Energy Efficiency Performance-Tracking Platform for Benchmarking Savings and Investments in Buildings

Measurement and verification procedures for energy efficiency investments

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This deliverable addresses how one can determine the performance of buildings and energy improvement measures through the EN-TRACK platform. This deliverable does not choose a singular solution, instead hybridising automated and industry-standard manual approaches. This deliverable also gives a view of the resultant services from these implementations, informing the further work of WP5, which seeks to commercialise and exploit these key services. Key references were made to information input from D1.1 and D1.3, which codify data requirements and collection practices. The concrete conclusions of this deliverable include the residual issues which need to be considered and addressed during software implementation, as well as lists of variables to support current and future services envisaged.

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Deliverable beneficiaries:

WP / Task
WP2: System Preparation (all tasks)
WP3: Enabling data collection at building owner-side (all tasks)
WP5: exploitation and business plan (Tasks 5.1 and 5.2)

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Abbreviations and Acronyms

List of abbreviations **only** related to this deliverable.

Please complete the following proposed one, deleting the unnecessary items.

Acronym	Description
CA	Consortium Agreement
DoA	Description of Action (annex I of the Grant Agreement)
EC	European Commission
GA	Grant Agreement
PC	Project Coordinator
PMC	Project Management Committee
PO	Project Officer
PS	Project Secretariat
QM	Quality Management
SC	Scientific Coordinator
TMT	Technical Management Team
TL	Task Leader
ToC	Table of Contents
WP	Work Package
WPL	Work Package Leader
IPMVP	International performance measurement and verification protocol
M&V	Measurement and Verification
NEBs	Non-energy Benefits
NRA	Non-routine Adjustments
CVRMSE	Coefficient of Variation (Root Mean Squared Error)
MBE	Mean Bias Error

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1 Executive summary

This document describes the limitations and opportunities inherent within automated and manual measurement and verification (M&V) methods provided through the EN-TRACK platform. It is important to note that full M&V procedures are nuanced, and case-sensitive, and should be completed by an accredited professional where the outputs are going to inform key contracts, financing or service agreements.

The deliverable analyses the services that EN-TRACK can feasibly provide now and into the future in Section 3, describing the necessary data input and therefore the feasibility of providing this service in the near-term. This work aims to aid the activities of Work Package 5 by providing a list of services which can be converted into value propositions, and possible revenue streams.

The deliverable describes the importance of wide-ranging data capture for these services. As such, it is proposed that the platform enables both automated synthesis of M&V outcomes (providing low transaction costs but lower data quality and fewer data features); alongside the manual input of M&V information, supported by automated data sufficiency checks, proposed guidance, and preliminary suggestions of specific IPMVP protocols. These two pathways are described in depth in Sections 5-6 with key supporting documentation, such as graphical process flows, presented in the Appendix.

The deliverable then considers how best to integrate the latest modelling approaches, proposing methods for the selection of preliminary modelling approaches using industry standard model assessment metrics such as Mean Bias Error and the Coefficient of Variation (Root Mean Squared Error).

The deliverable also discusses novel methods for the measurement and verification of Non-Energy Benefits through the COMBI and MBenefits approaches developed in partnership with the European Union. Decision trees and surveys for the selection of these approaches are provided alongside quantified increases in project value associated with specific non-energy benefits.

The deliverable concludes with descriptions aiding the implementation of the above services, which inform Work Packages 2 and 3, along with an assessment of specific services and related variables whose inclusion should be considered within Work Package 1.

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2 Introduction

2.1 Deliverable Scope

This deliverable examines the measurement and verification (M&V) services and solutions that the EN-TRACK platform can offer to its users, both now and also looking into the future. This deliverable also proposes a structured methodology to underpin the provision of these M&V services and solutions based on input from users of the platform.

It should be noted that, historically, M&V for individual projects has typically been carried out by accredited professionals on a case-by-case basis, and that there are inherent limitations as to what an automated platform such as EN-TRACK can achieve. These limitations are highlighted here, in the introduction, and covered further on in the report where relevant in relation to how these limitations may be addressed and the services that can reliably be provided.

One such limitation regards the suitability of EN-TRACK outputs for further reporting. EN-TRACK must not create the expectation that the results from EN-TRACK can be used as an auditable input to corporate reporting or due diligence exercises. There are no staff within EN-TRACK to assess the results to such an exacting standard or to be held responsible for them. In addition, though automated M&V approaches function well for statistically significant scales of project portfolios, where projects are distributed normally and united by specific energy end uses, EN-TRACK will not represent such a portfolio in its current iteration. This is due to the variety of energy end-uses and types of non-routine adjustments that will likely be present in the database, resulting from varied building typologies and end uses that will be stored in the platform. This variation will degrade automated predictions as the modelling approach will not be able to distinguish “regular” patterns of energy consumption.

There are methods that can be utilised to address this variation, notably the “categorise, cluster, regress” approach to modelling disparate building communities. However, this falls outside of the current EN-TRACK project. Nevertheless, the consortium needs to consider storing sensible data features to ensure compatibility for possible future use of such innovative approaches. In general, this deliverable advises against the omission of useful data features, though a balance must be struck to allow the data model to be efficient and navigable. The collation & maintenance of a register of historic M&V information and approaches is itself a service that the platform could provide to M&V professionals. This would not only act as a building logbook, recording changes to building fabric and systems over time, but would also allow for historic M&V data to be collected. This can also form a repository of standard approaches and, along with the data sufficiency exercised described below (Step 5: Determine data sufficiency), would enable the platform to provide forward-looking data collection requirements.

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2.2 Service Definition

Where input data can be integrated into the platform, the following services can be provided:

- Recording and comparing measured and verified outcomes to initial savings estimations (for individual measures or whole projects)
- Recording the user's selected M&V approach,and comparing outcomes where this selected approach differs from the approach suggested by EN-TRACK's automated procedure.
- Recording the usage of non-routine adjustments and their impact on measured and verified project outcomes.
- Recording changes to building fabric & systems over time, forming a "logbook" of interventions
- Storage of M&V data for future utilisation within the EN-TRACK platform.

3 EN-TRACK M&V Services Analysis

The table below shows the proposed platform M&V services, along with the required inputs and a proposed form for the outputs:

Table 1: Proposed M&V Services with relevant information to inform implementations.

Service	Required Inputs	Output Form
Recording and comparing measured and verified outcomes to initial savings estimations (for individual measures or whole projects)	1. Project Initial savings estimation (for individual measure or whole-project) 1. Measured and verified project savings 2. Other M&V indicators (model accuracy, number of non-routine adjustments, M&V approach (IPMVP option)).	Benchmarking showing percentage over/underperformance across the selected project portfolio, with the users own position highlighted. The output should allow for filtering or co-correlation by M&V indicators.
Recording the user's selected M&V approach, and comparing outcomes where this selected approach differs from	1. User's selected M&V approach	The output will use the benchmarking graphical form, displaying the distribu-

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the approach suggested by EN-TRACK's automated procedure.	2. Automated M&V suggestion (this will require the user to input pre- and post-installation data, their evaluation needs, expected project outcomes (savings %) and measurement boundaries).	tion of project under-/over-performance with two filters: M&V selection matches; M&V selection differs.
Recording the usage of non-routine adjustments and their impact on measured and verified project outcomes.	1. The user will input and describe their usage of non-routine adjustments (NRAs), which may include a categorical tag for common causes of adjustment.	The output will graphically show the correlation between the number of non-routine adjustments and percentage over- /underperformance. This can also be displayed through filtering the benchmarking outputs by number of NRAs.
Recording changes to building fabric & systems over time, forming a "logbook" of interventions	1. Existing data features describing the building fabric and system measures within energy efficiency interventions.	This would be output as a simple anonymised list for a given building

4 The proposed methodologies:

4.1 Divergence of methodologies

The EN-TRACK platform aims to collate and make available the maximum amount of energy performance data and data-centric services to its users. As such, a balance must be struck between gathering detailed, often qualitative data from human users (which is time intensive from the perspective of both the user and the curators of the platform), and the automated entry of large volumes of data, the quality of which will likely vary.

As such the platform needs to accommodate two pathways for considering the measurement and verification of project outcomes. The first of these pathways is designed for larger projects where M&V would have occurred regardless of the presence of the EN-TRACK platform. Here the platform can support this M&V by proposing industry best practice, guidance and useful

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resources, as well as storing the M&V outputs for future utilisation and analysis. This is discussed in the section titled “Pathway 1: Manual M&V”.

The second pathway is explored in the section titled “Pathway 2: Automated Analysis” and is designed to alleviate the burden of performing M&V for small and medium projects. Although the oversight and review of an accredited professional is necessary for these outputs to be utilised outside of the EN-TRACK platform, this approach uses data-centric modelling to perform the basic steps of M&V protocols, determining the sufficiency of the data, conducting modelling and using real-time data series to produce savings estimations.

Together these two methodologies allow for the maximum amount of insight into building performance and M&V to be stored and utilised through the EN-TRACK platform, now and into the future. They also enable the ongoing comparison of these methods and their outcomes at the portfolio and individual project scale.

4.2 Shared Methodological Considerations: Data Quality

The quality of modelling and forecasting is inherently tied to the quality of the data input over the course of the process, a consideration shared by both manual and automated M&V methods. As such, the first methodological step is to examine and raise issues of data quality. However, in order to do this, some associated meta data is required. Namely the system must, wherever possible, be able to differentiate between true observed data (i.e. meter readings) from the modelled data that utility companies use to estimate consumption where metering is unavailable or has failed. Feeding this estimated data into M&V models will bias the M&V procedure towards replication of the utility estimation model, rather than modelling the true nature of the building. As such, we will notify all users and data providers of the importance of ensuring their utility energy data includes estimation tags wherever possible. Also, this data will be excluded during the modelling process wherever possible.

Where a utility has failed to tag their estimated data point in provided data, there is little concrete remit. This is because detecting estimated data can be particularly difficult, particularly when it is interpolated from nearby datapoints. Even where a dissimilarity is detected, distinguishing periods of estimation from other non-routine events (NREs) remains an issue. Simple methods exist for identifying non-routine events and the resulting consumption data (including estimation). These can be applied during the modelling stage: first a baseline model and prediction is built, then observed data (from the post or pre-intervention stage) can be compared to generate a dissimilarity series over the observed time series. Then a change points algorithm can be applied to this dissimilarity time series. Where no estimations or other NREs have occurred, the difference between the behaviour of the train and test datasets (which may be pre- or post-intervention) will be stable. Although the implementation of this stage is not elementary, it would provide an additional valuable service to users by highlighting possible periods of estimation or other NREs for further investigation, as well as adding caveats to savings

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estimations where necessary. A systematic graphical description of this stage is provided in context in the appendix.

It is also important to consider the data quality of contextual data, such as the estimated expected savings that underpin the original proposed specification of the EEMs. Much of this information may be input from national audit schemes, such as that operating in Bulgaria. To facilitate the Bulgarian users, the platform will allow automatic uploading of data, based on a standardized summary of a developed Energy audit available in MS Excel. The quality assurance of the data withing the summary and the energy audit itself is responsibility of the Sustainable Energy Development Agency (SEDA), an executive agency within the Ministry of Energy. The SEDA is also responsible for the accreditation of the energy auditors in Bulgaria. All building owners are obliged to submit their Energy audits, together with the standardized summary to SEDA and, in case of discrepancies and inaccurate calculations, SEDA's experts send a formal request for the energy auditors to make the necessary adjustments.

5 Pathway 1: Manual M&V

The EN-TRACK methodology for providing manual M&V solutions to users will have six key steps, and the user will be engaged in the last two steps. The first step is internal to the EN-TRACK consortium: to map and select specific M&V approaches from the various publicly available or open-source options that exist currently. These selected approaches will then be proposed to the user through steps 1-5 of the methodology provided below, before the user is signposted to specific guidance and resources in step 6. The final step is for the user to carry out the data gathering and analysis defined within their selected M&V approach before submitting relevant data into the platform and gathering EN-TRACK outputs where necessary.

2. Define and describe the existing data
3. Define the expected projected outcomes
4. Define the evaluation needs and measurement boundaries
5. Propose IPMVP or equivalent option
6. Determine data sufficiency
7. Proffer M&V guidance and resources.

5.1 Mapping and Selecting Available M&V Approaches

EN-TRACK must select widely accepted M&V protocols for assuring objective, data-driven, traceable evaluation of the achieved savings from applied energy efficiency measures. Initial sources for these protocols include:

- ICP supported protocols (namely IPMVP options A-D)

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- CalTrack Protocols
- Comfortmeter (this will be used for the evaluation of non-energy benefits, supporting M&V protocols but not delivering any savings estimations).

However additional alternatives may be considered:

- ASHRAE Guideline 14
- FEMP M&V Guidelines (v4.0)
- Technology specific guidance (i.e. for irrigation[1]).

The key criteria, and the performance of the above protocols against these criteria are presented in the table below:

5.1.1 Step 1: Define & describe the existing data

Table 2: Key data features to be defined and described.

Data Feature	Automated Determi-nation?	Proposed Approach
Data Granularity (temporal)	☒	We need to determine the granularity of the data over time: is the data quarterly, monthly, daily, hourly or half hourly? This can be determined through automated analysis of input data.
Data Granularity (spatial)	☐	We need to determine the granularity of the data over the site: is the data for the primary meter or submeter? Are any data showing aggregated perspectives, or is there a need for disaggregation across a submetered network? Is the meter measuring specific outputs (i.e. amperage) or full power consumption? This would need user input to define the metering arrange-ments, which would be input by the user using a tree data structure, with attached tags for the various datasets.
Data coverage (temporal)	☒	We need to determine what proportion of the baseline and post-installation reporting period is covered by the input da-tasets.

[1] https://3hzk7prqhr33icsww1y4geu6-wpengine.netdna-ssl.com/wp-content/uploads/2019/09/Outdoor-Irrigation-MV-Protocol.pdf

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		This will require a definition of the start and end dates of these periods, but otherwise this can be determined through automated analysis of input data.
Data coverage (spatiotemporal)	☒	We need to determine what proportion of the metered and submetered networks is covered by the input datasets, and what proportion of the baseline and post-installation reporting period is covered by the metered/submetered datasets. Where data is missing, it may be possible to calculate or disaggregate the data. This will require a definition of the start and end dates of these periods, but otherwise this can be determined through automated analysis of input data. This would need user input to define the metering arrangements, which would be input by the user using a tree data structure, with attached tags for the various datasets.
Data coverage (energy vectors)	☒	We need to determine whether all energy vectors have been fully described for all meters across the whole reporting and baseline periods. This data coverage will consider both primary energy (i.e. fuel usage) as well as end use energy (i.e. kWh of thermal energy consumed), either through provision of both data sets, or the provision of an updated conversion factor, which may change over time. This feature will require a definition of all energy vectors present at the site and their various conversion factors (and whether these are dynamic), but otherwise this can be determined through automated analysis of input data.
Routine adjustments	☒	We need to determine which routine adjustments (normalisation) have been conducted. There is no method for confirming the application of these adjustments, therefore pre-adjustment data needs to be input alongside the adjustment/normalisation data sets. These data sets can be tagged with their data features (manually when data is input or titled in predictable way to allow the platform to automatically collate a list of routine adjustments.
Non-routine adjustments	☐	We need to determine which non-routine adjustments have been conducted or would be needed. The user will need to input this information, and a graphical format

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		would likely be most user-friendly (a timeline is shown for the data coverage periods of each metered/submetered network, with the ability to add in points and periods of non-routine adjustment). The EN-TRACK platform could automatically identify non-routine events and ask the user to input whether/when non-routine adjustments were conducted and why and how the non-routine adjustment was conducted.

5.1.2 Step 2 & 3: Define the expected projected outcomes and the evaluation needs/measurement boundaries

Below, we have separated the aspects of the expected project outcomes, and the evaluation needs, which determine the best IPMVP option for underpinning the site's M&V approach. The aspects related to expected project outcomes are highlighted in blue, whilst those related to the evaluation needs are highlighted in green.

The user will be asked a series of 12 questions, derived from Figure 1. These will be input into a suitability matrix (implemented in Figure 2). This will guide the user through the suitable options for their specific project and evaluation needs. The data sufficiency will then be layered on top of this suitability (Step 4) to propose IPMVP options.

ECM Project Characteristic	**Suggested Option**			
	A	**B**	**C**	**D**
Need to assess *ECMs* individually	X	X		X
Need to assess only total facility performance			X	X
Expected ***savings*** less than 10% of utility meter	X	X		X
Significance of some ***energy*** driving variables is unclear		X	X	X
Interactive effects of ECM are signficant or unmeasurable			X	X
Many future changes expected within ***measurement boundary***	X			X
Long term performance assessment needed	X		X	
Baseline data not available				X
Non-technical persons must understand reports	X	X	X	
Metering skill available	X	X		
Computer simulation skill available				X
Experience reading utility bills and performing regression analysis available			X	

Figure 1: The IPMVP's suggested option checklist for M&V options A-D.

If monthly data is the only available data, then expected savings should be >10%. Otherwise, per IPMVP Core 2016, Option C can be used for expected savings <10% if more granular data is available.

Although a decision tree implementation was tested for the data contained in Figure 1, there

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are few singular pathways that define specific options, leading to a complex graphic with minimal utility for the user. Instead, a “suitability” matrix approach was developed and tested in Excel (embedded below), which can rank the options in order of suitability, considering user checkbox responses.

Figure 2: A suitability matrix ranking the various IPMVP options based upon user input of expected projected outcomes and evaluation needs.

5.1.3 Step 4: Propose IPMVP option(s)

The EN-TRACK platform will present ranked IPMVP options, based on Figure 2, to the user. Further guidance can be provided to describe where discrepancies persist between the best IPMVP option and the input data sufficiency or the user’s expected projected outcomes and evaluation needs, as described in Step 5.

5.1.4 Step 5: Determine data sufficiency

The EN-TRACK platform will need to determine whether the input data satisfies the decision tree leading to one or more suitable IPMVP options. The decision tree will outline how the data is sufficient for each option, or where this is not the case, around which aspects the data is not sufficient. This stage will output a confirmed IPMVP option to be proposed where data is sufficient. Where data is still not sufficient, the user will be prompted to input further data or reconsider their initial selection of IPMVP options, returning the user to Step 4.

5.1.5 Step 6: Proffer M&V guidance and resources

The EN-TRACK platform will provide direct links to the IPMVP’s guidance, as well as the ICP’s Project Development Specification and embedded links, highlighting relevant sections for the

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given IPMVP option in the latter. The EN-TRACK platform can also link to open-access resources for completing savings calculations, linear regressions or values estimations. A list of relevant resources is provided below. This is an initial list that will continue to grow and be integrated in the platform as EN-TRACK progresses.

1. ICP Options M&V Plan templates
2. IPMVP Core Concepts/M&V Protocols
3. ISO50015 General Principles & Guidance
4. ASHRAE Guidelines
5. Nexant M&V Operational Guides
6. Universal Translator v3 (PG&E)
7. EN 16212:2012 Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods
8. Inverse Modeling Toolkit (ASHRAE)
9. ASTM E2797 Building Energy Performance Assessment (BEPA) standard
10. A list of independent-party assessors in various regions
11. Presentation guidelines for M&V concepts: Uncertainties etc

6 Pathway 2: Automated Analysis

6.1 Expected input data format

The automated method of M&V needs to be designed and implemented to capture the maximum number of projects, trading off detailed qualitative information provided by a human user with a lower transaction cost in producing projects. In parallel, with a manual method, we can assure that the maximum amount of project information is captured and made available through the EN-TRACK.

The automated method has been designed for two expected data formats. Firstly, data with an hourly or sub-hourly granularity, that which may be provided by smart meters. Secondly, and more likely, data coming from billing data in a monthly or annual format. These formats will capture both primary sources of automated data input into the platform, and scenarios are presented below and overleaf (Tables 3 and 4) to show how this data will be utilised in each scenario.

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Table 3: A definition of the expected data collection format for Hourly or Sub-Hourly data.

Scenario Title	Hourly or Sub-Hourly Granularity Data (Automated Input)
Weather Normalisation?	Yes, but tracking of building baseline temperature would vastly improve this normalisation.
Occupancy or other Normalisation?	No.
Source of baseline data	▪ pointOfDeliveryIDFromUser (time series data).
Source of explanatory data	▪ Normalisation (Routine adjustment): Weather Data ▪ Non-routine adjustment: No automated data source defined, though user could input this data manually.
Source of post-installation data	▪ pointOfDeliveryIDFromUser (time series data).
Sufficiency of each of the above	▪ Baseline data: 12+ months data coverage before intervention ▪ Post-installation data: 12+ months data coverage after intervention ▪ Normalising Data: Weather Data covering whole of baseline and reporting period. Where data is gappy, statistical inference must be used to enable normalisation.
Services the EN-TRACK platform could provide under this scenario	▪ Calculation of change in energy consumption normalised by weather data. This can represent a saving that has undergone the most basic form of measurement & verification, although the user cannot apply any further adjustments (routine or non-routine) without providing more data. ▪ Recording changes to building fabric & systems over time, forming a "log-book" of interventions.
Additional Services and their data needs	▪ Recording and comparing measured and verified outcomes to initial savings estimations (for individual measures or whole projects): This service requires initial savings estimation data ▪ Recording the user's selected M&V approach, and comparing outcomes where this selected approach differs from the approach suggested by EN-TRACK's automated procedure: This service requires users to complete and disclose an industry-standard M&V approach to the EN-TRACK platform. ▪ Recording the usage of non-routine adjustments and their impact on measured and verified project outcomes: This service requires the utilisation and tracking of non-routine adjustments.

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Table 4: A definition of the expected data collection format for Monthly or Annual data

Scenario Title	Monthly or Annual Granularity Data (Automated or Non-Automated Input)
Weather Normalisation?	Yes, though troublesome: the number of heated days will vary significantly from month to month, especially when considering non-domestic properties that may only be heated fully on weekdays. In addition, where manual meter readings are input, they may not correspond to the full month. For example July 2020 ended at midnight on Friday 31st July. If, for convenience, the meter reading was taken at 09:00 on Monday 3rd August, July's energy consumption would cover a period that was ~8% longer than it should be. As with the former scenario, the tracking of building baseline temperature would vastly improve this normalisation.
Occupancy or other Normalisation?	No.
Source of baseline data	▪ pointOfDeliveryIDFromUser (Online Form: time series data).
Source of explanatory data	▪ Normalisation (Routine adjustment): Weather Data ▪ Non-routine adjustment: No automated data source defined, though user could input this data manually.
Source of post-installation data	▪ pointOfDeliveryIDFromUser (Online Form: time series data).
Sufficiency of each of the above	▪ Baseline data: 12+ months data coverage before intervention ▪ Post-installation data: 12+ months data coverage after intervention ▪ Normalising Data: Weather Data covering whole of baseline and reporting period. Where data is gappy, statistical inference must be used to enable normalisation.
Services the EN-TRACK platform could provide under this scenario	▪ <u>Calculation of change in energy consumption normalised by weather data</u>. This can represent a saving that has undergone the most basic form of measurement & verification, although the user cannot apply any further adjustments (routine or non-routine) without providing more data. ▪ Recording changes to building fabric & systems over time, forming a “log-book” of interventions.
Additional Services and their data needs	▪ <u>Recording and comparing measured and verified outcomes to initial savings estimations (for individual measures or whole projects)</u>: This service requires initial savings estimation data ▪ <u>Recording the user’s selected M&V approach, and comparing outcomes where this selected approach differs from the approach suggested by EN-TRACK’s automated procedure</u>: This service requires users to complete and disclose an industry-standard M&V approach to the EN-TRACK platform. ▪ <u>Recording the usage of non-routine adjustments and their impact on measured and verified project outcomes</u>: This service requires the utilisation and tracking of non-routine adjustments.

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6.2 Implementation Scenarios

For each of the data stream scenarios presented above, the key implementation elements have been summarised overleaf (Tables 5 & 6), presenting the data sufficiency checks, transformations and analysis, output format and relevant error handling.

Table 5: A proposed step-by-step scenario for Hourly & Sub-Hourly data to assist in the implementation of EN-TRACK's M&V services

Scenario Title	Hourly or Sub-Hourly Granularity Data (Automated Input)
Data sufficiency checks	1. Energy Time Series Data (pointOfDeliveryIDFromUser): Complete years need to be utilised (twelve, twenty-four or thirty-six months), particularly where the weather is a variable affecting energy usage. Wherever possible, at least one complete year needs to be available for both the baseline and the reporting period. The user will provide the start and end timestamps of both the reporting and baseline periods. The Baseline Period must be as close to project start date, and Reporting Period must be as close to project completion date, as possible. Periods further away from project dates have higher chances of introducing additional required adjustments. Hourly or Sub-Hourly data is ideal: monthly data will only typically be used where savings exceed 10% of the baseline period energy consumption, if the platform is expected to confidently discriminate the savings from unexpected variations in baseline data. 2. Weather Data: Weather data must be available and have good coverage for the reporting and baseline periods (therefore requiring 24+ months of weather data). If the nearest weather station cannot cover this range, a further weather station will be used. Where coverage is sufficient for the reporting and baseline periods, but the weather data has minimal gaps, statistical inference can be used to populate these gaps. 3. Non-routine adjustments: Each non-routine adjustment will require a start and end date for its effects. In addition, where these adjustments are collected by the platform, the user will be prompted to provide some explanatory information, for example describing the static factor which shifted to cause the adjustment. These static factors are listed in "Section 6.3: Implementation examples".
Transformations and analysis (by individual service)	1. Extract reporting and baseline energy consumption data using start and end dates provided by the user. 2. Extract weather data using the start and end dates provided by the user in combination with the site postal code (for selecting the closest weather station) 3. Test the data sufficiency of the reporting, baseline and weather datasets. These datasets need to have minimal gaps. If any of the energy data is missing from the reporting period, a reporting period mathematical model can be created to fill in missing data,

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	however the reported savings for the missing period will identify these savings as missing data. For both periods, University of Texas guidance states that if less than 20% of data is missing or faulty for a selected period, the faulty data is excluded. However, if greater than 20% of data is missing or faulty for a selected period, a different period needs to be selected. In this case the user will be made aware of the data sufficiency issue and requested to reselect suitable baseline and reporting period start/end timestamps. 4. Once sufficient data is available, the required routine and non-routine adjustments will be considered. These may modify the energy consumption data by excluding specific periods, or normalising energy by variables such as weather or occupancy. This will enable the calculation of normalised savings. Here models based on interval data (often including factors derived from regression analysis) will correlate energy to one or more independent variables such as outdoor temperature, degree days, metering period length, production, occupancy or operating mode. Many statistical models are appropriate, and will be selected based upon statistical-evaluation indices, e.g.: coefficient of variation of the root mean squared error (CVRMSE) or mean bias error. 5. Finally the normalised savings calculations can be calculated using the equation below, whereby the baseline period energy consumption (based upon fixed historic conditions) is adjusted to represent the modelled consumption for the conditions of the reporting period, using the models developed above in step 4.: $$\text{Normalized Savings} = \begin{array}{l}(\text{Baseline Period Energy} \\ \pm \text{ Routine Adjustments to Fixed onditions} \\ \pm \text{ Non Routine Adjustments to Fixed Conditions}) \\ - (\text{Reporting Period Energy} \\ \pm \text{ Routine Adjustments to Fixed Conditions} \\ \pm \text{ Non Routine Adjustments to Fixed Conditions})\end{array} \quad \text{(Eq. 13)}$$
Output format	▪ Selected modelling approach (name and numerical correlation equation) + statistical-evaluation indices summaries for this model and others considered (R^2, CVRMSE, mean bias error) ▪ Calculated normalised savings (kWh) presented with reporting period start/end dates ▪ Flags for the presence of missing and inferred data.
Error handling and messages to the user	**If** the user submits incomplete or faulty data (energy consumption: baseline or reporting) **Then** the platform should determine whether 20% or more is missing or invalid (i.e. negative or non-numeric) for the given period, if so, it will request a new start/end timestamp for the given period. If the missing data represents less than 20% of the given period's readings, then this data will be excluded, and the issue flagged to the user at this point and the point of reporting normalised savings. **If** the user has not submitted the start/end timestamps of the baseline & reporting period **Then** the platform will not allow the user to advance until these timestamps have been provided. **If** the weather data for the nearest weather station is incomplete

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	Then the platform will test whether the missing data represents 20% or more of the required period. If so, the platform will select the next nearest weather station and report this to the user. If not the platform should conduct statistical inferences to fill these gaps, and report this approach to the user.

Table 6: A proposed step-by-step scenario for Monthly & Annual data to assist in the implementation of EN-TRACK's M&V services

Scenario Title	Monthly or Annual Granularity Data (Automated or Non-Automated Input)
Data sufficiency checks	1. Energy Time Series Data (pointOfDeliveryIDFromUser): As a rule of thumb, savings must exceed 10% of the baseline period energy consumption if the user expects to confidently discriminate savings from variation using monthly billing data. Care must also be taken as monthly utility bill data sometimes includes estimated datapoints, especially for small accounts. Unreported estimated meter readings create unknown errors for estimated months and subsequent months. Savings reports must also note when estimates are included in utility data, as when an electrical utility estimates a meter reading, no valid data exists for the electrical demand of that period. Where savings are sufficiently large, complete years' worth of monthly data will be utilised (twelve, twenty-four or thirty-six months), particularly where the weather is a variable affecting energy usage. At least one complete year needs to be available for both the baseline and the reporting period. The user must provide the start and end timestamps of both the reporting and baseline periods. The Baseline Period needs to be as close to project start date and Reporting Period needs to be as close to project completion date as possible. Periods further away from project dates have higher chances of introducing additional required adjustments. 2. Weather Data: Weather data must be available and have good coverage for the reporting and baseline periods (therefore requiring 24+ months of weather data). If the nearest weather station cannot cover this range, a further weather station will be used. Where coverage is sufficient for the reporting and baseline periods, but the weather data has minimal gaps, statistical inference can be used to populate these gaps. 3. Non-routine adjustments: Each non-routine adjustment will require a start and end date for its effects. In addition, where these adjustments are collected by the platform, the user will be prompted to provide some explanatory information, for example describing the static factor which shifted to cause the adjustment. These static factors are listed in "Section 6.3: Implementation examples".
Transformations and analysis (by	1. Extract reporting and baseline energy consumption data using start and end dates provided by the user.

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individual service)	2. Extract weather data using the start and end dates provided by the user in combination with the site postal code (for selecting the closest weather station) 3. Test the data sufficiency of the reporting, baseline and weather datasets. These datasets should have minimal gaps. If any of the energy data is missing from the reporting period, a reporting period mathematical model can be created to fill in missing data, however the reported savings for the missing period will identify these savings as missing data. For both periods, University of Texas guidance states that if less than 20% of data is missing or faulty for a selected period, the faulty data is excluded. However, if greater than 20% of data is missing or faulty for a selected period, a different period needs to be selected. In this case the user will be made aware of the data sufficiency issue and requested to reselect suitable baseline and reporting period start/end timestamps. 4. Once sufficient data is available, the required routine and non-routine adjustments will be considered. These may modify the energy consumption data by excluding specific periods, or normalising energy by variables such as weather or occupancy. This will enable the calculation of normalised savings. Here models based on interval data (often including factors derived from regression analysis) will correlate energy to one or more independent variables such as outdoor temperature, degree days, metering period length, production, occupancy or operating mode. Many statistical models are appropriate, and will be selected based upon statistical-evaluation indices, e.g.: coefficient of variation of the root mean squared error (CVRMSE) or mean bias error. 5. Finally, the normalised savings calculations can be calculated using the equation below., Here the baseline period energy consumption (based upon fixed historic conditions) is adjusted to represent the modelled consumption for the conditions of the reporting period, using the models developed above in step 4.: $$\text{Normalized Savings} = \begin{aligned}&(\text{Baseline Period Energy}\\ &\pm \text{Routine Adjustments to Fixed onditions}\\ &\pm \text{Non Routine Adjustments to Fixed Conditions})\\ &-(\text{Reporting Period Energy}\\ &\pm \text{Routine Adjustments to Fixed Conditions}\\ &\pm \text{Non Routine Adjustments to Fixed Conditions})\end{aligned} \quad \text{(Eq. 13)}$$ 6.
Output format	▪ Selected modelling approach (name and numerical correlation equation) + statistical-evaluation indices summaries for this model and others considered (R^2, CVRMSE, mean bias error) ▪ Calculated normalised savings (kWh) presented with reporting period start/end dates ▪ Flags for the presence of missing and inferred data.
Error handling and messages to the user	**If** the user submits incomplete or faulty data (energy consumption: baseline or reporting) **Then** the platform will determine whether 20% or more is missing or invalid (i.e. negative or non-numeric) for the given period, if so, it will request a new start/end timestamp for

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	the given period. If the missing data represents less than 20% of the given period's readings, then this data will be excluded, and the issue flagged to the user at this point and the point of reporting normalised savings. **If** the user has not submitted the start/end timestamps of the baseline & reporting period **Then** the platform will not allow the user to advance until these timestamps have been provided. **If** the weather data for the nearest weather station is incomplete **Then** the platform will test whether the missing data represents 20% or more of the required period. If so, the platform will select the next nearest weather station and report this to the user. If not the platform can conduct statistical inferences to fill these gaps, and report this approach to the user.

The above implementations have been described graphically in the Appendix (figure 5), along with their input data sources in figures 3 and 4.

6.3 Implementation examples

It is important to provide best practice examples when specifying and supporting software implementations. As such, the IPMVP's recommended static conditions can be considered as possible causes for non-routine adjustment, which may include, but are not limited to, the following:

- Occupancy type, occupancy density and run times
- Operating conditions (e.g., set points, lighting levels, ventilation levels) for each baseline period and season
- Significant equipment problems or outages during the baseline period:
  - In some cases, existing systems or facilities may not function properly, meet code, or otherwise be reflective of the true baseline conditions. In these cases the baseline may be adjusted so that it reflects the operation while meeting code or operation after needed repairs.
- Baseline adjustments may be made, for example, on systems that are not providing adequate ventilation.

In addition, high quality implementations of similar M&V methods have been well established by the CalTrack project[2] and its two key open-source software packages, eemeter[3] and eeweather[4]. These can form important exemplar implementations to help guide and support the work of EN-TRACK's software developers.

[2] https://www.caltrack.org/
[3] https://github.com/openeemeter/eemeter
[4] https://github.com/openeemeter/eeweather

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7 Selection of modelling approaches

The selection and application of modelling approaches within M&V is a complex issue and one that may be fraught with difficulties and snags. Table 7 (overleaf) presents a range of modelling approaches, along with their advantages and limitations, and the explanatory variables that have been used in prior investigations. From these approaches, three have been selected (in emphasis) as good candidates for initial implementation and testing, based upon their interpretability, feasible data requirements and computational load, and accuracy of predictions.

When modelling energy consumption for the estimation of building user energy savings, the platform will use the most appropriate modelling approach, which will depend on the individual context of the user's building and energy efficiency improvement package. Whilst qualitative analysis by an accredited professional would often lead to this selection, and this can be enabled through user specification of the desired modelling approach, the platform will also be able to assess and adopt the best modelling approach possible, though the user needs to be able to specify their own preference instead. The best method for this automated selection is to run all three modelling approaches contiguously, then store and compare the summary statistics, namely CV(RSME) (which measures the accuracy of the fit across the whole distribution) and MBE (which measures the presence of bias within the modelling approach). These two metrics will be given even weight in the selection of modelling approaches.

Table 7: A selection of building modelling approaches for use in M&V, with advantages, limitations and input variable for each. Models selected for preliminary assessment and implementation are emphasised in bold. Source: https://doi.org/10.1016/j.rser.2020.110027 .

Model	Advantages	Limitations	Explanatory variables used
Linear and nonlin-ear regression	**Easy to interpret and explain**	**Sometimes too simple to capture complex re-lationships**	**Indoor air temperature, outdoor air temperature, HVAC schedule**
Kernel regression	Better fitting than tra-ditional regression	Not ideal to predict long time intervals	Indoor air temperature, outdoor air temperature, HVAC schedule
Transfer functions	Can model dynamic ef-fects caused by ther-mal inertia	Requires indoor tem-perature data	Indoor air temperature, outdoor air temperature, solar radiation, HVAC schedule
Artificial neural net-works	Performs well with non-linear timeseries	Requires large amounts of data, tends to overfit, slow to train	Outdoor air temperature, wind speed and direction, visibility, air pressure, operating time, refriger-ant tonnage, running time of the system, refrigerating capacity, power rating of water pumps, dif-ferential temperature
Support vector ma-chine	Performs well even with small training da-tasets	Long computational time for large datasets	Outdoor air temperature, relative humidity, global solar radiation
Random forest	High predictive accu-racy	Hyper-parameters op-timization and cross-	Outdoor air and dew point temper-atures, relative humidity, hour of the day, day of the week, number

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		validation are needed to avoid overfitting	of occupants booked in the hotel, energy consumption of previous hour
Gradient boosting machine	Higher predictive accuracy than random forest	Hyper-parameters optimization and cross-validation are needed to avoid overfitting	Outdoor air temperature, time of the week, U.S. federal holidays
Bayesian inference	**Accurate uncertainty estimation**	**Priors are often difficult to justify and can be a major source of inaccuracy**	**Cooling Degree Days**
Gaussian processes	Able to capture complex (nonlinear) building energy behaviour	Computational and memory complexity	Outdoor air temperature, HVAC supply temperature, occupancy, relative humidity
Gaussian mixture regression	Dynamic confidence intervals	The optimization problem is not trivial to solve, long computation time	Outdoor air temperature, solar radiation, outdoor humidity
Generalised Additive Model	Improved CV(RMSE) compared to TOWT, and median estimated savings error lower than 3% of reporting period consumption, even where total training data is reduced	Higher data requirements than many models, computational load unknown.	Energy consumption data (with hourly or sub-hourly granularity), outdoor temperature, global horizontal radiation (GHI), wind speed, public holidays calendar, date of application of the analysed EEMs.

8 Financial Aspects of M&V

Along with the above services, we can assist EN-TRACK users in converting their energy consumption savings into financial summaries and forecasts, which is of particular utility to the Financial Institutions engaging with the EN-TRACK platform. Unfortunately, converting energy consumption savings into absolute financial savings is a difficult task to complete from a centralised perspective. Not only does saving energy often affect other costs associated with operating and maintaining a building, such as the frequency of replacing equipment, but also the direct energy savings fluctuate wildly with the energy tariff(s) they relate to.

Many sites will utilise variable tariffs, where prices will also rise as energy prices rise. In addition, time of use tariffs are popular for many sites, meaning that the value of savings varies with the time of day that energy is saved, with savings being greater during on-peak hours. A flexible solution to this would be to allow users to input an energy tariff rate of their choosing, which can be set to their fixed rate tariff, or utilise weighted average of on- and off-peak rates for time of use tariffs, though this is unlikely to capture all day-to-day variation.

For EN-TRACK users who are not on a fixed rate or capped tariff, the platform can also include an assumed energy price inflation, which could be forecast by the platform or input at a fixed

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rate (i.e. 3%) by the user. In order to fully capture and quantify site-specific energy cost savings, project-specific consumption savings timeseries would need to be paired with an equivalent granularity energy tariff timeseries, allowing savings to be calculated per month, hour, or sub-hour.

The downside of this approach is that it would increase the computational and data-gathering load of the EN-TRACK platform. In particular, it is unlikely that these energy tariff timeseries are available to most EN-TRACK users, and automatically inputting these timeseries from energy suppliers is prohibitively complicated on a site-by-site basis. This means that EN-TRACK users will most likely have to utilise an initial energy tariff rate and energy tariff inflation rate for forecasting financial savings in the near-term.

Despite the limitations of accurate dynamic forecasting, the platform can still provide useful outputs to the user, as described below:

- Measure lifespan savings: This figure provides the total non-adjusted financial savings across the installed measure's lifespan (0-n years). Where savings arise from multiple energy carriers, these will be treated and summed separately for each year using the relevant energy carrier tariffs. This figure can also be adjusted by a yearly interest or discount rate to provide a figure in terms of "today's money".
  - $Measure\ Lifespan\ Savings = \sum_0^n(energy\ carrier\ savings * energy\ carrier\ tariff)^{year\ 1} + (energy\ carrier\ savings * energy\ carrier\ tariff)^{year\ 2} + \cdots + (energy\ carrier\ savings * energy\ carrier\ tariff)^{year\ n}$

- Measure lifespan profit: This figure provides the total non-adjusted profits (savings minus costs) across the installed measure's lifespan (0-n years). Where savings arise from multiple energy carriers, these will be treated and summed separately for each year using the relevant energy carrier tariffs. This figure can also be adjusted by a yearly interest or discount rate to provide a figure in terms of "today's money".
  - $Measure\ Lifespan\ Profit = (\sum_0^n(energy\ carrier\ savings * energy\ carrier\ tariff)^{year\ 1} + (energy\ carrier\ savings * energy\ carrier\ tariff)^{year\ 2} + \cdots + (energy\ carrier\ savings * energy\ carrier\ tariff)^{year\ n}) - (\sum_0^n(summed\ costs)^{year\ 1} + (summed\ costs)^{year\ 2} + \cdots + (summed\ costs)^{year\ n})$
- Gross cash-flow generated (weekly/monthly/yearly): This figure provides a gross cashflow figure (income only) to the user, allowing them to determine how much cash-flow their measure generates, allowing the service of debt and other liabilities. This figure is useful where there are low, or no, ongoing costs, or where those costs should be separated from measure cashflow considerations (i.e. because they are ongoing costs that would have occurred regardless of the installed measure).

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- $\text{Gross cashflow generated (given period)} = \ (energy\ carrier\ savings * energy\ carrier\ tariff + other\ savings)_{given\ period}$

- Net cash-flow generated (weekly/monthly/yearly): This figure provides a gross cashflow figure (income only) to the user, allowing them to determine how much cash-flow their measure generates, allowing the service of debt and other liabilities. This figure is useful where there are low, or no, ongoing costs, or where those costs should be separated from measure cashflow considerations (i.e. because they are ongoing costs that would have occurred regardless of the installed measure).
    - $\text{Net cashflow generated (given period)} = \ (energy\ carrier\ savings * energy\ carrier\ tariff + other\ savings)_{given\ period} - (\frac{total\ measure\ cost}{number\ of\ given\ periods\ in\ measure\ lifespan} + other\ costs)_{given\ period}$

9 Measurement and verification of non-energy benefits

Although this section follows on from the consideration of financial aspects within the planning of measurement and verification activities, there is a debate about whether the quantification of non-energy benefits (NEBs) should occur before or after the consideration of project financing and cashflow. This depends in part on the project client and financier. The presence of NEBs may be useful for developing a strong business case in some instances, whilst other financiers may refute the estimation of NEBs. In order to handle this, it is proposed that NEBs are developed, quantified and communicated internally prior to submission to EN-TRACK. This will enable preliminary discussion of the most important NEBs and their value. It will also enable the utilisation of these figures as and when is needed for external communications.

This section builds upon Section 10 of Deliverable 1.1, which examined the need for, and the state of the art of, non-energy benefit (NEB) quantification. This work recommended the inclusion of both the MBenefits and COMBI approaches to NEBs, with a further recommendation to provide the option to input both pre-project and post-project Comfortmeter surveys to support the gathering of NEB data. With regards to the entry of Comfortmeter data into the platform, this will occur once the survey results have been processed, ideally storing the full customer report(s) as a rich text object or document/file datatype (I.e. PDF) in the "NonEnergyBenefit" module. The two approaches of the further recommendation are examined in further detail in the relevant sections below.

The user will first be engaged to determine which NEB approaches to apply to their project, through the questionnaire and response selections presented in Table 8 (below and overleaf).

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Table 8: A preliminary questionnaire to select which NEB methodologies to present to the user

Question	Suitable Methodologies based upon response
1) Would you like to receive an estimation of the NEBs that may be realised over the course of your project?	If yes, one or more surveys will be offered to the user. The estimation survey will be used unless the user answers “yes” to question 2 below. If the user answers “no” at this stage, exit the survey and NEB process.
2) Did you conduct a calculation/estimation of non-energy benefits during the pre-implementation stages of your project?	If the user answers “yes”, the EN-TRACK estimation methodology (see section entitled COMBI) will only be used where the answer to question 4 is “no”. In all other cases, offer the MBenefits survey methodology.
3) Did your project include a Comfortmeter survey at any stage, or would a post-implementation comfortmeter survey be available?	If the user answers “yes”, Comfortmeter data can be input as an object or file, alongside estimation/surveying of NEB financials. If the user answers “no”, set the relevant field to null and continue to question 4.
4) Are you able to complete a short, non-technical survey that describes the presence and value of NEBs within your project?	If the user answers “yes”, the short survey (see section titled MBenefits) will be presented alongside other methodologies. The user will be presented with the option of providing this data later if their answer is not “yes”. If the user answers “no” to this question but has answered yes to question 3, the platform should highlight where Comfortmeter results can be input at a later date.

9.1 MBenefits (surveying)

The Multiple Benefits, or MBenefits approach, relies on the user completing four analytical steps outside of the EN-TRACK platform. The results are then submitted to the platform via a data capture survey. The four analytical steps of MBEnefits are presented below:

1) Company Analysis: Analysis at company level to better understand its business model and value proposition. Although the aspects of business modelling are less relevant to the EN-TRACK platform, the company’s decision-making drivers can be integrated in the platform without compromising on anonymity.

2) Energy and Operations Analysis: This includes a conventional energy analysis, occurring at the project level. The dedicated operational analysis step determines a projects contribution to operational excellence, considering the four key components: Safety, Quality, Costs and Time. Some components will be more relevant to some business sectors than others.

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3) Strategic Impacts: This occurs at the project level, considering the impacts on value propositions, impacts on risks, and impacts on costs.

4) Financial impacts: This occurs at the project level, transferring the results of steps 2 and 3 into an impact on financial modelling parameters such as profitability.

The full data capture questionnaire can be found in Annex III, along with the necessary field types to be added to the EN-TRACK data model. As the MBenefits survey cannot be completed without the user having followed the relevant process, the survey will only be presented where the user has answered the preliminary survey to indicate its value. In addition to this, the user will be offered the following guidance and resources to assist in the completion of the approach:

- A summary of the training tools[5]
- Tips for effective communication to decision-makers[6]
- Summary of analysis tools[7]
- Guidelines for practitioners in identifying multiple benefits[8]
- Description of the Serious Game[9]
- Some of the training/webinar recordings in partner languages are available via YouTube[10].

9.2 COMBI (estimation)

D1.1 initially recommended a combined survey for determining which NEB approach to apply. Now, in contrast, the questions pertinent to the COMBI-inspired estimation of NEBs have now been separated. This is because the data most likely already exists and the user only needs to confirm the accuracy of the data within the platform and even then only where this approach is being utilised. The COMBI approach quantifies NEBs by the specific measure, and country, involved in the energy efficiency improvement, and although absolute values are presented at a national level by the COMBI tool, these have been converted into country and measure specific proportional increases to the value of energy cost savings. This has two important aspects, firstly it allows for approximation where individual project measure benefits have not been described relative to the kWh savings achieved, and secondly it integrates some of the interactive effects

[5] https://www.mbenefits.eu/static/media/uploads/site-6/library/Deliverables/d4.3_training_tools.pdf
[6] https://www.mbenefits.eu/static/media/uploads/site-6/library/Deliverables/d4.2_corrected-communication_tools.pdf
[7] https://www.mbenefits.eu/static/media/uploads/site-6/library/Deliverables/d4.1_mbs_identification_and_evaluation_tools.pdf
[8] https://www.mbenefits.eu/static/media/uploads/site-6/library/Deliverables/mbenefits_d2.2_full_20180831.pdf
[9] https://www.mbenefits.eu/static/media/uploads/site-6/library/Deliverables/d4.4-serious_game-final.pdf
[10] https://www.mbenefits.eu/training-center/training-workshops-webinars/

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of combining packages of energy efficiency measures (provided these interactive effects have been considered within the estimation of energy cost savings).

Question copy	Initial Data Source
1) Please confirm or modify the following selection of energy improvement measures applied over the course of your project: ▪ HVAC ▪ Window measures ▪ Refrigerators ▪ Washers ▪ Weatherization ▪ Lighting ▪ Education, associated with measure programs ▪ Water measures (comm' 1) ▪ Other measures	▪ energyEfficiencyMeasureType
2) Please confirm or respecify whether your project occurred in a commercial or residential building.	▪ buildingSpaceUseType
3) Please confirm or update the value of the project's energy benefits/cost savings with the most accurate figure you have available at this time.	▪ energySavingsValue ▪ Alternatively use (energyEfficiencyMeasure Investment * energyEfficiencyMeasureSavingsToInvestmentRatio)

The NEB values associated with specific EEI in specific European countries can be found in the Appendix (Tables 12 & 13). For comparison, historic NEB values gathered by the Government of Seattle are presented alongside these values in Table 9. The assumptions informing the quantification of NEBs through the COMBI methodology can be found here[11] for specific EEI actions, and here[12] for national-level policy assessment scenarios. Specific NEBs represented by these quantifications can be found in Figure 6 of the Appendix. The envisaged implementation of the NEB benefits module will refer to user input values (MBenefits), as well as a register of nation-specific impacts (COMBI), which will be provided to the user alongside links to the input assumptions and scenarios.

[11] https://combi-project.eu/scenarios-assumptions/eei-actions/
[12] https://combi-project.eu/scenarios-assumptions/combi-scenarios/

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10 Conclusion

This deliverable has provided a methodology for capturing a user's available M&V data, both in terms of the measured and verified data and the user's evaluation needs and measurement boundaries. The storage of M&V outputs (alongside initial savings predictions) needs to be considered as the primary service that the EN-TRACK platform provides as this underpins both current services and also the advanced services and statistical analyses that may become available as the platform's user group grows.

This raised multiple issues with the automated calculation and input of M&V data, which is much more diverse than simple energy consumption data, as collated below:

1. Even savings estimations can be difficult to express and store, as kWh figures may vary year to year depending on operation times.
2. Other approaches such as Energy Use Intensity (EUI) require the inclusion and connection of the normalising variables for any consumption data. These normalising variables, although generally difficult to input and manage, do provide key information, particularly around routine adjustments, which may require specific data, some of which may be easily procured, such as weather data.
3. Other data sources may be more difficult to input and manage, such as production data, input material characteristics data (humidity etc), occupancy data, plant usage changeover data (remapping machinery etc). As such the likely variables required for M&V services are displayed in the section below, categorised by their utilisation in both current and future services:

<u>Variables required for current services:</u>

1. Project Initial savings estimation (for individual measure or whole-project). These may be presented as kW reductions, kWh reductions or energy use intensity reductions (kWh/normalising unit [m3 / kg produced / occupant-hour])
2. Measured and verified project savings. These may be presented as kW reductions, kWh reductions or energy use intensity reductions (kWh/normalising unit [m3 / kg produced / occupant-hour])
3. Other M&V indicators: model accuracy (R2, Net Mean Bias Error etc), number of non-routine adjustments, M&V approach (IPMVP option, Property Energy Rating etc.).
4. User's selected M&V approach (categorical: IPMVP option, Property Energy Rating etc.)
5. Automated M&V suggestion (categorical: IPMVP option), which will require the user to input:
    a. pre- and post-installation data
    b. evaluation needs

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   c. expected project outcomes (savings %)
   d. measurement boundaries (whole facility or individual measures)

6. A numerical and long-form text field describing the usage of non-routine adjustments (NRAs), which may include a categorical tag for common causes of adjustment.

Variables supporting future services:

7. Building typology and end use (for clustering and categorising of project typologies)
8. The presence of interactive effects between measures (Boolean or array)
9. Data collection requirements for various IPMVP approaches
10. Significance of energy driving variables (additional tag for normalising data)
11. Repository of historic M&V approaches for a given building/building typology/measure combination (this would integrate all of the current service variables plus the above future service variables)

This deliverable recommends further engagement from the consortium to assist with the selection and prioritisation of M&V services. The consortium's engagement will also be required to integrate the additional variables supporting M&V services into the platform's data model, in order to ensure a robust and utilisable implementation.

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11 Appendix

11.1 Summary of Data Collection Sources

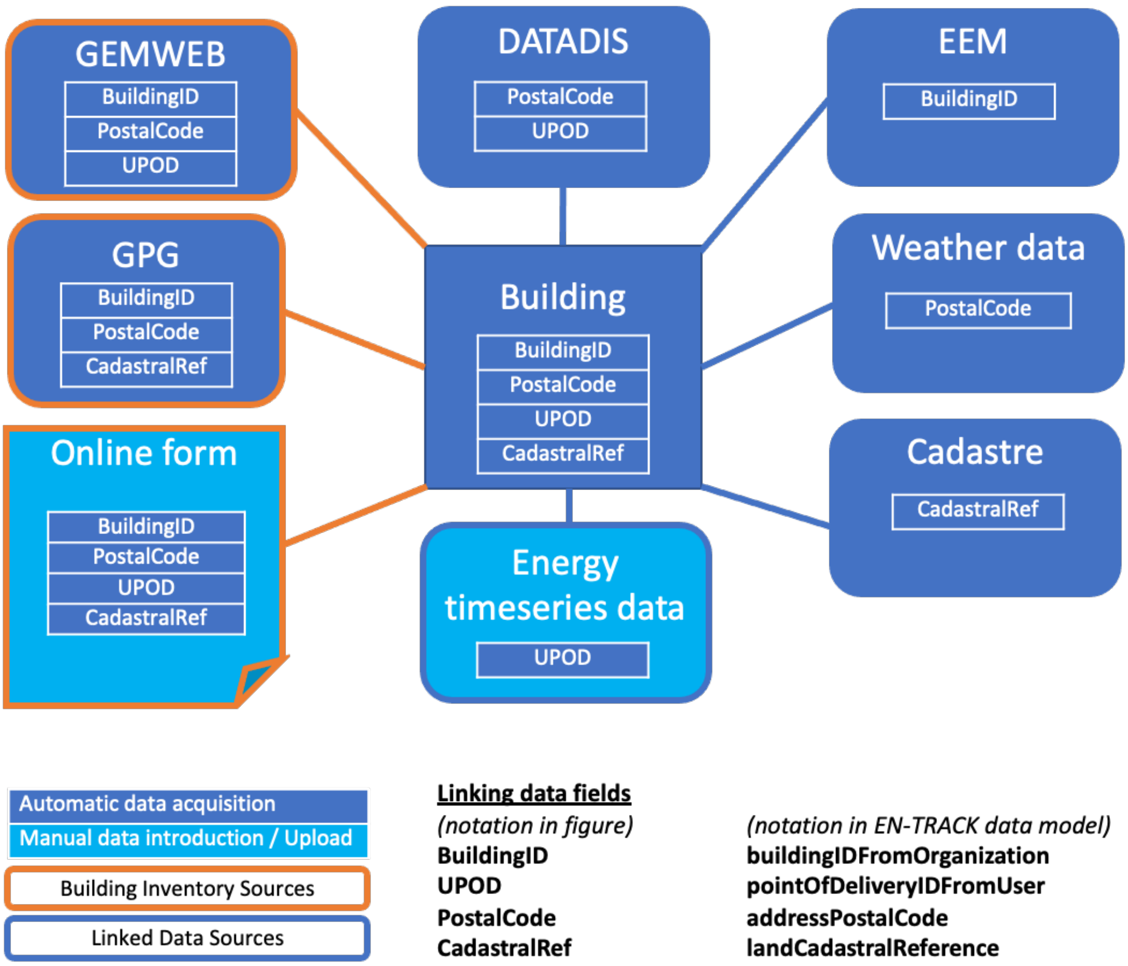

Figure 3: Linking of data sources at the Spanish pilot.

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11.1.1 Bulgarian pilot

The combining/combination and linking of the different data sources at the Bulgarian pilot is represented in Figure 4.

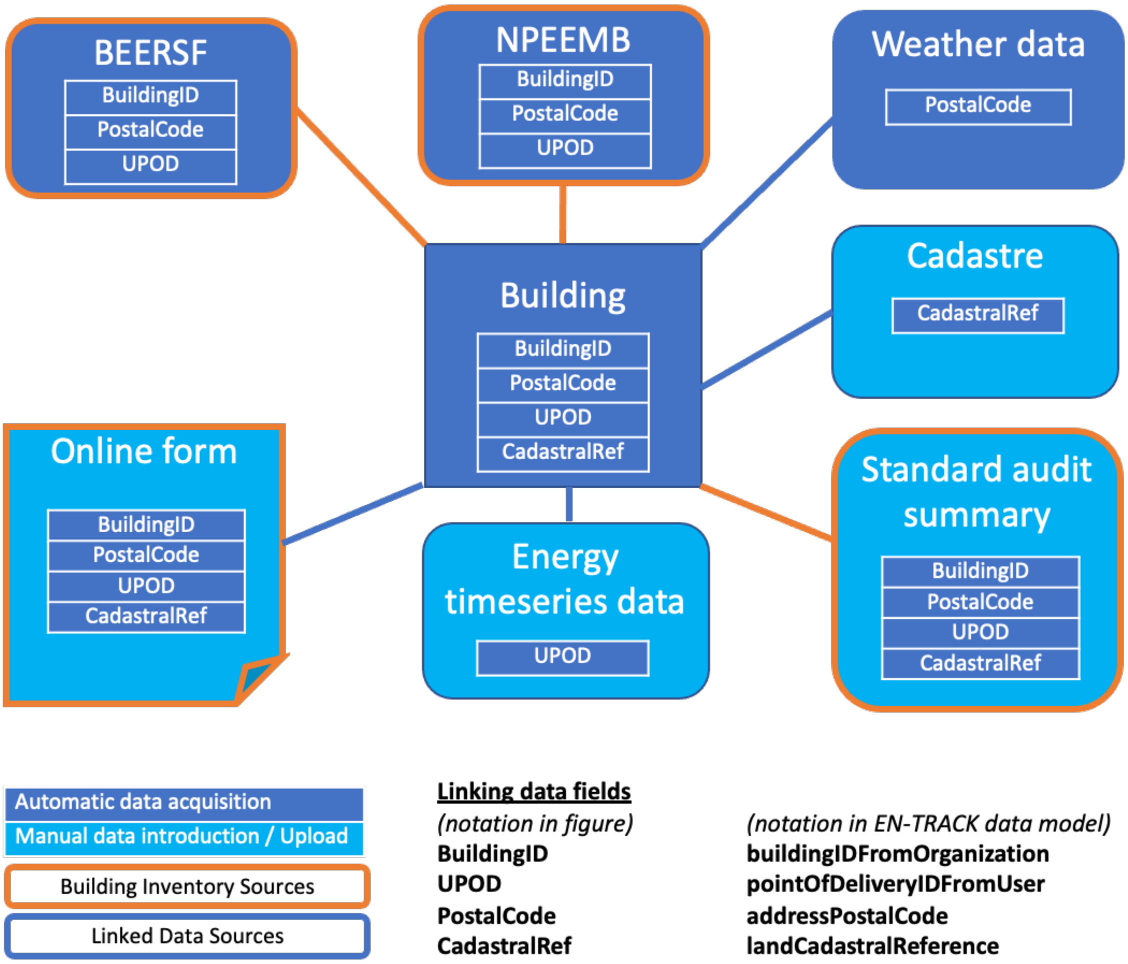

Figure 4: Linking of data sources at the Bulgarian pilot. The creation of a new building in the EN-TRACK system is initiated either from BEERSF, NPEEMRB, the Standard audit summary, or the Online form and these represent the BIS for the pilot. The rest of data sources add complementary information.

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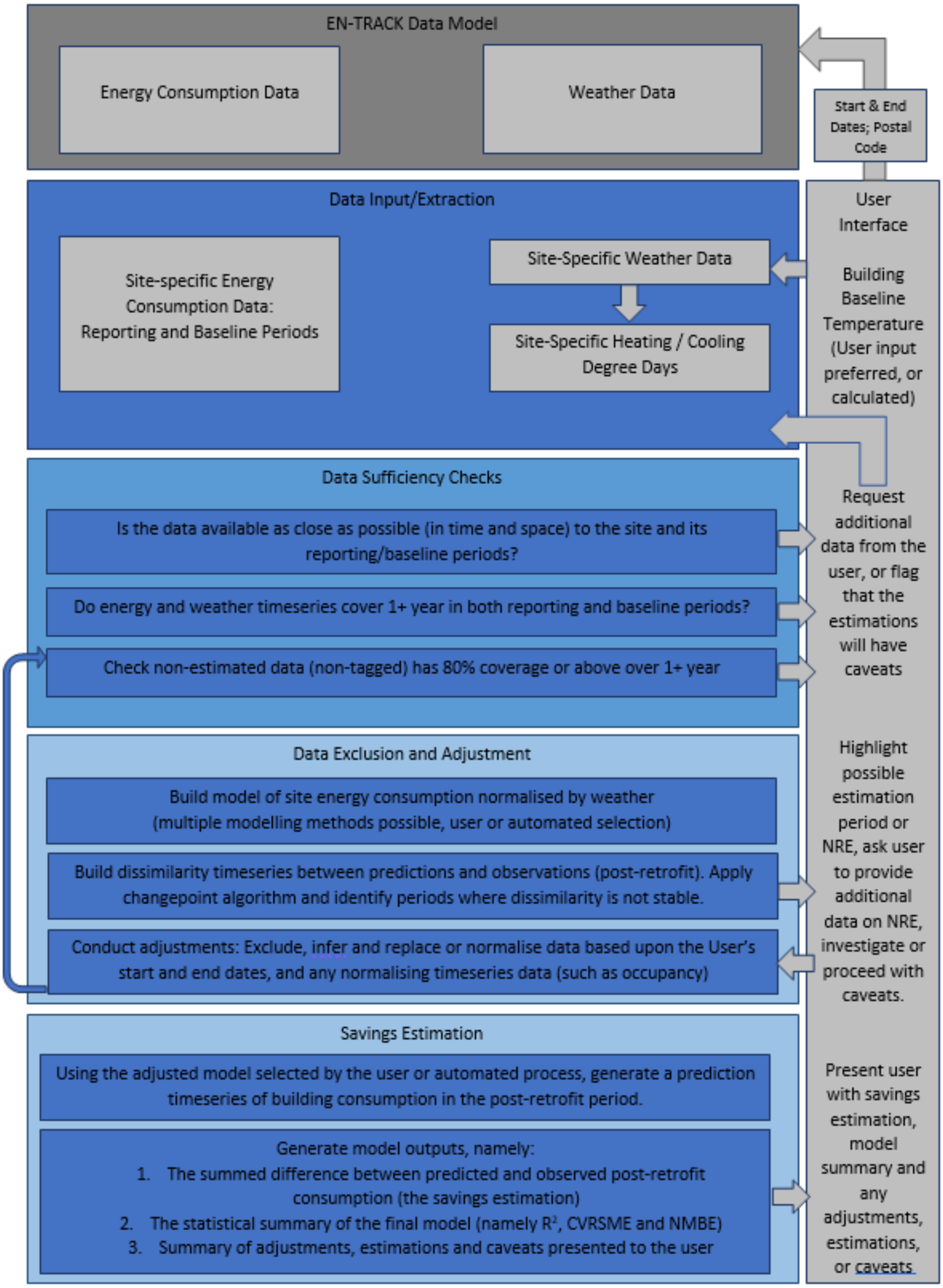

Figure 5: A graphical representation of the M&V estimation process for use in the implementation of the EN-TRACK platform.

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11.2 Non-Energy Benefits Annexes

Table 9 Estimated Value of Participant-Reported Non-Energy Benefits for comparison with other NEB quantifications — Extra NEB Value as a Percent of Energy Savings from the Measure (Source: Skumatz Economic Research Associates surveys)

End Use	Commercial	Residential
HVAC	100%	120%
Window measures	-	110%
Refrigerators	25%	100%
Washers	-	(small sample*)
Weatherization	-	60%
Lighting	40%	100% (multifamily only)
Education, associated with measure programs	-	10%(small sample*)
Water measures (comm' 1)	60%	-
Overall measures—all end uses	50%	-

Non-Energy Benefits in the Residential and Non-Residential Sectors- (seattle.gov)

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Table 10: Exemplar situations, problems, EEMs and their benefits to assist in the use of the MBenefits methodology.

Current situations and problems:

- The SOS1 building, intended for the practice of various sports by students and staff, is in a dilapidated state (the windows are 47 years old).
- A large part of the building is glazed (glazed facades and roof domes), in single glazing. Thermal inertia is almost non-existent. The condition of the building causes comfort problems for users: excessive heat in mid-season and summer, poor ventilation, insufficient lighting, humidity levels.
- The dilapidated state of all the installations leads to unnecessary maintenance costs (heating, ventilation, sanitary facilities) and material replacement costs (false ceilings).
- The dilapidated state of sanitary facilities (showers) leads to risks of deterioration in health and hygiene conditions, which are detrimental to the health of users.

Proposed energy-efficiency measures (8 in total) and their benefits:

- Complete and in-depth renovation of the building (envelope and interior technical installations).
- Installation of triple glazing on the facade and roof, controlled by an automatic regulation; replacement of lighting and false ceilings; renovation of ventilation; optimisation of heating; renovation of hot water production and sanitary installations.
- Significant improvement in the thermal quality, air quality, sanitary quality and visual quality of the building with a reduction in the risks of impact on the comfort and health of users.
- Reduction of many unnecessary maintenance and engineering costs (related to obsolescence).

Table 11: The survey to be used for the capturing the quantification of NEBs through the MBenefits methodology.

1) Please provide a short non-technical description of the current situations and problems your energy improvement measure aimed to address (long text):
2) Please provide a short non-technical description of the proposed energy improvement measures and their modelled benefits (long text):
3) What decision-making drivers underpinned your assessment of the investment project? (Open text or ENUM)
4) During the analysis of the project impacts, did you determine the projects contribution to any of the following components of operational excellence? (ENUM: not measured, improved, no impact, degraded)
   a) Safety

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b) Quality

c) Costs

d) Time

2) During the analysis of the project impacts, which energy services were determined to positively contribute to any of the following components of operational excellence? (ENUM: Heat, Ventilation, Cooling, etc)

a) Safety

b) Quality

c) Costs

d) Time

3) During the analysis of the project impacts, which energy services were determined to negatively contribute to any of the following components of operational excellence? (ENUM: Heat, Ventilation, Cooling, etc)

a) Safety

b) Quality

c) Costs

d) Time

4) Did the energy improvement impact any of the three aspects of competitive advantage, and if so, how? (Free text following the ENUM: No investigation [default], No impact found, positive impact, negative impact, mixed impact)

a) Impacts on Value Proposition:

b) Impacts on Risks:

c) Impacts on Costs:

5) Please describe and note the approximate net value of each component of operational excellence impacted by the energy improvement project:

a) Safety: Value | Description

b) Quality Value | Description

c) Costs Value | Description

d) Time Value | Description

6) Please state whether the approximate values above have been measured and verified, and describe the method used.

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Table 12: A presentation of the annualised net present value increases from the accounting of non-energy benefit values in the EN-TRACK pilot nations (i.e. these figures represent a percentage increase in project value from the starting point of energy savings alone). The represented NEBs are presented in Figure 6 (overleaf, right).

Annualised net present value increases from the accounting of **NON-ENERGY BENEFIT VALUES ONLY** (% increase above energy savings alone)

	Net value	Bulgaria	Spain
Buildings (residential): refurbishment	61%	58%	67%
Buildings (residential): new dwellings	146%	59%	79%
Buildings (residential): lighting	32%	51%	31%
Buildings (residential): cold appliances	47%	74%	70%
Buildings (tertiary): refurbishment	78%	102%	121%
Buildings (tertiary): new dwellings	66%	38%	65%
Buildings (tertiary): lighting	28%	37%	26%
Buildings (tertiary): cold appliances	37%	47%	33%
Transport (passenger): modal shift	0%	0%	0%
Transport (passenger): two-wheelers	267%	1800%	192%
Transport (passenger): cars	46%	24%	27%
Transport (passenger): public road/buses	228%	147%	202%
Transport (freight): modal shift	0%	0%	0%
Transport (freight): light duty trucks	0%	0%	0%
Transport (freight): heavy duty trucks	0%	0%	0%
Industry: high temperature process	20%	7%	13%
Industry: low/med temp. process	46%	44%	25%
Industry: process cooling	78%	89%	58%
Industry: electric processes	213%	335%	155%
Industry: motor drives	74%	70%	42%
Industry: HVAC	54%	37%	33%

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Figure 7: The decision tree for the selection of NEB methodologies to be presented to the user.

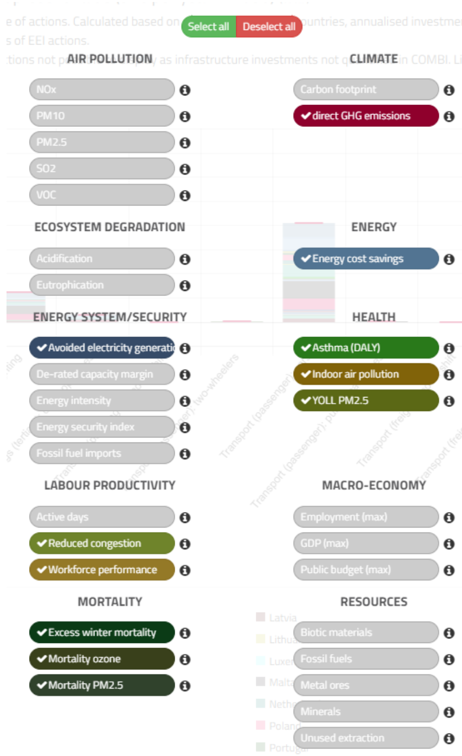

Figure 6: The NEBs representing additional value in Tables 12 and 13 (underleaf & overleaf)

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Table 13: A presentation of the annualised net present value increases from the accounting of non-energy benefit values in all European nations (these figures represent a percentage increase in project value from the starting point of energy savings alone). The represented NEBs are presented in Figure 6.

Annualised net present value increases from the accounting of **NON-ENERGY BENEFIT VALUES ONLY** (% increase above energy savings alone)

bn €/year (in 2030)	Net value	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Netherland	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	United Kingdom
Buildings (residential): refurbishment	61%	54%	69%	58%	34%	137%	54%	39%	51%	20%	56%	54%	59%	108%	60%	75%	42%	38%	56%	40%	60%	54%	337%	98%	63%	72%	67%	27%	77%
Buildings (residential): new	146%	188%	177%	59%	79%	234%	76%	146%	89%	91%	142%	157%	272%	77%	456%	296%	187%	87%	291%	104%	159%	76%	156%	95%	62%	109%	79%	122%	446%
Buildings (residential):	32%	28%	33%	51%	27%	24%	64%	21%	42%	20%	25%	32%	31%	22%	28%	49%	20%	-6%	18%	21%	39%	41%	28%	39%	48%	48%	31%	21%	33%
Buildings (residential): cold appliances	47%	44%	49%	74%	31%	80%	75%	40%	82%	48%	31%	33%	65%	44%	53%	76%	31%	-19%	33%	17%	64%	64%	47%	56%	58%	52%	70%	54%	40%
Buildings (tertiary):	78%	43%	70%	102%	47%	296%	45%	64%	26%	46%	115%	70%	379%	45%	50%	123%	26%	14%	100%	180%	62%	72%	176%	39%	27%	57%	121%	46%	78%
Buildings (tertiary): new	66%	71%	60%	38%	56%	65%	50%	105%	38%	172%	59%	55%	76%	45%	54%	68%	27%	-25%	42%	30%	74%	112%	-1250%	89%	31%	60%	65%	137%	94%
Buildings (tertiary): lighting	28%	21%	30%	37%	26%	27%	39%	18%	35%	17%	18%	32%	30%	20%	26%	42%	16%	-4%	17%	21%	24%	37%	23%	45%	30%	45%	26%	20%	29%
Buildings (tertiary): cold	37%	29%	46%	47%	28%	34%	56%	33%	52%	32%	26%	32%	41%	32%	36%	53%	23%	-9%	16%	31%	48%	50%	32%	53%	42%	49%	33%	30%	37%
Transport (passenger):	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Transport (passenger): two-	267%	713%	660%	1800%	100%	700%	333%	1333%	0%	1000%	304%	79%	97%	311%	480%	177%	0%	-300%	50%	0%	1392%	574%	522%	2500%	850%	50%	192%	1100%	424%
Transport (passenger): cars	46%	40%	58%	24%	41%	31%	30%	50%	32%	29%	63%	48%	41%	27%	35%	53%	33%	30%	52%	35%	45%	32%	32%	25%	26%	29%	27%	32%	62%
Transport (passenger): public road/buses	228%	280%	396%	147%	-122%	143%	210%	339%	400%	294%	269%	102%	120%	105%	194%	326%	143%	67%	100%	0%	1059%	224%	324%	172%	169%	57%	202%	155%	244%
Transport (freight): modal	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Transport (freight): light	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Transport (freight): heavy	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Industry: high temperature	20%	13%	21%	7%	10%	21%	12%	54%	6%	3%	16%	63%	22%	10%	4%	27%	17%	5%	6%	0%	22%	19%	35%	25%	19%	11%	13%	5%	17%
Industry: low/med temp.	46%	57%	40%	44%	49%	78%	44%	18%	54%	124%	43%	45%	37%	79%	77%	56%	10%	51%	52%	0%	84%	50%	18%	45%	13%	42%	25%	165%	42%
Industry: process cooling	78%	84%	71%	89%	86%	50%	137%	35%	77%	56%	49%	108%	57%	82%	44%	104%	78%	-21%	21%	0%	108%	144%	49%	136%	78%	85%	58%	68%	68%
Industry: electric processes	213%	196%	163%	335%	186%	267%	312%	117%	275%	124%	135%	329%	321%	191%	126%	299%	250%	-60%	56%	0%	272%	345%	120%	200%	193%	375%	155%	127%	182%
Industry: motor drives	74%	58%	74%	70%	66%	24%	94%	32%	74%	41%	48%	118%	45%	44%	59%	108%	53%	-13%	18%	0%	73%	115%	35%	104%	45%	101%	42%	34%	62%
Industry: HVAC	54%	60%	59%	37%	123%	643%	34%	37%	39%	16%	46%	52%	112%	29%	98%	97%	49%	30%	714%	0%	77%	87%	26%	61%	43%	145%	33%	23%	50%

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