NORTHEAST ENERGY EFFICIENCY PARTNERSHIPS

EVALUATING ENERGY EFFICIENCY: THE TOP 5 THINGS TO KNOW ABOUT THE EMERGING EVALUATION WORLD

June 2, 2014 / 9AM - 3PM
Newport RI

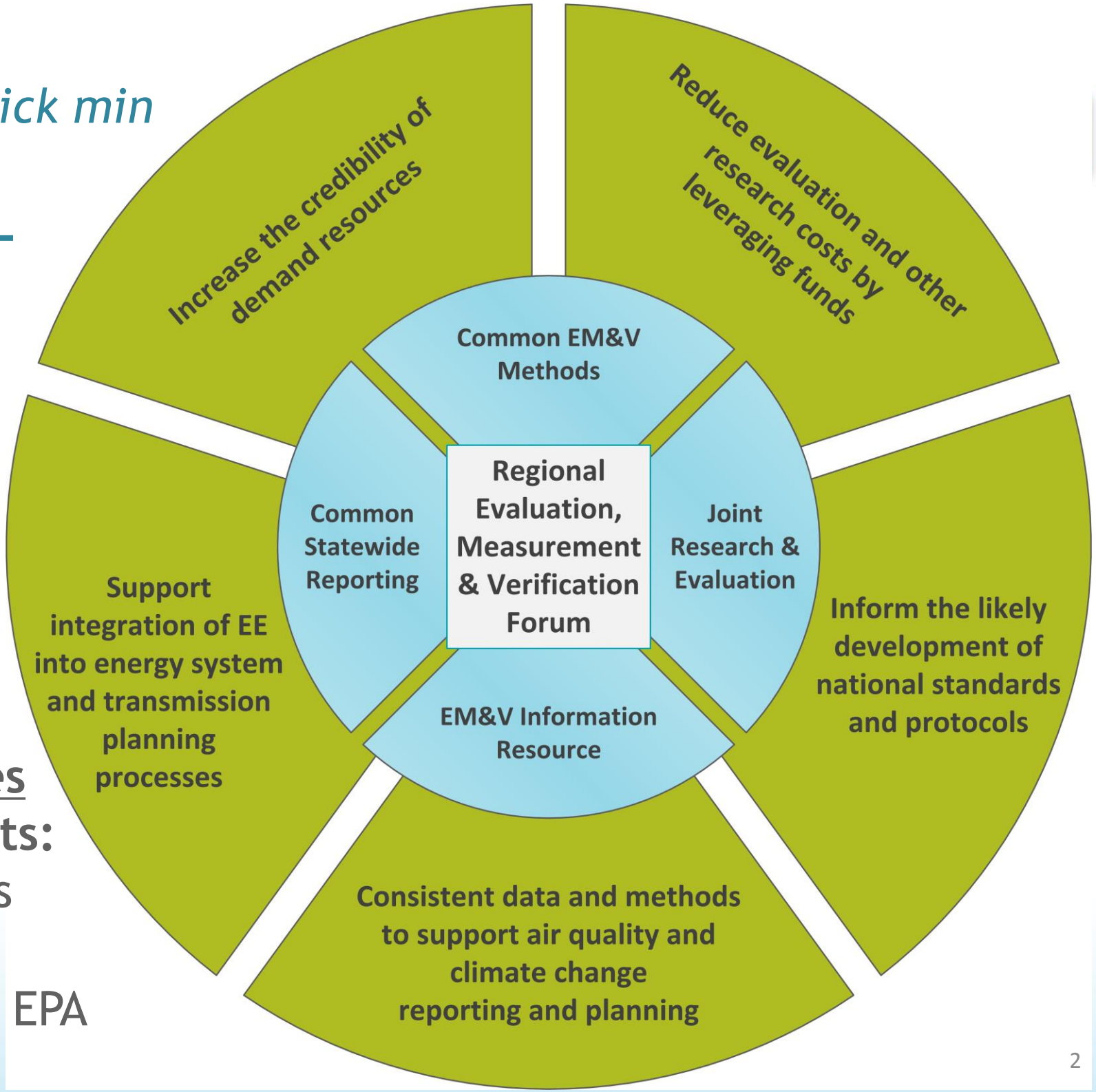
WHY THIS WORKSHOP?

Build a better understanding of:

1. Why do policymakers/regulators and system planners care about EM&V?
2. Tools and resources being developed to help build transparency and consistency in EM&V practices (by US DOE and the Regional EM&V Forum)
3. The growing and potential role of building analytics and new tools to support EM&V in a changing industry

First, 1 quick min on the

REGIONAL EM&V FORUM



9-10 States

Participants:

PUCs, SEOs

DEPs, PAs

ISOs, DOE, EPA

WORKSHOP FORMAT

For you to keep in mind today …

1. Informal format - yes with some presentations BUT with time for interactive discussion
2. Don't be shy to ask questions (or write them down on index cards)
3. Share your vision – how do YOU see the EM&V world evolving, opportunities and challenges?
4. Workshop is a mix of policy (high level) and engineering (wonky) – we will aim for right balance
5. Mix and mingle - meet someone new!

Note: US EPA CAA 111d) PR at 10:30am

HOW MUCH DO YOU KNOW (OR DID YOU LEARN)?

(Yes, it's out of focus…)

Regional EM&V Forum Team

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Regional EM&V Forum

http://neep.org/emv-forum/forum-products-and-guidelines/index

Northeast Energy Efficiency Partnerships

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NEEP EM&V METHODS PROJECT: WHAT'S IN YOUR EM&V MIX?

NEEP Summit 2014

June 2, 2014

OVERARCHING GOAL

Build credibility of EE as a resource by building transparency and basic understanding of EM&V practices to support EE resources in state, regional and national energy and environmental policies and markets.

EM&V REPORTING TODAY

- How do we demonstrate what EM&V activities are performed?
- How do we report accuracy and reliability of EE achievements?
- How do the EM&V method compare to other state practices?
- How do the EM&V methods align with any existing state, regional, or national protocols?

PROJECT OBJECTIVES

Create standard reporting to:

- Summarize EM&V methods
- Summarize EM&V rigor

Impact Evaluation EM&V Summary

"Study-level" form

Program Portfolio EM&V Summary

"Program-Level" form

Impact Evaluation EM&V Summary

"Study-level" form

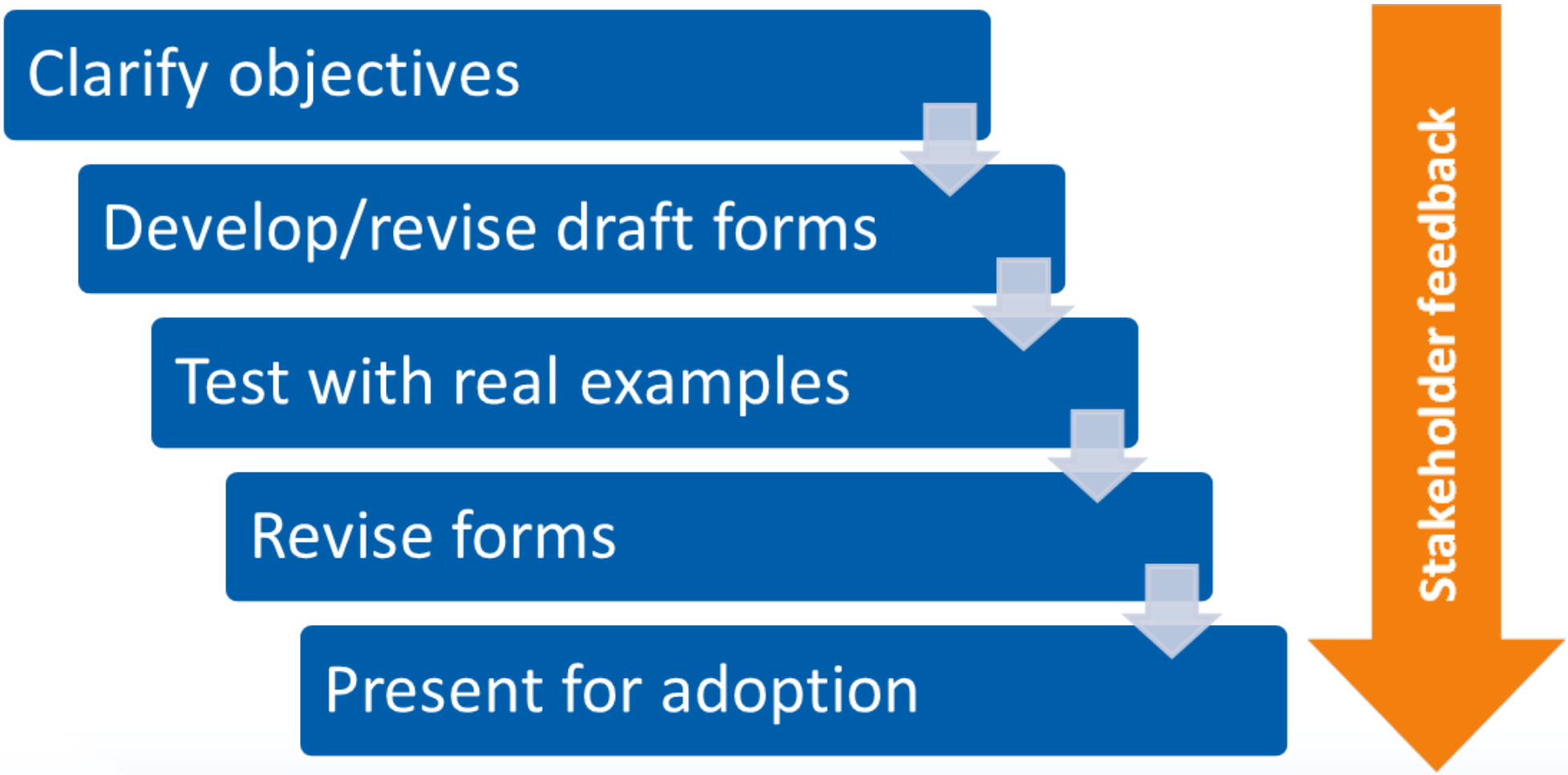
- Accompanies unique evaluation study
- Summarizes study objectives, **methods**, results, and rigor
- Primary audiences: PAs, EE Program regulators/consultants, regional system planners

Program Portfolio EM&V Summary

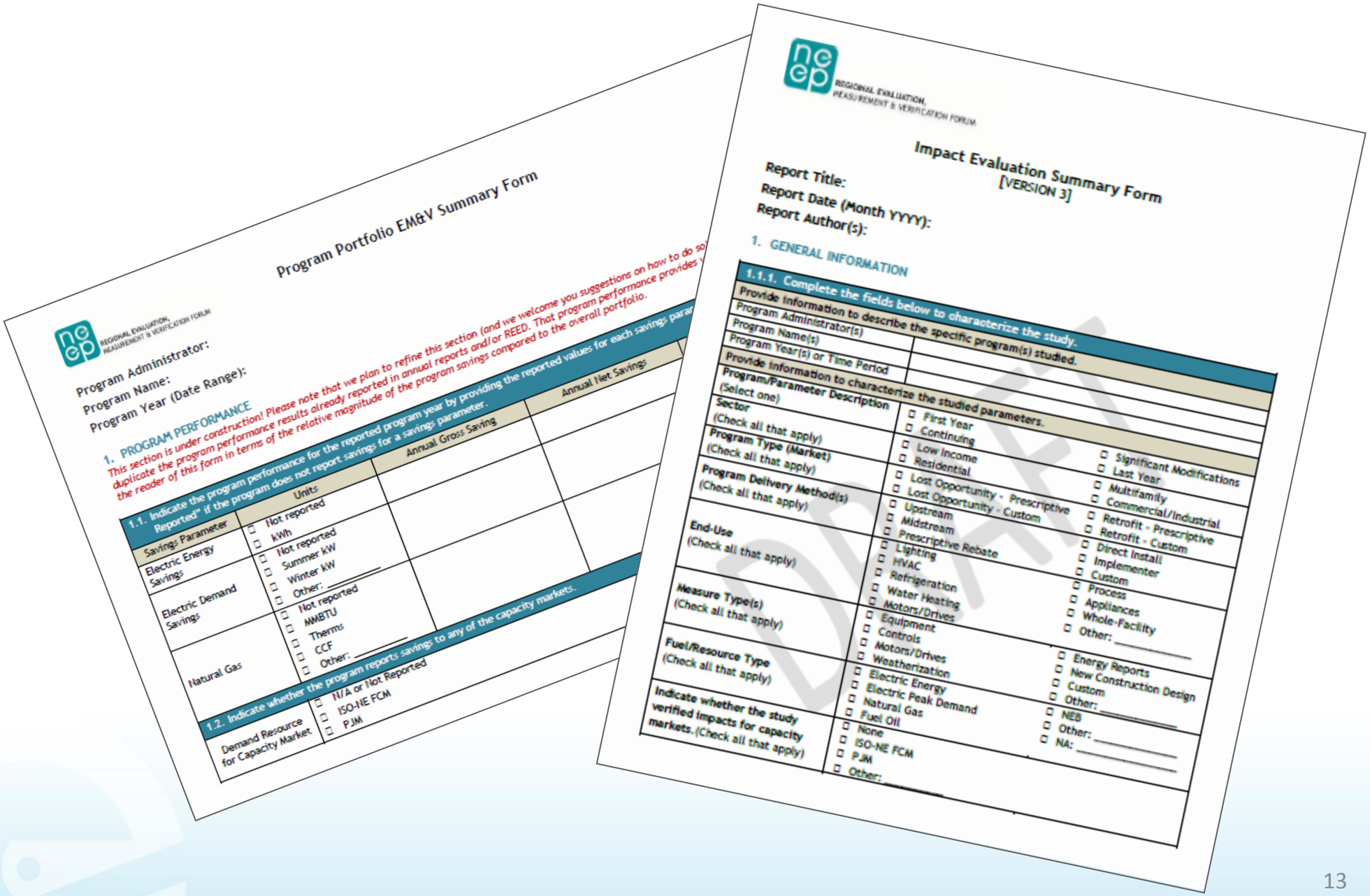
"Program-Level" form

- Accompanies annual reports
- Summarizes EM&V strategy, methods, and rigor for EE programs
- Primary audiences: energy and air quality regulators, regional system planners, EPA/DOE

PROCESS


Clarify objectives
Develop/revise draft forms
Test with real examples
Revise forms
Present for adoption
Stakeholder feedback

FORMS



Program Portfolio EM&V Summary Form

REGIONAL EVALUATION, MEASUREMENT & VERIFICATION FORUM

Program Administrator:
Program Name:
Program Year (Date Range):

1. PROGRAM PERFORMANCE

This section is under construction! Please note that we plan to refine this section (and we welcome you suggestions on how to do so
duplicate the program performance results already reported in annual reports and/or REED. That program performance provides
the reader of this form in terms of the relative magnitude of the program savings compared to the overall portfolio.

1.1. Indicate the program performance for the reported program year by providing the reported values for each savings para... Reported" if the program does not report savings for a savings parameter.		Annual Gross Saving	Annual Net Savings
Savings Parameter	Units		
Electric Energy Savings	☐ Not reported ☐ kWh		
Electric Demand Savings	☐ Not reported ☐ Summer kW ☐ Winter kW ☐ Other: _____		
Natural Gas	☐ Not reported ☐ MMBTU ☐ Therms ☐ CCF ☐ Other: _____		

1.2. Indicate whether the program reports savings to any of the capacity markets.	
Demand Resource for Capacity Market	☐ N/A or Not Reported ☐ ISO-NE FCM ☐ PJM

REGIONAL EVALUATION, MEASUREMENT & VERIFICATION FORUM

Impact Evaluation Summary Form
[VERSION 3]

Report Title:
Report Date (Month YYYY):
Report Author(s):

1. GENERAL INFORMATION

1.1.1. Complete the fields below to characterize the study.		
Provide information to describe the specific program(s) studied.		
Program Administrator(s)		
Program Name(s)		
Program Year(s) or Time Period		
Provide information to characterize the studied parameters.		
Program/Parameter Description (Select one)	☐ First Year ☐ Continuing	☐ Significant Modifications ☐ Last Year
Sector (Check all that apply)	☐ Low Income ☐ Residential	☐ Multifamily ☐ Commercial/Industrial
Program Type (Market) (Check all that apply)	☐ Lost Opportunity - Prescriptive ☐ Lost Opportunity - Custom	☐ Retrofit - Prescriptive ☐ Retrofit - Custom
Program Delivery Method(s) (Check all that apply)	☐ Upstream ☐ Midstream ☐ Prescriptive Rebate	☐ Direct Install ☐ Implementer ☐ Custom
End-Use (Check all that apply)	☐ Lighting ☐ HVAC ☐ Refrigeration ☐ Water Heating ☐ Motors/Drives	☐ Process ☐ Appliances ☐ Whole-Facility ☐ Other: _____
Measure Type(s) (Check all that apply)	☐ Equipment ☐ Controls ☐ Motors/Drives ☐ Weatherization	☐ Energy Reports ☐ New Construction Design ☐ Custom ☐ Other: _____
Fuel/Resource Type (Check all that apply)	☐ Electric Energy ☐ Electric Peak Demand ☐ Natural Gas ☐ Fuel Oil	☐ NEB ☐ Other: _____ ☐ NA: _____
Indicate whether the study verified impacts for capacity markets. (Check all that apply)	☐ None ☐ ISO-NE FCM ☐ PJM ☐ Other: _____	

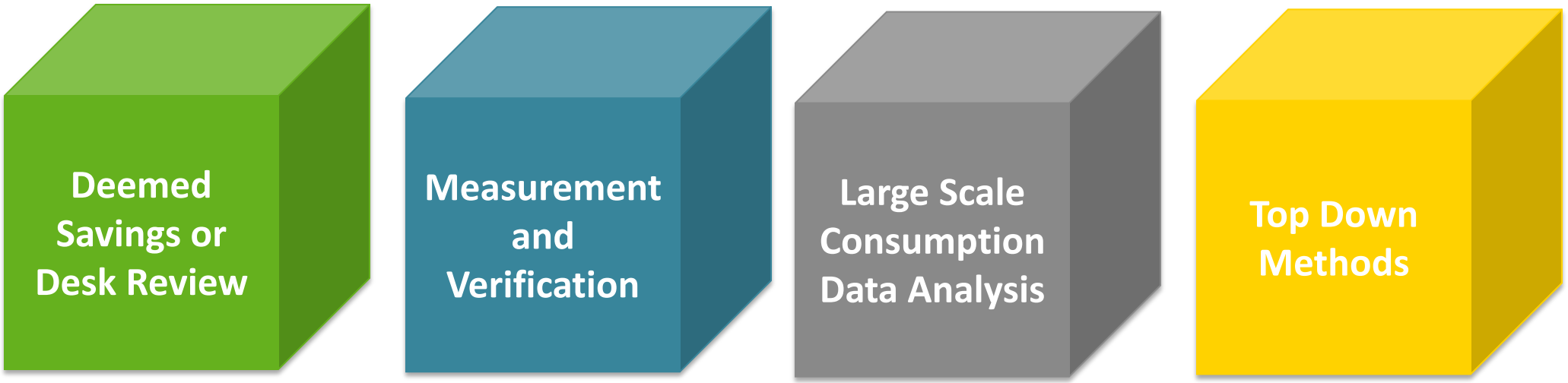
DRAFT

CHALLENGE: MANY AUDIENCES

- Program administrators
- Program evaluators and implementers
- State PUCs
- State Energy Offices
- ISO/RTO system planners
- State and regional air regulators
- US DOE
- US EPA
- Researchers (e.g., LBNL, ACEEE, NGOs, etc.)

CHALLENGE: "BOXING" EM&V METHODS

- How do we summarize EM&V activity in a way that is simple, fair, and complete?



- Selection of method has many influences:
  - Budget, schedule, program/participant size, program/measure type, study objectives

CHALLENGE: CHARACTERIZING EM&V RIGOR

- How do we define “rigor”?
  - No existing metrics to apply across all programs/measures
- Selection of rigor has many influences:
  - Budget, schedule, program/participant size, program/measure type, study objectives

CHALLENGE:
EM&V STANDARDS, PROTOCOLS, GUIDANCE

- Many EM&V documents existing that describe, recommend, or mandate EM&V methods
- It's often unclear when and how these are used
- *Compliance* may not be audited or may not be relevant

- Goal: indicate which documents are used without implying compliance or non-compliance

OUR NEXT STEPS

- Finalize forms for adoption
  - Taking feedback on current drafts
  - Standardizing terms
  - Improving form usability and instructions

- Milestone: Present for adoption by NEEP Steering Committee in July

CONTACTS

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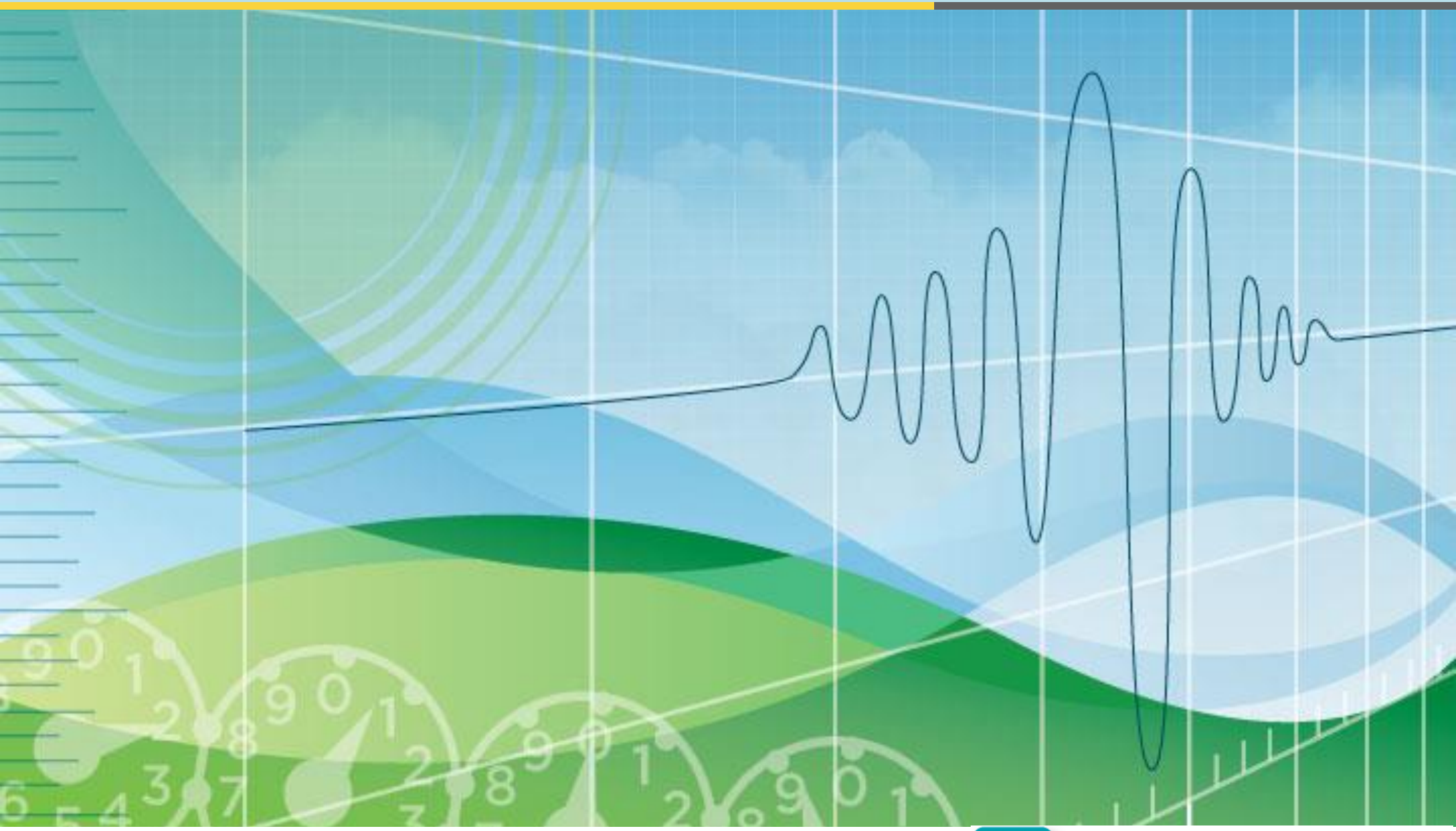
U.S. DEPARTMENT OF ENERGY



UNIFORM METHODS PROJECT

NORTHEAST ENERGY EFFICIENCY PARTNERSHIPS
FACILITATING PARTNERSHIPS TO ADVANCE ENERGY EFFICIENCY

Jointly managed by the DOE Office of Electricity Delivery and Energy Reliability and the Office of Energy Efficiency and Renewable Energy

WHY IS THIS PROJECT NEEDED?

- Seventeen Technical Reference Manuals (TRMs) have been identified, covering 21 states and D.C. (as of Spring 2012)
- Different methods for calculating savings for same measures
- Savings estimates for same measures varied widely with no clear explanation of the source
- Widespread use of the UMP protocols could provide consistency across TRMs

CURRENT EM&V PRACTICE

- There are multiple ways to calculate energy savings for the same energy efficiency measure or program.
  - Lack of methodological consistency leads to difficulty understanding and comparing results.
  - There is a general lack of transparency about the assumptions and details of savings calculations.

WHAT IS THIS PROJECT?

Develop Savings Calculation Protocols for Energy Efficiency Measures and Programs

- Addresses most common residential and commercial efficiency measures in incentive programs
- Presents step-by-step calculations for determining gross savings
- Includes additional sections to address cross-cutting evaluation requirements

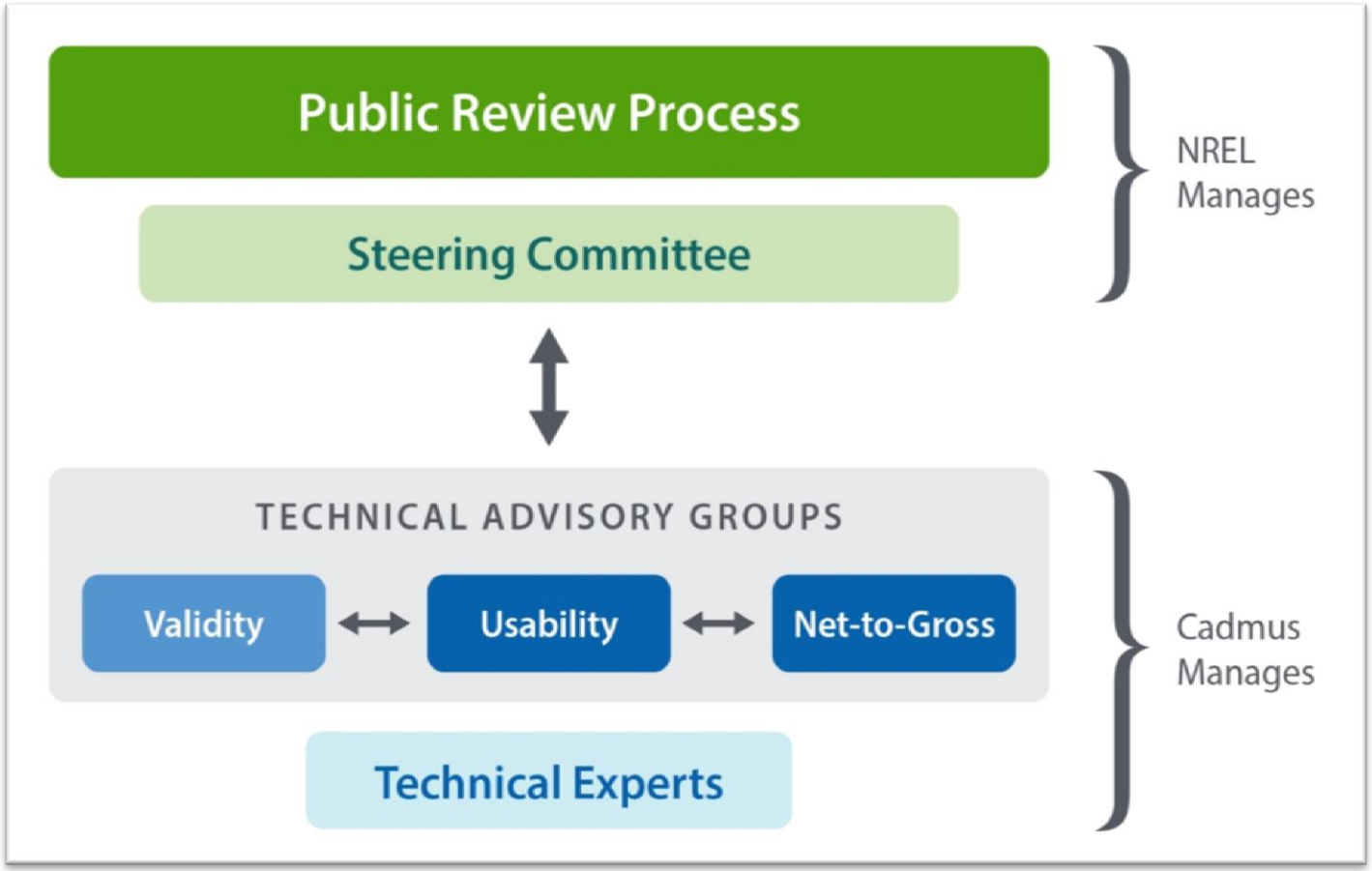
PROJECT GOALS & BENEFITS

- Create greater consistency of savings calculations
  - Quickly establish good M&V practices
  - Facilitate meaningful comparisons
- Provide transparency reduces uncertainty
- Support development of best practices for energy efficiency
  - Sets data requirements early on
  - Confidence when setting and meeting savings targets
- Provide educational value to broad stakeholder community
  - Protocols identify key inputs
  - Documentation of methods and calculations
  - Educating those new to EM&V
- Ultimately, lower M&V costs

INTENDED AUDIENCE

- Jurisdictions with no existing protocols or TRMs
- Regulators
- Program administrators
- Implementers
- Evaluators
- Three primary pathways for adoption
  - Formally by regulators
  - Adopted by program administrators and provided to implementers and evaluators
  - Recommended to clients by evaluators

PROJECT ORGANIZATION



STEERING COMMITTEE AND OBSERVERS

- **Steering Committee Leads Development Process**
- Steering Committee is Composed of:
  - Energy efficiency program administrators
  - Regulators from public service commissions
  - Investor-owned, public, and cooperative electric and gas utilities
  - Electric utility associations
  - Federal and state agencies involved in energy efficiency programs
  - Energy efficiency advocates
  - Regional energy efficiency organizations

TECHNICAL EXPERTS & TECHNICAL ADVISORY GROUP

ADM ENERGY RESEARCH AND EVALUATION

CADMUS

sbw ENERGY · WATER · EFFICIENCY

APEX ANALYTICS, LLC

WARREN ENERGY ENGINEERING, LLC

Itron

Left Fork Energy

Jacobson Energy Research LLC

KEMA DNV

ICF Marbek an ICF International Company

NREL NATIONAL RENEWABLE ENERGY LABORATORY

GDS Associates, Inc. Engineers and Consultants

Nexant

NAVIGANT CONSULTING

TETRA TECH

PROJECT ORGANIZATION

- Protocols developed in collaboration with energy efficiency program stakeholders:
  - Regulators
  - Program administrators
  - EM&V consultants (including the major U.S. firms that do a large portion of efficiency evaluations)
- Industry review process allowed for input from all stakeholders
- Public review process allowed for input from all interested parties

PROJECT'S SCOPE

- 2-Phase Project
- Develop and Publish 15–20 Protocols for Savings Calculations of Energy Efficiency Measures
  - Addresses most common residential and commercial efficiency measures (primarily) in ratepayer-funded programs
  - Presents step-by-step calculations for determining gross savings
  - Includes additional sections to address cross-cutting evaluation requirements
- Phase 1 Complete

PHASE 1 MEASURES

- **Efficiency Measure:**
  - Refrigerator recycling
  - Commercial lighting
  - Commercial lighting controls
  - Residential lighting
  - Residential furnaces and boilers
  - Commercial unitary and split system air conditioning equipment
  - Whole-building retrofit

- **Cross-Cutting Protocols:**
  - Sample design
  - Survey design
  - Metering
  - Calculation of peak impacts
  - Other evaluation topics (including rebound and persistence of savings)

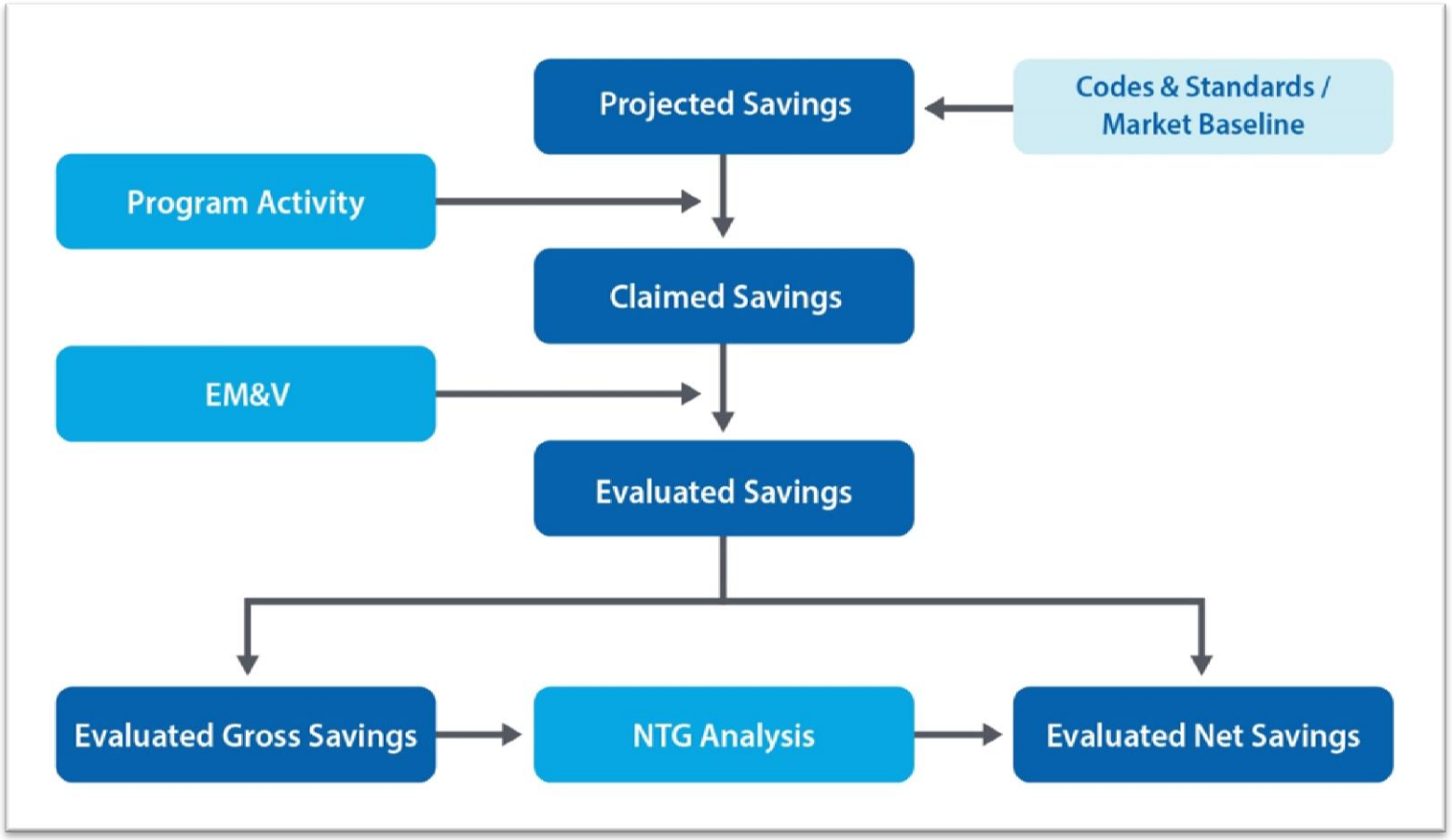
PHASE 2 PROTOCOLS (UNDER DEVELOPMENT)

- Efficiency Measures
  - Chillers
  - Commercial New Construction
  - Compressed Air Systems
  - Data Centers
  - HVAC Controls
  - Residential Behavior
  - Retro-commissioning
  - Variable Frequency Drives
  - Revision: Residential Lighting
- Cross-Cutting Measures
  - Net Savings: Methods and Practice

WHAT IS IN EACH PROTOCOLS

- Measure Description and Application
- Conditions of Protocol Application (s)
- Gross Savings Calculations
- Critical Parameters
- M&V Plan
- Data Requirements
- Other Evaluation Issues

ABOUT SAVINGS (DEFINITIONS)



THE (SIMPLE) PUBLIC REVIEW PROCESS

Expert completes draft >>> Cadmus reviews, edits, sends to TAG >>>TAG reviews, provides feedback >>> Expert addresses comments >>> Cadmus reviews, forwards to Steering Committee >>> NREL uploads document to Electronic Comment Tool (developed by PNNL) >>> "Stakeholder Review" opens for 4-6 weeks >>> Expert and TAG review comments, accept, accept with modification, or reject >>> Expert addresses comments, modifies draft >>> Commenters are notified of the disposition of their comments >>> Draft is "approved" by the TAG and Steering Committee, submitted for publication >>>Cheers!

- **~650 comments, 52 commenters, 46 organizations**

UMP IN PRACTICE (USE VARIES CASE BY CASE)

- PPL Electric Utilities
- MidAmerican
- Bonneville Power Administration
- Focus on Energy
- Ameren
- Arkansas
- Georgia
- Pennsylvania
- Michigan
- Iowa
- California
- Wisconsin
- Missouri
- Arizona

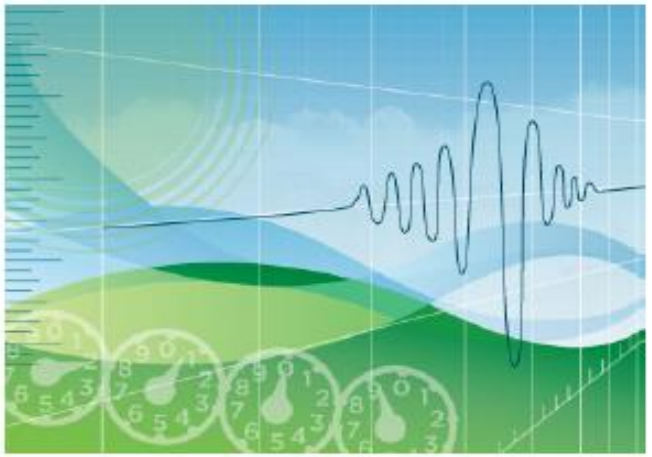
LOOKING AHEAD

- Efficiency Measures
  - Residential New Construction
  - Strategic Energy Management (SEM)
    - Commercial
    - Industrial
  - Gas Measures
- Updates and Refinements
- Tracking Adoption and Use
- Cross-Cutting Measures
  - Top-Down Methods
  - Reporting Template (NEEP Initiative)

WHERE TO FIND IT

- eere.energy.gov/ump

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



January 2012 — March 2013

Tina Jayaweera
Hossein Haeri
The Cadmus Group
Portland, Oregon

NREL Technical Monitor: Charles Kurnik

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Subcontract Report
NREL/SR-7A30-53827
April 2013

Contract No. DE-AC36-08GO28308

PROJECT TEAM

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DEVELOPMENT AND APPLICATION OF UMP EVALUATION PROTOCOLS

David Jacobson

Jacobson Energy Research

US DOE's EE Savings Protocols - Why, What, Where and How?

Evaluating Energy Efficiency Workshop

NEEP Annual Meeting

June 2, 2014 - Newport Hyatt Regency

JACOBSON ENERGY RESEARCH ROLE IN UMP PROCESS

- Author of Two Protocols- Small Commercial Unitary HVAC & Residential Furnaces and Boilers
- Technical Reviewer of Other Protocol for NEEP – Making sure that most NEEP members current methods comply with protocols

LIFE CYCLE OF A PROTOCOL

- Walk Through the Development of a Specific Protocol
- How the Protocols Document What is Being Done to Evaluate Specific Measures and Key Variable at some leading Organizations
- How the Protocol Documents What Should be Done to Evaluate a Specific Measure as Mid-Level Point of Rigor

KEY ELEMENTS OF EACH PROTOCOL

- Measure Description
  - technology (ie boilers and furnaces) and sector (Res, SF/MF) size (60 kBtu/hr to 300 kBtu/hr)
  - efficiency metric (AFUE)
- Application Conditions of Protocol
  - Typical delivery conditions (rebate program, new construction/end of life replacement)
  - Some assumptions (ie no unit downsizing)
- Savings Calculations
  - Basic savings calculations used for current estimates of savings; broad (kWh_{pre} – kWh_{post}) or very specific algorithms
- Measurement and Verification Plan
  - Which IPMVP option to be used and why
  - Which tracking data is required
  - General plan – which variables to study
  - How values for variable will be verified or measured, on-sites, billing analysis, metering, etc
  - Specific methods for measurement or data analysis – how to meter, which regression, etc
  - **Secondary approach** (more or less accurate)
- Sample Design

GENERAL PROTOCOLS

- Individual Protocols deal with gross energy (kWh, therms/MMbtu) savings
- Peak demand (kW) savings covered in a cross cutting measure protocol
- Net to Gross adjustments covered in an cross cutting measure protocol

FACTORS THAT SHAPE DETAILS OF PROTOCOLS

- Rise of TRMs to track savings of many simple prescriptive measures- lighting, HVAC equipment etc
  - Many TRMs use simplified equations to track savings for prescriptive measures
- Protocols Sit at Intersection of-
  - actual vs theoretical impact evaluation
  - tracking system design and data collection limitations
  - available evaluation budget relative to savings

EXAMPLE I – SMALL COMMERCIAL UNITARY/SPLIT AC

Prevailing TRM Equation-

$$\text{kWh Saved} = (\text{Size kBtu/hr}) \times (1/\text{eff}_{\text{baseline}} - 1/\text{eff}_{\text{installed}}) \times (\text{EFLH})$$

where eff = EER, SEER or IEER

- EER = peak efficiency at full load; SEER/IEER = seasonal efficiency, IEER just becoming available- not used yet by MOST programs
- Use of manufacturers AHRI ratings data for size and efficiency
- Meter/Measure Equivalent Full Load Hours(ELFH) using power as proxy for cooling load:
  ELFH = Annual kWh/peak kW
  peak kW = Peak Cooling in Btu/hr/EER
- Annual kWh based on regression: kW vs day of week, outdoor conditions(THI) and variables accounting for the number of hot days in a row

MAJOR POINTS FOR RECONCILIATION THIS PARTICULAR PROTOCOL

- Methods needs to work for prevailing TRM equations listed above even though many agree the equations are gross simplifications
- Measure is a core part of most EE portfolios but total savings as a percent of portfolio is generally small except for warmest climates
  - ❑ total savings limits EM&V budget available for impact evaluation, thus complexity/sophistication of methods
- Efficiency metrics changing to from EER/SEER to IEER but data collection/requirements lag
- Interaction with other related measures- demand controlled ventilation, sizing initiatives, EC motors, dual enthalpy economizers
- Measurement of cooling load is prohibitively expensive
- Simulation vs field measurements

Fundamental Assumptions

- Some Measurement of a Large Random Sample of Building Types and Usage Patterns by Climate Zone and Size is Better Than Building Simulation for Smaller Sample
- kW/ton, EER, SEER, IEER rating data not always accurate reflection of actual performance but delta of those quantities between standard and known high efficiency is reasonable measure of savings
- Though ELFH developed using EER, method provides reasonable results using SEER and IEER in equation too

How Protocol Compares to Existing Industry Practices

- Protocol based on recent best practice study:
  - "Regional EM&V Methods and Savings Assumption Guidelines, Northeast Energy Efficiency Partnerships (NEEP) EM&V Forum, May 2010"
- and actual large scale metering study for Northeast:
  - KEMA. (August 2011). "C&I Unitary HVAC Load Shape Project." Prepared for the Regional Evaluation, Measurement and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships (NEEP)
- Optional, more sophisticated method follows Navigant's work in hot/dry climates

Results???

- Methods consistent with some real world practice
- Good reference for those new to EM&V or more experienced
- Not quoted yet but many could cite as their methods comply

EXAMPLE II – RESIDENTIAL GAS FURNACES AND BOILERS

- High Savings/High Volume Measure
  - ❑ Core of Most Residential Gas EE Portfolios

- VERY Little Impact Evaluation Done of Measure

KEY CHALLENGES

- ***MULTIPLE*** Prevailing TRM Equations-

  Savings = Capacity*(Eff_{ee}/Eff_{base} – 1)*ELFH

  Savings = Capacity*($1/Eff_{base}$ – $1/Eff_{ee}$)*ELFH

  Savings = Capacity*(1 - Eff_{base}/Eff_{ee})*ELFH

where: Capacity = units size BTU/hr
ELFH = Equivalent Full Load Hours/yr
$Eff_{ee,base}$ = AFUE or Thermal Efficiency of high efficiency and base unit

- Difficult and Costly to Measure Units Gas Consumption, EFLH and AFUE Directly

- Difficulty In Finding Non-participant/Baseline data, ie customers who recently replaced a furnace/boiler with a standard efficiency unit(1/15-1/20 of population/yr)

SOLUTION -

- Lots of Algebra to Derive Correct Equations Under Different Assumptions (Equipment rating often given in INPUT BTU not output)
- Develop List of Key Simplifying Assumptions
  - ❑Heating usage can be disaggregated from utility gas bills using standard PRISM like techniques
  - ❑Units are replaced with same size units
  - ❑Equipment ratings are in *INPUT* BTUs
  - ❑Efficiency rating themselves(AFUE) may not be precise relative to real world performance but the *change* in rated efficiency is a good proxy for upgrade in performance
- Use Billing Analysis in Two Ways

1) $$Adjusted\ Savings = \frac{\frac{1}{AFUE_{code}} - \frac{1}{AFUE_{ee}}}{\frac{1}{AFUE_{replaced}} - \frac{1}{AFUE_{ee}}} \times \Pr e - PostHeating\ Savings$$

2) Savings = NAH_e*[($AFUE_e$ /$AFUE_b$)− 1]; CAP_{IN}*$ELFH_{POST}$*[($AFUE_e$ /$AFUE_b$)− 1]; where NAH_e=normalized annual heating consumption; ELFH=NAH_e/CAP

How Protocol Compares to Existing Industry Practices

- Protocol based on recent (at the time) best practice study:

Cadmus (Khawaja, Bronfman, Perussi w/ NMR, "High Efficiency Heating Equipment Process and Impact Evaluation", 2010; and

IEPEC 2011 Paper-Perussi, Jacobson, Khawaja, Todd, Crossman and Vaidya - "Igniting the Pilot Light: Impact Evaluation Methods for Time-of-Replacement Gas Heating and Water Heating Programs.

EXAMPLE III – COMMERCIAL LIGHTING FIXTURES

- Straight forward TRM Equations

Algorithms for Calculating Primary Energy Impact

$$\Delta kWh = \left[\sum_{i=1}^{n} \left(\frac{Count_i * Watts_i}{1000} \right)_{BASE} - \sum_{j=1}^{m} \left(\frac{Count_j * Watts_j}{1000} \right)_{EE} \right] (Hours)$$

$$\Delta kW = \sum_{i=1}^{n} \left(\frac{Count_i * Watts_i}{1000} \right)_{BASE} - \sum_{j=1}^{m} \left(\frac{Count_j * Watts_j}{1000} \right)_{EE}$$

- Difficulty in Conducting Pre-Installation Measurement and In Using Billing Analysis

- Decades of Experience Conducting Measurements

- After much editing the protocol reflects the prevailing methods
  - ❑ lighting loggers to get post hours of use
  - ❑ Pre hours of use = Post measured hours of use (no new controls installed)
  - ❑ Estimated HVAC interactive effects

EXAMPLE IV – COMMERCIAL NEW CONSTRUCTION - WHOLE BUILDING PERFORMANCE (IN DRAFT ROUND II)

- For Multi Measure Comprehensive Whole Building Performance programs/approach
- Assumed High Level of Engineering in Ex-Ante Tracking Savings Calculation and Ex-Post M&V (sometimes $25k-$50k/site)
- Accounts for High Level of Measure Interactions
- No Applicable TRM Equations or Methods; Very Site Specific
- Protocol is a general roadmap to How to do Simulation Based Impact Evaluation using sub-metered data and calibrating to whole building data (15 minute or monthly)
- No specific equations, detailed algorithms etc
- Good representation of best practice

EXAMPLE IV – COMMERCIAL NEW CONSTRUCTION - WHOLE BUILDING PERFORMANCE (IN DRAFT ROUND II)

Table 1. List of Models Used to Simulated Savings for New Construction ECMs

Model	Model Name and Purpose	Model Description
1	As-Built **Physical** *To calibrate simulations and assess uncertainty.*	Model and Simulate as found during site visit. Use the occupancy and building operation as reflected in billed energy history and sub-metered data. Simulate using actual local weather observations matching the consumption history period.
2	As-Built **Design** *To estimate typical usage at full occupancy.*	Base on As-Built Physical model. Use full design occupancy and expected "typical" building schedules. Use constructions and equipment efficiencies as found during site visits. Simulate using normalized weather data (e.g., TMY datasets).
3	As-Built **Expected Design** *To estimate difference between original and as-built models.*	Base on As-Built Design model. Use full design occupancy and expected "typical" building schedules. Use assumed (*ex-ante*) constructions and equipment efficiencies. Simulate using normalized weather data (e.g., TMY datasets).
4	**Whole-Building** Reference *To estimate savings of the EEMs*	Base on As-Built Design model. Use full design occupancy and expected "typical" building schedules. Apply baseline requirements defined by reference codes or standards. Simulate using normalized weather data (e.g., TMY).
5	**Measure Building** Reference *To isolate savings claimed by the participant.*	Base on Whole-Building Reference model. Use full design occupancy and expected "typical" building schedules. Apply baseline requirements defined by reference codes or standards. Include ECMs not incentivized by DSM program. Simulate using normalized weather data (e.g., TMY).

Protocol Highlights

- Some very algorithmic with a fair amount of detail (VFD, Unitary, Furnace/Boiler, Refrigerator Recycling)
- Some less specific detail (Whole Building Comprehensive) and more high level but still valuable road maps for approach
- Some push/pull on realities of pre-metering for measures designed to alter hours of operation-some call for it while other acknowledge hard to get
- Protocols are very measure or end-use oriented but some large EM&V effort are more focused on overall program level realization rates
- Evaluation still an art as much as a science and differences in opinion, chiller kW vs chilled water flow/delta T method-both reasonable

STREAMLINING EM&V: USING 'BIG DATA' AND AUTOMATED M&V TOOLS

- Speakers:
  - David Jump Ph.D, P.E., QuEST
  - Cody Taylor, US DOE Building Technology Office
- Moderator:
  - Tom Coughlin, National Grid

WHAT IS ALL THIS HOOPLA ABOUT "BIG DATA" ANYHOW!

EVERYTHING YOU NEED TO KNOW IS ON "WIKIPEDIA"

- **"Big Data"** is an electronic pop duo
  - **Big Data** is:… "a blanket term for any collection of data sets so large and complex that it becomes difficult to process using on-hand database management tools or traditional data processing applications.

BIG DATA YESTERDAY, NOW AND TOMORROW

- 1990's "How many homeowners have hot tubs, water beds and heated swimming pools?"
- 2000's how many customers have participated in EE and what did they do.
- 2010's how can we call in data from many sources to look at an end-user's energy behaviors, find opportunities, and monitor.

OUR PANEL:

- **David Jump Ph.D, P.E.,** Principal at Quantum Energy Services & Technologies, Inc. (QuEST)
- **Cody Taylor**, US DOE Building Technology Office

nationalgrid

• A internal tool under development in conjunction with NREL using “Open Studio” (opportunity identifier, customer engagement

•Monitoring based building tune up (market based use of building analytics)

•Smart Grid Pilot in Worcester (“Wustah” to those “from away”)

M&V 2.0
Technical Perspectives and Applications

June 2, 2014

David Jump, Ph.D., P.E.
Quantum Energy Services & Technologies, Inc.
(QuEST)

djump@quest-world.com

AGENDA

Part 1

- M&V 2.0
  - vs. M&V 1.0
  - Applications

Part 2

- PG&E/LBNL/QuEST Automated Baseline Evaluation Study & Protocols

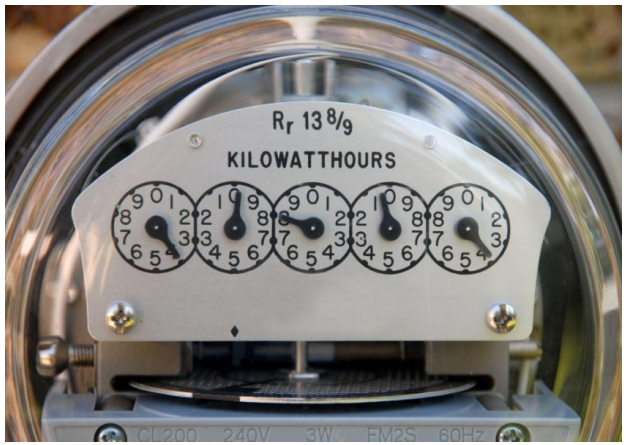
PART 1: M&V 2.0 DEFINITION

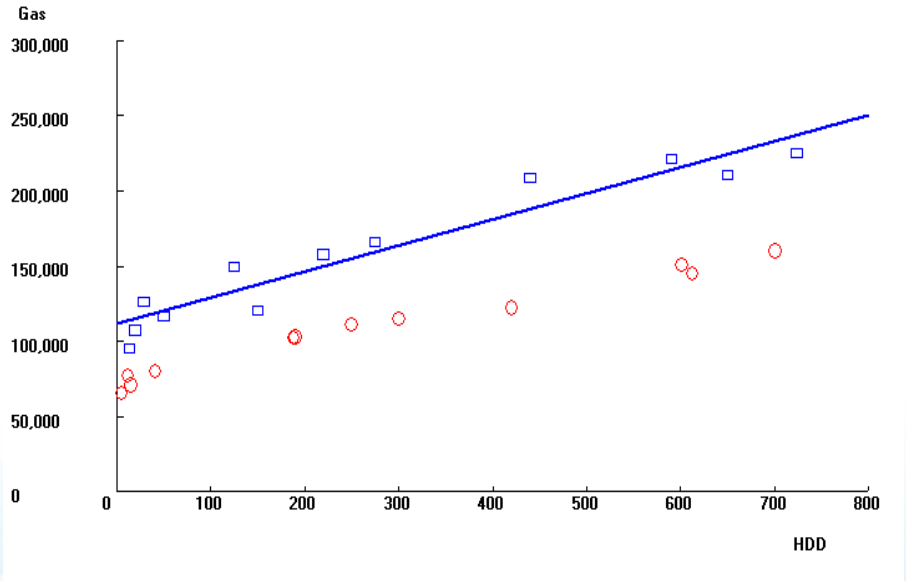
M&V 2.0 uses short time interval data and advanced analytics to determine actual savings in a building or building subsystem

- Data sources
  - Time-of-use meters (> 200 kW typ.)
  - Smart meters (residential, SMB)
  - Weather
- Intervals: 5, 15 minute, hourly, daily, etc.
- Analytics: multiple regressions including time as a variable, neural networks, bin methods, nearest-neighbor, etc.

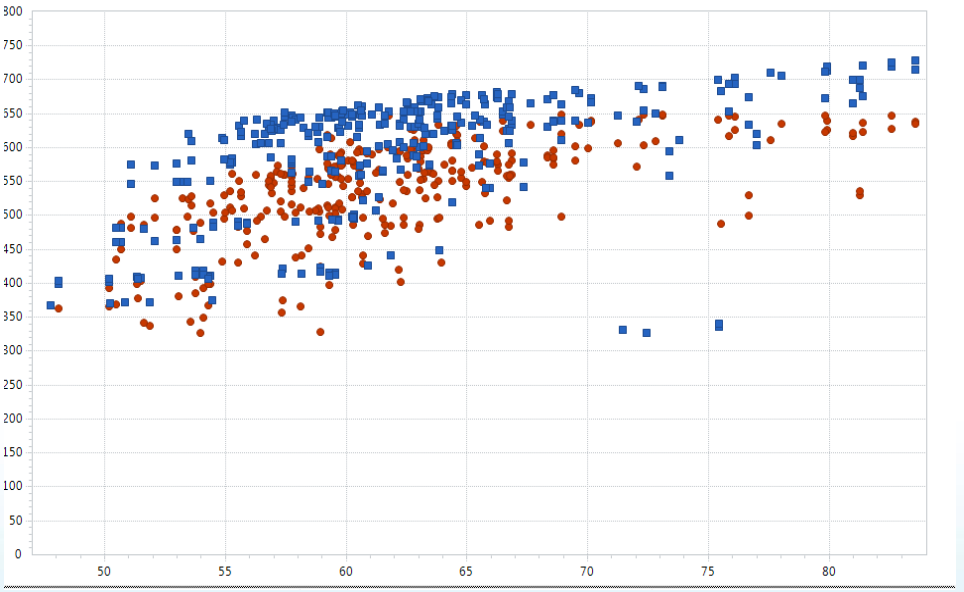
ILLUSTRATION – MONTHLY VS. INTERVAL DATA

M&V 1.0 - Monthly





M&V 2.0 - Interval



COMPARISON

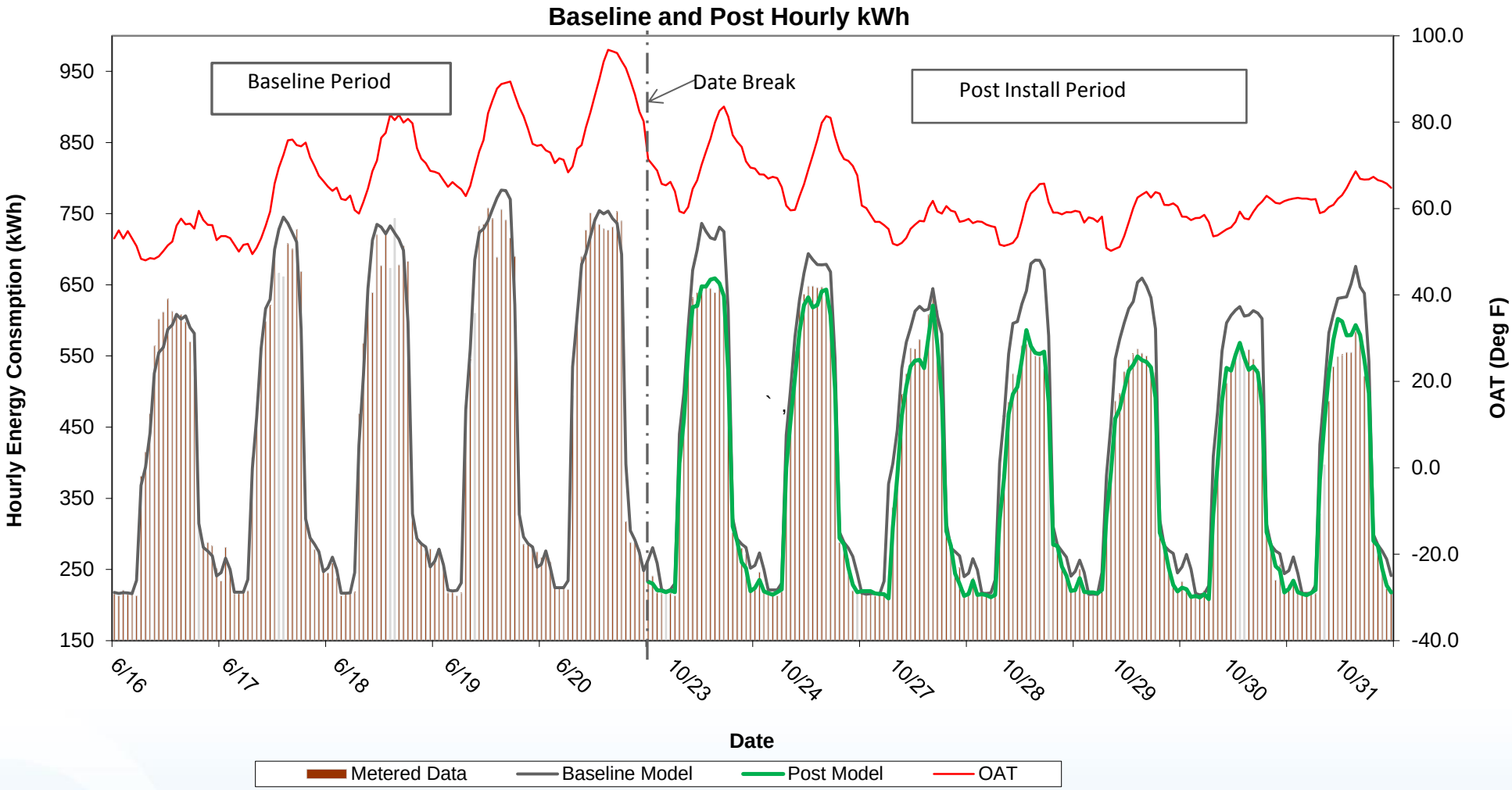
M&V 1.0 -Monthly Data

- Linear regressions
- 12 months/data points per year
- High uncertainty with moderate savings
  - Ex: 10% savings, 10% CV, 95% Confidence
  - 77% Uncertainty
- Monitoring duration
  - 12-month baseline & post

M&V 2.0 - Interval Data

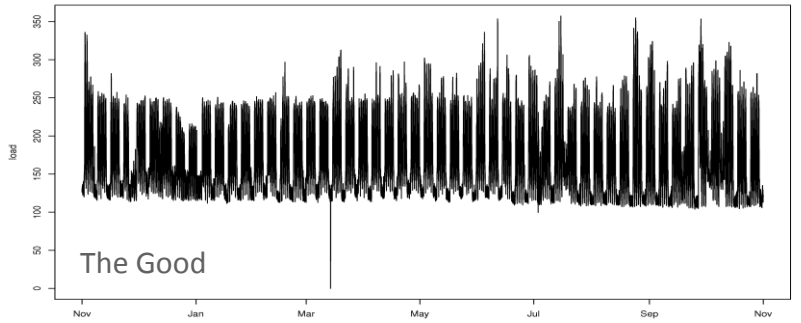
- Advanced analytics
- More data – 8760 hourly points per year
- 6-fold lower uncertainty with moderate savings
  - Ex: 10% savings, 10% CV, 95% confidence, significant autocorrelation (0.9)
  - 12% Uncertainty
- Monitoring duration
  - 3 & 6 month baseline
  - 3 & 6 month post
- Applicable to subsystem interval data

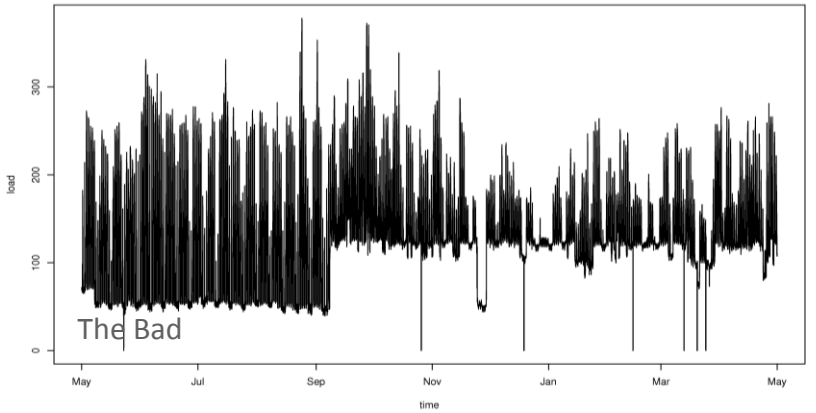
TIMELINE REPRESENTATION

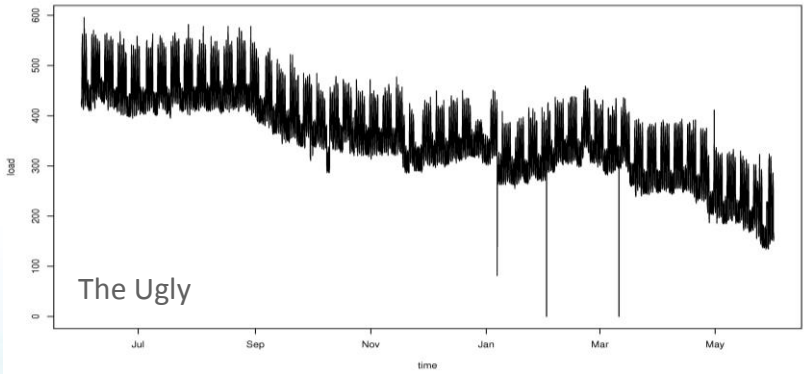


PREDICTABILITY

- Good buildings:
  - Predictable operation
- Bad buildings
  - Requires intervention?
- Ugly buildings
  - Cannot predict future use







WHOLE BUILDING M&V 2.0 ADVANTAGES

- Comprehensive: accounts for all ECM savings, including interactive effects
- Simple: few data streams required
- Shorter monitoring requirements: Baseline model development and savings estimations based on months, not years
- Higher quality: Estimates savings uncertainty
- Persistence: Fast feedback on building performance
- Scalable: one methodology for all buildings
- Lower administration costs: standardization & automation reduces time for savings analysis & technical review
- Tool Availability: public domain and embedded in EMIS

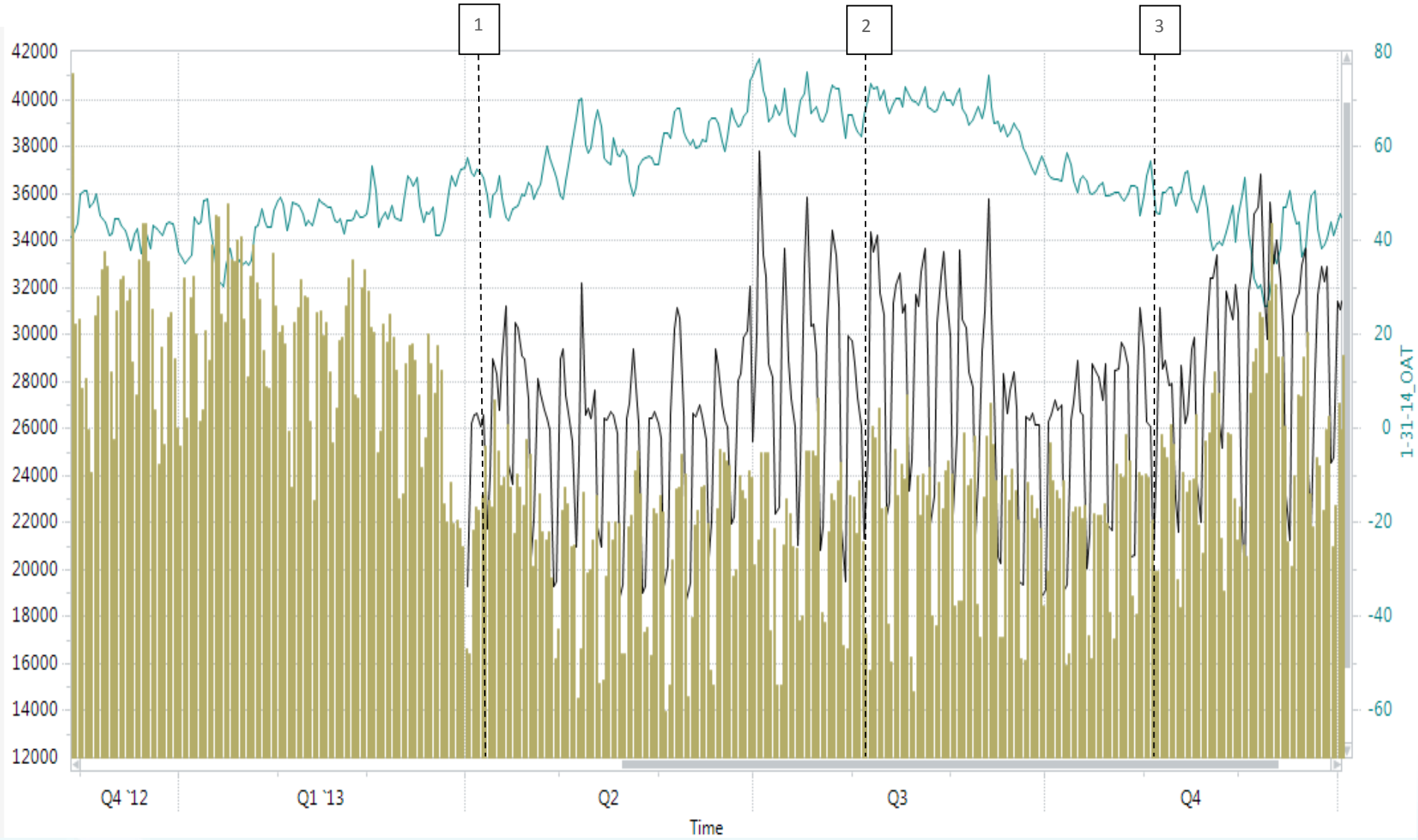
DISADVANTAGES

- Unable to determine savings above codes and standard requirements
- Intervention required for non-routine effects
  - Added loads
  - Temporary outages
  - Etc.
- Unpredictable buildings
  - Prescreening may be required

APPLICATIONS

- Quality Assurance
  - Parallel analysis to traditional deemed or engineering calculations
  - Ca. UC/CSU/CCC MBCx programs
- Programs where codes and standards do not apply
  - RCx
  - Controls
  - Behavioral
- Savings settlement method for
  - Comprehensive EE Programs
    - RCx, retrofit, behavioral, DR
  - Continuous Improvement
  - Pay for performance

PAY-FOR-PERFORMANCE



RESIDENTIAL APPLICATION

- Purpose: determine whether M&V 2.0 savings analysis could be implemented for 10 less-predictable single family residences using smart meter data and ambient temperatures from local weather stations.
- The efficiency upgrades in the homes included:
  - sealing against air infiltration
  - sealing air leaks in forced-air system ductwork
  - adding insulation in attics, walls and floors above code requirements
- Blind to the size, layout and construction of the houses, and to the actual number and type of measures installed.
- Energy savings estimates were not provided for this exercise, as the project administrator desired to obtain independent results.

RESULTS

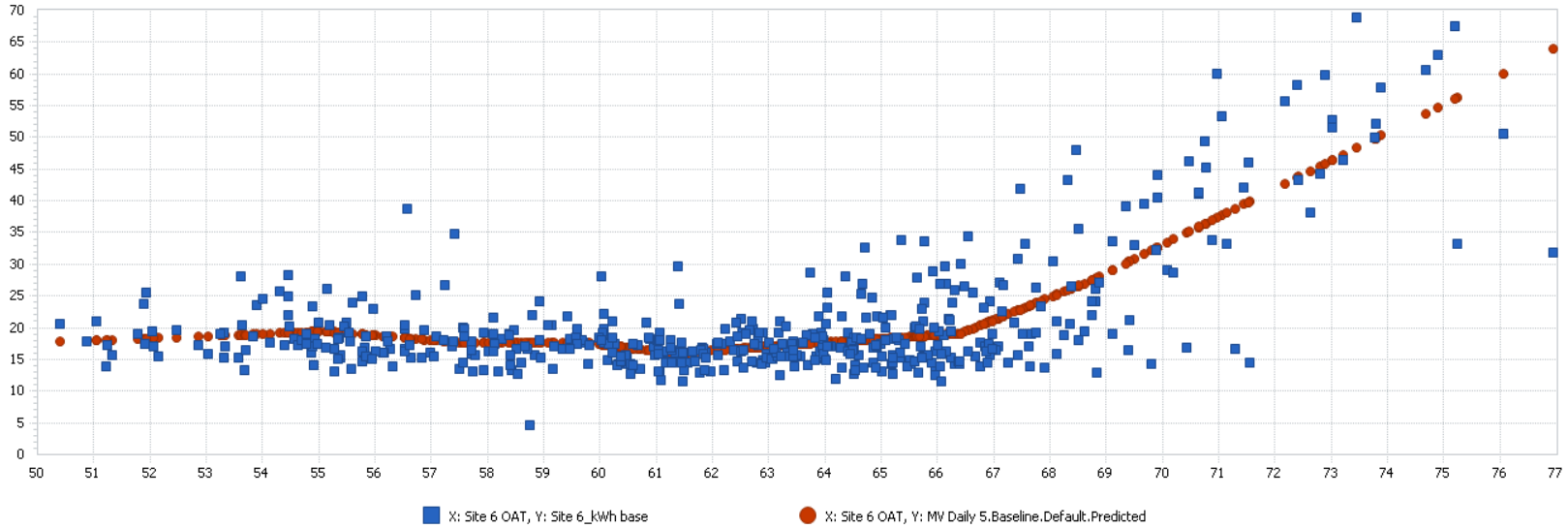
Site	Baseline Period (Months)	Post-Install Period (Months)*	Warm Season Included? (Y = May through Oct.)	Est. Annual Baseline Energy Usage	Baseline Model Statistics		Post-Install Model Statistics		Savings	
					R^2	CV-RSME	R^2	CV-RSME	kWh	%
1	11	13	through 8/21	9,086	0.7662	23.18%	0.7384	26.90%	50	1%
2	11	11	Y	4,999	0.7900	19.23%	0.6792	16.82%	95	2%
3	8	15	through 6/8	20,188**	0.2479	22.87%	0.1835	44.39%	8,875	44%
4	12	12	Y	3,303	0.5036	25.71%	0.1989	22.88%	384	12%
5	9	13	through 8/23	11,777**	0.5102	22.47%	0.7023	17.24%	740	6%
6	17	13	Y	7,122	0.6243	27.89%	0.5306	33.04%	1,039	15%
7	7	24	Y	10,817**	0.6274	24.08%	0.6795	22.34%	-1,481	-14%
8	11	12	Y	5,978	0.6560	32.91%	0.7033	28.69%	1,508	25%
9	11	12	Y	9,558	0.6020	26.02%	0.5739	23.50%	2,281	24%
10	11	13	through 8/1	3,736	0.4522	38.52%	0.4751	35.35%	-895	-24%

*Normalized savings for each site was based on period from 9/12/12 through 9/11/13.

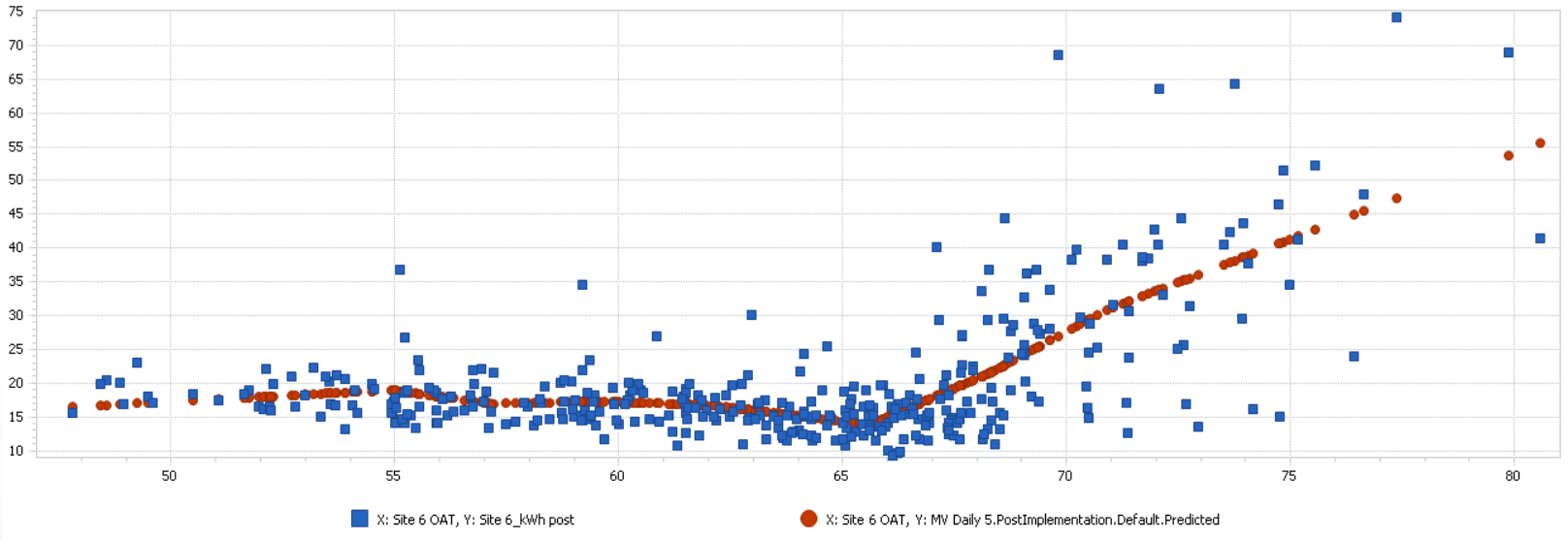
**Estimated based on fewer days of baseline kWh data

SITE 6

Baseline



Post-Install



PRELIMINARY FINDINGS

- Models are poor: low R^2 and high CV
- Poorest savings estimations (high and negative) from sites with:
  - Not enough baseline data
  - No baseline data in season when savings expected
- 6 out of 10 site showed reasonable savings
- Models can be improved:
  - Weekday vs. weekend operation
  - Remove less predictable houses

PART 2: EVALUATION OF M&V TOOLS

Public Domain

M&V Analysis Module

NorthWrite

Energy Charting and Metrics Tool

ASHRAE

Inverse Model Toolkit (RP 1050)

EMIS - Proprietary

pulse energy

FIRSTFUEL

C3

ASSESSMENT OF WHOLE BUILDING TOOLS

- **High level goal**: Enable the industry to harness emerging tools and devices to conduct M&V at dramatically lower cost, with comparable or improved accuracy

- LBNL and QuEST are growing a body of research in streamlining, automation, accuracy and uncertainty in M&V
  - Past and current support from CEC, PGE, and DOE-BTO

- **Today**: Share our work, place in context for NEEP objectives, and engage in dialogue to guide the work going forward

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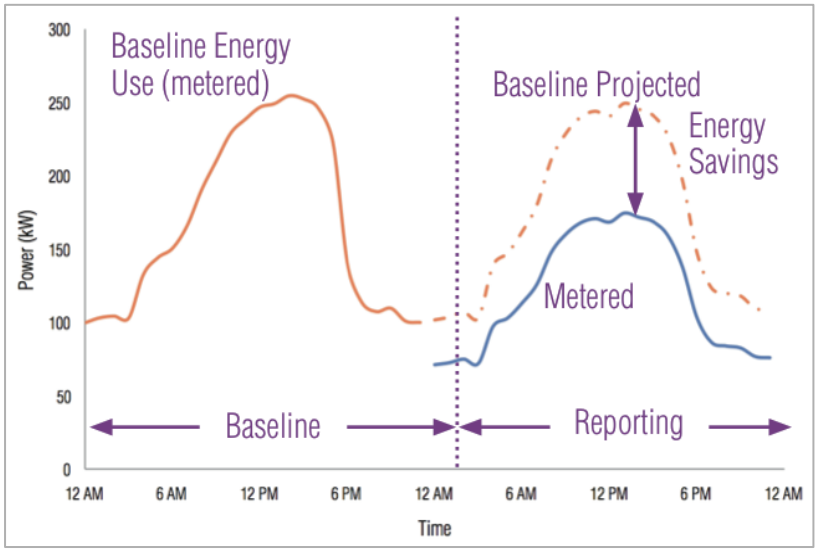
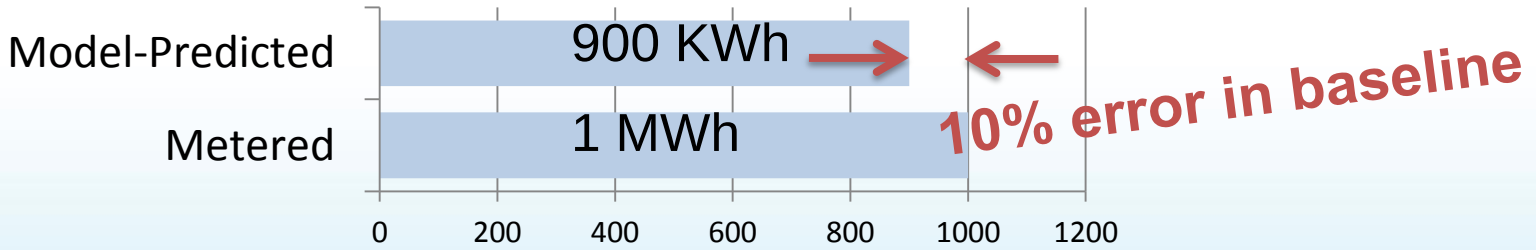
HOW ACCURATE IS THE BASELINE MODEL?

M&V Use Case



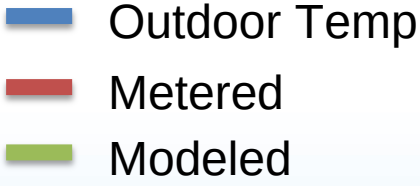
Error in reported savings is proportional to error baseline projection

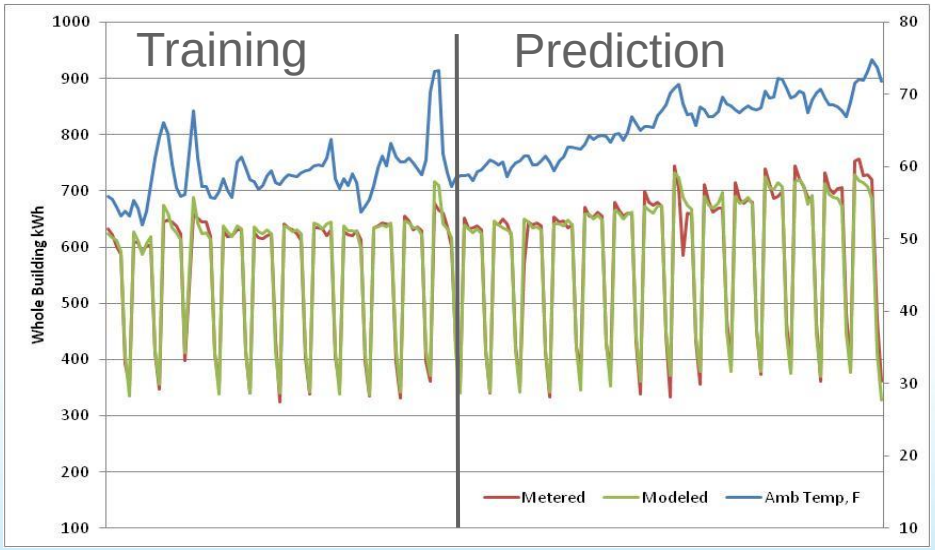
Error = **% difference** between total **metered** energy use, total **model-predicted use**



HOW DO WE ASSESS THESE ERRORS?

	Model	*Compare*	*Assess*
Baseline Model Test Data: Many buildings, metered data	• **Split data set** into training & prediction period. • **Train the model** by showing data, hiding prediction-period data; • **Generate post-period predictions**	Compare predicted data to actual data that was 'hidden' from model to quantify error. Repeat for many buildings	Calculate Performance Metrics, e.g. %Error, R^2, CV(RMSE) …





HOW DEEP DO SAVINGS HAVE TO BE?

Percentiles of Errors

Model	10%	25%	50%	75%	90%	Mean
Mean Week	0.82	2.21	4.82	9.63	19.42	8.40
Monthly CDD and HDD	0.69	2.09	4.53	10.03	19.38	8.46
Day, Time, and Temperature	0.69	2.17	4.51	9.26	19.41	8.42
Day and Change Point	0.73	2.02	4.70	9.22	18.84	8.24
Time of Week and Temperature	0.82	2.21	4.82	9.63	19.42	8.40

Can we identify buildings that will be most/least predictable?

CAN WE SCREEN OR TARGET BUILDINGS TO REDUCE UNCERTAINTY IN M&V?

Model	N	10%	25%	50%	75%	90%	Mean
Mean Week	23	3.48	4.10	5.20	5.90	8.32	6.47
Monthly CDD and HDD	72	3.40	4.10	5.45	7.43	9.99	6.82
Day, Time, and Temperature	112	2.70	3.35	4.70	7.55	10.20	6.67
Time of Week and Temperature	110	2.69	3.32	4.55	7.20	10.10	6.33

- No building type was more/less predictable than others (NAICS)
- Simple screening based on training period data reduces errors
- Mean error improves from 8% to 6% , median still ~5%
- In worst 10% of buildings error improves from 19% to ~10%
- Best 10% of buildings error rises (!) from <1% to 2-3%

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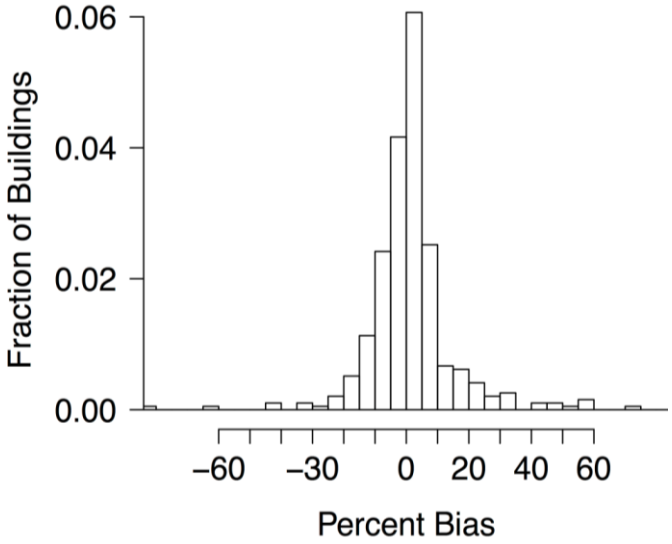
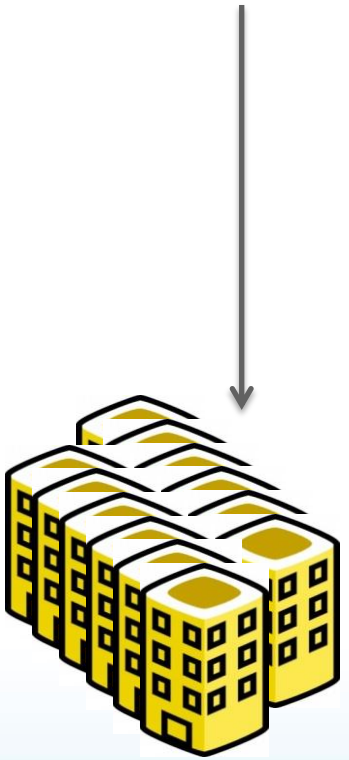
AGGREGATION OF BUILDINGS REDUCES ERROR TO 1-4%

- Although each savings estimate has error, some are too high and others too low





- Aggregation of buildings into a portfolio of ~40 buildings reduces total error to 1-4%

- This reduction in error is not ‘seen’ at the site but *is* at the program level where there is portfolio of participants, reporting at an aggregated level

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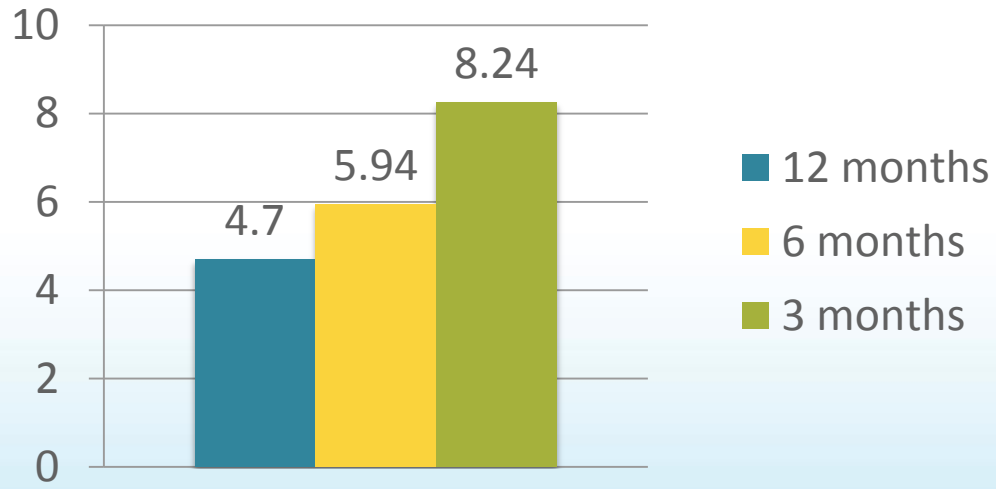
REDUCING TRAINING FROM 12 TO 6 MONTHS HAS MINIMAL IMPACT ON ACCURACY OF PREDICTIONS

	6 months	3 months
• Current guidance for whole building M&V	• Monthly models fare poorly • No significant degradation in mean, median accuracy • Large increase in error in worst 10% of buildings	• Significant degradation in accuracy • Differences in performance between baseline models appear

median % error for day and change point model



tolerate lower site-level accuracy

THANK YOU!

- Baseline Study & Protocol available from:

- http://www.etcc-ca.com/reports/commercial-building-energy-baseline-modeling-software-performance-metrics-and-method-testing

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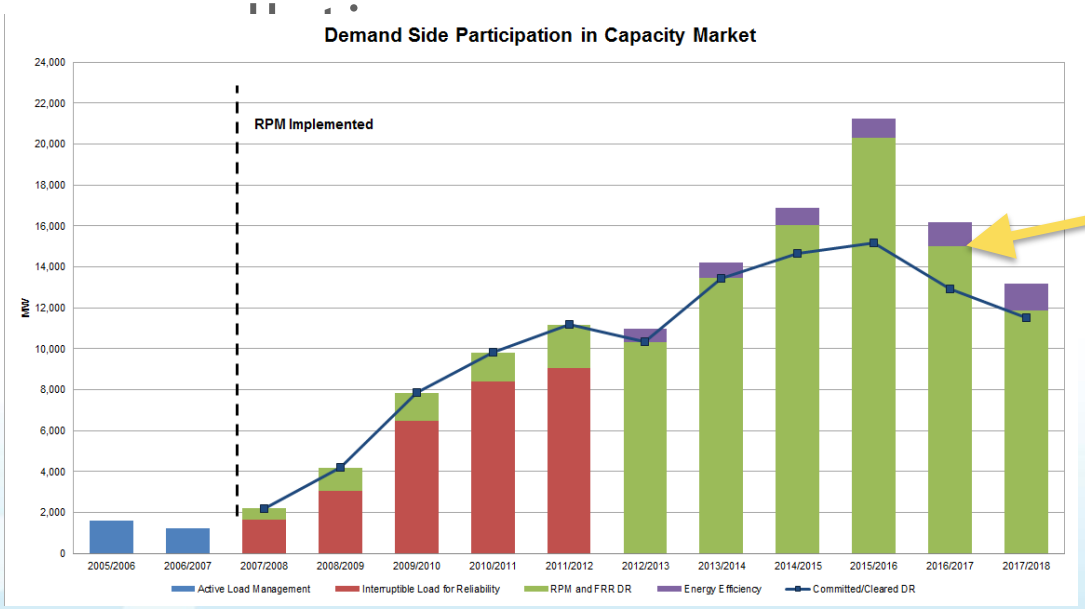
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Increasing Trust in Energy Efficiency

June 2, 2014

M&V WILL EVOLVE

- Energy efficiency = measuring something that never happened
- M&V has generally existed for two audiences:
  - Project Owners who want to know if they're getting what they paid for
  - Utility Regulators who want to know if funds are well-spent
- In present and near future it may have two more audiences:
  - Buyers in capacity markets who want to keep the lights on
  - State and federal air regulators who want to meet air



Purple = EE in PJM Capacity Market

M&V WILL EVOLVE

These audiences will demand an increasingly rigorous accounting of firm savings from energy efficiency

The energy efficiency industry needs to continue to increase trust in its results

WHOLE BUILDING M&V 2.0 ADVANTAGES

Much of the promise of M&V 2.0 centers on quality

- Comprehensive: accounts for all ECM savings, including interactive effects
- Simple: few data streams required
- Shorter monitoring requirements: Baseline model development and savings estimations based on months, not years
- Higher quality: Estimates savings uncertainty
- Persistence: Fast feedback on building performance
- Scalable: one methodology for all buildings
- Lower administration costs: standardization & automation reduces time for savings analysis & technical review
- Tool Availability: public domain and embedded in EMIS

DOE MOTIVATION: INDUSTRY NEED

Today

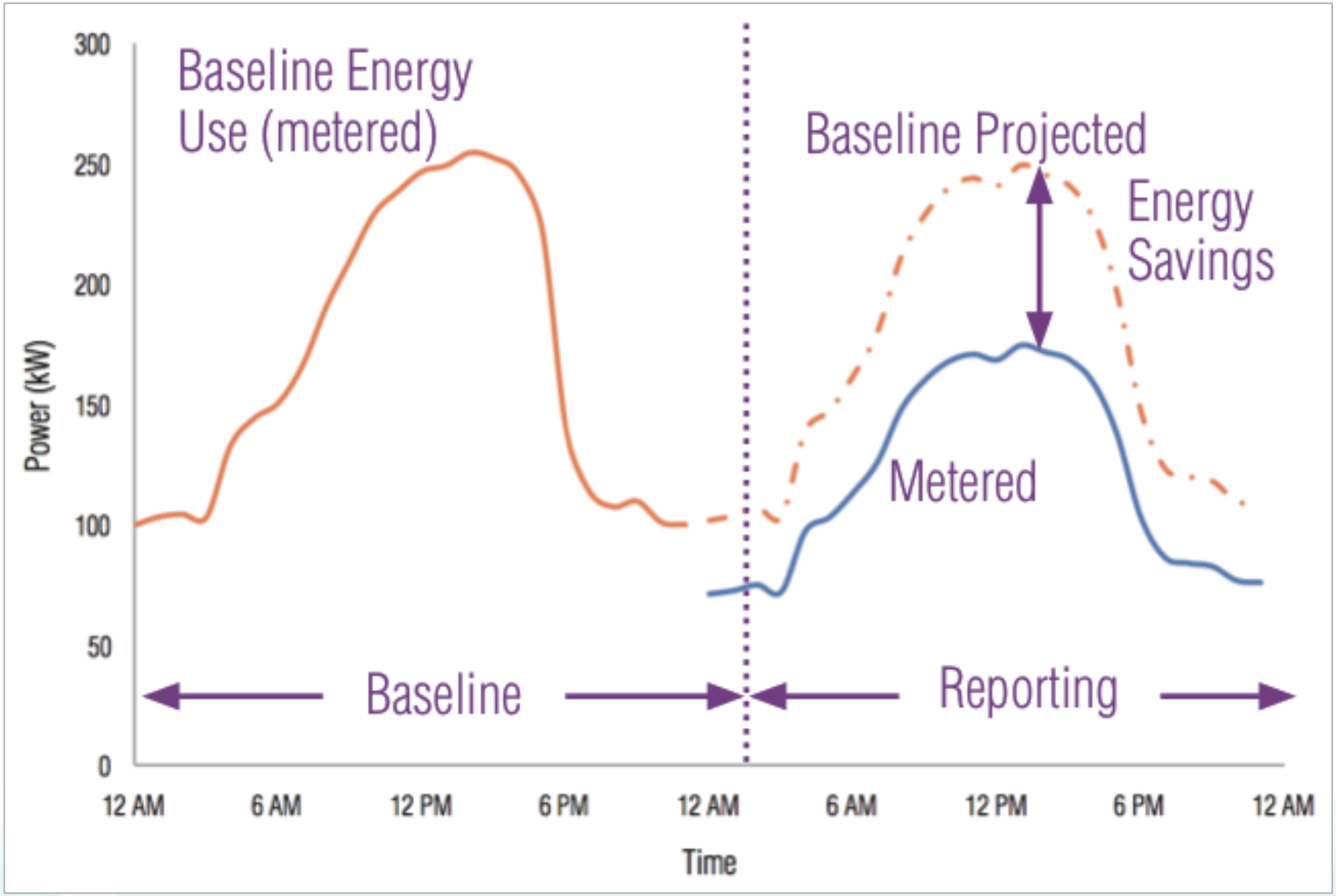
- Site-by-site M&V, **costly, difficult to scale, hard to calculate accuracy**
- **Small savings**, single-measure, modest programs **can get lost in noise**
- M&V by EMIS done in a **black box** – no disclosure of accuracy

Promise of M&V 2.0

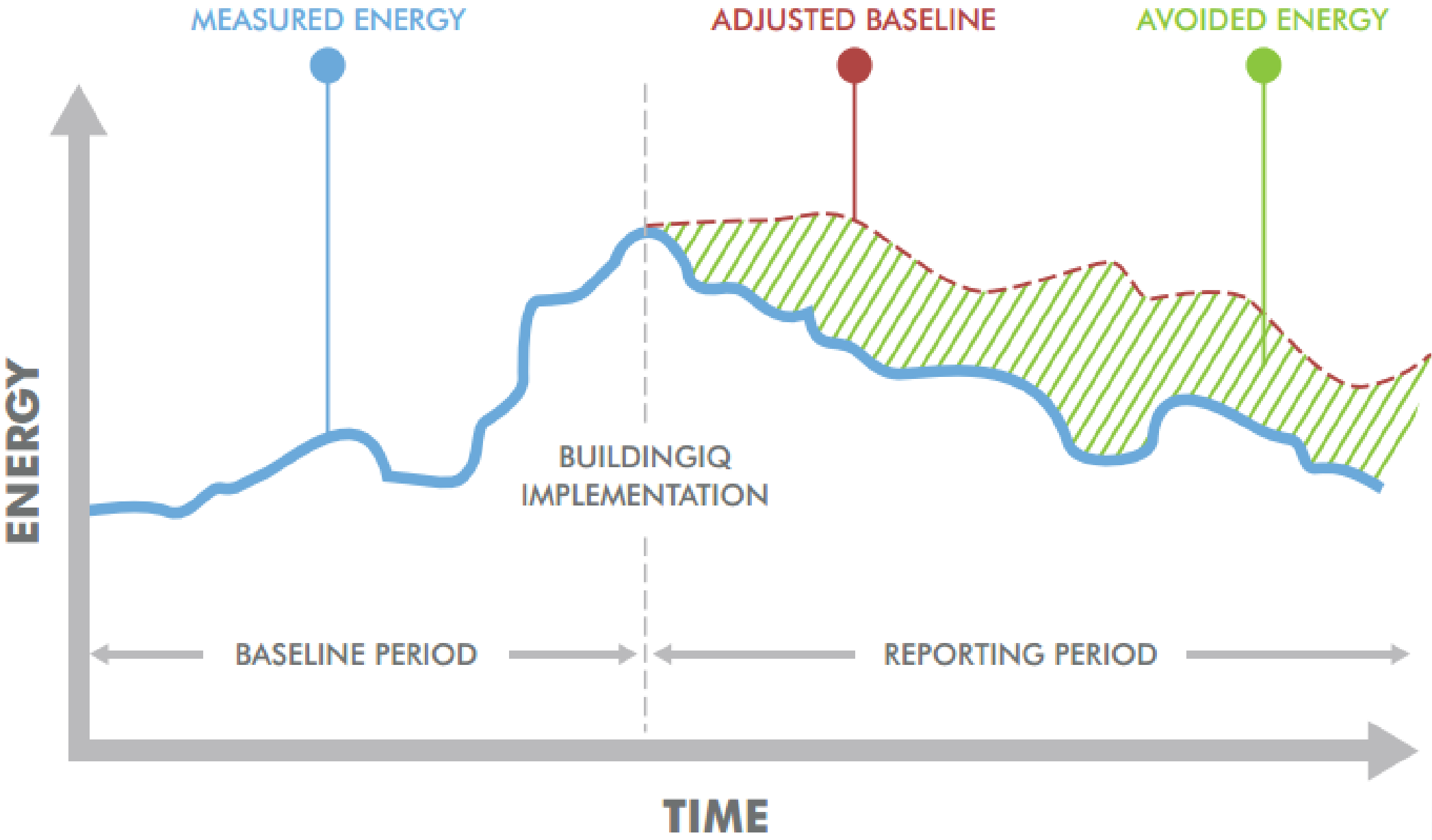
- Cost-effective whole building M&V, **automated to scale**
- **Whole building multi-measure programs** deliver **deeper savings,** including O&M, behavioral measures
- **Accuracy** of baseline models, uncertainty in savings are **disclosed**

ENERGY BASELINES FOR M&V

Savings = Projected - Metered



MANY IN THE MARKET CLAIM TO BE DOING



Source: BuildingIQ

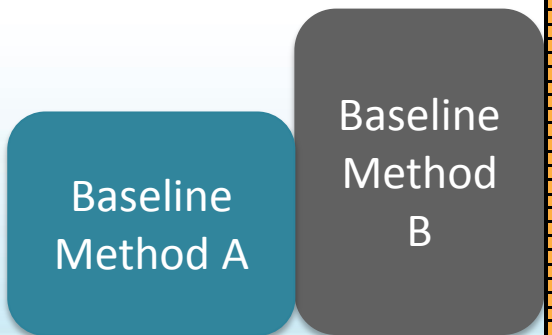
PROTOCOL TO ASSESS BASELINE PERFORMANCE ACCURACY

- Premise: statistical performance metrics can be used to evaluate automated baseline methods
  - To determine and compare accuracy of both **proprietary** and '**open**' methods

- Objective test protocols can remove key barriers – questions of accuracy, transparency and performance

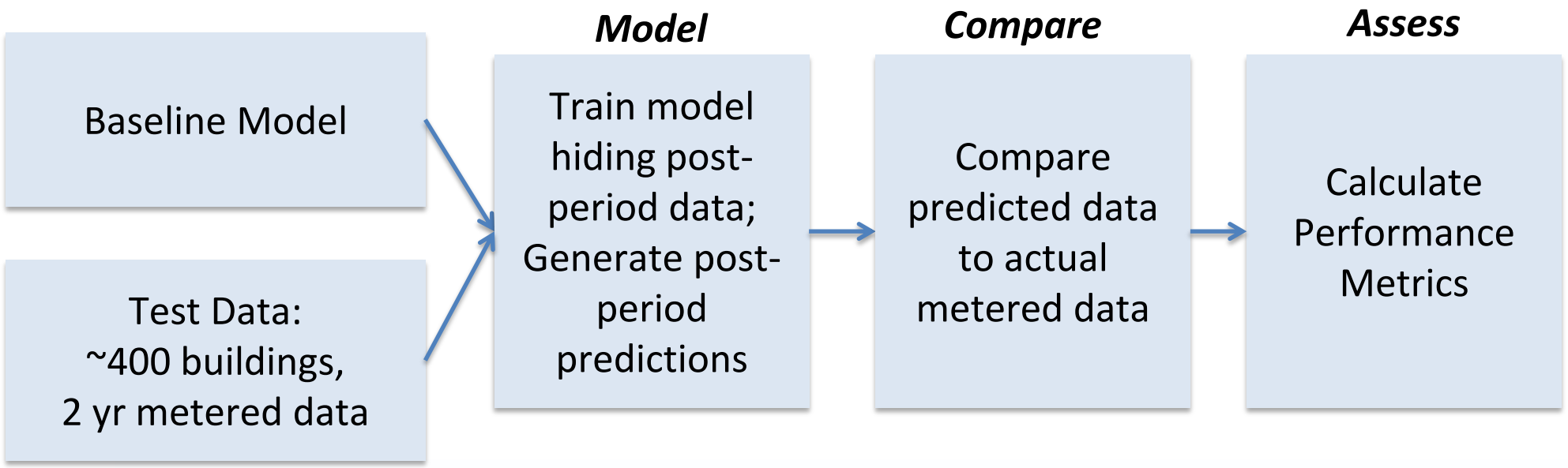
Planned Outcomes:

- Testing methodology, framework for use by public
- Performance metrics most relevant to M&V use case
- Ability to compare contrast tools/model accuracy based on those metrics



SCOPE OF CURRENT WORK

- Draft metrics
- Draft test protocol
- Demonstrate test protocol with submitted methods and data
- Publish metrics for submitted methods



WHERE ARE WE NOW?

- Working with interested stakeholders to select metrics and develop protocol
- Solicit submission of models to test this summer
- Publish report in spring 2015
- Reviewed many potential metrics
  suggested: *total normalized bias* and *CV(RSME)*
  - Total Bias (TB)
  - Total Error (TE)
  - Mean Bias (MB)
  - Total Normalized Bias (TNB)
  - Mean Absolute Percent Error (MAPE)
  - Normalized Mean Bias Error (NMBE)
  - Root Mean Squared Error (RMSE)
  - Coefficient of Variation of the Root Mean Squared Error [CV(RMSE)]
  - Coefficient of Determination (R2 or R squared)
  - Hypothesis and significance tests

THIS IS RESEARCH!

Questions yet to be answered

- What is the scope that this applies to? (method types, project types, % savings)
- How well does the test map to specific programs, building populations?
- Are there limitations to applicability?
- How to prevent/mitigate gaming?
- What test data is needed to provide meaningful results?

RECAP: WHY THIS IS IMPORTANT

- M&V 2.0 can bring benefits in more detailed, timely, accurate, and cost-effective results
- Need to establish a "path to acceptance" for emerging M&V methods
- Objective metrics and clear test protocols can help the "buyers" of M&V select M&V methods
- More attention to energy efficiency → need to continue to increase trust in savings

HOW DO YOU TRUST A MEASUREMENT?

HOW DO YOU TRUST A MEASUREMENT?

Questions?

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Cody Taylor

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202-287-5842