



# **A New Paradigm for Retrocommissioning: Moving Building Science to Green Collar Trades**

Presented by:  
Keith Forsman, PE  
Pacific Gas & Electric Company

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# Nationwide Savings Opportunities due to Retrocommissioning

5-15% whole building energy savings

- 2-3 year simple paybacks. Gregerson (1997)

15% median energy cost savings

- 150,000 sf for most buildings. Mills et al 2005

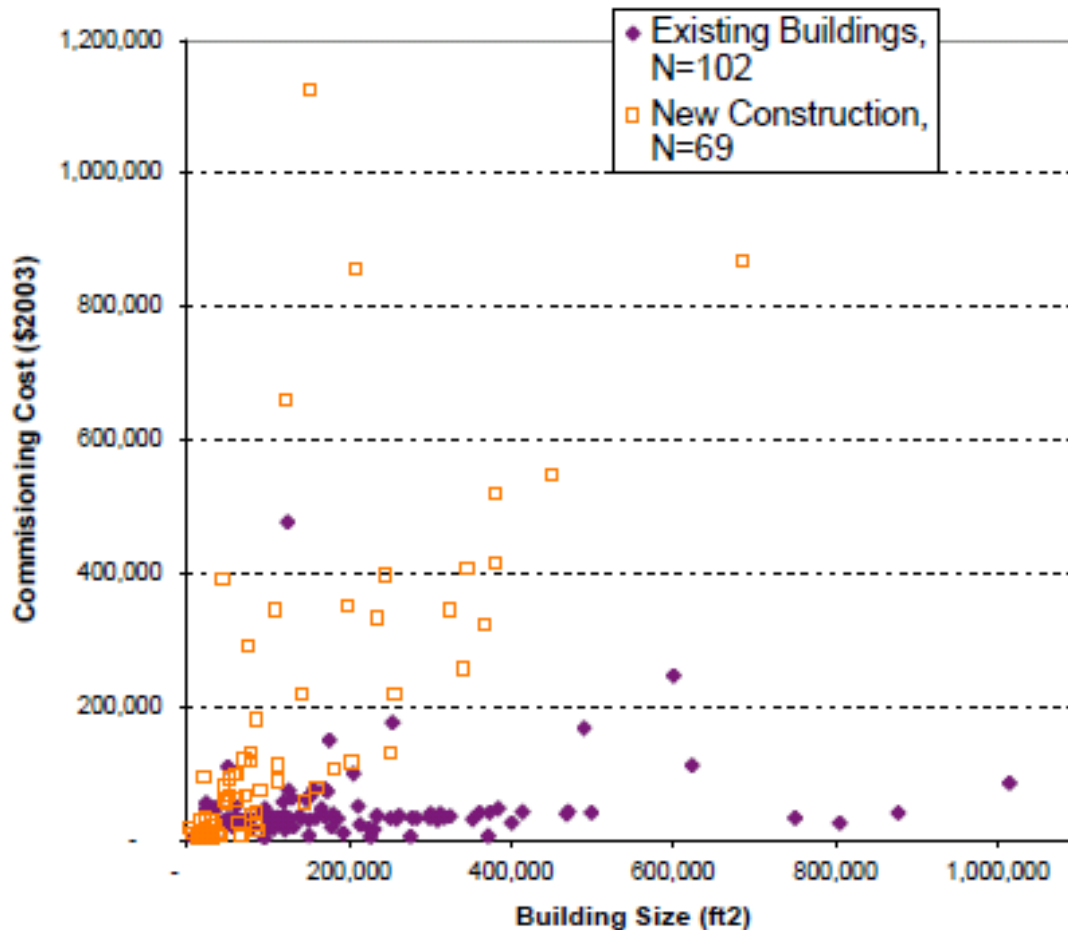
341 Billion kWh/yr potential savings

- 10% electricity savings
- Half of buildings > 100,000 sf
- Thorn & Nadel (2003)



# Retrocommissioning Costs

## Cost vs. Building Size



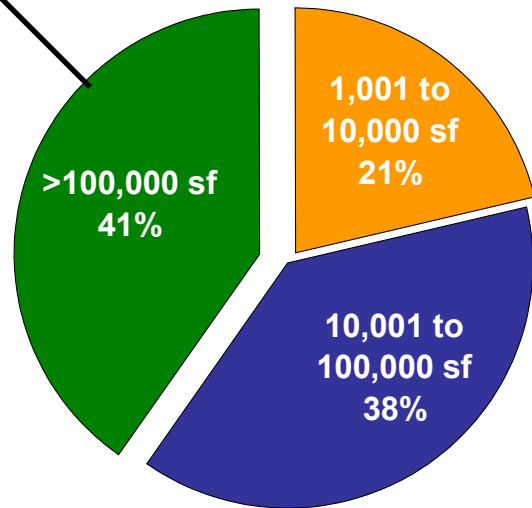
- Significant investment to secure customer
- Large fixed costs
- Retrocommissioning cost is relatively insensitive to area
- Best B/C ratio with large buildings
- Most programs > 100,000 sf

# US Commercial Building Floor Space and Energy Consumption by Building Floor Areas

Building Floor Space

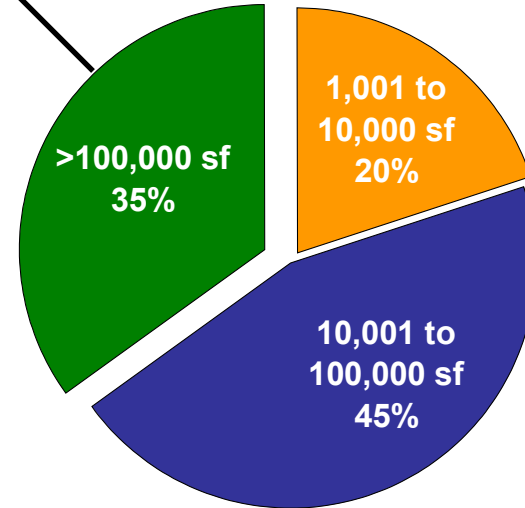
Building Energy Consumption

Traditional RCx



New Paradigm

Traditional RCx



New Paradigm

Ref. Table C21. *Electricity Consumption and Conditional Energy Intensity by Building Size for Non-Mall Buildings, 2003*. Commercial Buildings Energy Consumption Survey. US Energy Information Agency.

# RCx Programs

## Traditional

- Marketing of program to large building owners
- Selling and signing agreement
- Free audit only if implement measures
- Customer heartburn, promise to do something that they don't know what it is
- Audit
  - Engineers survey and leave recording meters
  - Evaluate monitored results
  - Write detailed technical report
- Report delivery
  - Convince owner to implement including measure incentives
- Installation verification

## New

- HVAC service companies offer to conduct free acceptance test and tune-up
- Title 24 (CA building code) short acceptance tests that identify common HVAC failures
- Service techs identify common HVAC failures using acceptance tests
- Free direct install of low cost measures
- Most savings don't rely on customer investment
- More expensive measures
- Deemed utility sponsored savings calculation and incentive offer given to owner

# New model advantages

## Less transaction costs

- Customer agreement and implementation
- Service contractor already has relationship

## Lower cost labor

- HVAC technician versus engineer

## Faster on-site process

- Tech already knows their way around
- Repeatable acceptance test protocol
- Easy repairs done at same time

# What is acceptance testing?

## Two components

1. Construction inspection
  - Is the specified equipment installed and calibrated?
2. Functional performance testing
  - Does the equipment work as intended?
  - Tests designed to uncover specification, installation or set-up problems

## Not replacing commissioning

Commissioning = broader scope



# Acceptance Tests

## Constant Volume Systems

- Outdoor Air
- Packaged HVAC Systems
- Air Distribution
- Air-Side Economizer

## Demand Control Ventilation

- Sensor and breathing zone
- Outside air damper

## Automatic Demand Shed Controls

- Reset set point on receipt of utility DR emergency signal

## VAV Systems

- Outdoor Air
- Supply Fan Variable Flow Controls
- Air-Side Economizer

## Hydronic System Tests

- Valve Leakage Test
- Supply Water Temperature Reset Controls
- Hydronic System Variable Flow Controls



# Acceptance Test Supported by CA Code Infrastructure

## Extensive Research

- Vetted by industry participants
- Designed to be reasonably accurate and quick

## Documentation

- Detailed documentation in Nonresidential Compliance Manual Acceptance Testing Chap.
- Overview “At-A-Glance” 2 page summary
- Detailed Test Descriptions and how to fill out forms

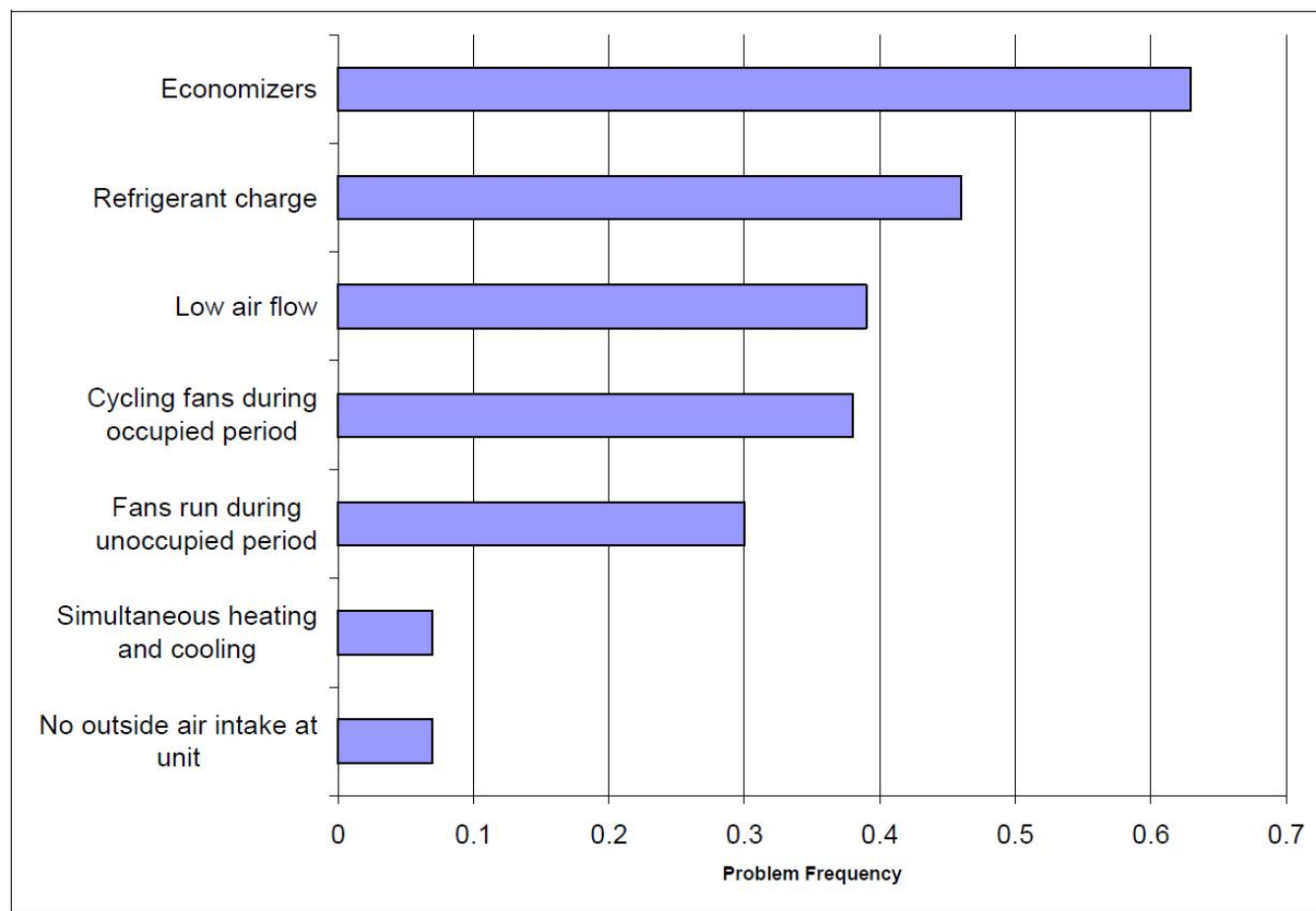
## T-24 Mandatory Requirement

- Required for all HVAC and lighting control systems

## Trainings

- Training for Designers, HVAC Contractors and Building Inspectors

# Common HVAC Failure Modes HVAC Systems < 4 yr old



Ref. Jacobs et al 2003.

# At-A-Glance Example

## At-a-Glance

### NA7.5.4 Air Economizer Controls Acceptance Use Form MECH-5A

#### Purpose of the Test

The purpose of functionally testing an air economizer cycle is to verify that an HVAC system uses outdoor air to satisfy space cooling loads when outdoor air conditions are acceptable. There are two types of economizer controls; Stand-alone packages and DDC controls. The stand-alone packages are commonly associated with small unitary rooftop HVAC equipment and DDC controls are typically associated with built-up or large packaged air handling systems. Test procedures for both economizer control types are provided.

For units with economizers that are factory installed and certified operational by the manufacturer to California Energy Commission economizer quality control requirements, the in-field economizer functional tests do not have to be conducted. A copy of the manufacturer's certificate must be attached to the MECH-5A. However, the Construction Inspection, including compliance with high temperature lockout temperature setpoint, must be completed regardless of whether the economizer is field or factory installed.

#### Instrumentation

None required

#### Test Conditions

Equipment installation is complete (including HVAC unit, duct work, sensors, control system, thermostats).

Non-DDC DX systems are required to have a two-stage thermostat.

HVAC system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations.

For those units having DDC controls, it may be necessary to use the building automation system (BAS) to override or temporarily modify the variable(s) to achieve the desired control. BAS programming for the economizer, cooling valve control, and related safeties must be complete.

For built-up systems all interlocks and safeties must be operable—for example, freeze protection, limit switches, static pressure cut-out, etc.

Document the initial conditions before overrides or manipulation of the settings. All systems must be returned to normal at the end of the test.

#### Estimated Time to Complete

Construction Inspection: 0.5 to 1 hours (depending on familiarity with the controls)

Functional testing: 0.5 to 2 hours (depending on familiarity with the controls and issues that arise during testing)



#### Acceptance Criteria

If the economizer is factory installed and certified, a valid factory certificate is required for acceptance. No additional equipment tests are necessary.

Air Economizer lockout setpoint complies with Table 144-C per Standards Section 144(e)3. Outside sensor location accurately reads true outdoor air temperature and is not affected by exhaust air or other heat sources.

All sensors are located appropriately to achieve the desired control.

During economizer mode, the outdoor air damper modulates open to a maximum position and return air damper modulates 100% closed.

The outdoor air damper is 100% open before mechanical cooling is enabled and for units 75,000 Btuh and larger remains at 100% open while mechanical cooling is enabled (economizer integration when used for compliance).

When the economizer is disabled, the outdoor air damper closes to a minimum position, the return damper modulates 100% open, and mechanical cooling remains enabled.

#### Potential Issues and Cautions

If conditions are below freezing when test is performed, coil(s) may freeze when operating at 100% outdoor air.

Outdoor air and relief dampers should be closed when the system is in unoccupied and warm-up modes, preventing problems with unconditioned air entering the building during unoccupied hours.

If the damper interlocks fail and the outdoor air damper does not open before the return damper closes, damage to the air handling unit or associated duct work may occur.

Air Economizers with poor mixing can have excessively stratified air streams that can cause comfort problems or freeze stat trips. Mixing problems are more likely to occur as the VAV system reduces flow, leading to reduced velocities in the mixing box and through the dampers. Check for exterior doors standing open and other signs of building over-pressurization when all units are on full economizer cooling (100% OSA).

Project information

<b>CERTIFICATE OF ACCEPTANCE</b>		<b>MECH-2A</b>
<b>NA7.5.1 Outdoor Air Acceptance</b>		<b>(Page 1 of 3)</b>
Project Name/Address:		
System Name or Identification/Tag:	System Location or Area Served:	
Enforcement Agency:	Permit Number:	
<i>Note: Submit one Certificate of Acceptance for each system that must demonstrate compliance.</i>		Enforcement Agency Use: Checked by/Date

Technician block

**FIELD TECHNICIAN'S DECLARATION STATEMENT**

- I certify under penalty of perjury, under the laws of the State of California, the information provided on this form is true and correct.
- I am the person who performed the acceptance requirements verification reported on this Certificate of Acceptance (Field Technician).
- I certify that the construction/installation identified on this form complies with the acceptance requirements indicated in the plans and specifications approved by the enforcement agency, and conforms to the applicable acceptance requirements and procedures specified in Reference Nonresidential Appendix NA7.
- I have confirmed that the Installation Certificate(s) for the construction/installation identified on this form has been completed and is posted or made available with the building permit(s) issued for the building.

Company Name:		
Field Technician's Name:	Field Technician's Signature:	
	Date Signed:	Position With Company (Title):

Reviewer block (licensed professional )

**RESPONSIBLE PERSON'S DECLARATION STATEMENT**

- I certify under penalty of perjury, under the laws of the State of California, that I am the Field Technician, or the Field Technician is acting on my behalf as my employee or my agent and I have reviewed the information provided on this form.
- I am a licensed contractor, architect, or engineer, who is eligible under Division 3 of the Business and Professions Code, in the applicable classification, to take responsibility for the scope of work specified on this document and attest to the declarations in this statement (responsible person).
- I certify that the information provided on this form substantiates that the construction/installation identified on this form complies with the acceptance requirements indicated in the plans and specifications approved by the enforcement agency, and conforms to the applicable acceptance requirements and procedures specified in Reference Nonresidential Appendix NA7.
- I have confirmed that the Installation Certificate(s) for the construction/installation identified on this form has been completed and is posted or made available with the building permit(s) issued for the building.
- I will ensure that a completed, signed copy of this Certificate of Acceptance shall be posted, or made available with the building permit(s) issued for the building, and made available to the enforcement agency for all applicable inspections. I understand that a signed copy of this Certificate of Acceptance is required to be included with the documentation the builder provides to the building owner at occupancy.

Company Name:		Phone:
Responsible Person's Name:	Responsible Person's Signature:	
License:	Date Signed:	Position With Company (Title):

Construction inspection

Functional testing

<b>CERTIFICATE OF ACCEPTANCE</b>		<b>MECH-2A</b>
<b>NA7.5.1 Outdoor Air Acceptance</b>		<b>(Page 2 of 3)</b>
Project Name/Address:		
System Name or Identification/Tag:	System Location or Area Served:	

**Intent:** *Verify measured outside airflow reading is within ± 10% of the total required outside airflow value found in the Standards Mechanical Plan (MECH-3C, Column H or Column I), per NA7.5.1.*

<p><b>Construction Inspection</b></p> <p>1 Instrumentation to perform test includes, but not limited to:</p> <ul style="list-style-type: none"> <li>a. Watch</li> <li>b. Calibrated means to measure airflow</li> </ul> <p>2 Check one of the following:</p> <ul style="list-style-type: none"> <li><input type="checkbox"/> Variable Air Volume (VAV) - Check as appropriate:             <ul style="list-style-type: none"> <li>a. Sensor used to control outdoor air flow must have calibration certificate or be field calibrated                 <ul style="list-style-type: none"> <li><input type="checkbox"/> Calibration certificate (attach calibration certification)</li> <li><input type="checkbox"/> Field calibration (attach results)</li> </ul> </li> </ul> </li> <li><input type="checkbox"/> Constant Air Volume (CAV) - Check as appropriate:             <ul style="list-style-type: none"> <li><input type="checkbox"/> System is designed to provide a fixed minimum OSA when the unit is on</li> </ul> </li> </ul>
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<b>NA7.5.1.1 Outdoor Air Acceptance</b>		
<b>A. Functional Testing</b> (Check appropriate column)	<b>CAV</b>	<b>VAV</b>
a. Verify unit is not in economizer mode during test - check appropriate column		
<b>Step 1: CAV and VAV testing at full supply airflow</b>		
a. Adjust supply to achieve design airflow		
b. Measured outdoor airflow reading (cfm)		
c. Required outdoor airflow (cfm) (from MECH-3C, Column I)		
d. Time for outside air damper to stabilize after VAV boxes open (minutes)		
e. Return to initial conditions (check)		
<b>Step 2: VAV testing at reduced supply airflow</b>		
a. Adjust supply airflow to either the sum of the minimum zone airflows or 30% of the total design airflow		
b. Measured outdoor airflow reading (cfm)		
c. Required outdoor airflow (cfm) (from MECH-3C, Column I)		
d. Time for outside air damper to stabilize after VAV boxes open and minimum air flow achieved (minutes)		
e. Return to initial conditions (check)		
<b>B. Testing Calculations &amp; Results</b>	<b>CAV</b>	<b>VAV</b>
<b>Percent OSA at full supply airflow (%O<sub>FA</sub> for Step 1)</b>		
a. %O <sub>FA</sub> = Measured outside air reading / Required outside air (Step1b/Step1c)	%	%
b. 90% ≤ %O <sub>FA</sub> ≤ 110%	Y / N	Y / N
c. Outside air damper position stabilizes within 15 minutes (Step 1d < 15 minutes)	Y / N	Y / N
<b>Percent OSA at reduced supply airflow (%O<sub>RA</sub> for Step 2)</b>		
a. %O <sub>RA</sub> = Measured outside air reading / Required outside air (Step2b/Step2c)	%	%
b. 90% ≤ %O <sub>RA</sub> ≤ 110%		Y / N
c. Outside air damper position stabilizes within 15 minutes (Step 2d < 15 minutes)		Y / N
<i>Note: Shaded boxes do not apply for CAV systems</i>		

# Utility-sponsored RCx measures energy savings and incentive calculation

## Tools

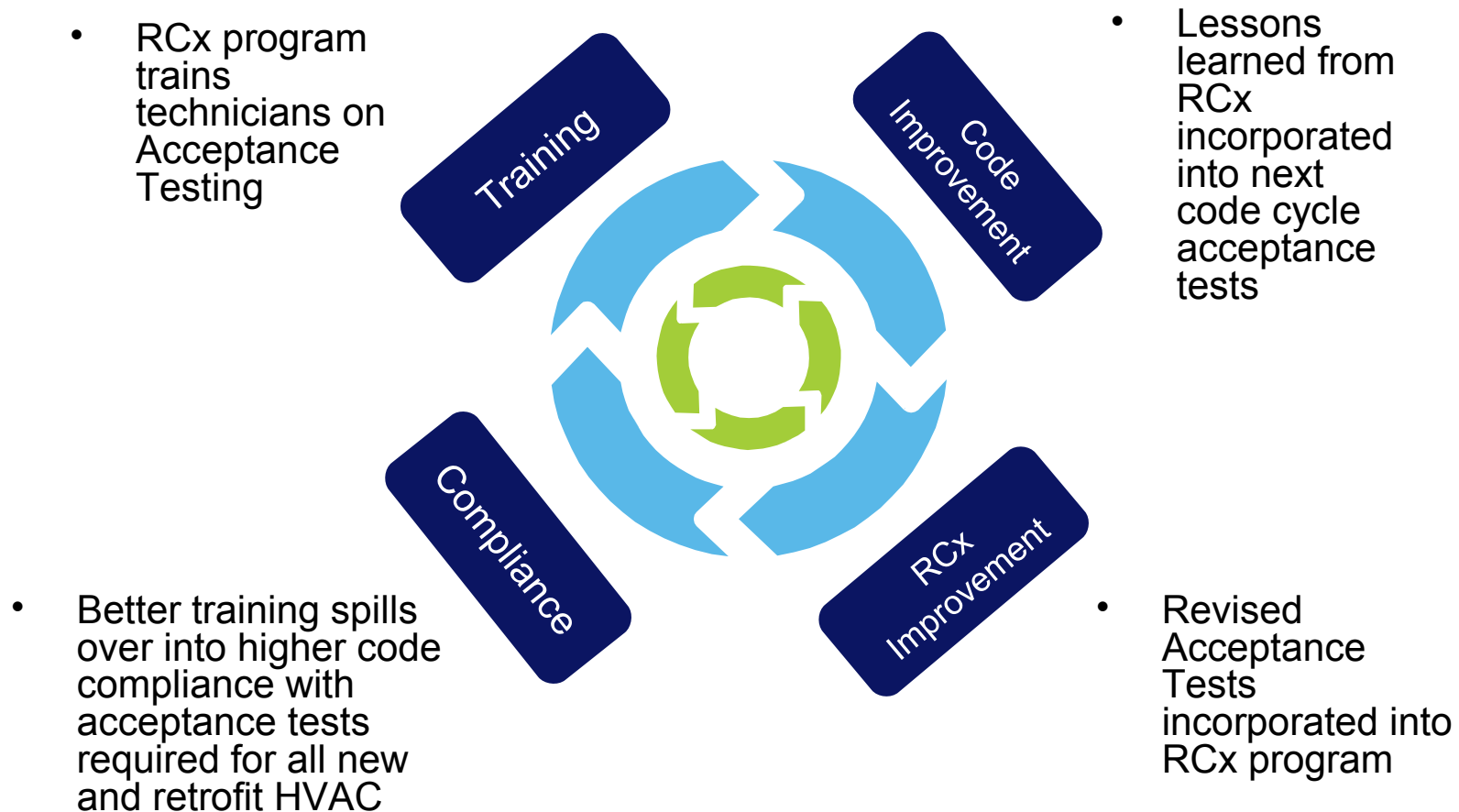
- SF Schedule
- Zone Temp Deadband
- Economizer
- SAT Reset
- DSP Reduction
- DSP Reset
- Boiler LO
- CHWST Reset
- CWST Reset
- CHW pump VFD
- Lighting Schedule
- Occupancy Sensors
- SF VFD



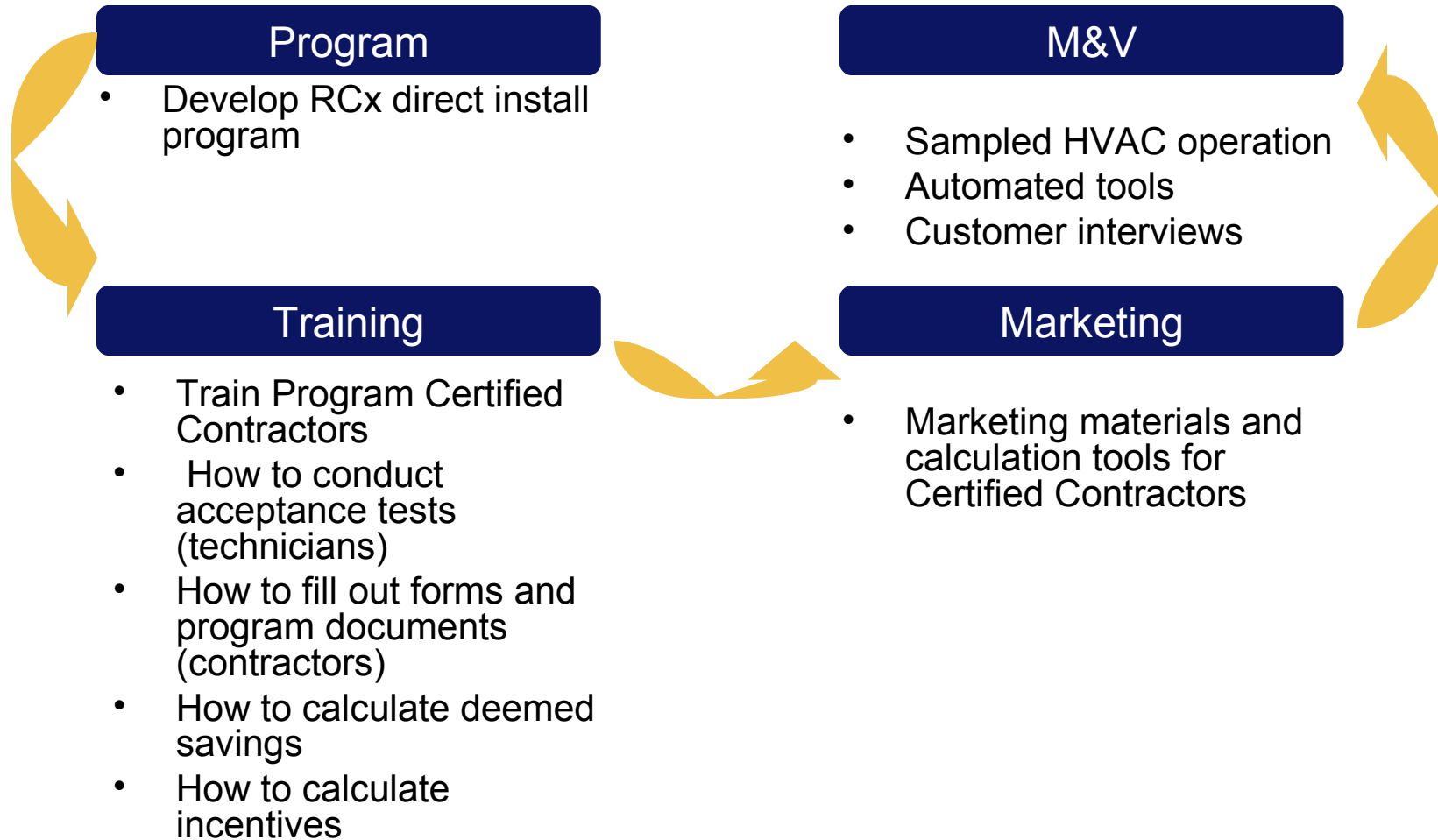
## Advantages

- Allowed for smaller projects (i.e. <50,000 kWh/yr savings).
- Larger projects must have peer reviewed M&V plan and engineering calcs.
- Make it easy for customer to assign RCx incentive payment to HVAC service contractor so it can be “on the spot” deal.

# Virtuous Circle: Codes & Standards and RCx Program Integration



# The Path to RCx Savings





# The Path to RCx Savings

- Develop RCx direct install program
- Train Program Certified Contractors
  - How to conduct acceptance tests (technicians)
  - How to fill out forms and program documents (contractors)
  - How to calculate deemed savings
  - How to calculate incentives
- Marketing materials and calculation tools for Certified Contractors
- Measurement and Verification

# Verification of Savings

## How much energy was really saved

- Pre and post measurement of a subsample

## Risk Management of contractor performance

- Acceptance testing pre and post tune up documentation
- Technology solution? – PDA tool with time stamp of data entry, software checking of data entry
- Sampled site inspection, interviews

## Interviews of customers

- How long since last commissioning?
- How much would you pay for service?
- Do you rent or own space?



# Puget Sound Energy Premium HVAC Service

- RCx program that makes use of HVAC technicians.
- Customer must sign up for 1 yr service contract with pre-qualified HVAC contractors.
- PSE gives contractors rebates for:
  - Adding economizers, sensors and 2 stg compr T-stat
  - Calibrating economizers
  - Refrigerant charge check
  - Adjusting airflow
  - Adjusting thermostat setpoints and schedules
  - Replacing or calibrating sensors

# Conclusions

## Small Building RCx

- RCx utility incentive programs can be expanded to smaller buildings (< 100,000 sf)
- Double potential savings from RCx

## Energy Savings

- US Technical savings potential is 34 Billion kWh/yr, 15,000 MW, \$4.8 Billion/yr
- Reduce pollution, generate wealth

## Jobs

- US Direct Employment Potential is 15,000 FTE “green collar” jobs
- Expand service work during off-season, likely bring full employment to twice as many people



# Acknowledgements

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