Agenda

"Roadmap" to Energy Efficiency in Affordable Housing
March 23, 2011, Chapel, Vermont College, Montpelier, VT
Sponsored by the Vermont Housing & Conservation Board & Vermont Green

8:45-9:15:	Coffee
9:15-9:30:	Welcome & Introduction – VHCB, Project Oversight Committee
9:30-11:00:	Presentation of Roadmap Report w/Q&A: Presenter: Andy Shapiro, Energy Balance
11:00-11:10:	Break
11:10-12:30:	Presentation of Optimal Mechanicals Report w/Q&A: Presenter: Cx Associates
12:30-12:45:	Break/Luncheon Served
12:45-1:45:	Luncheon presentation of International models of energy efficiency funding schemes. Presenter: Regulatory Assistance Project.
1:45-2:30:	Wrap-up discussion on next steps and way forward: Gus Seelig, VHCB & Attendees
2:30:	Adjourn

Email comments to
roadmap feedback email address:
roadmapfeedback@gmail.com

View comments:
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Download Reports at:

www.VHCB.org/roadmap.pdf
&
www.VHCB.org/optimal.pdf

Cx associates LLC

Mechanical Systems Optimization

Cx Associates, LLC

March 23, 2011

Cx associates LLC

Cx Associates' Team

- Matt Napolitan, PE, LEED AP
  - Modeling oversight
  - Lead author, Mechanical Systems Guide
- Ben Fowler
  - Systems Modeling, Comparative Analysis
  - Lead author, Research and Findings
- Jennifer L. Chiodo, PE, LEED AP
  - Lead author, Process Guide

Session Overview

- ✓ Introduction –
  - Team
  - Objectives
  - R&D Process
- ✓ Optimizing Mechanical Systems
  - Q&A
- ✓ Process Recommendations
  - Q&A

Mechanical Guide Objectives

- ✓ Tool for building owners, developers and design teams
- ✓ Performance metrics - Targets
  - Overall
  - System
  - Heating/Cooling
- ✓ Sample system configurations
- ✓ Guidelines for contract language
- ✓ Development process

R&D Process

- ✓ Site visits
- ✓ Interviews
- ✓ Stakeholder Collaboration
- ✓ Modeling
- ✓ Interaction with architectural roadmap

Mechanical Systems Optimization

- ✓ Design Considerations
- ✓ Heating & Cooling Systems
- ✓ Domestic Hot Water
    - Solar
- ✓ Ventilation
- ✓ Controls

Modeling

- Computer simulation and sizing software
- eQuest – 8760 hour modeling tool based on DOE2 modeling engine
- *Whole Building Performance Analysis* platform
- Order of priority:
  1. Optimize building envelope
  2. Select efficient mechanicals
  3. Size the equipment close to the loads

NO Oversized Heating Systems

- ✓ Building design load occurs *0.4%* of the time
- ✓ Oversized boilers may short cycle even under design conditions
- ✓ Don't improve comfort
- ✓ Increase energy use
- ✓ Shorten equipment life

Is the equipment right?

- ✓ Engineers complete the Modeling / Load Calculation Information Form
- ✓ Team verifies:
  - Envelope characteristics
  - Infiltration and ventilation rates
  - Occupancy
  - Building area ratios
- ✓ Engineer reports energy related indicators
  - Compare results to expectations
  - Modeled results from Mech Ops Guide

Modeling Results

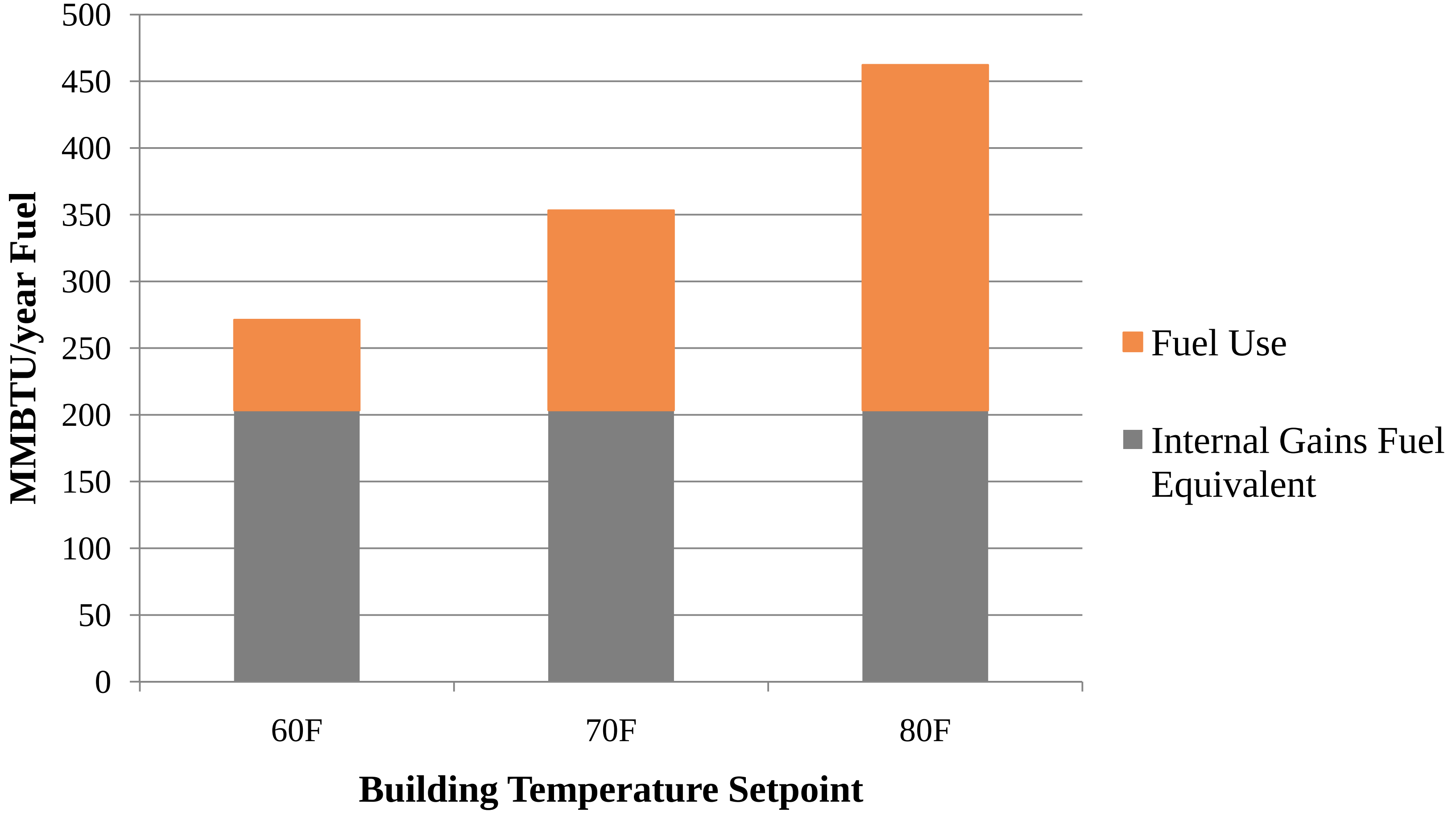
Energy Use Index - No Cooling	Duplex	Town House	Double Loaded Corridor
Number of Units	2	12	32
Building Floor Area (sq-ft)	2,498	12,670	33,000
Modeled Space Heat Fuel Use (MBTU/yr)	37,000	87,000	168,800
Modeled DHW Heat Fuel Use (MBTU/yr), with 50% by SDHW	28,550	117,500	276,885
Total Heat & DHW Fuel Use (MBTU/yr)	65,550	204,500	445,685
PUM Year 15 Low Esc.	**$123**	**$64**	**$52**
Modeled Peak Boiler Space Heat Load (MBTU/hr)	35.6	111.0	207.1
Modeled Peak DHW Generation Load (MBTU/hr)	50.0	105.0	210.0
Boiler Number and Size	1 @ 90 MBTU/hr	2 @ 105 MBTU/hr	4 @ 105 MBTU/hr

Key Points from Modeling

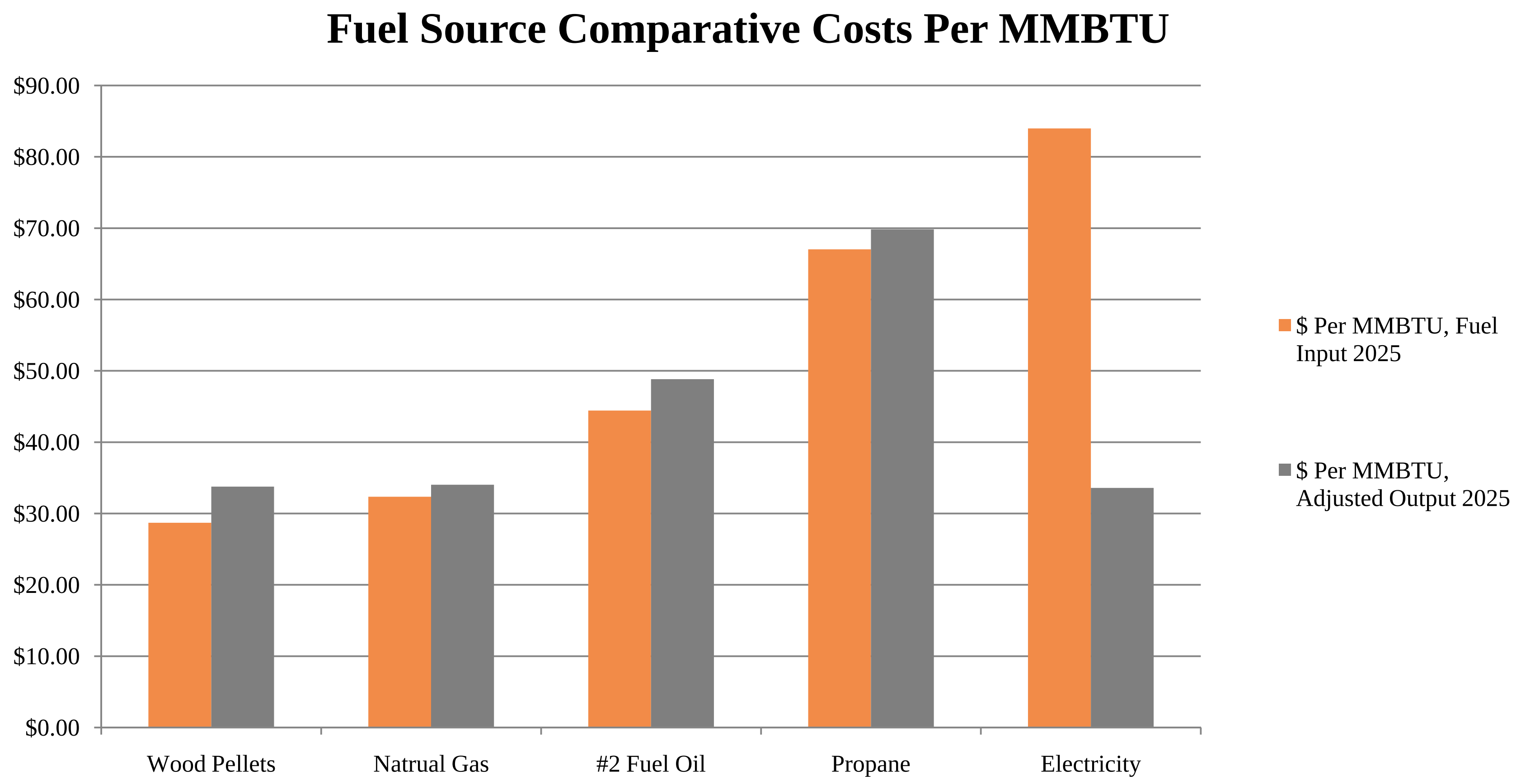
- ✓ High Performance Buildings Change the "Standard" Logic
  - Traditionally heating load is significantly higher than DHW - NO MORE!
  - Townhouse & DLC heating loads ≈ DHW
  - Duplex heating load = 71%
  - Annual fuel usage
    - Duplex Heat = 130% of DHW
    - Townhouse = 74% of DHW
    - DLC = 61% of DHW

ASSUMES 50% OF ANNUAL DHW ENERGY IS FROM SOLAR!

Internal Gains



Fuel Selection



Boilers

- ✓ Boiler selection:
  - Modulating where possible
  - AFUE Efficiencies – Condensing Boilers
    - Gas > 96% Eff
    - Oil > 91% Eff
  - Pellet > 85% Eff

Boilers

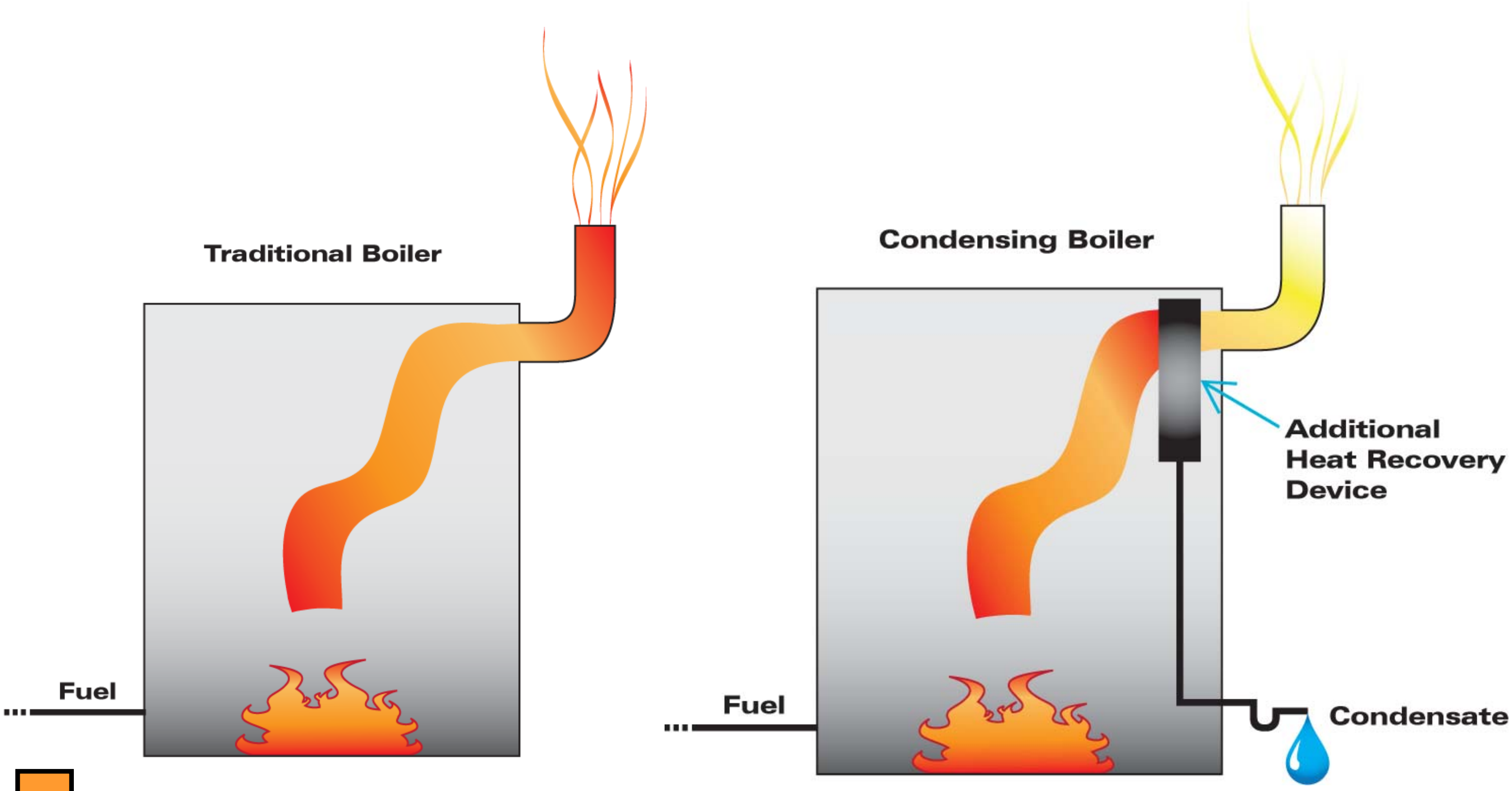
✓ Modular Boiler Arrangement

Condensing Fuel Boilers

- ✓ What is a condensing boiler?

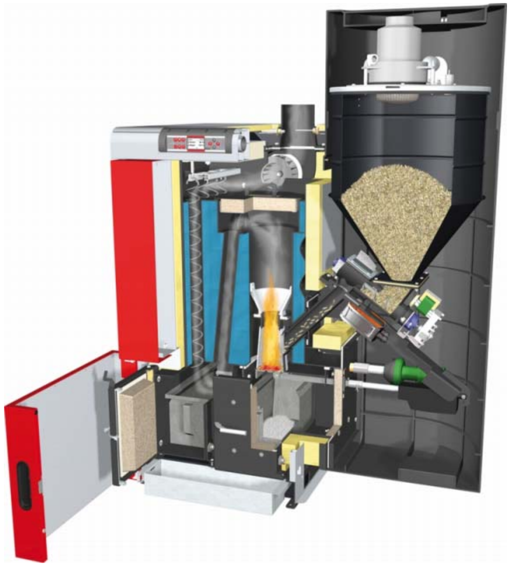
Condensing Fuel Boilers

✓ Up to 10% Additional Energy Available

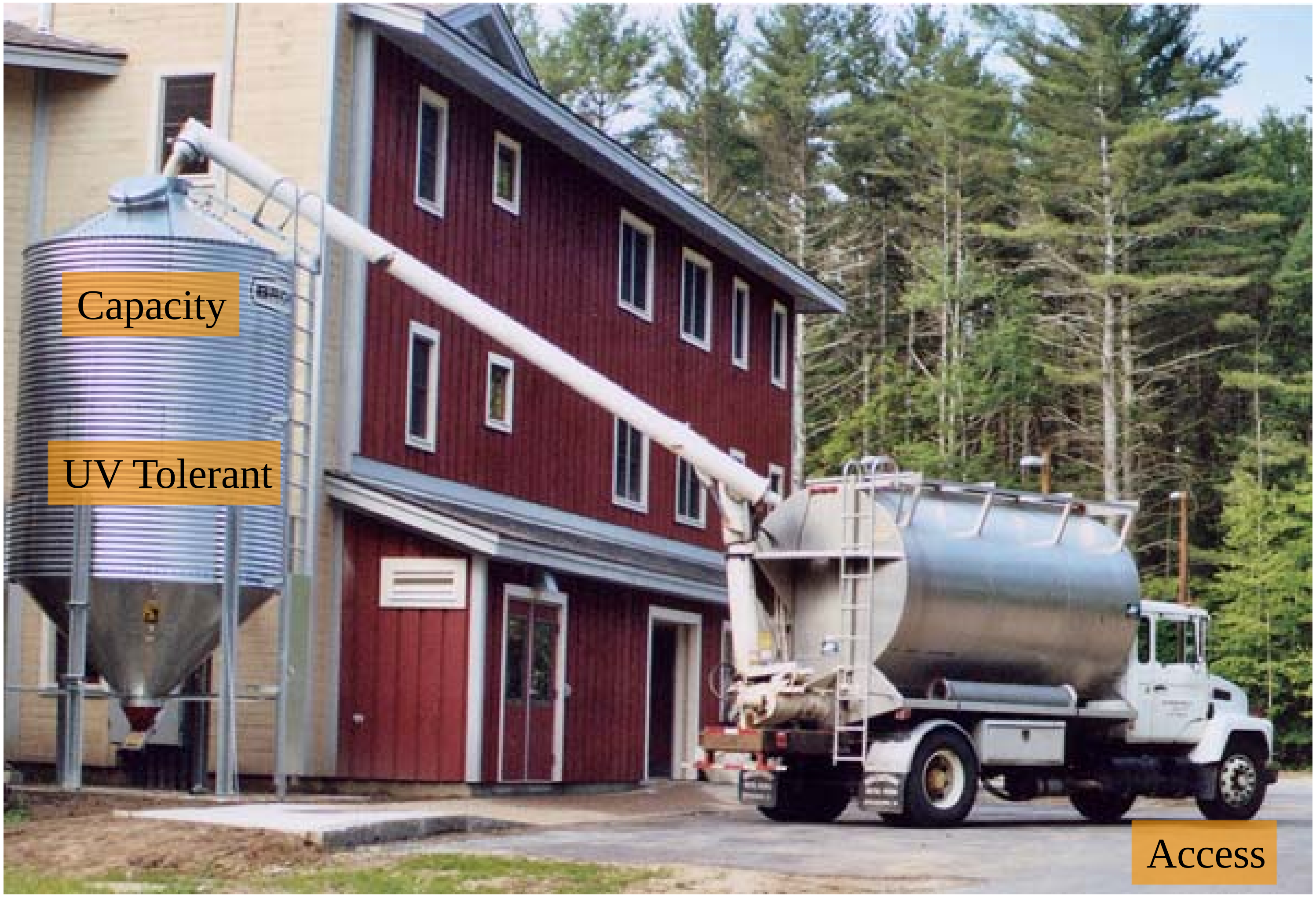


Biomass – Pellet Fuel

- ✓ Lowest dollar/BTU fuel
- ✓ Fuel related considerations
  - Bulk Fuel Availability
  - Access for delivery
  - Capacity to minimize deliveries
  - Fuel level indication
  - UV tolerant system
  - Fire separation
  - Pellet Quality



Biomass – Outdoor Pellet Storage



Biomass

- ✓ Pellet Quality
  - PFI – Pellet Fuels Institute
  - Premium Grade
    - Low Moisture
    - Low Ash Content
    - Low Fines Content
    - Small tolerances for size, shape and mass
  - In other words, very homogeneous

Thermal Energy Storage

- ✓ TES
- ✓ Buffer Tank
- ✓ Necessary for
  - Biomass
  - Non-modulating boilers
- ✓ Stores Heat
- ✓ Needs a Little Space
- ✓ Increases Boiler Efficiency
  - Reduces short cycling
  - Increases boiler fire time

Thermal Energy Storage

- ✓ DHW Priority
  - Boilers Focus on DHW, Not Space Heat
  - TES Acts as Additional Heat Source
- ✓ Additional Heating Capacity
  - Adds capacity to system
    - Without over-sizing
    - Without adding additional equipment (fuel consumers)
  - Effectively provides a margin of security for designers

Terminal Units

- ✓ Ratings: (heat output) /(linear foot)
  - Traditional Design
    - 180ºF supply water = Appx 750 BTU/h/LF output
  - Condensing Boiler Friendly
    - 130ºF supply water = Appx 250 BTU/h/LF output
    - Allows condensing boilers to remain in condensing mode

Building Type Modeled	BTU Per Liner Foot Perimeter
Double Loaded Corridor	132
Townhouse	129
Duplex	99

Non-heating Season Comfort

- ✓ High performance envelope keeps heat in
- ✓ Great in heating season
- ✓ Holds heat in mild weather
- ✓ Models show higher indoor temps in shoulder season
- ✓ People may need to open windows to release heat
- ✓ Mechanical cooling?

When Cooling is in the Mix

- ✓ Resident provided window ACUs are incompatible with casement windows
- ✓ If developer wants to allow tenant provided AC then include provision in design

OR

- ✓ Install cooling
  - High performance air source heat pump systems (can also meet heating PUM reqs for Townhouses & DLC)

Air Source Heat Pump - ASHP

- ✓ What Is It?
  - Heating
  - A/C
- ✓ Up to 8 indoor units for small systems
- ✓ Up to 50 indoor units for large scale systems

ASHP

- ✓ Electricity has highest cost per BTU available

HOWEVER

- ✓ High ASHP efficiency means effective delivery of heating or cooling.
- ✓ High efficiency mitigates high cost-per-BTU of electricity
- ✓ Able to meet heating PUM with performance envelope (except in duplex)

VRV - Variable Refrigerant Volume

- ✓ What Is It?
  - Large scale Air Source Heat Pump
- ✓ Allows load sharing
- ✓ Centralizes Outdoor Condensing Units

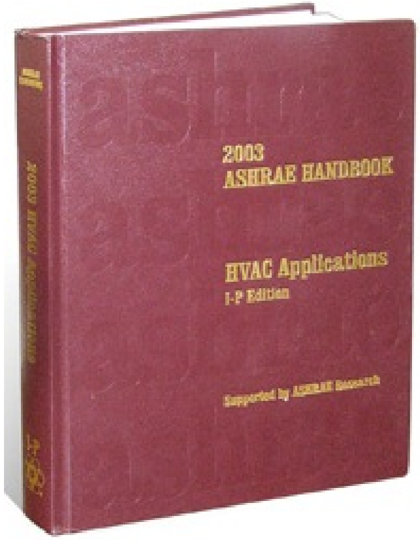
VRV - Variable Refrigerant Volume

- ✓ Refrigerant, not water is the distributed heat source / sink.
- ✓ Reference ASHRAE 15 /ASHRAE 34
  - American Society of Heating, Refrigeration and Air Conditioning Engineers
  - Safety Standard for Refrigeration Systems
  - Designation and Safety Classification of Refrigerants
- ✓ Consider adding alarm points to indicate a leak.

ASHP - Considerations

- ✓ Not plug-and-play like other systems
  - Components limited to existing manufacturer
- ✓ Service may be limited to “certified technicians”

Domestic Hot Water



- ✓ Systems tend to be oversized
- ✓ ASHRAE Handbook Applications
  - Detailed sizing information
- ✓ Determine occupancy mix and occupants per unit based on developer projections
  - Allows determination of Low, Medium or High Use

DHW Equipment Sizing

- ✓ Select combo of boiler & storage capacity
  - Meet load over all conditions

Table 8 Hot-Water Demand and Use Guidelines for Apartment Buildings (Gallons per Person at 120°F Delivered to Fixtures)

	Peak Minutes						Maximum	Average
Guideline	5	15	30	60	120	180	Daily	Daily
Low	0.4	1.0	1.7	2.8	4.5	6.1	20	14
Medium	0.7	1.7	2.9	4.8	8.0	11.0	49	30
High	1.2	3.0	5.1	8.5	14.5	19.0	90	54

DHW Distribution

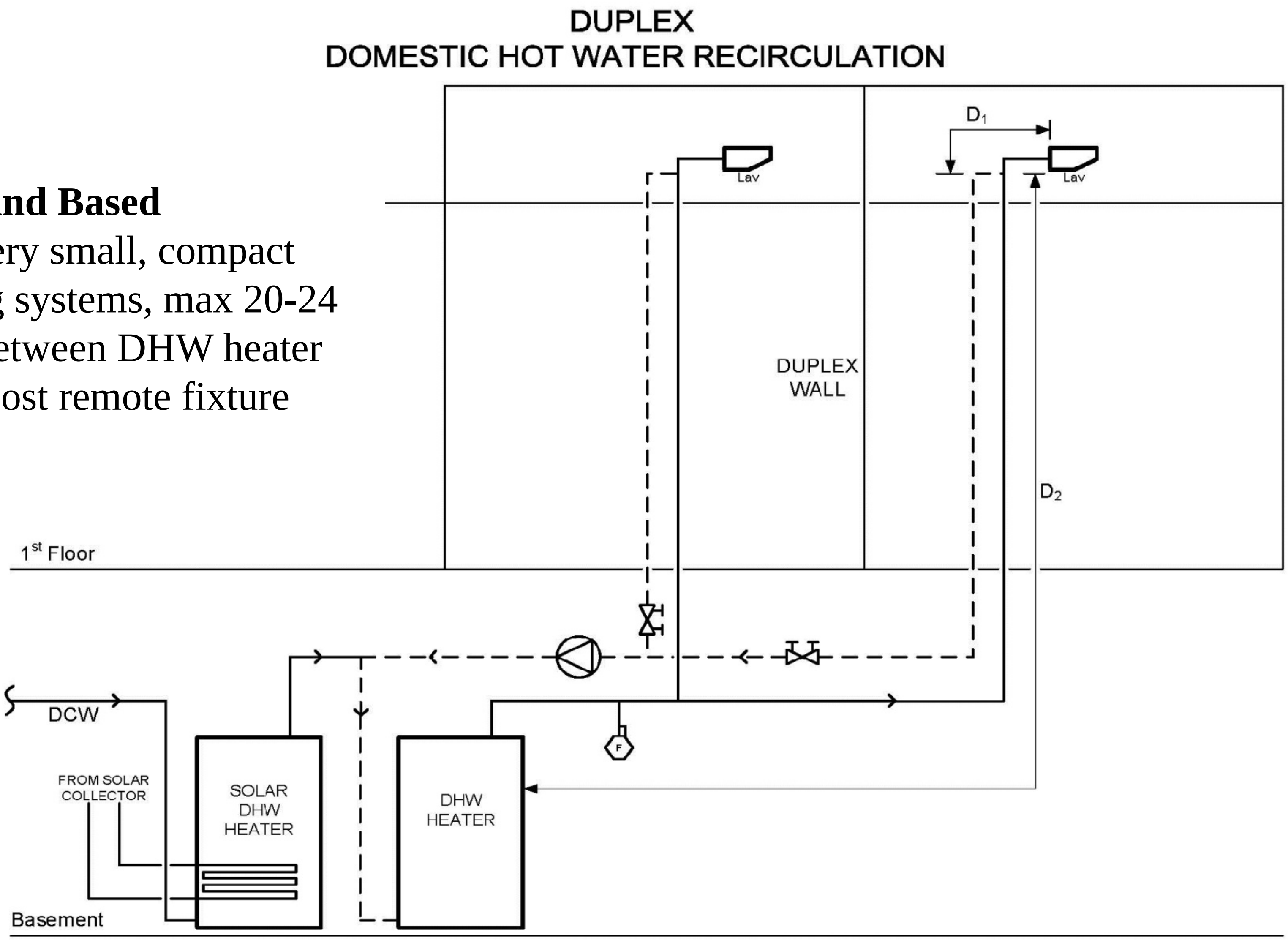
- ✓ Adds heat to the building
- ✓ Piping
  - Size with velocity in mind
- ✓ Insulation
  - Code requires 1" on DHW supply & recirculation
  - Recommendation – 2" insulation
- ✓ Recirculation Pump
  - EC motor if pump is available in "Lead-Free"

DHW Distribution - Recirculation

- ✓ Strategies for Recirculation
  - Continuous – NOT RECOMMENDED
    - Most pumping energy use
    - Highest heat loss to building
      - ✓ Issue in non-heating season
      - ✓ Uses more fuel to re-heat circulating water
  - Demand Based
  - Temperature Based
  - Timer Based
  - Based on 5 second wait time for Hot Water

Demand Based

For very small, compact piping systems, max 20-24 feet between DHW heater and most remote fixture



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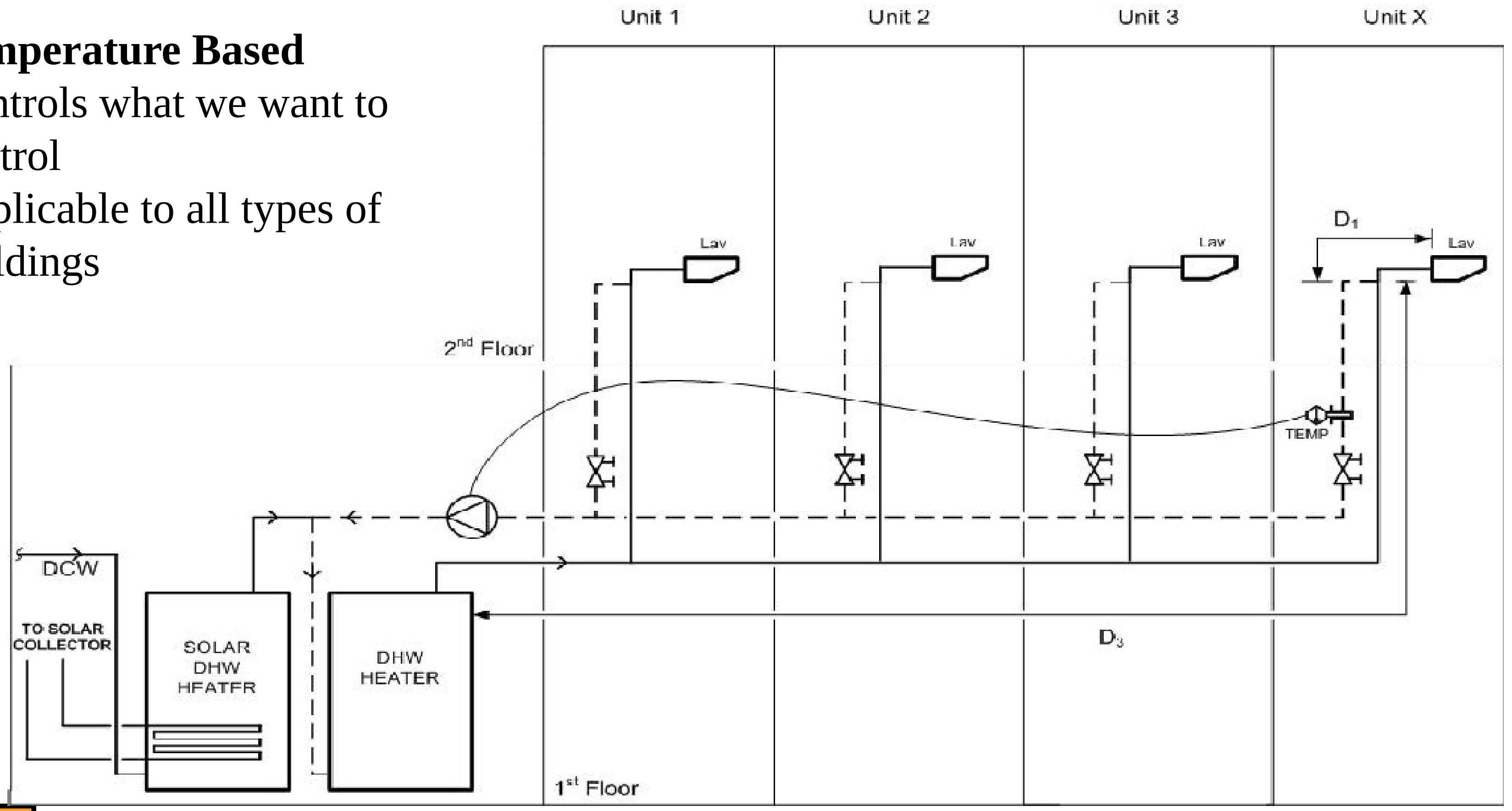
TOWN HOME
DOMESTIC HOT WATER RECIRCULATION
TEMPERATURE SENSOR APPROACH

Temperature Based

Controls what we want to control

Applicable to all types of buildings

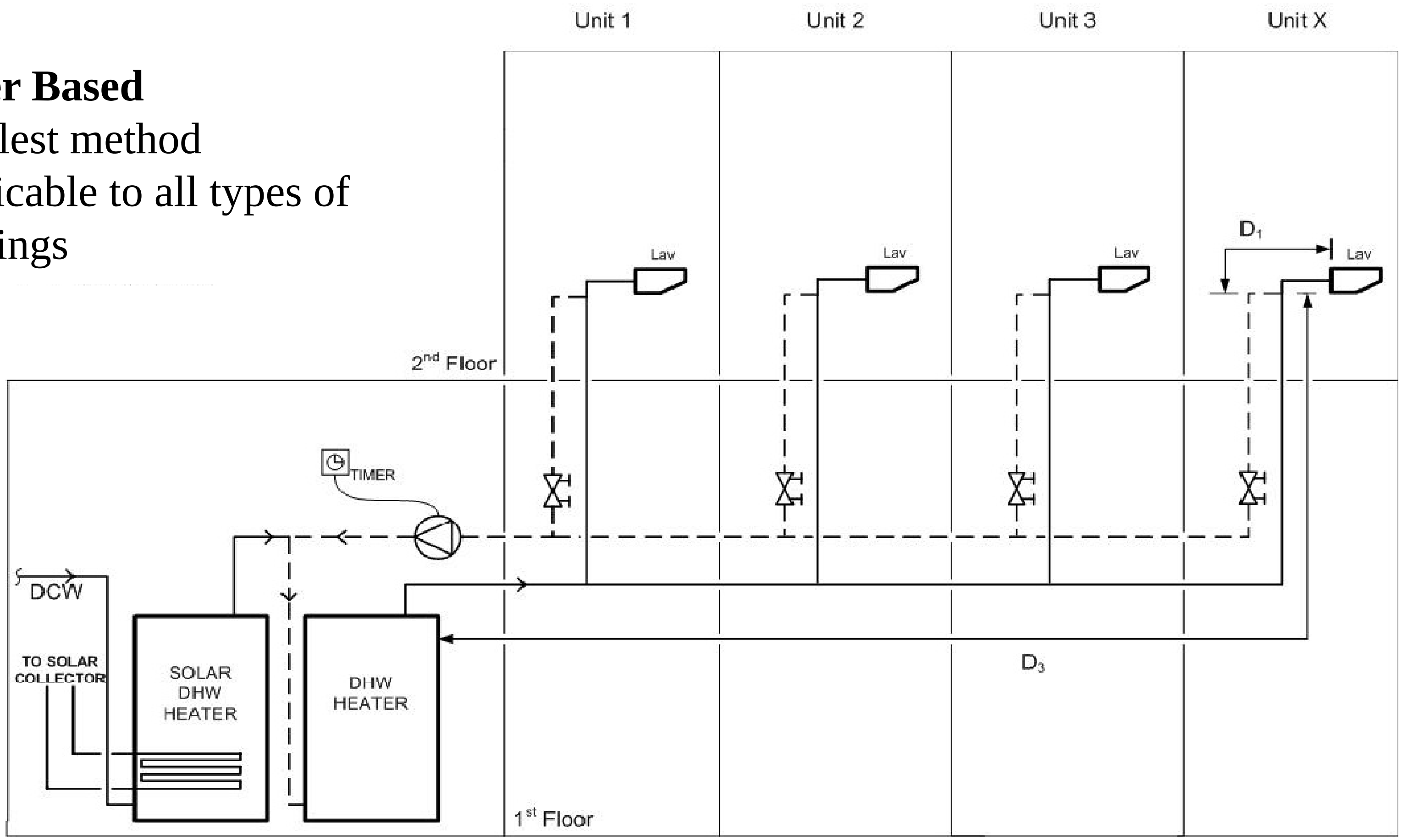


TOWN HOME
DOMESTIC HOT WATER RECIRCULATION
TIMER APPROACH

Timer Based

Simplest method

Applicable to all types of buildings



Solar DHW

- ✓ Need 50% Solar to meet affordability criteria
- ✓ 4-8 year simple payback
- ✓ Design Issues:
  - Site "Solar Access"
  - Building orientation
  - Roof pitch and style

Solar Collectors and Storage

Flat Plate Collector Area	Solar DHW Storage
10-15 Square Feet Per Building Occupant	1.5 gallons per square foot of collector area.

- ✓ Collectors
- ✓ Storage Tank
- ✓ Circulator & Controls
- ✓ Installation Considerations:
  - Structural: wind and snow loading
  - Mechanical room space
  - Chaseway for collector pipework and controls.

Ventilation

- ✓ Three applicable codes
  - VT RBEC
    - Minimum
  - ASHRAE STD 62.2
  - ASHRAE STD 62.1

Table 2.1

Capacity Requirements for Whole-House Ventilation Systems

# of Bedrooms	Minimum Rated Capacity (CFM[1])	Minimum # of Fans (if not centrally ducted system)
1	50	1
2	75	1
3	100	1
4	125	2
5	150	2
Homes over 3000 sq. ft.	0.05 x sq. ft.	2

[1] *CFM = cubic feet per minute*

Ventilation

- ✓ HRV / ERV
- ✓ Per-unit for townhouse and duplex
- ✓ Central for DLC
- ✓ Supply in bedrooms and common rooms
- ✓ Exhaust from bathrooms
- ✓ Maintenance

Heating Controls

- ✓ Efficient pumps
- ✓ Zone control
- ✓ System control

Heating Water Supply Temperature Reset

Outdoor Air Temperature	Hot Water Supply Temperature
0	130
55	100

Heating Plant Controls

Duplex

- ✓ On-board boiler controller
- ✓ Pumps run only on call for heat
- ✓ Do not use balance valves to control pump flow
- ✓ Pumps should have ECM motors – vary speed to match flow

Townhouse

- ✓ Same as Duplex except
- ✓ Tekmar type controller for multiple zones
- ✓ Ability to swap lead/lag circulation pumps
  - Allows for redundancy

DLC Pumping

- ✓ VFDs on system pumps
- ✓ Differential Pressure Control
- ✓ Automatic balance valves
- ✓ Lead/Lag pumps

Optimal Mechanicals in Short

- ✓ Keys to a Great Mechanical System
  - Integrated Design
  - Upfront Consensus
  - High Efficiency Equipment
  - Correct Terminal Devices
  - Optimized Controls
    - Multiple boilers fire in tandem
    - HW Reset
    - Lowest possible pressure set points for pumps

Questions?

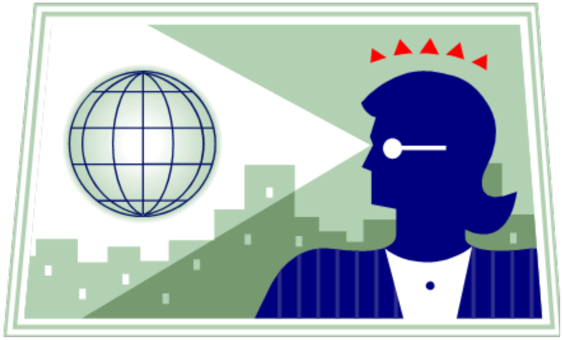
Addressing the Barriers

- ✓ Incentives
- ✓ Communication
- ✓ Integration
- ✓ Decision making process
- ✓ Shared Results

Project Vision

✓ Team Members Should Know

- Key attributes associated with project funding calculations
- Energy and operating costs
- Maintenance reserve fund
- Annual maintenance cost
- Lifetime of major components
- Occupancy types over building life



Point of View

Owner

- ✓ Vision of building
- ✓ Service to community
- ✓ Enduring Value
- ✓ Comfort
- ✓ Affordable operations
- ✓ Built on budget and on time
- ✓ Team of experts to execute vision

Design Team Member

- ✓ Selected on price ➡
  - Price is Owner's highest priority
- ✓ Low fee ➡
  - Fewer hours to design project
  - Less time for interaction, innovation and iterations
  - Redesign avoidance
  - Over sizing

Perspective

Engineer

- ✓ Systems approach
  - Controls increase efficiency
  - Optimize systems to meet energy target
- ✓ Systems have to fit in allotted space
- ✓ Boilerplate O&M is lowest first cost
- ✓ Only hears when a perceived failure occurs

Operator

- ✓ Components not systems
- ✓ Solve the immediate problem
- ✓ Unaware of energy target, building consumption or impact of changes

Owner's Project Requirements

- What will a successful project look like?

✓ Owner and user requirements

✓ Sustainability

✓ Energy Performance

✓ IEQ

✓ Operations & Maintenance

Example: OPR Evolution

- ✓ Defines 50 year roof life
- ✓ DD cost estimate requires project adjustments
- ✓ 40 year roof identified as best option
- ✓ Update OPR
- ✓ Design and construction include 40 year roofing material
- ✓ OPR provided to operator
- ✓ Property maintenance funds managed for 40 year roof replacement

Design Team Procurement

- ✓ Include project performance requirements in RFP and contract documents
- ✓ Selection Criteria
  - Knowledge and experience with high performance design
  - Successful execution within budget
  - Project performance – results
  - Team integration

Design Proposals

- ✓ How team will use OPR, RHEA and MSOG
- ✓ Process to achieve integration
  - Basis of Design
  - Building modeling/load calculations
  - Interactive method for prioritizing and selecting the final building components and design approaches
- ✓ Project examples including realized performance

Other Consultants

- ✓ Energy
  - Asset in ensuring right sizing
  - Independent view focusing on approach
  - Demonstrates priority of EE
- ✓ Commissioning
  - Independent view focusing on functionality
  - Verifies design, construction and ops against OPR
  - Docs available for recommissioning

Early Design Milestones

- ✓ Charrette
- ✓ Modeling
  - Mechanical system selection and sizing
  - Opportunity to iterate with envelope changes
- ✓ Basis of design
  - How the team will meet OPR
  - How incorporating energy performance req's

What's in the BoD?

- ✓ Project description
- ✓ Design assumptions (heating set point = 72°F)
- ✓ Standards and codes
- ✓ System Narratives
  - Why selected
  - How address the OPR
  - Expected performance
  - Controls

Design Reviews

- ✓ Leave enough time
- ✓ Document and track to ensure issues are addressed
- ✓ Include Commissioning Agent

Item	Ref	Reviewer Comments	Consultant Response	Response By & Date	Discussion	Responsible Party	Status
1	Mech Piping	Look at adding "sub-zone" isolation valves to allow for maintenance on one section of piping to limit disruptions.	Isolation valves shall be included in mains at select locations to allow for partial system shutdowns.	Mech Engineer - 12/03/10	12/06/10 – Plan review indicates some zoning included.	Mech Engineer	CLOSED

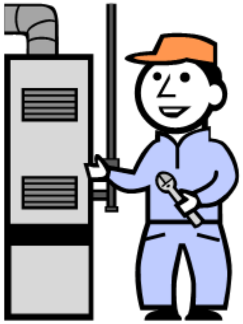
Capacity Discrepancies

- ✓ Document and understand uncertainty
- ✓ Address where feasible
  - Add performance testing to spec
  - Include an energy consultant on team
- ✓ If more capacity needed, consider:
  - Storage
  - Provision for future & budget
- ✓ Document agreements in writing

As-Built Document$

- ✓ Design docs are ***valuable***
- ✓ Range between $100-550k
- ✓ Ensure they are used by contractors as a basis for as-builts
- ✓ Verify drawings are updated to reflect installation prior to contractor payment
- ✓ After turn-over building management has responsibility
  - Know, Love, Use and Maintain them
  - Buildings have long lives
  - Future operators need to know what we did

Operations and Maintenance



- ✓ Include in-house personnel in OPR development and Design Review
- ✓ Look at training in design review
- ✓ Sub-contracts – require use and maintenance of as-built documents
- ✓ Include annual energy use review and report
- ✓ Ensure adequacy of staff training and allocation of resources

Post Occupancy

- ✓ Review OPR with O&M staff and share with occupants
- ✓ Expected building performance
  - Comfort
  - No ACU's in casement windows
  - Hot water within 5 seconds
- ✓ When things go wrong, address, document, reset

Ensuring Performance

Maintenance

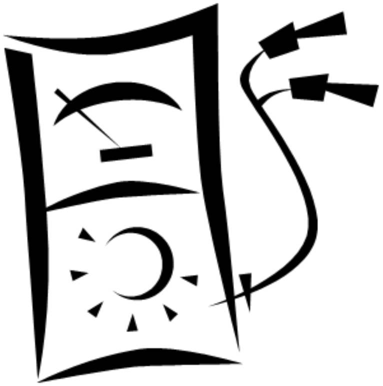
- ✓ Preventive
- ✓ Keeps components in working order
- ✓ Responds to complaints
- ✓ Documents failures/problems
- ✓ Records activities

Operations

- ✓ Understands systems
- ✓ Tracks & Reports
  - Preventive maintenance
  - Problems and complaints
  - Energy Use
- ✓ Looks for Trends
- ✓ Pursues optimal function
- ✓ Maintains records

Areas for Additional Exploration

- ✓ Master OPR for affordable housing
- ✓ Standardized training and proficiency for building operations and maintenance personnel
- ✓ Resident education
- ✓ Smart controls/smart grid – remote energy monitoring



Key Concepts

Contact Information

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