Opinion **Dynamics**

WE&T DELIVERABLE 30: KNOWLEDGE, SKILLS, AND ABILITIES MARKET STUDIES

HVAC Rooftop Package Units & Heat Pump Water Heaters

January 17, 2020

Research Goal

- The objective of this research is to identify knowledge, skills, and abilities associated with the duties and tasks that are most closely tied to ensuring the installation of equipment in such a way that prioritizes optimal energy efficiency outcomes
- Equipment (replacement of existing unit):
  - Rooftop Package Units (RTU), 5-tons or less, in small commercial setting
  - Heat Pump Water Heaters (HPWH) in residential setting

Research Steps

1. Identified Key Areas of Study
2. Completed Pre-Inventory Data Analysis
3. Workshop Sample Strategy and Recruitment
4. Design and Facilitate DACUM Workshop
5. Verification
6. Reporting

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Pre-Inventory Data Analysis

Pre-Inventory Data Analysis Objectives

To gain an understanding of existing information and data sources relevant to the selected areas of study to help ensure that the research team:

- Uses appropriate and familiar language in the development of workshop stimuli and homework;
- Understands the complexity of the occupations under study;
- Prioritizes key functions within a job that focus on energy efficiency;
- Probes effectively during two-day workshop to ensure important aspects are not missed; and
- Aligns this study with existing industry-specific job frameworks to increase industry buy-in

5-Ton Rooftop Package Units (RTU) in Small Commercial Setting

- Reviewed following resources to inform Pre-Inventory Data Analysis
  - U.S. Department of Labor Occupational Information Network
  - U.S. Bureau of Labor Statistics Occupational Outlook Handbook
  - Department of Energy and the National Renewable Energy Laboratory's Guidelines for Home Energy Professionals Project
  - ANSI/ACCA Standards 5 and 9
  - Knowledge Areas of Technician Expertise (KATEs) identified by North American Technician Excellence (NATE)
  - Competency and task lists developed by HVAC Excellence
  - New Buildings Institute: Rooftop Unit HVAC Efficiency: Repair, Retrofit, Replace
  - Manufacturer Specifications, Installation Guides, and Trainings

Heat Pump Water Heaters (HPWH) in Residential Setting

- Reviewed following resources to inform Pre-Inventory Data Analysis
  - U.S. Department of Labor Occupational Information Network
  - U.S. Bureau of Labor Statistics Occupational Outlook Handbook
  - U.S. Department of Energy and the National Renewable Energy Laboratory's Guidelines for Home Energy Professionals Project
  - U.S. Department of Energy Measure Guideline: Heat Pump Water Heaters in New and Existing Homes
  - U.S. Department of Energy Heat Pump Water Heater – Code Compliance Brief
  - Energy Star Considerations – Heat Pump Water Heaters
  - 2015 National Appliance Energy Conservation Act
  - Manufacturer Specifications, Installation Guides, and Trainings

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Background and Introduction to DACUM

Background

- Jobs can be best understood as a series of tasks and responsibilities that an employee conducts.
- A task is an action designed to contribute to a specified end result.
- Knowledge, skills, and abilities are what enable employees to perform these tasks. Often, these terms are used interchangeably; yet they represent distinctly different dimensions of a job. We define them on the next slide.

Definitions: Knowledge, Skills, Abilities

	Definition	Example: Driving a Car
Knowledge	The body of information needed to perform a task. It focuses on the actual understanding of particular concepts. It is theoretical and not practical.	A person can read a state's driver's manual on how to drive a car, but have no practical experience driving a car.
Skills	Reflects the practical application of the theoretical knowledge. They reflect capabilities or proficiencies developed through training or actual experience.	Once a person passes their Department of Motor Vehicle's written test, they obtain a learner's permit to develop the proficiency of driving a car prior to taking the driving test.
Abilities	Are underlying, enduring traits useful for performing tasks. They are often related to personal and social attributes that tend to be innate. There is a fine line between skills and abilities.	Driving a car requires the ability to safely perform a range of physical activities such as manipulating the controls for starting, stopping, and backing up.

What is a DACUM?

- An acronym for Developing a Curriculum
- Initially developed as a method to conduct needs assessments to inform curriculum development
- Has been used for over 40 years to conduct job analyses for other purposes
- Used in schools, colleges, government agencies, military organizations, business, and industry

DACUM Philosophy

- Expert workers can describe and define their job more accurately than anyone else
- An effective way to define a job is to precisely describe the duties and tasks that expert workers perform
- All tasks, in order to be performed correctly, demand certain knowledge, skills, tools, and worker behaviors

Examples: Job, Duty, Task, and Steps

Job	**Duty:** A cluster of related tasks (Usually 6-10 per job) **Task:** Specific meaningful units of work (Usually 6-20 per duty, 75-125 per job) **Step:** Specific elements or activities required to perform a task (Always 2+ per task)
Car Owner	**Duty:** Maintain the vehicle **Task:** Change the Motor Oil **Step:** Drain the old oil
Parent	**Duty:** Clothe children **Task:** Buy school clothes **Step:** Select correct sizes
Homeowner	**Duty:** Maintain the yard **Task:** Mow the lawn **Step:** Start the mower

DACUM Workshop Steps

- Review the job/occupation
- Identify duties (general areas of responsibility)
- Identify specific tasks performed
- Prioritize tasks
- For each high-priority task, identify:
  - Energy Efficiency considerations
  - Knowledge requirements
  - Skill requirements
  - Ability requirements
  - Tools, equipment, supplies, and materials
- Final review and revisions

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Learning from Expert Workers

DACUM Workshop Participants: HVAC RTUs

- Held in Southern California
- June 2019
- 11 HVAC Technicians who had 3 - 5 years HVAC experience and met one of the criteria below:
  - Completed or enrolled in a California or federal accredited HVAC apprenticeship
  - Completed at least five years of work experience at the journey level as defined by the California Department of Industrial Relations
  - Has a C-20 HVAC contractor license from the California State Contractor's Licensing Board or works for someone who does
  - Has Energy Efficiency/Whole Building Expertise/Experience

Workshop Participants: HPWHs

- Held in the Bay Area
- October 2019
- 6 plumbers with 2 - 5 years water heater experience who met one of the criteria below:
  - Has a C-36 plumbers' license from the California State Contractor's Licensing Board or works for someone who does
  - Completed at least five HPWH installations
  - Has energy efficiency knowledge

Online Verification Survey

- Other expert workers reviewed the workshop output
  - Validated results from both DACUM workshops
  - Rated the importance of the duties and tasks to optimizing energy efficiency
  - Reported whether a task, step, knowledge, skill, or ability was missing
- RTU: 43 respondents
  - California HVAC contractors who participated in IOU rebate programs or were listed as approved contractors on the IOU websites
  - $100 gift card for completing survey
- HPWH: 22 respondents
  - HPWH installers in the Northwest Energy Efficiency Alliance's Hot Water Solutions network, ETO's Trade Ally network, or Efficiency Maine's Registered Vendor list
  - $150 gift card for completing survey

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Findings

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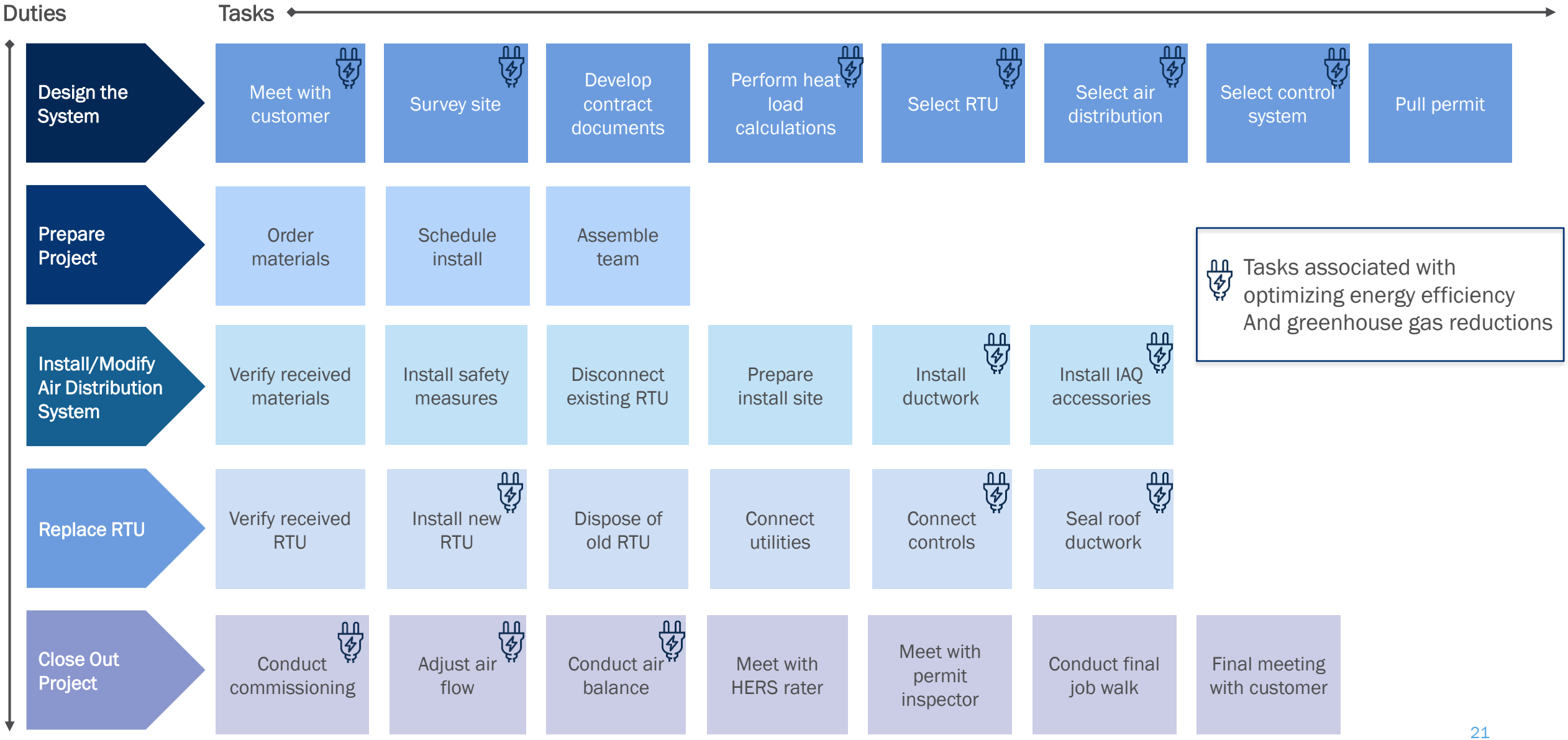
HVAC Packaged Rooftop Units (RTUs)

Job: HVAC Installer/Technician; Installation of Rooftop Packaged Units



Duties

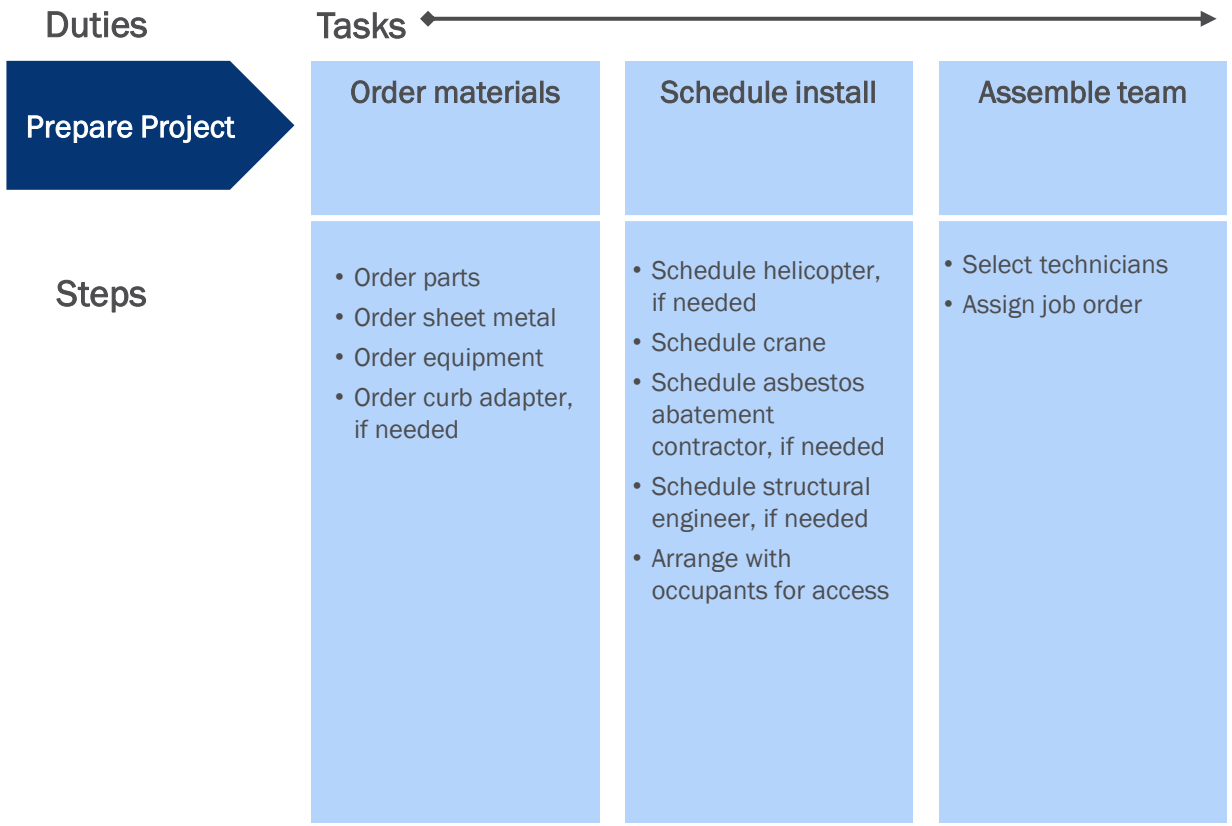
Tasks →

Design the System

Steps

Meet with customer	Survey site	Develop contract documents	Perform heat load calculations	Select RTU	Select air distribution	Select control system	Pull permit

• Conversation with customer
• Obtain accurate project information
• Test existing equipment (airflow and duct test)
• Give a price range
• Explore incentives and financing options
• Give customer ROI for high-efficiency option
	• Assess safety considerations
	• Meet with client to determine needs
	• Walk property to determine feasibility and accessibility
	• Determine equipment lift requirements
	• Consider distribution modification needs
	• Determine system control needs
	• Determine needed envelope improvements, if any
	• Review plans or blueprints
		• Review Title 24 code requirements
		• Sign the contract
			• Draw up building footprint
			• Measure
			  • Window size/type
			  • Insulation
			  • floor
			  • Wall
			  • Ceiling
			  • Roof material
			  • Room sizes
			  • Equipment load/plug load
			  • Occupational load
			  • Door sizes/type
			  • Duct insulation
			• Enter measurements into Manual J calculation program
				• Investigate alternative technologies like VRF
				• Match CFM to load calcs
				• Determine size/ tonnage/capacity
				• Determine mounting, vibration
				• Match/determine duct orientation
				• Match existing equipment footprint
				• Determine if panel upgrades needed
					• Select system type
					• Determine plenum sizes
					• Calculate duct sizes by room
					• Calculate main truck lines
					• Draw diagrams with
					  • Dampers
					  • Floor box and grille size/type of T-bar
					  • Air return
					• Add filter system and other IAQ accessories
					• Job walk/observe duct space
					• Revise system if necessary
						• Determine existing building compatibility (EMS, DDS, t-stat).
						• Explore control options with customer (Wi-Fi, digital)
						• Consider code compliance (smoke detectors, ventilation, economizers)
						• Select controls	


Duties
Tasks
Prepare Project
Order materials
Schedule install
Assemble team
Steps
• Order parts
• Order sheet metal
• Order equipment
• Order curb adapter, if needed
• Schedule helicopter, if needed
• Schedule crane
• Schedule asbestos abatement contractor, if needed
• Schedule structural engineer, if needed
• Arrange with occupants for access
• Select technicians
• Assign job order

Duties

Install/Modify Air Distribution System

Steps

Tasks

Verify received materials	Ensure safety measures	Disconnect existing RTU	Disconnect existing RTU (cont.)	Prepare install site	Install ductwork	Install IAQ accessories
• Compare order list to received list • Verify no discrepancies • Correct the discrepancies if needed • Verify material are in working order	• Ensure employees equipped with Personal Protection Equipment (PPE) • Install safety work platforms • Put fire alarm system on 'test' • Prepare for equipment lift by setting cones out	• Turn power off at breaker • Check it's powered off • Lock-out/tag-out of electrical • Separate electrical wiring from disconnect • Remove disconnect from unit • Disconnect low voltage wiring from terminal block • Disconnect condensate line • Turn off gas at shutoff • Disconnect gas pipe	SCENARIO A • Disconnect ductwork from unit • Disconnect unit from seismic straps SCENARIO B • Remove all fasteners from unit and curb • Remove duct sealant and gasket from original curb ALL SCENARIOS • Cover roof penetration between unit changeout • Dispose of hazardous materials • Check site after removal	SCENARIO A&B • Remove old adhesive from existing ductwork • Modify existing platforms and supports SCENARIO B • Install gasket material on existing curb and adaptor • Set curb adapter on existing curb • Secure adaptor to existing curb • Seal existing ductwork to curb adaptor SCENARIO C • Remove rooftop duct plenums through roof • Install new curb • Level new curb • Install new supply and return plenums • Seal plenums to curb	• Remove existing ductwork per design • Measure and cut ductwork and plenums based on design • Hang ductwork • Install dampers • Seal ductwork joints • Insulate ductwork • Install diffusers and registers • Repair any damaged ductwork as needed • Install duct smoke detectors	IF NECESSARY • Install filter rack • Install humidifier • Install UV light • Install other optional IAQ accessories

Note:

Scenario A: Connect to existing ductwork

Scenario B: Use an adapter curb

Scenario C: New curb

Duties

Tasks

Replace RTU

Steps

Verify received RTU	Install new RTU	Dispose of old RTU	Connect utilities	Connect controls	Seal roof ductwork
• Verify voltage • Verify size	• Remove old RTU • Set new unit on curb or stand • Connect supply and return duct • Seal curb and duct connections (Scenarios A and B) • Install economizer if needed • Put down curb tape/gasket • Install seismic strap • Install sound absorption if applicable	• Recover and dispose of refrigerant from existing RTU • Dispose of existing RTU	• Verify supply wiring ampacity • Verify breaker electrical supply ampacity • Connect gas lines • Check gas connections for leaks • Connect electric lines • Connect high voltage line	• Verify voltage of controls • Wire in smoke detector • Wire in economizer • Calibrate/set parameters economizer • Run test • Connect to Wi-Fi	• Determine lagging (tape) or putty type • Seal for leakage voltage, conduits, and gas line • Avoid sealing filter access • Determine duct sealant type • Apply duct sealant as needed • Check for air and water leakage • Paint in a light color

Note:

Scenario A: Connect to existing ductwork

Scenario B: Use an adapter curb

Duties

Tasks

Close out the project

Steps

Conduct commissioning	Conduct commissioning (cont.)	Adjust air flow	Conduct air balance	Meet with HERS rater	Meet with permit inspector	Conduct final job walk	Final meeting with customer

• Mount sensors
• Plug sensors in
• Perform sensor test
• Interpret results
• Verify operation
• Test economizer response
• Program schedule according to customer usage
• Set thermostat temperature range
• Conduct pre-Title 24 duct test
• Check leakage (if necessary)
• Check phase rotation
	• Check for excessive vibration (including wheel balance and fan blades)
	• Check temperature split
	• Checking current draw (amperage)
	• Check voltage
	• Confirm transformer tap
	• Check electrical connections for tightness
	• Visually inspect connections
	• Commission heating
	• Initial burn
	• Check gas pressure
	• Adjust as necessary
		• Take panels off
		SCENARIO 1 with belt drive
		  • Determine pulley sizes
		  • Adjust pulleys if necessary
		  • Determine belt sizes
		  • Adjust belts if necessary
		  • Measure static pressure
		  • Readjust as necessary
		SCENARIO 2 with direct drive
		  • Measure static pressure
		  • Adjust speed taps (if necessary)
			• Run unit for 20 minutes
			• Pre-test to determine baseline (gather baseline info at each damper)
			• Document findings
			• Adjust diffusers
			• Adjust dampers
			• Conduct post-test
			• Prepare air balance report
				• For the Title 24 test, if needed and when required by authority having jurisdiction		• Walk site one last time to check everything	• Give customer warranty package
							• Recommend maintenance to customer
							• Give customer manuals
							• Educate customer on use
							• Optional: present air balance report to customer
							• Collect payment

Knowledge of

- Air distribution principles; Duct runs and bend turns; Thermal imaging; Basic thermodynamics; Psychrometrics; Schematics or blueprints; Superheat and subcooling; Refrigerant types; Economizer fundamentals; Air flow tests; Plumbing fundamentals; Gas pressure adjustments; Mechanical and building codes including Title 24 requirements; Noise reduction strategies; Energy efficiency rebates; Energy management systems; Efficiency ratings (SEER, EER); Energy modeling; Interaction of HVAC with other building systems; ANSI/ACCA Standard 5 and 9; Pressure drop calculations (both air and water); Basics of trusses and beams in attic spaces; NFPA and HVAC shutdown; Thermostat setpoints and deadband for energy efficiency (if applicable)

Skills

- Fabricating copper tubing; Installing refrigerant line; Electrical skills and wiring skills; Safe handling of refrigerant containers; Properly evacuating refrigerant; Properly charging unit; Installation of indoor air handlers; Detecting leaks; Install ducting; Install thermostats; Install electronic air cleaners; Install economizer(s); Building construction skills; Teaching skills (to mentor apprentices); Communication skills; Decision-making skills; Delegation skills; Knowledge of employee skills; Reading schematics or blueprints; Perform air flow measurements; Logistics coordination; Math skills; Customer service skills; Safety skills; Time management; Organizational skills; Troubleshooting or problem-solving skills; Attention to detail

Abilities

- Open-mindedness; Team player; Tolerance for criticism; Flexibility or adaptability; Dependability; Stamina, agility, or physical labor

Tools

- Heat Load software to get Manual S/D/J; Microsoft word; Contract management software; Contractor dispatching software (also prepares proposals); Laptop (to help with connecting controls); Smart phone; Laser or digital thermometer; Camera; Tape measure; Calculator; Textbooks; Sheet metal cutters, Sawzall, Flashlight, Chainsaw; Safety gear/PPE, Sheet metal working tools; Hand and power tools (drills, Sawzall, ladders, hammers, levels); Tie band; UL-180 tape; Radios; Fire extinguisher; Fire retardant; Voltmeter/multimeter/ammeter (amp clamp); wire strippers; other standard hand and electrical tools; Digital gauge manifold; gauge; digital psychrometer; Anemometer; Manometer; Non-contact tachometer, Psychrometric target chart; Duct leakage testing equipment; Combustion analyzer; Differential pressure gauge; Thermocouples

Manuals or Resources

- ASHRAE Climate Data Manual; ACCA Manual S/D/J; AHRI Certification number, Title 24 non-residential; ASHRAE 90.1 International Energy Code; NATE training manuals; State and local building codes; Product catalog or website; Equipment manual; 608 certificate; Ugly's electrical reference manual; NEC manual

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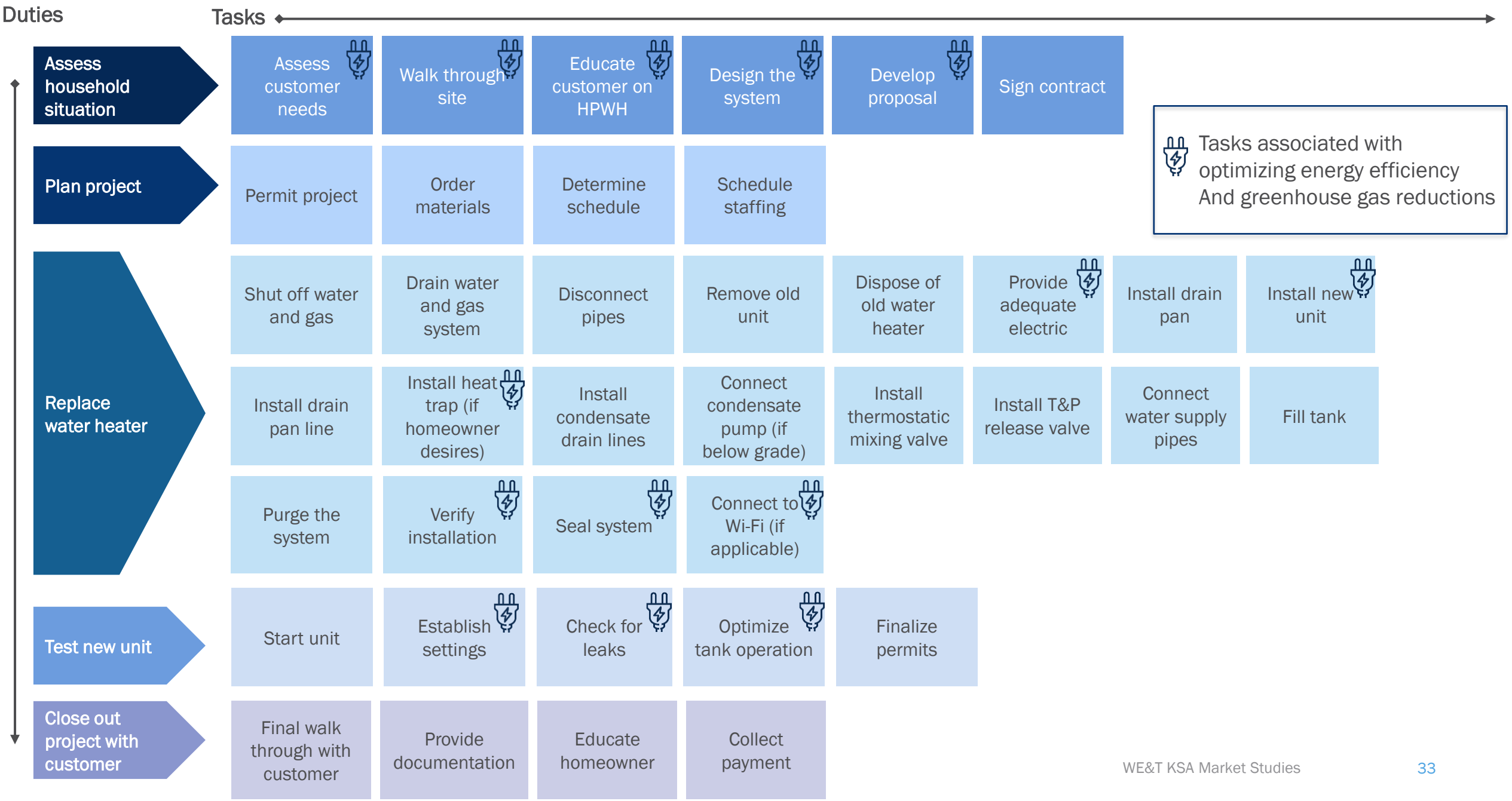
Heat Pump Water Heaters (HPWH)

Job: Plumber; Heat Pump Water Heater Residential Installer



Duties

Tasks →

Assess household situation

Steps

Assess customer needs	Walk through site	Educate customer on HPWH	Design the system	Develop proposal	Sign contract
• Build rapport with customer • Understand customer plans for house	• Verify installation space large enough • Verify installation space temperature is appropriate • Measure water pressure • Size tank • Determine electrical needs	• Provide good faith estimate (GFE) • Provide estimate of time frame • Discuss costs/financing • Educate customer on difference between HPWH and traditional electric water heaters • Determine if customer is serious	• Assess water demand • Estimate hot water peak usage • Measure installation space volume • Verify thermal expansion tank properly sized • Determine maximum water pressure • Determine insulation needs for hot water piping throughout whole home • Determine need for recirculating line • Determine recirculating pump size (if needed) • Check local codes	• Make materials list • Determine labor needs • Negotiate rates with electrician • Determine distance from removal area to truck • Summarize customer needs • Specify timeline • Specify form of payment • Provide total estimated cost	• Get deposit

Duties

Tasks →

Plan project

Steps

Permit project	Order materials	Determine schedule	Schedule staffing

• Call for permit			• Hire electrician
			• Set electrician schedule
			• Assign electrician specific duties
			• Hire trash removal company
			• If needed, hire the following:
			  • Restoration company
			  • Asbestos abatement contractor
			  • Framer
			  • Cleaning crew
			  • Expert to consult on design

Duties

Tasks →

Replace water heater

Shut off water and gas	Drain water and gas system	Disconnect pipes	Remove old unit	Dispose of old water heater	Provide adequate electric
Steps					
					• Verify wire size, breaker, and electric panel is adequate per nameplate specification, manufacturer requirements, and NEC code

Duties

Tasks

Replace water heater *(continued)*

Install drain pan	Install new unit	Install drain pan line	Install heat trap (if homeowner desires)	Install condensate drain lines	Connect condensate pump (if below grade)
Steps					
	• Ensure unit is level	• Verify if stand is needed			

Duties

Tasks →

Replace water heater *(continued)*

Install thermostatic mixing valve	Connect T&P release valve	Connect water supply pipes	Fill tank	Purge the system	Verify installation	Seal system	Connect to WiFi (if applicable)
Steps							
• Remove aerators • Run hot water at furthest faucet • Measure time until hot water comes out • Measure temperature at points of use • Re-test • Adjust as necessary	• Ensure copper or steel pipe is present • Connect discharge pipe • Ensure pipe terminates 6” above concrete • Check local codes • Ensure pipe to outside terminates in a safe location • Leave pipe bare (no fitting; leave open)	• Insulate pipes as needed		• Turn on power at quick disconnect switch • First open hot, then cold water at tub • Open water at all points of use • Let run for 1-5 minutes to ensure flowing • Turn water off • Reinstall aerators	• Conduct final visual safety check • Ensure no leaks from hose connections • Look for standing water • Ensure no water leaking from tank • Look at tank to find any holes or leaks • Check for leaks • Check temperature settings • Verify final temperatures • Verify noises are appropriate • Ensure adequate earthquake strapping	• Seal pipes • Caulk high-stress points • Patch any sheet rock holes • Seal flue at penetration	

Duties

Test new unit

Steps

Tasks

Start unit	Establish settings	Check for leaks	Optimize tank operation	Finalize permit(s)
	• Run in default settings • Set thermostat • Set timer • Choose operating mode	• Turn on faucets and check under sinks • Visually inspect tank	• Check temperature gauge • Ensure not too hot • Adjust as necessary • Clean site	

Duties

Close out project with customer

Tasks

Final walk through with customer	Provide documentation	Educate homeowner	Collect payment

Steps	• Provide homeowner the following:
	  • A copy of the permit
	  • The water heater manual
	  • Warranty information from manufacturer and installation company
		• Inform homeowner of timer and thermostatic settings
		• Inform homeowner of operational modes
		• Show homeowner the app
		• Educate homeowner on peak time usage
		• Show homeowner the shutoff valve
		• Show homeowner how to clean filter and document date
		• Verify homeowner knowledge
		• Tell homeowner to read manual	

Knowledge of

- Safety procedures; Local, state, and federal regulations or codes; Earthquake considerations; Energy efficiency or rebate programs from city, state, or manufacturer; How a heat pump works; Types of heat pumps; Wi-Fi compatibility and connectivity; How to avoid contamination; Types of valves; Pipe sizing and types; Tank sizing issues; Dielectric coupling; Temperature and humidity considerations; Ventilation needs; Manufacturer specifications; Proper installation techniques; Condensate lines; Condensate drains; Current, amps, and voltage; Circuit breakers; How to disconnect and cap gas lines; How to flush a system; Water heater noises; Market conditions; Materials carriers; Time to perform tasks; Risk mitigation strategies; Ethics; Permitting processes; When to schedule an inspection; Humidity considerations

Skills

- Communication skills; Establish rapport; Assess customer needs; Salesmanship; Determine value proposition; Customer service skills; Diplomacy skills; Management skills; Risk management skills; Planning skills; Procurement skills; Negotiation skills; Computer skills; Decision-making skills; Troubleshooting skills; Critical thinking skills; Attention to detail; Math skills; Use of measurement tools; Visualization skills; Team building skill; Calculate payback; Demonstrate your knowledge to customer; Interpret utility bills; Align proposal to household/customer; Read schematics; Conduct visual inspections; Assess risk; Identify proper subs and skills; Set clear expectations; Sequence work; Connect pipes; Work with Pex, PVC, and CPVC piping

Abilities

- Care for people's property; Preparedness; Leadership; Humbleness; Patience; Willingness to learn; Gratitude; Tolerance for criticism; Follow directions; Use hand tools; Hand-eye coordination

Tools

- Pressure gauge; Temperature gauge; Laser thermometer; Invoicing, management, or estimator software; Crescent and adjustable wrench; Channellock pliers; Pipe cutters; Dolly; Hose; Bucket; Level; Soldering kit; Torch kit; Multimeter; Sling psychrometer; Fire caulking and sealant; Caulk; Drywall blade or saw; Putty knife; Mud and/or putty; Solvents

Manuals and Resources

- Uniform Plumbing Code (UPC) codebook – illustrated version; Occupational Safety and Health Administration (OSHA) safety manual; National Electrical Code (NEC) manual; Equipment manual

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