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Measuring Up: M&V for the decarbonisation era

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Measurement and Verification (M&V) is the process of quantifying the energy and carbon savings resulting from energy efficiency and decarbonisation measures (EEMs) implemented in buildings or industrial facilities, using a structured approach to confirm that savings are real, measurable and attributable to the specific measures taken, rather than assumed.

Its primary application has perhaps been within performance-based projects, such as Energy Performance Contracts (EnPCs), where M&V determines payments in guaranteed or shared savings mechanisms. But the project pipeline feeding that has changed shape: cost still matters, but decarbonisation and net zero commitments are also a significant driver, and for many organisations the chosen route is electrification – swapping a fossil-fuelled system for an electric one, particularly when it comes to space heating or transport technologies.

Why do we need it?

M&V is needed to disaggregate the results of a project from what would have happened anyway, and from other

changes affecting energy consumption at the same time.

One of the key challenges is that energy savings cannot be measured directly – what is really being measured is avoided energy: metered consumption compared against a modelled estimate of what would have occurred had the project not gone ahead, i.e. the counterfactual, or ‘business-as-usual’ case.

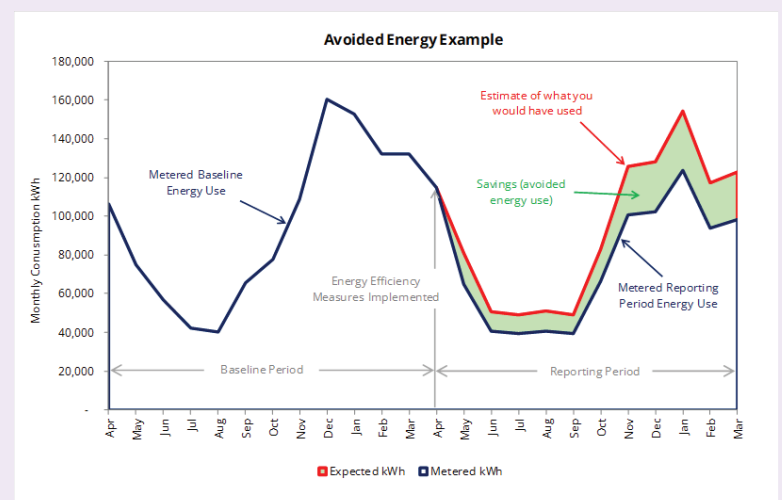
Establishing that counterfactual

always requires some calculation, usually derived from baseline behaviour with routine and non-routine ‘adjustments’ (more on these below) – which is why a properly measured saving will almost always differ from a simple before-and-after comparison.

Electrification projects add a further layer. Historically, an efficiency project was often a straightforward swap – a more efficient version of the same kit, on the same fuel, run the same way. Decarbonisation projects increasingly switch fuel entirely – a heat pump for a gas boiler, an EV fleet for a diesel one – and carbon is the comparison that’s of interest rather than just kWh. Less obviously, the replacement system may not operate the way its predecessor did: a heat pump operates differently to a boiler – checking that it is actually behaving as expected, rather than assumed to be, is a core part of M&V’s purpose.

There are two related but distinct activities: verifying savings against an agreed baseline, and ongoing measurement for good operational control, catching drift or underperformance early, independent of any formal savings calculation. Both matter, but the second is hugely valuable while organisations build experience with electrification measures.

Finally, because calculation and estimation are involved, some uncertainty is inevitable – understanding it relative to the value of the expected saving is essential to judging whether the chosen M&V method is fit for purpose.



Savings or avoided energy consumption or demand (IPMVP Core Concepts March 2022 EVO 10000 – 1:2022)

The Benefits of M&V

Beyond any single project, a structured M&V process pays off further: it gives stakeholders credible evidence of savings rather than assumptions; it de-risks performance-based contracts; by catching underperformance early it feeds a continuous improvement loop; and it provides the auditable trail increasingly expected behind reported savings.

M&V Protocols and Standards

Before considering M&V methods in more detail, it is worth noting the key protocols and standards behind them.

International Performance Measurement and Verification Protocol (IPMVP): developed and owned by the Efficiency Valuation Organization (EVO), IPMVP is the leading internationally recognised M&V framework. Its key principles are that good practice M&V should be:

- Accurate
- Complete
- Conservative
- Consistent
- Relevant
- Transparent

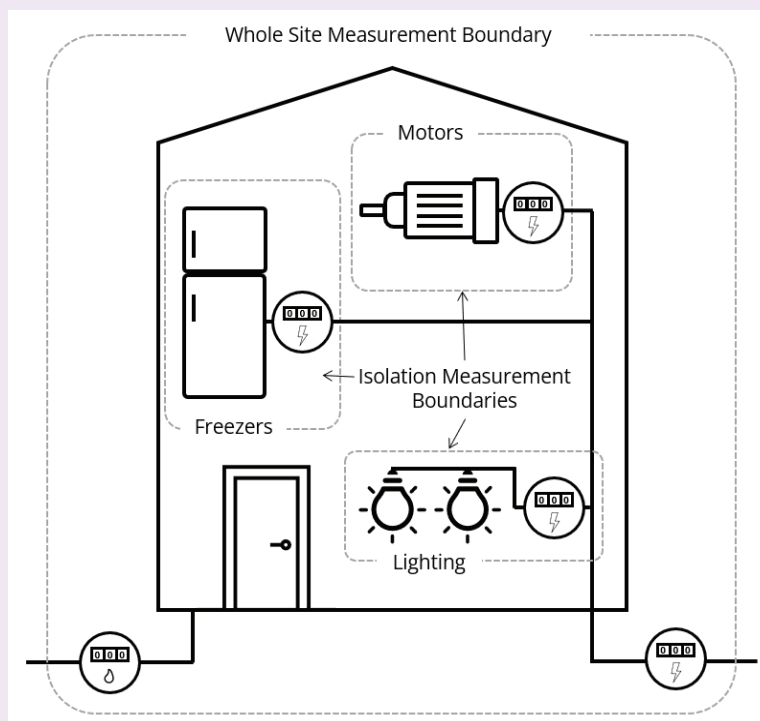
It sets out four options for evaluating EEMs, detailed below, which apply just as well to a fuel-switching measure as to a conventional efficiency upgrade.

ISO 50015: the international standard on M&V principles and guidance, sitting alongside related energy management standards such as ISO 50001. It is method-agnostic – using one or more IPMVP options meets this aspect of its requirements.

Key Components of M&V

Measurement & Verification Planning:

Before any EEMs are deployed, an M&V Plan sets out what will be measured, how often, and what baseline it will be compared against – including, for an electrification measure, which fuel is being displaced and which measurement boundary and unit of comparison (energy, cost or carbon) will apply. Agreeing this upfront matters because many disputes over savings come down to exactly these gaps – missing data or no agreed procedure for handling it – rather than to the measurement itself. The baseline should account for weather, production, occupancy and other relevant variables, and be agreed by all parties before work begins.



Measurement boundaries for M&V – whole site and example isolated measurement boundaries

Implementation: EEMs are installed to the design, with 'Operational Verification' (OV) checks specified – a low-cost way of confirming the potential to perform before full verification starts. This particularly matters for an electrification measure that operates differently to the original technology.

Savings Reporting: Post-project data is compared against the counterfactual modelled from the baseline data, rather than directly against the baseline itself, and the project's requirements determine what is reported – for a guaranteed savings project, was the guarantee met, and if not, what is the reconciliation process?

IPMVP M&V Approaches

IPMVP sets out four M&V options – A, B, C and D. The distinction between them is the Measurement Boundary: whether performance is isolated around the specific EEM (Options A and B) using sub-metering, or assessed across the whole facility (Options C and D) typically using utility metering.

Within an isolated boundary, Option A estimates one or more parameters (a lighting retrofit's operating hours, say) while Option B measures all of them directly – better suited to a variable load that can be isolated (most likely electric loads) but potentially requiring

new metering. Within a whole-facility boundary, Option C compares utility data before and after using a modelled baseline, while Option D 'calibrated simulation' can be used where no baseline data exists at all, such as for a new building. Which option fits a given project depends on factors such as whether the EEM can be isolated or is implemented alongside others, the value of the project, who carries the risk under any performance contract, and how much measurement effort is proportionate.

Take heat pumps as an example – the same technology can be measured in different ways depending on the details of a project and its setting: a standalone retrofit measured against a performance guarantee calls for different treatment than a heat pump included in a wider decarbonisation package, or one serving a brand-new building. In practice, all four IPMVP options could apply.

Option B:

Where the heat pump can be isolated and its performance matters in its own right – especially one measured against a performance guarantee – the most rigorous approach follows Option B: Retrofit Isolation (all parameters) with the electrical input separately metered

from the building's supply, and a heat meter measuring the delivered heat. The ratio of the two, usually over a full heating season, is the Seasonal Performance Factor (SPF) – an important operational indicator of how well the heat pump itself is running, since a single instantaneous Coefficient of Performance (COP) reading, which varies with temperature, load and commissioning, tells you little on its own.

Many projects involve switching from gas to electricity, and SPF on its own only describes how efficiently the heat pump is running, but doesn't give us everything we need to calculate savings. That still needs a credible counterfactual for the gas that would otherwise have been consumed, and the robust way to establish this is to model the site's own historic gas consumption against external temperature, and extend the weather-normalised baseline over the reporting period (see Adjustments, section, facing page). The saving is then that modelled baseline gas, less any residual gas still being consumed if the heat pump isn't covering the whole load, less the electricity the heat pump has used, converted to common units (e.g. carbon or cost).

As with any IPMVP option, the measurement boundary needs stating precisely – here, exactly which loads count towards SPF. The SEPOMO-Build project's H1 to H4 convention nests four such boundaries: H1 is the heat pump alone; H2 adds the source-side fan or pump (an air-source fan or a ground/water loop pump); H3 adds the backup heater; and H4 adds the building-side distribution fans or pumps. A heat pump can look good at H1 and still disappoint at H3/H4 if the backup heater is doing too much work. Circulation pumps in particular are worth checking against the baseline rather than assuming they're a new load – many gas systems already run distribution pumps of their own.

Heat itself is metered with a heat meter combining a flow-rate sensor with matched flow/return temperature sensors; an MID-certified meter to EN 1434 is worth specifying, checked for an accuracy class suited to heat pumps' typically low temperature differences. For M&V purposes, the wider boundaries are usually the more decision-relevant figures: a savings claim built only on SPF H1 would miss the backup heater's and distribution pumps' electricity entirely, potentially overstating the measured

saving – which is exactly why the boundary used needs to be stated plainly alongside any SPF figure.

Measured performance should reflect what the installation actually delivered, feeding ongoing monitoring and control as well as the savings figure – but it needs new metering and a full heating season before a robust result is available.

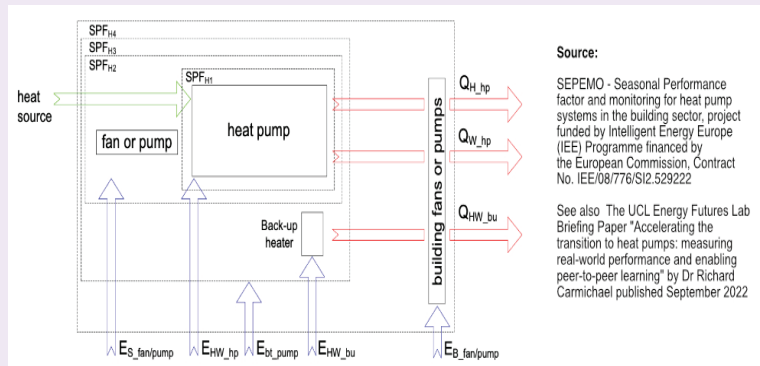
Option A:

An approach following Option A: Retrofit Isolation (key parameter) may have a metering set-up not too different from the Option B approach above – the difference is that at least one parameter is assumed rather than measured. Here, it's the heat demand: spot-checks of COP or a measured SPF establish the heat pump's efficiency, but that efficiency is then applied to an estimated or historic heat demand rather than the building's actual metered load, with an assumed or measured boiler efficiency doing the equivalent on the gas side to derive a notional 'gas that would have been used'.

This can be a reasonable simplification where variable heat demand is genuinely hard to attribute, and it still tells you how efficiently the equipment is capable of performing. What it misses is any check that the assumed demand matches what the building actually needed: pairing a measured efficiency, however robustly established, with an assumed demand disconnects the result from how the site runs across a full season, crediting much the same 'saving' whether the heat pump is well controlled and commissioned or not, and giving little ongoing feedback on how the installation is really performing.

Option C:

A switch from gas heating to an electric heat pump has a material impact on both utility meters – electricity rising as gas falls – so Option C is also a useful approach. This applies whether the heat pump is one of several measures rolled out together – alongside fabric upgrades, controls or solar, say – or a standalone installation serving a whole building and where isolation is not possible. Even where isolation is possible, there are good reasons to choose Option C: many organisations already track whole-site electricity and gas as part of routine energy management, so it reuses data that's collected anyway; utility meters are inherently robust (see Uncertainty, below), giving a credible



From the SEPEMO-Build project's H1–H4 measurement boundaries for a heat pump system
Source: SEPEMO-Build project (Seasonal Performance factor and monitoring for heat pump systems in the building sector), funded by the EU's Intelligent Energy Europe Programme

net-impact figure without the accuracy caveats that come with sub-metering; and it captures the full picture where other measures are being layered on at the same time. Historic utility data for each fuel is modelled against external temperature and other relevant independent variables, and those models are then extrapolated over the reporting period to give a normalised baseline for each fuel; those baselines are compared against what was actually used. The trade-off is that Option C captures everything happening on site, not just the heat pump – so where there's a lot of other change during the reporting period, disaggregating its contribution can require non-routine adjustment (see Adjustments, below), and the results are only as credible as how well that change has been tracked.

Option D:

For a heat pump or heat network serving a new building, with no pre-existing consumption to form a baseline, Option D applies: a calibrated simulation model predicts consumption with and without the measure. It is useful where no other option is available, but the resulting savings then rest on the simulation's assumptions rather than in-situ measurement.

Whichever option applies, the M&V Plan should say plainly what the counterfactual is and how it was derived, rather than leaving it as an unstated assumption. Three things are worth building in for a metered approach:

- Measure for a full heating season, and weather-normalise if a shorter dataset is unavoidable – SPF depends heavily on how cold the winter was.

- Meter the backup heater separately, and check commissioning early – a heat pump left to run hotter than necessary is a common and easily missed fault.
- State the combined uncertainty of the heat and electricity meters, since SPF's uncertainty combines both rather than being assumed away.

What are 'Adjustments'?

'Adjustments' have been referenced in this article and are often used in M&V, so what is meant by them and why are they relevant? It is worth first noting that there are two general types of adjustment – 'Routine' and 'Non-Routine' as follows.

Routine Adjustments: changes made to baseline or reporting period data to account for expected variation, such as colder weather increasing heating demand or lower production reducing consumption. Weather and production are 'independent variables' that must be accounted for to make a fair with/without-EEM comparison – this matters even more for electrified heating, whose efficiency is itself weather dependent, on top of weather's more familiar effect on heat demand. This is typically carried out via regression analysis, with statistical metrics validating how well the model explains the variation.

Non-Routine Adjustments: unexpected changes to something that would usually remain static within the boundary – floor area, primary use, a material plant change – quantified ideally through additional sub-metering or otherwise via an engineering calculation specific to the change, as covered in more detail by the IPMVP Application Guide on

Non-Routine Events and Adjustments. Left poorly monitored, these can starve M&V of good information and cause disagreement between parties, so a clear process for capturing and calculating them matters for transparent reporting.

Dealing with Uncertainty

It is important to consider whether a proposed method will yield sufficiently low uncertainty that the expected savings can actually be measured. The key sources are:

Modelling – regression analysis is used to determine relationships between independent variables (weather, production, etc.) and consumption; however, the resulting models are never a perfect fit, so it is important to quantify the associated error.

Metering – measurement devices carry some error in precision and accuracy, detailed by the manufacturer. Utility meters can be considered 100% accurate for M&V purposes under IPMVP, since consumption ties directly to billing; non-utility meters, typically including heat meters, unless they're the fiscal meter for a heat network, do not benefit from that assumption and should be specified with a suitable accuracy class, including for the low flow-return temperature differences discussed above.

Sampling – used to reduce measurement cost when similar EEMs are deployed many times over, such as light fittings, but care should be taken that it doesn't push uncertainty beyond acceptable limits.

A structured M&V process considers each of these sources and evaluates it relative to the value of the expected savings; where uncertainty is too high, this may point to an alternative approach, but assessing it always helps all parties understand the underlying measurement risk.

Professional qualifications

The EVO/AEE 'M&V Fundamentals and IPMVP' course leads to the Certified Measurement & Verification Professional (CMVP) qualification. EVO also offers Performance Measurement & Verification Analyst (PMVA) and Performance Measurement & Verification Analyst Expert (PMVE), the latter an advanced qualification for those regularly preparing or assessing M&V Plans.

CPD Entry Form

Please mark your answers below by placing a cross in the box. Don't forget that some questions might have more than one correct answer. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet, return it to the address below. Photocopies are acceptable.

Questions

Question 1. What does IPMVP stand for?

- ☐ International Performance Measurement & Verification Protocol
- ☐ International Performance Monitoring & Verification Protocol
- ☐ International Performance Monitoring & Validation Protocol
- ☐ International Performance Measurement & Validation Protocol

Question 2. Which is the International Standard on Measurement & Verification principles?

- ☐ 50001
- ☐ 50006
- ☐ 50008
- ☐ 50015

Question 3. Which of the following is NOT typically cited as a benefit of a structured M&V process?

- ☐ Giving stakeholders credible evidence of savings
- ☐ Feeding a continuous improvement loop across a portfolio
- ☐ Eliminating all uncertainty in measured savings
- ☐ Supporting compliance and reporting obligations

Question 4. Why is a single COP (Coefficient of Performance) reading a poor guide to a heat pump's real-world efficiency?

- ☐ COP varies considerably with outdoor temperature, load and commissioning quality
- ☐ COP can only be measured in a laboratory, never on site
- ☐ COP is not related to SPF in any way
- ☐ A heat pump's COP is fixed by the manufacturer and cannot change once installed

Question 5. Of the following, which type of project is most likely to be measured using IPMVP Option A?

- ☐ Building fabric upgrade
- ☐ Solar PV
- ☐ Lighting fitting retrofit
- ☐ Behaviour change

Question 6. What data is typically used under IPMVP Option C?

- ☐ Submeter data for the various loads being measured in the project
- ☐ Estimated data for key parameters such as hours or power
- ☐ Simulated building energy data
- ☐ The utility's fiscal meter data for gas and electricity

Question 7. What is an advantage of Option D?

- ☐ Regression analysis can be applied to historic data
- ☐ Submeter data can be used to develop baselines
- ☐ It provides an approach when no baseline data is available
- ☐ Parameters can be estimated

Question 8. What does SPF stand for in relation to heat pump performance?

- ☐ Standard Power Factor – a laboratory test rating only
- ☐ Seasonal Performance Factor – heat delivered divided by electricity consumed over a full season
- ☐ System Power Fraction – the share of backup heater use
- ☐ Seasonal Power Factor – a measure of electrical grid demand

Question 9. For a heat pump replacing a gas boiler, why is a measured SPF alone not enough to establish savings?

- ☐ SPF cannot be measured over a full heating season
- ☐ SPF only applies to whole-facility Option C projects
- ☐ SPF only describes the heat pump's own efficiency – savings still need a credible gas counterfactual, most robustly a weather-normalised historic baseline
- ☐ IPMVP does not permit SPF to be used in savings calculations

Question 10. Why is back-calculating a 'deemed' gas baseline from an assumed boiler efficiency a weak counterfactual for a heat pump project?

- ☐ Gas boilers never have a stated efficiency figure
- ☐ It is disconnected from how the site actually ran and doesn't reward good commissioning and control
- ☐ It always overstates the savings achieved
- ☐ IPMVP does not permit any use of assumed values

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