~~Retrocommissioning Evaluation Protocol~~

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Chapter *n*: Retrocommissioning Evaluation Protocol

The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures

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1 Measure Description

Retrocommissioning (RCx) is a systematic process for optimizing energy performance in existing buildings. It specifically focuses on improving the control of energy-using equipment~~,~~ ~~such as~~ (e.g., heating, ventilation, and air conditioning ~~(~~[HVAC~~)~~] equipment and lighting~~,~~) and typically does not involve equipment replacement. Field results have shown proper RCx can achieve energy savings ranging from 5% to 20%, with a typical payback of two ~~years' time~~years or less (Thorne 2003).

A study conducted on behalf of Lawrence Berkeley National Laboratory analyzed data from 11 utilities operating RCx programs across the United States~~; a data set that~~. The dataset included 122 RCx projects and ~~over~~more than 950 RCx measures (PECI~~,~~ 2009). ~~Figure 1 provides~~Table 1 lists a summary of the most common RCx measures, ~~by~~ highlighting the nine measures that represent the majority of the analyzed project savings.

~~Figure~~Table ~~1.~~1. Common RCx Measures

RCx Measure	~~%~~Percentage of Total Savings
Revise control sequence	21%
Reduce equipment runtime	15%
Optimize airside economizer	12%
Add~~ / ~~/optimize supply air temperature reset	8%
Add variable frequency drive to pump	6%
Reduce coil leakage	4%
Reduce~~ / ~~/reset duct static pressure ~~setpoint~~set point	4%
Add~~ / ~~/optimize optimum start/stop	3%
Add~~ / ~~/optimize condenser water supply temperature reset	2%

As shown in ~~Figure~~Table 2 (PECI 2010), RCx measures vary, depending on types of equipment and control mechanisms introduced or optimized. For example, some RCx measures control HVAC equipment according to a predefined schedule, while some measures introduce outdoor air temperature (OAT)-dependent controls.

~~Figure 2.~~Table 2. Categorization of RCx Measures

Control Mechanism	Equipment Type		
	HVAC Airside	HVAC Waterside	Lighting
Scheduled	Matching supply fan schedule to occupancy schedule	Adding/optimizing space setback temperatures	Matching lighting schedule to occupancy schedule
Variable	Optimizing airside economizer	Adding chilled water supply temperature set point reset strategy	Optimizing daylighting control

The method presented in this protocol provides direction regarding: (1) how to account for each measure’s specific characteristics~~,~~ and (2) how to choose the most appropriate savings verification approach.

~~In a~~The classic RCx process~~,~~ helps identify, implement, and maintain improvements to building systems and operations ~~are identified, implemented, and maintained~~ via the following five phases (BPA ~~2011~~2011a).

1. **Planning**. This phase involves screening buildings to determine whether they provide a good fit for RCx by assessing indicators such as equipment age and condition, building energy performance and size, and type of control system. Ideally, facilities should have an existing building automation system (BAS) in good working order, as well as HVAC equipment that is in relatively good condition. ~~If a~~A facility ~~does not have~~without a BAS~~, one could be installed~~ can install the system; however, ~~this~~the project would ~~be considered~~then become an HVAC controls and commissioning project rather than an RCx project. When a facility’s HVAC equipment nears the end of its useful life, undertaking RCx may not be appropriate~~, since~~ because control measures could become obsolete ~~when the~~with replaced equipment~~ is replaced~~.
2. **Investigation**. The investigation phase involves~~:~~ analyzing facility performance by reviewing building documentation~~,~~; performing diagnostic monitoring and functional tests~~, and~~; interviewing staff; identifying a list of recommended improvements; and estimating savings and costs. Evaluators should clearly differentiate valid RCx measures that meet program eligibility guidelines from retrofit measures and/or operation and maintenance (O&M) activities at this phase.
3. **Implementation**. The implementation phase involves~~:~~ prioritizing recommended measures and developing an implementation plan; implementing the measures; and testing to ensure ~~they operate as intended.~~proper operation. Implementation often entails an iterative approach, ~~since~~as the evaluator may need to determine the final control set points ~~may need to be determined~~ through several stages of modification and assessment. These stages ensure ~~that~~ building equipment continues to operate properly and ~~that occupant~~maintains the occupants’ comfort~~ can be maintained.~~. Typically, evaluators will review a facility’s BAS~~ is used~~ to assess how effectively RCx measures operate.
4. **Turnover**. The turnover phase involves~~:~~ updating building documentation (e.g., system operation manuals); developing and presenting a final report; and training building operators on proper ~~operations and maintenance (O&M).~~O&M.
5. **Persistence**. The persistence phase involves~~:~~ monitoring and tracking energy use over time; continually implementing persistence strategies~~, such as~~ (e.g., refining control measures or enhancing O&M procedures~~,~~) to ~~ensure that~~sustain savings~~ are sustained~~; and documenting ongoing changes. Depending on the availability of ~~program~~ resources and the ~~program~~ timeline, ~~this phase is~~program stakeholders may not always actively ~~supported by energy-efficiency programs~~support this phase.

2 Application Conditions of Protocol

The RCx program design includes activities ~~are designed~~intended to overcome a number of market barriers, as ~~shown~~listed in ~~Figure 3~~Table 3.

~~Figure~~Table ~~3.~~3. RCx Market Barriers

Market Segment	Barrier	Opportunities
Supply-Side Actors, End Users	~~Lack of~~No tangible examples of RCx performance *in situ*	Undertaking pilot projects
Supply-Side Actors	Lack of service provider capacity for undertaking the RCx investigation and implementation phases	Training for service providers
End Users	Lack of awareness and understanding of the RCx benefits	Education to increase building owner and operator awareness
End Users	Cost of undertaking RCx	Incentives

~~Energy~~Ideally, energy-efficiency programs ~~are designed to~~ overcome these barriers through various activities ~~addressing~~that address available opportunities. ~~RCx~~Retrocommissioning programs may include some or all of the following activities~~.~~:

- **Pilot projects**. Program administrators sometimes fund pilot projects to demonstrate the benefits of RCx to end users in their target markets. ~~Savings for these~~ Evaluators can verify pilot ~~projects would be verified~~ savings using the methods presented later in this protocol and, ~~ideally~~in theory, these savings ~~would~~will attract participants to the program.
- **Training**. Program administrators sometimes fund or develop training for service providers. In some jurisdictions, service providers do not routinely provide RCx services to their customer base. Thus, to develop RCx capacity in the market, program administrators might offer training to service providers on how to provide best practice RCx investigation and implementation services. Service providers may also require training on how to sell these services to their clients.
- **Education**. Program administrators sometimes develop educational materials and hold events or workshops for end users. Prior to making a decision to undertake RCx activities in their facilities, building management and building operators need to understand the business case for RCx. Detailed ~~cases~~case studies showcasing project savings are an example of education tools ~~that~~program staff can ~~be used~~use to facilitate this decision-making process.
- **Incentives**. Program administrators often provide incentives to undertake the RCx investigation, implementation, and persistence phases. Even though the payback for RCx measures is typically low, end users often require incentives to encourage them to move

forward with projects.[1]~~.~~ Incentives may also encourage end users to undertake projects sooner—or with a greater scope—than they would have without market intervention.

This protocol provides structured methods for determining energy savings resulting from the implementation of RCx measures. The approaches described here provide direction on how to verify savings consistently from pilot projects, as well as from projects implemented by program participants. It does not address savings achieved through training or through market transformation activities.

[1] Some programs may impose a penalty~~,~~ rather than an incentive. For example, if participants fail to implement the measures that fell below a certain payback threshold identified during the investigation phase~~ that fall below a certain payback threshold~~, they may not be eligible for the full investigation phase incentive.

3 Savings Calculations

Specific savings calculations[2] for RCx measures inherently vary, due to the breadth of possible RCx measures, which can differ by type of equipment or control mechanism. This section presents a high-level gross energy savings equation that is applicable to all RCx measures. ~~Detailed directions for specific measure categories are presented under~~ Section 4, *Measurement and Verification Plan*, includes detailed directions for calculating savings for specific measure categories.

~~Energy savings for all measures will be determined using~~Use the following general equation (EVO 2012~~):~~) to determine energy savings:

Equation 1

Energy Savings = (Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± ~~Non-Routine~~Nonroutine Adjustments

Where,

Energy Savings	= First-year energy consumption savings.
Baseline Energy	= ~~Pre-implementation~~Preimplementation consumption.
Reporting Period Energy	= ~~Post-implementation~~Postimplementation consumption.
Routine Adjustments	= Adjustments made to account for routinely changing independent variables (variables that drive energy consumption). ~~Savings should be normalized~~If applicable, normalize savings to typical meteorological year (TMY[3]) weather data, as well as other significant independent variables (e.g., occupancy, production data~~), if applicable.~~).
~~Non-Routine~~ Nonroutine Adjustments	= Adjustments made to account for parameters typically not expected to change during the implementation period. ~~If~~Account for these parameters if they change *and* this change influences the reporting period energy use~~, they should be accounted for~~ (e.g., changes to a facility's building envelope during implementation of an RCx HVAC measure). ~~This would~~Evaluators only ~~have~~need to ~~be considered if~~ consider nonroutine adjustments if verifying savings ~~were verified~~ using Option C of the

[2] As presented in the Introduction, the protocols focus on gross energy savings and do not include other parameter assessments, such as net-to-gross, peak coincidence factors, or cost-effectiveness.

[3] Evaluators should use the most recent typical meteorological year dataset. As of January 2014, the most comprehensive national typical meteorological year dataset is TMY3. Evaluators should confer with the local jurisdiction to see if they should use a different regional dataset.

International Performance Measurement and Verification Protocol (IPMVP).[4]

Determining RCx demand savings is not a straightforward extension of verified consumption savings (unlike lighting retrofits, ~~for example,~~ where evaluators can easily apply established load savings profiles ~~can easily be applied~~ to consumption savings data). For RCx projects, load savings profiles vary~~,~~ depending on the type of measures implemented and the distribution of ~~the measure types implemented~~these measures. If applicable, evaluators should produce load savings profiles on a measure-by-measure basis,[5] aggregate these profiles, and then apply ~~regional~~site-specific coincidence factors to determine coincident peak demand savings at the project level.

[4] ~~Whole~~ Option C is the “whole-facility ~~consumption analysis~~approach” to verifying savings.

[5] Alternatively, if verifying savings ~~are verified using~~by following Option C or D of the IPMVP, ~~the~~evaluators can measure or compute aggregate project-level load savings profile ~~could be measured or computed,~~ ~~negating~~and negate the requirement to build up the profile on a measure-by-measure basis. If using Option C ~~is being used~~, evaluators should investigate whether data from advanced metering infrastructure (e.g.~~.~~, interval meters) is available ~~in order~~ to increase the accuracy of billing data analyses.

4 Measurement and Verification Plan

This section ~~contains both~~outlines the recommended approaches to determining RCx energy savings and ~~the~~provides directions on how to use the approaches~~. The information is presented~~ under the following headings:

- ~~M&V Method~~
- Measurement and verification (M&V) method
- Data ~~Collection~~collection
- Interactive ~~Effects~~effects
- Specific ~~Savings Equations~~savings equations
- Regression ~~Model Direction~~model direction
- Deemed ~~Spreadsheet Tool Functionality Requirements~~spreadsheet tool functionality requirements.

4.1 ~~M&V~~Measurement and Verification Method

There is a structured method for determining the most appropriate approach to verifying RCx energy savings. This method balances the need for accurate energy-savings estimates with the need to keep M&V costs in check, relative to project costs and anticipated energy savings. Depending on ~~what~~which measures are implemented, different approaches to estimating the savings are appropriate. Following the IPMVP~~ protocols~~, the~~ following~~ options are:

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

Measurement is inherent with most RCx projects ~~since~~because RCx measures typically involve modifications made through a facility's BAS. As mentioned, ~~the~~RCx implementation (an iterative process~~, which~~) often ~~is iterative, ~~leverages metered data to evaluate and optimize changes ~~being made~~throughout the process. Therefore, in many cases, a retrofit isolation approach adhering to Option A or Option B of the IPMVP proves most logical. That said, scenarios exist where Option C, Option D, or even a deemed approach may be more appropriate. ~~Figure 4~~Figure 1 presents a decision flow chart for determining the approaches to follow.

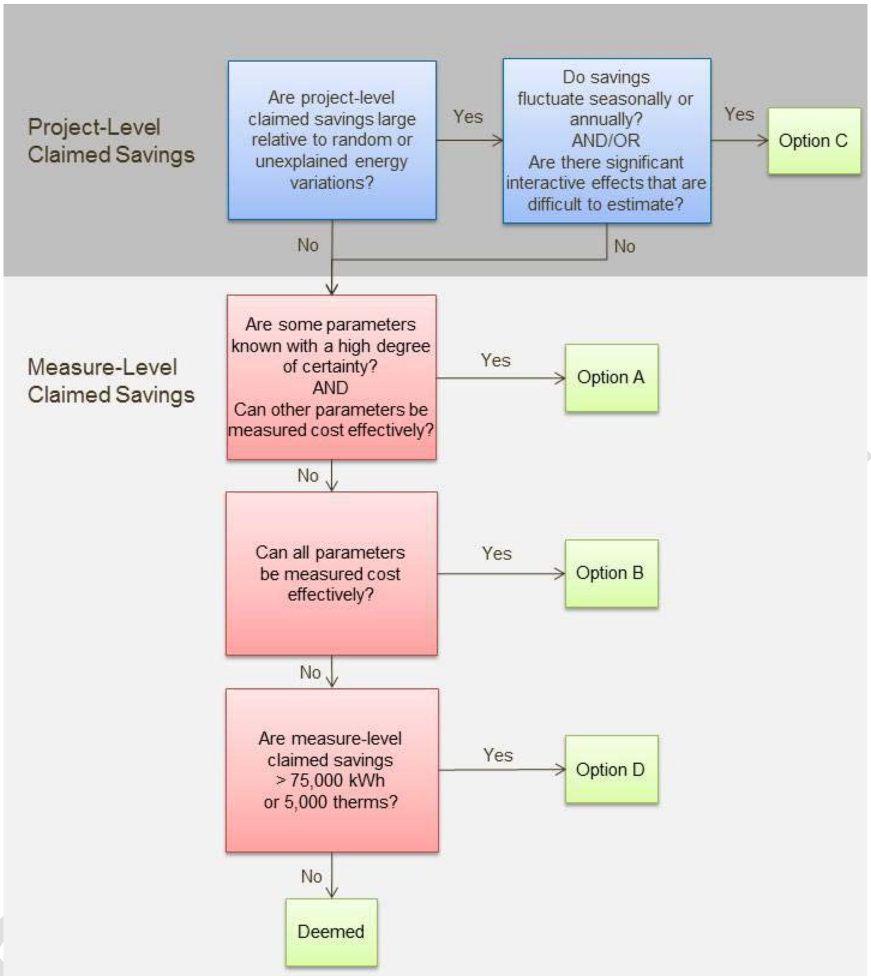
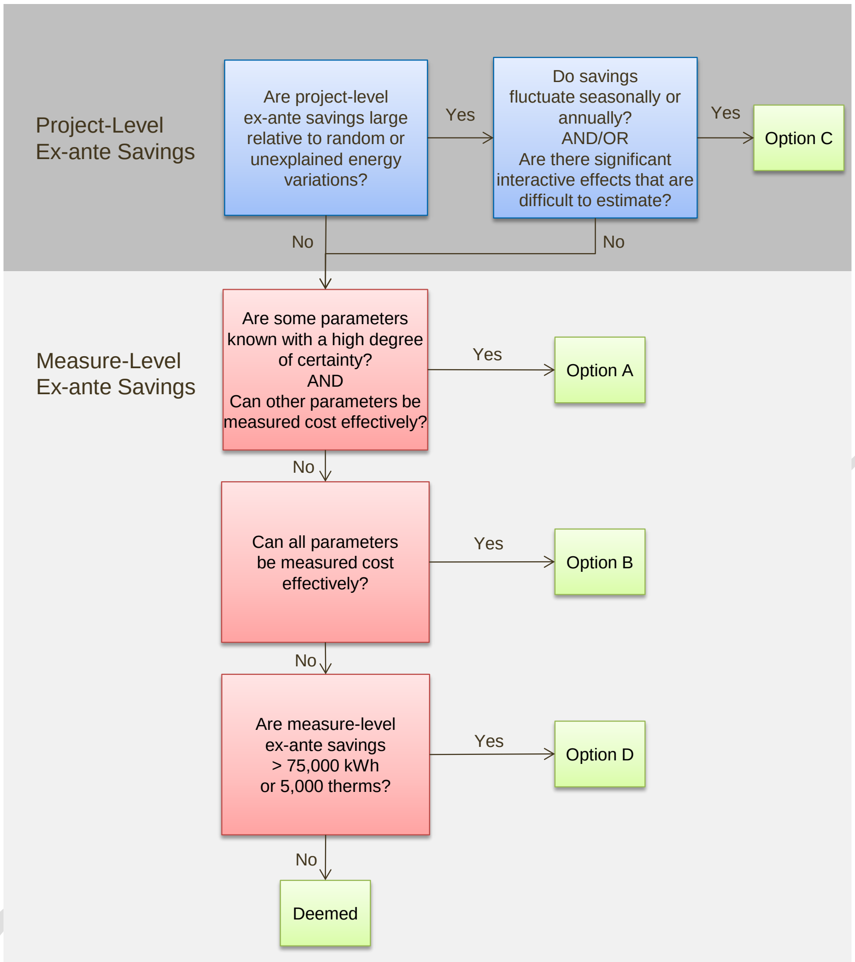


Figure 1. RCx ~~Approach—Decision Flow Chart~~approach—decision flow chart



~~The decision-making process shown in Figure 4~~The decision flow chart accounts for factors such as the magnitude of estimated savings and the measurement's cost-effectiveness. ~~The~~Begin the process ~~begins~~ by considering project-level savings~~.~~:

- ~~*Option C.* If~~**Option C.** Use a whole-facility approach—adhering with Option C of the IPMVP—if estimated project-level savings are large compared to the random or unexplained energy variations that occur at the whole-facility level[6]~~,~~ and if savings fluctuate over a seasonal or annual cycle (e.g.~~.~~., savings that fluctuate depending on OAT~~), a whole facility~~). This approach~~—adhering with Option C of the IPMVP—~~ is likely ~~is~~ the

[6] Typically savings should exceed 10% of the baseline energy for a particular meter (e.g.~~.~~., electricity meter) ~~in order~~ to confidently discriminate the savings from the baseline data when the reporting period is shorter than two years (EVO 2012).

most cost-effective approach for verifying savings. ~~This~~The whole-facility approach ~~proves~~is relatively inexpensive~~, as it involves analysis of~~ because evaluators can use utility ~~bill~~billing data~~. It has a~~ for the analysis. The downside~~, however, in~~ of the approach is that evaluators cannot perform verification ~~cannot be undertaken~~ until after collecting a full season or year of reporting period data ~~has been collected~~and monitoring and documenting any changes to the facility's static factors[7] over the course of the measurement period. Even if savings remain consistent month to month, Option C may provide the best approach if project measures cause complex, significant interactive effects. Such interactive effects are, by nature, difficult to estimate accurately. Also, if the effects are significant (large, relative to direct-measure savings), evaluators will be required to use a whole-facility approach~~ might be required~~ to measure impacts accurately. The reduced heating and cooling energy resulting from schedule changes to an air~~-~~handling unit, when control modifications have also been undertaken for both the heating and cooling systems, is an example of a complex significant interactive effect warranting Option C.

If Option C is ruled out, consider performing verification ~~should be considered~~ on a measure-by-measure basis~~.~~:

- **Option A.** If measures involve some parameters known with a high degree of certainty *and* other parameters can be measured cost-effectively, ~~then~~use a retrofit isolation approach adhering to Option A of the IPMVP~~ likely presents the most cost-effective approach for verifying savings.~~. In many cases, evaluators can collect metered data ~~can be collected~~ directly from the facility's BAS. If required, ~~additional~~the facility can add control points~~ can be added~~ to the BAS, either as part of the implementation process or specifically for M&V purposes. Where the BAS cannot provide the information, use temporary meters ~~may be used~~ to collect data~~,~~ (provided that costs are not prohibitive~~.~~).
- **Option B.** If a given measure's parameters are uncertain~~,~~ but can be measured cost-effectively, use a retrofit isolation approach~~,~~ adhering to Option B of the IPMVP~~ likely offers the most cost-effective approach for verifying savings. Metered data could be collected~~. Again, collect metered data (similar to Option A) either through the BAS or by using temporary meters.
- **Option D.** ~~A~~For measures where it is prohibitive to meter all required parameters, use a calibrated simulation approach adhering to Option D of the IPMVP~~ will have to be followed with measures for which it is prohibitive to meter all required parameters. Calibration should be undertaken~~. Undertake calibrations in two ~~forms~~ways: (1) calibrate the simulation ~~should be calibrated~~ to the actual baseline or reporting consumption data~~;~~

[7] Many factors can affect a facility's energy consumption, even though evaluators do not expect them to change. These factors are known as "static factors" and include the complete collection of facility parameters that are generally expected to remain constant between the baseline and reporting periods. Examples include: building envelope insulation, space use within a facility, and facility square footage.

and (2) confirm the reporting period inputs ~~should be confirmed~~ via the BAS front-end system, ~~wherever~~when possible.[8~~,~~,9]

- **Deemed.** Finally, if a measure is relatively common[10] and its estimated savings are small, ~~its~~evaluators can deem savings ~~may be deemed~~ rather than ~~simulated. Savings estimates can be considered "small" if they are~~ simulate them. Use this approach for common measures with savings less than 75,000 kilowatt-hours (kWh) or 5,000 therms[11] (PECI 2010). ~~A~~Use a spreadsheet tool ~~should be used~~ to calculate savings, adhering to functionality requirements presented later in the protocol.

4.2 Data Collection

Depending on the approach followed, these M&V elements will require particular consideration:

- The measurement boundary~~;~~
- The measurement period and frequency~~;~~
- The functionality of measurement equipment being used~~; and~~
- The savings uncertainty.

4.2.1 Measurement Boundary

For measures ~~that are assessed with an~~evaluators assess using Option A or Option B ~~approach~~ and that require metering external to the BAS, it will be important to define the measurement boundary. When determining boundaries—the location and number of measurement points required—consider the project's complexity and expected savings ~~should be considered~~:

- ~~A~~While a narrow boundary simplifies data measurement (e.g.~~,~~., a single piece of equipment), ~~but the~~ variables driving energy use outside the boundary (i.e., interactive effects) ~~will~~still need to be ~~accounted for;~~considered.
- A wide boundary will minimize interactive effects and increase accuracy (e.g.~~,~~., systems of equipment like chilled water plants and air~~-~~-handling units). However, as M&V costs may also increase, it is important to ensure ~~that~~ the expected project savings justify the increased M&V costs.

4.2.2 Measurement Period and Frequency

For all measures assessed with ~~an~~ Option A or Option B ~~approach,~~, consider two important timing metrics ~~should be considered~~:

- The measurement period (the length of the baseline and reporting periods~~); and~~)

[8] In many cases, the simulation should represent the entire facility; however, in some cases, depending on the facility's wiring structure, a similar approach could be applied to building ~~sub-meters~~submeters, such as distribution panels that include the affected systems.

[9] See ~~chapter on~~the Uniform Method Project's *Commercial New Construction Protocol* for more information on using Option D.

[10] If regulators are involved, going through the effort of deeming savings for a rare measure can be burdensome.

[11] Program administrators and evaluators may wish to customize these thresholds for particular programs and/or jurisdictions.

- The measurement frequency (how regularly to take measurements ~~are taken~~ during the measurement period).

As a general rule, choose the measurement period ~~should be chosen~~ to capture a full cycle of each operating mode. For example, if there is a control modification ~~has been made~~ to heating equipment, collect data ~~should be collected~~ over the winter and shoulder seasons.

~~The~~Choose the measurement frequency ~~should be chosen~~ by assessing the type of load measured:

- **Spot** ~~*Measurement*~~**measurement:** For constant loads, measure power ~~can be measured~~ briefly, preferably over two or more intervals.
- **Short-**~~*Term Measurement*~~**term measurement:** For loads predictably influenced by independent variables (e.g., HVAC equipment influenced by OAT), take short-term consumption measurements ~~should be taken~~ over the fullest range of possible independent variable conditions, given M&V project cost and time limitations. [12] For systems expected to have ~~non-linear~~nonlinear dependence (such as air-handling units with outside air economizers), measurements should incorporate sufficient range to characterize the full breadth of conditions.
- **Continuous** ~~*Measurement*~~**measurement:** For variable loads, measure consumption data ~~should be measured~~ continuously, or at appropriate discrete intervals, over the entire measurement period.

~~Direction~~See Section 4.4, *Specific Saving Equations*, for direction regarding measurement periods and frequency for specific measure types ~~are provided under the "Specific Saving Equations" subheading~~.

4.2.3 Measurement Equipment

When meters external to the BAS are required, ~~the meter selection process should~~ follow these guidelines to select a meter:[13]

- Size the meter for the range of values expected most of the time.
- Select the meter repeatability and accuracy that fits the budget and intended use of the data.
- Install the meter as recommended by the manufacturer.
- Calibrate the meter ~~the meter~~ before it goes into the field, and maintain calibration~~,~~ as recommended by the manufacturer. If possible, select a meter with a recommended calibration interval that is longer than the anticipated measurement period.

[12] For example, if a chiller plant undergoes control modifications ~~have been made to a chiller plant~~, the measurement frequency should be long enough to capture the full OAT operating range. In a temperate climate zone, evaluators can accomplish this ~~could be accomplished~~ by taking measurements over a four-week period in the shoulder season~~,~~ and another four-week period during the summer season.

[13] For more information on selecting measurement equipment, see the ~~cross-cutting chapter on~~Uniform Methods Project's *Metering Cross-Cutting Protocols.*

If BAS data is used, evaluators should exercise due diligence by determining when the BAS was last calibrated and by checking the accuracy of the BAS measurement points.

4.2.4 Savings Uncertainty

~~Accuracy~~If possible, quantify the accuracy of measured data[14] ~~should be quantified~~and, if ~~possible, and~~ practical, conduct an error propagation ~~analyses should be undertaken~~analysis to determine overall impacts on the savings estimate.

4.3 Interactive Effects

For projects following Option A, Option B, or deemed approaches, consider and estimate interactive effects ~~should be considered and estimated,~~ if they are significant. For example, if a facility reduces an air-~~-~~handling unit supply fan schedule ~~is reduced~~, not only will direct fan savings ~~will~~ be achieved, but significant cooling and heating energy savings may be realized due to decreases in conditioned ventilation air supplied to the space.

~~Interactive~~Estimate interactive effects ~~should be estimated~~ using equations that apply the appropriate engineering principles. Ideally, ~~these analyses would be undertaken using~~use a spreadsheet tool adhering to the same functionality requirements discussed in Section 4.6 for the ~~Deemed Spreadsheet Tool.~~ deemed spreadsheet tool to conduct these analyses. When interactive effects are ~~expected to be~~ large, it may be possible to measure them rather than ~~applying~~apply engineering estimates. ~~-~~In the "supply fan" example discussed in the paragraph above, an evaluator can meter the chilled water plant ~~could be metered~~ to determine the cooling load reduction.

Interactive effects for projects being verified using Option C or Option D are typically included in facility-level savings estimates.

4.4 Specific Savings Equations

If following Option A or Option B ~~is followed,~~, verify savings ~~will need to be verified~~ using equations matching a given measure's characteristics~~:~~ —specifically, whether savings are dependent on independent variables (such as OAT) and ~~how~~ the control mechanism for affected equipment ~~is controlled~~.

~~Figure 5 presents~~Figure 2 shows the three categories of savings equations, with further explanations following the flow chart~~:~~.

[14] Metering accuracy is only one element of savings uncertainty.~~-~~ Inaccuracies also result from modeling, sampling, interactive effects, estimated parameters, data loss, and measurements being taken outside of a meter's intended range.

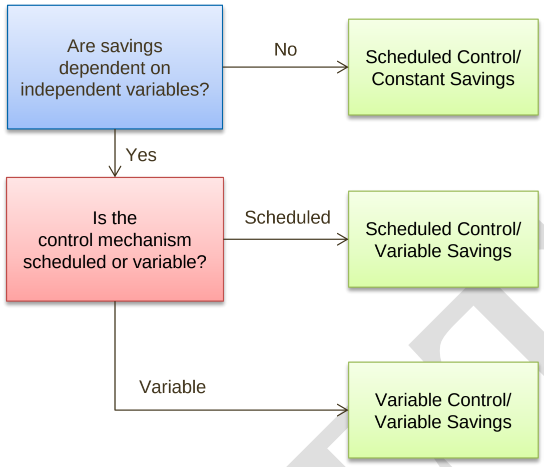
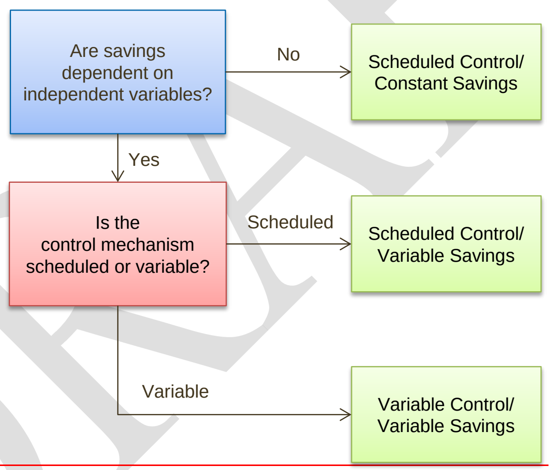


Figure ~~5.~~2. Savings ~~Equation Categories~~equation categories



4.4.1 Scheduled Control/Constant Savings

This savings equation category encompasses scheduled control measures on equipment not influenced by independent variables (such as OAT); therefore, this is the most straightforward equation category.

Lighting schedule optimization ~~presents~~is an example of a measure verified using this savings equation category. In this example, lighting ~~would be~~is turned off according to a schedule (scheduled control), and constant savings ~~would be~~is achieved while it is off (constant savings~~)~~).[15]~~.~~

Equation 2

Scheduled Control/Constant Savings = Baseline Energy – Reporting Period Energy

Where,

Scheduled Control/Constant Savings = First-year energy consumption savings resulting from a scheduled control measure with constant savings.

Baseline Energy = $HRS_{baseline} \times kW_{controlled}$

Reporting Period Energy = $HRS_{reporting} \times kW_{controlled}$

And,

$HRS_{baseline}$ = Annual operating hours during the baseline: ~~If~~if this parameter is not known with a high degree of certainty, ~~it should be measured. Short~~take short-term measurements ~~should be taken~~ for the duration of each existing schedule type.

$HRS_{reporting}$ = Annual operating hours during the reporting period: ~~Short~~take short-term measurements ~~should be taken~~ for the duration of each new schedule type.

$kW_{controlled}$ = Electric demand controlled by scheduling measure: ~~If~~if this parameter is not known with a high degree of certainty, ~~it should be measured. Spot~~take spot measurements ~~should be taken~~ during the baseline or reporting period.

4.4.2 Scheduled Control/Variable Savings

This savings equation category encompasses scheduled control measures on equipment influenced by independent variables (such as OAT). Space setback temperature optimization provides an example of a measure verified using this savings equation category. In this example, the heating space temperature set point ~~would be~~is lowered according to a schedule during

[15] While a single piece of equipment (one lighting fixture) may have a constant load, the system (lighting throughout a building) may have some variability. ~~-~~In a lighting system that includes a degree of occupant control (such as switches in private offices) nearly ~~one hundred percent~~100% of fixtures may operate midday, but substantially fewer may be on at the beginning or end of the day when the savings due to scheduling would likely occur.

unoccupied hours (scheduled control), and the savings achieved ~~would~~will vary, depending on OAT (variable savings).

Following Equation 3, ~~Figure 6 presents~~Table 4 lists the five-step process for determining adjusted baseline and reporting period energy consumption.

Equation 3

Scheduled Control/Variable Savings = Adjusted Baseline Energy – Adjusted Reporting Period Energy

Where,

Scheduled Control/Variable Savings = First-year energy consumption savings resulting from a scheduled control measure with variable savings.

Adjusted Baseline Energy = $\sum_{All\ Schedule\ Types} Adj\ Baseline\ Consumption_{Schedule\ Type}$ and determined through the five-step process ~~presented below.~~listed in Table 5.

Adjusted Reporting Period Energy = ~~$\sum_{All\ Schedule\ Types} Adj\ Reporting\ Period\ Consumption_{Schedule\ Type}$~~ $\sum_{All\ Schedule\ Types} Adj\ Reporting\ Per$ determined through the five-step process ~~presented below.~~listed in Table 5.

Figure 6.Table 4. Adjusted Consumption for Scheduled Control/Variable Savings Measures

Step	Details
1. Develop baseline/ reporting regression model(s) by measuring equipment operation and independent variables.	Take short-term measurements at representative load levels for the affected equipment for each schedule type. Take coincident measurements of the independent variable(s). Do a regression analysis to determine the relationship between independent variables and equipment load. This relationship should be expressed in terms of an equation (baseline/reporting period model). Note: if there are schedules for occupied and unoccupied times during the reporting period, evaluators will need two regression models are required, one for each set of data.
2. Develop a bin operating profile[16]profile[a] by normalized independent variable data.	Develop bin data tables presenting the following data *(one table for each schedule type)*: • ***Independent Variable***: • Create approx. 10 bins over the normalized independent variable data range. (e.g., if the equipment's energy consumption varies depending on weather, use normalized TMY.) • ***Load***: • Calculate the normalized load by applying the baseline/reporting period regression model to the midpoint of each bin. • ***Annual Hours***: • Use short-term measured data to estimate hours of operation within in each bin, or base this on TMY data and the equipment operating schedule.
	Independent Variable: Create approximately 10 bins over the normalized independent variable data range (if the equipment's energy consumption varies depending on weather, use TMY data). **Load**: Calculate the normalized load by applying the baseline/reporting period regression model to the midpoint of each bin. **Annual Hours**: Use short-term measured data to estimate hours of operation within each bin or base this on TMY data and the equipment operating schedule.
3. Calculate the baseline/reporting period consumption at each load bin for each schedule type.	Adj $Consumption_{Load,Shedule}$ Adjusted $Consumption_{Load,Schedule\ Type} = Load_{Schedule\ Type} \times Annual\ Hrs_{Schedule\ Type}$

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[16] Alternatively, if the independent variable is OAT, an hourly profile could be developed over the full operating schedule of the affected equipment.

Step	Details
4. Sum the consumption savings across bins for each schedule type.	$\sum_{All\ Load\ Bins_{Schedule\ Type}} Adj\ Consumption_{Load,Schedule\ Type}$
5. Sum the consumption savings across schedule types.	$\sum_{All\ Schedule\ Types} Adj\ Consumption_{Schedule\ Type}$

[a] Alternatively, if the independent variable is OAT, evaluators can develop an hourly profile over the full operating schedule of the affected equipment.

4.4.3 Variable Control/Variable Savings

This savings equation category encompasses variable control measures on equipment influenced by independent variables, such as OAT. Introducing a chilled water supply temperature set point reset strategy serves as an example of a measure that would be verified through this savings equation category. In this example, the chilled water supply temperature set point would beis determined depending on OAT (variable control), and the savings achieved wouldwill vary depending on OAT (variable savings).

Following Equation 4, Figure 7presentsFollowing Equation 4, Table 5 lists the four-step process for determining the adjusted baseline and reporting period energy consumption.

Equation 4

Variable Control/Variable Savings = Adjusted Baseline Energy – Adjusted Reporting Period Energy

Where,

Variable Control/Variable Savings = First-year energy consumption savings resulting from a variable control measure with variable savings.

Adjusted Baseline Energy = $\sum_{All\ Load\ Bins} Adj\ Baseline\ Consumption_{Load}$ determined through the four-step process presented belowlisted in Table 6.

Adjusted Reporting Period Energy = $\sum_{All\ Load\ Bins} Adj\ Reporting\ Period\ Consumption_{Load}$ determined through the four-step process presented belowlisted in Table 6.

Figure 7.

Table 5. Adjusted Consumption for Variable Control/Variable Savings Measures

<table>
<tr><th>Step</th><th colspan="3">Details</th></tr>
<tr><td>1. Develop baseline/ reporting regression model(s) by measuring equipment operation and independent variables.</td><td colspan="3">Take short-term measurements at representative load levels for the affected equipment for each schedule type.

Take coincident measurements of the independent variable(s).

Do a regression analysis to determine the relationship between independent variables and equipment load. This relationship should be expressed in terms of an equation (baseline/reporting period model).</td></tr>
<tr><td rowspan="3">Develop a bin operating profile[a] by normalized independent variable data.</td><td colspan="3">Develop bin data tables presenting the following data:</td></tr>
<tr><td>Independent Variable</td><td>Load</td><td>Annual Hours</td></tr>
<tr><td>2. Develop a bin operating profile[17] byCreate approximately 10 bins over the normalized independent variable data. range (e.g., if the equipment's energy consumption varies depending on weather, use TMY data).</td><td>Calculate the normalized load by applying the baseline/reporting period regression model to the midpoint of each bin.</td><td>• Develop bin data tables that present the following data:
<table><tr><th>• Independent Variable</th><th>• Load</th><th>• Annual Hours</th></tr><tr><td>• Create approx. 10 bins over the normalized independent variable data range. (e.g., if the equipment's energy consumption varies depending on weather, use normalized TMY.)</td><td>• Calculate the normalized load by applying the baseline/reporting period model to the midpoint of each bin.</td><td>• Use short-term measured data to estimate hours of operation within in each bin, or base this on TMY data and the equip</td></tr></table></td></tr>
</table>

Inserted Cells

[17] Alternatively, if the independent variable is OAT, an hourly profile could be developed over the full operating schedule of the affected equipment.

Step	Details
	~~ment operating schedule.~~ Use short-term measured data to estimate hours of operation within each bin, or base this on TMY data and the equipment operating schedule.
~~3.~~ Calculate the baseline/ reporting period consumption at each load bin.	Adjust Consumption Adj $Consumption_{Load}$ = Load x Annual ~~Hrs~~Hours
~~4.~~ Sum the consumption savings across ~~all load~~ bins.	$$\sum_{All\ Load\ Bins} Adj\ Consumption_{Load}$$

[a] Alternatively, if the independent variable is OAT, evaluators can develop an hourly profile over the full operating schedule of the affected equipment.

4.5 Regression Modeling Direction

~~To calculate~~Calculating normalized savings~~,~~ ~~for the majority of projects—~~whether following the IPMVP's Option A, Option B, or Option C~~,~~— will require the development of a baseline and reporting period regression model[18] ~~will need to be developed for the majority of projects. There are.~~[19] Use one of the following three types of analysis methods ~~can be used~~ to create ~~a~~the model:

- *Linear Regression:* For one routinely varying significant parameter (e.g., OAT~~)~~).[20]~~.~~
- *Multivariable Linear Regression*: For more than one routinely varying significant parameter (e.g., OAT, occupancy).
- *Advanced Regression*: ~~Such as~~For a multivariable, nonlinear fit requiring a polynomial or exponential model.[21]~~.~~

~~[18] This could either be a single regression model that uses a dummy variable to differentiate the baseline/reporting period data, or two independent models for the baseline and reporting period respectively.~~

[19] This could either be a single regression model that uses a dummy variable to differentiate the baseline/reporting period data or two independent models for the baseline and reporting period, respectively.

[20] One of the most common linear regression models is the three-parameter change point model. For example, a model that represents cooling electricity consumption ~~would~~ will have one regression coefficient that describes ~~non-weather~~ nonweather-dependent electricity use, a second regression coefficient that describes the rate of increase of electricity use with increasing temperature, and a third parameter that describes the change point temperature, also known as the balance point temperature, where weather-dependent electricity use begins.

[21] ~~Advanced~~Evaluators may need to use advanced regression methods ~~might be required~~ if RCx activities impact manufacturing or industrial process equipment.

~~When required, these~~Develop all models ~~should be developed~~ in accordance with best practices~~,~~ and ~~they should~~ only ~~be used~~use them when they are statistically valid (see ~~subsection~~Subsection 4.5.2, *Testing Model Validity*). If no significant independent variables arise (as with a lighting schedule measure), ~~a model is~~evaluators are not required~~,~~ to use a model because calculated savings will be inherently normalized.

4.5.1 Best Practice Model Development

~~Energy~~Use energy and independent variable data ~~should be~~that is representative of a full cycle of operation. ~~Thus, for~~For example, if facility staff implement a heating space temperature setback measure, collect energy data across the full range of ~~OATs~~OAT for each of the operating schedules (occupied and unoccupied) for each season, as shown in ~~Figure 8.~~ ~~**Figure 8.**~~Table 6.

Table 6. Example of Data Required for Model Development

	Shoulder Season	Winter Season
Occupied ~~Hrs~~Hours	Short-term energy measurements during occupied hours. Measurements should be representative of the full range of shoulder-season OAT (approximately 10 OAT bins).	Short-term energy measurements during occupied hours. Measurements should be representative of the full range of winter-season OAT (approximately 10 OAT bins).
Unoccupied ~~Hrs~~Hours	Short-term energy measurements during unoccupied hours. Measurements should be representative of the full range of shoulder-season OAT (approximately 10 OAT bins).	Short-term energy measurements during unoccupied hours. Measurements should be representative of the full range of winter-season OAT (approximately 10 OAT bins).

~~The~~Analyze the data collected ~~should be analyzed~~ to identify outliers. ~~This involves employing approaches such as the cumulative sum (CUSUM)[22] of differences technique or by visually inspecting a plot of the energy consumption data versus the independent variable data.~~ Only remove outliers when there is a tangible explanation ~~can be provided~~ to support the erratic data points. Discussion of how to identify outliers is outside the scope of this protocol.

4.5.2 Testing Model Validity

To assess the model's accuracy, ~~review~~begin by reviewing the parameters listed in ~~Figure 9~~Table 7 (EVO 2012).

~~Figure 9.~~

~~[22] The CUSUM technique involves running independent variable data through the model and comparing energy consumption outputs to actual energy consumption data. Differences are summed over the range of independent variable inputs. If no significant outliers arise, the plotted sum of differences should be a horizontal line, intersecting zero on the y-axis (i.e., the differences should be insignificant).~~

Table 7. Model Statistical Validity Guide

Parameter Evaluated	Description	Suggested Acceptable Values
Coefficient of Determinationdetermination (R^2)	A measure of the extent that the regression model explains variations in the dependent variable from its mean value are explained by the regression model.	> 0.75
T-statistic (absolute value)	An indication of whether regression model coefficients are statistically significant.	> 22[a]
Mean bias error	An indication of whether the regression model overstates or understates actual energy consumption.	Will depend on the measure, but generally: < +/- < ±5%

If any[a] Determine the t-statistic threshold based on the evaluator's chosen confidence level; a 95% confidence level requires a t-statistic of these parameters fall outside their1.96. Evaluators should determine an acceptable ranges, the regression model is confidence level depending on project risk (i.e., savings risk), budget, and other considerations.

A model outside the suggested range indicates parameter coefficients that are relatively poorly determined, with the result that normalized consumption will have relatively high statistical prediction error. Ordinarily, evaluators should not considered statistically valid, and should not be useduse such a model for normalization, unless the analysis includes appropriate statistical treatment of this prediction error. Discussion of how to normalize data. proceed in such circumstances is outside the scope of this protocol.

When possible, attempts should be madeattempt to enhance the regression model by increasing:

- Increasing or shifting the measurement period; by incorporating
- Incorporating more data points; by including
- Including independent variables that were previously unidentified; or by eliminating
- Eliminating statistically insignificant independent variables.

Also, when assessing model validity, consider coefficient of variation (CV) of the root mean squared error (RMSE), fractional savings uncertainty, and residual plots. Refer to ASHRAE Guideline 14-2002 and Bonneville Power Administration's *Regression for M&V: Reference Guide* for direction on how to assess these additional parameters.

4.6 Deemed Spreadsheet Tool Functionality Requirements

When collecting measured energy data is not cost-effective and claimed (*ex ante)* savings estimates for a given measure are sufficiently small (75,000 kWh or 5,000 therms), use a deemed approach can be used to calculate savings. In this scenario, the protocol recommends using a spreadsheet tool should be used to calculate savings, and this tool should meet these general requirements.:

- ***The*Ensure model *should be transparent.*transparency.** A third party should be able to review the spreadsheet tool and clearly understand how the evaluator derived all savings outputs have been derived.. To this end, clearly explain and reference all inputs and calculation algorithms ~~should be clearly explained and referenced~~ within the spreadsheet~~,~~. Do not lock or hide cells or sheets ~~should not be locked or hidden,~~ and check to ensure all links ~~should not be broken~~work properly.

- ~~*Relevant*~~**Use relevant secondary data** ~~*should be used.*~~**.** When using secondary data ~~are used~~ as inputs to savings algorithms, ensure they ~~should be~~are relevant to the project's region or jurisdiction. ~~This~~Substantiate input relevancy ~~should be substantiated~~ within the spreadsheet. For example, if using assumed values for hours of operation for heating equipment ~~are assumed,~~, take these secondary data ~~should be taken~~ from a regional resource (e.g., a technical resource manual from the most applicable demand-side management authority).
- ~~*Input*~~**Verify input elements** ~~*should be verified,*~~ **either on-site or through the BAS front-end system.** Even when using a deemed approach, verify and update some inputs with actual site observations~~,~~ (rather than ~~by~~ solely relying on secondary data~~.~~). For example, confirm a new lighting schedule ~~should be confirmed~~ through the BAS front-end system and ~~noted~~note it in the spreadsheet tool.
- ~~*Default*~~**Establish default values for unverifiable parameters** ~~*should be established*. For certain~~ **.** Use default values for parameters that cannot be verified~~, default values should be used.~~ . For example, clearly state assumed values for motor efficiencies and load factors ~~should be clearly stated~~.

The Building Optimization Analysis Tool,[23]~~,~~ developed by Portland Energy Conservation~~,~~ Inc., (PECI 2010) provides an example of a best-practice benchmark for RCx spreadsheet tools. Although the protocol does not require the following ~~rigor~~ level ~~is not required~~of rigor, ideally, a best-~~-~~practice spreadsheet tool should:

- Incorporate regional TMY data~~;~~
- Incorporate regional building archetype templates~~; and~~
- Undergo a calibration process~~, testing algorithms~~ by using measured data from previous regional projects~~.~~ to test algorithms.

[23] ~~Download for free at: http://www.cacx.org/resources/rcxtools/spreadsheet_tools.html~~ Download the tool for free at: www.cacx.org/resources/rcxtools/spreadsheet_tools.html.

5 Sample Design

~~Chapter 11:~~Consult the Uniform Methods Project's *Sample Design* ~~describes~~*Cross-Cutting Protocols* for general sampling procedures ~~that should be consulted~~ if the RCx program project population is sufficiently large~~,~~ or if the evaluation budget is constrained. ~~-~~Ideally, use stratified sampling ~~should be undertaken by partitioning~~to partition RCx projects by measure type, facility type, and/or project size. ~~This stratification~~Stratification ensures ~~that~~evaluators can confidently extrapolate sample findings ~~can be extrapolated confidently~~ to the remaining project population. ~~The~~Regulatory or program administrator specifications typically govern the confidence and precision-level targets that influence sample size ~~are typically governed by regulatory or program administrator specifications~~.

6 Other Evaluation Issues

When claiming lifetime and net program RCx impacts, evaluators should consider persistence and net-to-gross (NTG)~~ should be considered~~ in addition to first-year gross impact findings.

6.1 Persistence

Persistence of savings encompasses both the retention and the performance degradation of measures. ~~ ~~Evaluators should consider persistence on a program-by-program basis because the persistence of RCx projects can vary widely depending on the distribution of measure types implemented and, perhaps more significantly, on how well facility staff maintains the modifications~~ are maintained. Chapter 13:~~. Consult the Uniform Methods Project's *Assessing Persistence and Other Evaluation Issues* ~~can be consulted~~*Cross-Cutting Protocols* for more information.

6.2 Net-~~-~~to-~~-~~Gross

~~The cross-cutting net-to-gross chapter discusses an approach for~~Consult the Uniform Methods Project's *Estimating Net Energy Savings: Methods and Practice* for a discussion about determining net program impacts at a general level, including direction on how to assess ~~free-ridership.~~freeridership. Supplementary to ~~this general section~~that chapter, however, evaluators may consider assessing participant spillover if evidence emerges of participants implementing no-cost measures. This would specifically apply to no-cost measures identified during the investigation phase, but not explicitly included under the scope of program-funded RCx implementation activities.

If no-cost measures exist~~, but~~ and there are no savings claims~~ have been made~~, the attribution evaluation may involve interviews with building operators and their service providers to obtain estimates of the savings magnitude resulting from these measures. Participant spillover would positively influence ~~on~~ the program's overall NTG factor.

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