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環保促進會

Training Course:
Building Energy Management (Session 1)

Instructor: Ir Gary, Kar Kit CHU

Moderator: Mr. Felix LAM

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Supporting Organizations:

AEE Hong Kong Chapter
美國能源工程師學會香港分會

BEAM
建築環保評估協會

BSOMES
Building Services Operation and Maintenance Executives Society
屋宇設備運行及維修行政人員學會

CIOB
THE CHARTERED INSTITUTE OF BUILDING

CIWEM
Chartered Institution of Water and Environmental Management
Hong Kong Branch

香港中華總商會
CGCC The Chinese General Chamber of Commerce, Hong Kong
120
Since 1900 成立

香港中華廠商聯合會
The Chinese Manufacturers' Association of Hong Kong

energy institute
Hong Kong

HKAEE
香港能源工程師學會
Hong Kong Association of Energy Engineers

HKGCC
Hong Kong General Chamber of Commerce
香港總商會 1861

HONG KONG INSTITUTE of ENVIRONMENTALISTS
HKIOE

HKILA
THE HONG KONG INSTITUTE OF LANDSCAPE ARCHITECTS
香港園境師學會

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香港環專會
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THE HONG KONG INSTITUTE OF SURVEYORS
香港測量師學會

HKIE
THE HONG KONG INSTITUTION OF ENGINEERS
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Environmental Division
環境分部

HKWMA
HONG KONG WASTE MANAGEMENT ASSOCIATION
香港廢物管理學會

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Training Course on "Building Energy Management"

Presented by:

Ir Gary, Kar Kit CHU *BSc MPhil*

MHKIE MAEE MIEEE MIET
CEM®, CEA®, CMVP®, CAP, CBCP®
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Session 1 – 2021.1.13 (3 hours)

- Introduction of energy management system and relevant guidelines and regulations for building
- Retro-commission implementation (Energy Audit vs RCx)
- Measurement & Verification of Energy Performance

Introduction of energy management system and relevant guidelines and regulations for building

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Introduction of energy management system and relevant guidelines and regulations for building

- International
  - ISO 50001 family
  - GB/T 23331-2019 能源管理體系
  - GB/T 35031.X-2018 使用者端能源管理系統
  - BS EN 16247 family
    - BS EN 16247-2 Energy audits - Part 2 Buildings
  - AS/NZS 3598 family
    - AS/NZS 3598.1 Energy Audits - Commercial Buildings
  - ASHRAE (90.1, 100, 211, 90.4, ...)

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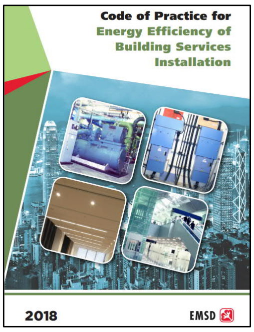
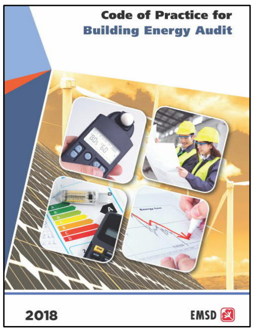
Introduction of energy management system and relevant guidelines and regulations for building

- Hong Kong
  - ISO 50001 family
  - Buildings Energy Efficiency Ordinance (BEEO) Cap 610
    - Building Energy Code (BEC) and Energy Audit Code (EAC)
  - Technical Guidelines on Retro-commissioning (RCx)





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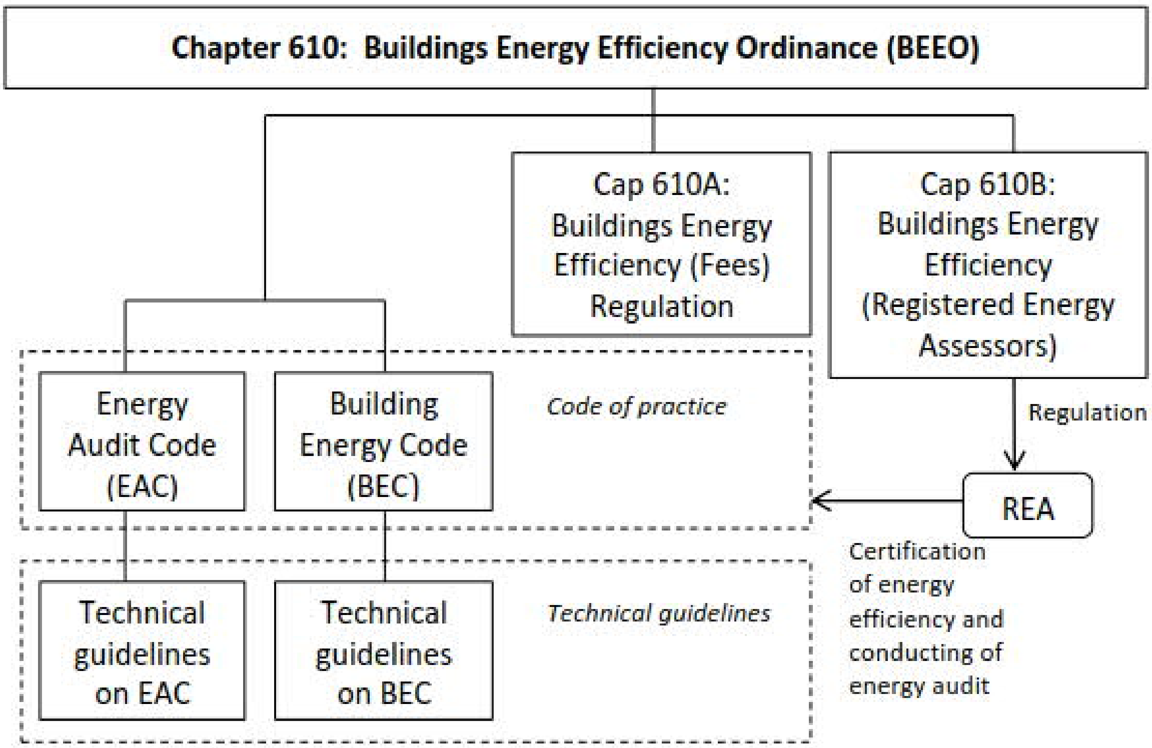
BEEO Legislative Framework



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BEEO Legislative Framework

Energy Audit

- Commercial building
- Composite building – commercial portion

Energy Efficiency Standards

- Hotel & guesthouse
- Educational building
- Community building (Social Service, Elderly Centers)
- Municipal services (Library, Indoor Game Hall, Market etc.)
- Hospital & clinic
- Government building
- Airport passenger building
- Railway station
- Commercial building
- Industrial building – common area
- Residential building – **common area**
- Composite building –
  - (schedule 1) prescribed portion
  - **common area** of residential portion or industrial portion

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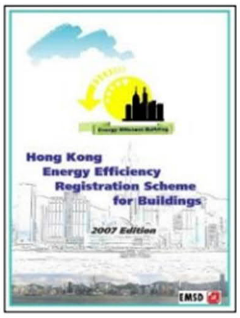
Building Energy Code (BEC) and Energy Audit Code (EAC)

10/1998
HK Energy Efficiency Registration Scheme for Buildings (Voluntary Basis)

12/2010
BEEO was published in gazette

12/2015
BEC 2015 & EAC 2015

1998 1999 2000 2001 2002 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019



09/2012
BEEO came into full operation
BEC 2012 & EAC 2012

11/2018
BEC 2018 & EAC 2018

Gazette Notice: 2018.11.16 – Take Effect on 2019.8.16

Review in a 3 years interval (2018, 2021, 2024, ...)
Making reference to:
- *the latest technology development;*
- *Recognized international standards from other countries including Mainland China, USA, UK, Singapore and Australia.*

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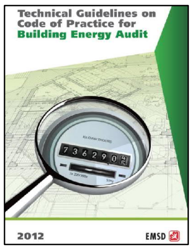
KEY Terminology



EMO (Energy Management Opportunity)

- The ways to achieve energy efficiency and conservation
- Step 3 – Identification ➔ Comparative Normalized Performance Indicators:
  - Chiller/Heat Pump, VRF - kWh/annum
  - Air distribution system (PAHU, AHU, other ventilation) – W per litre/s
  - Water distribution system (Pumping) – W per litre/s
  - Lighting power density – W/m^2
  - EUI of the building – $MJ/m^2/annum$

Any Measurements?

Clause 7.4.7 Examples of Evaluation & Appraisal for Potential EMO Identification (2018)

- Step 4 – Cost Benefit Analysis of EMO
  - Simply Payback vs Net Present Value (NPV)

(Technical Guidelines on Code of Practice for Building Energy Audit)

The implementation of EMO is NOT MANDATORY under the Ordinance

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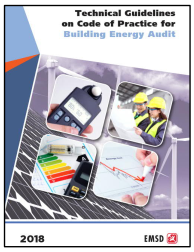
KEY Terminology



ESO (Energy Saving Opportunity)

- Collection of operational data of energy consuming equipment/systems, followed with site measurement testing and data analysis and then come up with proposed Energy Saving Opportunities (ESOs).
- Through the implementation of the ESOs, the operational performance of building systems improve which in turn enhances the building energy efficiency.
- Ensure the energy consuming equipment / systems operate properly as *design* or users' requirements and to identify some area of *improvements*.

(Technical Guidelines on Retro-commissioning – RCx)

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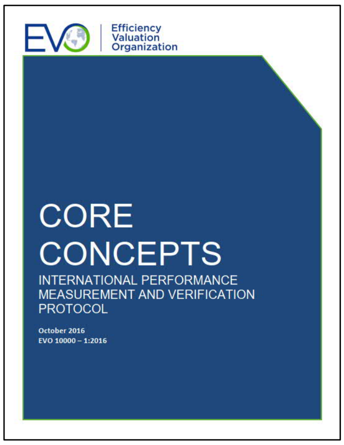
KEY Terminology

ECM (Energy Conservation Measure)

- Action or set of actions designed to improve efficiency or conserve energy or water or manage demand.



(IPMVP Core Concepts 2016 Oct – EVO 10000-1)

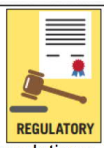
Why important?

- Hong Kong Government Policy – 2015~2025+
  - Hong Kong to achieve energy intensity reduction by 40% by 2025 using 2005 as the base:

Economics

1/7th of buildings in Hong Kong (~ 6,400 buildings) participated in the $450million Building Energy Efficiency Fund Scheme (BEEFS) programme

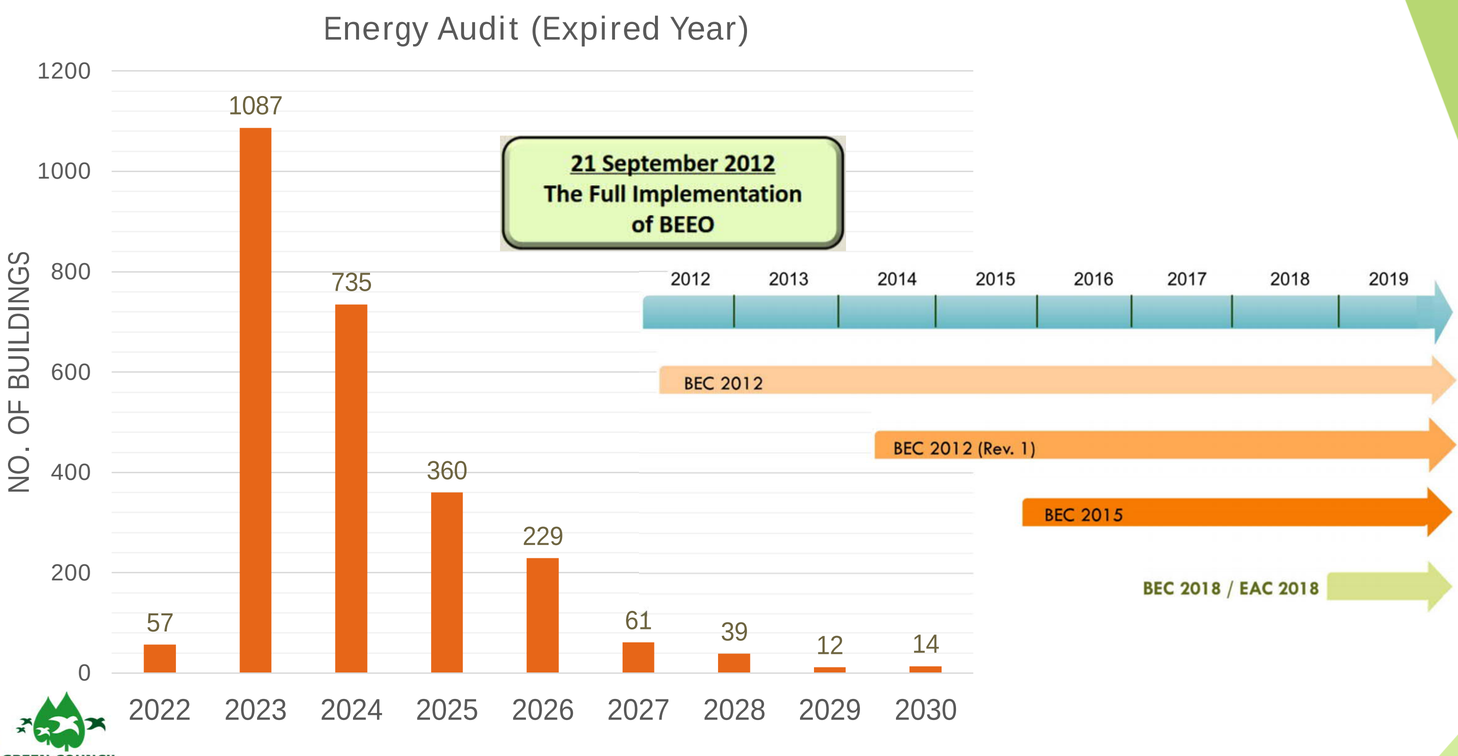
Regulatory



- Buildings Energy Efficiency Ordinance (BEEO);
- Building (Energy Efficiency) Regulation ;
- Energy Efficiency (Labelling of Products) Ordinance

- In November 2020, Chief Executive of HKSAR announced in the 2020 Policy Address that Hong Kong would strive to achieve carbon neutrality before 2050.

Why important?



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Why important?

Cap. 610 Buildings Energy Efficiency Ordinance

Part 1
Preliminary

Division 3—Certificate of Compliance Registration

10. Certificate of Compliance Registration for buildings

(1) If a developer has submitted a stage two declaration in respect of a building, the Director must, subject to subsection (2), issue a Certificate of Compliance Registration to the developer in respect of the building within 3 months after the day on which the declaration is received.

(2) The Director may refuse to issue a Certificate of Compliance Registration to a developer if—

(a) the Director has reasonable grounds to believe that the stage two declaration concerned or a document accompanying it pursuant to section 9(2)(c) is false or misleading in any material particular; or

(b) the Director has yet to receive any information or document from the developer under section 9(4).

(3) If the Director refuses to issue a Certificate of Compliance Registration to a developer under subsection (2), the Director must, as soon as reasonably practicable—

(a) issue a notice of the refusal to the developer; and

(b) state the reasons for the refusal in the notice.

(4) Subject to section 13(5), a Certificate of Compliance Registration is valid for 10 years.

Part 4
Energy Audit

22. Energy audit requirement

(1) The owner of a building must cause an energy audit to be carried out in accordance with this section at intervals no longer than 10 years in respect of the central building services installations of the building.

(2) The first energy audit for the central building services installations of a building issued with a Certificate of Compliance Registration must be carried out within 10 years after the building is first issued with a Certificate of Compliance Registration.

(3) The first energy audit for the central building services installations of a building without a Certificate of Compliance Registration must be carried out according to the schedule specified in Schedule 5.

(4) An energy audit must be carried out—

(a) by a registered energy assessor; and

(b) in accordance with a code of practice.

(5) A registered energy assessor who carries out an energy audit in respect of a building must, within 30 days after issuing an Energy Audit Form, send a copy of the Energy Audit Form and an energy audit report on the audit to the Director.

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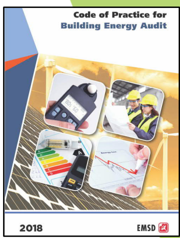
Retro-commission implementation – Energy Audit vs RCx Process (Hong Kong)

Difference between Retro-commissioning (RCx) and Energy Audit (EA)



- An EA involves the systematic *review* of the energy consuming equipment/systems in a building to identifying Energy Management Opportunities (EMO) which provides useful information for the building owner to decide on and implement the energy saving measures for environmental consideration and economic benefits.
- An EA commences with the *collection of relevant information* that may affect the energy consumption of the building, followed with the reviewing of the collected information, the analysis of the conditions and performance of existing equipment, systems and installations along with energy bills.
- EA can achieve energy efficiency and conservation through the implementation of EMOs identified in the energy audit.

Difference between Retro-commissioning (RCx) and Energy Audit (EA)

- RCx is more focused on *checking* whether the energy consuming equipment/ systems *operate properly as per design or user requirements*, and to identify areas of improvement (e.g. shifting of system control settings, inaccurate sensors, improper operational schedules and improper air & water balancing, etc.).
- RCx also incorporates the identification and implementation of ESOs, as well as providing an ongoing commissioning plan for the building owner/operators to maintain the building's performance to high levels of energy efficiency.

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Retro-commission implementation – Definition (Hong Kong)

- A cost-effective and systematic process to periodically check an existing building's performance;
- The process identifies operational improvements that can effectively reduce energy consumption, lower energy bills and improve indoor environment;
- "Retro-commissioning (RCx)" covers the scope of "existing building commissioning", "recommissioning" and "continuous commissioning"

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Retro-commission implementation – Definition (US or others)

Re-Commissioning

- Repeating commissioning activities as needed when a building is modified, or significant time has passed since the previous commissioning activities.

Retro-Commissioning / Existing Building Commissioning (EBCx) – LOW/NO cost

- Commissioning an existing building (that was NOT commissioned previously).

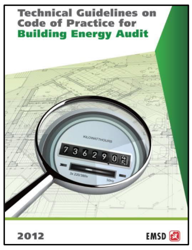
What is the Key Elements on Energy Audit & RCx ?

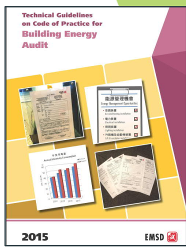
Energy Audit Process* (2012, 2015 & 2018)

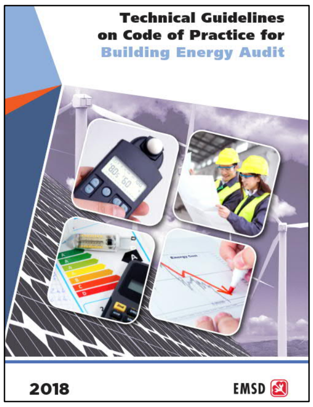
Overall Management Plan of Building / Corporation

EAC Energy Audit Steps: Pre-audit Preparation

- Planning
  - Preparation for Energy Audit
    - Defining Energy Audit Scope
    - Forming Energy Audit Team including REA
    - Estimating Time Frame and Budget
- Information Collection, Analysis and Comparison
  - Step 1 – Collection of Building Information
  - Step 2 - Review of Energy Consuming Equipment — M&V Related
  - Step 3 - Identification of EMO — M&V Related
  - Step 4 - Cost Benefit Analysis of EMO — M&V Related (2018)
- Reporting
  - Step 5 - Recommendations — M&V Related (2018)
  - Step 6 – Compiling Energy Audit Report — M&V Related







Energy audit being completed on or after 16th August 2019

(*) Technical Guidelines on Code of Practice for Building Energy Audit

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Energy Audit Process* (2012, 2015 & 2018)

STEP 2

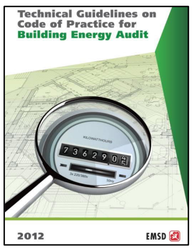
Review of Energy Consuming Equipment (Focus on CBSI)

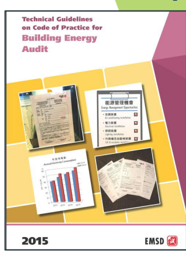
Review: Compile records, with site inspections and where necessary supplementary information collection

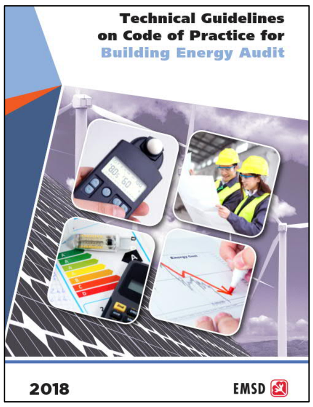
Types and Components	Technical & Operation Characteristics
Air-conditioning - chillers, heat pumps, unitary air-conditioners - AHUs, fans - Pumps - Other equipment	Types, capacity ratings and operating characteristics Control mechanism
Lighting - Luminaires	Power quality Metering provisions
Lifts and escalators	Utilization pattern
Other equipment - e.g. motors of plumbing & drainage pumps, water feature pumps, filtration plant pumps, etc.	Other notable characteristics affecting energy consumption

Review: Identify and calculate power and energy consumptions — M&V Related

- based on operation records
- based on technical brochures (with adjustments to suit)
- take measurements where necessary to supplement the operation records
- apply external metering where necessary







(*) Technical Guidelines on Code of Practice for Building Energy Audit

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Energy Audit Process* (2012, 2015 & 2018)

STEP 3

Identification of EMO

Evaluation and appraisal of findings in STEP 2

Energy performance VS Corresponding operating conditions

- Chiller/heat pump (kWh/annum)
- AHU / PAHU (W/litre/s air flow)
- Pump (W/litre/s flow)
- Lighting power density (W/m²)
- Other equipment
- EUI of building

Comparative Normalized Performance Indicators

→ Compare with original design

→ Reference to codes, international guidelines, established local practices

Also Assess operation hours for integration with power consumption to arrive at annual energy consumption

Viability study of EMO

Obvious opportunities

- Repairing / replacing deteriorated equipment
- Avoiding excessive provision on lighting, air flow, etc.
- Introducing occupants' behavior change
- Matching equipment operating schedule with area requirement

Further measures

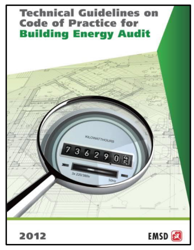
- Exploring more efficient means for system operation
- Deploying energy recovery system(s)
- Applying on-site renewable energy system(s)
- Enhancing automatic control
- Achieving system balance regarding distribution of media
- Matching between equipment capacity and system load profile

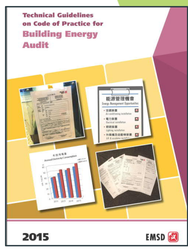
⇩

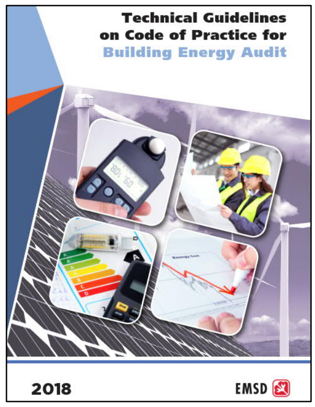
Potential EMO

M&V Related

M&V Related (2018)







(*) Technical Guidelines on Code of Practice for Building Energy Audit

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Energy Audit Process* (2012, 2015 & 2018)

STEP 4

Cost Benefit Analysis of EMO

- Energy saving estimate
- Categorization into Cat I, Cat II and Cat III
- Cat II and Cat III : cost vs energy saving

STEP 4

Cost Benefit Analysis of EMO

- Estimation of energy saving

Energy Saving = Measured / collected energy use before implementation of EMO - Estimated energy use after implementation of EMO

* Consider service life and degradation of equipment

- Categorization into Cat I, Cat II and Cat III
- Cost benefit analysis (for Cat II and Cat III)

Cost VS Energy Saving

→ Specify energy price used for evaluation

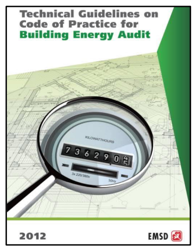
→ Record conditions for consistent comparison

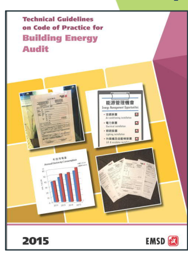
→ Cover a complete operating cycle

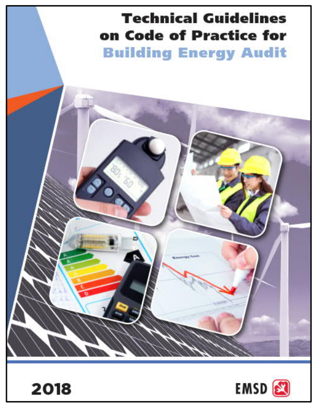
→ Indicate methodology of energy projection

Measurement interval
Metering information
Utilization patterns
Ambient temperature
Conditioned area
Lighting levels
Ventilation rate
Occupancy type

M&V Related (2018)







(*) Technical Guidelines on Code of Practice for Building Energy Audit

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Energy Audit Process* (2012, 2015 & 2018)

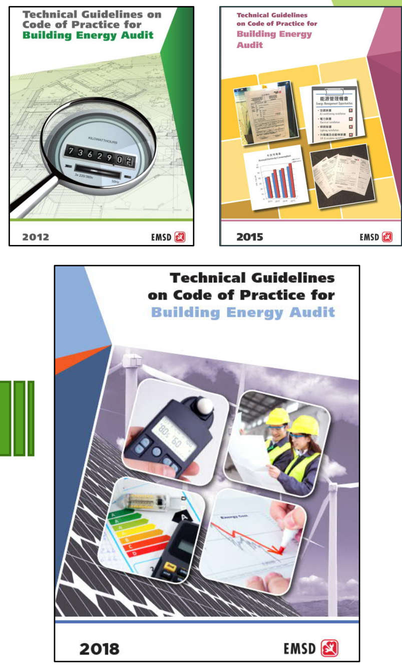
STEP 5

Recommendations
- Due regard : energy saving and cost benefit
- Make use of O&M activities

STEP 5

Recommendations
- Due regard : energy saving, cost benefit, robustness of energy data
- Describe intended result and procedures
  e.g. inspection, function test, data trending
- Summarize measurement device / parameter / time interval
- Make use of O&M activities
- Suggest future studies

M&V Related (2018)



(*) Technical Guidelines on Code of Practice for Building Energy Audit

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Energy Audit Process* (2012, 2015 & 2018)

STEP 6

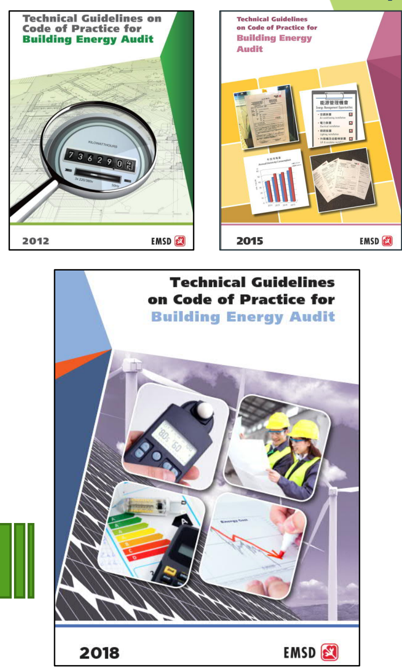
Energy Audit Report
- Executive Summary
- Objective and scope
- Equipment / systems operating characteristics
- Potential EMO : energy savings and cost benefit analyses
- Recommendations with due regard to O&M programme

M&V Related

STEP 6

Energy Audit Report
- Executive Summary
- Objective and scope
- Equipment / systems operating characteristics
- Robust energy data record by measurement / operation record
- Potential EMO : energy savings and cost benefit analyses
- Recommendation with due regard to O&M programme & follow-up

M&V Related (2018)



(*) Technical Guidelines on Code of Practice for Building Energy Audit

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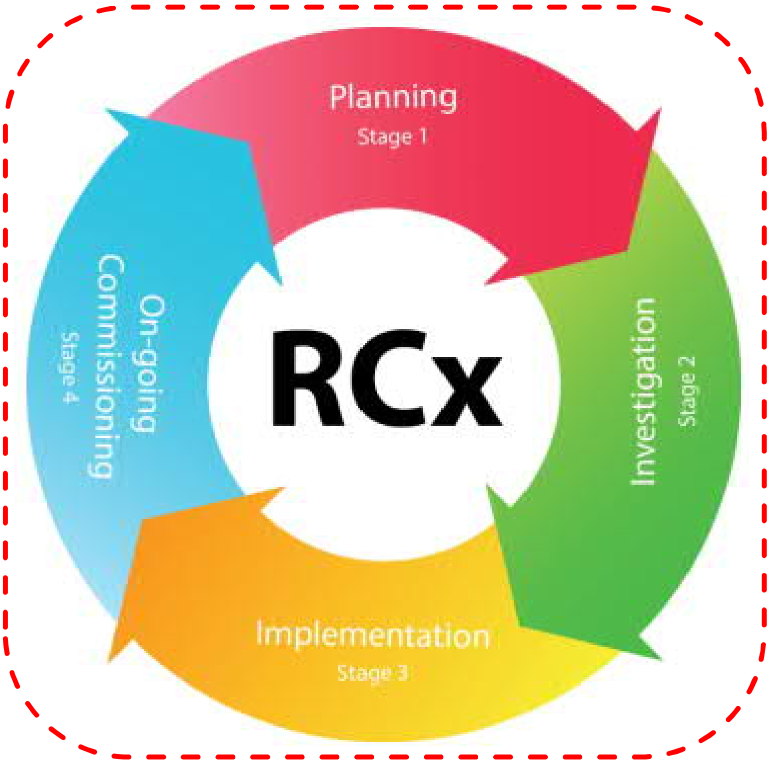
Retro-Commissioning Process**

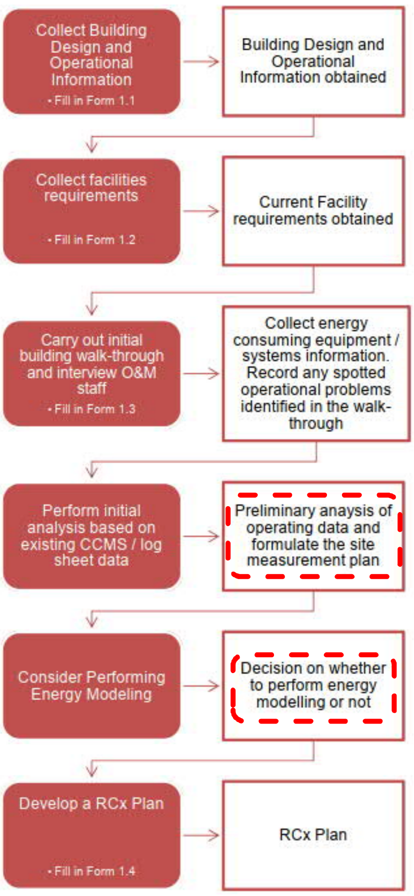


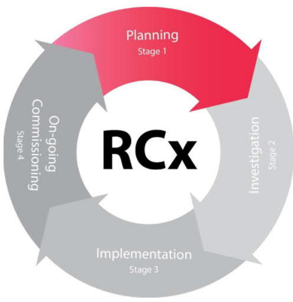
M&V Related

(**) Technical Guidelines on Retro-commissioning & Supplementary Information

Retro-Commissioning Process**

Stage 1 - Planning





M&V Related

M&V Related

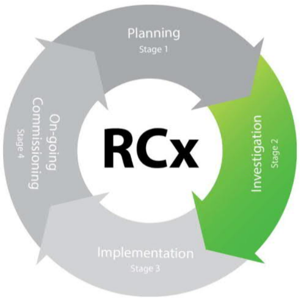
(**) Technical Guidelines on Retro-commissioning & Supplementary Information

Retro-Commissioning Process**

Stage 2 - Investigation

Collect Trend Logged Data • Fill in Form 2.1-1 • Fill in Form 2.1-2	Trend logged data Collected
Analyze Trend Logged Data	Analysis of Trend Logged Data
Identify potential ESOs • Fill in Form 2.3 • Fill in Form 2.4	List of potential ESOs prepared
Agreement of Measurement and Verfication methods for proposed ESOs	Measurement and Verficiation methods for proposed ESOs agreed with Building Owner
Selection of ESOs for implementation	List of selected ESOs agreed with Building Owner

M&V Related



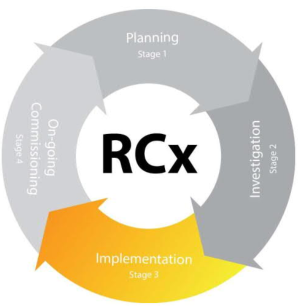
(**) Technical Guidelines on Retro-commissioning & Supplementary Information

Retro-Commissioning Process**

Stage 3 - Implementation

Implement of selected ESOs	Implementation of selected ESOs
Performing Measurement and Verification	Measured and Verified energy saving for each implemented ESOs
Develop a RCx Final Report	RCx Final Report prepared
Develop an on-going Commissioning Plan	On-going commissioning plan and list of persistence strategies prepared
Conduct Training for O&M Staff	

M&V Related



(**) Technical Guidelines on Retro-commissioning & Supplementary Information

RCx stages with M&V steps

Technical Guidelines on Retro-commissioning & Supplementary Information -
4.4.2 Performing Measurement and Verification

The M&V report typically includes (as defined in ISO 50015-2014):

1. List of implemented ESOs
2. ESOs that were planned but not implemented
3. Changes in implemented ESOs as per original plans
4. Documentation of facility adjustments
5. Energy performance or energy improvement results

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Measurement & Verification of Energy Performance –

- What is M&V?
- An introduction to the International Performance Measurement and Verification Protocol (IPMVP);
- M&V options A, B, C & D;
- Role of M&V;

What is M&V?

Simply

M&V provides

PROOF

of the effectiveness of Energy

Management

"Measurement & Verification (M&V) is the process of using *measurements* to reliably determine *actual saving* created within an individual facility by an energy management program."

ECM (Energy Conservation Measure)

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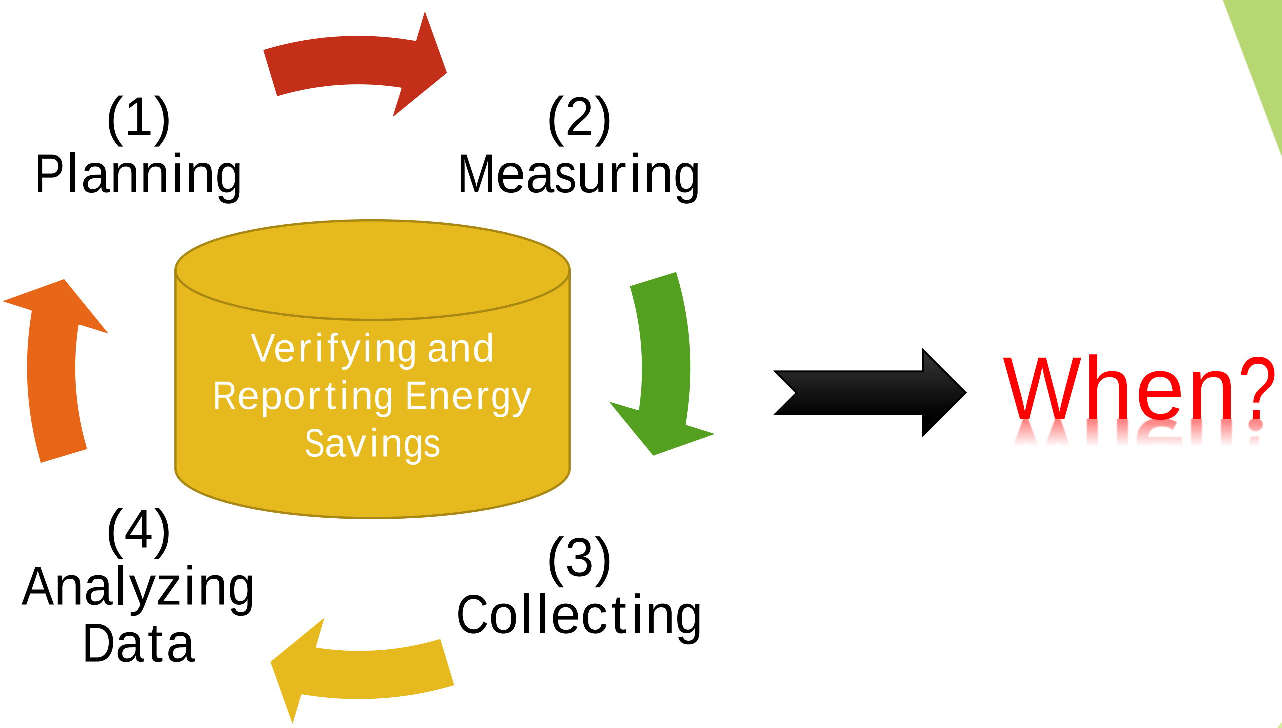
What is M&V?



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The Nature of M&V

- M&V is the *meter of an Energy Efficiency Project*
- It is required to calculate achieved energy savings with any degree of *Accuracy/Reliability*
- Calculating energy savings is unique:
  - Determined by comparing measured energy use after an Energy Efficiency project to the equivalent energy "Baseline" prior to its implementation.
  - Comes from the ABSENCE of energy use and therefore cannot be measured like kWh generated.

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Can Measure Savings?

- Savings are the absence of energy use.
- We cannot measure what we do not have.
- We do *not* 'measure' savings!

- We *do* measure energy use.
- We *analyze* measured energy use to determine savings.

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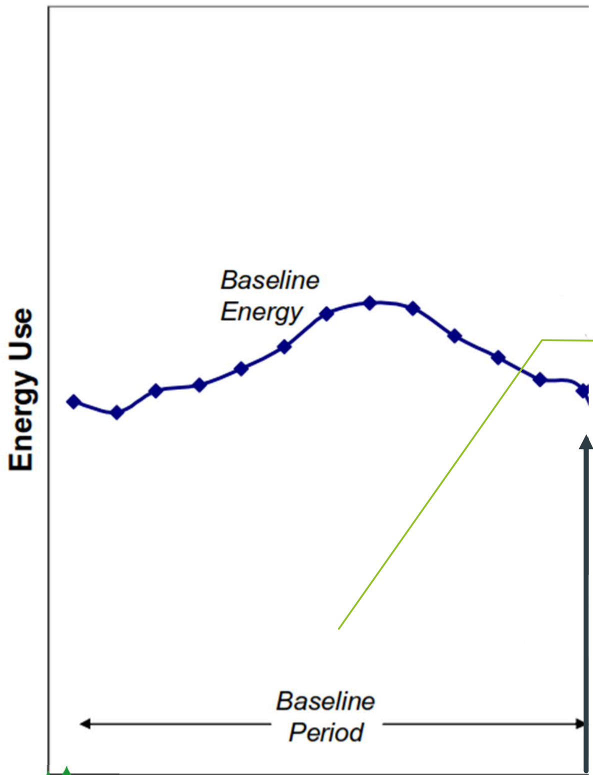
Can Measure Savings?

We can measure what we DID use

... and calculate the change in usage

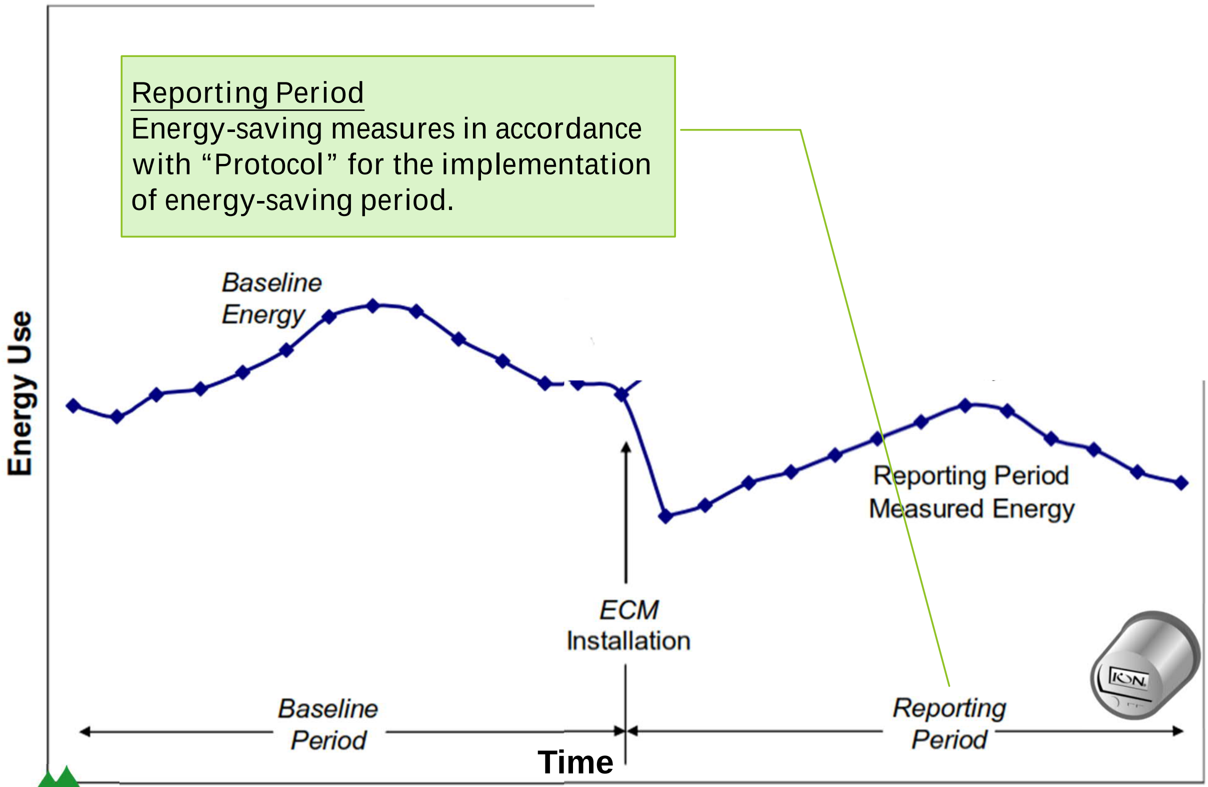
BUT change does not equal savings

... making *appropriate adjustments* for changes in conditions.



Baseline Period

- Before carrying out energy-saving project, choose a time period that can represent the operation of energy-consuming facilities or systems;
- If the measurement is stable enough, the time required for the baseline period may be short;
- The baseline period may take long enough to reflect a complete operating cycle in which the system or facility contains different operating modes.


Reporting Period
Energy-saving measures in accordance with “Protocol” for the implementation of energy-saving period.
Baseline Energy
Reporting Period Measured Energy
ECM Installation
Baseline Period
Reporting Period
Time
Energy Use

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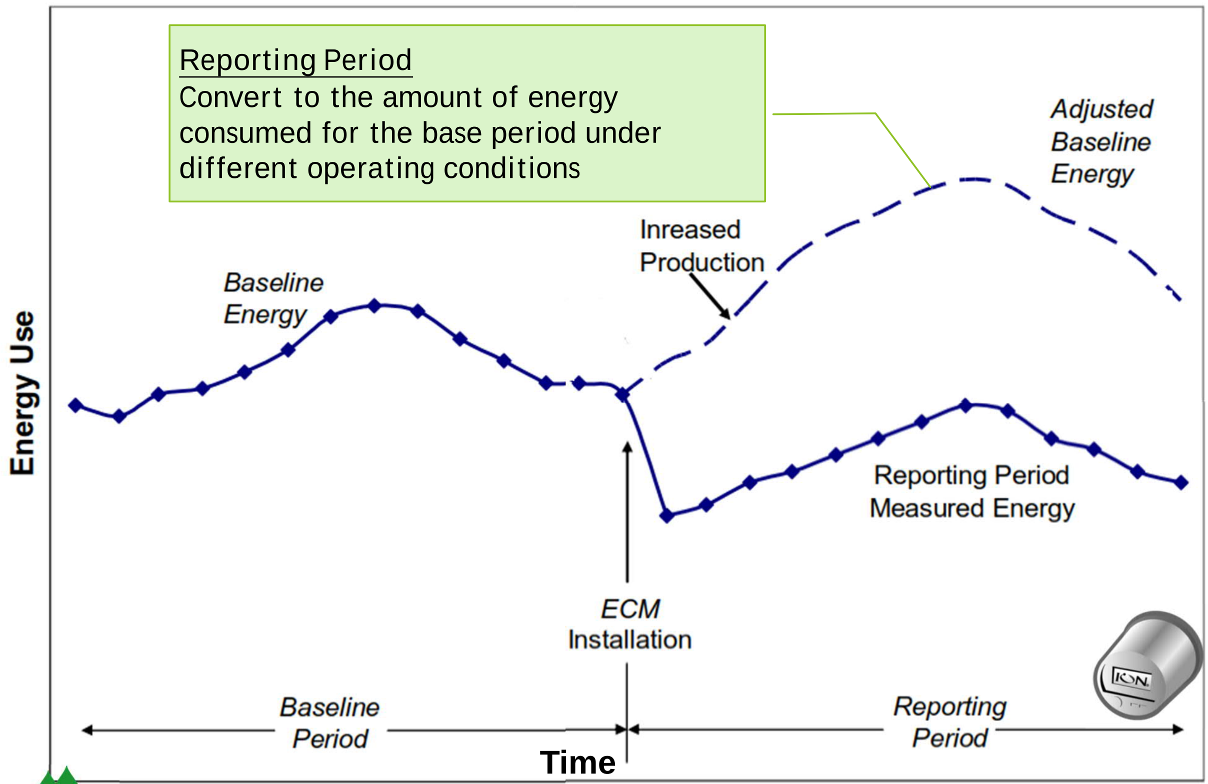
Reporting Period
Convert to the amount of energy consumed for the base period under different operating conditions
Adjusted Baseline Energy
Inreased Production
Baseline Energy
Reporting Period Measured Energy
ECM Installation
Baseline Period
Reporting Period
Time
Energy Use

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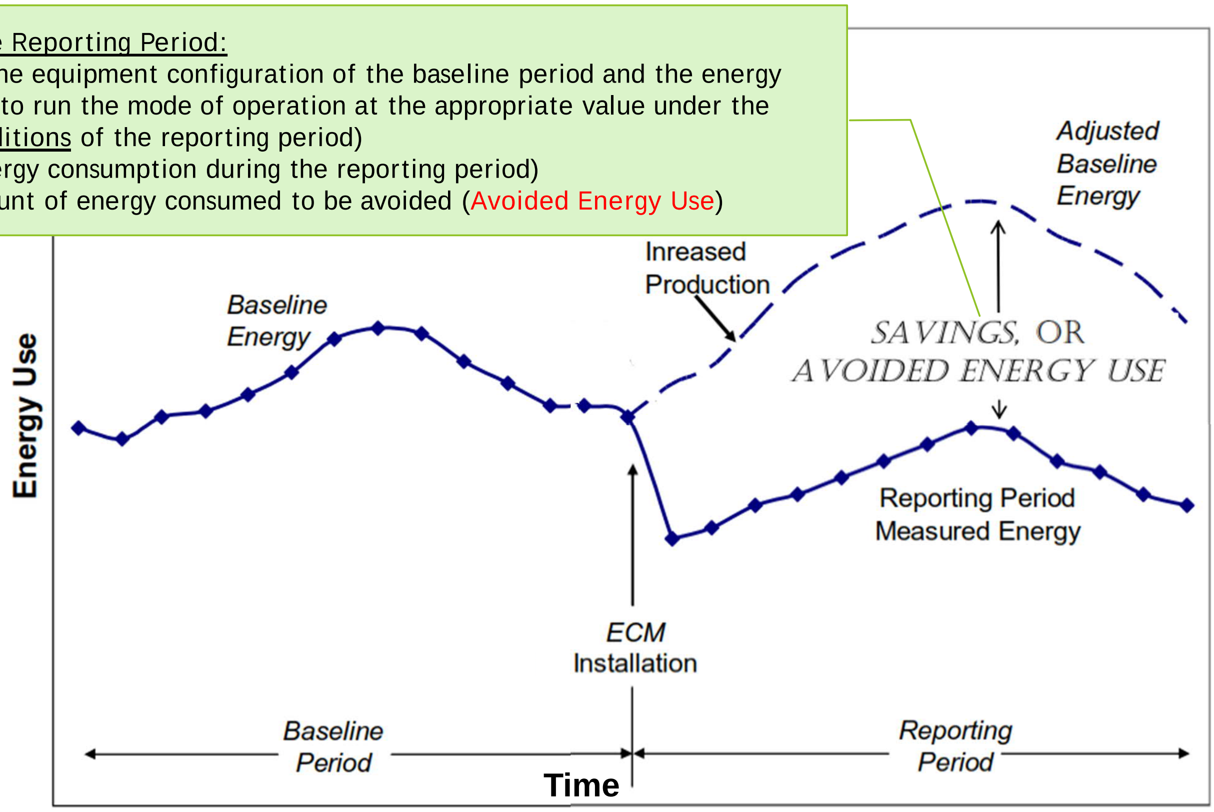
During the Reporting Period:
(Convert the equipment configuration of the baseline period and the energy consumed to run the mode of operation at the appropriate value under the same conditions of the reporting period)
– (Real energy consumption during the reporting period)
= The amount of energy consumed to be avoided (Avoided Energy Use)



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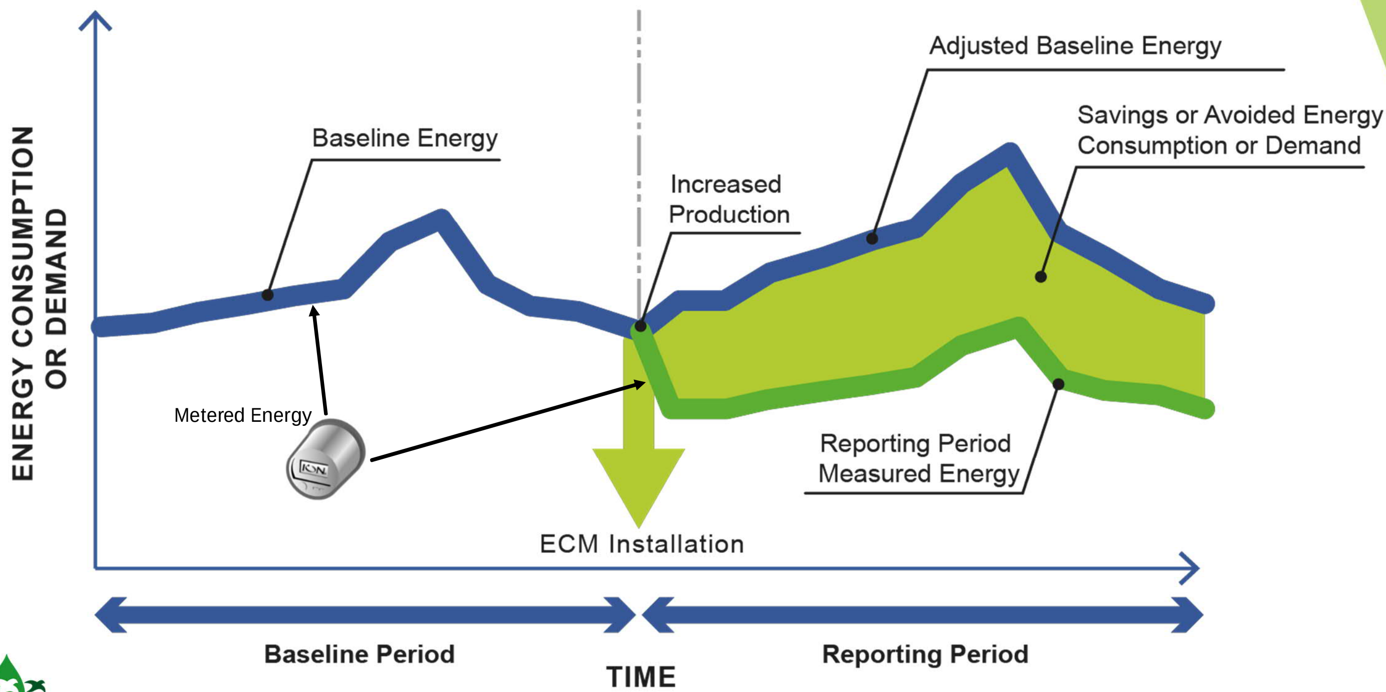
Basic Concept



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Basic Equation

The Basic Savings Equation (IPMVP Eq. 1)*:

Savings reported for any period

= (Baseline Period energy – Reporting Period energy)

± Adjustments

(*) IPMVP Core Concepts (October 2016)

$$\textbf{Savings} = (\text{Baseline Period Energy} - \text{Reporting Period Energy}) \pm \text{Adjustments} \qquad \textbf{(Eq. 1)}$$

"Savings" -
Accountant point of view (Accounting Savings)

- Accountants often use the word "savings" to describe "cost reductions". They make *no adjustments*.
- So, when talking about 'savings' we have to be very careful to explain our meaning.
- We must report the common set of conditions (apples) we are using for stating "savings".

Performance measurement requires an "**apples to apples**" comparison

Baseline Period | Reporting Period

We "*adjust*" baseline and reporting period energy use to the same set of conditions, for valid comparisons

“Savings” or “Avoidance”?

- Energy users usually want to know how much their bills would have been if they had not taken energy efficiency action. They want to know how much energy or cost they AVOIDED.
- To report avoided cost, M&V engineers *“adjust”* baseline period energy use to the conditions of the reporting period.
- And sometimes simply call cost avoidance “savings”, at risk of confusion with accountant reports.

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Types of “Savings”

Energy (Cost) Avoidance?

OR

Normalized Savings?

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Which type of savings?

Energy (Cost) Avoidance:

- To explain the impact on current costs;
- Variable conditions mean savings change even though the ECM maybe unchanged;
- The most common way of reporting the benefit of an ECM.

Normalized Savings:

- To explain how savings compare to predictions made under *"normal"* conditions;
- To stabilize saving reports, so they do not fluctuate with current conditions.

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Energy (Cost) Avoidance

Saving reported for any period

= Adjusted Baseline Period energy (cost)

- Reporting Period energy (cost)

±Non-Routine Adjustments of baseline energy to reporting-period conditions

See IPMVP Core Concepts (October 2016), Chapter 5.4.1 (Eq. 4)

Avoided Energy Consumption =		Adjusted Baseline Energy	
	–	Reporting Period Energy	**(Eq. 4)**
	±	Non Routine Adjustments to Reporting Period Conditions	

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Normalized Savings

Saving = (Baseline-Period Use or Demand – Reporting-Period Use or Demand) ± Adjustments

OR

Saving reported for any period
= Adjusted Baseline Period energy (cost)
- Adjusted Reporting Period energy (cost)
(Non-Routine adjustments should also be taken in account)

See IPMVP Core Concepts (October 2016), Chapter 5.4.2 (Eq. 7)

Normalized Savings =		(Baseline Period Energy	**(Eq. 7)**
	±	Routine Adjustments to Fixed Conditions	
	±	Non Routine Adjustments to Fixed Conditions)	
	–	(Reporting Period Energy	
	±	Routine Adjustments to Fixed Conditions	
	±	Non Routine Adjustments to Fixed Conditions)	

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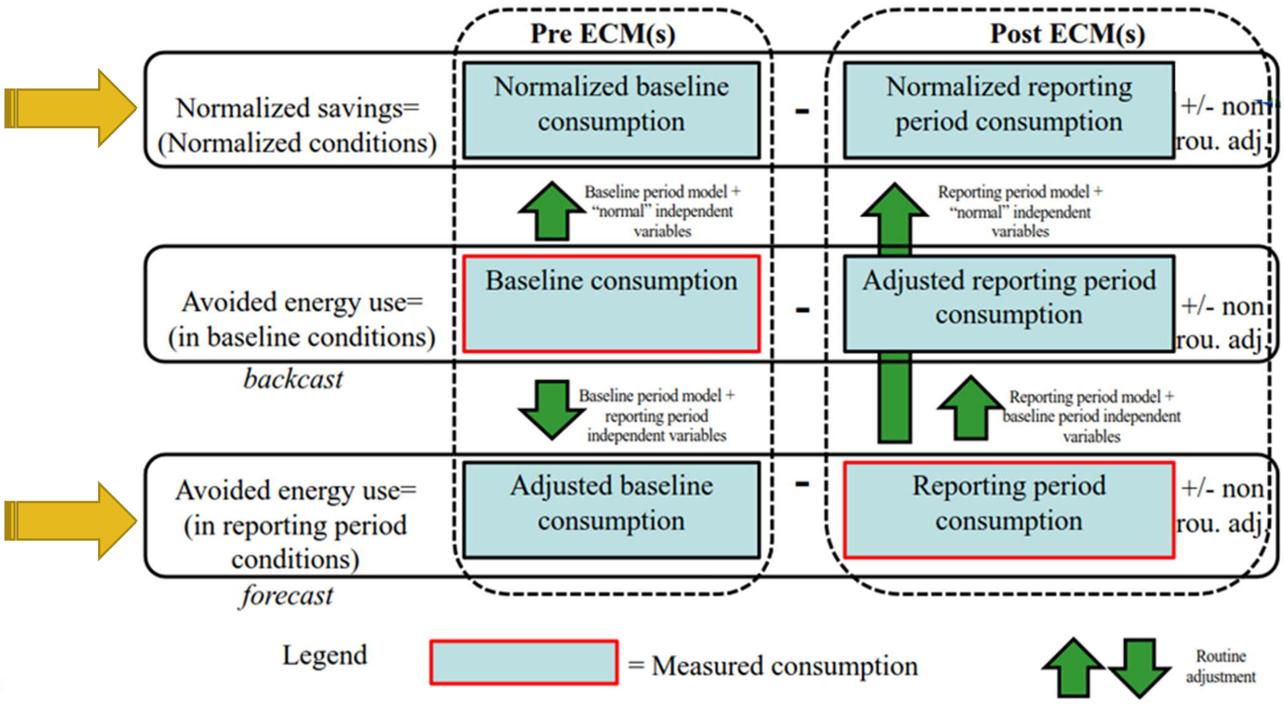
Approaches for saving calculations



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Discussion

In 2017, we spent $3M on electric bills. We hired an Energy Manager on 1/1/2018 who implemented a comprehensive energy management program. In 2018 we spent $4M.

We should

a. Fire our Energy Manager
b. Praise our Energy Manager
c. We need more information before making a decision

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Take a Break
15 minutes

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Q&A

Discussion

- In 2017, we spent $3M on electric bills. We hired an Energy Manager on 1/1/2018 who implemented a comprehensive energy management program. In 2018 we spent $4M.
- But we also added 7,000 sq. meter, increased enrolment by 7%, increased community rentals by 9% and absorbed a 5% electric price increase. Oh, we had a record-setting hot summer.
- Based on the 2017 baseline, our M&V software calculated that without our energy management program we would have spent $4.8M in 2018. It looks like we avoided a cost of $800,000 in 2018.

Discussion

We should

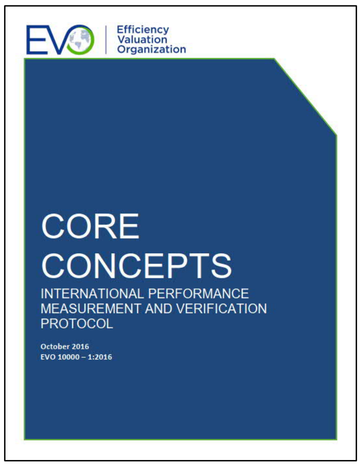
b. Praise our Energy Manager

Remarks:

- You cannot simply compare year-to-year out of pocket expenditures.
- You have to compare what you did spend with how much you would have spent in the absence of energy efficiency, in other words, how much you avoided spending.

IPMVP

- Efficiency Valuation Organization (EVO) is originated as a committee under a US DOE Initiative (1994), now a non-profit US corporation with worldwide membership and influence.
- A 20 years non-profit organization that owns/manages International Performance Measurement and Verification Protocol (IPMVP) - Published (1997).
- Developed (2009) International Energy Efficiency Financing Protocol (IEEFP).
- MISSION is to ensure that the savings and impact of energy efficiency and sustainability projects are *accurately measured and verified*.
- EVO provides M&V training and certification programs in over 20 countries to professionals through local private training entities.



EVO & IPMVP

- Protocols
  - M&V, Financing
- Training, Certification
  - Certification (CMVP®) is joint with the Association of Energy Engineers (AEE)
  - "Certified Energy Savings Verifier" (CESV) – Indonesia, France, Canada and other markets
- Building Community, Promoting Efficiency
  - Subscriber services through www.evo-world.org industry newsletter, blog, library, discounts, pre-release access to public comments
  - World-wide partnerships for communication, training and development

EVO | Efficiency Valuation Organization

IPMVP Overview

- Presents a framework and defines terms used in determining 'savings' after implementation of a project.
- Specifies the topics to be addressed in an M&V Plan for a specific project.
- Allows flexibility in creating M&V Plans, while adhering to the principles of:
  1. Accuracy (準確性)
  2. Completeness (完整性)
  3. Conservativeness (保守性)
  4. Consistency (一致性)
  5. Relevance (相關性) and
  6. Transparency (透明度)

EVO | Efficiency Valuation Organization

IPMVP Overview

"Accurate"

- M&V reports should be as accurate as the M&V budget will allow.
- M&V costs should normally be small relative to the monetary value of the savings being evaluated.
- M&V expenditures should also be consistent with the financial implications of over- or under-reporting of a project's performance.
- Accuracy tradeoffs should be accompanied by increased conservativeness in any estimates and judgements.

"Complete"

- The reporting of energy savings should consider all effects of a project. M&V activities should use <u>measurements to quantify the significant effects</u>, <u>while estimating others</u>.

IPMVP Overview

"Conservative"

- Where judgements are made about uncertain quantities, M&V procedures should be designed to <u>under-estimate savings</u>.

"Consistent"

- The reporting of a project's energy effectiveness should be consistent across:
  - different types of energy efficiency projects;
  - different energy management professionals for any one project;
  - different periods of time for the same project; and
  - energy efficiency projects and new energy supply projects.

IPMVP Overview

"Relevant"

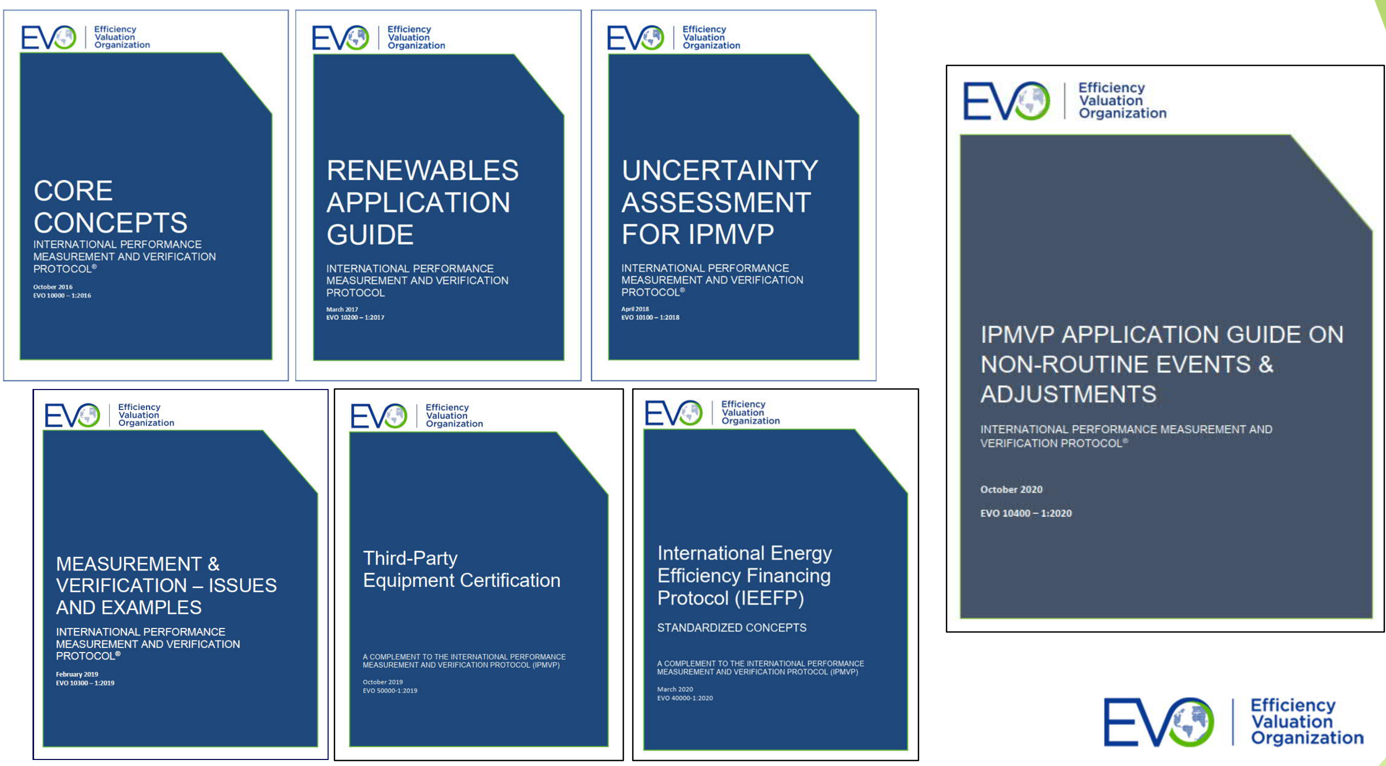
- The determination of savings should measure the performance parameters of concern, or least well known, while other less critical or predictable parameters may be estimated.

"Transparent"

- All M&V activities should be clearly and fully disclosed. Full disclosure should include presentation of all of the elements defined for the contents of an M&V Plan and a savings report, respectively.

Efficiency Valuation Organization

IPMVP (Current Edition)

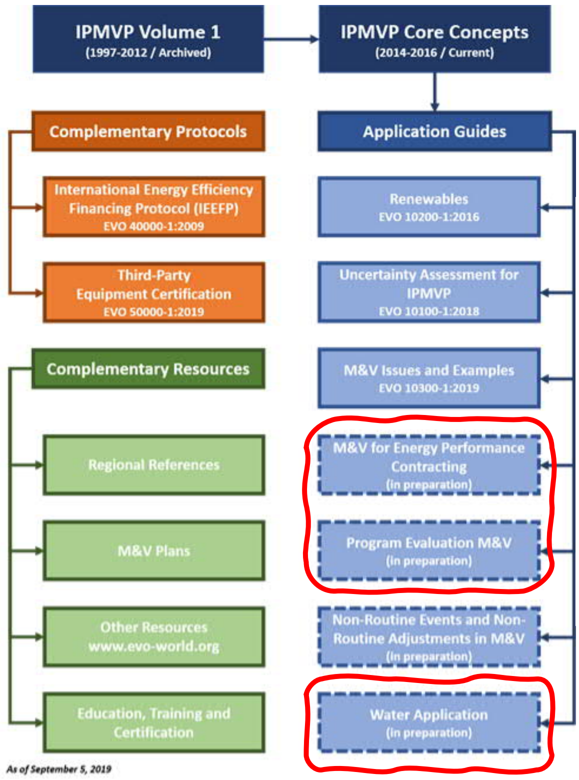


Efficiency Valuation Organization

IPMVP (Current Edition – M&V Plan)

Efficiency Valuation Organization

IPMVP (Coming Edition)



UPCOMING APPLICATION GUIDES

M&V for Energy Performance Contracting EVO 10XXX-1:20XX (In preparation)	This application guide is intended to provide additional information to the facility owner or industrial facility manager that would like to implement an energy performance contract involving guaranteed savings by an energy services company.
Program Evaluation M&V EVO 10XXX–1: 20XX (In preparation)	This application guide provides guidance on utilizing the IPMVP for energy efficiency (EE) program gross impact evaluation. It seeks to bridge the gap between program evaluation guidance documents and the IPMVP and to provide more detailed guidance to impact evaluators planning, reviewing, or conducting M&V within impact evaluation.
Non-Routine Events and Non-Routine Adjustment in M&V EVO 10XXX-1:20XX (In preparation)	Routine events are factors that are expected to change routinely and can be accounted for (through regressions or other techniques) to adjust both the baseline and reporting periods to the same set of conditions. Non-routine events are factors that were not expected to change, but that will affect the building's energy use. This guide will address the proper identification, quantification, and application of non-routine events and adjustments.
Water Application EVO 10XXX–1:20XX (In preparation)	This application guide presents the application of the IPMVP framework to water savings.

Efficiency Valuation Organization

IPMVP

IPMVP – It is not EVERYTHING

IPMVP does NOT cover in detail:

- Design of meter and instrumentation systems
- Cost estimating of M&V activities
- Energy engineering
- Statistical analysis

IPMVP is NOT a Cookbook

- It still needs careful application to each project

IPMVP Alignment with ISO 50001?

ISO 50001 provides a framework of requirements for organizations to:

- Develop a policy for more efficient use of energy;
- Fix targets and objectives to meet the policy;
- Use data to better understand and make decisions about energy use;
- Measure the results;
- Review the effectiveness of the policy;
- Continually improve energy management.

But ISO 50006 and ISO 50015 are efforts to address the requirements for setting up baselines and measuring progress towards successfully implementing 50001.

ISO 50001 – Family (Current)

ISO technical committee ISO/TC 301 – Energy management and energy savings:

- ISO 50002:2014, Energy audits – Requirements with guidance for use;
- ISO 50003:2014, Energy management systems – Requirements for bodies providing audit and certification of energy management systems;
- ISO 50004:2020, Energy management systems – Guidance for the implementation, maintenance and improvement of an energy management system;
- ISO 50006:2014, Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance;
- ISO 50007:2017, Energy services – Guidelines for the assessment and improvement of the energy service to users;
- ISO 50015:2014, Energy management systems – Measurement and verification of energy performance of organizations – General principles and guidance;

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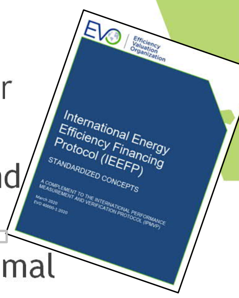
ISO 50001 – Family (Current)

ISO technical committee ISO/TC 301 – Energy management and energy savings:

- ISO 50021:2019, Energy management and energy savings — General guidelines for selecting energy savings evaluators;
- ISO/TS 50044:2019, Energy saving projects (EnSPs) — Guidelines for economic and financial evaluation;
- ISO 50045:2019, Technical guidelines for the evaluation of energy savings of thermal power plants;
- ISO 50046:2019, General methods for predicting energy savings;
- ISO 50047:2016, Energy savings – Determination of energy savings in organizations;
- ISO 50049:2020, Calculation methods for energy efficiency and energy consumption variations at country, region and city levels;



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ISO 50001 – Family (Current)

ISO technical committee ISO/TC 301 – Energy management and energy savings:

- ISO 17741:2016, General technical rules for measurement, calculation and verification of energy savings of projects;
- ISO 17742:2015, Energy efficiency and savings calculation for countries, regions and cities;
- ISO 17743:2016, Energy savings – Definition of a methodological framework applicable to calculation and reporting on energy savings;
- ISO/IEC 13273-1:2015, Energy efficiency and renewable energy sources – Common international terminology – Part 1: Energy efficiency;
- ISO/IEC 13273-2:2015, Energy efficiency and renewable energy sources – Common international terminology – Part 2: Renewable energy sources.

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ISO 50001 – Family (Current)

- ISO 17741:2016 – General technical rules for measurement, calculation and verification of energy savings of projects.

- ISO 17743:2016 – Energy savings — Definition of a methodological framework applicable to calculation and reporting on energy savings.

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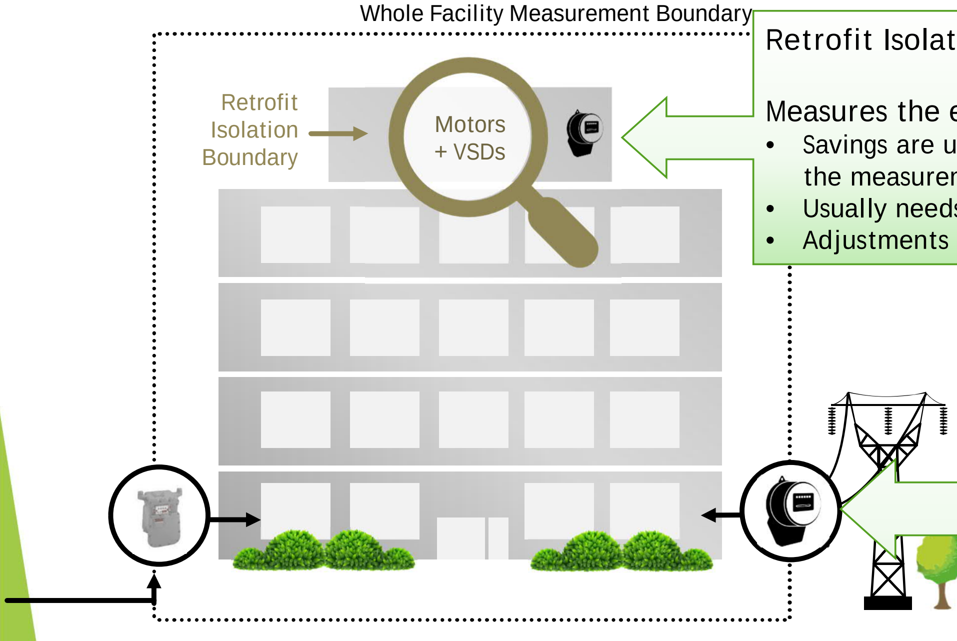
M&V options – A, B, C & D



Retrofit Isolation Method (Option A, B):

Measures the effect of the retrofit, only
- Savings are unaffected by changes beyond the measurement boundary
- Usually needs a new meter
- Adjustments can be simple

Whole Facility Method (Option C, D):
Measures all effects in the facility:
- Retrofits AND other changes (intended and unintended)
- Often uses the utility meter
- Adjustments can be complex

Depends on Measurement Boundary

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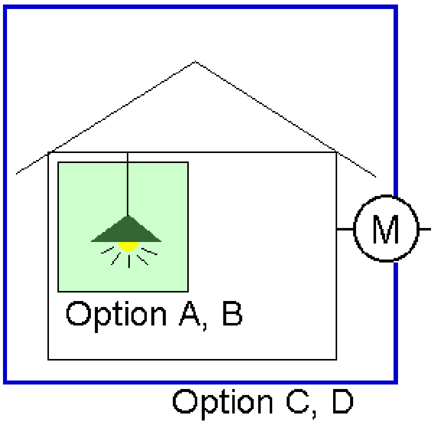
M&V options – TWO Basic Methods

Retrofit Isolation Method (Option A, B):

Measures the effect of the retrofit, only
- Savings are unaffected by changes beyond the measurement boundary
- Usually needs a new meter
- Adjustments can be simple
- If you want to assess a particular RETROFIT



Whole Facility Method (Option C, D):

Measures all effects in the facility:
- Retrofits AND other changes (intended and unintended)
- Often uses the utility meter
- Adjustments can be complex
- If you want to manage your TOTAL energy use

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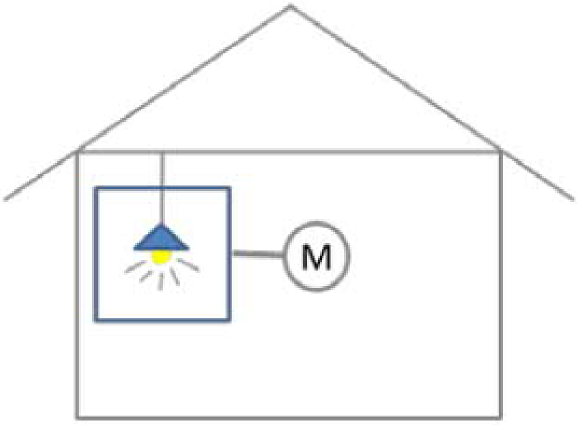
Retrofit Isolation (Option A or B)

Option A – Retrofit Isolation:

Key Parameter(s) Measurement

Option B – Retrofit Isolation:

All Parameters Measurement



Option A and B

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Example 1 – Option A vs Option B

	Option A	Option B
Baseline Period (measurement)	400 kW	200,000 kWh
Reporting Period (measurement)	300 kW	150,000 kWh
Estimated operating hours	500 hrs	
Avoided Energy	(400-300) x 500 = 50,000kWh	50,000 kWh

Option A – measure only the KEY part of the energy computation,
for example:
A contractor is only responsible for a load reduction (or only responsible for a reduction in operating hours, but not both)

Option B – measure all factors governing energy use,
for example:
A contractor is responsible for controls which dim lights automatically and control operating periods.

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Remarks – Option A (Uncertainty)

Option A:

(called Retrofit Isolation: Key Parameter Measurement) allows a possible reduction in measurement cost, but introduces some uncertainty in the estimated quantity.

All parties must ACCEPT the uncertainty associated with the ESTIMATE.

The choice between Options A and B allows flexibility to suit the situation.

Example 2 – Option A vs Option B

	Option A	Option B
Baseline period	Spot measurement 200 kW	Continuous measurement 320,000 kWh
Reporting period	Spot measurement 130 kW Estimated utilization 200 days per year x 8 hours per day = 1600 hours per year	Continuous measurement 208,000 kWh
Energy savings	(200 kW – 130 kW) = 70 kW x 1600 hours per year = 112,000 kWh	320,000 kWh - 208,000 kWh = 112,000 kWh

Case I (Option A)

- 200 kW Motor
- 8 hours per day of run time
- 200 days per year
- Replaced by 130 kW motor

Case II (Option B)

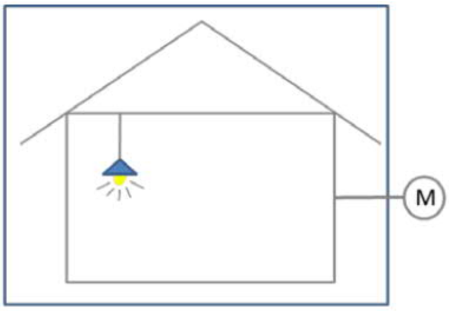
- 200 kW Motor replaced by 130 kW motor
- Run intermittently – not sure how many hours it runs per year
- One year of sub-meter data is available

Whole Facility (Option C or D)

Select based on DATA availability:

Option C – Whole Facility:

- Need both baseline and reporting period data.
- Estimated Saving > 10%



Option C and D

Option D – Calibrated Simulation:

- When there is no meter (or facility to meter) in the baseline, baseline data can be 'manufactured' under controlled circumstances.

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Example – Option C

Baseline period electricity bill (Jul 1999 – 29 days)

= 800,000 kWh

Reporting period electricity bill (Jul 2001 – 31 days)

= 600,000 kWh

RAW difference = 800,000 – 600,000 = 200,000 kWh

i.e.

Adjustment of baseline for meter reading period length & weather = +100,000 kWh

Avoided Energy = 300,000 kWh

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Summary of IPMVP Options

- The IPMVP has four M&V Options: A, B, C, and D
- The Options are generic M&V approaches for <u>energy and water saving projects</u>.
- <u>Four Options</u> provide a range of approaches for determining energy savings, to suit the characteristics of the ECMs being implemented and the desired balance between reporting

ACCURACY and COST

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M&V Option E?

http://www.rsbdubai.gov.ae/wp-content/uploads/2014/01/ref_RSB-MV-protocol_20140113.pdf

Regulatory and Supervisory Bureau (RSB) for the Electricity and Water Sectors – Government of Dubai: "Measurement and Verification Protocol (January 2014)"

NOT M&V

4.5. Option E – Deemed Savings (DS)

For Option E, which is not covered in IPMVP and not regarded as an M&V Option in some literature, savings are determined based on engineering calculations using typical equipment characteristics and operating schedules without field testing or metering. Instead, verification may consist of checking units installed & confirmation of proper operation of the equipment / measure. Given the absence of direct verification of energy savings, the risks related to the ECM are placed virtually entirely with the client.

The Savings Equation depends strongly on the type of ECM and could be:

Savings (Option E) = Number of ECM related equipment installed x
Operating time of ECM related equipment x
Calculated typical saving per ECM related equipment

Typical examples for Option E concern relatively inexpensive ECMs such as e.g. the application of window films.

Since no actual measurements or complex calculations are required, Option E is the least expensive with a typical cost of less than 1% of the total project cost. At the same time, the accuracy obtained from Option E is typically lower than other options.

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Role of M&V

Increase energy savings

- Accurate determination (measurements) of energy savings gives facility owners and managers valuable feedback on their energy conservation measures (ECMs).
- This feedback helps them adjust ECM design or operations to improve savings, achieve greater persistence of savings over time, and lower variations in savings.

Document financial transactions

- Some projects, the energy efficiency savings are the basis for performance-based financial payments and/or a guarantee in a performance contract.
- A well-defined and implemented M&V Plan can be the basis for documenting performance in a transparent manner and subjected to independent verification.

Enhance the value of "Carbon Emission Reduction" credits

- Use of an M&V Plan for determining energy savings improves emissions-reduction reports compared to reports with no M&V Plan.

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Role of M&V

Enhance financing for efficiency projects

- A good M&V Plan increases the transparency and credibility of reports on the outcome of efficiency investments.
- This credibility can increase the confidence that investors and sponsors have in energy efficiency projects, enhancing their chances of being financed.

Manage energy budgets

- Even where savings are not planned, M&V techniques help managers evaluate and manage energy usage to account for variances from budgets.
- M&V techniques are used to adjust for changing facility-operating conditions in order to set proper budgets and account for budget variances.

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Quiz 1

Savings from a lighting project are to be based on lamp and ballast manufacturer specifications and estimated lighting hours. This is:

1. IPMVP Option A
2. IPMVP Option B
3. IPMVP Option D
4. None of the above

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Quiz 2

An Energy Performance Contractor proposes to verify savings using a computer model based on building blueprints and average weather data. Model calibration is considered too expensive and will not be performed. This is an application of:

1. IPMVP Option C
2. IPMVP Option D
3. IPMVP Option B
4. None of the above

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Quiz 3

A lighting project installs new fixtures to reduce kW and occupancy sensors to reduce operating hours. What is the correct way to calculate kWh savings?

1. $(kW_{old} - kW_{new}) * (hours_{new})$
2. $(kW_{new}) * (hours_{old} - hours_{new})$
3. $(kW_{old} - kW_{new}) * (hours_{old} - hours_{new})$
4. $(kW_{old} * hours_{old}) - (kW_{new} * hours_{new})$

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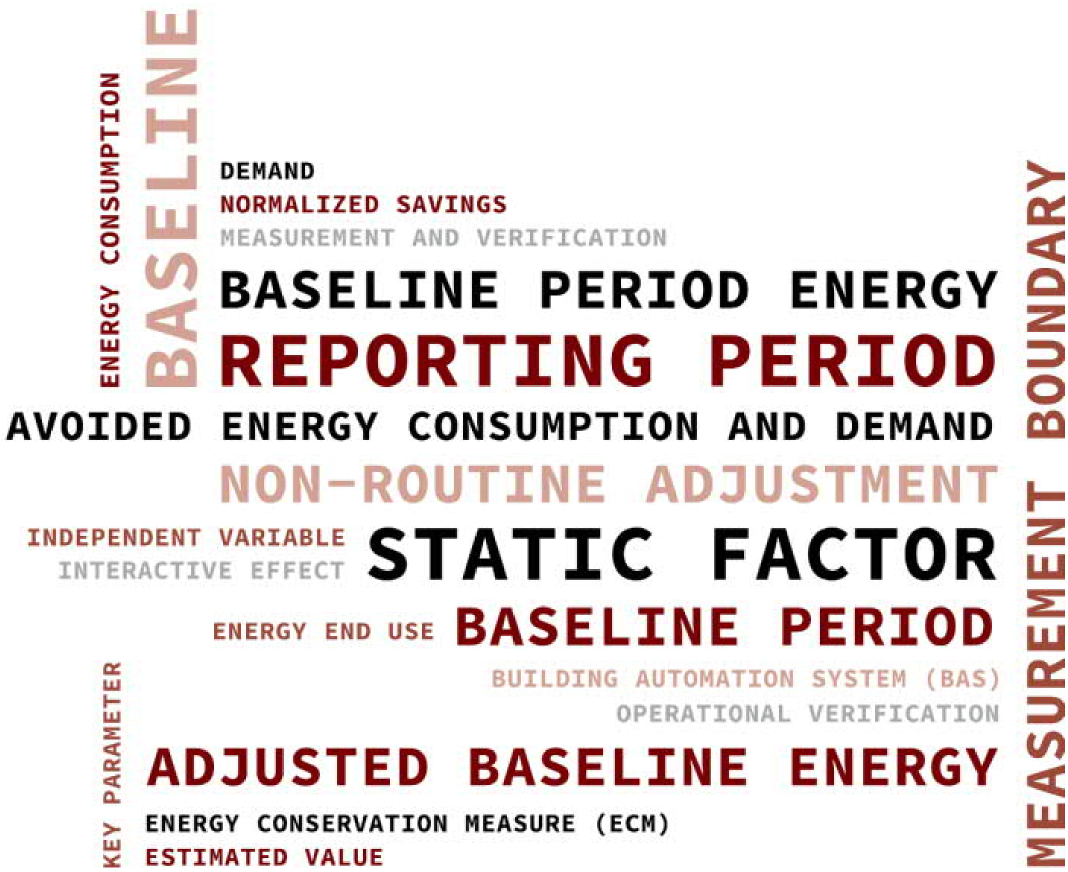

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Thank you very much

Q&A

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Remarks:
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Training Course:
Building Energy Management (Session 2)

Instructor: Ir Gary, Kar Kit CHU

Moderator: Mr. Felix LAM

Guest Speakers: Mr. Thomas Yeung, Mr. K.K. Wu, Mr. C.W. Chan from The Hongkong Electric Co., Ltd.

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Supporting Organizations:

Training Course on "Building Energy Management"

Presented by:

Ir Gary, Kar Kit CHU *BSc MPhil*

MHKIE MAEE MIEEE MIET
CEM®, CEA®, CMVP®, CAP, CBCP®
LEED® Green Associate, BEAM Pro (NB, EB, BI)
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Session 2 – 2021.1.15

- Measurement & Verification of Energy Performance
- Case Sharing
- Reference Materials / Q&A

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Measurement & Verification of Energy Performance –

- RECAP – "Normalized Savings"
- Concepts of Baseline Adjustments
- Skill requirements of the M&V?

Types of "Savings"

RECAP

Energy (Cost) Avoidance?

OR

<u>Normalized Savings</u>?

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Normalized Savings:

RECAP

- To explain how savings compare to predictions made under *"normal"* conditions;
- To stabilize saving reports, so they do not fluctuate with current conditions.
- Normal conditions may be any fixed set of conditions – (eg. long term average, or 2006 values, or …..).
- To report "normalized savings," both baseline and reporting period energy (costs) must be under the same set of normal conditions.
- We must adjust:
  - baseline period use to the *fixed normal conditions*, and
  - reporting period use to the *fixed normal conditions*.

(Please refer Session 1 – Page 49)

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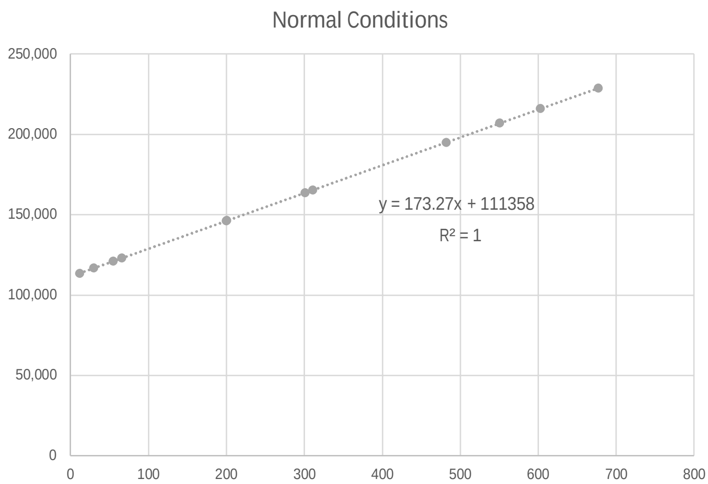
Normalized Savings - Example:

Normal Conditions

Normal Date	Normal HDD	Total Normal Gas Consmption (mcf)
March	551	206,830
April	482	194,874
May	301	163,512
June	200	146,012
July	55	120,888
August	12	113,437
September	30	116,556
October	66	122,794
November	201	146,185
December	311	165,245
January	677	228,662
February	603	215,840



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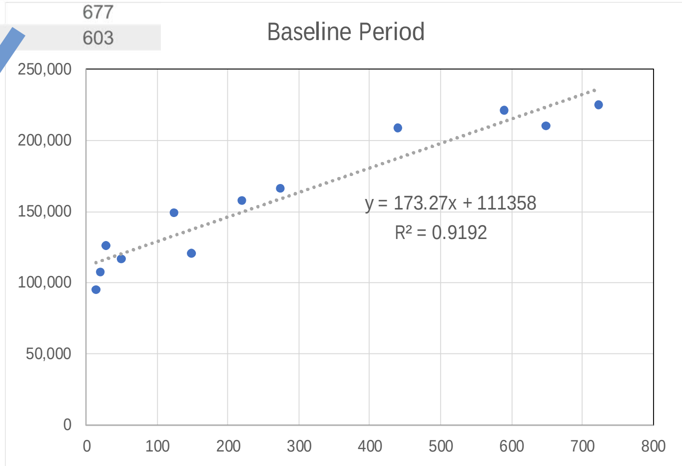
Normalized Savings - Example:

Baseline Period

Baseline HDD (2015)	Baseline Period - Gas Consumption (mcf)
650	210,692
440	208,664
220	157,886
150	120,793
50	116,508
20	107,272
14	95,411
29	126,423
125	149,253
275	166,202
590	221,600
723	224,958

Normal Date	Normal HDD
March	551
April	482
May	301
June	200
July	55
August	12
September	30
October	66
November	201
December	311
January	677
February	603



$y = 173.27x + 111358$

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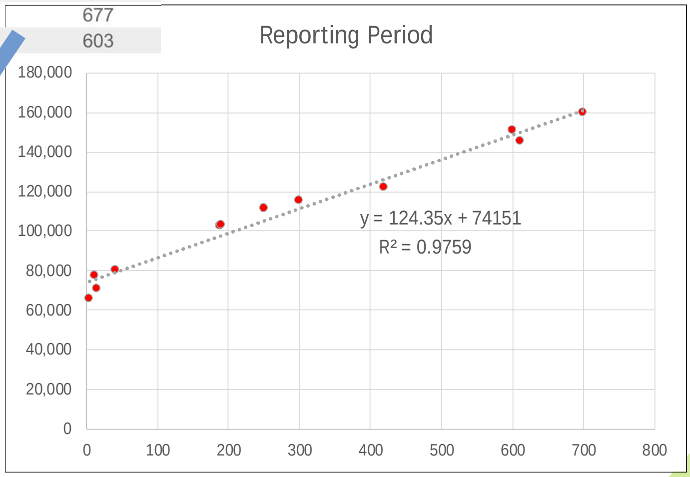
Normalized Savings - Example:

Reporting Period

Reporting HDD (2016)	Reporting Period - Gas Consumption (mcf)
601	151,008
420	122,111
188	102,694
250	111,211
41	80,222
15	71,023
5	65,534
12	77,354
190	103,000
300	115,112
700	160,002
612	145,111

Normal Date	Normal HDD
March	551
April	482
May	301
June	200
July	55
August	12
September	30
October	66
November	201
December	311
January	677
February	603



$y = 124.35x + 74151$

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Normalized Savings – Results:

Baseline HDD (2015)	Baseline Period - Gas Consumption (mcf)	Adjusted Baseline (At Normal Conditions)	Reporting HDD (2016)	Reporting Period - Gas Consumption (mcf)	Adjusted Reporting (At Normal Conditions)	Normaized Savings (mcf)
650	210,692	206,830	601	151,008	142,668	64,162
440	208,664	194,874	420	122,111	134,088	60,786
220	157,886	163,512	188	102,694	111,580	51,932
150	120,793	146,012	250	111,211	99,021	46,991
50	116,508	120,888	41	80,222	80,990	39,898
20	107,272	113,437	15	71,023	75,643	37,794
14	95,411	116,556	5	65,534	77,882	38,675
29	126,423	122,794	12	77,354	82,358	40,436
125	149,253	146,185	190	103,000	99,145	47,040
275	166,202	165,245	300	115,112	112,824	52,421
590	221,600	228,662	700	160,002	158,336	70,326
723	224,958	215,840	612	145,111	149,134	66,706
						617,166

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Basic Equation

RECAP

The Basic Savings Equation (IPMVP Eq. 1)*:

Savings reported for any period

= (Baseline Period energy – Reporting Period energy)

± Adjustments

(*) IPMVP Core Concepts (October 2016)

Savings =		(Baseline Period Energy	
	–	Reporting Period Energy)	**(Eq. 1)**
	±	Adjustments	

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Why we need Adjustments?

- An energy retrofit was performed but … the plant ***production was also lower*** this year than last.

- How much of the resultant cost reduction was due to the
  - *retrofit*?
  - *production change*?

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Adjustments

Performance measurement requires an "apples to apples" comparison

Baseline Period

Reporting Period

We "*adjust*" baseline and reporting period energy use to the same set of conditions, for valid comparisons

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Adjustments

Such changes may include:

- Changes in facility use or operating conditions;
- Changes in occupancy;
- Changes in equipment operating schedules;
- Changes in indoor environmental conditions (such as thermostat settings);
- Changes in outdoor environmental conditions (solar shading, etc);
- Additions of new energy-using equipment;
- Facility refurbishment or rehabilitation.

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Adjustments

- The *"Adjustments"* can be trivial, simple or complex.
- M&V budgets (cost of M&V) usually determine how simple or complex the "*Adjustments*" are.
- The extent of the *"Adjustments"* depends on:
  - the need for accuracy,
  - the complexity of factors driving energy use, and
  - the amount of equipment having its performance assessed (i.e. "measurement boundary")

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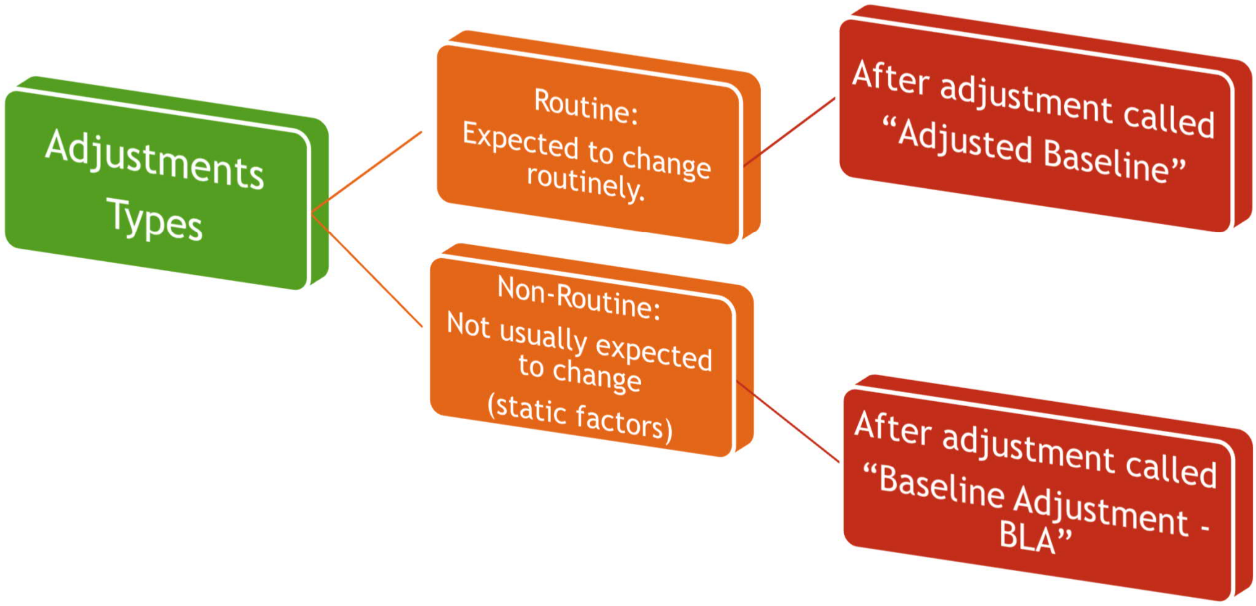
Adjustments Types



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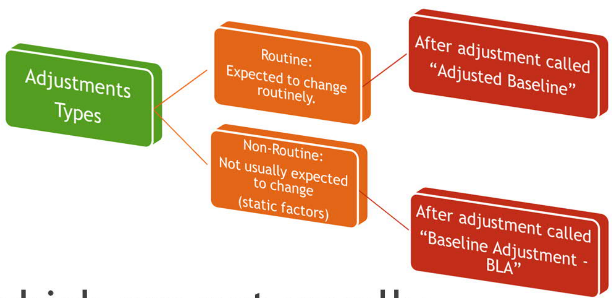
Basis for Adjustments

Routine Adjustments

- For any energy-governing factors, expected to change routinely during the reporting period, such as weather or production volume.



Non-Routine Adjustments

- For those energy-governing factors which are not usually expected to change called “STATIC FACTORS”

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"Static factors" examples

- Amount of space being heated or air conditioned;
- Type of products being produced or number of production shits per day;
- Building envelop characteristics (new insulation, windows, doors, air tightness);
- Amount, type or use of the facility's and the users' equipment;
- Indoor environmental standard (e.g. light levels, temperature, ventilation rate);
- Occupancy type or schedule.

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Skill requirements of the M&V?

- Industry Area – Required know how about the process/production
  - Define the Boundaries of Measurement
- Interactive Effects (i.e. Lighting & Cooling, Kitchen)
- Baseline Data / Period
  - Independent Variables, Static Factors
  - Short Period to avoid unnecessary cost and uncertainty
  - Metering Accuracy / Calibration
- M&V Cost
  - M&V Planning
  - Metering Cost (Metering Plan)
- Data/Statistic Analysis (Sampling/Modeling/Uncertainty/Rounding)

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WHO perform the M&V?

Australia

- As of June 2017, the CMVP® designation was inscribed into the scheme for Project Based Activities in Victorian Law. The Victorian Energy Efficiency Target (Project-Based Activities) Regulations 2017 states that any independent assessor on M&V projects must be registered as an approved Measurement and Verification Professional by the Essential Services Commission (ESC).
- Professionals who wish to be approved as a Measurement and Verification Professional must hold and maintain a current CMVP certification status. Any professional providing assessments on M&V projects must maintain all requirements set forth under this regulation.

South Africa

- The South African Institute of Electrical Engineers (SAIEE) has granted Engineering Council of South Africa (ESCA) Continued Professional Development (CPD) credits for persons taking AEE's international CEM®, CEA®, CMVP®, CWEP, and REP programs.

United Arab Emirates

- The RSB (Government of Dubai, RSB for Electricity & Water), Effective 2 September 2015, new applicants for Provisional Accreditation will require a CMVP® in addition to either a CEA® or a CEM®.

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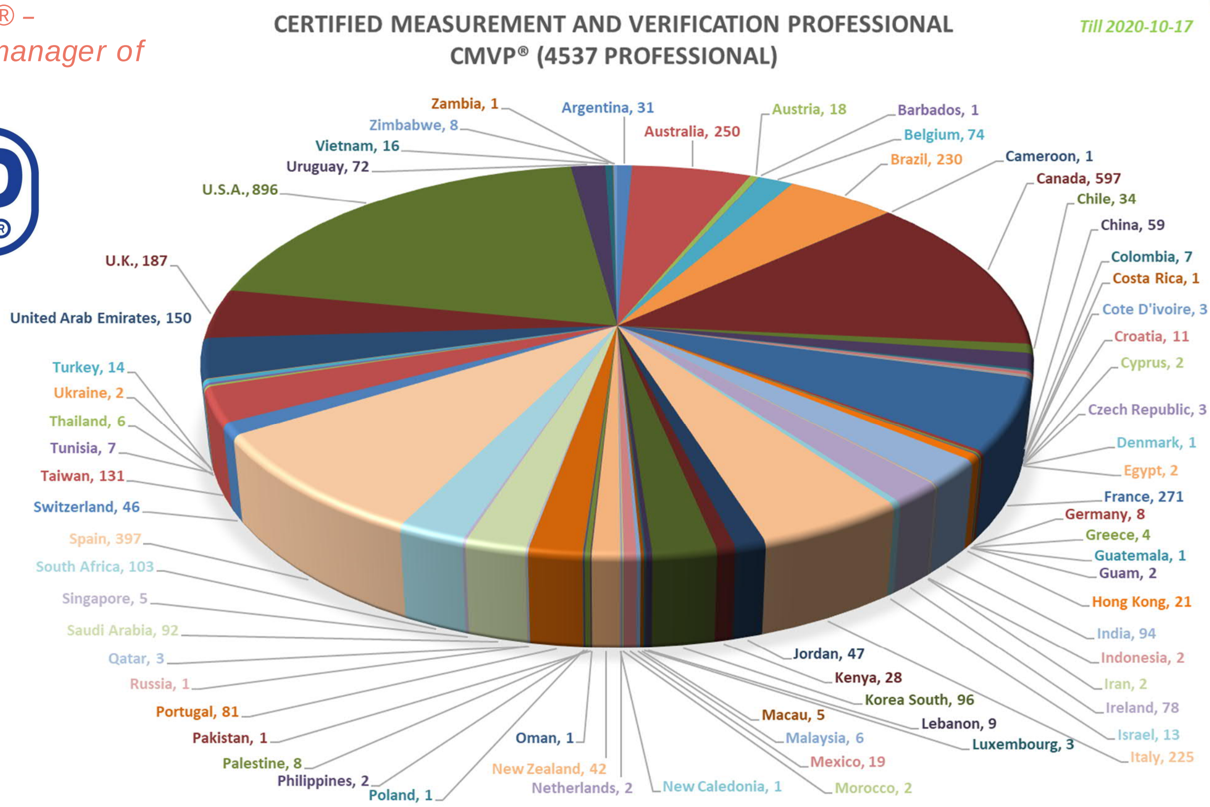
Role of CMVP® – As a project manager of M&V projects

CMVP®



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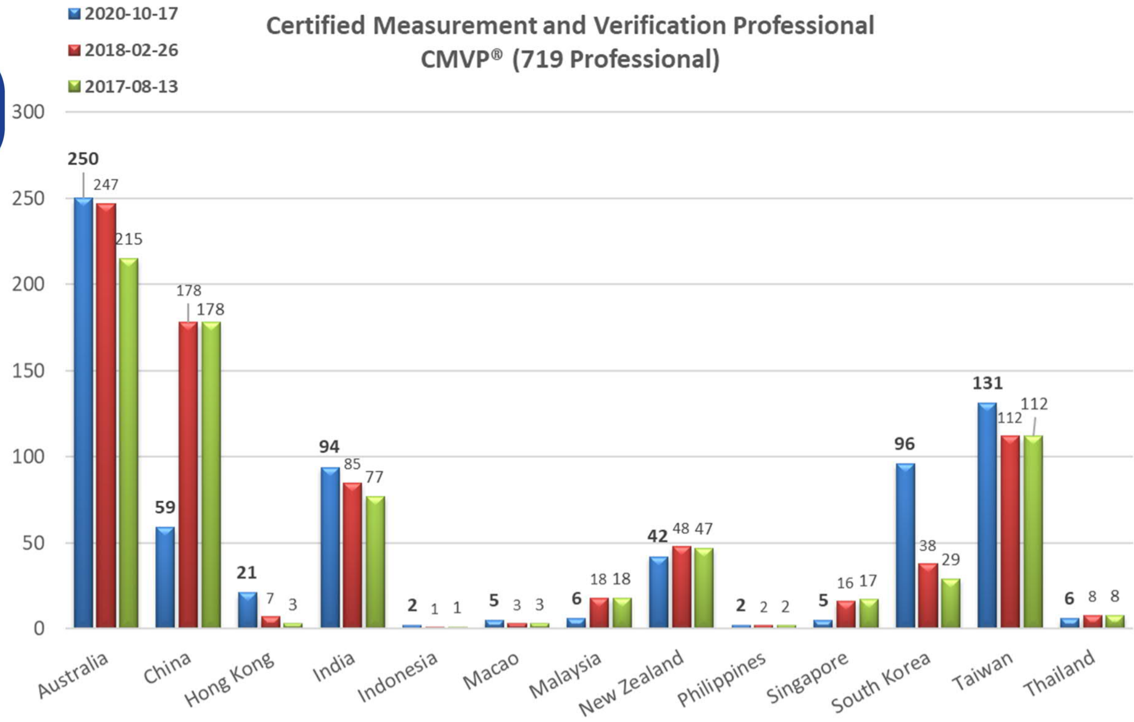
https://www.aeecenter.org/certifications/certifications/certified-measurement-verification-professional

Role of CMVP® –
As a project manager of
M&V projects



https://www.aeecenter.org/certifications/certifications/certified-measurement-verification-professional

Case Sharing –

- Measurement Boundary
- M&V Plan
- Lighting Project with Sampling Technique

Measurement Boundary / Interactive Effect

Measurement Boundary

- Notional boundaries drawn *around equipment, systems or facilities* to segregate those which are relevant to saving determination from those which are not.
- All Energy Consumption and Demand of equipment or systems within the boundary must be *measured or estimated*

Interactive Effect

- Energy impacts created by and Energy Conservation Measure (ECM) that cannot be measured with the *Measurement Boundary*

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Measurement Boundary / Interactive Effect

Saving may be determined for an ENTIRE FACILITY or a PORTION , depending on the ECM characteristics and the purpose of the reporting:

- If (…) equipment: a measurement boundary should be drawn around that equipment

  ➔ Option A or B

- If (…) total facility: the meters (…) total facility can used

  ➔ Option C

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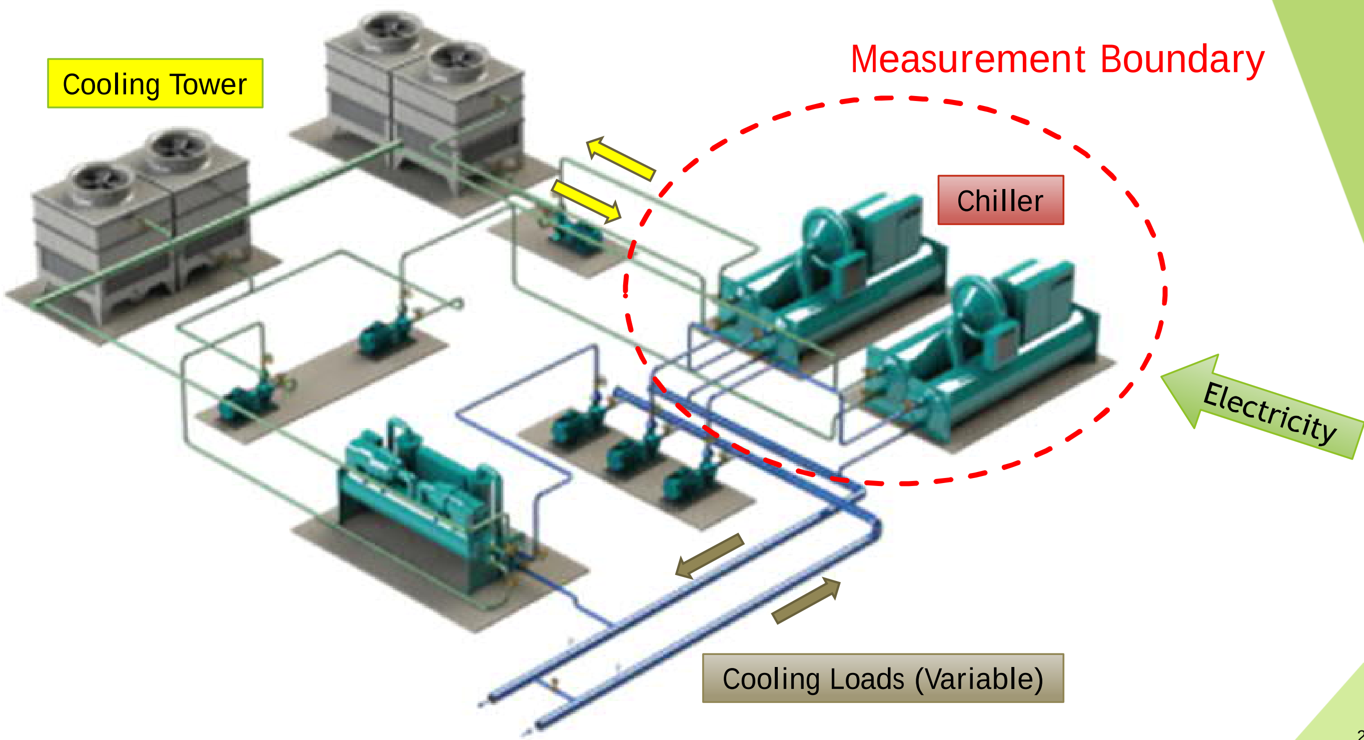
Example

Need additional meter?
Need additional measurement(s) or information?



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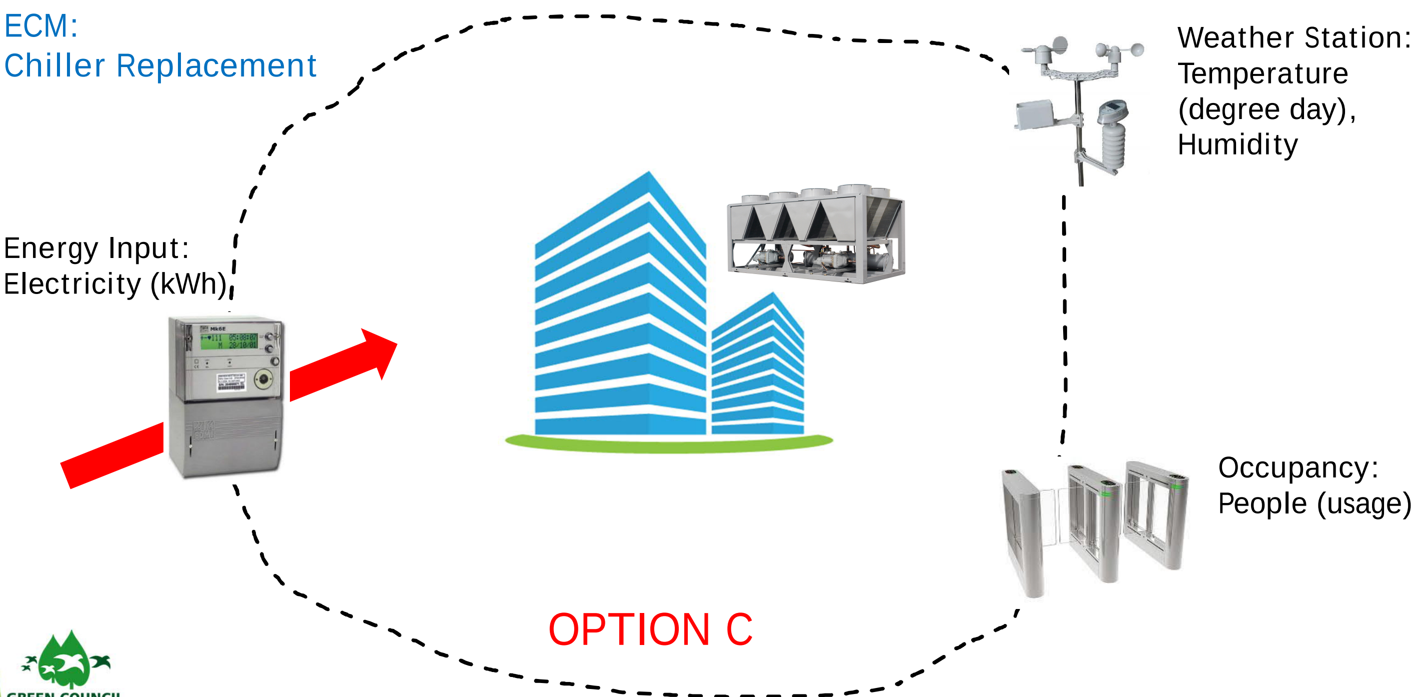
Typical building – Central AC Unit(s)

CASE 1

ECM:
Chiller Replacement



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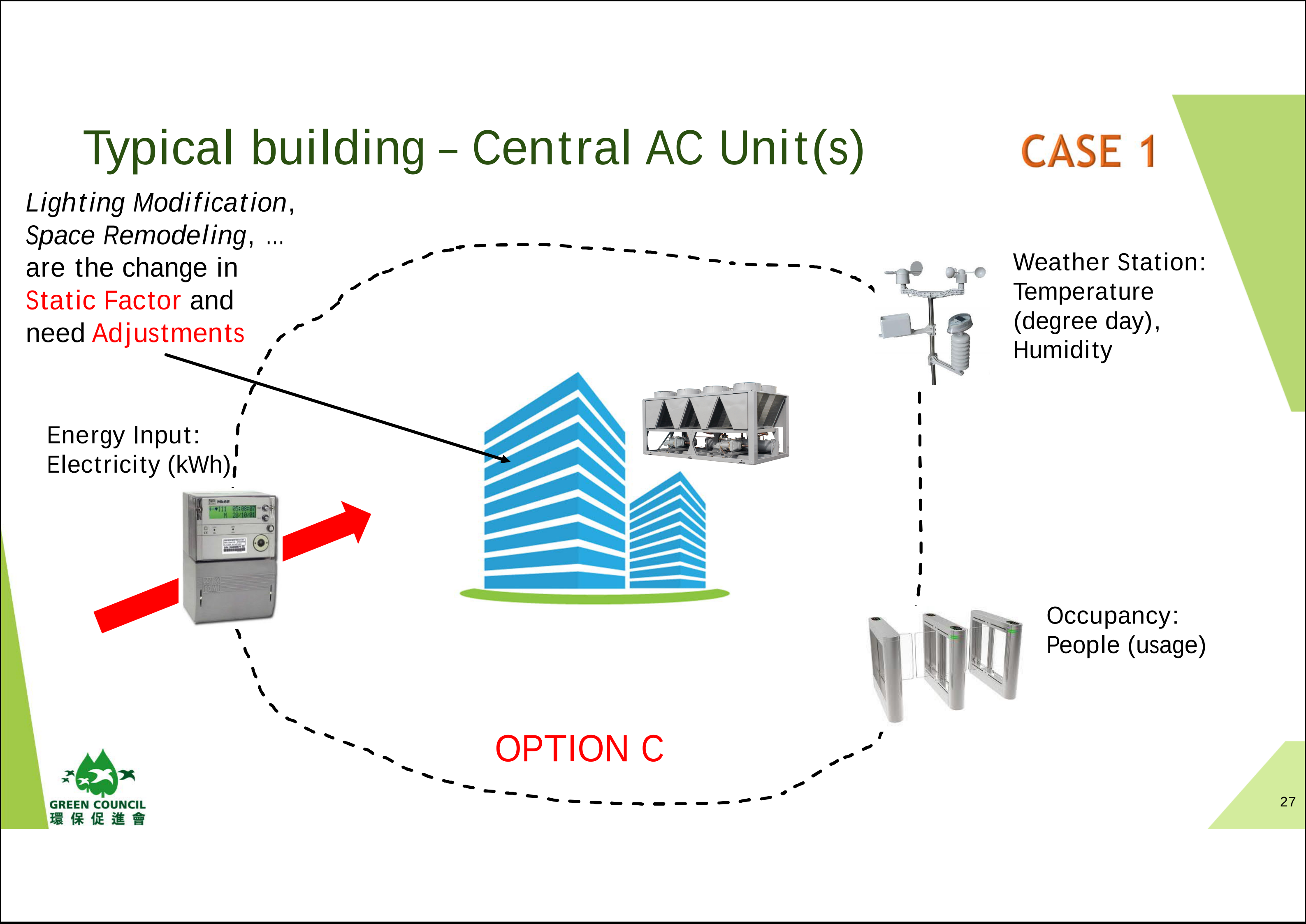
Typical building – Central AC Unit(s)
CASE 1
Lighting Modification, Space Remodeling, … are the change in Static Factor and need Adjustments
Weather Station: Temperature (degree day), Humidity
Energy Input: Electricity (kWh)
Occupancy: People (usage)
OPTION C
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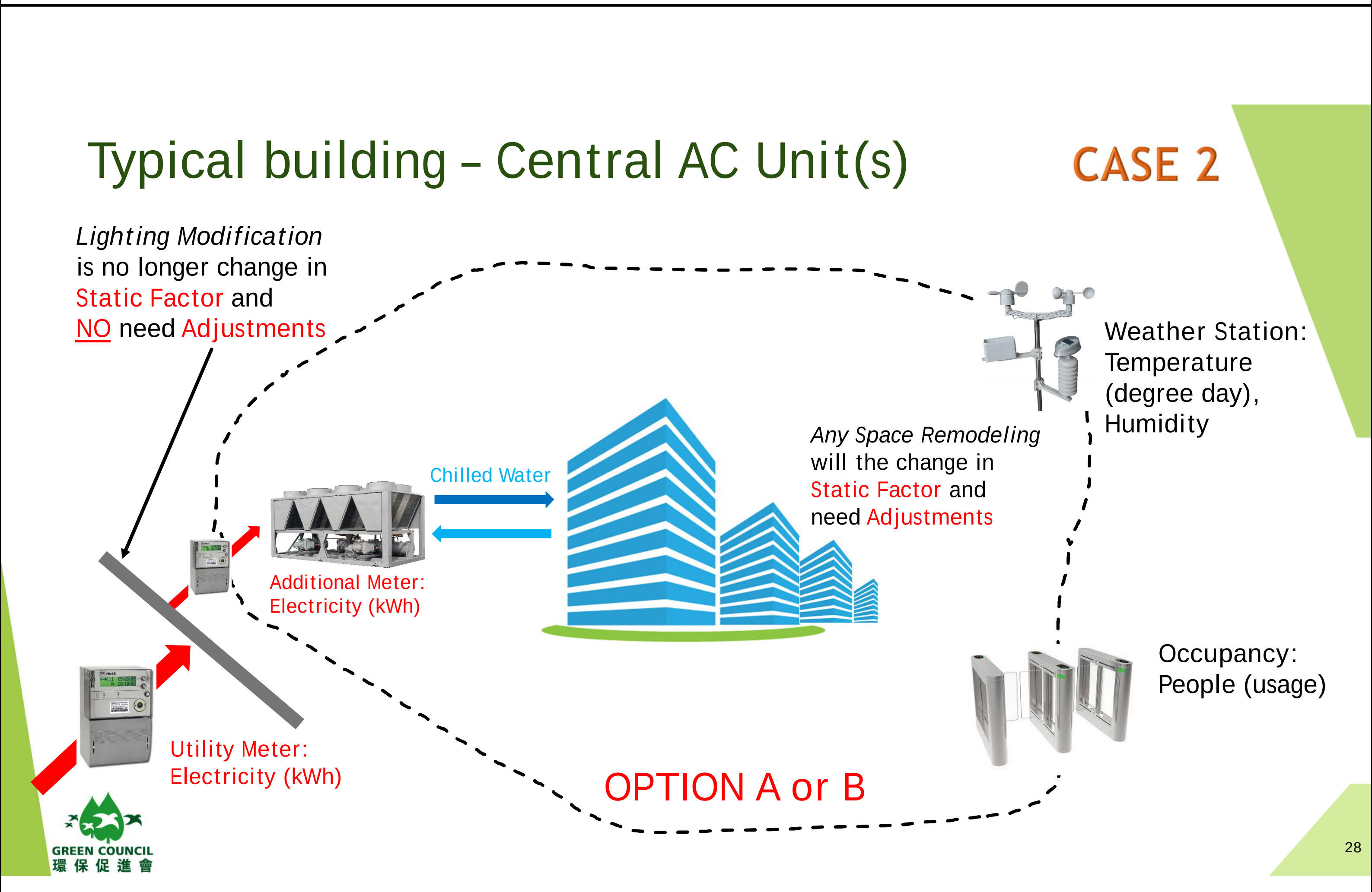
Typical building – Central AC Unit(s)
CASE 2
Lighting Modification is no longer change in Static Factor and NO need Adjustments
Weather Station: Temperature (degree day), Humidity
Chilled Water
Any Space Remodeling will the change in Static Factor and need Adjustments
Additional Meter: Electricity (kWh)
Utility Meter: Electricity (kWh)
Occupancy: People (usage)
OPTION A or B
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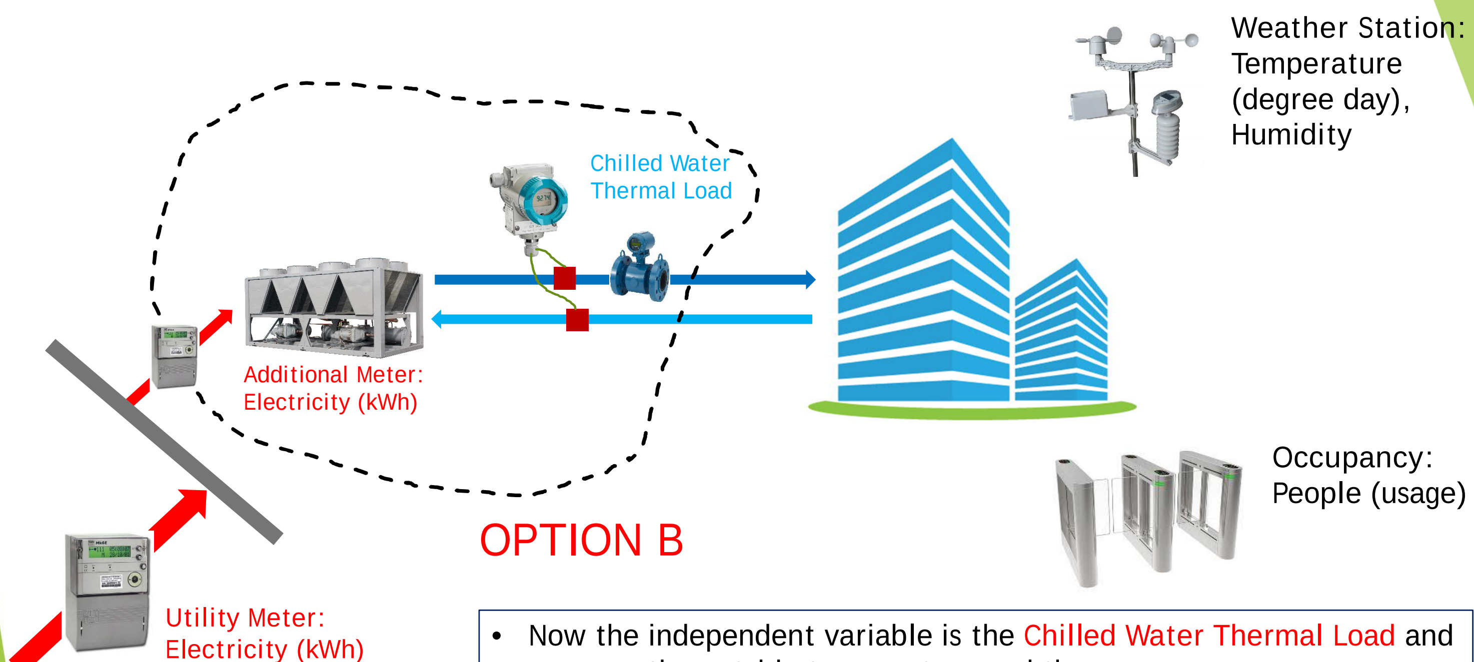
Typical building – Central AC Unit(s)

CASE 3



- Now the independent variable is the Chilled Water Thermal Load and no more the outside temperature and the occupancy.

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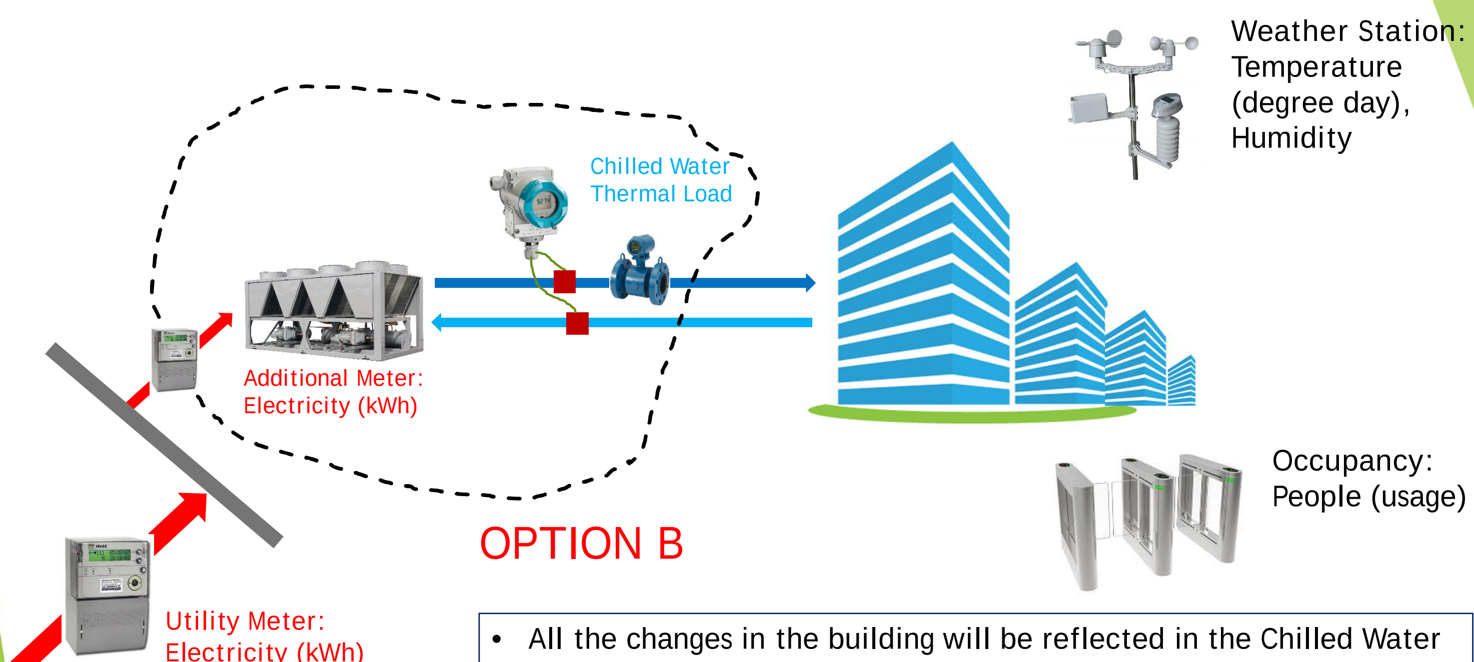
Typical building – Central AC Unit(s)

CASE 3



- All the changes in the building will be reflected in the Chilled Water Thermal Load already (OUTSIDE of the measurement boundary)

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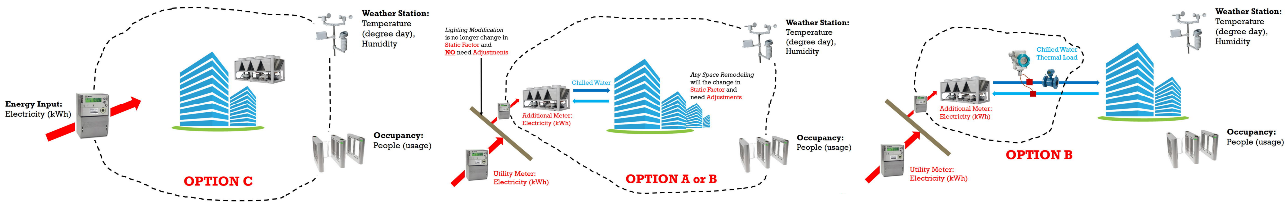
Pros & Cons

	CASE 1	CASE 2	CASE 3
PROS	• Baseline already ‘exists’ • No additional meter(s)	• Only 1 meter required • Chiller performance	• Chiller performance • No longer static factors
CONS	• Many Static factors • Need Adjustments	• Measure baseline period • Some static factors	• Measure baseline period • More meters added



M&V Plan (General Guidelines)

- Description of energy conservation measures (ECMs) and their intended results. (*)
- Definition of the M&V objectives and constraints consistent with the energy savings project objectives and constraints. (*)
- Identification of the *measurement boundary* and the *M&V options* to be utilized.
- Specification of M&V options & analysis procedures, algorithms, and assumptions.
- Documentation of the baseline conditions (facility characteristics, equipment data, operational considerations, and energy consumption data). (*)
- Specification of measurement equipment, measurement points, measurement period (pre- and post-installation) and measurement analysis.
- Identification of any planned changes in the building characteristics or operations. (*)
- Definition of analytical procedures and models to be used.
- Identification of the post-installation period conditions.

(*) Including in Energy Audit Process

M&V Plan (General Guidelines)

- Methods for making relevant baseline adjustments.
- Specification of the energy prices to be used for calculating cost savings. (*)
- Specification of the accuracy and uncertainty in the savings estimates and quality assurance procedures to minimize the risk.
- Definition of the responsibilities for the monitoring of the energy use data and baseline conditions.
- Specification of software, budget, and resource needs.
- Definition of the reporting format for the M&V results.
- *Operational verification* procedures that will be used to verify successful implementation of each ECM. (*)

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(*) Including in Energy Audit Process

M&V Plan (REMARKS)

For M&V Options A and D the following considerations need to be included:

- For Option A, documentation details of any stipulated parameters showing the overall significance of these parameters to the total expected saving and describing the uncertainty inherent in the stipulation.
- For Option D, documentation of the details (name and version number) of the simulation software, providing details of input files, output files, weather reference files, measurements, assumptions and calibration, accuracy, etc

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M&V Plan (TEMPLATE)


Efficiency Valuation Organization

M&V PLAN TEMPLATE

INTERNATIONAL PERFORMANCE MEASUREMENT AND VERIFICATION PROTOCOL (IPMVP)

October 1, 2020

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(*) Including in Energy Audit Process

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M&V Plan – Example ("SCHOOL A")

BACKGROUND AND FACILITY'S DESCRIPTION

- The "School A" is located in downtown Québec (Canada), and each year it receives over 1,000 students registered in different programs. The programs offered in this institution are grouped in the following categories: 1) Motorized equipment; 2) Leather, textile and clothing; 3) Restaurant and catering.
- In addition to administrative offices and classes, the building houses engineering workshops, garages, kitchens, a restaurant and a semi-Olympic sized swimming pool.
- The engineering workshops and garages cover more that <u>20% of the building's total surface area</u>;
- The kitchens - including the bakeries, pastry areas and butcher's - use almost <u>10% of the total surface area</u>;
- Inventory of the building's heating, ventilation, and air conditioning systems (HVAC) as well as that of its compressors and domestic water heaters on the followings:

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M&V Plan – Example ("SCHOOL A")

BACKGROUND AND FACILITY'S DESCRIPTION

Year constructed	1968
Surface area	24,577 m^2
Energy sources and uses	➢ Electricity • Lighting • Ventilation • Air conditioning • Compressors • Welding equipment • Computer hardware • Other ➢ Natural gas • Boilers and direct-fired air heaters
Type of heating	Hot water and direct-fired air heaters
Energy consumption at reporting period	50,114 GJ
Energy intensity at reporting period	1.76 GJ/m^2

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1. Energy Conservation Measure (12 items)

	ECM	Description	Annual Savings
1	Optimization of auditorium ventilation system controls	The addition of variable frequency drives will enable air flow into the auditorium to be controlled. To reduce the energy the fans consume, air flow will be adjusted according to auditorium occupancy. A CO_2 sensor will ensure a minimum fresh air flow. It will also enable zone damper controls to be adjusted, which will reduce fresh air intake into the CA-1 system.	$2,236
2	Optimization of garage ventilation system controls	The addition of variable frequency drives will enable air flow into the garage to be controlled. For the safety of the garage users, air volume will be adjusted based on carbon monoxide (CO) and nitrogen dioxide (NO_2) levels. The system will also adjust flow depending on whether the exhaust collector is on and the room's motion detector is activated.	$53,112
3	Optimization of cafeteria ventilation system controls	Variable frequency drives will be added to reduce air flow into this room. Flow will be controlled based on cafeteria occupancy and vent hood use. To optimize the system, motion detectors, CO_2 sensors and zone dampers will be installed.	$925

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1. Energy Conservation Measure (12 items)

	ECM	Description	Annual Savings
4	Optimization of body shop ventilation system controls	Existing equipment will be replaced with a variable frequency drive system. Heating will be provided by a glycol coil connected to the low-temperature system. The system can be used to pressurize the hall to avoid spreading contaminants to other sectors. A motion detector in the room will determine when the system operates.	$29,982
5	Optimization of gym ventilation system controls	Motion detector, CO_2 sensor and zone damper systems will be added to optimize fresh air input.	$6,231
6	Heat recovery and air preheating in the A-15, A-16 and A-17 systems	The recovery system will be connected to the low-temperature system, which will enable the building's domestic water to be preheated.	$14,780

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1. Energy Conservation Measure (12 items)

	ECM	Description	Annual Savings
7	Temperature reduction with night setback	Temperature set points will be lowered at night by 2 °C—a very conservative value. If this reduction does not cause building users any discomfort or inconvenience, the building manager will further lower temperature set points.	$4,512
8	Hot water supply system temperature adjustment	The existing hot water system will be converted into a variable flow system in each zone.	$62,232
9	Variable displacement pump in the peripheral heating system	The entire high-temperature hot water system will be controlled through the building's energy management system. Water temperature will be tightly controlled through temperature sensors to reduce system loss. Differential pressure sensors will lower the pumping system flow rate by about 40%.	
10	Heating of the high-temperature hot water system with an electric boiler	This measure proposes adding an electric boiler for off-peak heating. Using an instant power reading, a 300 kW or so electric boiler will be able to feed hot water into the system during off-peak hours.	

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1. Energy Conservation Measure (12 items)

	ECM	Description	Annual Savings
11	Heating of the low-temperature system with a heat pump	An air-to-water heat pump system will be installed. To maximize the system's operating range and capacity, outside air will be mixed with air from the building's exhaust systems. The installation of a solar wall is planned, which will preheat the outside air used by the heat pumps.	$33,708
12	Mechanical pool dehumidifier and heat recovery	This measure proposes replacing the DA-1 system with an energy-recovering mechanical dehumidifier as well as replacing the existing ventilation system. The dehumidifier will recover energy that can be used to heat the space in winter and mid-season. It will also heat the pool water and one of the heating systems if needed.	$23,267

Estimate of Total Project Savings

	Annual Consumption Before	Annual Consumption After	Savings	Savings	Savings
Electricity	4,715,280 kWh	6,318,475 kWh	-1,603,195 kWh	-$ 124,404	-34%
Natural gas	874,601 m^3	116,453 m^3	760,903 m^3	$ 353,153	87%
Total	50,114 GJ	27,055 GJ	23,059 GJ	$ 228,749	46%

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M&V Plan – Example ("SCHOOL A")

2. Measurement OPTION and BOUNDARY

IPMVP Option Used to Determine Savings
Option C According to the IPMVP, Volume I

Justification of the Selected Option, Gain/Reporting Period Ratio
The measurement option for the whole facility was chosen because the energy providers' meters are used to assess the energy performance of the whole facility. This option determines collective savings for all energy conservation measures (ECMs) implemented.

Measurement Boundary
Option C: Whole Facility

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M&V Plan – Example ("SCHOOL A")

3.1 Baseline Period

The baseline period starts on July 1, 2010, and ends on June 30, 2011, corresponding to a 1-year period.

3.1 Baseline Electricity Consumption

Billing Period		Electricity Consumption
From	To	kWh
2010-07-01	2010-07-31	321,120
2010-08-01	2010-08-31	335,520
2010-09-01	2010-09-30	412,560
2010-10-01	2010-10-31	394,560
2010-11-01	2010-11-30	424,080
2010-12-01	2010-12-31	409,680
2011-01-01	2011-01-31	431,280
2011-02-01	2011-02-28	418,320
2011-03-01	2011-03-31	433,440
2011-04-01	2011-04-30	393,120
2011-05-01	2011-05-31	401,760
2011-06-01	2011-06-30	339,840
Total		4,715,280

3.1 Baseline Natural Gas Consumption

Billing Period		Natural Gas Consumption
From	To	m^3
2010-06-25	2010-07-26	7,970
2010-07-27	2010-08-24	12,244
2010-08-25	2010-09-23	26,441
2010-09-24	2010-10-25	49,478
2010-10-26	2010-11-23	78,797
2010-11-24	2010-12-21	112,010
2010-12-22	2011-01-26	159,910
2011-01-27	2011-02-23	144,722
2011-02-24	2011-03-24	119,151
2011-03-25	2011-04-25	87,995
2011-04-26	2011-05-25	50,595
2011-05-26	2011-06-26	25,288
Total		874,601

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M&V Plan – Example ("SCHOOL A")

3.4 Independent Variables

- For electricity consumption, the relevant independent variables are the heating degree-days (HDD) and the number of class days

Period		Heating Degree-Days (°C)	Number of class days
From	To		
2010-07-01	2010-07-31	12.7	0
2010-08-01	2010-08-31	19.4	6
2010-09-01	2010-09-30	147.6	20
2010-10-01	2010-10-31	353.4	20
2010-11-01	2010-11-30	526.7	20
2010-12-01	2010-12-31	767.5	15.5
2011-01-01	2011-01-31	876.0	14
2011-02-01	2011-02-28	773.7	18
2011-03-01	2011-03-31	696.8	17
2011-04-01	2011-04-30	436.3	15
2011-05-01	2011-05-31	220.9	17.5
2011-06-01	2011-06-30	54.2	0
Total		**4,885**	**163**

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M&V Plan – Example ("SCHOOL A")

3.4 Independent Variables

- For natural gas consumption, the relevant independent variables are the heating degree-days (HDD)

Period		Heating Degree-Days
From	To	°C
2010-06-25	2010-07-26	19.4
2010-07-27	2010-08-24	22.1
2010-08-25	2010-09-23	109.6
2010-09-24	2010-10-25	321.8
2010-10-26	2010-11-23	447.2
2010-11-24	2010-12-21	670.2
2010-12-22	2011-01-26	982.8
2011-01-27	2011-02-23	778.2
2011-02-24	2011-03-24	690.1
2011-03-25	2011-04-25	530.1
2011-04-26	2011-05-25	248.0
2011-05-26	2011-06-26	78.1
Total		**4,898**

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M&V Plan – Example (“SCHOOL A”)

3.5 Static Factors

- Static factors include equipment and operating. If a change occurs in the data and parameters, the baseline must be adjusted (permanently or temporarily).
- A series of static factors to be monitored for this project:

Static factors	Source of Data
Building or area utilization	Detailed feasibility study of the energy efficiency project and floor drawings
Building occupancy rate	Detailed feasibility study of the energy efficiency project
Building floor area	Floor drawings
Number and capacity of heating, ventilation, and air conditioning systems (HVAC)	Present M&V plan
Building standards and legislation governing ambient conditions	Client's conditions
Building utilization schedule	Present M&V plan and detailed feasibility study of the energy efficiency project
Hours of operation of HVAC systems	Present M&V plan
Lighting hours of operations	Detailed feasibility study of the energy efficiency project
Outdoor air supply rate	Detailed feasibility study of the energy efficiency project
Temperature setpoints	Detailed feasibility study of the energy efficiency project
Hot and chilled water temperature	Detailed feasibility study of the energy efficiency project

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M&V Plan – Example (“SCHOOL A”)

4.0 Reporting Period

- The reporting period starts after ECM(s) implementation.
- A one-year reporting period corresponds to a period of 12 consecutive months.

5.0 Description of the Baseline Adjustment Methodology

5.1 Basis for Adjustment

Retained Option	Equation
Avoided energy use (or energy savings)	Avoided energy use = Baseline energy (±) **Routine** adjustments to reporting period conditions (±) **Non-routine** adjustments to reporting period conditions (-) Reporting period energy

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M&V Plan – Example ("SCHOOL A")

5.2 Routine Adjustments

5.2.1 Electricity

Baseline electricity consumption data are adjusted according to the following equation:

$$y = 56.59\ x_1 + 3{,}274\ x_2 + 325{,}430$$

where
y = Adjusted electricity consumption (kWh);
x_1 = Heating degree-days (°C);
x_2 = Number of class days;
325,430 = Baseline consumption (kWh).

The regression analysis is considered satisfactory according to generally accepted standards for this type of analysis. The following table presents statistical indicators for this regression:

Multiple Coefficient of Determination	Value	Recommendations
Coefficient of determination (R^2)	0.92	> 0.75
Coefficient of variation of the RMSE	0.030	< 0.2
t-statistic (for variable x_1)	4.15	< -2 or > 2
t-statistic (for variable x_2)	5.58	< -2 or > 2
t-statistic (for baseline consumption)	43.39	< -2 or > 2

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M&V Plan – Example ("SCHOOL A")

5.2 Routine Adjustments

5.2.2 Natural Gas

Baseline natural gas consumption data are adjusted according to the following equation:

$$y = 159.73\ x_1 + 7{,}692$$

where
y = Adjusted natural gas consumption (m3);
x1 = Heating degree-days (°C);
7,692 = Baseline consumption (kWh).

The regression analysis is considered satisfactory according to generally accepted standards for this type of analysis. The following table presents statistical indicators for this regression:

Multiple Coefficient of Determination	Value	Recommendations
Coefficient of determination (R^2)	0.99	> 0.75
Coefficient of variation of the RMSE	0.082	< 0.2
t-statistic (for variable x_1)	5.58	< -2 or > 2
t-statistic (for baseline consumption)	2.72	< -2 or > 2

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M&V Plan – Example ("SCHOOL A")

5.3 NON-Routine Adjustments

Baseline adjustment in case of equipment addition/removal/shutdown or change in operation:

- In the event that the facility adds/removes/shuts down equipment or changes its operations, data will be collected from drawings and specifications, equipment specifications, manufacturer and contractor information and/or short-term measurement campaigns.
- The procedure will be based on the impact of such changes on static factors.
- The new devices' operating hours may be estimated, at the client's convenience, based on the type of use.

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M&V Plan – Example ("SCHOOL A")

6.0 Energy Price Adjustments

7.0 Meter Specifications

8.0 Monitoring Responsibilities

Monitoring Responsibilities – Independent Variables

Person in Charge	Data	Frequency
ESCO: **Mr. Brown** **Eng., Technical Expert**	Heating degree-days, data collected from Environment Canada	Monthly
	Number of class days, data collected from the School A school calendars	Annually

Monitoring Responsibilities – Energy Data

Person in Charge	Data	Frequency
School A: **Mr. White** **Facility Controller, Material Resource Services**	Hydro-Québec meter	Monthly
	Gaz Métro meter	

Monitoring Responsibilities – Static Factors

Person in Charge	Data	Frequency
School A: **Mr. White** **Facility Controller, Material Resource Services**	Changes in occupancy schedules	Monthly
	Changes in systems schedules	
	Equipment addition/removal/shutdown in the building	Addition: 5 days after Removal: 5 days before Shutdown: Once a month

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M&V Plan – Example ("SCHOOL A")

12.0 Format of the M&V Report

M&V report for the "School A" – Date XX-XX-XXXX

1. Facility consumption and demand data (utility bills)
   a. Electricity consumption and demand data
   b. Natural gas consumption data
   c. Summary chart of facility consumptions and demands
2. Baseline period adjustment data
   a. Independent variables
   b. Static factors
3. Readjusted baseline period calculation
4. Energy savings calculations (kWh, m^3 and $)
5. Evaluation of cumulative savings from the start of the project, on a yearly basis

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M&V Plan (Checklist)

With reference to IPMVP Core Concepts 2016

✓	M&V Plan Component
1.	FACILITY AND PROJECT OVERVIEW
	Overall description of facility: Adequate and clear?
	Overall description of proposed project: Adequate and clear?
	List of all ECMs in the project: Adequate and clear?
	Reference to any energy audit reports or other analysis used to scope the project: Attached and available?
2.	ECM INTENT (Complete for each measure)
	Measure description: Specific, adequate and clear?
	How the measure saves energy or other resources: Adequate and clear?
	Affected equipment inventory: Adequate and clear?
	Expected savings: Clearly stated?
3.	SELECTED IPMVP OPTION AND MEASUREMENT BOUNDARY
	Option selected: Is it appropriate?
	Measurement boundary defined: Is it clear what the boundary is?
	Are the likely significant interactive effects identified? e.g. a lighting upgrade will increase winter heating energy
	Description of any interactive effects and their likely impact on project savings: Are they clearly described and quantified?

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M&V Plan (Checklist)

With reference to IPMVP Core Concepts 2016

✓	M&V Plan Component
4.	BASELINE: PERIOD, USAGE AND CONDITIONS (within each measurement boundary)
	Identification of baseline period: Does it include start dates, end dates, etc?
	Baseline energy data (dependent variable): Clearly presented?
	Baseline independent variables: Clearly presented?
	Baseline static factors: Adequately identified and described, within the measurement boundary?
5.	REPORTING PERIOD
	Identify the reporting period(s). Is it specifically described?
	Are reporting period dates (start and end) clearly shown?
	If baseline and reporting periods are of different lengths is there an explanation as to how the time frames will be normalized to enable an even and reliable comparison?
6.	BASIS OF ADJUSTMENT
	Clearly shows whether adjusting to reporting period conditions, baseline conditions, or to normalized conditions?
	Are routine adjustments clearly identified?
	Are any adjustments that may be need to be made to the baseline to account for baseline equipment problems or code compliance issues that will be addressed by the ECM identified?
	Is there clear general description of how adjustments for changes to static factors will be made?
	For known baseline adjustments that will need to be made, has the data and methodology for undertaking these adjustments been clearly described, and is it reasonable?

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M&V Plan (Checklist)

With reference to IPMVP Core Concepts 2016

✓	M&V Plan Component
7.	CALCULATION METHODOLOGY AND ANALYSIS PROCEDURE
	Are specify data analysis procedures, model description and assumptions that will be used to calculate savings for each reporting period presented, including supporting spreadsheets? Is this adequate and error-free?
	For each model used define and identify all independent variables, dependent variables and other model related terms, coefficients, constants and statistical methods, and the range of independent variables over which the model is valid. Is this clearly presented, adequate and error-free?
	Are sampling methods clearly described?
	Is the methodology for calculating savings clearly described?
	Is the error analysis/uncertainty clearly described?
8.	ENERGY PRICES
	Are the tariff's that will be used to calculate the cost savings clearly identified?
	Is how the monetary value of savings will be adjusted if utility tariffs change described, clearly listing any assumed or stipulated values?

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M&V Plan (Checklist)

With reference to IPMVP Core Concepts 2016

✓	M&V Plan Component
9.	METER SPECIFICATION
	Are utility meters clearly identified?
	Are any non-utility meters clearly identified and described, including the loads metered?
	Is the meter reading and witnessing protocol described and adequate?
	Are meter commissioning and calibration procedures adequately described?
	Is there a description of how data will be accessed/transferred?
	Is there a description of what will be done to mitigate data losses?
10.	MONITORING RESPONSIBILITIES
	Are there clear responsibilities allocated for collecting, analysing, archiving and reporting the data, covering energy data, independent variables, static factors and periodic inspection findings?
11.	EXPECTED ACCURACY
	Is the expected accuracy associated with measurement, data capture, sampling and data analysis clearly specified, along with overall uncertainty?
	Are qualitative and any feasible quantitative measurements related to the level of uncertainty described?
	Is there a description of how uncertainty will be calculated and presented in the planned savings report(s)?

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M&V Plan (Checklist)

With reference to IPMVP Core Concepts 2016

✓	M&V Plan Component
12.	BUDGET
	Is the budget and resources required for M&V reporting provided, including covering setup costs, data collection costs, any data storage costs, report generation costs, meetings?
	Is the M&V reporting budget reasonable? (3% to 10% of savings)
13.	REPORT FORMAT
	Is a template for the report(s) provided?
	Is the reporting frequency stated?
14.	QUALITY ASSURANCE
	Are QA procedures clearly identified and in place?
ADDITIONAL REQUIREMENTS FOR OPTION A	
	Are the variables that that will be estimated identified?
	Are the values of the estimated variables and the source of these values clearly shown and adequate?
	Are the range of likely estimated savings within the range of plausible values of the estimated parameter shown?
	Are the periodic inspections that will be performed in the reporting period to verify that the equipment is still in place and operating as assumed shown, including frequency of inspection and responsibility?

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Lighting Project

- De-lamping
- Upgrade energy efficient lighting
- Install the occupancy sensor or intelligence controller

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Lighting Project

Purpose

- The lighting efficiency improvement project aimed to reduce the connected lighting load while maintaining the light level within XXXXXXXXXX guidelines/standards.

Measurement Boundary

- Project savings will be determined within a measurement boundary that encompasses only the 9,500 light fixtures (Fluorescent (9000 fixtures) & Incandescent (500 fixtures) subject to the retrofit project.
- Measurements will be made of the electrical power required by the fixtures only.

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Lighting Project

Interactive Effects - the measurement boundary EXCLUDES:

- Energy interactions with the building heating and cooling systems.
  - Assumed that the cost of extra winter heating in the perimeter zones is approximately offset by the summer cost savings in the electric air conditioning system. Therefore heating and cooling interactive effects will be ignored.
- The possible impact of occupants adding task lights connected to the building electrical distribution in random places which will not be measured when measuring light fixture power. Therefore the possible interactive effect of task lamps is expected to be minimal and is ignored.

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Lighting Project

IPMVP Option

- Option A was selected as it offers the best opportunity to minimize the costs of evaluating savings performance of the lighting contractor.

Measurement Equipment

But how many?

- Lighting power will be measured by random sampling of the power required by the fixtures of each type. Power will be measured by a freshly calibrated true RMS wattmeter owned by the contractor.
- This meter has a rated accuracy of 2% of reading.

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Lighting Project

Measurement Process

- The contractor will measure power flow at randomly selected light switches, during unoccupied periods.
- The switches randomly chosen as measurement points will be recorded in the pre-retrofit test so that the same locations can be used after retrofit.
- Sampling will be performed until the variances noted yield an error in sampling of no more than 10% for the existing fixtures and 2% for the new ones (based on IPMVP Uncertainty Assessment 2019 Jul – Eq. #5).

Standard Error (SE) of the Mean of a Sample ($\mathbf{s(\bar{x})}$)

This measure is used in estimating the precision of the average $\mathbf{s(\bar{x})}$ (estimated through a sample) and is calculated as the sample standard deviation (s) divided by $\sqrt{n}$.

$$s(\bar{x}) = \frac{s}{\sqrt{n}} \qquad \text{Equation 5}$$

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Lighting Project

Measurement Process

- The post retrofit measurements will be made at as many of the pre-retrofit measurement points as needed, or more, to achieve this sampling error specification. A minimum of 100 lamps shall be assessed in the post-retrofit sampling of each lamp type.
- Each measurement will record the number of operating lamps, burned out lamps and fixtures connected to the switch, verified by turning the switch "ON" and "OFF".
- A licensed electrician will do the measurement and power flow will be measured long enough to ensure a stable reading has been obtained, expected to be only a few seconds at each switch.

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Lighting Project

Baseline Energy

- The pre-retrofit measurements will be made one week before the retrofit process. The mean power of each fluorescent and each incandescent lamp will be determined, along the net sampling error achieved.

Independent Variables

- Measurements will be made of installed lighting load immediately before and after retrofit.
- There are no routinely varying factors affecting lighting power in this short time frame, so NO independent variables are measured for use in the savings computation.

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Lighting Project (Baseline)

Pre-Retrofit Lighting Power

Baseline Fluorescent Fixtures

Room	Number of Fixtures	Number of Lamps Operating	Number of Lamps Non-Operating	Power (watts)	Watts per Operating Lamp
1-2	3	12	0	557	46.42
1-5	4	15	1	701	46.73
1-22	4	16	0	752	47.00
1-27	12	43	5	2,025	47.09
1-31	6	24	0	1,150	47.92
1-35	6	22	2	1,040	47.27
5-24	15	58	2	2,771	47.78
5-25	3	10	2	477	47.70
5-29	12	46	2	2,202	47.87
5-33	22	84	4	3,998	47.60
Total		1373	71	60,955	
Mean Wattage Operating Lamps =				**44.40**	
	n-1 =	1,372			
			Burnout Fraction =	**4.9%**	
			Number of Fixtures in Building =	9,000	
			Number of Lamps in Building =	36,000	
			Estimated Total Burnouts =	1,770	
			Estimated Number of Operating Lamps (N) =	34,230	
			Computed Sampling Error	**$\boxed{7\%}$**	

$$SE = \frac{s}{\sqrt{n}} = 0.07(7\%)$$

where
s=2.5891,
n=1373

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Lighting Project (Baseline)

Baseline Incandescent Fixtures					
Room	Number of Fixtures	Number of Lamps: Operating	Number of Lamps: Non-Operating	Power (watts)	Watts per Operating Lamp
1 A West Corr	25	25	0	1,503	60.12
2 B North Corr	40	38	2	2,240	58.95
2 C East Corr	20	19	1	1,142	60.11
3 C South Corr	10	8	2	477	59.63
3 A North Corr	15	15	0	901	60.07
4 B East Corr	22	21	1	1,259	59.95
4C South Corr	33	30	3	1,720	57.33
5 A North Corr	40	35	5	2,100	60.00
5 B South Corr	22	20	2	1,102	55.10
Total		211	16	12,444	
Mean Wattage Operating Lamps =				**58.98**	
	n-1 =	210			
			Burnout Fraction =	**7.0%**	
		Number of Fixtures in Building =		500	
		Number of Lamps in Building =		500	
		Estimated Total Burnouts =		35	
Estimated Number of Operating Lamps (N) =				465	
		Computed Sampling Error		**8%**	

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Lighting Project

Post-Retrofit (for Reporting)

- It will be assumed that this same burnout rate will apply on average for each lamp type after retrofit.
- A post-retrofit test will be conducted one week after retrofit. It will be the same as the baseline test and reported in the same form as the baseline test.
- It is expected that less sampling will be needed to achieve the 2% post-retrofit sampling error specification, since all fixtures are new.
- Light levels will also be measured at random in the space by building management staff to ensure XXXXXXXXXX guidelines/standards have been maintained.

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Lighting Project (Post-Retrofit)

Post-Retrofit Fluorescent Fixtures					
		Number of Lamps			
Room	Number of Fixtures	Operating	Non-Operating	Power (watts)	Watts per Operating Lamp
1-2	3	6	0	194	32.33
1-5	4	8	0	255	31.88
1-22	4	8	0	256	32.00
1-27	12	24	0	766	31.92
1-31	6	12	0	388	32.33
1-35	6	12	0	380	31.67
1-36	18	36	0	1,148	31.89
1-49	5	10	0	325	32.50
1-52	9	18	0	577	32.06
Total		134	0	4,289	
Mean Wattage Operating Lamps =				**32.01**	
	n-1 =	133			
			Burnout Fraction =	**0.0%**	
	Number of Fixtures in Building =			8,700	
	Number of Lamps in Building =			17,400	
	Estimated Total Burnouts =			-	
Estimated Number of Operating Lamps (N) =				17,400	
	Computed Sampling Error			**2%**	

Post-Retrofit Incandescent Fixtures					
		Number of Lamps			
Room	Number of Fixtures	Operating	Non-Operating	Power (watts)	Watts per Operating Lamp
1 A West Corr	25	25	0	344	13.76
2 B North Corr	40	40	0	566	14.15
2 C East Corr	20	20	0	281	14.05
3 C South Corr	10	10	0	144	14.40
3 A North Corr	15	15	0	209	13.93
Total		110	0	1,544	
Mean Wattage Operating Lamps =				**14.04**	
	n-1 =	109			
			Burnout Fraction =	**0.0%**	
	Number of Fixtures in Building =			500	
	Number of Lamps in Building =			500	
	Estimated Total Burnouts =			-	
Estimated Number of Operating Lamps (N) =				500	
	Computed Sampling Error			**2%**	

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Lighting Project

Stipulation

- There is a large variation in occupancy patterns, and occupancy is beyond the contractor's control. Therefore it was agreed to stipulate the operating hours (Option A).
- Lighting period loggers were installed in 20 rooms as representative of the occupancy patterns of the facility. Loggers were installed for one week in each selected room and it was demonstrated the fluorescent lights (58 hours per week) and the incandescent lamps (152 hours per week).

Reporting Conditions

- In order to report energy cost avoidance, the savings will be computed under:
  - stipulated post-retrofit operating hours and
  - assuming the same burnout rate as observed immediately before retrofit.

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Lighting Project

Measurement Cost and Accuracy

- The contractor will charge $XXXX for the savings report described herein.
- Beyond the uncertainty associated with the stipulation of operating hours, the net combined error of measurement and maximum allowable sampling error (IPMVP Uncertainty Assessment 2019 Jul, Eq. #22) will be:

Quantifiable accuracy of the baseline wattage (Acc.b) = $\sqrt{M^2 + Sb^2}$ = ±10.2%

Quantifiable accuracy of the post-retrofit wattage (Acc.p) = $\sqrt{M^2 + Sp^2}$ = ±2.8%

Then total quantifiable accuracy of the savings = $\sqrt{Acc.b^2 + Acc.p^2}$ = ±10.6%

Where:

M = Meter accuracy (+/-2%)
Sb = Sampling error maximum in baseline readings (+/-10%)
Sp = Sampling error maximum in post-retrofit readings (+/-2%)

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Lighting Project

Saving Formula

$$\text{Annual Demand Savings (kWmonth)} = \left[\frac{(Wb \times Nb)}{1{,}000} - \frac{(Wp \times Np \times \boxed{Bb})}{1{,}000}\right] \times 12$$

$$\text{Annual Consumption Savings (kWh/year)} = \left[\frac{kWmonth}{12}\right] \times H \times \left(\frac{365 days / year}{7 days / week}\right)$$

Where:

Wb = Baseline Mean Wattage
Nb = Estimated Number of Operating Lamps in the baseline
Wp = Post Retrofit Mean Wattage
Np = Number of new lamps installed
Bb = Burnout fraction observed in baseline test
H = Stipulated weekly hours of lamp operation

Prices:

Demand $12.21/kw-month
Consumption 7.32 cents/kWh

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Lighting Project

		Fluorescent Lamps	Incandescent Lamps
Measured Data:			
	Baseline		
	Wb (Watts)	44.40	58.98
	Nb (number)	34,230	465
	Bb (burnout)	5.2%	7.6%
	Post Retrofit		
	Wp (Watts)	32.01	14.04
	Np (number)	17,400	500
Stipulated Data:			
	H (per week)	58	152
Computed Savings:			
	kWh	2,990,786	165,494

		Fluorescent Lamps	Incandescent Lamps
Uncertainly Analysis:			
	Baseline		
	Meter accuracy	2%	2%
	Sampling Error	7%	8%
	Total Accuracy:	7%	8%
	Post Retrofit		
	Meter accuracy	2%	2%
	Sampling Error	2%	2%
	Total Accuracy:	3%	3%
	Total Accuracy of Saving:	7.8%	8.7%
		2,990,786 ± 7.8%	165,494 ± 8.7%

$$= \left[\frac{44.40 \times 34{,}230}{1000} - \frac{(32.01 \times 17{,}400)}{1000} \times (1 - 5.2\%)\right] \times 58 \times 52$$

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Lighting Project

Summary

The M&V Plan for this retrofit assumes:

- Operating hours will be measured before the retrofit. The hours for the lighting fixtures will be the same before and after the equipment retrofit for the purpose of energy savings calculations.
- Fixture powers before and after the retrofit will be measured.
- Interactive effects on heating and cooling equipment from the lighting retrofit will NOT be considered.
- Lighting levels will not decrease as a result of the lighting equipment retrofit. Existing lighting levels have been measured and recorded for each area.

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Reference Materials / Q&A

References Materials - Guidelines

ASHRAE Guideline 14-2014:

- Measurement of Energy, Demand, and Water Savings

US DOE FEMP:

- M&V Guidelines - Measurement and Verification for Performance-Based Contracts *Version 4.0*
  https://www.energy.gov/sites/prod/files/2016/01/f28/mv_guide_4_0.pdf

California Energy Evaluation Protocols:

http://www.calmac.org/events/EvaluatorsProtocols_Final_AdoptedviaRuling_06-19-2006.pdf

U.S.: Energy Efficiency Program Impact Evaluation Guide:

https://www4.eere.energy.gov/seeaction//topic-category/evaluation-measurement-and-verification

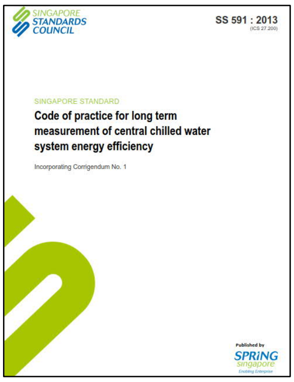
Australia: Measurement and Verification Operational Guide:

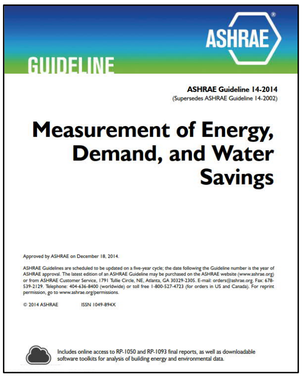
https://www.environment.nsw.gov.au/search?q=Measurement%20and%20Verification

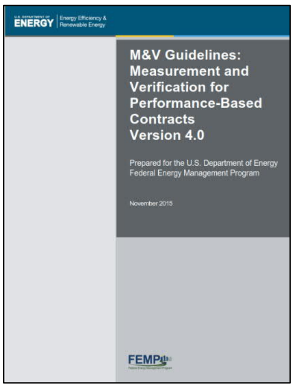
Singapore Standard – SS 591:2013:

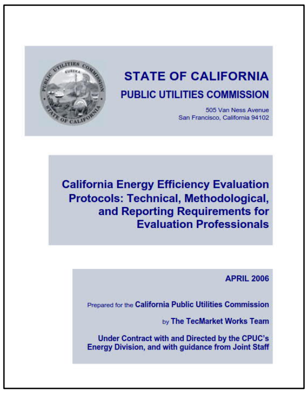
- Code of practice for long term measurement of central chilled water system energy efficiency

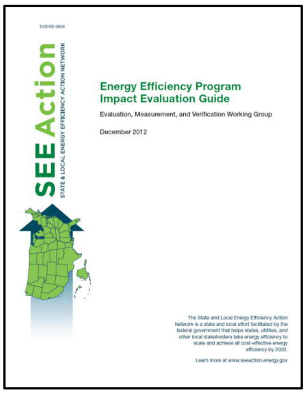
References Materials - Guidelines

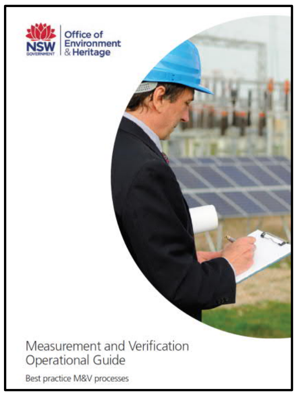












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References Materials – M&V Software Tools

- Energy Charting and Metrics Tool plus Building Re-tuning and Measurement and Verification (ECAM+) – *version 6.0*:
  - https://buildingretuning.pnnl.gov/ecam.stm
- RMV2.0 is an open-source R package for performing advanced measurement and verification 2.0 (M&V 2.0)
  - https://lbnl-eta.github.io/RMV2.0/
- Universal Translator 3 (UT3 Release - August 2017 - version 3.0.1708.2913 Release 3)
  - http://utonline.org/cms/node/235
  - https://simulationresearch.lbl.gov/sites/all/files/phil_haves_-_development_of_diagnostic_and_measurement_and_verification_tools_for_commercial_buildings.pdf

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Quiz – Case Analysis

In a medical clinic, with several services including outpatient, intensive care and radiological examinations, an upgrade of the lighting to LED was undertaken.

In the *baseline period*, the power drawn by a sample of each type of luminaire and the time of use in each environment was measured. It was verified that the lighting usage was determined by the occupancy of the clinic. There was an access control device at the entrance to the clinic which enabled a relationship to be established between the number of people in the clinic and the daily consumption of the lighting.

In the *reporting period*, power usage of a sample of the LEDs was also measured, and the daily consumption was calculated using the relationship established in the baseline between occupancy and lighting usage. In this case:

A. Occupation is a static factor, which can be determined by the registry at the clinic entrance
B. Occupation is an independent variable
C. The procedure is incorrect because the overall power draw of the lighting has not been measured
D. The interactive effect on the air conditioning system does not depend on occupancy.

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Thank you very much

Q&A

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25 January 2021

Training Course for Building Energy Management (Session 2)

Experience Sharing by Winner of
Hanson Grand RCx (Implementation) Award
Energy Saving Championship Scheme 2019

Agenda

1. GREEN INITIATIVES OF HK ELECTRIC

2. INTRODUCTION TO ELECTRIC TOWER

3. ESO 1 - OPTIMISATION OF CRAC UNITS BY CONTINUOUSLY MATCHING COOLING OUTPUT TO HEAT LOAD USING AI TECHNOLOGY TO REDUCE ENERGY CONSUMPTION

4. ESO 2 - OPTIMISATION OF CENTRALIZED MVAC INSTALLATION BY UPGRADING AIR-COOLED CHILLED WATER PLANT TO WATER-COOLED CHILLED WATER PLANT AND ENHANCING PAUS/AHUS WITH VARIABLE SPEED DRIVE

5. ESO 3 - LIGHTING ENHANCEMENT WORK AT VARIOUS OPERATIONAL AREAS

6. CHALLENGES & FUTURE ENHANCEMENTS

HK Electric - S.U.S.T.A.I.N

Operating the business in a responsible manner while meeting the long-term needs of the community

Corporate CSR Committee

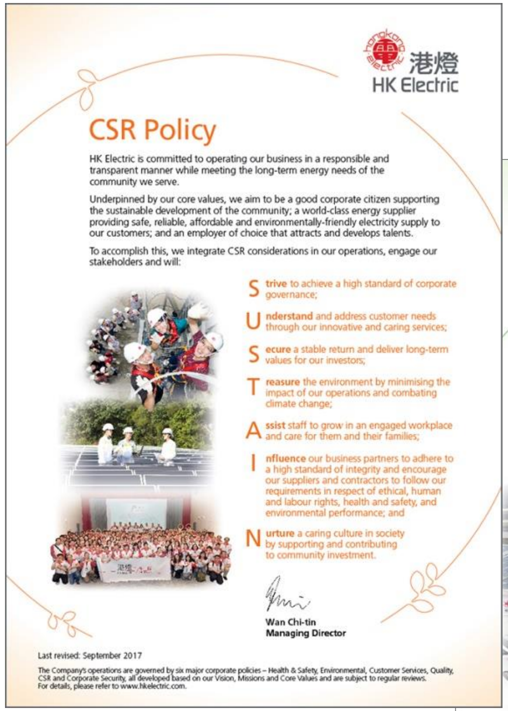
- Senior Management

Environment Committee

- Management and Administration

Environment Management System

- Execution Division / Department


港燈 HK Electric

CSR Policy

HK Electric is committed to operating our business in a responsible and transparent manner while meeting the long-term energy needs of the community we serve.

Underpinned by our core values, we aim to be a good corporate citizen supporting the sustainable development of the community; a world-class energy supplier providing safe, reliable, affordable and environmentally-friendly electricity supply to our customers; and an employer of choice that attracts and develops talents.

To accomplish this, we integrate CSR considerations in our operations, engage our stakeholders and will:

S **trive** to achieve a high standard of corporate governance;

U **nderstand** and address customer needs through our innovative and caring services;

S **ecure** a stable return and deliver long-term values for our investors;

T **reasure** the environment by minimising the impact of our operations and combating climate change;

A **ssist** staff to grow in an engaged workplace and care for them and their families;

I **nfluence** our business partners to adhere to a high standard of integrity and encourage our suppliers and contractors to follow our requirements in respect of ethical, human and labour rights, health and safety, and environmental performance; and

N **urture** a caring culture in society by supporting and contributing to community investment.

Wan Chi-tin
Managing Director

Last revised: September 2017

The Company's operations are governed by six major corporate policies – Health & Safety, Environmental, Customer Services, Quality, CSR and Corporate Security, all developed based on our Vision, Missions and Core Values and are subject to regular reviews. For details, please refer to www.hkelectric.com.


港燈 HK Electric

Environmental Policy

HK Electric is committed to protecting the environment and supporting sustainable development by conducting our business in an environmentally responsible manner.

We aim to continuously improve our environmental performance and minimise the impact of our operation on the environment while supporting the Government's environmental and climate policies.

To accomplish this, we will comply fully with all applicable laws and regulations, manage environmental risks systematically and integrate environmental considerations into all aspects of our business operation.

In addition, we will:

G **enerate**, deliver and use electricity efficiently, and migrate towards low-carbon power generation by progressively replacing coal with natural gas in our fuel mix;

R **einforce** the "4R" policy to reduce, reuse, recover and recycle materials and resources, and promote biodiversity and conservation;

E **ncourage** and facilitate the wider use of renewable energy and contribute to Hong Kong's transformation into a smart city through innovation;

E **mbrace** sustainable purchasing practices and adopt best practicable technologies and processes to conserve natural resources;

N **urture** environmental awareness amongst our business partners while educating and supporting the public on the smart and efficient use of energy;

E **nsure** commitment from all employees and all levels of management, and provide them with the necessary training and resources;

R **eport** our environmental performance and related information on a regular basis, and maintain a close dialogue with our stakeholders.

Wan Chi-tin
Managing Director

Last revised: October 2018

The Company's operations are governed by six major corporate policies – Health & Safety, Environmental, Customer Services, Quality, CSR and Corporate Security, all developed based on our Vision, Missions and Core Values and are subject to regular reviews. For details, please refer to www.hkelectric.com.

Corporate Green Initiatives – Saving Targets

5-year In-House Saving Target for office premises (2024 vs 2019):

Corporate Saving Initiatives	Proposed Reduction Target
Energy Saving	-5%
Water Saving	-1%
Paper Saving	-10%
Waste Reduction (newly added)	-10%

Achievement in 2019 for office premises (with 2016 as baseline)

Corporate Saving Initiatives	Actual Saving
Energy Saving	≈ 18%
Water Saving	≈ 15%
Paper Saving	≈ 4%

Electric Tower

No. of Storey:	25 Storeys
Building Age:	23 Years
Total GFA:	Approx. 54,681.462 sq. m

R/F AC PLANT & COOLING TOWER

21/F SYSTEM CONTROL CTR

20/F E&M FLOOR

19/F STAFF CANTEEN & AMENITY CTR

17/F-18/F AUX. OFFICE & BADMINTON CRT

16/F AUX. OFFICE & LECTURE THEATRE

15/F AUX. OFFICE & TRAINING CTR

13/F – 14/F WAREHOUSE

12/F IT DATA CENTRE

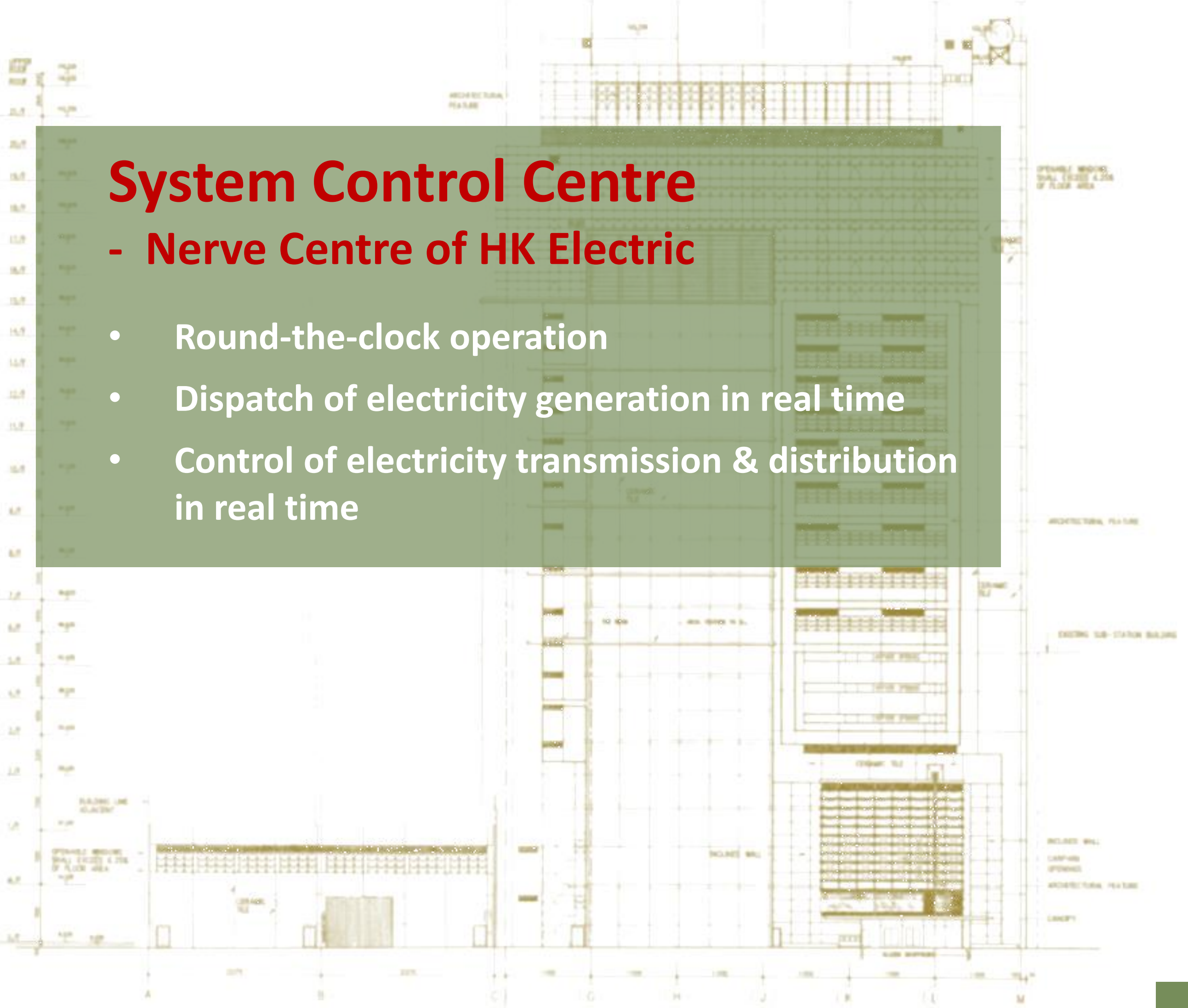
6/F-11/F WAREHOUSE

3/F – 5/F CARPARK

2/F LORRY PARKING & WORKSHOP

1/F GARAGE & WORKSHOP

G/F – M/F WAREHOUSE



System Control Centre

- Nerve Centre of HK Electric

- Round-the-clock operation
- Dispatch of electricity generation in real time
- Control of electricity transmission & distribution in real time

ESO 1

Optimisation of CRAC Units by Continuously Matching Cooling Output to Heat Load Using AI Technology to Reduce Energy Consumption

ESO 1: Optimisation of CRAC Units by Continuously Matching Cooling Output to Heat Load Using AI Technology to Reduce Energy Consumption

Cool Aisle Containment (CAC)

HK Electric Data Centre

- Data Centre equipped with ~ 70 server racks and 8 CRAC units built at 2015 and operated from 2016.
- Cool Aisle Containment (CAC) are installed to improve the energy efficiency.

Energy Saving Opportunities

- Saving the majority of energy from shutting down redundant cooling resources and reducing the speed of variable fans.

Symptom & Investigation Parameters

- Investigation period (Jun-Aug, 2018), our average Power Usage Effectiveness (PUE) was **1.74**.
- Compared with the industry, there is room for improvement in energy efficiency by achieving the better PUE at **1.7**.

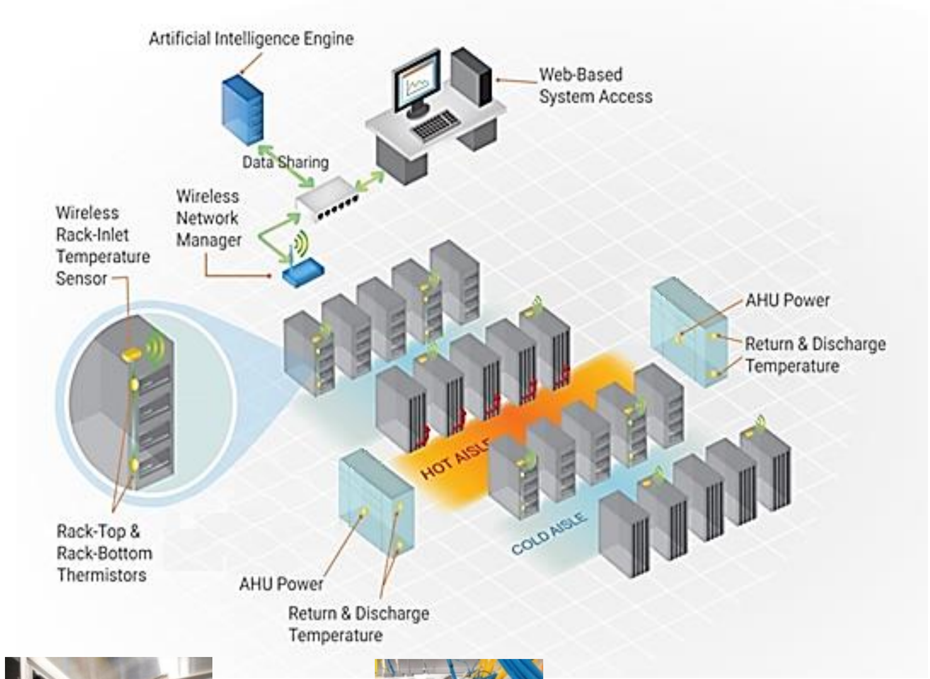
Possible Root Causes

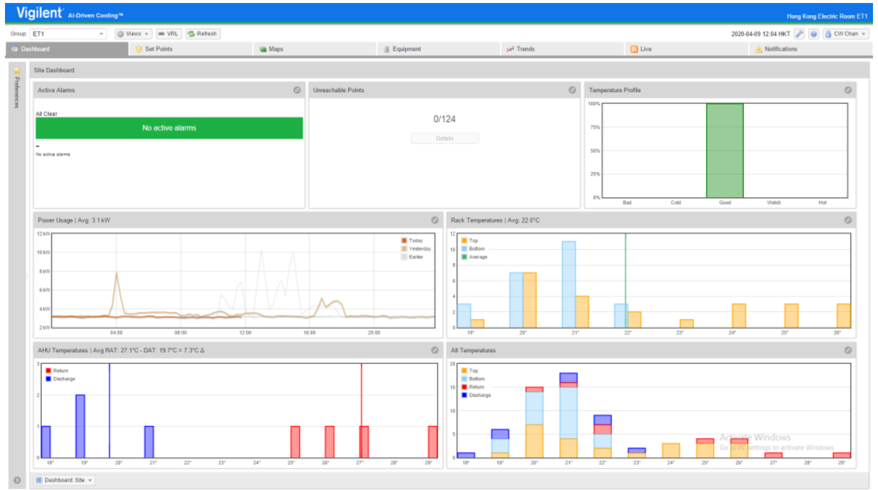
- Cooling delivered to various IT facilities in cold aisle containment is not always equal to the heat generated by the current IT load.
- High speed fans is more than the air circulation required, leading to waste of energy.

Improved Parameters

e power consumption of CRAC units at Data Centre reduced. Achieved better PUE.

ESO 1: Optimisation of CRAC Units by Continuously Matching Cooling Output to Heat Load Using AI Technology to Reduce Energy Consumption





Site Dashboard (Web)

Solution Setup

Rack Sensors
Collect temperature
erval

Rack-top Wireless Transmitter

Wireless Access Point

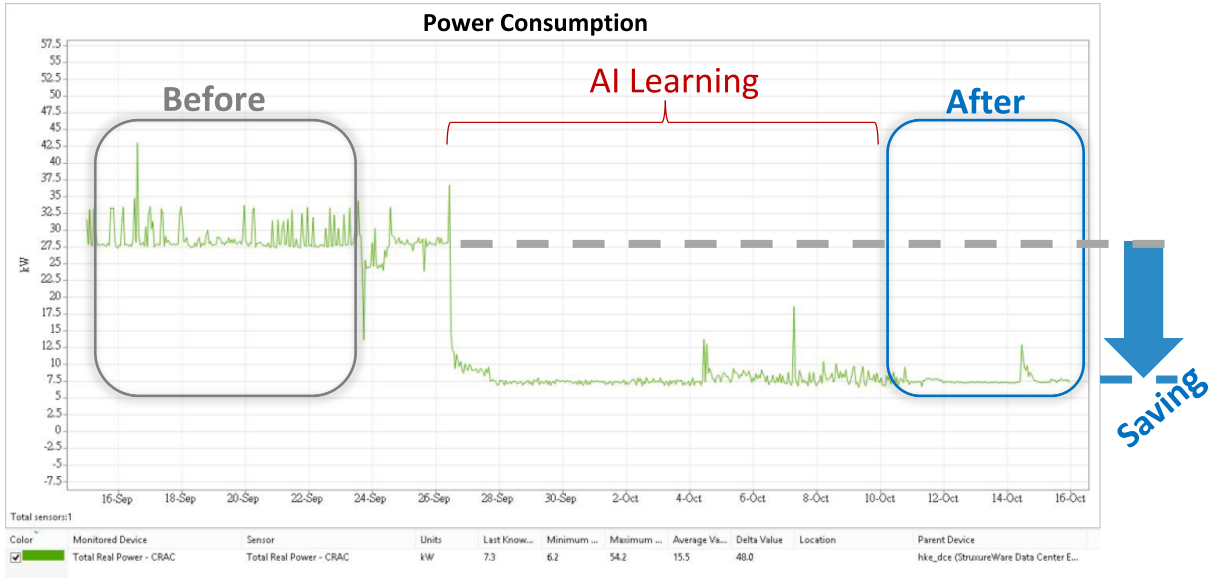
AI Engine
(1) Aggregates data and learn;
(2) Issues control commands after 5 to 10 minutes

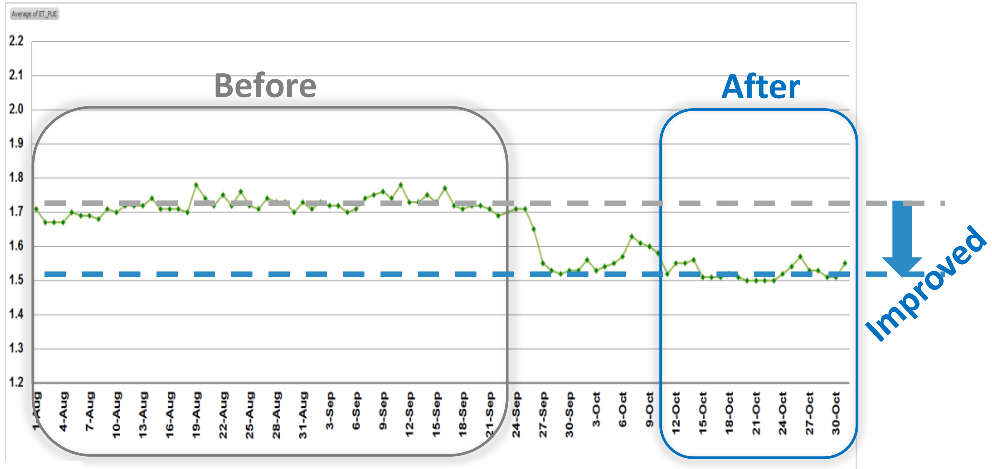
CRAC units
Receive commands to
(1) On/Off; (2) Adjust fan speed

港燈 HK Electric 125 香港背後的動力 The Power behind Hong Kong

ESO 1: Optimisation of CRAC Units by Continuously Matching Cooling Output to Heat Load Using AI Technology to Reduce Energy Consumption

CRAC Power (Fan Power) Consumption	
Before (kWh) **28**	After (kWh) **8**
Reduced by **20 kWh (71%)**	
Annual Saving	
Energy Savings (kWh) **175,200 kWh**	Carbon Emissions ($kgCO_2e$) **141,912 kg**





PUE

Average Power Usage Effectiveness (PUE)	
Before (1 Aug to 23 Sep) **1.72**	After (10 Oct to 30 Oct) **1.53**
Improved By **0.19 (11%)**	

ESO 2

Optimisation of Centralized MVAC Installation by Upgrading Air-cooled Chilled Water Plant to Water-cooled Chilled Water Plant and Enhancing PAUs/AHUs with Variable Speed Drive

1. Upgrading Air-cooled Chilled Water Plant to Water-cooled Chilled Water Plant in 2014-2016

- Installation of oil-free chillers (3 x 300 Tr) to maximise part-load efficiency

- Installation of variable-speed control (VSD) for all chilled water pumps, cooling water pumps and cooling towers to improve energy performance

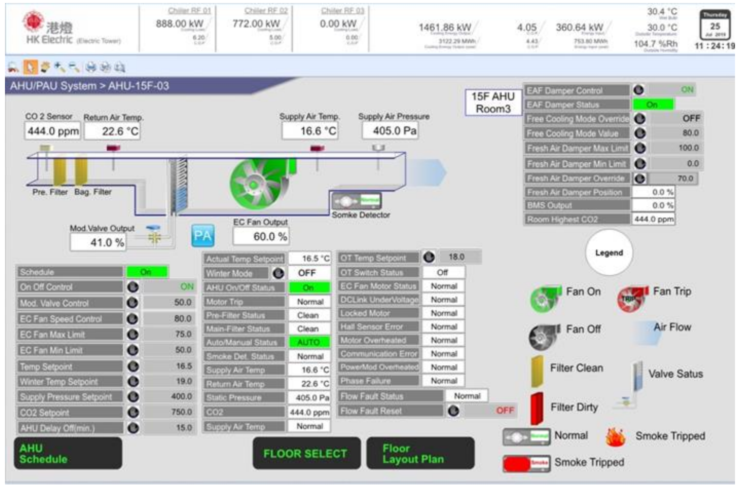
- Installation of automatic condenser tube cleaning system to remove foulants and scales of the chillers

Estimated Energy Saving:
1,000,000 kWh/annum

2. Replacement of 38 sets of the electronically commutated (EC) fans in the air handling units in 2017-2018

3. Installation of Building Management System for the AHUs and PAUs to facilitate monitor and control as well as RCx

4. Installation of VSD control for the primary air units (PAU) to vary fresh air intake into the building based on zone CO_2 levels



Additional features: -

- Installation of overtime buttons (OT Buttons) at individual zone for air conditioning supply after office hours
- Provision of free cooling through PAUs when the ambient temperature < 16°C

Estimated Energy Saving: 500,000 kWh/annum

ESO 3

Lighting Enhancement Work at Various Operational Areas

ESO 3: Lighting Enhancement Work at Various Operational Areas

Energy Saving Opportunities	Possible Root Causes	Symptoms & Investigation Parameters	Improved Parameters
1. Lighting Enhancement at "EXIT" Signs and Staircases 2. Lighting Enhancement at Warehouse 3. Lighting Enhancement at 2/F - 5/F Carpark	Lighting system of common areas switched on for 24 hours even when they are unoccupied	24 operating hours of lighting System	• De-lamping/ High efficiency lamp replacement • Installing motion / photo sensors • Reduce power consumption of lighting system per zone

LED "Exit" sign

LED "Exit" sign

T5 Flu at Staircases

Induction High Bay Lights

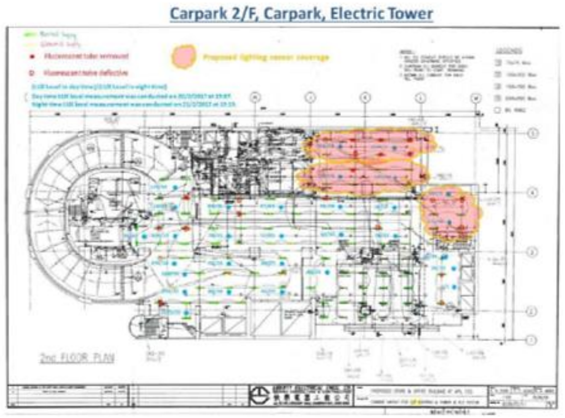
Total **660** nos. of LED "Exit" sign and T5 fluorescent tubes have been replaced
Estimated Energy Saving of **96,000** kWh/annum

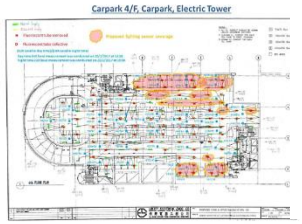
Total **234** nos. of Induction High Bay Lights have been replaced
Estimated Energy Saving of **14,000** kWh/annum

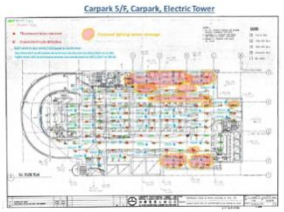
ESO 3: Lighting Enhancement Work at Various Operational Areas

Phase I: 2016-2017

Photo-cell control







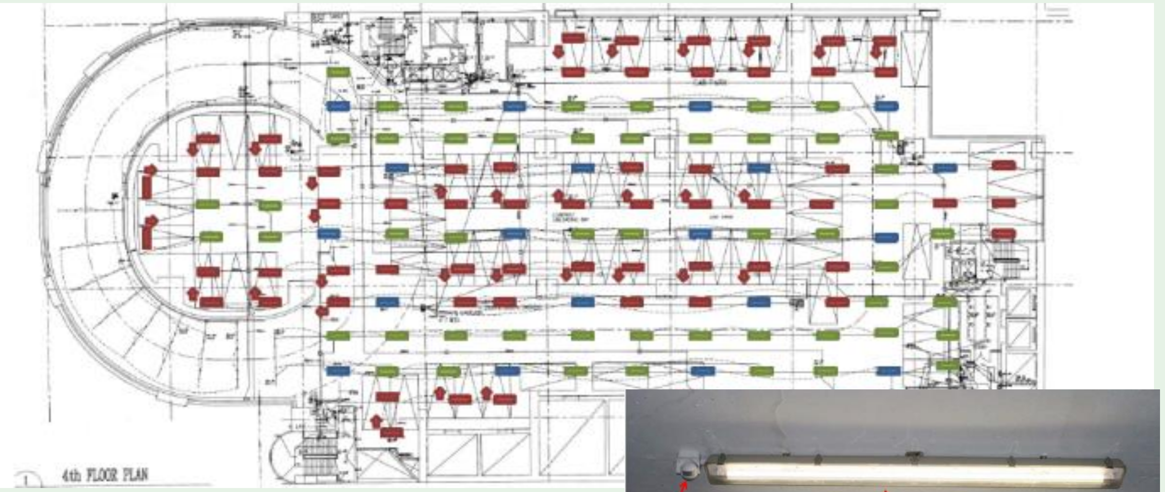
Operating Hours (Assuming from 18:00 – 07:00)

Total 120 nos. of Photo-cell control T5 Fluorescent Tube Lighting Fittings with Light Sensor Control

Estimated Energy Saving of 18,000 kWh/annum

Phase II: 2018-2019

Occupancy Sensor Control



Occupancy sensor at semi open area and above parking slot

Normal and E-lighting at main driveway

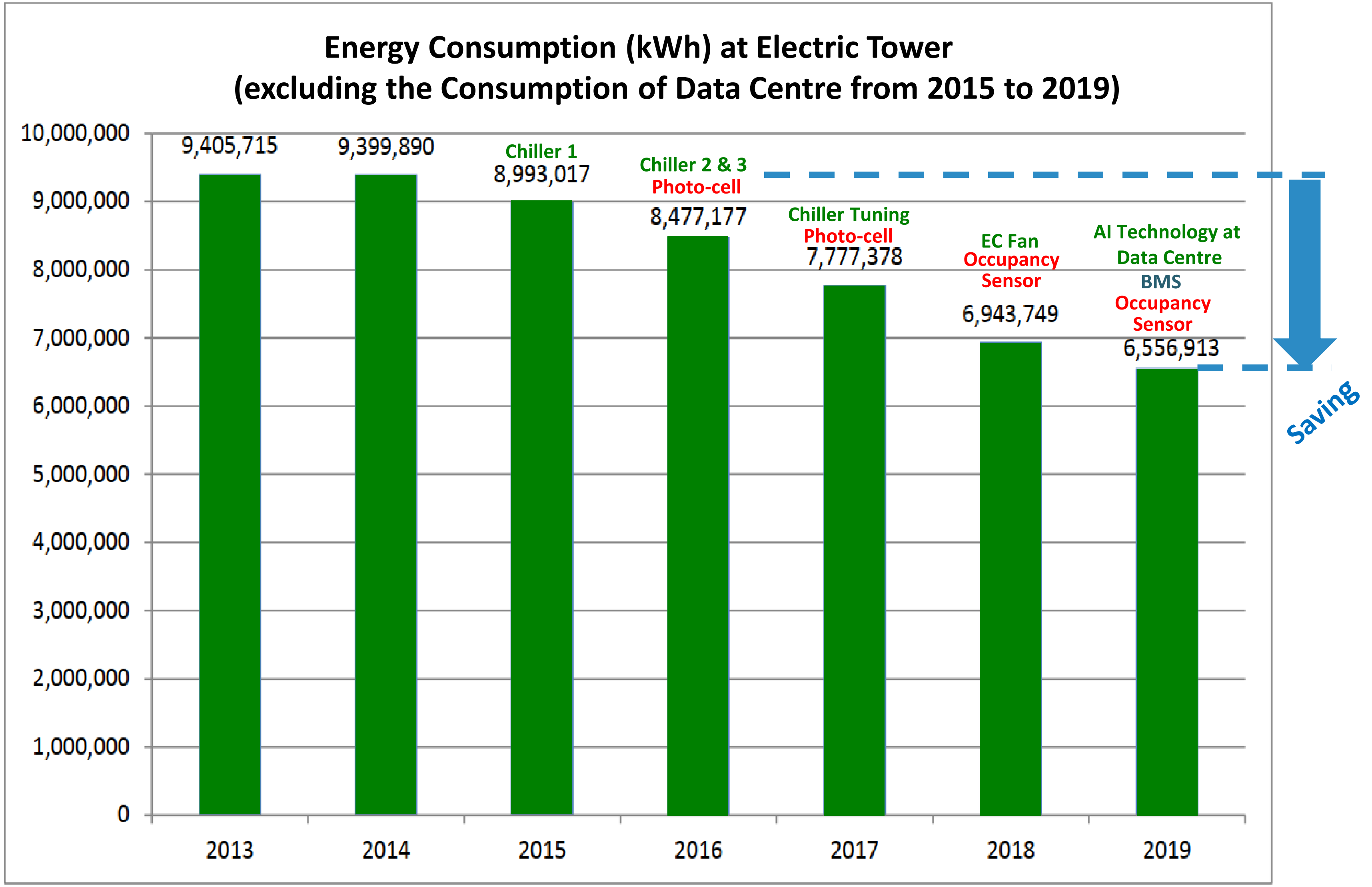
Operating Hours (Assuming no usage between 21:00 - 0700, 70% usage between 0700-2100)
Total 199 nos. of T5 Fluorescent Tube Lighting Fittings replaced with T5 LED with Occupancy Sensor Control
Estimated Energy Saving of 50,000 kWh/annum

Phase III: 2020

On-going Commissioning

Installation of Occupancy Sensor has effectively reduced the energy consumption during both day-time and night-time. The result was found to be satisfactory.
We have planned to expand the coverage of Occupancy Sensors to other part of the carpark area to maximize energy saving.

Overall Outcome



Challenges & Future

ESO 1	ESO 2	ESO 3
Respond quickly to changes in IT load and temperature within the **Data Centre** and external seasonal changes	With HK Electric's **System Control Centre** located at Electric Tower, non-stop operation of the air conditioning system in Electric Tower is essential for maintaining reliable electricity supply to our customers	**Continuous adjustment and monitoring** are required to suit the operational needs and environment

Moving forward, we shall continue the co-operation among various parties in the on-going implementation of the RCx project.

Based on the study results of the RCx project, **Improvement Strategy or Plan** will be formulated to pursue further energy saving, in particular, by making use of modern technologies and advanced energy-efficient equipment.

Thank You