



# Leveraging Your BAS: A Tiered Approach to Performance Monitoring

Is your BAS ready for the Meter-matic?

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## Energy Manager's – Building Performance Maxim

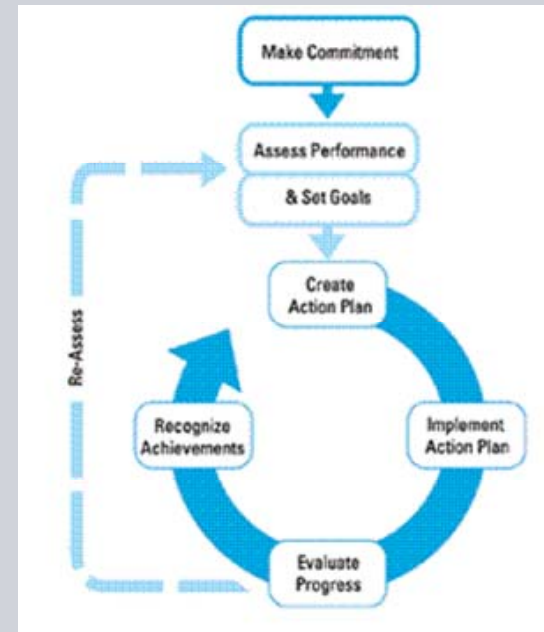
You can't improve performance  
- If you don't manage.

You can't manage.  
- If you don't measure.

You can't measure  
- If you don't collect data.

## Organizations That Manage Building Performance

- Government (Federal, State and local)
- K-12 School Districts
- Real Estate (Corporate & Commercial)
- Universities
- Healthcare
- Big Box
- Retail
- Manufacturing
- Hospitality



Energy Star Energy Management Steps, [www.energystar.gov](http://www.energystar.gov)

## U.S. Federal Energy Requirements Executive Order 13423 (signed January 24, 2007)

- Mandates an annual 3 percent reduction and cumulative 30% reduction in energy intensity by 2015 (compared to an FY 2003 baseline).
- Reduce greenhouse gas emissions and achieve in 10 years, the same level of energy efficiency improvement that federal agencies achieved in the last 20 years.
- EO 13514, signed in October 2009, ensures that the energy efficiency requirements of EO 13423 remain in effect.

## Building Performance Standards & Guidelines

	BASIC Benchmark Bills to Meters	INTERMEDIATE Building Level Monthly to Weekly	ADVANCED System Level Daily to Hourly
<b>Federal Government</b>	<ul style="list-style-type: none"> <li>•Energy Star [EISA of 2007]</li> <li>•Energy Manager [EPA of 2005]</li> </ul>		<ul style="list-style-type: none"> <li>•EPA of 2005</li> </ul>
<b>LEED- EBOM</b>	<ul style="list-style-type: none"> <li>• <b>EAp1 Building Operating Plan</b></li> <li>• EAp1 ASHRAE Level 1 Audit</li> <li>• EAp2 Energy Star</li> </ul>	<ul style="list-style-type: none"> <li>• EA3.1 Building Automation System.</li> <li>• EA2.1 ASHRAE Level2 Audit</li> <li>• EA2.2 No cost/low Cost</li> </ul>	<ul style="list-style-type: none"> <li>• EAc3.2 System-level metering.</li> <li>• EA2.3 Continuous Commissioning Plan</li> </ul>
<b>ASHRAE Std 189.1 MANDATORY</b>	<ul style="list-style-type: none"> <li>• <b>Building Operating Plan</b></li> <li>• Energy Star</li> </ul>		Consumption management system for energy and water.
<b>Performance Measurement Protocols for Commercial Buildings</b>	<ul style="list-style-type: none"> <li>• <b>Building Operating Plan</b></li> <li>• EUI and ECI.</li> <li>• Energy Star</li> <li>• Initial Costs: \$0</li> <li>• Annual Cost \$1000 -\$2000</li> </ul>	<ul style="list-style-type: none"> <li>• Weekly or Monthly energy use for building and major energy users by sub metering or data analysis.</li> <li>• Initial Costs: \$1000:</li> <li>• Annual Costs \$2000 -\$10,000 (100,000 sq.ft building)</li> </ul>	<ul style="list-style-type: none"> <li>• System-level metering to track energy performance hourly or daily for whole-building and sub-meter data.</li> <li>• Initial Costs: \$1000 to \$50,000</li> <li>• Annual Costs:\$1000 to \$10,000 (1,000,000 sq.ft building)</li> </ul>

## Example of Cost Justification

Installed Cost	Payback Period (Yrs)	Annual Cost	Annual Savings*	Minimum Annual Utility Bill
\$10,000	3	\$2,000	5%	\$107,000
\$20,000	3	\$5,000	10%	\$117,000
\$5,000	3	\$1,000	5%	\$53,333

Action	Observed Savings
<b>Installation of Meters</b>	<b>0% to 2% the Hawthorne Effect</b>
<b>Bill Allocation Only</b>	<b>2.5% to 5% Improved Occupant Awareness</b>
<b>Building Tune-Up and Load Management</b>	<b>5% to 15% (simple O&amp;M improvements and managing demand loads per electricity rate schedule)</b>
<b>Continous Commissioning</b>	<b>15% to 45% (Ongoing O&amp;M improvements and continuing management attention).</b>

*from Guidance for Electric Metering in Federal Buildings, February 2, 2006, DOE/EE-0312, page 10*

## Energy Codes - HVAC and Lighting Controls

HVAC Controls	Energy Codes
Automatic Shutdown:	90.1-2010; 6.4.3.3.1 IECC-2009; 505.2.4.3
Setback Controls	90.1-2010; 6.4.3.3.2 IECC-2009; 503.2.4.3.2
Manual Occupant override (maximum 2 hours)	90.1-2010; 6.4.3.3.1
Economizers	90.1-2007; 6.5.1 IECC-2009; 503.
<b>Air System Design</b> <ul style="list-style-type: none"> <li>- Fan Power Limitation (variable-speed-drives)</li> <li>- Set Point reset (for DDC systems)</li> <li>- Multi-Zone Supply Air Reset</li> </ul>	90.1-2007; 6.5.3.2.1 6.5.3.2.3 6.5.3.3.3 IECC-2009; 503.4.5.4
<b>Hydronic Variable Flow Systems</b> <ul style="list-style-type: none"> <li>- Pump Isolation</li> <li>- Chilled &amp; Hot-Water Temperature Reset(&gt;300,000 Btu/h)</li> </ul>	90.1-2007; 6.5.4.1 6.5.4.2 6.5.4.3
Optimum Start Stop Controls	90.1-2010; 6.4.3.3.3
Lighting Controls	Energy Codes
Automatic Shutdown	90.1-2007; 9.4.1.1 IECC-2009; 505.2.2.2
Manual Occupant override (maximum 2 hours)	90.1-2007; 9.4.1.1

Slide 8

# Building Automation System

## Pareto's Principle, Use the 80/20 Rule

**80/20 Rule states: 20% of actions produce 80% of the results, or 80% of effects come from 20% of causes.**

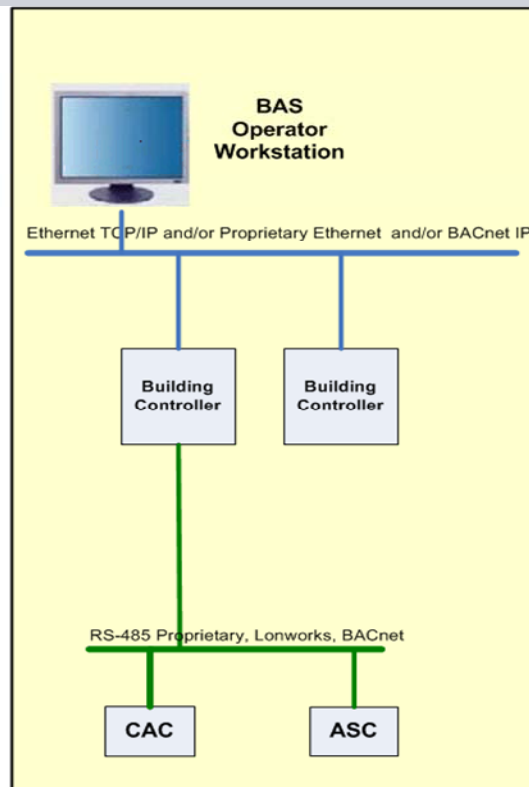
<b>Effect (Result)</b>	<b>Cause (Action)</b>
Equipment runs beyond scheduled operating hours..	TOD Scheduled hours Holiday Calendar – all business holidays Operator override disables scheduling.
AHU has high energy consumption, during part-loads (e.g., mild weather)	Reset of Equipment set points has been overridden by Building Operator or reset not implemented..
AHU has high energy consumption, during part-loads (e.g., mild weather)	Multiple causes: Damper is stuck, Wrong changeover value for climate zone, bad sensor (e.g., OAT).
AHU has high energy consumption, during unoccupied periods.	Night setback /setup is not implemented. Global command to set zones from occupied - unoccupied – occupied not issued by BAS

# Building Automation System- Performance Monitoring

	<b>BASIC</b> Data Collection and Trending	<b>INTERMEDIATE</b> Basic plus Trend Data Analysis	<b>ADVANCED</b> Intermediate plus Advanced Monitoring
<b>Software Requirements</b>	Standard BAS OWS		
<b>Graphics:</b>	Graphic with Performance Data from trend logs with link to equipment graphic.		
<b>Data Tables</b>	AHU Summary Table Chilled Water Plant Table		
<b>Tend Logs</b>	Meter data( gas, electricity, steam, chilled water, etc..) Outdoor air temperature.		
<b>Report Formats</b>	Export trend log data for long term storage and report generation.		
<b>Best Practices</b>	Check run-time schedules. Check set points Verify reset of setpoints Verify trend collection		

# Building Automation System Basic Level – Performance Monitoring

- User Account
- Graphics
- Scheduler TOD & Event
- Global Commanding
- Programming
- Trend Data & Trend Logs
- Alarm Log & History
- Report Builder
- Point Types for metering
  - Analog Input
  - Pulse Accumulator



## Building Automation System Basic Level – Best Practice

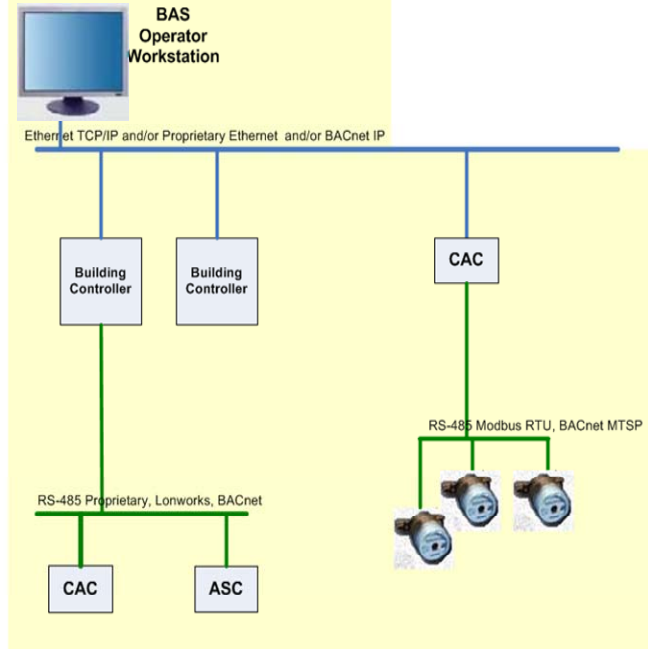
Best Practice	When?	Benefit
Scheduled report to show <u>run-time</u> of HVAC devices.	Daily	Verify equipment is operating according to Schedule. <b>[ASHRAE 90.1]</b>
Schedule report to show points left in <u>Operator Priority</u> .	Daily	Returns points in Operator priority to normal control of HVAC control programs (i.e., scheduler, setpoints). <b>[ASHRAE 90.1]</b>
Verify trend data uploaded from BAS controllers to BAS workstation.	Daily	Trend logs are available for use at BAS workstation
Verify that zones go into night setback/setup.	Weekly or Monthly	Ensures that night setback/setup are operating, so energy savings can be achieved. <b>[ASHRAE 90.1]</b>
Verify operation of Start-Stop Optimization application.	Weekly or Monthly	Optimizes equipment runtime <b>[ASHRAE 90.1]</b>

## Building Automation System- Performance Monitoring

	Basic: Data Collection and Trending	Intermediate: Basic plus Trend Data Analysis	Advanced: Intermediate plus Advanced Monitoring
<b>Software Requirements</b>	Standard BAS OWS	Add Dynamic Plotter Application that displays trend log value pairs vs. time plots.	
<b>Graphics:</b>	Graphic with Performance Data from trend logs with link to equipment graphic.	Add performance data to equipment graphic (link to Dynamic Plot for system.	
<b>Data Tables</b>	AHU Summary Table Chilled Water Plant Table	Expand metrics results table include metrics such as energy targets.	
<b>Tend Logs</b>	Meter data( gas, electricity, steam, chilled water, etc.) Outdoor air temperature.	Add equipment performance data	
<b>Report Formats</b>	Export trend log data for long term storage and report generation.	Add X-Y plots, example: Daily building power vs. average daily outdoor-air temperature.	
<b>Best Practices</b>	Check run-time schedules. Check set points Verify reset of set points Verify trend collection	Operating Mode vs. building power use to verify scheduling is implemented. Operating mode vs. zone temperature (e.g., Max, Min, Average, Std Dev)	

## Building Automation System Intermediate Level – Performance Monitoring

- Basic Level Applications
- Dynamic Trend Plotter
- Remote Notification



## BAS Network Elements of Performance Monitoring

Category	Network
Reporting Accuracy	Select the Network to maximize system throughput. For high-speed, high-performance, <u>Ethernet is recommended.</u>
Accurate Records	<u>A standard time sync service, time syncs server.</u> Access to the server clock is restricted by physical and software security measures. Time functions in BAS are synchronized to the system server
System Security	Access rights to system records and client applications are all controlled using Windows integrated security

## Control Functionality Required Elements of Performance Monitoring

Description	BAS Controller
Reporting Accuracy	A/D converter(s) in controller support end-to-end accuracy requirements for sensor readings
Accurate Records	Synchronized (Interval) and Event Driven Trending. Adjustable trend buffer high threshold limit will notify workstation when to upload trend data records from field panel.
Protection of Records	Battery backup of field panel application programs. Firmware program stored in EEPROM.
System Security	User Account required to access building controller from control system front end
Record Retention	Dependent on available memory in controller. Size for worst case (e.g., 7-days at 15-minutes)

## Sensor Level - Electric Meter Types

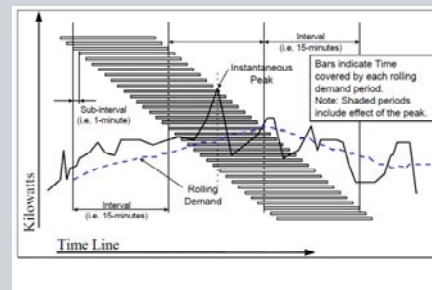
Device	Description	Typical Use
<b>Pulse Output</b>	<ul style="list-style-type: none"> <li>Provides only kWh value</li> </ul>	<ul style="list-style-type: none"> <li>On non-pulse initiating meter</li> <li>Need contact installed on meter (by utility)</li> <li>Non-critical submetering</li> </ul>
<b>Pulse Splitter</b>	<ul style="list-style-type: none"> <li>Replicates existing meters signal</li> </ul>	<ul style="list-style-type: none"> <li>On existing, pulse-initiating kWh meter.</li> <li>Non-critical submetering</li> </ul>
<b>Energy Meter</b>	<ul style="list-style-type: none"> <li>Basic: kWh and kW only</li> <li>Enhanced: kWh, kW, kVa, kVar, Amps, Volts.</li> <li>Meter is inside CTs,</li> <li>No external PT s required for 480V.</li> <li>No Manual Readout</li> </ul>	<ul style="list-style-type: none"> <li>Non-critical submetering</li> <li><math>\pm 1 - 3\%</math> (non-revenue grade)</li> <li>ANSI – C12.1</li> </ul>
<b>Power Meter</b>	<ul style="list-style-type: none"> <li>Features of Enhanced Energy Meter</li> <li>Also includes: Power Factor, Hz</li> <li>Requires 5 Amp CTs</li> <li>Alarmed and Manual Readout</li> </ul>	<ul style="list-style-type: none"> <li>Main Meter, Utility Substation, Tenant Billing</li> <li><math>\pm 1\%</math> or less (Revenue Grade)</li> <li>ANSI – C12.16</li> </ul>
<b>Circuit Meter</b>	<ul style="list-style-type: none"> <li>Features of Power Meter plus more.</li> <li>Also includes: Peak Demand</li> <li>Requires 5-Amp CTs</li> <li>Alarmed and Manual Readout</li> </ul>	<ul style="list-style-type: none"> <li>Main Meter &amp; Utility Substation</li> <li>Power Quality Management</li> <li><math>\pm 0.5\%</math> or less (Revenue Grade)</li> <li>ANSI – C12.16</li> </ul>

## Not all Meters are created Equal

What accuracy do you need? 1%? Revenue-grade?

How do you measure Demand? Instantaneous? Sliding-window?

What communications protocol do you need? Lon? Modbus? BACnet?



## Power Quality Alarms

Category	Types	Duration	Common Cause	Metering Device
Short Duration (Temporary)	Sags, Swells, Interruptions	3 sec – 1min	Faults, Motor Starting	Energy Meter Power Meter Circuit Meter
Long Duration	Under-voltage Over-voltage Sustained Interruptions	> 1 min	Poor Voltage Regulation, Overloaded Feeder	Energy Meter Power Meter Circuit Meter
Current Unbalance		Steady State	Unbalanced loads, Equipment failure	Energy Meter Power Meter Circuit Meter
Voltage Unbalance		Steady State	Unbalanced loads, Equipment failure	Power Meter Circuit Meter

## Sensor Level: Flow Meters – At a Glance

Criteria	Positive Displacement	Orifice/DP Transmitter	Venturi	Annubar	Turbine	Vortex Shedding	Ultrasonic	Thermal
Accuracy	Good	Moderate	Good	Good	Good	Good	Moderate	Good
Turndown Ratio	10:1	<5:1	<5:1	10:1	75:1	20:1	10:1 /20:1	75:1
Repeatability	Good	Good	Good	Very Good /Good	Low	Very Good	Good	Good
Installation Ease	Easy	Easy	Moderate	Easy	Difficult	Moderate	Very Easy	Easy
Pressure Loss	Medium	Medium	Low	Low	Medium	Low	None	Low
Recalibration	Infrequent	Frequent	Infrequent	Infrequent	Frequent	Infrequent	Moderate	Infrequent
Capital Cost	Low	Low	Moderate	Low	Moderate	Moderate	High	Low
Installed Cost	Moderate	Low	Moderate	Low	Moderate	Moderate	Low	Low
Maintenance Cost	Low	High	Moderate	Low	Moderate	Low	Low	Low

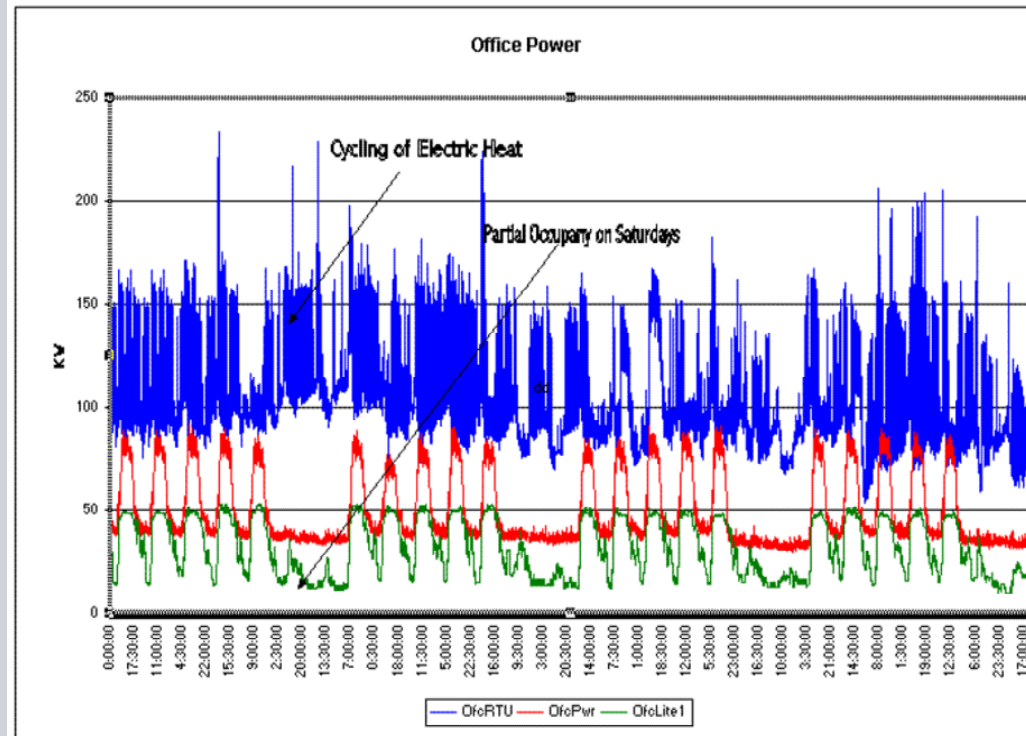
## Sensor Level: Overview of BTU Meters

Device	Description	Typical Use
<b>BAS Controller</b>	<ul style="list-style-type: none"> <li>• Measures volume, energy, temperature, and peak energy</li> <li>• Requires flow meter and Temperature sensors.</li> <li>• Use high accuracy sensors (i.e., match pair)</li> <li>• Communications: BACnet (Ethernet)</li> <li>• <b>Application program for energy <u>MUST include compensation</u></b></li> <li>• <b><u>Will need functional testing during commissioning.</u></b></li> </ul>	<ul style="list-style-type: none"> <li>• Building Level or plant level</li> </ul>
<b>BTU Meter</b>	<ul style="list-style-type: none"> <li>• Measures volume, energy, temperature, and peak energy</li> <li>• Integrated flow meter (impeller) and Temperature sensors components.</li> <li>• Use high accuracy sensors (i.e., match pair)</li> <li>• <b>Communication protocols: RS-485: LON, BacNet, ModBus</b></li> <li>• <b>Energy calculations include: compensation for density or specific heat</b></li> <li>• <b>Factory tested, certification available from manufacturer.</b></li> <li>• <b>Manual readout display (available in some models)</b></li> </ul>	<ul style="list-style-type: none"> <li>• Building Level or plant level</li> </ul>

## Building Automation System Intermediate Level – Best Practice

Best Practice	When?	Benefit
Review equipment performance graphic to see that equipment operation is tracking target values.	Daily	Ensures that major energy using equipment is operated efficiently.
Review Building Load Profile for the last 7-days.	Daily or Weekly	Easy to identify changes in equipment operating schedule (s). Identify impact of equipment left in operator override.
Verify Historical trend data has been stored to BAS Operator Workstation in CSV format.	Weekly	Historical trend data files can be imported to Advanced metering system at later date.
Verify System Activity Alarm Log has been stored in CSV format on BAS Operator workstation.	Weekly	System Activity Log documents how the BAS was operated (e.g. set point , scheduler, operator commands).

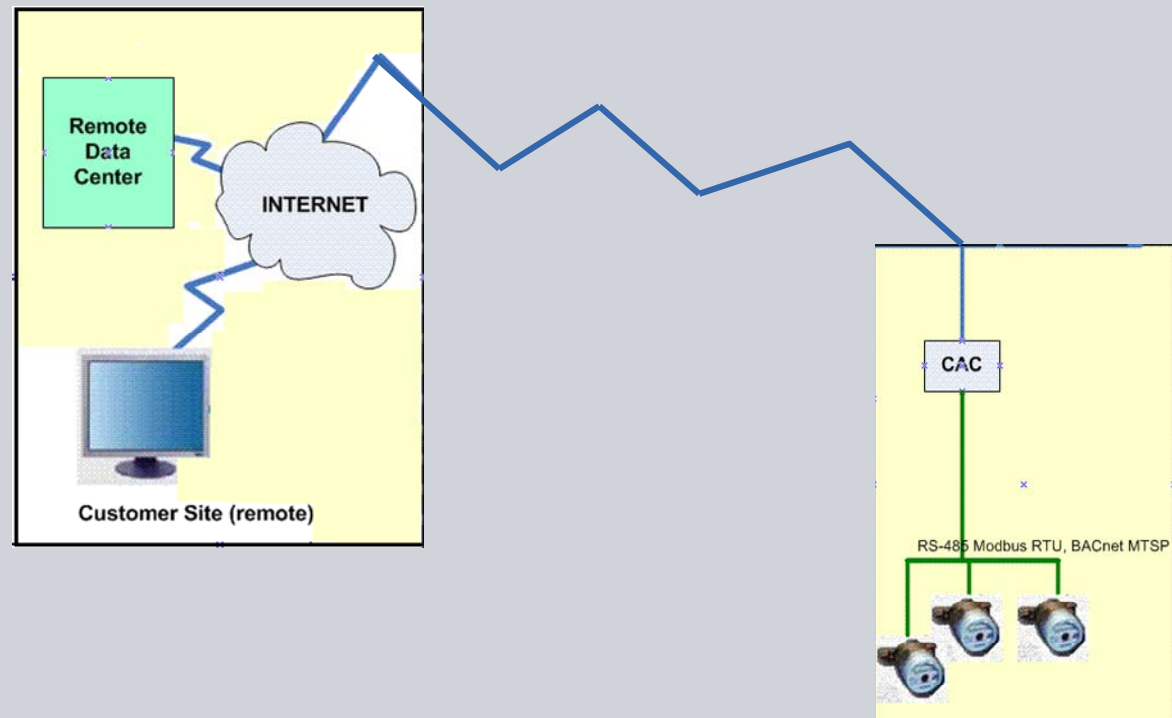
## Performance Monitoring – Intermediate Level: Basic + Trendlog Time Plots



## Building Automation System- Performance Monitoring

	Basic: Data Collection and Trending	Intermediate: Basic plus Trend Data Analysis	Advanced: Intermediate plus Advanced Monitoring
<b>Software Requirements</b>	Standard BAS OWS	Add Dynamic Plotter Application that displays trend log value pairs vs. time plots.	Third-party software that specializes in Advance report generation, for advanced metering and notification.
<b>Graphics:</b>	Graphic with Performance Data from trend logs with link to equipment graphic.	Add performance data to equipment graphic (link to Dynamic Plot for system.	
<b>Data Tables</b>	AHU Summary Table Chilled Water Plant Table	Expand metrics results table include metrics such as energy targets.	
<b>Tend Logs</b>	Meter data( gas, electricity, steam, chilled water, etc..) Outdoor air temperature.	Add equipment performance data	
<b>Report Formats</b>	Export trend log data for long term storage and report generation.	Add X-Y plots, example: Daily building power vs. average daily outdoor-air temperature.	X-Y plot diagnostics (scatter plot) Hysteresis (Load Profile) Carpet Plot (weekly)
<b>Best Practices</b>	Check run-time schedules. Check set points Verify Start-Stop Optimize Verify trend collection	Operating Mode vs. building power use to verify scheduling is implemented. Operating mode vs. zone temperature (e.g., Max, Min, Average, Std Dev)	Compare carpet plots of equipment serving zone (e.g., lights, HVAC, plug-loads).

## Building Automation System Advance Level – Performance Monitoring



## ASHRAE Standard 189.1-2009 Consumption Management

### Consumption Management

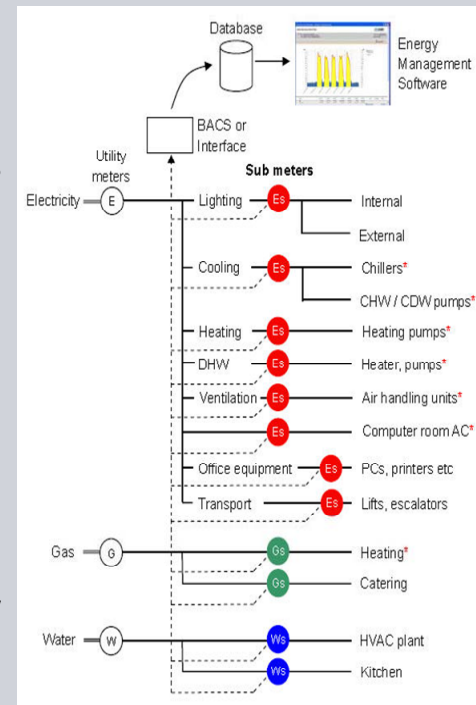
- Measurement devices with remote communication capability
- Collect energy consumption data from each energy supply source to the building
- Where thresholds are exceeded, install submeters for each use category

### Consumption Data Collection

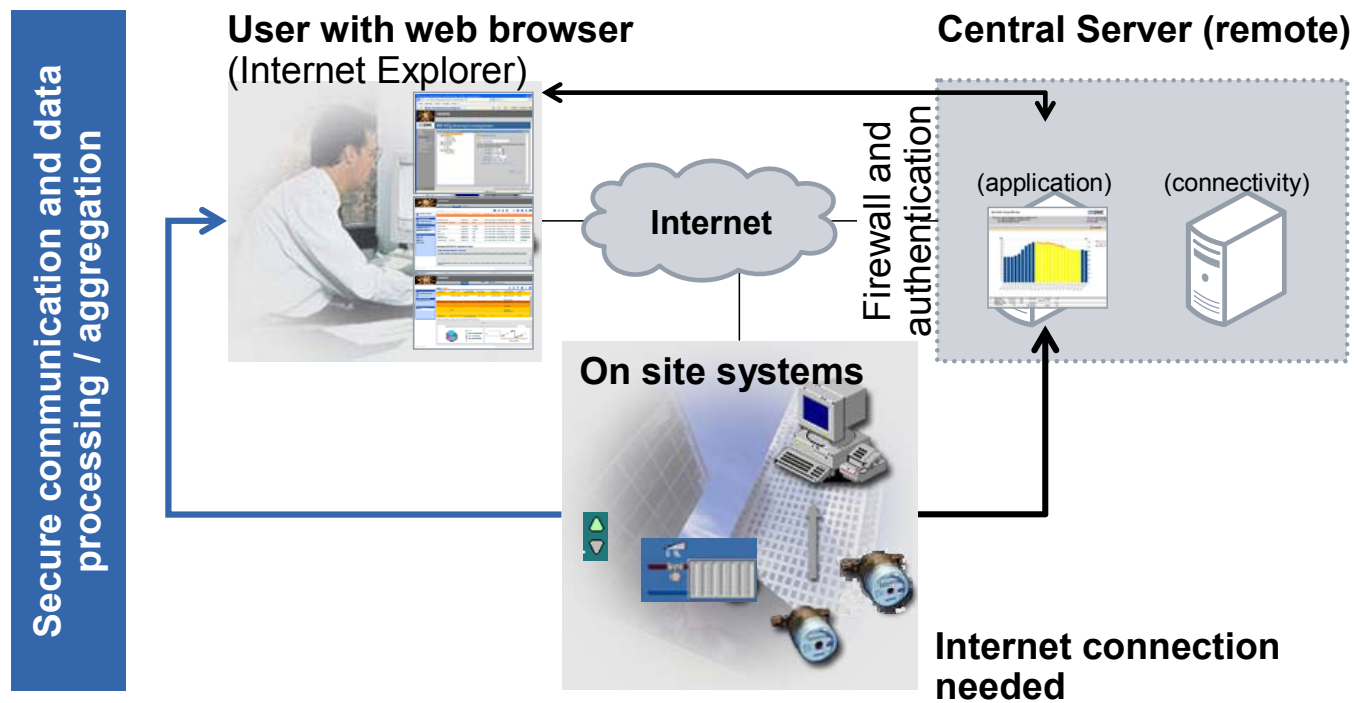
- Automatically communicate consumption data to meter data management system.
- At minimum, meters shall provide daily data and shall record hourly energy profiles.
- Hourly profiles to shall be to assess building performance at least monthly.

### Data Storage and Retrieval

- Electronically store data for a minimum of 36 months
- Create user reports showing hourly, daily, monthly and annual consumption.

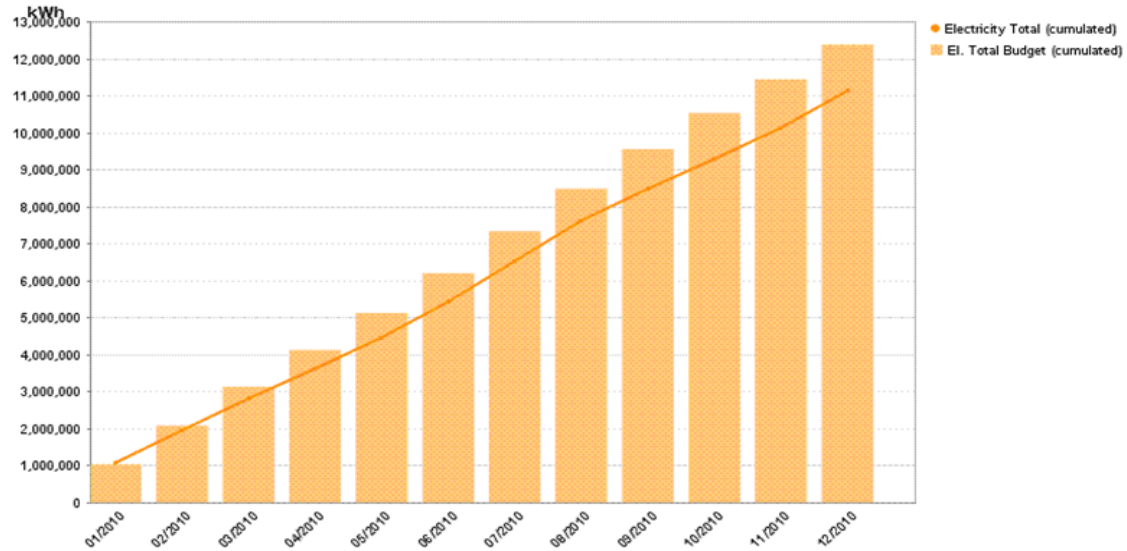


## Consumption Management System (Remote) Data collection and Event handling

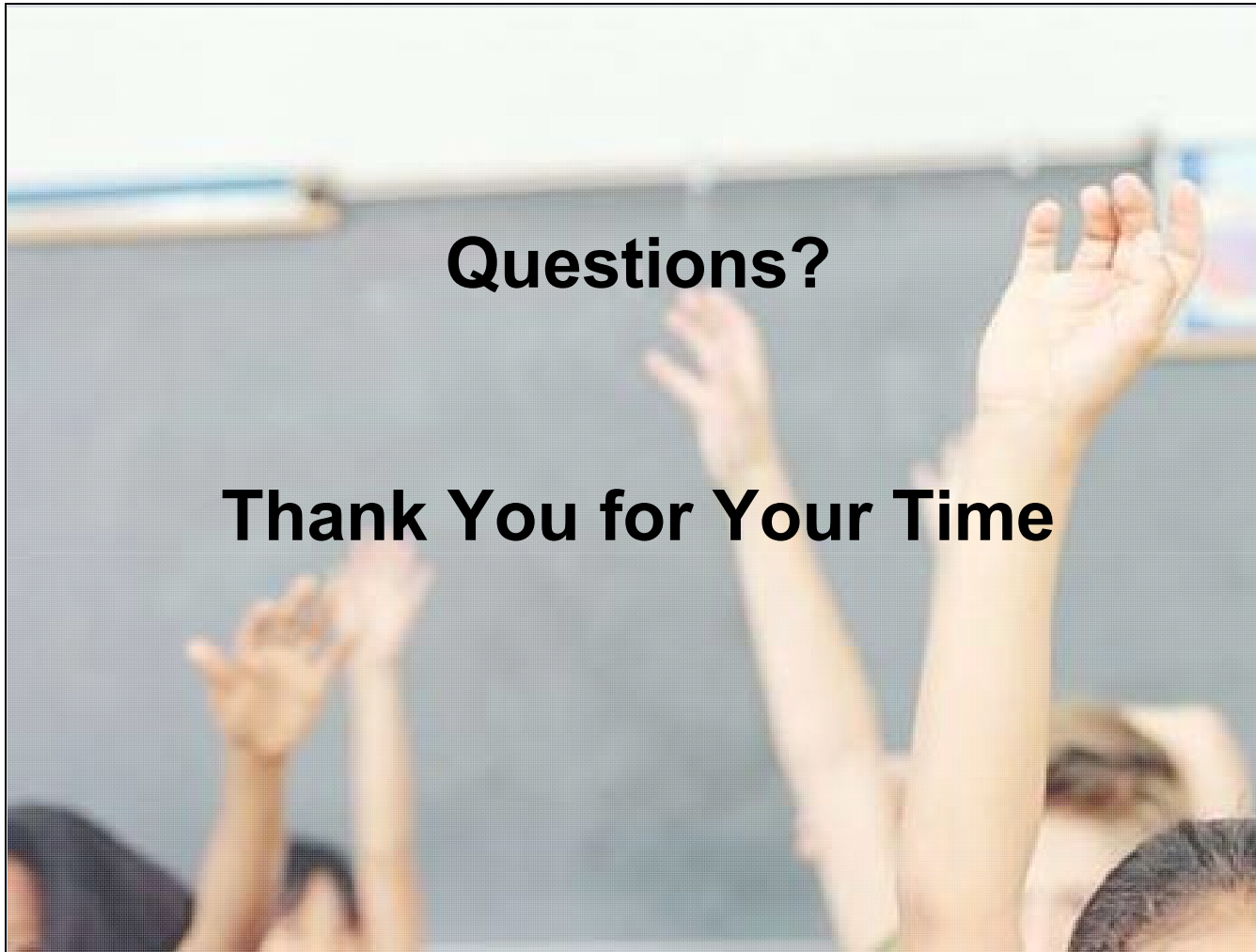


## Performance Monitoring – Advance Level: Intermediate + Report Generation

Portfolio Budget Cumulative



Date	Electricity Total (cumulated) kWh	El. Total Budget (cumulated) kWh	El. Total Diff. abs. (cumulated) kWh	El. Total Diff. rel. %
01/2010	1,070,613.35	1,037,982.82	32,630.53	3.14
02/2010	1,933,821.49	2,082,793.49	-148,972.00	-7.15



## ASHRAE Standard 189.1-2009 Consumption Measurement - Source

**TABLE 6.3.3A Water Supply Source Measurement Thresholds**

Water Source	Main Measurement Threshold
Potable water	1000 gal/day (3800 L/day)
Municipally reclaimed water	1000 gal/day (3800 L/day)
Alternative source of water	500 gal/day (1900 L/day)

**TABLE 7.3.31A Energy Source Thresholds**

Energy Source	Threshold
Electrical service	>200 kVA
On-site renewable electric power	All systems > 1 kVa (peak)
Gas and district services	>1,000,000 Btu/h (300 kW)
Geothermal energy	>1,000,000 Btu/h (300 kW) heating
On-site renewable thermal energy	>100,000 Btu/h (30 kW)

**ASHRAE Standard 189.1-2009**  
**7.3.3.3 Energy Consumption Management - Subsystems**

**TABLE 7.3.3.1B System Energy Use Thresholds**

Use (Total of All Loads)	Subsystem Threshold
HVAC system	Connected electric load > 100 kVa
HVAC system	Connected gas or district services load > 500,000 Btu/h (150 kW)
People moving	Sum of all feeders > 50 kVa
Lighting	Connected load > 50 kVa
Process and plug process	Connected load > 50 kVa Connected gas or district services load > 250,000 Btu/h (75 kW)