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Modeling Vs. Reality – Measurement & Verification of New Construction Energy Performance

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Why Measure & Verify?

- Design & Modeling
 - Hypothetical!
 - Projected building energy performance
- Construction/Implementation
 - Variations
 - Commission
 - Test & balance
- Measurement & Verification (M&V)
 - Validate design intent w.r.t. energy efficiency
 - Need to establish a projected baseline

Energy Savings

Energy Savings =

Projected Baseline Energy Use **MINUS** Post-Construction Energy Use

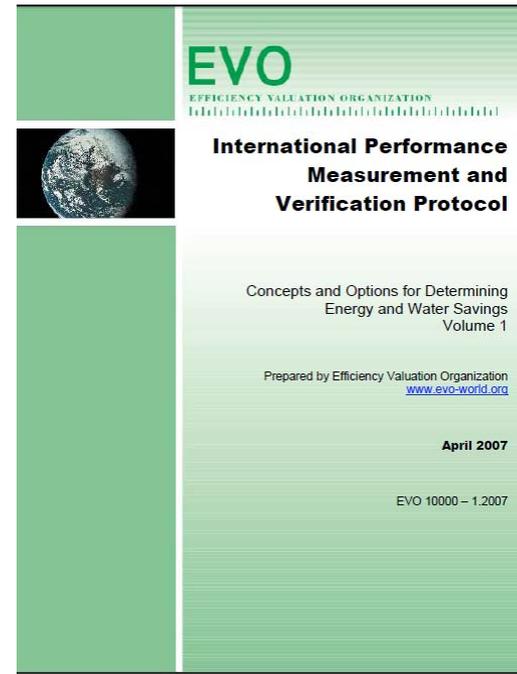
Projected Baseline

- What is the “Baseline” for new construction
 - Hypothetical?
 - May be defined by minimum requirements set by codes and standards
 - ASHRAE 90.1
 - CA Title 24 for utility incentives
 - Typical designs based on standard practices
 - Other similar buildings built in the past
 - Before identification of energy efficiency areas

Post Construction Energy Use

- Actual metered and/or sub-metered data
- Calibrated “as-built” building energy model (simulated)
 - Need to establish “period of operation”

M&V Protocols



M & V Methods

- Option A – Partially measured ECM isolation
 - spot measurements
- Option B – ECM isolation
 - continuous measurements
- Option C – Whole building comparison
 - metering/billing
 - Regression Analysis
- Option D – Whole building calibrated simulation
 - modeling w/ measurements

M&V Plan

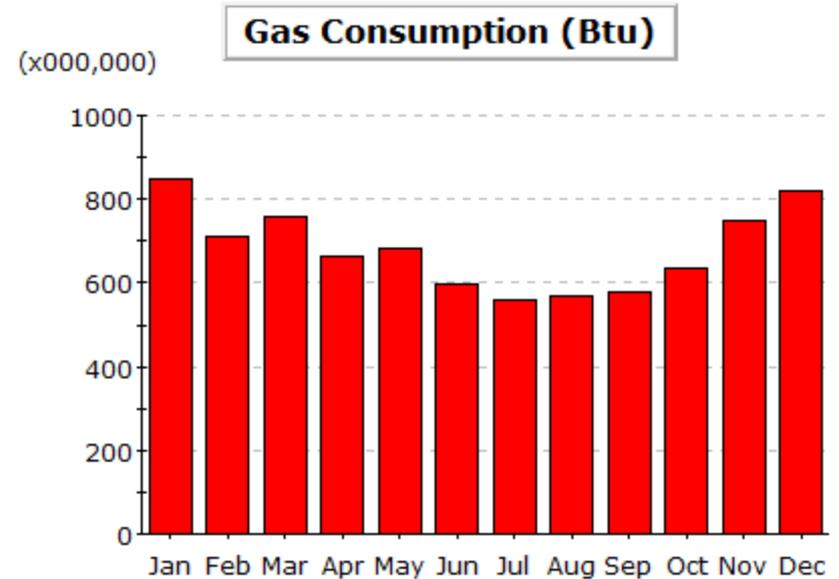
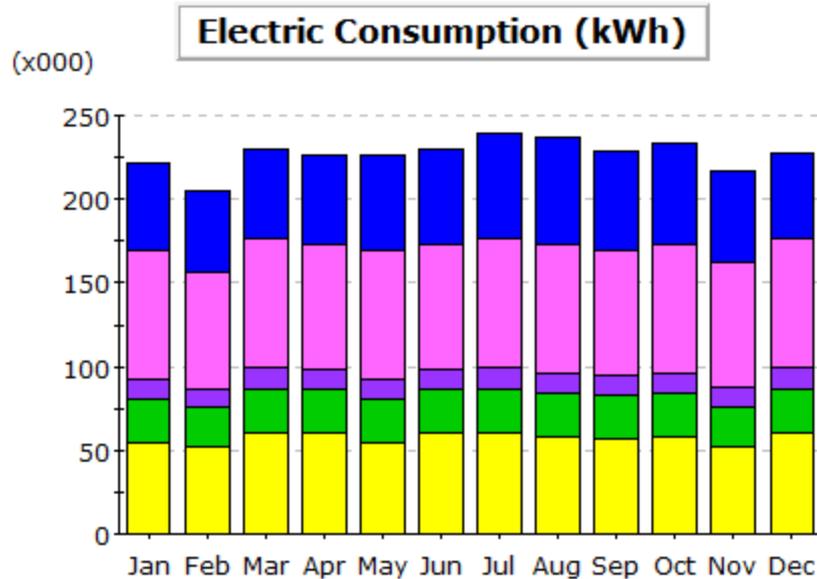
- Document design intent
 - ECMs & baseline design
 - Energy-saving strategies
 - Equipment performance specs
- Determine M&V options
 - IPMVP protocols
 - Identify sub-metering or data collection needs & methods
 - M&V Intervals/Frequency
- Option D – Building Simulation
 - Other options may be useful (beyond this presentation)
- **M&V plan development should be an integral part of design process**

Building Energy Models – Typical Outputs

- **Understanding for Effective Review & Decision Making**
- More than colorful charts & overwhelming data?
 - Based on eQUEST
 - 100s of pages of output data
- Energy use breakdowns
 - by building system
 - Chillers, AHUs, Pumps, Lights, Plug Loads
 - by season/month
 - by thermal component
 - Floors, walls, zones, infiltration, ventilation, etc.
 - Demand profiles
 - Utility costs
 - Space temperature profiles
- Interactions & incremental analysis

Output Examples - Charts

Monthly Energy Consumption



- | | | |
|-----------------|------------------|----------------|
| Area Lighting | Pumps & Aux. | Space Heating |
| Task Lighting | Ventilation Fans | Refrigeration |
| Misc. Equipment | Water Heating | Heat Rejection |
| Exterior Usage | Ht Pump Supp. | Space Cooling |

Monthly Energy Consumption Data

Electric Consumption (kWh x000)

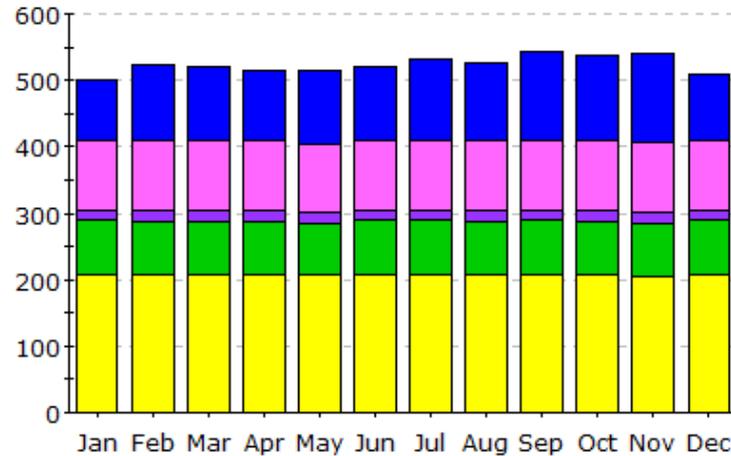
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	51.4	48.1	53.5	52.6	56.1	56.8	62.7	63.3	59.2	60.2	53.8	51.4	669.1
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	77.4	69.9	77.4	74.9	77.4	74.9	77.4	77.4	74.9	77.4	74.9	77.4	911.5
Pumps & Aux.	12.2	11.1	12.2	11.8	12.2	11.8	12.2	12.2	11.8	12.2	11.8	12.2	144.1
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	25.1	23.5	26.9	26.7	25.1	26.7	26.9	26.1	25.7	26.1	23.7	26.9	309.4
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	55.0	52.0	59.9	59.8	55.0	59.8	59.9	57.5	57.3	57.5	52.1	59.9	685.8
Total	221.1	204.5	230.0	226.0	225.8	230.1	239.1	236.6	229.0	233.5	216.4	227.8	2,719.8

Gas Consumption (Btu x000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	847.4	713.1	756.0	665.4	684.6	598.6	558.4	570.1	576.3	633.0	747.2	820.8	8,170.9
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	847.4	713.1	756.0	665.4	684.6	598.6	558.4	570.1	576.3	633.0	747.2	820.8	8,170.9

Monthly Electric Demand Profile

Electric Demand (kW)



Electric Demand (kW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	90.3	115.5	110.8	104.7	111.2	111.6	121.0	117.2	133.6	129.8	133.5	98.6	1,377.6
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	104.1	104.1	104.1	104.1	104.1	104.1	104.2	104.1	104.4	104.2	104.3	104.1	1,249.9
Pumps & Aux.	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	197.4
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	81.9	81.1	81.1	81.1	77.2	81.9	81.9	81.1	81.9	81.1	81.6	81.9	974.0
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	207.2	207.2	207.2	207.2	207.2	207.2	207.2	207.2	207.2	207.2	203.9	207.2	2,483.3
Total	500.0	524.4	519.7	513.6	516.1	521.3	530.8	526.0	543.6	538.8	539.7	508.3	6,282.3

Space Temperature Data

HOUR	TOTAL HOURS AT TEMPERATURE LEVEL AND TIME OF DAY																								TOTAL	
	1AM	2	3	4	5	6	7	8	9	10	11	12	1PM	2	3	4	5	6	7	8	9	10	11	12		
ABOVE 85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80-85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70-75	6	1	0	0	166	251	251	323	365	365	365	365	365	365	365	333	295	275	253	210	139	86	50	23	5217	
65-70	359	364	364	363	197	111	110	38	0	0	0	0	0	0	0	32	70	90	112	155	226	279	315	342	3527	
60-65	0	0	1	2	2	3	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	
BELOW 60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

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* NOTE 1) THE TEMPERATURE COUNTS ARE MADE ONLY FOR
*         THE HOURS WHEN THE FANS ARE ON
*
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Once Again... Energy Savings

Energy Savings =

Projected Baseline Energy Use **MINUS** Post-Construction Energy Use

- Post-construction energy use
 - Option 1 – Metered energy use
 - Option 2 – Energy use estimated by “calibrated as-built model”

Building Energy Models for M&V

- **Calibrated As-built Model**
 - Reflects as-built conditions
 - Reflects actual operation
 - May involve periodic verification of building/systems operation
 - Occupancy & usage
 - Control sequences
 - Set points
 - Equipment performance
- **Projected Baseline Model**
 - Can also be developed from as-built model by “backing-out” energy efficiency

Calibrated “As-Built” Model – Commissioning Reports

- Use of commissioning reports
 - equipment performance
 - sequence of operations
 - Actual set points
 - Should document significant deviations from design
 - Use of Test & Balance Data
 - Measured flow data
 - Measured performance data

Option 1 or Option 2

- Option 1 – Metered energy use
 - Requires a highly calibrated baseline
 - Inherently includes equipment degradation over time
- Option 2 – Calibrated as-built model
 - Minimizes impact of errors in simulation as long as similar errors are made in both Projected Baseline and As-Built models
 - Does NOT include equipment degradation over time

Modeling Based M&V – Where and When?

- Presence of complex interactive energy efficiency measures energy efficiency
- Need for whole building performance evaluation
- Need for high degree of accuracy
- Funding for M&V
- Metering and/or sub-metering in place with need for tenant billing

Questions???

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