MINISTRY OF INDUSTRY AND TRADE

EU - VIET NAM SUSTAINABLE ENERGY TRANSITION PROGRAMME (SETP)

Global Gateway

Funded by the European Union

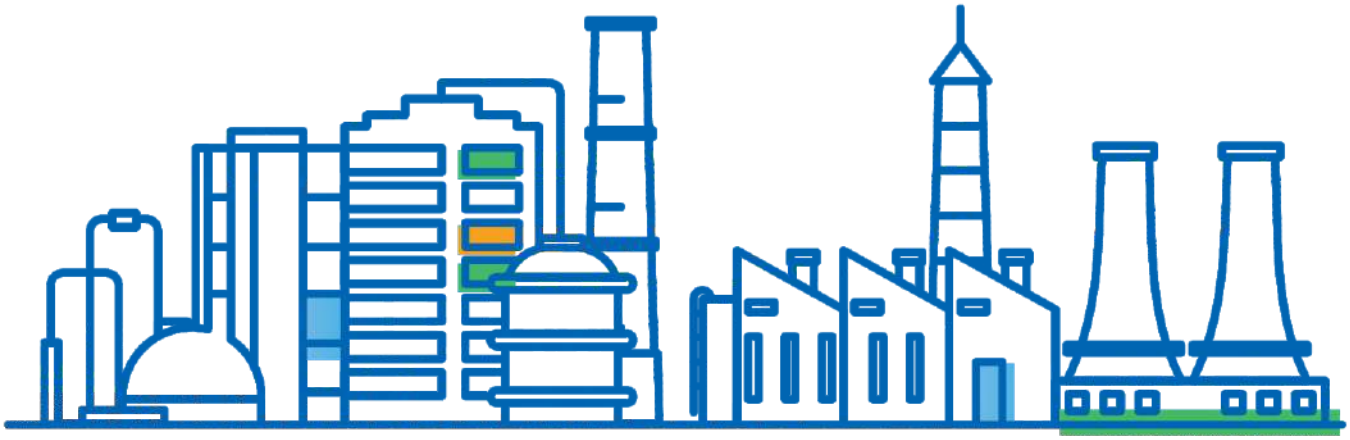
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Project "Accelerating energy efficiency (EE) in large industries through energy management system, system optimisation and the promotion and adoption of EE in SMEs" (IEEP)

TRAINING PROGRAMME

MEASUREMENT AND VERIFICATION OF THE ENERGY PERFORMANCE - ISO 50015

Ho Chi Minh, 19 - 20/05/2024



AGENDA

TRAINING COURSE ON ENERGY MANAGEMENT SYSTEM - MEASUREMENT AND VERIFICATION OF THE ENERGY PERFORMANCE OF AN ORGANIZATION - ISO 50015

From 19 to 20 May 2025

At Victory Hotel - 14 Vo Van Tan Street, Ward 6, District 3, Ho Chi Minh City

Day 1: 19/05/2025

Time	Contents	Speakers
8.00-8.30	Registration and welcome	
8.30-8.35	Participants Introduction	UNIDO Project
8.35-8.45	Opening speech	MOIT/UNIDO Project
8.45-9.15	Programme Introduction and Introductions	International Expert
9.15-10.00	ISO50015 - Key principles and Business Case	International Expert
10.00-10.15	**Tea break**	
10.15-10.30	Key principles exercise	International Expert and Trainees
10.30-12.00	M&V in the context of ISO 50001 and ESCO projects	International Expert
12.00-13.15	**Lunch at the Hotel**	
13.15-13.45	Exercise on M&V	International Expert and Trainees
13.45-15.00	M&V Planning	International Expert
15.00-15.15	**Tea break**	
15.15-17.00	M&V Planning Exercises	International Expert and Trainees

Day 2: 20/05/2025

Time	Contents	Speakers
8.00-8.30	Registration	
8.30-9.30	Measurement Instruments and Uncertainty	International Expert
9.30-10.30	Uncertainty exercise	International Expert and Trainees
10.30-10.45	**Tea break**	
10.45-11.30	M&V calculations	International Expert
11.30-12.00	Exercise on M&V Calculation	International Expert
12.00-13.15	**Lunch at the Hotel**	
13.15-13.30	Exercise on M&V Calculation (continue)	International Expert and Trainees
13.30-14.30	Post Project Report	International Expert
14.30-15.15	Case studies	International Expert
15.15-15.30	**Tea break**	
15.30-16.10	Process review	International Expert
16.10-17.00	Wrap up and Q&A	International Expert and Trainees

Measurement & Verification (M&V) Training

UNIDO International Energy Efficiency and EnMS Training

M&V Training Day 1

Delivered by: Richard Morrison, Stefan Walta

Housekeeping

- Emergency exits
- Toilets
- Mobile phones
- Breaks
- Lunch
- Please restrict email to break times

Introductions

- Name
- Company
- Energy Management Experience
- What do you expect to learn over these two days?

Why this course?

M&V is essential to further success.

- We need to quantify the savings achieved
  - We need to measure
- Effort and approach to should be proportional to scale of savings
- Provide confidence in results

Did you get what you paid for?

Why do we need M&V at all?

- What is the purpose of measuring and verifying savings?
- Who cares about the answer?
- Who will look at the results?
- What can you learn from the M&V Process?
- How does this integrate with ISO50001?

Agenda for Day 1

	Topic	Duration	Start Time	End Time
Day 1	Programme Introduction and Introductions	00:30	09:00	09:30
	ISO50015 - Key principles and Business Case	00:45	09:30	10:15
	Key principles exercise	00:15	10:15	10:30
	Coffee	00:15	10:30	10:45
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	M&V Planning	01:30	13:30	15:00
	Coffee	00:15	15:00	15:15
	M&V Planning Exercises	01:15	15:15	16:30

Agenda for Day 2

	Topic	Duration	Start Time	End Time
Day 2	Measurement Instruments and Uncertainty	01:00	08:30	09:30
	Uncertainty exercise	01:00	09:30	10:30
	Coffee	00:15	10:30	10:45
	M&V calculations	00:45	10:45	11:30
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	Wrap up and Q&A	00:30	16:00	16:30

Discussion

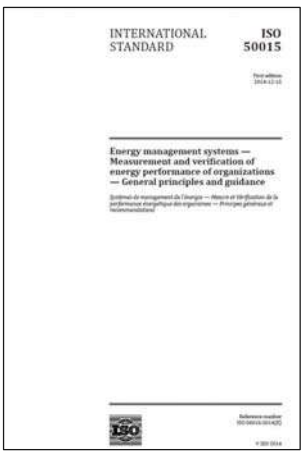
Outline an improvement project which you found difficult to quantify the savings from?

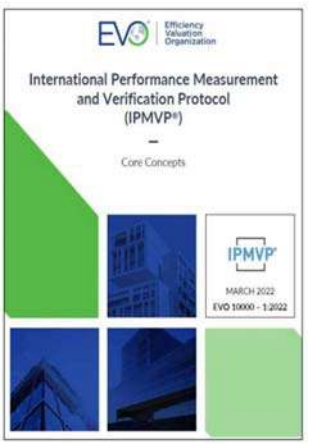
How did you approach quantifying it ?

What were the limitations to your approach?

Standards and Protocols

- ISO50015-2014
- IPMVP
- Other





ISO 50015 - Key Principles

Key Principles are guidance not requirements
Aid in decision making

- Appropriate accuracy and management of uncertainty
- Transparency and reproducibility of M&V process(es)
- Data management and measurement planning
- Competence of the M&V practitioner
- Impartiality
- Confidentiality
- Use of appropriate methods

Accuracy and uncertainty

Factors to consider:

- What is the purpose of the M&V?
- How big is the saving?
- What level of uncertainty is acceptable?
- What steps can be taken to mitigate uncertainty

Include a statement on accuracy with results within the M&V report.

Transparency and reproducibility

- We need confidence in the process
- Document the process in a manner that ensures reproducibility
- Source of all information should be clear and traceable

Data management and measurement planning

- What will be measured?
- How will it be stored and retained?
- Measures needed to prevent loss or change?
- What instrumentation will be used?
- Frequency of measurement?

Competence of the M&V practitioner

A competent practitioner will lead to confident results

- Do regulations apply?
  - – certified, approved list, mandatory qualification
- Competence can be defined by organisation requesting M&V
- Practitioner should declare competence

Impartiality

- Promotes confidence
- What makes a M&V practitioner impartial?
  - Should and M&V practitioner be a third party?
- Disclose any conflict of interest as it arises
- Include a statement surrounding impartiality in report

Confidentiality

- M&V practitioner should have access to necessary confidential data
- Where this is not possible, highlight how this affects results
- M&V practitioner should not disclose confidential information

Use of appropriate methods

- Follow established good practices
- Include rationale for choice of method and calculation in M&V plan

Business Case

Why do M&V?:

- "In God we trust, all others bring data."
  - W. Edwards Deming
- Keeping it honest
- Continuous improvement of energy knowledge – what works and how well

Key principles exercise

How would you apply the key principles to the following scenario?

Look at each principle and decide what measures you would take to satisfy the principles.

A 20,000 m^2 distribution warehouse upgrades lighting from 400 watt metal halide to 185 watt LED.

There are 500 fittings and all are replaced one-for-one with no controls upgrade.

All lights are on from 6 am to 10 pm, 6 days per week

Some Definitions

Energy Performance Improvement: Improvement in measurable results related to energy efficiency, energy use, or energy consumption compared to the energy baseline

Energy Baseline: quantitative reference providing an basis for comparison of energy performance

Measurement and Verification M&V: process of planning, measuring, collecting data, analysing, verifying, and reporting energy performance or energy performance improvement for defined M&V boundaries

M&V Boundary: organisational, physical, site, facility, equipment systems, processes or activity limits within which energy performance or energy performance improvement is measured and verified

Adjustments: adjustments made to the energy baseline to account for usual and unusual changes in relevant variables

EPIA: Energy performance improvement action

It’s Coffee Time

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M&V for ISO 50001 systems V ESCO projects

	ISO 50001 Improvements	ESCO
Scope	Project or site	Project or site
Purpose of M&V	Determine energy saving and energy performance improvement of EPIAs	Establish specific energy saving figure of EPIAs so that ESCO can be paid accordingly
What we measure	Avoided Energy (EnPI Improvement) (Associated Co2 or cost)	Avoided Energy Associated CO2 or monitory value
Priorities	Confirmation of energy saving and energy performance improvement for the organisation	Clear unambiguous determination of the energy saving that is agreed by both parties (see IPMVP)
Independence	Important	Critically important

Scope of M&V

How do we draw a line around the area to be measured?

Consider:

- Scale of savings
- Scale and cost of project
- Complexity
- Metering options
- Uncertainty

Scope of M&V – Exercise 1

Consider the following scenario and discuss:

A steel plant recently adjusted a process temperature for slab discharge with an expected reduction in HFO usage of about 1% of site usage.

Scope of M&V – Exercise 2

Consider the following scenario and discuss:

A textile plant embarked on a compressed air improvement project. They identified and repaired air leaks and replaced the old compressor plant with VSD controlled compressors.

Compressed air was responsible for 11% of site electricity use.

ISO 50001 – Clause 6.2.3

When planning how to achieve its objectives and energy targets, the organization shall establish and maintain action plans that include:

– what will be done;

— what resources will be required;

— who will be responsible;

— when it will be completed;

– how the results will be evaluated, including the method(s) used to verify energy performance improvement

ENERGY OBJECTIVES, ENERGY TARGETS

ENERGY ACTION PLANS

ISO 50001 – Clause 6.2.3

the method used to verify energy performance improvement

Options – combination of:

- How will the improvement be reflected in EnPI(s)?
- How will the improvement be measured – before v after?
- How do we know the intended actions were completed and that the intended outcomes resulted?

Note: See also ISO 50004:2020 clause 6.2.3

ISO 50001 – Clause 9.1 Monitoring, Measurement, analysis & evaluation of energy performance & the EnMS

The organization shall ensure that the key characteristics of its operations that determine energy performance are monitored, measured and analysed at planned intervals.

1) the effectiveness of the action plans in achieving objectives and targets;
2) ……..
3) ……..
4) evaluation of actual versus expected energy consumption.

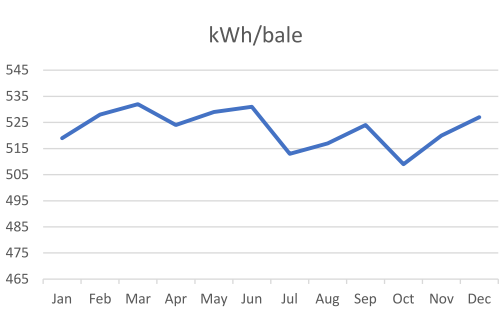
Discussion of approach – Example 1

Textile plant air compressor example:
(Plant checked and repaired air leaks and also replaced the old compressor plant with VSD controlled compressors. Compressed air was responsible for 11% of site electricity use). Graph shows typical performance before improvements were made.

EnPI: kWh/bale (electricity)

Expected saving: 4%
of site electricity

How will you know
a saving has been made?



Example 2

A plant upgrades their air compressors so that normal average power demand drops from 180 kW to 105 kW to supply same air quantity. The air compressors operate continuously.

At the same time a production line shuts down so that the demand is decreased by 15%. Assume that kWh/Nm^3 is constant for all compressors.

What is the saving in kWh per year?

Example 2

Remember it is the amount of energy used in the absence of the measure taking place

	Pre EPIA	EPIA	Pre-EPIA would have used	
Power	180	120	180	kW
decrease	0%	15%	15%	
Power	180	102	153	kW
	24	24	24	hr
	365	365	365	days
Hours	8,760	8,760	8,760	hrs/yr
kWh/yr	1,576,800	893,520	1,340,280	kWh
Saving			446,760	kWh
	0.14	0.14	0.14	$/kWh
Running cost	220,752	125,093	187,639	$
Saving			62,546	$

See you in 45 minutes!

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Exercise on M&V

A distillery has upgraded its steam boilers to burn natural gas in place of heavy fuel oil. Over a representative three-month period before the upgrade, the plant burns 1,211 tonnes of HFO.

A suitable 3-month period after the upgrade is selected as the reporting period. The amount of natural gas consumed is 11,948,600 kWh.

What is the % saving?

What assumptions did you make?

Exercise on M&V

	Old Fuel Source		New Fuel Source	
	HFO		NG	
a	10.786	kWh/kg		
b	1,211	tonnes		
c=(a*b)	13,061,846	kWh	11,948,600	kWh
			1,113,246	kWh
			8.5	% saving

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M&V Planning

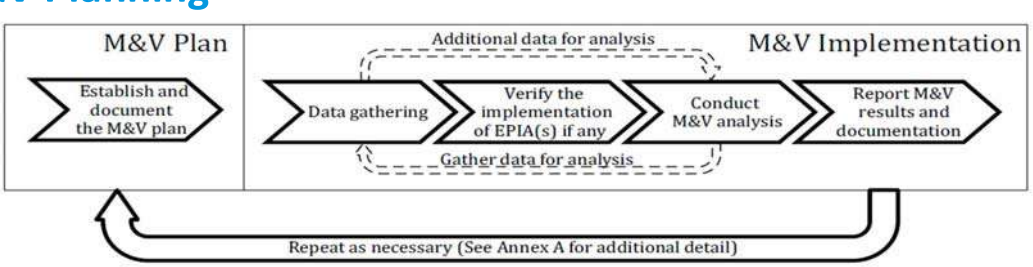


Figure 1 — Fundamental steps in the M&V process

Six steps in M&V process to include in plan:

1. Establish and document plan
2. Data gathering
3. Verify implementation of EPIAs
4. Conduct M&V analysis
5. Report results
6. Review / repeat

M&V Planning

Implementation needs are described in plan

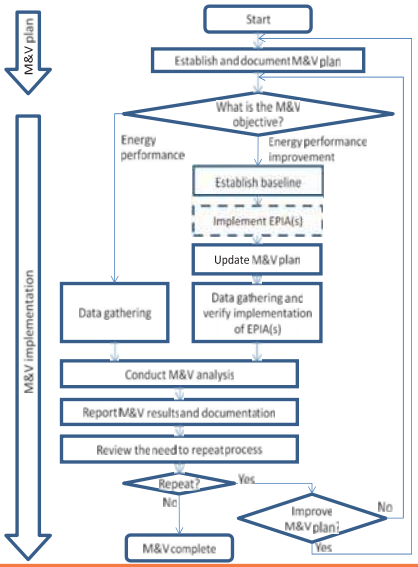


Figure A.1 Overview of the measurement and verification flow (from ISO 50015:2014 - courtesy ISO)

Scope and purpose (1 of 2)

Plan should describe:

- the organisation
- reasons for M&V
- parties responsible for the M&V
- confidentiality requirements
- parties who will receive the results
- legislative or other requirements
- physical scope of M&V

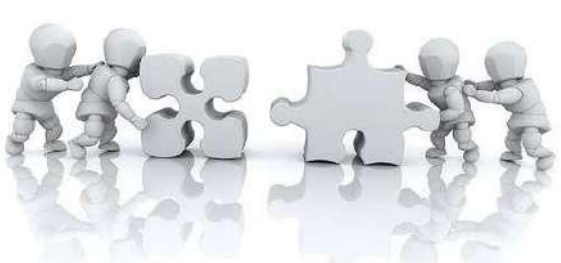
Scope and purpose (2 of 2)

- what is being measured and verified, EnPI(s) or EPIA(s) (Energy Performance Improvement Action)
- potential consequential effects
- M&V method used
- data to be collected and analysed
- applicable accuracy or uncertainty requirements to be met
- frequency and format of M&V reports
- process for updating M&V plan
- confirmation of capability of the M&V practitioner

Energy performance improvement actions 1

Need clear description of what will be done i.e. EPIAs

- description of EPIA(s) and baseline
- how EPIA will contribute to energy performance;
- expected improvement or maintenance in energy performance from EPIA(s)
- responsibility for implementing the EPIA(s)
- how the EPIA(s) will be implemented



Energy performance improvement actions 2

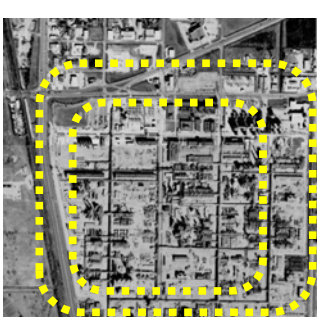
Need clear description of what will be done i.e. EPIAs (continued)

- timeframe and sequence for implementation of each EPIA
- location for EPIA(s)
- EPIA(s) costs, if relevant to the M&V objectives
- how implementation of the EPIA(s) will be physically verified
- description of consequential effects and identification of whether quantified

M&V boundaries

Consider:

- Scope and purpose of M&V
- Nature of EPIAs
- Calculation and M&V method
- Measurement systems in place



Could be whole or part of organisation

Include reason for choice of boundaries where relevant and impact of boundaries on uncertainty

Preliminary M&V plan assessment

Develop and document the current energy uses, facilities and equipment

Identify:

- Measurement / reporting period
- Data needed for data-gathering plan
- Data needed for baselines and adjustments
- Availability and quantity of energy data need for additional data
- Equipment and other resources needed for M&V

Consider ISO50001 Planning for collection of energy data

Data to be collected (or acquired by measurement as applicable) and retained documented information shall include:

- …
- …
- e) data specified in action plans.

Note: This is linked to Clause 6.3.3 discussed earlier on how to evaluate the results of action plans in ISO50001.

Energy performance metrics including EnPIs

- Describe EnPIs in use which will be part of M&V
  - Include relevant variables
  - If necessary, develop new EnPI(s)
  - Potentially integrated into EnMS later by the organisation

Need to consider the development of a long term EnPI if there is the potential for energy performance deterioration of the EnPI

Energy performance metrics including EnPIs

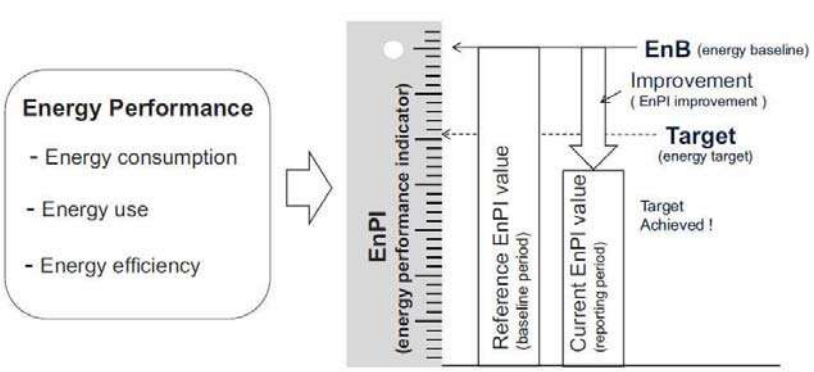


Figure 1 — Relationship between energy performance, EnPIs, EnBs and energy targets

Figure courtesy ISO (ISO 50006)

Relevant variables and static factors

- identify relevant variables and static factors
- determine typical operating range of the relevant variables
- determine level of the static factor
- determine a representative period of time
- identify data source(s) for relevant variable and static factors
- identify and describe consequential effects that may occur
- variables or static factors determined not to be relevant

M&V method and calculation method (1 of 2)

When deciding on protocol/calculation method, consider:

- purpose of the M&V
- accuracy requirements
- relevant experience of the M&V practitioner
- nature of the EPIA(s) or energy performance metrics
- nature of the organization / choice of M&V boundaries
- information from preliminary M&V planning assessment
- legal, regulatory or other requirements
- costs of methods under consideration

M&V method and calculation method (2 of 2)

Include in plan:

- Description of M&V method and references
- Enough detail to allow reproducibility
- Rationale for the choice of the method selected

Data gathering plan

Describe data to be collected including the following information:

- name of variable
- data source, existing or new
- data quality (appropriateness, accuracy, validation, reliability, completeness, etc.)
- identification of outliers and gaps
- frequency at which data will be collected
- measurement type (continuous, spot etc.)
- method of collection
- individual(s) responsible for measurements,
- preparation/access to measurement points
- operating constraints
- type of meter or sensor

Establishment of the energy baseline

Typically establish baseline before EPIAs implemented

Plan should include:

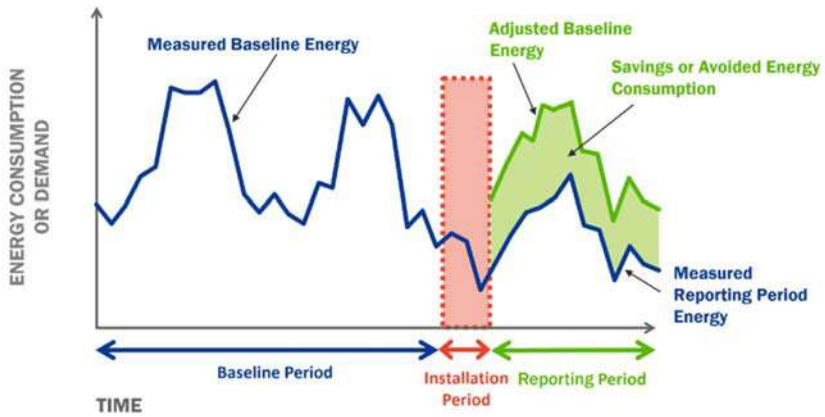
- Raw data for baseline (or reference to where it is stored)
- Time period for baseline
- Process to establish baseline
- Processed data – e.g. regression model determined

Considerations for Energy baseline

What should you consider when establishing the Baseline?

- Seasonality (or cycle of variation)
- Length of baseline period
- Availability of metering data
- Complexity of the EPIA
- Capital investment
- Size of the saving

Establishment of the energy baseline



IPMPV approach Figure courtesy IPMVP

Adjustment of the energy baseline

Plan should include:

- How need for non-routine adjustments will be monitored
- Procedure to make these adjustments
- If non-routine adjustments already expected, then include method

Resources required

Include:

- Budget
- Measurement equipment
- Data access
- Human resources (incl. competency etc.)
- Statement that resources are appropriate to scope and purpose of M&V

Roles and responsibilities

Document:

- Roles and responsibilities
- Communication channels
- Contact details and how changes are updated
- Competencies determined

Documentation of the M&V plan

Document elements mentioned already with following principles in mind:

- Promotion of confidence
- Traceability
- Repeatability
- Reproducibility
- Consistency

Records should support decisions made and establish an audit trail.

It’s Coffee Time

	Topic	Duration	Start Time	End Time
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Exercise on M&V Planning - Car Park Lighting 1

Write a M&V plan for the following case. List all assumptions made.

A supermarket chain is upgrading its car park lighting. It has chosen a medium sized store to pilot the technology. There are 422 stores in total for planned future work. High pressure sodium fittings will be replaced by LED. The supermarket is undertaking the project to save energy and maintenance costs but also to lower carbon emissions in line with its CSR policy.

The car park is completely outdoors on ground level. The store opens everyday 24 hours except for three days per year for National Holidays.

Old fittings will be replaced by new ones on the same poles. While final selections have not been made, it is expected that the 190 type 70W SON fittings will be replaced by 30W LED equivalents.

Assume an average unit rate of 0.14US$ per kWh day and night for electricity.

Exercise on M&V Planning - Car Park Lighting 2

What adjustments do you need to make to your plan if all the following changes are made to the project?

A The new lighting will have improved controls to allow dimming to 50% of power between 12 am and 5 am

B A light sensor will be used to switch lighting on at dusk and off at dawn

C Because local area voltage variations have been known caused failure in similar LED fittings, the supermarket is insistent that failures be monitored and accounted for in case they influence the savings measurement.

D The corporate energy manager would like to use an energy metric to quantify the savings for future car park lighting projects.

Questions?

Thank you

See you tomorrow

Measurement & Verification (M&V) Training

UNIDO International Energy Efficiency and EnMS Training

M&V Training Day 2

Delivered by: Richard Morrison, Stefan Walta

Housekeeping

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- Lunch
- Please restrict email to break times

Measurement Instruments and Uncertainty

- Key principles and business case
- M&V in ISO 50001 v ESCO
- M&V Planning

- Questions?

Agenda for Day 2

	Topic	Duration	Start Time	End Time
Day 2	Measurement Instruments and Uncertainty	01:00	08:30	09:30
	Uncertainty exercise	01:00	09:30	10:30
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Measurement Instruments and Uncertainty

- Types of instruments
- Choice of instrument
- Uncertainty and mitigation

Note: The measurement instruments required will have been identified in the measurement plan

Portable measurement instruments

Voltmeter / ammeter / power meter

- Need to know power factor for power readings
- Spot measurement or logging
- Choose range to suit
- May need specialist to use

Portable measurement instruments

Combustion analyser

- Combustion efficiency improvements
- Maintenance tool

Portable measurement instruments

Ultrasonic flow meter

- Liquid flow
- Clamp-on/non-invasive
- May need to remove insulation
- Should measure pipe wall thickness – accuracy?

Portable measurement instruments

Thermal measurements

- Thermal imaging for comprehensive surface measurement
- Thermometers for spot checks

Integrated measurement instructions

- Simple meters – power, current, pressure, temperature etc
- Possibly combined with monitoring/logging system – BMS, SCADA, DCS
- Consider accuracy of sensor combined with logging/display
- Advantage that sensors likely to be already suited to application
- Exercise caution with energy metering systems

Choosing suitable metering equipment

- Range of use
- Suitability of sensor – e.g. for temperature surface/immersion
- Meter should not influence measured quantity
- Precision – ideally should be 10x precise than required tolerance
- Repeatability – repeated measurement should get same result
- Resolution – smallest unit or difference that system can detect
- Stability – how well is calibration retained over time or in different environments – temperature, humidity etc.

Uncertainty

- How bad could it be?
- Or how good?
- What level of uncertainty is acceptable for the purposes of this M&V?
- To assess uncertainty, use sensitivity analysis – which adjustments cause more change to result?
- See Annex B of ISO 50015 for uncertanty examples

Sources of Uncertainty

- M&V method chosen
- calculation method chosen
- M&V boundaries chosen
- choice of significant energy use
- excluded energy types
- frequency of data collection
- data intervals
- measurement method
- energy consumption model diagnostics and bias;
- competency
- sample size
- measurement equipment
- consequential effects

Combining uncertainty components

Can approximate combined tolerance by the following:

Relative precision RP = $\sqrt{RP_1^2 + RP_2^2 + \cdots}$

Example:

- Energy saved is estimated at 200 kWh calculate from 10 hr x 20kW
- If hours are measured ±10 min, RPhours = 0.17/10 = ±.017 or ±1.7%
- If kW are measured ±0.2kW, RPkW = 0.2/20 = ±.01 or ±1%

RP = $\sqrt{1.7^2 + 1^2}$ = 2.0%

Reducing Uncertainty

- Alternative M&V methods
- More accurate measurement equipment
- More frequent – allowing for changing conditions
- Calibration
- Cross checking – possible alternative to calibration
- Parallel measurement by different means

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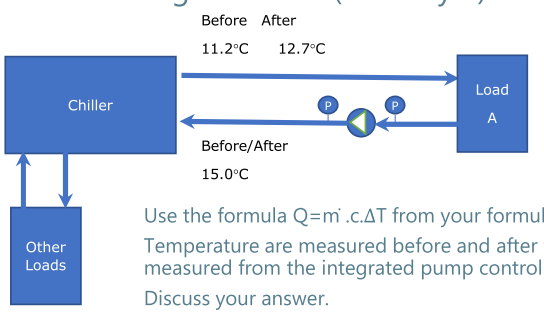
Uncertainty Exercise

A brewery has a large central air-cooled chiller plant providing chilled water for the plant. In section A of the plant a number of measures are carried out to reduce the cooling load. The water volume flow stays the same. Determine the saving in chilled water with a margin of error (x kW ±y%)



Use the formula $Q=\dot{m}.c.\Delta T$ from your formulae sheet.

Temperature are measured before and after the chiller using sensors with an accuracy of ±0.1°C. Flow is measured from the integrated pump controller and is constant 15.2 kg/s ±2%.

Discuss your answer.

If you wanted to improve the precision of the answer, what could you do?

Uncertainty Exercise

- Formula $Q = m*C_p*\text{Delta T}$
- Q = energy in kW
- C_p = specific heat capacity of water kJ/kgK
- Delta T Temp difference

Note: Statistically, the range will be less than adding all the tolerances as they are unlikely to be extreme at the same time.

Before	After	Units	Note
15.2	15.2	kg/s	Mass flow
4.2	4.2	kJ/kgK	cp water (no glycol added)
15	15	°C	temperature in
11.2	12.7	°C	temperature out
3.8	2.3	K	temp diff
242.6	146.8	kW	
	95.8	kW	Saving
0.1	0.1	K	tolerance on sensor in
0.1	0.1	K	tolerance on sensor out
0.14	0.14	K	tolerance on temperature difference
3.7%	6.1%		tolerance on temperature difference as %
2.0%	2.0%		tolerance on mass flow
4.2%	6.5%		tolerance on total power calculation
	7.7%		tolerance on total power difference calculation
Answer:	96 kW ±8%		

It's Coffee Time

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M&V Calculations

Saving = Energy that would have been used*

MINUS — Energy actually used

*If the EPIAs had not been implemented

M&V Calculations

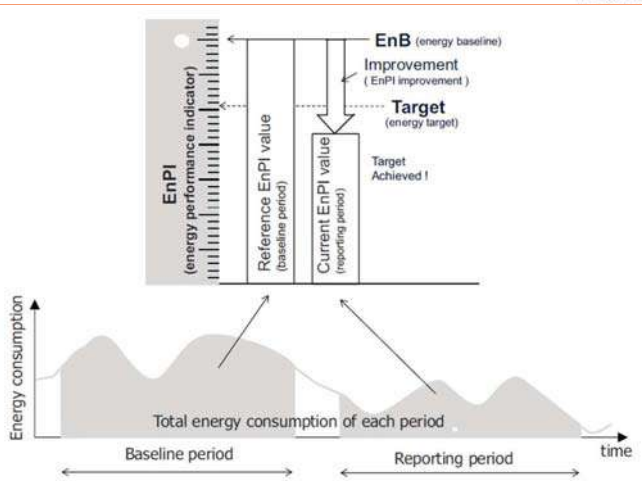


Figure 3 — Concept of baseline period and reporting period for an EnPI

Figure courtesy ISO (ISO 50006)

M&V Calculations

- Select baseline period
- Gather data for this period
- Use it to establish model of normal usage
- Implement EPIA and measure results (reporting period)
- Predict usage for reporting period
  (= baseline + routine adjustments)
- Make non-routine adjustments to predicted usage
- Calculate saving

M&V Calculations

Can also be expressed as follows:

$$ES = B_{peu} \pm A_{routine} - R_{peu} \pm A_{non\text{-}routine}$$

Where

ES	=	energy savings
B_{peu}	=	baseline period energy use
R_{peu}	=	reporting period energy use
A_{routin}	=	routine adjustments
$A_{non\text{-}routine}$	=	non-routine adjustments

Routine Adjustments

- Adjustments to account for changes in relevant variables
- Predetermined
- Could be built in to regression formula
- E.g. production volume, weather, product properties etc.

Non-routine Adjustments

- Made to account for
  - unusual changes in relevant variables (outside of normal range)

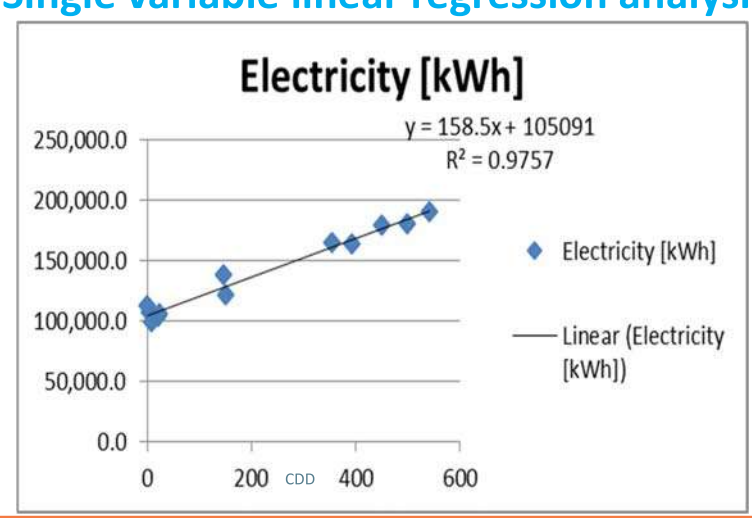
  or
  - static factors
- Static factor: does not routinely change,

  e.g. process or operational changes
  e.g. facility size, product change

Regression Analysis Recap

- Simple Regression
- Multi-regression
- Items to take care of when using the analysis

Steps: Single variable linear regression analysis



Regression Revisited - Straight line formula

- Y = mX + C
- Energy (E) = Factor (F) * Driver (D) + Constant (c)
- E = FD+c
- In the previous case:

  Electricity = 158.5* CDD + 105091
- This formula can be used to predict expected consumption for any given driver
- We can compare **predicted vs. actual usage** to indicate changes in performance.

In general

- Expected energy consumption can be any function of relevant driving factors, D

  E = f(D1, D2, ……. Dn)
- Use the simplest effective model
- A straight-line relationship is often good enough

The main message

- Establish relationships between energy consumptions and appropriate energy (driving) factors
- Sometimes called "performance characteristics"
- Use these to calculate **expected consumption** based on production activity, prevailing weather etc.
- Thereby detect unexplained deviations

Steps: Multi-variable linear regression analysis

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.940601644
R Square	0.884731453
Adjusted R Square	0.85911622
Standard Error	4910.773928
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1665877415	8.33E+08	34.53927	5.99375E-05
Residual	9	217041305.1	24115701		
Total	11	1882918720			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	24848.98769	15881.10198	1.564689	0.152095	-11076.56091	60774.54	-11076.56091	60774.53629
tons	2.549170827	0.494038127	5.159867	0.000595	1.431578939	3.666763	1.431578939	3.666762715
CDD	33.58479232	9.093848921	3.693133	0.004973	13.01307684	54.15651	13.01307684	54.15650779

Statistical Terms

P-value, the P-value represents the probability that there is NOT a statistically significant relationship between variables. Therefore, a low P-value (preferably below 0.05) can be interpreted to indicate that it is unlikely that two variable are NOT related.

For example, lets say a farmer collected data on the number of chickens on his farm and the number of eggs produced for any given month. He determined that for his given data set the P-Value was of 0.03. What does this mean? From this we can conclude that there is a 3 in 100 chance that the number of egg produced is NOT related to the number of chickens.

R^2 is the measurement of how well a regression model fits actual data points. The value can range from 0 to 1 where 1 represents a perfect fit of the regression to the actual data.

In Summary, since we want to consider variables that both have a statistically significant impact on the energy consumed and that we can effectively model, both the P-value and R^2 will be considered.

Statistical Terms

Interpretation

- P-value for each X and Y
- P-value is the probability that the X and Y pair are not correlated.
- If the p-value is less than 0.05, there is less than a 5% chance that the X and Y pair are not correlated (95% confidence interval).
- Determine if results make sense

Statistical Terms Interpretation

1) Review the p-values at the bottom of the data entry chart. Ensure the p-value for each variable is less than 0.05. Variables that have high p-values should be removed from the analysis (remove the variable as an input and rerun the analysis).
2) The F-test is a test of model significance. Ensure the p-value for the model is less than 0.05.
3) Review the R^2 value for the regression equation. (The R^2 value quantifies the amount of variation in the dependent variable, Y, which is explained by the regression equation. Ideally, you would like for the R^2 value to be high, indicating that you have a model that explains a large portion of the variation in energy consumption.)
4) If the R^2 value for the model is low, review the factors to determine if a factor that can impact energy usage has been overlooked.
5) Determine, based on process knowledge, whether the regression makes sense.

Demonstration

The following demo shows how a regression model can be used to show savings from energy saving improvements

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M&V **Calculation Kaolin Processing 1**

Exercise is on a Kaolin processing plant, is a white, alumina-silicate used in making paper, plastics, rubber, paints and many other products. The plant uses spray dryer to produce powdered kaolin.

From your supplied data file - using 2014 as a baseline year, find a model to predict energy use for following period.

a) Show the expected energy use for each month
b) Show the Energy Intensity Index (EII) as a percentage of the actual above or below the expected energy use
c) Show the difference and CUSUM for each month
d) Graph the values
e) A process improvement implemented to make spray drying process more energy efficient. It was commissioned end Dec 2023
f) What are the savings in kWh gas to end Dec 2024?
g) What happened April 2024 to Sept 2024?
h) Are the savings calculated indicative of the real potential of the project?
i) What are the consequences for M&V of this project?

See you in 45 minutes!

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Implementation and Post Project M&V Report

- Data gathering
- Verification of EPIA implementation
- Changes during the project
- M&V analysis
- M&V Report

Data gathering

- Collect data per M&V plan (discussed on Day 1 slides)
- Check early in process that data collection is as intended

Verification of EPIA implementation

- Record (or get evidence of) implementation of actions
- Note changes / lack of implementation and reasons
- Changes to M&V plan as a consequence
  (e.g. M&V method, boundary, relevant variables, static factors, data available)

Changes during the project

- Any other project related changes with M&V consequences should be noted
- Adjust M&V plan bearing in mind the key principles:
- Appropriate accuracy and management of uncertainty
- Transparency and reproducibility of M&V process(es)
- Data management and measurement planning
- Competence of the M&V practitioner
- Impartiality
- Confidentiality
- Use of appropriate methods

M&V analysis

- Determine the savings
- Follow the M&V Plan
- Output is measured and verified energy performance results
- Include consideration of EPIAs with overlapping results e.g. boiler upgrade and heat-load reduction – the combined saving would be somewhat less than each individual element summed.

M&V Report (1 of 2)

- Document the M&V Report according to the M&V plan developed prior to the project

Include

- Scope
- Roles and responsibilities
- Assessment of uncertainty
- Clear, simple description of business case for implementation and context of business

M&V Report (2 of 2)

Include:

- List of EPIAs implemented including additional measures
- EPIAs not implemented and reasons why
- Other project changes
- Whether changes to static factors were needed
- Energy performance improvement results as well as relative financial, legal, regulatory and other results as required by plan
- Challenges (data availability, operational changes) and how they were addressed

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Case Study Compressed Air

The Kaolin plant described earlier has a central compressed air plant. This consists of four constant speed screw compressors and a drying plant.

Data for the period Jan 2023 to Dec 2024 is supplied in the excel data sheet. A new VSD compressor was added to the plant and the controls reconfigured so that the existing compressors ran fully loaded where possible and the VSD compressor handled the variable load. This was commissioned at the end of May 2024.

Case Study Compressed Air

a) What is the saving in kWh for the months June to December 2024?

b) The organisation uses kWh/m^3 as an EnPI for the compressed air system. What is the improvement in this EnPI for the second six months of 2024 compared to the previous year?

c) There was an incident in September 2024 which meant an additional 1,200,000 m^3 was used for an emergency cooling situation.

Make an appropriate non-routine adjustment to the savings figure.
This requires an evaluation of expected September 2024 usage with lower airflow based on baseline model and also based on new situation.

Case Study - Office Lighting

A three storey office building had its lighting upgraded to LED. The existing lighting was fluorescent switch-start with 2,480 T8 1500mm twin fittings. Samples are measured as drawing 142 watts on average. 2% of the lamps were noted to have failed. A check on maintenance records noted that 2% was indeed a normal burnout rate. Monitoring of a normal week established that lighting was all on between 7:30 am and 5:30 pm for five work days. The office is closed 8 days per year for public holidays.

Due to rearrangement of fittings to suit the used spaces, approximately 10% less fittings were required (2224). The replacements dimmed automatically in response to outside lighting conditions. A representative sample circuits from each floor was monitored over a two-week period to measure usage of the new circuits. Research established a failure rate of 0.5% to be normal for the selected LED fitting. The average usage over the two-week period (10 working days) was found to be 19,550 kWh. Electricity cost $0.11/kWh

- a. What was the annual usage in kWh and cost before the upgrade?
- b. What was the annual usage in kWh and cost after the upgrade?
- c. What was the saving in kWh and cost?
- d. Comment on the M&V approach – what would you improve and why?

It's Coffee Time

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Process Review

Review each step of process

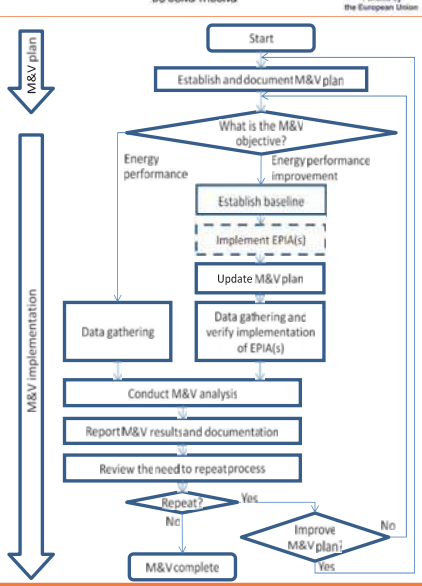


Figure A.1 Overview of the measurement and verification flow (from ISO 50015:2014 - courtesy ISO)

Process Review

Review the need to repeat the process

- Is frequency adequate?
- M&V planning shortfalls
- Data quality or availability issues
- Project delays
- Changes to EPIAs
- Were acceptable saving achieved?
  (Project issues / incorrect projections / modification needed to achieve savings?)
- As specified in M&V plan
- Other issues encountered

Process Review

Establish and document M&V Plan

- Sufficient?
- Cover all aspects of implementation?

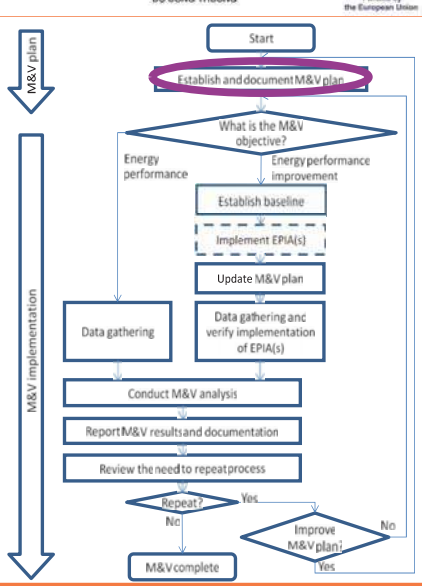


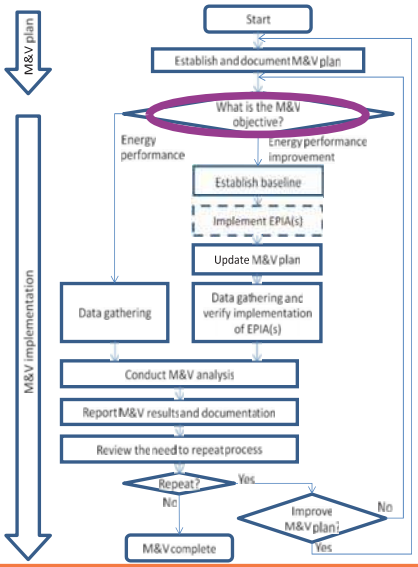
Figure A.1 Overview of the measurement and verification flow (from ISO 50015:2014 - courtesy ISO)

Process Review

Objective – scope & purpose

- Reasons for M&V
- Roles
- Boundaries
- Method
- Data collection plan
- Accuracy / uncertainty
- Update process
- Competence

- Figure A.1 Overview of the measurement and verification flow (from ISO 50015:2014 - courtesy ISO)

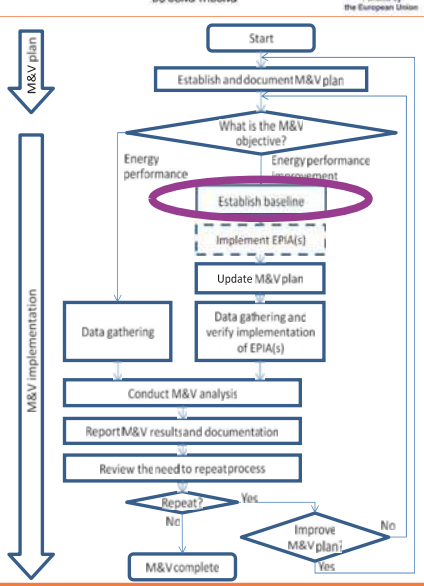


Process Review

Baseline

- Raw data for baseline
- Time period for baseline
- Process to establish baseline
- Processed data – e.g. regression model determined

Figure A.1 Overview of the measurement and verification flow (from ISO 50015:2014 - courtesy ISO)



Process Review

Implement EPIAs

- Changes to EPIAs
- Relevant changes to M&V

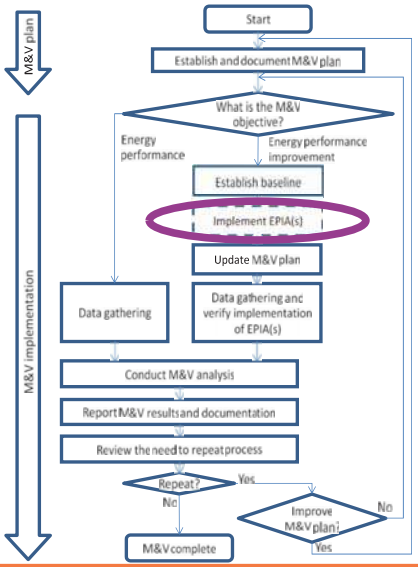


Figure A.1 Overview of the measurement and verification flow
(from ISO 50015:2014 - courtesy ISO)

Process Review

Update plan

- Changes to resources
- Feasibility of planned actions

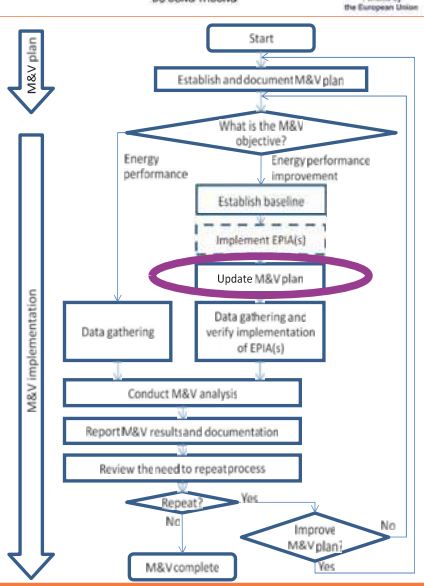
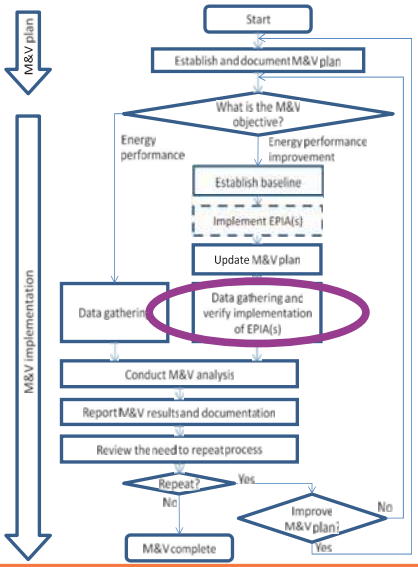


Figure A.1 Overview of the measurement and verification flow
(from ISO 50015:2014 - courtesy ISO)

Process Review

Data gathering
- Adequate plan
- Data quality
- Data availability
- Challenges

Verify
- Status of EPIA implementation



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Process Review

M&V Analysis

- Determine the savings
- Follow the M&V Plan
- Is output measured and verified energy performance result?
- EPIAs with overlapping considered?

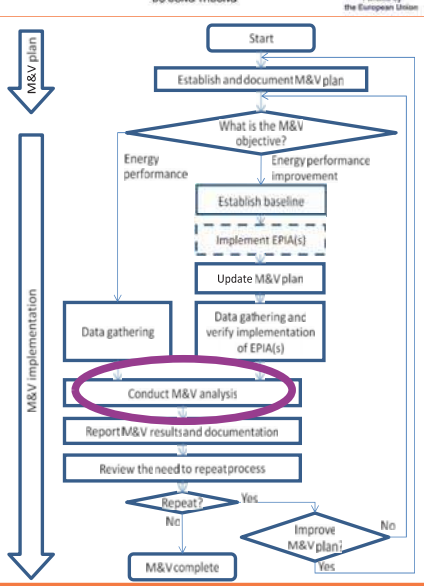


Figure A.1 Overview of the measurement and verification flow (from ISO 50015:2014 - courtesy ISO)

Process Review

M&V Report

- Documented per plan
- Scope, roles
- Uncertainty
- Business context
- EPIAs and changes
- Savings quantified
- Challenges and approach

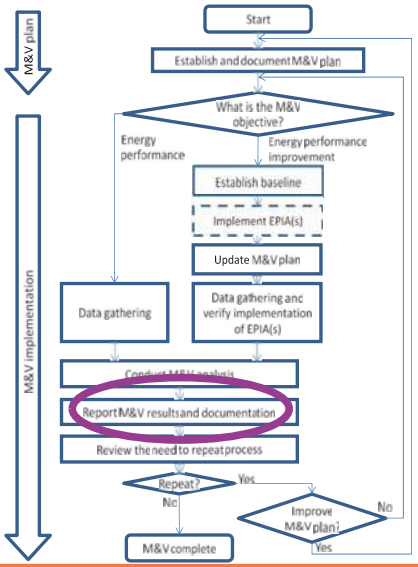
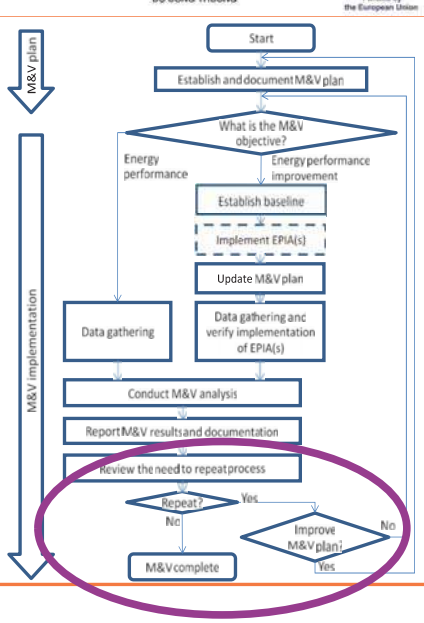


Figure A.1 Overview of the measurement and verification flow (from ISO 50015:2014 - courtesy ISO)

Process Review

Process review

- Take decisions
- Update plan
- Repeat as needed



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ISO 50015 - Key Principles

- Appropriate accuracy and management of uncertainty
- Transparency and reproducibility of M&V process(es)
- Data management and measurement planning
- Competence of the M&V practitioner
- Impartiality
- Confidentiality
- Use of appropriate methods

Questions?

Thank you

Best of luck with developing robust M&V reports to demonstrate Energy and CO_2 savings.