Greenfield Municipal Center

CMVP Capstone Project

M&V; Plan Development Workbook

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Organization: _____ **Instructor:** Steve Kromer

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Scenario Brief — The Building

Greenfield Municipal Center is a 62,000 sq ft mixed-use government facility in the mid-Atlantic region (Climate Zone 4A). Original construction ~1995, two stories, no prior major retrofits. The County of Greenfield has entered into a 15-year Energy Savings Performance Contract (ESPC) with an ESCO to implement four energy conservation measures.

Wing	Use	Area (sq ft)	HVAC	Schedule
A	Office (open-plan + private)	35,000	AHU-1: Gas furnace, DX cooling Fan: 15 HP constant volume	M-F 7am–6pm
B	Public library & community meeting	15,000	AHU-2: Electric heat pump, DX cooling Fan: 10 HP constant volume	M-Sat 8am–9pm Sun 12–5pm
C	Data center / IT	2,000	CRAC-1: 5-ton DX, 24/7 No heating	24/7
Common	Lobby, corridors, mechanical rooms	10,000	AHU-3: Gas furnace, DX cooling Fan: 5 HP constant volume	M-F 6am–10pm

Envelope: Steel stud walls R-11, built-up roof R-15, double-pane clear windows (U-0.55, SHGC 0.60), ~25% WWR.

Scenario Brief — The Retrofit Package

ECM	Description	Scope	Combined Savings
ECM-1	LED lighting + occupancy/daylight controls	Wings A & B only	All four ECMs
ECM-2	Chiller/DX replacement (higher COP)	All units	together produce
ECM-3	Roof insulation upgrade (R-15 → R-30)	Entire building	122,390 kWh/yr
ECM-4	VFDs on AHU supply fans	AHU-1, 2, 3	(10.5% of baseline)

ESPC Contract Context

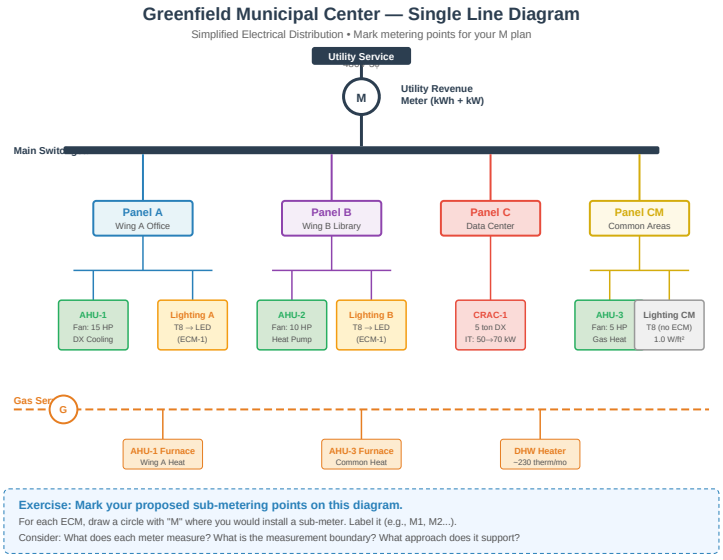
- 15-year contract term with guaranteed annual savings
- Annual M&V reporting required to verify savings and authorize payments
- Savings shortfall risk borne by ESCO; savings surplus shared 80/20 (owner/ESCO)
- Owner responsible for maintaining normal building operations
- Baseline conditions documented at contract signing; NRA protocol defined in M&V plan

Stakeholders

Stakeholder	Role
County of Greenfield	Building owner, contract signatory, receives savings
ESCO (contractor)	Designs, installs, and maintains ECMs; guarantees savings
Lender	Finances the ESPC; repaid from guaranteed savings stream
Utility (Greenfield Electric & Gas)	Provides energy; may offer incentives; supplies billing data
Building occupants	County employees (Wing A), library patrons (Wing B), IT staff (Wing C)
M&V professional (you)	Develops M&V plan, collects data, reports savings, resolves disputes

Utility Rates

Electric: $0.090/kWh energy + $0.015/kWh fuel adj. = $0.105/kWh blended; Demand: $12.50/kW-month (15-min peak); Customer: $125/month
Gas: $1.03/therm + $0.12/therm transport = $1.15/therm blended; Customer: $45/month
Emission factors: Electricity 0.92 lb CO_2/kWh (PJM grid); Gas 11.7 lb CO_2/therm



PHASE 1 — Context, Boundaries, and Approach Selection

Worksheet 1A — Stakeholder & Risk Matrix

Complete after Modules 0–2

Stakeholder	Interest / Concern	Risk if M&V; Fails	Risk Domain(s)
County of Greenfield (owner)			■ Technical ■ Commercial ■ Legal ■ Regulatory
ESCO (contractor)			■ Technical ■ Commercial ■ Legal ■ Regulatory
Lender			■ Technical ■ Commercial ■ Legal ■ Regulatory
Utility			■ Technical ■ Commercial ■ Legal ■ Regulatory
Building occupants			■ Technical ■ Commercial ■ Legal ■ Regulatory
M&V; professional (you)			■ Technical ■ Commercial ■ Legal ■ Regulatory
Other: (carbon credits, ESG reporting, ...)			■ Technical ■ Commercial ■ Legal ■ Regulatory

What guiding principles would you prioritize for this project? Why?

_____

_____

_____

PHASE 1 — Context, Boundaries, and Approach Selection

Worksheet 1B — Measurement Boundaries

Complete after Module 3. Mark boundaries on the single line diagram (Scenario Brief p.2).

ECM	Measurement Boundary Description	What's Inside the Boundary	What's Outside	Fuels
ECM-1 Lighting				■ Electric ■ Gas ■ Both
ECM-2 Chiller				■ Electric ■ Gas ■ Both
ECM-3 Envelope				■ Electric ■ Gas ■ Both
ECM-4 VFDs				■ Electric ■ Gas ■ Both

For ECM-3 (envelope), why might you need to include both fuels in the measurement boundary?

_____

_____

_____

Are there any ECMs where the measurement boundary should overlap? Why?

_____

_____

_____

PHASE 1 — Context, Boundaries, and Approach Selection

Worksheet 1C — Approach Selection

Complete after Module 3. For each ECM, select the approach and method, then justify your choice.

ECM-1: LED Lighting (Wings A & B)

Approach	■ Retrofit isolation ■ Whole facility
Method	■ Key parameter measurement ■ Continuous performance verification ■ Statistical / inverse model ■ Calibrated simulation / forward model
cf. IPMVP	■ Option A ■ Option B ■ Option C ■ Option D
Justification	

ECM-2: Chiller/DX Replacement

Approach	■ Retrofit isolation ■ Whole facility
Method	■ Key parameter measurement ■ Continuous performance verification ■ Statistical / inverse model ■ Calibrated simulation / forward model
cf. IPMVP	■ Option A ■ Option B ■ Option C ■ Option D
Justification	

ECM-3: Roof Insulation (R-15 → R-30)

Approach	■ Retrofit isolation ■ Whole facility
Method	■ Key parameter measurement ■ Continuous performance verification ■ Statistical / inverse model ■ Calibrated simulation / forward model
cf. IPMVP	■ Option A ■ Option B ■ Option C ■ Option D
Justification	

ECM-4: VFDs on AHU Fans

Approach	■ Retrofit isolation ■ Whole facility
Method	■ Key parameter measurement ■ Continuous performance verification ■ Statistical / inverse model ■ Calibrated simulation / forward model
cf. IPMVP	■ Option A ■ Option B ■ Option C ■ Option D
Justification	

Are there interactive effects between any ECMs? Which ones? How will you account for them?

_____

_____

PHASE 2 — Modeling, Baselines, and Adjustments

Worksheet 2A — Baseline Data Analysis

Complete after Modules 4–5. Record observations from the projected scatter plots and model fitting.

Electric Consumption vs. Outdoor Air Temperature

What pattern do you observe?	
Estimated heating change point	_____ °F
Estimated cooling change point	_____ °F
Estimated baseload (deadband)	_____ kWh/month
Best model type	■ 2P ■ 3P ■ 4P ■ 5P

Gas Consumption vs. Outdoor Air Temperature

What pattern do you observe?	
Estimated change point	_____ °F
Estimated baseload	_____ therms/month
Best model type	■ 2P ■ 3P ■ 4P ■ 5P

Model Validation (record from projected screen)

Statistic	Electric Model	ASHRAE G14 Limit	Pass ?	Gas Model	ASHRAE G14 Limit	Pass ?
NMBE	_____%	±5% (monthly)	■	_____%	±5%	■
CV(RMSE)	_____%	15% (monthly)	■	_____%	15%	■
R^2	_____	≥0.75	■	_____	≥0.75	■

Is this model adequate for reporting savings? What concerns do you have?

_____

_____

_____

PHASE 2 — Modeling, Baselines, and Adjustments

Worksheet 2B — Static Factors & NRA Protocol

Complete after Module 4. Identify static factors and define your non-routine adjustment protocol.

Static Factors Inventory

Static Factor	Baseline Value	How Monitored	What Triggers an NRA?
Building occupancy			
Operating schedule			
Data center load			
Conditioned floor area			

NRA Protocol

Who is responsible for reporting changes to static factors?

_____

How will the NRA be quantified? (check all that apply)

■ Engineering calculation ■ Sub-metered data ■ Stipulated from manufacturer data ■ Adjusted model refit

How will disputes about NRAs be resolved?

_____

_____

At what threshold does a change in a static factor require a non-routine adjustment rather than being absorbed as model noise?

_____

_____

PHASE 2 — Modeling, Baselines, and Adjustments

Worksheet 2C — ECM-1 Lighting Stipulation Calculation

Complete after Module 6. Calculate stipulated savings for the LED retrofit.

Space	Qty	Base W	Retro W	ΔW	Annual Hrs	kWh Saved
Wing A — Open Office (2nd fl)	120	128	40	88	2,860	
Wing A — Open Office (1st fl)	120	128	40	88	2,860	
Wing A — Private Offices	80	96	32	64	2,600	
Wing A — Conference Rooms	40	128	40	88	1,200	
Wing A — Corridors & Restrooms	60	64	20	44	3,380	
Wing B — Reading Rooms	100	128	40	88	3,900	
Wing B — Stacks	150	96	32	64	2,600	
Wing B — Meeting Rooms	30	128	40	88	1,500	
Wing B — Circulation & Entry	40	64	20	44	4,160	
TOTAL (740 fixtures)						

Formula: kWh Saved = ΔW × Qty × Annual Hours ÷ 1,000

Basis for operating hours:

■ Published schedule ■ Metered data (logger) ■ Engineering estimate ■ Other: _____

Does this stipulated savings total match the whole-facility model savings? If not, why not?

_____

_____

What are the interactive effects of reducing lighting load? How do they affect heating? Cooling?

_____

_____

_____

PHASE 2 — Modeling, Baselines, and Adjustments

Worksheet 2D — ECM-4 VFD Metering Plan

Complete after Module 6. Design the continuous performance verification plan for the VFD retrofit.

Parameters to Measure Continuously

Parameter	Meter Type	Accuracy	Location	Logging Interval
Fan motor kW				
Fan speed (Hz or %)				
Airflow (CFM)				
Supply air temp				

Pre-retrofit measurement period (how long? why?):

_____

_____

Post-retrofit measurement period (how long? why?):

_____

_____

What happens if you lose 2 weeks of data mid-reporting period?

_____

_____

Safety considerations for electrical metering:

_____

_____

Estimated metering cost: $_____

Evidence vs. Inference for ECM-4

List what you are **measuring** (evidence) vs. what you are **calculating** (inference).

Evidence (measured)	Inference (calculated)

PHASE 3 — Planning, Reporting, and Defense

Worksheet 3A — M&V Plan Assembly

Complete after Modules 7–8. Confirm all plan sections and define the schedule.

M&V Plan Sections Checklist

- ■ Executive summary (project description, ECMs, expected savings)
- ■ Baseline conditions (Worksheet 2A data, static factors from 2B)
- ■ Approach and method for each ECM (from Worksheet 1C)
- ■ Measurement boundary diagrams (from Worksheet 1B)
- ■ Metering specifications — ECM-4 (from Worksheet 2D)
- ■ Stipulation basis — ECM-1 (from Worksheet 2C)
- ■ NRA protocol (from Worksheet 2B)
- ■ Schedule of M&V; activities and reporting (below)
- ■ Risk and responsibility matrix (from Worksheet 1A)

Schedule of M&V Activities

Activity	Responsible Party	Frequency	Deliverable
Utility bill collection			
Weather data retrieval			
Fan metering data download			
Static factor review			
Annual savings calculation			
Annual report submission			
Operational verification			

Cost-Benefit

Estimated annual M&V; cost	$_____
Estimated annual savings value (from Worksheet 3B)	$_____
M&V; cost as % of savings	_____%

Is this cost-effective? What is the industry rule of thumb?

_____

_____

PHASE 3 — Planning, Reporting, and Defense

Worksheet 3B — Savings Calculation & Reporting

Complete after Module 9. Record savings from the projected screen, apply NRA, and value the savings.

Monthly Savings (record from projected screen)

Month	Baseline Model Prediction (kWh)	Reporting Actual (kWh)	Monthly Savings (kWh)	Notes
Jan				
Feb				
Mar				
Apr				
May				
Jun				
Jul				
Aug				
Sep				
Oct				
Nov				
Dec				
TOTAL				

Do you notice anything unusual in months 8–12? What happened? How would you adjust?

_____

_____

After NRA Adjustment

Gross savings (before NRA)	_____ kWh
NRA quantity (data center expansion)	_____ kWh
Net adjusted savings	_____ kWh
Fractional savings uncertainty (from screen)	_____ %
Statistically significant at 90% confidence?	■ Yes ■ No ■ Borderline

Valuation

Electric savings	_____ kWh × $0.105/kWh = $_____
Gas change	_____ therms × $1.15/therm = $_____
Net cost savings	$_____
CO■ reduction (electric)	_____ kWh × 0.417 kg/kWh ÷ 1,000 = _____ metric tons
CO■ change (gas)	_____ therms × 5.302 kg/therm ÷ 1,000 = _____ metric tons
Net CO■ reduction	_____ metric tons

PHASE 3 — Planning, Reporting, and Defense

Worksheet 3C — Plan Defense Preparation

Final phase. Prepare your 5-minute presentation and anticipate challenges.

Your 5-Minute Presentation

1. Approach selection (1 min) — Which approaches did you select for each ECM and why?

_____

_____

2. Baseline model (1 min) — What does your model tell you? How good is it?

_____

_____

3. Reporting period findings (1 min) — What happened during the reporting period that required adjustment?

_____

_____

4. Reported savings (1 min) — What are your final savings, uncertainty, and valuation?

_____

_____

5. Lessons learned (1 min) — What would you do differently with more budget or time?

_____

_____

Anticipated Challenges — Prepare Your Responses

"Why didn't you use continuous performance verification for the lighting ECM?"

_____

_____

"The gas bill went up after the retrofit. How do you explain that to the building owner?"

_____

_____

"Your savings are barely statistically significant. Should we switch to daily data?"

_____

_____

"The ESCO says the NRA shouldn't count against their guaranteed savings. Do you agree?"

_____

_____