TRI-COUNTY
REGIONAL ENERGY NETWORK
SAN LUIS OBISPO • SANTA BARBARA • VENTURA

Mechanical Systems in Detail

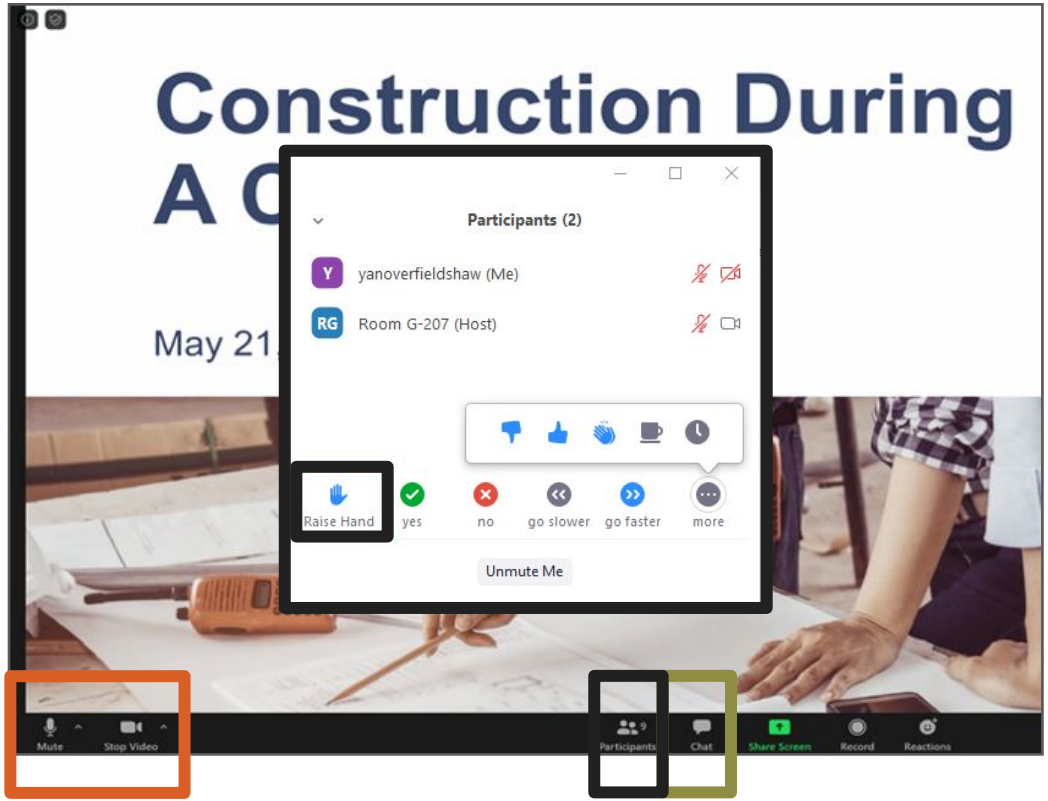
Ken Levenson – Passive House Network

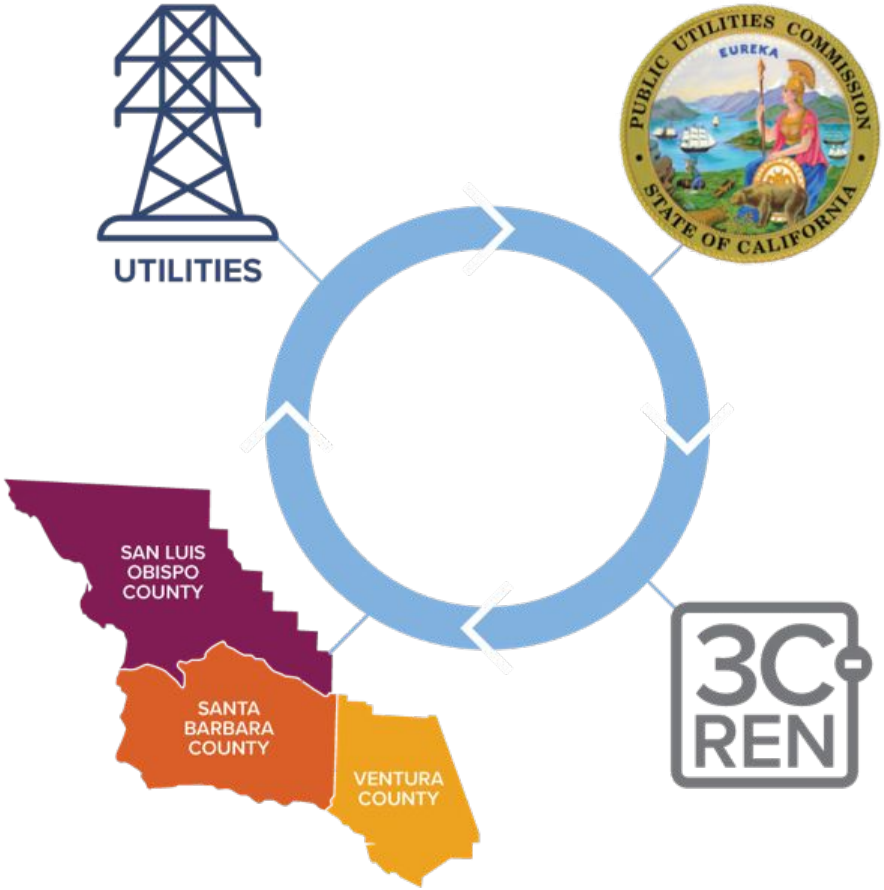
June 26, 2025

The Passive House Network

Zoom Orientation

- Add an **introduction** in the chat.
  Be sure **full name** is displayed.
- Did you call in? Please **share** first and last name with us.
- Please **mute** upon joining
- Use the "**Chat**" to share questions or comments
- Under "**Participant**" select "**Raise Hand**" to share a question or comment verbally
- Session may be **recorded** and posted to 3C-REN's on-demand page
- Slides/recording are **shared** after most events
- 3C-REN does **not** allow **AI notetakers**, unless used to accommodate a disability.





Tri-County Regional Energy Network

3C-REN is a collaboration between the tri-counties

Our programs reduce energy use for a more sustainable, equitable and economically vibrant Central Coast

Our free services are funded via the CPUC, bringing ratepayer dollars back to the region

Our Services

Incentives

HOME ENERGY SAVINGS

3c-ren.org/for-residents
3c-ren.org/multifamily

COMMERCIAL ENERGY SAVINGS

3c-ren.org/commercial

Contractors can enroll at
3c-ren.org/contractors

Training

BUILDING PERFORMANCE TRAINING

3c-ren.org/events
3c-ren.org/building

ENERGY CODE CONNECT

3c-ren.org/code

View past trainings at
3c-ren.org/on-demand

Technical Assistance

AGRICULTURE ENERGY SOLUTIONS

3c-ren.org/agriculture

ENERGY ASSURANCE SERVICES

3c-ren.org/assurance

Passive House
Mechanical Systems in Detail

Sendero Verde, Handel Architects

The Network

Global Knowledge. Regional Context. Local Applications





















Passive House Seattle
The Passive House Network

Passive House Rocky Mountains
The Passive House Network

Passive House Minnesota
The Passive House Network

Passive House Pennsylvania
The Passive House Network

Passive House Washington DC
The Passive House Network

New Jersey Passive House
The Passive House Network

Passive House Empire State
The Passive House Network

Passive House Northeast
The Passive House Network

PHCA PASSIVE HOUSE CALIFORNIA

NORTH AMERICAN CERTIFIERS CIRCLE
PASSIVE HOUSE CERTIFIER

International PASSIVE HOUSE Association 1PHA

Passive House Institute

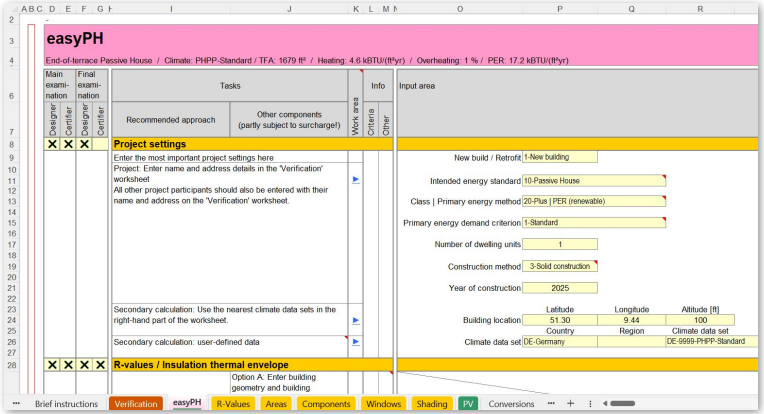
DESIGNER
CERTIFIED PASSIVE HOUSE DESIGNER

CERTIFIED PASSIVE HOUSE TRADESPERSON
TRADESPERSON

Certified Passive House
Passive House Institute

Submission Deadline, September 30th

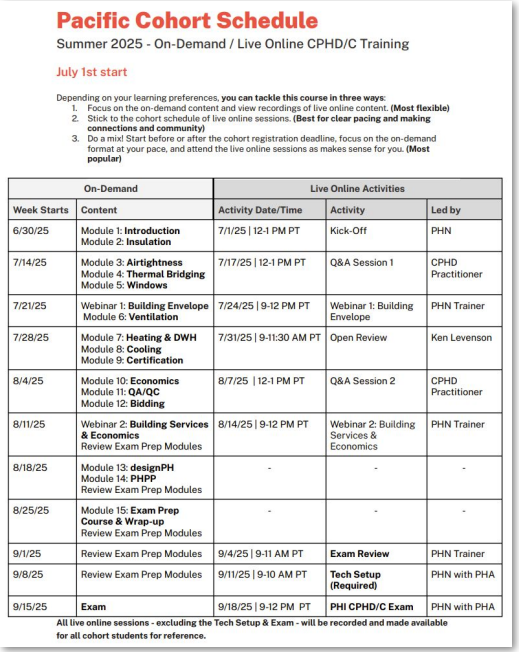
Thursday, July 24



Summer Cohorts kick off July 1

Incentives are available.

Training is a prerequisite for success.



Pacific Cohort Schedule

Summer 2025 - On-Demand / Live Online CPHD/C Training

July 1st start

Depending on your learning preferences, **you can tackle this course in three ways**:

1. Focus on the on-demand content and view recordings of live online content. **(Most flexible)**
2. Stick to the cohort schedule of live online sessions. **(Best for clear pacing and making connections and community)**
3. Do a mix! Start before or after the cohort registration deadline, focus on the on-demand format at your pace, and attend the live online sessions as makes sense for you. **(Most popular)**

On-Demand		Live Online Activities		
Week Starts	**Content**	**Activity Date/Time**	**Activity**	**Led by**
6/30/25	Module 1: **Introduction** Module 2: **Insulation**	7/1/25 | 12-1 PM PT	Kick-Off	PHN
7/14/25	Module 3: **Airtightness** Module 4: **Thermal Bridging** Module 5: **Windows**	7/17/25 | 12-1 PM PT	Q&A Session 1	CPHD Practitioner
7/21/25	Webinar 1: **Building Envelope** Module 6: **Ventilation**	7/24/25 | 9-12 PM PT	Webinar 1: Building Envelope	PHN Trainer
7/28/25	Module 7: **Heating & DWH** Module 8: **Cooling** Module 9: **Certification**	7/31/25 | 9-11:30 AM PT	Open Review	Ken Levenson
8/4/25	Module 10: **Economics** Module 11: **QA/QC** Module 12: **Bidding**	8/7/25 | 12-1 PM PT	Q&A Session 2	CPHD Practitioner
8/11/25	Webinar 2: **Building Services & Economics** Review Exam Prep Modules	8/14/25 | 9-12 PM PT	Webinar 2: Building Services & Economics	PHN Trainer
8/18/25	Module 13: **designPH** Module 14: **PHPP** Review Exam Prep Modules	-	-	-
8/25/25	Module 15: **Exam Prep Course & Wrap-up** Review Exam Prep Modules	-	-	-
9/1/25	Review Exam Prep Modules	9/4/25 | 9-11 AM PT	**Exam Review**	PHN Trainer
9/8/25	Review Exam Prep Modules	9/11/25 | 9-10 AM PT	**Tech Setup (Required)**	PHN with PHA
9/15/25	**Exam**	9/18/25 | 9-12 PM PT	**PHI CPHD/C Exam**	PHN with PHA

All live online sessions - excluding the Tech Setup & Exam - will be recorded and made available for all cohort students for reference.

https://passivehousenetwork.org/designer-training/

Passive House **Mechanical Systems** in Detail

This course dives deep into the focus of building mechanical systems with a particular focus on ventilation and hot water systems. Looking at the design and construction of a range of system types, the course will examine ventilation, heating, cooling, and hot water topics of performance specifications, coordination, sequencing, inspection, testing, and reporting.

Learning Objectives:

1. Describe Passive House goals and methodology as they translate to mechanical systems.
2. Outline typical Passive House heating, cooling, ventilation and hot water systems, focusing on the pros and cons of choices.
3. Describe Passive House ventilation and hot water installation considerations and the process to hit Passive House goals.
4. Outline quality assurance and quality control measures used to verify mechanical systems' performance and reach certification.

Instructor:
Ken Levenson, Executive Director, The Passive House Network.
Ken was a practicing architect for over three decades, completing early Passive House projects in New York City. Committed to accelerating Passive House growth and knowledge sharing, he co-founded 475 High Performance Building Supply, was a founding member of the Phius Passive House Alliance, a co-founder of New York Passive House and of NAPHN, which would become The Passive House Network (PHN). Today, as Executive Director of PHN, Ken continues to focus on driving building industry culture change with Passive House education.

Where are you located?

(please answer in the chat)

What’s your job/role?

(architect, consultant, owner etc...)

How familiar are you with Passive House?

(heard of it, know a bit about it, fairly knowledgeable, practice it)

Personal Start: A Townhouse Retrofit

Brooklyn, NY

Agenda

- Context of Passive House
- Context of Mechanical Systems
- Strategy
- Ventilation
- Heating & Cooling
- DHW
- Other Systems + Solar
- Case Studies
- Resources

Waring School, Massachusetts, Opal Architecture

1. Context of Passive House
2. Context of Mechanical Systems
3. Strategy
4. Ventilation
5. Heating & Cooling
6. DHW
7. Other Systems + Solar
8. Case Studies
9. Resources

Context of Passive House: Enclosure First

<u>Enclosure (architecture) drives performance.</u>

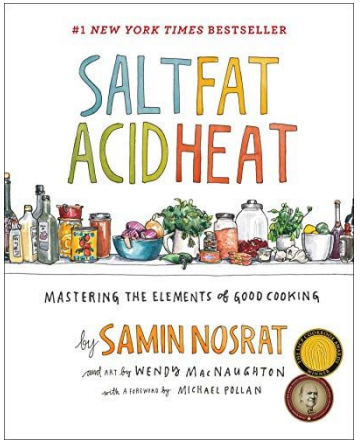
- Maintain healthy indoor air quality
- Efficient space cooling & heating
- Efficient Hot Water

- Reduced emissions (efficient)
- “Net Zero” (balance of demand & production)

How we use fundamental elements matters

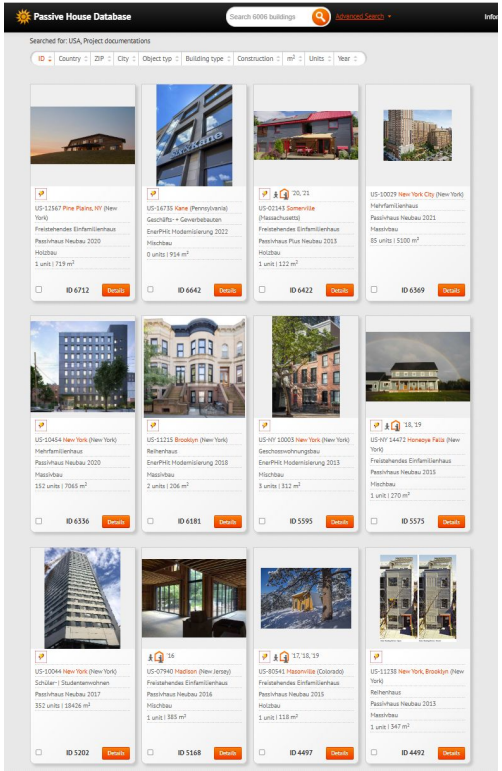
“I was working as a physicist. I read that the construction industry had experimented with adding insulation to new buildings and that energy consumption had failed to reduce. This offended me – it was counter to the basic laws of physics. I knew that they must be doing something wrong. So I made it my mission to find out what, and to establish what was needed to do it right.”

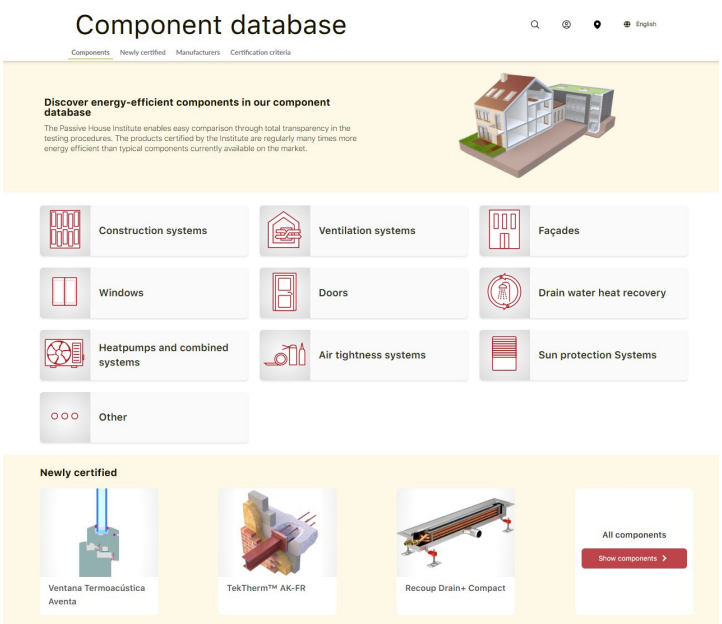
- Wolfgang Feist



Passive House masters the elements of high-performance building.

Access what's available: Project documentation, Certified Components, Manufacturer Directory





The Passive House Network

Education | Community | Resources | Events | LOGIN | MY ACCOUNT

FACADE SYSTEMS THERMAL BREAKS

Manufacturer/Supplier	Specialty	Offers PHI Certified Components	HQ Location	Link
Cascadia Clip	rainscreen support		British Columbia	https://www.cascadiawindows.com/products/cascadia-clip
Eco Cladding		Yes	Virginia	https://www.ecocladding.com/
Epat		Yes	Germany/Michigan	https://www.epat.com/address-USA
Engineered Assemblies			Ontario	https://www.engineeredassemblies.com/
Fero Corp	brick veneer supports	Yes	Alberta	https://ferocorp.com/
SFS Group		Yes	Germany/PA	https://www.sfs.com/ch/en/

STRUCTURAL THERMAL BREAKS

Manufacturer/Supplier	Specialties	Offers PHI Certified Components	HQ Location	Link
Armatherm Thermal Bridging Solutions		Yes	Massachussetts	https://www.armatherm.com/
Schaeck	balcony supports	Yes	Germany/NJ	https://www.schaeck.com/en-us/home
Thermal Breaks Ltd.		Yes	UK	https://thermal-breaks.group/
Thermoblock			Arizona	https://www.thermoblockicf.com/

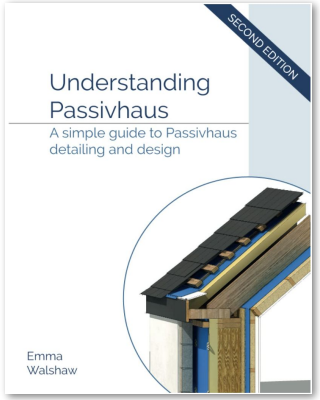
AIRTIGHTNESS & VAPOR CONTROL

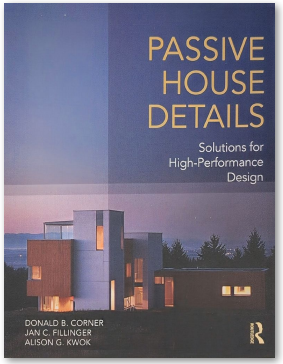
Manufacturer/Supplier	Specialty	Offers PHI Certified Components	HQ Location	Link
Delta - Dorken			Canada	https://www.dorken.com/en/
Hanno		Yes	Germany	https://worldclassquality.com/
Intelligent Membranes		Yes	UK	https://www.intelligentmembranes.com/
Pertel		Yes	Ireland/NY	https://www.pertel.com/
Pro Clima		Yes	Germany/NY	https://475.supply/collections/pro-clima
Prosoco			Kansas	https://prosoco.com/
Retrotec	blower door		Washington	https://retrotec.com/
Rothoblaas		Yes	Italy	https://www.rothoblaas.com/
Siga		Yes	New York	https://www.siga.swiss/us_en/products
Soprema			Ohio	https://www.soprema.us/
Stego	sub slab		California	https://www.stego-industries.com/
VaproShield			Washington	https://vaproshield.com/
TEC (Minneapolis Blower Door)	blower door		Minnesota	https://www.energyconservatory.com/

WINDOWS, DOORS & SHADING SYSTEMS

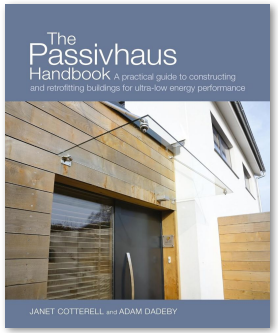
Manufacturer/Supplier	Specialty	Offers PHI Certified Components	HQ Location	Link
Alpen		Yes	Colorado	https://www.thinkalpen.com/
Amberline			Massachussetts	https://amberlinewindows.us/
Bewiso	simulated double-hung		Austria/NY	http://www.bewiso.eu/
Cardinal	glazing, spacers	Yes	Minnesota	https://www.cardinalcorp.com/
Cascadia	fiberglass		British Columbia	https://www.cascadiawindows.com/
Decouvinck		Yes	Ohio	https://decouvinckna.com/
Eco Windows			Connecticut	https://ecowindowsusa.com/
Edge-Tech	spacers		Texas	https://www.quanex.com/product/for-architects/warm-edge-spacers/
ENERsign		Yes	Germany/CO	https://www.enersign.com/en/
EuroLine Windows		Yes	British Columbia	https://euroline-windows.com/
Fakro	skylights		Poland/Illinois	https://shop.fakrousa.com/
Gamma North America		Yes	Ontario	https://gammanna.com/
GlassCurtain	curtain wall		Alberta	https://glasscurtain.ca/
Helia	exterior shading	Yes	Germany/MN	https://www.tannerbp.com/helia-exterior-blinds
Ikon Windows			New York	https://www.ikonwindows.com/
Inline Fiberglass			Ontario	https://www.inlinefiberglass.com/
Innotech Windows		Yes	British Columbia	https://www.innotech-windows.com/

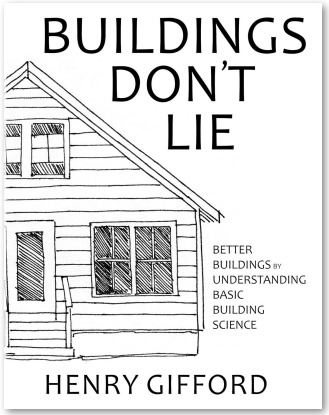
Books

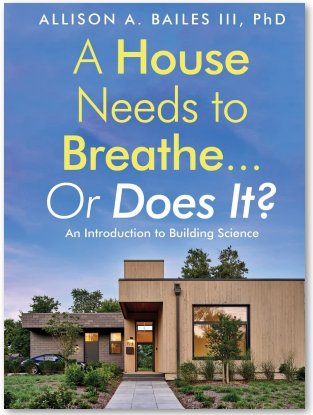




https://issuu.com/lafamillecarbonic/docs/passive_architecture_en







Realization: Passive House efficiency underlies what we value most.

Occupants (home, school, work)

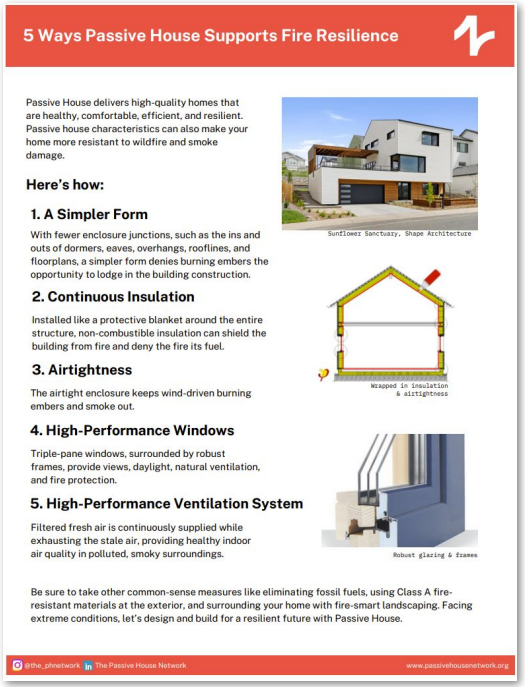
- Comfortable
- Healthy indoor air quality
- Fewer allergies
- More alert
- Quiet
- Resilient & Safe
- Affordable operation & maintenance
- High levels of satisfaction

Owners

- Affordable upfront cost
- Fewer callbacks
- Reduced maintenance
- Perpetual energy savings
- Happy occupants and lower vacancy
- Higher sale price
- Durable high quality asset
- Lower risk investment

Ryall Sheridan Architects, VT

Wildfire Resilience



5 Ways Passive House Supports Fire Resilience

Passive House delivers high-quality homes that are healthy, comfortable, efficient, and resilient. Passive house characteristics can also make your home more resistant to wildfire and smoke damage.

Sunflower Sanctuary, Shape Architecture

Here's how:

1. A Simpler Form

With fewer enclosure junctions, such as the ins and outs of dormers, eaves, overhangs, rooflines, and floorplans, a simpler form denies burning embers the opportunity to lodge in the building construction.

2. Continuous Insulation

Installed like a protective blanket around the entire structure, non-combustible insulation can shield the building from fire and deny the fire its fuel.

Wrapped in insulation & airtightness

3. Airtightness

The airtight enclosure keeps wind-driven burning embers and smoke out.

4. High-Performance Windows

Triple-pane windows, surrounded by robust frames, provide views, daylight, natural ventilation, and fire protection.

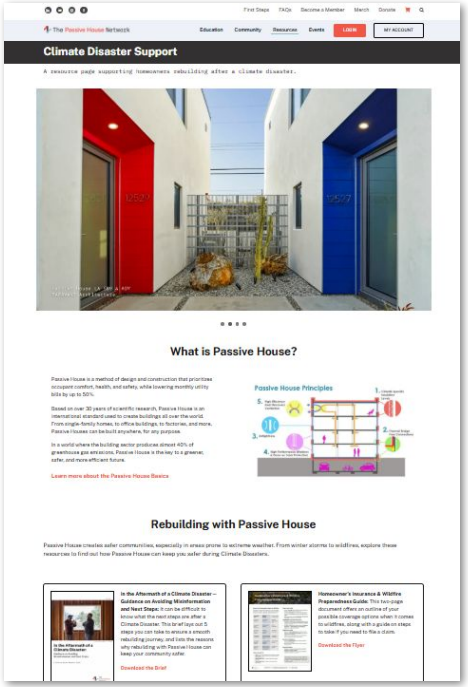
Robust glazing & frames

5. High-Performance Ventilation System

Filtered fresh air is continuously supplied while exhausting the stale air, providing healthy indoor air quality in polluted, smoky surroundings.

Be sure to take other common-sense measures like eliminating fossil fuels, using Class A fire-resistant materials at the exterior, and surrounding your home with fire-smart landscaping. Facing extreme conditions, let's design and build for a resilient future with Passive House.

@the_phnetwork The Passive House Network www.passivehousenetwork.org



Climate Disaster Support

A resource page supporting homeowners rebuilding after a climate disaster.

What is Passive House?

Passive House is a method of design and construction that prioritizes occupant comfort, health, and safety, while lowering monthly utility bills by up to 50%.

Based on over 30 years of scientific research, Passive House is an international standard used to create buildings all over the world. From single-family homes, to office buildings, to factories, and more, Passive Houses can be built anywhere, for any purpose.

In a world where the building sector produces almost 40% of greenhouse gas emissions, Passive House is the key to a greener, safer, and more efficient future.

Learn more about the Passive House Basics

Passive House Principles

Rebuilding with Passive House

Passive House creates safer communities, especially in areas prone to extreme weather. From winter storms to wildfires, explore these resources to find out how Passive House can keep you safer during Climate Disasters.

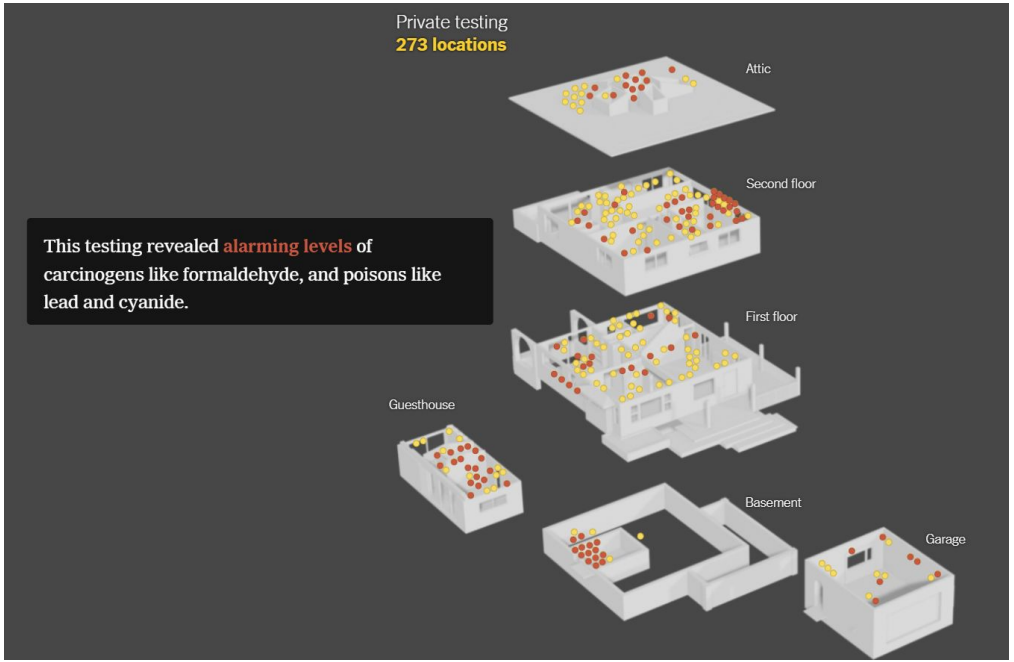
In the Aftermath of a Climate Disaster -- Guidance on Avoiding Misinformation and Next Steps: It can be difficult to know what the next steps are after a Climate Disaster. This brief lays out 5 steps you can take to ensure a smooth rebuilding journey, and lists the reasons why rebuilding with Passive House can keep your community safer.

Download the Brief

Homeowner's Insurance & Wildfire Preparedness Guide: This two-page document offers an outline of your possible coverage options when it comes to wildfires, along with a guide on steps to take if you need to file a claim.

Download the Flyer

Smoke infiltration damage



A Simple Idea

Goals Include:

1. Comfort
2. Health
3. Efficiency
4. Durability

We build for the long term.

Homes...

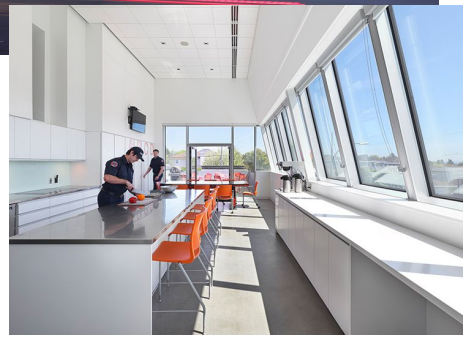
Affordable Housing


Brownsville, Brooklyn


Sendero Verde, East Harlem

Recreation & Emergency Services

Gale & Snowden, St Sidwell’s Point, Exeter, UK



HCMA, Vancouver, BC

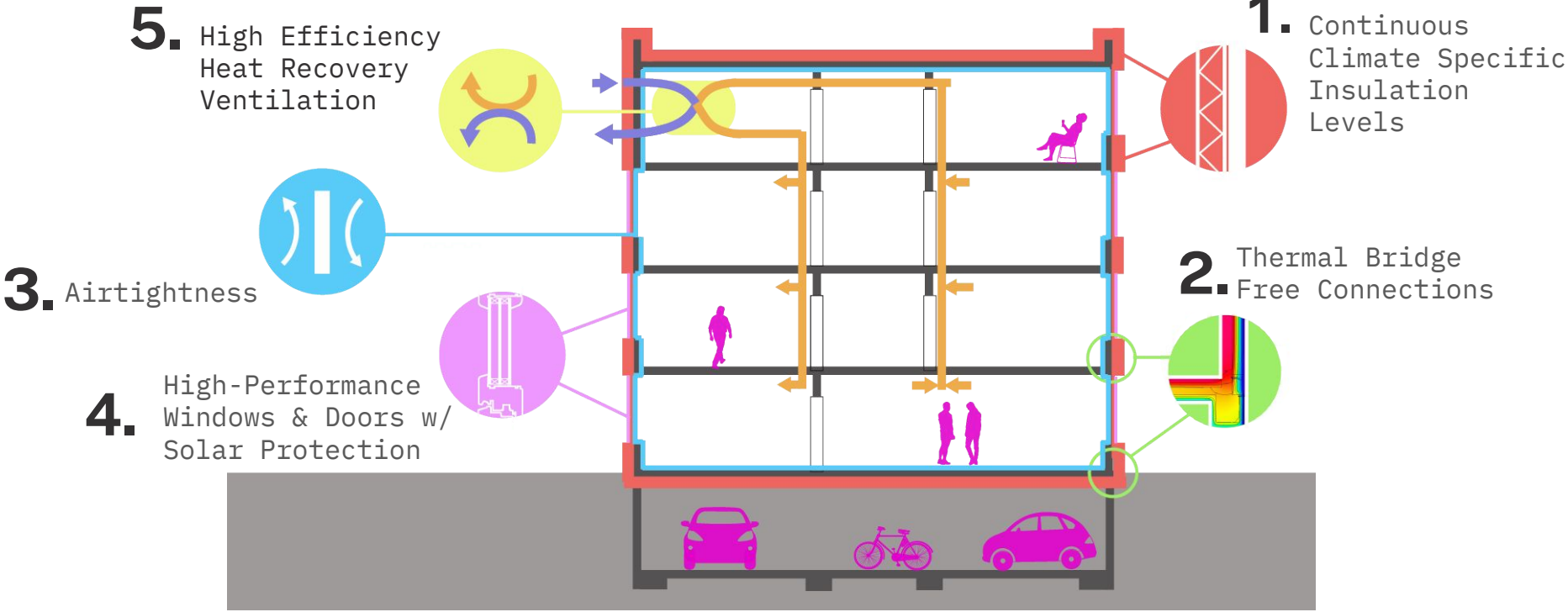
Schools

Opal Architecture, Bar Harbor, Maine

Architecture Research Office, Brooklyn NY

Wood, Steel, Concrete

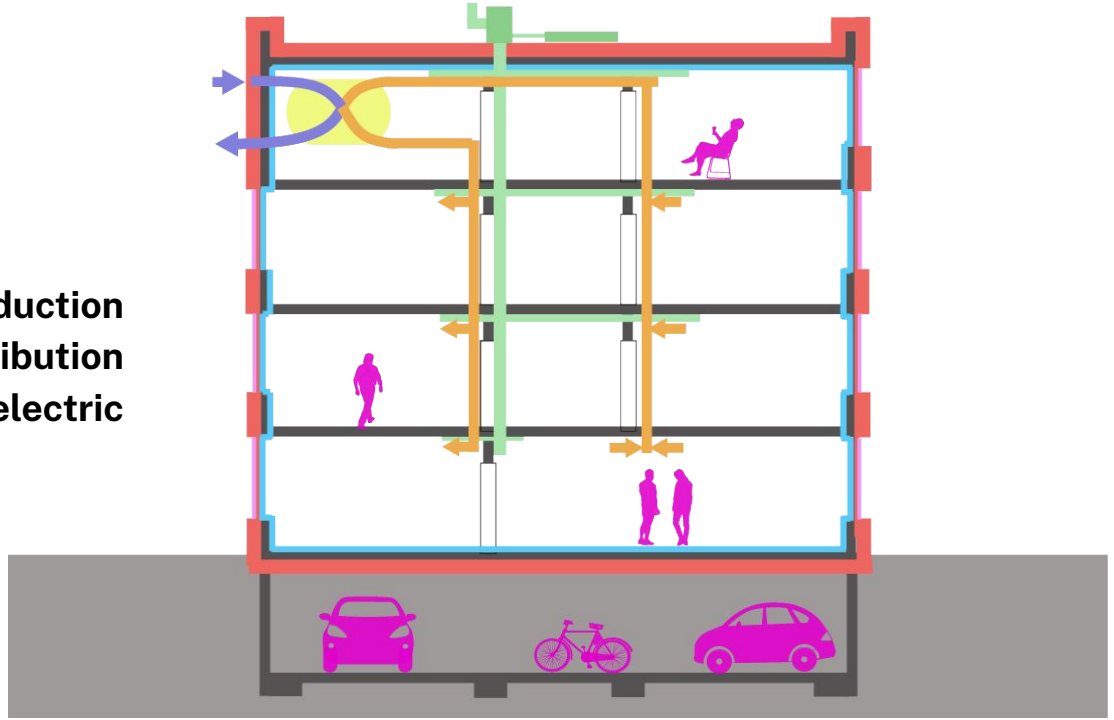
5 Principles of Construction (the drivers)



These are the 5 things builders must focus on most intently.

THEN: Right size Heating & Cooling Systems

75% equip sizing reduction
Efficient distribution
Often all-electric



Energy Modeling: Calculating Predictable Performance

https://passivehouse.com/04_phpp/04_phpp.htm

Window area orientation (main orientations)	Global radiation	Shading	Dirt	Non-vertical radiation incidence	Glazing fraction	SHGC	Solar irradiation reduction factor
Standard values →	kWh/(ft²yr)	0.75	0.95	0.85			
North	14	0.56	0.95	0.85	0.58	0.50	0.26
East	33	0.79	0.95	0.85	0.63	0.50	0.40
South	62	0.81	0.95	0.85	0.74	0.50	0.49
West	34	0.81	0.95	0.85	0.63	0.50	0.41
Horizontal	53	1.00	0.95	0.85	0.00	0.00	0.00
Total or average value for all windows.						0.50	0.43

Heating degree hours [°F.day/yr]: 7440

Go to glazing list | Go to window frames list

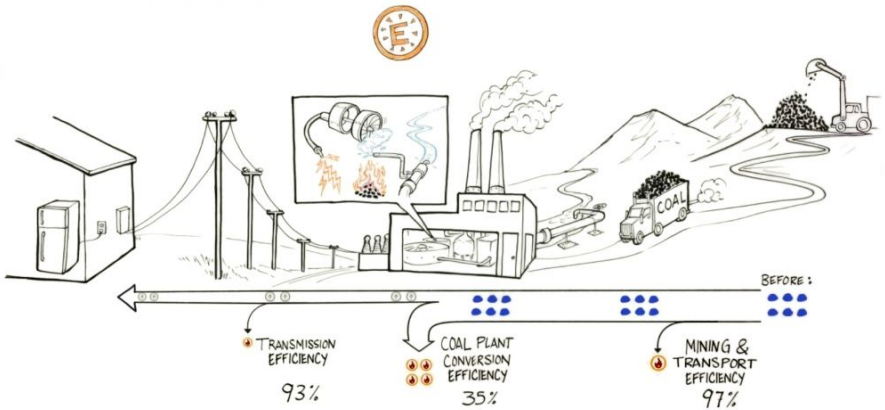
Qua n-tity	Description	Deviation from north	Angle of inclination from the horizontal	Orien- tation	Window rough ope Width	Height	Installed in Selection from 'Areas' worksheet	Glazing Selection from 'Components' worksheet	Frame Selection from 'Components' worksheet	g-Value Perpen- dicular radiation	U-Value Glazing	Frames (avg.)	Ψ Glazing edge (Avg.)	Installation si left	right	bottom
		°	°		ft	ft		1-Sorting: LIKE LIST	Sort: AS LIST	-	BTU/hr.ft².F	BTU/hr.ft².F	BTU/hr.ft².F	BTU/hr.ft².F or 1/0		
1	W104	90	90	East	3.00	4.86	4-Wall_9351_E	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W107	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W106	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W105	90	90	East	3.00	4.85	4-Wall_9351_E	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	D125	90	90	East	3.00	6.67	4-Wall_9351_E	01ud-Triple-Insulated-Kr08	03ud AD575 Door	0.50	0.11	0.32	0.029	1	1	1
1	W155	90	90	East	3.00	4.06	4-Wall_9351_E	01ud-Triple-Insulated-Kr08	01ud Si82+Fixed	0.50	0.11	0.19	0.018	1	1	1
1	W135	270	90	West	2.33	3.50	5-Wall_9544_W	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W134	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W133	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W132	270	90	West	3.00	4.85	5-Wall_9544_W	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W156	270	90	West	3.00	4.06	5-Wall_9544_W	01ud-Triple-Insulated-Kr08	01ud Si82+Fixed	0.50	0.11	0.19	0.018	1	1	1
1	W140	0	90	North	2.33	2.33	6-Wall_9368_N	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1
1	W139	0	90	North	2.33	3.50	6-Wall_9368_N	01ud-Triple-Insulated-Kr08	02ud Si82+Operable	0.50	0.11	0.19	0.018	1	1	1

How can we assess our all renewable future?

"Old" Passive House

- **Primary Energy (PE)** - source energy under "today's" grid
  - Fixed threshold typically between 38 and 45 kBtu/sf.yr
  - Electricity site to source factor = 2.6
  - Natural gas site to source factor = 1.1

Effectively penalizes all electric buildings



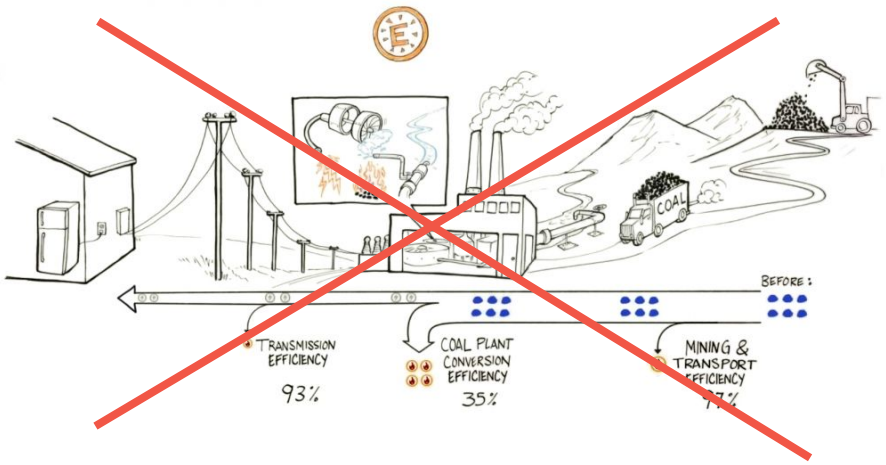
Credit: Bronwyn Barry/PassiveHouseBB

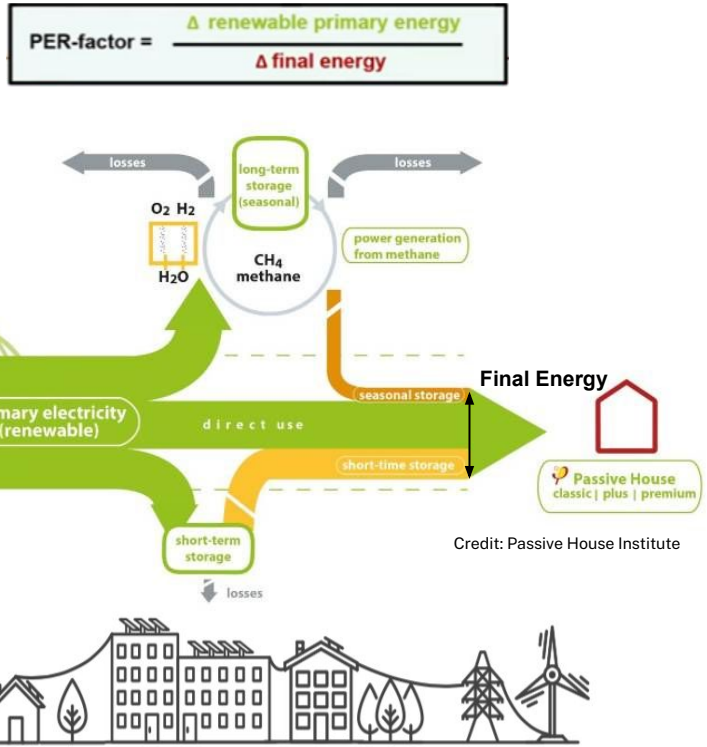
Traditional look at source energy and emissions is not effective in analyzing efficiency of an all-renewable system.

ASHRAE's recently installed photovoltaic (PV) system.

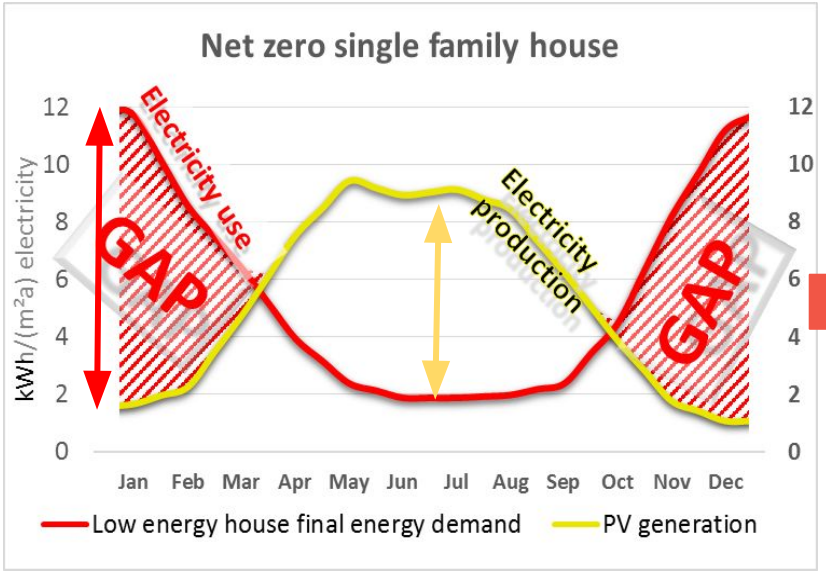
Shift Focus: Analysis to fit our all renewable future

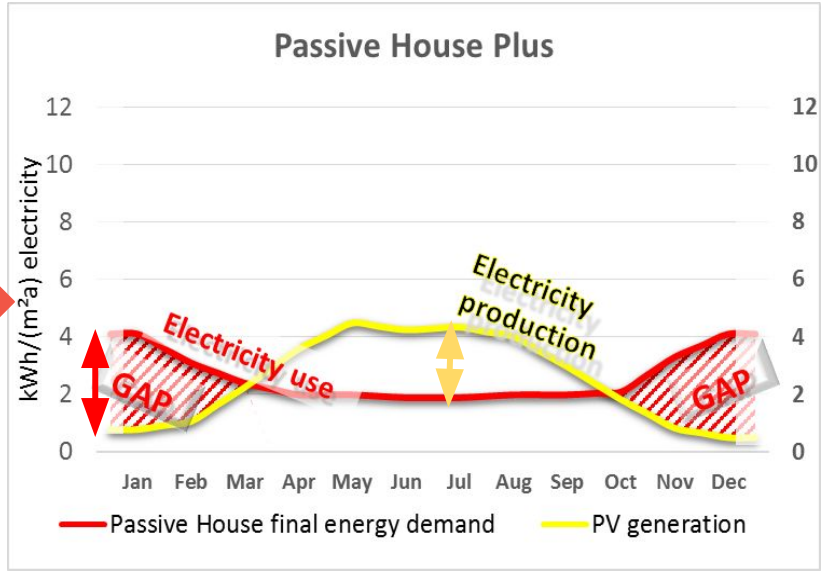
Passive House looks beyond the emissions analysis and to renewable production & utilization.





Passive House Enables Optimized Alignment





Passive House reduces demand and tunes it to the power supply.

Credit: Passive House Institute

Effectiveness: Use, Climate, Site, Assessment

New approach to all-renewable electric system bring new categories of questions.

1. Use Specific

How well does our demand match supply? (seasonal alignment)

How do different demand profiles differ in matching supply? (DHW, Heating, Cooling, Dehumidification, Plug Loads)

2. Climate Specific (production)

How effective is the supply? (solar, wind, hydro)

How effective are different methods of renewable supply in my location? (climate/region/grid)

3. Site Specific (Production)

Best way to contribute to supply? (on-site, remote)

How to assess effective on-site use? (floor area or footprint)

4. Assessment Method

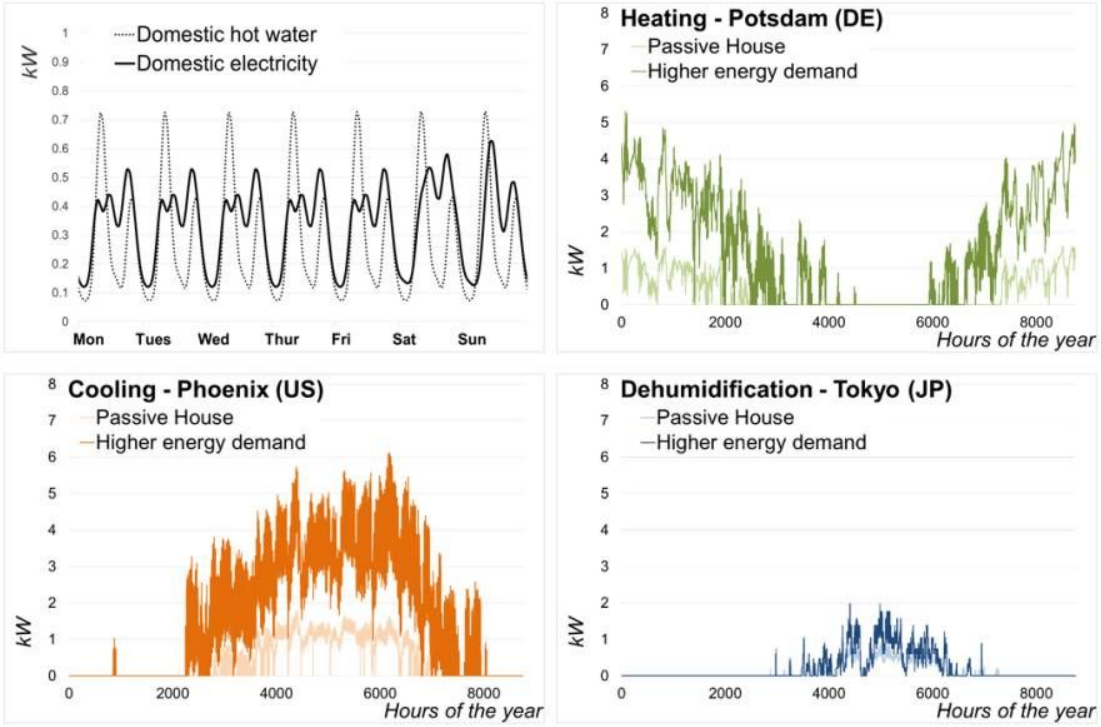
What's the best assessment method of supply & demand? (combined offset like net zero or independently?)

No longer a question of carbon emissions, or even of achieving "net zero."

Specific Use Demands & Different Climates:

Use Categories

1. Hot Water
2. Other Elec Uses
3. Heating
4. Cooling
5. Dehumidification



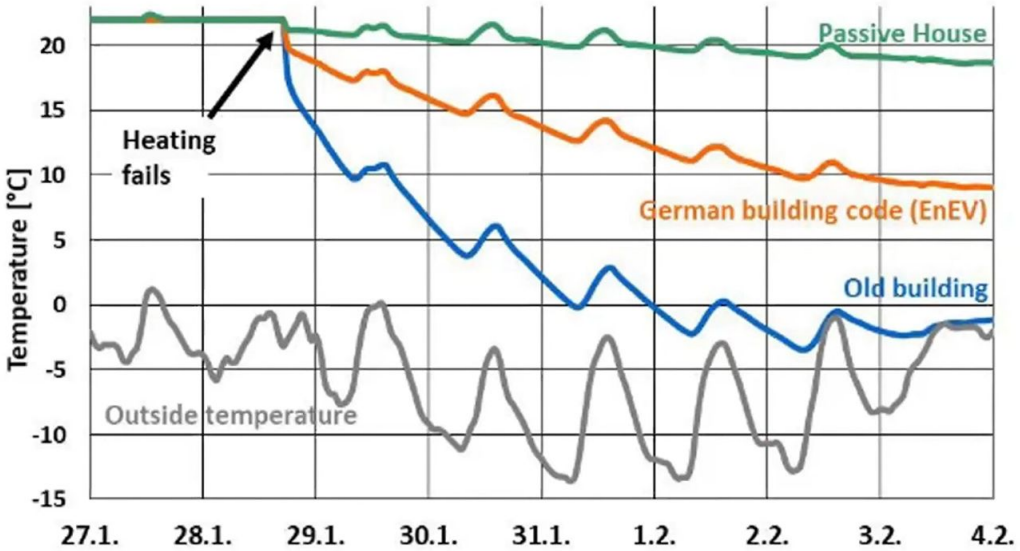
Credit: Passive House Institute

Second: Load Shifting with Thermal Resilience

Because thermal temperatures are stable there is much greater flexibility in when the space conditioning happens.

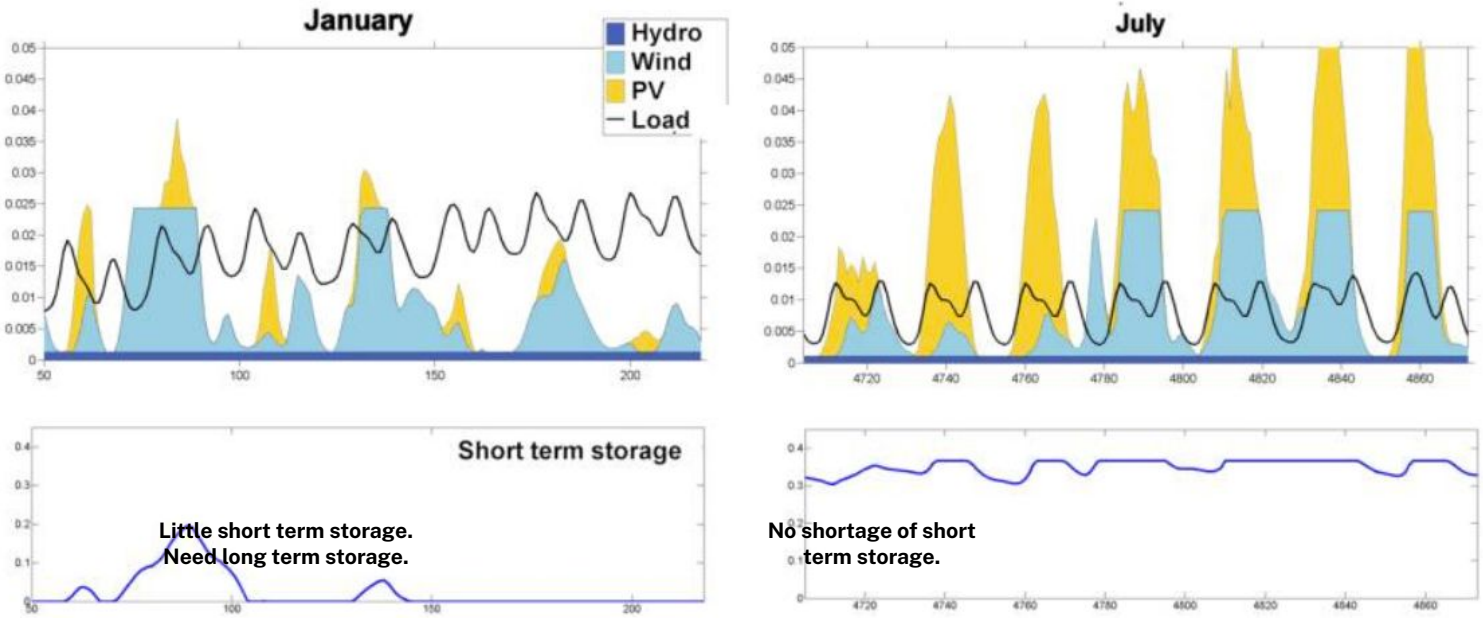
Use power off-peak.

Think thermos.



Credit: Passive House Institute

Match of Supply to Use Determines Storage Need



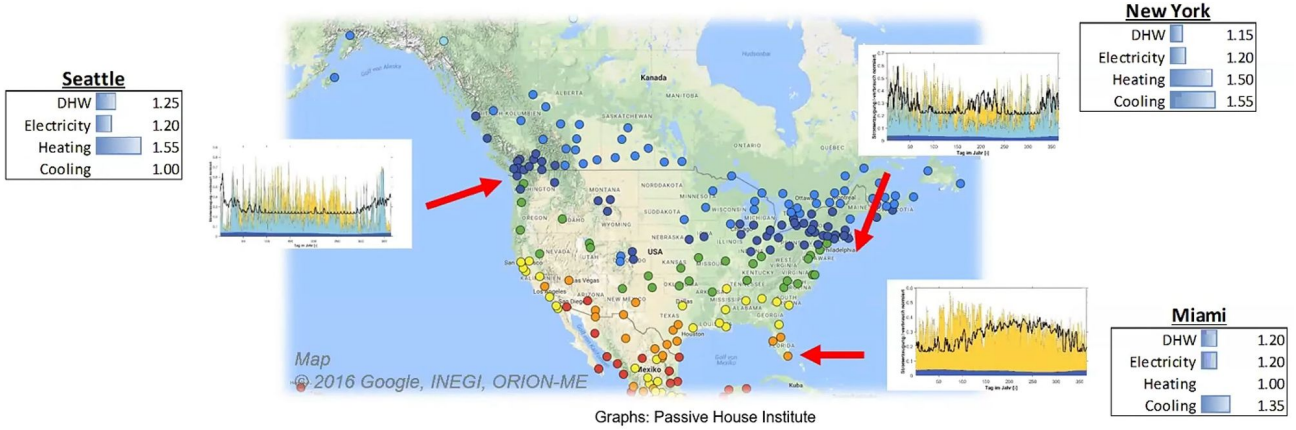
Example of hourly load profiles of RE electricity (cumulative) and electricity demand for a Passive House in Stuttgart. The left represents a week during winter with little RE availability, compared to a week during summer on the right, with much higher RE supply. The two graphs below show the simultaneous storage level of the short-term storage. Credit: Passive House Institute

What your doing and where you're doing it matters.

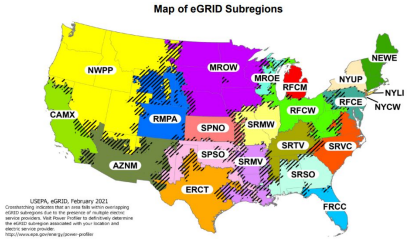
PER weighting factors different for:

- Electricity use → consumer specific
- Location → climate specific

Electric Factors are regionally, climate, *and* consumer use specific

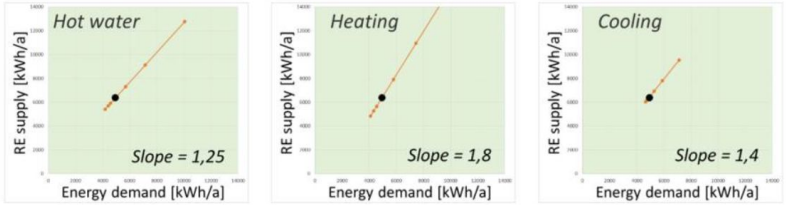


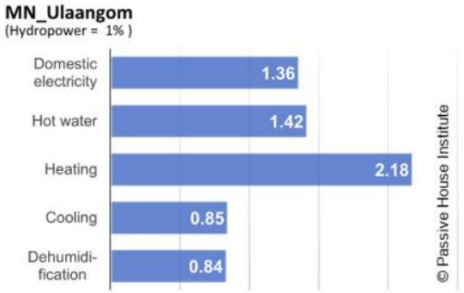
Graphs: Passive House Institute

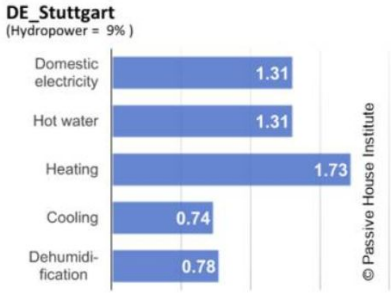


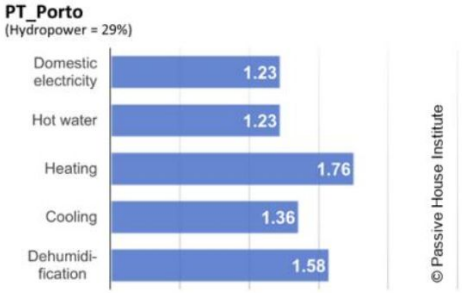
PER Factors

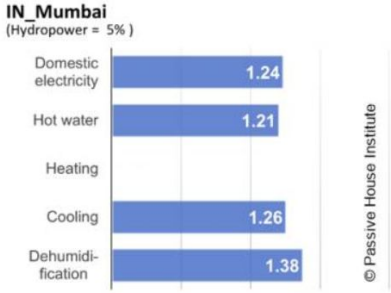
Boise ID











The hourly RE profile depends on the proportion of solar and wind energy in the mix, in addition to the fixed percentage of hydropower.

Both extremes (no solar or no wind), as well as four intermediate steps are modelled, which results in six calculations for the demand profile. The PER factor is determined based on the most favourable combination of wind and solar energy.

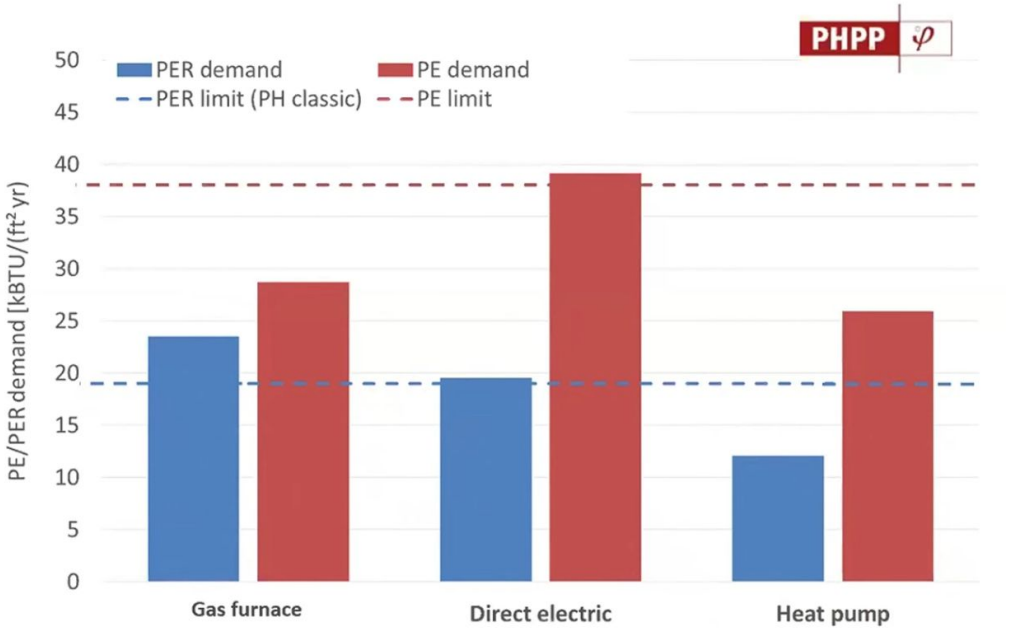
Traditional Weighting vs. PER

Figure 1 – Source-Site Ratios for all Portfolio Manager Energy Meter Types

Energy Type	U.S. Ratio	Canadian Ratio	PER factor
Electricity (Grid Purchase)	2.80	1.96	1 - 2 depending on use
Electricity (Onsite Solar or Wind - regardless of REC ownership)	1.00	1.00	
Natural Gas	1.05	1.01	1.75
Fuel Oil (No. 1,2,4,5,6, Diesel, Kerosene)	1.01	1.01	2.3
Propane & Liquid Propane	1.01	1.04	
Steam	1.20	1.33	
Hot Water	1.20	1.33	
Chilled Water	0.91	0.57	
Wood	1.00	1.00	
Coal/Coke	1.00	1.00	
Other	1.00	1.00	

PER makes fossil use difficult in Berkeley CA

Based on certified Passive House project in Berkeley, California
ID 6064 on www.passivehouse-database.org



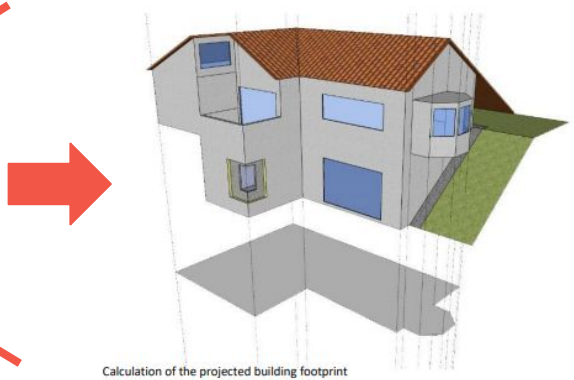
Credit: Passive House Institute

Supply: Shifts to Independent Assessment

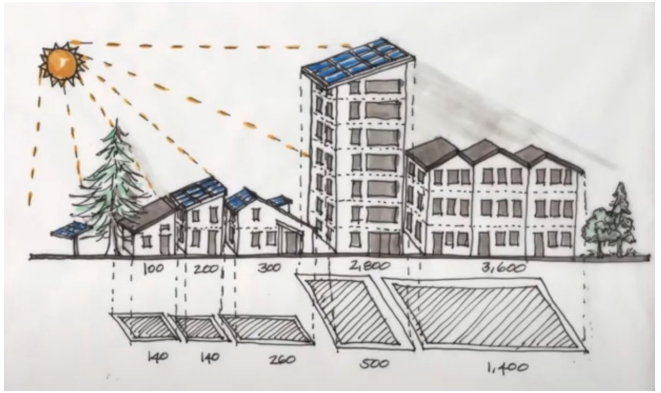
The question is how to most effectively contribute to the power supply?

Supply: Independent Assessment. No offsets.

Net Zero goes away. Instead: How are we utilizing the building footprint?



Calculation of the projected building footprint



Supply: Shift to footprint

Consequently, we don’t penalize tall buildings.

Calculation of the projected building footprint

1. Context of Passive House

2. Context of Mechanical Systems

3. Strategy

4. Ventilation

5. Heating & Cooling

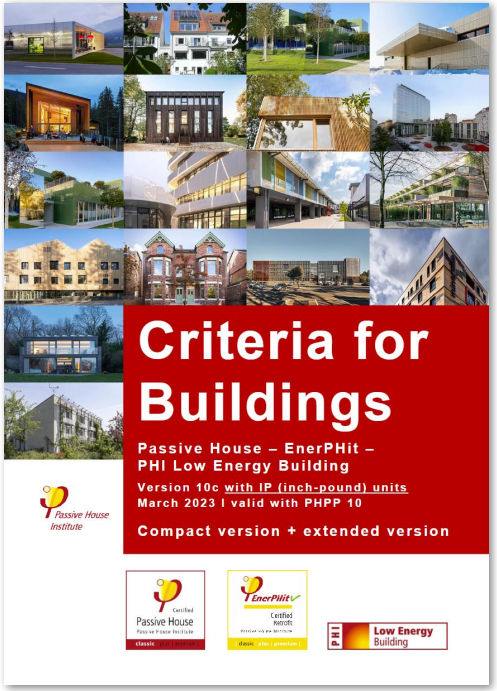
6. DHW

7. Other Systems + Solar

8. Case Studies

9. Resources

Criteria focuses on comfort, health, energy & durability:



1. **Enclosure quality**
   - Continuous insulation
   - Thermal bridge free
   - Airtightness
   - High-Performance Windows & Doors
2. **Ventilation**
   - Continuous & distributed
   - Balanced
   - High efficient heat recovery
3. **Mechanical Systems**
   - Heating
   - Cooling
   - DHW
4. **Energy**
   - Heat demand/load
   - Cooling demand/load
   - Dehumidification
   - Overall energy use
   - Possible renewable production

Mechanical System's Purpose

- Maintain healthy indoor air quality
- Efficient space cooling & heating
- Efficient Hot Water

- Reduced emissions (efficient)
- "Net Zero" (balance of demand & production)

Criteria: Energy

Measured against
“Treated Floor Area”
and “finished volume.”

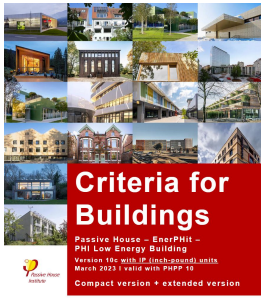


Table 1 Passive House criteria

			Criteria[1]			Alternative Criteria[2]
Heating						
Heating demand	[kBTU/(ft²yr)]	≤	4.75			-
Heating load[3]	[BTU/(hr.ft²)]	≤	-			3.17
Cooling						
Cooling + dehumidification demand	[kBTU/(ft²yr)]	≤	4.75 + variable allowance[4]			
Airtightness						
Pressurization test result n_{50}	[1/hr]	≤	0.6			
Renewable Primary Energy (PER)[5]			Classic	Plus	Premium	
PER demand[6]	[kBTU/(ft²yr)]	≤	19.02	14.26	9.51	±4.75 kBTU/(ft²yr) deviation from criteria...
Renewable energy generation[7] (with reference to projected building footprint)	[kBTU/(ft²yr)]	≥	-	19.02	38.04	...with compensation of the above deviation by different amount of generation[8]

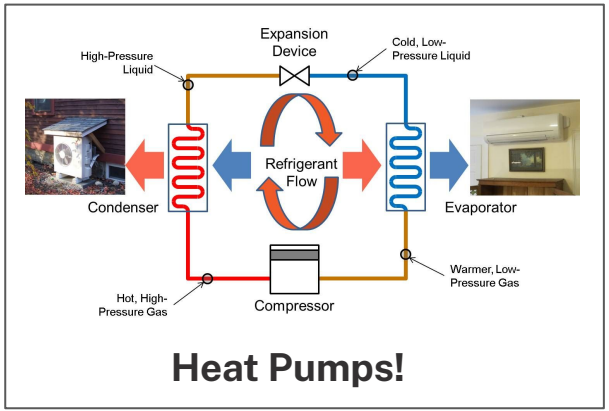
Table 5 PHI Low Energy Building criteria

			Criteria[1]	Alternative Criteria[2]
Heating				
Heating demand	[kBTU/(ft²yr)]	≤	9.51	
Cooling				
Cooling + dehumidification demand	[kBTU/(ft²yr)]	≤	Passive House requirement[3] + 4.75	
Airtightness				
Pressurization test result n_{50}	[1/hr]	≤	1.0	
Renewable Primary Energy (PER)[4]				
PER demand[5]	[kBTU/(ft²yr)]	≤	23.77	Exceeding the criteria up to +4.75 kBTU/(ft²yr) is permitted...
Renewable energy generation[6] (with reference to projected building footprint)	[kBTU/(ft²yr)]	≥	-	...with compensation of the above deviation by additional generation

What are typical systems for Passive House?

Occupancy:

1. Single Family
2. Multifamily



PER Use Categories

1. Heating - Heat Pumps
2. Cooling - Heat Pumps
3. Dehumidification - Heat Pumps
4. Domestic Hot Water - Heat Pumps
5. Other Elec Uses
    a. Ventilation
    b. Cooking (induction)
    c. Clothes Drying (resistance or heat pump)
    d. LED lighting & misc plug loads.
    e. Car

Criteria: MEP

Ventilation:

1. Core Passive House principle.
2. Extensive certification requirements.
3. Commissioning key to Certification.

Heating & Cooling:

1. No hard rules but must be efficient.
2. While heat pumps are now common any type of system is possible.
3. Typical successful approaches.
    a. Keep it simple and small (right sized):
    b. Combined heat/cooling systems
    c. Minimize refrigerant lines.

Domestic Hot Water:

1. Efficient piping layout - minimizing circulation.
2. Well insulated hot water piping & accessories.
3. Efficient heater: Heat pump encouraged.
4. Efficient circulation pumps.
5. Bath waste water heat recovery encouraged.

Appliances & Lighting:

1. Efficient appliances and lighting.
2. All-electric encouraged.

“Do no harm”: Minimize “accidental” heating & cooling. Only use what you need.

THEN: Renewables & Smart Systems

Hamilton Architects, Northern Ireland

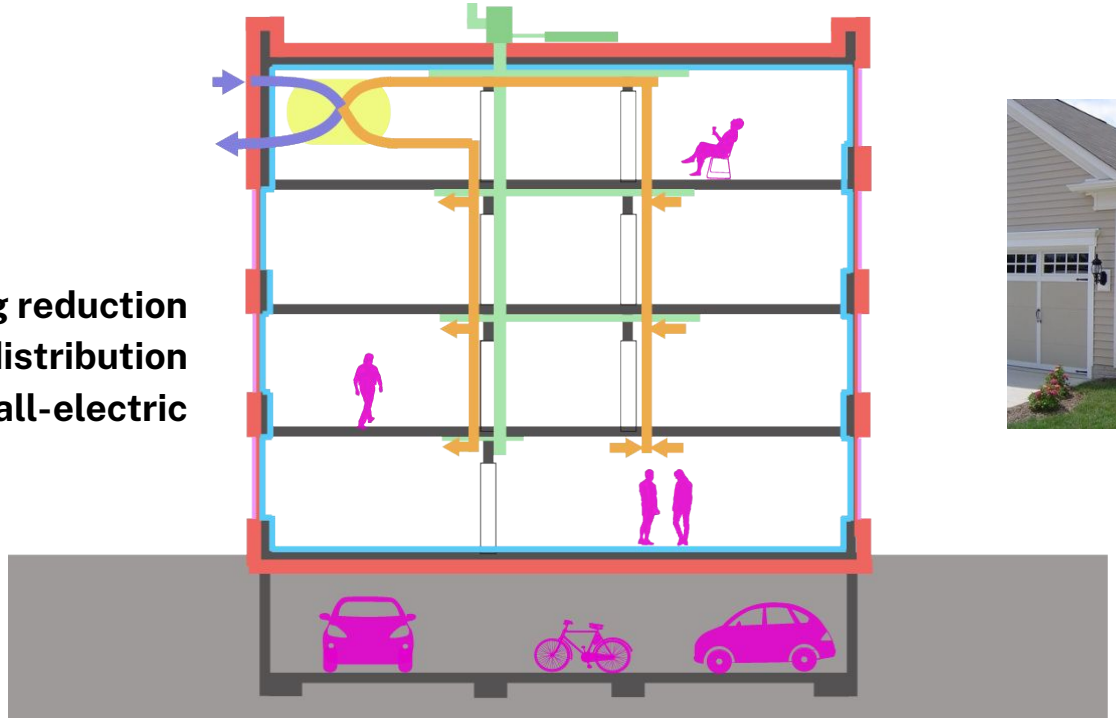
TE Studio, Minneapolis, MN

Smart controls & renewables *should enhance high-performance, not compensate for poor performance!*

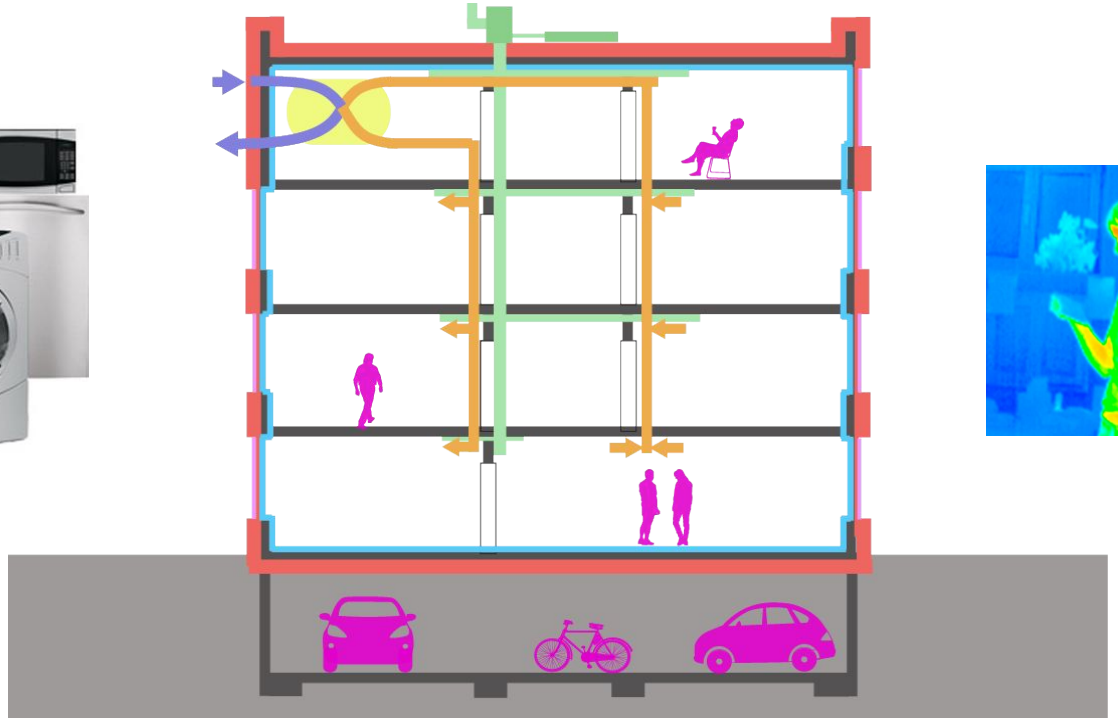
1. Context of Passive House
2. Context of Mechanical Systems
3. **Strategy**
4. Ventilation
5. Heating & Cooling
6. DHW
7. Other Systems + Solar
8. Case Studies
9. Resources

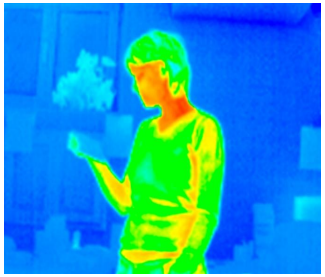
THEN: Right size Heating & Cooling Systems

75% equip sizing reduction
Efficient distribution
Often all-electric



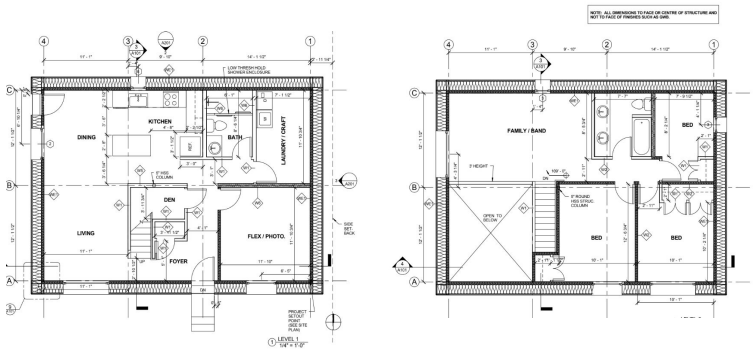
Internal Uses & Heat Gains (minimize overheating)





Layout Mechanical Systems' Needs Early

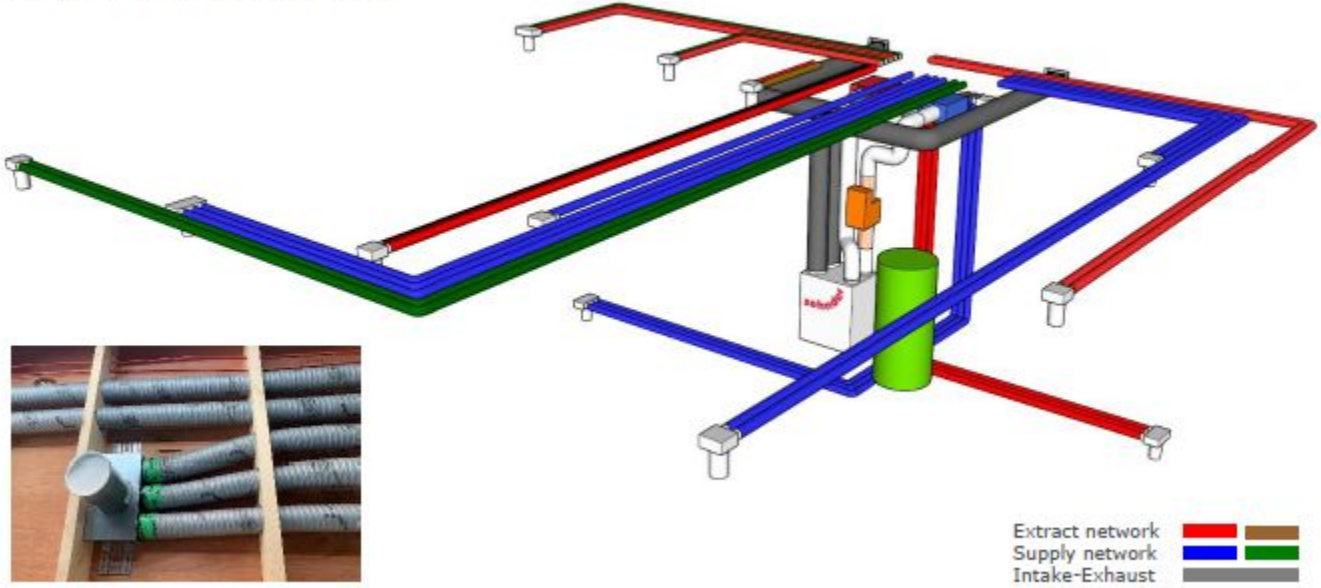
- Multifamily Passive House building require:
  - highly efficient energy recovery ventilation
  - well-insulated domestic hot water supply
  - appropriately sized cooling/heating systems.
- Too many multifamily design teams ignore the space these systems require until after the floor plan is set.
- The solution is to visualize the building from the inside out early in Schematic Design:
  - Choose centralized or localized ventilation system.
  - Locate hot water tanks and the heat pumps that feed them.
  - Choose the mechanical cooling strategy.



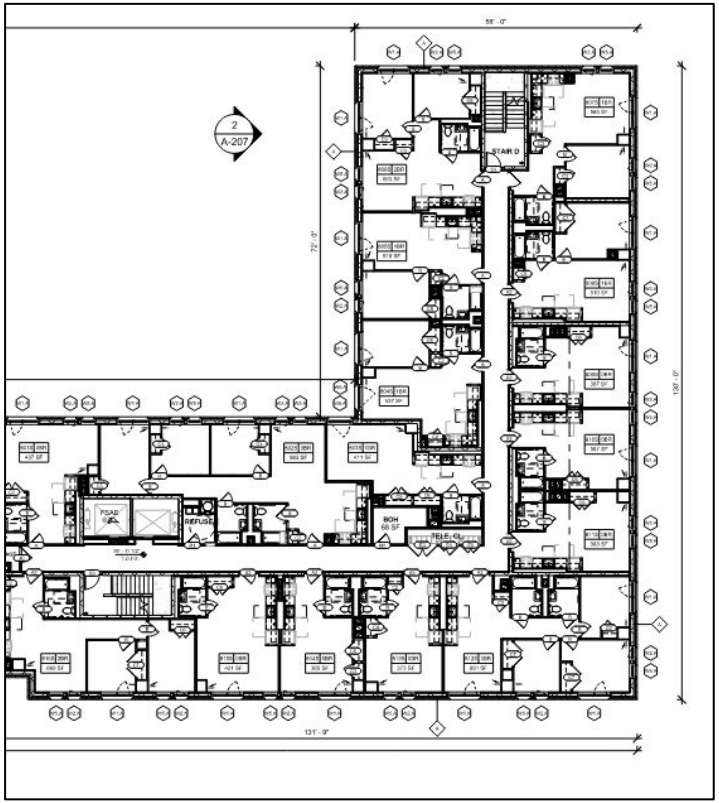
Give room for efficient layout that delivers effectively.
Must be able to access ventilation ductwork (leak testing) and hot water piping (insulating)

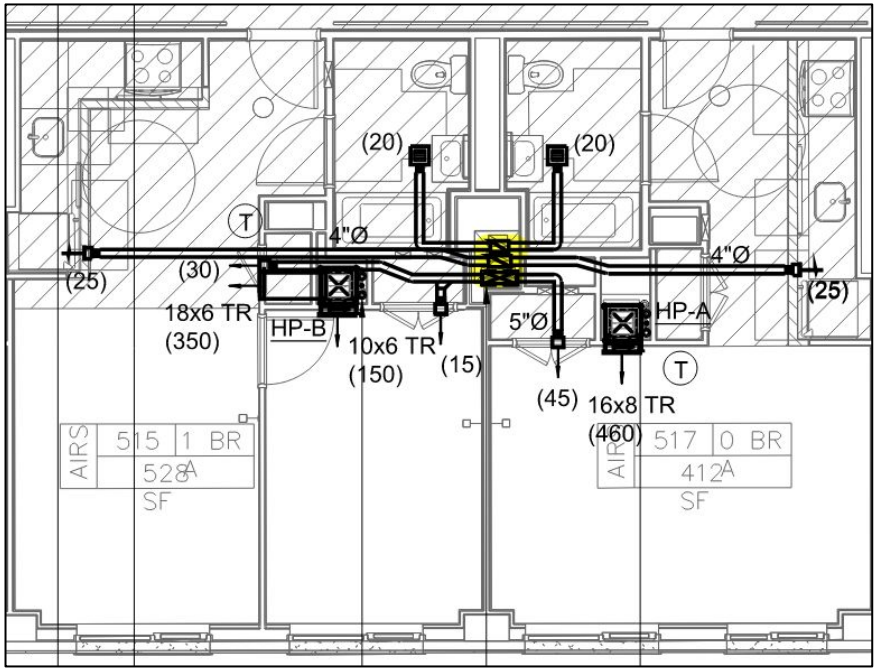
Single Family Ventilation Layout

This 3-dimensional model of the ventilation system helped the design team avoid structural and other building services conflicts, balance duct lengths for system efficiency and easy provisioning, and ensure that the mechanical room was adequately dimensioned and laid out.

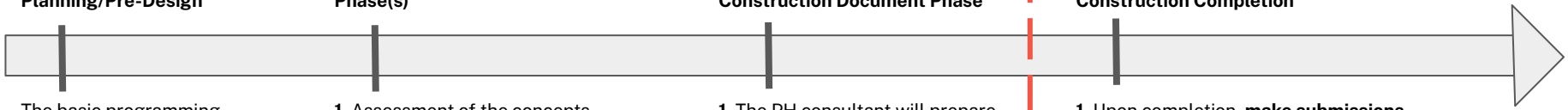


Compact Layouts





Certification Process Integration & Overview



Initial Check
Planning/Pre-Design

The basic programming complete, engage a Certifier, and have the Certifier conduct an **initial check** of programmatic assumptions and certification criteria - to **clarify how aspects will be assessed in the certification**.

Preliminary Review SD/DD
Phase(s)

1. Assessment of the concepts for the design, insulation and building services, and of the **preliminary version of the PHPP** calculation for **consistency with the certification criteria**.
2. The PH consultant **assembles key information**.
3. The Certifier will provide **feedback and suggestions** so you can optimize your design and specifications and update the PHPP energy model.

Design Stage Review
Construction Document Phase

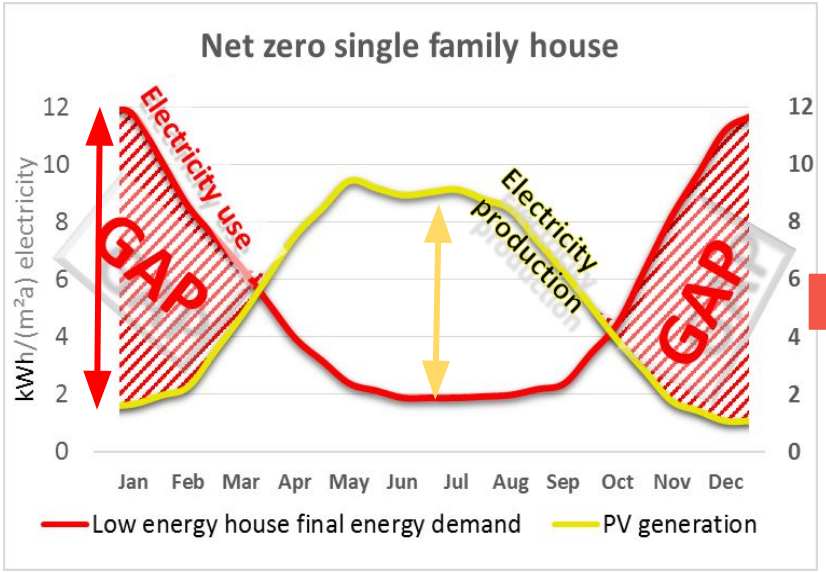
1. The PH consultant will prepare the detailed **certification submittal package** (PHPP, plans, specifications, and required supporting documentation) **according to your Certifier's guidance**.
2. Make corrections to your Certifier requests and **re-submit until your Certifier can conditionally assure** certification when construction is completed.
3. Your Certifier will **issue a design stage assurance letter** that, as designed, the building can be certified.

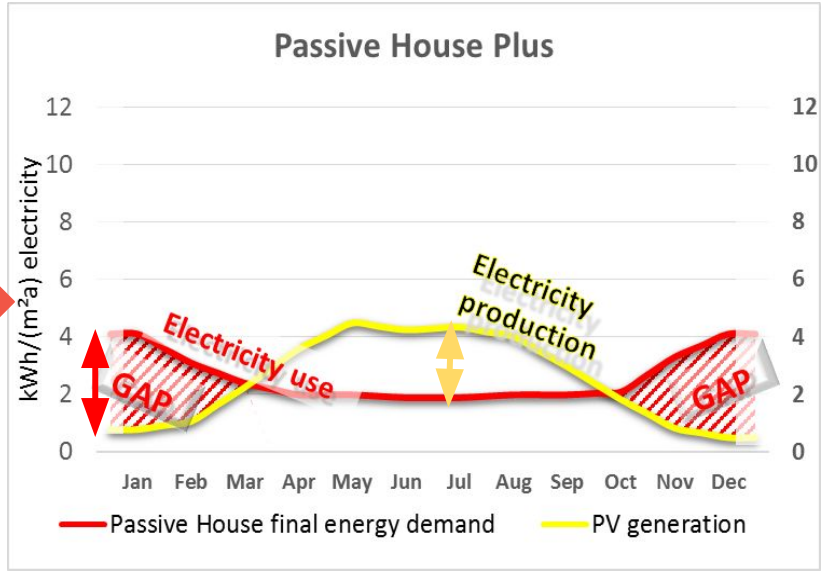
Final Review
Construction Completion

1. Upon completion, **make submissions** for Certifier's final review.
- As-built PHPP energy model and plans per PHI certification protocols
- Photo documentation per PHI certification protocols.
- Blower door test results per PHI certification protocols.
- Ventilation system commissioning report per PHI certification protocols.
- Executed Builder Assurance Certificate that building has been constructed to the as-built plans and energy model per PHI certification protocols.

2. If your building meets all certification criteria, you will receive the building certificate.
3.Post the certificate on your website and attach the plaque to your new Passive House building.
4. List your newly certified building in PHI's online international project directory.

Passive House Enables Optimized Alignment: Grid Friendly





Passive House reduces demand and tunes it to the power supply.

Credit: Passive House Institute

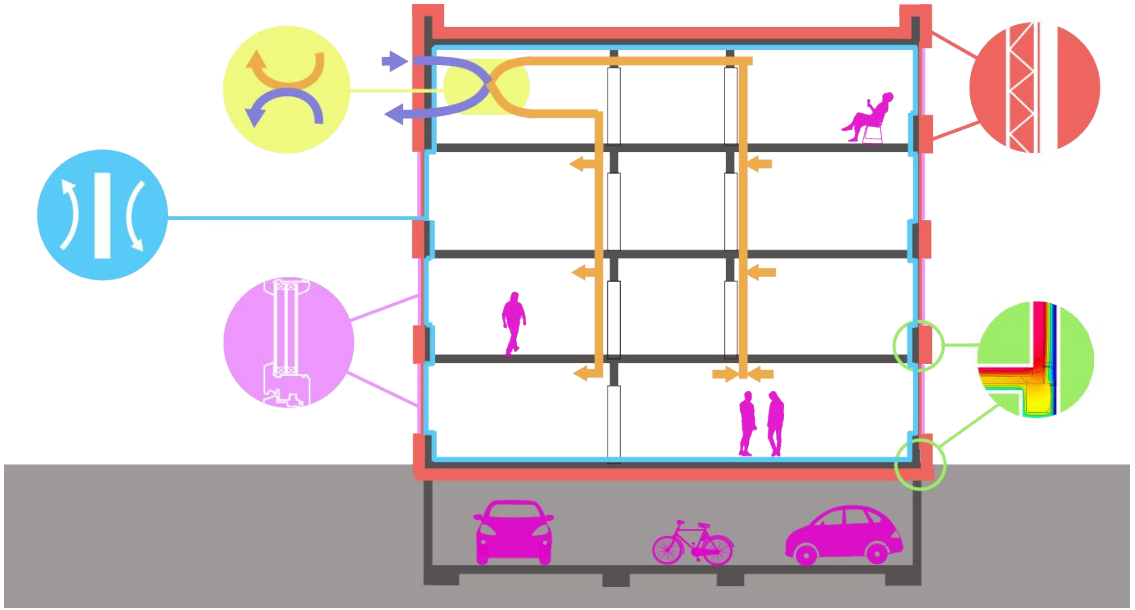
1. Context of Passive House
2. Context of Mechanical Systems
3. Strategy
4. Ventilation
5. Heating & Cooling
6. DHW
7. Other Systems + Solar
8. Case Studies
9. Resources

Passive House Ventilation

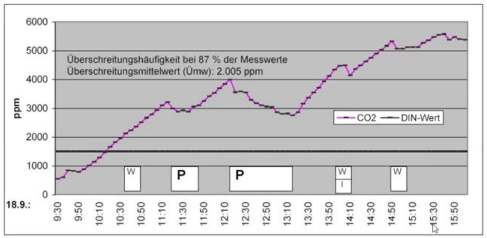
5.

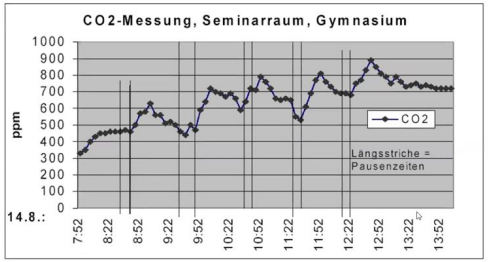
High Efficiency
Heat Recovery
Ventilation

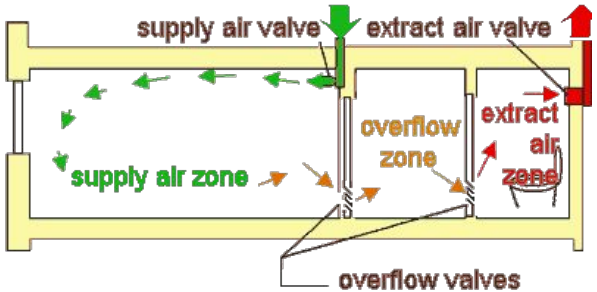
- Good air quality
- Continuous Operation
- Balanced ventilation
- Heat/Energy recovery

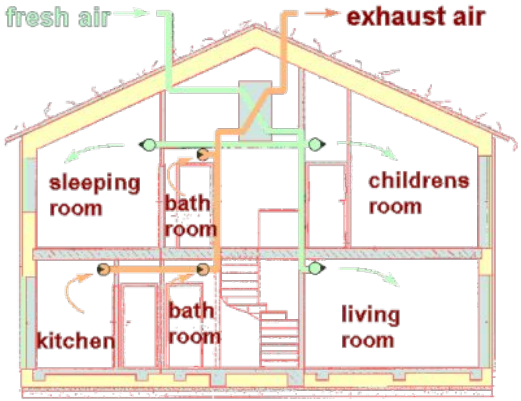


Criteria: Ventilation

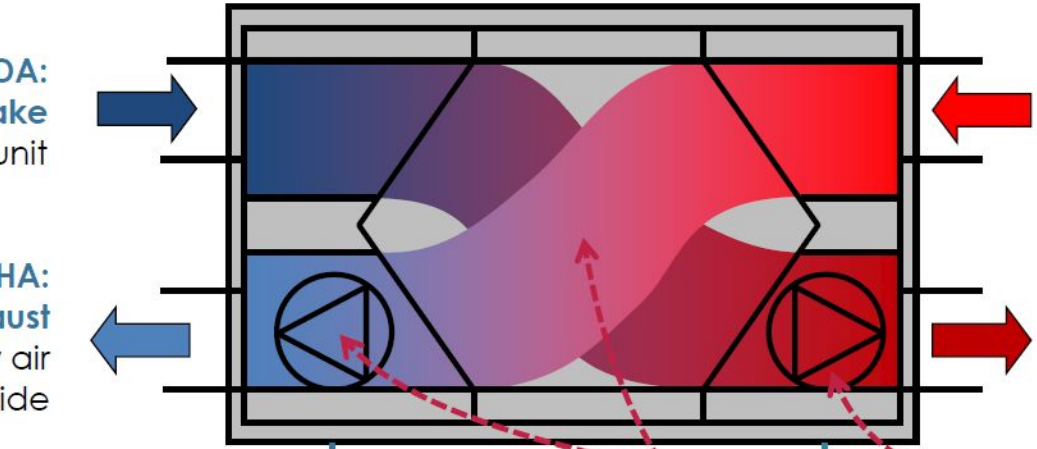








Heat Recovery Ventilation Unit



ODA:
Outdoor air intake
fresh air into unit

EHA:
Exhaust
post-recovery air
to outside

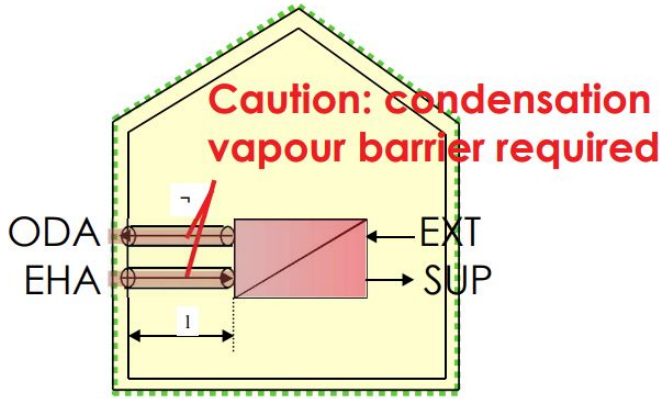
EXT:
Extract air
stale air from
baths/kitchens/stores

SUP:
Supply air
fresh air into living rooms,
offices, classrooms

Fans

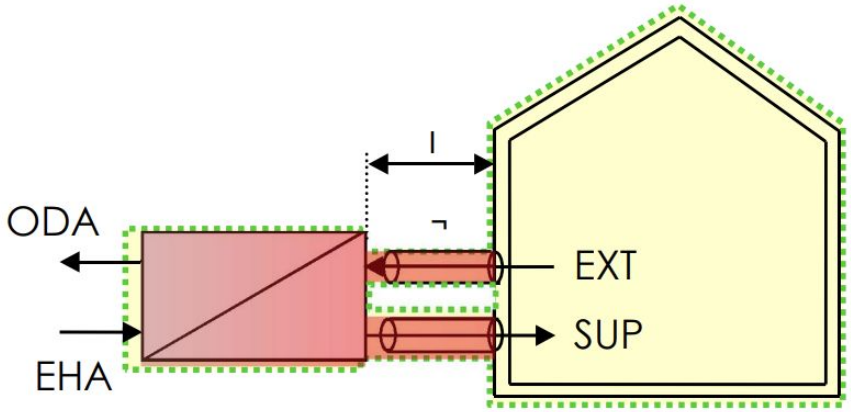
Heat/energy
recovery core

Placement of unit inside or outside



1. Ventilation unit <u>inside</u> thermal envelope:
2-4" vapor-tight insulation required, keep ducts as short as possible – so locate the H/ERV near the enclosure!

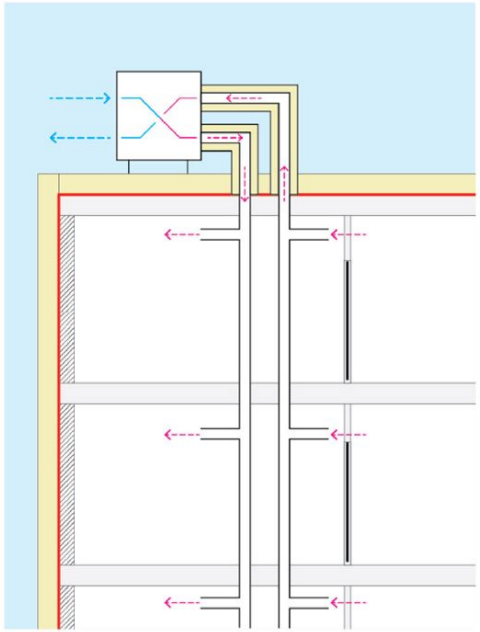
2. Ventilation unit <u>outside</u> thermal envelope:
2-4" insulation so no heat is lost between the building and the H/ERV. In a semi-conditioned basement 1-2" insulation on EHA and ODA may be prudent.



Balanced Ventilation

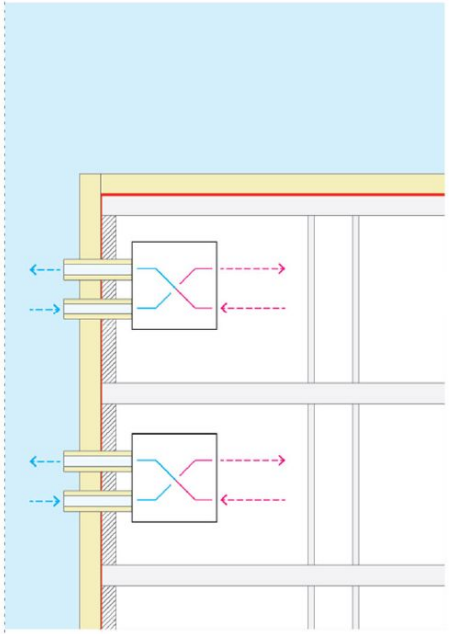
Centralized:

One main ventilator unit for the entire building



Decentralized:

Multiple ventilators distributed throughout the building



PH Ventilation Systems Considerations

The Passive House Network

- Duct insulation for intake and exhaust ducts with vapor-tight seal.
- Sound level – ventilation system must not be noisy.
  - ≤ 25 db(A): supply air to rooms
  - ≤ 30 db(A): rooms in non-residential buildings and exhaust air rooms in residential buildings
- Filtration for both supply and exhaust air.
  - MERV 13-14 to filter incoming air pollutants
  - MERV 6 to filter Extract return (only needed to protect heat exchange core)

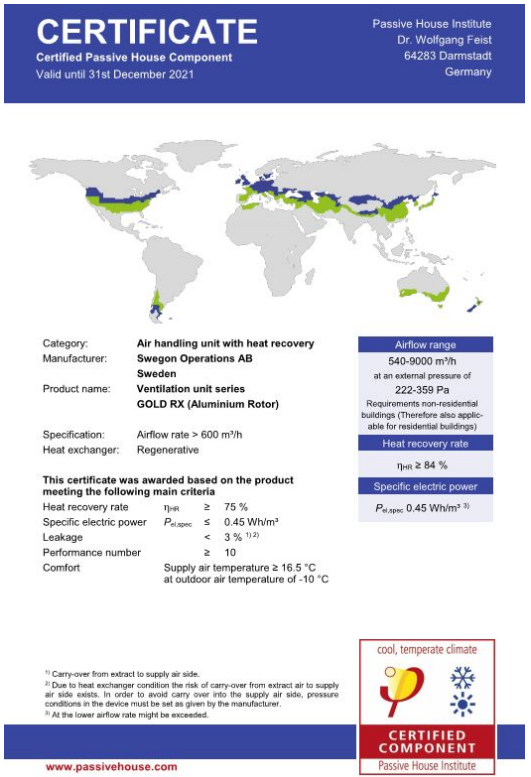
Intake and exhaust duct insulation

Merv 13 filter sample

PH Ventilation Design Criteria

The Passive House Network

- Energy recovery > 75%
- Fan power efficiency < 0.765 W/CFM.
- Supply > 62°F on winter design day.
- Supply air to all served spaces: living rooms, bedrooms, offices, classrooms etc…
- Exhaust from all services spaces: kitchens, bathrooms, utility rooms etc…
- Overall supply and exhaust must be balanced to be with within 10% of each other.



CERTIFICATE

Certified Passive House Component

Valid until 31st December 2021

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category: Air handling unit with heat recovery
Manufacturer: Swegon Operations AB, Sweden
Product name: Ventilation unit series GOLD RX (Aluminium Rotor)

Specification: Airflow rate > 600 m³/h
Heat exchanger: Regenerative

This certificate was awarded based on the product meeting the following main criteria

Heat recovery rate	η_{HR}	≥	75 %
Specific electric power	$P_{el,spec}$	≤	0.45 Wh/m³
Leakage		<	3 % [1) 2)]
Performance number		≥	10
Comfort	Supply air temperature ≥ 16.5 °C at outdoor air temperature of -10 °C		

Airflow range
540-9000 m³/h
at an external pressure of
222-359 Pa
Requirements non-residential buildings (Therefore also applicable for residential buildings)

Heat recovery rate
η_{HR} ≥ 84 %

Specific electric power
$P_{el,spec}$ 0.45 Wh/m³ [3)]

1) Carry-over from extract to supply air side.
2) Due to heat exchanger condition the risk of carry-over from extract air to supply air side exists. In order to avoid carry over into the supply air side, pressure conditions in the device must be set as given by the manufacturer.
3) At the lower airflow rate might be exceeded.

cool, temperate climate

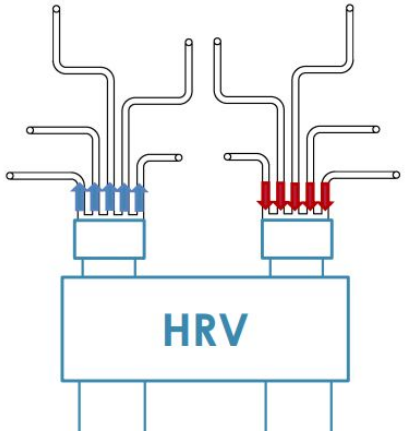
CERTIFIED COMPONENT
Passive House Institute

www.passivehouse.com

ERV/HRV – Single Unit/Small Scale

Manifold

A manifold divides up all the air at one point, and smaller individual ducts (usually all the same size) run to and from each space. One manifold for supply air, one for extract air.

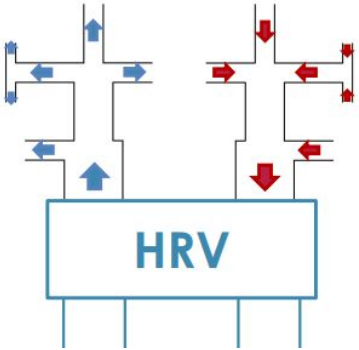


CERTIFIED COMPONENT
Passive House Institute

ERV/HRV – Large Scale

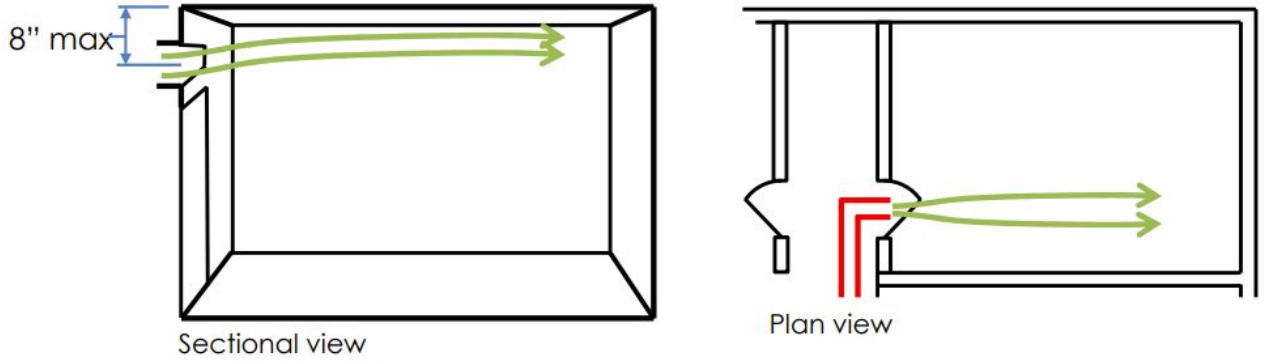
Trunk & Branch

Two large ducts leave the H/ERV, one for supply and one for extract, and along each one branches tap off for each room, and the duct gets smaller at each branch (moving away from the unit).



Coanda Effect

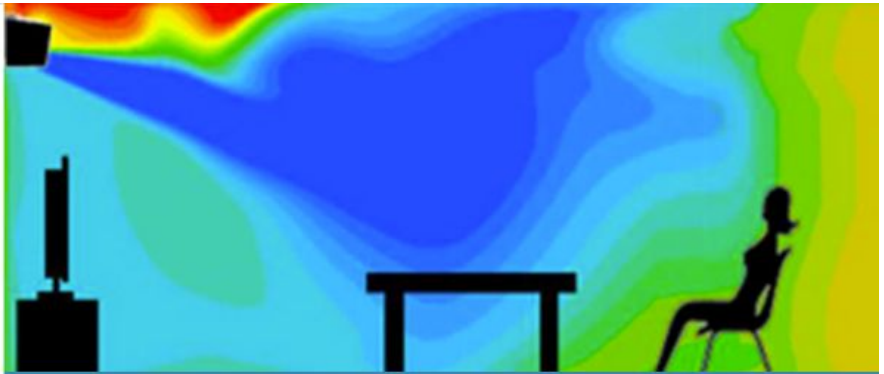
- The *Coanda Effect* (aka surface effect) is the tendency of a fluid flow to be 'attracted' to a nearby surface parallel to the direction of flow.



Use the Coanda effect to 'throw' air across room, no need to duct across room

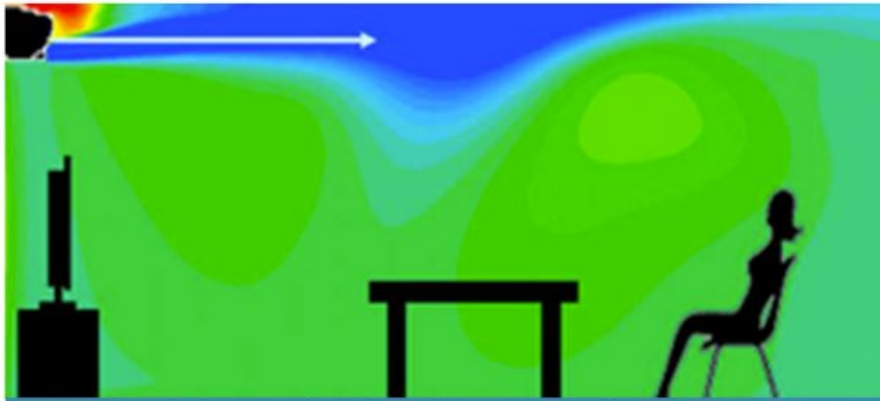
The **Coanda Effect** (aka surface effect) is the tendency of a fluid flow to be 'attracted' to a nearby surface parallel to the direction of flow.

Use High-Sidewall and the Coanda effect to 'throw' air across room, no need to duct across room (saves time and money)



High Speed = no Coanda effect. Shorter throw, lower mixing esp. in far corners

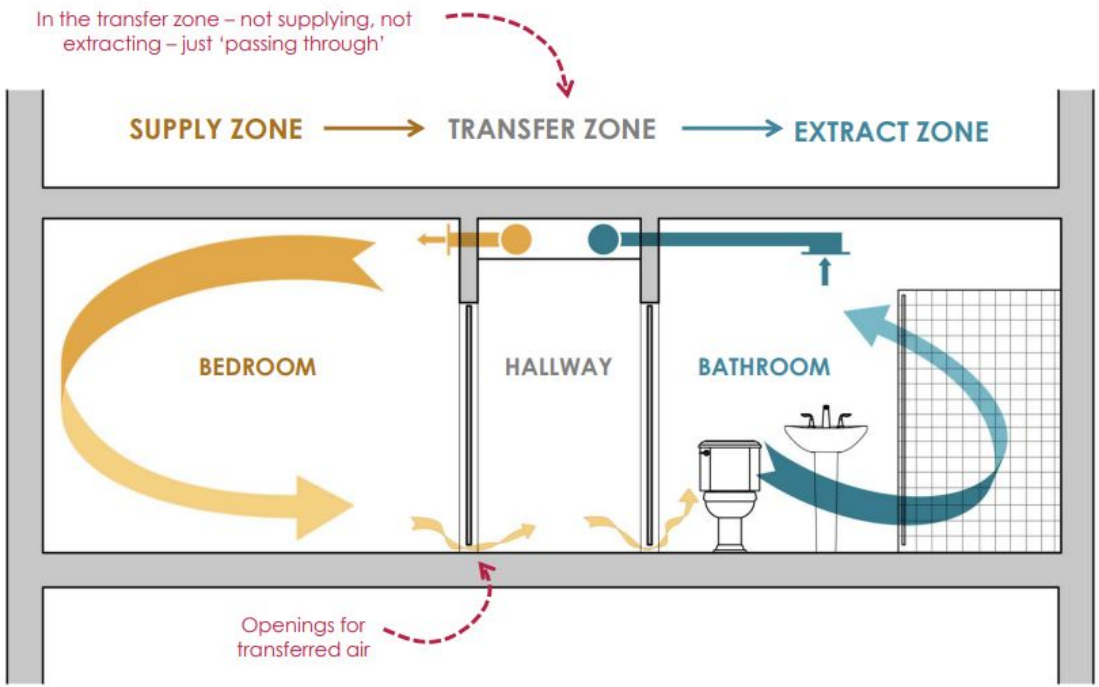
Source: Daikin



Low Speed = Coanda effect. Further throw, better mixing

Source: Daikin,

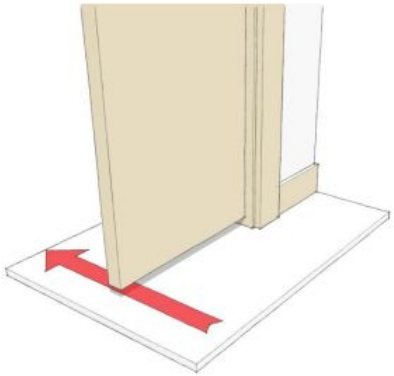
Cascade Ventilation



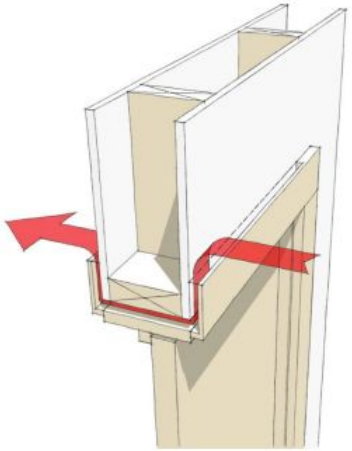
Transfer Details

For 24 cfm:

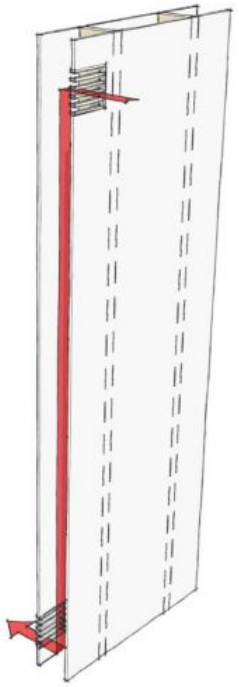
(<1 Pa pressure drop desired in all cases)



Door undercut (3/4")



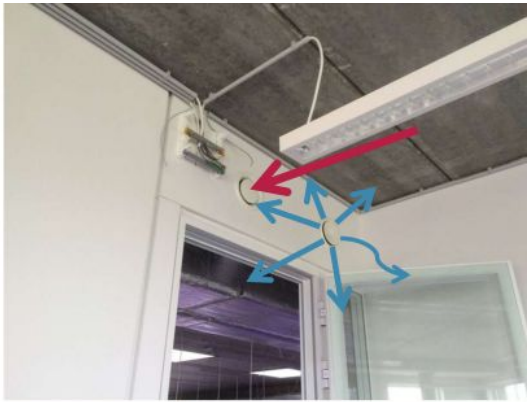
Back-vented lintel (3/4")

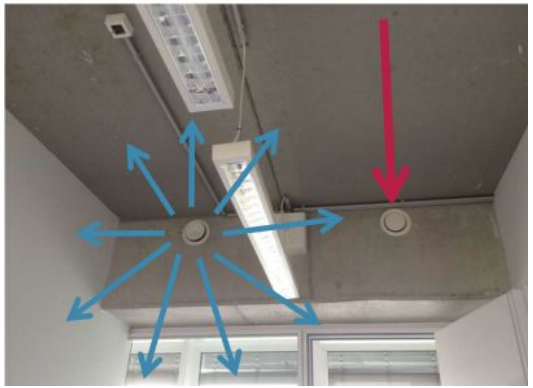


Transfer duct assemblies ($24\ in^2$)

Avoid Short Circuiting

- Ventilation strategy for this Passive House office project involves providing both supply air and extract air in the one space (normally just supply is provided)
- The two registers in the top image are very close together and might compromise whole-room air exchange rate (verify through design)
- The two registers in the lower image are sufficiently spaced to minimize short-circuiting between supply and return air paths





Avoiding Interference

- Twin registers positioned close to floor in corner of room
- Might compromise positioning of furniture in the future to avoid blocking air flow
- Often better to place at higher levels - cheaper too due to shorter ducts!

Ductwork

All ductwork must:

- Be securely mounted to structure
- Be kept clean during construction (capped)
- Avoid restrictions and complex paths whenever possible
- Follow local requirements for fire protection/separation (fire/smoke dampers, etc)

Labeling and good organization is critical, esp. with 'home-run' (manifold) systems

Sound Attenuators

Within the well-insulated and airtight enclosure of a Passive House, interior noise is more noticeable. Therefore, noise from the ventilation system must be controlled:

- Fan noise – use duct silencers at the beginning of the ductwork
- HRV vibration to the duct system – use short flex connections between the HRV and the ductwork (next page)
- "Crosstalk" noise (room-to-room transfer) – in trunk & branch systems, use duct silencers between any two rooms that are directly connected by a duct

- Sound attenuators used to reduce cross-talk through ducting
- Tubular liner typically enclosed by layer of sound absorbing mineral wool
- Should not impose undue system resistance or impede duct cleaning

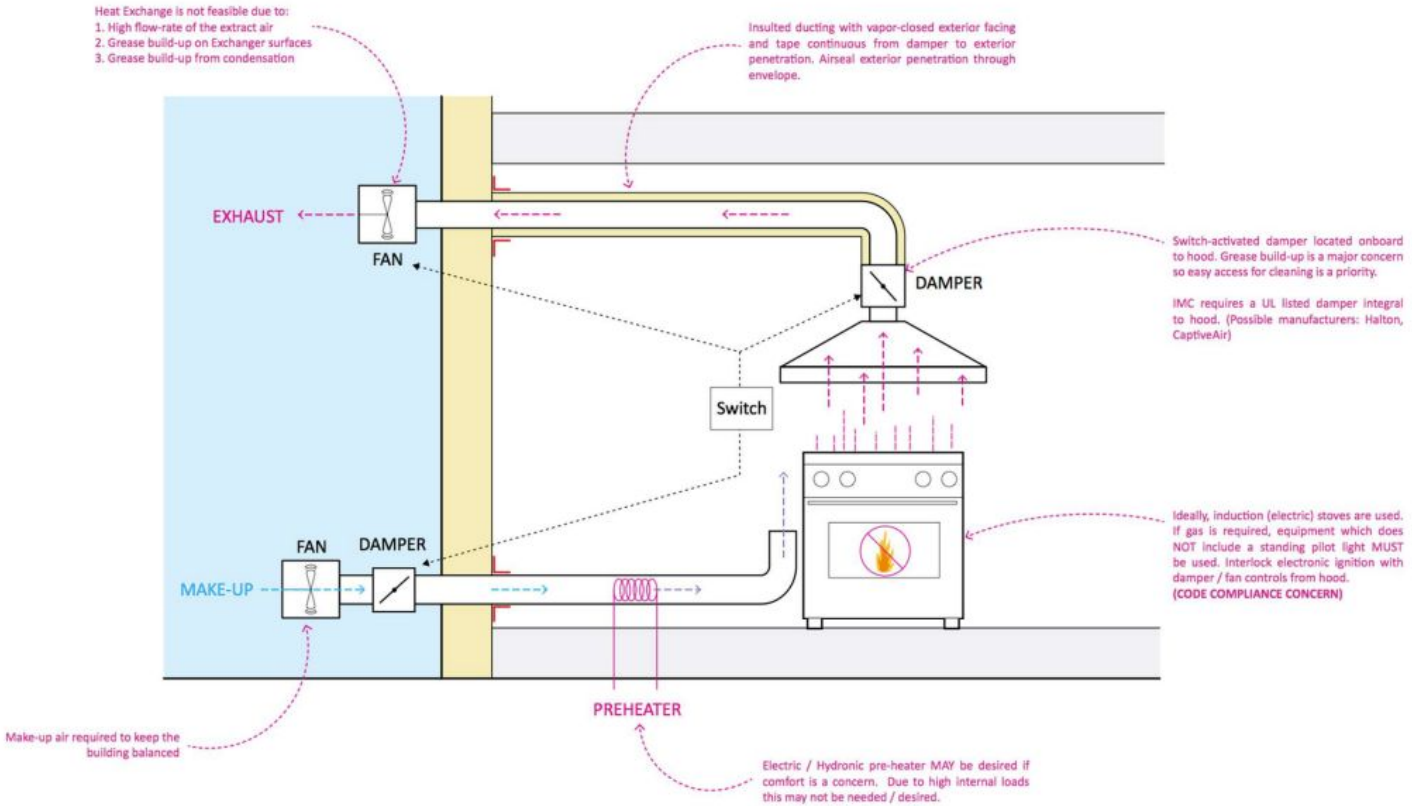
Sound Attenuators

Flexible connectors between ducts and H/ERV minimize vibration noise from H/ERV fans.

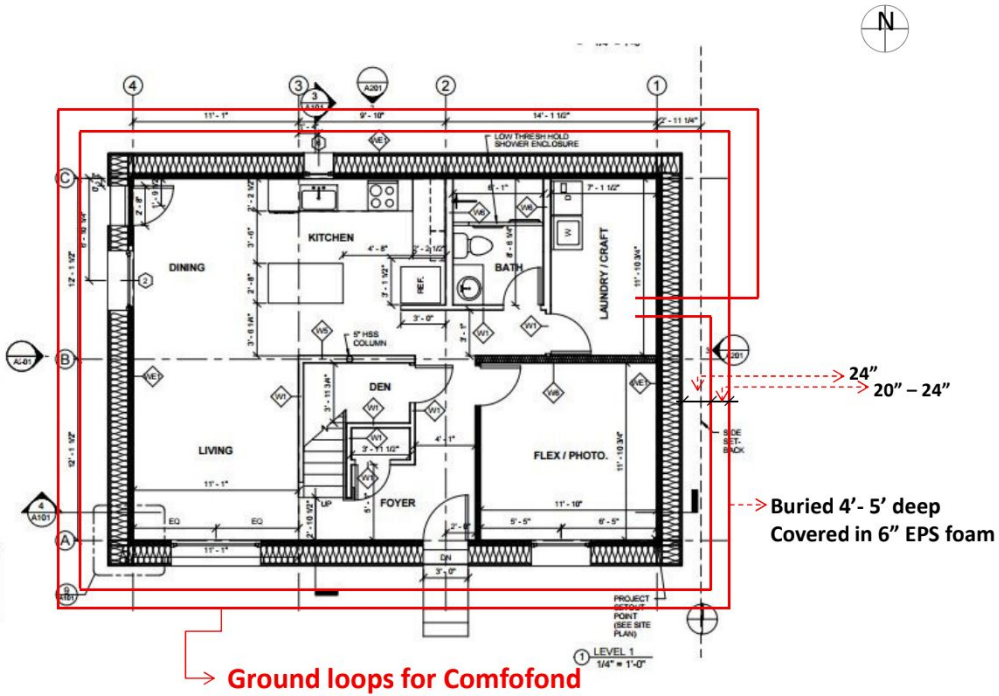
Recirculating Kitchen Venting

- Extract grille in ceiling connected to ERV and working 24/7
- Recirculating hood with charcoal filter directly above the stove
- Operable window for purge ventilation if needed

Kitchen Hood Exhaust is possible <u>but not recommended</u>



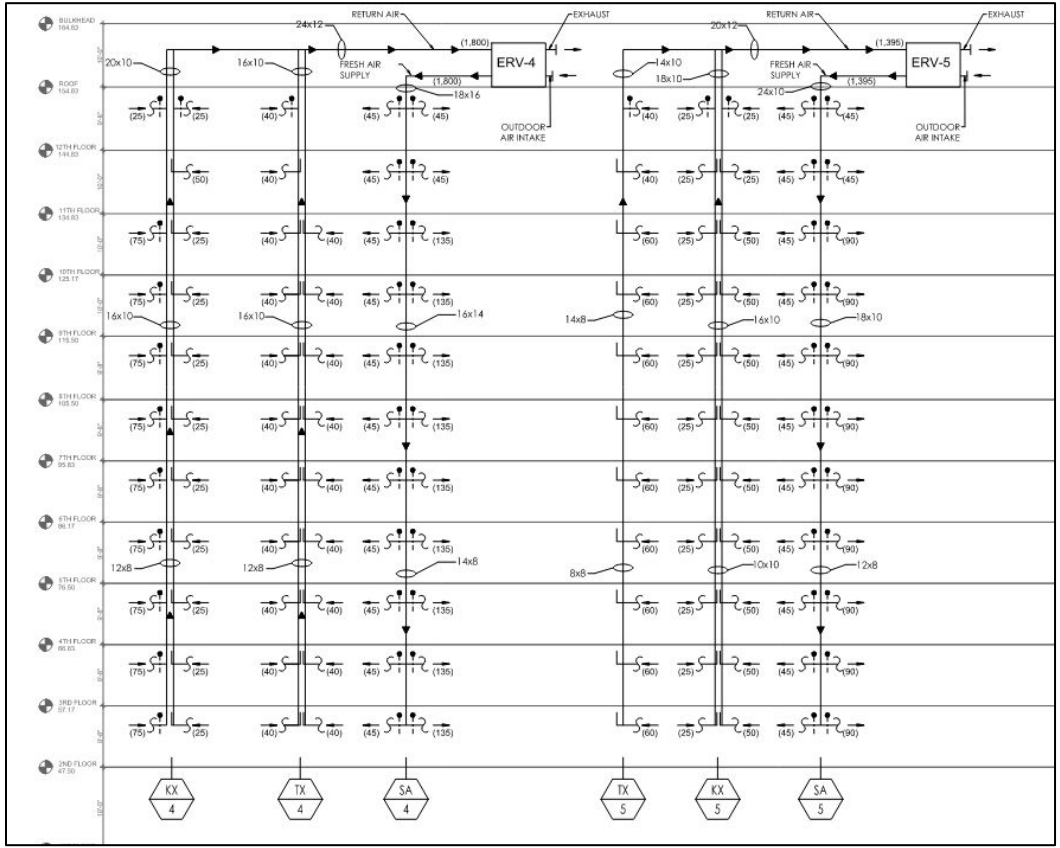
Temper Air: ground loop or electric



Zehnder ComfoAir Q with
ComfoFond-L Q

Centralized

- Layout and install in a MF project.



Duct leakage test not required but…

Testing standard needs to test volumetric leakage rates.
Recommended 2% leakage maximum

Applicable Duct Leakage testing standards:

Typical from Mechanical Engineer:
ANSI/RESNET/ICC 380 or ASTM E1554-07: Standard Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization | SMANCA HVAC Air Duct leakage Test Manual Thresholds – Class A

Passive House Institute:
Minimum requirement: ATC4 EN 16798
Large Project: ATC3 EN 16798
When SUP/ETA in same shaft or hygienic issues present: ATC2 EN 16798

Industry standard specs for sealing can result in 30%+ leakage.

https://passivehousenetwork.org/product/multifamily-ventilation-duct-leakage-targets-strategies-and-lessons-learned/

Constant Airflow Register (CAR)

CAR Dampers – Sample Spec Sheets

aldes Page 2 | CAR3

How to Specify Aldes: CAR3

Step 1: Reference the model code below and performance details within this specifications sheet to select the appropriate CAR3.

Step 2: Determine the required **PRESSURE RANGE** for the CAR3 based on the anticipated external static pressure of the system at the installed CAR3 location.
NOTE: The CAR3-L (low-pressure) is designed for systems with pressures between 0.12 and 1.2 in. w.g. (30 to 300 Pa), and CAR3-H (high-pressure) between 0.4 and 2.8 in. w.g. (100 to 700 Pa).

Step 3: Select the desired **AIRFLOW RANGE.**
NOTE: Ranges available: 4, 5, 6, 8 or 10. Each has a unique range for both low- and high-pressure variants.
See *Airflow Settings and Performance Data* for additional details. Factory calibration of the CAR3 is available on request.

Step 4: Select the **ROUND DUCT SIZE.**
NOTE: This number cannot be less than the **AIRFLOW RANGE:** i.e. an airflow range of 5 requires a duct size of 5 or 6 inches, R5 or R6 respectively.

Model Code Example

CAR3-L4-R4

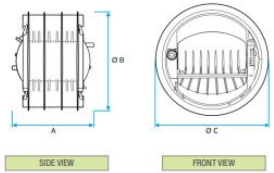
PARENT MODEL
Constant Airflow Regulator

PRESSURE RANGE
L: Low-Pressure (0.12-1.2 in. w.g.)
H: High-Pressure (0.4-2.8 in. w.g.)

AIRFLOW RANGE
Low-Pressure
4: 15-85 CFM (25-144 m³/h)
5: 35-180 CFM (59-306 m³/h)
6: 45-260 CFM (76-442 m³/h)
8: 70-385 CFM (119-655 m³/h)
10: 110-620 CFM (187-1053 m³/h)
High-Pressure
4: 30-160 CFM (51-272 m³/h)
5: 55-260 CFM (93-442 m³/h)
6: 60-370 CFM (102-629 m³/h)
8: 130-630 CFM (220-1070 m³/h)
10: 170-900 CFM (289-1529 m³/h)

ROUND DUCT SIZE
R4: 4 inch
R5: 5 inch
R6: 6 inch
R8: 8 inch
R10: 10 inch

CAR3 Dimensions

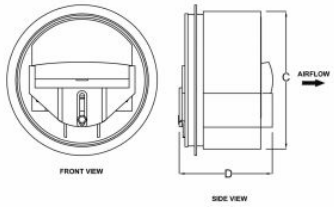


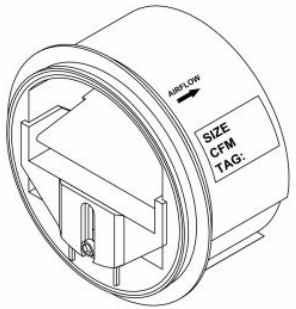
TAILLE CONDUIT	A	ØB	ØC
4" (100 mm)	3" (78 mm)	3.8" (97 mm)	4.1" (104 mm)
5" (125 mm)	3.8" (97 mm)	4.8" (121 mm)	5.2" (132 mm)
6" (150 mm)	4.6" (118 mm)	5.8" (148 mm)	6.1" (155 mm)
8" (200 mm)	6.7" (170 mm)	7.7" (196 mm)	8.2" (208 mm)
10" (250 mm)	8.3" (211 mm)	9.6" (244 mm)	10.2" (259 mm)

SUBMITTAL DATA
eFlow-Constant Airflow Regulator (CAR)

Application and Design

eFlow-CAR is factory set Constant Airflow Regulator designed to save significant amount of energy and money by precisely controlling airflow into or out of space, regardless of static pressure, and all along providing high Indoor Air Quality (IAQ). eFlow CAR is composed of fire resistant ABS plastic. It contains a self regulating aero-wing and spring piston design to maintain a factory preset air flow. These CAR's are designed to operate in pressure range Low Pressure (.08"-.4"w.c.), Standard Pressure (0.2"-1" w.c) and High Pressure (0.6"-2.4" w.c). They automatically adjust for variable duct pressures caused by building pressure, thermal stack effect, dust build up and other variable factors. This Constant Airflow Regulator creates cost effective answer to balancing air systems for HVAC and ventilation in high rise buildings, without the requirement for on-site balancing, electrical/pneumatic controls or sensors. eFlow-CAR may contribute to meeting USGBC LEED Building and Passive House Certification. eFlow CAR requires no maintenance under normal conditions.





Standard Construction

eFlow-CAR: Classified UL R38307 / UL-2043 for heat release rate and smoke optical density.

Damper (nominal)	C	D
☐ 3 (76)	3.0 (76)	2.2 (55)
☐ 4 (101.6)	3.8 (96.5)	2.8 (70)
☐ 5 (127)	4.8 (121.9)	3.4 (86)
☐ 6 (152.4)	5.8 (147.2)	3.6 (91)
☐ 8 (203.2)	7.7 (195)	3.6 (91)
☐ 10 (254)	9.6 (245)	4.7 (120)

**Size in inches(millimeters)

☐ Low Pressure Range of Operation Static Pressure	
Minimum	.08" w.c.
Maximum	0.4" w.c.

☐ Standard Pressure Range of Operation Static Pressure	
Minimum	0.2" w.c.
Maximum	1.0" w.c.

☐ High Pressure Range of Operation Static Pressure	
Minimum	0.6" w.c.
Maximum	2.4" w.c.

Job Name:
Location:
Architect:
Engineer:
Contractor:

☐ eFlow-Constant Airflow Regulator(CAR)
(Supply, Exhaust)

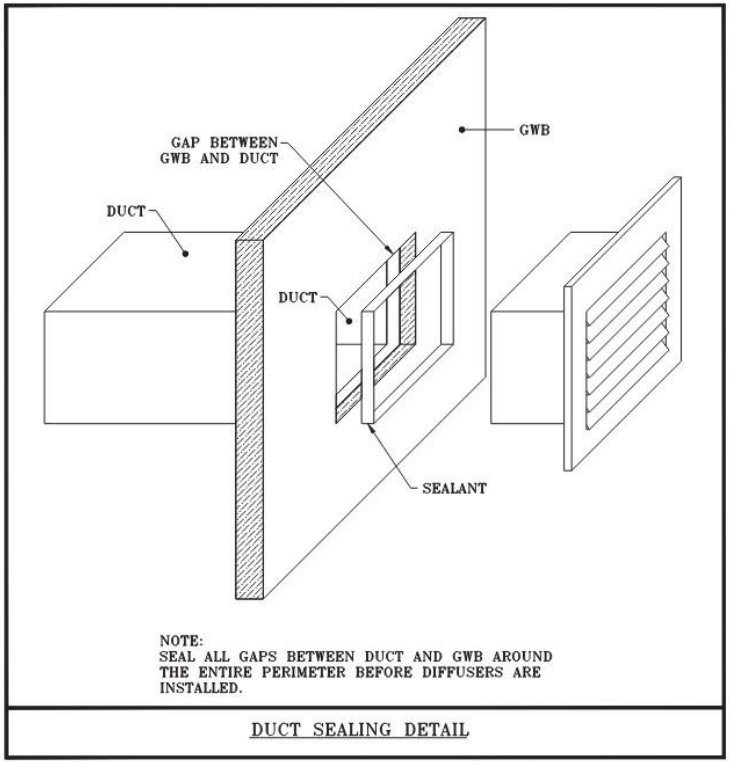
DRAWN BY:	DATE:	REV. DATE:	REV. NO.	APPROVED BY:	DWG. NO.
IL	12-08-2018	02-19-2019		EL	

eFlow USA, LLC,184 S. Livingston Avenue, STE 9107, Livingston, NJ 07039, www.eFlowUSA.net, 1-833-FLOW-USA

Avoiding Leakage

Duct-to-interior drywall sealing

- Work with the Mechanical Engineer to ensure a detail for this is included in the drawings, and ensure the construction team is aware of it and who is responsible for completing it.



Aeroseal

- Technology that seals up leaks, holes, or misalignments in ductwork
- Seals all the difficult to reach and pinhole sized leaks
- Low VOC
- Required a licensed operator and an injection plan of how they plan to break up and seal the various duct ventilation risers
- Essentially mandatory for central systems, to achieve the needed air flow rates and fan energy efficiency

System Verification Items

- Total supply and exhaust are within 10% of each other (and should be at least meeting the design flows indicated on the drawings)
- Air flow measurements at ERV units (traverse) in addition to all grille measurements
- Wattage of ERVs
- Testing, Adjusting, Balancing (TAB) company should be a certified air balancing professional

Sizing Unit

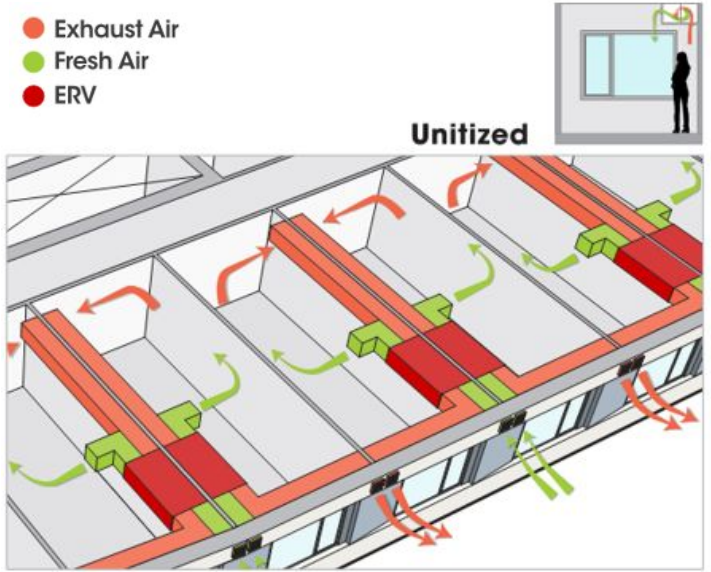
- To maximize efficiency of ERVs, they **should be sized at least 1.5-2 times the expected CFM** the unit will run at.
- This will ensure maximum heat recovery efficiency and fan efficiency.
- This will also ensure that there is extra capacity in the system, to overcome extra flow that may be needed to overcome duct leakage
- PH Consultant and Mechanical engineer to review during system selections

	Width in	Height in	Length in	Weight lb	Min air flow CFM	Max air flow CFM
GOLD RX 05	32.5	40.25	61.25	515-612	170	1377
GOLD RX 07	39.25	46.75	65.75	619-782	170	1589
GOLD RX 08	39.25	46.75	65.75	650-799	424	2119
GOLD RX 11	47.25	55	75.25	940-1160	424	2331
GOLD RX 12	47.25	55	75.25	990-1219	424	2966
GOLD RX 14	55.25	65	84	1259-1642	424	3496
GOLD RX 20	55.25	65	84	1259-1642	636	4450

Decentralized / Unitized

Unitized

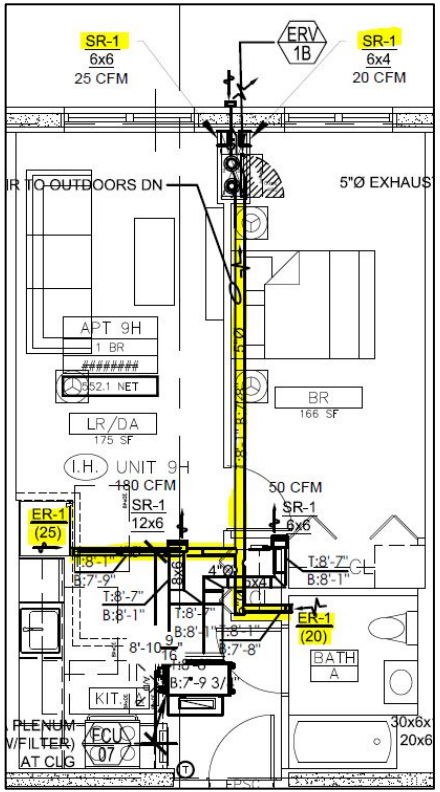
- Typically, the ERV unit is located in a small closet near the exterior wall.
    - Reality – often times the closet is very small and cramped, making duct runs difficult and servicing the unit hard (access door sizes vs ERV size)
- If located near the corridor wall, long duct runs between ERV and exterior can have big implications in PH model. Minimize as much as possible, and account for in the energy model accordingly early so the impact is known before too far long in design.



- System examples of individual sysetms (more commonly seen in smaller projects like single family homes)

Individual (unitized)

- Detailed layout and install in a MF project.



Inspections & Commissioning

Checklist Inspections

6. Mechanical Ventilation

6.1 The installed ventilation units(s) match the specifications in the Project Documents (incl. manufacturer, model, heat/energy recovery, location, duct dimensions and user controls).

6.2 The register/valve locations, transfer areas, dampers, make-up air systems where required (e.g. for kitchens/dryers) are consistent with the Project Documents.

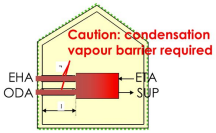
6.3 Ducts connecting the ventilation unit with the thermal envelope are dimensioned and insulated in accordance with the Project Documents.

6.4 Sound attenuation devices (where specified by the designer) have been installed as per the Project Documents. No obvious aural discomfort issue for occupants has been observed.

6.5 H/ERV condensate drain is present, operational and designed to prevent gases entering from drains or sewers

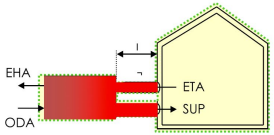
6.6 Ducts, registers, filters and the ventilation unit appear to be free from dust and debris.

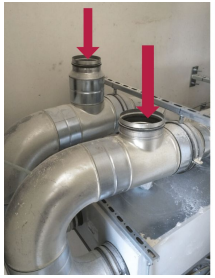
Courtesy of Peel Passive House



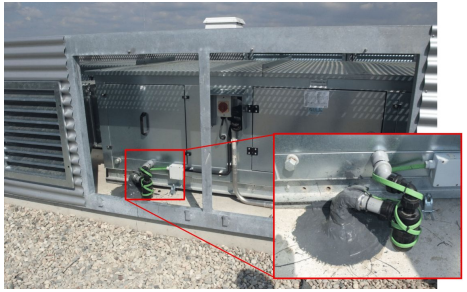
1. Ventilation unit inside thermal envelope:
2-4" vapor-tight insulation required, keep ducts as short as possible – so locate the H/ERV near the enclosure!

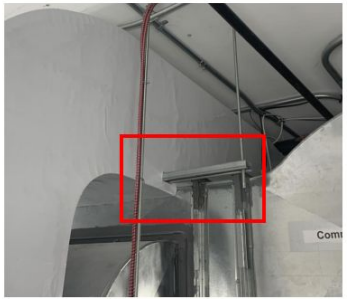
2. Ventilation unit outside thermal envelope:
2-4" insulation so no heat is lost between the building and the H/ERV. In a semi-conditioned basement 1-2" insulation on EHA and ODA may be prudent.





- Do not leave duct ends open during construction
- Especially critical where ducts face upwards!
- Difficult to clean afterwards and will clog up new filters when system is commissioned





Ventilation Commissioning Report

Commissioning report

Back to compact version: ►3.2.6

Criteria

- **HRV commissioning report** including **at least** the following information:
  - description of the property
  - location/address of the building
  - name and address as well as signature of the tester
  - time of flow rate adjustment
  - manufacturer of the ventilation system and type of device
  - adjusted volume flow rates for typical volume flow in operation
  - mass flow/volumetric flow balance for outdoor air and exhaust air (maximum imbalance of 10 % for each device, see 3.2.6.5.i)
  - measuring device / method (see 3.2.6.g).

A report must be provided regarding the adjustment of all supply and extract air valves. If for technical reasons this is not possible for individual large ventilation units (> 353 cfm), then at least the volume flow rates in the ventilation unit (outdoor air/exhaust air) and in the main ducts of the ventilation system must be measured. See also: Commissioning of single-room ventilation units. Recommended template: "Final Protocol Worksheet for Ventilation Systems": "Initial start-up", source PHPP Download Package.

© Acin

Zero pressure compensating flow measuring instruments are the most accurate

Vane anemometers typically allow measurement of volumetric flow rate, air flow speed and temperature

Training for commissioning agents is vital for accurate results

Commissioning Checklist	x
Ensure flow rates are commissioned to the standard flow rate as modelled in the PHPP. *Note: this may not always be aligned with the flow rates on the mech drawings as the drawings may be showing the max/design flow rates.*	
Traverse measurement should be taken at the ventilation unit to measure the total outdoor and exhaust air flow rates *Note to CPHC: this total flow is what needs to be carried in the PHPP rather than just the sum of the outlets.* ***These flow rates need to be balanced to within 10% of each other.***	
Photos of the display screen of the ventilation unit should be taken showing the total flow rates *Note: this should be aligned with the traverse reading.*	
If the supply air is passing through in room fan coils then the commissioning agent should be aware of how the fan coil fans have been modelled in the PHPP *Note: if the fan coils have been modelled as running 24/7 in the PHPP at a "low" flow rate then this is how the system would need to be commissioned. The same would be the case if the fan coil fan are not modelled as running outside of heating/cooling season then they should not be running during commissioning.*	
Review that the pressure drop calculations have been carried out and the total pressure drop in the system is not above the certified range stated on the PHI certificate	
Note to CPHC: Take photos of the installed filters	
If there is a damper at the suite connection that can read the total flow rate to the apartment and the supply air is passing through "always active" fan coils then the total apartment flow rate can be carried in the report. The induvial supply outlets still need to be measured, however as the total flow rates at the outlets will be a sum of the recirculation and supply air we just need to confirm the total flow to the room is at least the planned standard supply rate.	
Provide evidence of the programming schedule i.e. if there are non-res areas in the building where the ventilation unit is turned off or set back then evidence of this should be provided	
A **digital** report with the measured flow rates at both the outlets and the ventilation unit needs to be provided. A hand written report is not acceptable.	

Courtesy of Peel Passive House

Ventilation Report

FINAL PROTOCOL WORKSHEET for Ventilation Systems: Initial Start-up
Supply- / Extract-Air Ventilation System with Heat Recovery

Project	
Object:	End-terrace house
Location Street, No.:	Passive street 123
Location Postcode, Town	12345 Passive City
Building Owner Name:	John Doe
Building Owner Phone No.:	0
Year of Construction	2017

Initial Start-up	
Company:	Passive House Ventilation
Person in Charge:	John Smith
Street, No.:	Passive street 12
Postcode, City:	12345 Passive City
Phone No.:	00000
Date:	07 / 01 / 2017

Ventilation System	
Manufacturer:	Passive House Ventilation
Product Name:	Passive House unit
Unit No.:	00000
Control No.:	00000

1. Record of the air flow volumes, supply and extract air

Nr.	Room	Design			Measurement 1		Measurment 2		Measurment 3		Type of Valve	Adjustment	Flow-Through	Noise	Filter Grade	Filter Clean?
		V_{SU}	V_{EX}	$V_{THROUGH}$	V_{SU}	V_{EX}	V_{SU}	V_{EX}	V_{SU}	V_{EX}			$V_{STHROUGH}$			
		m³/h	m³/h	m³/h	m³/h	m³/h	m³/h	m³/h	m³/h	m³/h			m/s	dB(A)		
1	Hobby room	35			45.1		30		37		Jet nozzle		0.6	20	F7	yes
2	Storage room		20			36		26		21	Poppet Exhaust Air		0.8	22	G4	yes
3	Technical space		20			41.2		18		20.3	Poppet Exhaust Air		0.7	22	G4	yes
4	Office	20			31.6		19.6		19.6		Jet nozzle		0.6	20	F7	yes
5	Living / kitchen	60	60		62.4	45.2	57.4	65.3	59.5	61.2	Jet nozzle/poppet exhaust air		1.0	20	F7/G4	yes
6	Master bathroom		40			12.7		34.2		41	Poppet Exhaust Air		0.6	22	G4	yes
7	Bedroom 2	20			21.9		26		20.7		Jet nozzle		0.6	20	F7	yes
8	Bedroom 3	20			28		26.9		19.1		Jet nozzle		0.6	20	F7	yes
9	Master bedroom	25			20.6		26.1		26.1		Jet nozzle		0.7	20	F7	yes
10	Bathroom		20			40.1		22.1		19.9	Poppet Exhaust Air		0.6	22	G4	yes
11	WC		20			43.6		23		19.6	Poppet Exhaust Air		0.7	22	G4	yes
12																yes / no
13																yes / no
14																yes / no
15																yes / no
	sum:	180.00	180.00	---	209.60	218.80	186.00	188.60	182.00	183.00			---	---	---	---

2. Balance of airflow volume

		Measurement 1			Measurement 2		Measurement 3		Disbalance	Type of Control	Adjustment	Noise	Filter Grade	Filter Clean?
					V_{AUL}	V_{FOL}	V_{AUL}	V_{FOL}	V_{AUL}	V_{FOL}				Measurement		
					m³/h	m³/h	m³/h	m³/h	m³/h	m³/h				dB(A)		
1	fresh air inlet				210	---	186	---	182	---	1#	BUS		30	F7	yes
2	exhaust air outlet				---	219	---	189	---	183		BUS		30	G4	yes

3. Initial start-up accomplished according to manufacturer's specifications: yes

Signature: Signature

Sample documents for building certification © Passive House Institute 2023
Find out more at: www.passipedia.org/certification/certified_passive_houses/example_documents

Ventilation Units & Accessories

Manufacturer/Supplier	Specialty	Offers PHI Certified Components	HQ Location	Link
Acin	air flow meter		Netherlands	https://acin.nl/en/
Aldes	constant airflow regulator	Yes	Quebec / FL	https://www.aldes-na.com/
Brink		Yes	Netherlands / NY	https://475.supply/collections/brink
Ephoca			Italy	https://ephoca.com/
IceAir			New York	https://www.ice-air.com/
Lunos			Germany / NY	https://475.supply/collections/lunos
Minotair Ventilation Inc.			Quebec	https://www.minotair.com/home_us/
Oxygen 8		Yes	British Columbia	https://oxygen8.ca/
Swegon		Yes	Sweden / Ontario	https://www.swegon.com/na/
Ventacity		Yes	Oregon	https://www.ventacity.com/
Zehnder		Yes	Netherlands / ME	https://zehnderamerica.com/

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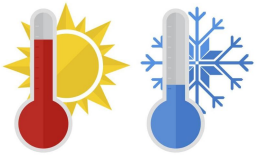
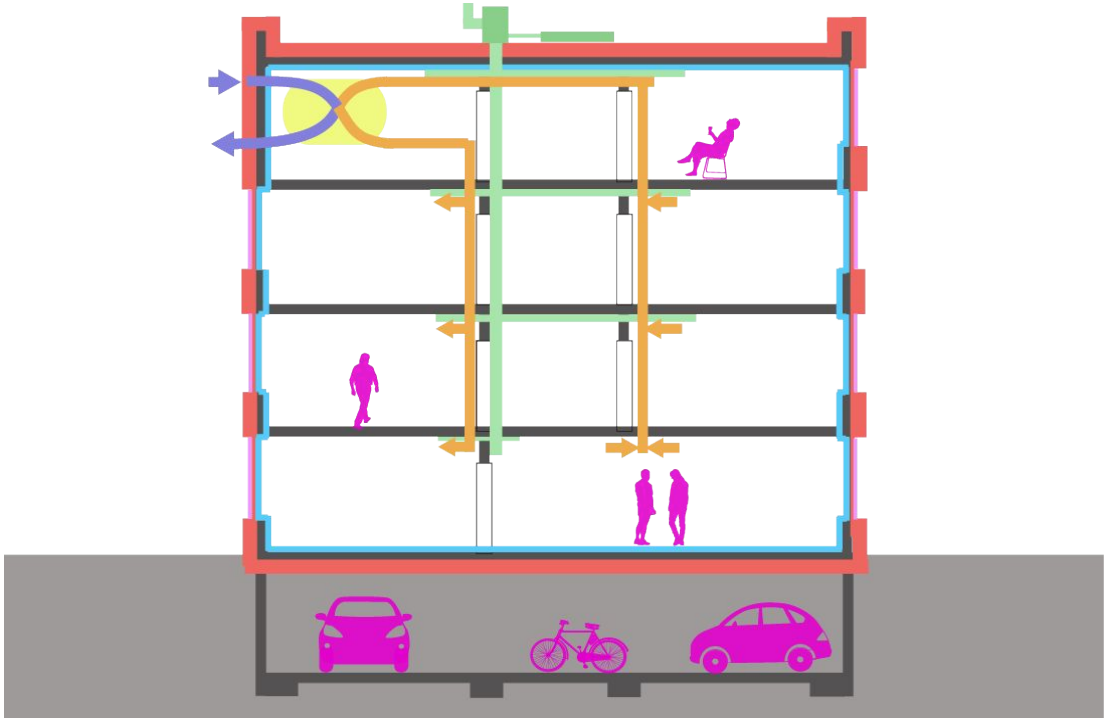
Right Size Heating & Cooling Systems

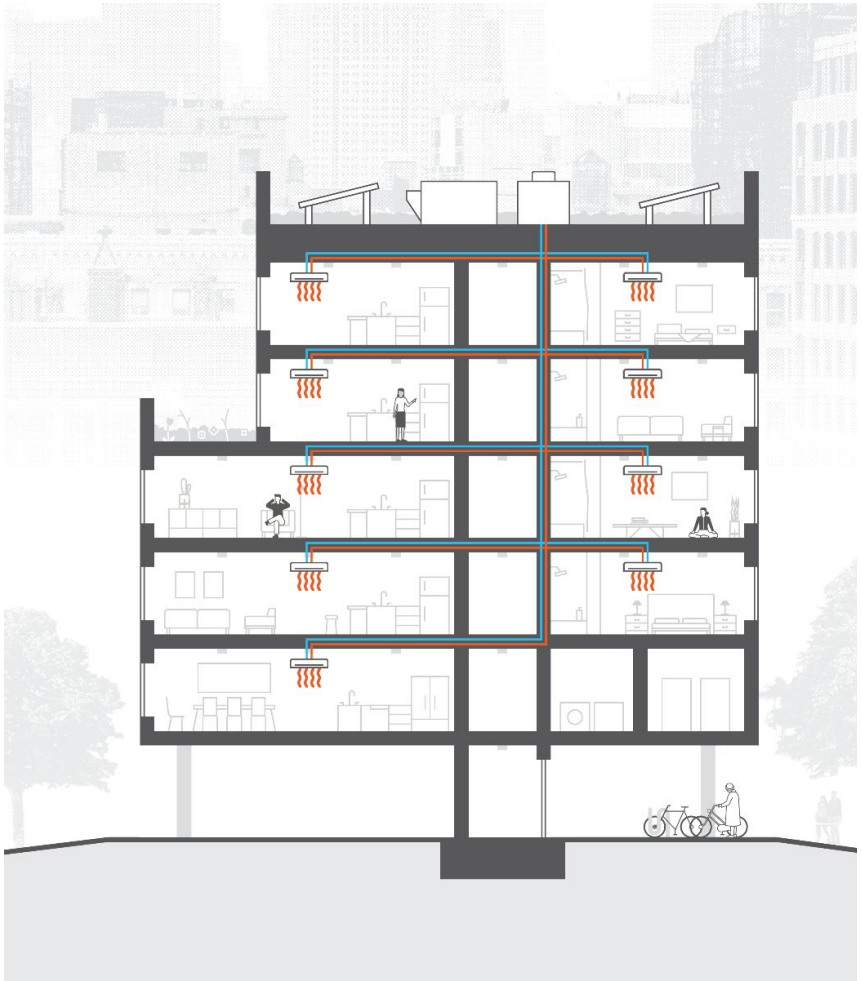
- Often up to 75% reduction in equip sizing.
- Practically any kind of heating and cooling system can be used in a Passive House.
- Critical is efficient design with relatively compact distribution and right sizing of equipment.
- Typically heat pump technology capable of providing heating and cooling.
- Typically runs separately from, and independently of, ventilation air.





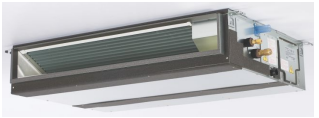
Heating & Cooling Systems

- Current PH projects primarily utilize heat pump technology.
- Heat pump technology types include:
  - **Air source**: takes heat from (and rejects heat to) the outside air and pushes it to the inside. Moves heat in/out of a building.
  - **Ground source**: takes heat from (and rejects heat to) the ground via a water loop. Moves heat in/out of a building.
  - **Water source**: terminal units take heat from (and rejects heat to) a water loop in the building. Moves heat around a building.



Air Source Heat Pumps

- Mini-Split
  - Split and mini (<1.5 tons or so)
  - Ducted (compact) or ductless
  - Usually 1:1
- Multi-Split (multi-port, multi-zone)
  - One outdoor unit, 2+ indoor units
  - Ducted, ductless, or mix
  - 1.5 to 4 tons typically
- VRF (variable refrigerant flow)
  - Numerous modular outdoor units, 6-12 tons typical
  - Many indoor units, many types

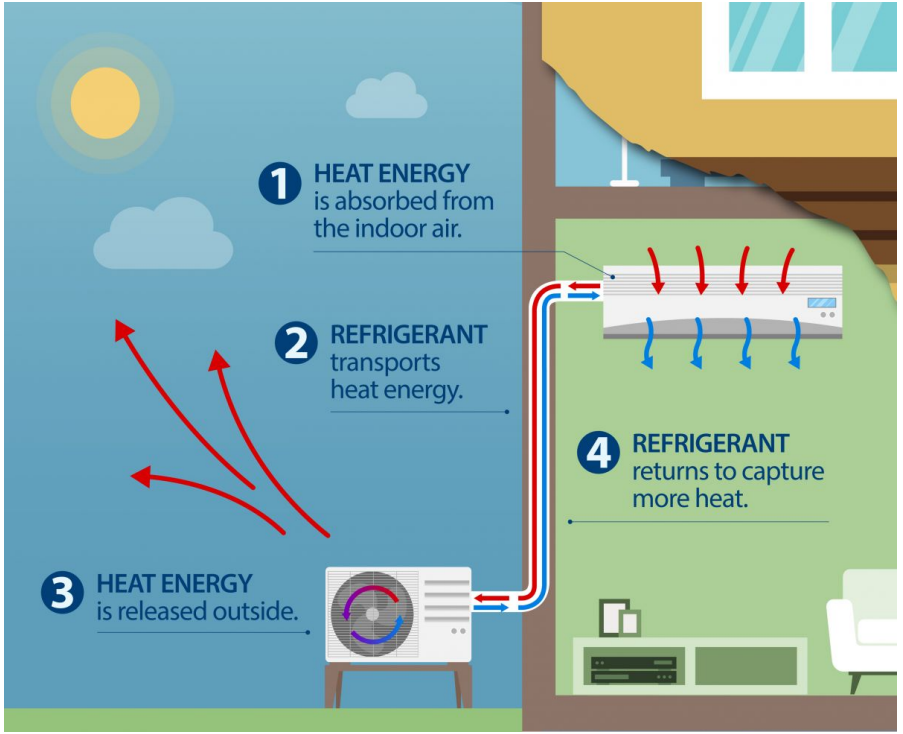


Heat Pump Comparisons

Packaged Terminal Heat Pumps (Cold Climate)	Mini-Split Heat Pumps (Cold Climate)	Multi-Split Heat Pumps (Cold Climate)	Variable Refrigerant Flow (VRF)	Ground Source Heat Pumps (GSHPs)
				
Through-wall unit provides efficient heating + cooling to a single room. Current brands include Ice-Air and Innova/Ephoca	Small outdoor compressor provide efficient heating + cooling to fan coil units in a single apartment. Easy to install	Small outdoor compressor provide efficient heating + cooling to fan coil units in a multiple zones.	Large rooftop compressors provide efficient heating + cooling to fan coil units in multiple apartments. May include heat recovery which increases efficiency.	Geothermal wells transfer thermal energy to provide efficient heating + cooling to fan coil units in multiple apartments.

Air Source

- Heat is harvested from air and pushed into air.
- Electric compressors and valves move refrigerant from one place to another.
- An air-source heat pump can deliver one-and-a-half to three times* more heat energy to a home than the electrical energy it consumes (energy.gov).
- Heat pump moves heat rather than converting it from a fuel like combustion heating systems do.



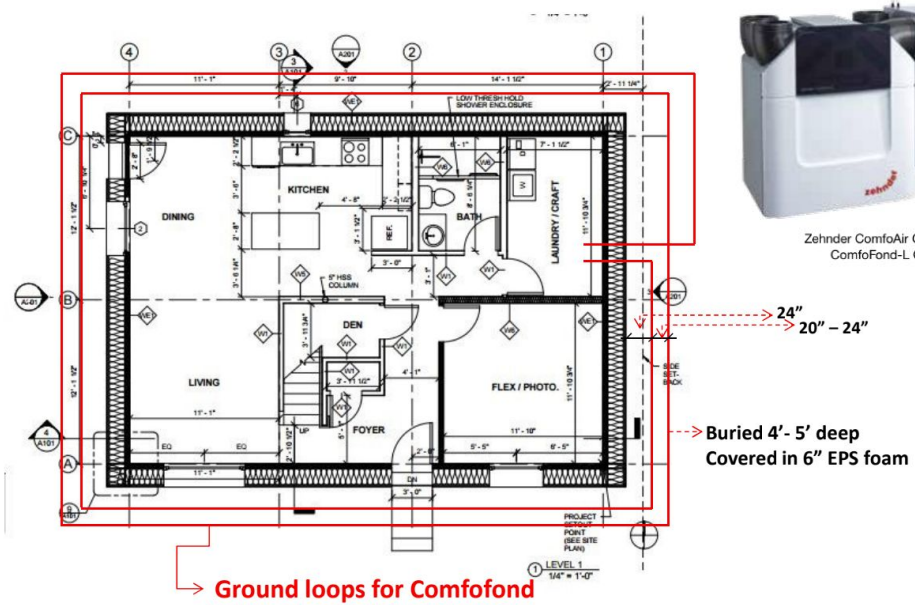
Single Family: Heating, Cooling & Dehumidification

Much smaller load and great flexibility in locating distribution outlets: surface mounted, recessed, ducted.

Smaller Multifamily

- Small outdoor unit combined with a single indoor unit
- Sometimes referred to as “one to one” systems
- May be a solution for very small projects, or smaller retrofits (< 7 stories)
- Not common on mid to larger size multifamily projects
- Refrigerant leak risk - medium

Temper Air: ground loop or electric



Zehnder ComfoAir Q with ComfoFond-L Q

Category: **Air handling unit with heat recovery**
Manufacturer: **Zehnder Group Zwolle B.V. Netherlands**
Product name: **ComfoAir Q350 HRV, Comfort Vent Q350 HRV**

Specification: Airflow rate < 600 m³/h
Heat exchanger: Recuperative

This certificate was awarded based on the product meeting the following main criteria

Heat recovery rate	η_{HR}	≥ 75 %
Specific electric power	$P_{el,spec}$	≤ 0.45 Wh/m³
Leakage		< 3 %
Comfort	Supply air temperature ≥ 16.5 °C at outdoor air temperature of –10 °C	

Airflow range
70–270 m³/h
Heat recovery rate
η_{HR} = 90 % [1]
Specific electric power
$P_{el,spec}$ = 0.24 Wh/m³

[1] At an airflow of 138 m³/h, a heat recovery of η_{HR} = 91 % is reached. Due to the frost protection strategy at outdoor temperatures of -15 °C the air flow rate is reduced to about 200 m³/h.

cool, temperate climate

CERTIFIED COMPONENT
Passive House Institute

www.passivehouse.com

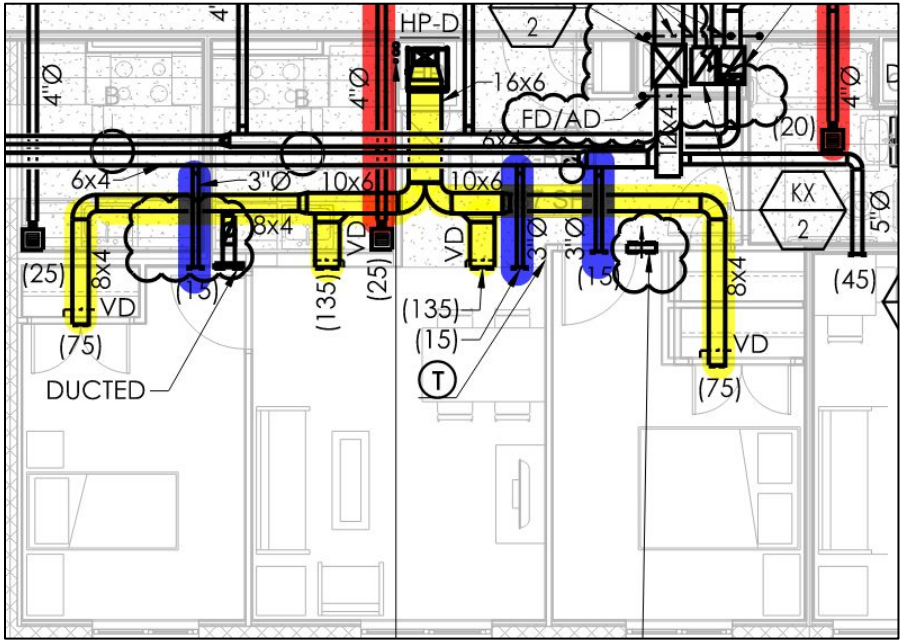
HRV built-in pre-heater unit

Ceiling access doors to ComfoWell and activated carbon housing

Localized heat sources (bathroom in-floor heat)

Keep Ventilation Separate from Cooling

- If ducted, must keep ventilation duct work completely separate from heating / cooling system ductwork.
    - Very difficult to properly balance air flows.
    - Increased fan energy penalty from air handler running 24/7
    - More wear and tear on equipment



Exhaust air: kitchens and baths (red)
Supply air: living room and bedrooms (blue)
Heating/cooling (yellow)

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Hot Water

- DHW has historically been the harder system to electrify, however more options are now available on the market.
- Usage of hot water remains consistently higher among people in the US (e.g. we use a lot more than Europe)
- Key design considerations for systems include:
    - Minimizing piping run lengths throughout a building
    - Pipe insulation
    - Location and quantity of storage tanks needed

DHW and Energy Use

- **Reducing the use of hot water** is largely dependent on occupants, but an efficient water heater and distribution system can still make a big difference on the total energy used by **reducing unnecessary losses**.

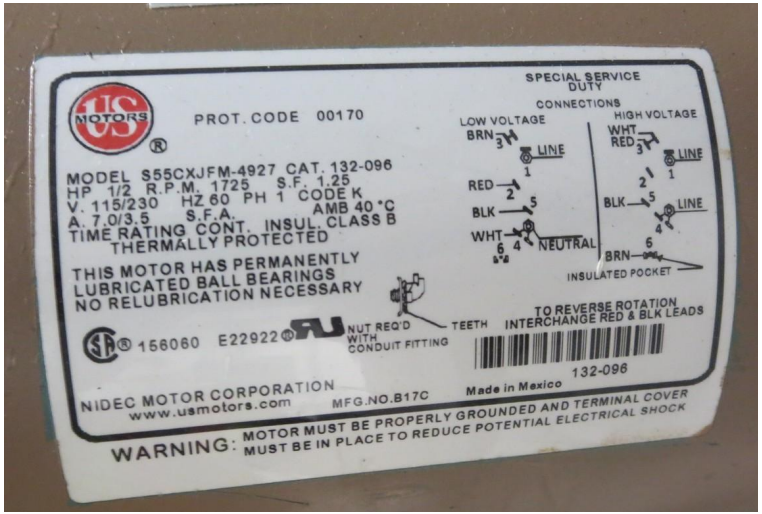
- **Overall strategy:**
  - Minimize demand using low-flow devices
  - Use small-diameter pipes
  - Minimize losses through insulation
  - Optional - use heat recovery from wastewater
  - Optional - generate hot water on-site from solar collector

DHW Pipe Insulation

- Insulation thicknesses to align with PHPP assumptions and local energy code requirements.
- Insulation to be continuous at all hanger locations.
- Runout piping to be fully insulated to the greatest extent possible.

DHW – Recirculation Pumps

- Ensure DHW pump sizes align with PHPP assumptions.
- Some systems may utilize a demand recirculation system that turns off the recirc pump during periods of low DHW use.



Single Family: Domestic Hot Water

Much smaller load and great flexibility in locating distribution outlets: surface mounted, recessed, ducted.

Considerations:

- Heat pump inside is loud.
- If heat exchange is not ducted, will likely cause thermal discomfort.

Packaged unit with heat pump on top of tank & ducted to exterior.

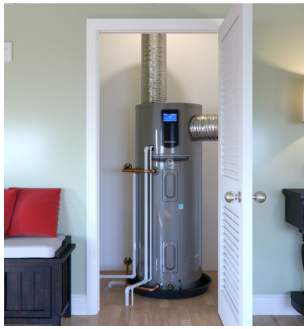
Split unit with heat pump outside similar to AC.

2025 Mandatory Requirements: Hot Water

~~Deleted~~, Added, Existing, Modified

- Heat Pump Water Heaters (HPWH)
  - **mandatory in Prescriptive**
  - Extensive definitions
    - Integrated vs split-refrigerant vs split hydronic
  - Installation requirements
    - Ducted (R-6 insulation)
    - Non-ducted unit space volume
    - Filter access
    - Backup heat source (integrated elec element)
  - Gas instantaneous no longer allowed
  - For <500SF elec point of use (instantaneous or tank) allowable.
  - Controls

- If gas hot water heater installed (Performance)
  - HWHP ready - space and circuits



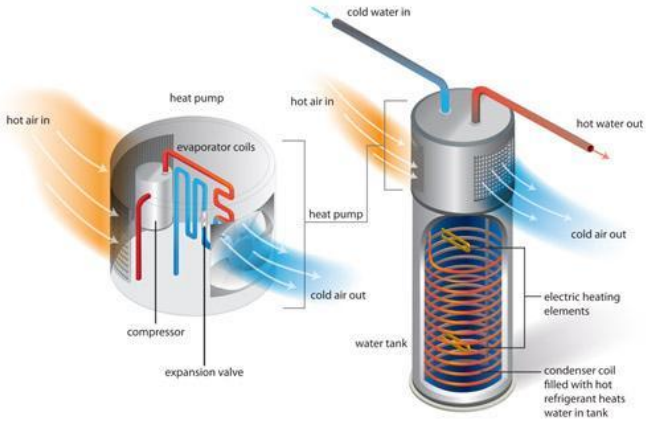
Integrated and Ducted

Integrated/Not Ducted

Split Hydronic

Decentralized Hot Water

- Common options include
  - Conventional storage water heaters (gas, electric)
  - Tankless or on-demand water heaters (gas, electric)
  - Solar water heaters
  - Tankless coil / indirect water heaters
  - Heat pump water heaters



Combined Heat Pump System

Source: Energy Star, SANCO2

Split Heat Pump System

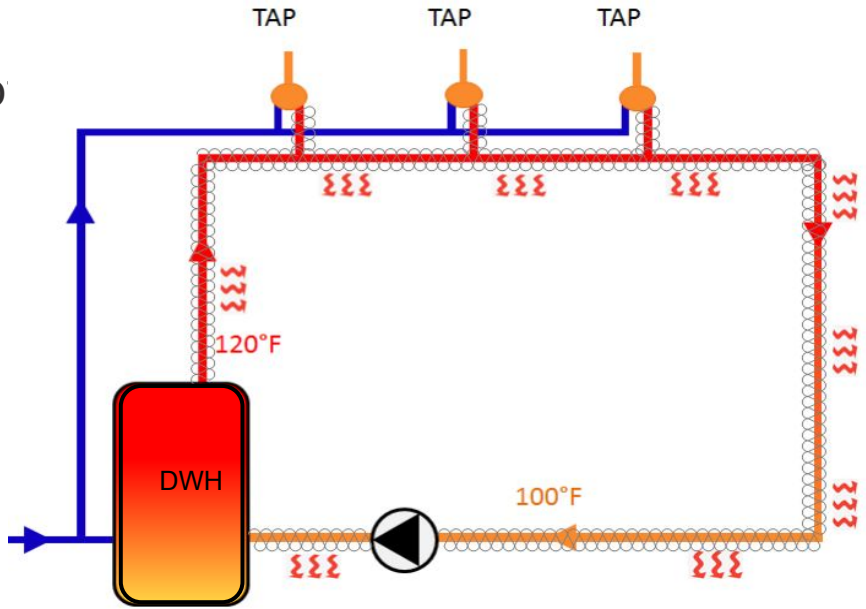
Centralized

DHW & Plumbing

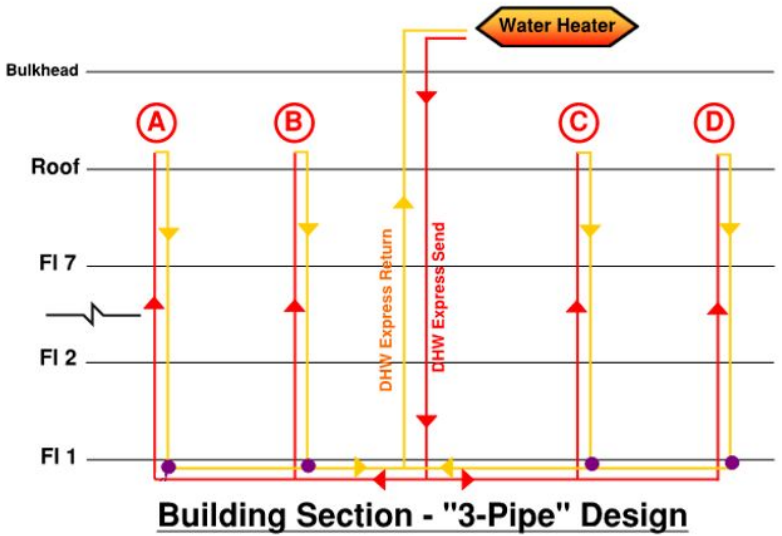
- Similar to other projects, at the time of construction, there weren’t sufficient equipment options available for electrified DHW production
- Gas fire domestic hot water heaters
- Box design for DHW piping layout
- Pipe insulation meeting energy code levels
- Low flow and water sense water fixtures

Centralized with Recirculation

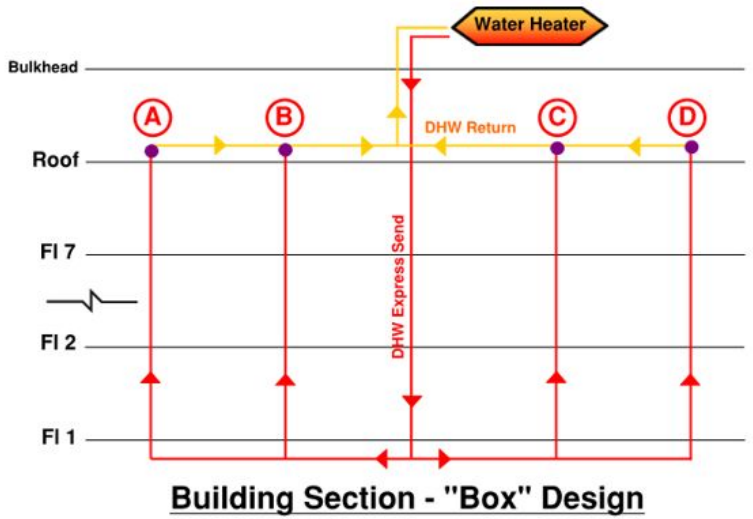
- Central systems are installed with recirculation which circulates the ho water around the building 24/7.
- Pipe insulation helps, but there is more we can do in terms of system piping layout.



Minimize Pipe Runs in Design & Installation



Building Section - "3-Pipe" Design



Building Section - "Box" Design

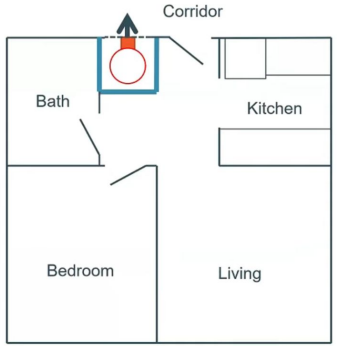
Multifamily
Decentralized / Unitized

Multifamily Domestic Hot Water: Decentralized

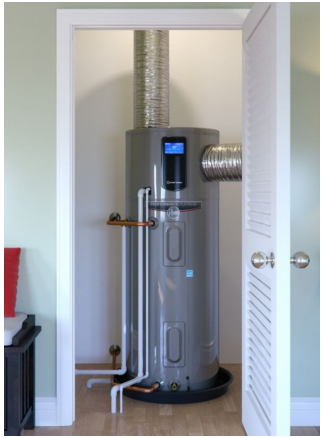
Efficient piping runs.

Individual Hot Water Heat Pumps.

Duct to, and access from the corridor, for best performance.



Credit: Steven Winter Associates

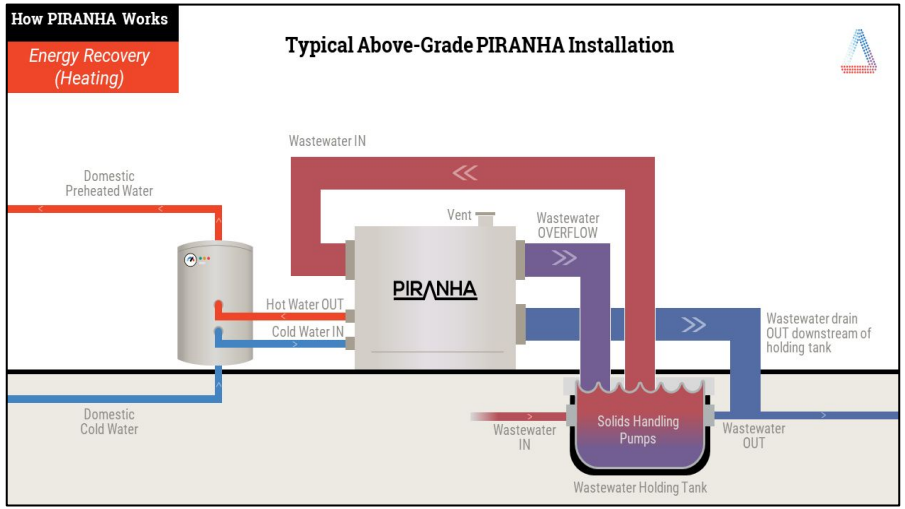


DHW – Air Source

- Source
  - **Air source**
  - Water source
  - Ground source
- Technology
  - **Cold climate**
  - **Split** vs integral
  - **High** vs mid temperature
  - **Central** vs decentral
- Deployment
  - **Full** vs part load
  - **Multifamily** vs single family
  - **New construction** vs retrofit

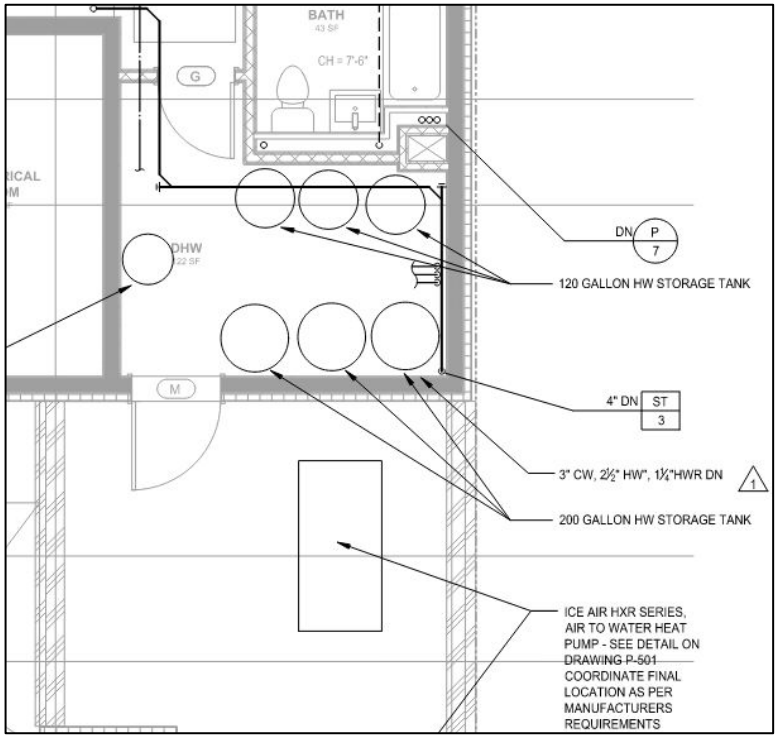
DHW – Wastewater Heat Recovery

- Wastewater energy
  - heat pump systems such as PIRANHA by SHARC
  - ThermoDrain



MF Heat Pump Hot Water - Other Considerations

- Most DHW plants are located at roof level
- Heat pump DHW doesn't make the hot water very fast, so lots of storage tanks are needed
- Need more space than previous, to hold these DHW storage tanks
- Extra weight of the storage tanks



HEATING, COOLING & HOT WATER

Manufacturer/Supplier	Specialty	Offers PHI Certified Components	HQ Location	Link
Colmac Waterheat			Washington	https://colmacwaterheat.com/
Ephoca	through wall		Italy	https://ephoca.com/
Fujitsu General America			New Jersey	https://www.fujitsu-general.com/us/
IceAir	through wall		New York	https://www.ice-air.com/
Mitsubishi Electric Trane HVAC US			Georgia	https://metahvac.com/
Panasonic			Japan/Netherlands/NJ	https://iaq.na.panasonic.com/hvac
Sharc Energy	waste water heat recovery		Vancouver BC	https://www.sharcenergy.com/
Stiebel Eltron			Germany	https://www.stiebel-eltron-usa.com/
Thermodrain – EcoInnovation	waste water heat recovery		Quebec	https://ecoinnovation.ca/
Sanco Water Heater	CO2 heat pump		Michigan	https://eco2waterheater.com/

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Other Electrical Uses

Ventilation Units: Efficiency is critical - both heat recovery & fan power.

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Swegon

BRINK

OXYGEN 8

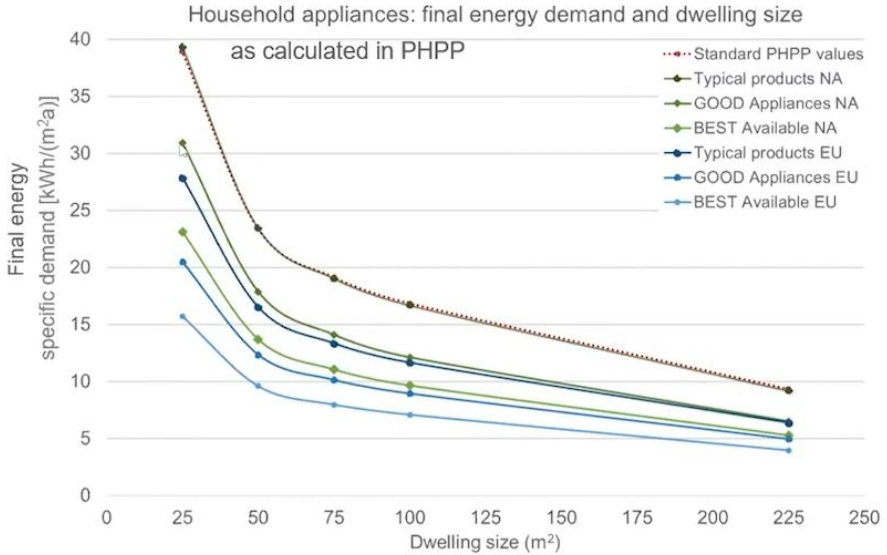
zehnder
always the best climate

Induction Cooktops & Elec Ovens:

energy
ENERGY STAR

Unvented Condensing or Heat Pump Clothes Dryer

PHPP Defaults vs Possibilities



Number of occupants, frequency of use of appliances and values for consumer electronics and small devices as calculated in PHPP.
Typical products represent the average efficiency of the appliance sold in a given year, good and best appliances were selected from top performing lists [TOPTEN 2018, IEA4E, ENERGYSTAR]

Car

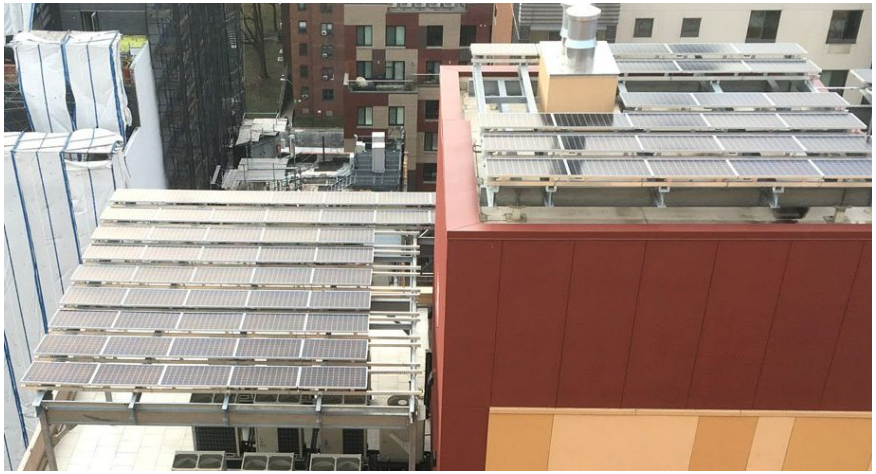
Cars are not calculated in the home energy demand of a Passive House.

HOWEVER, the reduction in energy demand Passive House provides, can effectively deliver free car charging.

Electrical (Lighting & PV)

- Full LED lighting package
- Occupancy / vacancy sensors at all common area locations
- Solar PV over the full roof areas to the greatest extent possible

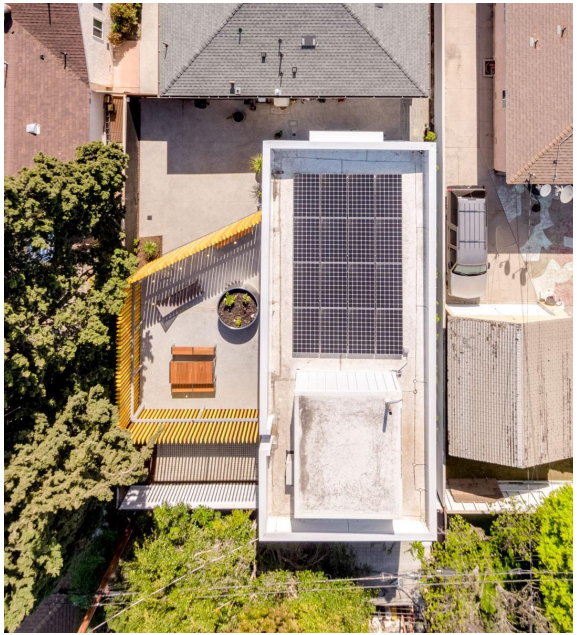
Calculation of the projected building footprint



Performance: BESS Self-Utilization Credit

~~Deleted~~, Added, Existing, Modified

In context of Long-term System Cost and peak Cooling Energy limits, it encourages more direct integration, allowing smaller solar panel installation to meet requirements while increasing resiliency.



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2. Context of Mechanical Systems
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7. Other Systems + Solar
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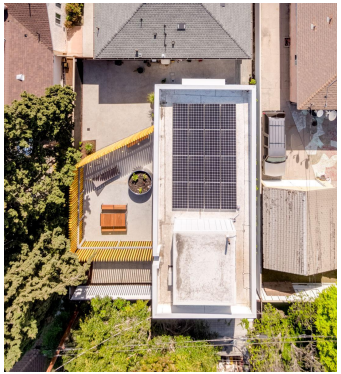
9. Resources

Single Family: Los Angeles

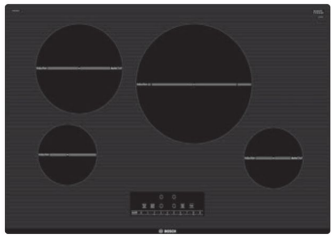
- 1791 SF
- Heating load – 1850 BTU/540 watts
- Cooling load – 5400 BTU/1580 watts
- Net Zero with 9kW Solar PV



Credit: Paravant Architects

Equipment

- Induction cooktop
- Condensing dryer
- Heat pump water heater
- Mini-split heating/cooling
- Heat recovery ventilation
- Exterior shades



Sunnyvale CA Retrofit

- 1500 SF
- Heating load – 4795 BTU/1405 watts
- Cooling load – 2650 BTU/775 watts
- Net zero – 9 kW solar PV system

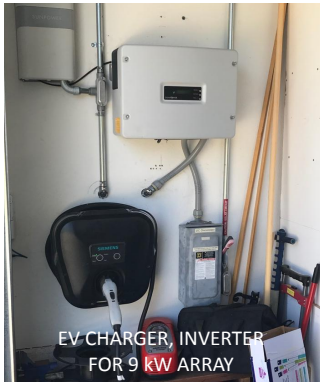
Credit: Bronwyn Barry/PassiveHouseBB

Equipment


INDUCTION COOKTOP WITH DIRECT VENT TO EXTERIOR


80 GA SE ACCELERA 300 HEAT PUMP WATER HEATER


1-TON DUCTED MINI-SPLIT HEAT PUMP (ECM MOTOR)

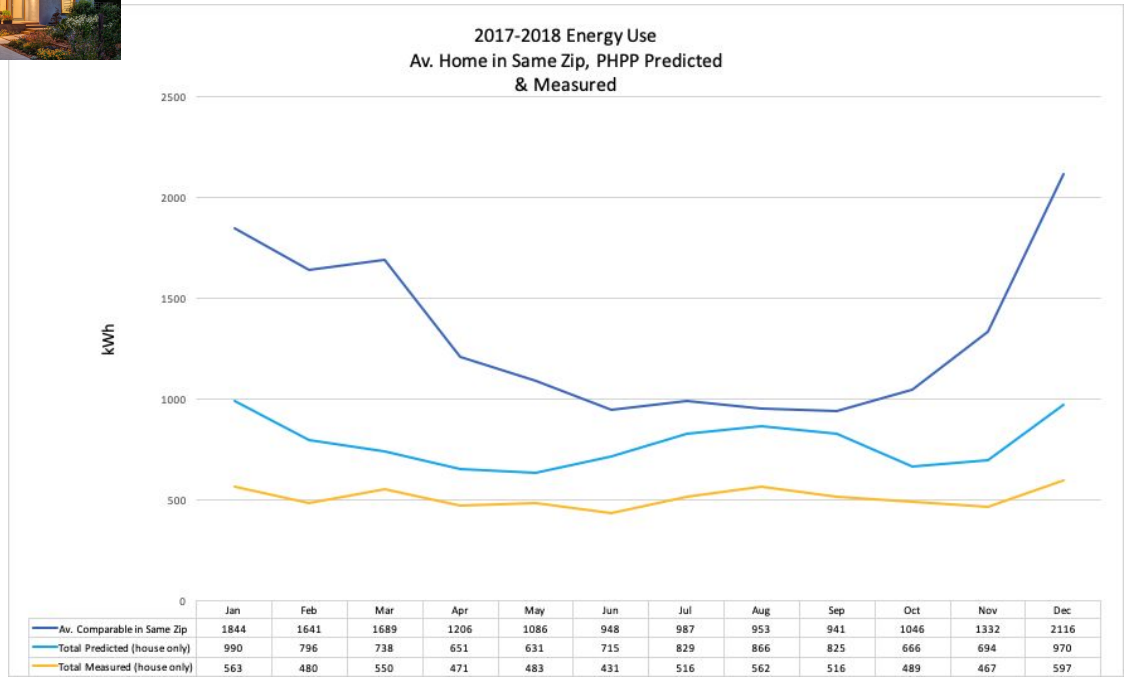

EV CHARGER, INVERTER FOR 9 kW ARRAY


ZEHNDER COMFOAIR 350 HEAT RECOVERY VENTILATOR


FUJITSU COMPRESSOR (VERY LOW DB RATING)

Credit: Bronwyn Barry/PassiveHouseBB

Crushing Heat Demand (& Total Energy)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Av. Comparable in Same Zip	1844	1641	1689	1206	1086	948	987	953	941	1046	1332	2116
Total Predicted (house only)	990	796	738	651	631	715	829	866	825	666	694	970
Total Measured (house only)	563	480	550	471	483	431	516	562	516	489	467	597

TOTALS:
Av. Home in Same Zip:
15,788 kWh

Passive House:
6,125 kWh

= 38% of standard

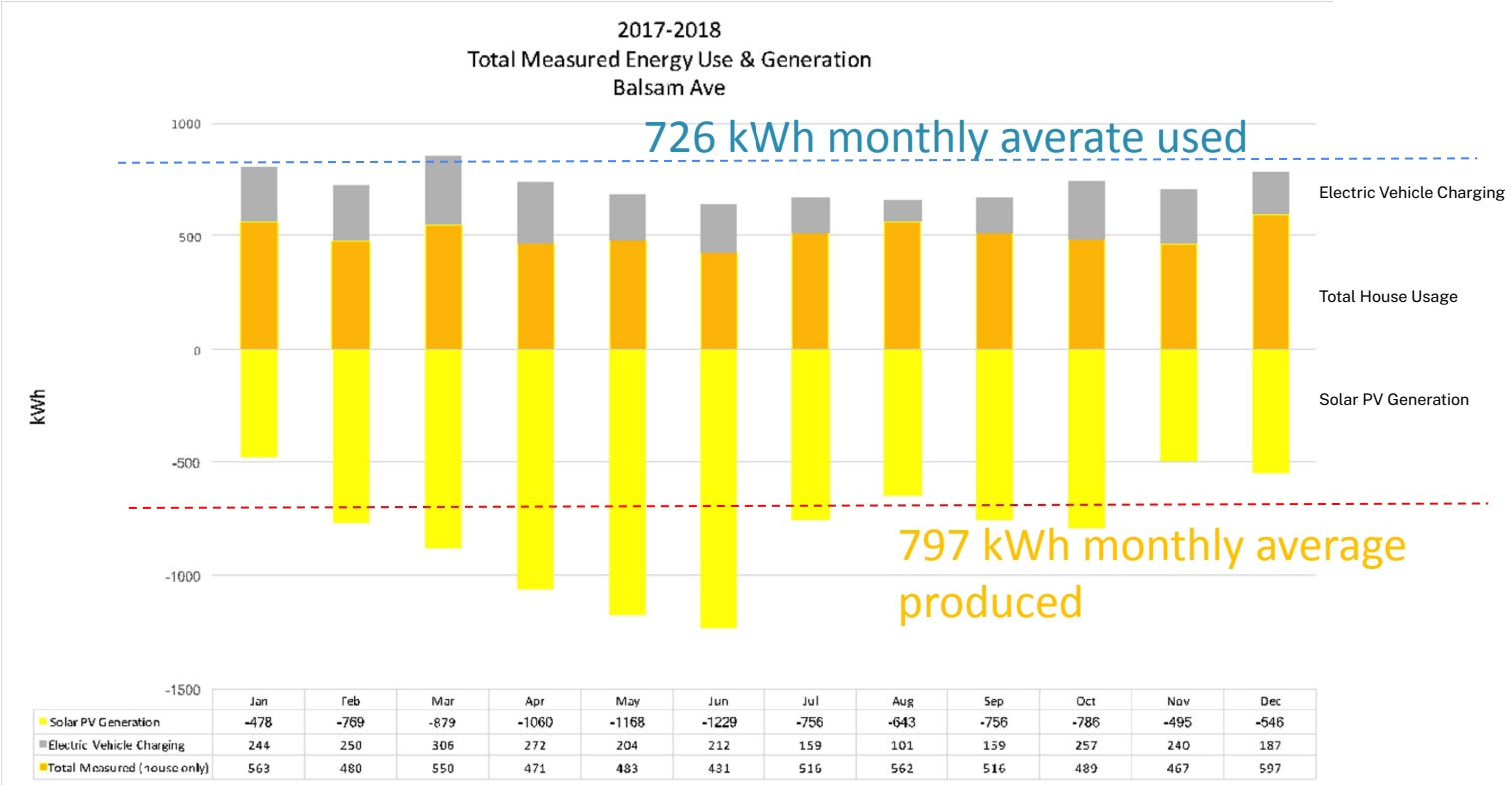
DIFFERENTIAL AT WINTER PEAK:
Av. Home in Same Zip:
2,516 kWh

Passive House:
597 kWh

= 23% of standard

Credit: Bronwyn Barry/PassiveHouseBB

Tuned Performance for “True Net Zero” w/ car



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar PV Generation	-478	-769	-879	-1060	-1168	-1229	-756	-643	-756	-786	-495	-546
Electric Vehicle Charging	244	250	306	272	204	212	159	101	159	257	240	187
Total Measured (house only)	563	480	550	471	483	431	516	562	516	489	467	597

Credit: Bronwyn Barry/PassiveHouseBB

Hotel Marcel: Certified Retrofit, New Haven CT

- 90,000 SF
- 165 Guest Rooms, Conf Center, Restaurant
- 1.5 MWh microgrid with over 1,000 solar panels

Credit: Becker + Becker Architects

All Electric Hot Water

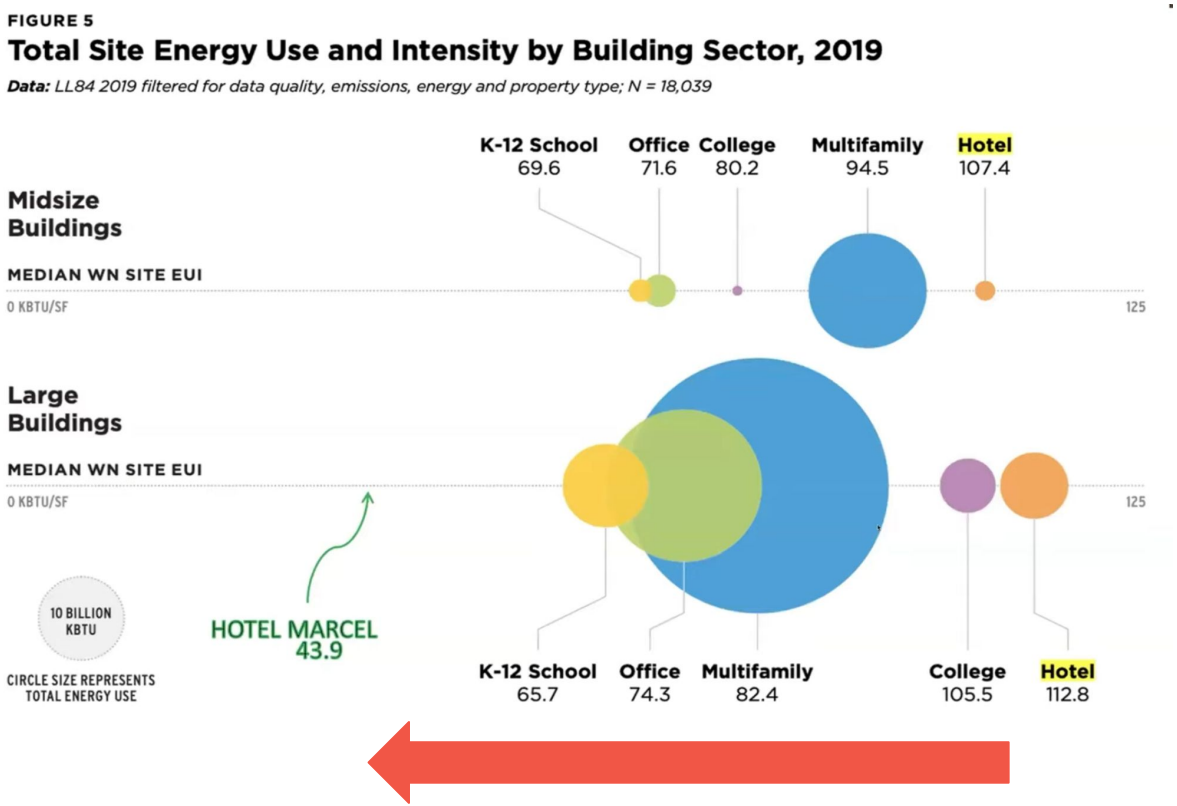
Mitsubishi Heat20 air source heat pumps

Credit: Becker + Becker Architects

Commercial Electric Dryers & Kitchen!

Electrolux Heat Pump Dryers

60% Reduction in Energy Use



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Resources

1. A Comparison of Canadian and European Energy Standards for Household Appliances - https://passivehousenetwork.org/featured/appliance-modeling-guide/
2. BC Hydro Building Envelope Thermal Bridging - https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/power-smart/builders-developers/building-envelope-thermal-bridging-guide-v1-6.pdf
3. Building Certifier Scope of Services - https://passivehousenetwork.org/wp-content/uploads/2024/07/Building-Certifier-Scope-of-Services-JULY-2024-UPDATE.pdf
4. Building Database - https://passivehouse-database.org/index.php?lang=en
5. Building for People - https://islandpress.org/books/building-people#desc
6. Certification Criteria - https://passivehouse.com/03_certification/02_certification_buildings/08_energy_standards/08_energy_standards.html
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10. Certified Passive House Designer Training - https://passivehousenetwork.org/designer-training/
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12. Construction Cost Analysis of High-Performance Multi-Unit Residential Buildings in British Columbia - https://passivehousenetwork.org/wp-content/uploads/2024/10/CONSTRUCTION-COST-ANALYSIS-OF-HIGH-PERFORMANCE-MULTI-UNIT-RESIDENTIAL-BUILDINGS-IN-BRITISH-COLUMBIA-V3.1.pdf
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33. Sample Submission Documents - https://passipedia.org/certification/certified_passive_houses/example_documents
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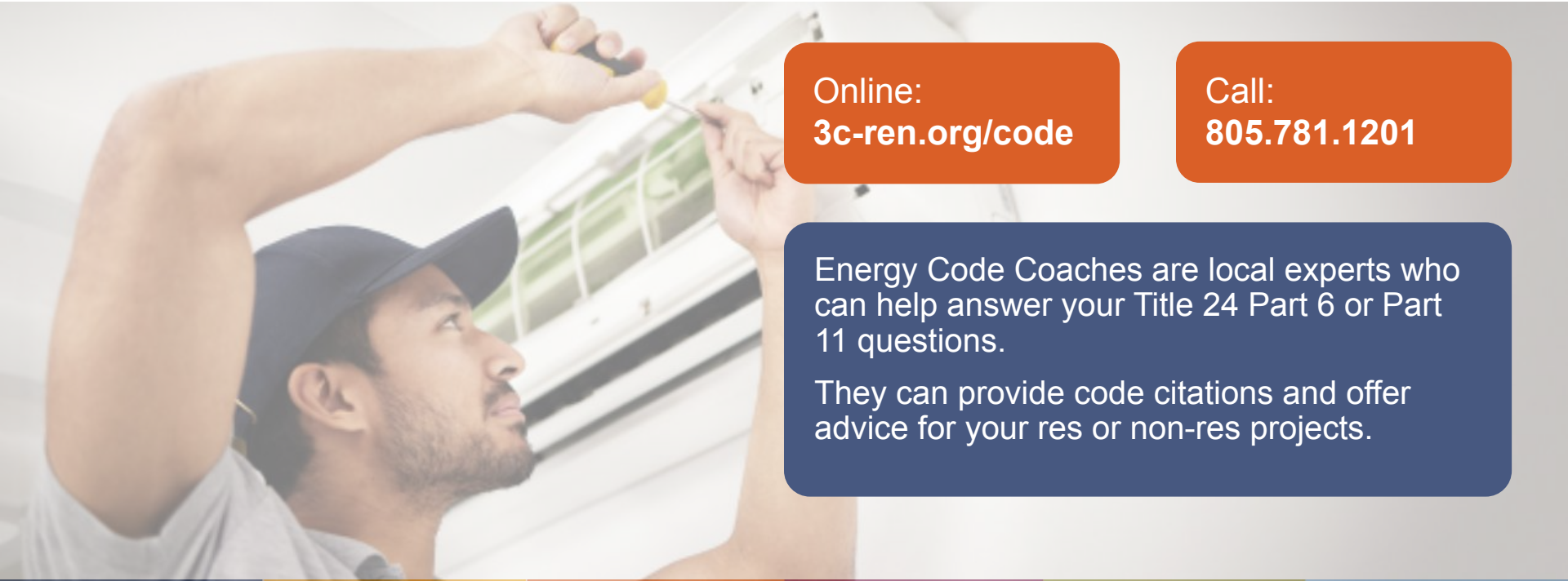
37. Understanding Passivhaus - https://www.firstinarchitecture.co.uk/understanding-passivhaus/
38. Unlocking livable, resilient, decarbonized housing with Point Access Blocks - https://www.larchlab.com/wp-content/uploads/2022/01/Eliason_CoV-Point-Access-Blocks-report_v1.2.pdf
39. Vancouver Passive House Verification Plan Checklist - https://passivehousenetwork.org/wp-content/uploads/2024/07/Vancouver-Passive-House-Verification-Plan-Checklist-2023.pdf
40. Ventilation Duct Leakage Testing - https://passivehousenetwork.org/product/multifamily-ventilation-duct-leakage-targets-strategies-and-lessons-learned/

Thank you.

www.passivehousenetwork.org

Questions about Title 24?

3C-REN offers a *free* Code Coach Service



Online:
3c-ren.org/code

Call:
805.781.1201

Energy Code Coaches are local experts who can help answer your Title 24 Part 6 or Part 11 questions.

They can provide code citations and offer advice for your res or non-res projects.

Closing

Continuing Education Units Available

- Contact dresurreccion@co.slo.ca.us for AIA LUs

Coming to Your Inbox Soon!

- Slides & Recording

Get Passive House Certified (*FREE)!

- Certified Passive House Designer/Consultant Pacific Summer 2025 Cohort
- 5-Day Passive Design/Build Bootcamp in Santa Barbara (Sept 29 – Oct 3)

Upcoming PHN Courses:

- July 16 – Enclosure in Detail
- Aug 14 – Intro to Passive House Trades

Any phone numbers who joined? Please share your name!

Thank you!

More info: **3c-ren.org**

Questions: **info@3c-ren.org**

Email updates: **3c-ren.org/newsletter**

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