change their electricity consumption behaviors.

Energy savings from IHDs benefit both consumers and utilities. Consumers benefit from using less electricity because it directly translates into a lower electricity bill. Environmentally-conscious customers derive additional value from cutting back their electricity consumption because it decreases their carbon footprint. Energy savings at the system level keep the consumption growth under check, and this often means avoiding incremental capacity, transmission, and distribution investments. Utilities further benefit from reduced greenhouse gas emissions as a result of energy savings. According to demand response, utilities may find that IHDs, used in conjunction with time-varying rates, increase reduction of peak demand. For utilities, reduction in peak
demand means that expensive peaking units will not need to run as often, and less overall capacity will need to be procured from capacity markets. IHDs and dynamic pricing programs together provide stronger demand response than dynamic pricing can accomplish alone. Thus, IHDs can contribute to energy conservation and demand response, while providing for smoother load profiles and greater electric grid stability.

The effects of various direct feedback systems on consumer behavior have been researched in utility pilot programs in the last four decades. Results have demonstrated that direct feedback motivates behavior change, resulting in energy savings ranging up to 20 percent.

Recently, technology advances have facilitated the spread of metering displays. Several pilot programs conducted by utilities companies worldwide have shown good results in terms of energy saved and demand response management. One of these success cases was conducted in 2007 by three large utilities companies in Massachusetts (USA). These utilities distributed IHDs to 3,512 customers prior the starting of pilot program, which lasted around six months. In this period, results showed that 63% of the participants changed their electricity-use behavior after using the IHD, mainly with habits related to:

44 IHDs were sold to customers at a price ranging from free charge to 49,99 $
Regarding to the usefulness of the data provided by the IHD, 47% of surveyed participants who had installed and used this device indicated that overall energy use data was the most useful information. In contrast, 37% stated that the most useful information provided was data on energy used by specific appliances. In terms of bill impacts, among participants who changed their behavior, 60% indicated that they had noticed a decrease in their electricity bill. Almost half of those thought they had saved from 5 to 10% on their electricity bill. In terms of network capacity, utility observed considerable reduction of energy consumption on peaks of demand, by the comparison of the aggregated curve before and after the pilot programme.

Other large utilities in USA and Canada have carried out analogous pilot experiments with IHDs, obtaining quite similar results in terms of consumer's utility bill savings derived from habit changes and benefits for the electric system through electric load grading.
8.2.2 Dynamic pricing in the mass market

Another demand response strategy highly related with real-time energy consumption monitorization is dynamic pricing. These mechanisms allow utility companies to dynamically change energy pricings in order to encourage customers to reduce energy consumption on peaks. Consumers, through the use of Advance Metering Infrastructures (AMI) and IHDs, can be aware of the energy price in every moment of the day, adapting their consumption and moving non critical loads from expensive (peak) hours to cheaper (valley) hours (load shifting), so that the daily load curve becomes more flat.

This management tool does not as main objective the reduction of overall consumption of the client, but rather its redistribution, so that the client, through pricing incentives, ceases to contribute to the growth of the daily peak of the system.

By this view, the level of service of end customers is not affected because, depending on how much are willing to save or pay as a surcharge, they have the choice to decide which consumption will be shifted to cheaper hours, keeping in the peak the ones that consider of high priority. Obviously, the more consumption moved (washing machines, dishwashers, ovens, etc.), the greater percentage of energy will be invoiced at a reduced price, and therefore the greater will be the benefit that it is noticed in the bill.

As an example of the application of these programs, in this section is illustrated a pilot program carried out in California between 2003 and 2005 (Statewide Pricing Pilot). The experiment was conducted by a mid-sized utility, assuming typical residential customers with about 1,000 kWh per month during summer. Several different rate structures were tested, including tariffs where price during the peak period was roughly 70% higher than the standard rate and about twice the value of
the price during the off-peak period. The pilot program considered different residential areas (zones), and also considered different rates for normal or critical\(^{45}\) weekdays.

As a result, consumers reduced peak-period energy use on critical days between 8% and 16%:

![Energy use reduction with dynamic pricing](image)

\(^{45}\) Critical days are those with high energy consumption in the system

By the use of dynamic pricing, the utility achieved a considerable reduction of network congestion, measuring the comparison of the aggregated curve before and after the pilot programme.
8.2.3 Direct load control and time-of-use rates

Other common mechanisms to manage demand response through pricing options are direct load control (DLC) and time-of-use (TOU) rates.

In contrast to dynamic pricing options, DLC programs can be implemented utilizing the existing metering infrastructure by simply installing a switch on the most consuming selected appliances, which is operated via a radio signal. DLC programs provide utilities with a high degree of control over load reductions.

Many utilities have effectively implemented successful DLC programs. In summer 2006, Hydro One in Ontario, Canada, launched a new residential DLC program. This utility provided customers with a free smart thermostat allowing participants and the utility to control the setting on their central air conditioning remotely over the Internet. The technology also gave the utility company the ability to increase the temperature of the participant's house up to a maximum of two degrees during critical events in the summer, reducing peaks on demand curve.

On the other hand, in the same way as DLC, TOU rates do not require AMI for implementation. TOU customers are typically metered using a special device which separately captures their total consumption during the peak and off-peak periods. TOU rates give utilities the ability to influence peak consumption through rate design by charging a higher rate during the peak period than the off-peak period, but unlike DLC, they cannot be dispatched in real time.

TOU rates have been deployed widely across residential consumers in the USA for the past 30 years. Salt River Project and Arizona Public Service are examples of utilities that have successfully implemented residential TOU rates, offering multiple TOU options to encourage a higher rate of participation, and combining one of the options with a demand charge. Both utilities have stressed the importance of educating customers about the rates, potential bill savings, and benefits to the grid. In Canada, the province of Ontario is currently rolling out AMI. By the end of 2010, it is expected that all customers will be on default TOU rates. These rates will feature three pricing periods, with peak period prices for electric generation being three times...
the off-peak period price and the mid-peak period price two times the off-peak period price.

<table>
<thead>
<tr>
<th>Demand response reference products</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is a clear relationship between energy efficiency and demand response programs: ECMs can be aimed to control the intraday energy consumption and hence the load curve on the system</td>
</tr>
<tr>
<td>IHDs provide valuable information to customers about their real-time energy consumption, making easier instant changes on habits and hence, energy savings for customers and less energy load on demand peaks</td>
</tr>
<tr>
<td>Dynamic pricing allows utility companies to dynamically change energy pricings in order to encourage customers to reduce energy consumption on peaks</td>
</tr>
<tr>
<td>DLC programs can be implemented utilizing the existing metering infrastructure by installing a switch operated via a radio signal on the selected appliances, which can be automatically disconnected on demand peaks</td>
</tr>
<tr>
<td>Customers with time-of-use contracts have different tariffs for peak and off-peak periods. TOU rates give utilities the ability to influence peak consumption through rate design by charging a higher rate during the peak period than the off-peak period</td>
</tr>
</tbody>
</table>

### 8.2.4 Active Demand Management: GAD research programme

Finally, GAD research programme has been considered for this study because of its interest in terms of demand response. GAD is a Project formed by a consortium of 15 Spanish entities and research centers, aimed at optimize the energy consumption in low and medium tension, through the application of new mechanisms of active demand side management.

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46 GAD in Spanish stands for “Gestión Activa de la Demanda”, which direct translation is Active Demand Management

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The project is lead by Iberdrola Distribution, one of the biggest Spanish utilities. One of the main purposes is to diminish the environmental impact of electric infrastructures, by the reduction of the construction of new generation plants and the integration of renewable sources into the distribution network. On the other hand, it is sought the promotion of the research of new mechanisms and technologies to the supervision and control of electric demand in domestic and industrial devices, by the application of different final customer and electric mains typologies, allowing to:

- Provide Spanish demand side management technologies
- Impulse the development of technological infrastructures for energy consumption
- Research new strategic technology lines on R+D

On the other hand, new management mechanisms will require electrical net automation, which will help to improve the quality of electrical supply system. The ability to automatically manage electrical loads will allow the optimal integration of renewable sources, aimed to shift as far as possible peaks of consumption to peaks of renewable production.

Summarizing, GAD programme seeks to answer to the next questions:

1. Reduce CO2 emissions, following the principles of sustainable energy consumption agreed in Kyoto protocol
2. Facilitate the integration of distributed generation, improving the management in electrical nets interconnection
3. Diversify energy sources, contributing to the reduction of energy dependency of external countries
4. Improve energy efficiency in final consumers, increasing the information of energy consumption provided to customers
5. Improve the quality of energy supply, trying to minimize peak loads shifting these to valley zones and reducing the possibility of failures
6. Increase the efficiency of electrical mains use, by reducing load peaks and better gauging the capacity of the nets

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7. Better consumption information, by the use of Automatic Meter Management (AMM), establishing new protocols and standards for the application of these devices

8. Optimization of investments in new residential energy installations, aiming to reduce the energy consumption in household sector by the application of standardized method in devices, systems and communications for manage energy consumption in buildings

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**Figure 59: Architecture of an intelligent electrical distribution network**

Source: GAD programme

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### 8.3 Interaction between demand response and M&V

One of the aspects to be taken more into account when designing a demand response program is the way the results are going to be measured. This is a key issue to the success of the initiative because it identifies and quantifies the benefits
obtained. This measurement and verification process must satisfy the following characteristics:

- **Fair**: with ground rules understood and accepted by all stakeholders
- **Accurate**: with appropriate level of detail to assess the outcomes from all possible viewpoints
- **Replicable**: allowing its use as a standard, generating reliable and credible results

Despite this importance, it should be clear that the information requirements of demand response programs are not always equally demanding than those of other energy efficiency initiatives discussed in this document. In a classical improving energy efficiency action (equipment replacement, improvement of installations, etc.), sponsoring company (ESCO) agrees to specific outcomes that justify their fees, in this case, the M&V becomes the main process project.

In case of DR programs, while the M&V is still important, motivation for its use varies substantially.

On one hand, promoters of demand response initiatives must be able to assess the results, not only to justify the investment but also to evolve the program, identify improvements, and propose new DR initiatives. In this regard, those responsible will be interested to know the overall results, comparisons of total consumption before and after implementation of the initiatives, the feedback from users about the initiatives, etc., ignoring the detail of each individual's energy performance.

Additionally, in most DR services, the M&V is also necessary to settle financial commitments to each customer (billing at different energy prices, service interruption, etc.). For this task, more related to the operation of the program, it is necessary to monitor the behavior of each individual client, not to evaluate the results but as a part of the DR process.

Generally, when demand response products are related to a group of initiatives but not to a specific one, bottom-up calculation methods like international M&V guides are not applicable, hindering the individual measurement of the results achieved. In
these cases, top-down approaches can be more suitable, measuring the initiative results directly on the electrical network. This measurement can be made at different levels, from the measurement of the load curve on a single home or small sample group of homes in a neighborhood, to the measurement of this curve in a whole district area. As the sample selected is bigger, it can be seen how the different demand response products are contributing to change the general load curve, and how the global effect on the electric mains is the sum of the different individual results achieved.
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• **Importance of Energy Efficiency Benchmarking and Energy Efficiency and Savings Calculation Methodologies.** TF 190, Jean-Louis Plazy
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ANNEX II: GLOSSARY

- **Avoided energy use**: energy savings in the reporting period if no ECM was implemented in the baseline period in conditions of the reporting period
- **ASHRAE**: American Society of Heating, Refrigerating and Air-Conditioning Engineers
- **Baseline conditions**: set of physical conditions that existed before the implementation of the ECM
- **Baseline Energy or Demand**: energy or demand measures during the baseline period. Baseline consumption can be determined using utility bills, placing energy meters, or simulating the baseline consumption on the facility
- **Baseline period**: period of time selected prior of the implementation of the ECM
- **Commissioning**: process of documenting and verifying the performance of facility systems making the necessary adjustments to meet its intended purpose. The Commissioning should be also verified by an independent agent
- **DOE-FEMP**: measure and verification guide for federal energy projects under the Federal Energy Management Program. This guide is published by The US Department of Energy (DOE)
- **Energy Conservation Measure (ECM)**: an operation or set of operations implemented for the purpose of increasing the energy efficiency of equipment or systems in a facility. It also can reduce energy or demand without changing efficiency
- **Energy Performance Contracts (EPCs)**: documents where the contractor (normally ESCO) provides and arranges financing and implementation of energy improvements. Usually is covered with the savings generated by the implementation of the ECM. Sometimes are also called Energy Savings Performance Contracts (ESPC)
- **Energy Savings Measurement Guide (ESMG)**: energy savings measuring and verification guide published by the Australian Government under the Energy Efficiency Opportunities Program
- **Energy Service Company (ESCO)**: organization or company that designs, finances, procures, installs, and possibly maintains one or more ECMs in a facility
- **Independent variable**: parameter that is expected to change regularly and have a measurable impact on the energy use of a building or system
- **Interactive effects**: energy impacts resulting from changes to one system that are capable to influence to another system
- **Heat Ventilation and Air Conditioning (HVAC)**: System for climate control in buildings. Its objective is to maintain good indoor air quality and provide thermal comfort
- **Measurement boundary**: limit established through equipment in order to determine which of them are important to calculate savings. There are two possible approaches: measuring isolated equipment of measuring total energy performance of a facility
- **Measurement and Verification (M&V)**: evaluation process for determining energy savings by implementing an ECM in a facility
- **M&V Plan**: document that includes the guidelines to apply the M&V process to a specific project
- **Metering**: energy data collected using measuring mechanisms. It is used to check that the ECM functions in accordance with the M&V plan
- **Normalized savings**: adjustments made to the savings due to changes in the baseline conditions during the reporting period
- **Non-Routine adjustments**: changes made to the baseline and the post-retrofit energy data referred to compensate for unexpected changes
• **Proxy**: measured parameter substituted in place of direct measurement of an energy parameter, where a relationship between the two has been proven on site

• **Regression analysis**: statistical technique that describes the correlation between dependent variables and specified independent variables

• **Reporting period**: period of time selected after the implementation of the ECM in which savings are calculated

• **Retrofit**: an ECM installed in order to substitute older parts or equipment in a system for new or modernized ones. This terminology is only used by ASHRAE

• **Routine adjustments**: changes made to the baseline and the post-retrofit energy data referred to expected variations in independent variables

• **Savings determination**: savings are calculated by the difference between baseline and post-retrofit energy data including the adjustments that account the differences in conditions between the baseline and the reporting period. These conditions are determined by surveys, inspections, spot-measurements and metering activities. The general approach is to establish the baseline conditions as a reference in order to report any differences that will occur during the reporting period

• **Static factors**: those aspects of a system which affect energy use although there are not used for doing any routine adjustments. These aspects should include fixed, environmental, operational and maintenance characteristics

• **Super Energy Performance Contracts (SEPCs)**: EPCs under the Federal Energy Management Program

• **Verification**: control activities during the reporting period to guarantee that the M&V plan reaches its purpose

• **Uncertainty**: the range or interval in which is probably situated a verified data with a certain degree of confidence
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