DGS Department of General Services
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In-House Commissioning Toolkit for Small Buildings

12/6/06

DGS

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pier
PUBLIC INTEREST ENERGY RESEARCH
"Research Powers the Future"

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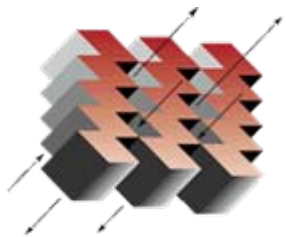

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What is PIER?

- **Public Interest Energy Research Program**
  - Initiated in 1998 as a part of California electricity deregulation and funded at ~ $62M/Yr
  - It's the research counterpart to the public goods energy efficiency program administered by the utilities and the Renewables Program administered by the CEC
  - The mission of PIER is to conduct public interest energy research that seeks to improve the quality of life...by providing environmentally sound, safe , reliable and affordable energy services and products

What is Building Commissioning?

The *California Commissioning Guide: New Buildings* says:

When a building is commissioned it undergoes an intensive quality assurance process that begins during design and continues through construction, occupancy, and operations. Commissioning ensures that the new building operates as the owner intended and that building staff are prepared to operate and maintain its systems and equipment.

California Commissioning Guidelines (available at www.cacx.org)

Commissioning Benefits

- **When new buildings undergo a well-defined Cx process—which ensures, verifies, and documents that the owners' project requirements are met—the building performs better and comes closer to meeting the owners' needs.**
  - Commissioned buildings have lower operating costs (including energy and maintenance costs) than buildings which are not commissioned.
  - They also have more acceptable environmental quality and provide a more comfortable and productive working environment.
  - Mills et al (2004)* found that, on average, Cx resulted in considerable energy and non-energy benefits, with an average simple energy payback time of 4.8 years.

**** "The Cost Effectiveness of Commercial Building Commissioning " (2004). Evan Mills, Lawrence Berkeley National Laboratory***

Corrected Deficiencies

Table 10. Results from Measures Matrices: New construction (20 projects) [yellow highlights indicate most common measures, deficiencies, and combinations]

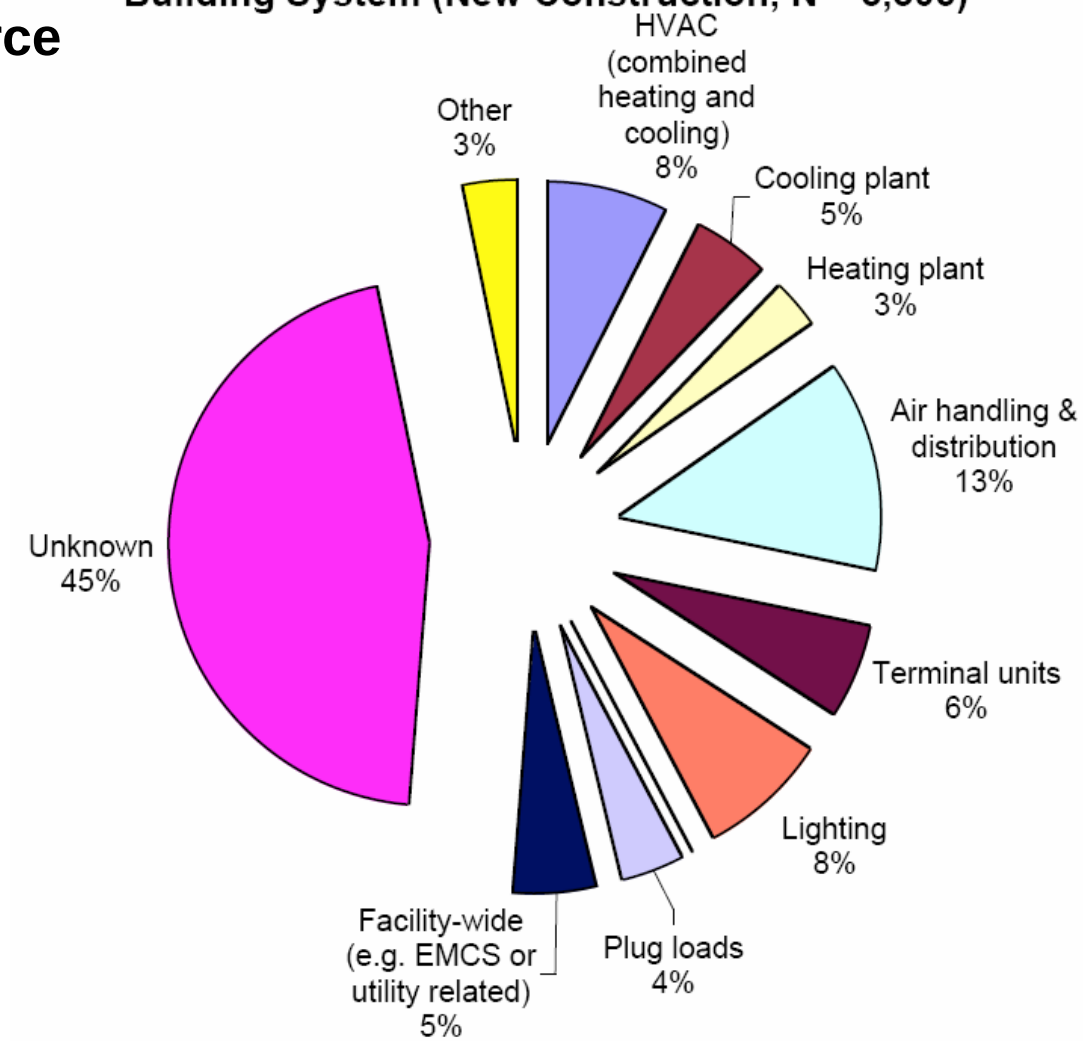
N (paired) = 157

		Measures																		
		Design, Installation, Retrofit, Replacement				Operations & Control									Maintenance						
Deficiencies		D1 Design change	D2 Installation modifications	D3 Retrofit/equipment replacement	D4 Other	OC1 Implement advanced reset	OC2 Start/Stop (environmentally determined)	OC3 Scheduling (occupancy determined)	OC4 Modify setpoint	OC5 Equipment staging	OC6 Modify sequence of operations	OC7 Loop tuning	OC8 Behavior modification/manual changes to operations	OC9 Other	M1 Calibration	M2 Mechanical fix	M3 Heat transfer maintenance	M4 Filtration maintenance	M5 Other	Deficiency unmatched to specific measure	Total
HVAC (combined heating and cooling)	V	0	8	0	0	2	0	0	3	1	0	1	0	3	6	9	1	2	2	108	146
Cooling plant	C	0	3	0	0	0	1	0	1	0	1	1	0	1	1	2	0	0	0	84	95
Heating plant	H	1	1	0	0	0	0	0	1	1	1	1	0	1	2	0	0	0	0	49	58
Air handling & distribution	A	0	7	2	0	1	0	0	3	0	7	2	0	4	2	14	1	0	3	222	268
Terminal units	T	1	5	0	0	0	0	2	5	0	2	1	0	0	3	1	0	1	0	98	119
Lighting	L	0	0	0	0	0	0	1	0	0	0	0	0	0	8	1	0	0	0	161	171
Envelope	E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plug loads	P	0	1	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	81	85
Facility-wide (e.g. EMCS or utility related)	F	0	1	0	0	0	0	0	0	1	2	0	0	8	0	3	0	0	0	69	84
Other	O	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	108	111
Deficiency unmatched to specific measure		12	82	4	22	0	0	0	90	37	52	133	0	14	78	140	14	3	263		1137
Total		14	108	6	22	3	1	3	103	41	66	139	0	31	103	171	16	6	268	1101	

Corrected Deficiencies

- **Air-handling and distribution ranked as the highest source of deficiencies,**
- **Followed by lighting and HVAC plant.**
- **~ 2/3 of the study characterized deficiencies were related to the overall HVAC system**
  (45% of the deficiencies data set were not characterized)

Fig 31. Number of Deficiencies Identified by Building System (New Construction, N = 3,305)



Commissioning Motivations

- **Cost and Energy Savings**
  - Energy - 10 to 15 Percent over non-commissioned buildings
  - Reduced change orders
- **Customer / Occupant Satisfaction**
  - Improved comfort and indoor air quality
- **Smoother Construction Process**
  - Avoided construction problems, reduced callbacks
- **Meet the LEED rating requirements**


“Get onboard…the train has left and we are moving forward”

Executive Order S-20-04

Signed December 14, 2004

Green Building Action Plan

- **Design, construct and operate all State facilities as "LEED Silver" or higher**
  - New & renovated buildings > 10,000 sq. ft.

- **"Building projects less than 10,000 sq. ft. shall use the same design standard, but certification is not required."**

LEED

- **Leadership in Energy and Environmental Design (LEED)**
  - Green building rating system
  - Administered by U.S. Green Building Council (www.usgbc.org)
- **Building Criteria for:**
  - Sustainable Sites
  - Water Efficiency
  - Energy & Atmosphere
  - Materials & Resources
  - Indoor Environmental Quality
  - Innovation in Design

EA Prerequisite 1: Fundamental Building Commissioning

EA Credit 3: Enhanced Commissioning

- **Point System with Levels of Certification**
  - Certified, Silver, Gold, Platinum

Building Commissioning Defined

- **Coordinated Process to Optimize Building Performance**
- **Quality Assurance Process**
  - Articulate/verify owners project requirements
  - Construction observation / warranty enforcement
  - Controlling first costs
  - Training building operators
  - Optimizing performance (comfort, reliability, safety, energy)
  - Creating more cohesion among team members
  - Enhancing safety and risk management

In-House Commissioning (Cx) Toolkit

- **Executive Summary**
- **Roadmap/Instructions**
- **Tools:**
  - Owner's Project Requirements
  - LEED Cx Requirements
  - Basis of Design
  - Cx Plan
  - Contract Requirements
  - Functional Performance Test Forms
  - Cx Summary Report
- **Other Resources**

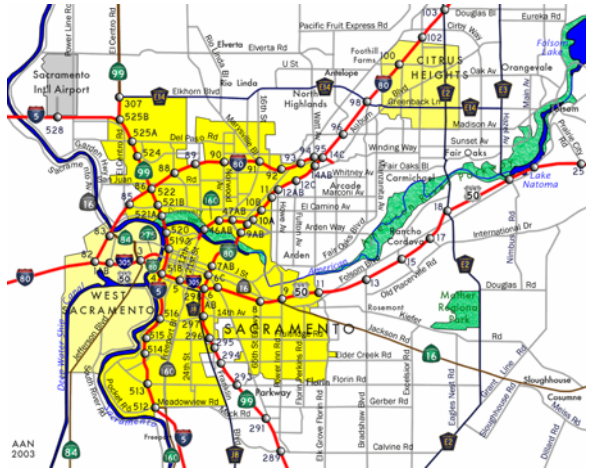
www.green.ca.gov/CxToolkit

Cx Toolkit – Executive Summary

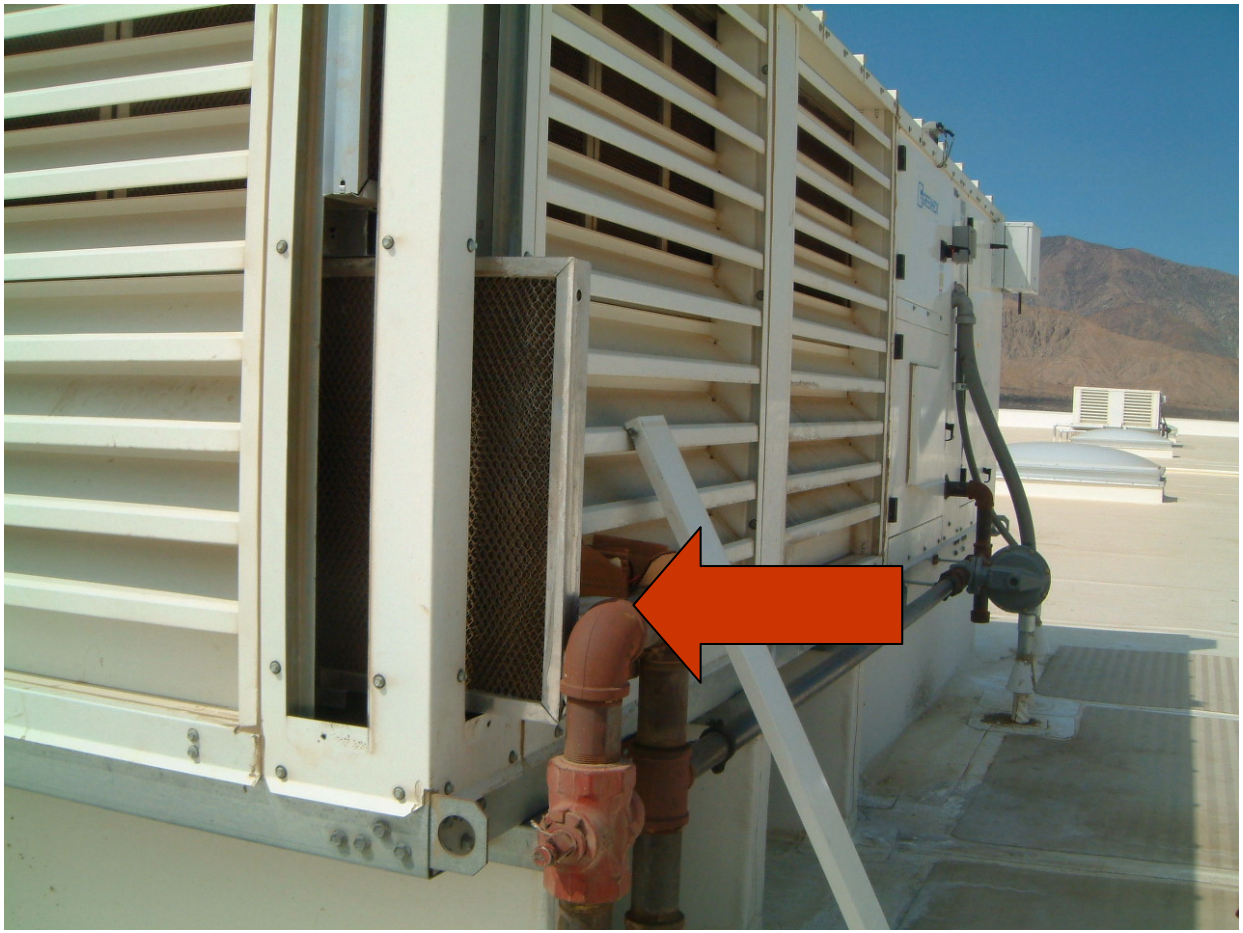
- **One-page Summary of Cx Toolkit**
  - Definition of Cx
  - Executive Order S-20-04
  - LEED Cx Requirements
  - Purpose & Content of Toolkit
  - Benefits of Cx Integration

Cx Toolkit – Roadmap/Instructions

- **Instructions on Use of Toolkit**
- **Integrate Cx as Early as Possible**
  - Portions can be integrated in budget pkg.
- **Identify Cx Provider**
  - Design Phase – Design engineer
  - Construction Phase – M/E Inspection Specialists
- **Develop Cx Plan**
- **Implement Activities in Cx Plan**



Commissioning Motivations



Source: Architectural Energy Corporation

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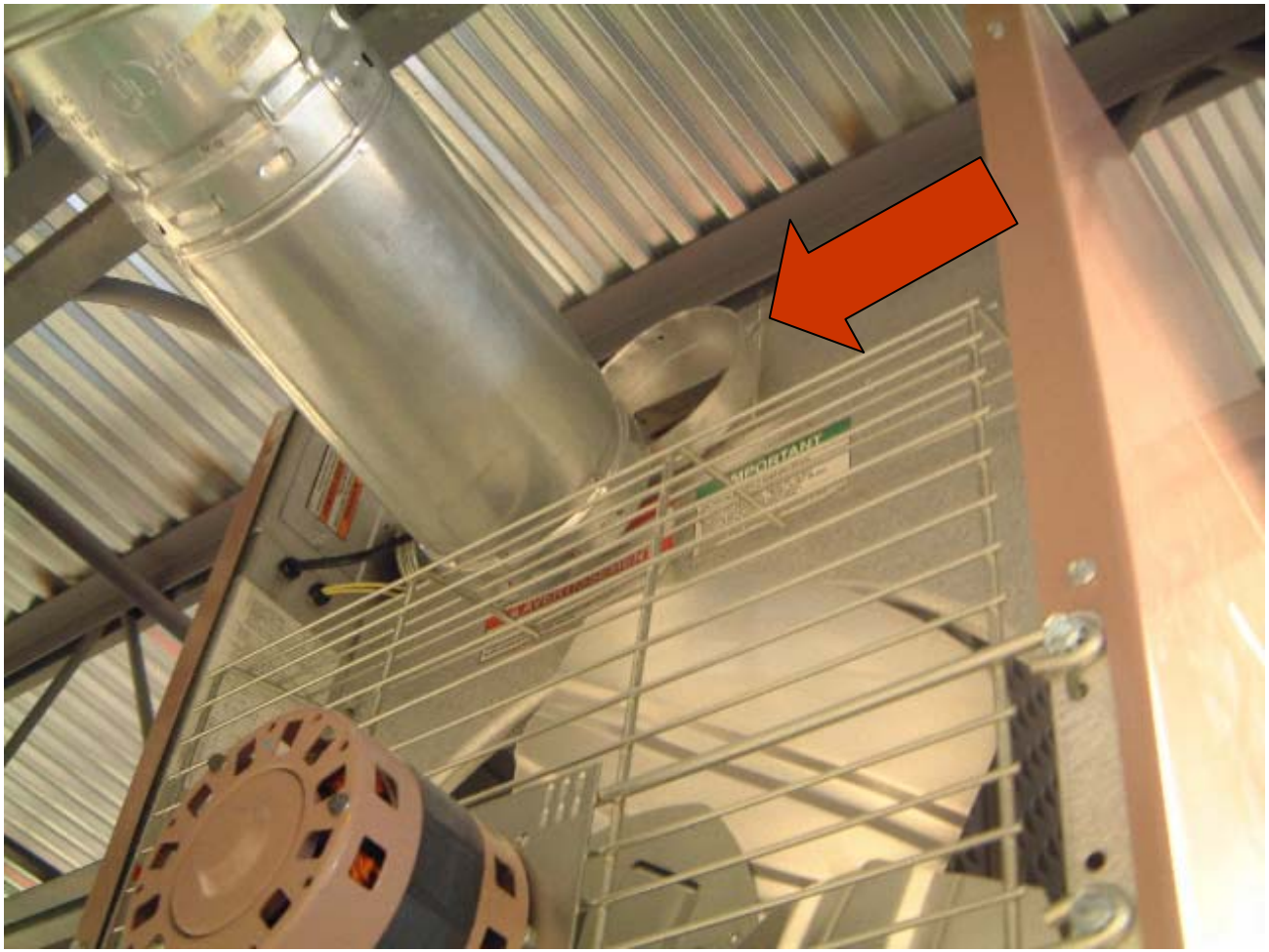
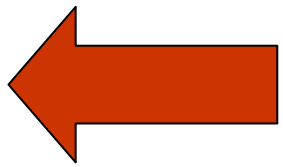


Source: Architectural Energy Corporation

Pop Quiz

“OPR” stands for…

a. **Owner’s Project Requirements**



b. **Onerous Project Requirements**

c. **Owner’s Petty Rants**

d. **Outstanding Pork Ragu**

e. **Other Person’s Responsibility**

DGS Commissioning Toolkit

- Owner's Project Requirements
- Basis of Design
- Commissioning Plan
- Commissioning Specifications
- A&E Commissioning Scope of Work
- Functional Performance Test Forms
- Commissioning Summary Report

Owner's Project Requirements (OPR)

- Owner and User Requirements
- Environmental and Sustainability Goals
- Energy Efficiency Goals
- Indoor Environmental Quality Requirements
- Equipment and Systems Expectations
- Building Occupant and O&M Personnel Expectations

Basis of Design (BOD)

- **HVAC System**
  - Narrative Description of System
  - Reasons for System Selection
  - Load Calculations
  - Sequence of Operations
- **Indoor Lighting System**
  - Narrative Description of System
  - Reasons for System Selection
  - Lighting Design Criteria
  - Lighting Power Design Targets
- **Water Heating System**
  - Narrative Description of System
  - Reasons for System Selection
  - Water Heating Load Calculations

Commissioning Plan

- General Project Information
- Commissioning Goals
- Systems to be Commissioned
- Commissioning Team Information
- Commissioning Process – Activities, Schedule and Responsibilities

Commissioning Plan Activities

Commissioning Activity	Timing (Project Phase)	Responsibility
Owner's project requirements (OPR)	Concept / Budget	Project team, led by Project Director, with CxA review
Cx Plan	Concept / Budget or PP	CxA
Basis of Design (BOD)	PP or WD	Design Team, with CxA review
Cx Specifications	WD	Design Team, with CxA review

Commissioning Plan Activities (cont.)

Commissioning Activity	Timing (Project Phase)	Responsibility
Cx Kick-off Meeting	Const.	Lead by CxA, attended by Contractor
Develop pre-functional checklists	WD or Const.	CxA (or Design Team)
Develop functional test procedures	WD or Const.	CxA (or Design Team)
Complete prefunctional checklists	Const.	Contractor, with CxA (or Inspector) review

Commissioning Plan Activities (cont.)

Commissioning Activity	Timing (Project Phase)	Responsibility
Perform functional performance testing	Const.	Contractor, with CxA (or Inspector) guidance, witness and approval
Commissioning acceptance	Const.	CxA
Cx Summary Report	Const.	CxA

Commissioning Specifications

- **Describes contractor participation requirements**
- **Division 1 Section**
  - 01810 General Commissioning Requirements
- **References in relevant mechanical and electrical sections**
- **Currently under development – to be posted soon**

A&E Scope of Work

- **Describes additional scope for commissioning role of design team**
- **Currently under development**

Functional Performance Test (FPT) Forms

- **HVAC**
  - Packaged rooftop AC units
  - Split system AC units
- **Lighting**
  - Occupancy sensor controls
- **Water Heating**
  - Storage water heater
  - Point-of-use water heater

FPT – Packaged AC Unit

- **Page One**
  - General project info
  - Prefunctional checklist

Project Name:		
Equipment Tag:		
Test Date/Time:		
Participants:	**Name**	**Organization**
Comments:		

Operating Schedule - *Record time-of-day and setpoints and note any deviation from DESIGN*

	DAY OF THE WEEK							
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**	**Override available?**
Design:	**7AM-6PM**	**7AM-6PM**	**7AM-6PM**	**7AM-6PM**	**7AM-6PM**	**override**	**override**	Yes
Actual:								
Comments:								

Prefunctional Checklist

Record values for current setpoints, control parameters, limits, delays, lockouts, etc.and note any deviation from design.

Parameter	Per Design	Observed
Power to unit		
Power disconnects installed and labeled.		
Thermostat is wired to the HVAC system correctly		
Thermostat meets deadband control requirements		
Space temperature sensor calibrated		
Occupied, unoccupied, and holiday schedules programmed		
Pre-occupancy purge has been programmed		
Set up and set back setpoints programmed as required		
Thermostat located within the zone that the HVAC unit serves		
Unoccupied avg. zone set points (e.g. 85°Fsetup/60°Fsetback)		
Schedule override		
Condensate drain connected		
CO2 sensor location		
CO2 sensor calibrated		
Return air damper moves through full range		
Outdoor air damper moves through full range		
No excessive damper linkage slop.		
Permanent label attached.		
Unit secure and level.		
Maintenance access ok.		
Test, adjust and balance complete with deficiencies corrected.		
Outdoor air economizer switchover type and setting		
Casing condition ok.		

FPT – Packaged AC Unit (cont.)

Simulation Mode/Test	Desired System Response (check box if observed) ☑	Other Observed Syste
1. Heating during occupied condition		
Set control system or programmable thermostat to occupied mode (e.g. adjust clock time to normal working hours). Adjust thermostat to 5 deg higher than current room temperature.	☐ Supply fan operates continually. ☐ Gas-fired furnace, heat pump, or electric heater stages on. ☐ No cooling is provided by the unit. ☐ Outside air damper is open to minimum position.	
2. No load during occupied condition		
Leave system in occupied mode. Adjust thermostat setpoint to equal current room temperature.	☐ Supply fan operates continually. ☐ Neither heating or cooling is provided by the unit. ☐ Outside air damper is open to minimum position.	
3. Heating during unoccupied condition		
Set control system or programmable thermostat to unoccupied mode (e.g. adjust clock to after-hours time). Adjust thermostat to 5 deg higher than current room temperature.	☐ Supply fan cycles on. ☐ Gas-fired furnace, heat pump, or electric heater stages on. ☐ No cooling is provided by the unit. ☐ Outside air damper is open to minimum position.	
4. No load during unoccupied condition		
Leave control system or programmable thermostat in unoccupied mode (e.g. adjust clock to after-hours time). Adjust thermostat to equal current room temperature.	☐ Supply fan shuts off. ☐ Neither heating nor cooling is provided by the unit. ☐ Outside air damper closes completely.	
5. Cooling during occupied condition		
Return control system or programmable thermostat to occupied mode (e.g. adjust clock time is during normal working hours). Adjust thermostat to 5 deg lower than current room temperature. To ensure that airside economizer does not turn on, either warm economizer sensor or if unit has adjustable airside economizer sensor, adjust sensor down to turn off economization.	☐ Supply fan operates continually. ☐ No heating provided. ☐ Compressor turns on and provides cooling. ☐ Outside air damper is open to minimum position.	
6. Economizer operation (if unit equipped with economizer)		
Leave system in occupied mode. Adjust thermostat to 5 deg lower than current room temperature. If outdoor air temperature is lower than return air temperature, verify that economizer dampers are open for 100% outdoor air. Otherwise, use cold spray on outdoor air sensor to simulate condition. Then remove cold spray and verify that economizer dampers return to minimum air position (or warm the outdoor air sensor to simulate condition).	☐ Supply fan operates continually. ☐ No heating provided. ☐ Outside air dampers open to 100%. ☐ There are no signs of building overpressurization. ☐ Outside air dampers return to minimum position.	
7. Cooling during unoccupied condition		
Set control system or programmable thermostat to unoccupied mode (e.g. adjust clock to after-hours time). Adjust thermostat to 5 deg lower than current room temperature.	☐ Supply fan operates continually. ☐ No heating provided. ☐ Compressor turns on and provides cooling. ☐ Outside air damper is open to minimum position.	
8. Manual Override (if system has this capability)		

Simulation Mode/Test	Desired System Response (check box if observed) ☑
1. Heating during occupied condition	
Set control system or programmable thermostat to occupied mode (e.g. adjust clock time to normal working hours). Adjust thermostat to 5 deg higher than current room temperature.	☐ Supply fan operates continually. ☐ Gas-fired furnace, heat pump, or electric heater stages on. ☐ No cooling is provided by the unit. ☐ Outside air damper is open to minimum position.
2. No load during occupied condition	
Leave system in occupied mode. Adjust thermostat setpoint to equal current room temperature.	☐ Supply fan operates continually. ☐ Neither heating or cooling is provided by the unit. ☐ Outside air damper is open to minimum position.

Commissioning Summary Report

- **General Project Information**
- **Commissioning Team Information**
- **Executive Summary**
  - Commissioning Process Summary
  - Outstanding Issues
  - Observations and Conclusions
- **History of Deficiencies**

Conclusion / Other Resources

- **Start Now – Begin with Owner's Project Requirements**
- **Online Toolkit – www.green.ca.gov/CxToolkit**
- **Other Useful websites/documents:**
  - California Cx Guide for New Buildings: www.documents.dgs.ca.gov/green/commissionguidenew.pdf
  - California Commissioning Collaborative: www.cacx.org
  - Portland Energy Conservation, Inc. (PECI): www.peci.org
  - Building Commissioning Association (BCxA): www.bcxa.org
  - Cx Assistant Cx Tool: www.ctg-net.com/edr2002/cx
  - LEED-NC v2.2 Reference Guide
    - Prerequisite 1 – pp 149-161;
    - Credit 3 – pp 205-210