sustaiNability

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Protocol for the valuation of results of investment actions

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1 Introduction

The SustaiNAVility project has been devised to improve energy efficiency, renewable energy and mobilise investments under Navarra's Energetic Plan, in the following scope: public entities (municipalities), public buildings, private buildings and companies.

Specifically, WP5 is focused on the mobilisation of investments for the fulfilment of Energy Efficiency and Renewable Energies measures projects implementation in the Industry and Services, through the systematic detection of possibilities of action to improve the energy efficiency and through a programme of regional incentives.

On the other hand, through task 5.6 "FOLLOW UP OF THE INVESTEMENTS AND MONITORING OF RESULTS" an evaluation of the expected results is necessary with the implementation of the proposed measures in order to monitor them.

For this purpose, a specific methodology will be developed in each measure proposed for the monitoring and evaluation of the results, defining it and facilitating it to each company for each investment to be made, which must be carried out once the measure is developed and implemented on the basis of the expected results.

The monitoring plan for the savings achieved will be developed, according to the International Performance Measurement and Verification Protocol (IPMVP) prepared by EVO (Efficiency Valuation Organization) and internationally recognized.

The IPMVP and the methodology to be followed for each of the actions of the project according to this protocol are described below.

2 International Performance Measurement and Verification Protocol (IPMVP)

The **International Performance Measurement and Verification Protocol** (IPMVP) was developed by the American non-profit organization EVO (Efficiency Valuation Organization) and documented in different publications as an aid to the correct evaluation of investments in energy efficiency, efficiency in the use of water, demand management and renewable energy projects:

The basic principles that characterize the IPMVP Protocol are:

- **Accurate**. The Measurement and Verification reports have to be as accurate as the budget and savings allow.

- **Full**. It must include all the possible effects of the project on energy savings.

- **Conservative**. When estimating with inaccurate amounts, savings should be underestimated.

- **Relevant**. All the worst known relevant parameters should be measured. The least critical or most easily predictable can be estimated.

- **Transparent**. All activities and procedures used must be documented and fully accessible.

Some of the key elements of this protocol are:

- Limit of Measurement. Savings can be determined for the entire facility or just a portion of it, depending on the purpose of the report.
- Selection of the Measurement Period. The length of the reference periods and the savings statement must be selected with special care.
- Adjustment Methods. Two types:

  - *Routine Adjustments*: due to parameters that influence energy and that experience variations during the savings demonstration period, such as weather conditions or the level of production of the plant.

  - *Non-Routine Adjustments*: due to parameters that influence energy and are not expected to change over time: size of the installation, design and operation of existing equipment, number of work shifts or type of occupants.

2.1 IPMVP options

The Protocol Options are described below.

2.1.1 Option A. Isolated verification of the Energy Efficiency Measure (EEM). Key parameter measurement

Savings are determined by measuring at the installation the key parameter that determines the energy consumption of the system where the Energy Efficiency Measure (EEM) has been implemented.

The measurement can be carried out continuously or punctually, depending on the expected variation of the parameter to be measured and the duration of the savings demonstration period.

An estimate is made of the parameter that has not been selected to be measured at the installation (historical data, manufacturer's specifications or technical assumptions).

Option A is suitable if the following conditions exist:

- The uncertainty of the estimates is acceptable.
- The effectiveness of an EEM can be evaluated with a routine inspection of the estimated parameters.
- The estimation of the parameters is less expensive than if it were measured (Option B) or simulated (Option D).
- The key parameter in EEM performance is well known.

In option A, the savings equation does not require any adjustment and only involves measuring a single parameter and estimating the rest, so the equation can be simplified, leaving it as follows:

$$\text{Savings} = (\text{Measured Parameter } P_{ref.} - \text{Measured Parameter } P_{demo}) - \text{Estimated Value}$$

2.1.2 Option B. Measurement of all parameters

The saving is determined by measuring the energy consumption of the system in which the EEM has been implemented in the installation.

The measurement is carried out continuously or punctually, depending on the expected variation in savings and the duration of the savings demonstration period.

This option is valid for most isolated EEM verifications and, although it allows much more precise results to be obtained, especially when conditions are variable, in certain cases it can be very complex and expensive to obtain measurements of all necessary parameters.

As all the parameters are measured, it is not necessary to make any adjustment in the savings equation, so it can be simplified as follows:

$$\text{Option B Savings} = \text{Reference Energy} - \text{Energy Savings Demonstration Period}$$

2.1.3 Option C. Verification of the Entire Installation

Savings are determined by measuring the energy consumption of the entire installation, or a part of it.

The measurement of all the energy consumption of the installation is carried out continuously during the savings demonstration period.

This option is valid when the following circumstances exist:

- The energy performance of the entire installation is evaluated, since several EEMs have been implemented and in some of these improvements it may be excessively complex to obtain measurements using isolated verification techniques (options A/B).
- Expected savings are high, around 10% compared to the reference period.
- No significant changes are expected in the installation during the savings demonstration period.
- It is possible to relate the energy consumption with the independent variables.
- It is possible to implement a system that records static variables to introduce possible non-routine adjustments.

2.1.4 Option D. Calibrated Simulation

Savings are determined by simulating the energy consumption of the entire installation, or a part of it.

The simulation has to be able to model the current energy performance of the installation.

This option often requires special skills to perform calibrated simulations.

Option D is useful when the energy data for the reference period are not available (because it is a new installation or because there are no metering equipment during that period) or for the savings demonstration period, never both. It is also feasible when obtaining measurements from the other options is excessively expensive or complex.

Once the simulation model has been calibrated, the energy saving equation can be applied:

Savings = $\text{Energy}_{\text{ref}}$ Calibrated Model without EEM - $\text{Energía}_{\text{demo}}$ savings Model Calibrated with EEM

2.2 Content of the M&V plan

The Protocol establishes a methodology for the preparation and design of M&V Plans based on the following steps:

- Specify the necessary method of Measurement and Verification to determine whether it should be for the entire installation or, on the contrary, it is necessary to focus on a specific saving measure and make an isolated verification (measurement limit).

- Select the most appropriate IPMVP option based on the client's needs and decide the conditions that will be taken into account for the consumption adjustments in the savings demonstration period, in addition to taking into account its duration. For this, it is convenient to carry out an energy audit that specifies all the data of the reference period, such as the energy consumed the independent variables or the static variables.
- Register the consumption and operations of the reference period and prepare a Measurement and Verification Plan that contains the data of the previous steps to define the next steps.
- Design and calibrate and commission any necessary measuring equipment and, once installed, check that they are adapted to the purpose of the designed EEMs.
- Compile the previously defined consumption and operations of the savings demonstration period and calculate the savings in energy and monetary terms to prepare the savings demonstration report.

The content of a Measurement and Verification Plan must be:

- Objective of the EEM: description of the measure, its objective, the start-up procedure, etc.
- Protocol option selected and measurement limit.
- Reference period: document the conditions of the reference period and the energy data of the measurement limit.
- Demonstration savings period.
- Basis for adjustment: adjustment conditions considered.
- Analysis procedure: justification of calculations, algorithms used and assumptions of each savings report.
- Energy prices: indication of energy prices that will be used to evaluate savings and how to adjust to future price variations.
- Measurement specifications: measurement points and periods for taking readings if the measurement is not continuous.
- Monitoring responsibilities: assign the responsibilities for preparing reports and records of consumption, independent and static variables, within the measurement limit during the savings demonstration period.
- Expected precision: evaluate the expected precision of the measurement, data collection, sampling and analysis of the data.
- Budget: define the budget and resources necessary to determine savings.
- Report format: define the format and content of the savings demonstration reports.
- Quality: specify the procedures to ensure quality.

3 Replacement of compressors of the current compressed air installation by compressor with speed variator in plastics processing plant

3.1 Introduction

The company, which is dedicated to the transformation of plastics, manufacturing various PVC compounds for different applications, has proposed an energy conservation measure that consists of the modification of the compressed air generation installation incorporating a new compressor of 160 kW of power with a speed variator that replaces the current ones and, which remain in reserve situation within said installation.

Likewise, simultaneously with this replacement, the centralization of the compressed air generation facility is planned in a single room, since, at present, each of the compressors is located in different areas of the plant according to the production lines to which they cover.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

3.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the power consumption of the compressor by reducing the main losses in screw compressors with fixed regulation that occur when the compressors go into unloaded or empty, once they reach the maximum pressure and until the installation reaches the minimum starting pressure and that are due to:

- The compressor in discharge consumes approximately 30% to 40% of the nominal power of the installation.
- Likewise, a compressor with start-stop operation needs to generate more pressure than necessary to cover the operating range of the equipment. For each additional bar the equipment will consume 7% more electrical energy.
- Also in each load / vacuum cycle, the compressor must vent the internal air to the outside for a new cycle start.

2. Selected IPMVP Option and Measurement Boundary

The compressed air system will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The electrical energy consumed by the compressor system will be measured through the control panel of the compressors themselves in the compressor room.

This measurement limit ignores any reduction in waste heat drawn from the compressor room by wall-mounted exhaust fans, since the compressor room air is discharged outside the building, it has no impact on the requirements of plant cooling or heating. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

In order to propose the planned measure, we started from measurements carried out in the installation prior to EEM, where it has been observed that one of the compressors works practically at 100% of its load while the other does it at 57%, the remaining 43% being unloaded. This means that the average daily consumption demanded for compressed air is around 151.36 kWh.

During the period of baseline test, that plant was producing 17,178 tonnes and the plant was operating three shifts a day, five days a week.

During this baseline test, there were two fixed speed screw compressors of 75 kW each in different rooms.

4. Reporting Period

The operating personnel of the plant will read the data collected in the control panel of the compressors and will record it according to the periodicity proposed by the production department of the plant in order to prepare the expected reports (e.g. monthly).

5. Basis for Adjustment

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when the plant was in operation and collect the compressor meter readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm \text{Non-Routine Adjustments}$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 151.36 kWh for the number of days in the established period.

Actual = Total energy measured in the compressor control panel for the period.

Non-Routine Adjustments = any adjustments needed due to changes in compressed air system design or operation or changes in plant operations. The plant engineer will compute these amounts after reviewing any changes to production or to the compressed air system which might affect compressor energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times Rate$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the electricity prices of the supply company will be used.

The electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The measurements of the compressor consumption will be collected by the person in charge from the data given by the control panel of the same for the established period. Each reading will include a signature of the person doing the reading.

If a meter reading is lost during the reporting period, the plant engineer will interpolate the previous and next shift readings to estimate the missing reading. The energy savings reports will indicate how many estimated readings were involved in each reporting period.

9. Monitoring Responsibilities

With a periodicity set by the production department of the plant, the configuration of the compressor control parameters, such as pressure and sequencing devices, will be reviewed.

10. Expected Accuracy

The probability distribution of electricity meter readings about their mean values is assumed to be 'normal.' The variations created by meter precision are included in the observations and the associated standard deviations.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- *Operating staff forget to read the meter*. Any meter reading that is missed can be estimated from subsequent actual readings. Though estimates may add more than the usual variability to the data, the net error in the results will be small and not controllable at any reasonable cost.
- *Actual meter readings are not made, though the log sheet is filled in*. When the plant engineering department collects the monthly meter reading log sheet from the MCC he/she will check that the last recorded reading is close to the actual reading at the time. Any discrepancies can be traced back to the person signing the readings.
- *Changes to the compressed air system or plant operations that affect compressed air energy use are:*
    - *not identified*. The plant engineering department will regularly review plant records of all sorts to ensure it is aware of all compressed air changes. It will also periodically examine system control settings and operations. If reported savings change by more than 10%, the plant engineering department will resurvey all installed compressed air equipment and operations, to ensure all necessary non-routine adjustments have been made.
    - *identified, but not included in a non-routine adjustment*. The necessity of making an adjustment for any particular small change may not be clear. However if reported savings change by more than 10%, a thorough survey of the compressed air system will help to identify the relative significance of all changes.

4 Replacing the current machine cooling installation by means of towers with high efficiency air condensed water chillers in a bearing manufacturing plant

4.1 Introduction

The company, which is dedicated to the manufacture of double angular contact bearings for the automotive industry, has proposed an energy conservation measure that consists of the replacement of the current water cooling system with cooling towers for KYL1 with a new system consisting of water chillers, as well as the integration of the current KYL4 system.

Hydraulic modifications has been made to install two new air-condensed water cooling equipments with high-efficiency Carrier chillers. One of the currently installed equipment (30GK120) will be integrated into the system as it is in good condition.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

4.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the power consumption of the installation due to:

- Best performance of installed high-efficiency chillers
- Elimination of cooling tower pumps and improved performance of newly installed pumps. The compressor in discharge consumes approximately 30% to 40% of the nominal power of the installation.

2. **Selected IPMVP Option and Measurement Boundary**

The machine cooling system will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The electrical energy consumed by the machine cooling system will be measured through the energy management system available to the company.

The heat generated by the chillers has no impact on the cooling or heating requirements of the plant as they are located outside. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

When carrying out the feasibility study of the project to replace the current process refrigeration installation, the starting point was made from the operating data provided by the company and the energy consumption for the baseline period was calculated, depending on the outside temperature and the thermal loads of the installation.

According to the results obtained in the study, the energy consumption of the baseline period would be 1,546,991 kWh/year and its energy cost of € 131,977.50/year.

The conditions under which the energy consumption for the baseline period has been calculated are as follows:

Climatology	
City	Pamplona, ESP
Schedule	On all day: Monday to Sunday
	Different thermal loads
Loads (Cooling)	
Load (Monday to Friday)	1.000 kW
Load (Saturday to Sunday)	400 kW

During the period of baseline test, the plant was operating three shifts, seven days a week.

During this baseline test, the installation consists of:

Machine cooling system KYL1

The main equipment associated with this system is three cooling towers with an electrical power of 15 kW each, forced draft and equipped with a modular type axial fan. Under normal operating conditions, the air-water contact causes an evaporation of part of the water of approximately 1% of the total water flow for every 7°C of cooling.

The temperature at which the liquid is found after cooling the process is approximately 30-35°C, which is why it passes through the cooling towers, where with a maximum thermal jump of 3°C, it is cooled.

One of the cooling towers works permanently and has a frequency inverter installed, while the other 2 cooling towers work as reinforcement depending on the needs. Using the inverter allows you to adjust the fan speed according to your needs.

Machine cooling system KYL4

Pumping system

The two refrigeration installations described have different pumps associated with each of the systems:

- Cooling tower pumps. Three pumps of 15 kW each.
- KYL1 cooling impulsion pumps. Two pumps of 55 kW each.
- KYL4 cooling impulsion pumps. Three pumps of 5.5 kW each and two of 7.5 kW.
- Emulsion system pumps. Two pumps of 37 kW and another two of 45 kW each.
- Turning process pumps. A 30 kW pump.
- Hydraulic oil pumps. One of 75 kW.
- Litex pumps and lapping. Two pumps of 18.5 kW each, two of 30 kW and another two of 15 kW.
- Heating system pumps. One of 18.5 kW.

An energy model will be established through a regression analysis that relates the energy consumption with the independent variables, such as the number of degree days of cooling and/or heating (CDD and/or HDD). The regression model will take the following form:

$$Energy\ consumption(kWh) = a + b_1CDD + b_2HDD$$

where:

a is the baseline HVAC system not dependent on independent variables (e.g. base load ventilation power consumption),

b_1 is the coefficient of the independent variable CDD,

b_2 is the coefficient of the independent variable HDD.

4. Reporting Period

The operating personnel of the plant will collect the data from the company's energy management system and record them according to the periodicity proposed by the plant's production department to prepare the expected reports (for example, monthly).

5. Basis for Adjustment

The data will be analyzed and savings calculated according to the prepared M&V plan. Post-implantation performance will be analyzed against baseline to:

- Calculate the savings, adjusting the independent variables
- If included, adjust savings for interactive effects.
- Estimate the uncertainty of savings.

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when it was in operation and collect the facility data from the company's energy management system. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm \text{Non-Routine Adjustments}$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 1,546,991 kWh/year.

Actual = Total energy measured in the company's energy management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times Rate$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the electricity prices of the supply company will be used. The electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The measurements of the consumption of the installation will be collected by the person in charge from the data provided by the energy management system for the established period. Each reading will include the signature of the person doing the reading.

If a meter reading is lost during the reporting period, the plant engineer will interpolate the readings from the previous and next shift to estimate the missing reading. The energy savings reports will indicate how many estimated readings were involved in each reporting period.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Uncertainty

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- Operating personnel forget to read the meter. Any meter reading that is lost can be estimated from subsequent actual readings. Although the estimates may add more variability than usual to the data, the net error in the results will be small and uncontrollable at a reasonable cost.
- No actual meter readings are made, even though log sheet is completed. When the plant engineering department collects the monthly meter reading log sheet from the MCC, it will verify that the last reading recorded is close to the actual reading at that time. Any discrepancies can be traced back to the person signing the readings.
- Changes in the facility or in plant operations that affect the use of energy in the plant are:
  - *unidentified. The plant engineering department will periodically review plant records of all types to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all equipment and operations in the facility, to ensure that all necessary non-routine adjustments have been made.*
  - *identified, but not included in a non-routine adjustment. The need to make an adjustment for any* particular small change may not be clear. However, if the reported savings change by more than 10%, a careful study of the facility will help identify the relative importance of all changes.

5 Replacing the current steam boilers with a steam boiler with the incorporation of more efficient systems in food industry

5.1 Introduction

The company, which is dedicated to the manufacture of fats and meat meal, has proposed an energy conservation measure that consists of the replacement of the current steam generation system with two natural gas boilers with a single natural gas pyrotubular steam boiler with a steam production of 16,000 Kg/h. and the incorporation of more efficient systems.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

5.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation due to the incorporation of the following equipment that makes it more efficient:

- **Frequency converter in the combustion equipment engine** as auxiliary equipment of the combustion equipment, which allows the conditioning of the speed of the combustion equipment engine to the operating conditions, optimally controlling the combustion air fan in all ranges of operation, considerably reducing electricity consumption, there is a reduction in noise and the load on cold starts is reduced.

- **O_2 control in combustion equipment**, as auxiliary equipment of combustion equipment for combustion optimization, being able to produce fuel savings up to a maximum of approximately 0.5%, by stabilizing the rest of the oxygen content in the exhaust gases, exhaust, damping disturbances such as variation in air temperature, air pressure and the calorific value of the fuel.

- **Combustion air preheater by recovering heat from combustion gases**, as auxiliary equipment of the boiler for the recovery of heat from the combustion gases coming from the steam boiler, to raise the temperature of the mixing air for combustion.

2. Selected IPMVP Option and Measurement Boundary

The steam boiler will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option A.

The electricity associated with the burner and fan boiler auxiliaries is excluded from this limit as it is a not very significant improvement compared to the rest.

The natural gas consumed by the steam generation system will be measured through the natural gas bills issued by the supply company, since it is the only point of consumption of this energy in the company.

The heat generated by the boiler has no impact on the cooling or heating requirements of the plant, as it is located in a specific room that does not have air conditioning. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

When carrying out the feasibility study of the action to replace current steam boilers with a more efficient one, the latest combustion measurements carried out by the company have been used in order to obtain their current performance and compare it, with which it would be obtained with the new one that will have a heat recovery unit.

According to the results of the measurements obtained, the calculation of the average yield has been made with the following parameters:

	Averages combustion parameters
Gas temperature	212,7 °C
% O_2	3,9%
CO	0 ppm

With these data, the energy balance was made, giving a boiler efficiency of 89.62%

According to the data obtained from the company's natural gas bills, the energy consumption of the base period would be 31,185,654 kWh / year and its energy cost of € 937,069.89.

During the period of baseline test, the plant was operating three shifts, 252 days/year.

The plant's initial steam generation facility consists of two natural gas boilers of 4,000 Kg/h and 6,000 Kg/h of steam to cover the plant's steam demand. These boilers are located in a single room designed for this purpose.

The post-retrofit annual energy use for Equation in section 6 is determined from the base year use and taking into account the returns measured before and after implementation:

Post-retrofit annual energy = Base year annual energy use * Base year performance / Post-retrofit performance + Correction to post-retrofit condition

C is an unknown quantity required to convert the projected base year usage of the new boiler to post-retrofit conditions.

4. Reporting Period

Savings will be calculated annually for the following year using the boiler efficiency data measured each year. The natural gas consumption data from the utility company invoices will be saved.

5. Basis for Adjustment

The data will be analyzed and savings calculated according to the prepared M&V plan. Post-implantation performance will be analyzed against baseline to:

- Calculate the savings, adjusting the independent variables
- If included, adjust savings for interactive effects.
- Estimate the uncertainty of savings.

Routine adjustments are needed to bring post-retrofit energy use to the conditions of the base year. This is exactly the correction amount C.

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when it was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

S = ABL – Actual ± Non-Routine Adjustments

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 1,546,991 kWh/year.

Actual = Total energy measured in the company's energy management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

Period Cost Avoidance = S x Rate

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the natural gas prices of the supply company will be used. The natural gas Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

Measurements of the parameters that allow us to calculate the efficiency of the boiler under the same conditions as the base year will be carried out.

Natural gas bills will be saved and used in order to evaluate the consumption of the boiler, since it is the only point of consumption of this energy.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Uncertainty

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- Operating personnel forget to read the meter. Any meter reading that is lost can be estimated from subsequent actual readings. Although the estimates may add more variability than usual to the data, the net error in the results will be small and uncontrollable at a reasonable cost.
- No actual meter readings are made, even though log sheet is completed. When the plant engineering department collects the monthly meter reading log sheet from the MCC, it will verify that the last reading recorded is close to the actual reading at that time. Any discrepancies can be traced back to the person signing the readings.
- Changes in the facility or in plant operations that affect the use of energy in the plant are:
  - *unidentified. The plant engineering department will periodically review plant records of all types to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all equipment and operations in the facility, to ensure that all necessary non-routine adjustments have been made.*
  - *identified, but not included in a non-routine adjustment. The need to make an adjustment for any* particular small change may not be clear. However, if the reported savings change by more than 10%, a careful study of the facility will help identify the relative importance of all changes.

6 Substitution of a digester in batch by another in continuous in food industry

6.1 Introduction

The company, which is dedicated to the manufacture of fats and meat meal, has proposed an energy conservation measure that consists of the replacement of current smelting-digestion system in line 1 by means of a batch digester with another Continuous Digester for the cooking of animal by-products continuously.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

6.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation by improving the energy efficiency of the equipment, due to:

- A lower average steam consumption per tm of water evaporated in the digester in continuous.
- Lower installed electrical power.

The estimated average steam consumption of the equipment is 1.4 t. of steam for each t. of evaporated water and an installed capacity of 90 kW.

2. **Selected IPMVP Option and Measurement Boundary**

The digester will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The electricity associated with the digester equipment is excluded from this limit as it is a not very significant improvement compared to the rest.

The natural gas consumed by the steam generation system will be measured through the natural gas bills issued by the supply company, since it is the only point of consumption of this energy in the company.

The heat generated by the digester has no impact on the cooling or heating requirements of the plant, as it is located in a specific room that does not have air conditioning. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

To calculate the energy consumption of the base period with the discontinuous digester of line 1, the data of average steam consumption per ton of evaporated water of the equipment provided by the supplier was used.

The data that have been taken into account to calculate the energy consumption and costs of the current installation are the following:

	Batch digester
Average steam consumption	1,6 tm steam/tm evaporated water
M.P. consumption 2018 line 1	17.982 t.
Medium humidity	56,5%
Steam pressure	10 bar

(*) Considering the average boiler feed water temperature of 80 °C.

With these data, a steam consumption of 16,255 tons / year, a natural gas consumption of 11,872,659 kWh / year and an energy cost of € 356,750.92 have been calculated for the base period. During the period of baseline test, the plant was operating three shifts, 252 days/year.

At the present time, for the foundry-digestion process in each of the lines, the company has an installation using a batch digester designed to cook, sterilize or hydrolyze animal by-products, where the raw material is heated by a cover heated by indirect steam while being agitated by a rotating shaft heated by steam. The water inside the raw material evaporates under controlled conditions and the dried material is discharged to continue its process.

The estimated average steam consumption of the equipment is 1.6 t. of steam for each t. of evaporated water and an installed power of 110 kW.

4. Reporting Period

The savings will be calculated annually for the following year using the data of the parameters collected from the team's management system with the periodicity included in the M&V plan. The natural gas consumption data from the utility company bills will be saved.

5. Basis for Adjustment

The data will be analyzed and savings calculated according to the prepared M&V plan. Post-implantation performance will be analyzed against baseline to:

- Calculate the savings, adjusting the independent variables
- If included, adjust savings for interactive effects.
- Estimate the uncertainty of savings.

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when it was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm \text{Non-Routine Adjustments}$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 1,546,991 kWh/year.

Actual = Total energy measured in the company's energy management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times Rate$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the natural gas prices of the supply company will be used. The natural gas Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The values of the PLC parameters available in the digester will be collected and will allow us to calculate the steam consumption equipment and therefore the natural gas consumption.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Uncertainty

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- Operating personnel forget to read the meter. Any meter reading that is lost can be estimated from subsequent actual readings. Although the estimates may add more variability than usual to the data, the net error in the results will be small and uncontrollable at a reasonable cost.

- No actual meter readings are made, even though log sheet is completed. When the plant engineering department collects the monthly meter reading log sheet from the MCC, it will verify that the last reading recorded is close to the actual reading at that time. Any discrepancies can be traced back to the person signing the readings.

- Changes in the facility or in plant operations that affect the use of energy in the plant are:

    - *unidentified. The plant engineering department will periodically review plant records of all types to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all equipment and operations in the facility, to ensure that all necessary non-routine adjustments have been made.*

    - *identified, but not included in a non-routine adjustment. The need to make an adjustment for any* particular small change may not be clear. However, if the reported savings change by more than 10%, a careful study of the facility will help identify the relative importance of all changes.

7 Installation of photovoltaic solar energy for self-consumption in the agri-food industry

7.1 Introduction

The company, which is dedicated to the manufacture of non-carbonated beverages, nectars and packaged fruit juices, has proposed the installation of a photovoltaic solar plant for the generation of electric energy in self-consumption and without grid injection.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the Procedure for Measuring and Reporting the Performance of Photovoltaic Systems in Buildings of the National Renewable Energy Laboratory (Technical Report NREL/TP-550-38603 October 2005).

7.2 M&V plan

1. **Identify project goals**

The purpose for conducting the performance analysis is determining energy cost savings accruing from the PV system.

This M&V plan is also proposed in order to know:

- The energy produced by the photovoltaic system.
- The part of the electrical power of the plant that is generated on site.

2. **Determine the boundaries of the site to be analyzed**

The entire photovoltaic system is included

3. **Select Tier 1 or Tier 2 analysis**

In this case, a Tier 1 analysis is carried out and the following main data will be determined:

- Net production of the photovoltaic system
- Net electricity use of the facility
- Total electricity use of the facility.
- Equivalent hours of nominal maximum photovoltaic production.

4. **Specify desired accuracy of results**

The precision of the results will be that given by the monitoring equipment installed

5. **Develop estimated budget for performance analysis**

Labour costs are assumed to be zero, as there has been no record of labour to collect the data, calculate the results, or prepare the M&V Plan.

They have been accepted by the management of the operations and engineering departments as new normal tasks. Because the installed monitoring equipment is digital, no recalibration costs will be incurred.

6. **Identify period of analysis**

The analysis period according to Level 1 will be annual to evaluate long-term trends and verify energy savings

7. **Gather basic site and PV system data**

The specific information on the building and the photovoltaic system are those collected in the installation project carried out

8. **Obtain pre-existing performance data**

There is no previous data because it is a new installation

9. **Select performance metrics to be measured**

The measurement data to be collected are:

- Total PV System Production.
- Net PV System Production.
- Equivalent Annual Hours of Peak Rated PV Production.
- Total Facility Electricity Use.

10. **Specify frequency of each measurement**

As it is a Level 1 analysis, monthly data is required

11. **Determine feasibility of measurements**

The feasibility of the proposed measurements will be determined according to the existing measurement devices in the installation

12. Calculate uncertainty of measurements

You will document the precision of each measuring device and apply common statistical methods to calculate the uncertainty of the metrics obtained by adding, subtracting, multiplying and dividing the measured data.

The accuracy requirements determined in Step 4 must be balanced against the costs of measurement and analysis.

13. Data Collection and Analysis

Data analysis consists of determining the values of all required results based on the data collected and will be performed in accordance with the following best practices:

- Energy Balances. In cases where one metric is the sum of (or difference between) several other metrics, the recommended practice is to measure each metric individually and use the summation as a check on the consistency of the data. This is also a more accurate way to determine a total, rather than summing the constituent metrics. Any inconsistencies should be reconciled (corrected, or at least understood and reported).
- Immeasurable parameter. If a parameter cannot practically be measured directly, it may need to be determined based on a sum of or difference between other metrics. However, this practice sacrifices the benefit of energy balance checking, and is less accurate.
- Missing Data. If intervals of data are missing because of a DAS malfunction, one of the following approaches should be applied:
  - Extend the period of data collection so that a complete year of data is obtained, and modify the period of analysis to use the complete year of data.
  - Report "Missing Data" in lieu of metrics for the periods affected.
  - Apply the best available method for estimating the missing data, and include the uncertainty introduced by this method in the reported measurement uncertainty. (Large, continuous gaps are more difficult than intermittent lapses to restore.).

14. Monthly Analysis

The procedure for this analysis must consider the following sections:

- *Identify months of analysis*. They may be the standard months from January to December or, in the event that due to the company's needs, the annual period does not follow this criterion, it may be 12 approximately equal divisions of one year.
- *Use average daily values*. Monthly results should be reported as monthly totals in table form and as average daily values in graphical form. The use of daily mean values avoids weighting the results by the number of days per month, which can vary slightly from month to month.

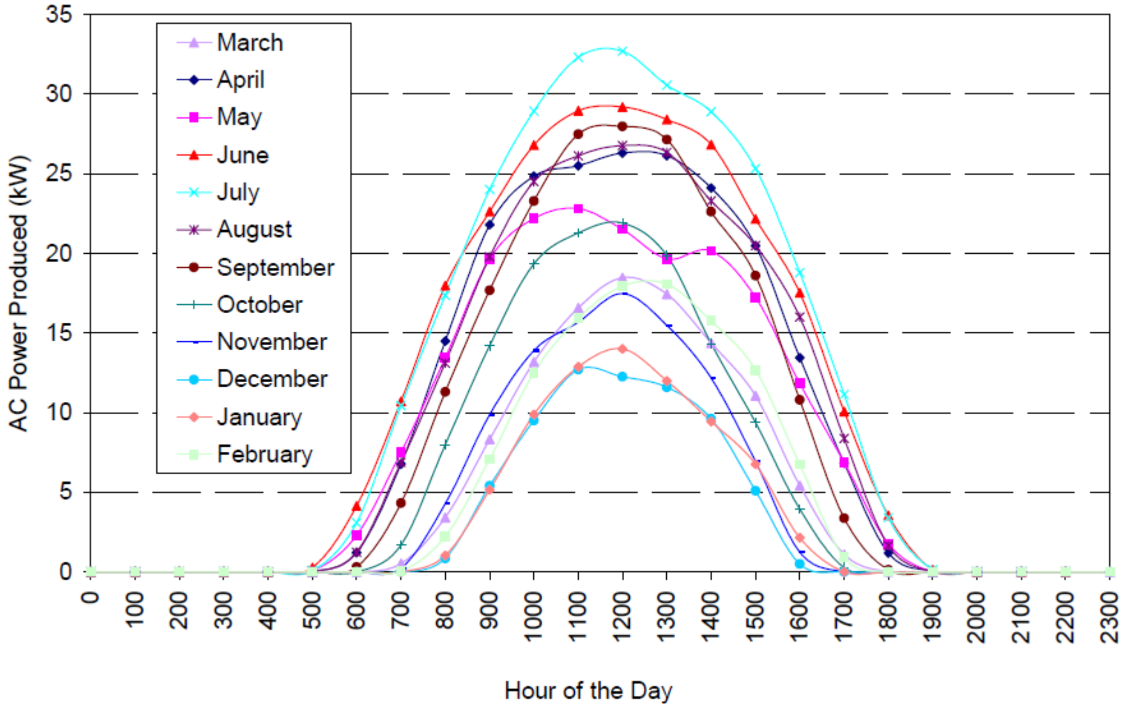
- *Identify the year of analysis*. Annual totals are determined by adding 12 consecutive monthly totals and adjusting the number of days included. A year of analysis consists of 365 consecutive days, regardless of whether the data was collected during a leap year. In the event that the 12 consecutive months amount to a little more or less than 365 days, the total must be adjusted by adding or subtracting the average daily values symmetrically at the beginning and end of the year of analysis.

15. Reporting Format

The final report of this procedure must include:

- Project definition form, which must include the points specified in this procedure.
- Table of monthly results, including all the parameters listed in the measurement plan following a format as shown.

Metric	Month												Annual
	1	2	3	4	5	6	7	8	9	10	11	12	
Net PV Production													
Total Facility Energy Use													
Facility Electrical Load Offset by PV Production													
PV System AC Electricity Generation Effectiveness													
Net Facility Electricity use													
Peak Demand of Net Facility Electricity Use													
Peak Demand of Total Facility Electricity Use without PV System													
Reduction of Peak Demand Resulting from PV System													
Energy Cost Savings Resulting from PV System													



To report the cost results in a way that facilitates their interpretation, the following sections should be used

- Electricity costs of the facilities (€/year).
- Electricity costs of the installation without photovoltaic system (€/year).
- Energy cost savings as a result of the photovoltaic system (€/Year/ m^2).

8 Substitution of cogeneration engines for more efficient ones in the food industry

8.1 Introduction

The company, which is dedicated to the manufacture and markets artificial cellulose, collagen and fibrous casings for meat products, has proposed an energy conservation measure that consists of the replacement two of the engines of the cogeneration installation in its phase 1 of 3.33 MW each, coupled to a 6.3 kV synchronous generator of 3,695 kVA, with natural gas consumption of 8,663 kW (unit) and exhaust gas recovery of 1,417 kW (unit) to generate process steam and use of 1,496 kW (unit) of high temperature heat in a process distribution water circuit with water temperatures of 94ºC-76ºC with two other natural gas engines of equal power (3,300 kW electric each), coupled to a synchronous generator at 6.3 kV of 3,695 kVA with natural gas consumption of 7,457 kW (unit) and exhaust gas recovery of 1,237 kW (unit) for process steam generation and use of 1,380 kW (unit) of high temperature heat in a water distribution circuit to process.

This replacement supposes the adaptation of the current facilities with the following modifications:

- The **bench** of each of the engines has been adapted, since the dimensions of the new engines are somewhat larger and weigh more than the replaced ones.
- A modification has been made to the gas supply line to this installation since the minimum gas supply pressure for the new engine is 5.3 bar compared to 3 bar for the previous one.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

8.2 M&V plan

1. Aim of the Energy Efficiency Measure (EEM)

The EEM reduces the energy consumption of the installation by improving the electrical performance of the equipment by going from an initial installation performance of 40% to a new performance of the new equipment greater than 46%, which, although this implies a lower energy recovery capacity, for the same production of electrical energy the overall balance represents an energy saving compared to the initial installation.

2. Selected IPMVP Option and Measurement Boundary

The cogeneration installation will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The heat generated by the engines has no impact on the cooling or heating requirements of the plant, as it is located in a specific room that does not have air conditioning. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

To calculate the energy consumption of the baseline period, the data collected in the installation management system were used.

With these data, the installation with the replaced engines supposed a natural gas consumption of 141,146,026 kWh/year and a heat recovery of 47,468,688 kWh/year (52,742,987 kWh/year of natural gas consumption in a boiler with a performance of 0.9), which meant a net natural gas consumption of 88,403,039 kWh/year for the installation. During the period of baseline test, the plant was operating three shifts a day, seven days a week.

During this baseline test, the equipment installed in phase N ° 1 of 9,990 kW, object of this project, is made up of three natural gas turbogenerators of 3.33 MW each, coupled to a 6.3 kV synchronous generator of 3,695 kVA, with natural gas consumption of 8,663 kW (unit) and exhaust gas recovery of 1,417 kW (unit) to generate process steam and use of 1,496 kW (unit) of high temperature heat in a process distribution water circuit with water temperatures of 94°C-76°C.

4. Reporting Period

The savings will be calculated annually for the following year using the data of the parameters collected from the team's management system with the periodicity included in the M&V plan. The natural gas consumption data from the utility company bills will be saved.

5. Basis for Adjustment

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when the plant was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

S = ABL – Actual ± Non-Routine Adjustments

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 151.36 kWh for the number of days in the established period.

Actual = Total energy measured in the equipment management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

Period Cost Avoidance = S x Rate

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the natural gas and electricity prices of the supply company will be used.

The natural gas and electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The values of the parameters of the equipment management system will be collected and will allow us to calculate the electricity generated and the heat recovered in the installation and therefore the consumption of natural gas.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Expected Accuracy

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- *Operating staff forget to read the meter.* Any meter reading that is missed can be estimated from subsequent actual readings. Though estimates may add more than the usual variability to the data, the net error in the results will be small and not controllable at any reasonable cost.
- *Actual meter readings are not made, though the log sheet is filled in.* When the plant engineering department collects the monthly meter reading log sheet from the MCC he/she will check that the last recorded reading is close to the actual reading at the time. Any discrepancies can be traced back to the person signing the readings.
- *Changes to the cogeneration installation or plant operations that affect engine energy use are:*
    - *unidentified. The plant engineering department will periodically review plant records of all kinds to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all facility equipment and operations to ensure all necessary non-routine adjustments have been made.*
    - *identified, but not included in a non-routine adjustment.* The necessity of making an adjustment for any particular small change may not be clear. However if reported savings change by more than 10%, a thorough survey of the compressed air system will help to identify the relative significance of all changes.

9 Installation of photovoltaic solar energy for self-consumption in the agri-food industry

9.1 Introduction

The company, which is dedicated to the manufacture and markets artificial cellulose, collagen and fibrous casings for meat products, has proposed the installation of a photovoltaic solar plant for the generation of electric energy in self-consumption and without grid injection.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the Procedure for Measuring and Reporting the Performance of Photovoltaic Systems in Buildings of the National Renewable Energy Laboratory (Technical Report NREL/TP-550-38603 October 2005).

9.2 M&V plan

1. **Identify project goals**

The purpose for conducting the performance analysis is determining energy cost savings accruing from the PV system.

This M&V plan is also proposed in order to know:

- The energy produced by the photovoltaic system.
- The part of the electrical power of the plant that is generated on site.

2. **Determine the boundaries of the site to be analyzed**

The entire photovoltaic system is included

3. **Select Tier 1 or Tier 2 analysis**

In this case, a Tier 1 analysis is carried out and the following main data will be determined:

- Net production of the photovoltaic system
- Net electricity use of the facility
- Total electricity use of the facility.
- Equivalent hours of nominal maximum photovoltaic production.

4. **Specify desired accuracy of results**

The precision of the results will be that given by the monitoring equipment installed

5. **Develop estimated budget for performance analysis**

Labour costs are assumed to be zero, as there has been no record of labour to collect the data, calculate the results, or prepare the M&V Plan.

They have been accepted by the management of the operations and engineering departments as new normal tasks. Because the installed monitoring equipment is digital, no recalibration costs will be incurred.

6. **Identify period of analysis**

The analysis period according to Level 1 will be annual to evaluate long-term trends and verify energy savings

7. **Gather basic site and PV system data**

The specific information on the building and the photovoltaic system are those collected in the installation project carried out

8. **Obtain pre-existing performance data**

There is no previous data because it is a new installation

9. **Select performance metrics to be measured**

The measurement data to be collected are:

- Total PV System Production.
- Net PV System Production.
- Equivalent Annual Hours of Peak Rated PV Production.
- Total Facility Electricity Use.

10. **Specify frequency of each measurement**

As it is a Level 1 analysis, monthly data is required

11. **Determine feasibility of measurements**

The feasibility of the proposed measurements will be determined according to the existing measurement devices in the installation

12. Calculate uncertainty of measurements

You will document the precision of each measuring device and apply common statistical methods to calculate the uncertainty of the metrics obtained by adding, subtracting, multiplying and dividing the measured data.

The accuracy requirements determined in Step 4 must be balanced against the costs of measurement and analysis.

13. Data Collection and Analysis

Data analysis consists of determining the values of all required results based on the data collected and will be performed in accordance with the following best practices:

- Energy Balances. In cases where one metric is the sum of (or difference between) several other metrics, the recommended practice is to measure each metric individually and use the summation as a check on the consistency of the data. This is also a more accurate way to determine a total, rather than summing the constituent metrics. Any inconsistencies should be reconciled (corrected, or at least understood and reported).
- Immeasurable parameter. If a parameter cannot practically be measured directly, it may need to be determined based on a sum of or difference between other metrics. However, this practice sacrifices the benefit of energy balance checking, and is less accurate.
- Missing Data. If intervals of data are missing because of a DAS malfunction, one of the following approaches should be applied:
  - Extend the period of data collection so that a complete year of data is obtained, and modify the period of analysis to use the complete year of data.
  - Report "Missing Data" in lieu of metrics for the periods affected.
  - Apply the best available method for estimating the missing data, and include the uncertainty introduced by this method in the reported measurement uncertainty. (Large, continuous gaps are more difficult than intermittent lapses to restore.).

14. Monthly Analysis

The procedure for this analysis must consider the following sections:

- *Identify months of analysis*. They may be the standard months from January to December or, in the event that due to the company's needs, the annual period does not follow this criterion, it may be 12 approximately equal divisions of one year.
- *Use average daily values*. Monthly results should be reported as monthly totals in table form and as average daily values in graphical form. The use of daily mean values avoids weighting the results by the number of days per month, which can vary slightly from month to month.

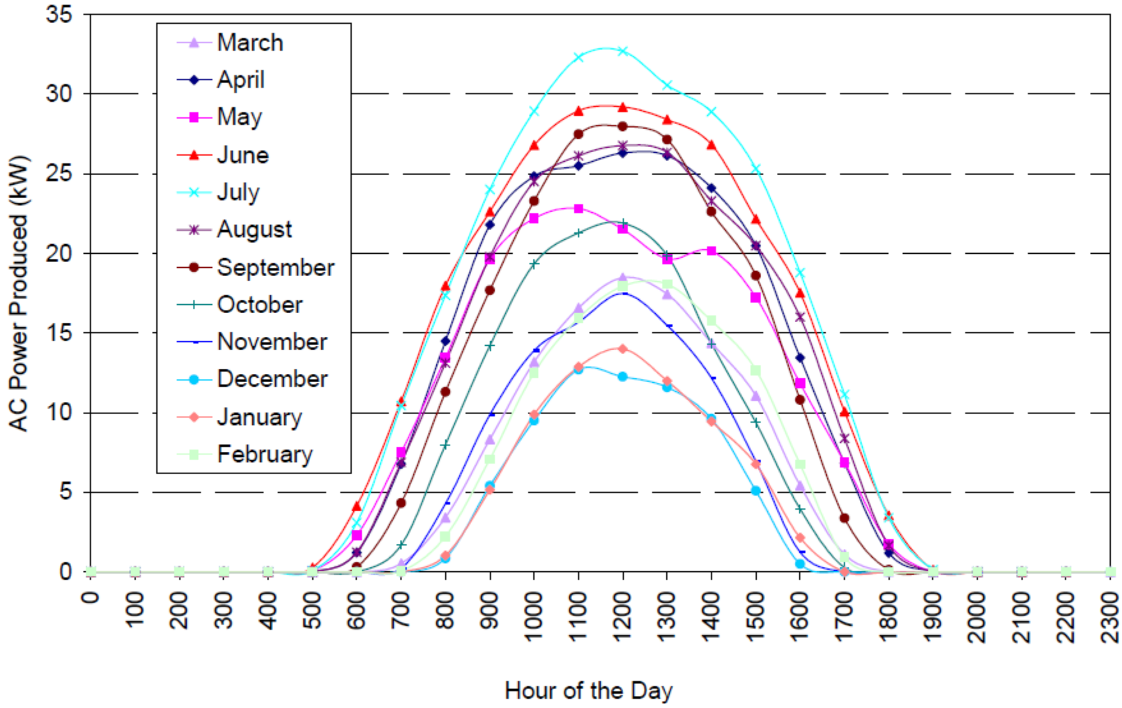
- *Identify the year of analysis*. Annual totals are determined by adding 12 consecutive monthly totals and adjusting the number of days included. A year of analysis consists of 365 consecutive days, regardless of whether the data was collected during a leap year. In the event that the 12 consecutive months amount to a little more or less than 365 days, the total must be adjusted by adding or subtracting the average daily values symmetrically at the beginning and end of the year of analysis.

15. Reporting Format

The final report of this procedure must include:

- Project definition form, which must include the points specified in this procedure.
- Table of monthly results, including all the parameters listed in the measurement plan following a format as shown.

Metric	Month												Annual
	1	2	3	4	5	6	7	8	9	10	11	12	
Net PV Production													
Total Facility Energy Use													
Facility Electrical Load Offset by PV Production													
PV System AC Electricity Generation Effectiveness													
Net Facility Electricity use													
Peak Demand of Net Facility Electricity Use													
Peak Demand of Total Facility Electricity Use without PV System													
Reduction of Peak Demand Resulting from PV System													
Energy Cost Savings Resulting from PV System													



To report the cost results in a way that facilitates their interpretation, the following sections should be used

- Electricity costs of the facilities (€/year).
- Electricity costs of the installation without photovoltaic system (€/year).
- Energy cost savings as a result of the photovoltaic system (€/Year/ m²).

10 Replacement of current lighting with another with LED technology in the paper industry

10.1 Introduction

The company, which is dedicated to the to the manufacture of pulp and paper, has proposed an energy conservation measure that consists in replacing the current lighting system in the reel storage areas with another with LED technology, more efficient maintaining or improving the performance of the previous system as a way to influence the optimization of this installation.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

10.2 M&V plan

1. **Purpose**

The lighting efficiency improvement project aimed to reduce the connected lighting load while maintaining the light level.

2. **Measurement Boundary**

Project savings will be determined within a measurement limit that encompasses only the lighting equipment replaced in the project.

Measurements will be made only with the electrical power required by the accessories.

3. **Interactive Effects**

There are no energy interactions of the project with heating and cooling systems, since in the areas where the project is carried out there are no such facilities.

The measurement limit excludes the potential impact of occupants adding work lights connected to the building's electrical distribution at random locations that will not be measured when measuring lamp wattage.

4. IPMVP Option

IPMVP Option A was selected as it offers the best opportunity to minimize the costs of evaluating savings performance of the lighting project

5. Measurement Equipment

Lighting power will be measured by random sampling of the power required by the fixtures of each type. Power will be measured by a freshly calibrated true RMS wattmeter owned by the contractor. This meter has a rated accuracy of 2% of reading.

6. Measurement Process

A direct measurement of a sample of selected devices is made using an instantaneous power meter (for power consumption)

A wide range of samples should be taken to minimize uncertainty. It is important that the number of accessories involved is known (before and after) to correctly calculate the savings. This can be complemented by measurements in other parts of the project to ensure that all system losses are captured.

7. Baseline Energy

In the measurements for the base period, the average power of each lamp to be replaced will be determined, together with the net sampling error achieved. This information will be attached to this M&V Plan.

8. Independent Variables

Measurements will be made of installed lighting load immediately before and after retrofit. There are no routinely varying factors affecting lighting power in this short time frame, so no independent variables are measured for use in the savings computation.

9. Baseline Conditions

The fraction of equipment melted during will be recorded for all lighting switches measured. It will be assumed that this same wear rate will apply on average for each type of lamp after implantation.

10. Post-Retrofit Test

A post-retrofit test will be conducted one week after retrofit. It will be the same as the baseline test, and reported in the same form as the baseline test. It is expected that less sampling will be needed to achieve the 2% post-retrofit sampling error specification, since all fixtures are new. The *mean lamp* wattage of each type will be reported, along with the exact number of lamps installed of each type.

Light levels will also be measured at random in the space by building management staff to ensure standards have been maintained.

11. Stipulation

The number of hours of operation are estimated based on the occupation profiles and are shared with the managers

12. Reporting Conditions

When reporting avoided energy costs, savings will be calculated based on stipulated hours of operation after implantation and assuming the same wear rate that was observed immediately prior to implantation.

13. Computation Method

Electrical demand and consumption savings will be computed as follows:

$$\text{Annual Demand Savings (kWmonth)} = \left[\frac{(Wb \times Nb)}{1{,}000} - \frac{(Wp \times Np \times Bb)}{1{,}000}\right] \times 12$$

$$\text{Annual Consumption Savings (kWh/year)} = \left[\frac{kWmonth}{12}\right] \times H \times \left(\frac{365 days / year}{7 days / week}\right)$$

Where:

Wb = Baseline Mean Wattage

Nb = Estimated Number of Operating Lamps in the baseline

Wp = Post Retrofit Mean Wattage

Np = Number of new lamps installed

Bb = Burnout fraction observed in baseline test

H = Stipulated weekly hours of lamp operation

These demand and consumption savings will be calculated separately for each type of lamp and added together.

The cost reduction will be calculated for the total demand and the total energy savings using the electricity cost according to the prices of the supply company and the base demand.

14. Measurement Cost and Accuracy

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

15. Report Form

Reports will show savings for each reporting period in total.

11 Replacement of current fixed speed compressors with one with a variable speed drive in a precast concrete plant

11.1 Introduction

The company, which is dedicated to the manufacture of precast concrete for construction with two differentiated processes, carousel installation and manufacture of prestressed parts, has proposed an energy conservation measure that consists of the modification of the compressed air generation installation incorporating a new compressor of 75 kW of power with a speed variator that replaces the current ones.

This action is completed with the following equipment:

- KAESER 30 kW screw compressor.
- Low consumption refrigerant dryer.
- SIGMA AIR MANAGER master controller, model: SAM 4.0-4.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

11.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the power consumption of the compressor by reducing the main losses in screw compressors with fixed regulation that occur when the compressors go into unloaded or empty, once they reach the maximum pressure and until the installation reaches the minimum starting pressure and that are due to:

- The compressor in discharge consumes approximately 30% to 40% of the nominal power of the installation.
- Likewise, a compressor with start-stop operation needs to generate more pressure than necessary to cover the operating range of the equipment. For each additional bar the equipment will consume 7% more electrical energy.
- Also in each load / vacuum cycle, the compressor must vent the internal air to the outside for a new cycle start.

2. Selected IPMVP Option and Measurement Boundary

The compressed air system will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The electrical energy consumed by the compressor system will be measured through the control panel of the compressors themselves in the compressor room.

This measurement limit ignores any reduction in waste heat drawn from the compressor room by wall-mounted exhaust fans, since the compressor room air is discharged outside the building, it has no impact on the requirements of plant cooling or heating. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

In order to propose the measure planned in this action, we have started from measurements carried out in the current installation over a typical week and, extrapolating the resulting average demand for compressed air consumption, an annual energy consumption of about 184,772 kWh is calculated.

During the period of baseline test, that plant was producing 4,146 ml. of prestressed pieces and 51,715 m^2 of parts manufactured on a carousel. The plant was operating 10 hours/day for 221 days/year.

According to the data for 2019, the following production has been obtained:

During this baseline test, there were two fixed speed screw compressors of 37 kW.

4. Reporting Period

The operating personnel of the plant will read the data collected in the control panel of the compressors and will record it according to the periodicity proposed by the production department of the plant in order to prepare the expected reports (e.g. monthly).

5. Basis for Adjustment

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when the plant was in operation and collect the compressor meter readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm Non\text{-}Routine\ Adjustments$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 151.36 kWh for the number of days in the established period.

Actual = Total energy measured in the compressor control panel for the period.

Non-Routine Adjustments = any adjustments needed due to changes in compressed air system design or operation or changes in plant operations. The plant engineer will compute these amounts after reviewing any changes to production or to the compressed air system which might affect compressor energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$Period\ Cost\ Avoidance = S \times Rate$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the electricity prices of the supply company will be used.

The electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The measurements of the compressor consumption will be collected by the person in charge from the data given by the control panel of the same for the established period. Each reading will include a signature of the person doing the reading.

If a meter reading is lost during the reporting period, the plant engineer will interpolate the previous and next shift readings to estimate the missing reading. The energy savings reports will indicate how many estimated readings were involved in each reporting period.

9. Monitoring Responsibilities

With a periodicity set by the production department of the plant, the configuration of the compressor control parameters, such as pressure and sequencing devices, will be reviewed.

10. Expected Accuracy

The probability distribution of electricity meter readings about their mean values is assumed to be 'normal.' The variations created by meter precision are included in the observations and the associated standard deviations.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- *Operating staff forget to read the meter.* Any meter reading that is missed can be estimated from subsequent actual readings. Though estimates may add more than the usual variability to the data, the net error in the results will be small and not controllable at any reasonable cost.
- *Actual meter readings are not made, though the log sheet is filled in.* When the plant engineering department collects the monthly meter reading log sheet from the MCC he/she will check that the last recorded reading is close to the actual reading at the time. Any discrepancies can be traced back to the person signing the readings.
- *Changes to the compressed air system or plant operations that affect compressed air energy use are:*
    - *not identified.* The plant engineering department will regularly review plant records of all sorts to ensure it is aware of all compressed air changes. It will also periodically examine system control settings and operations. If reported savings change by more than 10%, the plant engineering department will resurvey all installed compressed air equipment and operations, to ensure all necessary non-routine adjustments have been made.
    - *identified, but not included in a non-routine adjustment.* The necessity of making an adjustment for any particular small change may not be clear. However if reported savings change by more than 10%, a thorough survey of the compressed air system will help to identify the relative significance of all changes.

12 Replacement of current steam boilers with a steam boiler with the incorporation of more efficient systems in the food industry

12.1 Introduction

The company, which is dedicated to the manufacture and markets artificial cellulose, collagen and fibrous casings for meat products, has proposed an energy conservation measure that consists of the replacement of one of the boilers of the current steam generation system with another of the three-pass gas pyrotube type horizontally located and designed for the burning of gas and hydrogen of 20,000 Kg/h of steam production and the incorporation of more efficient systems.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

12.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation due to the incorporation of the following equipment that makes it more efficient:

- **Steam reheater**, will be located at the beginning of the path of the third gas pass (front of the generator) and will receive the saturated steam generated in the boiler at 10 to 11 bar (g) to increase its saturation temperature at full load of 175 °C to 250 °C.

- **Frequency variator** as auxiliary equipment of the combustion equipment, which allows the conditioning of the engine speed of the combustion equipment to the operating conditions, optimally controlling the combustion air fan in all operating ranges, reducing considerably electrical consumption, there is a reduction in noise and the load is reduced in cold starts.

- **Continuous O_2 control system with additional detection of CO LAMBDA LT3 / KS1D**, as auxiliary equipment of the combustion equipment for combustion optimization, being able to produce fuel savings up to a maximum of approximately 1.95%, by stabilizing the rest of the oxygen content in the exhaust gases.

2. Selected IPMVP Option and Measurement Boundary

The steam boiler will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option A.

The electricity associated with the burner and fan boiler auxiliaries is excluded from this limit as it is a not very significant improvement compared to the rest.

The natural gas consumed by the steam generation system will be measured through the natural gas bills issued by the supply company, since it is the only point of consumption of this energy in the company.

The heat generated by the boiler has no impact on the cooling or heating requirements of the plant, as it is located in a specific room that does not have air conditioning. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

When carrying out the feasibility study for the replacement of the current steam boiler with a more efficient one, the starting point was the consumption data collected and provided by the company for the steam generation installation with conventional boilers of the plant.

According to the data provided by the company, the energy consumption of the base period would be 141.913.500 kWh/year and its energy cost of € 3.553.699,00.

During the period of baseline test, the plant was operating three shifts, 365 days/year.

The plant's initial steam generation facility consists of two natural gas boilers of 30,000 Kg/h and 40,000 Kg/h of steam. These boilers are located in a single room designed for this purpose.

The post-retrofit annual energy use for Equation of point 6 is determined from the base year use and taking into account the returns measured before and after implementation:

Post-retrofit annual energy = Base year annual energy use * Base year performance / Post-retrofit performance + Correction to post-retrofit condition

C is an unknown quantity required to convert the projected base year usage of the new boiler to post-retrofit conditions.

4. Reporting Period

Savings will be calculated annually for the following year using the boiler efficiency data measured each year. The natural gas consumption data from the utility company invoices will be saved.

5. Basis for Adjustment

The data will be analyzed and savings calculated according to the prepared M&V plan. Post-implantation performance will be analyzed against baseline to:

- Calculate the savings, adjusting the independent variables
- If included, adjust savings for interactive effects.
- Estimate the uncertainty of savings.

Routine adjustments are needed to bring post-retrofit energy use to the conditions of the base year. This is exactly the correction amount C.

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when it was in operation and collect the facility data from the company's energy management system. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm Non\text{-}Routine\ Adjustments$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 1,546,991 kWh/year.

Actual = Total energy measured in the company's energy management system for the period.

Non-routine adjustments = any adjustments required due to changes in facility design or operation or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or compressed air system that may affect the compressor's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$Period\ Cost\ Avoidance = S \times Rate$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the natural gas prices of the supply company will be used. The natural gas Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

Measurements of the parameters that allow us to calculate the efficiency of the boiler under the same conditions as the base year will be carried out.

Natural gas bills will be saved and used in order to evaluate the consumption of the boiler, since it is the only point of consumption of this energy.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Uncertainty

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- Operating personnel forget to read the meter. Any meter reading that is lost can be estimated from subsequent actual readings. Although the estimates may add more variability than usual to the data, the net error in the results will be small and uncontrollable at a reasonable cost.
- No actual meter readings are made, even though log sheet is completed. When the plant engineering department collects the monthly meter reading log sheet from the MCC, it will verify that the last reading recorded is close to the actual reading at that time. Any discrepancies can be traced back to the person signing the readings.

- Changes in the facility or in plant operations that affect the use of energy in the plant are:

    - *unidentified. The plant engineering department will periodically review plant records of all types to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all equipment and operations in the facility, to ensure that all necessary non-routine adjustments have been made.*

    - *identified, but not included in a non-routine adjustment. The need to make an adjustment for any* particular small change may not be clear. However, if the reported savings change by more than 10%, a careful study of the facility will help identify the relative importance of all changes.

13 Substitution of a sulphuric acid concentrator for another more efficient system in the food industry

13.1 Introduction

The company, which is dedicated to the manufacture and markets artificial cellulose, collagen and fibrous casings for meat products, has proposed an energy conservation measure that consists of the replacement of the current evaporation equipment for acidic viscose regeneration baths by others with mechanical vapour recompression.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

13.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation because the main advantage of mechanical vapour recompression technology is its lower energy consumption compared to other.

2. **Selected IPMVP Option and Measurement Boundary**

The concentrator installation will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The heat generated by the equipment has no impact on the cooling or heating requirements of the plant, as it is located in a specific room that does not have air conditioning. Therefore, there are no interactive effects from this EEM.

3. **Baseline: Period, Energy and Conditions**

The baseline period was immediately before EEM implantation was considered.

To calculate the energy consumption of the baseline period, the data collected in the installation management system were used.

With these data, the energy consumption for the base period is 59,270,400 kWh / year of natural gas and 1,579,368 kWh / year of electrical energy.

During the period of baseline test, the plant was operating three shifts a day, seven days a week.

During this baseline test, the equipment installed at the plant are a total of 4 "Lurgi" water evaporation facilities to recover acidic viscose regeneration baths made up of double effect equipment, vacuum evaporation and use steam as an energy source.

The characteristics of these facilities are as follows:

	Lurgis 2 y 4	Lurgis 3 y 5
Evaporated / Distilled Flow (l/h)	3,000	5,400
Type	Double effect	Double effect
Steam consumption (Kg/h)	3,000	7,000
Electric consumption (kWh)	77	111

4. Reporting Period

The savings will be calculated annually for the following year using the data of the parameters collected from the equipment management system with the periodicity included in the M&V plan. The natural gas consumption data from the utility company bills will be saved.

5. Basis for Adjustment

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when the plant was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm \text{Non-Routine Adjustments}$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 151.36 kWh for the number of days in the established period.

Actual = Total energy measured in the equipment management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times \text{Rate}$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the natural gas and electricity prices of the supply company will be used.

The natural gas and electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The values of the parameters of the equipment management system will be collected and will allow us to calculate the steam consumption and, therefore, the consumption of natural gas and electricity of the equipment.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Expected Accuracy

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- *Operating staff forget to read the meter*. Any meter reading that is missed can be estimated from subsequent actual readings. Though estimates may add more than the usual variability to the data, the net error in the results will be small and not controllable at any reasonable cost.
- *Actual meter readings are not made, though the log sheet is filled in*. When the plant engineering department collects the monthly meter reading log sheet from the MCC he/she will check that the last recorded reading is close to the actual reading at the time. Any discrepancies can be traced back to the person signing the readings.
- *Changes to the cogeneration installation or plant operations that affect engine energy use are:*
  - *unidentified. The plant engineering department will periodically review plant records of all kinds to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all facility equipment and operations to ensure all necessary non-routine adjustments have been made.*
  - *identified, but not included in a non-routine adjustment*. The necessity of making an adjustment for any particular small change may not be clear. However if reported savings change by more than 10%, a thorough survey of the compressed air system will help to identify the relative significance of all changes.

14 Replacing the crystallizer for a more efficient one in the food industry

14.1 Introduction

The company, which is dedicated to the manufacture and markets artificial cellulose, collagen and fibrous casings for meat products, has proposed an energy conservation measure that consists of the replacement of the current evaporation equipment for acidic viscose regeneration baths by others with mechanical vapour recompression.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

14.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation because the main advantage of mechanical vapour recompression technology is its lower energy consumption compared to other.

2. **Selected IPMVP Option and Measurement Boundary**

The concentrator installation will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The heat generated by the equipment has no impact on the cooling or heating requirements of the plant, as it is located in a specific room that does not have air conditioning. Therefore, there are no interactive effects from this EEM.

3. **Baseline: Period, Energy and Conditions**

The baseline period was immediately before EEM implantation was considered.

To calculate the energy consumption of the baseline period, the data collected in the installation management system were used.

With these data, the energy consumption for the base period is 25,542,020 kWh/year of natural gas and 924,000 kWh/year of electrical energy.

During the period of baseline test, the plant was operating three shifts a day, seven days a week.

During this baseline test, the equipment installed at the plant is a Crystallizer, whose operation is similar to that of the evaporator-concentrator, and is made up of a horizontal boiler, uses steam as an energy source for heating, vacuum pump to carry out the evaporation at low temperature and water from the cooling tower to obtain the distillate.

This equipment is simple effect, vacuum evaporation and uses steam as an energy source.

The characteristics of these facilities are as follows:

	DPM 100.000
Evaporated / Distilled Flow (l/h)	4,167
Type	Simple effect
Steam consumption (Kg/h)	4,525
Electric consumption (kWh)	110

4. Reporting Period

The savings will be calculated annually for the following year using the data of the parameters collected from the equipment management system with the periodicity included in the M&V plan. The natural gas consumption data from the utility company bills will be saved.

5. Basis for Adjustment

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when the plant was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm \text{Non-Routine Adjustments}$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 151.36 kWh for the number of days in the established period.

Actual = Total energy measured in the equipment management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times \text{Rate}$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the natural gas and electricity prices of the supply company will be used.

The natural gas and electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The values of the parameters of the equipment management system will be collected and will allow us to calculate the steam consumption and, therefore, the consumption of natural gas and electricity of the equipment.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Expected Accuracy

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- *Operating staff forget to read the meter.* Any meter reading that is missed can be estimated from subsequent actual readings. Though estimates may add more than the usual variability to the data, the net error in the results will be small and not controllable at any reasonable cost.
- *Actual meter readings are not made, though the log sheet is filled in.* When the plant engineering department collects the monthly meter reading log sheet from the MCC he/she will check that the last recorded reading is close to the actual reading at the time. Any discrepancies can be traced back to the person signing the readings.
- *Changes to the cogeneration installation or plant operations that affect engine energy use are:*
    - *unidentified. The plant engineering department will periodically review plant records of all kinds to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all facility equipment and operations to ensure all necessary non-routine adjustments have been made.*
    - *identified, but not included in a non-routine adjustment.* The necessity of making an adjustment for any particular small change may not be clear. However if reported savings change by more than 10%, a thorough survey of the compressed air system will help to identify the relative significance of all changes.

15 Change of heating system using natural gas boilers for high efficiency heat pumps with heat recovery in the metallurgical industry

15.1 Introduction

The company, which is dedicated to the manufacture of double angular contact bearings for the automotive industry, has proposed an energy conservation measure that consists of the replacement of the current hot water generation facility for heating with natural gas boilers and the rooftop cooling facility with a facility that incorporates heat pumps for the generation of hot and cold water for these needs.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

15.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation because it incorporates improvements in the air conditioning system in all its phases of the installation.

- ***Generation***

  For the generation of hot and cold water for the air conditioning system, high-efficiency electric machines such as water-water chillers and water-air will be used.

  In the winter operating regime, preference will be given to the use of any of the water-water machines to take advantage of its residual energy, so that both hot water for air conditioning and cold water can be used for the process that the heat pump will generate in its work cycle, which will result in the efficiency of the system.

- ***Distribution***

  An air return system is available from the interior of the already air-conditioned building, so that the energy of this return air is used, air conditioning only the outside air necessary for the renewal of the air in the building, which means a significant increase in the efficiency of the installation.

2. Selected IPMVP Option and Measurement Boundary

The concentrator installation will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The heat generated by the equipment has no impact on the cooling or heating requirements of the plant as it is located outside. There are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

To calculate the energy consumption of the baseline period, the data collected in the installation management system were used. With these data, the energy consumption for the base period is 3,777,000 kWh/year of natural gas and 1,236,862 kWh/year of electrical energy.

During the period of baseline test, the plant was operating three shifts a day, 322 days/year.

During this baseline test, the heating system installed at the plant consists of 2 natural gas superheated water boilers of 4,000,000 Kcal/h and 6,000,000 Kcal/h.

On the other hand, the cooling system of production area is made up of 8 air-to-air rooftop machines with 209.77 kW of cooling power each.

An energy model will be established through a regression analysis that relates the energy consumption with the independent variables, such as the number of degree days of cooling and/or heating (CDD and/or HDD). The regression model will take the following form:

$$Energy\ consumption(kWh) = a + b_1 CDD + b_2 HDD$$

where:

a is the baseline HVAC system not dependent on independent variables (e.g. base load ventilation power consumption),

b_1 is the coefficient of the independent variable CDD,

b_2 is the coefficient of the independent variable HDD.

4. Reporting Period

The savings will be calculated annually for the following year using the data of the parameters collected from the equipment management system with the periodicity included in the M&V plan.

5. Basis for Adjustment

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when the plant was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm \text{Non-Routine Adjustments}$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 151.36 kWh for the number of days in the established period.

Actual = Total energy measured in the equipment management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times Rate$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the electricity prices of the supply company will be used.

The electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The values of the parameters of the equipment management system will be collected and will allow us to calculate the consumption of electricity of the equipment.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Expected Accuracy

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- *Operating staff forget to read the meter.* Any meter reading that is missed can be estimated from subsequent actual readings. Though estimates may add more than the usual variability to the data, the net error in the results will be small and not controllable at any reasonable cost.
- *Actual meter readings are not made, though the log sheet is filled in.* When the plant engineering department collects the monthly meter reading log sheet from the MCC he/she will check that the last recorded reading is close to the actual reading at the time. Any discrepancies can be traced back to the person signing the readings.
- *Changes to the cogeneration installation or plant operations that affect engine energy use are:*
    - *unidentified. The plant engineering department will periodically review plant records of all kinds to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all facility equipment and operations to ensure all necessary non-routine adjustments have been made.*
    - *identified, but not included in a non-routine adjustment.* The necessity of making an adjustment for any particular small change may not be clear. However if reported savings change by more than 10%, a thorough survey of the compressed air system will help to identify the relative significance of all changes.

16 Oil regeneration facility for machine cooling in the metallurgical industry

16.1 Introduction

The company, which is dedicated to the manufacture of double angular contact bearings for the automotive industry, has proposed an energy conservation measure that consists in the installation of a regenerative oil filter with DST technology, exclusive to the SKF group, as a complement to the current filtering system.

The particularity of this regenerating filter is its ability to return the lapping oil to the initial conditions, maintaining its technical characteristics like those of a new liquid forever.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

16.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation because its implementation allows to have the lapping liquid with all the original characteristics, which means that, on the one hand, it is not necessary to compensate with pressure and flow in the centralized installation the deficiencies of the liquid, and on the other hand, the energy consumption in each of the 40 lapping machines is reduced and, finally, the current filtering installation will also see a reduction in electricity consumption.

2. **Selected IPMVP Option and Measurement Boundary**

The concentrator installation will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option B.

The heat generated by the equipment has no impact on the cooling or heating requirements of the plant as it is located outside. There are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

To calculate the energy consumption of the baseline period, the data collected in the installation management system were used.

With these data, the energy consumption for the base period is 4,382,097 kWh/year of electrical energy.

During the period of baseline test, the plant was operating three shifts a day, 322 days/year.

During this baseline test, the current filtering system installed at the plant consists of a cellulose pre-layer filter installed in bypass between the dirty liquid and clean liquid tanks. The filter is continuously working at full load, according to the attached graph.

The centralized pumping system is made up of different pumping groups with different powers with a frequency variator in the most powerful motors. All pumping groups run at full load to supply factory demand.

The basement pumping group drives 100 m^3/h to the dirt tank of the pre-coat filter, where another pumping group is also working at 100 m^3/h, which performs the filtering function and returns the filtered liquid to the tank clean in the gallery.

Finally, we have the gallery's pumping system to send the canal machines centrally.

4. Reporting Period

The savings will be calculated annually for the following year using the data of the parameters collected from the equipment management system with the periodicity included in the M&V plan.

5. Basis for Adjustment

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when the plant was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm Non\text{-}Routine\ Adjustments$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above.

Actual = Total energy measured in the equipment management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times \text{Rate}$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the electricity prices of the supply company will be used.

The electricity Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

The values of the parameters of the equipment management system will be collected and will allow us to calculate the consumption of electricity of the equipment.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Expected Accuracy

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- *Operating staff forget to read the meter*. Any meter reading that is missed can be estimated from subsequent actual readings. Though estimates may add more than the usual variability to the data, the net error in the results will be small and not controllable at any reasonable cost.
- *Actual meter readings are not made, though the log sheet is filled in*. When the plant engineering department collects the monthly meter reading log sheet from the MCC he/she will check that the last recorded reading is close to the actual reading at the time. Any discrepancies can be traced back to the person signing the readings.
- *Changes to the cogeneration installation or plant operations that affect engine energy use are:*
  - *unidentified. The plant engineering department will periodically review plant records of all kinds to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all facility equipment and operations to ensure all necessary non-routine adjustments have been made.*
  - *identified, but not included in a non-routine adjustment*. The necessity of making an adjustment for any particular small change may not be clear. However if reported savings change by more than 10%, a thorough survey of the compressed air system will help to identify the relative significance of all changes.

17 Solar photovoltaic installation for self-consumption and sale of surpluses in an energy production and supply company

17.1 Introduction

The company, which is dedicated to the activity of generation and sale of energy fluids in the industrial park where it is located, has proposed the installation of a photovoltaic solar plant for the generation of electric energy in self-consumption and without grid injection.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the Procedure for Measuring and Reporting the Performance of Photovoltaic Systems in Buildings of the National Renewable Energy Laboratory (Technical Report NREL/TP-550-38603 October 2005).

17.2 M&V plan

1. **Identify project goals**

The purpose for conducting the performance analysis is determining energy cost savings accruing from the PV system.

This M&V plan is also proposed in order to know:

- The energy produced by the photovoltaic system.
- The part of the electrical power of the plant that is generated on site.

2. **Determine the boundaries of the site to be analyzed**

The entire photovoltaic system is included

3. **Select Tier 1 or Tier 2 analysis**

In this case, a Tier 1 analysis is carried out and the following main data will be determined:

- Net production of the photovoltaic system
- Net electricity use of the facility
- Total electricity use of the facility.
- Equivalent hours of nominal maximum photovoltaic production.

4. **Specify desired accuracy of results**

The precision of the results will be that given by the monitoring equipment installed

5. **Develop estimated budget for performance analysis**

Labour costs are assumed to be zero, as there has been no record of labour to collect the data, calculate the results, or prepare the M&V Plan.

They have been accepted by the management of the operations and engineering departments as new normal tasks. Because the installed monitoring equipment is digital, no recalibration costs will be incurred.

6. **Identify period of analysis**

The analysis period according to Level 1 will be annual to evaluate long-term trends and verify energy savings.

7. **Gather basic site and PV system data**

The specific information on the building and the photovoltaic system are those collected in the installation project carried out

8. **Obtain pre-existing performance data**

There is no previous data because it is a new installation

9. **Select performance metrics to be measured**

The measurement data to be collected are:

- Total PV System Production.
- Net PV System Production.
- Equivalent Annual Hours of Peak Rated PV Production.
- Total Facility Electricity Use.

10. **Specify frequency of each measurement**

As it is a Level 1 analysis, monthly data is required

11. **Determine feasibility of measurements**

The feasibility of the proposed measurements will be determined according to the existing measurement devices in the installation

12. Calculate uncertainty of measurements

You will document the precision of each measuring device and apply common statistical methods to calculate the uncertainty of the metrics obtained by adding, subtracting, multiplying and dividing the measured data.

The accuracy requirements determined in Step 4 must be balanced against the costs of measurement and analysis.

13. Data Collection and Analysis

Data analysis consists of determining the values of all required results based on the data collected and will be performed in accordance with the following best practices:

- Energy Balances. In cases where one metric is the sum of (or difference between) several other metrics, the recommended practice is to measure each metric individually and use the summation as a check on the consistency of the data. This is also a more accurate way to determine a total, rather than summing the constituent metrics. Any inconsistencies should be reconciled (corrected, or at least understood and reported).
- Immeasurable parameter. If a parameter cannot practically be measured directly, it may need to be determined based on a sum of or difference between other metrics. However, this practice sacrifices the benefit of energy balance checking, and is less accurate.
- Missing Data. If intervals of data are missing because of a DAS malfunction, one of the following approaches should be applied:
    - Extend the period of data collection so that a complete year of data is obtained, and modify the period of analysis to use the complete year of data.
    - Report “Missing Data” in lieu of metrics for the periods affected.
    - Apply the best available method for estimating the missing data, and include the uncertainty introduced by this method in the reported measurement uncertainty. (Large, continuous gaps are more difficult than intermittent lapses to restore.).

14. Monthly Analysis

The procedure for this analysis must consider the following sections:

- *Identify months of analysis*. They may be the standard months from January to December or, in the event that due to the company's needs, the annual period does not follow this criterion, it may be 12 approximately equal divisions of one year.
- *Use average daily values*. Monthly results should be reported as monthly totals in table form and as average daily values in graphical form. The use of daily mean values avoids weighting the results by the number of days per month, which can vary slightly from month to month.

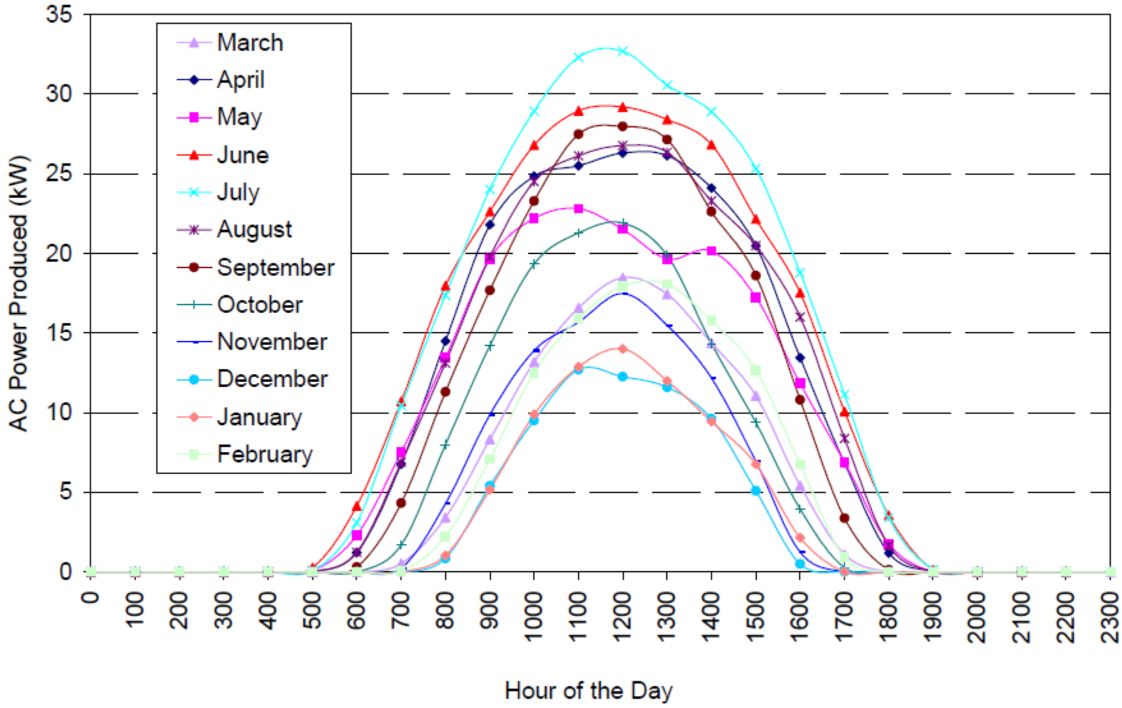
- *Identify the year of analysis.* Annual totals are determined by adding 12 consecutive monthly totals and adjusting the number of days included. A year of analysis consists of 365 consecutive days, regardless of whether the data was collected during a leap year. In the event that the 12 consecutive months amount to a little more or less than 365 days, the total must be adjusted by adding or subtracting the average daily values symmetrically at the beginning and end of the year of analysis.

15. Reporting Format

The final report of this procedure must include:

- Project definition form, which must include the points specified in this procedure.
- Table of monthly results, including all the parameters listed in the measurement plan following a format as shown.

Metric	Month												Annual
	1	2	3	4	5	6	7	8	9	10	11	12	
Net PV Production													
Total Facility Energy Use													
Facility Electrical Load Offset by PV Production													
PV System AC Electricity Generation Effectiveness													
Net Facility Electricity use													
Peak Demand of Net Facility Electricity Use													
Peak Demand of Total Facility Electricity Use without PV System													
Reduction of Peak Demand Resulting from PV System													
Energy Cost Savings Resulting from PV System													



To report the cost results in a way that facilitates their interpretation, the following sections should be used

- Electricity costs of the facilities (€/year).
- Electricity costs of the installation without photovoltaic system (€/year).
- Energy cost savings as a result of the photovoltaic system (€/Year/ m^2).

18 Replacement of the current hot water boiler for a condensing one in the automotive auxiliary industry

18.1 Introduction

The company, which is dedicated to different types of products, through the re-manufacture of transmissions, the manufacture of bars and to a lesser extent the manufacture of Propshafts, has proposed an energy conservation measure that consists of the replacement of the current hot water boiler with natural gas condensing boilers with the incorporation of more efficient systems.

Next, a Measurement and Verification (M&V) plan is presented so that the company has a method to monitor the results provided by the implementation of the measure and evaluate the savings obtained with it.

The M&V plan follows the guidelines of the International Performance Measurement and Verification Protocol (IPMVP).

18.2 M&V plan

1. **Aim of the Energy Efficiency Measure (EEM)**

The EEM reduces the energy consumption of the installation because the replacement of the current hot water boiler by natural gas condensing boilers with the incorporation of more efficient systems implies:

- Annual operating performance> 109%.
- Low polluting emissions.
- Low power consumption thanks to modulating fan: 10 to 536 W (C 640-1150) maximum depending on power.

2. **Selected IPMVP Option and Measurement Boundary**

The hot water boiler will be isolated from the rest of the plant and its energy use will be measured following IPMVP Option A.

The electricity associated with the burner and fan boiler auxiliaries is excluded from this limit as it is a not very significant improvement compared to the rest.

The natural gas consumed by the steam generation system will be measured through the natural gas bills issued by the supply company, since it is the only point of consumption of this energy in the company.

The heat generated by the boiler has no impact on the cooling or heating requirements of the plant, as it is located in a specific room that does not have air conditioning. Therefore, there are no interactive effects from this EEM.

3. Baseline: Period, Energy and Conditions

The baseline period was immediately before EEM implantation was considered.

When carrying out the feasibility study of the action to replace the current hot water boiler with a more efficient one, the starting point was the consumption data collected and provided by the company for the current hot water generation facility in plant.

According to the data obtained from the company's natural gas bills, the energy consumption of the base period would be 1,490,243 kWh/year and its energy cost of € 38,497.73.

During the period of baseline test, the plant was operating three shifts, 211 days/year.

During de baseline period, for the generation of hot water from the plant for use in the production of DHW, heating and process water for exchange in the washing process, the company has a boiler and a two-position burner of 1,600 kW.

An energy model will be established through a regression analysis that relates the energy consumption with the independent variables, such as the number of degree days of cooling and/or heating (CDD and/or HDD). The regression model will take the following form:

$$Energy\ consumption(kWh) = a + b_1 CDD + b_2 HDD$$

where:

a is the baseline HVAC system not dependent on independent variables (e.g. base load ventilation power consumption),

b_1 is the coefficient of the independent variable CDD,

b_2 is the coefficient of the independent variable HDD.

The post-retrofit annual energy use for Equation in section 6 is determined from the base year use and taking into account the returns measured before and after implementation:

Post-retrofit annual energy = Base year annual energy use * Base year performance / Post-retrofit performance + Correction to post-retrofit condition

C is an unknown quantity required to convert the projected base year usage of the new boiler to post-retrofit conditions.

4. Reporting Period

Savings will be calculated annually for the following year using the boiler efficiency data measured each year. The natural gas consumption data from the utility company invoices will be saved.

5. Basis for Adjustment

The data will be analyzed and savings calculated according to the prepared M&V plan. Post-implantation performance will be analyzed against baseline to:

- Calculate the savings, adjusting the independent variables
- If included, adjust savings for interactive effects.
- Estimate the uncertainty of savings.

Routine adjustments are needed to bring post-retrofit energy use to the conditions of the base year. This is exactly the correction amount C.

The savings resulting from the EEM will be reported in the operating conditions of the reporting period, using the analysis procedure described in Section 6.

6. Analysis Procedure

For each reporting period, the production department will use the plant's operating records to determine when it was in operation and collect the equipment readings. For each report, energy savings will be calculated using IPMVP Equation 1b) as follows:

$$S = ABL - Actual \pm \text{Non-Routine Adjustments}$$

Where:

S = Avoided energy use in the period, in kWh

ABL = Adjusted Baseline energy in period, from mean baseline energy shown in Section 3, above. ABL will be 1,546,991 kWh/year.

Actual = Total energy measured in the company's energy management system for the period.

Non-routine adjustments = any adjustments required due to changes in the design or operation of facilities or changes in plant operations. The plant engineer will calculate these amounts after reviewing any changes in production or installation that may affect the equipment's energy use.

The monetary savings will be computed for each period using the utility Rate shown in Section 7, as follows:

$$\text{Period Cost Avoidance} = S \times Rate$$

The M&V planner will calculate the total avoided cost for each reporting period.

7. Energy Prices

To calculate the economic savings for each period, the natural gas prices of the supply company will be used. The natural gas Rates will be modified each time the utility company prices change, so that current prices are always used in reporting cost avoidance.

8. Meter Specifications

Measurements of the parameters that allow us to calculate the efficiency of the boiler under the same conditions as the base year will be carried out.

Natural gas bills will be saved and used in order to evaluate the consumption of the boiler, since it is the only point of consumption of this energy.

9. Monitoring Responsibilities

With a periodicity established by the production department of the plant, the configuration of the control parameters of the installation will be reviewed.

10. Uncertainty

The uncertainty of the savings should be estimated, based on the measurement approach, location, impact of variables, duration of measurement, and equipment used. See the Process Guide for further guidance on how to calculate and express uncertainty.

11. Budget

Labour costs are assumed to be zero since there has been no recording of the labour to read the meter during the baseline, compute the baseline values, or prepare the M&V Plan. Ongoing meter reading, computing of savings and monitoring of conditions will not be measured in future. These ongoing costs are presumed to be trivial. They have been accepted by the management of the operations and engineering departments as normal new tasks. Because the meter is fully digital, no re-calibration costs will be incurred.

12. Report Format

Reports will show savings for each reporting period in total.

13. Quality Assurance

The primary risks in this M&V process are listed below with specific quality assurance steps that will be used to address each.

- Operating personnel forget to read the meter. Any meter reading that is lost can be estimated from subsequent actual readings. Although the estimates may add more variability than usual to the data, the net error in the results will be small and uncontrollable at a reasonable cost.

- No actual meter readings are made, even though log sheet is completed. When the plant engineering department collects the monthly meter reading log sheet from the MCC, it will verify that the last reading recorded is close to the actual reading at that time. Any discrepancies can be traced back to the person signing the readings.
- Changes in the facility or in plant operations that affect the use of energy in the plant are:
  - *unidentified. The plant engineering department will periodically review plant records of all types to ensure that it is aware of all changes to the facility. It will also periodically review the configuration and control operations of the system. If the reported savings change by more than 10%, the plant engineering department will re-inspect all equipment and operations in the facility, to ensure that all necessary non-routine adjustments have been made.*
  - *identified, but not included in a non-routine adjustment. The need to make an adjustment for any* particular small change may not be clear. However, if the reported savings change by more than 10%, a careful study of the facility will help identify the relative importance of all changes.

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