Multifamily Developer Bootcamp

phius con
CHICAGO 2022

ONION FLATS

Tim McDonald
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215.783.5591

ON THE MENU

1. Early work and Integrated Design Process
2. Interest in cost-effective Sustainability
3. The New Gravity Project
4. Policy and Leverage Points
5. Developing a Guide to Multifamily Affordable PH

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ONION FLATS
DEVELOPMENT

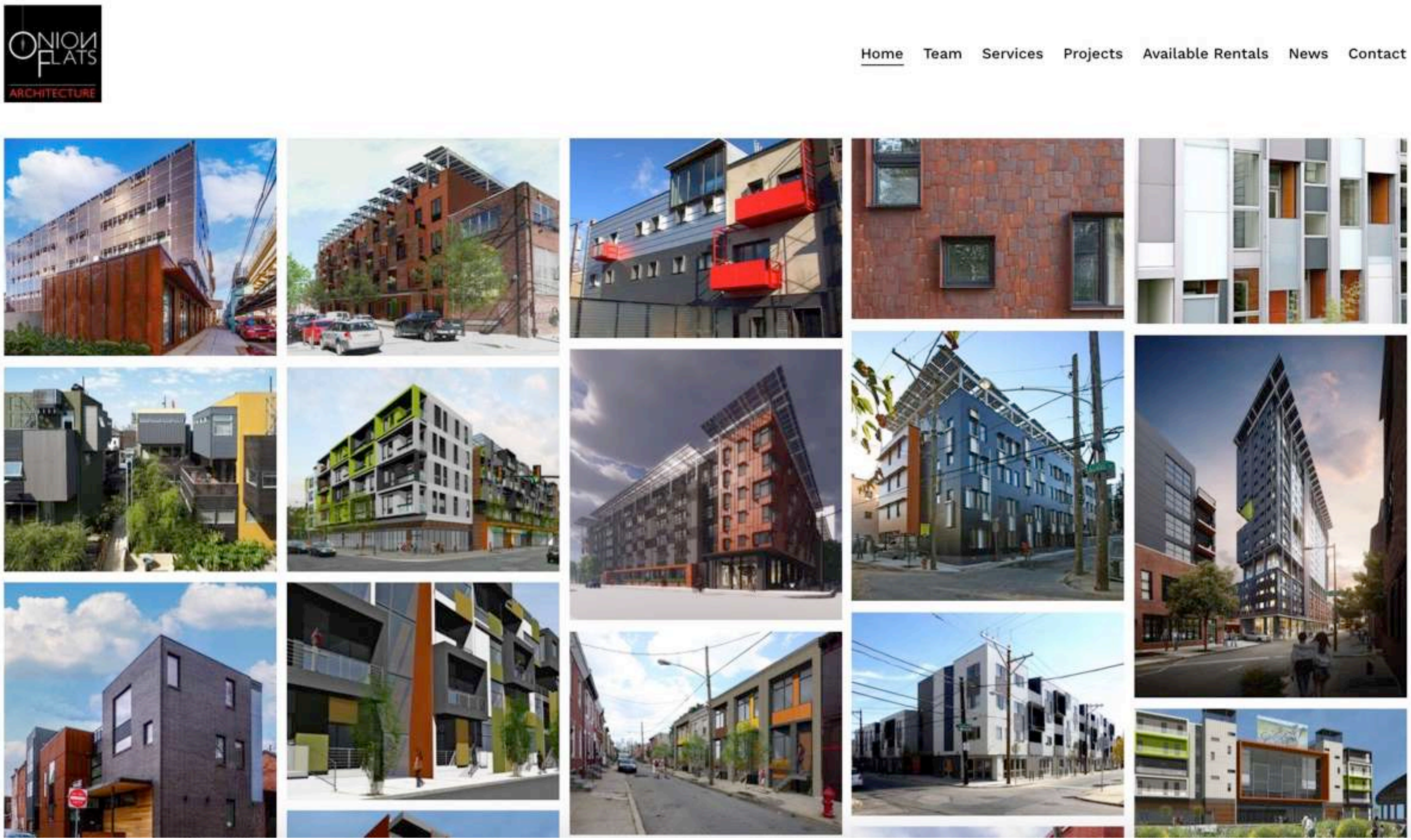
ONION FLATS
ARCHITECTURE

ONION FLATS
CONSTRUCTION

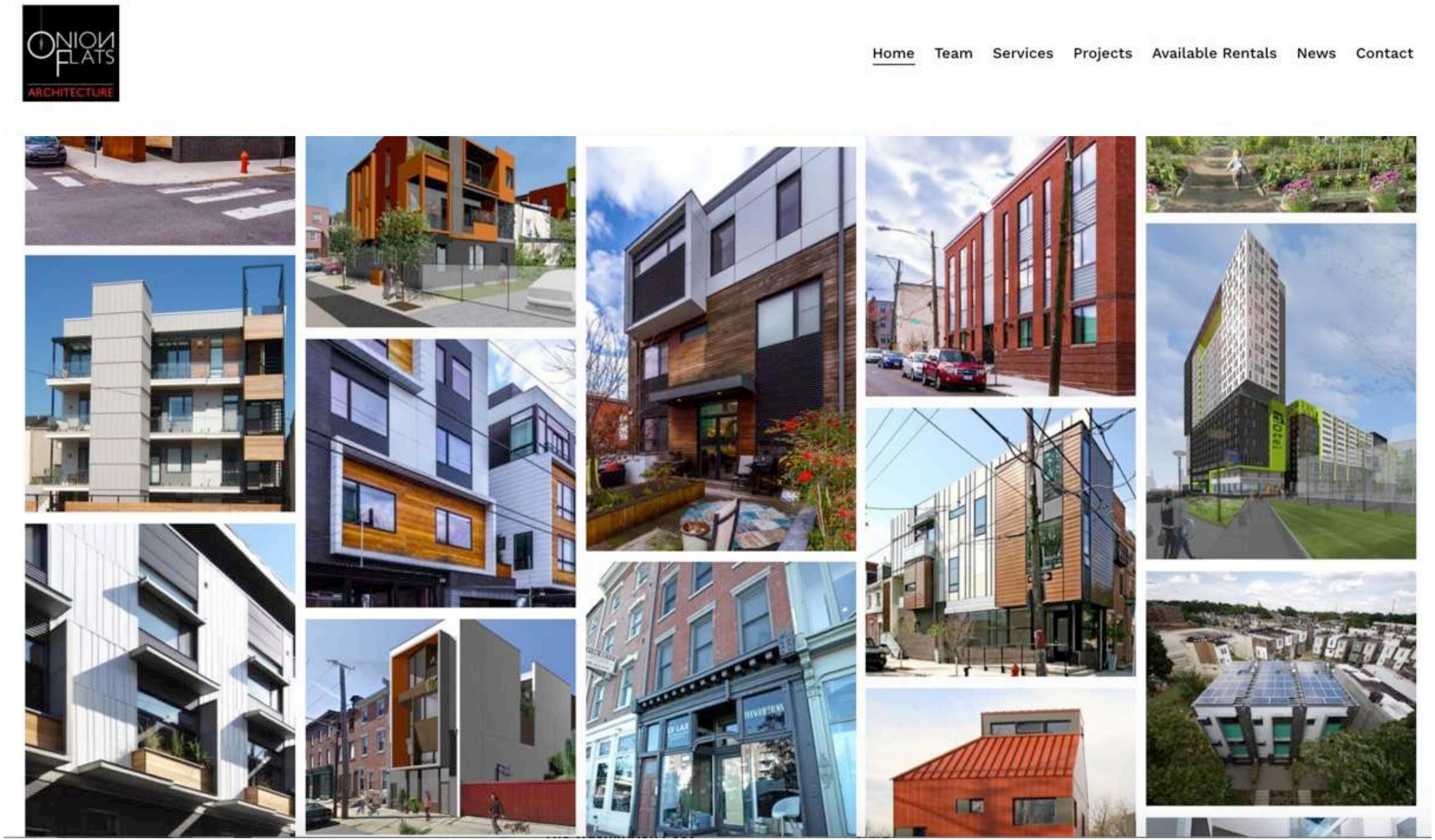
GREEN ROOFS
GRASS
SOLAR SYSTEMS

25 YEARS

1997 - *2022*


ONION FLATS
ARCHITECTURE
Home
Team
Services
Projects
Available Rentals
News
Contact

1997 - 2022


ONION FLATS
ARCHITECTURE
Home
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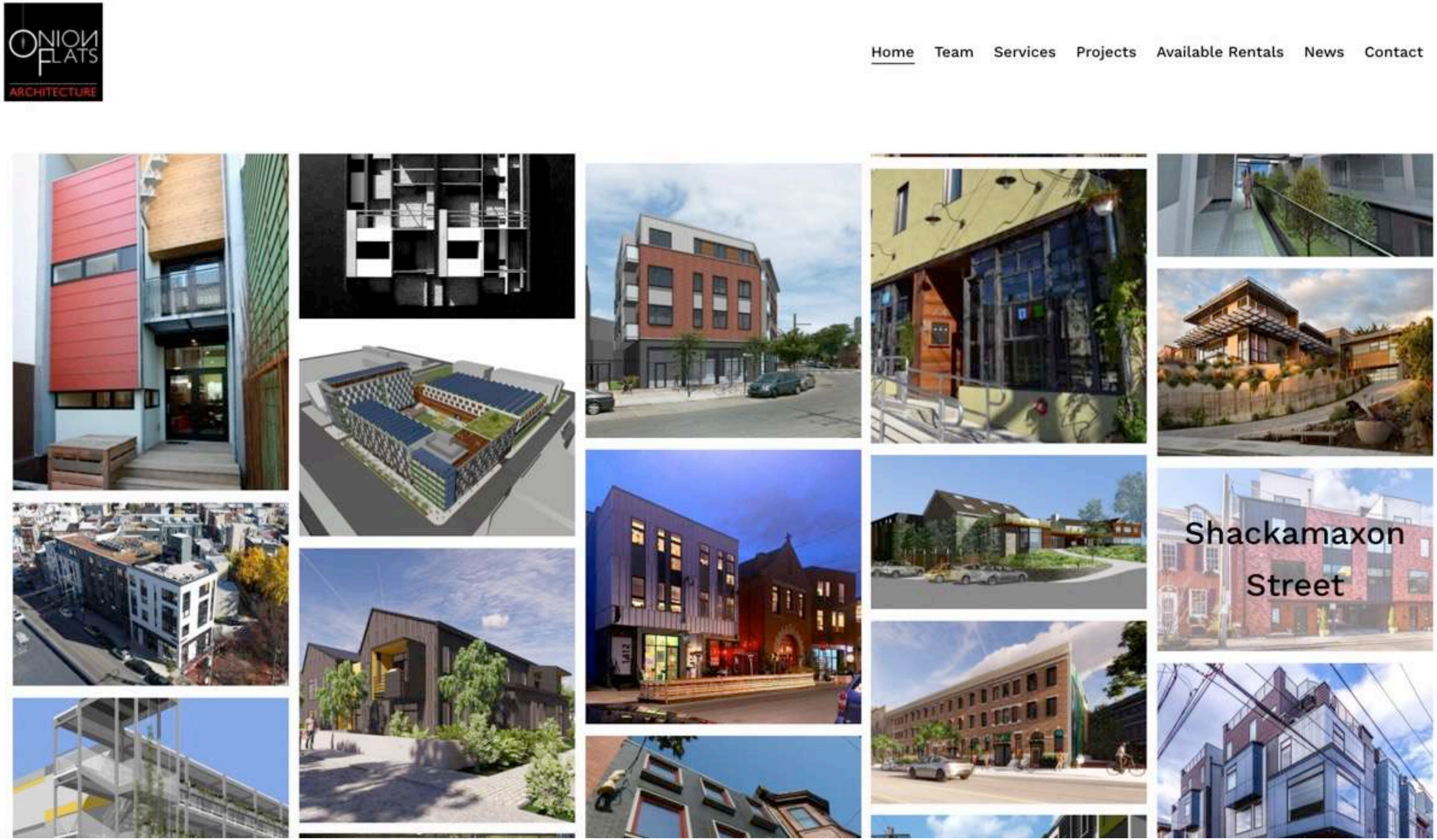
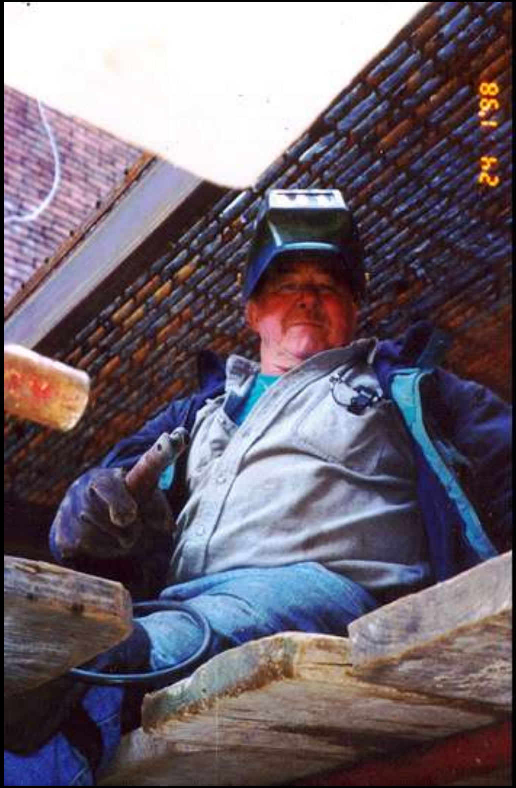
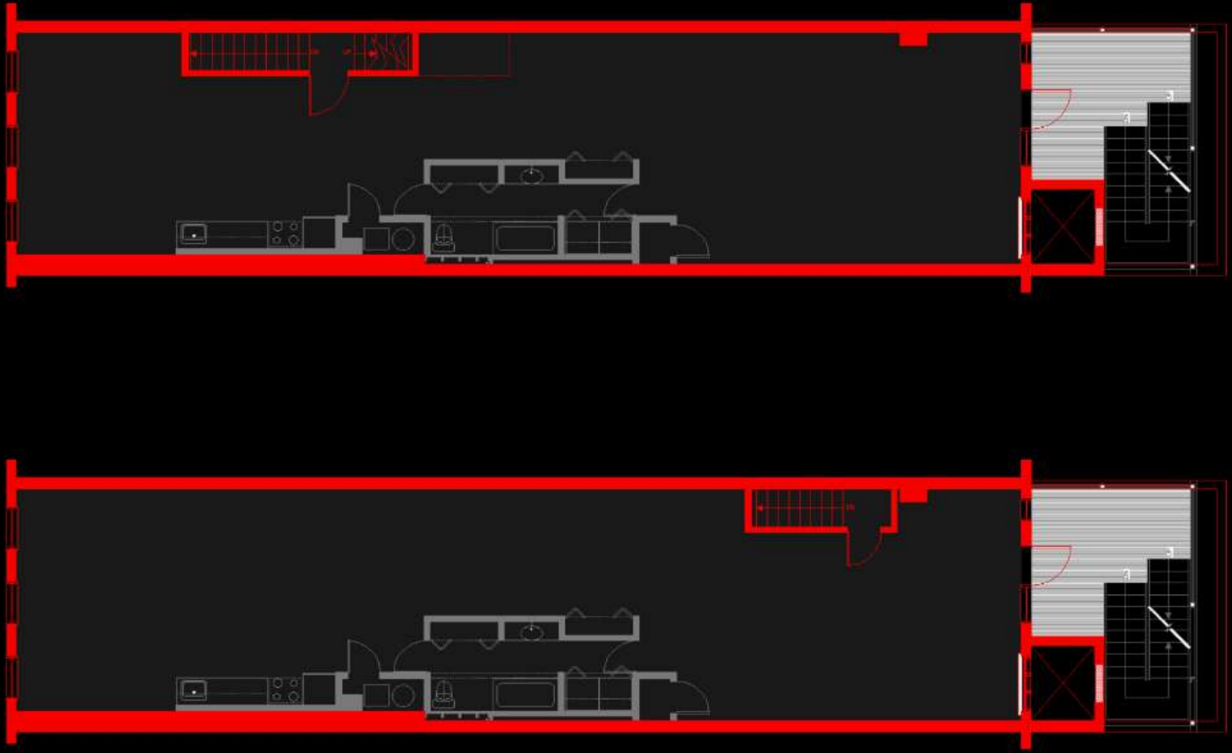
1997 - 2022


ONION FLATS ARCHITECTURE
Home
Team
Services
Projects
Available Rentals
News
Contact
Shackamaxon Street

1997 - *2022*

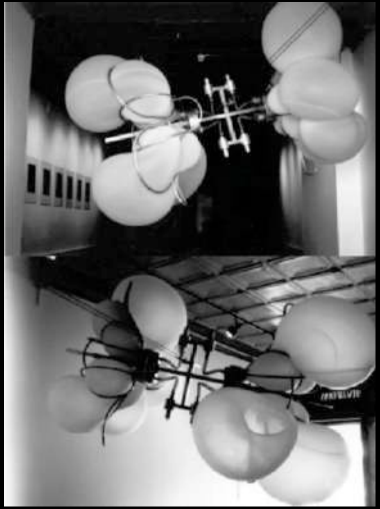
MARKET FLATS, 1997
mixed use residential/retail


24 1 '98



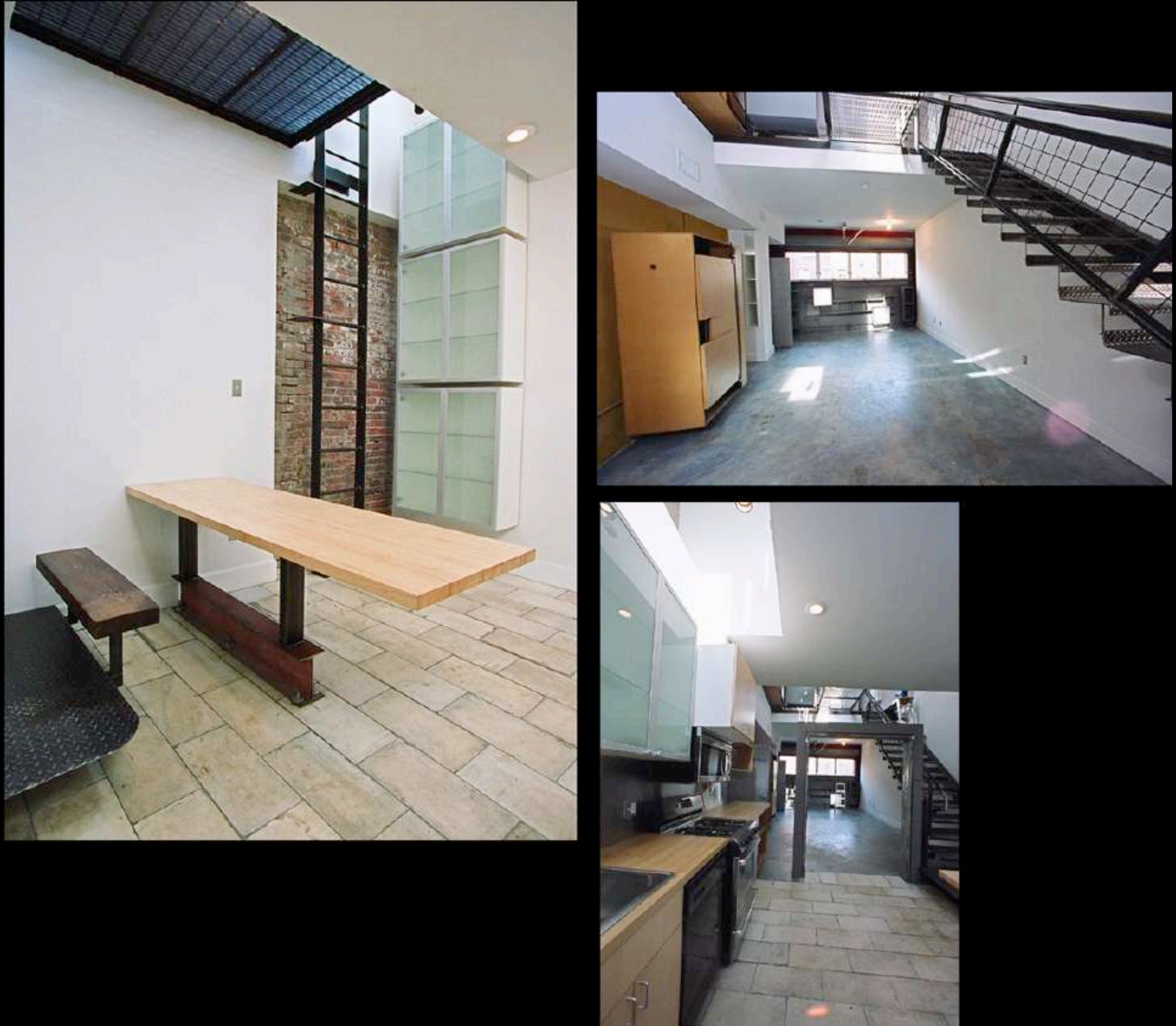
EX-LAX
THE CHOCOLATED LAXATIVE
PATENTS
PRESCRIPTIONS
120

EX-LAX
PRESCRIPTIONS



Bohlin Cywinski Jackson
Sketches Models Buildings
FAARM • 126 Market Street • Philadelphia PA • 1.7 - 2.18 2000

CAPITAL FLATS, 1999: 8 “experiments in dwelling”

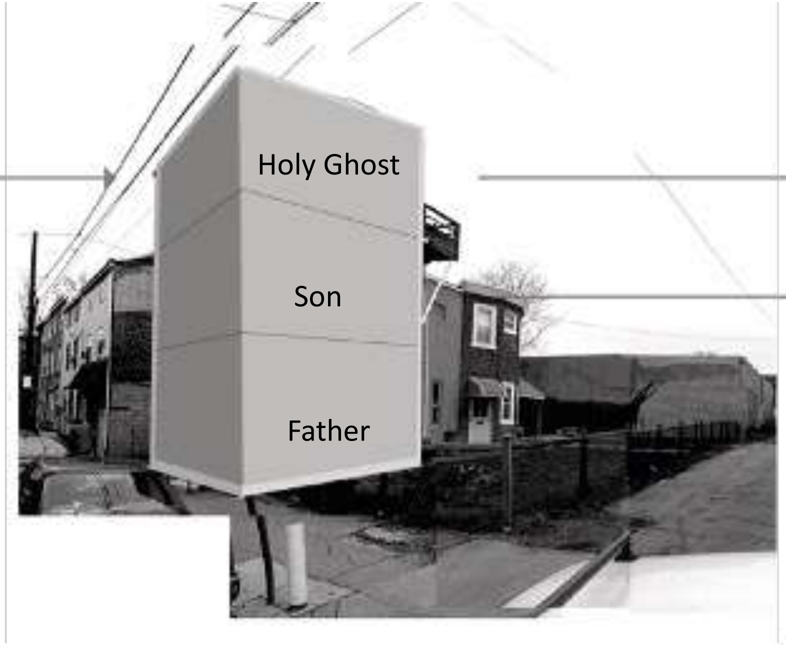


RAG FLATS 2006: 11 Units


DUPONT
Homewrap

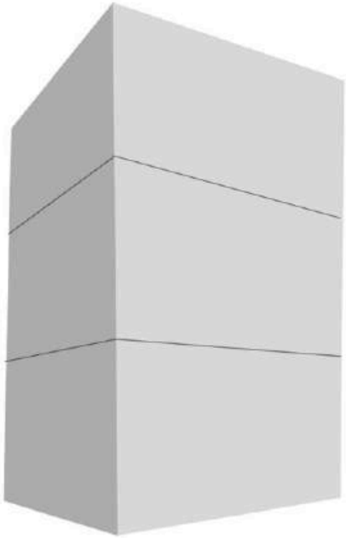

E Montgomery Ave
E Montgomery Ave
E Montgomery Ave
Belgrade St
Gaul St
Miller St
E Berks St
E Berks St
Belgrade St
Miller St
E Berks St
E Berks St
E Berks St
E Hewson St
E Hewson St
Belgrade St
E Hewson St
E Thompson
25 feet
10 m

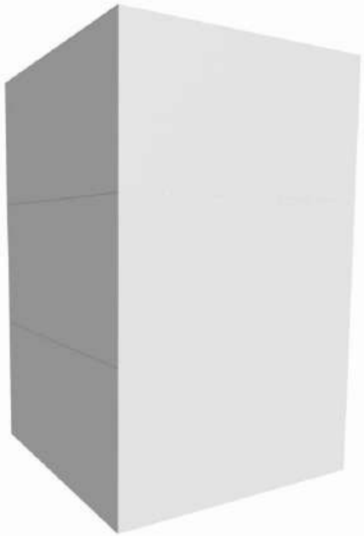
THE GIVEN

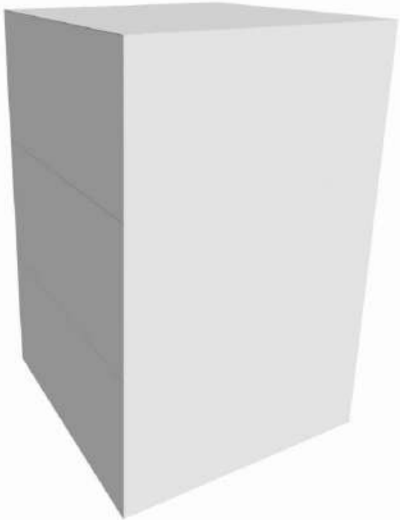


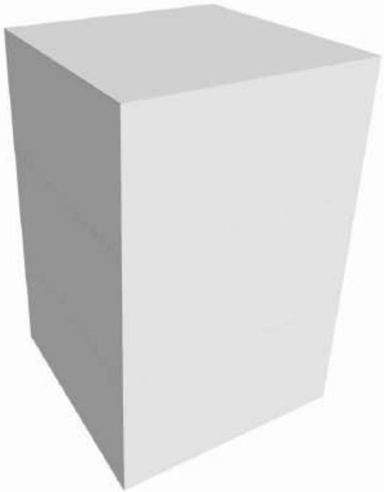
ISOLATED

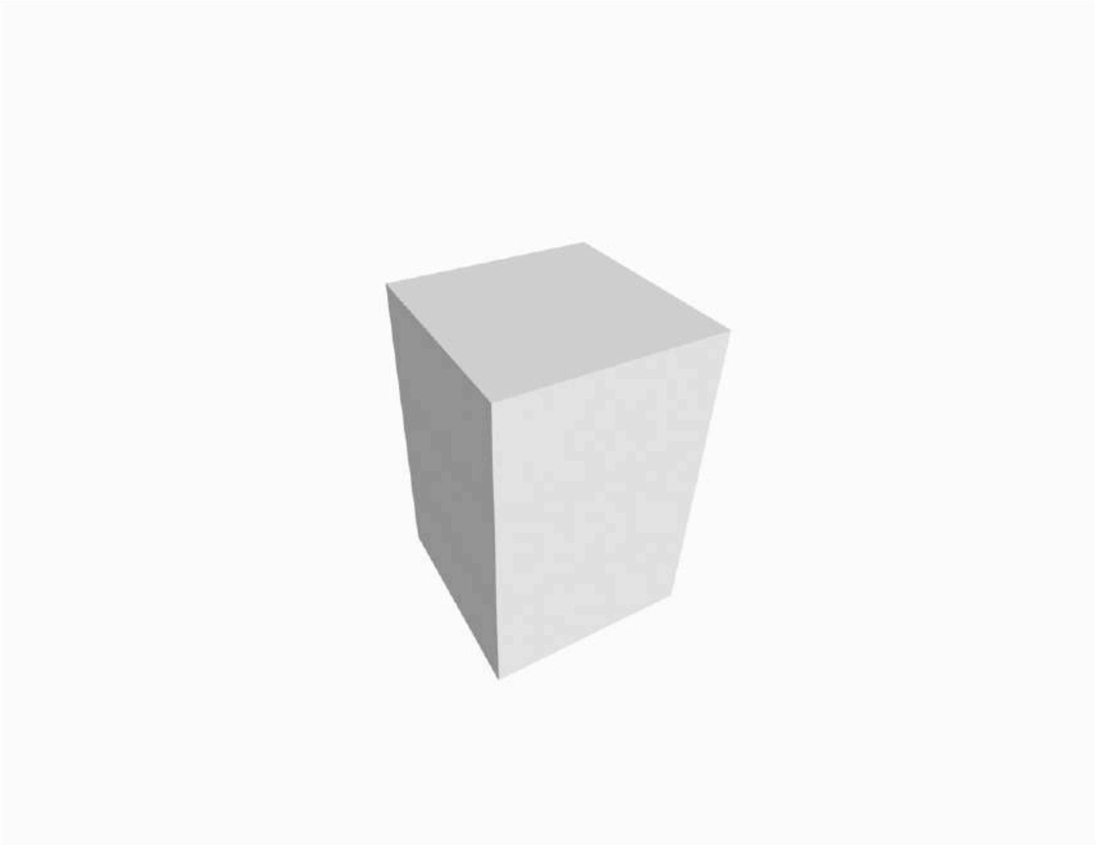
The Philadelphia “Trinity”

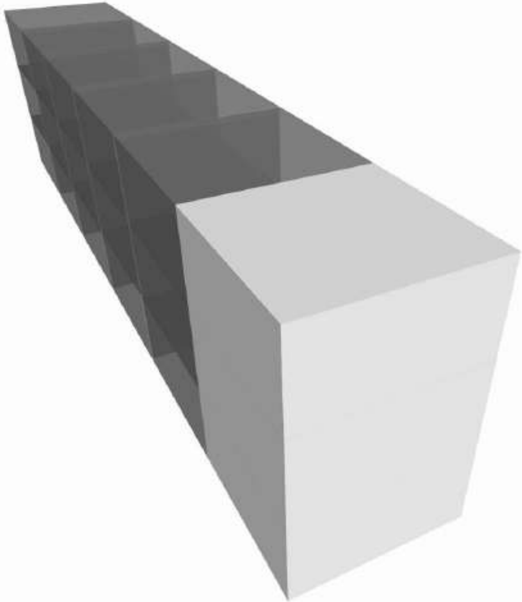


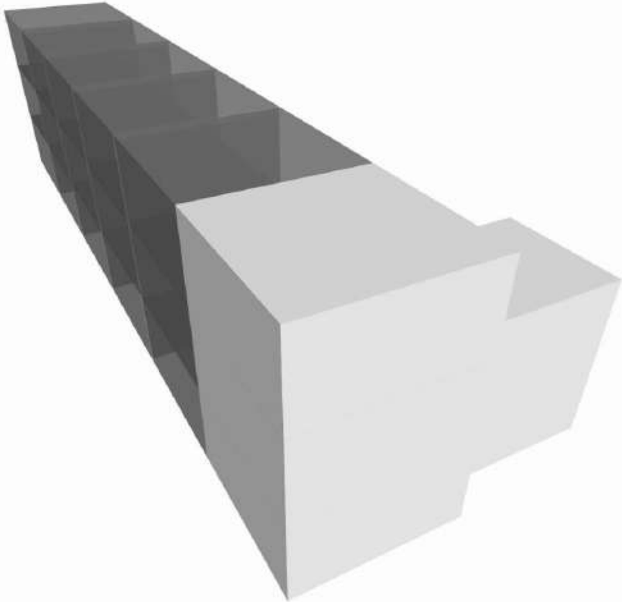


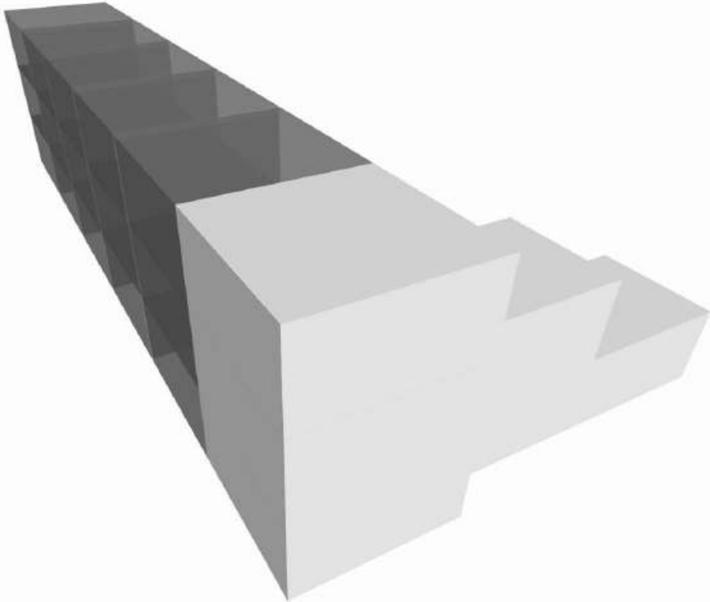


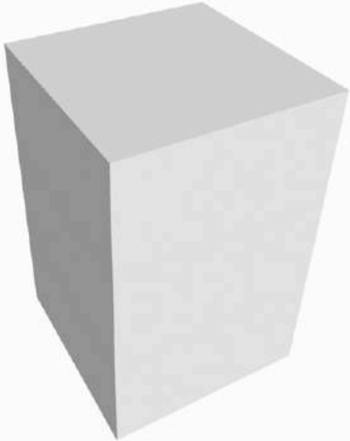


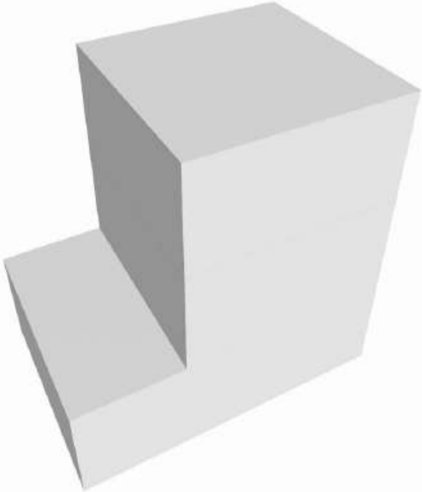


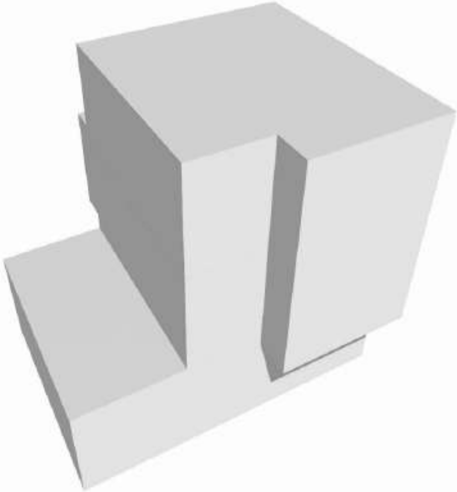


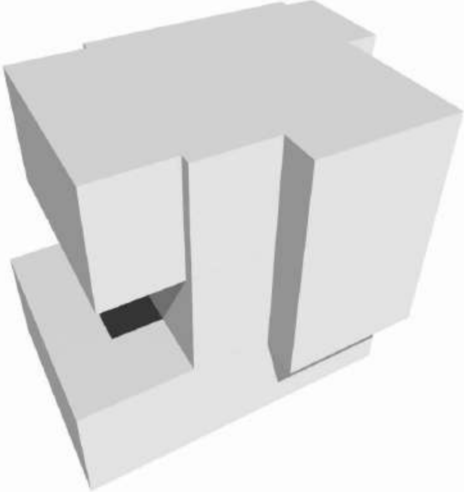


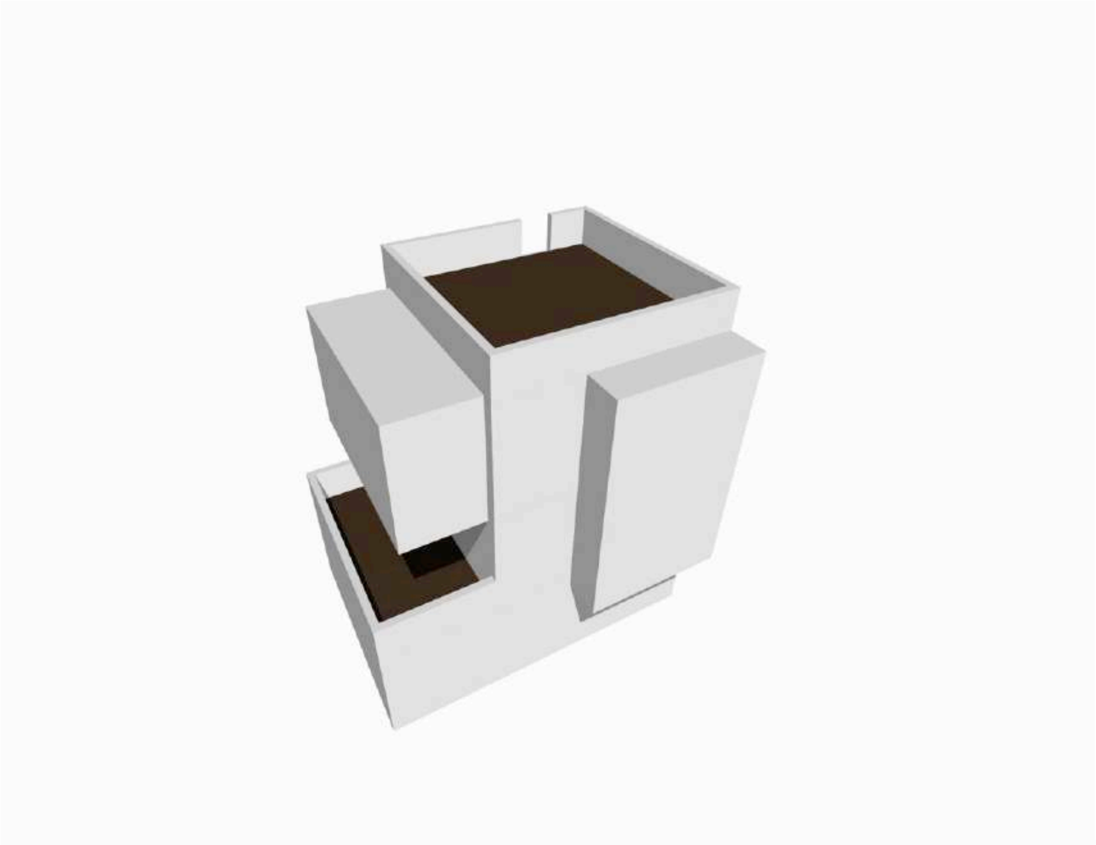


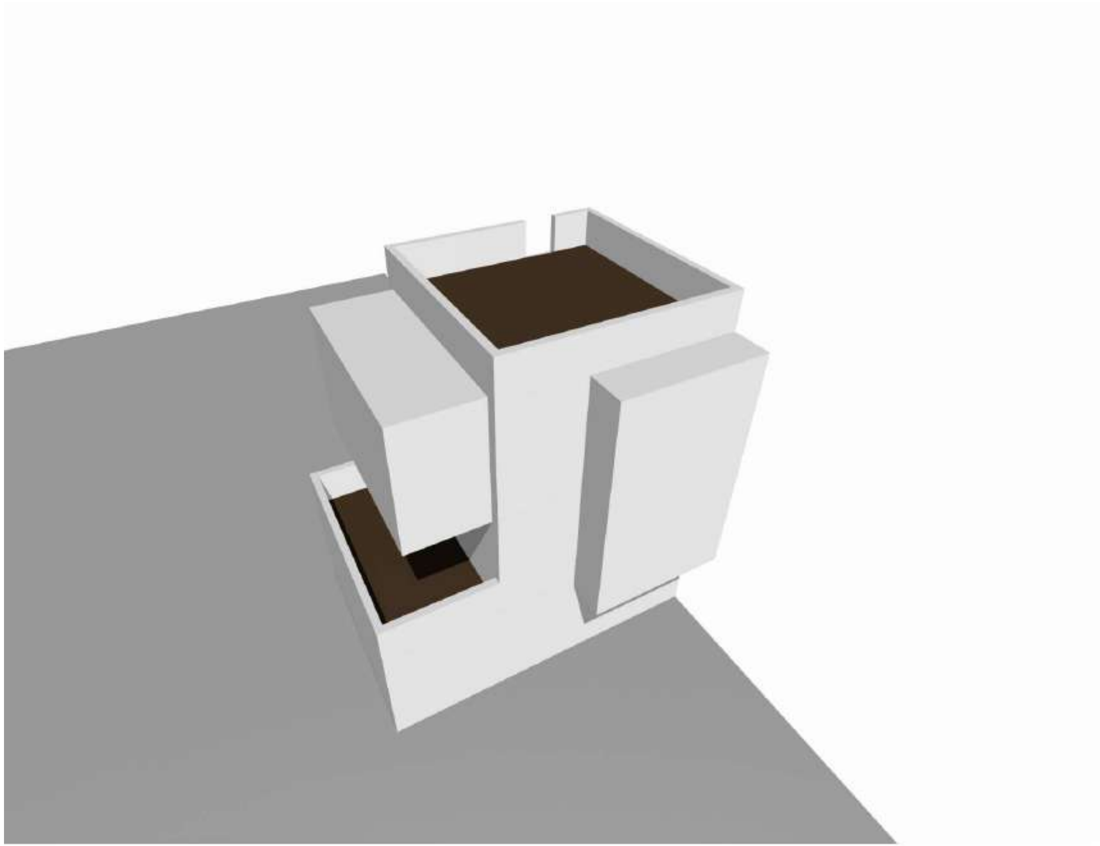


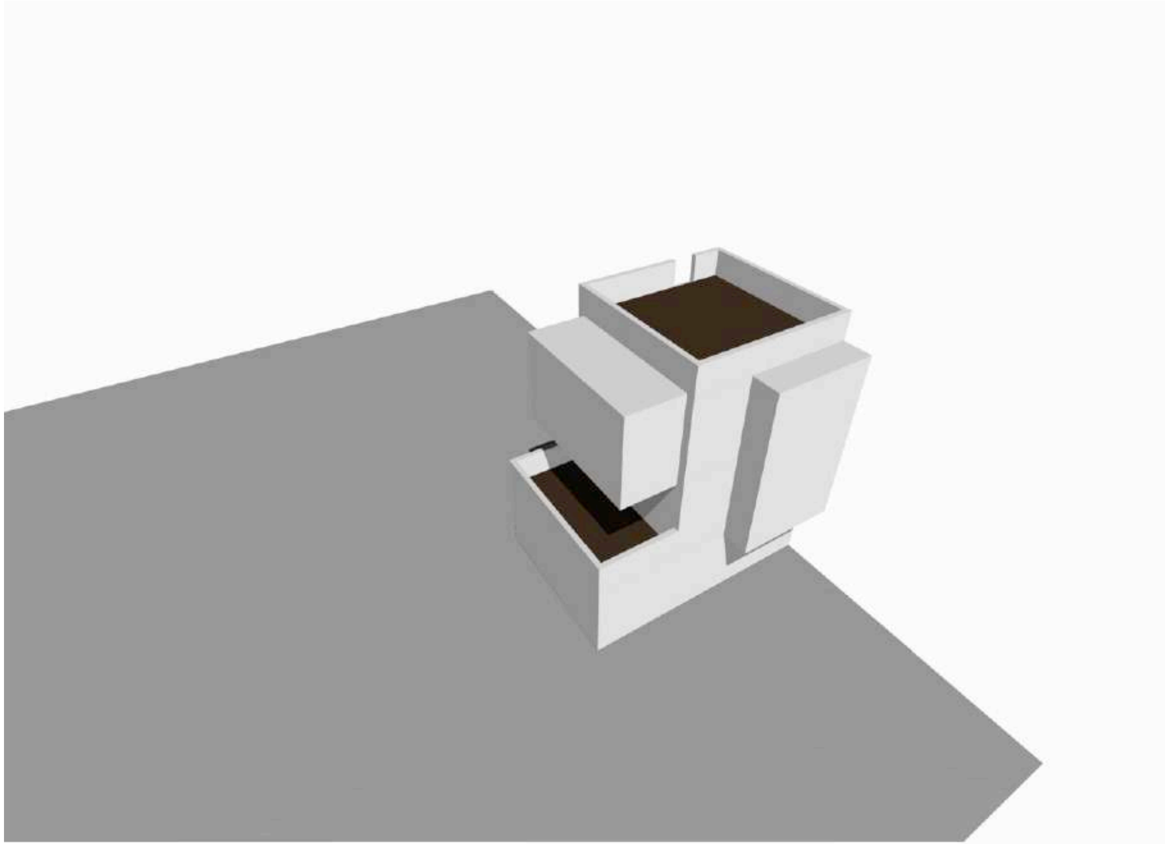


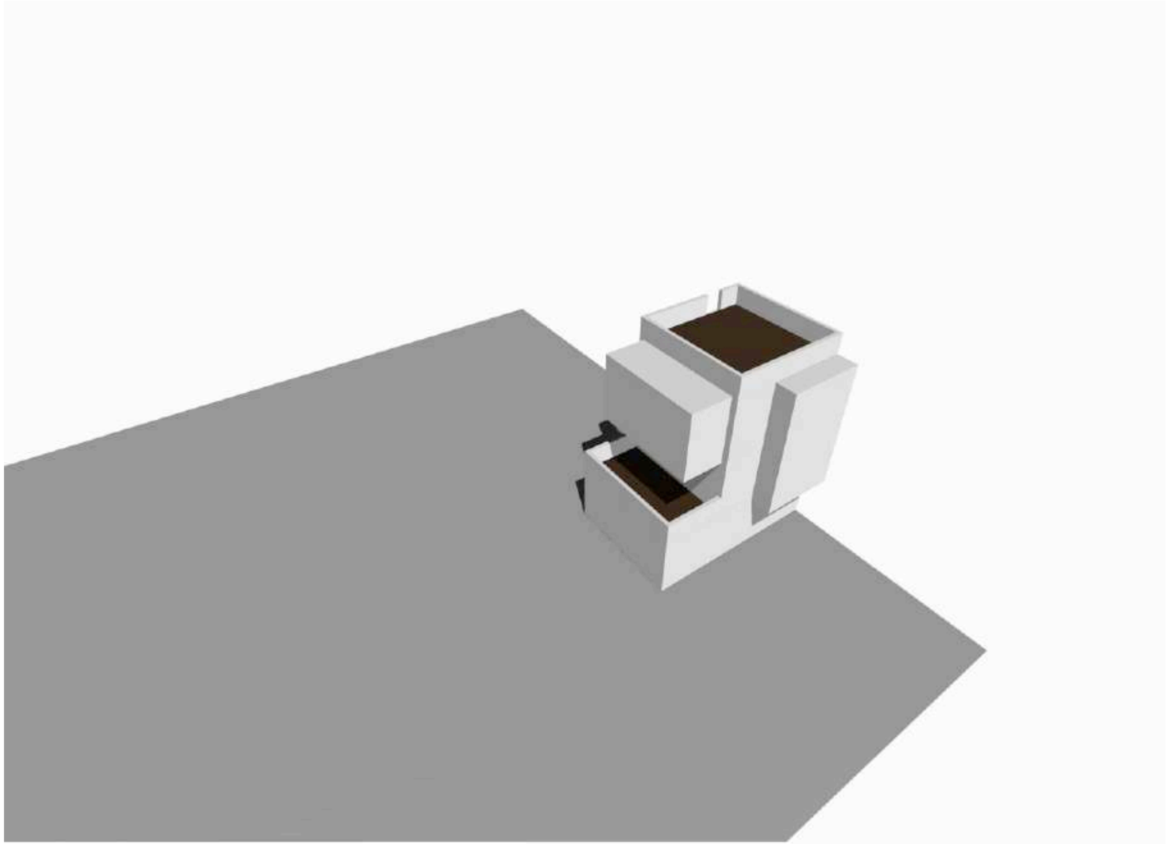


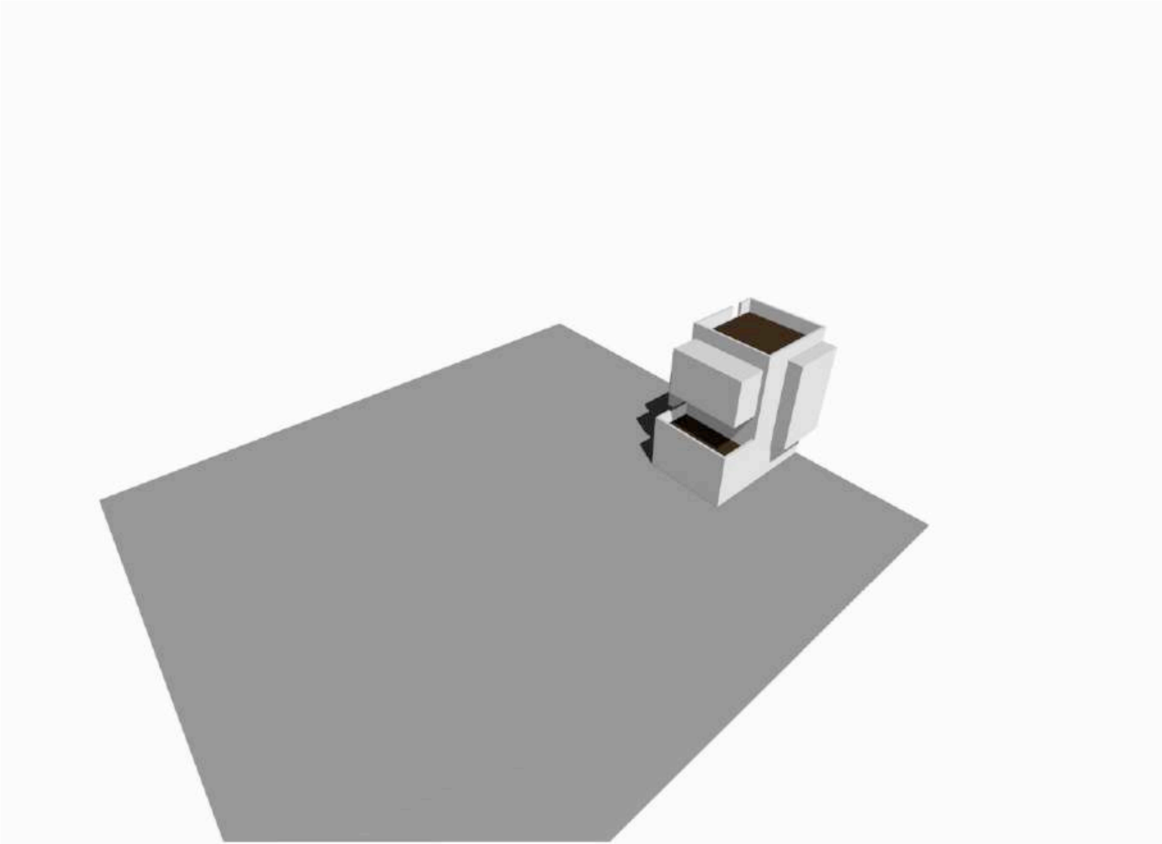


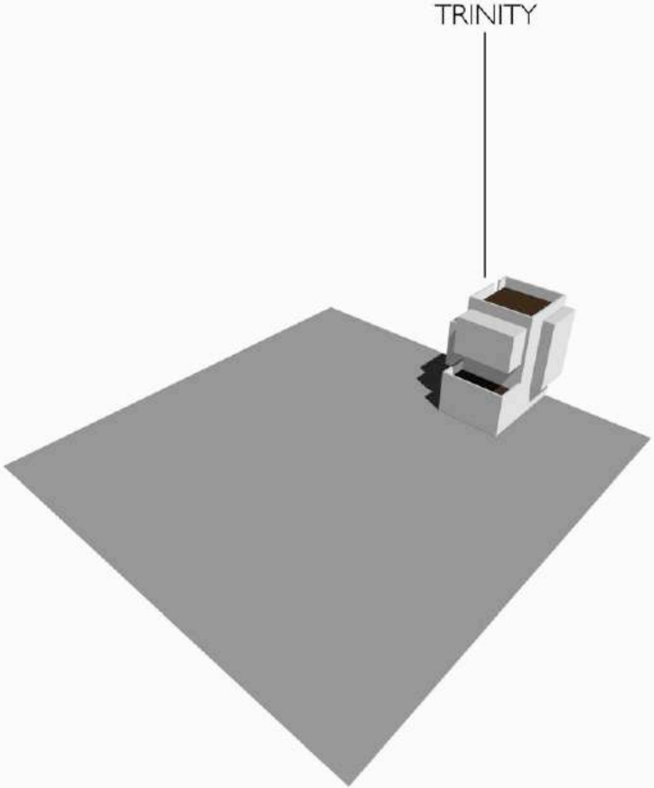






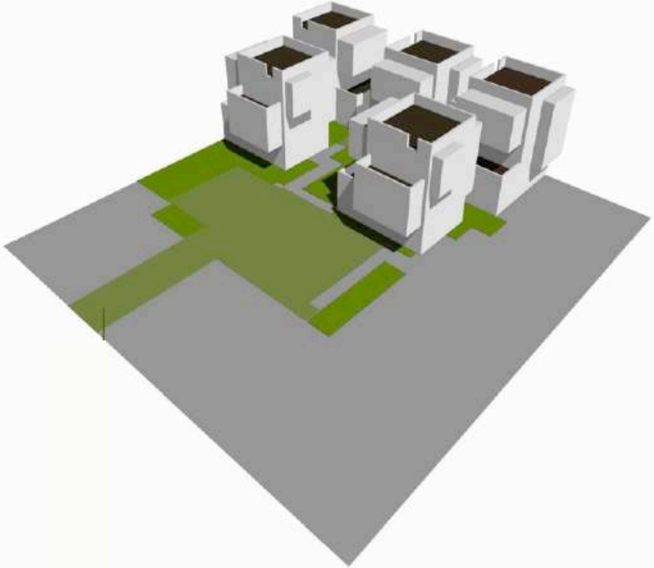






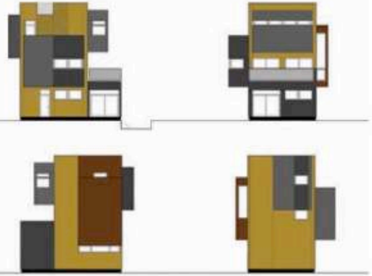
TRINITY

TRINITY




610
D

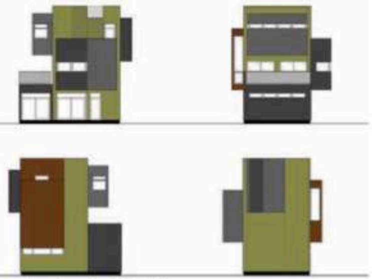
Elevations for Trinity "A"



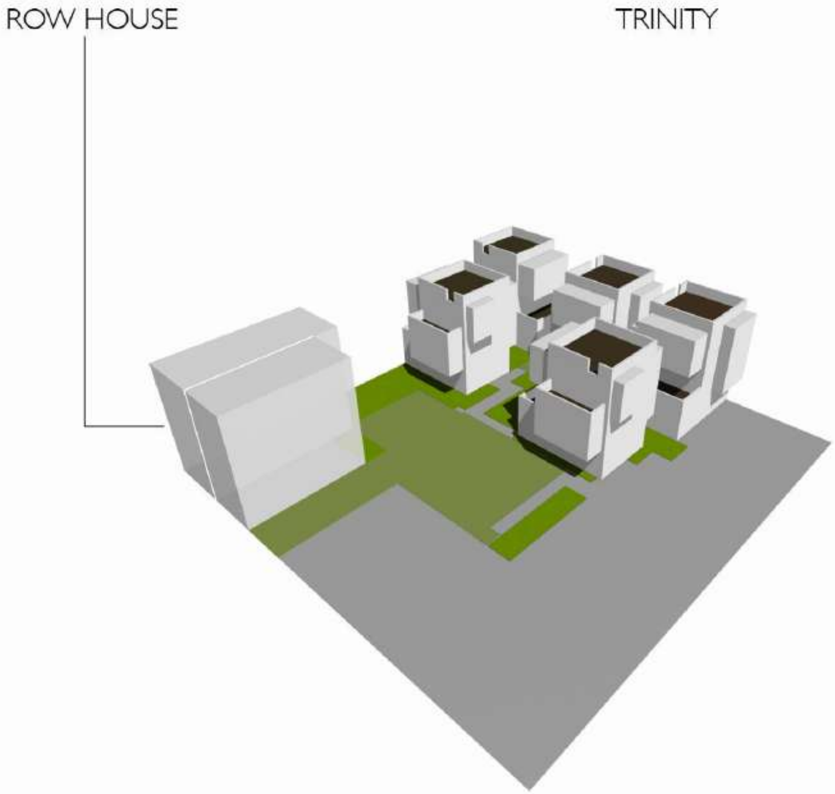
Elevations for Trinity "B"

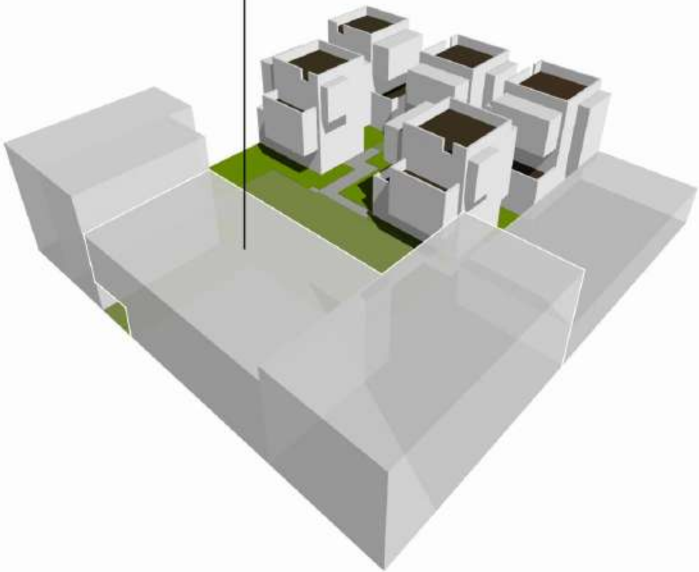
Elevations for Trinity "B"

Elevations for Trinity "C"



Elevations for Trinity "D"


ROW HOUSE
TRINITY

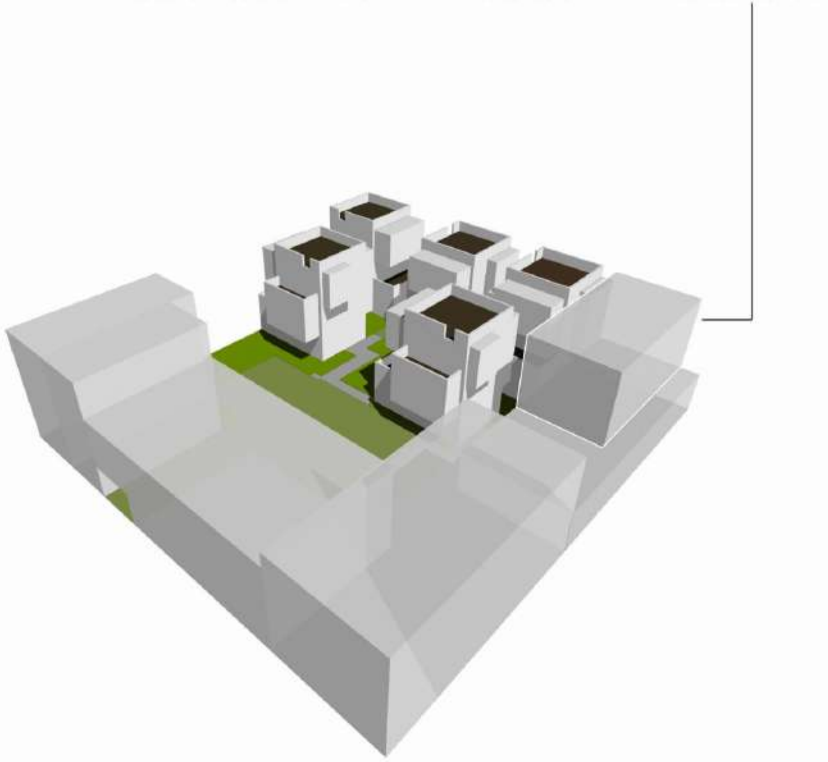


ROW HOUSE

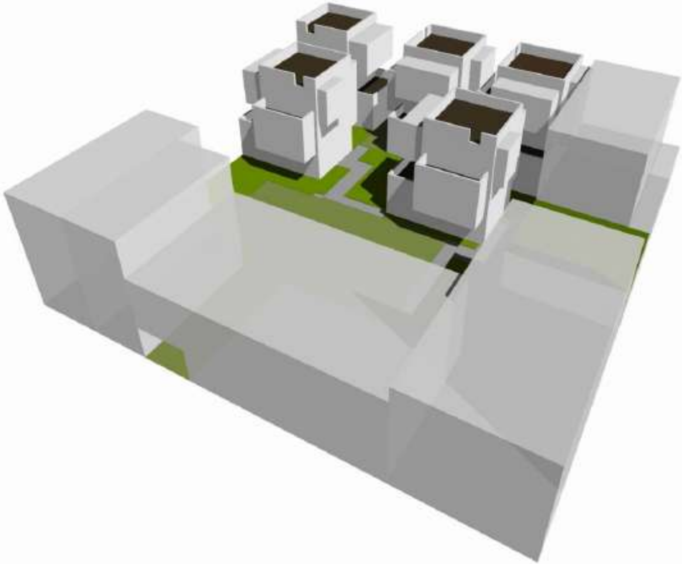
INDUSTRIAL LOFT

TRINITY

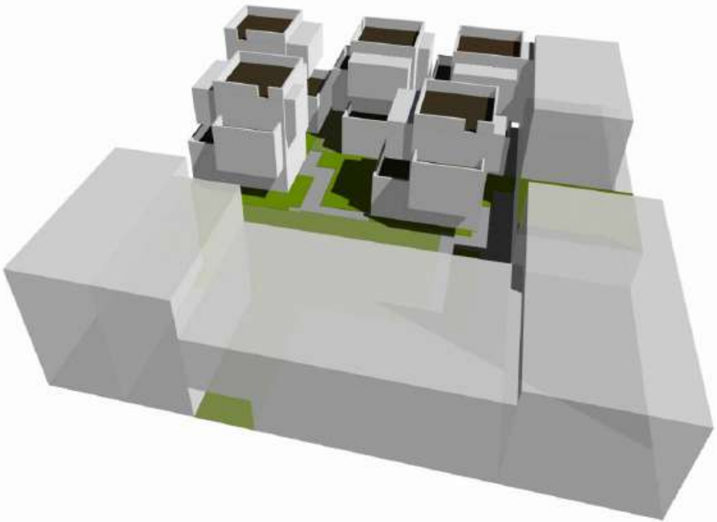
ROW HOUSE INDUSTRIAL LOFT TRINITY PAVILLION

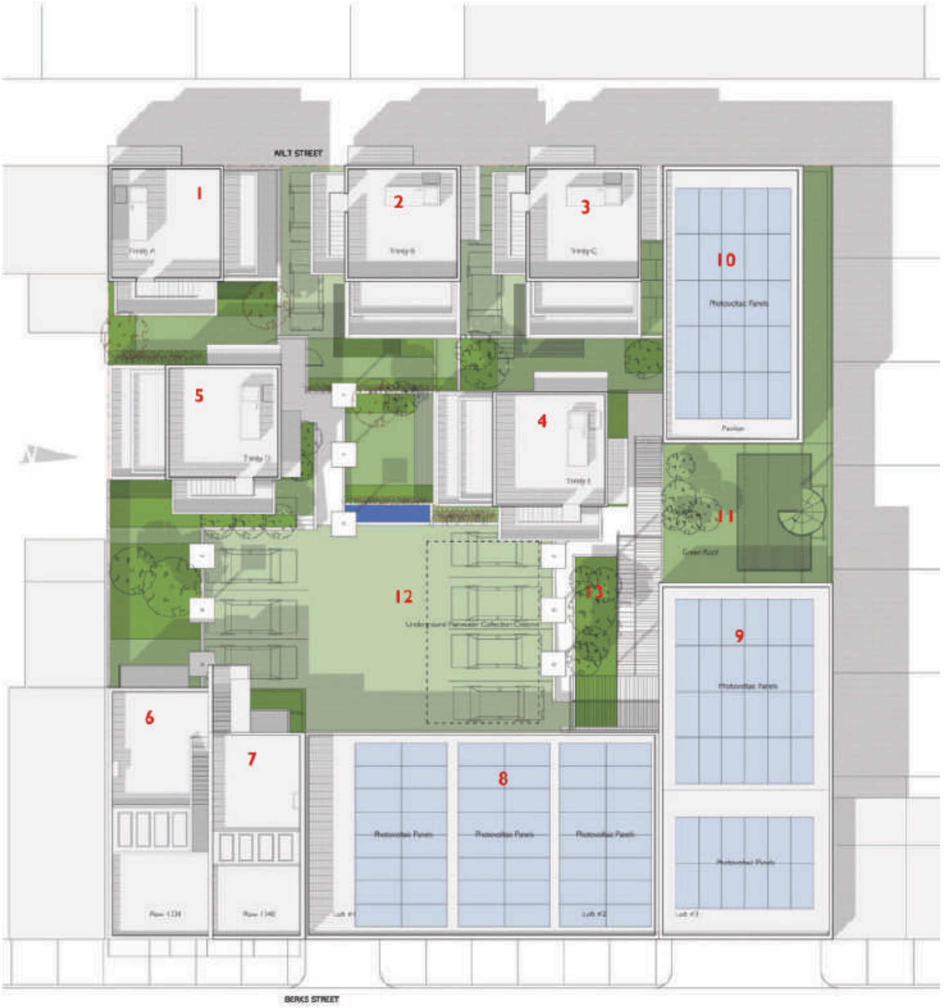


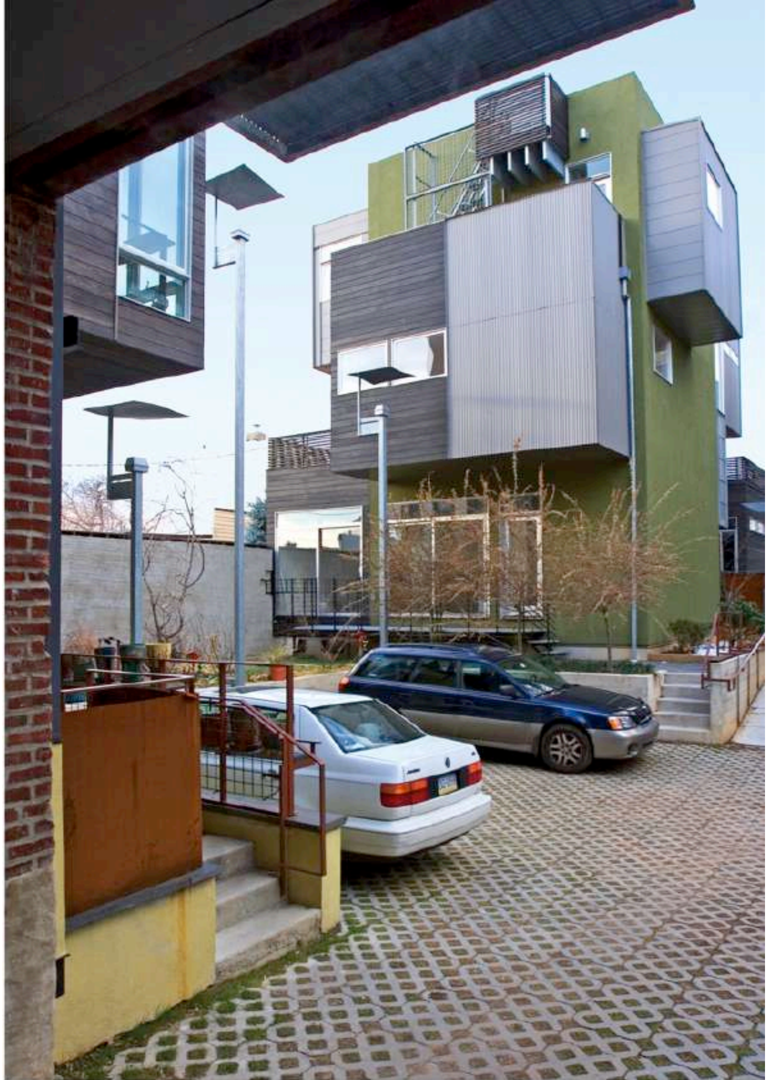
ROW HOUSE INDUSTRIAL LOFT TRINITY PAVILLION

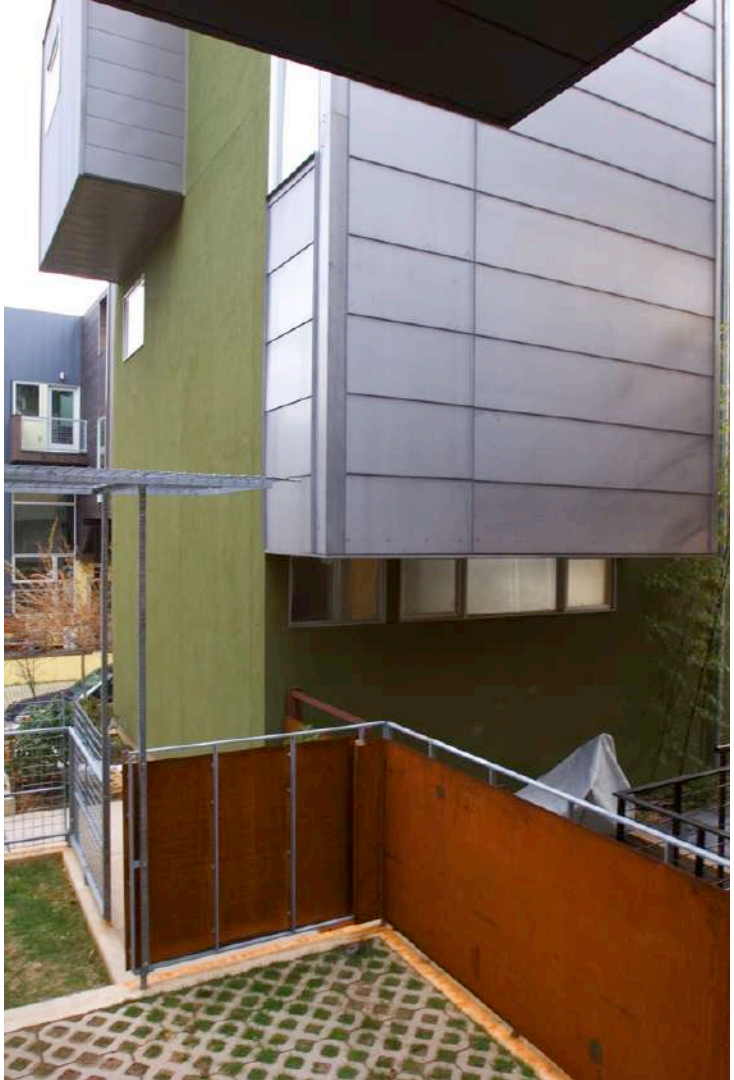


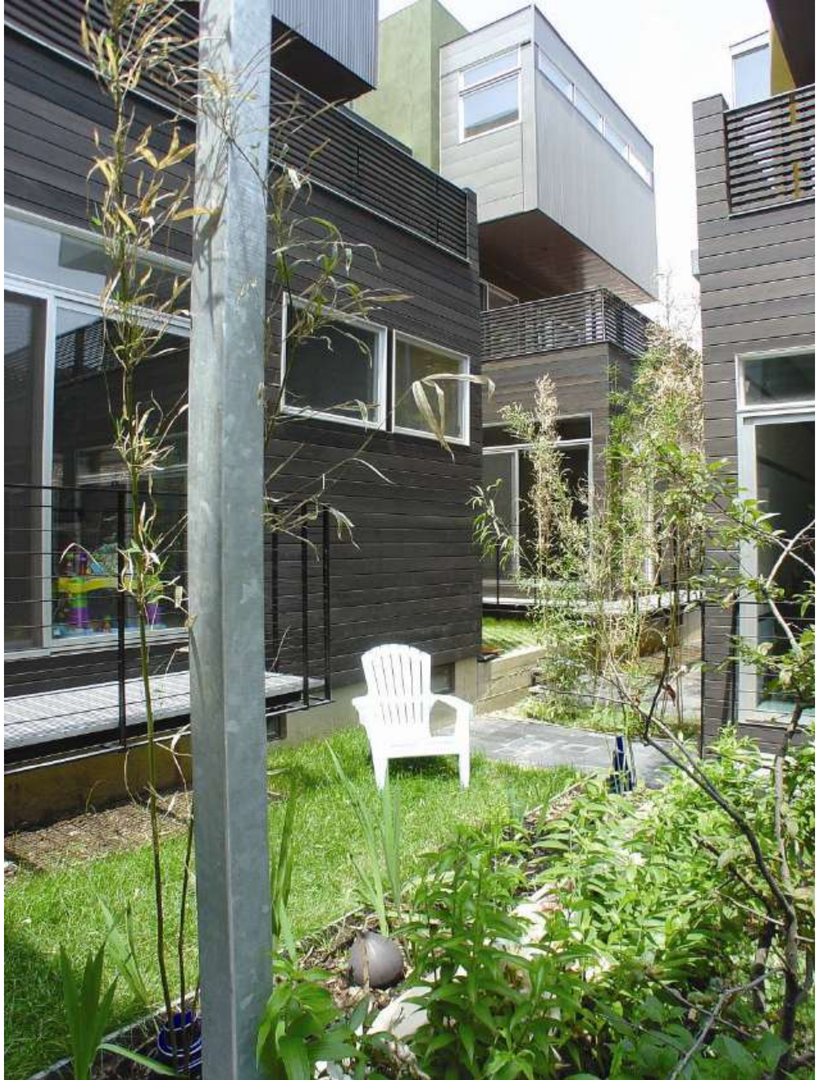
ROW HOUSE INDUSTRIAL LOFT TRINITY PAVILLION




WILT STREET
1
Trinity A
2
Trinity B
3
Trinity C
10
Photovoltaic Panels
Pavilion
5
Trinity D
4
Trinity E
11
Green Roof
12
Underground Rainwater Collection Cisterns
13
9
Photovoltaic Panels
6
7
8
Photovoltaic Panels
Photovoltaic Panels
Photovoltaic Panels
Photovoltaic Panels
Row 1338
Row 1340
Loft #1
Loft #2
Loft #3
N
BERKS STREET





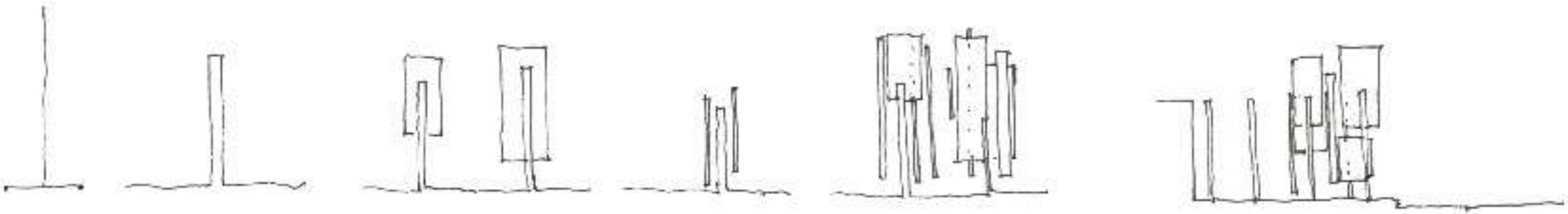


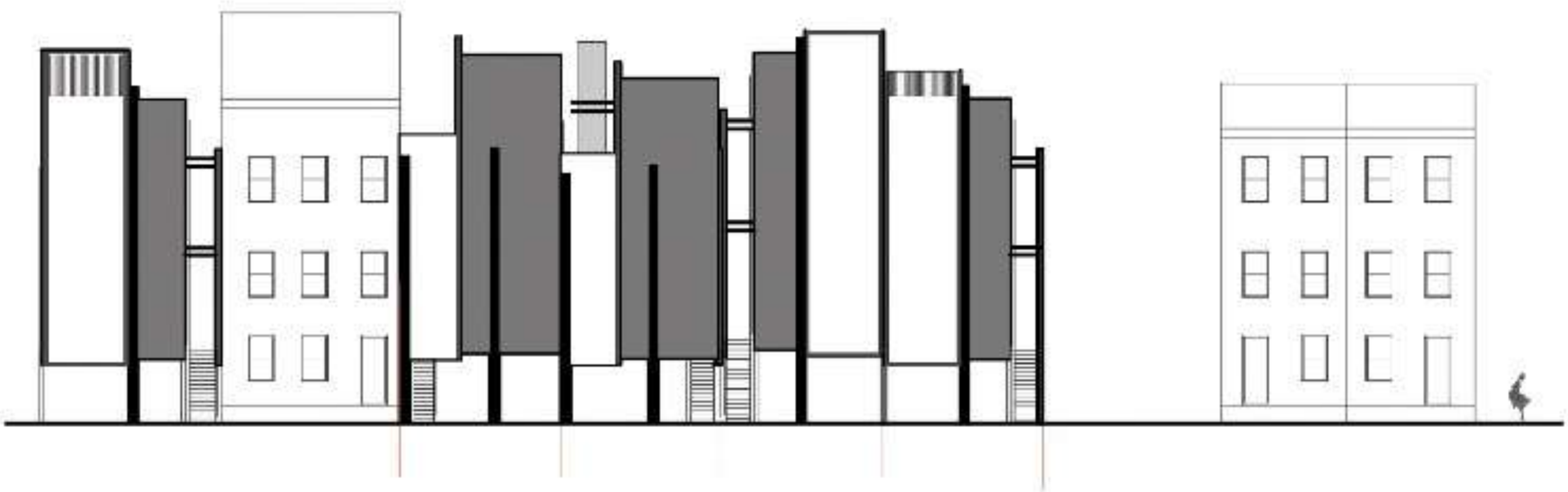


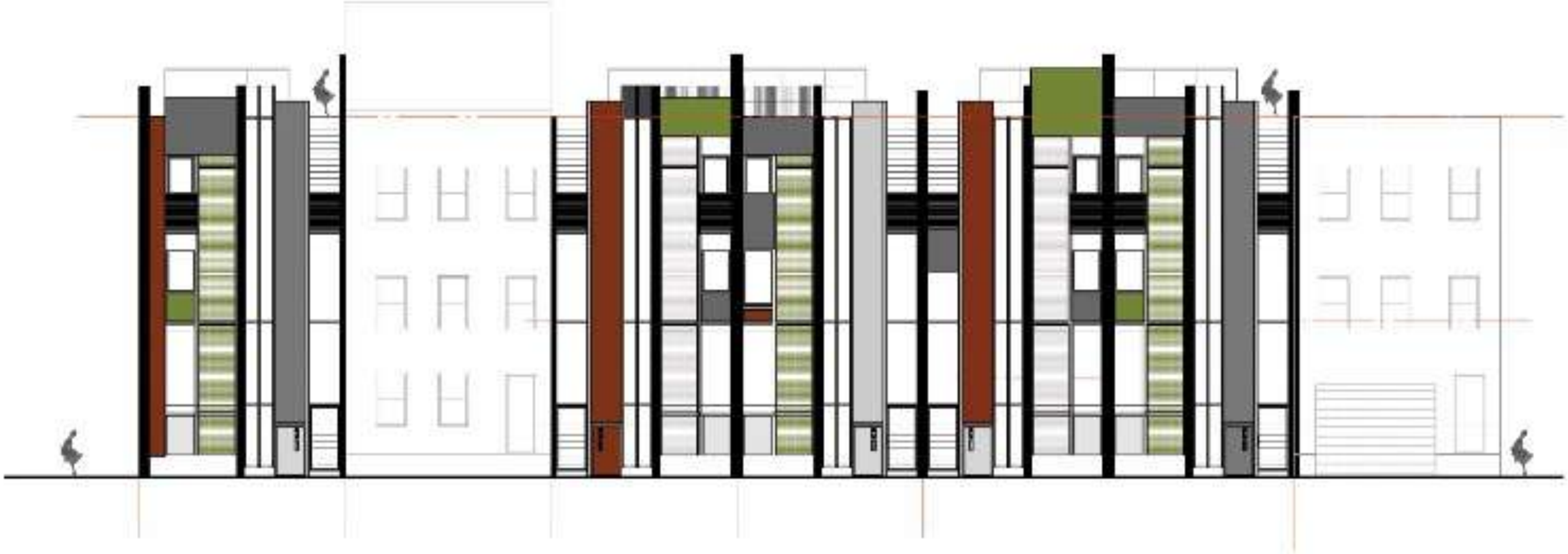
DuPont
Tyvek
HomeWrap

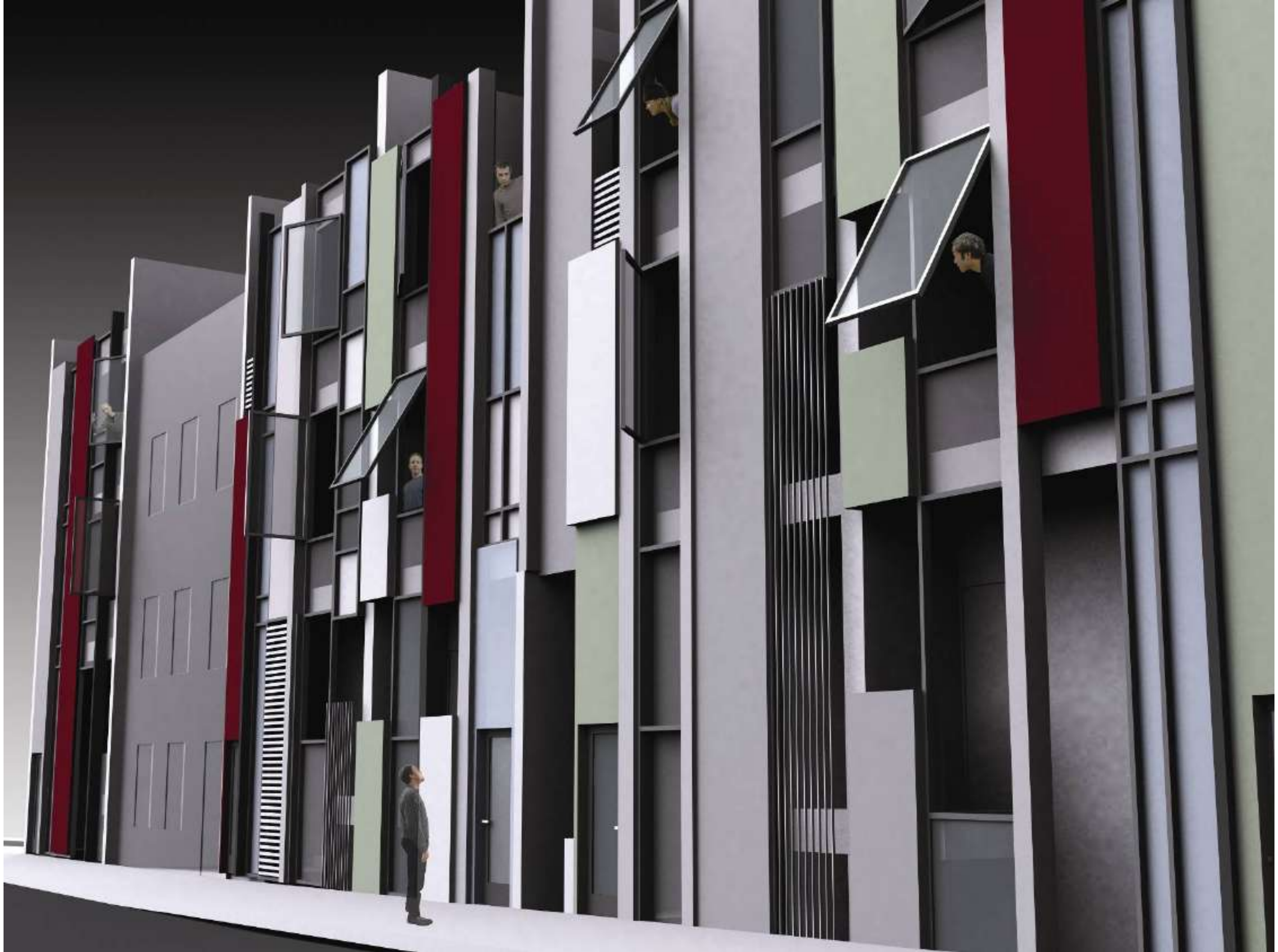
THIN FLATS

THIN FLATS, 2008: 9 units 1STLEED PLATINUM DUPLEXES IN THE USA

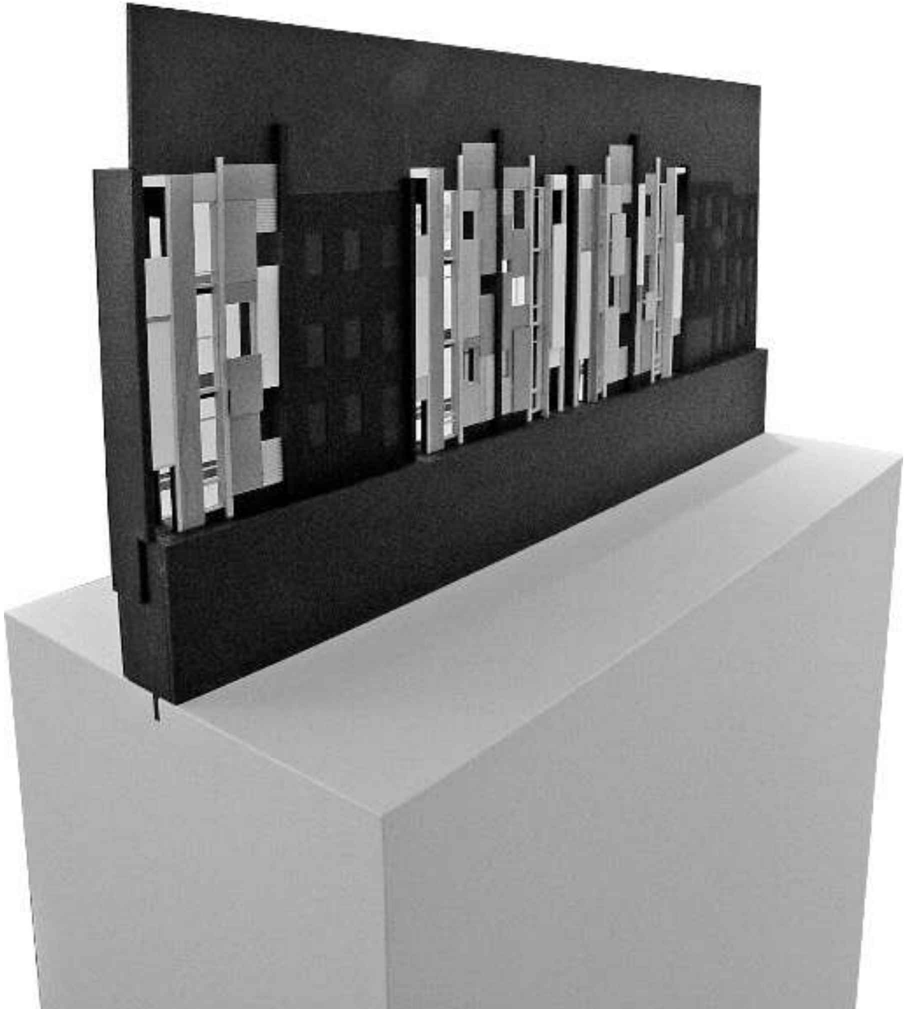




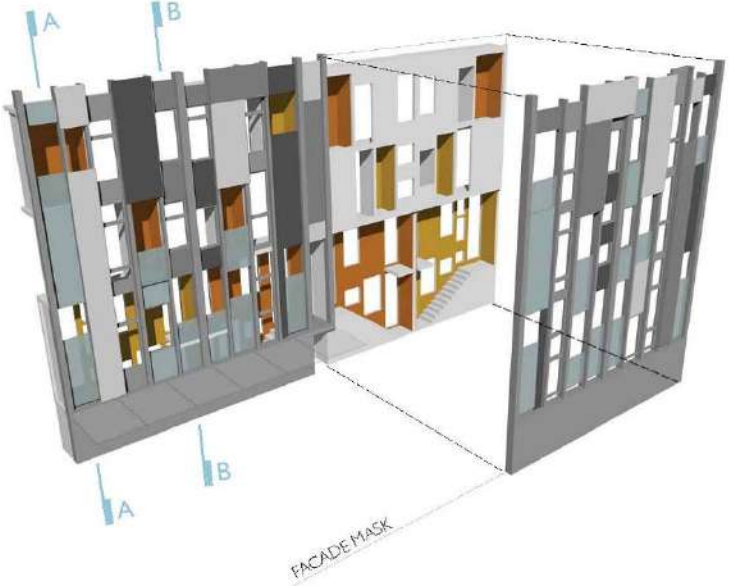


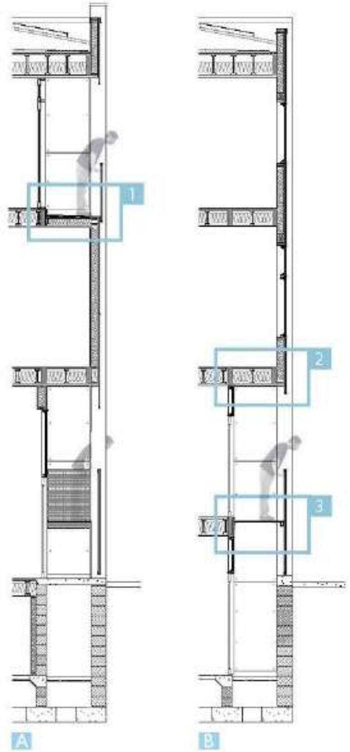


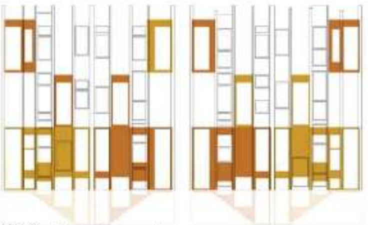

LAUREL
ONE WAY
ONE WAY
STOP

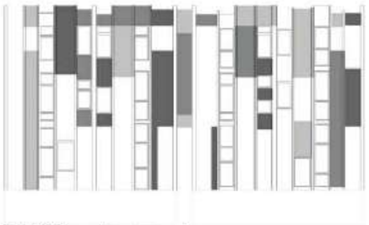


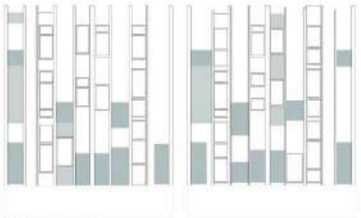

GRACE

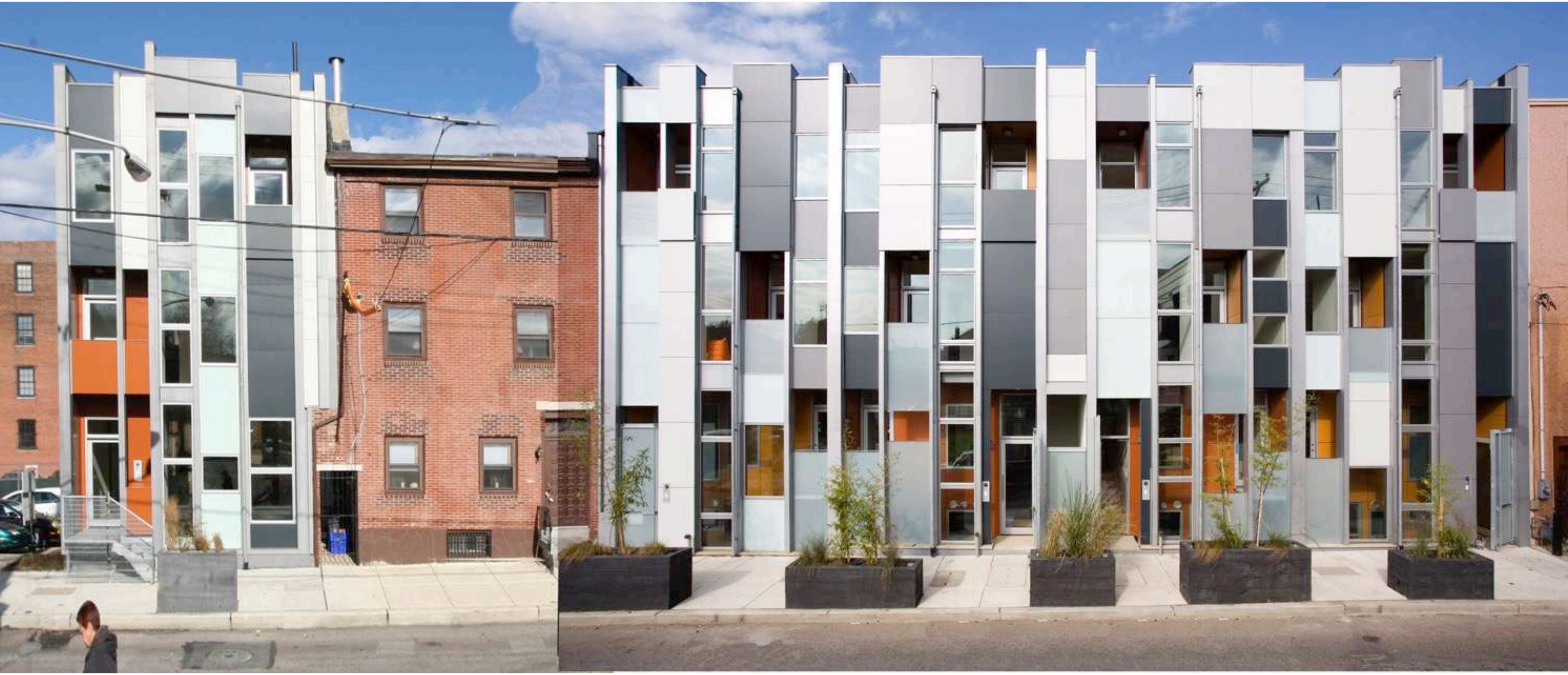





VOID: polychrome trespa panel


SURFACE: monochrome trespa panel

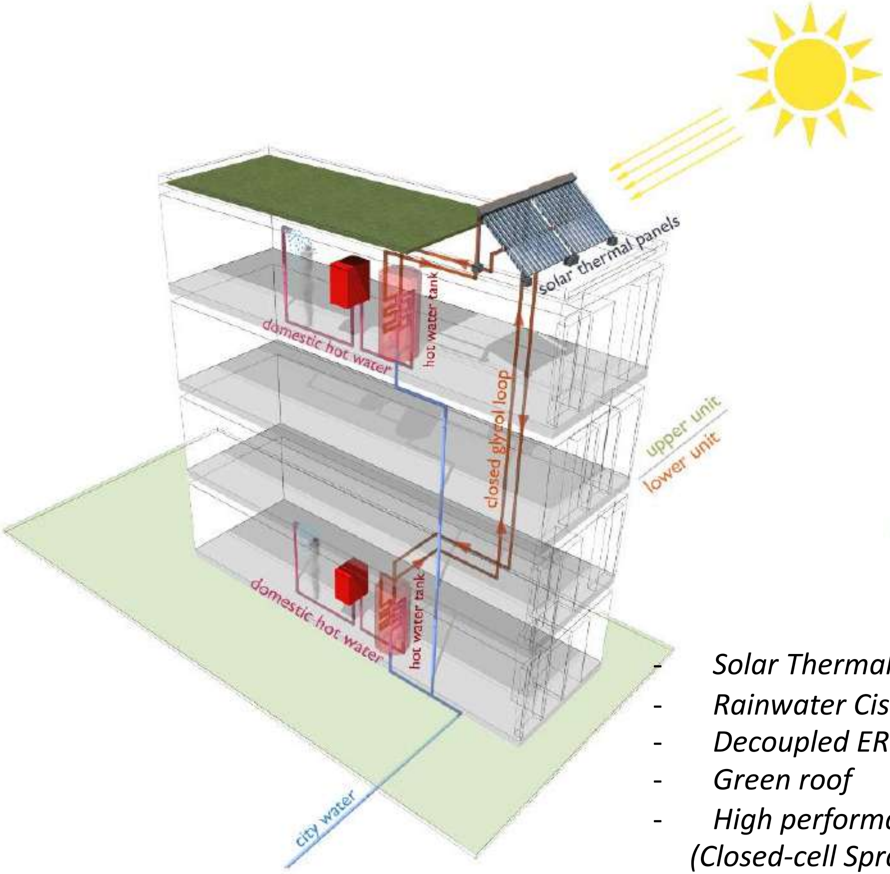

VEIL: translucent glass

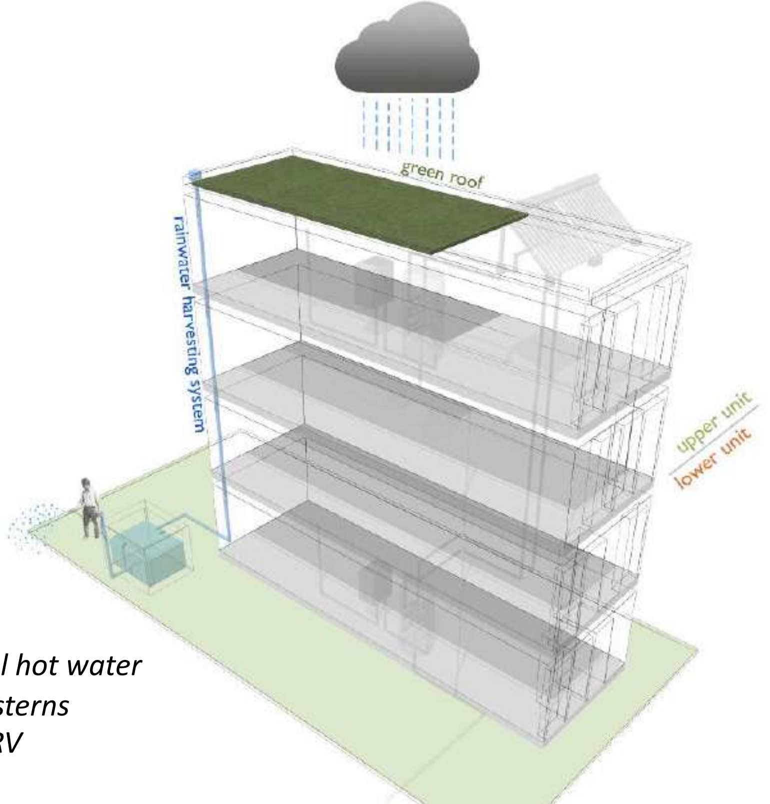


Opening Day, September 14, 2008



UPPER UNIT
LOWER UNIT





- *Solar Thermal hot water*
- *Rainwater Cisterns*
- *Decoupled ERV*
- *Green roof*
- *High performance envelop (Closed-cell Spray foam in walls)*
- *1.2 ACH50*

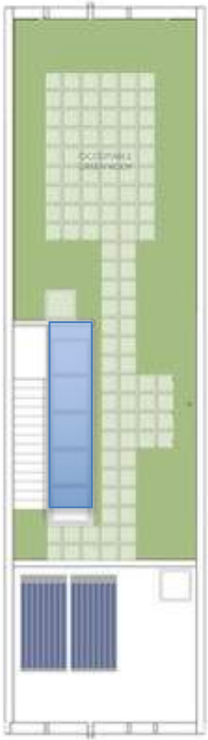
UPPER UNIT

GARDEN LEVEL

1ST LEVEL

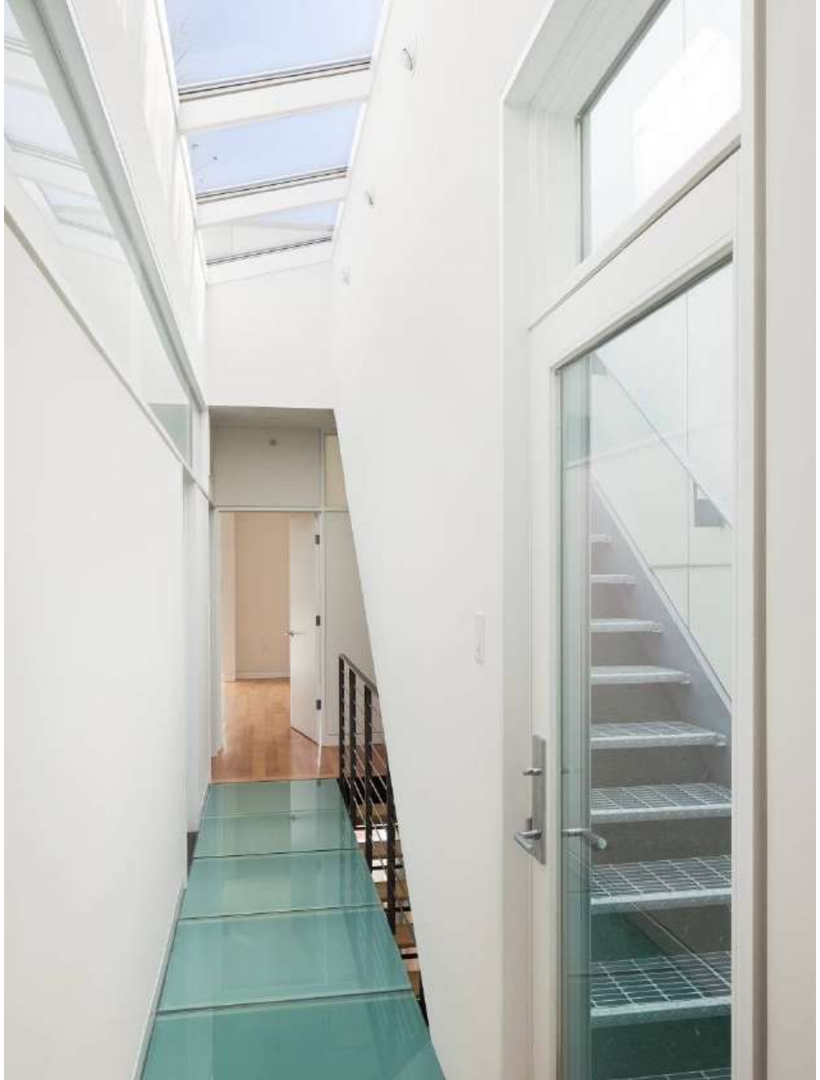
2ND LEVEL

3RD LEVEL



ROOF LEVEL

LOWER UNIT



THIN FLATS

U.S. GREEN BUILDING COUNCIL
LEED PLATINUM
USGBC

THIN FLATS

U.S. GREEN BUILDING COUNCIL
LEED PLATINUM
USGBC

- Sustainable Sites
- Water Efficiency
- Energy & Atmosphere
- Materials & Resources
- Indoor Environmental Quality
- Locations & Linkages
- Awareness & Education
- Innovation in Design
- Regional Priority

Energy & Atmosphere

and contribute **45%** of U.S. GHG emissions

EIA 2012

Ed Mazria, Greenbuild Philly 2013

urban environments emit 75% of global GHGs

UN Habitat

Ed Mazria, Greenbuild Philly 2013

THE NEW GRAVITY

Follow the Leaders, Berlin, Germany 2011, Isaac Cordal, popularly known as “Politicians discussing global warming”

2015 United Nations Climate Conference, ***COP 21***

PARIS, France

".....FIRST year that over 200 countries signed the agreement in global solidarity"

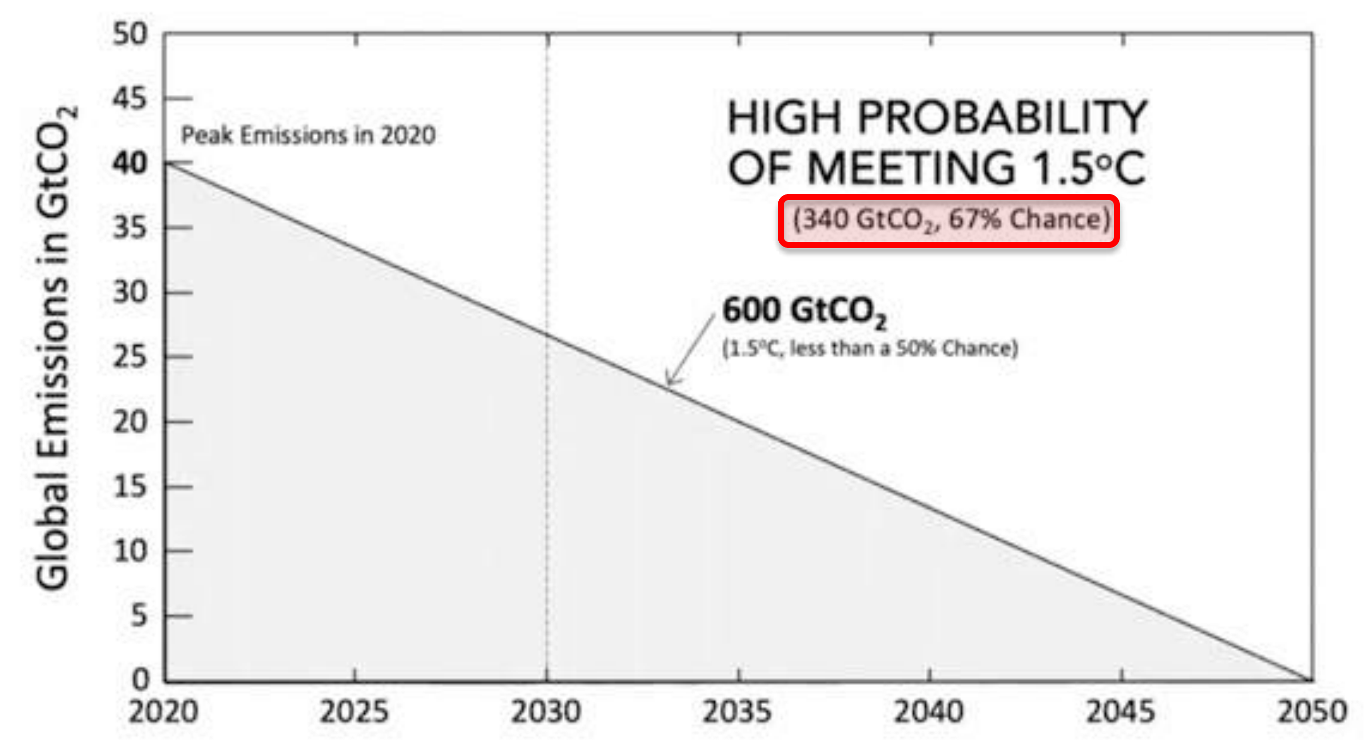
COP27
SHARM EL-SHEIKH
EGYPT 2022

"NZE/CARBON NEUTRAL BUILDINGS AS STANDARD PRACTICE BY 2050"

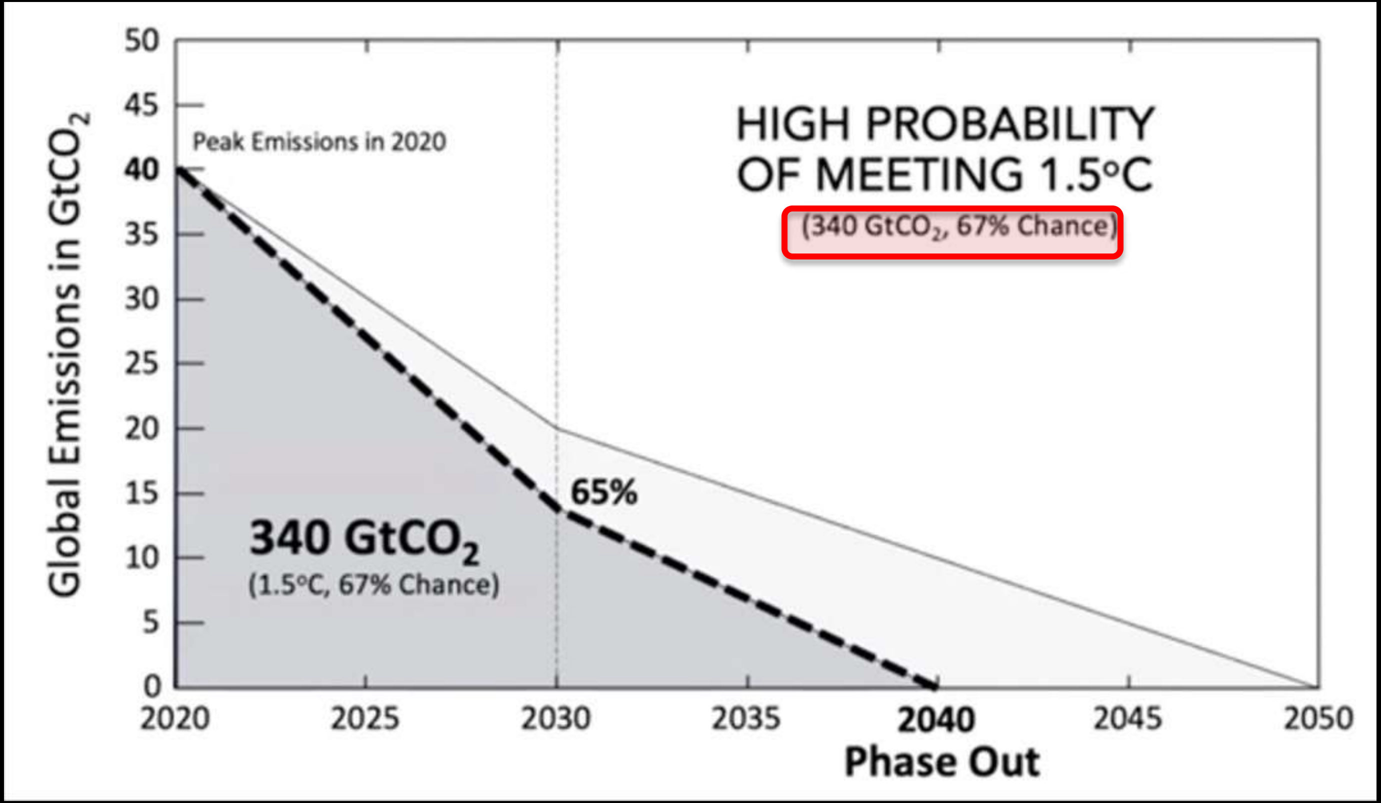
COP27
SHARM EL-SHEIKH
EGYPT 2022

https://www.mcc-berlin.net/en/research/co2-budget.html

“NZE/CARBON NEUTRAL BUILDINGS AS STANDARD PRACTICE BY 2050”



Ed Mazria, New Gravity Conference, 2020



Ed Mazria, New Gravity Conference, 2020

18 YEARS!!!

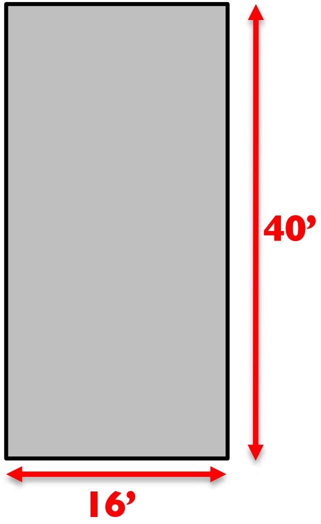
CARBON NEUTRAL BUILDINGS by 2040

18 YEARS!!!

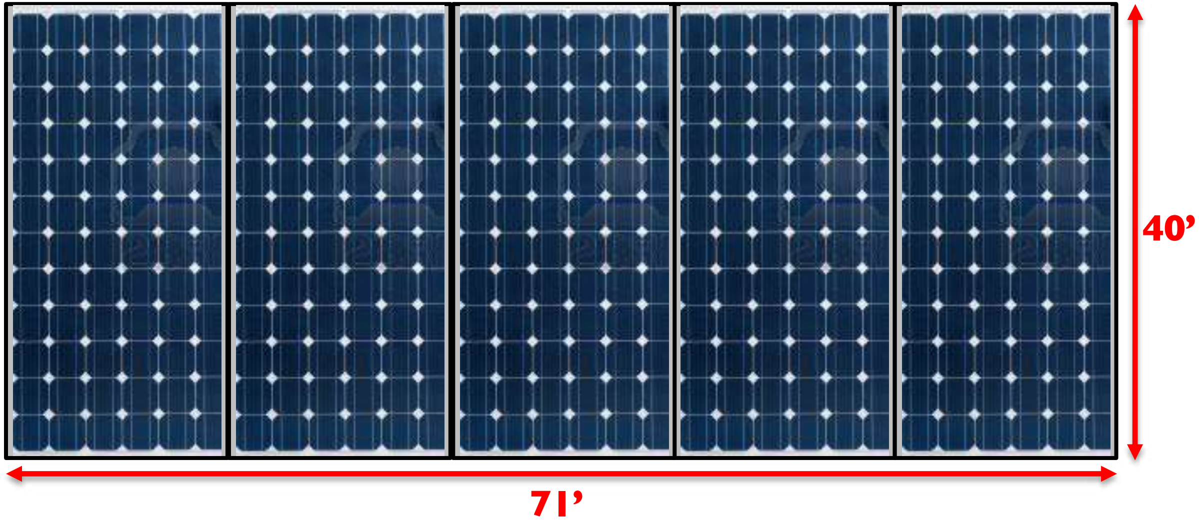
BUILDINGS MUST GENERATE WHAT THEY NEED

CARBON NEUTRAL BUILDINGS by 2040

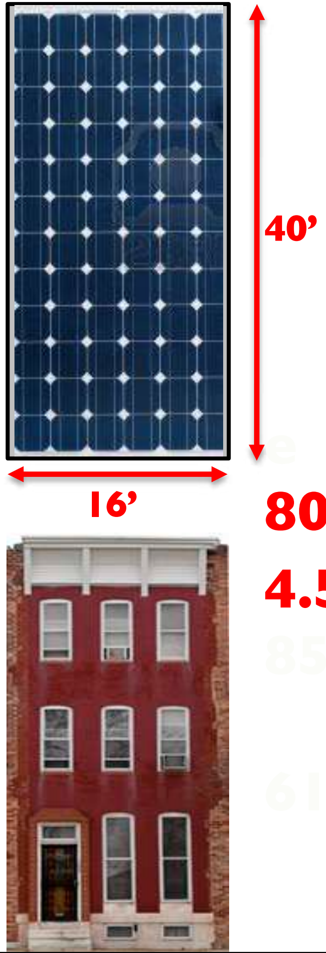
ON THEIR OWN SITE WITH RENEWABLE ENERGY



1900 sf home
39,000 kWh/yr



1900 sf home
39,000 kWh/yr
2832 sf roof



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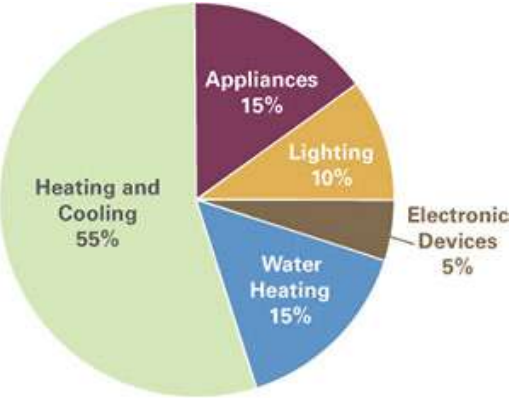
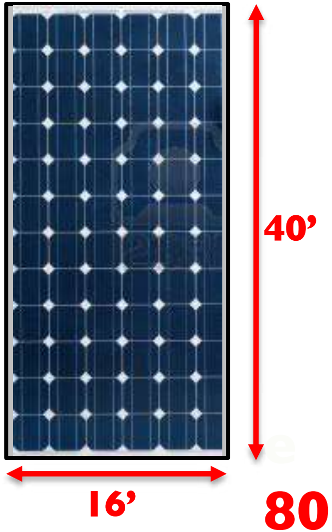
80% REDUCTION

4.5 kWh/sf/yr

8550 kWh/yr

615 sf roof



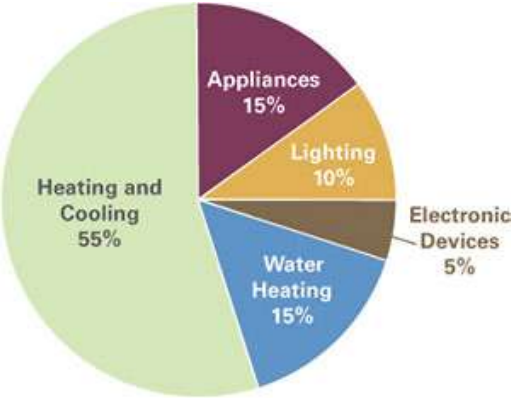


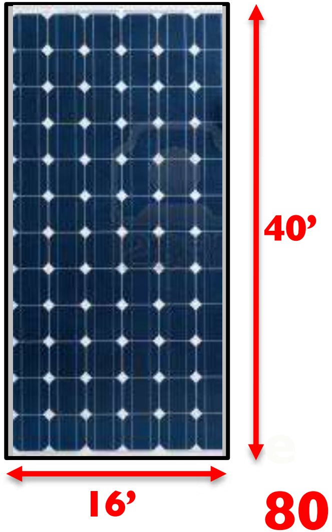
80% REDUCTION

4.5 kWh/sf/yr

8550 kWh/yr

615 sf roof





80% REDUCTION

4.5 kWh/sf/yr

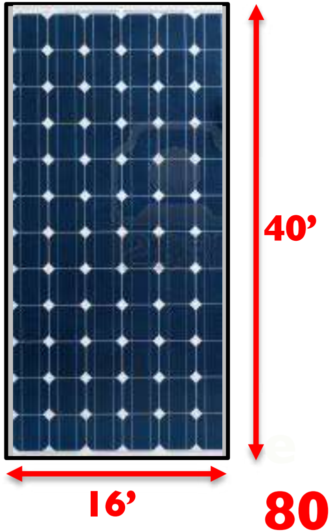
8550 kWh/yr

615 sf roof

Certified
Passive House
Passive House Institute

PHIUS
Passive House Institute US

“Fabric First” approach



80% REDUCTION

4.5 kWh/sf/yr

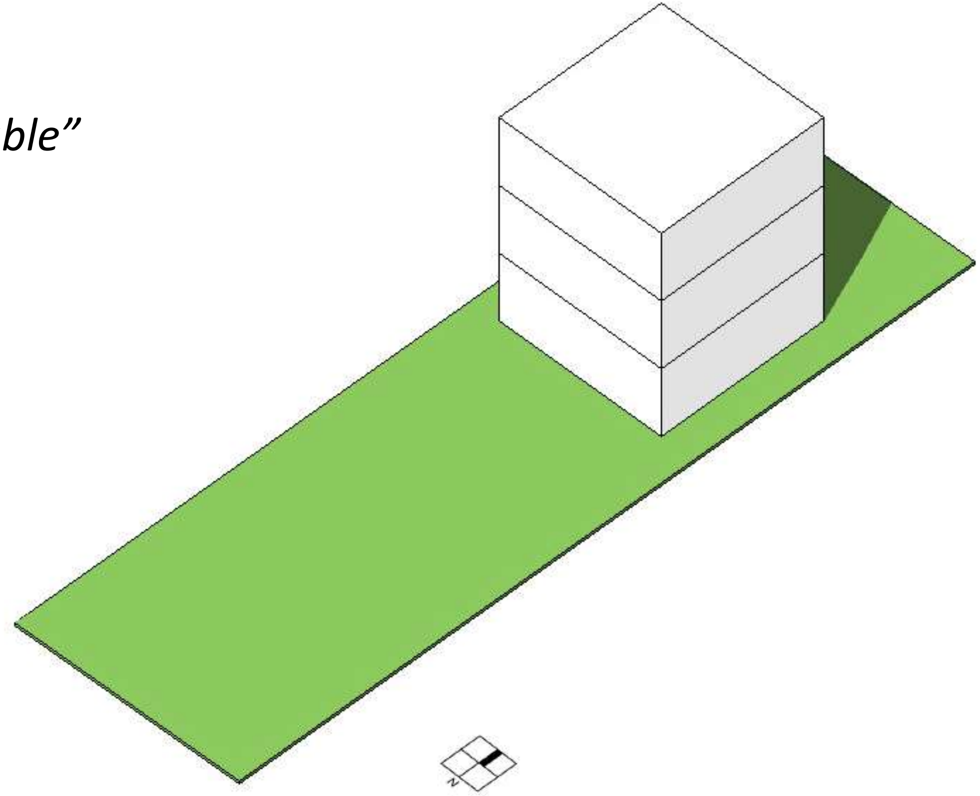
8550 kWh/yr

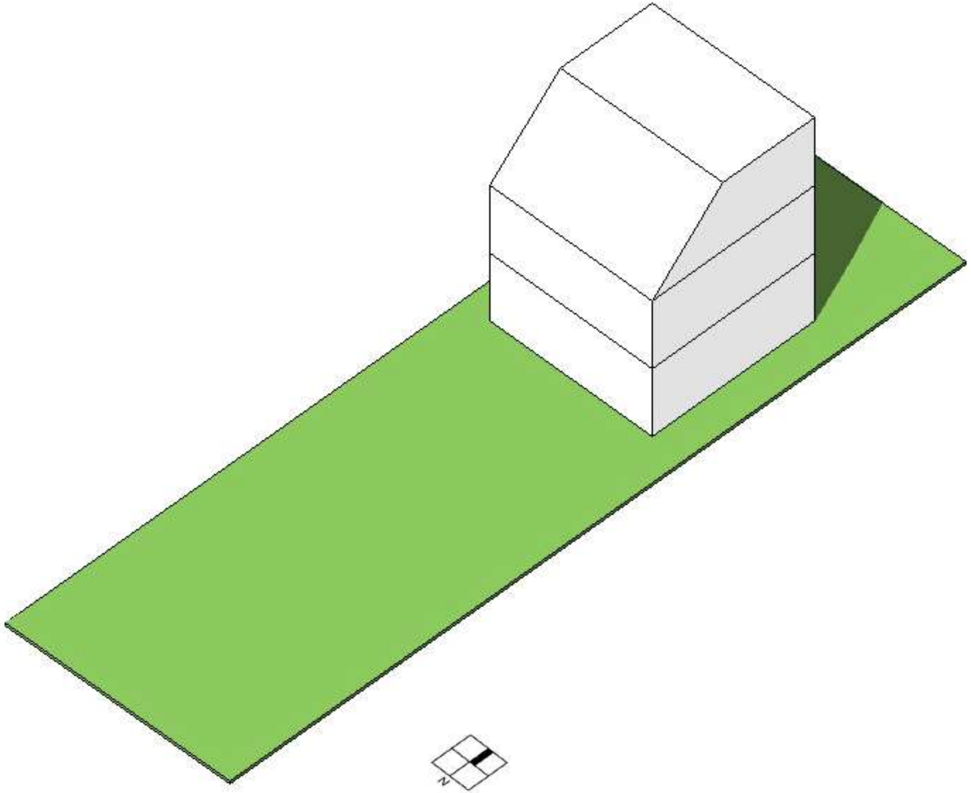
615 sf roof

TED, 2010: FROM THE GROUND UP International Competition, Syracuse NY

Competition Requirements

$150,000 home
"Highly Sustainable"

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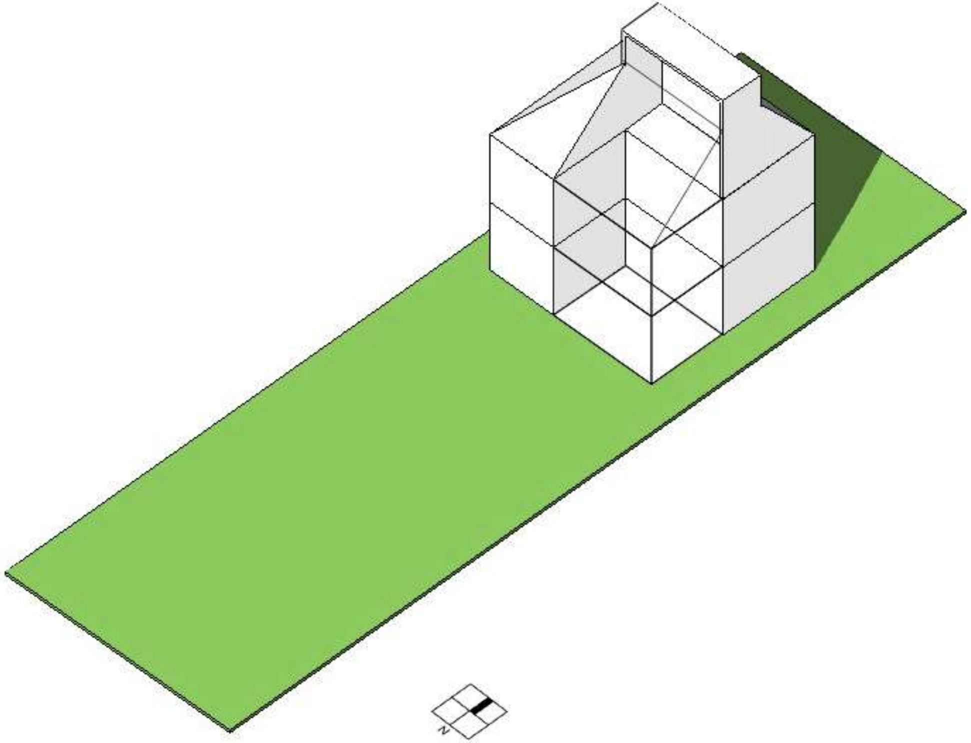
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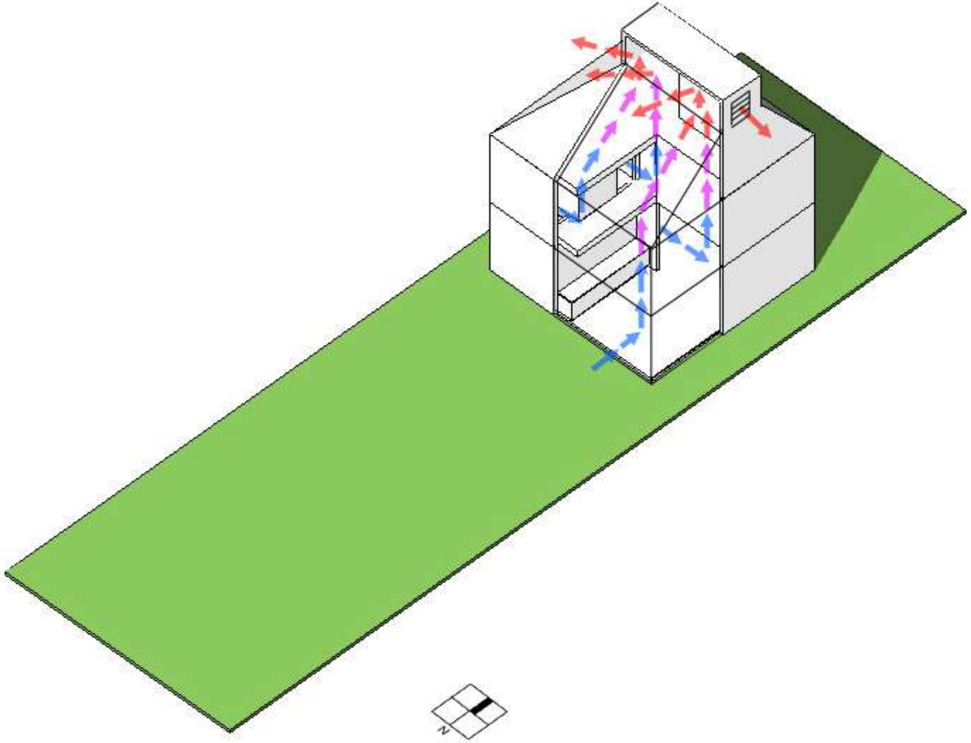
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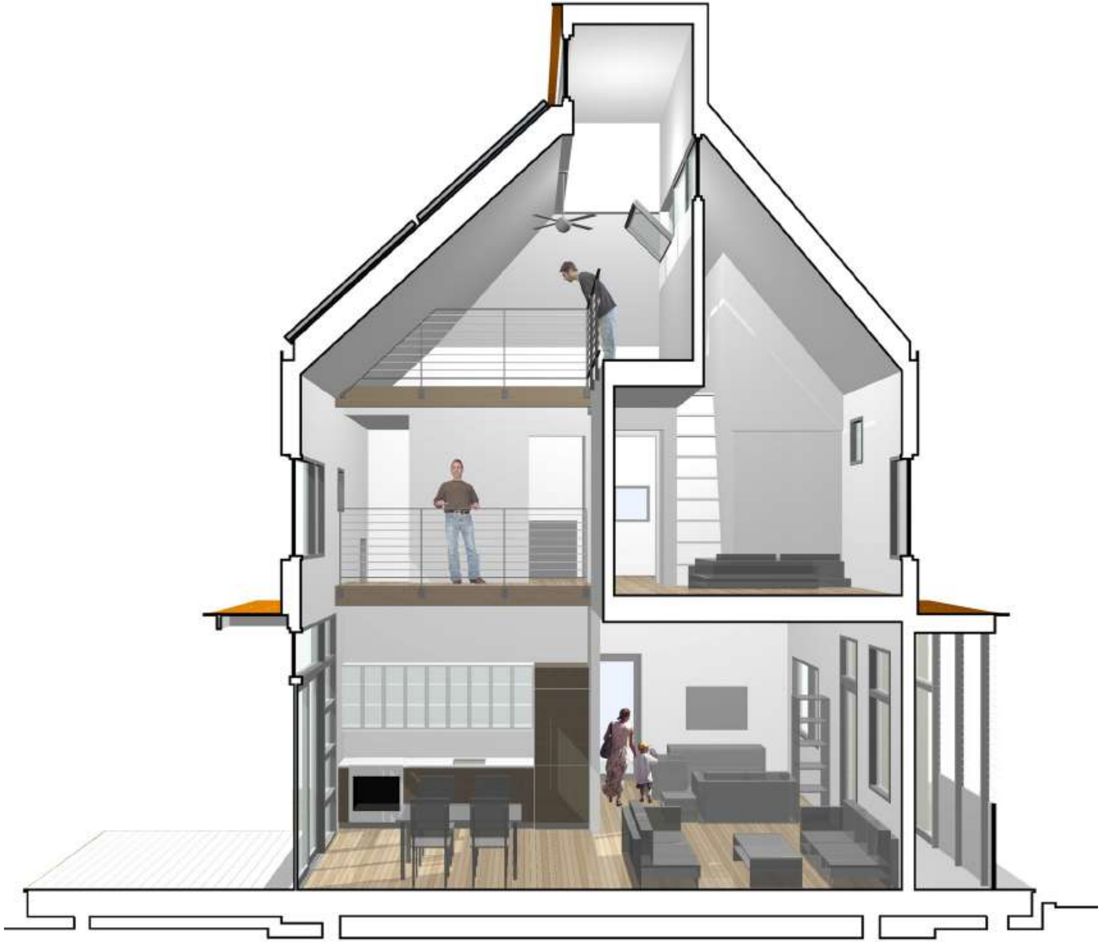


POSSIBLE CONFIGURATIONS

01	A	2 BED, 2 BATH, LOFT	1100 sqft
02	A+F	3 BED, OFFICE, 2 BATH, LOFT	1226 sqft
03	B	3 BED, 2 BATH, LOFT	1100 sqft
04	B+F	4 BED, 2 BATH, LOFT	1226 sqft
05	C	4 BED, 2 BATH, LOFT	1238 sqft
06	C+F	5 BED, 2 BATH, LOFT	1363 sqft
07	D: DUPLEX UNIT 1	1 BED, 1 BATH	576 sqft
	DUPLEX UNIT 2	1 BED, 1 BATH, LOFT	656 sqft
08	D+F: DUPLEX UNIT 1	1 BED, 1 BATH	576 sqft
	duplex unit 2	2 BED 1 BATH, LOFT	787 sqft
09	E:	2 BED, OFFICE, 2 BATH, LOFT	1100 sqft
10	E+F: duplex unit 1	3 BED, OFFICE, 2 BATH, LOFT	1238 sqft

A

BASE UNIT
2 BEDROOM: 1100 SF

B

3 BEDROOM (1 HC ACCESSIBLE): 1100 SF

C

4 BEDROOM: 1238 SF

D

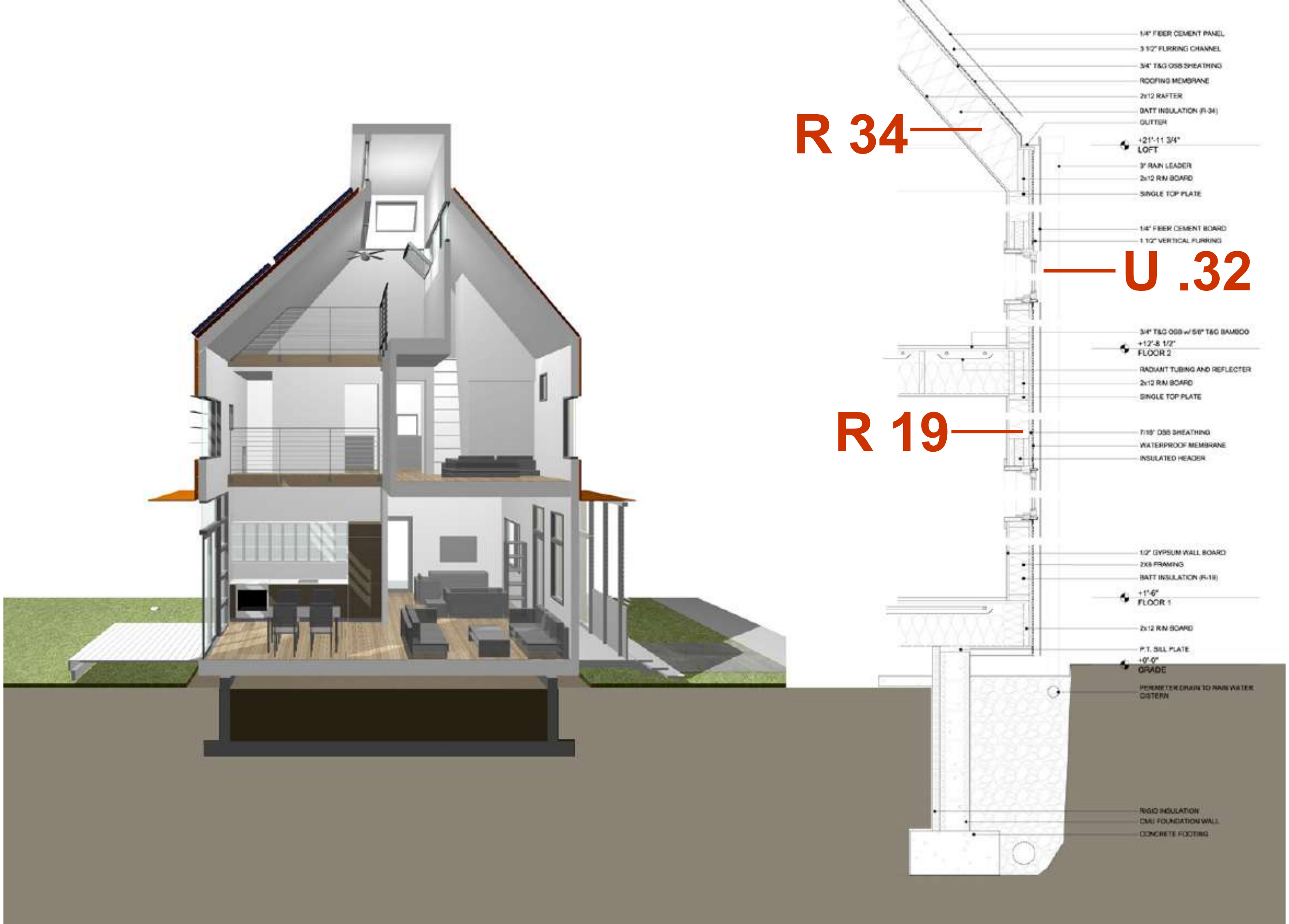
DUPLEX (TWO ONE BEDROOM UNITS): 1238 SF

E

3 BEDROOM, ONE HOME OFFICE: 1238 SF

F

1 BEDROOM WITH ADDITION: 1363 SF MAX

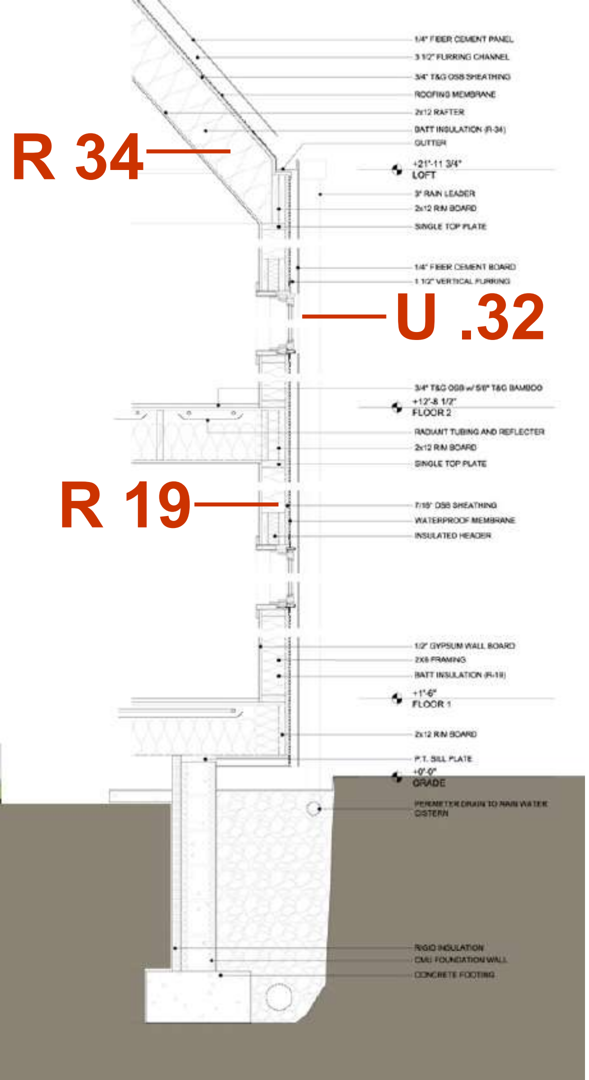

1/4" FIBER CEMENT PANEL
3 1/2" FURRING CHANNEL
3/4" T&G OSB SHEATHING
ROOFING MEMBRANE
2x12 RAFTER
BATT INSULATION (R-34)
GUTTER
+21'-11 3/4"
LOFT
3" RAIN LEADER
2x12 RIM BOARD
SINGLE TOP PLATE
1/4" FIBER CEMENT BOARD
1 1/2" VERTICAL FURRING
3/4" T&G OSB w/ 5/8" T&G BAMBOO
+12'-8 1/2"
FLOOR 2
RADIANT TUBING AND REFLECTER
2x12 RIM BOARD
SINGLE TOP PLATE
7/16" OSB SHEATHING
WATERPROOF MEMBRANE
INSULATED HEADER
1/2" GYPSUM WALL BOARD
2X8 FRAMING
BATT INSULATION (R-19)
+1'-6"
FLOOR 1
2x12 RIM BOARD
P.T. SILL PLATE
+0'-0"
GRADE
PERIMETER DRAIN TO RAIN WATER CISTERN
RIGID INSULATION
CMU FOUNDATION WALL
CONCRETE FOOTING

R 34

U .32

R 19

WIMPY SHELL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BATT INSULATION (R-34)
GUTTER
R 34
+21'-11 3/4"
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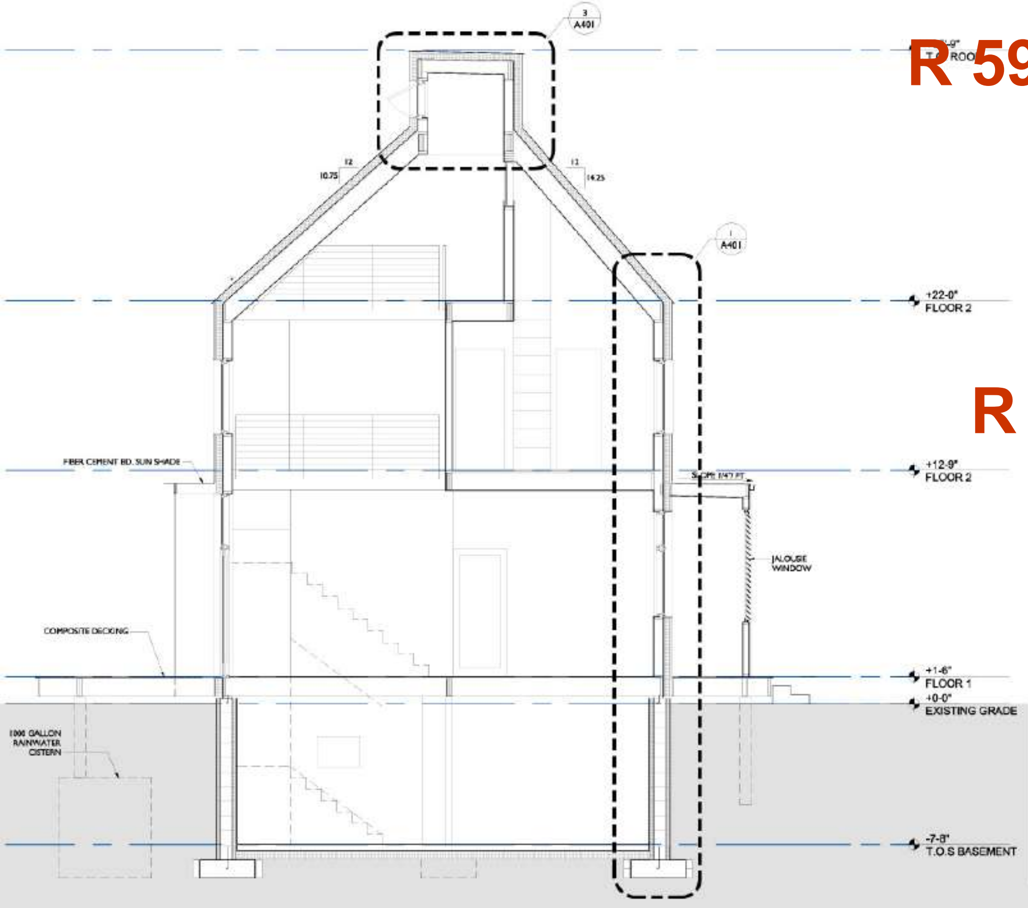
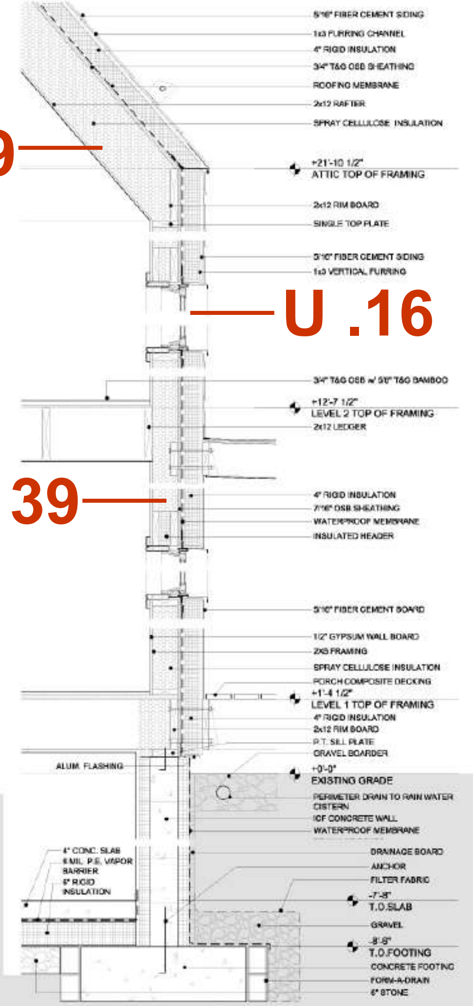
GRADE
PERIMETER DRAIN TO RAIN WATER CISTERN
RIGID INSULATION
CMU FOUNDATION WALL
CONCRETE FOOTING

PASSIVE HOUSE SHELL



② TRANSVERSE SECTION
1/4" = 1'-0"

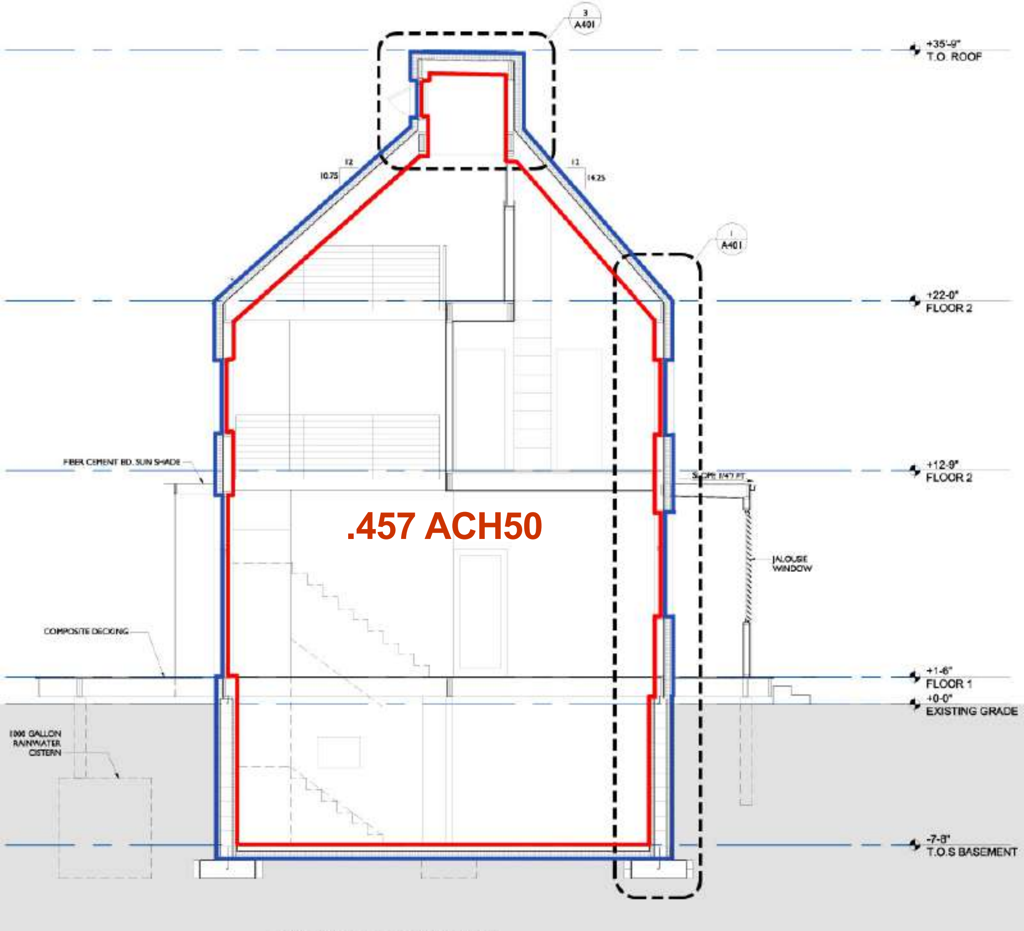


R 59

U .16

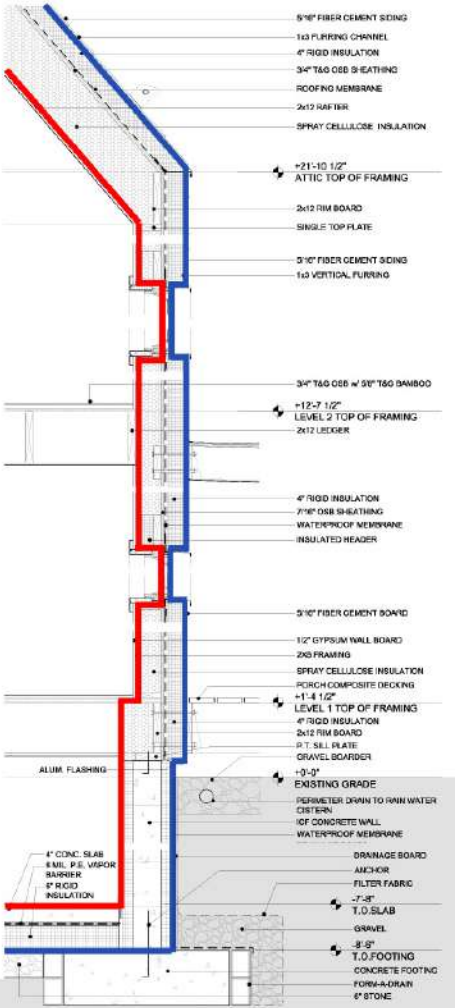
R 39

① WALL SECTION
3/4" = 1'-0"



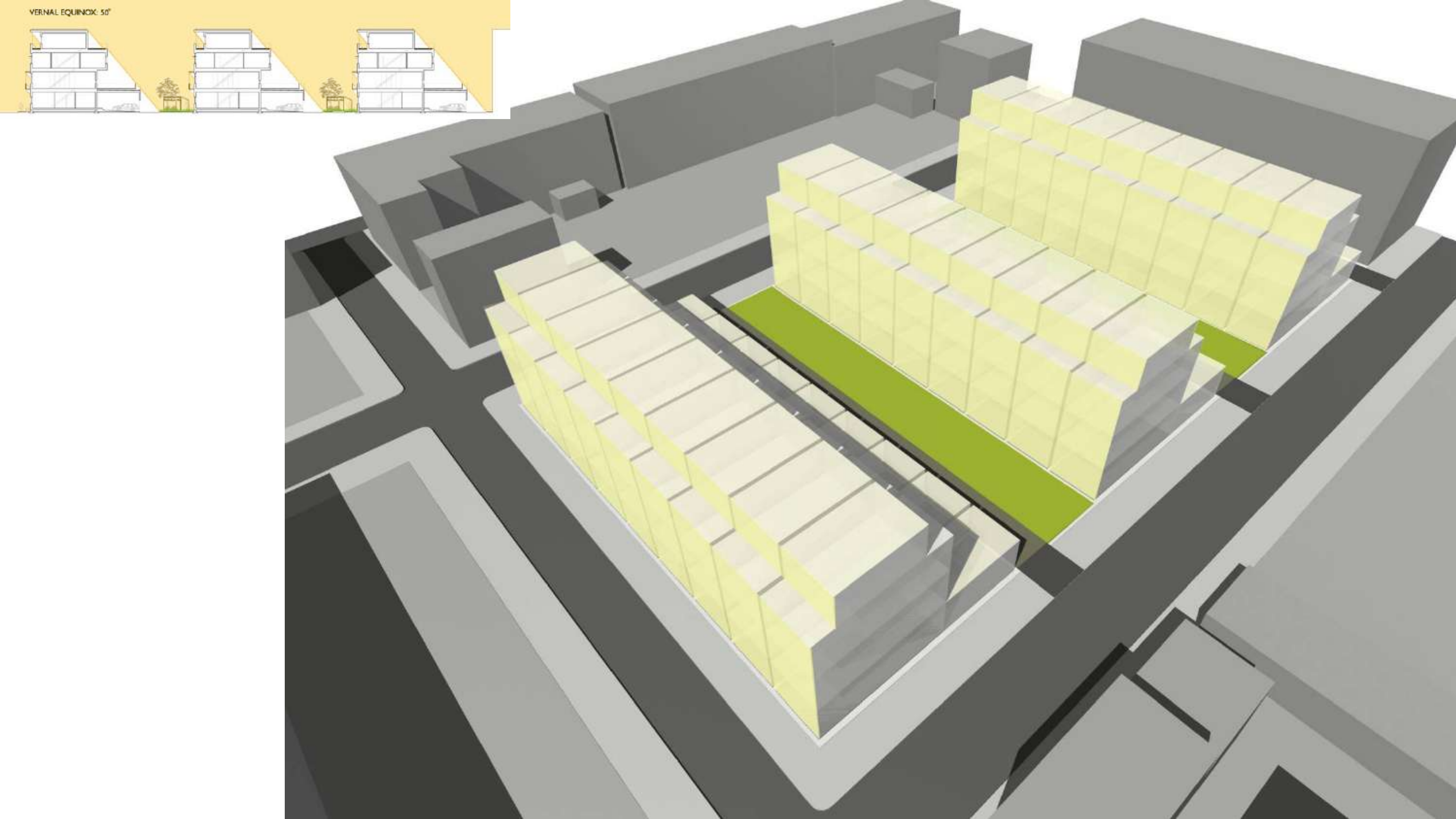
.457 ACH50

② TRANSVERSE SECTION
1/4" = 1'-0"



① WALL SECTION
3/4" = 1'-0"

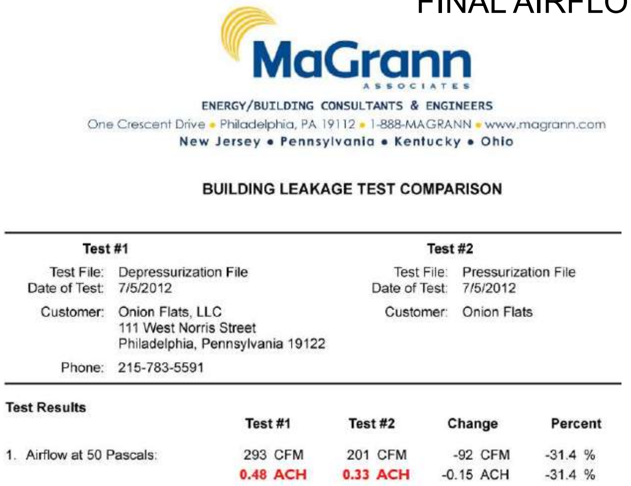
STABLE FLATS 2015: 26 townhomes


VERNAL EQUINOX: 50°


SUMMER SUN
WINTER SUN
solar electric
solar hot water


BODINE STREET
GEORGE ST
ONE WAY

FINAL AIRFLOW **.49 ACH 50**



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New Jersey • Pennsylvania • Kentucky • Ohio

BUILDING LEAKAGE TEST COMPARISON

Test #1

Test File: Depressurization File
Date of Test: 7/5/2012
Customer: Onion Flats, LLC
111 West Norris Street
Philadelphia, Pennsylvania 19122
Phone: 215-783-5591

Test #2

Test File: Pressurization File
Date of Test: 7/5/2012
Customer: Onion Flats

Test Results

	Test #1	Test #2	Change	Percent
1. Airflow at 50 Pascals:	293 CFM	201 CFM	-92 CFM	-31.4 %
	0.48 ACH	0.33 ACH	-0.15 ACH	-31.4 %

** 12 Months of Measured Data*

$150.00 sf

Address	TFA sf	12 Months kWh Total	PV kWh	NET	COST $/Yr
235 George	1908	13,088	4172	8916	$1079 **$90/m**
Typical Code Building		**40,068**	**68% BETTER**		**$4407** **$367/m**

BELFIELD HOMES
PHILADELPHIA, PENNSYLVANIA 19141

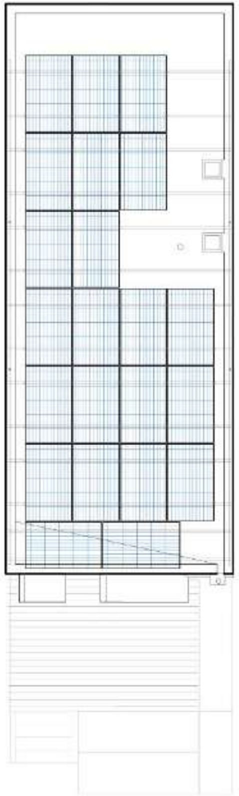
ONION FLATS

NON-PROFIT
COMMUNITY
ORGANIZATION

RAISE OF HOPE

PHILADELPHIA
REDEVELOPMENT
AUTHORITY

BELFIELD TOWNHOMES, 2006: 3 subsidized housing units



UNIT ROOF LVL

UNIT PLAN LVL 3

UNIT PLAN LVL 2

UNIT PLAN LVL 1

FIRST

CERTIFIED

PASSIVE HOUSE
IN
PENNSYLVANIA

START: APRIL 20, 2012

CERTIFICATE OF OCCUPANCY: JULY 20, 2012

2014
Passive House Award
Award Recipient
Passive House Institute

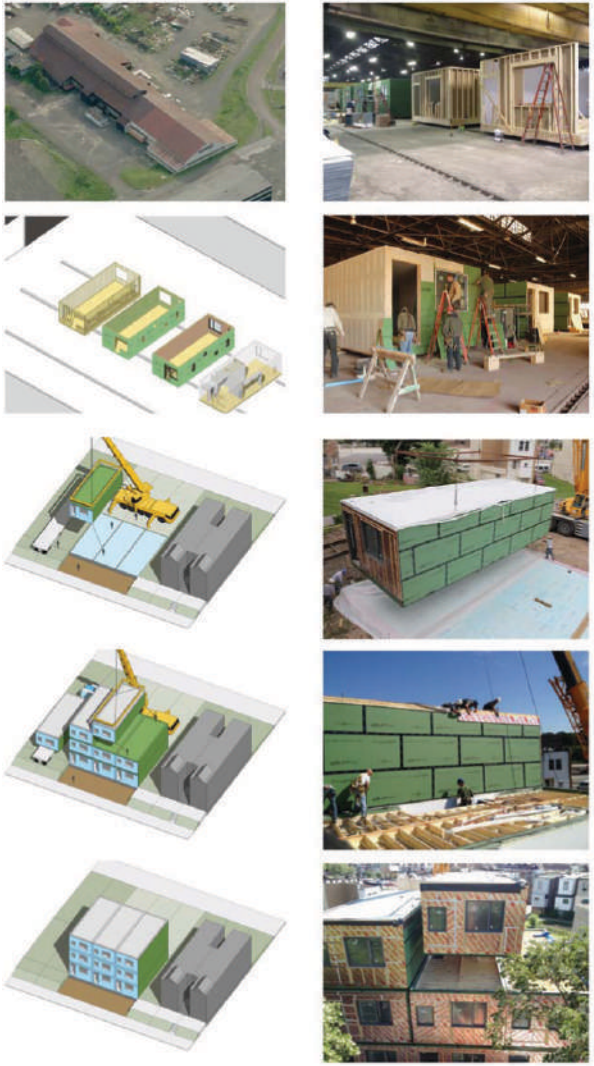
Certified
Passive House
Passive House Institute

RECIPIENT OF THE
2014 INTERNATIONAL
PASSIVE HOUSE AWARD

PHIUS
Passive House Institute US

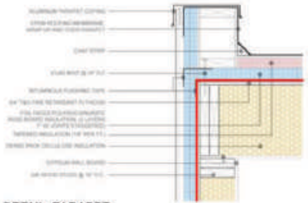
SECOND PLACE WINNER
2015 PHIUS AWARD
"AFFORDABLE HOUSING"

AIA
2013
HONOR
AWARD

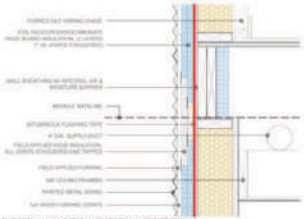


FACTORY BUILD

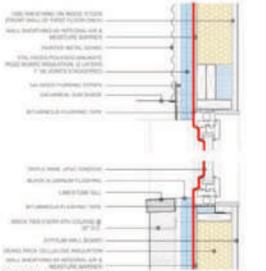
SITE ASSEMBLE



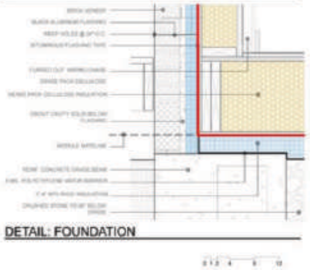
DETAIL: PARAPET



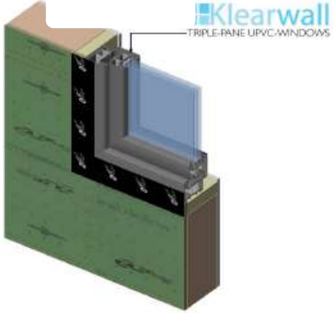
DETAIL: MODULE CONNECTION

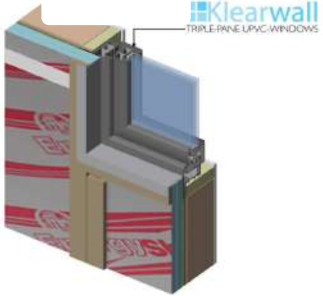


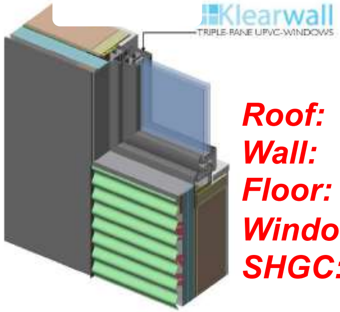
DETAIL: WINDOW



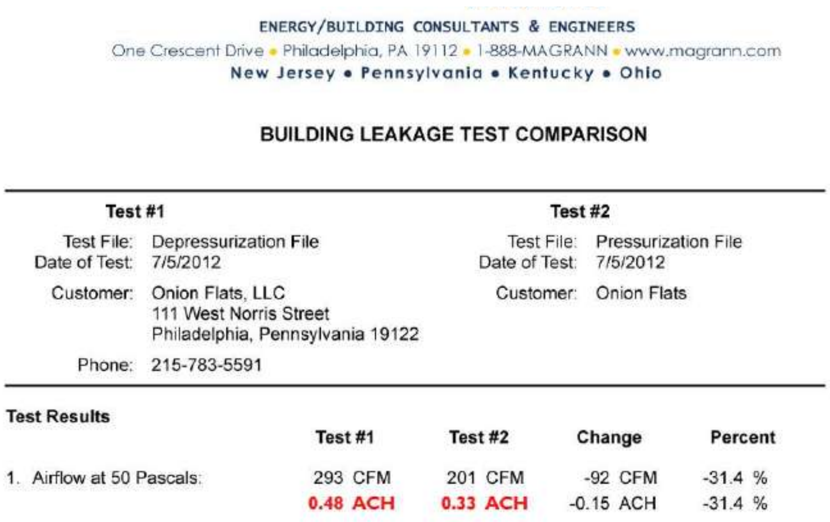
DETAIL: FOUNDATION







Roof: R52.3
Wall: R33.6
Floor: 58.4
Window: .11
SHGC: .63



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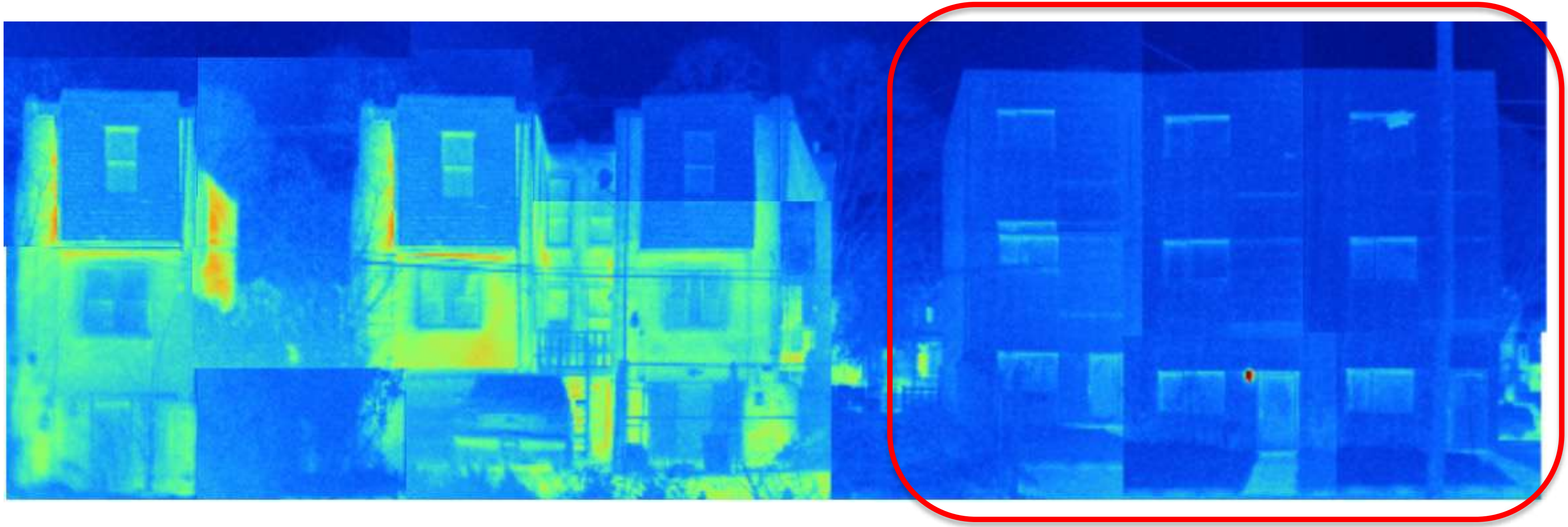
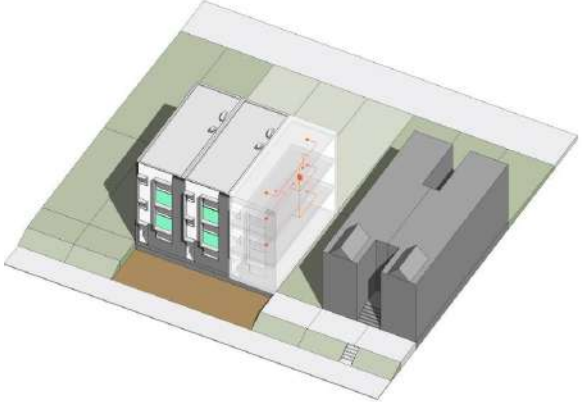
	0.48 ACH	**0.33 ACH**	-0.15 ACH	-31.4 %

FINAL AIRFLOW: **0.405 ACH 50**

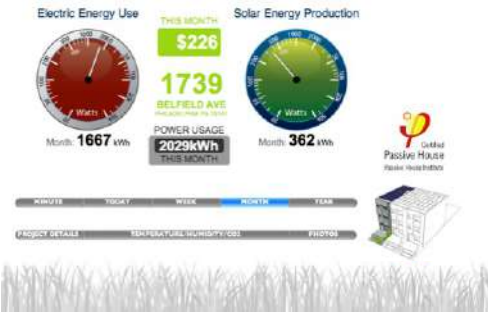
PASSIVE HOUSE MAX **0.6 ACH 50**





Sensors

	Name	Last Reading	Type
●	Unit 1; LVL1-LivingRm	73°F	Temperature
●	Unit 1; LVL1-Hall	75°F	Temperature
●	Unit 1; LVL1-BedRm (Back)	73°F	Temperature
●	Unit 2; LVL2-BedRm (Back)	75°F	Temperature
●	Unit 2; LVL2-Hall	73°F	Temperature
●	Unit 1; LVL2-WashRm	75°F	Temperature
●	Unit 2; LVL2-BedRm (Frnt)	73°F	Temperature
●	Unit 2; LVL3-Mech Rm	75°F	Temperature
●	Unit 2; LVL3-BedRm (Frnt)	73°F	Temperature
●	Unit 2; LVL3-Office (Back)	75°F	Temperature
●	Unit 2: LVL 3 - Mech Rm; Inside Retrun Air Duct	77°F	Temperature
●	Unit 2: LVL 3 - Mech Rm; Inside Retrun Air Duct	450 ppm	VOC
●	Unit 2: LVL 3 - Mech Rm; Inside Retrun Air Duct	%	Humidity
●	Unit 1; LVL1-Hall	453 ppm	VOC
●	Unit 1; LVL1-Hall	45%	Humidity
●	Unit 1; LVL2-WashRm	450 ppm	VOC
●	Unit 1; LVL2-WashRm	44%	Humidity



Electric Energy Use

Month: 1667 kWh

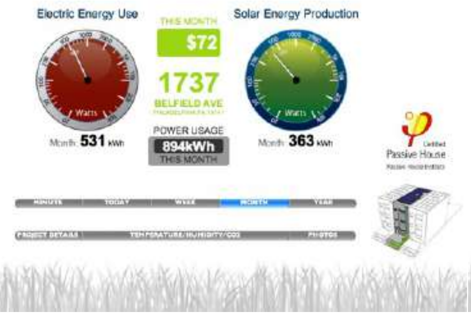
THIS MONTH $226

1739 BELFIELD AVE

POWER USAGE 2029kWh THIS MONTH

Solar Energy Production

Month: 362 kWh



Electric Energy Use

Month: 531 kWh

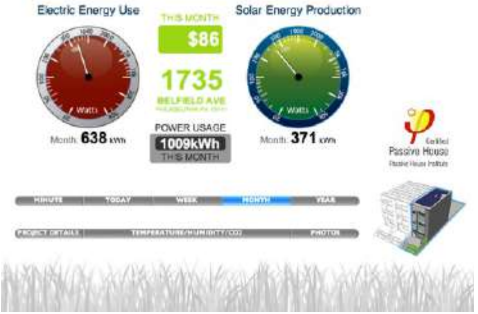
THIS MONTH $72

1737 BELFIELD AVE

POWER USAGE 894kWh THIS MONTH

Solar Energy Production

Month: 363 kWh



Electric Energy Use

Month: 638 kWh

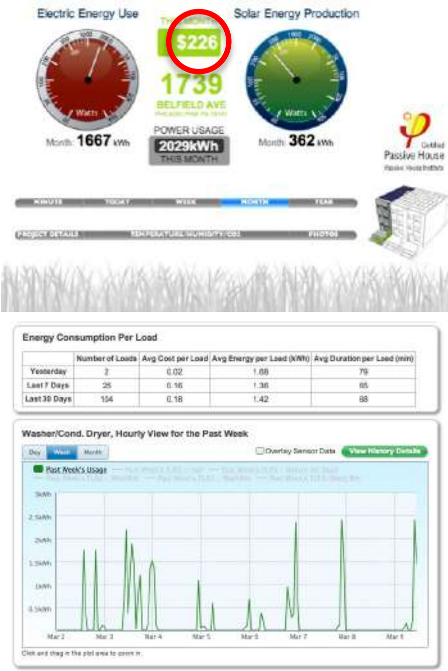
THIS MONTH $86

1735 BELFIELD AVE

POWER USAGE 1009kWh THIS MONTH

Solar Energy Production

Month: 371 kWh

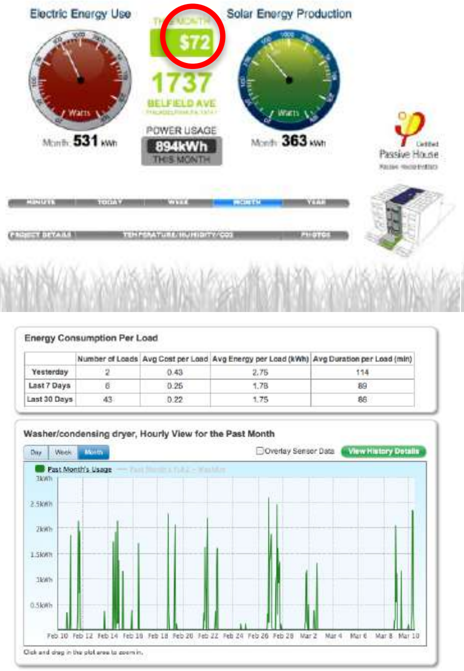


Energy Consumption Per Load

	Number of Loads	Avg Cost per Load	Avg Energy per Load (kWh)	Avg Duration per Load (min)
Yesterday	2	0.02	1.88	79
Last 7 Days	25	0.16	1.36	85
Last 30 Days	154	0.18	1.42	88

Washer/Cond. Dryer, Hourly View for the Past Week

Click and drag in the plot area to zoom in.

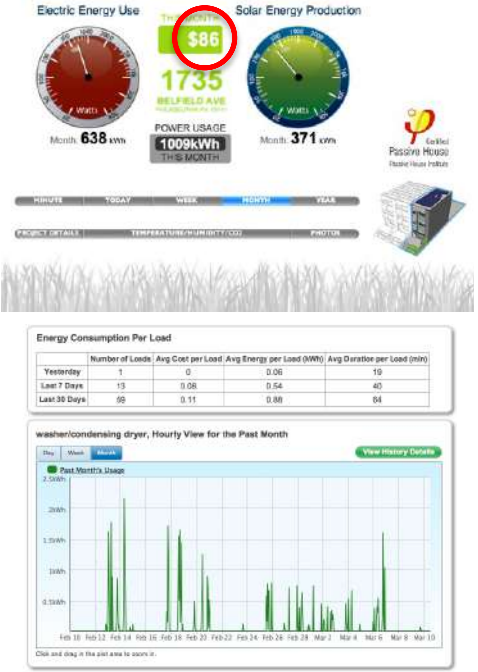


Energy Consumption Per Load

	Number of Loads	Avg Cost per Load	Avg Energy per Load (kWh)	Avg Duration per Load (min)
Yesterday	2	0.43	2.75	114
Last 7 Days	6	0.25	1.78	89
Last 30 Days	43	0.22	1.75	86

Washer/condensing dryer, Hourly View for the Past Month

Click and drag in the plot area to zoom in.

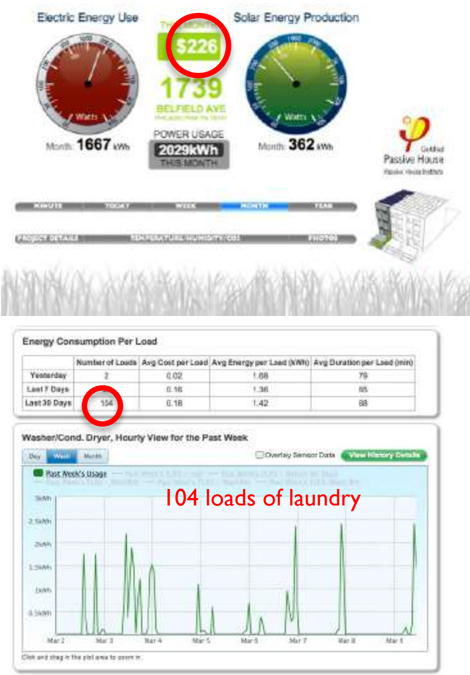


Energy Consumption Per Load

	Number of Loads	Avg Cost per Load	Avg Energy per Load (kWh)	Avg Duration per Load (min)
Yesterday	1	0	0.06	19
Last 7 Days	13	0.08	0.54	40
Last 30 Days	69	0.11	0.88	64

washer/condensing dryer, Hourly View for the Past Month

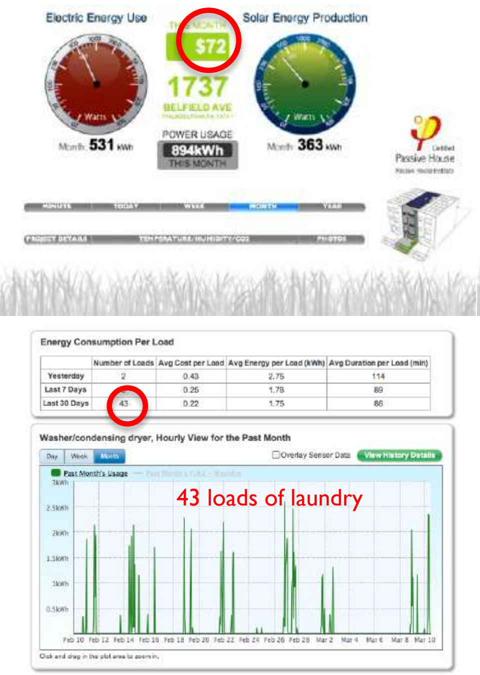
Click and drag in the plot area to zoom in.



Energy Consumption Per Load

	Number of Loads	Avg Cost per Load	Avg Energy per Load (kWh)	Avg Duration per Load (min)
Yesterday	2	0.02	1.68	79
Last 7 Days	[illegible]	0.16	1.36	85
Last 30 Days	104	0.18	1.42	88

104 loads of laundry



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Yesterday	2	0.43	2.75	114
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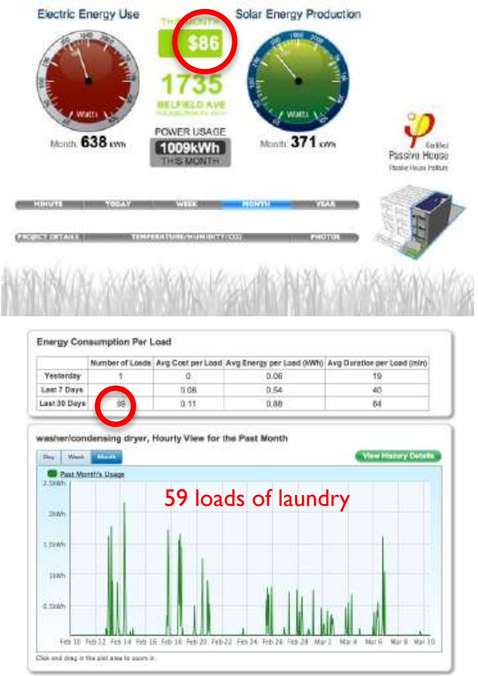
Last 30 Days	43	0.22	1.75	86

43 loads of laundry



Energy Consumption Per Load

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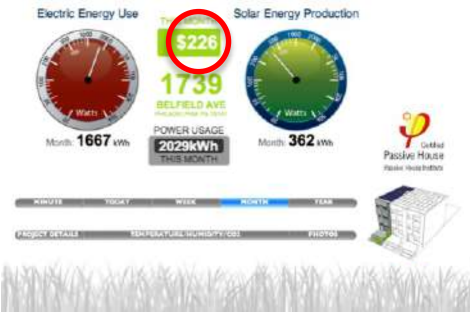
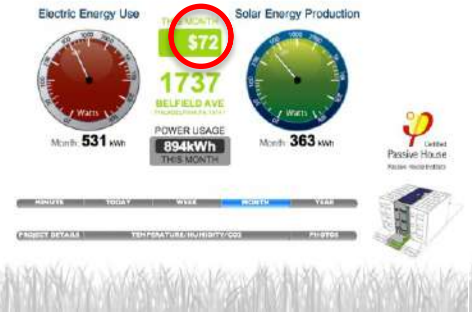
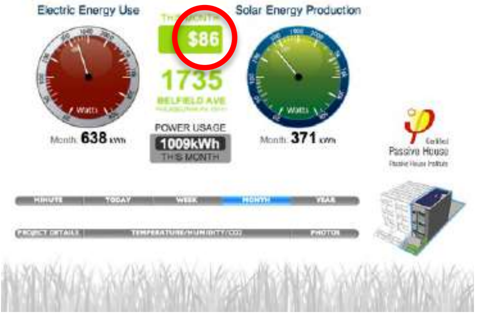
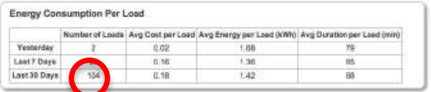
Yesterday	1	0	0.06	19
Last 7 Days	[illegible]	0.08	0.54	40
Last 30 Days	59	0.11	0.88	64

59 loads of laundry









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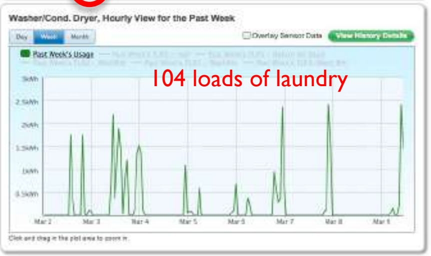
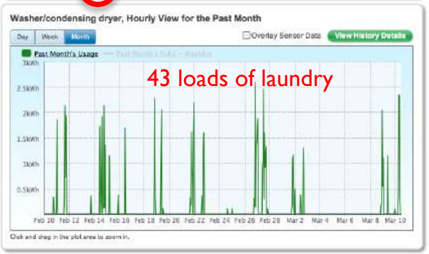
Last 7 Days	[illegible]	0.16	1.36	65
Last 30 Days	104	0.18	1.42	68



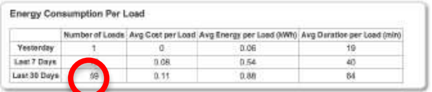
104 loads of laundry

Energy Consumption Per Load

	Number of Loads	Avg Cost per Load	Avg Energy per Load (kWh)	Avg Duration per Load (min)
Yesterday	2	0.43	2.75	114
Last 7 Days	[illegible]	0.25	1.78	89
Last 30 Days	43	0.22	1.75	86

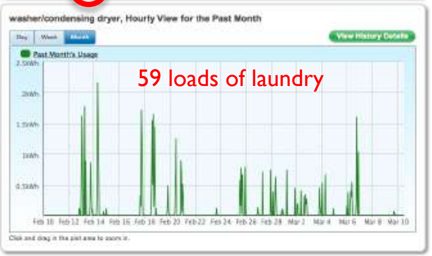


43 loads of laundry

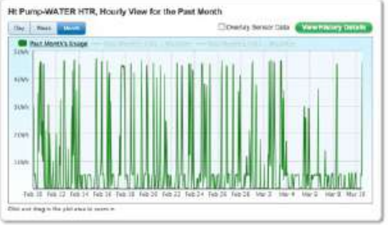


Energy Consumption Per Load

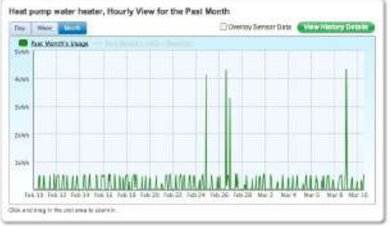
	Number of Loads	Avg Cost per Load	Avg Energy per Load (kWh)	Avg Duration per Load (min)
Yesterday	1	0	0.06	19
Last 7 Days	[illegible]	0.08	0.54	40
Last 30 Days	59	0.11	0.88	64



59 loads of laundry



$107.00
For hot water and
laundry alone



$21.00

$22.00

*** 12 Months of Measured Data***

	Address	TFA sf	12 Months kWh Total	PV Production kWh	$/Yr	SITE (kBTU/TFA) kBTU/sf/yr	kWh/sf/yr
	**1739**	1480.6	17,466	5710	$1120	**40**	13
					Passive House	*15*	*4.5 (66%)*
					$93.00/MONTH		
	**1737**	1480.6	10,809	5631	$497	**25**	7
					Passive House	*15*	*4.5 (36%)*
					$41.00/MONTH		
	**1735**	1480.6	9568	5577	$383	**22**	6
					Passive House	*15*	*4.5 (25%)*
					$32.00/MONTH		

CONSTRUCTION COSTS

	PER UNIT	PROJECT TOTAL
GENERAL CONDITIONS	$1,500	$4,500
EXCAVATION & GRADING	$3,000	$9,000
FOUNDATIONS	$7,000	$21,000
HELICAL PIERS	$6,500	$19,500
SITE UTILITIES (WATER / SEWER / ELECTRIC)	$10,000	$30,000
SOLAR PV (5 KW PER HOUSE - 15KW TOTAL)	$15,000	$45,000
TOTAL SITE WORK	$43,000	$129,000
FRAMING / INSULATION / SHEETROCK / PAINT	$50,250	$150,750
EXT. WINDOWS & DOORS	$9,850	$29,550
MECHANICAL SYSTEM	$8,500	$25,500
PLUMBING & SPRINKLERS	$9,500	$28,500
ELECTRICAL	$5,500	$16,500
CABINETRY / COUNTERTOPS	$5,500	$16,500
APPLIANCES	$6,200	$18,600
HARDARE & FINISHES	$9,300	$27,900
EXTERIOR CLADDING	$4,500	$13,500
E-MONITORING	$1,900	$5,700
LABOR / INSPECTIONS / OH-P / DELIVERY / INSTALL	$95,000	$285,000
TOTAL MODULAR	$206,000	$618,000.00
TOTAL HARD COSTS	**$249,000**	**$747,000.00**
COST PER SQFT **(1920 SQFT x 3 HOMES = 5760 SQFT)**		**$129.69**

Why isn’t ALL
AFFORDABLE HOUSING
Built to the PH standard?

PHFA

PENNSYLVANIA HOUSING FINANCE AGENCY

MAKE ALL AFFORDABLE HOUSING NET-ZERO-ENERGY-CAPABLE BY 2030

9% Low Income House Tax Credit (LIHTC)

QAP

Qualified Allocation Plan

POINTS-BASED SYSTEM

Total points	120
Community and Economic Impact	30
- Underserved Areas	
- Senior Occupancy Developments	
- Preservation	
Development Characteristics	25
- Smart Site Selection	
- Enterprise Green Communities	
Resident Population and Services	50
- Income and Rent Targeting	
- Designated Populations and Supportive Services	
- Accessible Units	
- Large Families	
Development Process	15
- Noncompliance	
- Ability to Proceed	
Development Cost Savings	10

POINTS-BASED SYSTEM

Total points	**120**
Community and Economic Impact	**30**
- Underserved Areas	
- Senior Occupancy Developments	
- Preservation	
Development Characteristics	**25**
- Smart Site Selection	
- Enterprise Green Communities	
- PASSIVE HOUSE	**10**
Resident Population and Services	**50**
- Income and Rent Targeting	
- Designated Populations and Supportive Services	
- Accessible Units	
- Large Families	
Development Process	**15**
- Noncompliance	
- Ability to Proceed	
Development Cost Savings	**10**

38% applied as Passive House projects

7 PH projects Funded

Construction Cost Summary from PHFA Applications

2015 Costs

Single Family / Townhouse

Proj. No.	County	Climate Zone	Units (by BR Qty)					Total Units	Bldg. Area	Constr. $	$ /Unit	$/SF
			0	1	2	3	4+					
SF-1	Franklin	5A			33	21		54	70,218	7,051,522	130,584	100
SF-2	Schuylkill	5A		3	9	5		17	21,151	2,238,725	131,690	106
SF-3	Philadelphia	4A		5	19	31	5	60	79,795	9,363,626	156,060	117
SF-4	Allegheny	5A			26	19		45	63,548	8,863,631	196,970	117
SF-5	Lycoming	5A		16	34			50	66,147	8,141,437	162,829	123
SF-6	Bradford	5A		10	24	16		50	62,956	7,964,823	159,296	127
SF-7	Centre	5A			20	20		40	53,652	7,523,233	188,081	140
SF-8	Lebanon	5A			46	16		62	84,168	11,742,459	189,395	140
SF-9	Bradford	5A		2	26	12		40	59,954	8,369,296	209,232	140
SF-10	Butler	5A		3	39	18		60	67,904	9,827,275	163,788	145
SF-11	Erie	5A			9	34		43	53,454	7,870,669	183,039	147
SF-12	Dauphin	5A		3	3	25	4	35	61,504	9,192,750	262,650	149
SF-13	Berks	5A		22	20	16		58	62,097	9,305,340	160,437	150
SF-14	Franklin	5A		7	25	24		56	77,469	11,791,991	210,571	152
SF-15	Luzerne	5A		26	15	15		56	56,250	8,968,491	160,152	159
SF-16	Union	5A		5	12	8	6	31	43,868	7,071,066	228,099	161
SF-17	Chester	4A		48	12			60	58,349	9,809,238	163,487	168
SF-18	Allegheny	5A		4	30	18		52	77,351	12,979,386	249,604	168
SF-19	Berks	5A		10	21	11		42	57,722	9,785,000	232,976	170
SF-20	Montgomery	4A		16	24	15		55	61,480	11,113,700	202,067	181
SF-21	Delaware	4A		8	34	14		56	65,790	12,184,074	217,573	185
SF-22	Philadelphia	4A			17	16	2	35	45,476	8,905,240	254,435	196
SF-23	Allegheny	5A		14	9			23	28,205	5,552,583	241,417	197
SF-24	Westmoreland	5A		28	8			36	43,872	8,331,567	231,432	245
SF-25	Philadelphia	4A		10	19	11		40	46,757	11,453,809	286,345	245

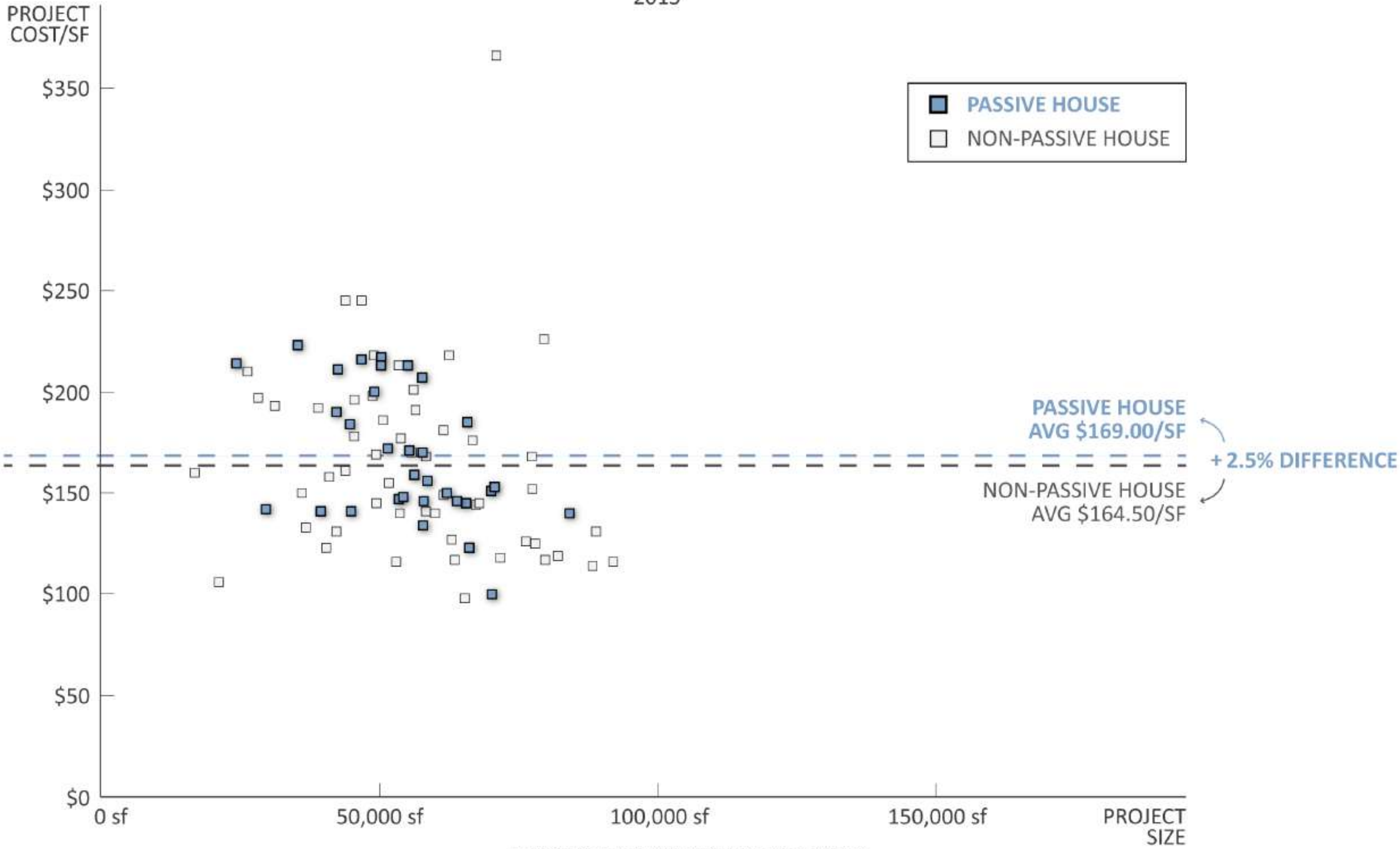
Adaptive Reuse

AR-1	Lehigh	5A		34	4	11		49	65,339	6,392,809	130,465	98
AR-2	Erie	5A		29	16			45	53,021	6,152,972	136,733	116
AR-3	Philadelphia	4A	12	54				66	77,975	9,751,707	147,753	125
AR-4	Allegheny	5A	2	49	4			55	65,577	9,514,764	172,996	145
AR-5	Delaware	4A		53				53	51,690	8,030,480	151,518	155
AR-6	Philadelphia	4A		44				44	49,406	8,361,579	190,036	169
AR-7	Montgomery	4A		33	3	7		43	55,832	9,468,816	220,205	170
AR-8	Philadelphia	4A			28	10		38	53,840	9,515,893	250,418	177
AR-9	Dauphin	5A	5	17	6			28	45,434	8,075,064	288,395	178
AR-10	Allegheny	5A		33	3			36	50,664	9,436,523	262,126	186
AR-11	Philadelphia	4A		46				46	56,478	10,795,027	234,675	191
AR-12	Philadelphia	4A		27	10			37	48,768	9,658,098	261,030	198
AR-13	Philadelphia	4A		30	21			51	62,509	13,609,683	266,857	218
AR-14	Washington	4A		17	7			24	35,299	7,856,113	327,338	223
AR-15	Philadelphia	4A		62				62	70,991	25,995,741	419,286	366

Multi-Story / Elevator

MS-1	Northumberland	5A		35				35	40,397	4,276,084	122,174	106
MS-2	Dauphin	5A		22	14	14		50	88,314	10,055,562	201,111	114
MS-3	Dauphin	5A		18	59			77	92,000	10,668,511	138,552	116
MS-4	Lancaster	5A		46	6			52	71,758	8,456,719	162,629	118
MS-5	Blair	5A		33	20			53	82,070	9,727,007	183,528	119
MS-6	Chester	4A		46	15			61	76,340	9,638,964	158,016	126
MS-7	Lancaster	5A		13	39	26		78	88,910	11,681,226	149,759	131
MS-8	Clearfield	6A		24	6			30	42,254	5,551,584	185,053	131
MS-9	Indiana	5A		40				40	36,743	4,898,995	122,475	133
MS-10	Bradford	5A		50	6			56	57,817	7,738,172	138,182	134
MS-11	Cambria	5A		32	11			43	44,887	6,341,616	147,479	141
MS-12	Dauphin	5A		38	16			54	58,335	8,201,250	151,875	141
MS-13	Mifflin	5A		30	4			34	39,447	5,559,187	163,506	141
MS-14	Fayette	5A		12	12			24	29,586	4,192,325	174,680	142
MS-15	Allegheny	5A		24	12	13		49	67,340	9,698,634	197,931	144
MS-16	Lackawanna	5A		44	4			48	49,460	7,159,738	149,161	145
MS-17	Lehigh	5A		54	7			61	63,949	9,318,159	152,757	146
MS-18	Centre	5A		37	11			48	57,959	8,490,644	176,888	146
MS-19	Chester	4A		41	3	5		49	54,287	8,007,477	163,418	148
MS-20	Fayette	5A		21	3			24	36,064	5,407,359	225,307	150
MS-21	Chester	4A		61	3			64	70,083	10,557,500	164,961	151
MS-22	Allegheny	5A		54	12			66	70,689	10,787,052	163,440	153
MS-23	Allegheny	5A		40	6			46	58,617	9,134,790	198,582	156
MS-24	Wayne	6A		36	4			40	40,959	6,460,530	161,513	158
MS-25	Centre	5A			12			12	16,796	2,683,900	223,658	160
MS-26	Beaver	5A		40	12			52	55,361	9,468,440	182,085	171
MS-27	Lancaster	5A		51				51	51,500	8,871,635	173,954	172
MS-28	Allegheny	5A		52	8			60	66,733	11,716,729	195,279	176
MS-29	Montgomery	4A		40	4			44	44,687	8,202,314	186,416	184
MS-30	Montgomery	4A		50				50	42,265	8,029,015	160,580	190
MS-31	Crawford	5A		36	4			40	38,953	7,490,675	187,267	192
MS-32	Philadelpia	4A		9	8	7		24	31,220	6,031,050	251,294	193
MS-33	Westmoreland	5A		47				47	49,080	9,825,224	209,047	200
MS-34	Philadelphia	4A		58	4			62	56,120	11,262,762	181,657	201
MS-35	Philadelphia	4A	60					60	57,672	11,915,227	198,587	207
MS-36	Philadelphia	4A		20	4			24	26,284	5,523,620	230,151	210
MS-37	Philadelphia	4A		34	11			45	42,523	8,964,723	199,216	211
MS-38	Philadelphia	4A		52				52	50,275	10,703,403	205,835	213
MS-39	Philadelphia	4A		39	11			50	53,416	11,371,112	227,422	213
MS-40	Philadelphia	4A		45	5			50	55,099	11,747,269	234,945	213
MS-41	Philadelphia	4A		24				24	24,284	5,194,462	216,436	214
MS-42	Philadelphia	4A		45				45	46,754	10,118,014	224,845	216
MS-43	Philadelphia	4A		53				53	50,312	10,900,733	205,674	217
MS-44	Philadelphia	4A		54				54	48,965	10,664,381	197,489	218
MS-45	Philadelphia	4A	88					88	79,650	18,005,791	204,611	226

CONSTRUCTION COST OF PROPOSED PROJECTS TO PHFA
2015



DATA SOURCE: PENNSYLVANIA HOUSING FINANCE AGENCY

St, John Nueman
Phila, PA
52 Units

PHIUS
Passive House Institute US

Wynne
Phila, PA
51 Units

Certified
Passive House
Passive House Institute

Sacred Heart
Allentown, PA
61 Units

Certified
Passive House
Passive House Institute

WhiteHall
Spring City, PA
49 Units

Certified
Passive House
Passive House Institute

Hillcrest
Pittsburgh, PA
65 Units

PHIUS
Passive House Institute US

Washington Square
Townhomes
Chambersburg, Pa
54 Units

PHIUS
Passive House Institute US

Mann Edge
Lewistown, Pa
34 Units

Certified
Passive House
Passive House Institute

7 Passive House Projects *COMPLETED*

Construction Cost Change from Application to Construction Completion

Proj. No.	Total Units	Residt'l Bldg. Area	$/SF @ Applic	$/SF @ Cost Cert	% Change
2015-443	51	62,509	$ 218	$ 186	-15%
2015-431	52	43,868	$ 296	$ 287	-3%
2015-436	23	28,205	$ 197	$ 193	-2%
2015-608	40	40,959	$ 158	$ 157	-1%
2015-810	35	61,504	$ 149	$ 149	-1%
2015-419	28	45,434	$ 178	$ 178	0%
2015-809	37	48,768	$ 198	$ 199	1%
2015-612	31	43,868	$ 161	$ 162	1%
2015-804	88	79,650	$ 226	$ 228	1%
2015-416	66	70,689	$ 153	$ 155	2%
2015-466	40	53,652	$ 140	$ 144	3%
2015-619	34	39,447	$ 141	$ 145	3%
2015-806	49	54,287	$ 148	$ 151	3%
2015-445	50	55,099	$ 220	$ 226	3%
2015-439	53	51,690	$ 155	$ 163	5%
2015-448	44	49,406	$ 169	$ 177	5%
2015-449	61	63,949	$ 149	$ 157	5%
2015-616	24	36,064	$ 150	$ 160	7%
2015-620	53	82,070	$ 119	$ 129	8%
2015-807	43	55,832	$ 170	$ 185	9%
2015-614	45	53,021	$ 116	$ 128	10%
2015-440	52	50,275	$ 213	$ 233	10%
2015-415	56	56,250	$ 159	$ 176	10%
2015-610	54	70,218	$ 100	$ 111	11%
2015-467	45	63,548	$ 139	$ 154	11%
2015-459	12	16,796	$ 160	$ 181	13%

NON-PASSIVE HOUSE

Application	Completion
$171 SF	$176 SF
	3% Higher

PASSIVE HOUSE

Application	Completion
$161 SF	$168 SF
	4% Higher

**NOTE 3-5% Contingency added to budgets after application*

YEAR 2

2016

10 PH projects Funded

A NATIONAL Net-Zero-Energy Initiative by 2030

Construction Cost Summary for PHFA 2016 Applications

Single Family / Townhouse

Proj. No.	County	Climate Zone	Units by BR Qty					Total Units	Resid. Bldg. Area	Resid. Constr. $	$ / Unit	$ / SF
			0	1	2	3	4+					
SF-01	Dauphin	5A		14	16	15	15	60	99,625	10,419,031	173,651	105
SF-02	Lebanon	5A		9	32	14		55	78,627	8,446,000	153,564	107
SF-03	Lycoming	5A		20	40			60	82,730	9,436,382	157,273	114
SF-04	Columbia	5A			7	17		24	48,499	5,669,777	236,241	117
SF-05	Philadelphia	4A		5	19	31	5	60	79,795	9,739,093	162,318	122
SF-06	Wyoming	5A			30	12		42	72,100	9,168,380	218,295	127
SF-07	Erie	5A		8	20	18		46	85,819	10,964,900	238,367	128
SF-08	Lancaster	5A		6	33	21		60	78,825	10,259,118	170,985	130
SF-09	Cumberland	5A			18	34		52	75,275	9,921,606	190,800	132
SF-10	Centre	5A		6	24	18		48	75,737	10,193,457	212,364	135
SF-11	Lehigh	5A		19	27	16		62	71,254	9,631,860	155,353	135
SF-12	Lancaster	5A		41	79	18		138	154,370	21,137,388	153,169	137
SF-13	Erie	5A			9	31		40	53,454	7,870,669	196,767	147
SF-14	Montgomery	4A			19	29		48	59,976	8,858,000	184,542	148
SF-15	Lebanon	5A			49	13		62	82,974	12,349,192	199,181	149
SF-16	Cumberland	5A			10	30	10	50	72,707	10,865,524	217,310	149
SF-17	Schuylkill	5A		1	11	5		17	21,544	3,225,548	189,738	150
SF-18	Berks	5A		10	21	11		42	57,722	8,755,000	208,452	152
SF-19	Berks	5A		22	20	16		58	62,097	9,440,383	162,765	152
SF-20	Franklin	5A		6	21	21		48	66,583	10,404,256	216,755	156
SF-21	Lehigh	5A		9	15	20	4	48	53,333	8,377,963	174,541	157
SF-22	Chester	4A		19	18	11		48	58,541	9,248,927	192,686	158
SF-23	Cumberland	5A		5	22	8		35	44,186	7,656,200	218,749	173
SF-24	Montgomery	4A		8	21	15	6	50	65,907	11,589,411	231,788	176
SF-25	Allegheny	5A		35	16	14		65	87,255	15,376,648	236,564	176
SF-26	Delaware	4A		8	34	14		56	65,212	11,914,849	212,765	183
SF-27	Philadelphia	4A			17	16	2	35	45,476	9,441,620	269,761	208
SF-28	Armstrong	5A			24			24	28,812	6,017,450	250,727	209
SF-29	Philadelphia	4A			28	14		42	47,964	10,022,268	238,625	209
SF-30	Philadelphia	4A		11	10	11		32	31,619	6,732,433	210,389	213
SF-31	Philadelphia	4A		8	19	24	4	55	66,383	19,011,723	345,668	286
SF-32	Philadelphia	4A	45					45	23,302	7,408,602	164,635	318

Adaptive Reuse Bldgs.

AR-01	Monroe	5A		36	4			40	54,215	5,753,672	143,842	106
AR-02	Luzerne	5A	6	54	2			62	88,489	9,900,711	159,689	112
AR-03	Philadelphia	4A	12	54				66	77,978	10,123,117	153,381	130
AR-04	Allegheny	5A		33	8			41	70,409	9,181,888	223,948	130
AR-05	Butler	5A		44	18			62	73,114	10,046,992	162,048	137
AR-06	Washington	5A		24				24	41,046	6,169,663	257,069	150
AR-07	Allegheny	5A	2	49	4			55	65,190	10,592,039	192,583	162
AR-08	Delaware	4A		50				50	50,548	8,727,828	174,557	173
AR-09	Philadelphia	4A		60				60	65,041	11,803,992	196,733	181
AR-10	Philadelphia	4A		74				74	93,285	20,223,060	273,285	217
AR-11	Philadelphia	4A	20	37				57	63,960	14,005,881	245,717	219
AR-12	Perry	5A		28	3			31	36,152	8,548,665	275,763	236

Multi-Story / Elevator Buildings

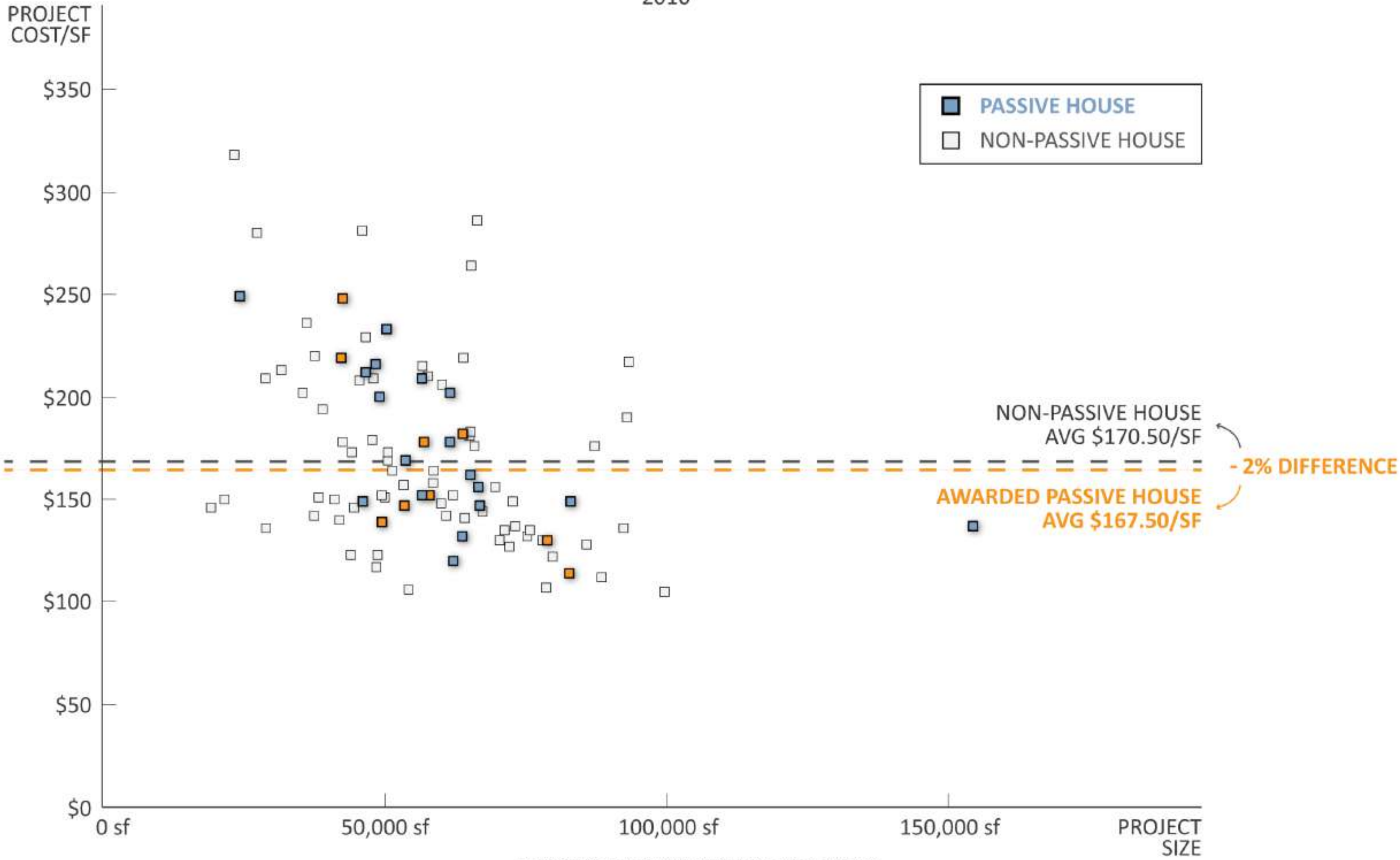
MS-01	Berks	5A		40	20			60	62,149	7,432,636	123,877	120
MS-02	Tioga	6A		34	6			40	48,735	5,999,734	149,993	123
MS-03	Dauphin	5A		35	2			37	43,964	5,421,065	146,515	123
MS-04	Bradford	5A		38	12	6		56	63,768	8,446,000	150,821	132
MS-05	Lancaster	5A		46	6			52	92,370	12,565,629	241,647	136
MS-06	Fayette	5A		12	12			24	28,904	3,942,323	164,263	136
MS-07	Cambria	5A		32	11			43	49,491	6,879,001	159,977	139
MS-08	Clearfield	6A		24	6			30	41,915	5,855,263	195,175	140
MS-09	Chester	4A		56	3			59	64,180	9,033,100	153,103	141
MS-10	Centre	5A		16	34			50	60,912	8,666,068	173,321	142
MS-11	Clinton	5A		28	4			32	37,454	5,333,806	166,681	142
MS-12	Allegheny	5A		24	12	13		49	67,340	9,698,634	197,931	144
MS-13	Luzerne	5A		32	3			35	44,543	6,503,636	185,818	146
MS-14	Dauphin	5A		20				20	19,157	2,803,860	140,193	146
MS-15	Butler	5A		68				68	66,845	9,821,302	144,431	147
MS-16	Westmoreland	5A		15	13	8		36	46,095	6,855,424	190,428	149
MS-17	Lackawanna	5A		12	12	8	4	36	50,019	7,560,000	210,000	151
MS-18	Northumberland	5A		32				32	38,240	5,789,694	180,928	151
MS-19	Centre	5A		37	11			48	57,959	8,781,136	182,940	152
MS-20	Lackawanna	5A		44	4			48	49,460	7,493,999	156,125	152
MS-21	Allegheny	5A		30	34			64	69,605	10,837,117	169,330	156
MS-22	Dauphin	5A		43	11			54	51,319	8,411,465	155,768	164
MS-23	Montgomery	4A		60				60	58,681	9,643,959	160,733	164
MS-24	Adams	5A		39	4			43	50,532	8,515,443	198,034	169
MS-25	Clarion	5A		48				48	53,668	9,090,720	189,390	169
MS-26	Allegheny	5A		40	6			46	56,969	10,124,143	220,090	178
MS-27	Allegheny	5A		28	8			36	42,500	7,582,274	210,619	178
MS-28	Chester	4A		47	13			60	61,551	10,982,435	183,041	178
MS-29	Delaware	4A		38	3			41	47,797	8,539,207	208,273	179
MS-30	Allegheny	5A		52	8			60	63,861	11,647,354	194,123	182
MS-31	Philadelphia	4A		37	44			81	93,000	17,635,125	217,718	190
MS-32	Crawford	5A		36	4			40	38,953	7,552,475	188,812	194
MS-33	Westmoreland	5A		47				47	49,080	9,801,657	208,546	200
MS-34	Bucks	4A		56	10			66	61,576	12,448,922	188,620	202
MS-35	Lycoming	5A		23	11			34	35,437	7,169,151	210,857	202
MS-36	Philadelphia	4A		61				61	60,137	12,416,322	203,546	206
MS-37	Bradford	5A		40	10			50	56,580	11,852,026	237,041	209
MS-38	Philadelphia	4A		58	4			62	57,653	12,079,768	194,835	210
MS-39	Philadelphia	4A		52				52	46,619	9,903,739	190,457	212
MS-40	Philadelphia	4A	60					60	56,672	12,174,301	202,905	215
MS-41	Philadelphia	4A		45				45	48,351	10,464,750	232,550	216
MS-42	Montgomery	4A		50				50	42,265	9,236,729	184,735	219
MS-43	Allegheny	5A		29	4			33	37,592	8,284,054	251,032	220
MS-44	Philadelphia	4A		46	4			50	46,640	10,701,164	214,023	229
MS-45	Philadelphia	4A		53				53	50,312	11,711,200	220,966	233
MS-46	Philadelphia	4A		34	11			45	42,520	10,560,747	234,683	248
MS-47	Philadelphia	4A		24				24	24,284	6,040,593	251,691	249
MS-48	Philadelphia	4A		60				60	65,340	17,249,402	287,490	264
MS-49	Luzerne	5A		36				36	27,296	7,653,000	212,583	280
MS-50	Philadelphia	4A		48				48	46,000	12,915,822	269,080	281

YEAR 2 A NATIONAL Net-Zero-Energy Initiative by 2030

2016

CONSTRUCTION COST OF PROPOSED PROJECTS TO PHFA

2016



DATA SOURCE: PENNSYLVANIA HOUSING FINANCE AGENCY

Morningside Crossing
Pittsburgh, PA
46 Units

Glassport
Glassport, PA
55 Units

Mt. Lebanon Sr. Housing
Pittsburgh, PA
60 Units

Roxbury Place
Johnstown, PA
43 Units

Westminster @ Windy
Phillipsburg, PA
48 Units

Parade St. Commons
Erie, PA
40 Units

The Willows
Landisville, PA
60 Units

Muncy Green
Muncy, PA
60 Units

Montgomery Park
Norristown, PA
50 Units

Anthony Wayne Senior
Phila, PA
45 Units

10 Passive House Projects *COMPLETE*

YEAR 3-4

2017-18

8 PH projects Funded

A NATIONAL Net-Zero-Energy Initiative by 2030

Construction Cost Summary of 2018 PHFA Applications

Single Family / Townhouses

Ref. No.	County	Climate Zone	Units by BR Qty 0	1	2	3	4+	Total Units	Resid. Bldg Area	Resid Constr $	$ / Unit	$ / SF
SF-01	York	5A			10	13		23	44,064	4,475,121	194,570	102
SF-02	Dauphin	5A				22	22	44	66,603	8,409,248	191,119	126
SF-03	York	5A		6	23	24	3	56	72,013	9,258,025	165,322	129
SF-04	Berks	5A			24	22		46	66,030	8,557,500	186,033	130
SF-05	Lebanon	5A		18	26	16		60	76,101	10,333,056	172,218	136
SF-06	Franklin	5A			7	25		32	54,375	8,150,464	254,702	150
SF-07	Philadelphia	4A		2	5	11	2	20	29,503	4,490,975	224,549	152
SF-08	Lackawanna	5A		12	12	8	4	36	50,019	7,805,595	216,822	156
SF-09	Franklin	5A		6	21	21		48	66,583	10,727,005	223,479	161
SF-10	Multiple Co's	5A	52					52	52,330	8,909,580	171,338	170
SF-11	York	5A		18	9	7		34	35,636	6,396,969	188,146	180
SF-12	Allegheny	5A		47	10			57	48,150	9,106,659	159,766	189
SF-13	Westmoreland	5A		3	6	9		18	20,489	4,108,548	228,253	201
SF-14	Allegheny	5A		4	7	9		20	26,198	5,407,155	270,358	206
SF-15	Armstrong	5A			24			24	29,147	6,230,195	259,591	214
SF-16	Susquehanna	6A		34	2			36	31,103	7,031,404	195,317	226
SF-17	Philadelphia	4A			17	16	2	35	45,476	10,281,980	293,771	226
SF-18	Philadelphia	4A		11	10	12		33	34,388	8,875,449	268,953	258
SF-19	Philadelphia	4A		28	12			40	46,232	12,214,948	305,374	264
SF-20	Philadelphia	4A		12	18	11	9	50	71,903	21,367,901	427,358	297

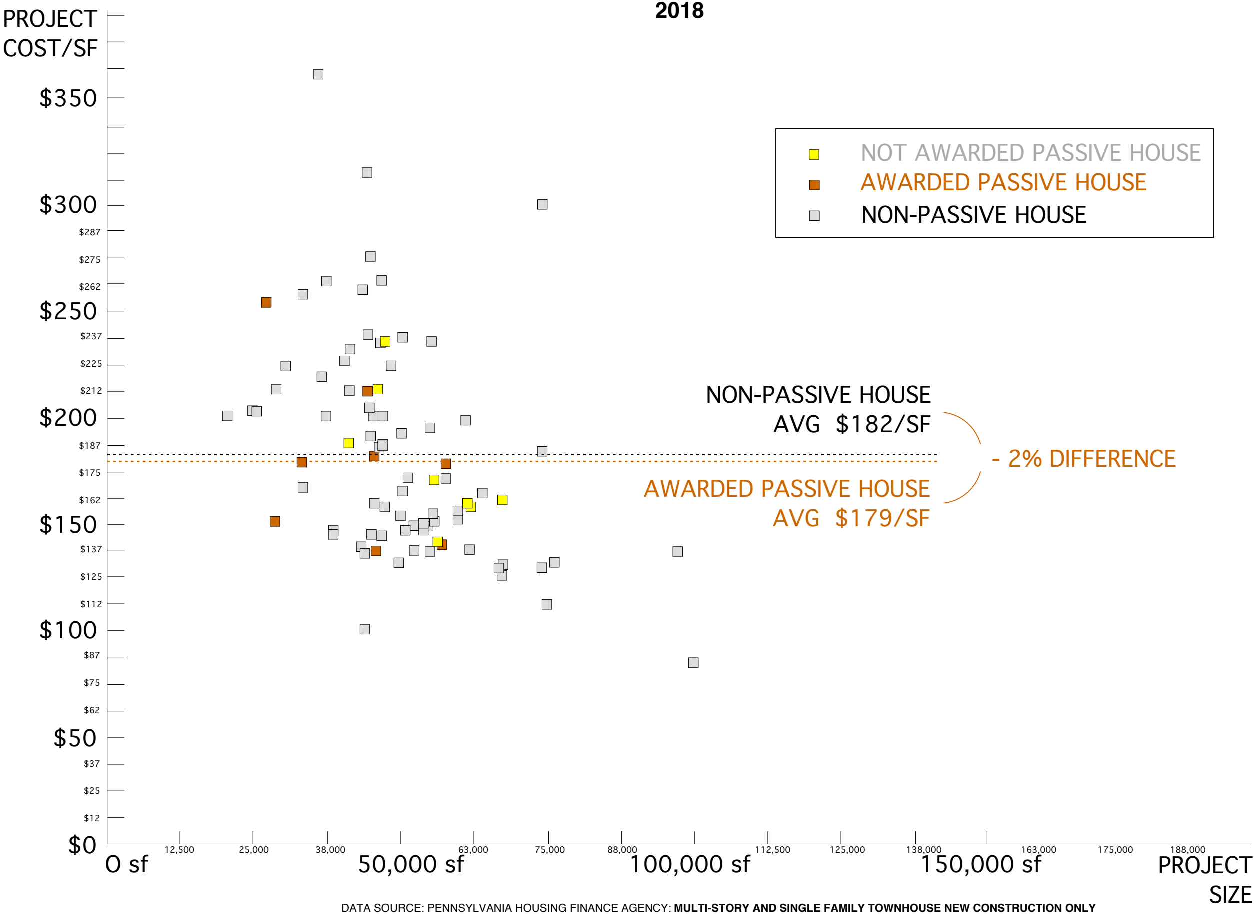
Construction Cost Summary of 2018 PHFA Applications

Multi-Story / Elevator Buildings

Ref. No.	County	Climate Zone	Units by BR Qty 0	1	2	3	4+	Total Units	Resid. Bldg Area	Resid Constr $	$ / Unit	$ / SF
MS-01	Erie	5A			45			45	100,201	8,587,936	190,843	86
MS-02	Lancaster	5A		44	18			62	76,045	8,306,538	133,976	109
MS-03	Lancaster	5A		45	15			60	68,993	8,544,047	142,401	124
MS-04	Cumberland	5A		14	12	16		42	49,581	6,440,993	153,357	130
MS-05	Berks	5A		45	12			57	59,916	7,892,757	138,469	132
MS-06	Westmoreland	5A		15	13	8		36	46,095	6,087,669	169,102	132
MS-07	Fayette	5A		18	18			36	42,820	5,679,247	157,757	133
MS-08	Dauphin	5A		35	2			37	43,928	5,896,750	159,372	134
MS-09	Bradford	5A		38	12			56	63,759	8,603,563	153,635	135
MS-10	Allegheny	5A		30	10			40	54,495	7,335,750	183,394	135
MS-11	Lancaster	5A		46	6			52	94,440	12,791,060	245,982	135
MS-12	Centre	5A		16	34			50	60,599	8,371,068	167,421	138
MS-13	Montgomery	4A		42	14			56	60,166	8,477,023	151,375	141
MS-14	Luzerne	5A		32	3			35	44,543	6,416,086	183,317	144
MS-15	Clinton	5A		28	4			32	37,454	5,470,901	170,966	146
MS-16	Dauphin	5A		20	29			49	53,976	8,066,609	164,625	149
MS-17	Washington	5A		21	25			46	53,310	8,000,885	173,932	150
MS-18	Franklin	5A		36	4			40	54,596	8,326,929	208,173	153
MS-19	Chester	4A		57	3			60	60,931	9,310,170	155,170	153
MS-20	Northumberland	5A		32	4			36	43,826	6,998,140	194,393	160
MS-21	York	5A		16	26	8		50	63,425	10,125,538	202,511	160
MS-22	Allegheny	5A		27	18	9		54	64,875	10,797,000	199,944	166
MS-23	Westmoreland	5A		43	4			47	50,680	8,439,569	179,565	167
MS-24	Clearfield	5A		24	6			30	35,984	6,065,728	202,191	169
MS-25	Beaver	5A		44	8			52	57,297	9,797,660	188,417	171
MS-26	Northampton	5A		12	33	15		60	60,212	10,329,351	172,156	172
MS-27	Montgomery	4A		60				60	61,110	10,869,266	181,154	178
MS-28	Dauphin	5A		38	11			49	48,638	8,730,738	178,178	180
MS-29	Montgomery	4A		66	8			74	74,468	13,541,230	182,990	182
MS-30	Clarion	5A		39	3			42	48,847	8,988,545	214,013	184
MS-31	Philadelphia	4A		28	13			41	49,625	9,204,879	224,509	185
MS-32	Lehigh	5A		27	13			40	40,937	7,663,199	191,580	187
MS-33	Allegheny	5A		31	3	1		35	46,015	8,714,276	248,979	189
MS-34	Butler	5A		30	13	1		44	50,825	9,697,495	220,398	191
MS-35	Delaware	4A		58				58	57,365	11,293,126	194,709	197
MS-36	Bucks	4A		68	1			69	62,844	12,503,344	181,208	199
MS-37	Delaware	4A		38	3			41	43,515	8,746,409	213,327	201
MS-38	Blair	5A		43	2			45	47,642	9,595,216	213,227	201
MS-39	Tioga	5A		34	6			40	32,800	6,591,082	164,777	201
MS-40	Lycoming	5A		18	6			24	26,749	5,419,721	225,822	203
MS-41	Philadelphia	4A		44				44	46,306	9,443,528	214,626	204
MS-42	Philadelphia	4A		52				52	46,619	9,893,465	190,259	212
MS-43	Crawford	5A		37	2			39	40,256	8,580,594	220,015	213
MS-44	Allegheny	5A		46				46	48,600	10,405,629	226,209	214
MS-45	Luzerne	5A		36				36	36,784	8,100,000	225,000	220
MS-46	Philadelphia	4A		11	11	8		30	39,650	8,957,527	298,584	226
MS-47	Allegheny	5A		19	13	11		43	41,797	9,558,272	222,285	229
MS-48	Philadelphia	4A		46	4			50	48,315	11,197,257	223,945	232
MS-49	Philadelphia	4A	60					60	57,672	13,556,215	225,937	235
MS-50	Philadelphia	4A		45				45	48,351	11,428,626	253,969	236
MS-51	Philadelphia	4A		37	10			47	50,527	12,095,152	257,344	239
MS-52	Philadelphia	4A		32	6	6		44	44,889	10,869,638	247,037	242
MS-53	Philadelphia	4A		24				24	24,284	6,253,770	260,574	258
MS-54	Allegheny	5A		30	20			50	37,290	9,905,483	198,110	266
MS-55	Philadelphia	4A		20	30			50	46,110	12,718,548	254,371	276
MS-56	Philadelphia	4A		48				48	45,000	14,294,705	297,806	318
MS-57	Philadelphia	4A		46				46	31,878	11,701,929	254,390	367

CONSTRUCTION COST OF PROPOSED PROJECTS TO PHFA

2018



NON-PASSIVE HOUSE
AVG $182/SF

- 2% DIFFERENCE

AWARDED PASSIVE HOUSE
AVG $179/SF

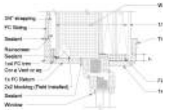
DATA SOURCE: PENNSYLVANIA HOUSING FINANCE AGENCY: **MULTI-STORY AND SINGLE FAMILY TOWNHOUSE NEW CONSTRUCTION ONLY**

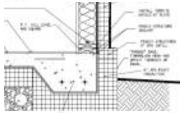
YEAR 3-4 A NATIONAL Net-Zero-Energy Initiative by 2030

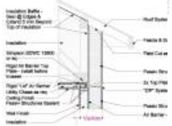
2017-18

THE WHITEHALL: *missionfirsthousing.org* *2017* *49units of Veteran housing*

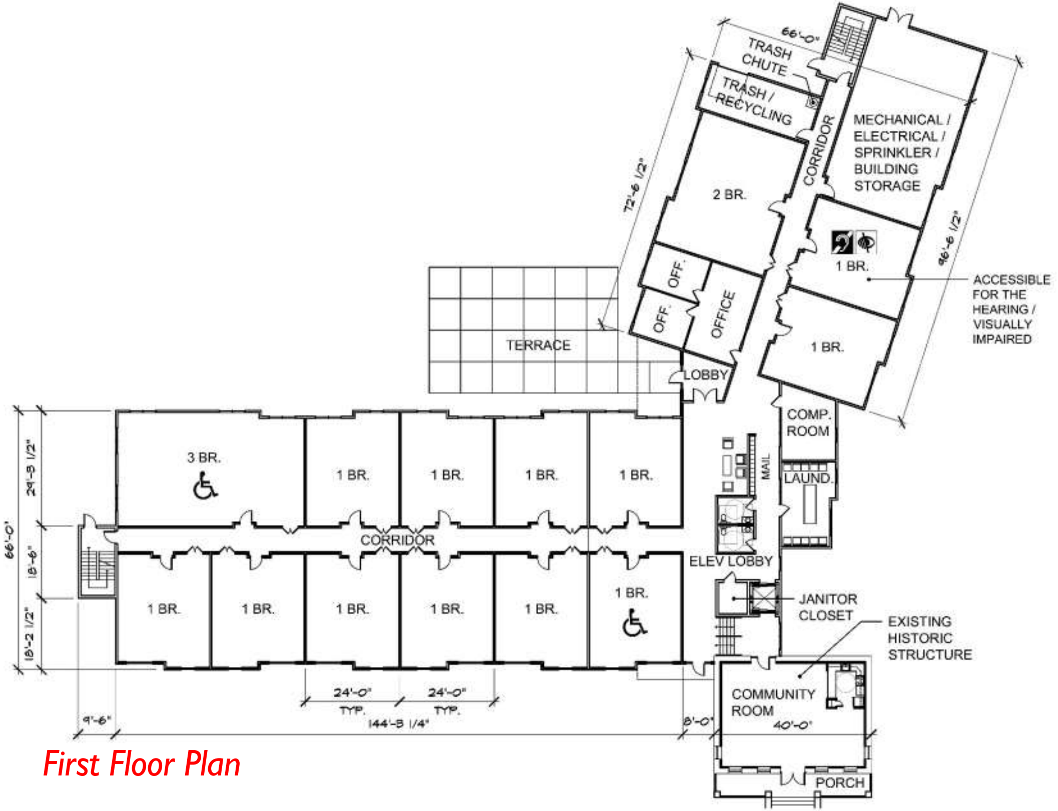
2015 Final Design – 49 Units







1. Wall:
    - Adam Cohen's BuildSmart panelized wall system
    - 2x6 stud with Dense-Pack Cellulose (R3.8/inch) in cavity, OSB, 3.5" EPS, Zip Panel
    - ***TOTAL R33***
    - Windows: Come pre-installed in wall system: Klearwall Future Proof, glass has Uvalue of .11 BTU/hr/ft2, with SHGC of .61(window muntins reduce SHGC to .57
2. Slab:
    - Adam Cohen BuildSmart preformed EPS slab/foundation system, thermal bridge free.
    - ***TOTAL R26.3***
3. Roof:
    - Roof truss with 18" of Cellulose
    - ZIP panel as Air Barrier underside of truss to be fully taped at joints and to Zip panel at wall.
    - A service cavity below the Air barrier with Chicago grid will allow for lighting, wiring sprinklers, etc without puncturing the Air Barrier
    - ***TOTAL: R50***
4. Domestic Hot water:
    - State 50 gallon Heat Pump Water Heater (HPWH) with a COP of 2.75, one per unit
5. Ventilaton:
    - Three Ultimate Aire 2000DX ERV centralized and ducted system for all of the 49 apartments and corridors, ancillary areas and Community Room. The ERV should be located in attic space.
    - Addressed discrepancy between PH and Energy Star with respect to 5ach requirement by ducting the kitchen hood directly to outside with magnetic damper. Flow rates for units:
    - 1bdrm units: 47cfm
    - 2bdrm units: 71 cfm
    - 3 bdrm units: 83 cfm
6. Heating/Cooling:
    - Fujitsu ducted mini-splits within each apartment with ganged condensers at grade. They have an HSPF between 12.2-11.5 BTU/h/W and a SEER of 19.7-21.5 depending on size of units.
7. Laundry
    - 5 commercial washers and dryers in common laundry room
    - Gas dryers vented to outside with magnetic dampers and gas DHW dedicated in room.
8. Construction costs: Not sure right now but originally at $148sf
9. CHALLENGES
    - shifting from decentralized Zehnder units, one per unit, to centralized US manufacturer. Took hit in performance.
    - Shift to BuildSmart wall/foundation system but I think good move for overall coordination. Taking risk, however, because this has not been tested.



First Floor Plan

2015 Final Design – 49 Units

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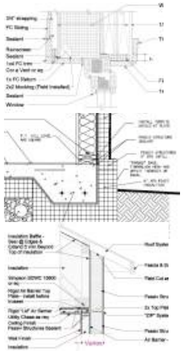

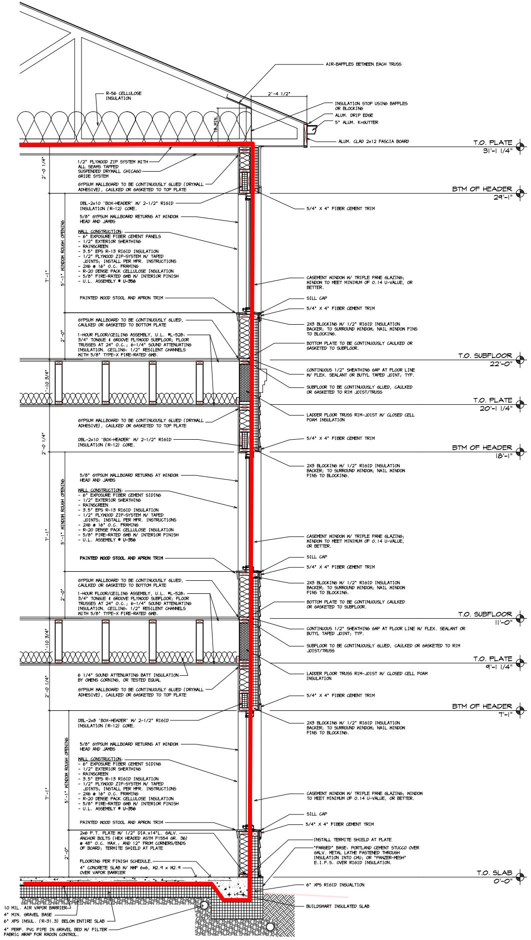

Typ Wall Section

THE WHITEHALL: *missionfirsthousing.org* *2017* *49units of Veteran housing*

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PRE-DRYWALL BLOWER DOOR TEST
September 26, 2016

.5 ACH50

FINAL DRYWALL BLOWER DOOR TEST

April 17, 2017

.42 ACH50

THE WHITEHALL: *missionfirsthousing.org* *2017* *49units of Veteran housing*

The Whitehall Utility Cost Comparison

	1 BR	2 BR	3 BR
Housing Authority Allowances	$103.00	$138.00	$169.00
Calculated Passive House	$42.37	$60.45	$80.97

Impact of Utility Costs on Operating Budget

	Housing Authority Allowances	**Calculated Passive House**
TTP For All Units	$545,748	$545,748
Less Utilities	$64,548	$27,372
Rent	$481,200	$518,376
Operating Costs	$382,084	$382,084 *
Net Income	$99,116	$136,292

CHIP: "*Understates the case: operating costs include common area utilities, which are lower in Passive House construction than in traditional construction. So the operating costs in the Housing Authority scenario would be higher, meaning that the actual difference in Net Income is higher than shown"

***THE WHITEHALL:** missionfirsthousing.org* *2017* *49units of Veteran housing*

Impact of Utility Costs on Operating Budget

	Housing Authority Allowances	Calculated Passive House
Net Operating Income	$99,116	$136,292
Debt Coverage Ratio*	1.8	1.8
Payment (NOI/DCR)	$55,064	$75,718
Max Mortgage (30 yrs @ 5.5%)	$800,000	$1,100,000
*1.07 in Year 15		

CHIP: "Passive House lets you borrow/leverage more money to build more housing."

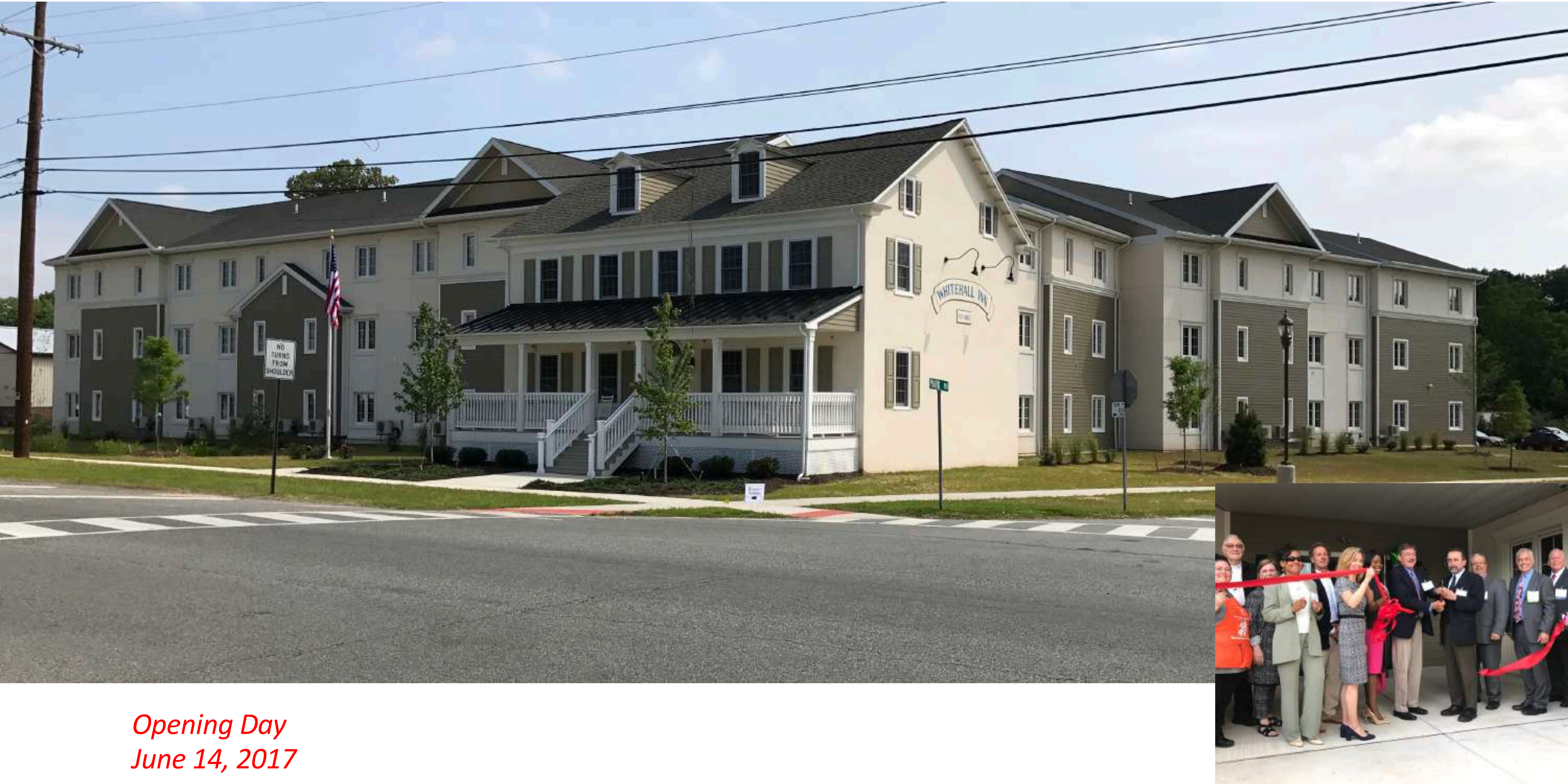
THE WHITEHALL: *missionfirsthousing.org* *2017* *49units of Veteran housing*

Impact of Utility Costs on Operating Budget

	Housing Authority Allowances	Calculated Passive House
Total Development Cost	$12,750,000	$12,750,000
LIHTC Equity	$11,000,000	$11,000,000
Soft Debt/Grants	$450,000	$450,000
Mortgage	**$800,000**	**$1,100,000**
Total	$12,250,000	$12,550,000
Deferred Fee Required	$500,000	$200,000
Gross Fee	$1,500,000	$1,500,000
Net Fee	**$1,000,000**	**$1,300,000**

CHIP: "We're a nonprofit, which means we don't put the net fee in our pockets. We put that money into new developments. Higher net fees mean we can house more people."

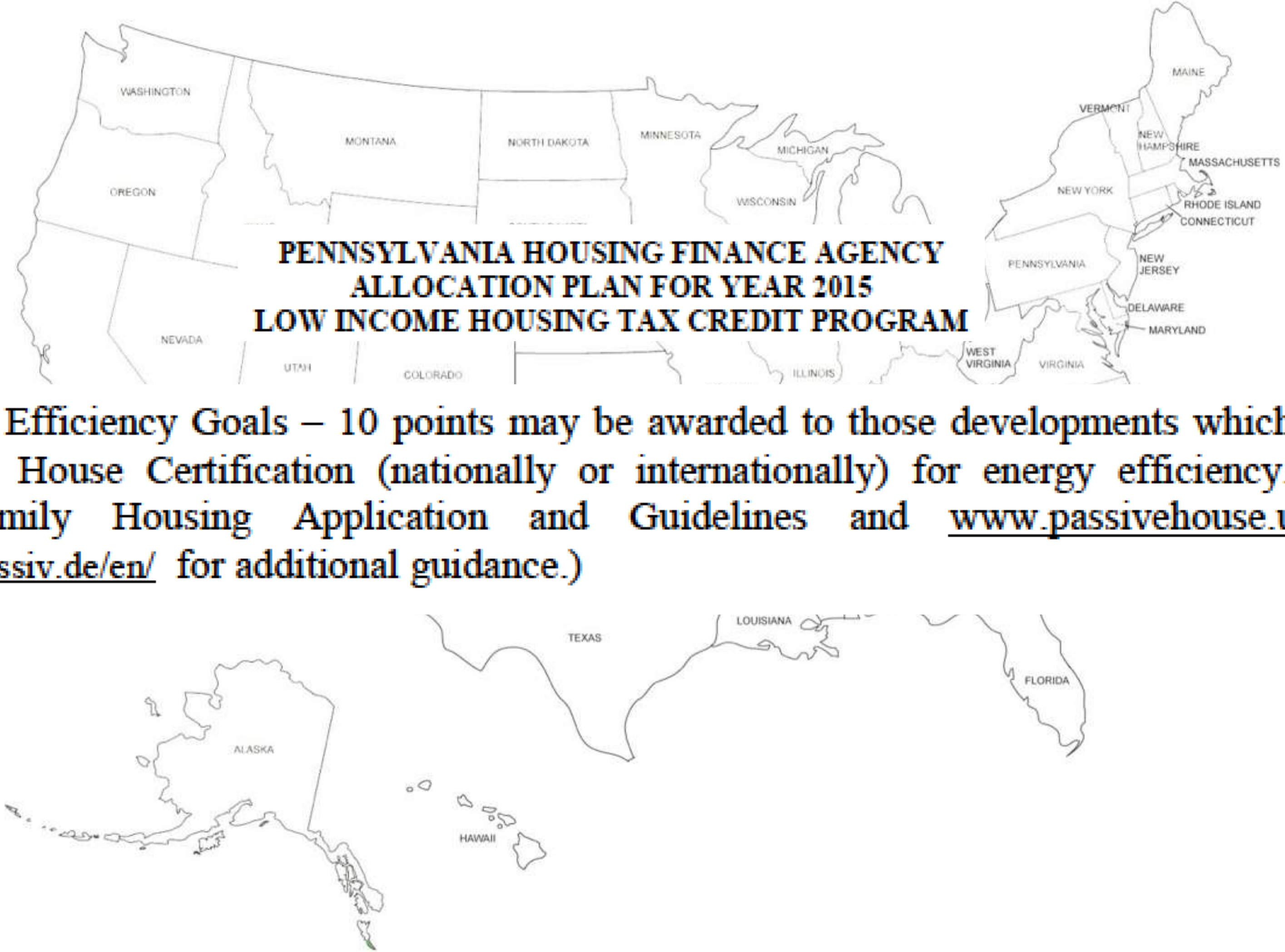
***THE WHITEHALL:** missionfirsthousing.org* *2017* *49units of Veteran housing*

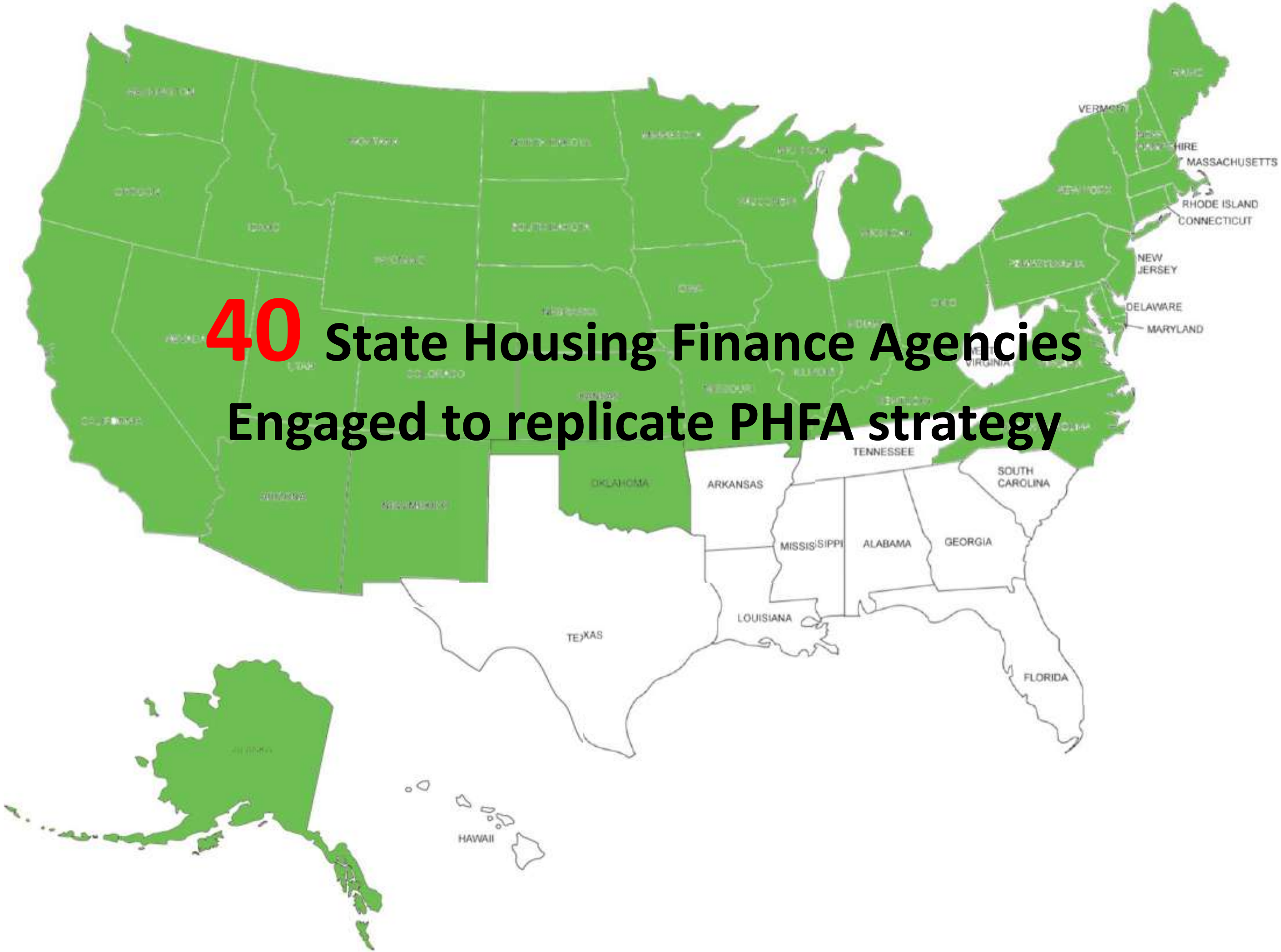


Opening Day
June 14, 2017

THE WHITEHALL: *missionfirsthousing.org* *2017* *49units of Veteran housing*

- Energy Efficiency Goals – 10 points may be awarded to those developments which meet Passive House Certification (nationally or internationally) for energy efficiency. (See Multifamily Housing Application and Guidelines and www.passivehouse.us or http://passiv.de/en/ for additional guidance.)





40 State Housing Finance Agencies Engaged to replicate PHFA strategy

18 COMMITTED!!

1 California
2 Connecticut
3 District of Colombia
4 Delaware
5 Idaho
6 Illinois
7 Maryland
8 Massachusetts
9 Montana
10 New Hampshire
11 New Jersey
12 New York
13 Ohio
14 Pennsylvania
15 Rhode Island
16 South Dakota
17 Vermont
18 Virginia

PENNSYLVANIA

NEW YORK

17 COMMITTED

CONNECTICUT

NYC: *The House at Cornell Tech, Knickerbocker Commons, Sendero Verde*

NEW HAMPSHIRE: *Gilford Village Knolls*

OHIO: *Fairwood Commons*

SOUTH DAKOTA: *Student Passive House Project and Copper Pass Apartments*

RESEARCH ON PASSIVE HOUSE IN QAPs

- States with differentiation from LEED get more PH projects
  - ✓ PA 23 projects (10 pt. bonus/150)
  - ✓ CT 6 projects (3 pt. bonus/104)
  - ✓ VT 1 project (1 of 30 checks)
  - ✓ SD 1 project ($500K bonus)
  - ✓ MA ~12 projects (2 points/182)- but also $3K per unit MassSave incentive

- Having PH as equivalent to LEED is not effective way to incentivize PH
  - ✓ 12 States- no PH projects

....14 ON THEIR WAY!!

WASHINGTON

OREGON

NEVADA

UTAH

MINNESOTA

IOWA

MISSOURI

OKLAHOMA

WISCONSIN

MICHIGAN

INDIANA

KENTUCKY

MAINE

ALASKA

....14 ON THEIR WAY!!

WASHINGTON

OREGON

NEVADA

Vermont: *Elm Place*

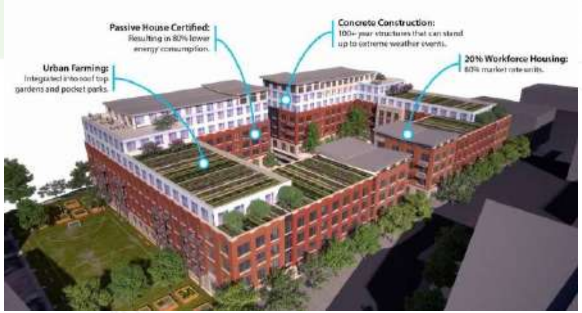
WISCONSIN

Oregon: *The Orchards at Orenco*

Maine: *Bayside Anchor Passive House*
Village Centre Passive House

ALASKA

Minnesota: *West Side Flats*



Missouri: *Second and Delaware, Kansas City*

AFFORDABLE HOUSING

AFFORDABLE HOUSING

Architects, Engineers, Builders

AFFORDABLE HOUSING

↑ ↑

Architects, Engineers, Builders

↓ ↓

MARKET-RATE HOUSING

Catalyst for radical and significant transformation of the

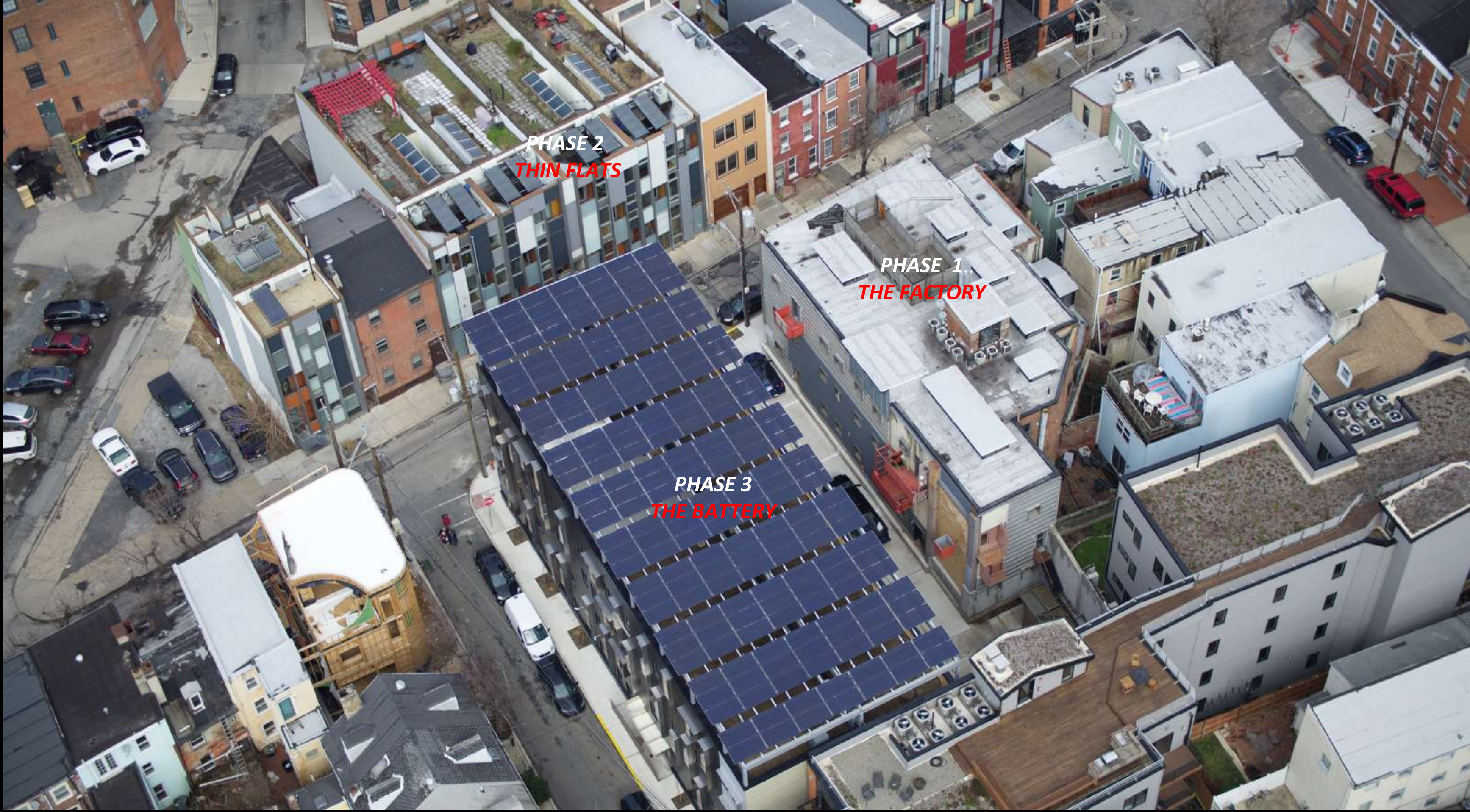
HOUSING INDUSTRY…..

AFFORDABLE HOUSING

Architects, Engineers, Builders

MARKET-RATE HOUSING

CAPITAL FLATS : 3 PHASES, 42 UNITS, 18 YEARS



CAPITAL FLATS : 3 PHASES, 42 UNITS, 18 YEARS

PHASE 3: THE BATTERY 2017

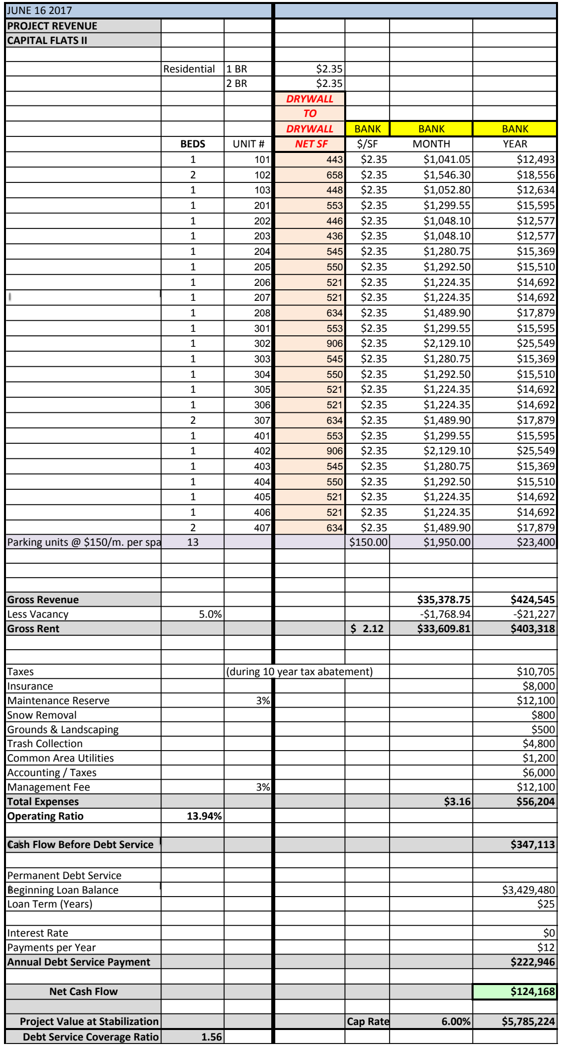
- *25 Apartments (500-1000sf)*
- *17,400 sf*
- *R34 walls*
- *R 54 roof/floors*
- *.13 Uvalue windows*
- *.6 SHGC*
- *Centralized VentilationERV, 82% efficient*
- *Centralized Hot Water: Geothermal*
- *Centralized heating/cooling: Geothermal VRF*
- *Centralized Electric Metering*
- *77 kw PV array to get to Net Zero*

PHASE 3: THE BATTERY 2017


100 W 199
LAUREL ST

$169/sf

COMPS agreed to by BANK



JUNE 16 2017						
PROJECT REVENUE						
CAPITAL FLATS II						
	Residential	1 BR	$2.35			
		2 BR	$2.35			
			DRYWALL			
			TO			
			DRYWALL	BANK	BANK	BANK
	BEDS	UNIT #	***NET SF***	$/SF	MONTH	YEAR
	1	101	443	$2.35	$1,041.05	$12,493
	2	102	658	$2.35	$1,546.30	$18,556
	1	103	448	$2.35	$1,052.80	$12,634
	1	201	553	$2.35	$1,299.55	$15,595
	1	202	446	$2.35	$1,048.10	$12,577
	1	203	436	$2.35	$1,048.10	$12,577
	1	204	545	$2.35	$1,280.75	$15,369
	1	205	550	$2.35	$1,292.50	$15,510
	1	206	521	$2.35	$1,224.35	$14,692
	1	207	521	$2.35	$1,224.35	$14,692
	1	208	634	$2.35	$1,489.90	$17,879
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Parking units @ $150/m. per spa	13			$150.00	$1,950.00	$23,400
Gross Revenue					**$35,378.75**	**$424,545**
Less Vacancy	5.0%				-$1,768.94	-$21,227
Gross Rent				**$ 2.12**	**$33,609.81**	**$403,318**
Taxes		(during 10 year tax abatement)				$10,705
Insurance						$8,000
Maintenance Reserve		3%				$12,100
Snow Removal						$800
Grounds & Landscaping						$500
Trash Collection						$4,800
Common Area Utilities						$1,200
Accounting / Taxes						$6,000
Management Fee		3%				$12,100
Total Expenses					**$3.16**	**$56,204**
Operating Ratio	**13.94%**					
Cash Flow Before Debt Service						**$347,113**
Permanent Debt Service						
Beginning Loan Balance						$3,429,480
Loan Term (Years)						$25
Interest Rate						$0
Payments per Year						$12
Annual Debt Service Payment						**$222,946**
Net Cash Flow						**$124,168**
Project Value at Stabilization				**Cap Rate**	**6.00%**	**$5,785,224**
Debt Service Coverage Ratio	**1.56**					

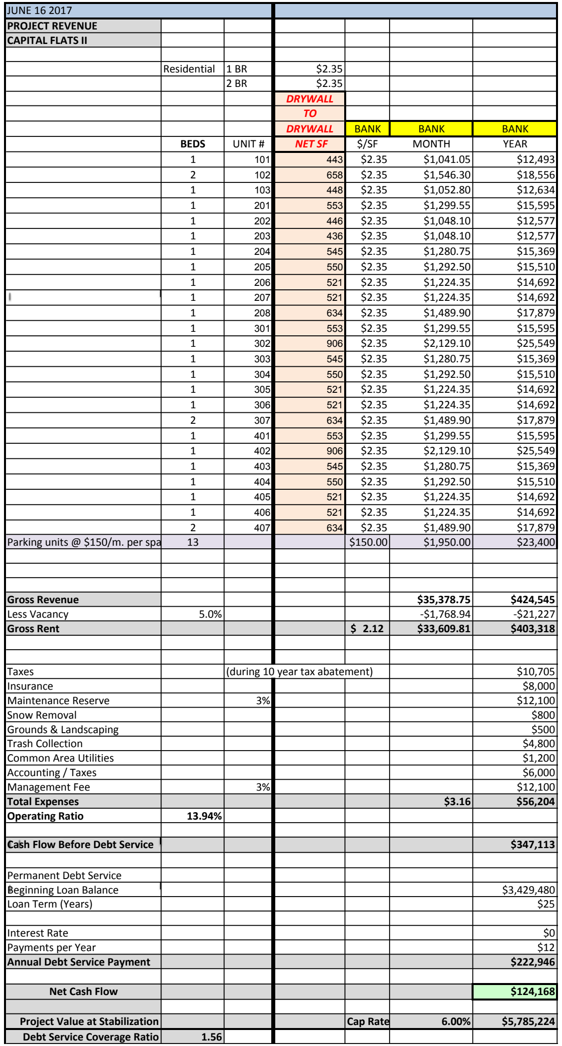
AVERAGE RENT:
$1337/MONTH
$2.35 SF

COMPS agreed to by BANK

AVERAGE RENT: $1337/MONTH $2.35 SF

DEBT SERVICE RATIO:

1.56



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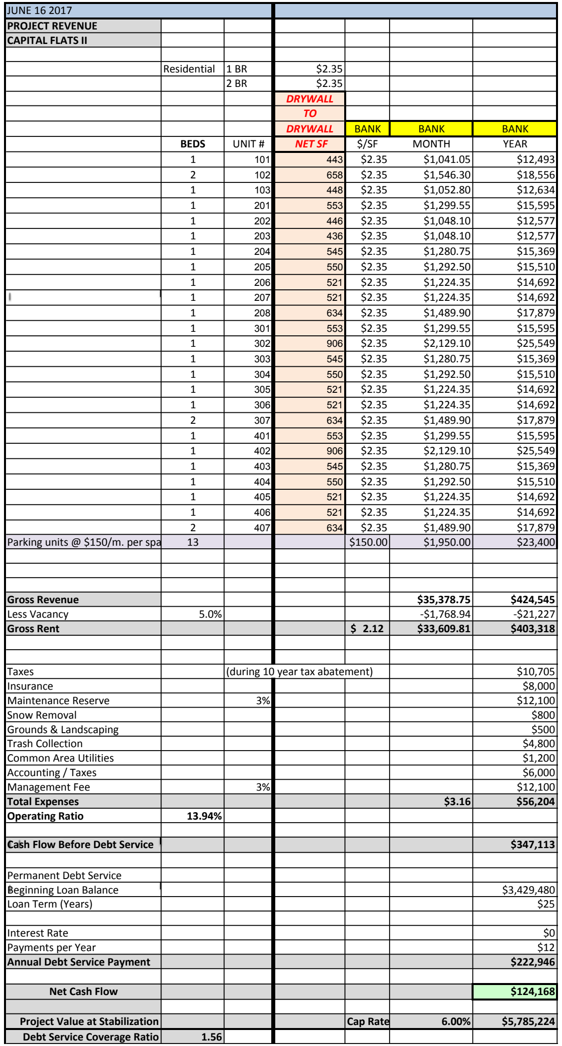

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What the BANK was willing to lend

CAPITAL 2 COSTS

	DESCRIPTION OF WORK	SCHEDULED VALUE
1	Concrete/Site/Excavation	$230,724.00
2	Windows/Doors/Panelized	$313,454.47
3	Rough Carpentry	$216,616.00
4	Finish Carpentry	$102,143.00
5	Cabinetry/Appliances/Fixtures	$237,376.00
6	Insulation	$88,655.00
7	Roofing Greenroof	$157,682.00
8	Exterior Cladding	$209,205.00
9	Drywall, Metal Studs	$177,251.00
10	Interior Doors/Frames/Hardware	$61,873.00
11	Flooring	$130,875.00
12	Paint	$92,520.00
13	Specialties: Steel	$79,371.00
14	Fire Sprinklers	$44,100.00
15	Plumbing	$173,700.00
16	HVAC	$150,975.00
17	Electric	$161,411.00
18	General Reqs	$232,511.00
19	OH& Profit	$315,998.44
20	Soft Costs	$305,000.00
21	Contingencies	$183,545.53
22	Solar Racking and Panels	
	TOTAL	***$3,664,986.44***

COMPS agreed to by BANK

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ACTUAL RENTS

16-Jun	***16-Jun***	***16-Jun***	
$/SF	***PRICING***	***YEAR***	
$2.93	$1,300.00	15,600.00	
$2.74	$1,800.00	21,600.00	
$2.90	$1,300.00	15,600.00	
$2.89	$1,600.00	19,200.00	
$3.14	$1,400.00	16,800.00	
$3.21	$1,400.00	16,800.00	
$2.75	$1,500.00	18,000.00	
$2.73	$1,500.00	18,000.00	
$2.69	$1,400.00	16,800.00	
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$2.52	$1,600.00	19,200.00	
$2.89	$1,600.00	19,200.00	
$2.98	$2,700.00	32,400.00	
$2.75	$1,500.00	18,000.00	
$2.73	$1,500.00	18,000.00	
$2.69	$1,400.00	16,800.00	
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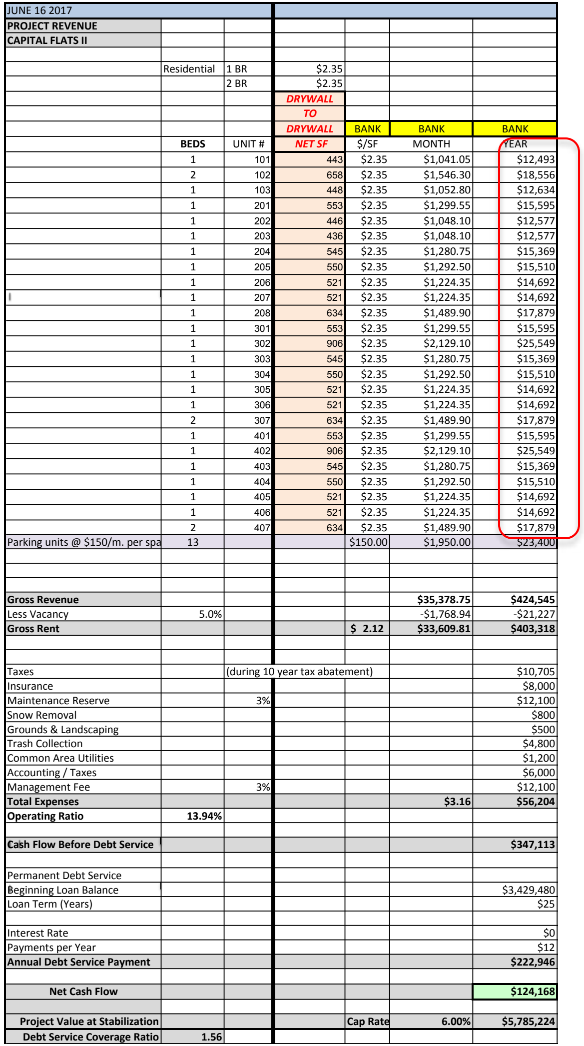
$2.52	$1,600.00	19,200.00	
$2.89	$1,600.00	19,200.00	
$2.98	$2,700.00	32,400.00	
$2.75	$1,500.00	18,000.00	
$2.73	$1,500.00	18,000.00	
$2.69	$1,400.00	16,800.00	
$2.69	$1,400.00	16,800.00	
$2.52	$1,600.00	19,200.00	
$2.79	$1,950.00	23,400.00	
		$498,600.00	
		-$21,227	
		$519,827.25	
		$56,204	
		$463,622.93	
		$222,946	
		$240,677.36	**Net Cash Flow**
		$7,727,048.75	**Project Value at Stabilization**

COMPS agreed to by BANK



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	1	406	521	$2.35	$1,224.35	$14,692
	2	407	634	$2.35	$1,489.90	$17,879
Parking units @ $150/m. per spa	13			$150.00	$1,950.00	$23,400
Gross Revenue					**$35,378.75**	**$424,545**
Less Vacancy	5.0%				-$1,768.94	-$21,227
Gross Rent				**$ 2.12**	**$33,609.81**	**$403,318**
Taxes		(during 10 year tax abatement)				$10,705
Insurance						$8,000
Maintenance Reserve		3%				$12,100
Snow Removal						$800
Grounds & Landscaping						$500
Trash Collection						$4,800
Common Area Utilities						$1,200
Accounting / Taxes						$6,000
Management Fee		3%				$12,100
Total Expenses					**$3.16**	**$56,204**
Operating Ratio	**13.94%**					
Cash Flow Before Debt Service						**$347,113**
Permanent Debt Service						
Beginning Loan Balance						$3,429,480
Loan Term (Years)						$25
Interest Rate						$0
Payments per Year						$12
Annual Debt Service Payment						**$222,946**
Net Cash Flow						**$124,168**
Project Value at Stabilization				**Cap Rate**	**6.00%**	**$5,785,224**
Debt Service Coverage Ratio	**1.56**					

AVERAGE RENT:

$1337/MONTH

$2.35 SF

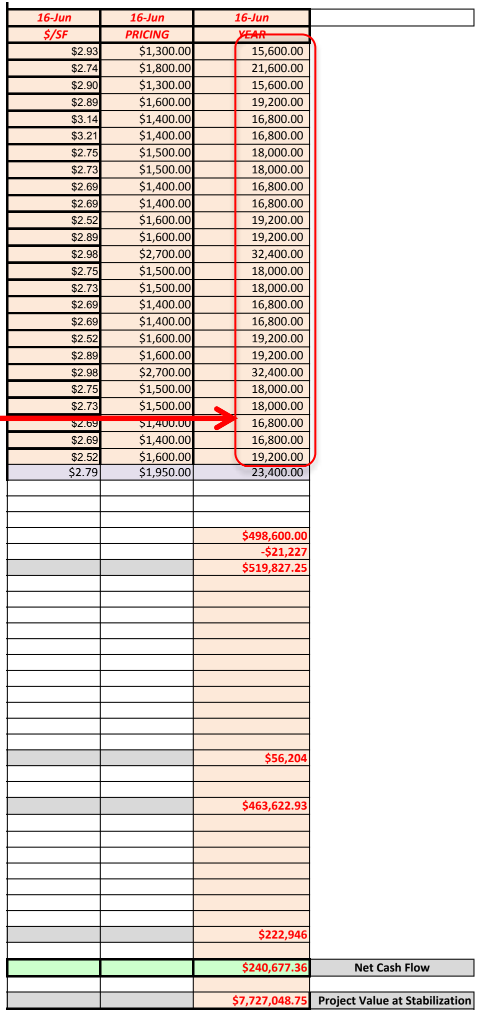
DEBT SERVICE RATIO:

1.56

ACTUAL RENTS

15% INCREASE

- *Integrated project Team*
- *More efficient*
- *Better design:*
- *Solar canopy and array*
- *Rent includes utiliites*
- *Basement storage space*
- *Electric car charging*
- *Interactive building*



16-Jun	*16-Jun*	*16-Jun*	
$/SF	*PRICING*	*YEAR*	
$2.93	$1,300.00	15,600.00	
$2.74	$1,800.00	21,600.00	
$2.90	$1,300.00	15,600.00	
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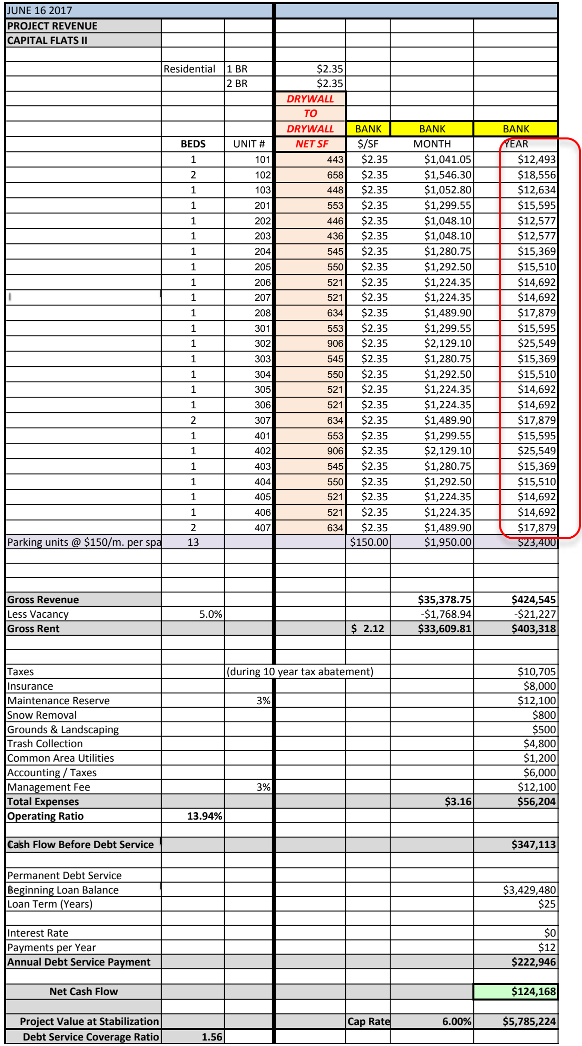
$2.79	$1,950.00	23,400.00	
		$498,600.00	
		-$21,227	
		$519,827.25	
		$56,204	
		$463,622.93	
		$222,946	
		$240,677.36	**Net Cash Flow**
		$7,727,048.75	**Project Value at Stabilization**

COMPS agreed to by BANK



JUNE 16 2017						
PROJECT REVENUE						
CAPITAL FLATS II						
	Residential	1 BR	$2.35			
		2 BR	$2.35			
			DRYWALL TO DRYWALL	BANK	BANK	BANK
	BEDS	UNIT #	***NET SF***	$/SF	MONTH	YEAR
	1	101	443	$2.35	$1,041.05	$12,493
	2	102	658	$2.35	$1,546.30	$18,556
	1	103	448	$2.35	$1,052.80	$12,634
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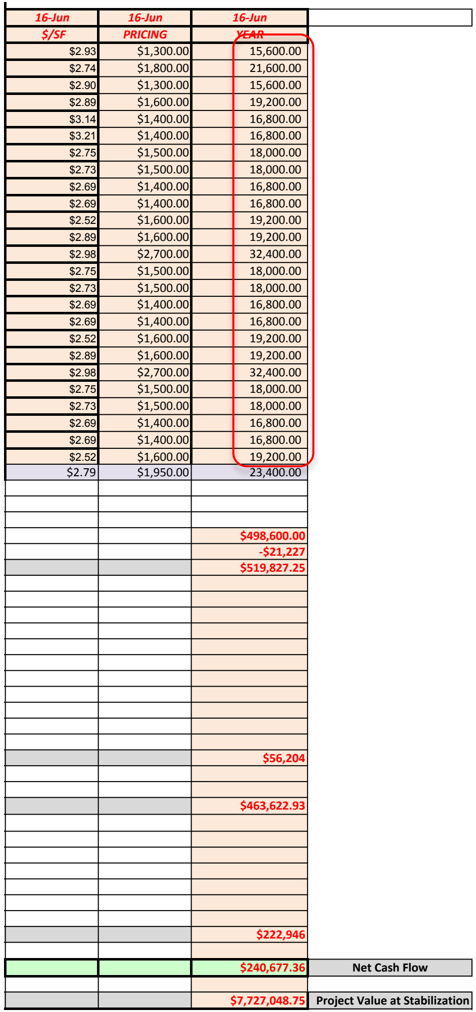
Payments per Year						$12
Annual Debt Service Payment						**$222,946**
Net Cash Flow						**$124,168**
Project Value at Stabilization				**Cap Rate**	**6.00%**	**$5,785,224**
Debt Service Coverage Ratio	**1.56**					

AVERAGE: $1337.00

AVERAGE RENT: $1337/MONTH $2.35 SF

DEBT SERVICE RATIO: 1.56

AVERAGE: $1584.00 Still below Market Rate!!!



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$/SF	***PRICING***	***YEAR***	
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		$519,827.25	
		$56,204	
		$463,622.93	
		$222,946	
		$240,677.36	**Net Cash Flow**
		$7,727,048.75	**Project Value at Stabilization**

COMPS agreed to by BANK

AVERAGE RENT: $1337/MONTH $2.35 SF

DEBT SERVICE RATIO: 1.56

1.56

JUNE 16 2017						
PROJECT REVENUE						
CAPITAL FLATS II						
	Residential	1 BR	$2.35			
		2 BR	$2.35			
			DRYWALL			
			TO			
			DRYWALL	BANK	BANK	BANK
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Total Expenses					**$3.16**	**$56,204**
Operating Ratio	**13.94%**					
Cash Flow Before Debt Service						**$347,113**
Permanent Debt Service						
Beginning Loan Balance						$3,429,480
Loan Term (Years)						$25
Interest Rate						$0
Payments per Year						$12
Annual Debt Service Payment						**$222,946**
Net Cash Flow						**$124,168**
Project Value at Stabilization				**Cap Rate**	**6.00%**	**$5,785,224**
Debt Service Coverage Ratio	**1.56**					

$116,000.00 More NET Revenue

16-Jun	***16-Jun***	***16-Jun***	
$/SF	***PRICING***	***YEAR***	
$2.93	$1,300.00	15,600.00	
$2.74	$1,800.00	21,600.00	
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COMPS agreed to by BANK

JUNE 16 2017						
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AVERAGE RENT:
$1337/MONTH
$2.35 SF

DEBT SERVICE RATIO:
1.56

$1,941,825.00
Increased Valuation

16-Jun	16-Jun	16-Jun	
$/SF	PRICING	YEAR	
$2.93	$1,300.00	15,600.00	
$2.74	$1,800.00	21,600.00	
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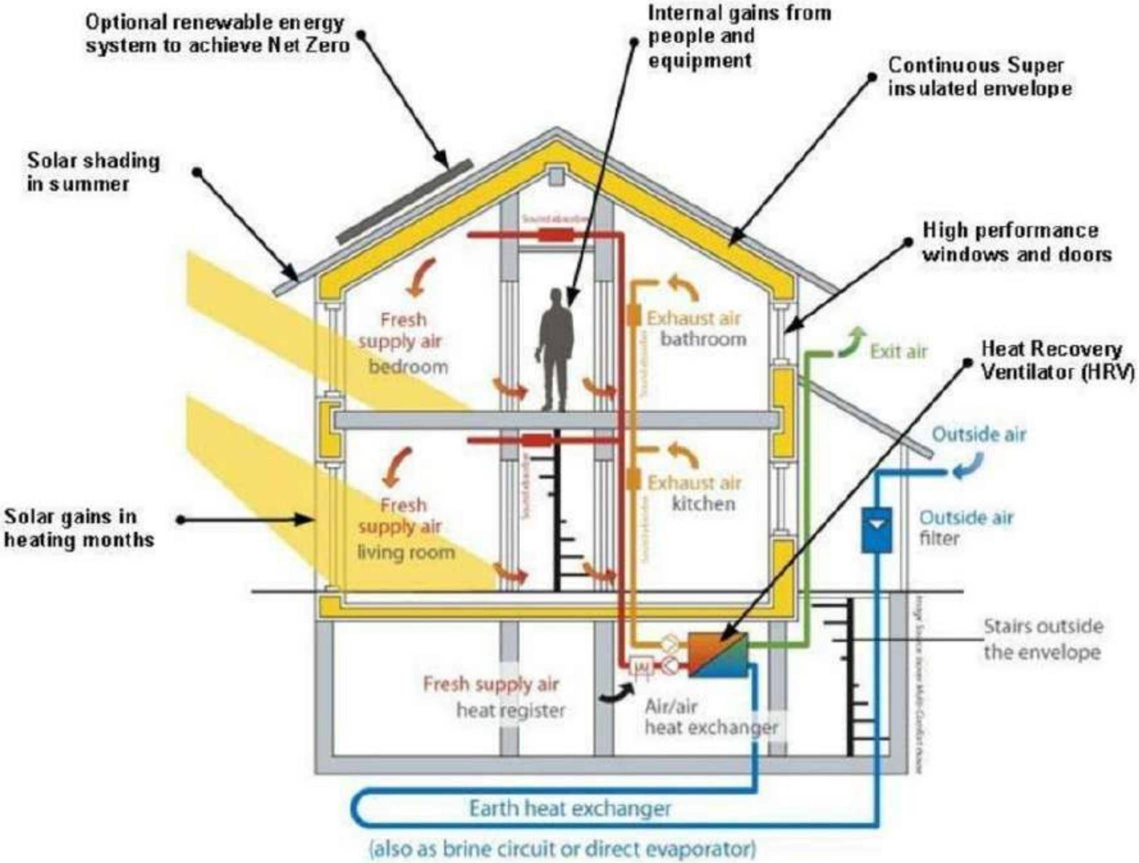


Passive House Diagram

1

2

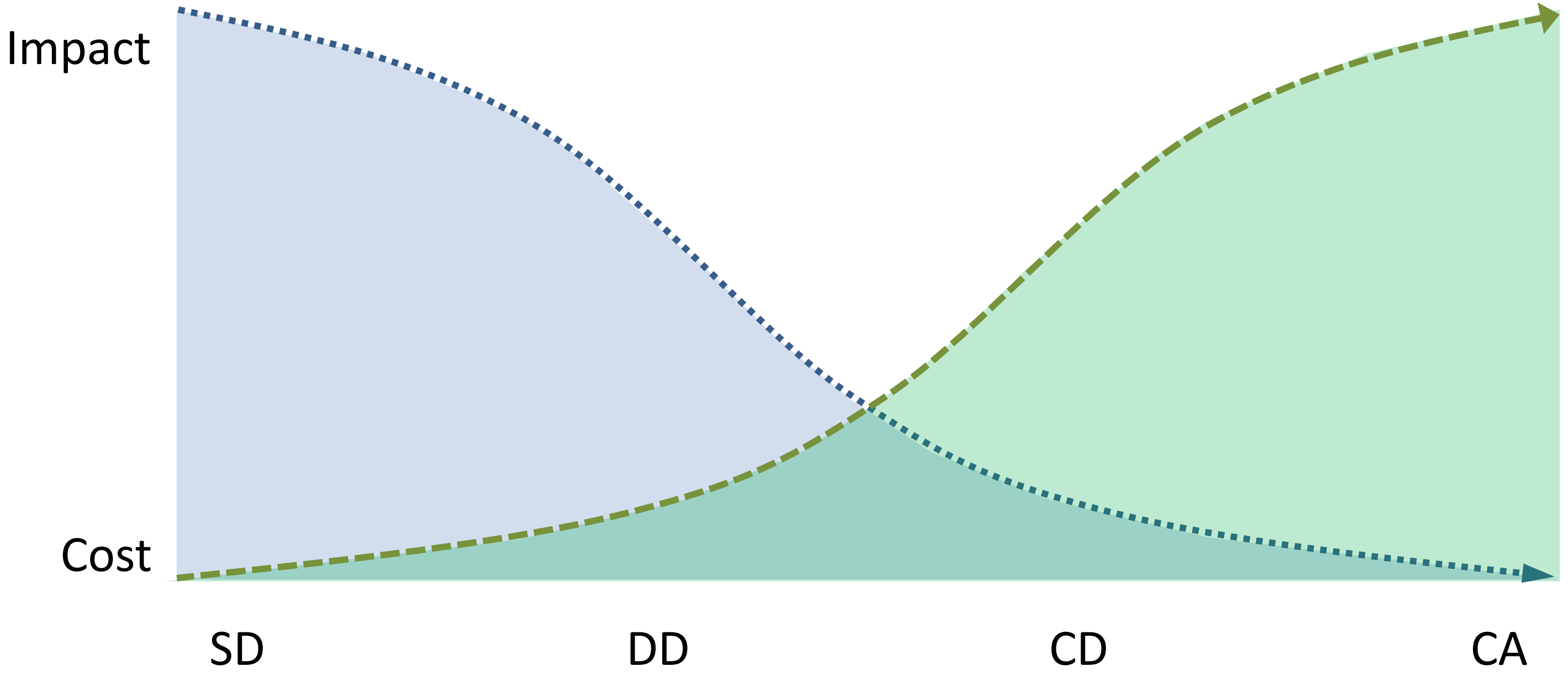
3

4

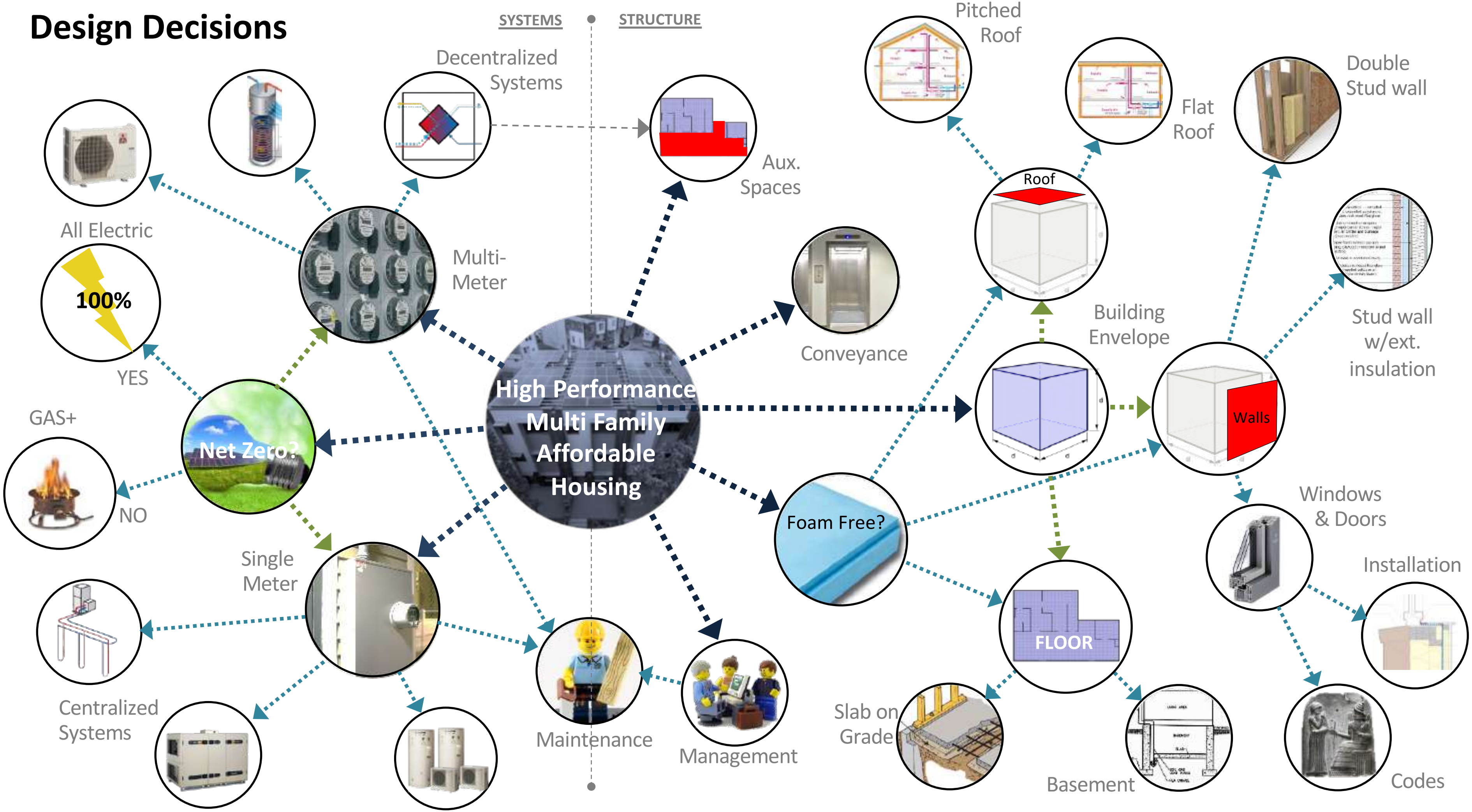
5

6

Decision Making



Design Decisions



SYSTEMS • STRUCTURE

High Performance Multi Family Affordable Housing

Multi-Meter

Decentralized Systems

All Electric

Net Zero?

YES

GAS+

NO

Single Meter

Centralized Systems

Maintenance

Management

Aux. Spaces

Conveyance

Foam Free?

Building Envelope

Roof

Pitched Roof

Flat Roof

Walls

Double Stud wall

Stud wall w/ext. insulation

Windows & Doors

Installation

Codes

FLOOR

Slab on Grade

Basement

Typical Design Process

Broad Decisions

Detailed Decisions

Programming… Massing….

Systems…

Passive House Design Process

Broad Decisions

Detailed Decisions

Programming… Massing… Envelope Systems…

MANUAL

FOR MULTI-FAMILY PASSIVE HOUSE/NET ZERO ENERGY CAPABLE AFFORDABLE HOUSING

#1: NET-ZERO-ENERGY CAPABLE?

YES

ALL-ELECTRIC BUILDING
(No non-renewable fuel can be used)

NO

NON-RENEWABLE FUEL CAN BE USED
- Gas, propane, oil can be used for heating/cooling, domestic hot water, cooking

#2: METERING

ONE METER
Developer pays utilities

IMPLICATIONS
- Centralized Ventilation system (located on roof, roughly one unit for 10-15 apartments)
- Centralized hot water system (solar thermal or geothermal) OR Decentralized HPWHs
- Centralized heating/cooling system (two ways to go here, either air-sourced Mitsubishi/Fujitsu VRF system or “ground-source" geothermal system”)
- Solar Photovoltaic centralized system without arrays and ONE meter.

PROS
- Simplified monthly payments for tenants
- Less maintenance on ventilation/heating/cooling/hot water systems as they are centralized in one place
- Less penetrations in envelop for ventilation system
- Freed up space in apartments as no mechanical closets are required
- Less cost and space required for electric meters (one) and solar meters (one)
- Owner should be monitoring the energy consumption of the units any way and a while there will only need to be ONE electric meter, owner will be able to still monitor the electricity consumption of each unit
- Owner receives the benefit of the solar electricity generation.

CONS
- Fire dampers required on ventilation supply and returns as they pass horizontal 1 hour assembly
- Owner has more management costs related to billing tenants if they go over maximum amount of energy per month

MULTIPLE METERS
Tenants pay all utilities

IMPLICATIONS
- Decentralized Ventilation (Individual ERV/HRV in each unit)
- Decentralized Hot Water (Individual Heat Pump water heaters in each unit)
- Decentralized Heating/Cooling (Individual Mini-split heat pumps within each unit, one condenser per unit
- Water (Owner meter's water consumption and charges tenants or is included in rent
- Solar PV is broken into a series of "arrays" that corespond to each unit and tied to unit's meter

PROS
- Owner is not managing or paying for utilities, tenants are. Tenants get benefit of solar electric generation not owner.

CONS
- Requires more maintenance for owner
  - Filters in ventilation/heating/cooling/hot water systems need to be cleaned/replaced 3-4 per year.
- Coordination challenge of maintenance with all tenants because systems are inside their units.
- Two punctures in the envelope for ERV/HRV (1 supply and 1 exhaust for each unit) which is labor intensive and has potential for air leakage.
- ERV/HRV takes up space in apartments and needs to be located within 10 of exterior wall with two insulated ducts to the outside per unit.
- Heat pump water heaters take up space in apartment, add to heating load to space and require ventilated closet.
- Capital costs of wiring and space required for multiple individual electrical meters and solar meters.
- Tenants get benefit of solar electric generation not owner.
- Owner not in control of monitoring energy consumption of units

#3: ENVELOP

FOUNDATION

Slab on Grad

PROS
- Cost effective
- Monolithic pour with monolithic insulating forms,

CONS
- No basement for storage/utilities

PRODUCTS
- Prefabricated Insulated Structural Foam formwork
  - Buildsmart: Only negative with Buildsmart is lack of diversity from a design perspective
- Site Built
  - Structural High density EPS, inexpensive
  - Foamglass: expensive

Basement

PROS
- Storage and utilities

CONS
- Expensive

WALLS..........

Stud wall with exterior insulation

PROS
- Cost effective
- Air barrier is on OUTSIDE; reduces penetrations
- Everyday framing techniques; little training

CONS
- Exterior insulation adds labor costs depending on insulation type

Drying in two directions: Vapor Closed
- Rigid foam insulation on exterior
Wall cavity drys to interior, exterior foam drys to exterior
- Foam has greater global warming potential
- Some foams loose Rvalue in more extreme temps
- less expensive

Drying in One direction: Vapor Open
- Rigid insulation on exterior fully open drying potential
eg: Roxul, Gutex, cork
- Less global warming potential
- Maintains Rvalue in more extreme temps
- More expensive

Double Stud wall

PROS
- No exterior insulation
- Vapor Open construction
- "Anti-foam" people love this

CONS
- Air barrier is on INTERIOR; complicates penetrations and framing
- Expensive
- Not everyday framing techniques
- Complicated air-barrier details

PRODUCTS
- Intello air barriers
-

ROOF............

Pitched

PROS
- Cost effective
- Air barrier is on INSIDE; bottom side of trusses
- Everyday framing techniques; little training
- Cost Effective roofing membrane options
- Cost effective loose-fill insulation (cellulose, fiberglass...)

CONS
- Limits to "contemporary" design aesthetic options

Flat

PROS
- Cost effective
- Air barrier is on OUTSIDE; reduces penetrations; roof sheathing doubles as air barrier
- Everyday framing techniques; little training

CONS
- Requires exterior rigid insulation

#4: WINDOWS/DOORS

- **Fentrend: window sourcing**
- **Buildsmart: Klearwall windows built in**
  - eliminates need for research or installation costs associated with windows and doors
- **Intus, Klearwall......**

#5: VENTILATION

CENTRALIZED ERV/HRV
- Ventacity
- RenewAire
- Ultimate Aire

* Note: Look for latent and sensible efficiencies high enough so as NOT to require additional heating or dehumidification on supply side of unit

#6: HEATING/COOLING

AIR SOURCE
- VRF: Centralized but also capable of metering
  - Mitsubishi, Fujitsu
- Mini-splits (Mitsubishi, Fujitsu)
  - Non-ducted less expensive and in small apartments, ducted is not necessary
  - Ducted: more expensive, doubling duct work but fool-proof

GROUND SOURCE
- Geothermal : Water to refrigerant systems (Mitsubishi, Fujitsu)
  - more expensive but 30% Federal tax credit put's it on par with air-sorurce
  - more energy efficient than air-source
- Geothermal : Water to water, "chilled beam" technology
  - more expensive but worthy of further research

#7: DOMESTIC HOT WATER

AIR SOURCE
- Decentalized Heatpump water heaters

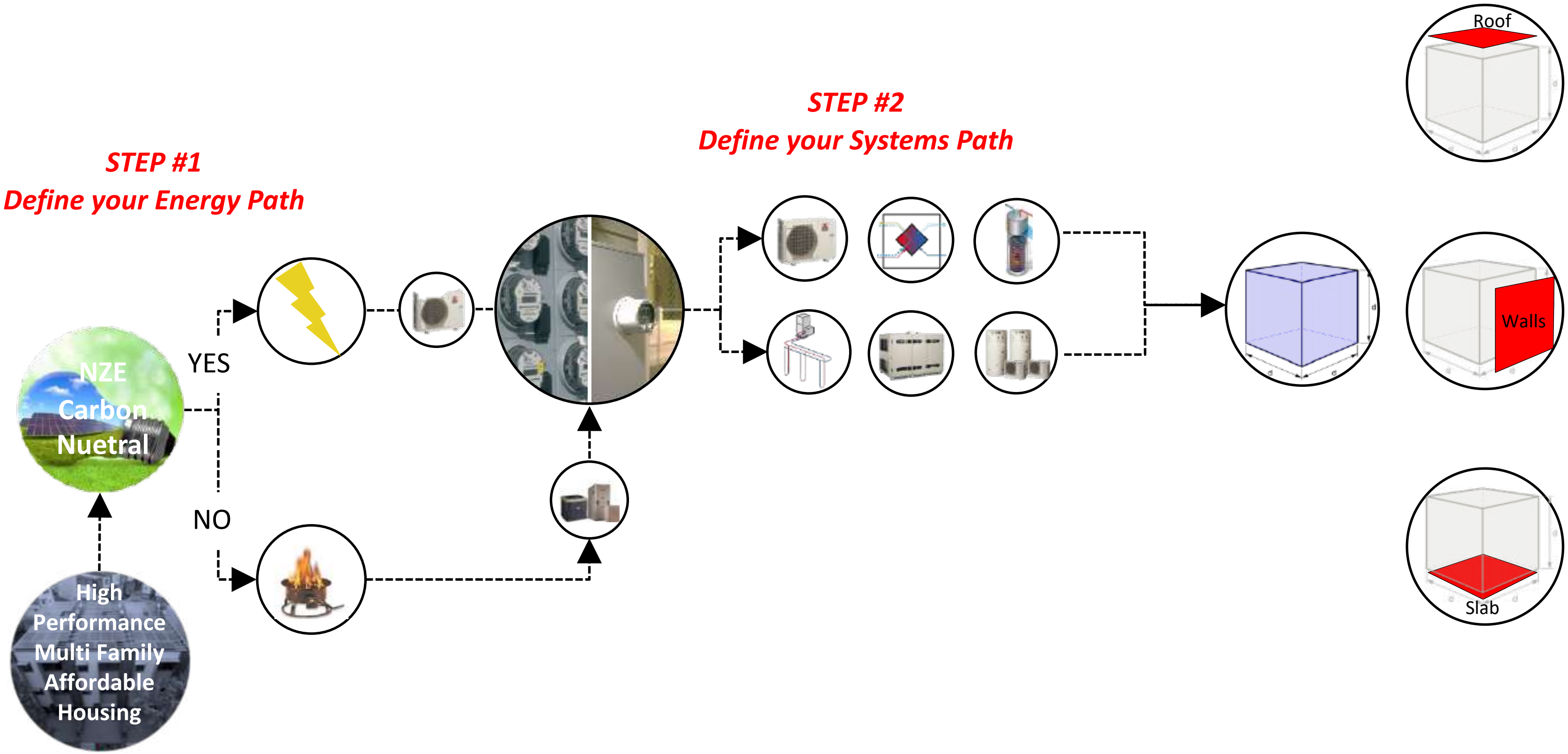
GROUND SOURCE
- Geothermal : Water to refrigerant systems (Mitsubishi, Fujitsu)
  - more expensive but 30% Federal tax credit put's it on par with air-sorurce
  - more energy efficient than air-source
- Geothermal : Water to water, "chilled beam" technology
  - more expensive but worthy of further research

SOLAR THERMAL
- Expensive but very efficient;

#8: ENERGY MONITORING

PURPOSE
- Tool for preventative maintenance
- Tool for optimizing performance
- Tool for communication between owner/tenants and larger community
- Promotional tool for marketing the project to policy/governmental/financial partners

HARDWARE/SOFTWARE
- Site Sage, Powerwise, Lucid, Hobo.....



STEP #1
Define your Energy Path

STEP #2
Define your Systems Path

STEP #3
Define your Envelop Path

High Performance Multi Family Affordable Housing

NZE Carbon Nuetral

YES

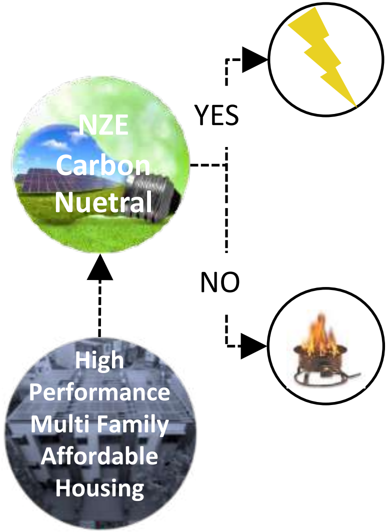
NO

Roof

Walls

Slab

STEP #1
Define your Energy Path



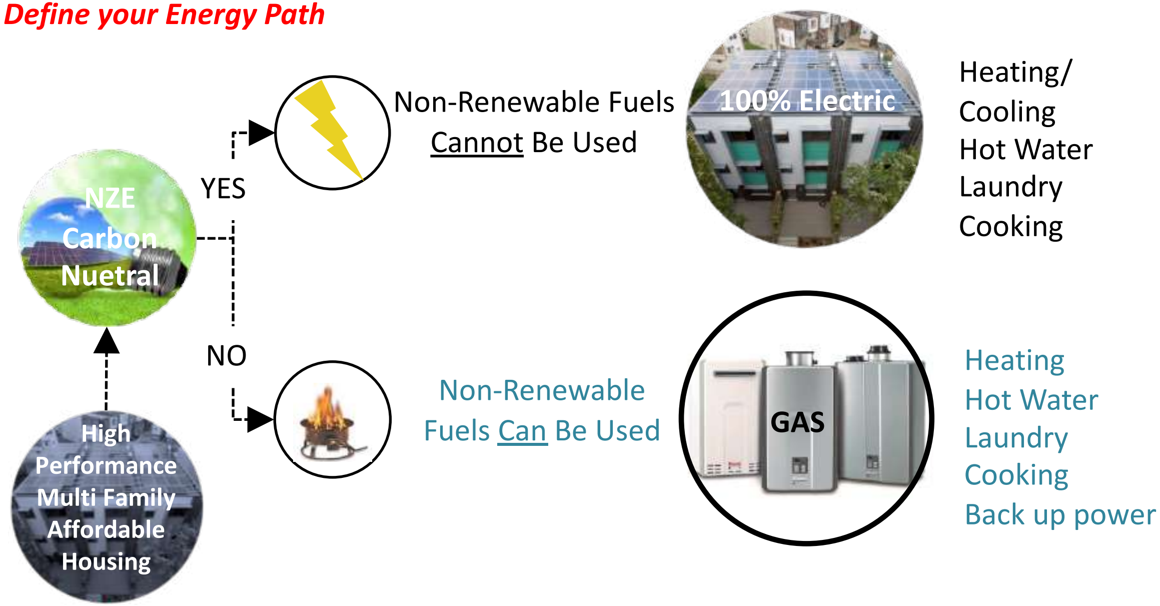
NZE Carbon Nuetral

YES

NO

High Performance Multi Family Affordable Housing

STEP #1
Define your Energy Path



High Performance Multi Family Affordable Housing

NZE Carbon Nuetral

YES

Non-Renewable Fuels Cannot Be Used

100% Electric

Heating/
Cooling
Hot Water
Laundry
Cooking

NO

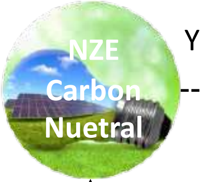
Non-Renewable Fuels Can Be Used

GAS

Heating
Hot Water
Laundry
Cooking
Back up power

STEP #1

Define your Energy Path



YES

Non-Renewable Fuels
<u>Cannot</u> Be Used

Heating/
Cooling
Hot Water
Laundry
Cooking

Pros

- Only ONE utility to manage
- Can get to Net Zero
- Less venting requirements
- Less capital costs on installation of utility, more space

Cons

- No gas cooking
- No gas DHW
- No gas Laundry

NO

Non-Renewable
Fuels <u>Can</u> Be Used

Heating
Hot Water
Laundry
Cooking
Back up power

Pros

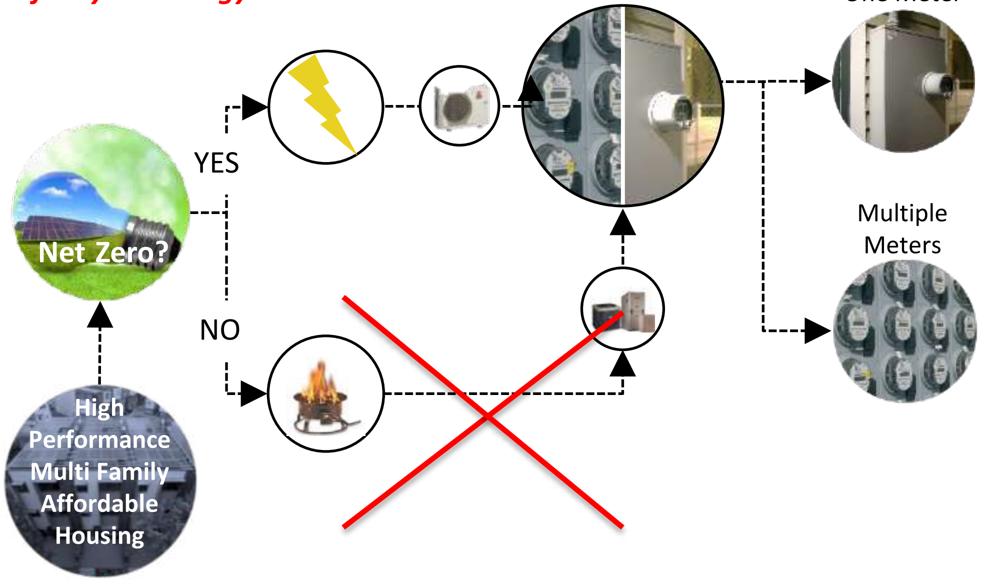
- Efficient with centralized systems
- Cheap fuel

Cons

- Capital costs for new utility, all piping, venting and make-up air requirements
- Indoor Air quality and contaminants
- Not Carbon-Nuetral

STEP #1
Define your Energy Path

STEP #2
Define your Systems Path



High Performance Multi Family Affordable Housing

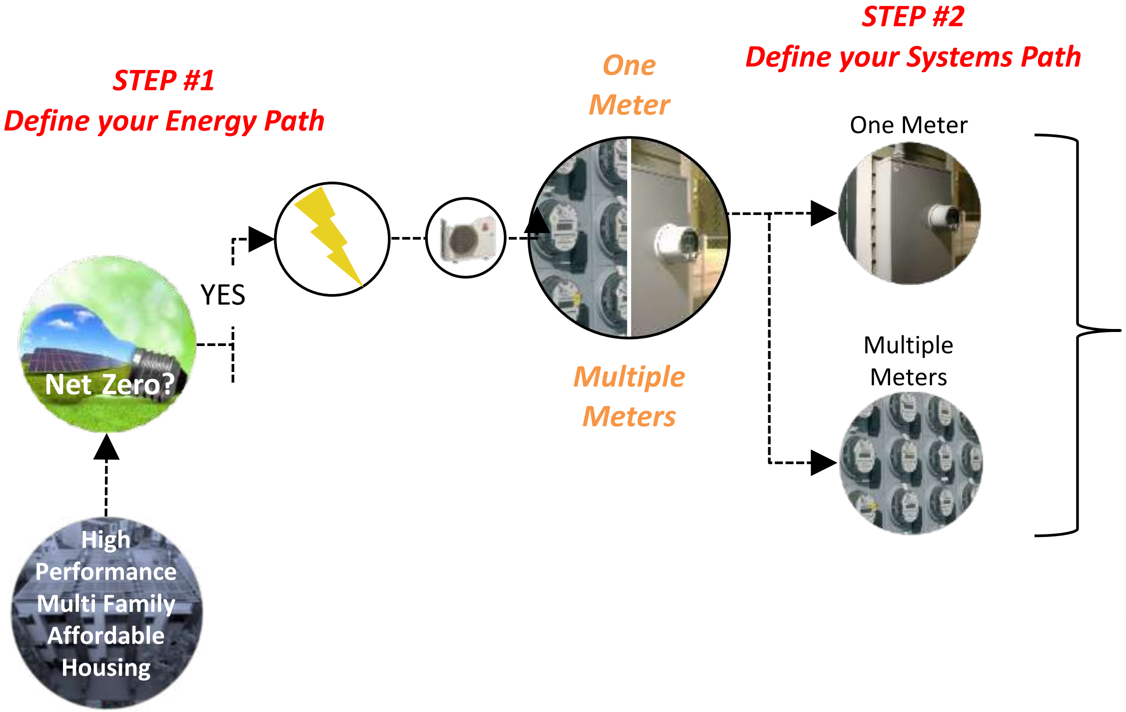
Net Zero?

YES

NO

One Meter

Multiple Meters



STEP #1
Define your Energy Path

High Performance Multi Family Affordable Housing

Net Zero?

YES

One Meter

Multiple Meters

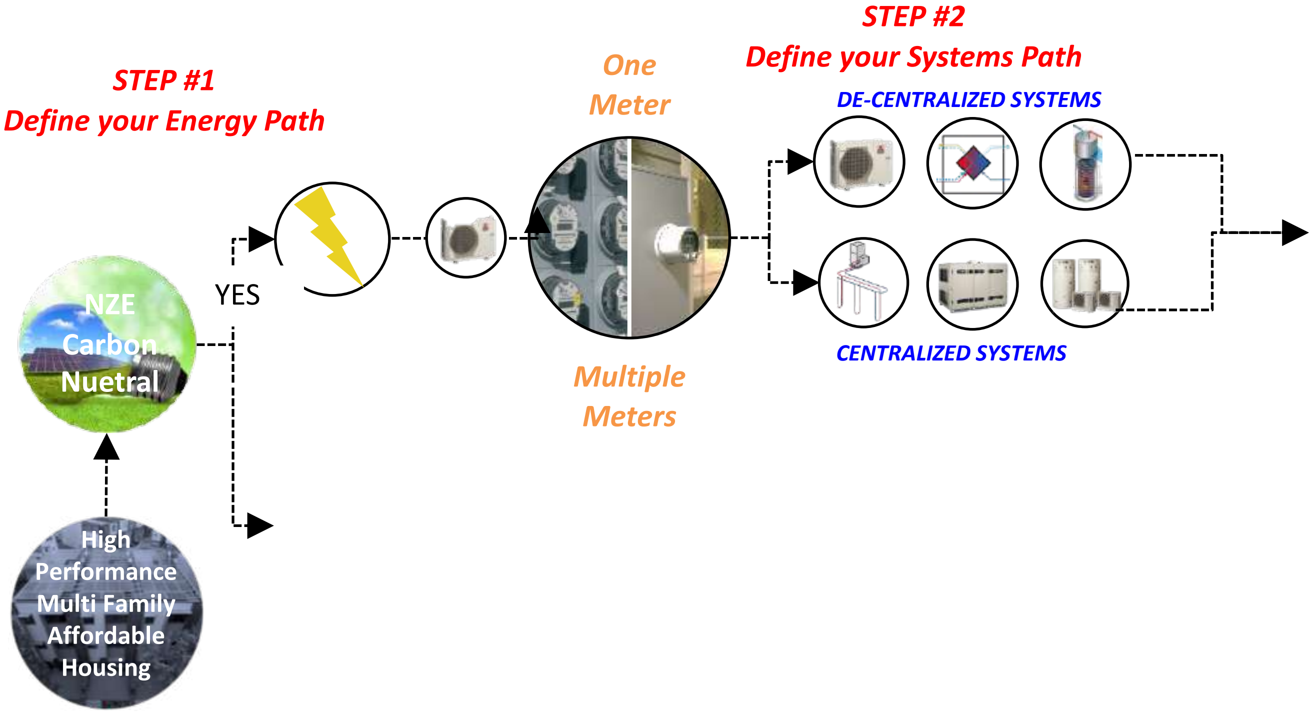
STEP #2
Define your Systems Path

One Meter

Multiple Meters

Metering Strategy Will Affect:

- Equipment Selection
- Space Planning
- Maintenance Schedule
- Fire Protection
- Rental Agreements



STEP #1

Define your Energy Path

High Performance Multi Family Affordable Housing

NZE Carbon Nuetral

YES

One Meter

Multiple Meters

STEP #2

Define your Systems Path

DE-CENTRALIZED SYSTEMS

CENTRALIZED SYSTEMS

One Meter

CENTRALIZED SYSTEMS

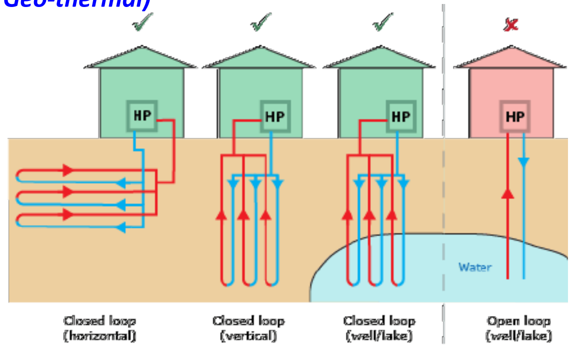
IMPLIES CENTRALIZED SYSTEMS

- Centralized heating/cooling
- Centralized Hot water
- Centralized ventilation
- One solar array
- Monitoring vs metering

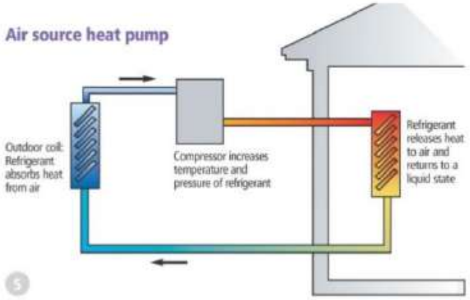
HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)



Air-Sourced Heat Pump



One Meter

CENTRALIZED SYSTEMS

IMPLIES CENTRALIZED SYSTEMS

- *Centralized heating/cooling*
- Centralized Hot water
- Centralized ventilation
- One solar array
- Monitoring vs metering

HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)

The Battery, PHIUS + Certified, 2017, OPEN LOOP, "STANDING COLUMN" GEO WELLS

One Meter

CENTRALIZED SYSTEMS

IMPLIES CENTRALIZED SYSTEMS

- ***Centralized heating/cooling***
- Centralized Hot water
- Centralized ventilation
- One solar array
- Monitoring vs metering

HEATING/COOLING

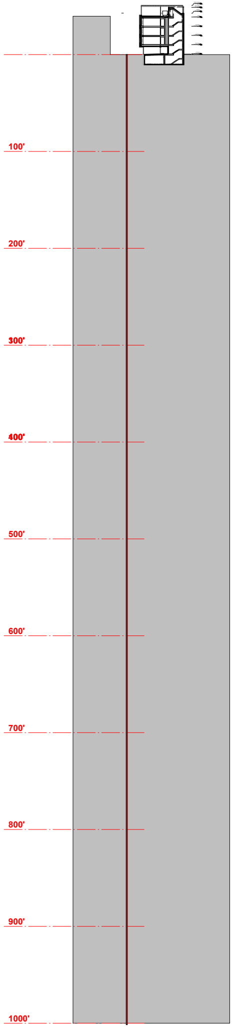
Ground-Sourced Heat Pump

(Geo-thermal)

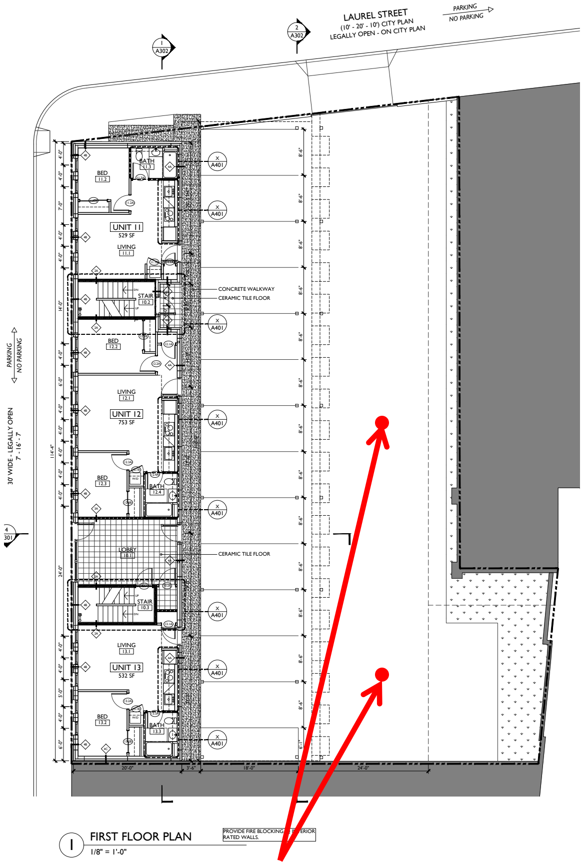
HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)



GEOTHERMAL 1000' Deep section



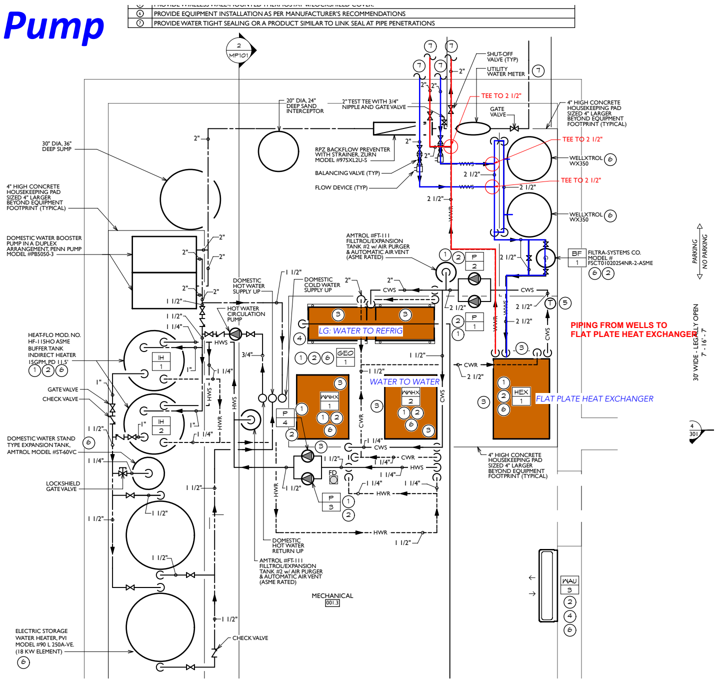
1 FIRST FLOOR PLAN
1/8" = 1'-0"

2 – 1000' deep Standing Column Geothermal Wells
ALL heating/cooling and domestic hot water for ALL 25 apartments

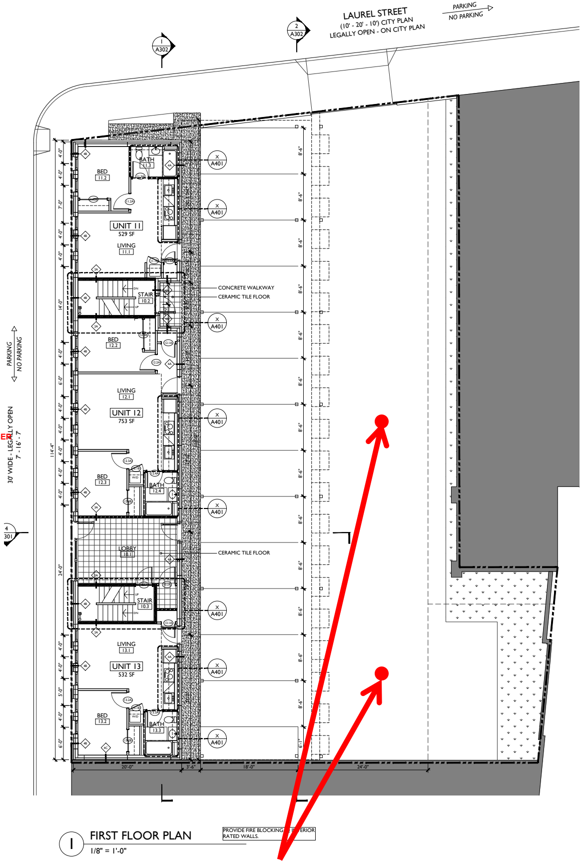
HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)



BASEMENT MECHANICAL ROOM



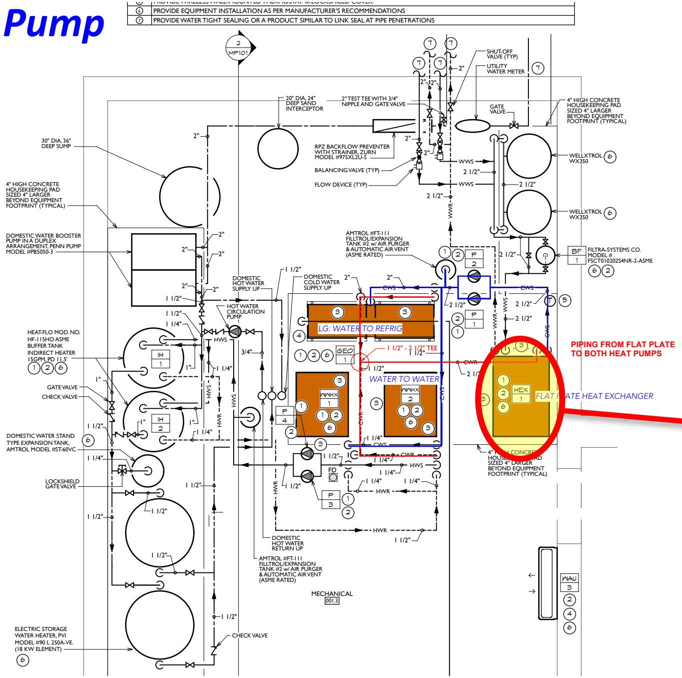
2 – 1000' deep Standing Column Geothermal Wells

ALL heating/cooling and domestic hot water for ALL 25 apartments

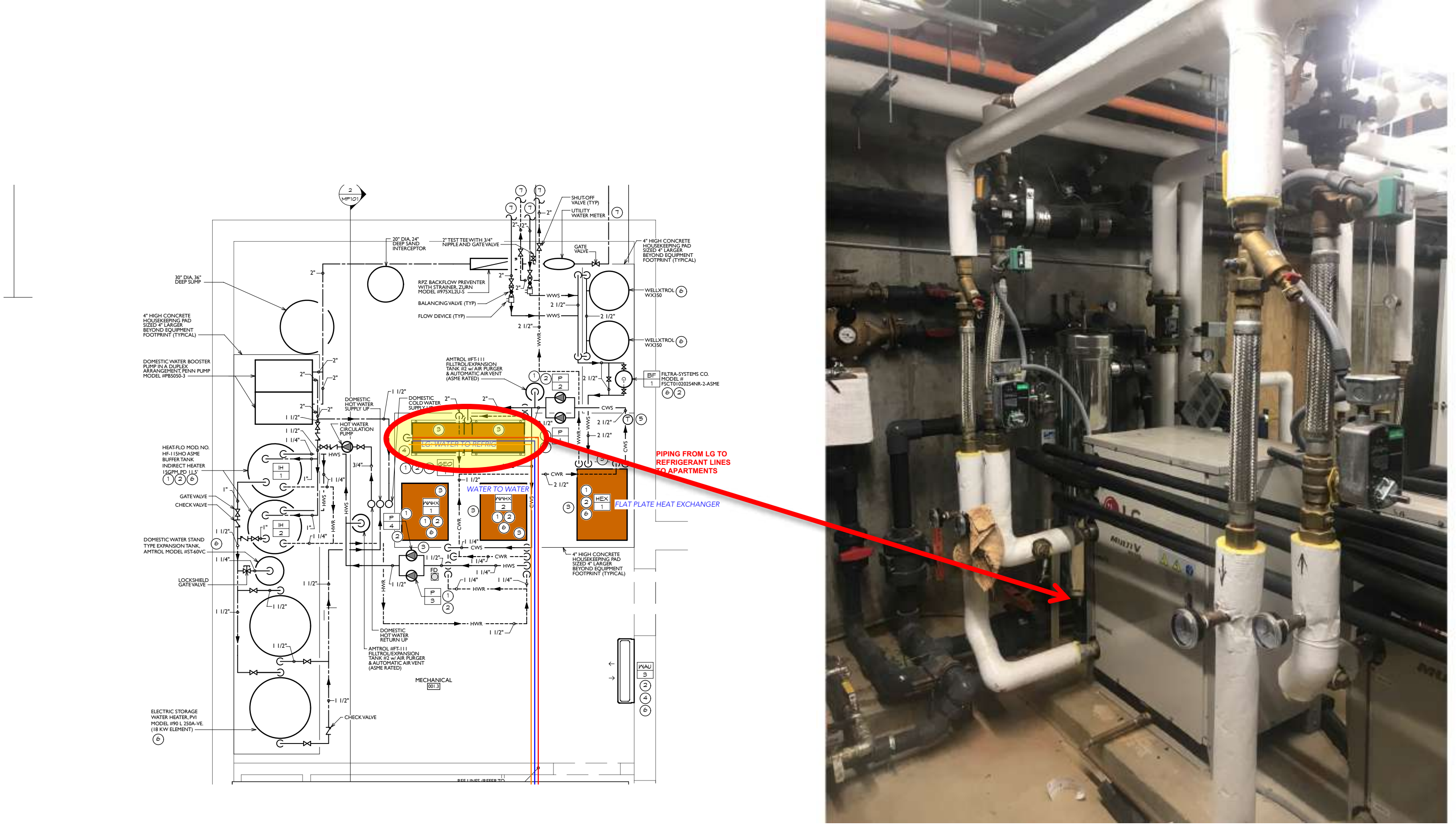
HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)



FLAT PLATE HEAT EXCHANGER



PIPING FROM LG TO REFRIGERANT LINES TO APARTMENTS

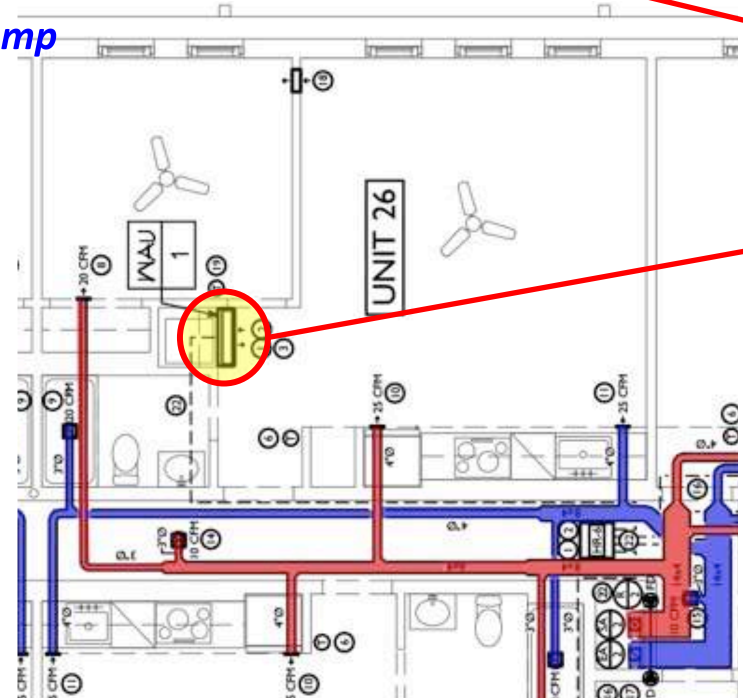
WATER-TO-REFRIGERANT HEAT PUMPS

HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)

OPEN TRANSOM TO BEDROOM



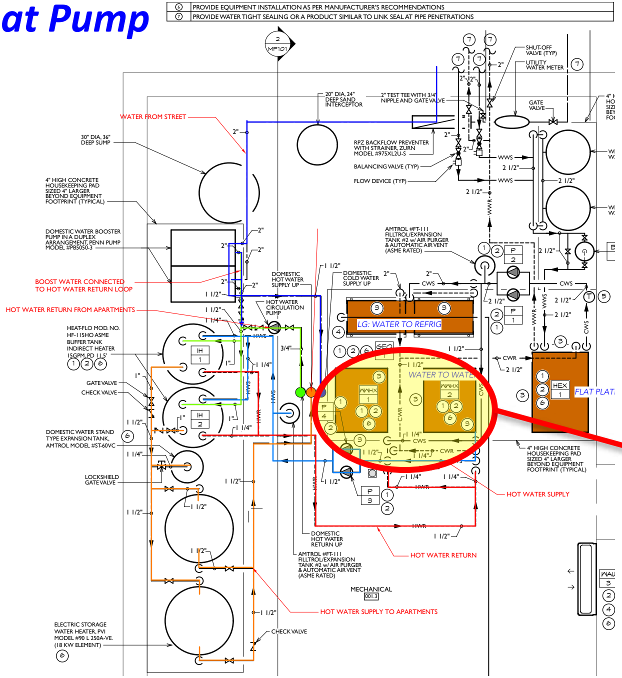
Ductless Evaporator located next to open transom and intentionally located above laundry for easyconnection of condensate drain

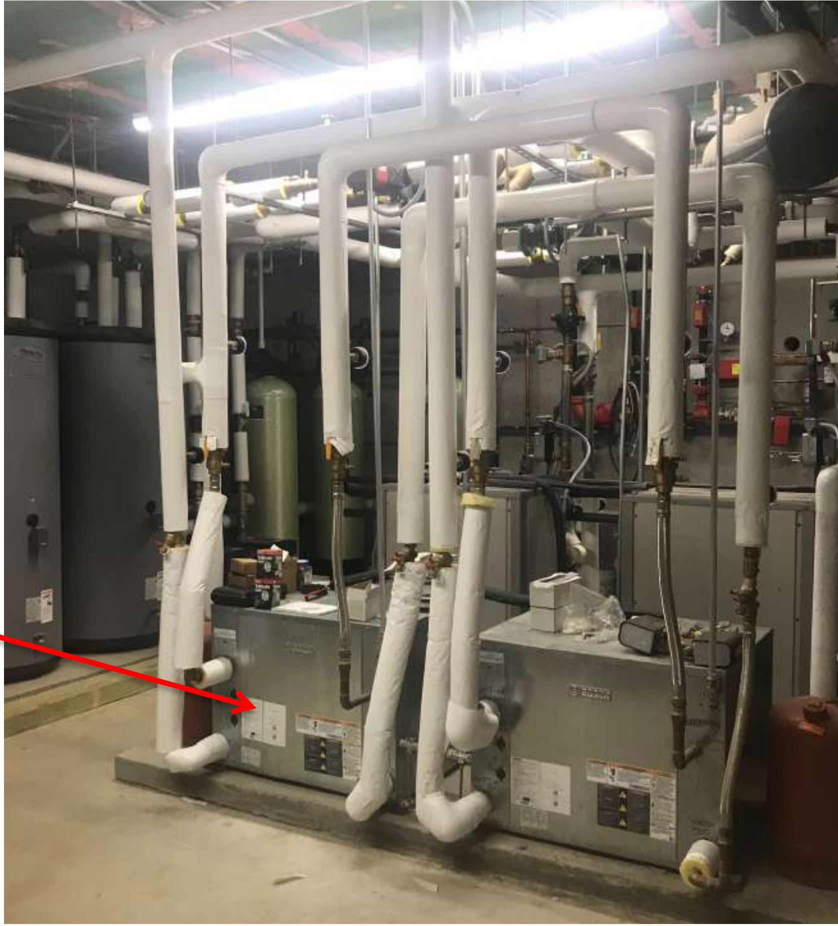
WATER-TO-REFRIGERANT HEAT PUMPS

HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)



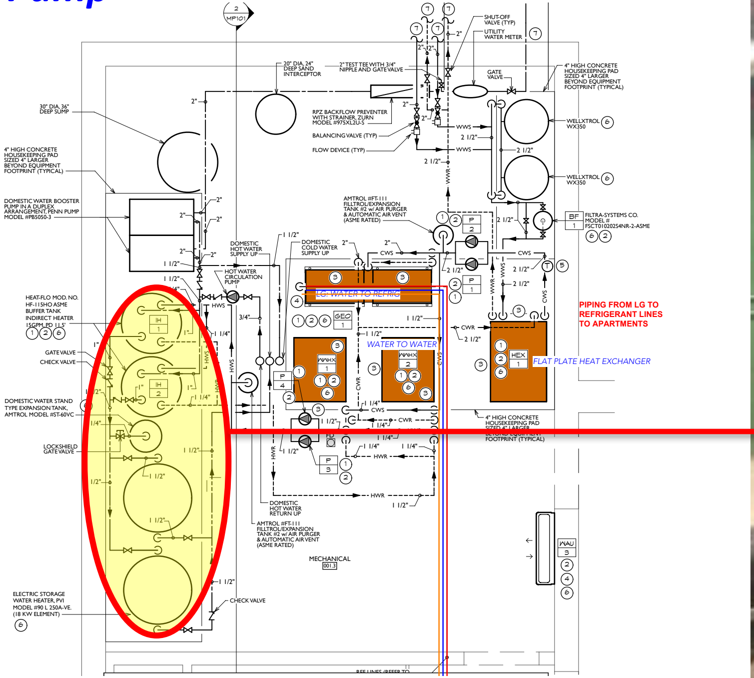


WATER-TO-WATER HEAT PUMPS

HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)

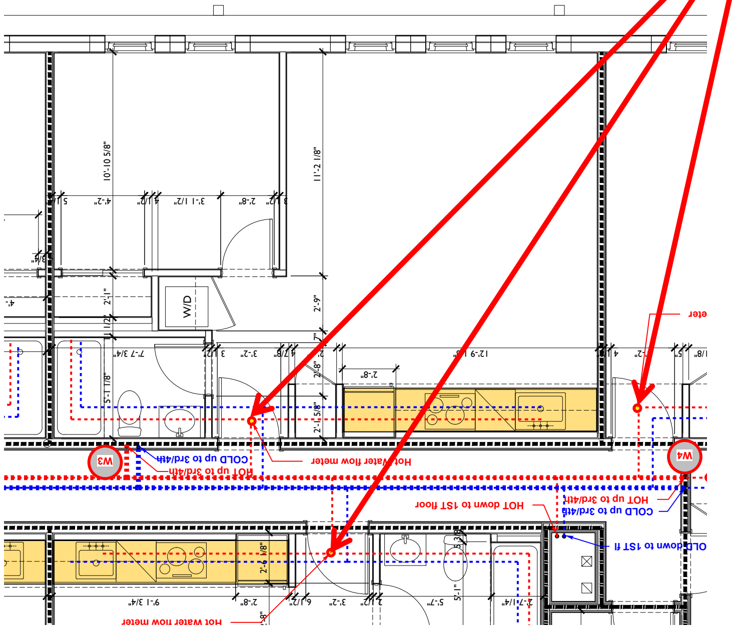


DHW STORAGE TANKS

HEATING/COOLING

Ground-Sourced Heat Pump

(Geo-thermal)



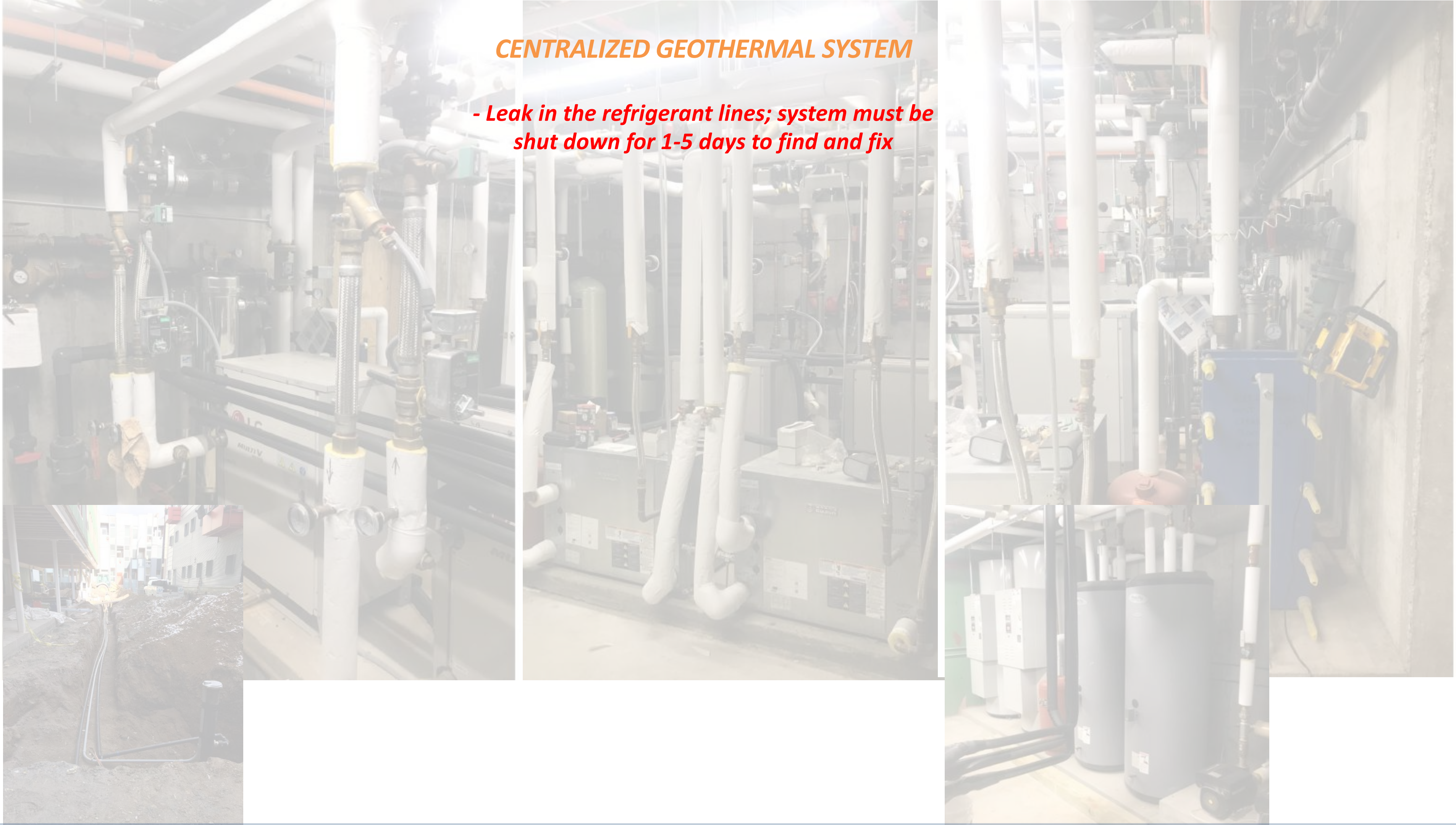
HOT WATER FLOW METER PER APARTMENT

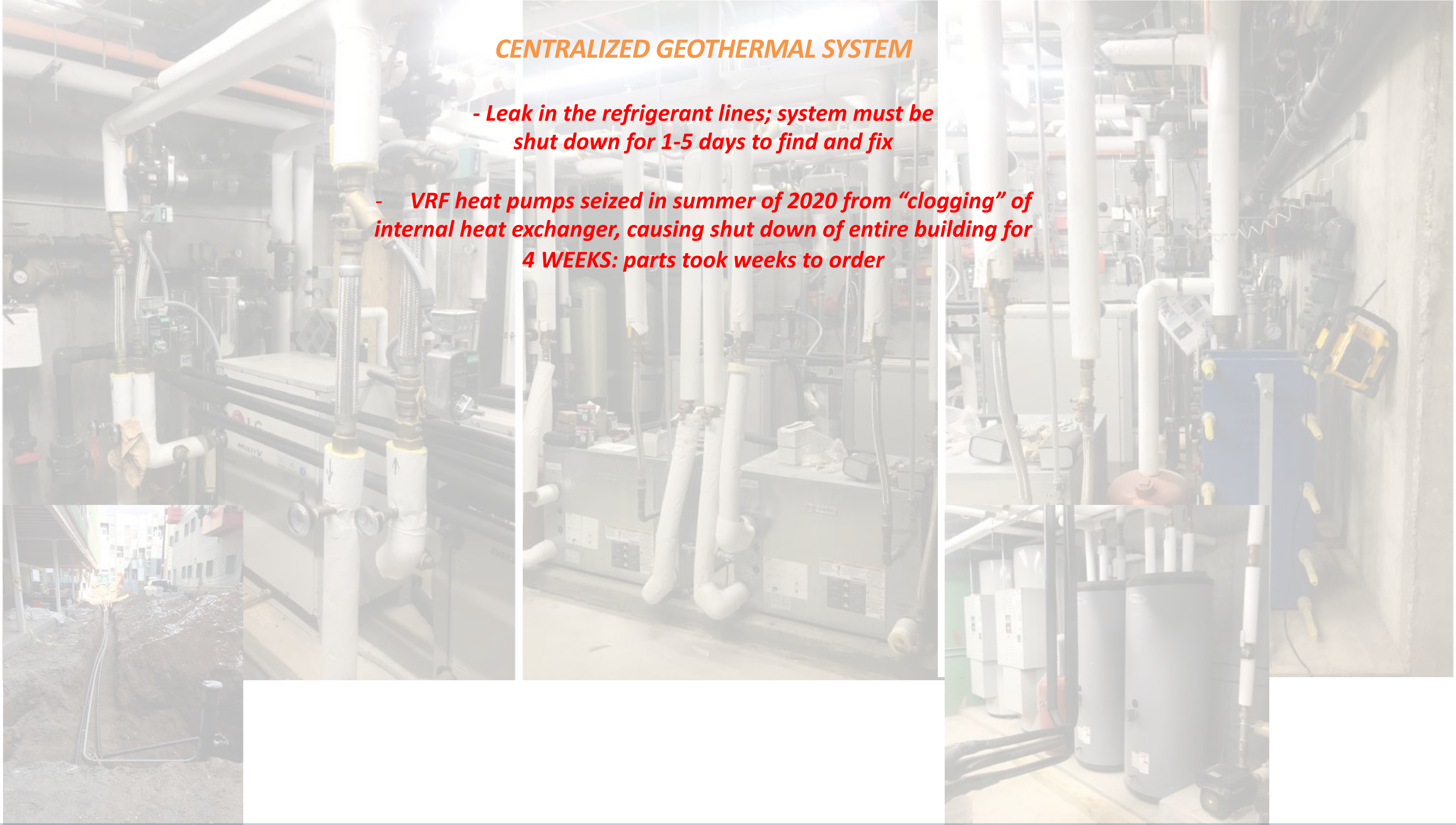
DHW METERING

CENTRALIZED GEOTHERMAL SYSTEM

CENTRALIZED GEOTHERMAL SYSTEM

- Leak in the refrigerant lines; system must be shut down for 1-5 days to find and fix

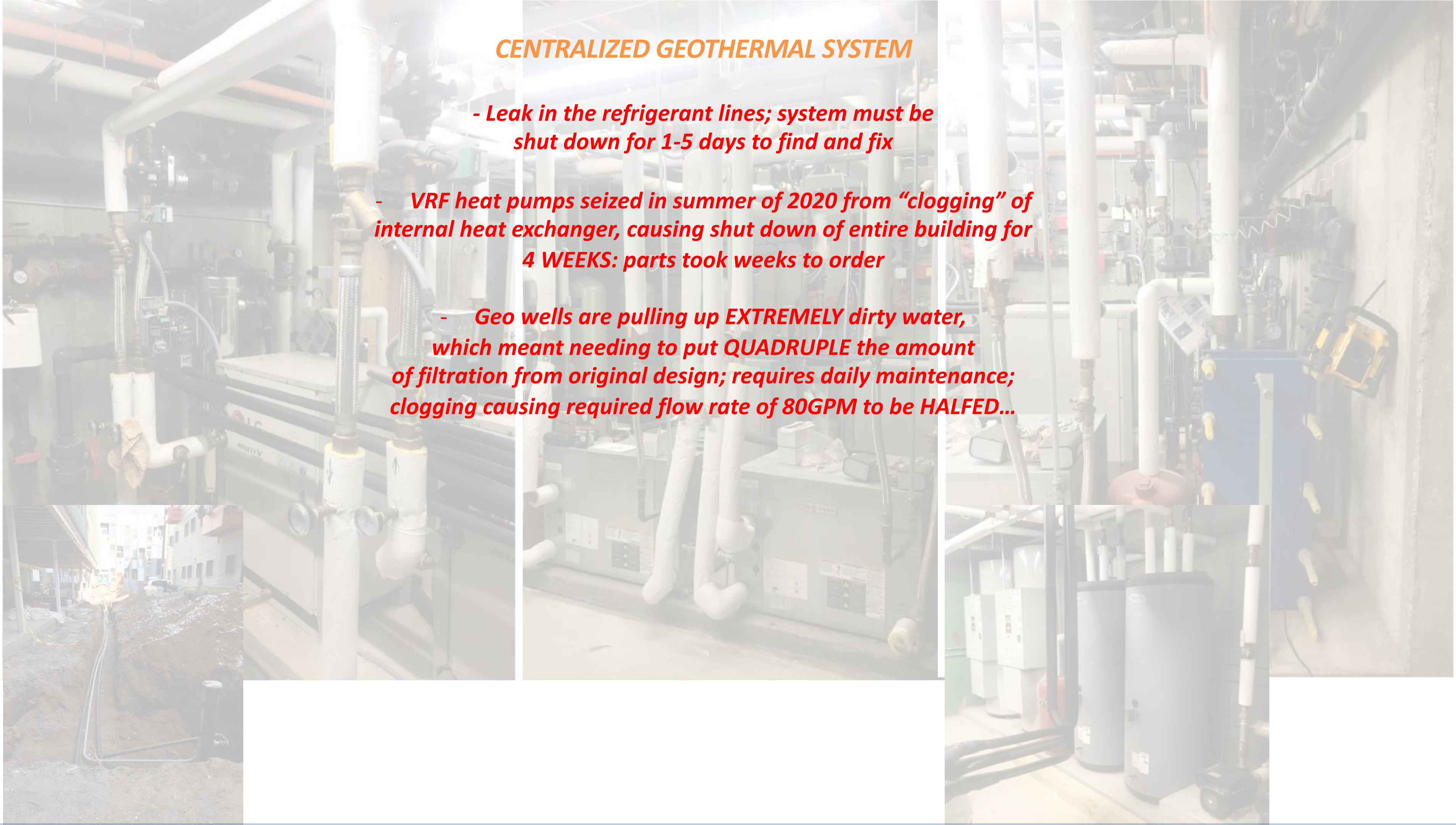




CENTRALIZED GEOTHERMAL SYSTEM

- Leak in the refrigerant lines; system must be shut down for 1-5 days to find and fix

- VRF heat pumps seized in summer of 2020 from “clogging” of internal heat exchanger, causing shut down of entire building for 4 WEEKS: parts took weeks to order

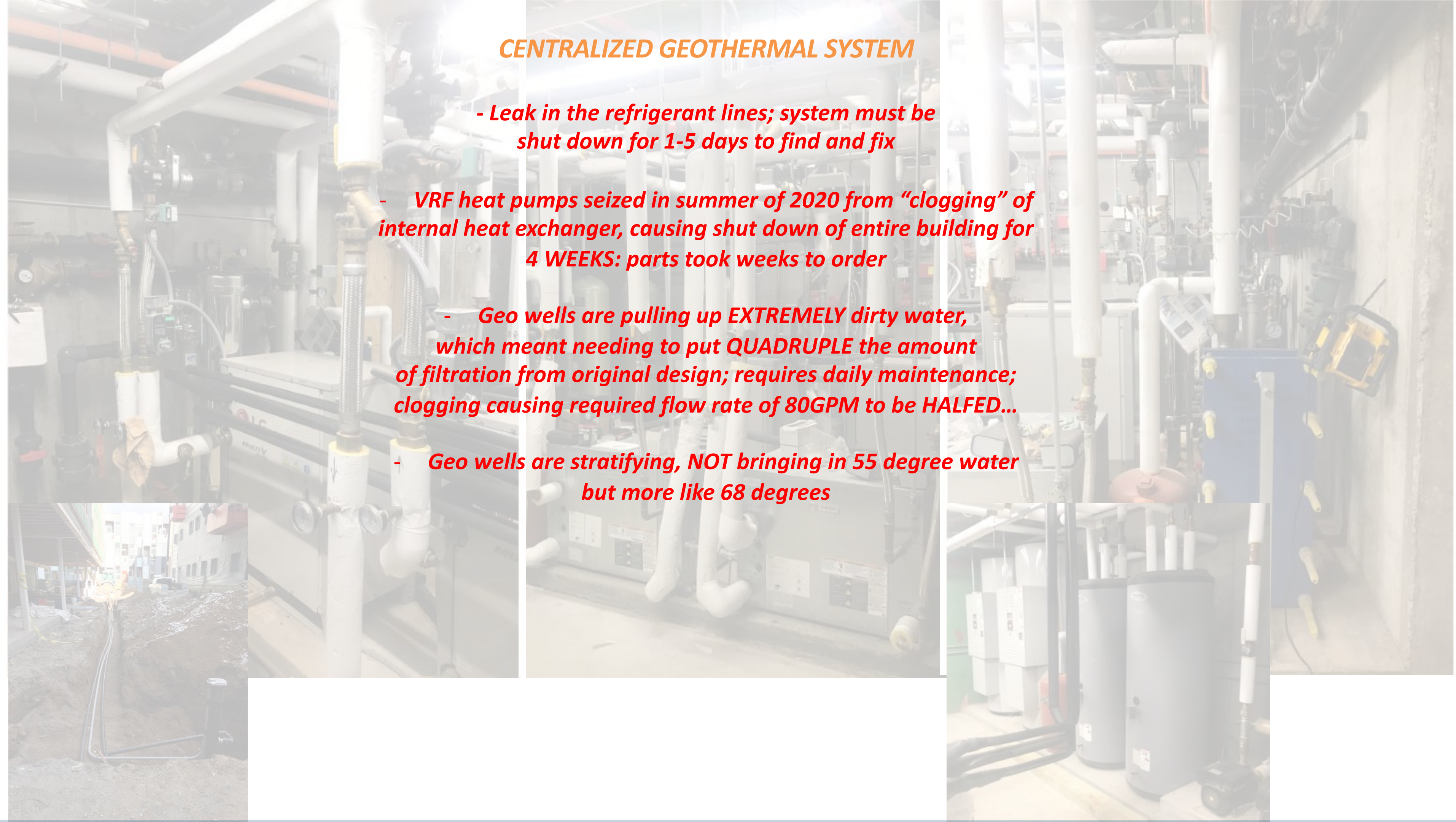


CENTRALIZED GEOTHERMAL SYSTEM

- *Leak in the refrigerant lines; system must be shut down for 1-5 days to find and fix*

- *VRF heat pumps seized in summer of 2020 from "clogging" of internal heat exchanger, causing shut down of entire building for 4 WEEKS: parts took weeks to order*

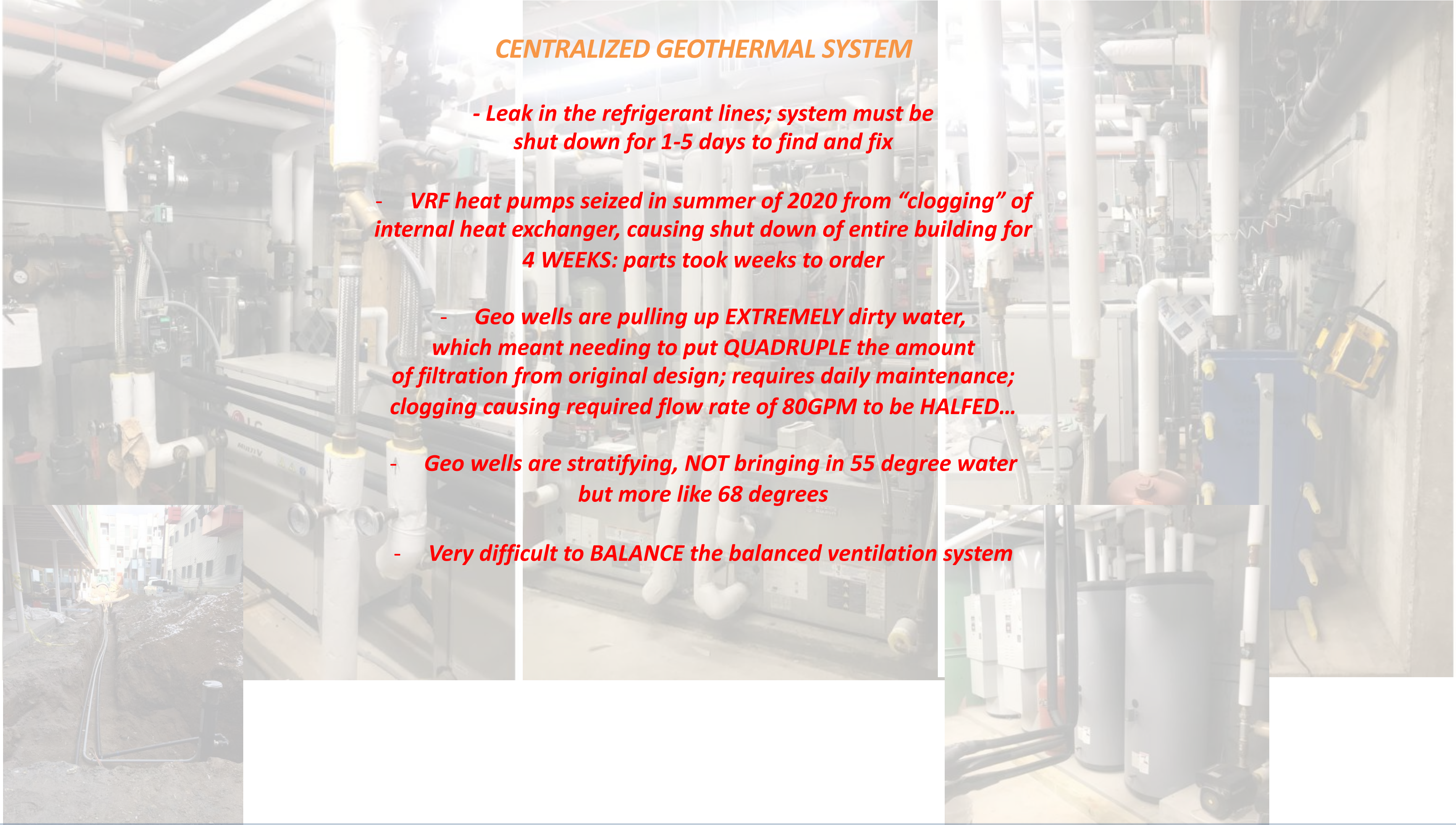
- *Geo wells are pulling up EXTREMELY dirty water, which meant needing to put QUADRUPLE the amount of filtration from original design; requires daily maintenance; clogging causing required flow rate of 80GPM to be HALFED…*



CENTRALIZED GEOTHERMAL SYSTEM

- *Leak in the refrigerant lines; system must be shut down for 1-5 days to find and fix*
- *VRF heat pumps seized in summer of 2020 from "clogging" of internal heat exchanger, causing shut down of entire building for 4 WEEKS: parts took weeks to order*
- *Geo wells are pulling up EXTREMELY dirty water, which meant needing to put QUADRUPLE the amount of filtration from original design; requires daily maintenance; clogging causing required flow rate of 80GPM to be HALFED…*
- *Geo wells are stratifying, NOT bringing in 55 degree water but more like 68 degrees*

CENTRALIZED GEOTHERMAL SYSTEM



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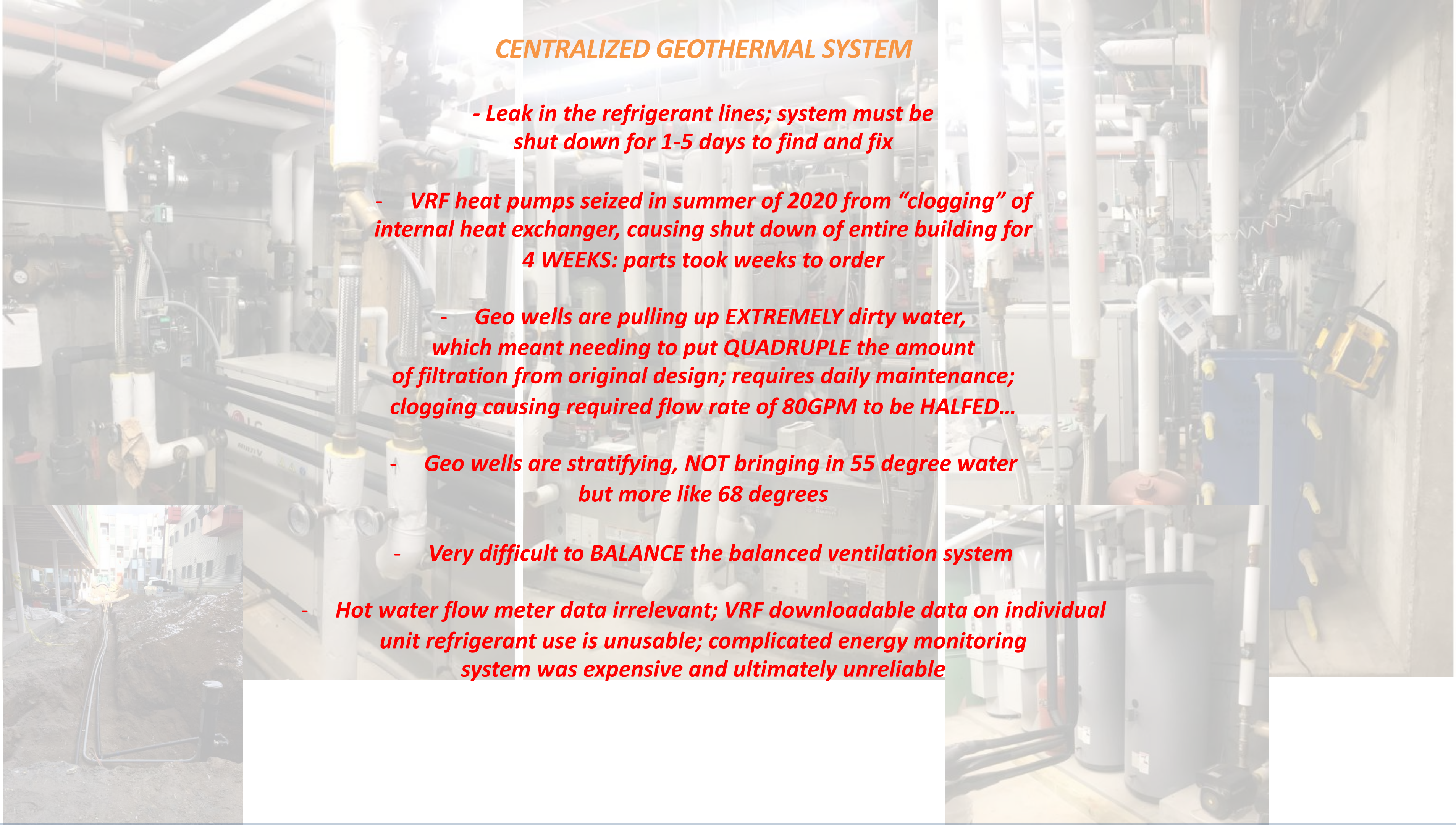
- *VRF heat pumps seized in summer of 2020 from “clogging” of internal heat exchanger, causing shut down of entire building for 4 WEEKS: parts took weeks to order*

- *Geo wells are pulling up EXTREMELY dirty water, which meant needing to put QUADRUPLE the amount of filtration from original design; requires daily maintenance; clogging causing required flow rate of 80GPM to be HALFED…*

- *Geo wells are stratifying, NOT bringing in 55 degree water but more like 68 degrees*

- *Very difficult to BALANCE the balanced ventilation system*



CENTRALIZED GEOTHERMAL SYSTEM

- *Leak in the refrigerant lines; system must be shut down for 1-5 days to find and fix*

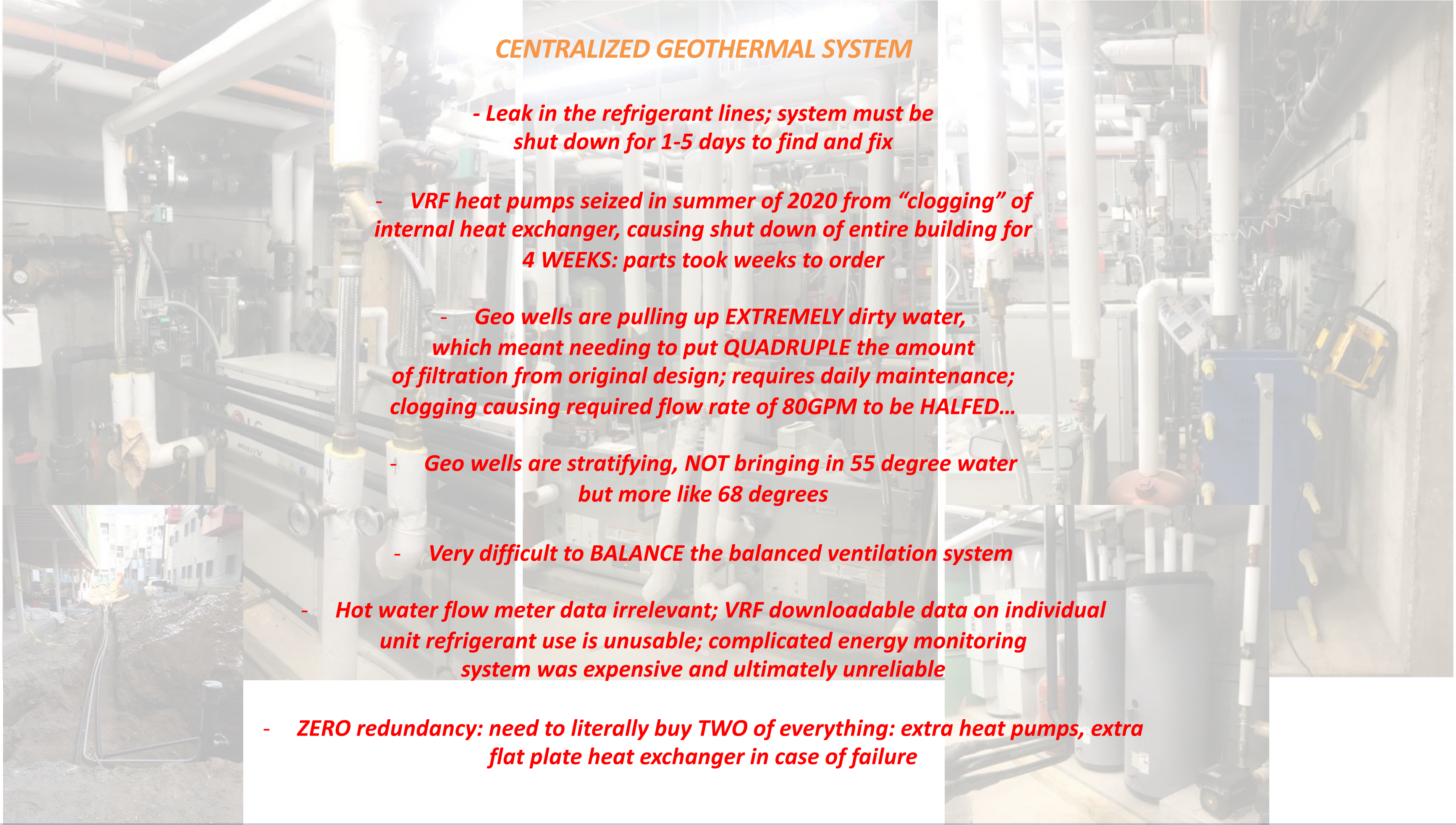
- *VRF heat pumps seized in summer of 2020 from "clogging" of internal heat exchanger, causing shut down of entire building for 4 WEEKS: parts took weeks to order*

- *Geo wells are pulling up EXTREMELY dirty water, which meant needing to put QUADRUPLE the amount of filtration from original design; requires daily maintenance; clogging causing required flow rate of 80GPM to be HALFED…*

- *Geo wells are stratifying, NOT bringing in 55 degree water but more like 68 degrees*

- *Very difficult to BALANCE the balanced ventilation system*

- *Hot water flow meter data irrelevant; VRF downloadable data on individual unit refrigerant use is unusable; complicated energy monitoring system was expensive and ultimately unreliable*



CENTRALIZED GEOTHERMAL SYSTEM

- Leak in the refrigerant lines; system must be shut down for 1-5 days to find and fix
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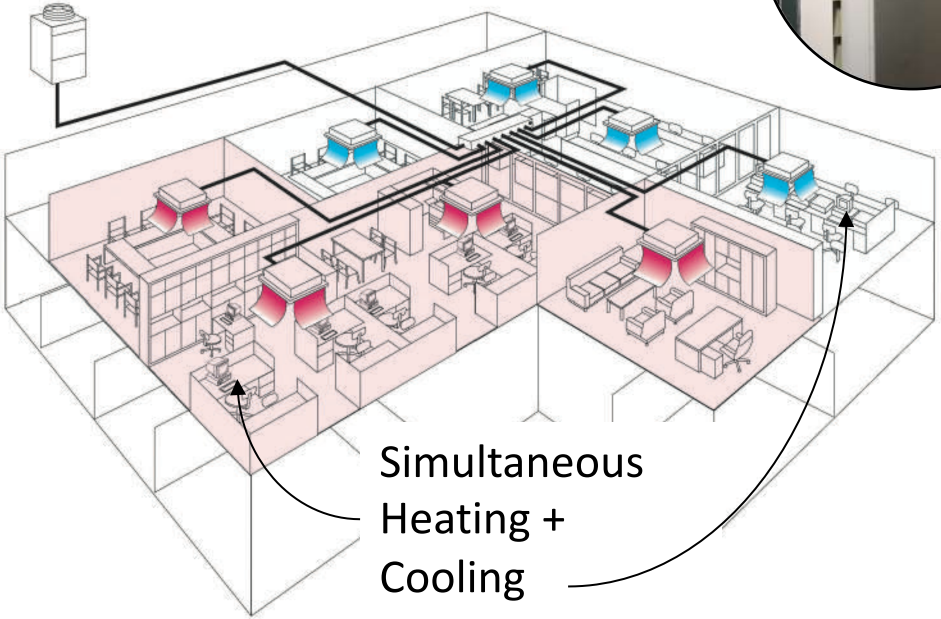
- Geo wells are pulling up EXTREMELY dirty water, which meant needing to put QUADRUPLE the amount of filtration from original design; requires daily maintenance; clogging causing required flow rate of 80GPM to be HALFED…
- Geo wells are stratifying, NOT bringing in 55 degree water but more like 68 degrees
- Very difficult to BALANCE the balanced ventilation system
- Hot water flow meter data irrelevant; VRF downloadable data on individual unit refrigerant use is unusable; complicated energy monitoring system was expensive and ultimately unreliable
- ZERO redundancy: need to literally buy TWO of everything: extra heat pumps, extra flat plate heat exchanger in case of failure

HEATING/COOLING

Air-Sourced Heat Pump

Rooftop VRF



Simultaneous
Heating +
Cooling

One Meter

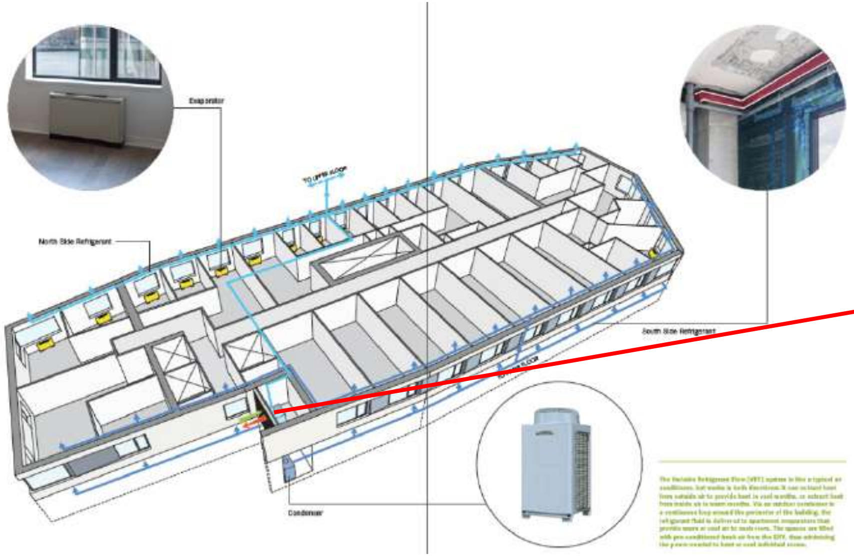
IMPLIES CENTRALIZED SYSTEMS

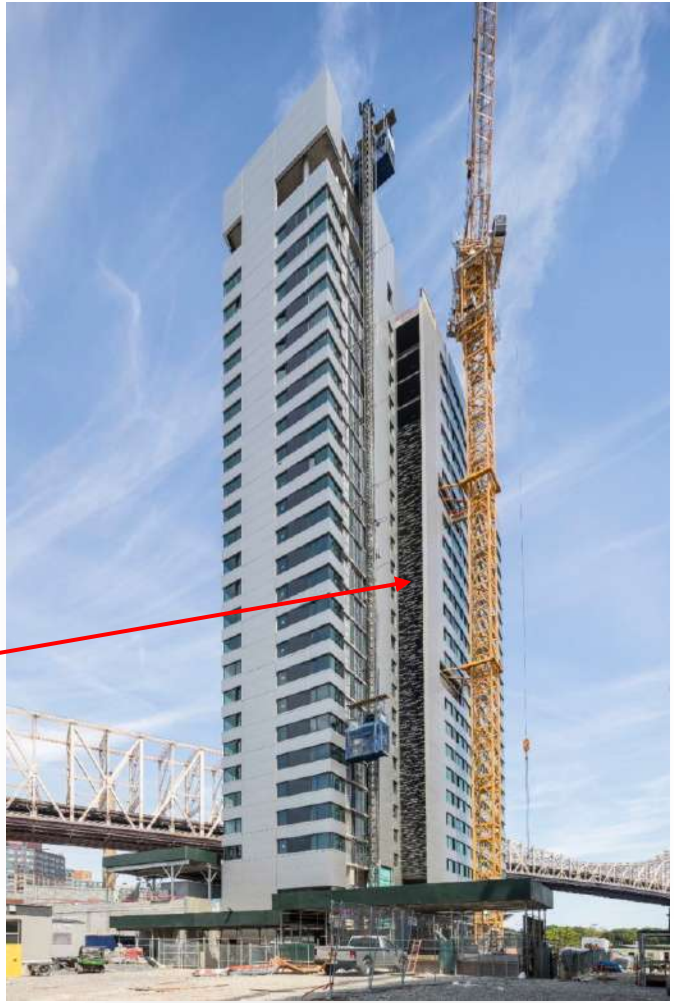
- ***Centralized heating/cooling***
- Centralized Hot water
- Centralized ventilation
- One solar array
- Monitoring vs metering

HEATING/COOLING

Air-Sourced Heat Pump

Semi-Centralized VRF (one per floor)





The House at Cornell Tech, Roosevelt Island, NYC, PHI certified; Handel Architects LP

HOT WATER

Ground-Sourced Heat Pump

(Geo-thermal)

The Battery, PHIUS + Certified, 2017, DHW tanks for 25 units

Air-Sourced Heat Pump

One Meter

CENTRALIZED SYSTEMS

IMPLIES CENTRALIZED SYSTEMS

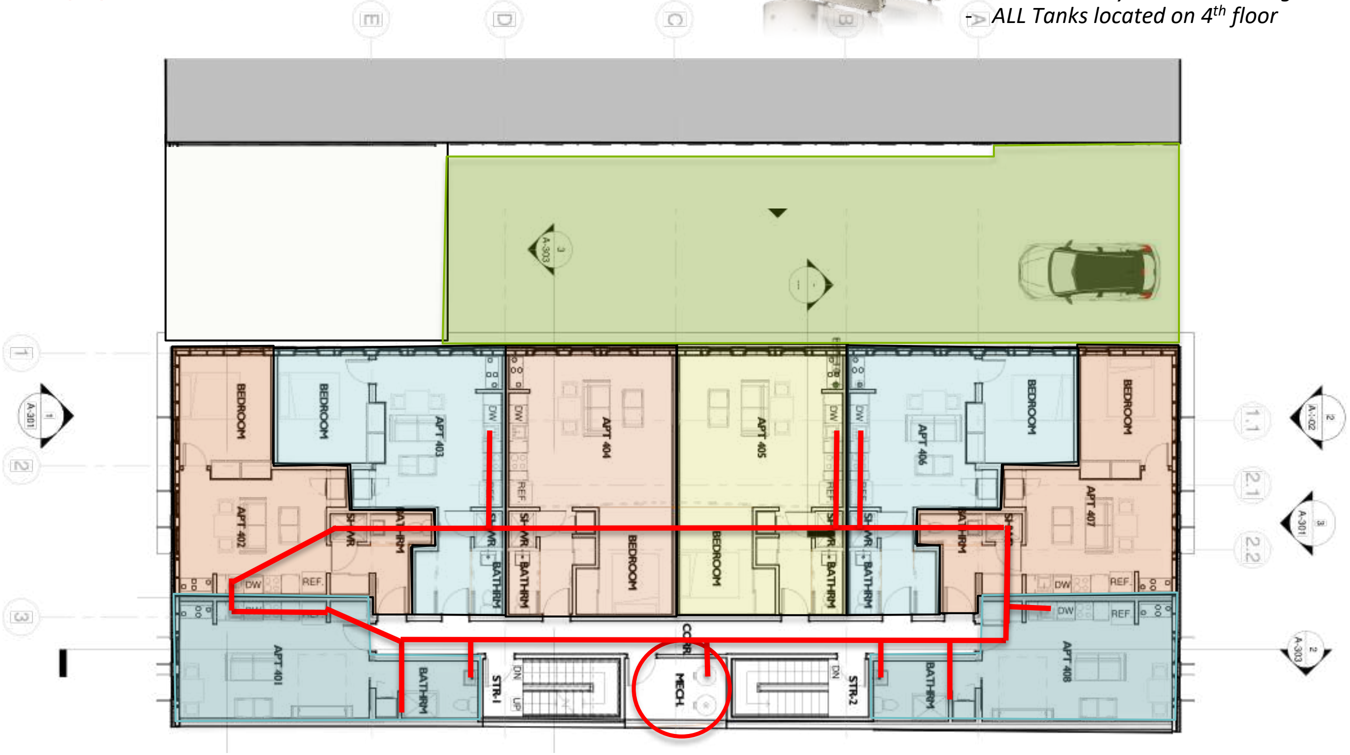
- Centralized heating/cooling
- ***Centralized Hot water***
- Centralized ventilation
- One solar array
- Monitoring vs metering

HOT WATER:
CENTRALIZED vs SEMI-CENTRALIZED

HOT WATER

SANDEN

- *SEMI- Decentralized*
- *Heat pumps on roof*
- *FAST recovery time: less storage*
- *ALL Tanks located on 4th floor*



4TH FLOOR

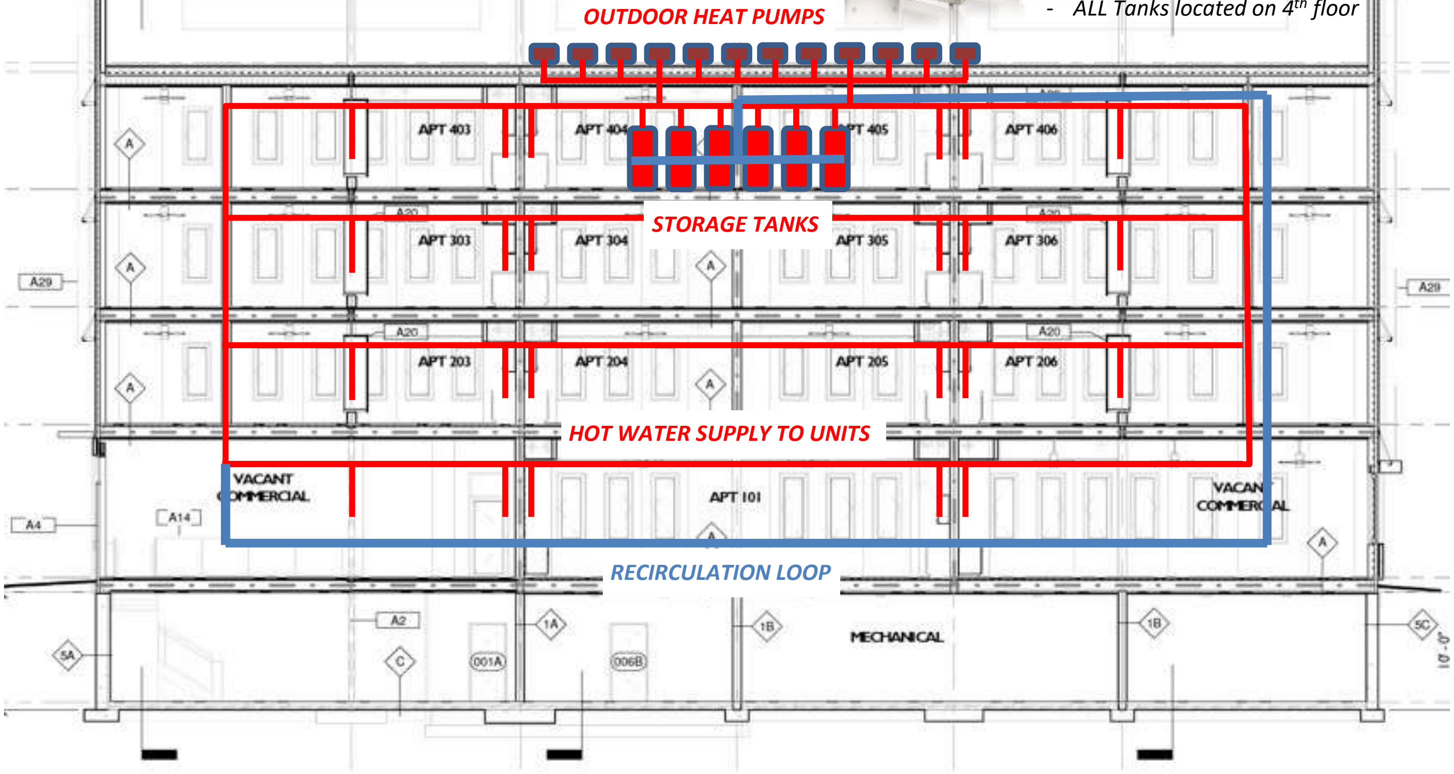
INITIAL Domestic Hot Water Strategy: CENTRALIZIED

HOT WATER

HOT WATER

SANDEN

- *SEMI- Decentralized*
- *Heat pumps on roof*
- *FAST recovery time: less storage*
- *ALL Tanks located on 4th floor*



INITIAL Domestic Hot Water Strategy: CENTRALIZIED

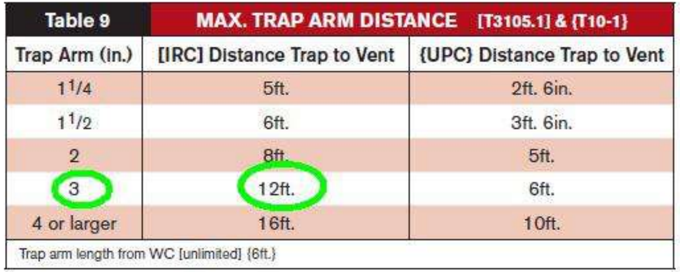
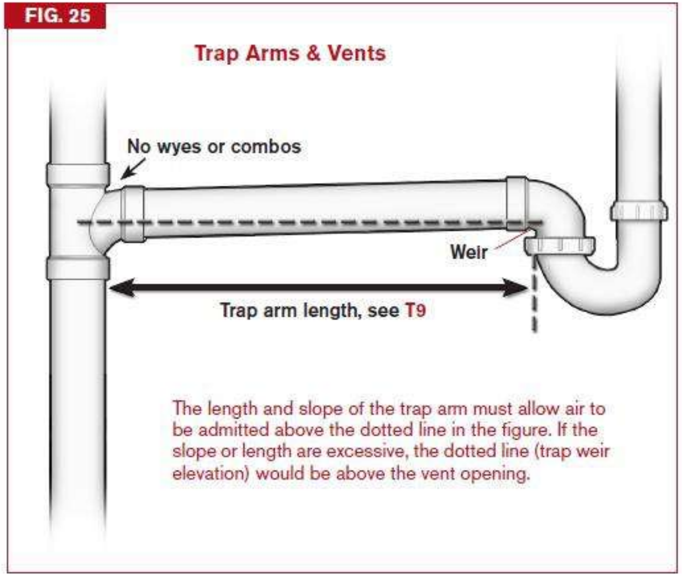


Table 9	MAX. TRAP ARM DISTANCE [T3105.1] & {T10-1}	
Trap Arm (in.)	[IRC] Distance Trap to Vent	{UPC} Distance Trap to Vent
1 1/4	5ft.	2ft. 6in.
1 1/2	6ft.	3ft. 6in.
2	8ft.	5ft.
3	12ft.	6ft.
4 or larger	16ft.	10ft.

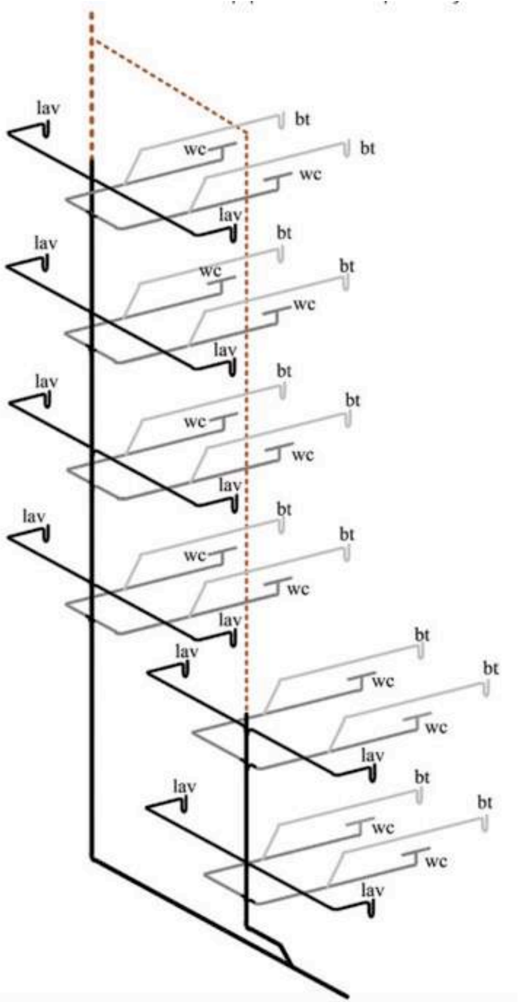
Trap arm length from WC [unlimited] {6ft.}

FIG. 25



Trap Arms & Vents

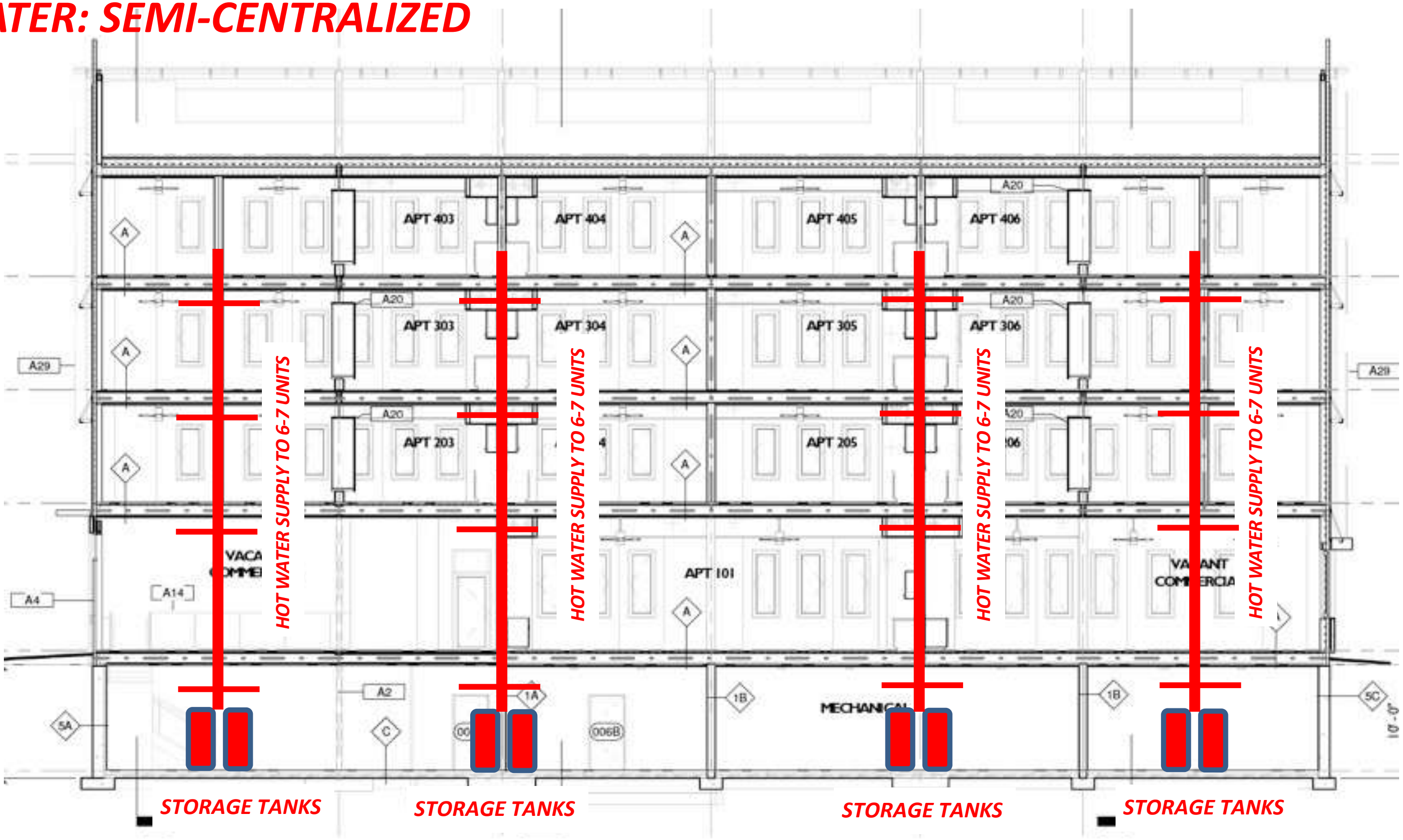
The length and slope of the trap arm must allow air to be admitted above the dotted line in the figure. If the slope or length are excessive, the dotted line (trap weir elevation) would be above the vent opening.



Single Stack System for a Six Story Building

FINAL Domestic Hot Water Strategy: FOLLOW THE VENT STACK!!

HOT WATER: SEMI-CENTRALIZED



FINAL Domestic Hot Water Strategy: FOLLOW THE VENT STACK!!

HOT WATER

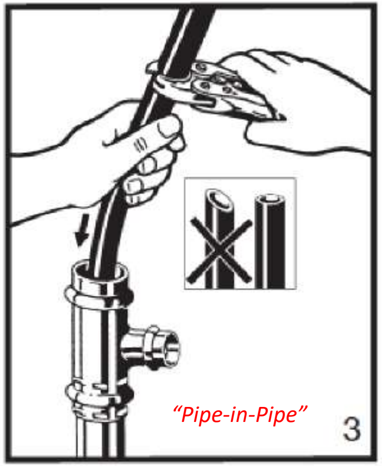
RHEEM HPWH

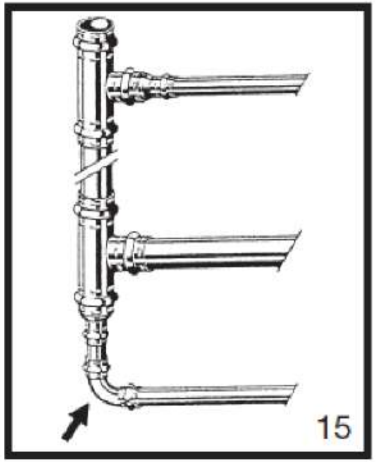
- ½ PRICE!!
- ½" the piping/heat loss
- Located in basement
- Free cooling/dehumidification basement
- No heat pumps on roof
- Proven technology

2^{ND} -4^{TH} FLOORS

FINAL Domestic Hot Water Strategy: SEMI-CENTRALIZED

HOT WATER





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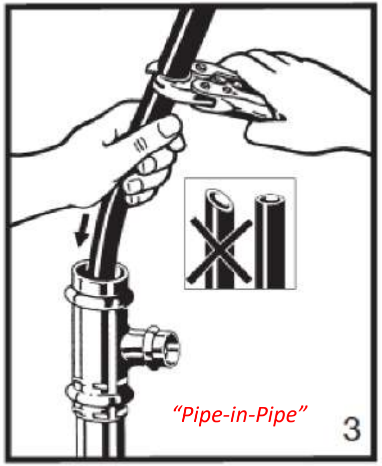
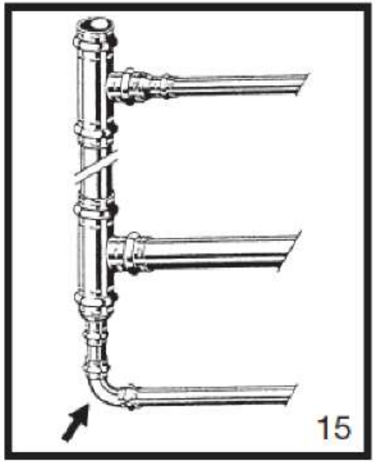
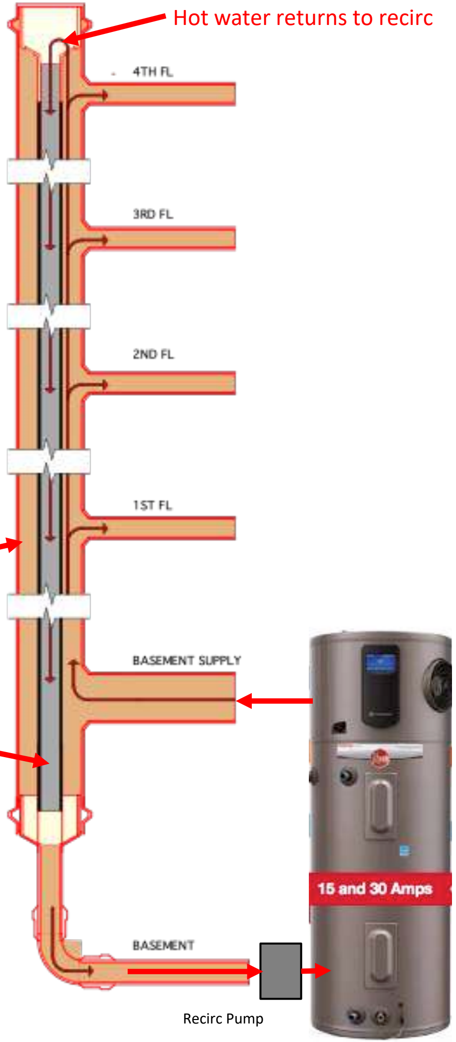
2^{ND} -4^{TH} FLOORS

PIPE-IN-PIPE Recirculation Loop Strategy

HOT WATER







Hot water returns to recirc

Copper Hot water supply line to apartments

PVC Recirc line

PIPE-IN-PIPE Recirculation Loop Strategy

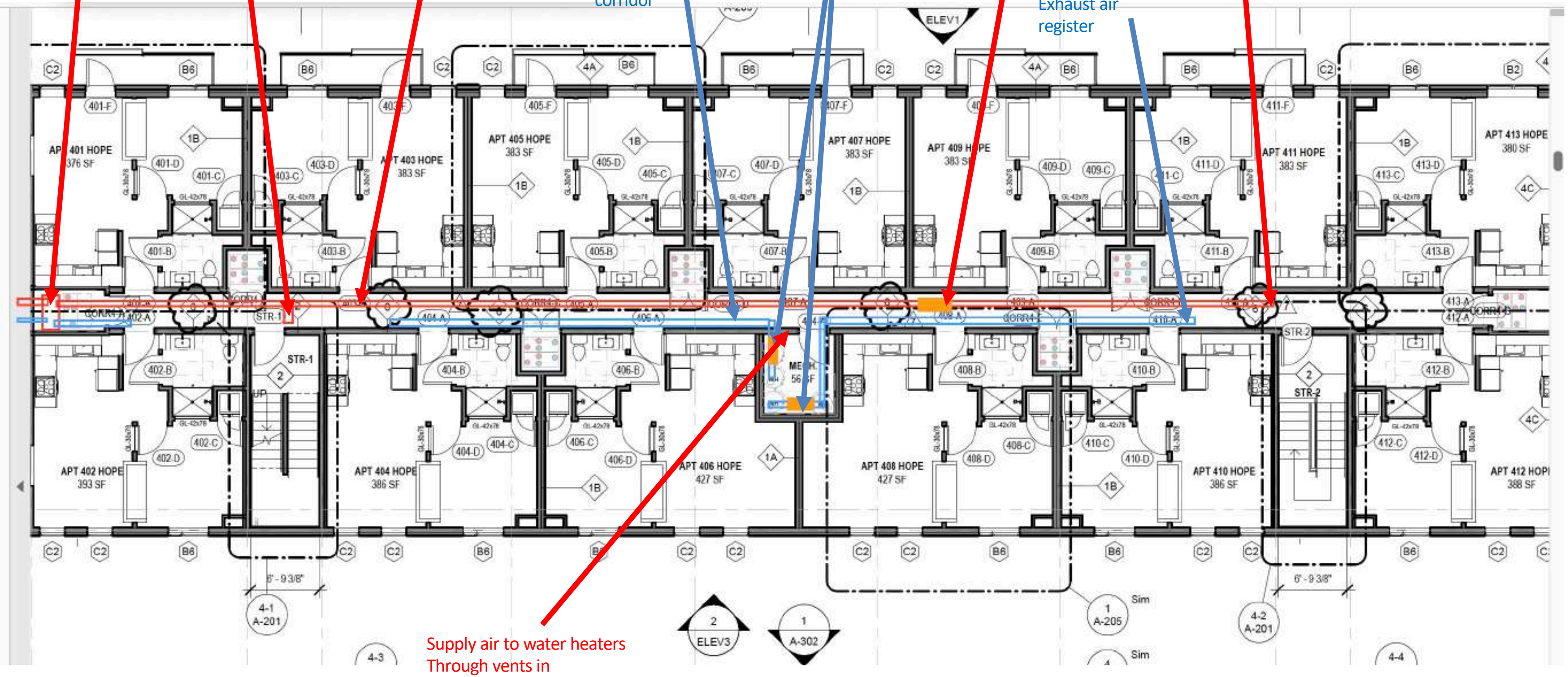
HOT WATER

2 – 80 gallon HPWH for 6-7 Apartments

HOT WATER: HORIZONTAL STRATEGY WITH OFF-THE-SHELF HPWH

Copper Flats: 88 units

HOT WATER: HORIZONTAL STRATEGY WITH OFF-THE-SHELF HPWH



Minotair dedicated to hallway only

Supply air register

Supply air from Minotair

Ducted Exhaust duct from 2 water heaters dumping cold air halfway down corridor

300 cfm in-line fan for water heater exhaust

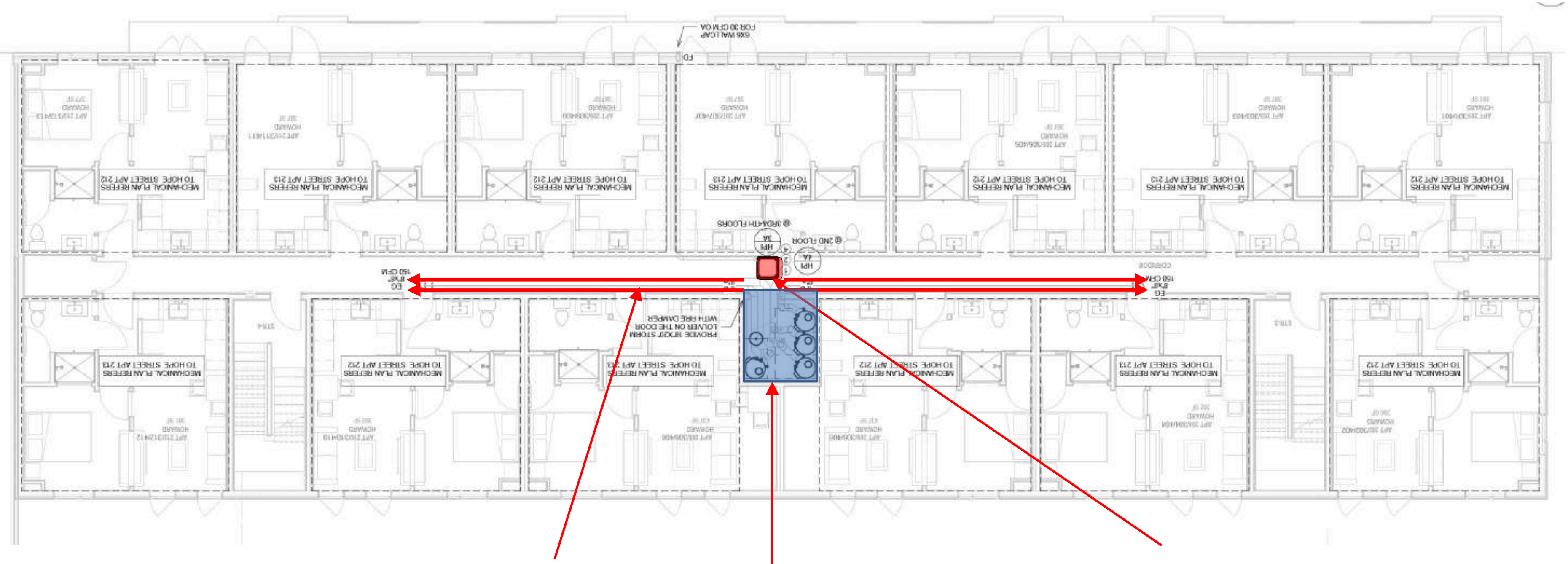
In-line fan to move tempered air to end of corridor

Exhaust air register

Supply air register

Supply air to water heaters Through vents in wall/doors

HOT WATER: HORIZONTAL STRATEGY WITH OFF-THE-SHELF HPWH



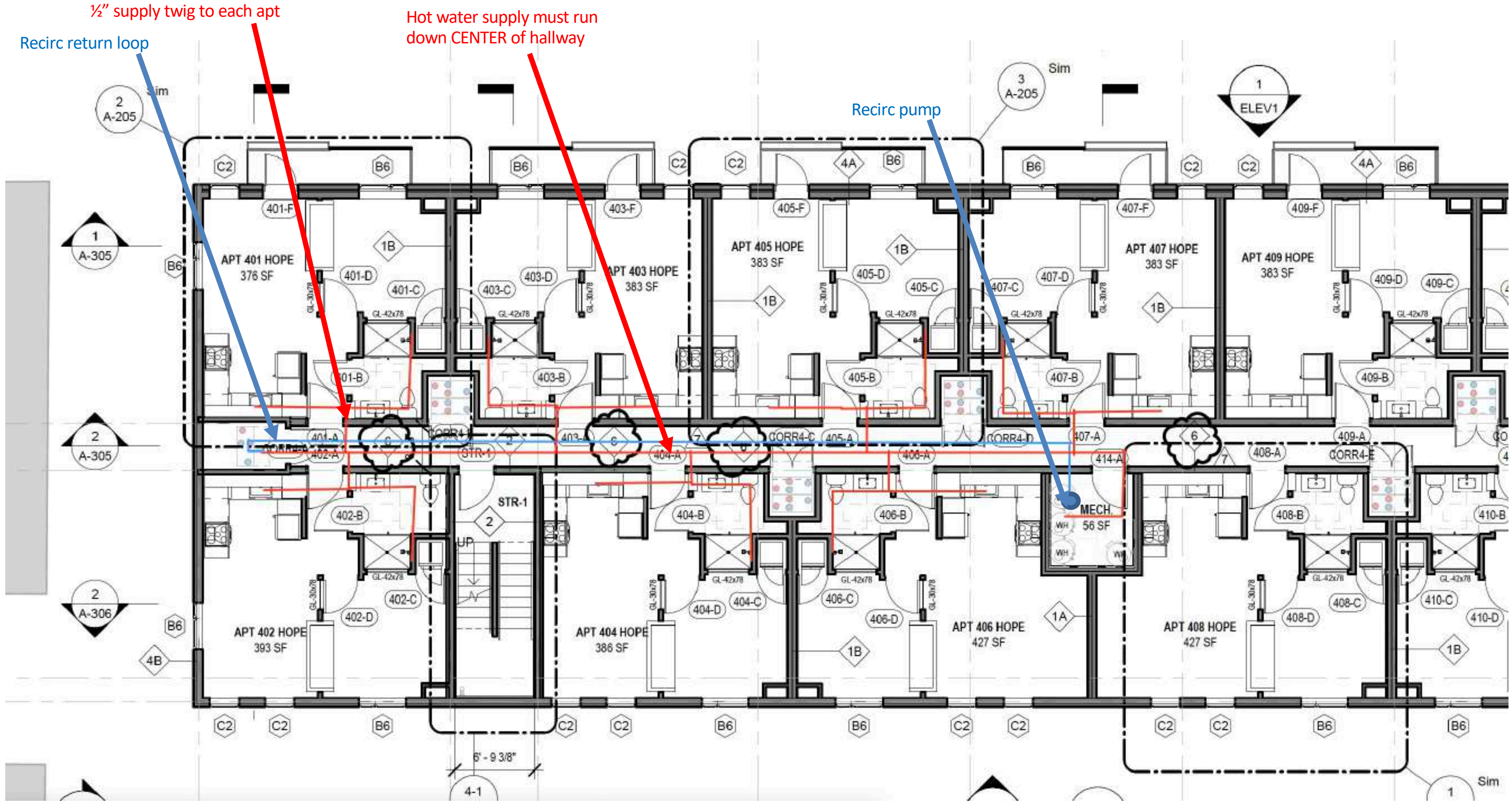
One exhaust duct from each HPWH

4 – 80 gal HPWH per floor

Minisplit for tempering hallway

Copper Flats: 88 units

HOT WATER: HORIZONTAL STRATEGY WITH OFF-THE-SHELF HPWH



½" supply twig to each apt

Recirc return loop

Hot water supply must run down CENTER of hallway

Recirc pump

VENTILATION

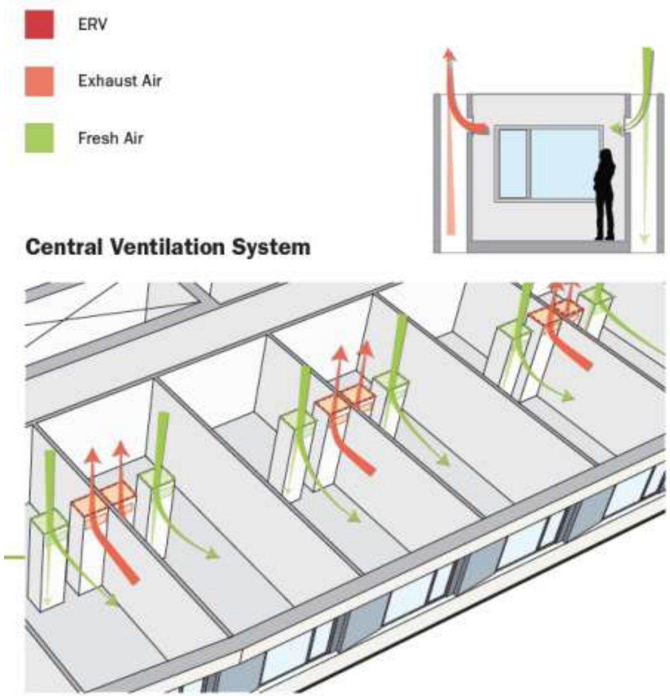
ERV/HRV - Centralized

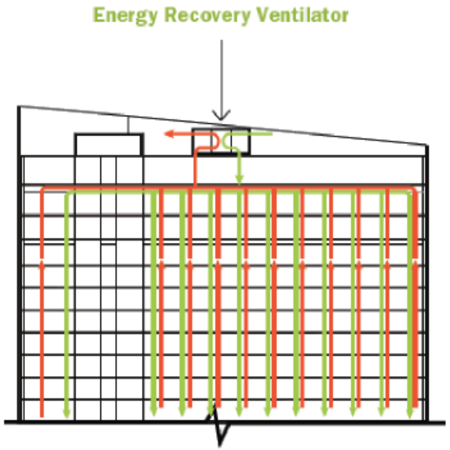
One Meter

**IMPLIES
CENTRALIZED SYSTEMS**

- Centralized heating/cooling
- Centralized Hot water
- ***Centralized ventilation***
- One solar array
- Monitoring vs metering

VENTILATION
ERV/HRV - Centralized

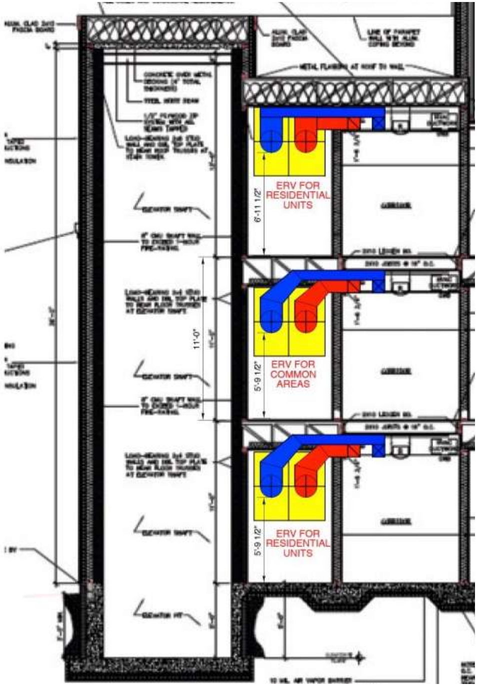


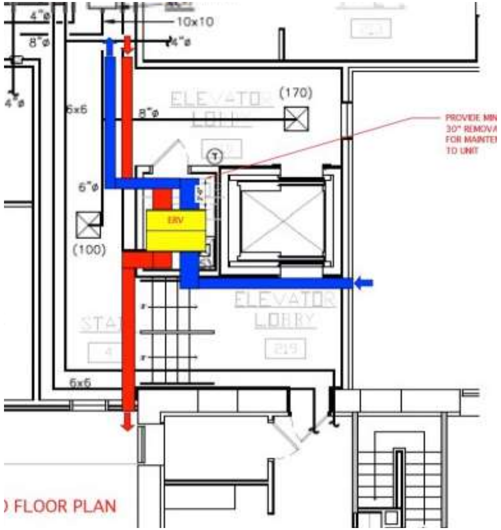


The House at Cornell Tech, PHI certified
Centralized roof-mounted ERV

VENTILATION

ERV/HRV – Semi Centralized

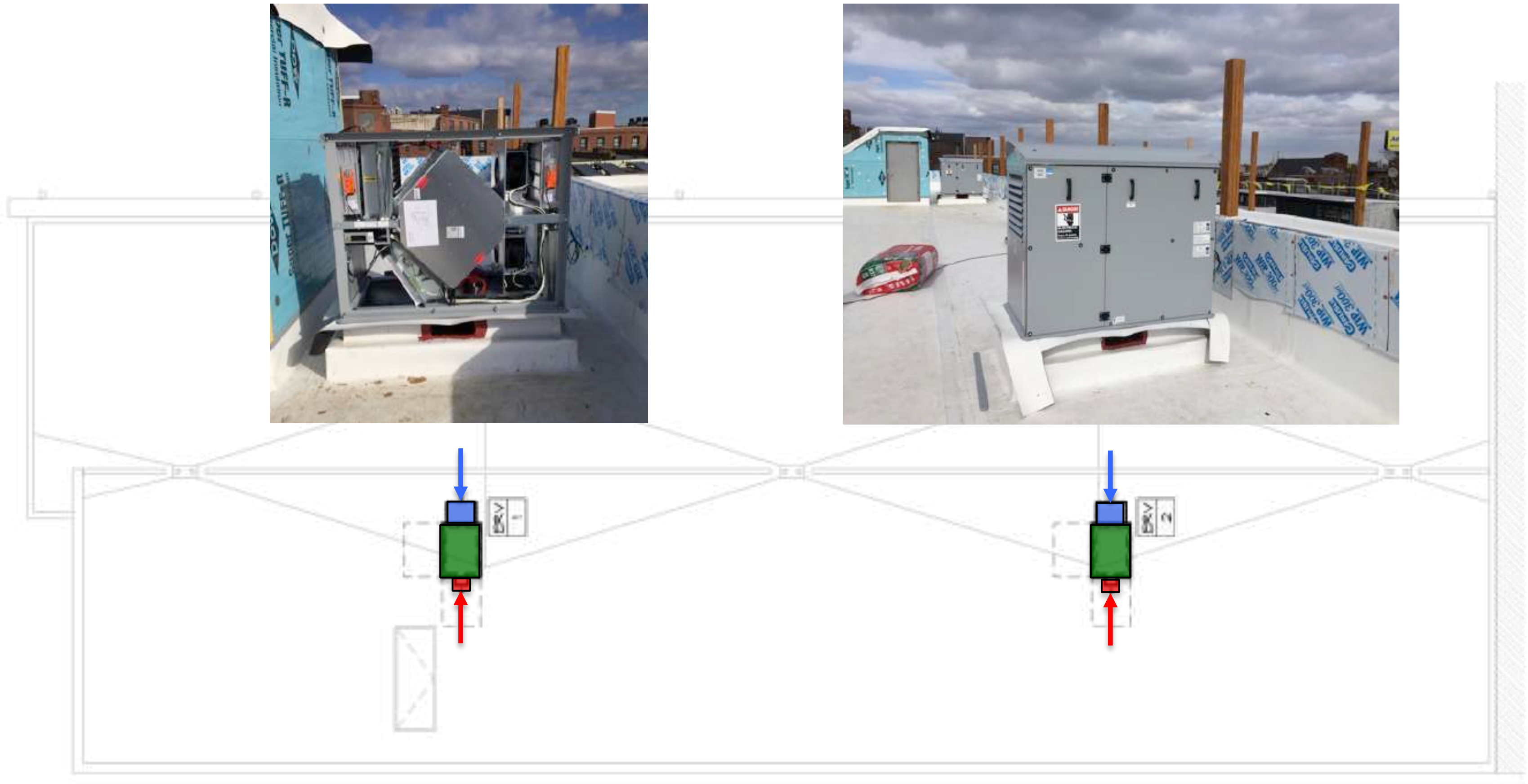




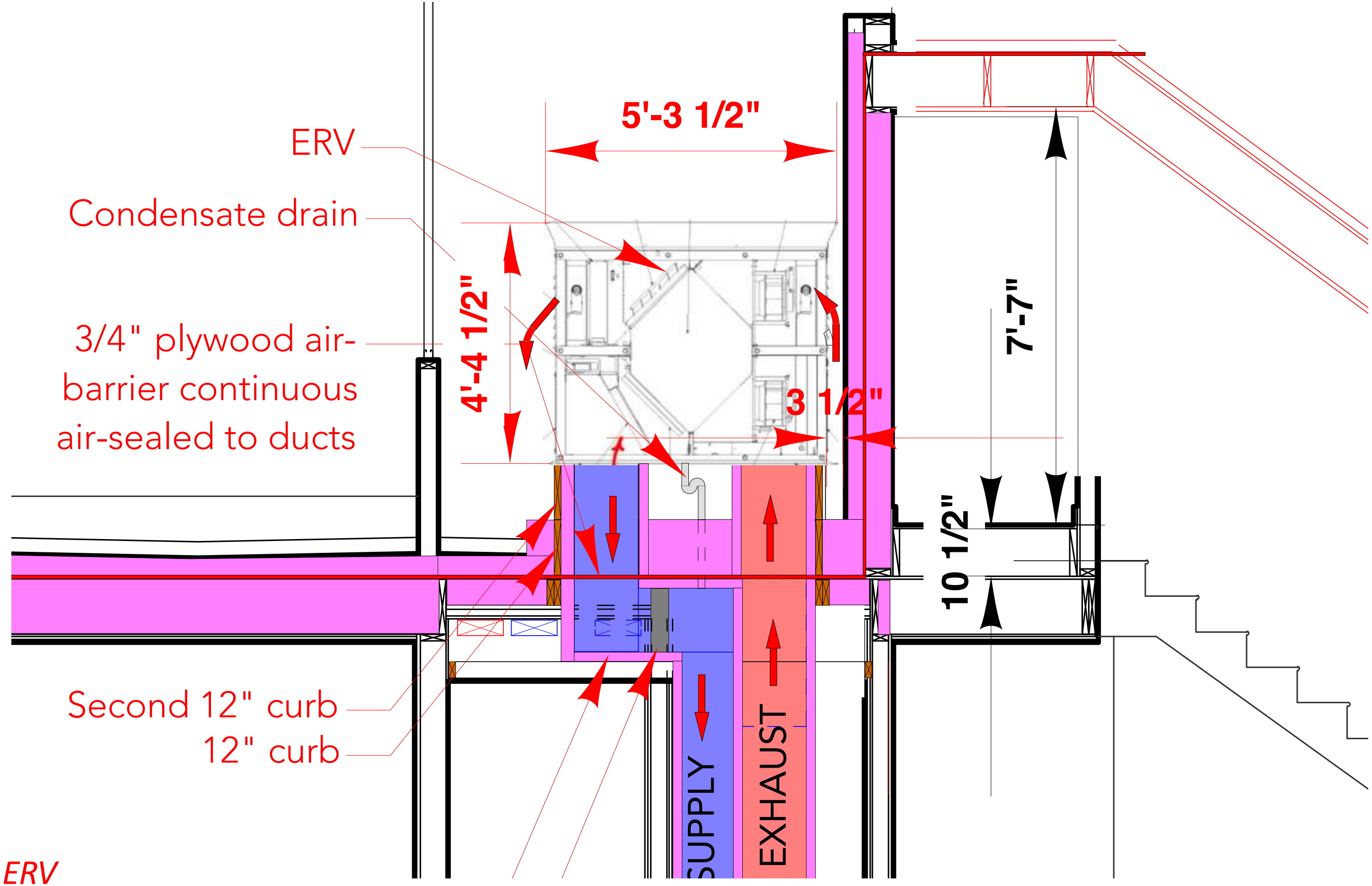
The Whitehall, Semi Centralized Ventilation System

The Battery, PHIUS + Certified, 2017; 77 KW "BIFACIAL" PV ARRAY WITH ONE METER

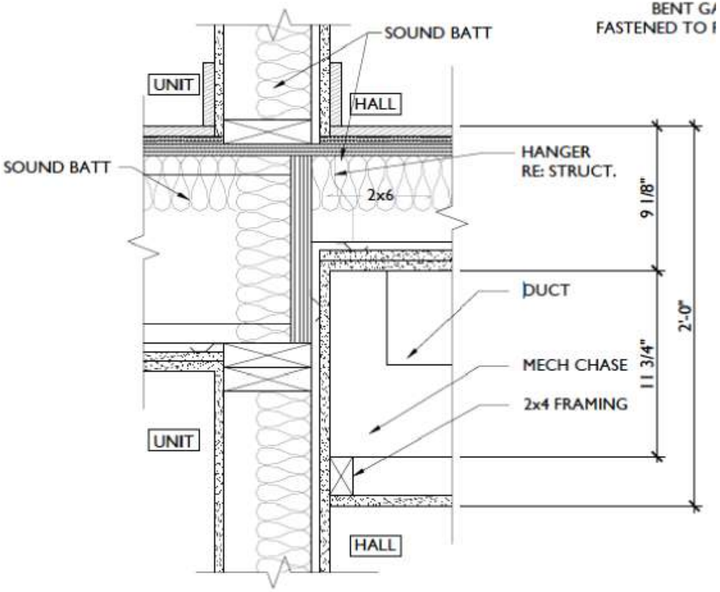
Roof: Curb for ERVs



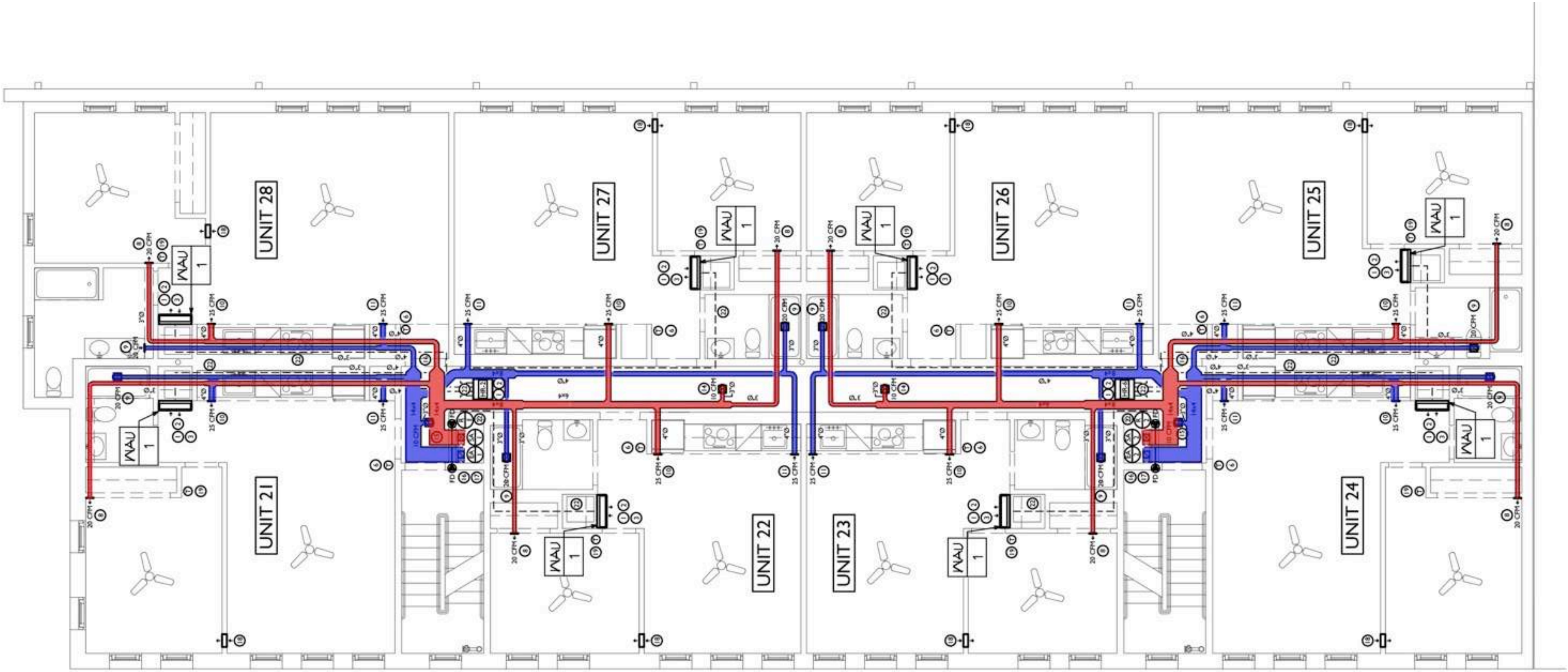
Balanced/Centralized Ventilation, 2 Ventacity 2000cfm ERVs



Ducting to ERV



8 WALL SECTION @ HALL
1 1/2" = 1'-0"



Balanced/Centralized Ventilation, 2 Ventacity 2000cfm ERVs

SOLAR

One Meter

The Battery, PHIUS + Certified, 2017; 77 KW "BIFACIAL" PV ARRAY WITH ONE METER

IMPLIES CENTRALIZED SYSTEMS

- Centralized heating/cooling
- Centralized Hot water
- Centralized ventilation
- ***One solar array***
- Monitoring vs metering

SOLAR

$169/SF

The Battery, PHIUS + Certified, 2017; 77 KW "BIFACIAL" PV ARRAY WITH ONE METER

One Meter

IMPLIES CENTRALIZED SYSTEMS

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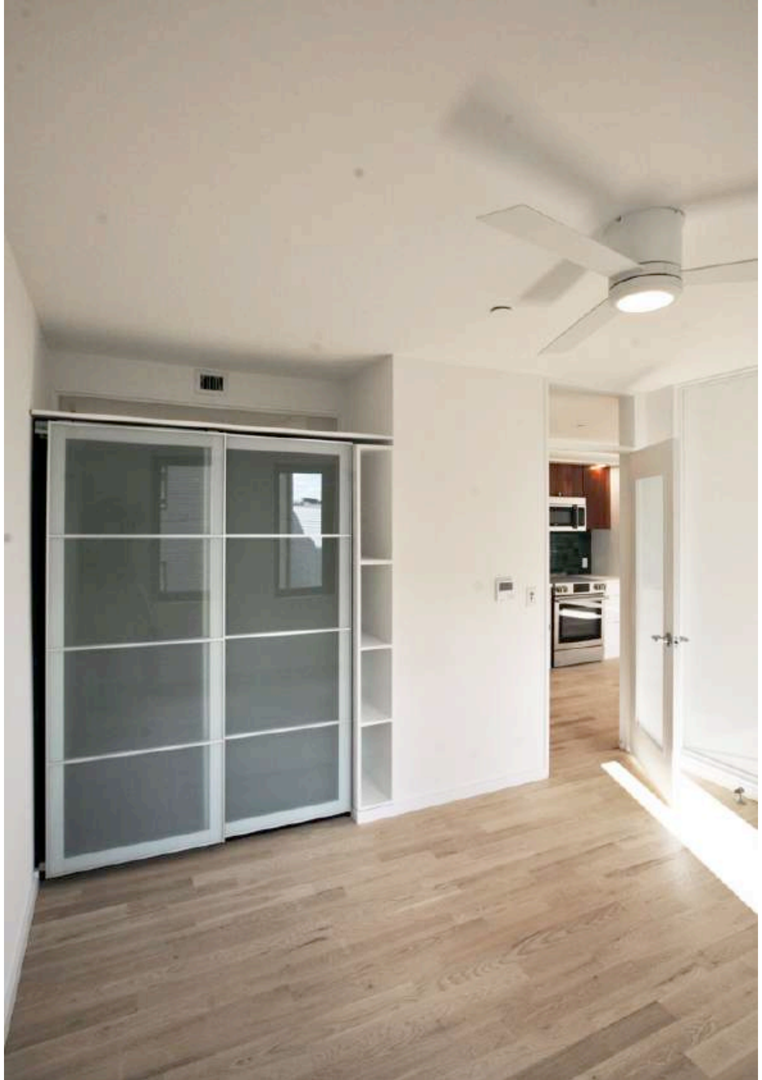
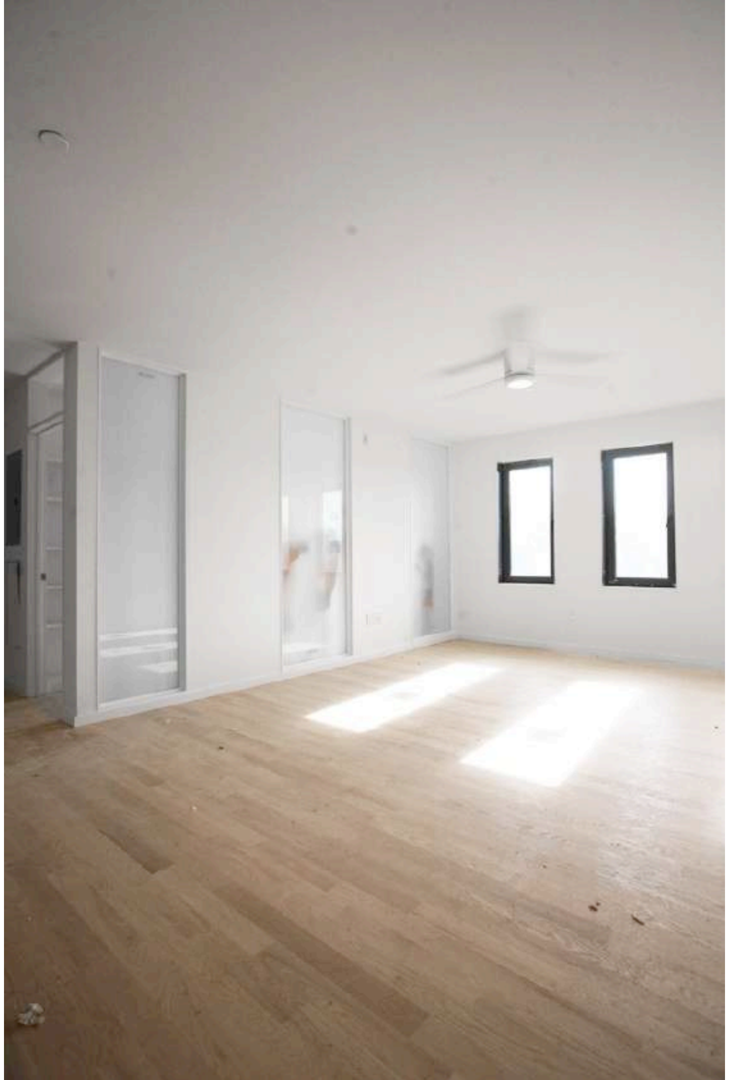
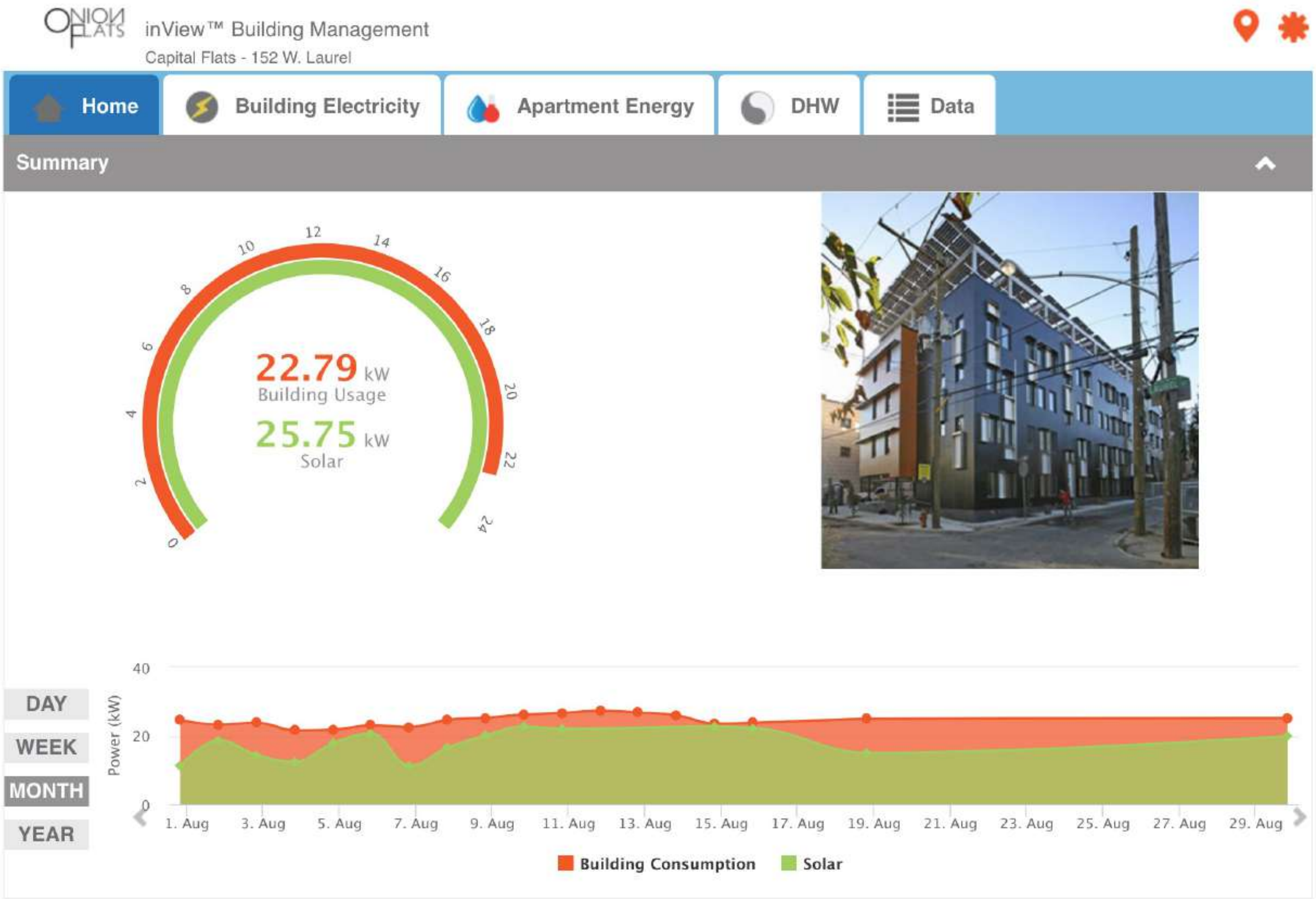






inView™ Building Management

Capital Flats - 152 W. Laurel

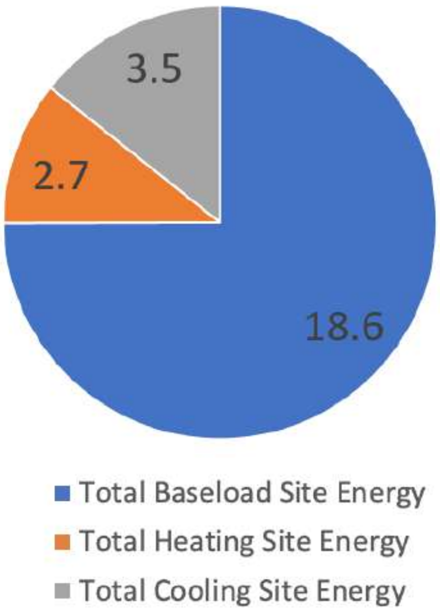
Summary

22.79 kW Building Usage

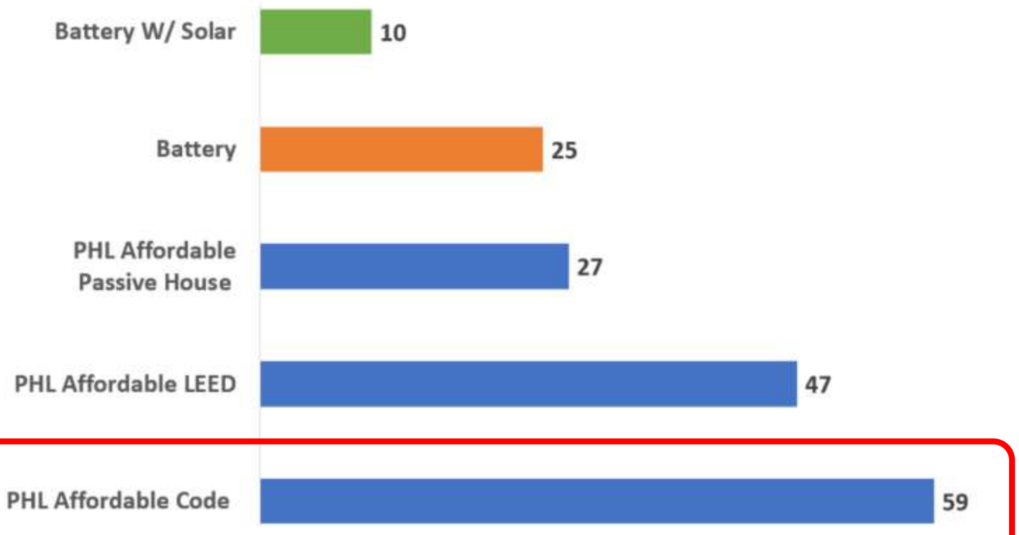
25.75 kW Solar

Battery End Use

2020-2021



EUI: Site Energy Use Intensity Comparison (kBtu/SF)



83% BETTER THAN CODE BLDG

SOLAR

One Meter

FRONT FLATS, 2019; 176 KW "BIFACIAL" PV ARRAY on façade AND ROOF WITH ONE METER

IMPLIES CENTRALIZED SYSTEMS

- Centralized heating/cooling
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- ***One solar array***
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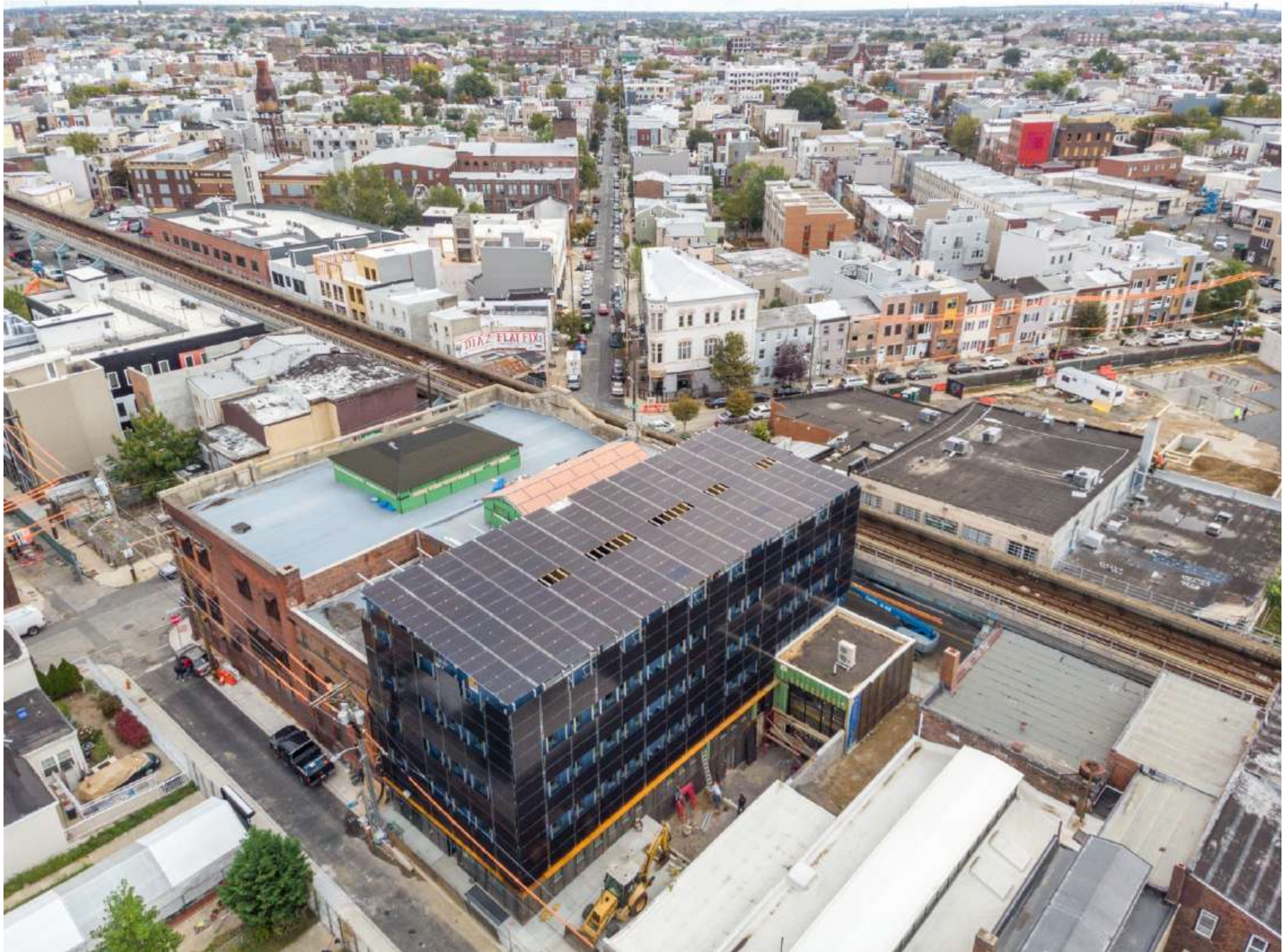
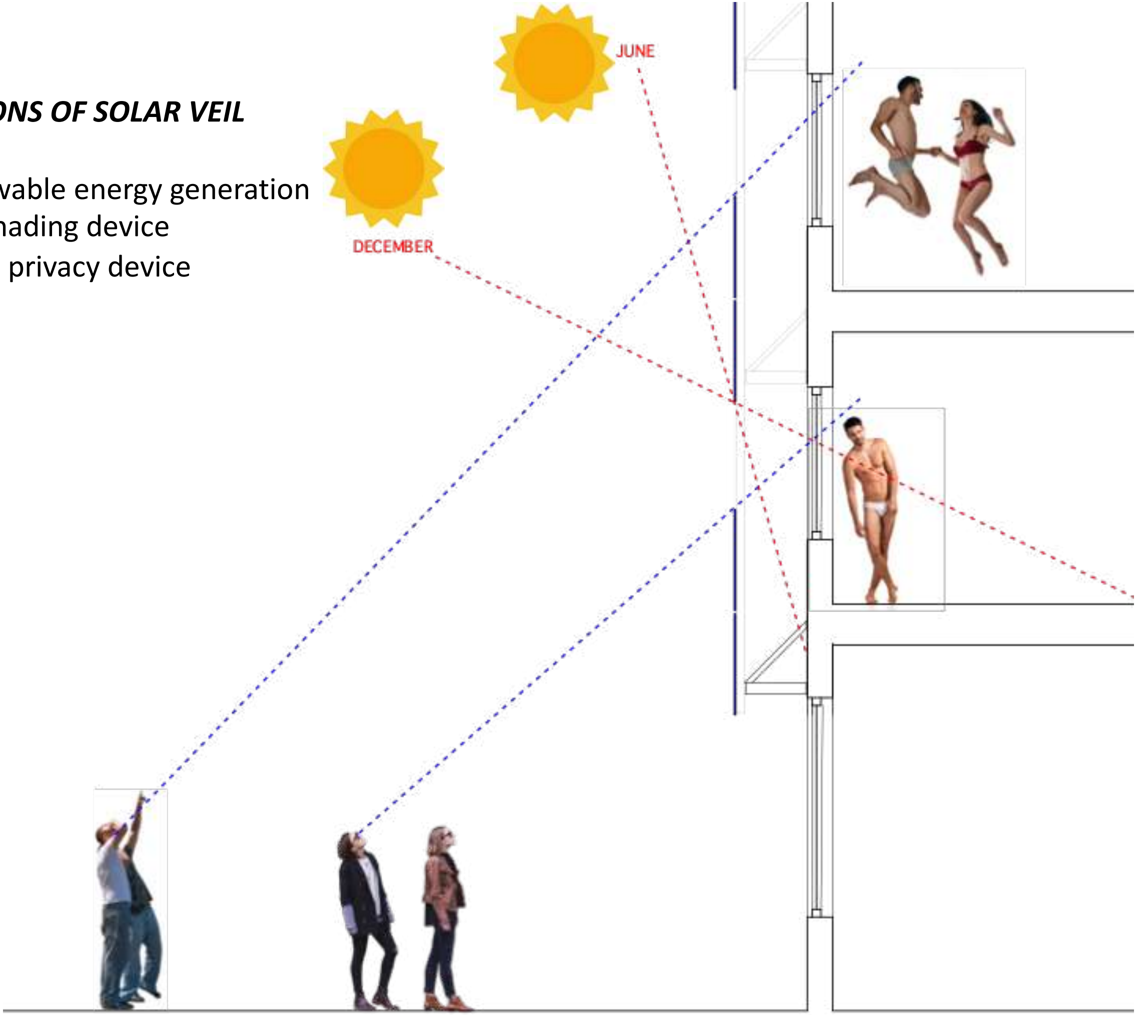
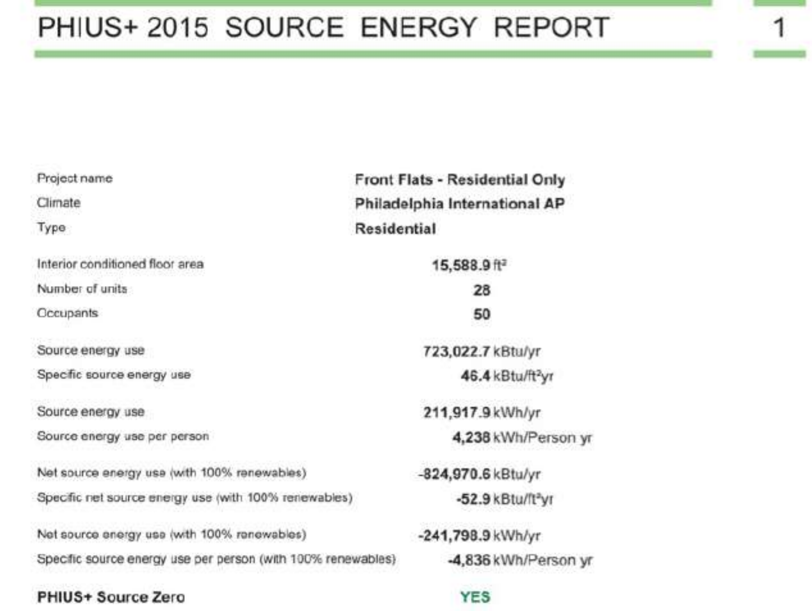

DIAZ FLAT FIX

$180/SF

FUNCTIONS OF SOLAR VEIL

- Renewable energy generation
- Sun shading device
- Visual privacy device





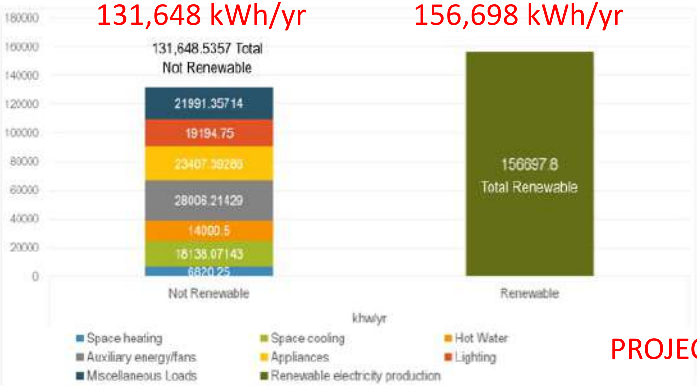
PHIUS+ 2015 SOURCE ENERGY REPORT

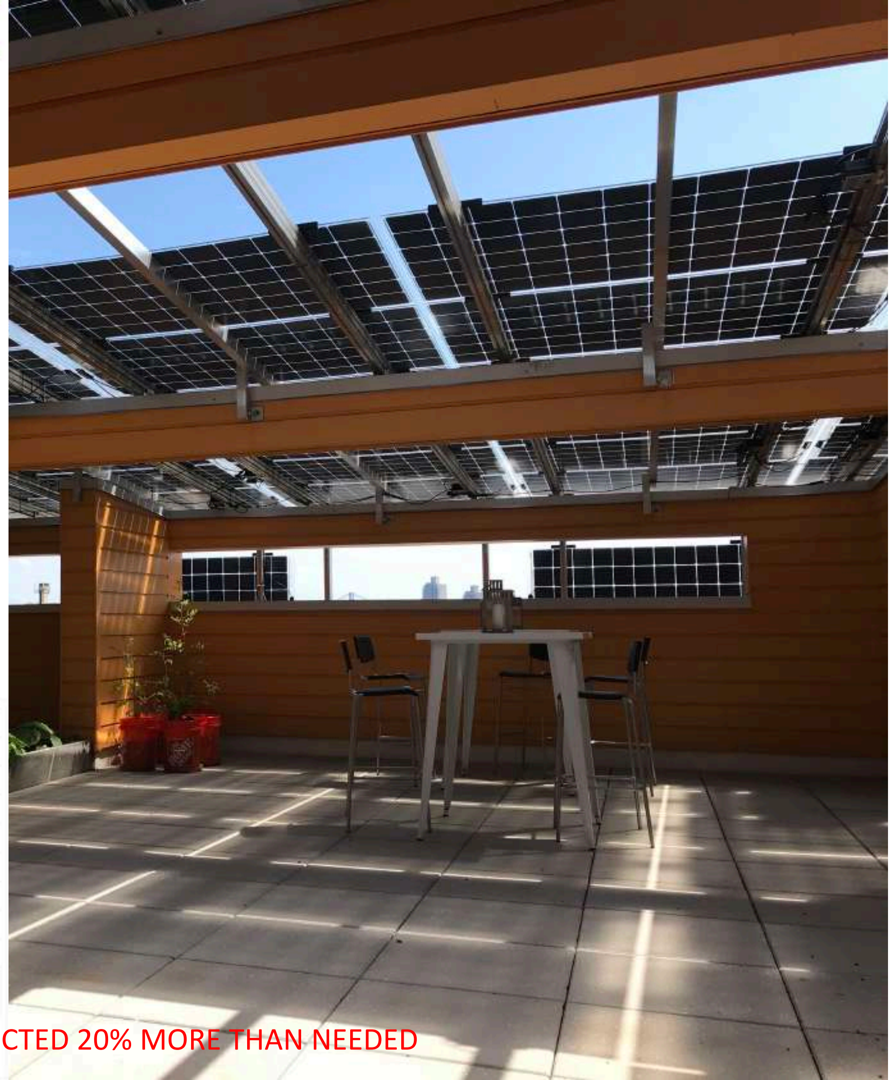
1

Project name	**Front Flats - Residential Only**
Climate	**Philadelphia International AP**
Type	**Residential**
Interior conditioned floor area	**15,588.9** ft²
Number of units	**28**
Occupants	**50**
Source energy use	**723,022.7** kBtu/yr
Specific source energy use	**46.4** kBtu/ft²yr
Source energy use	**211,917.9** kWh/yr
Source energy use per person	**4,238** kWh/Person yr
Net source energy use (with 100% renewables)	**-824,970.6** kBtu/yr
Specific net source energy use (with 100% renewables)	**-52.9** kBtu/ft²yr
Net source energy use (with 100% renewables)	**-241,798.9** kWh/yr
Specific source energy use per person (with 100% renewables)	**-4,836** kWh/Person yr
PHIUS+ Source Zero	**YES**

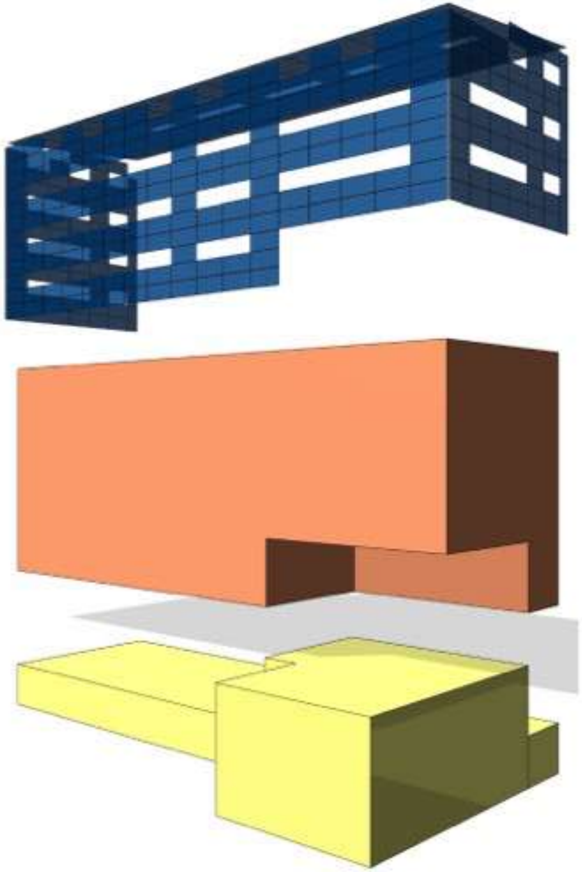
CONSUMPTION
131,648 kWh/yr

PRODUCTION
156,698 kWh/yr





PROJECTED 20% MORE THAN NEEDED



SOLAR PRODUCTION

165,260kWh/yr

PROJECTED
156,698 kWh/yr

RESIDENTIAL CONSUMPTION

138,501 kWh/yr

PROJECTED
131,648 kWh/yr

OFFICE/STORAGE CONSUMPTION

30,402 kWh/yr

TOTAL BUILDING CONSUMPTION

168,904 kWh/yr

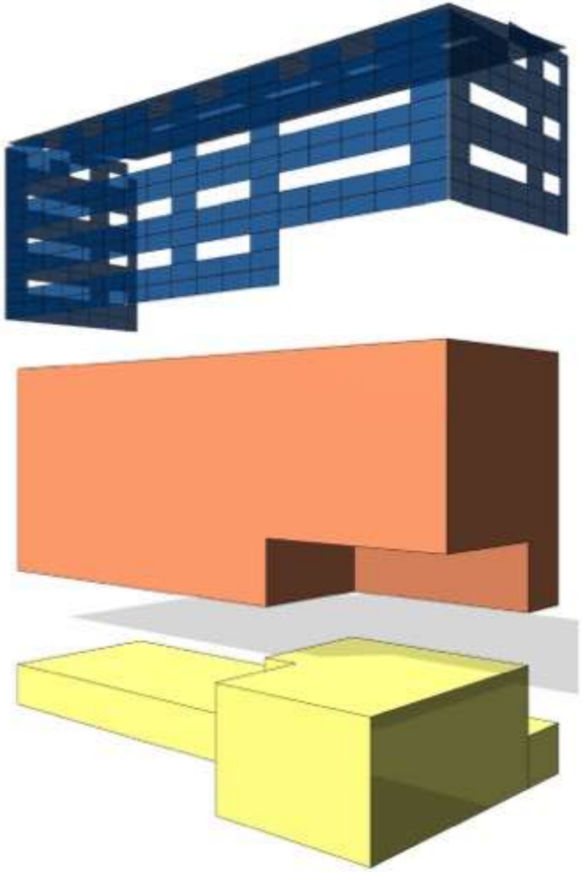
NET ***POSITIVE*** RESIDENTIAL ENERGY PRODUCTION

26, 758 kWh/yr

PROJECTED
25,050 kWh/yr

MONITORED ACTUAL 2020 CONSUMPTION/PRODUCTION

2020 Month	Solar Generation kWh	Total Building Usage kWh
Jan	12,207	9,819
Feb	11,346	9,106
Mar	15,290	9,412
Apr	14,797	9,124
May	15,290	10,065
Jun	18,708	17,237
Jul	16,156	21,471
Aug	13,866	21,706
Sep	15,411	17,411
Oct	12,262	15,399
Nov	11,749	14,593
Dec	8,177	13,562
Total	165,260	168,904



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UTILITIES AS REVENUE

$40/month x 28 x 12 =

$13,440.00

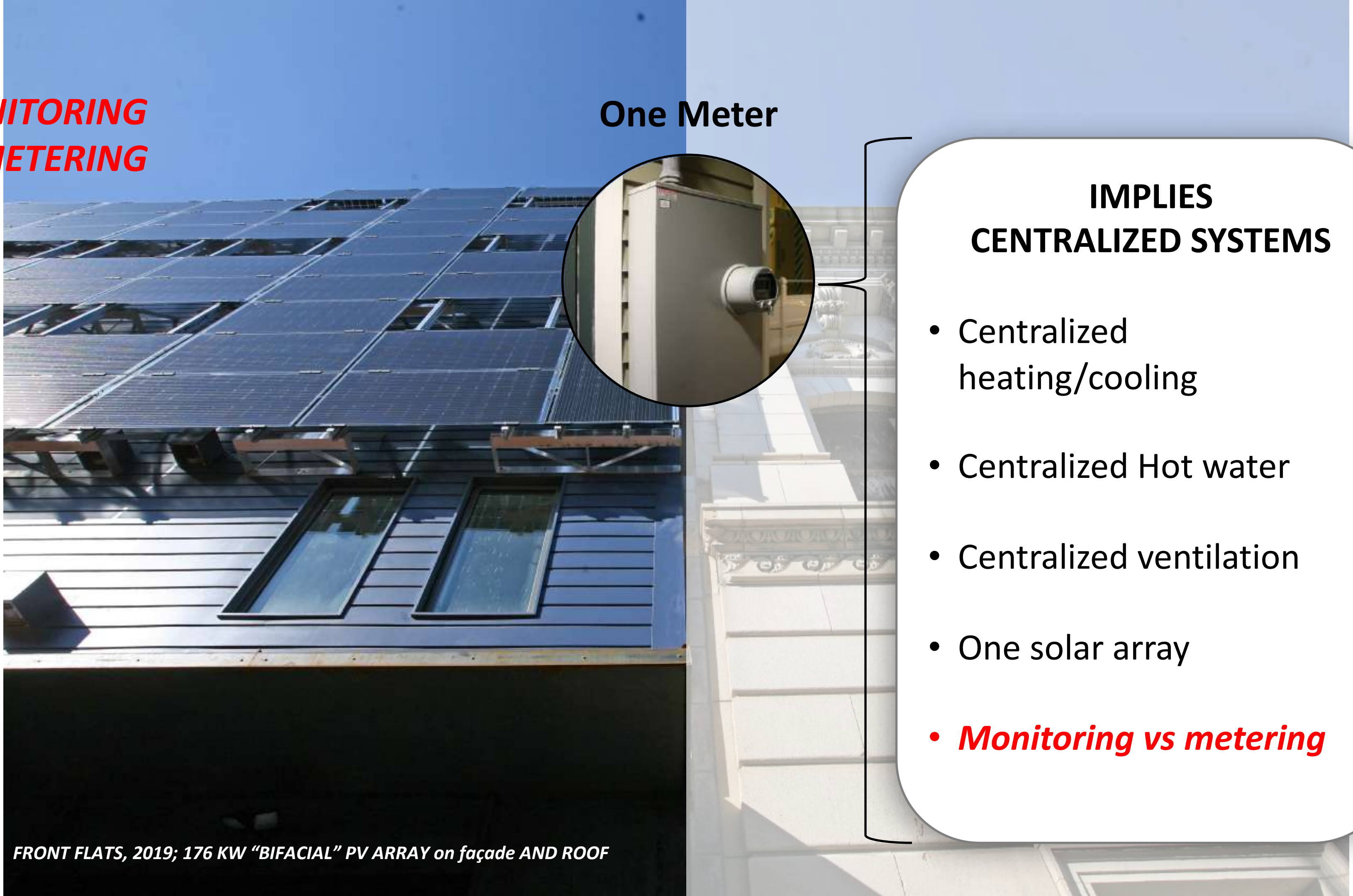
26,758 kWh x $.12=

$3211.00

$16,651.00

ADDITIONAL REVENUE

MONITORING VS METERING



FRONT FLATS, 2019; 176 KW "BIFACIAL" PV ARRAY on façade AND ROOF

IMPLIES CENTRALIZED SYSTEMS

- Centralized heating/cooling
- Centralized Hot water
- Centralized ventilation
- One solar array
- *Monitoring vs metering*

MONITORING VS METERING

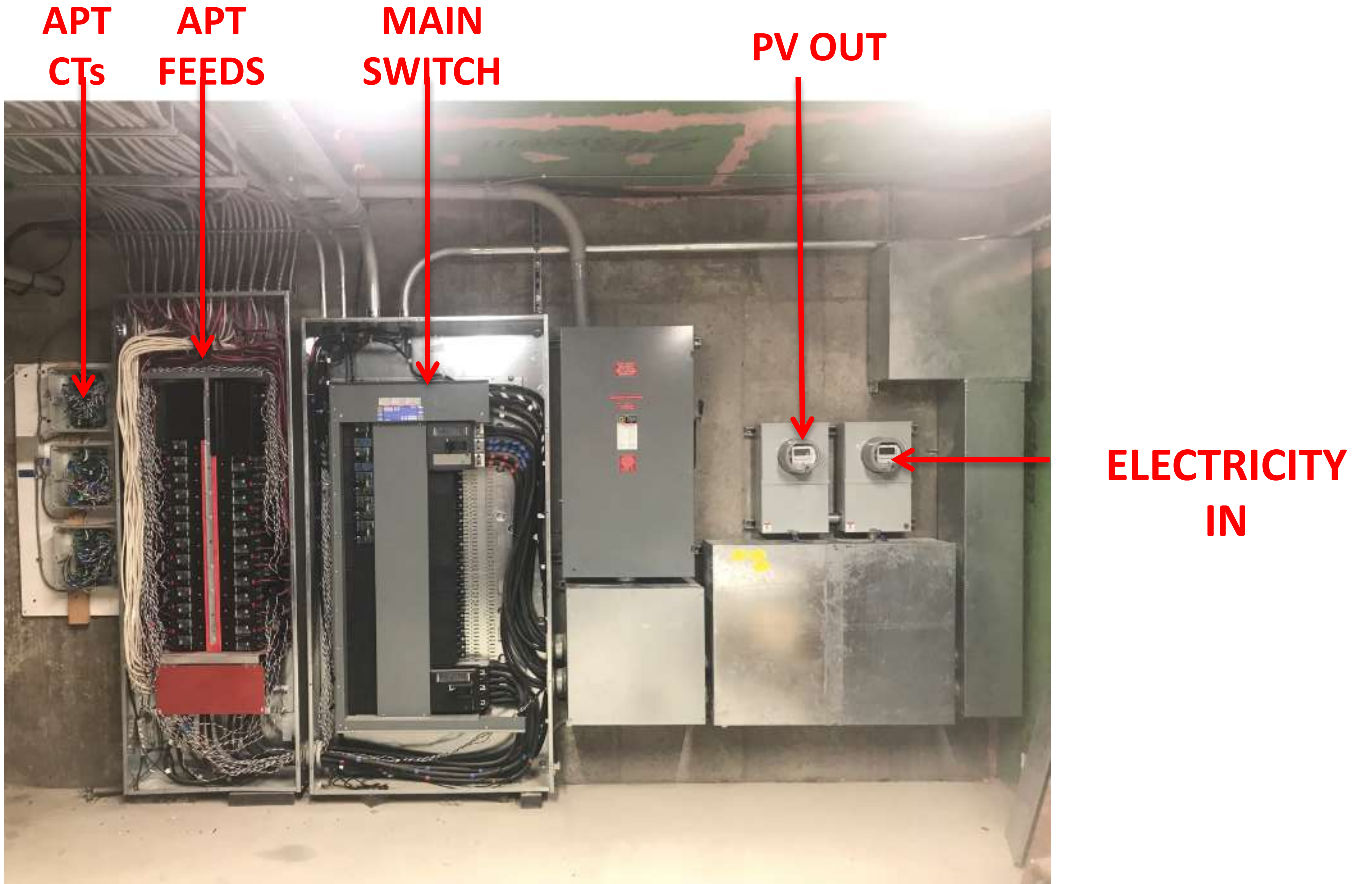
TENANTS CHARGED FLAT UTILITY FEE OF $40/month

MONITORING VS METERING

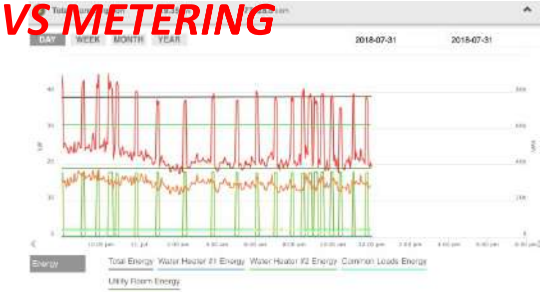
The Battery, PHIUS + Certified, 2017; 77 KW "BIFACIAL" PV ARRAY WITH ONE METER

MONITORING VS METERING

TENANTS CHARGED FLAT UTILITY FEE OF $50/month



MONITORING VS METERING



The Battery, PHIUS + Certified, 2017; Overall building consumption and electricity production

One Meter

IMPLIES CENTRALIZED SYSTEMS

- Centralized heating/cooling
- Centralized Hot water
- Centralized ventilation
- One solar array
- ***Monitoring vs metering***

MONITORING VS METERING

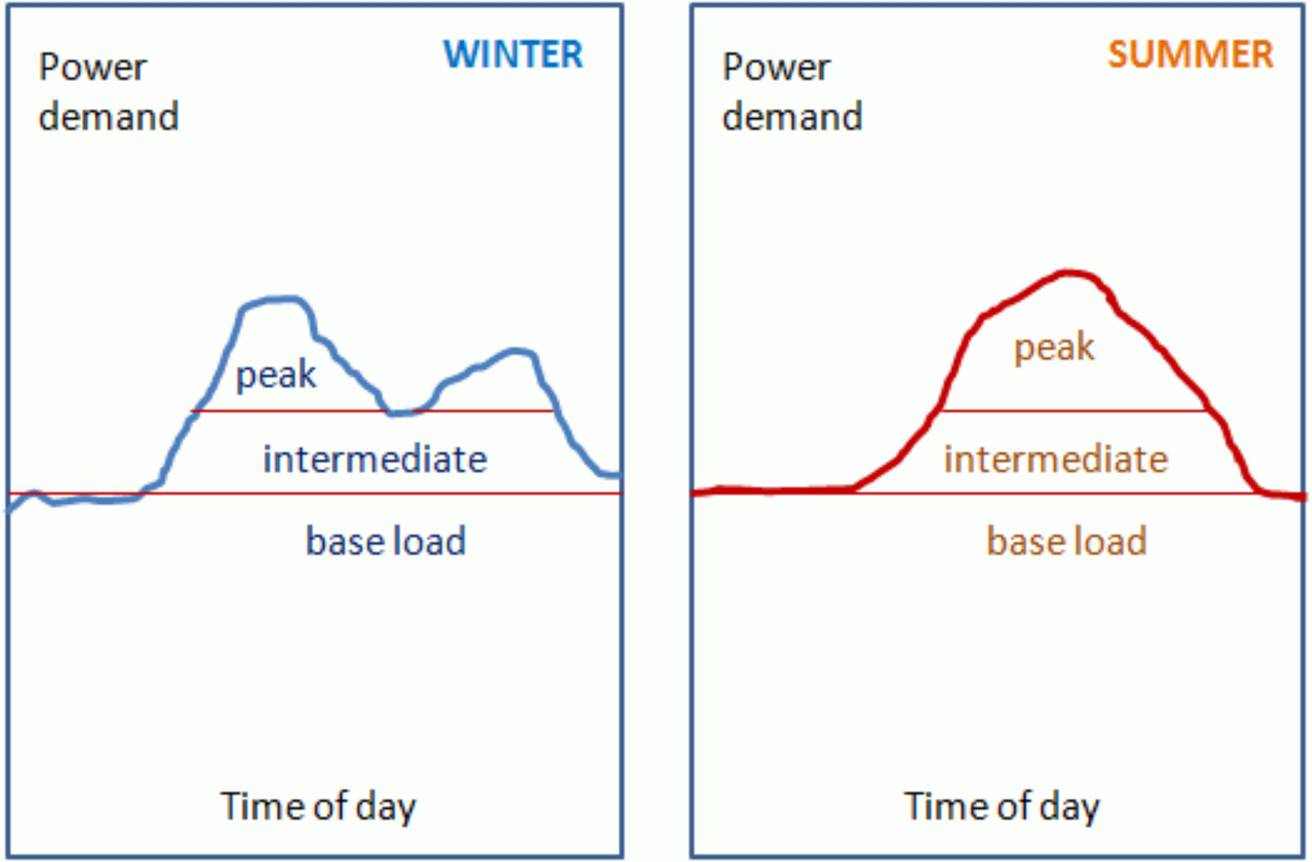
INCENTIVIZE + EDUCATE

MONITORING VS METERING

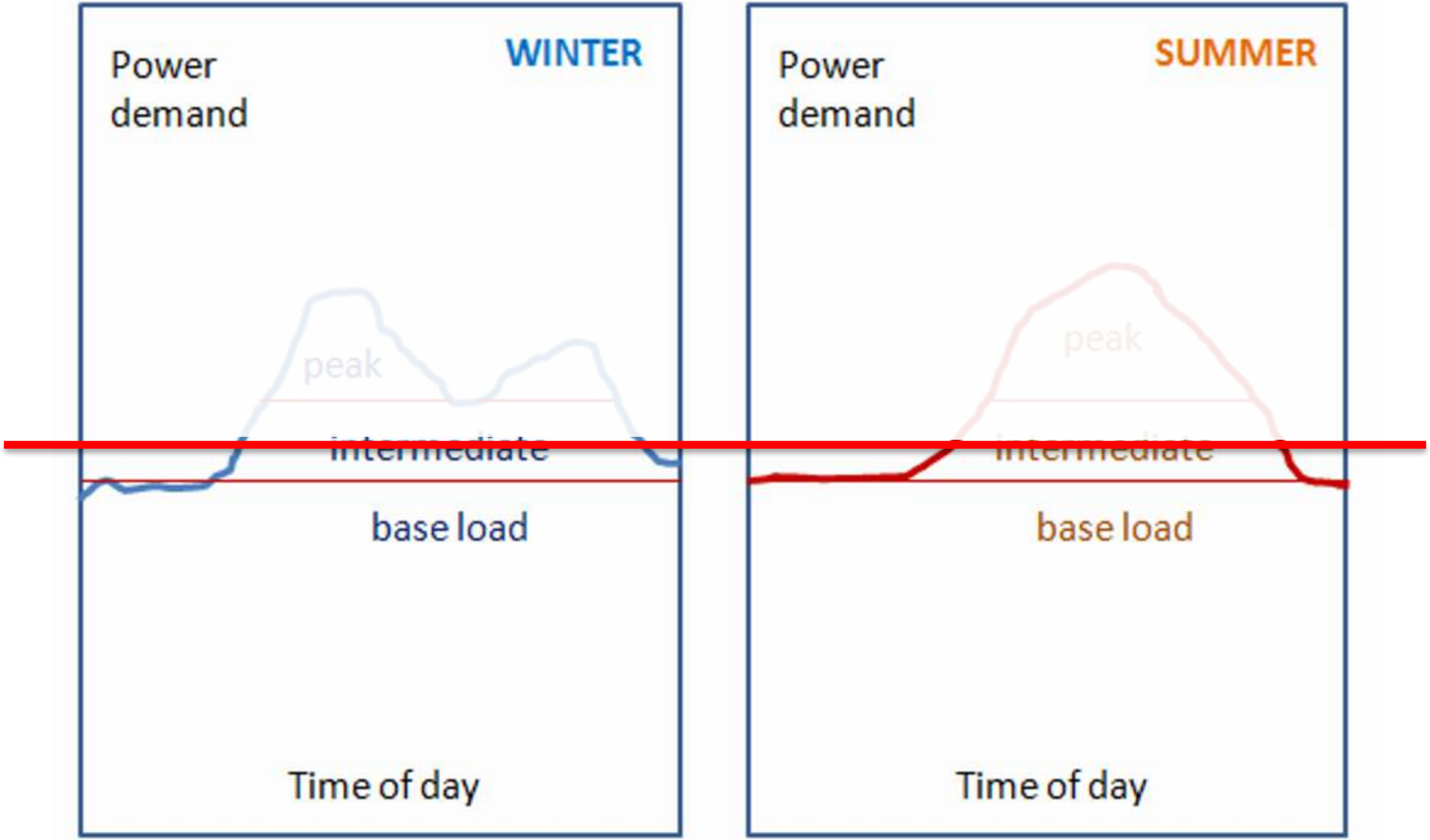
INCENTIVIZE + EDUCATE

WHO'S WHO???

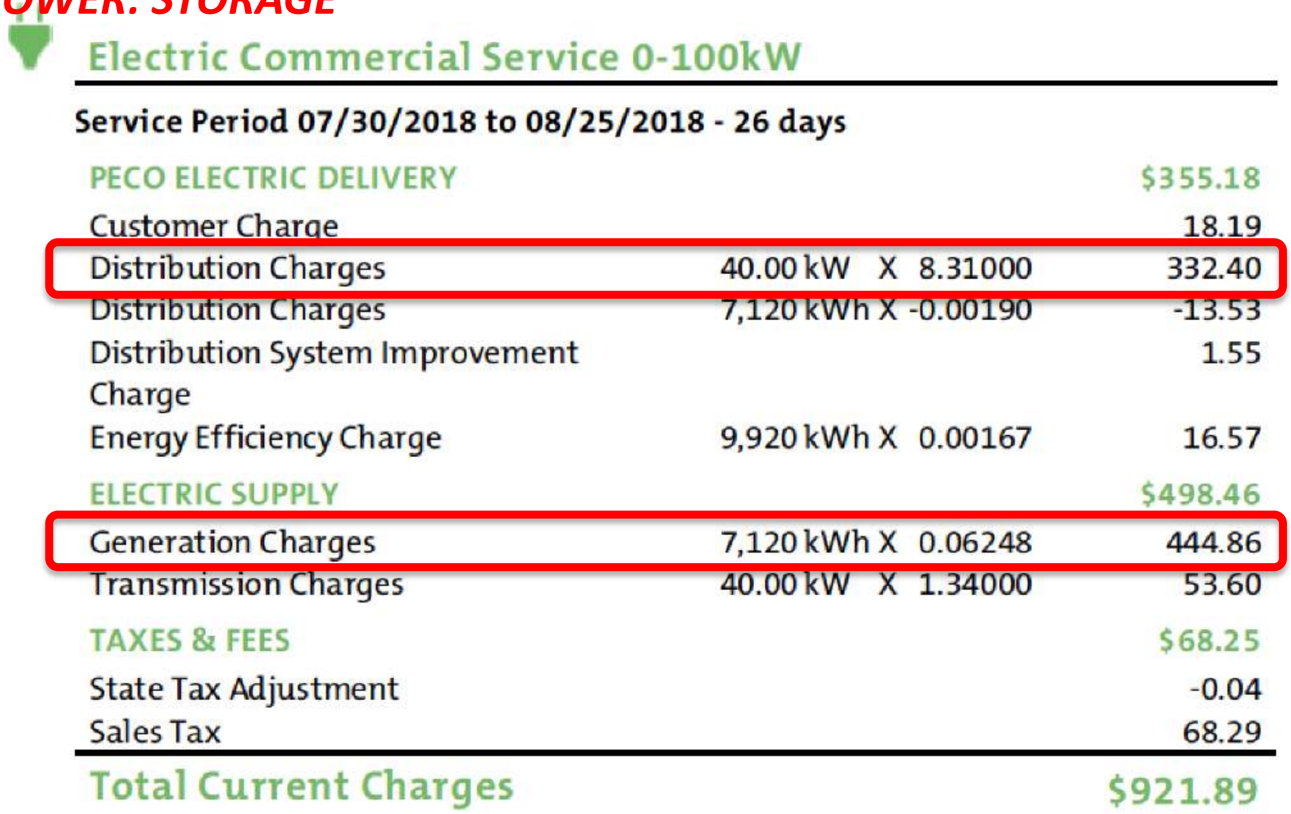
BACK-UP POWER: STORAGE



BACK-UP POWER: STORAGE



BACK-UP POWER: STORAGE



Electric Commercial Service 0-100kW

Service Period 07/30/2018 to 08/25/2018 - 26 days

PECO ELECTRIC DELIVERY			$355.18
Customer Charge			18.19
Distribution Charges	40.00 kW	X 8.31000	332.40
Distribution Charges	7,120 kWh	X -0.00190	-13.53
Distribution System Improvement Charge			1.55
Energy Efficiency Charge	9,920 kWh	X 0.00167	16.57
ELECTRIC SUPPLY			$498.46
Generation Charges	7,120 kWh	X 0.06248	444.86
Transmission Charges	40.00 kW	X 1.34000	53.60
TAXES & FEES			$68.25
State Tax Adjustment			-0.04
Sales Tax			68.29
Total Current Charges			**$921.89**

!!!!

DEMAND CHARGE

BACK-UP POWER: STORAGE

The case for bidirectional EV charging is growing stronger

Bidirectional charging through vehicle-to-grid technology could help boost resiliency for the grid as well as EV fleet owners.

By **Audrey Henderson** August 5, 2022

Ford touts the Ford 150 - Lightning's bidirectional grid-integration capabilities as a key benefit of the vehicle. Pictured, Chris Ashely, an owner in Washington, D.C. Photo courtesy of Ford

100 kWh storage: $145,000

98 kWh storage: $70,000

BACK-UP POWER: STORAGE

100 kWh storage: $145,000

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98 kWh storage: $70,000

....and it's a truck!!!

BACK-UP POWER: STORAGE

100 kWh storage: $145,000

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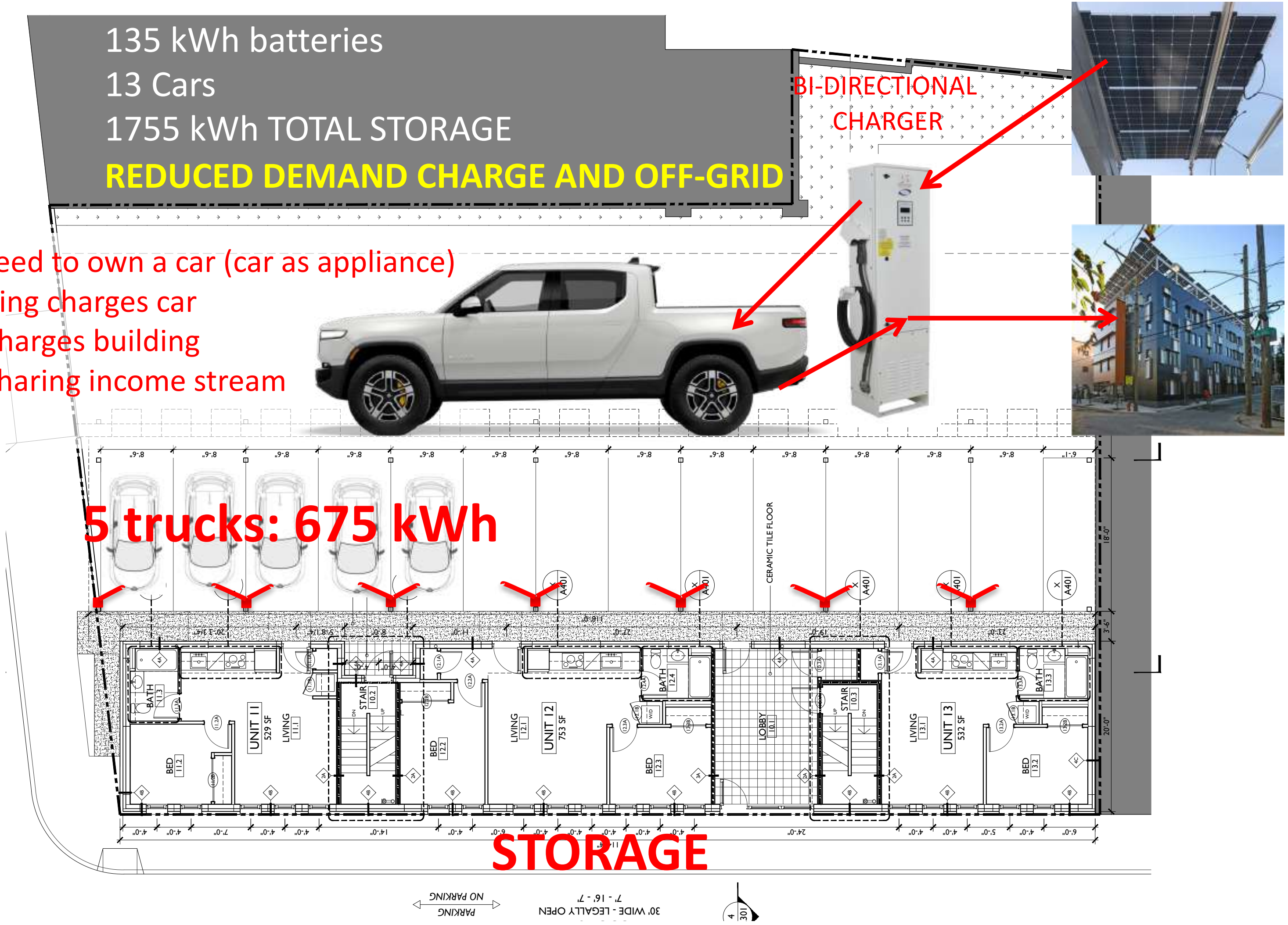
135 kWh storage: $80,000

….and it's a truck!!!



135 kWh batteries

13 Cars

1755 kWh TOTAL STORAGE

REDUCED DEMAND CHARGE AND OFF-GRID

BI-DIRECTIONAL CHARGER

1. No need to own a car (car as appliance)
2. Building charges car
3. Car charges building
4. Car sharing income stream

5 trucks: 675 kWh

STORAGE

One Meter

CENTRALIZED SYSTEMS

PROS

- Less cost and space required for electric meters (one)
- Owner pays distribution charges on only one meter
- Owner receives the benefit of the solar electricity generation
- Less penetrations in envelope and less filter maintenance on Centralized ventilation system
- No coordination with tenants needed in order to perform routine maintenance on Centralized systems (clean or replace filters 3-4 times per year)

CONS

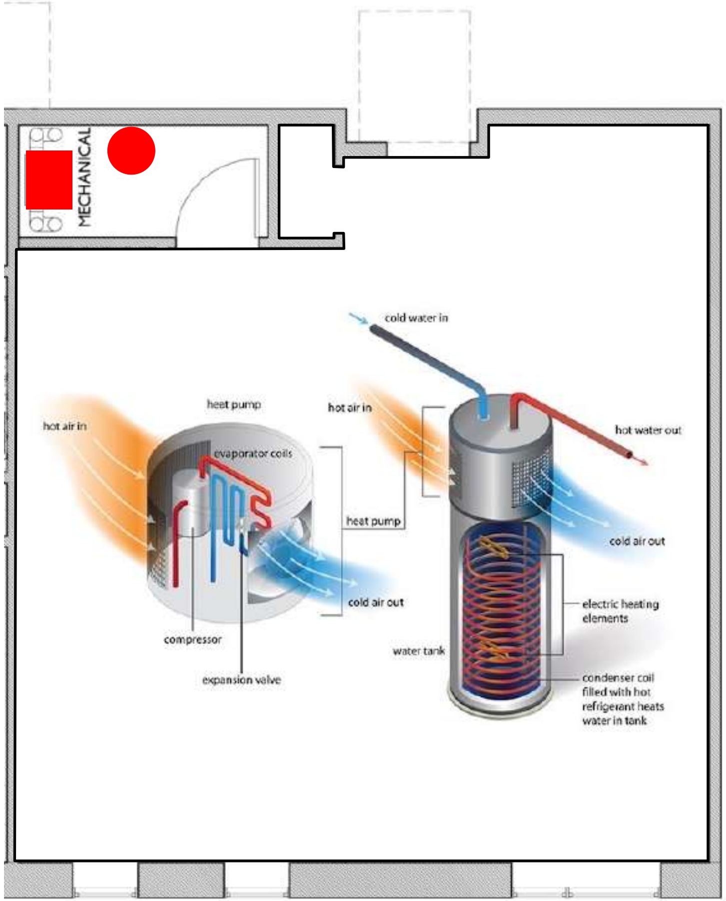
- Potential over-use of energy by tenants if "Incentive/Penalty" program is not put in place by owner.
- Owner has more management costs related to billing tenants
- Fire dampers required on ventilation supply and returns as they pass through the horizontal 1 hour assembly unless ERV/HRVs are located on each building floor serving only that floor
- When a Centralized system needs repair, all tenants may be without an essential service

Multiple Meters

DE-CENTRALIZED SYSTEMS

IMPLIES
DE-CENTRALIZED
SYSTEMS

Multiple Meters



DE-CENTRALIZED SYSTEMS

IMPLIES DE-CENTRALIZED SYSTEMS

- Hot Water (Individual Heat Pump water heaters in each unit)
- Ventilation (Individual ERV/HRV in each unit)
- Heating/Cooling (Individual Mini-split heat pumps within each unit, one condenser per unit

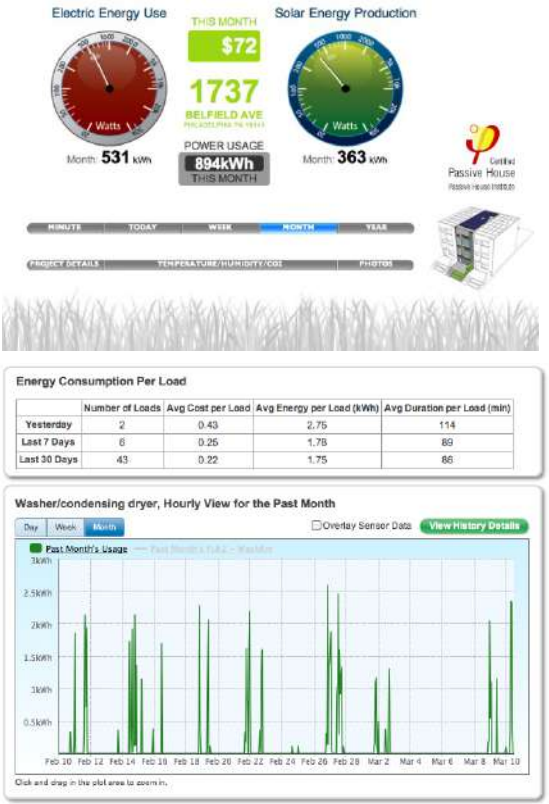
Multiple Meters

Top: Stables Townhomes, bottom: Belfield Townhomes, PHI Certified 2012

IMPLIES DE-CENTRALIZED SYSTEMS

- Hot Water (Individual Heat Pump water heaters in each unit)
- Ventilation (Individual ERV/HRV in each unit)
- Heating/Cooling (Individual Mini-split heat pumps within each unit, one condenser per unit
- Solar array per unit

Multiple Meters



Energy Consumption Per Load

	Number of Loads	Avg Cost per Load	Avg Energy per Load (kWh)	Avg Duration per Load (min)
Yesterday	2	0.43	2.75	114
Last 7 Days	6	0.25	1.78	89
Last 30 Days	43	0.22	1.75	86

Washer/condensing dryer, Hourly View for the Past Month

Belfield Townhomes, PHI Certified 2012, Circuit-by-circuit monitoring

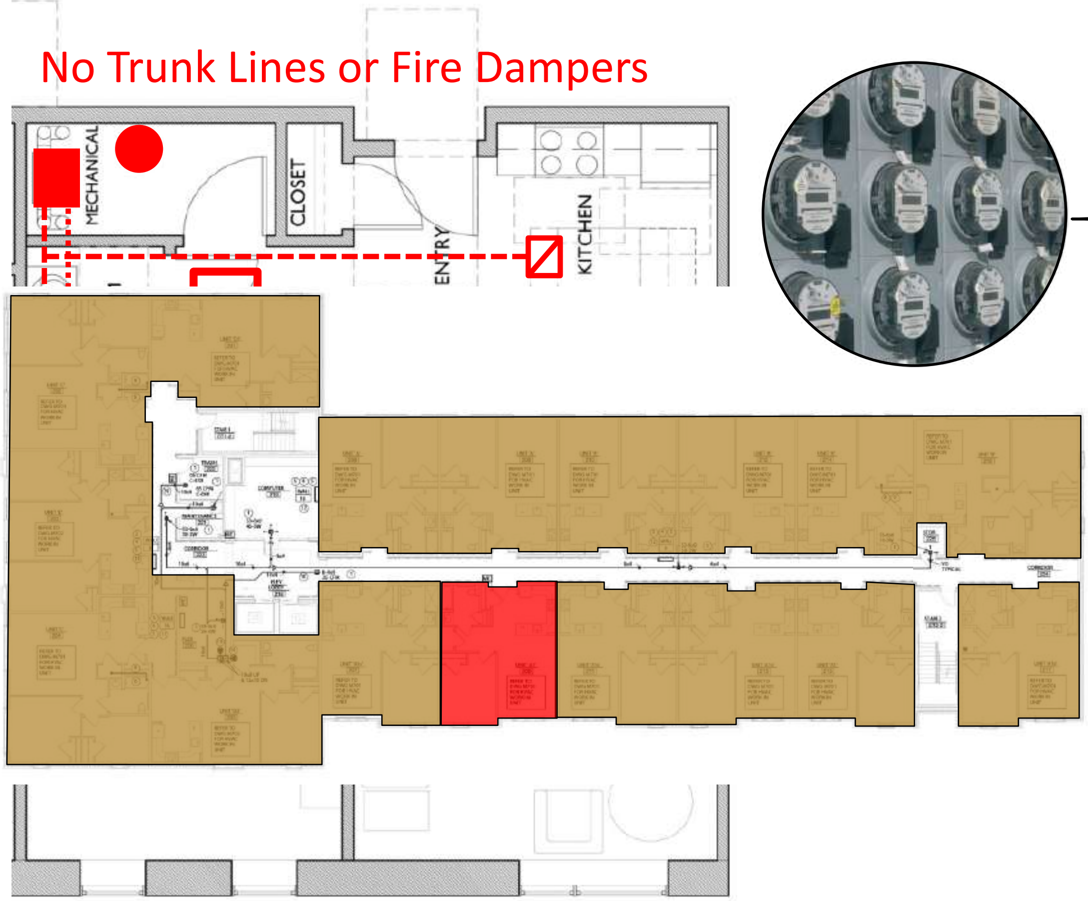
Sensors

	Name	Last Reading	Type
🟢	Unit 1; LVL1-LivingRm	73°F	Temperature
🟢	Unit 1; LVL1-Hall	75°F	Temperature
🟢	Unit 1; LVL1-BedRm (Back)	73°F	Temperature
🟢	Unit 2; LVL2-BedRm (Back)	75°F	Temperature
🟢	Unit 2; LVL2-Hall	73°F	Temperature
🟢	Unit 1; LVL2-WashRm	75°F	Temperature
🟢	Unit 2; LVL2-BedRm (Frnt)	73°F	Temperature
🟢	Unit 2; LVL3-Mech Rm	75°F	Temperature
🟢	Unit 2; LVL3-BedRm (Frnt)	73°F	Temperature
🟢	Unit 2; LVL3-Office (Back)	75°F	Temperature
🟢	Unit 2; LVL 3 - Mech Rm; Inside Retrun Air Duct	77°F	Temperature
🟢	Unit 2; LVL 3 - Mech Rm; Inside Retrun Air Duct	450 ppm	VOC
🔴	Unit 2; LVL 3 - Mech Rm; Inside Retrun Air Duct	%	Humidity
🟢	Unit 1; LVL1-Hall	453 ppm	VOC
🟢	Unit 1; LVL1-Hall	45%	Humidity
🟢	Unit 1; LVL2-WashRm	450 ppm	VOC
🟢	Unit 1; LVL2-WashRm	44%	Humidity

IMPLIES DE-CENTRALIZED SYSTEMS

- Hot Water (Individual Heat Pump water heaters in each unit)
- Ventilation (Individual ERV/HRV in each unit)
- Heating/Cooling (Individual Mini-split heat pumps within each unit, one condenser per unit
- Solar array per unit
- Monitoring vs metering

Multiple Meters

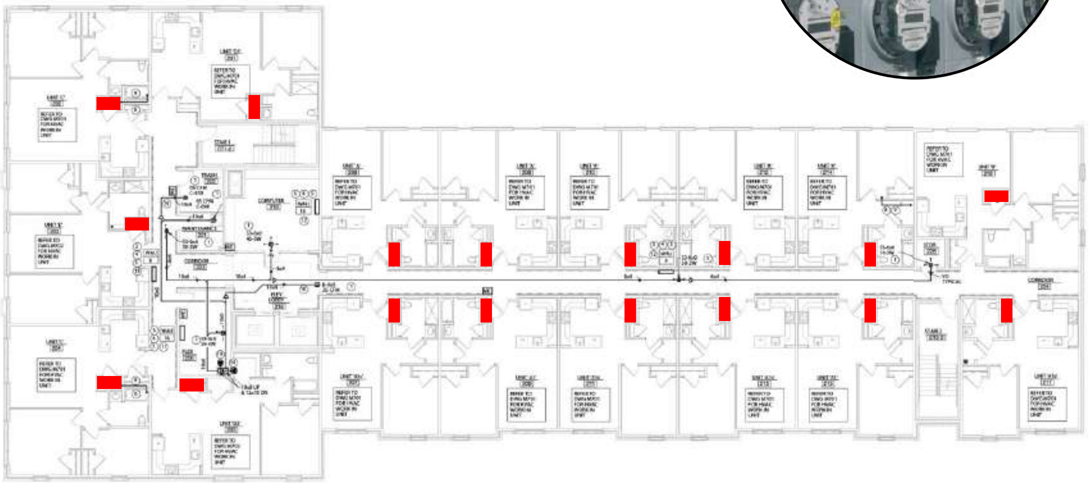


No Trunk Lines or Fire Dampers

PROS

- Owner is not managing or paying for utilities, tenants are.
- Simplified ductwork piping and fire protection.
- If one system needs maintenance, the rest of the tenants are unaffected.

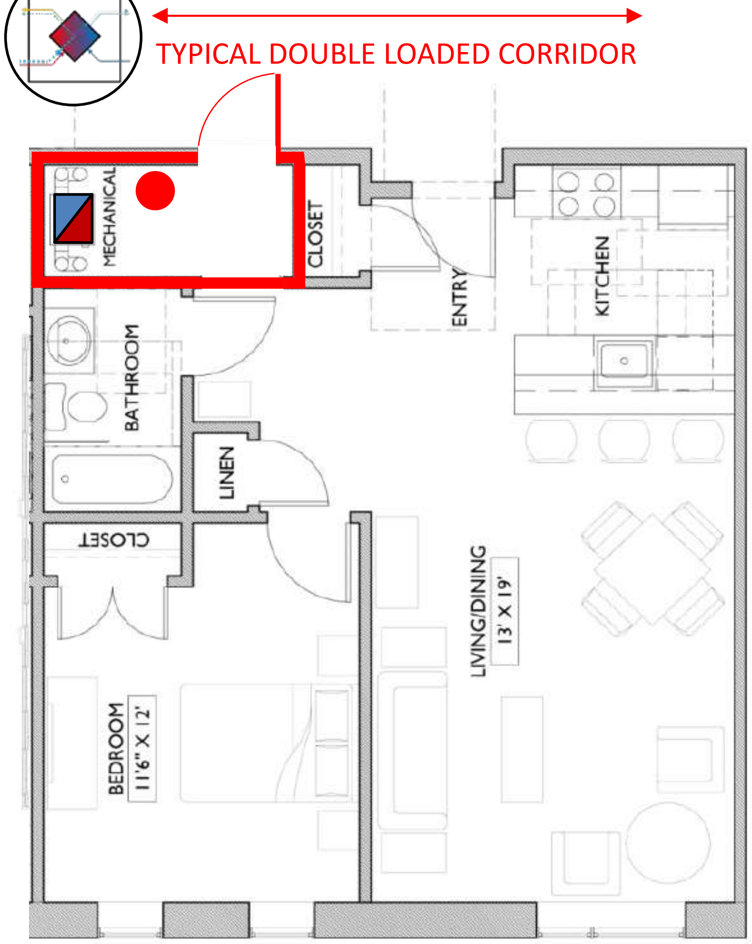
Multiple Meters

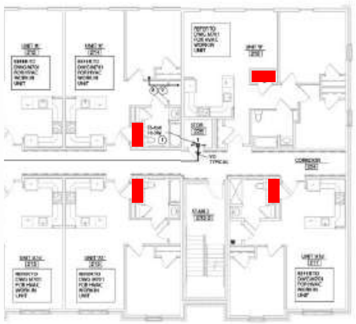


CONS

- Requires more maintenance for owner.
- Filters in HVAC & DHW systems need to be maintained 3-4 per year.
- Coordination challenge of maintenance with all tenants because systems are often inside their units.

Multiple Meters





CONS

- Requires more maintenance for owner.
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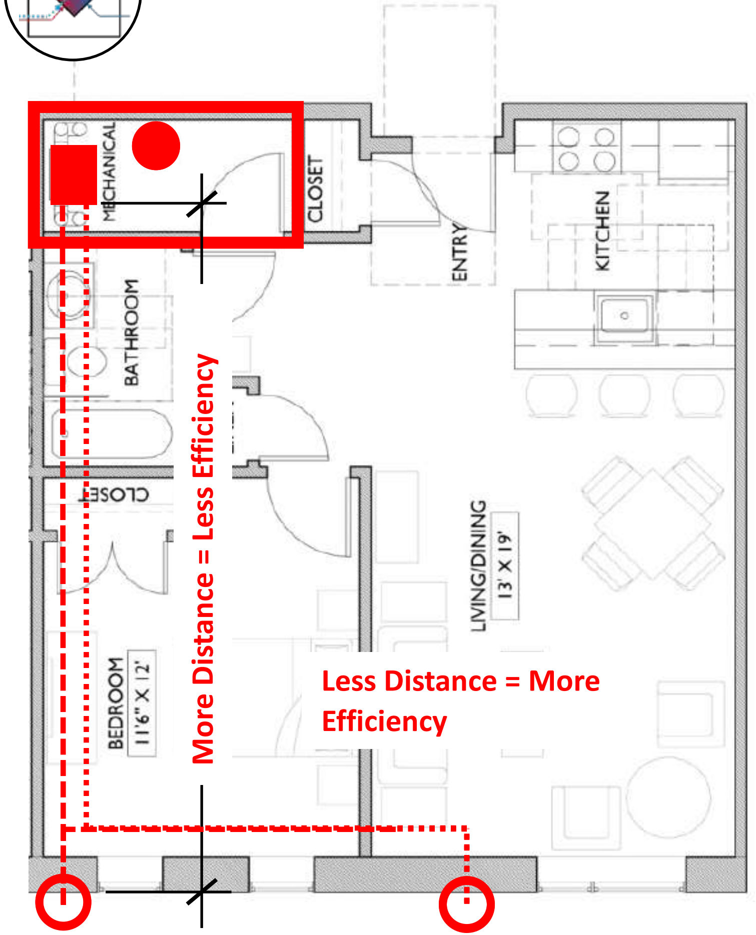
- HVAC / DHW equipment takes up space in apartments (+ cold air!)

Multiple Meters



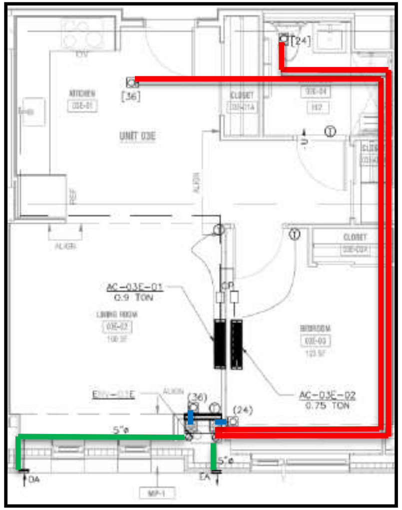
More Distance = Less Efficiency

Less Distance = More Efficiency

CONS

- Requires more maintenance for owner.
- Filters in HVAC & DHW systems need to be maintained 3-4 per year.
- Coordination challenge of maintenance with all tenants because systems are often inside their units.
- HVAC / DHW equipment takes up space in apartments (+ cold air!)
- Two punctures in the envelope per ERV/HRV (1 supply and 1 exhaust for each unit) - labor intensive & potential for air leakage.
- >Distance = <Efficiency

Multiple Meters



Hanac Corona Senior Residence, NYC, PHI Certified; ERV located on outside wall….AEA

CONS

- Requires more maintenance for owner.
- Filters in HVAC & DHW systems need to be maintained 3-4 per year.
- Coordination challenge of maintenance with all tenants because systems are often inside their units.
- HVAC / DHW equipment takes up space in apartments (+ cold air!)
- Two punctures in the envelope per ERV/HRV (1 supply and 1 exhaust for each unit) - labor intensive & potential for air leakage.
- >Distance = <Efficiency

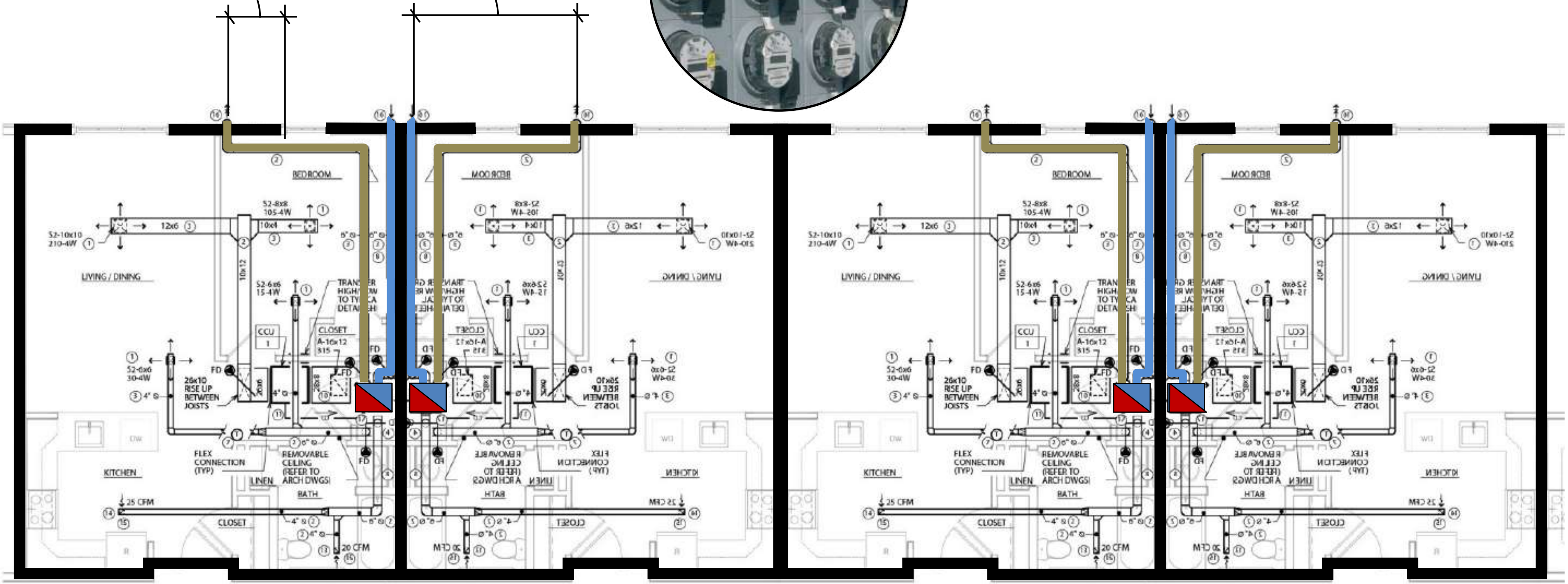
Multiple Meters

🟫 **Exhaust**

🟦 **Supply**

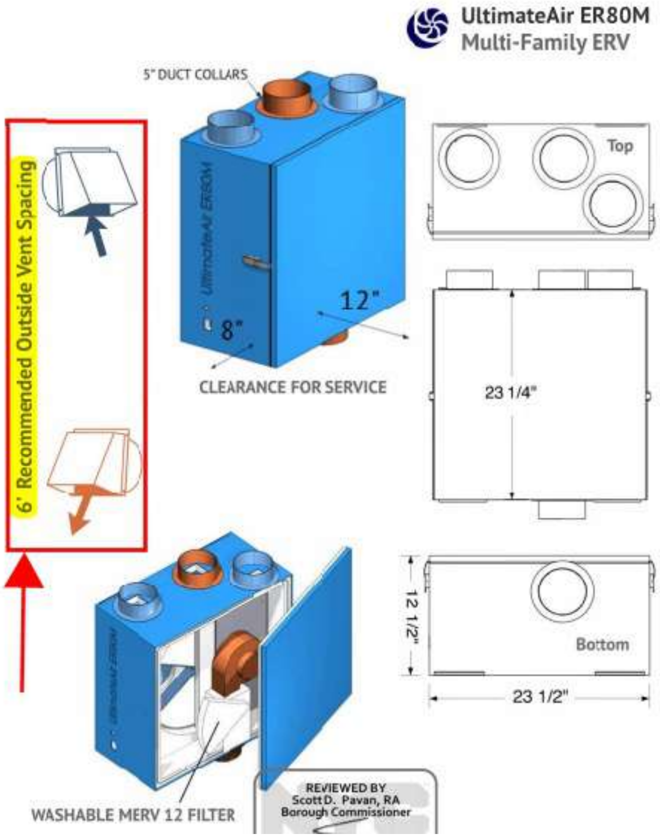
3’ MIN.

10’ MIN.



DOB Special Permission Solution

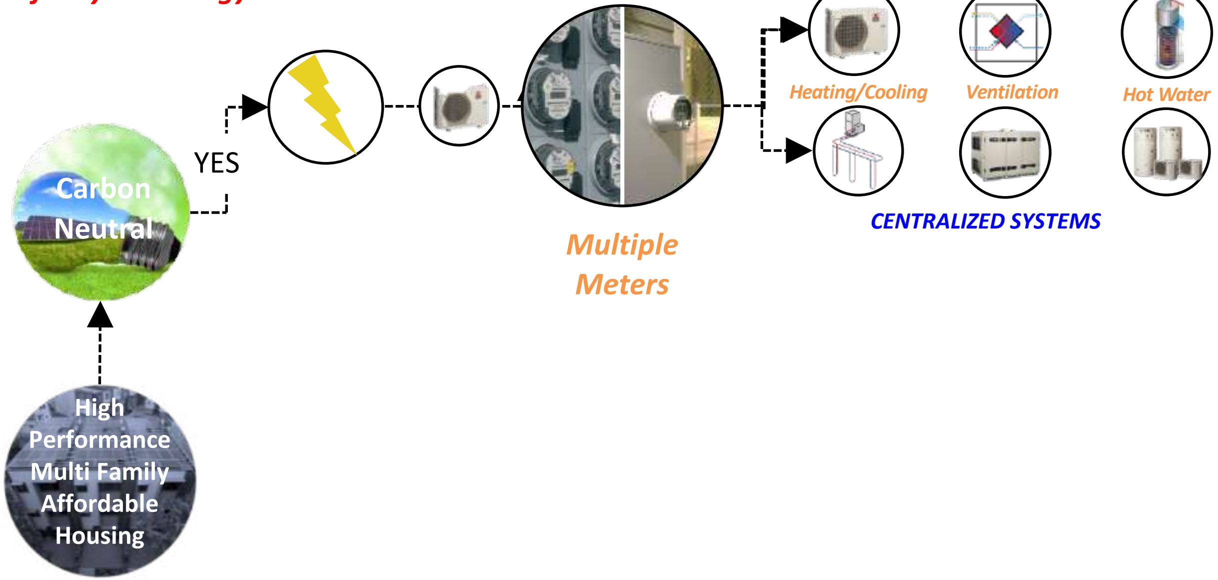
10’ distance between exhaust and supply



Curtis + Ginsberg Architects LLP, Park Avenue Green, NYC

STEP #1
Define your Energy Path

STEP #2
Define your Systems Path



High Performance Multi Family Affordable Housing

Carbon Neutral

YES

One Meter

Multiple Meters

DE-CENTRALIZED SYSTEMS

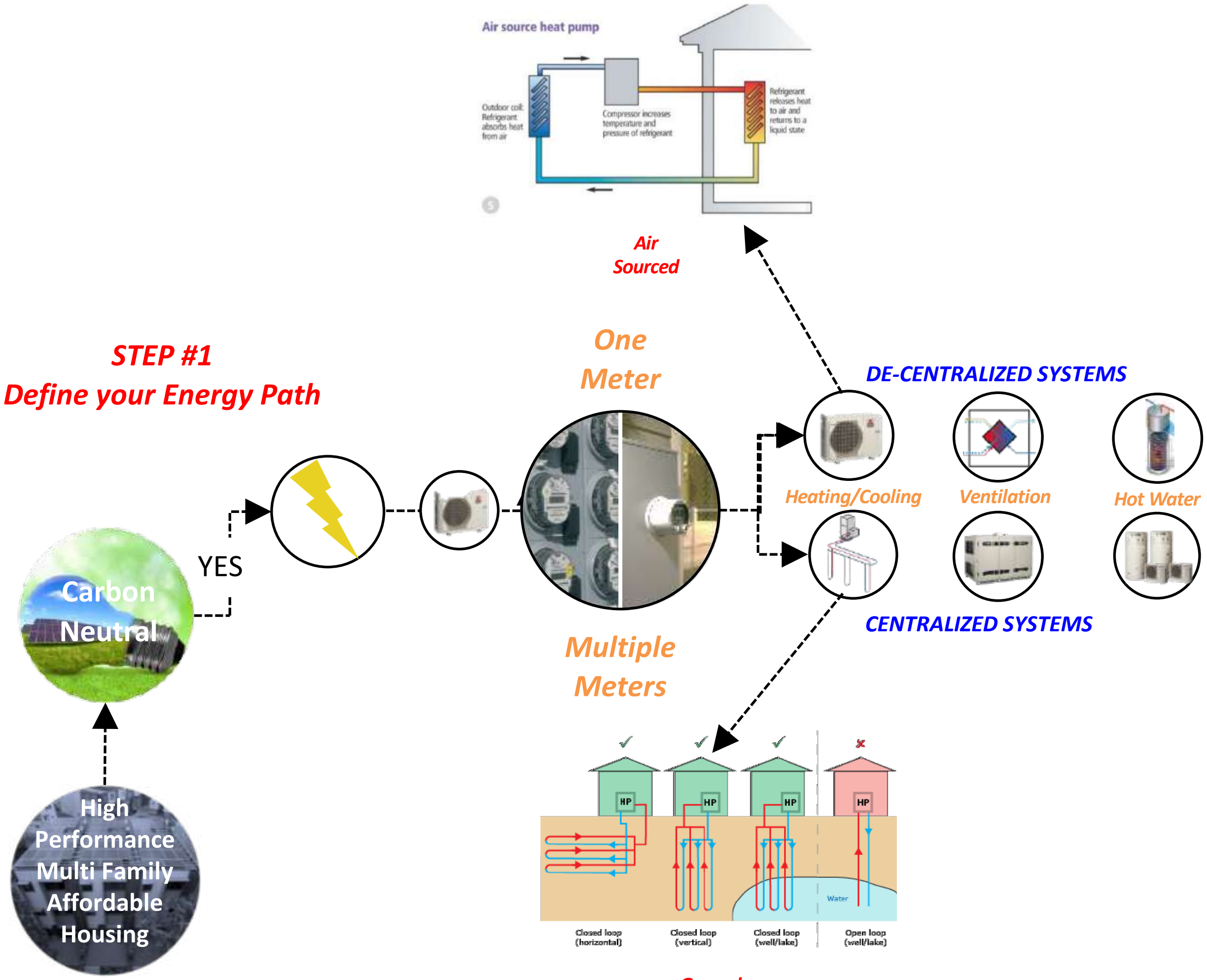
Heating/Cooling

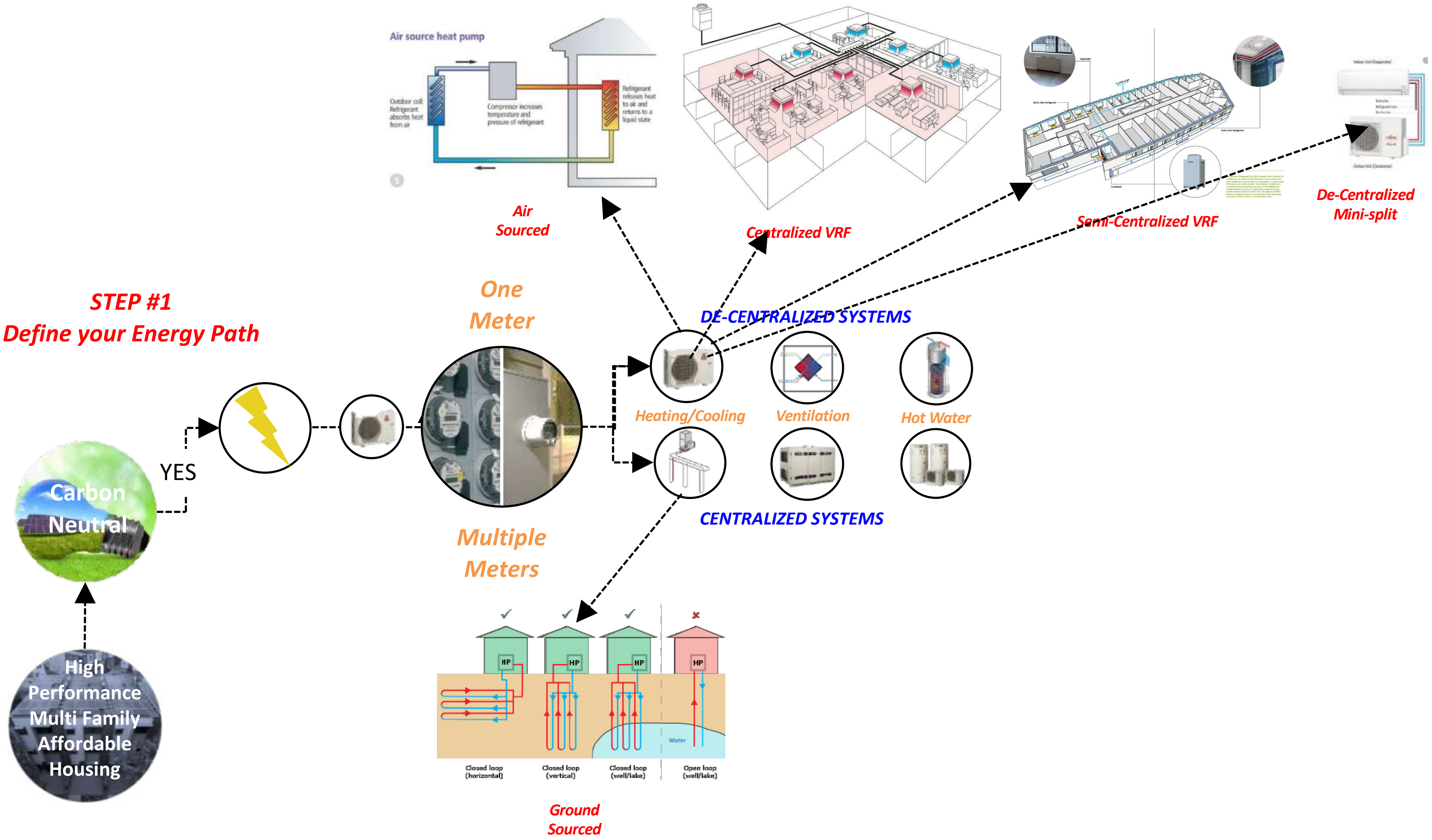
Ventilation

Hot Water

CENTRALIZED SYSTEMS

STEP #1
Define your Energy Path





STEP #1
Define your Energy Path

High Performance Multi Family Affordable Housing

Carbon Neutral

YES

One Meter

Multiple Meters

DE-CENTRALIZED SYSTEMS

Heating/Cooling

Ventilation

Hot Water

CENTRALIZED SYSTEMS

Air Sourced

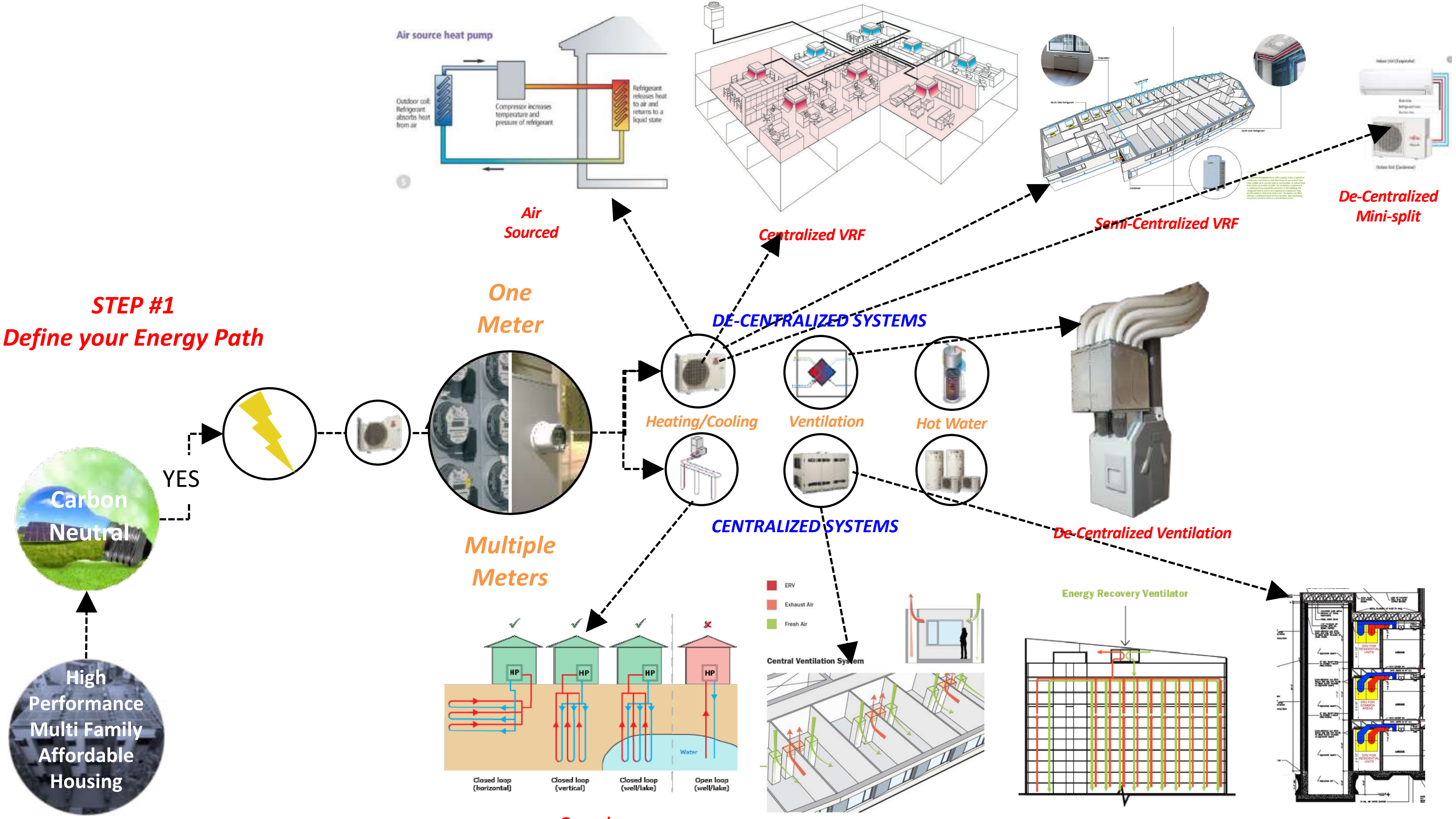
Centralized VRF

Semi-Centralized VRF

De-Centralized Mini-split

Ground Sourced

STEP #1
Define your Energy Path



Carbon Neutral

High Performance Multi Family Affordable Housing

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Multiple Meters

DE-CENTRALIZED SYSTEMS

Heating/Cooling

Ventilation

Hot Water

CENTRALIZED SYSTEMS

Air Sourced

Centralized VRF

Semi-Centralized VRF

De-Centralized Mini-split

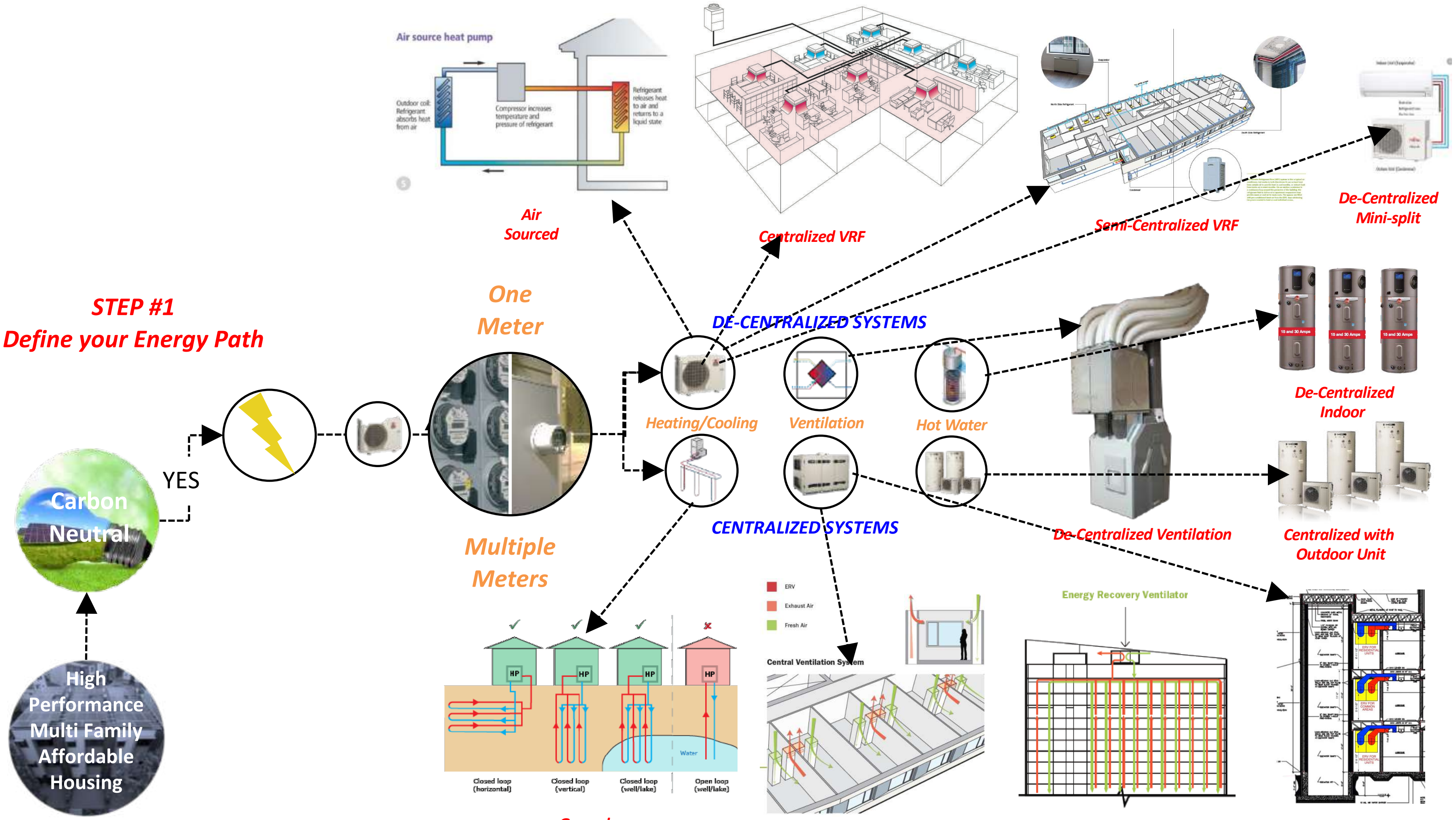
De-Centralized Ventilation

Ground Sourced

Centralized Ventilation

Semi- Centralized Ventilation

STEP #1
Define your Energy Path



High Performance Multi Family Affordable Housing

Carbon Neutral

YES

One Meter

Multiple Meters

Heating/Cooling

Ventilation

Hot Water

DE-CENTRALIZED SYSTEMS

CENTRALIZED SYSTEMS

Air Sourced

Centralized VRF

Semi-Centralized VRF

De-Centralized Mini-split

De-Centralized Indoor

De-Centralized Ventilation

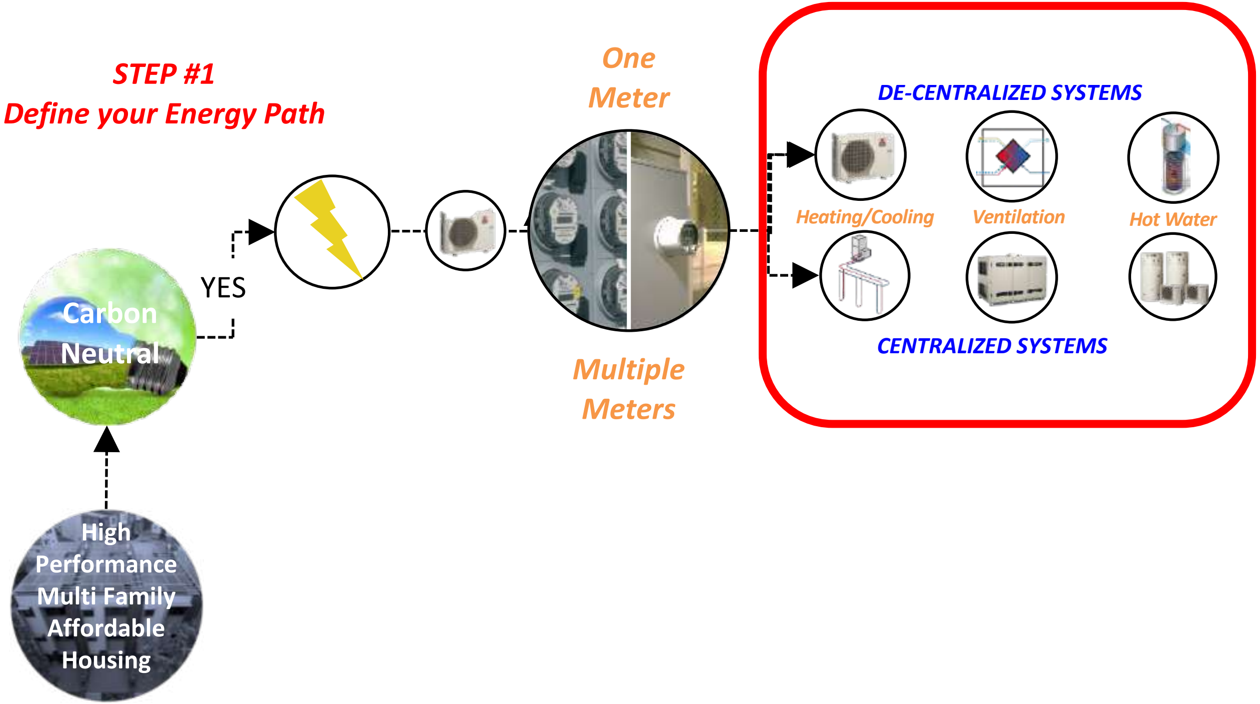
Centralized with Outdoor Unit

Ground Sourced

Centralized Ventilation

Semi- Centralized Ventilation

STEP #1
Define your Energy Path



High Performance Multi Family Affordable Housing

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Multiple Meters

DE-CENTRALIZED SYSTEMS

Heating/Cooling

Ventilation

Hot Water

CENTRALIZED SYSTEMS

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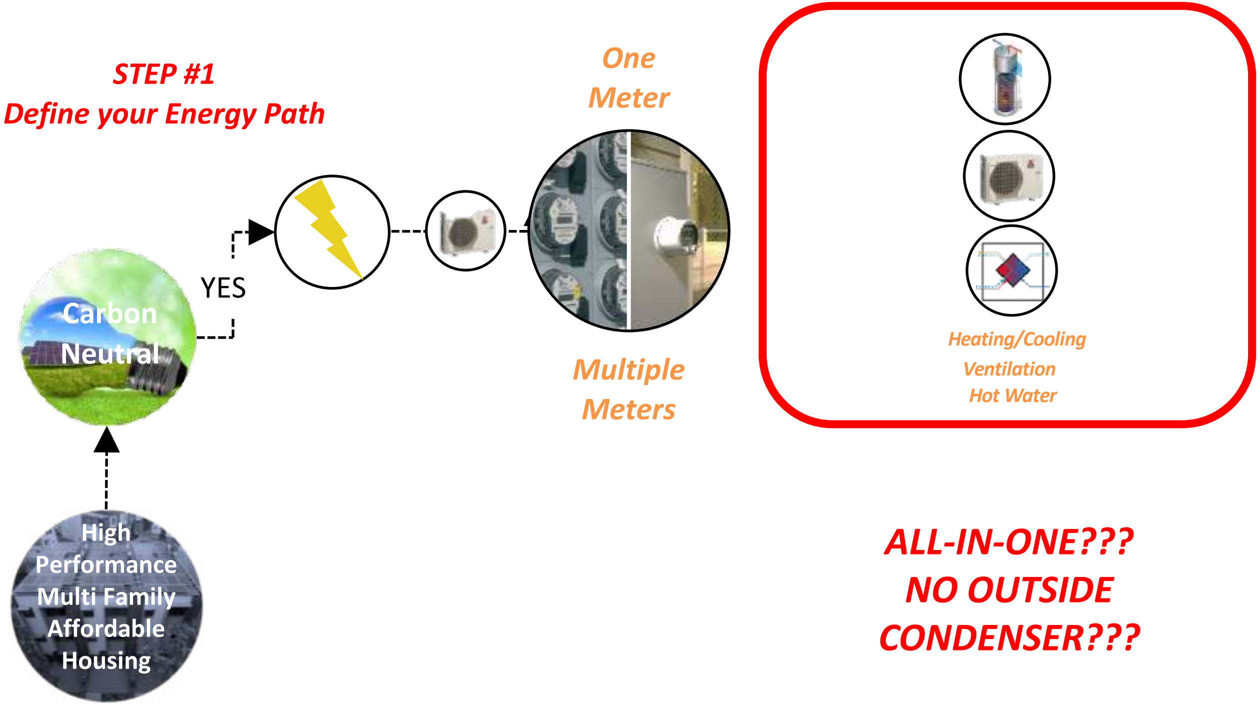

High Performance Multi Family Affordable Housing

Carbon Neutral

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One Meter

Multiple Meters

Heating/Cooling
Ventilation
Hot Water

ALL-IN-ONE???
NO OUTSIDE CONDENSER???

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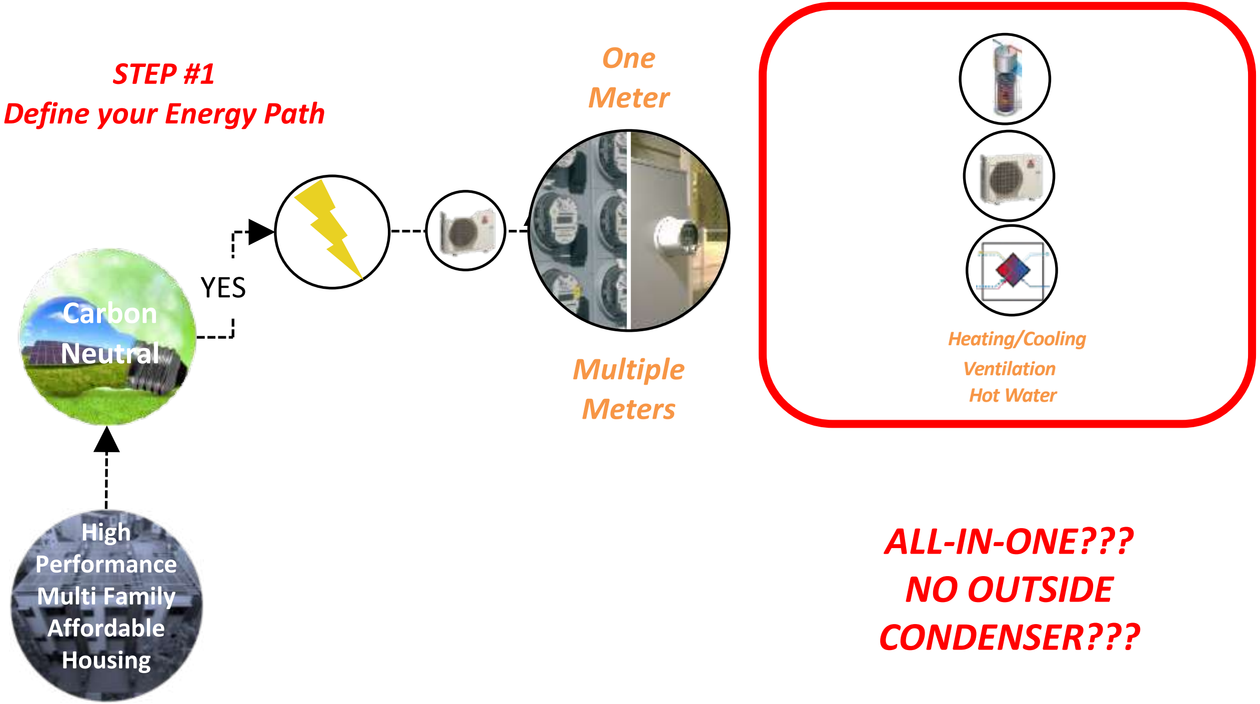

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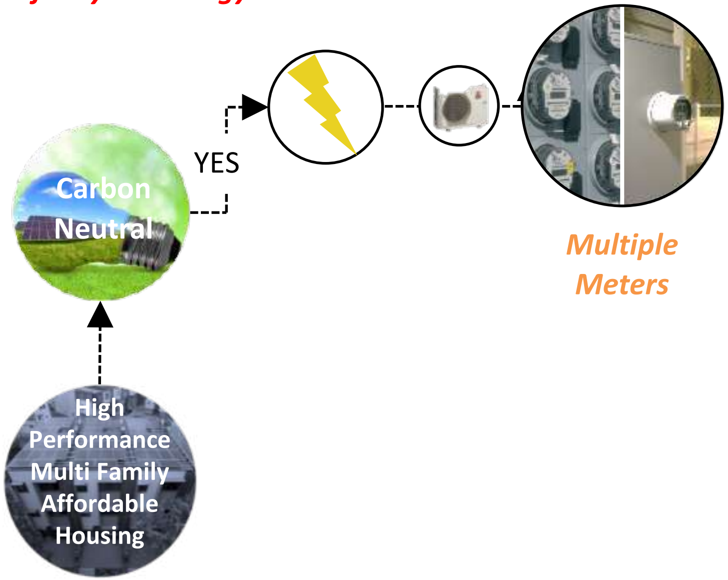
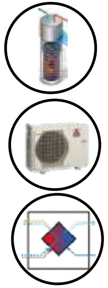


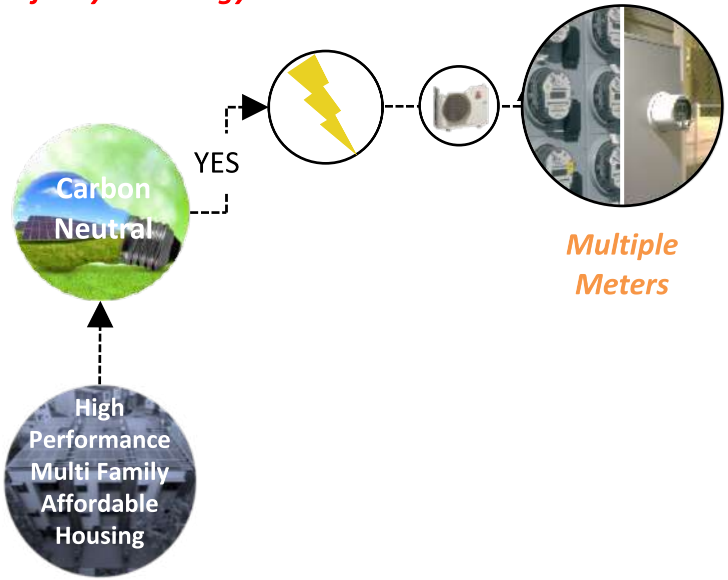


Heating/Cooling
Ventilation
Hot Water

ALL-IN-ONE???
NO OUTSIDE CONDENSER???

THE ILLUSIVE "MAGIC BOX"

STEP #1
Define your Energy Path



High Performance Multi Family Affordable Housing

Carbon Neutral

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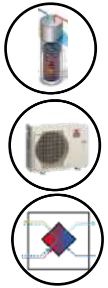
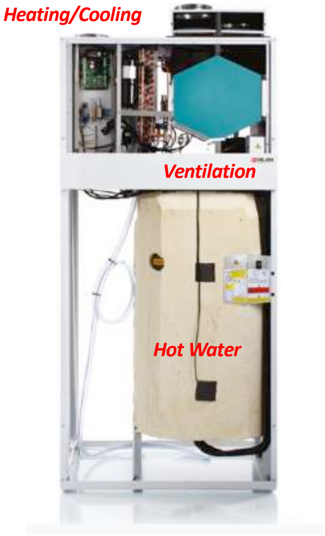
Multiple Meters



Heating/Cooling
Ventilation
Hot Water



ALL-IN-ONE???
NO OUTSIDE CONDENSER???

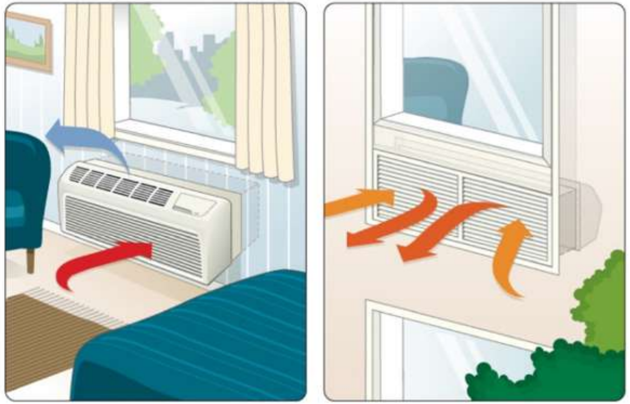
THE ILLUSIVE “MAGIC BOX”

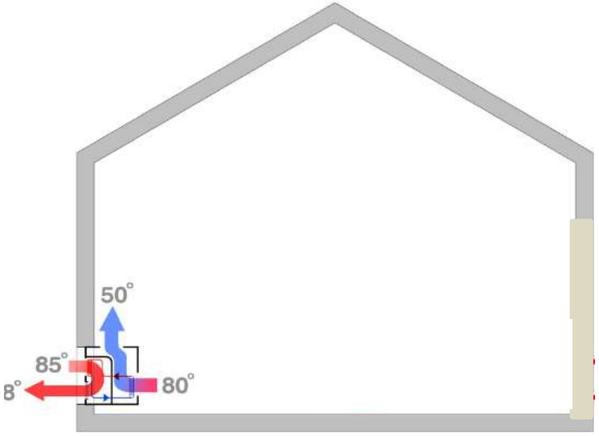
AZ85H12DAC

GE® Zoneline Single Package Vertical Heat Pump

Features and Benefits

- 11,700/11,500 BTUH Cooling Capacity
- 10,400/10,300 BTUH Heating Capacity
- 10.6/10.6 E.E.R. (BTUH/Watt)
- 3.4/3.4 C.O.P.
- R-410A Refrigerant
- Vertical Design Optimizes Floor Space—Unique Sleeve Design Makes It Easier to Install
- Freeze Sentinel™ Protects Unoccupied Rooms Against Freeze-Up (Requires RAVRMS kit)
- Three-Way, Slide-Out Chassis with Specially Designed Case Makes Maintenance and Service Quick and Easy
- Full Corrosion Treatment on Outside Coils and Other Components is Standard





WALL UNIT (AKA PTAC)

AZ85H12DAC

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Features and Benefits

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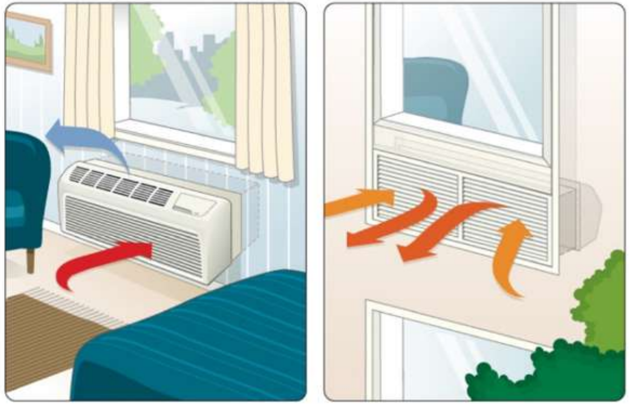
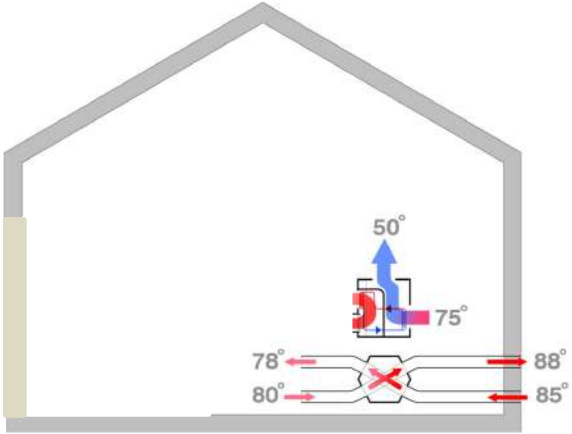
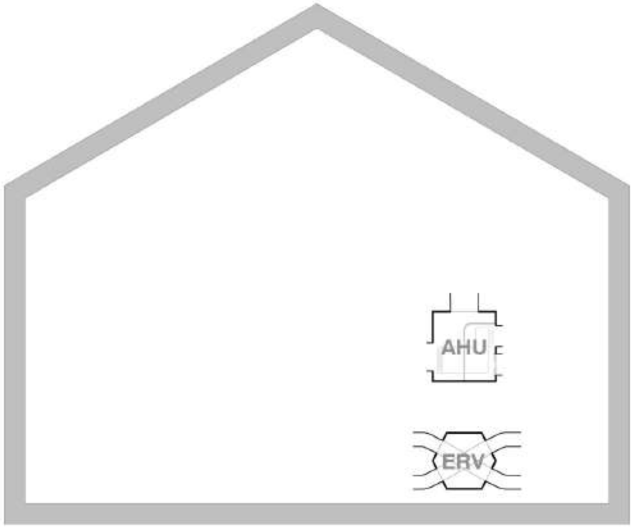


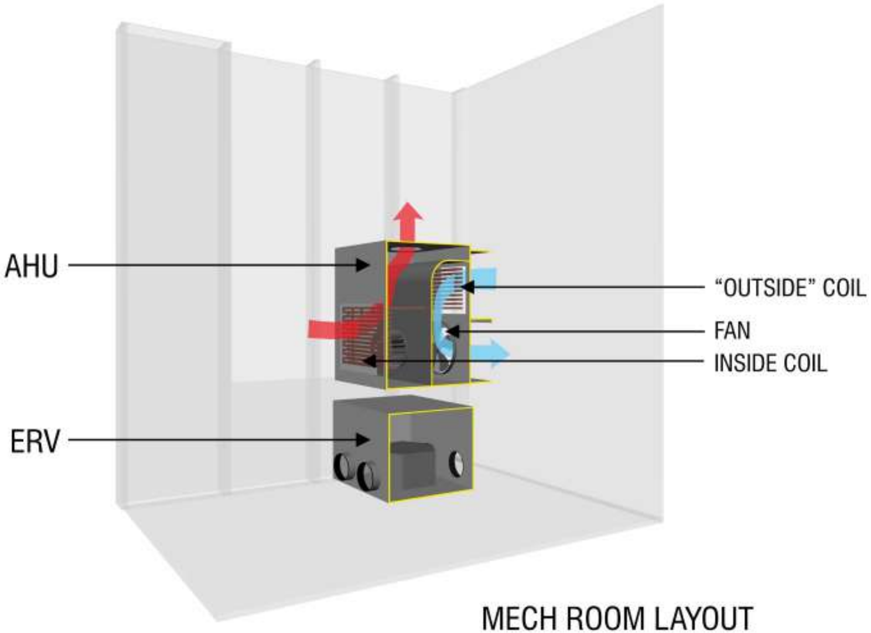




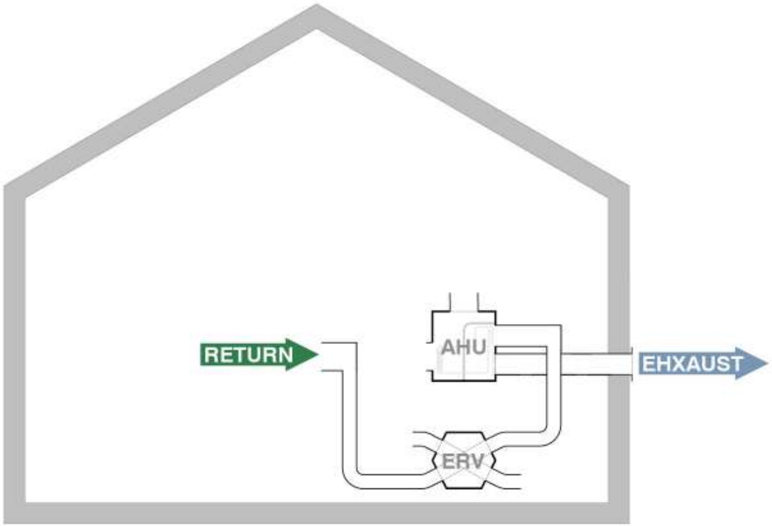
COMPONENTS:

AHU: GE Zoneline Thru-wall Heat Pump

ERV: ULTIMATE AIR RecoupAerator 200DX



MECH ROOM LAYOUT



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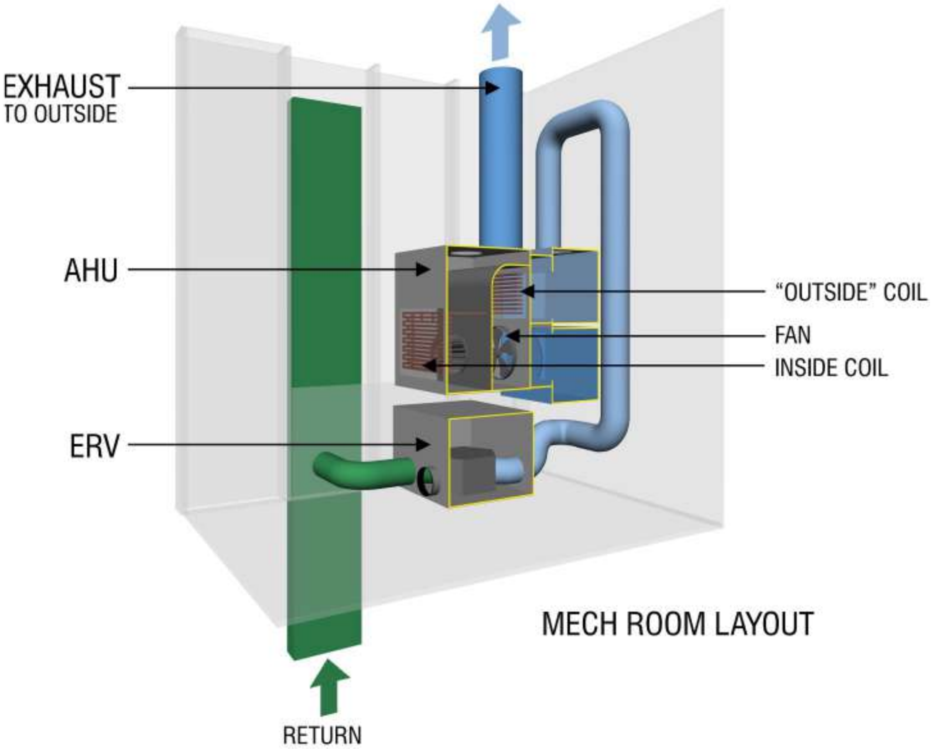

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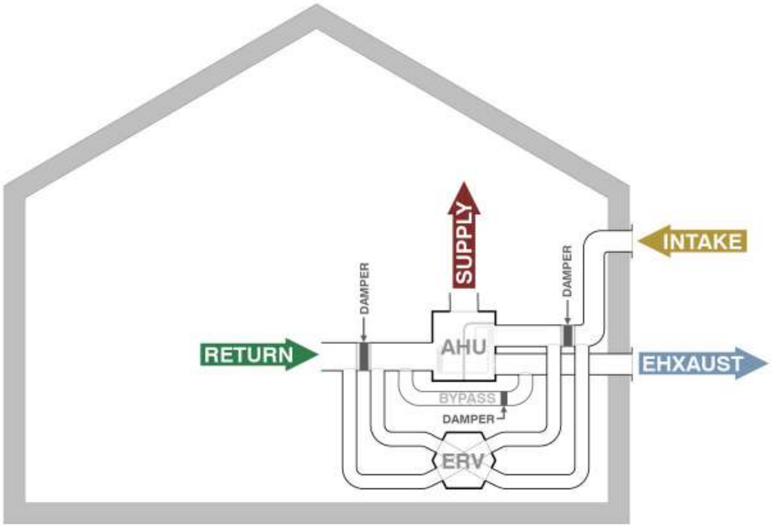

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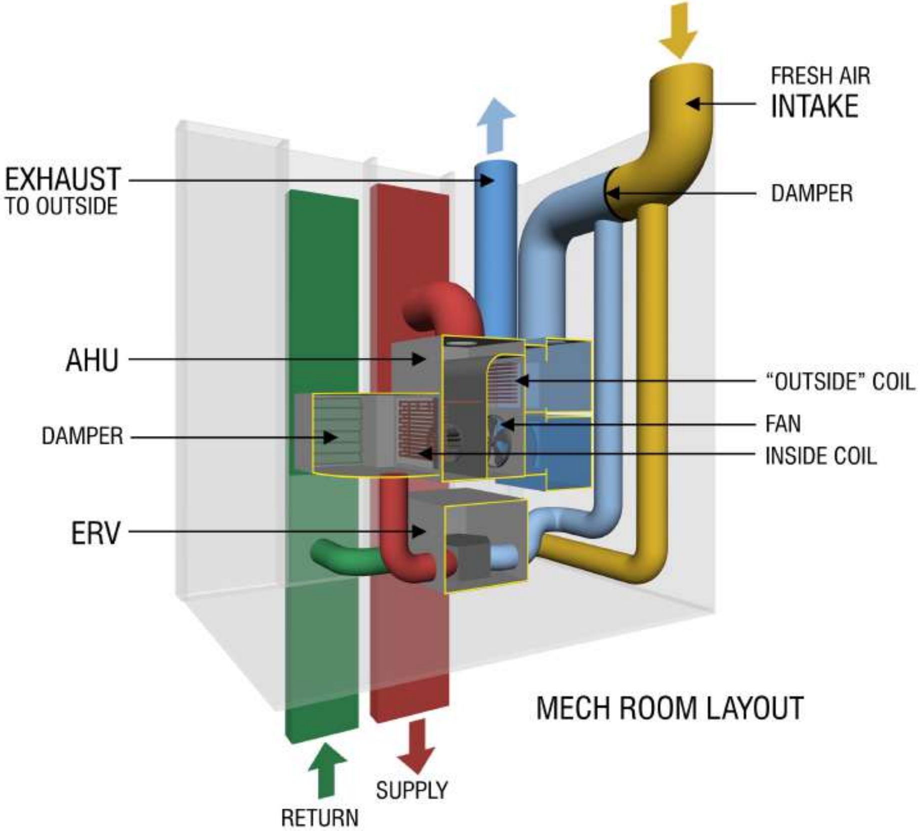

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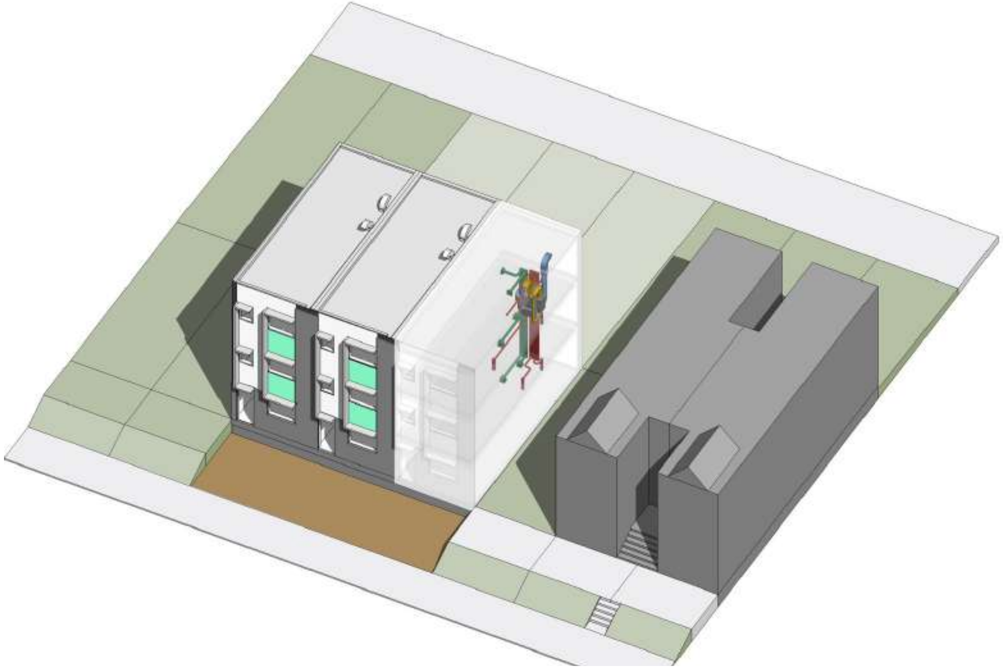
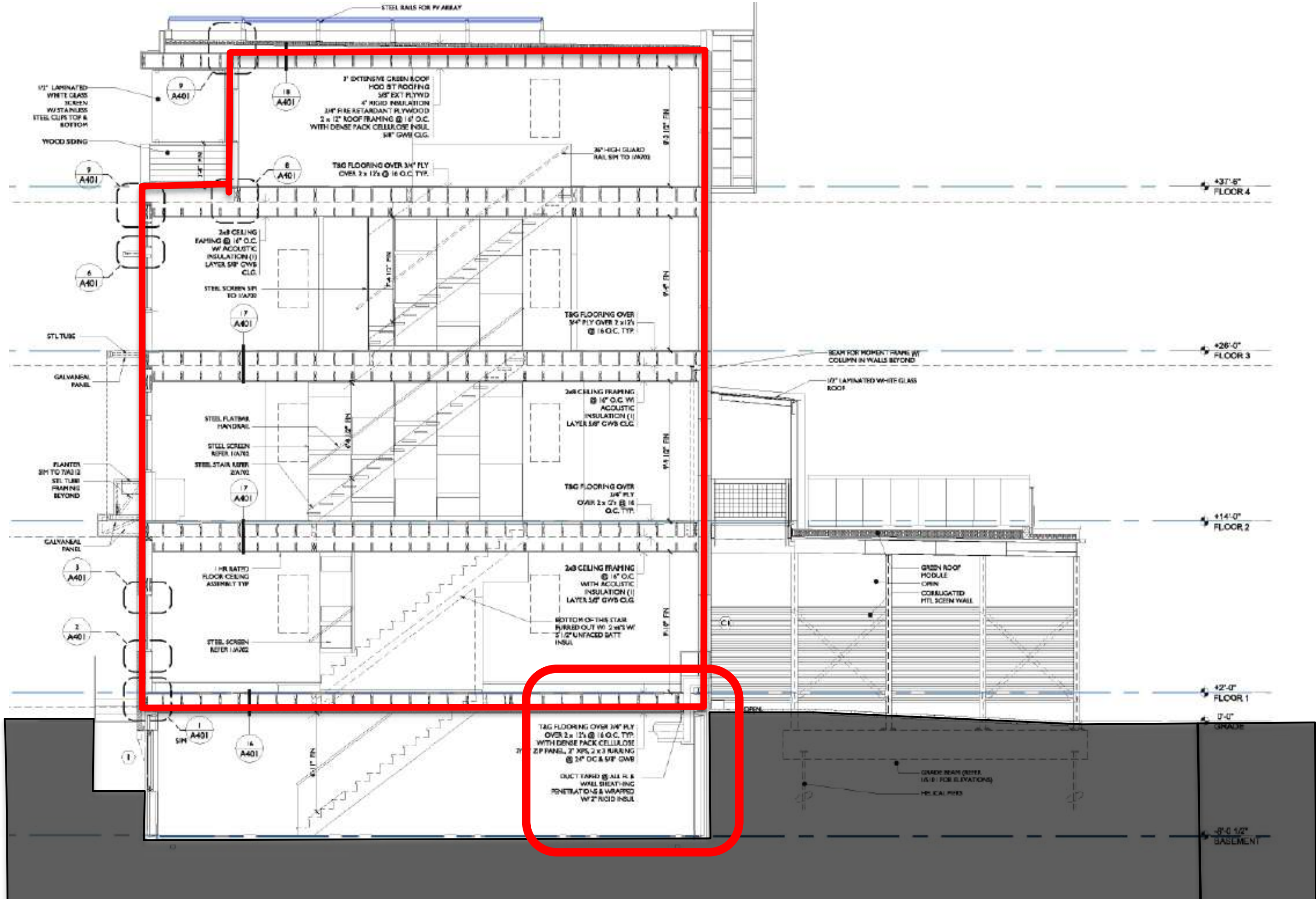


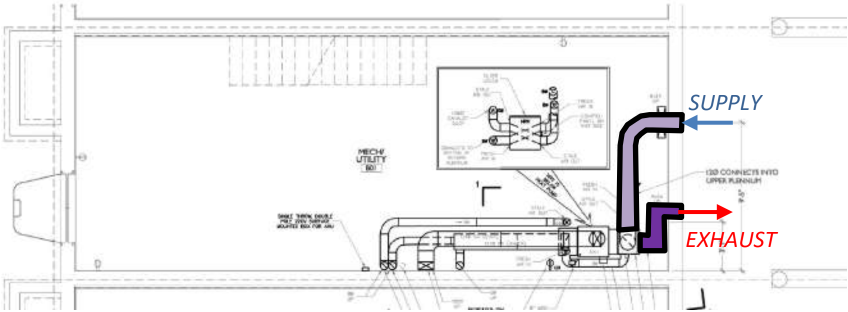
BELFIELD TOWNHOUSES: 2010-2012

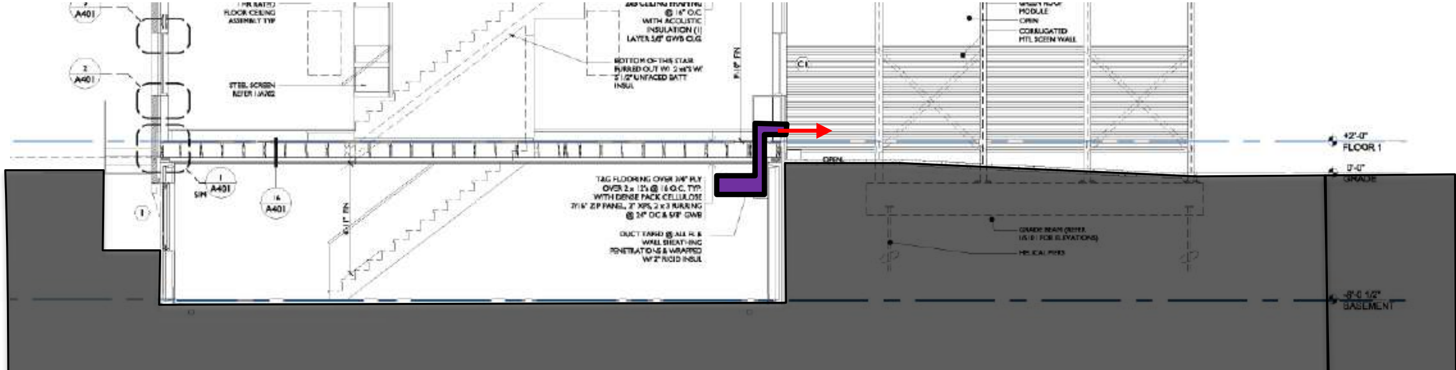
BELFIELD TOWNHOUSES: 2010-2012

STABLES 2015: 27 townhomes

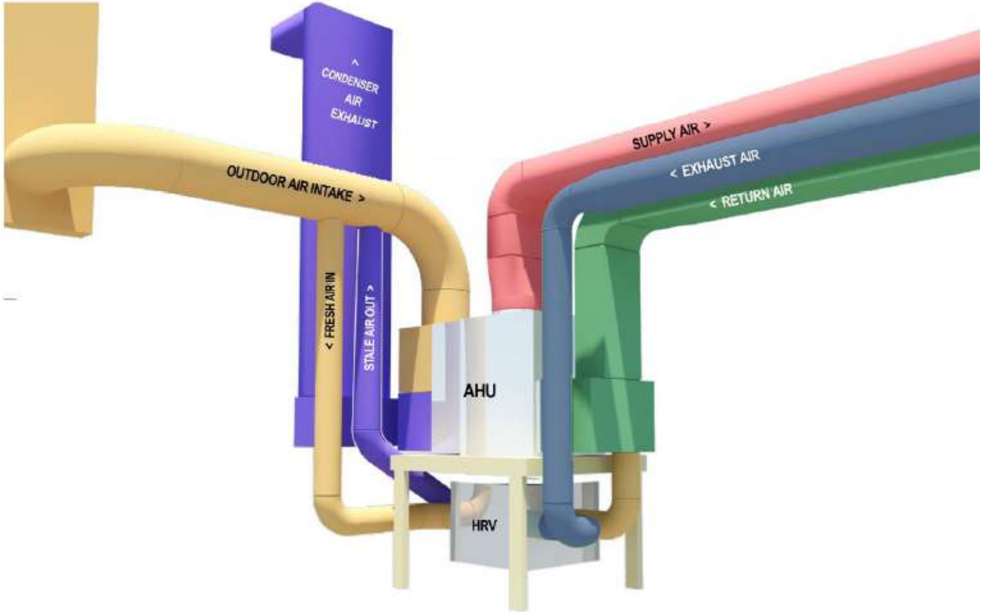


Basement Mech room





Basement Mech room

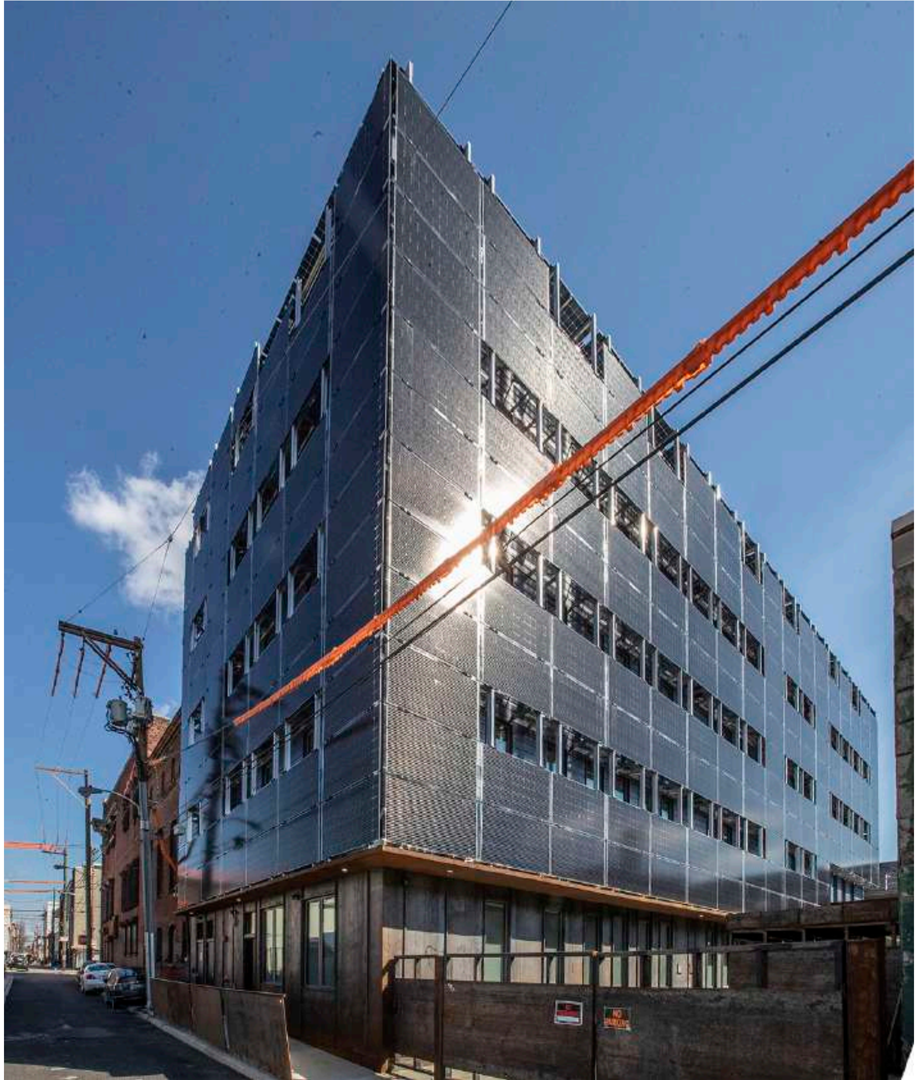


Basement Mech room

MODULAR

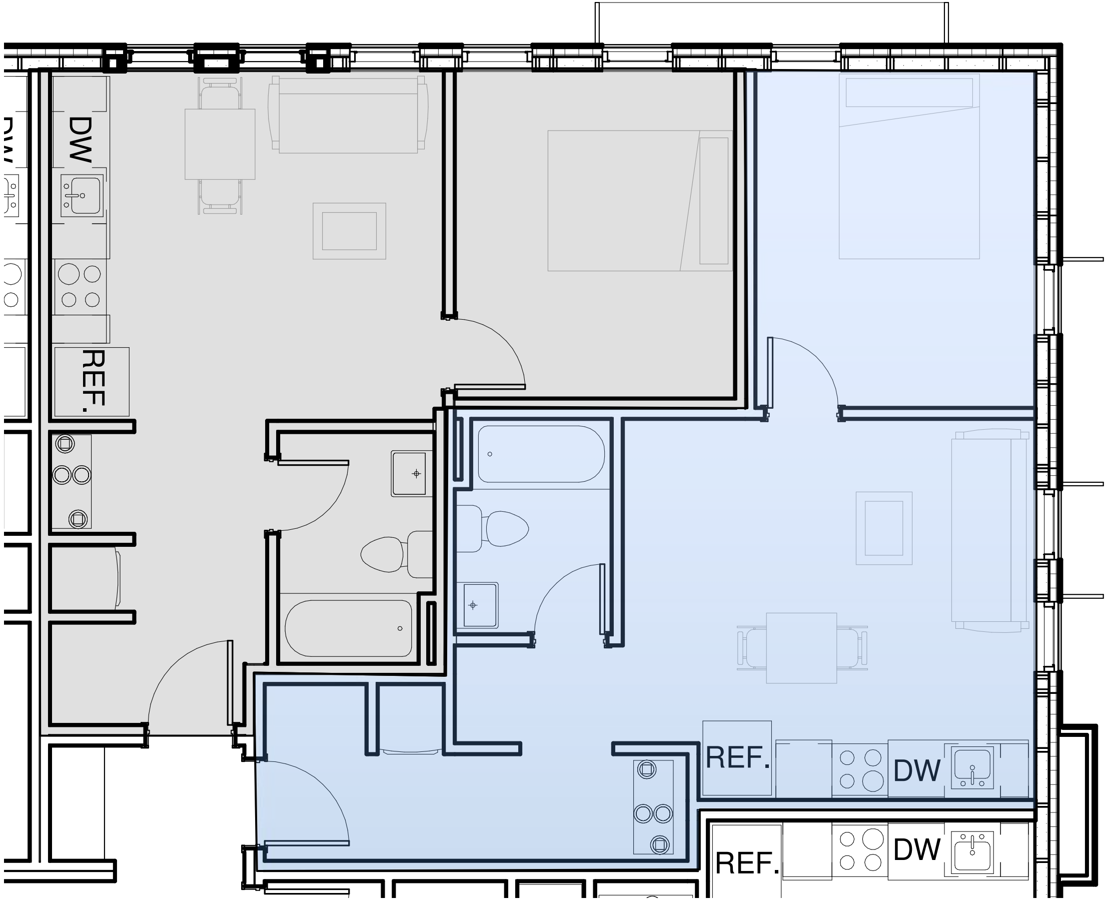
Second Floor level interior

- *28 Apartments (300-500sf)*
- *24,141 sf*
- *R34 walls, panelized system*
- *R 54 roof/floors*
- *DE-Centralized VentilationERV*
- *DE-Centralized heating/cooling*
- *SEMI-Centralized Hot Water*
- *Centralized Electric Metering*
- *174 kw PV array*

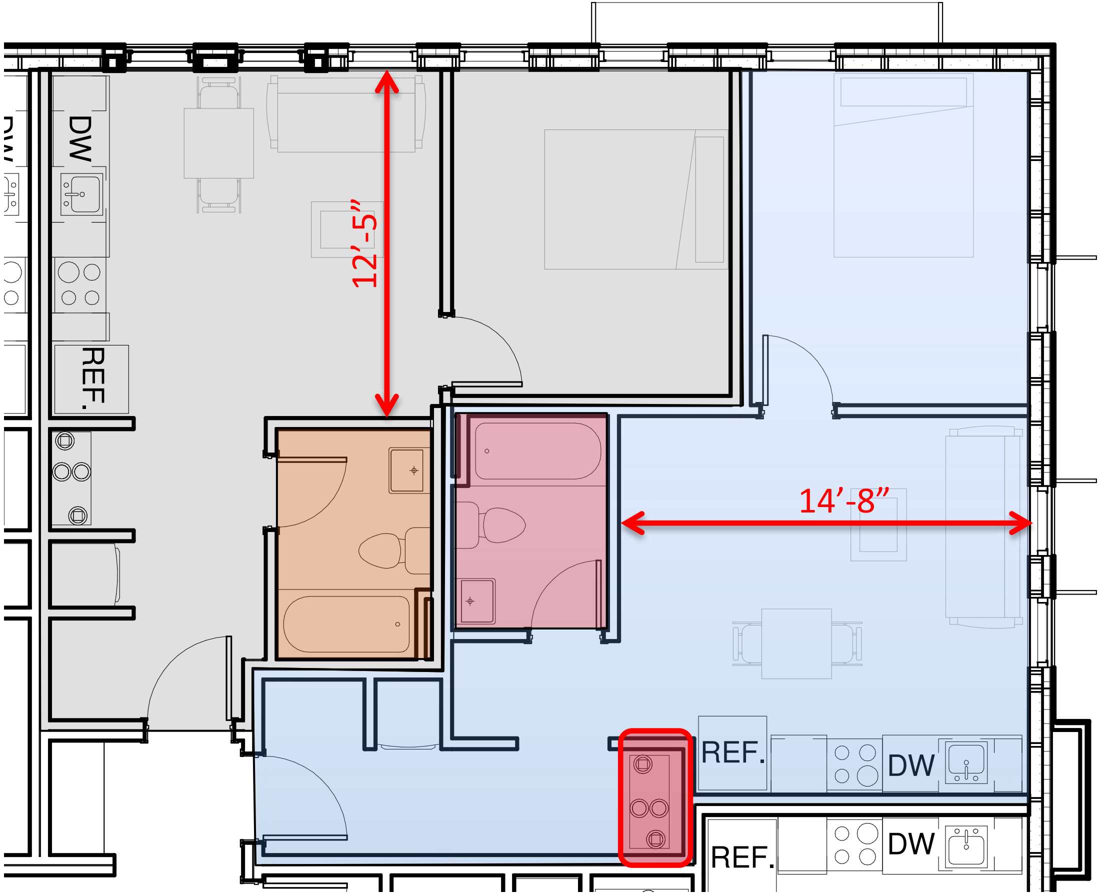


FRONT FLATS 2019: 28 units and Office

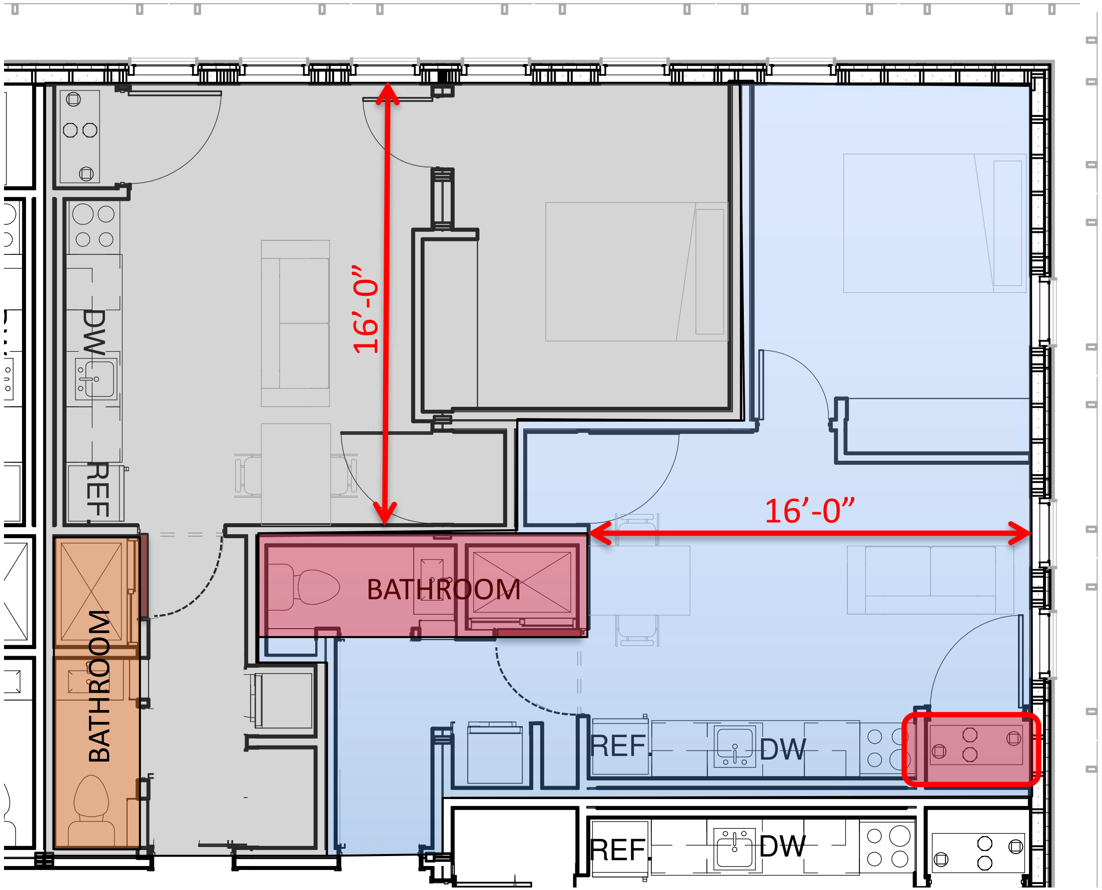
Original 450sf, 1-bed unit



Original 450sf, 1-bed unit

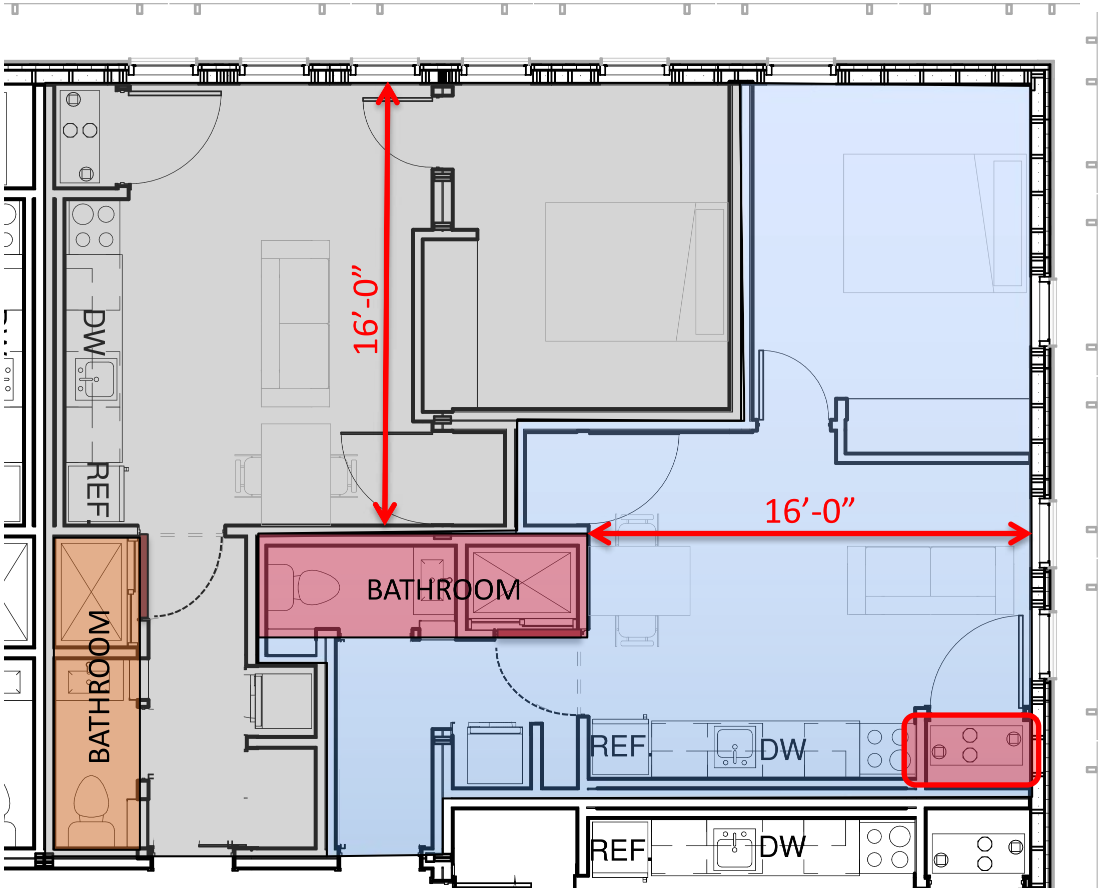


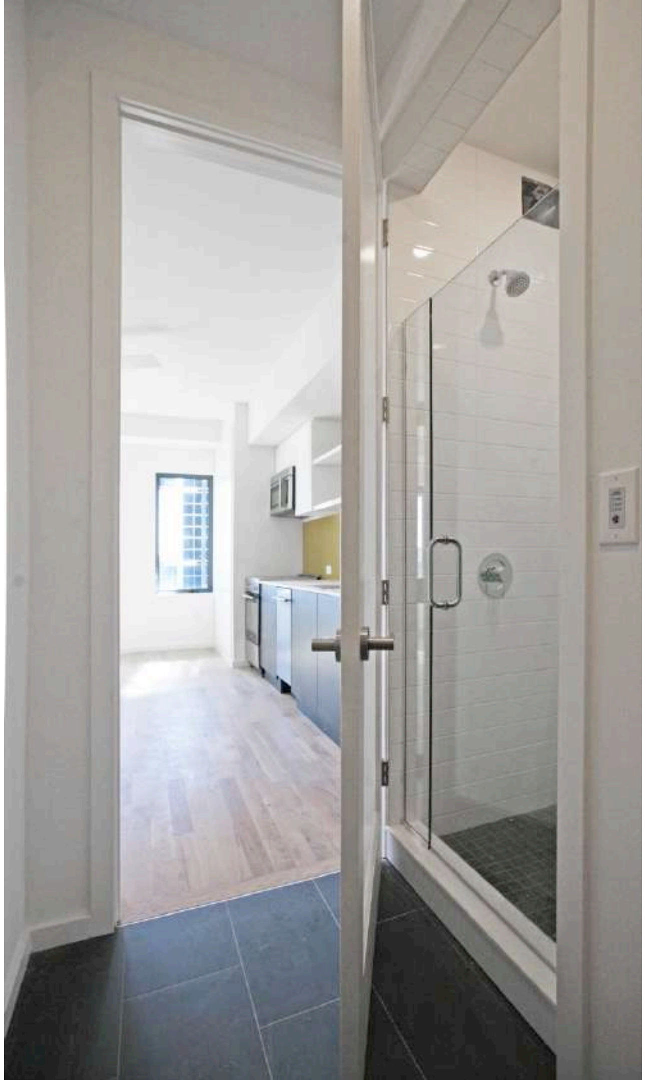
NEW 450sf, 1-bed unit



Marcel Duchamp's door at Rue Larrey
that is both open and closed
1927

NEW 450sf, 1-bed unit





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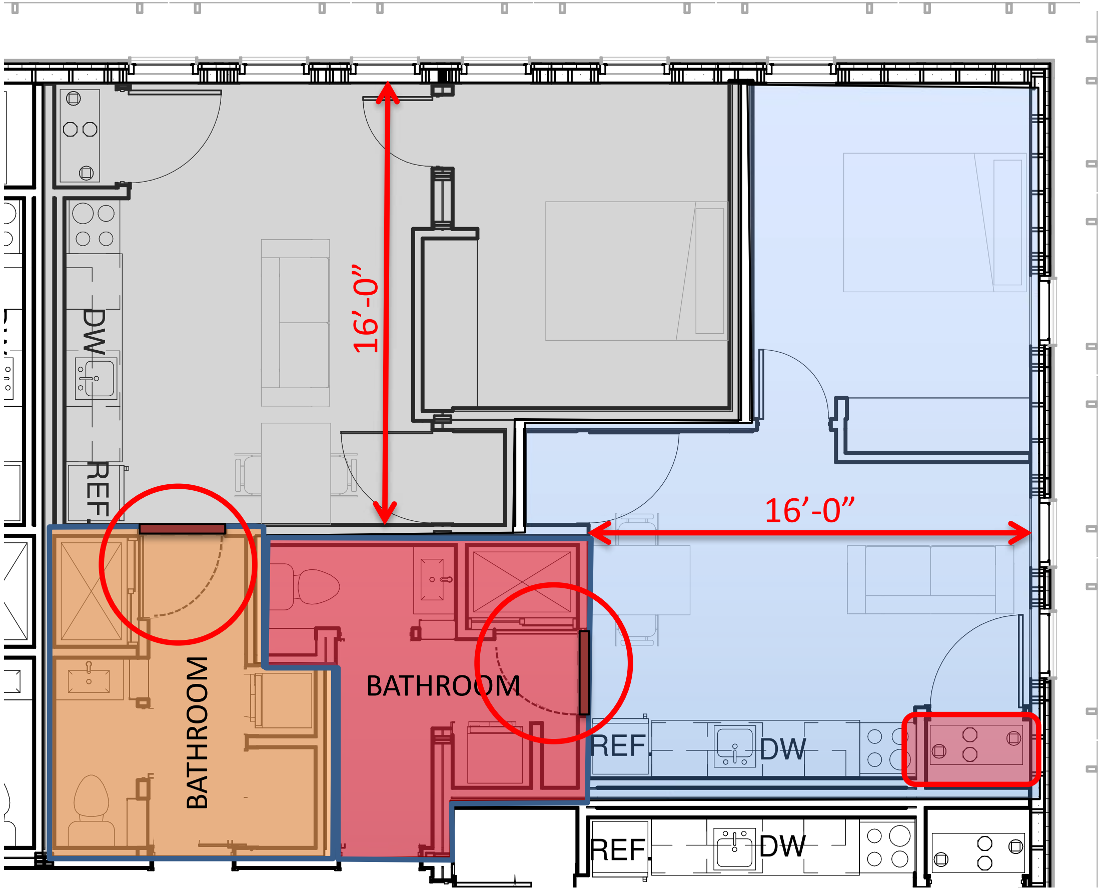
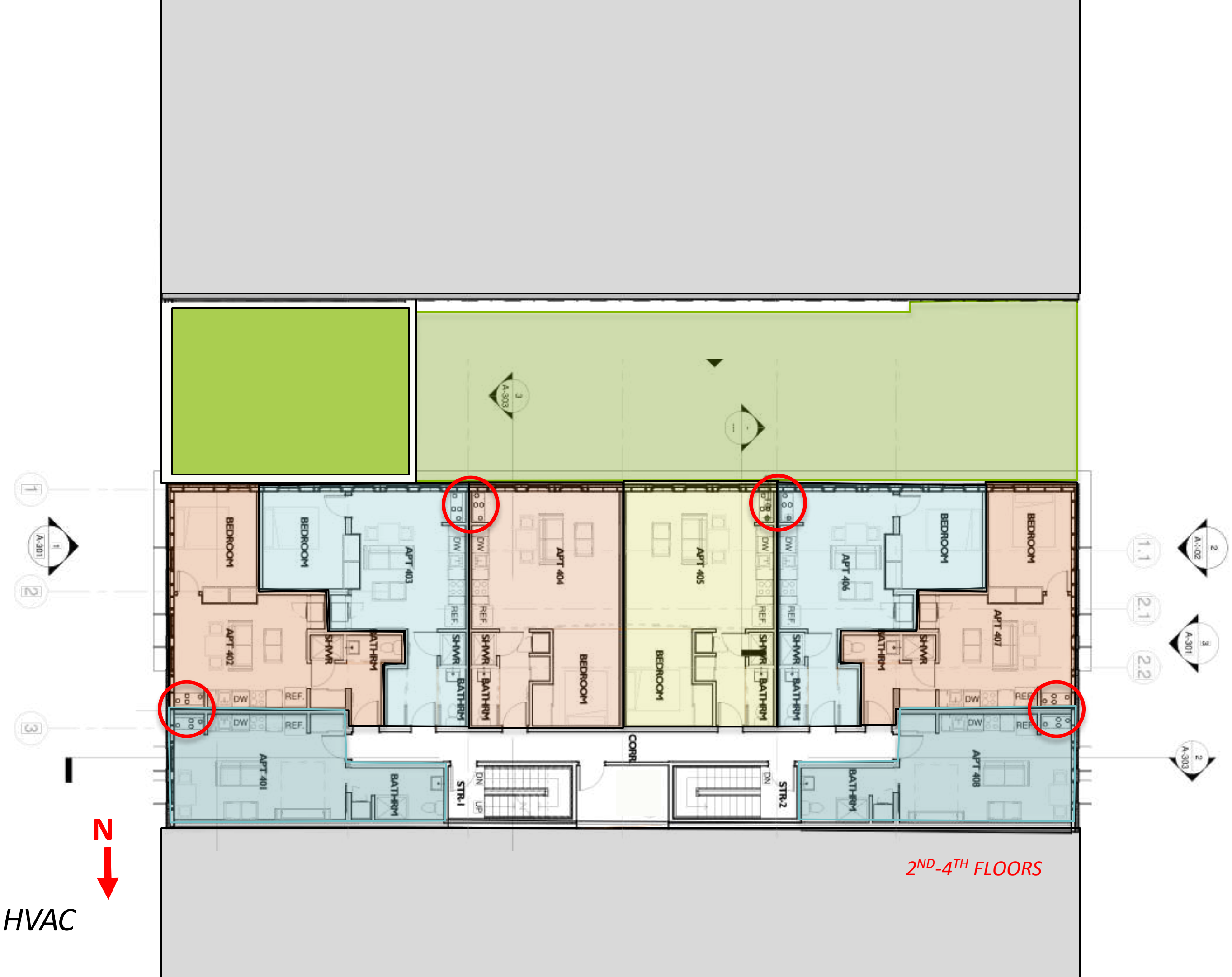
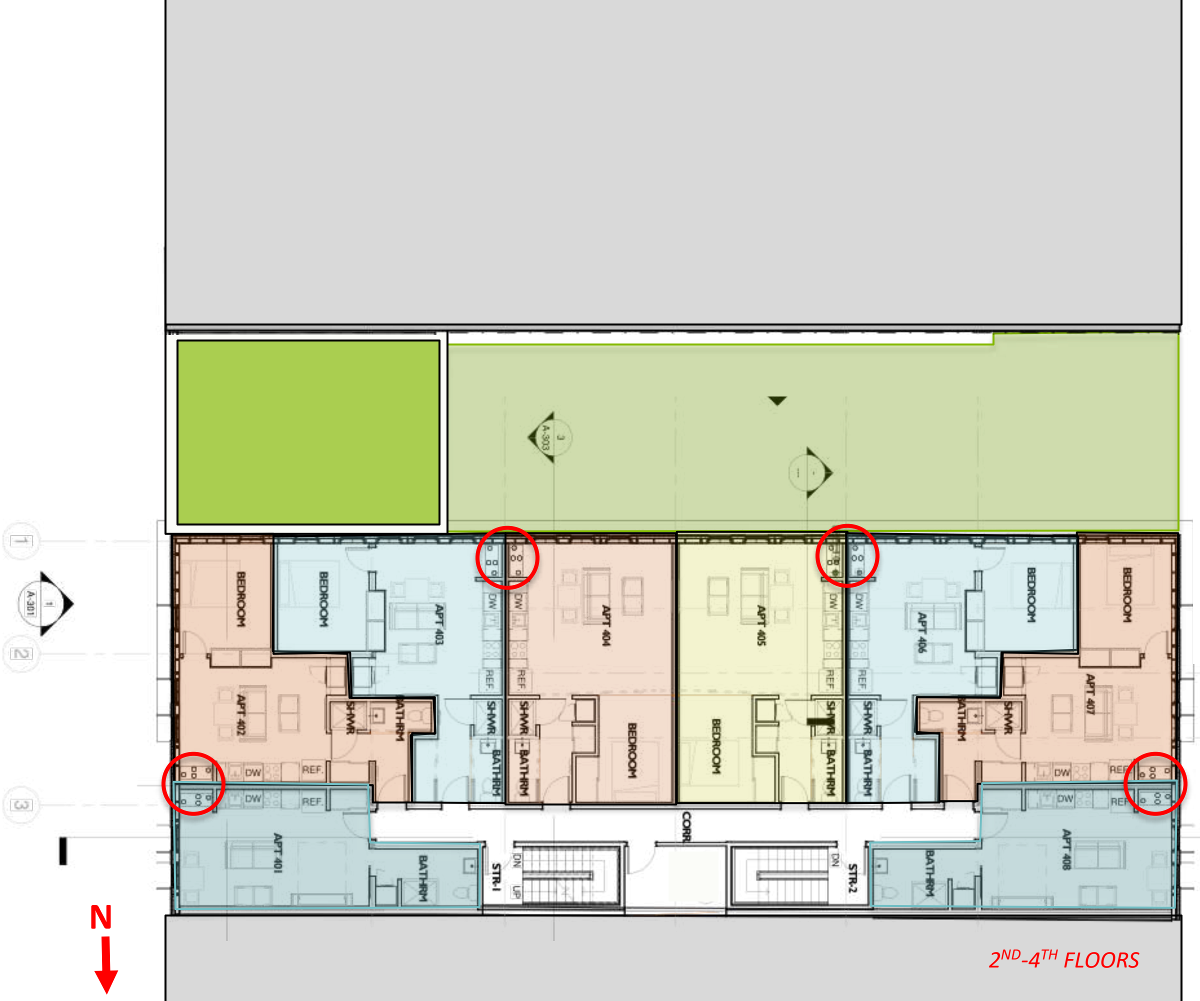




2ND-4TH FLOORS

Decentralized HVAC



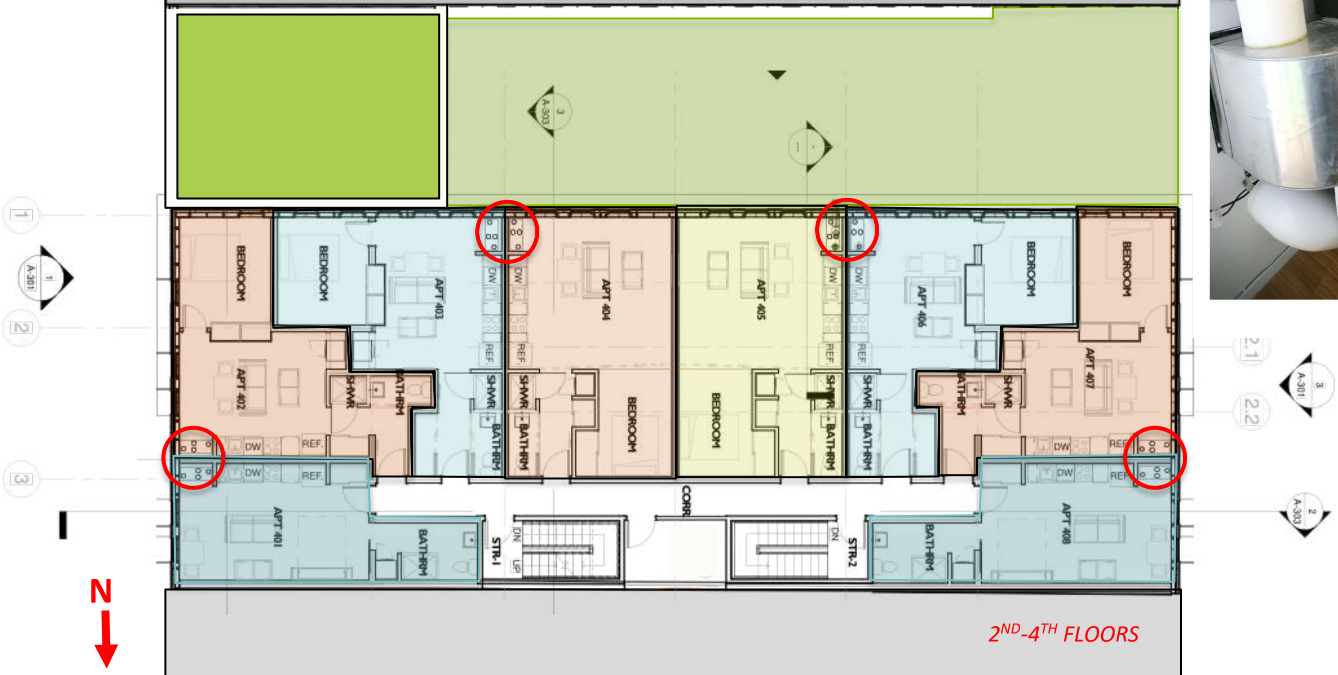
2^{ND}-4^{TH} FLOORS

Decentralized HVAC

HEATING, COOLING, VENTILATION, DEHUMIDIFICATION

MINOTAIR

- *Decentralized*
- *Combination ERV, heating, cooling, dehumidification*
- *Condenser self-contained*
- *No separate HVAC needed for hallways*



2ND-4TH FLOORS

Decentralized HVAC

Common Area HVAC strategy

HEADING, COOLING, VENTILATION, DEHUMIDIFICATION

MINOTAIR

- *Decentralized*
- *Combination ERV, heating, cooling, dehumidification*
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HEATING, COOLING, VENTILATION, DEHUMIDIFICATION

MINOTAIR

- *Decentralized*
- *Combination ERV, heating, cooling*
- *Condenser self-contained*
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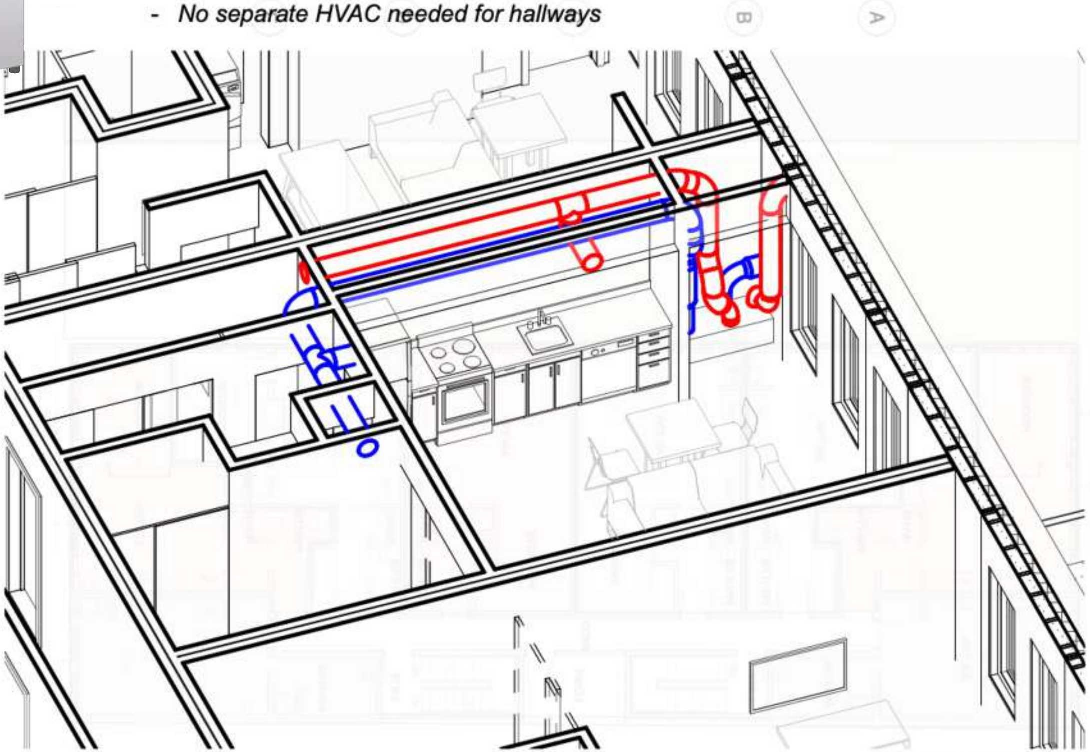


DUCTING STRAGETY

Common Area HVAC strategy

HVAC Closet merged with Kitchen cabinetry

Interior

Interior

Interior

Interior

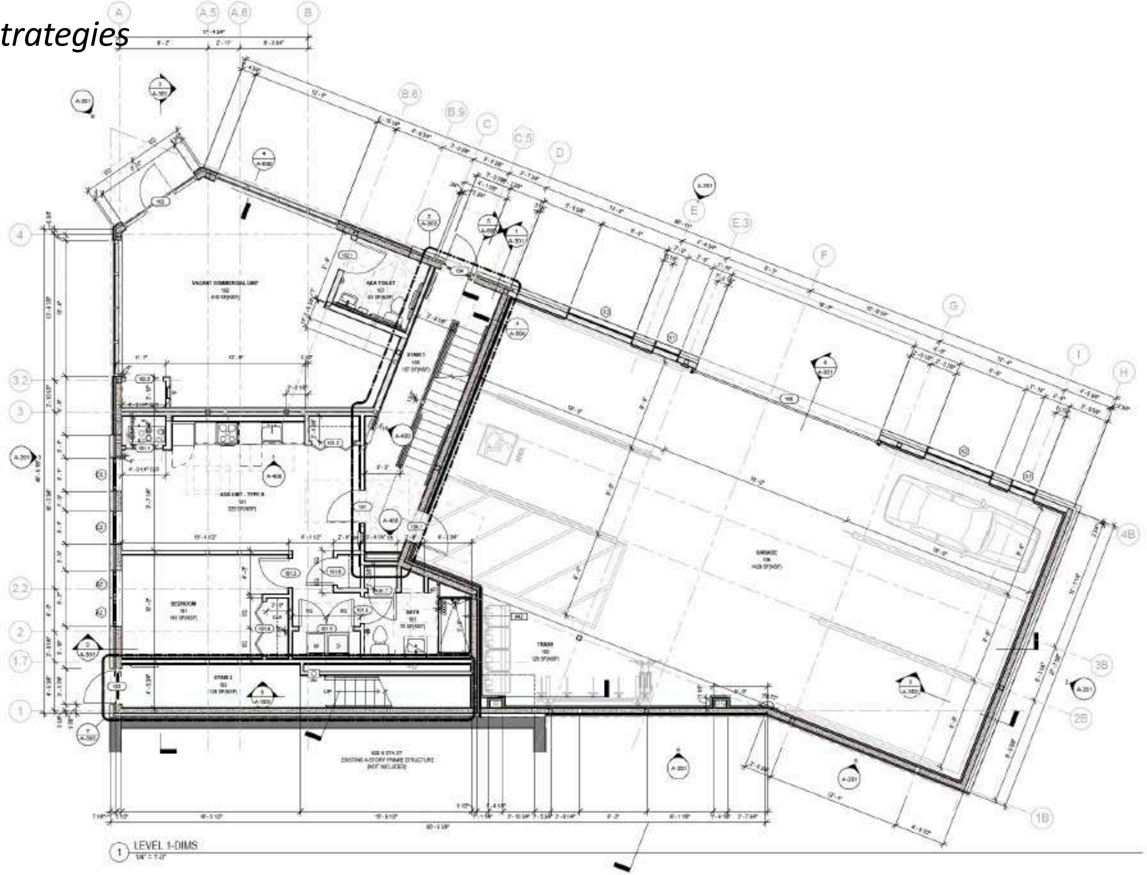
De-Centralized Strategies

5th FLATS: Philadelphia, 16 units, 1 commercial space

De-Centralized Strategies

5th FLATS: Philadelphia, 16 units, 1 commercial space

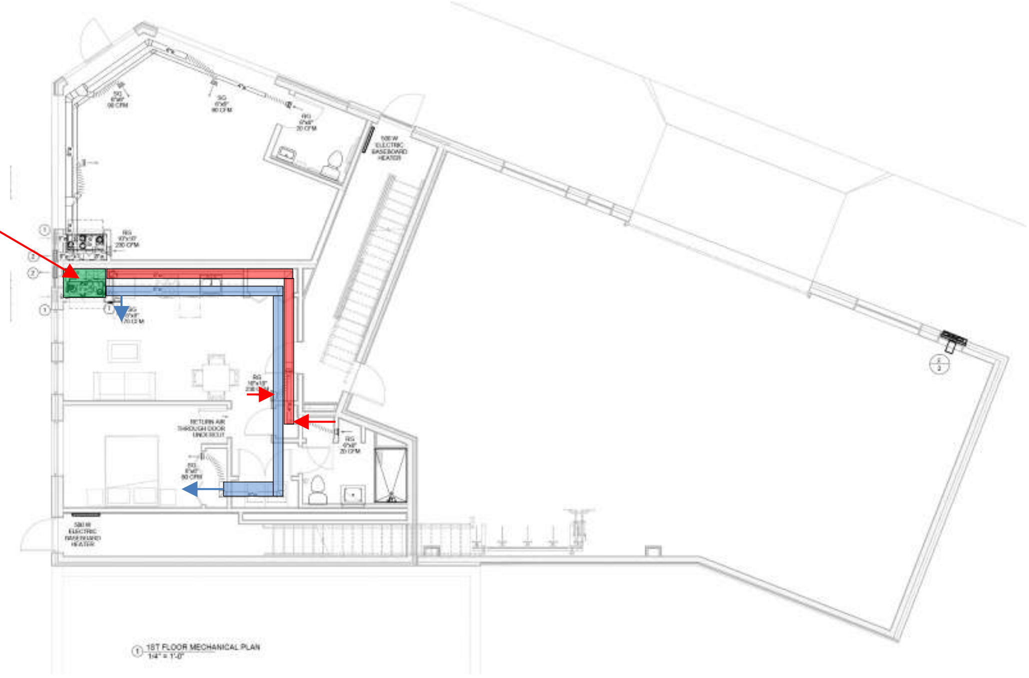
De-Centralized Strategies



GROUND FLOOR

5th FLATS: Philadelphia, 16 units, 1 commercial space

De-Centralized Strategies

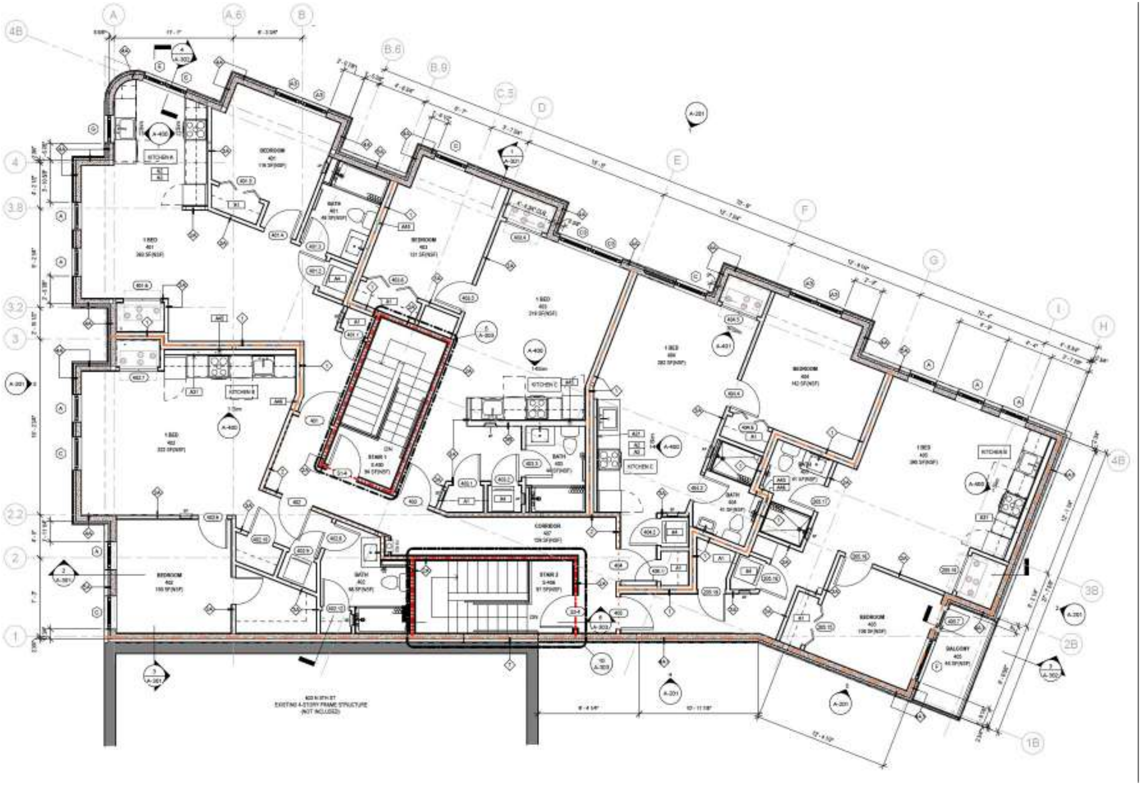


Minotair Closet

GROUND FLOOR

5th FLATS: Philadelphia, 16 units, 1 commercial space

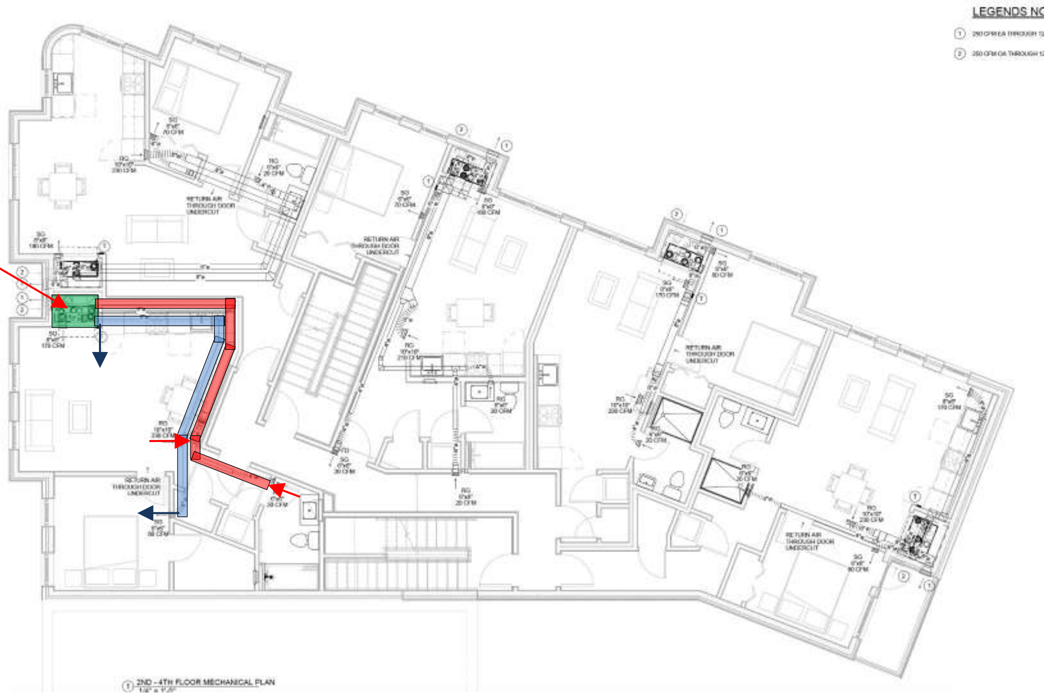
De-Centralized Strategies



2-4 FLOORS

5th FLATS: Philadelphia, 16 units, 1 commercial space

De-Centralized Strategies

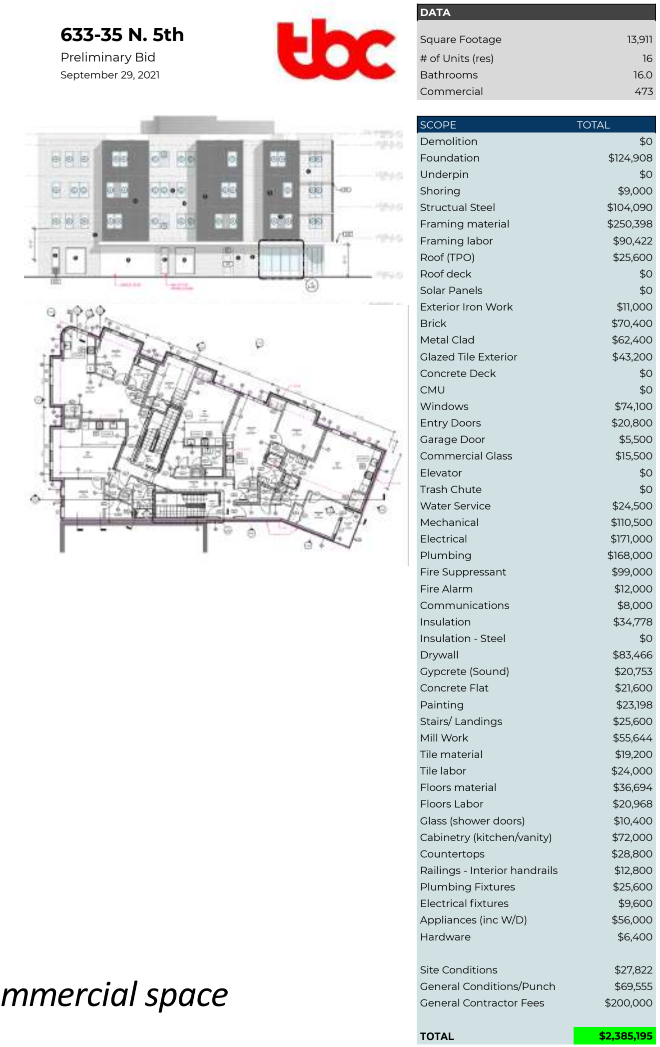


Minotair Closet

2-4 FLOORS

5th FLATS: Philadelphia, 16 units, 1 commercial space

De-Centralized Strategies



633-35 N. 5th
Preliminary Bid
September 29, 2021

DATA	
Square Footage	13,911
# of Units (res)	16
Bathrooms	16.0
Commercial	473

SCOPE	TOTAL
Demolition	$0
Foundation	$124,908
Underpin	$0
Shoring	$9,000
Structual Steel	$104,090
Framing material	$250,398
Framing labor	$90,422
Roof (TPO)	$25,600
Roof deck	$0
Solar Panels	$0
Exterior Iron Work	$11,000
Brick	$70,400
Metal Clad	$62,400
Glazed Tile Exterior	$43,200
Concrete Deck	$0
CMU	$0
Windows	$74,100
Entry Doors	$20,800
Garage Door	$5,500
Commercial Glass	$15,500
Elevator	$0
Trash Chute	$0
Water Service	$24,500
Mechanical	$110,500
Electrical	$171,000
Plumbing	$168,000
Fire Suppressant	$99,000
Fire Alarm	$12,000
Communications	$8,000
Insulation	$34,778
Insulation - Steel	$0
Drywall	$83,466
Gypcrete (Sound)	$20,753
Concrete Flat	$21,600
Painting	$23,198
Stairs/ Landings	$25,600
Mill Work	$55,644
Tile material	$19,200
Tile labor	$24,000
Floors material	$36,694
Floors Labor	$20,968
Glass (shower doors)	$10,400
Cabinetry (kitchen/vanity)	$72,000
Countertops	$28,800
Railings - Interior handrails	$12,800
Plumbing Fixtures	$25,600
Electrical fixtures	$9,600
Appliances (inc W/D)	$56,000
Hardware	$6,400
Site Conditions	$27,822
General Conditions/Punch	$69,555
General Contractor Fees	$200,000
TOTAL	**$2,385,195**

- ***13,911 SF***
- ***16 UNITS***
- ***$2.4 MILLION BUDGET***
- ***$172 SF***

BUDGET

5th FLATS: Philadelphia, 16 units, 1 commercial space

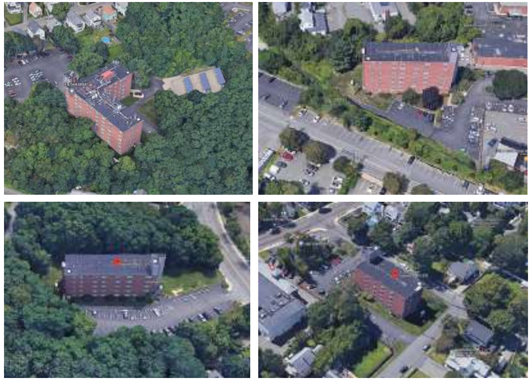
……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

Linden: 32 units Madison, WI

Switch from Ephoca to mini-splits

Copper Flats: 88 units Phila, PA

Switch from Minotair to mini-splits



Fairweather: 600 units Salem, MA

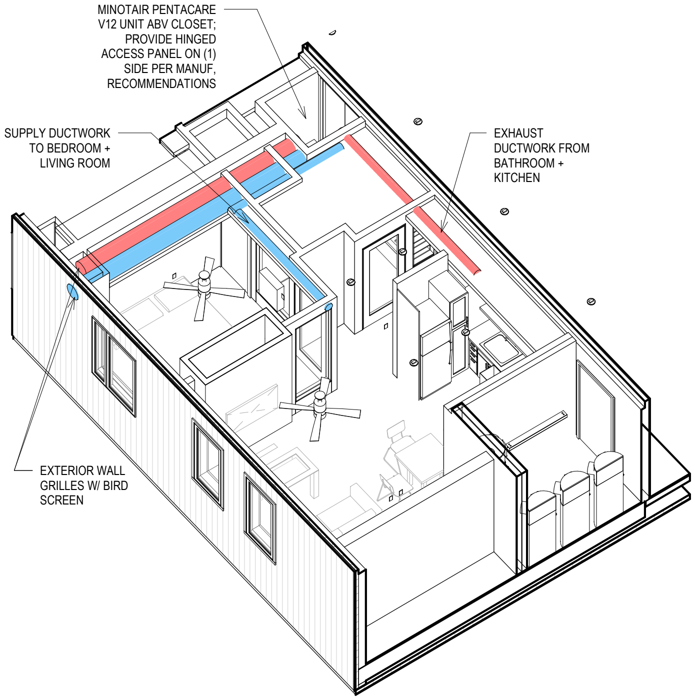
Switch from Ephoca to Centralized HEX

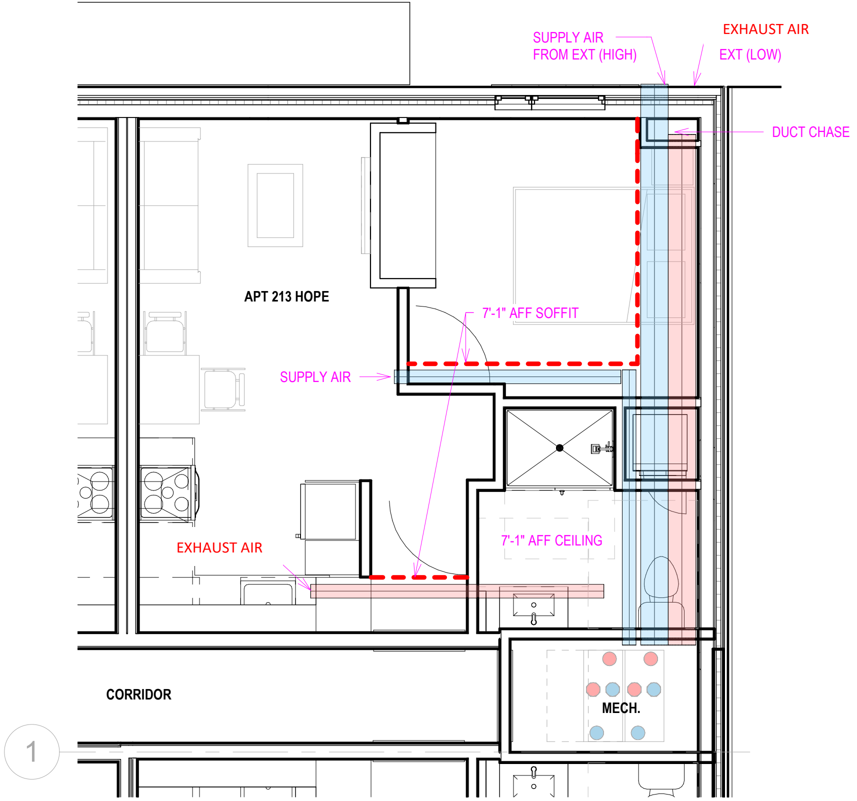
……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

Copper Flats: 88 units Phila, PA

Switch from Minotair to mini-splits and ERVs

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……





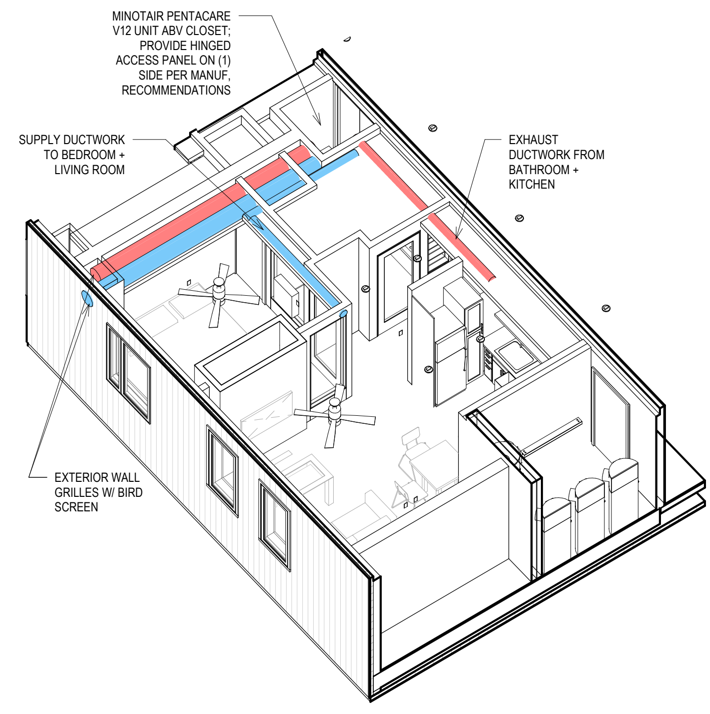
1 HOPE ST TYP ALT MINOTAIR-UNIT 213

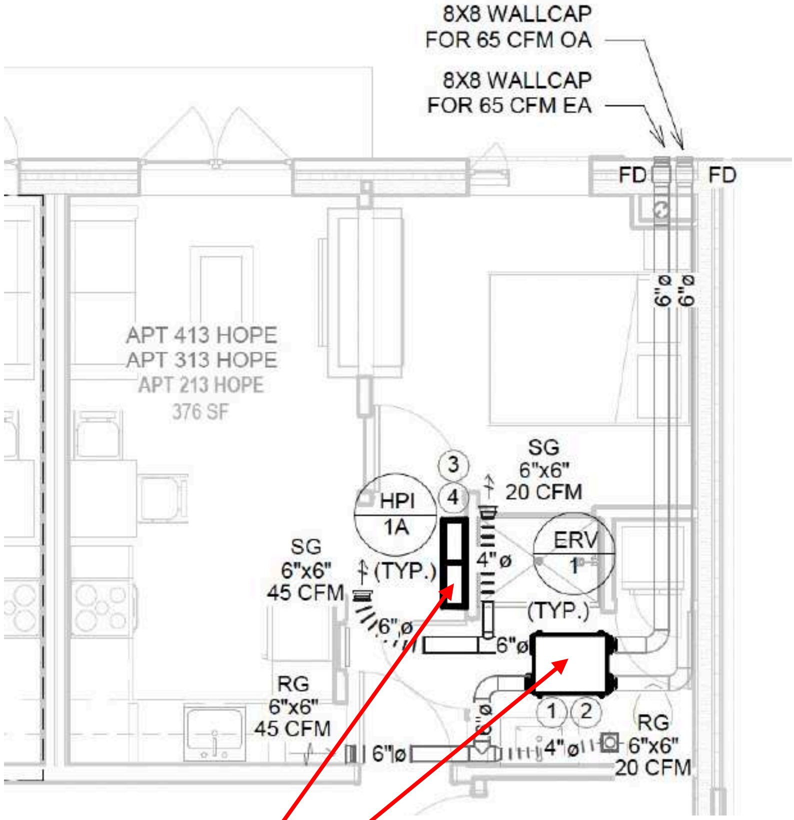
1/4" = 1'-0"

Copper Flats: 88 units Phila, PA

Switch from Minotair to mini-splits and ERVs

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……





Ductless Mini-split

Panasonic ERV

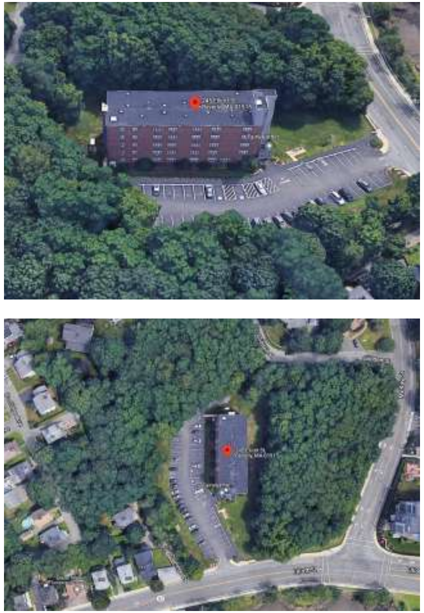
Copper Flats: 88 units Phila, PA

Switch from Minotair to mini-splits and ERVs

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

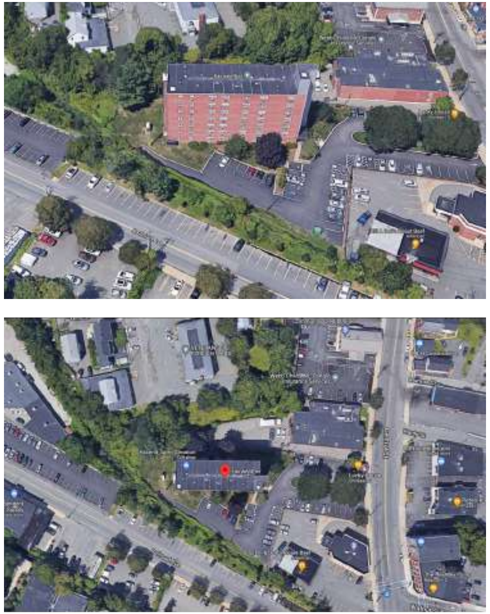
FAIRWEATHER SALEM

FAIRWEATHER BEVERLY



FAIRWEATHER DANVERS

FAIRWEATHER PEABODY



Fairweather: 600 units Salem, MA

Switch from Ephoca to Centralized HEX

PLACETAILOR

RMI
ENERGY. TRANSFORMED.

BUILDING EVOLUTION CORPORATION
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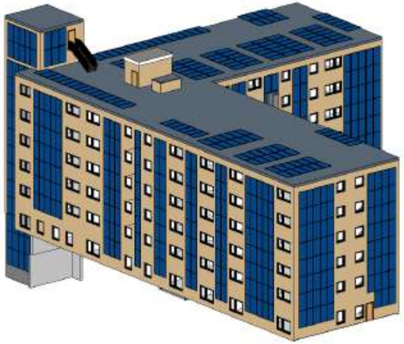
POAH

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

FAIRWEATHER SALEM

127 unit, 73,920 sf, 6 stories
Feasibility Study
Deep Energy Retrofit
Goals:

1. ***Research 7 Panelized manufacturers for most cost-effective, factory-built, high performance envelop, including new roof***
2. ***Research 3-4 HVAC strategies for most cost-effective approach to bringing heating, cooling and ventilation to every apartment and communal space***
3. ***Research all-electric centralized Domestic Hot Water Systems to replace gas boiler***
4. ***Eliminate all gas equipment and appliances from building for all-electric building***
5. ***Create WUFI model of proposed design to meet the Passive House standard.***
6. ***Incorporate as much PV renewable energy as possible with goal of Net Zero Energy.***
7. ***Create preliminary budget for DER***

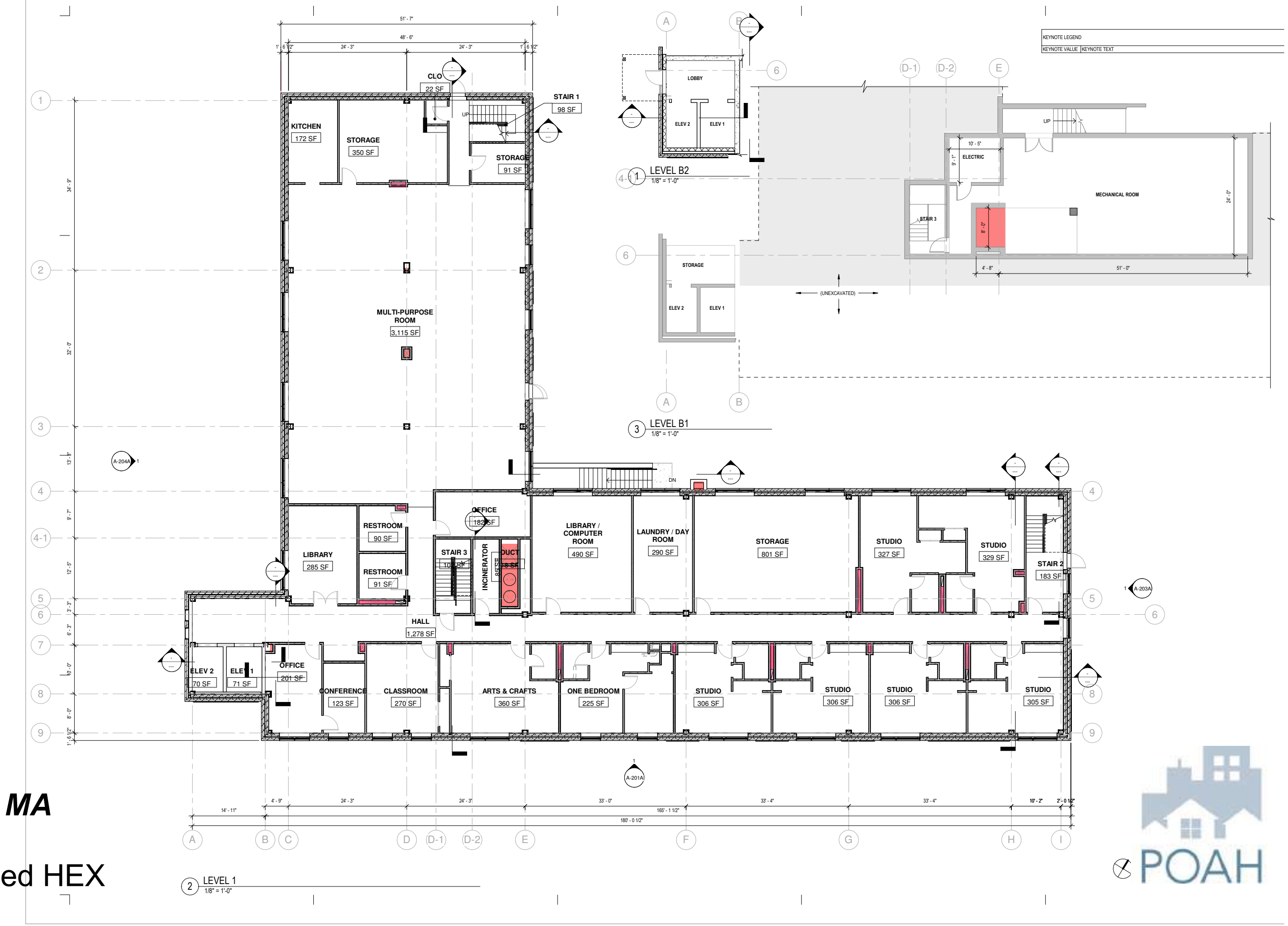


Fairweather: 600 units Salem, MA

Switch from Ephoca to Centralized HEX

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

FAIRWEATHER SALEM



Fairweather: 600 units Salem, MA

Switch from Ephoca to Centralized HEX

POAH

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

FAIRWEATHER SALEM

Fairweather: 600 units Salem, MA

Switch from Ephoca to Centralized HEX

POAH

HVAC/DHW SYSTEMS

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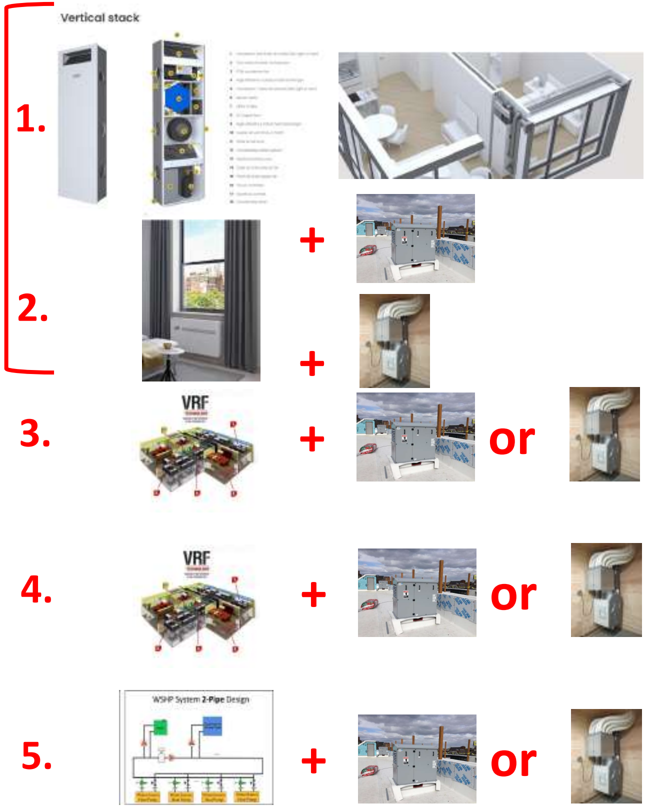
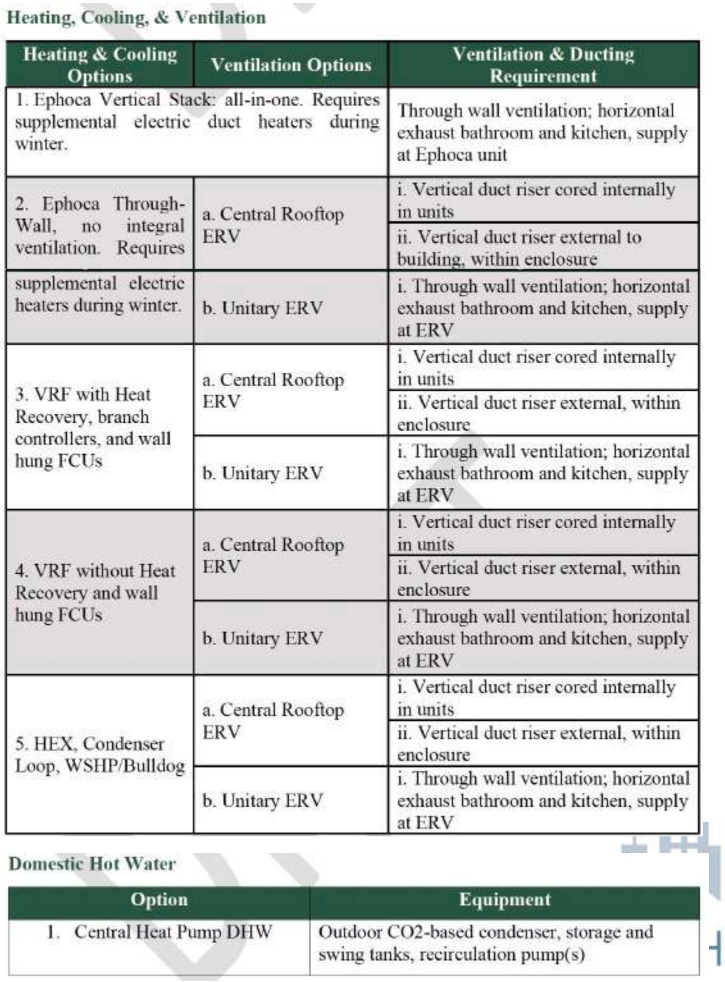
ephoca





Heating, Cooling, & Ventilation

Heating & Cooling Options	Ventilation Options	Ventilation & Ducting Requirement
1. Ephoca Vertical Stack: all-in-one. Requires supplemental electric duct heaters during winter.		Through wall ventilation; horizontal exhaust bathroom and kitchen, supply at Ephoca unit
2. Ephoca Through-Wall, no integral ventilation. Requires supplemental electric heaters during winter.	a. Central Rooftop ERV	i. Vertical duct riser cored internally in units
		ii. Vertical duct riser external to building, within enclosure
	b. Unitary ERV	i. Through wall ventilation; horizontal exhaust bathroom and kitchen, supply at ERV
3. VRF with Heat Recovery, branch controllers, and wall hung FCUs	a. Central Rooftop ERV	i. Vertical duct riser cored internally in units
		ii. Vertical duct riser external, within enclosure
	b. Unitary ERV	i. Through wall ventilation; horizontal exhaust bathroom and kitchen, supply at ERV
4. VRF without Heat Recovery and wall hung FCUs	a. Central Rooftop ERV	i. Vertical duct riser cored internally in units
		ii. Vertical duct riser external, within enclosure
	b. Unitary ERV	i. Through wall ventilation; horizontal exhaust bathroom and kitchen, supply at ERV
5. HEX, Condenser Loop, WSHP/Bulldog	a. Central Rooftop ERV	i. Vertical duct riser cored internally in units
		ii. Vertical duct riser external, within enclosure
	b. Unitary ERV	i. Through wall ventilation; horizontal exhaust bathroom and kitchen, supply at ERV

Domestic Hot Water

Option	Equipment
1. Central Heat Pump DHW	Outdoor CO2-based condenser, storage and swing tanks, recirculation pump(s)

Fairweather: 600 units Salem, MA

Switch from Ephoca to Centralized HEX

HVAC/DHW SYSTEMS:

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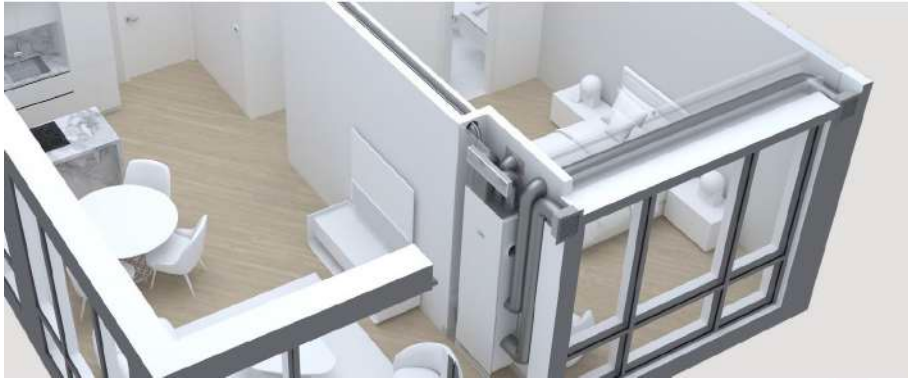
1. Ephoca Vertical Stack

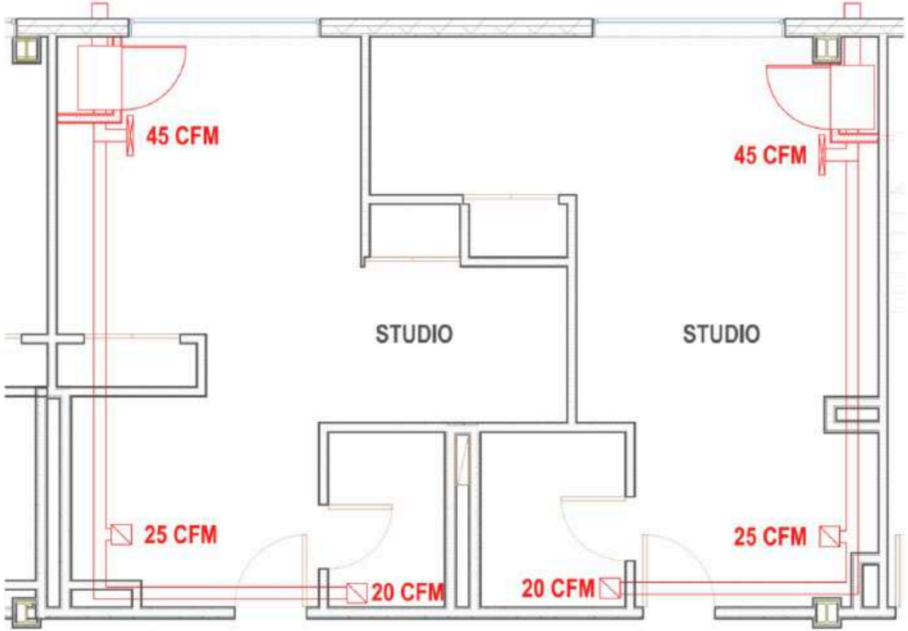
PROS
- Single heating/cooling/ventilation solution
- Easy to schedule installation
- Can exhaust bathroom and kitchen area
- Does not require fire-stopping and smoke dampers
- Reduced risk of refrigerant leak in apartments

CONS
- Added maintenance costs due to individual unit filters
- Higher operating cost compared to centralized heat recovery VRF system
- Requires two penetrations through enclosure per apartment
- More work in occupied rehab compared to wall hung FCUs and central ventilation system
- Lower ERV efficiency compared to central ventilation system
- Will require electric resistance heating for winter design conditions

Vertical stack

ephoca





HVAC/DHW SYSTEMS:

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2. Ephoca Wall mounted + De-coupled ventilation

PROS

- Re-use existing enclosure penetration locations
- Does not require fire-stopping and smoke dampers
- Easy to schedule installation
- Reduced risk of refrigerant leak in apartments

CONS

- Added maintenance costs due to individual unit filters
- Higher operating cost compared to centralized heat recovery VRF system
- Requires two penetrations through enclosure per unit without benefit of ventilation
- May not be adequately sized for common spaces
- May require electric resistance heating for winter design conditions
- Does not address ventilation needs

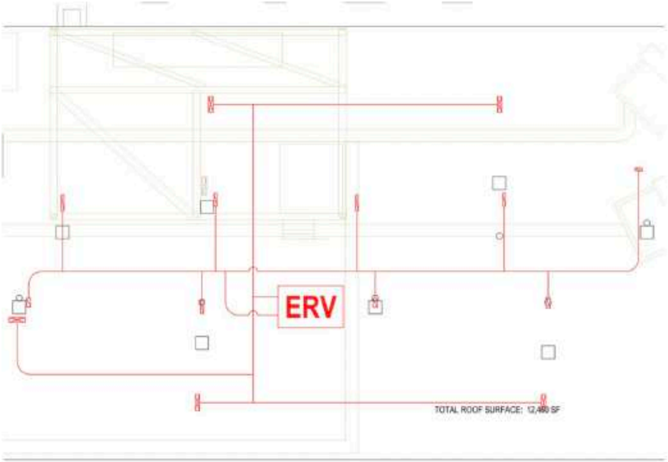

Figure 6: Rooftop layout with internal supply duct risers

Heating/Cooling

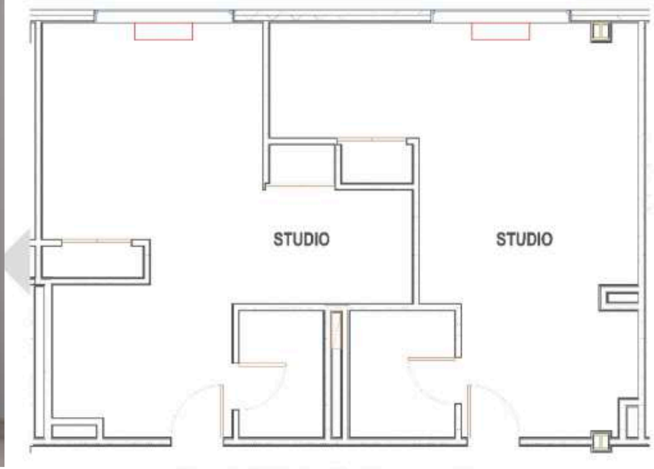

Figure 2: Through wall unit apartment layout

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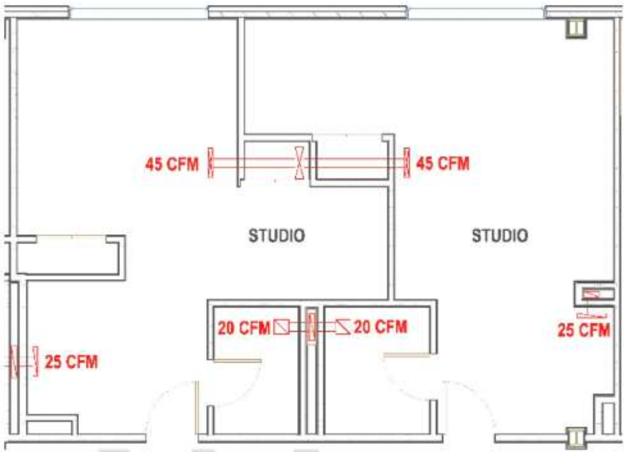
Ventilation



HVAC/DHW SYSTEMS:

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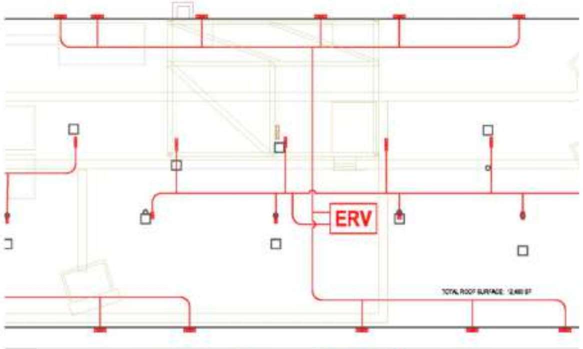
3. VRF w/Heat Recovery and wall hung FCUs + De-coupled ventilation

PROS

- Lowest overall operating cost with heat recovery benefit
- Wall-mounting FCUs does not take away real estate in apartments
- Improved comfort with independent control of heating and cooling
- System can scale to heating/cooling load requirements
- Central maintenance (condensers, controls)

CONS

- Reduces roof space availability for solar array
- Limited space within building to mount branch controllers, may have to be installed on roof in purpose built semi-conditioned space
- Vertical chases for refrigerant lines may still require fire-stopping
- Externally run refrigerant lines will still require maintenance access



Heating/Cooling

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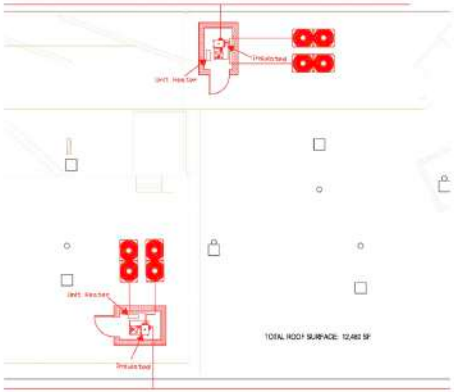

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Ventilation

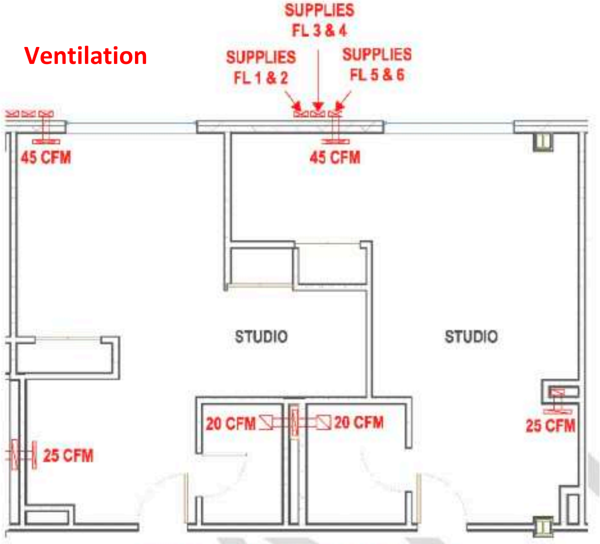

Figure 10: External ductwork staggered

HVAC/DHW SYSTEMS:

BUILDING EVOLUTION CORPORATION
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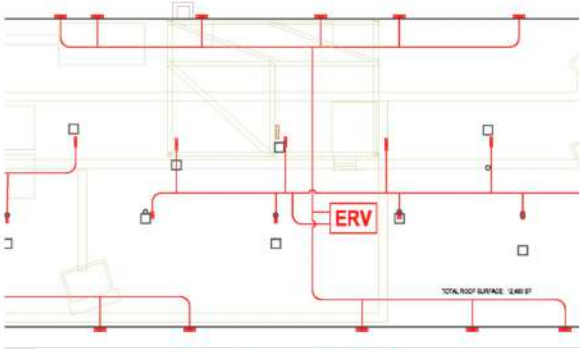
4. VRF WITHOUT Heat Recovery and wall hung FCUs + De-coupled ventilation

PROS

- Lower cost compared to heat recovery VRF option
- Does not require branch controllers
- Wall-mounting FCUs does not take away real estate in apartments
- System can scale to heating/cooling load requirements
- Central maintenance (condensers, controls)

CONS

- Higher operating cost compared to heat recovery VRF option
- Reduces roof space availability for solar array
- Reduced comfort without independent control of heating and cooling
- Vertical chases for refrigerant lines may still require fire-stopping
- Externally run refrigerant lines will still require maintenance access



Heating/Cooling

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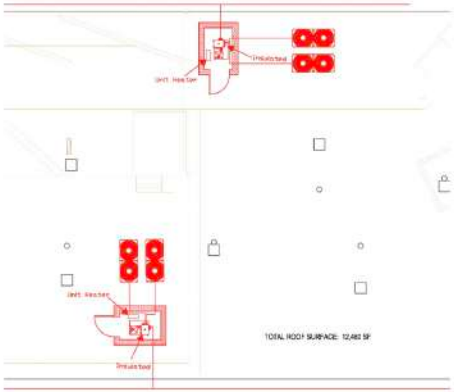

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Ventilation

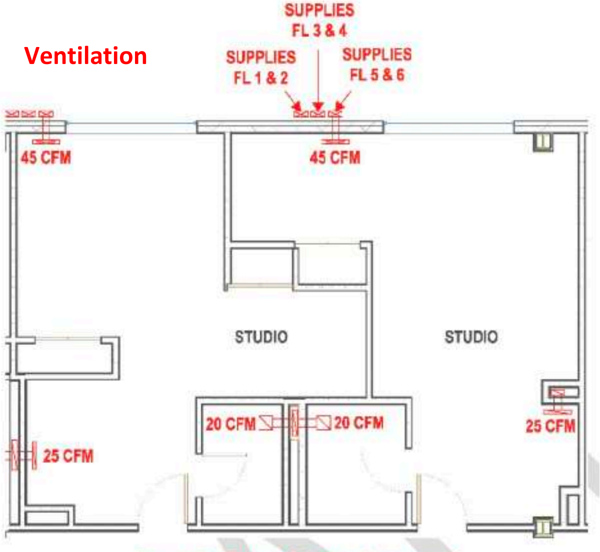

Figure 10: External ductwork staggered

HVAC/DHW SYSTEMS:

BUILDING EVOLUTION CORPORATION
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5. HEX, Condenser Loop, WSHP/Bulldog + De-coupled ventilation

PROS
- Simultaneous heating and cooling with heat recovery
- Reduced refrigerant running through occupied space
- CUs can be located at grade in a central location to serve the entire building.
- May be less expensive than other central options as contractors are familiar with WSHPs, and two pipe hydronic systems

CONS
- Lower efficiency compared to VRF system
- Loss of real estate in apartments

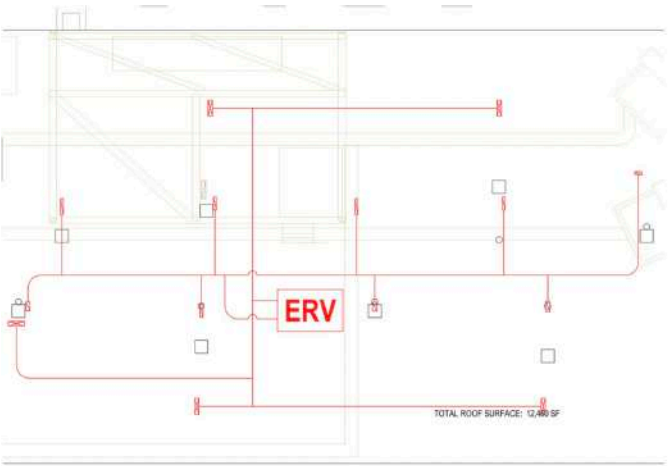
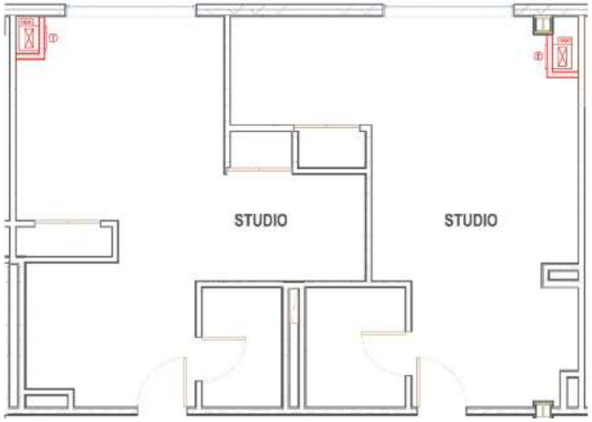


Figure 6: Rooftop layout with internal supply duct risers

Heating/Cooling



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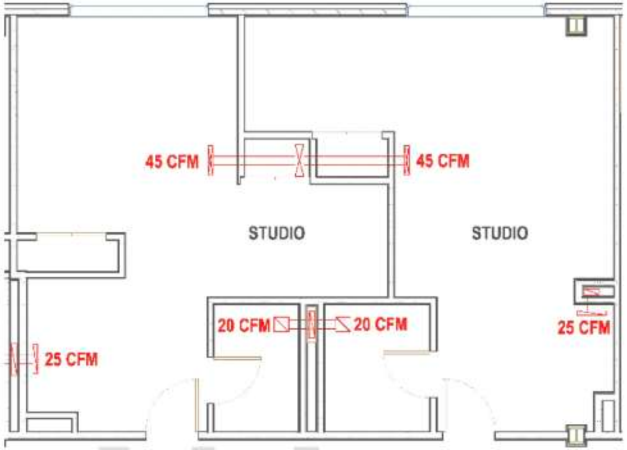
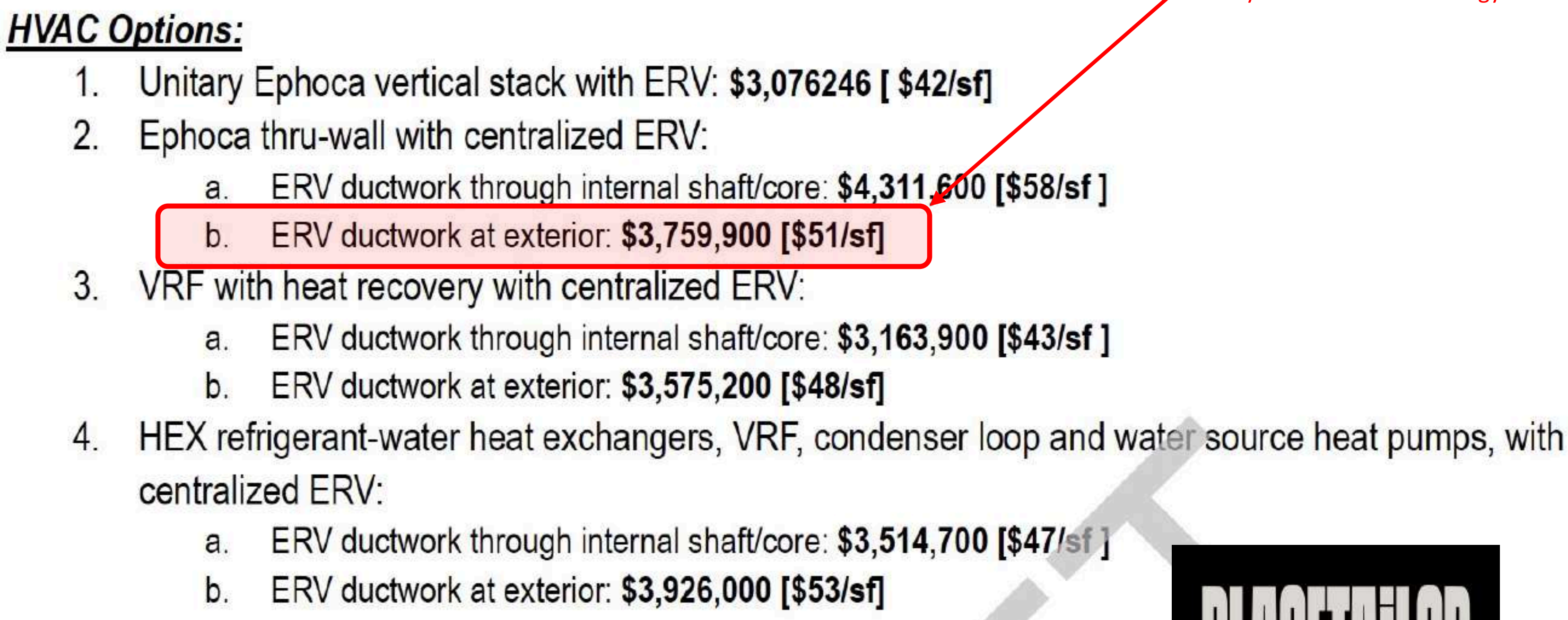
Ventilation



HVAC/DHW SYSTEMS:

Initially chosen as best strategy



HVAC Options:

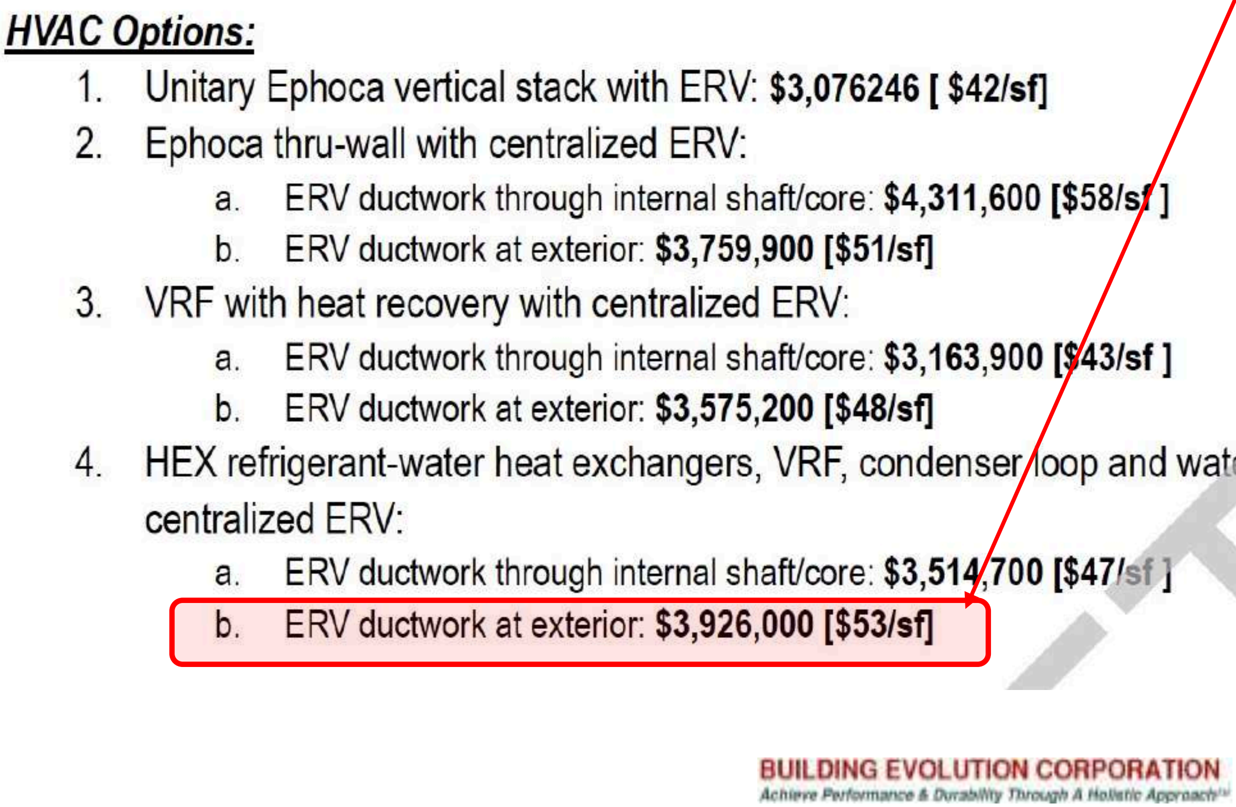
1. Unitary Ephoca vertical stack with ERV: **$3,076246 [$42/sf]**
2. Ephoca thru-wall with centralized ERV:
   a. ERV ductwork through internal shaft/core: **$4,311,600 [$58/sf]**
   b. ERV ductwork at exterior: **$3,759,900 [$51/sf]**
3. VRF with heat recovery with centralized ERV:
   a. ERV ductwork through internal shaft/core: **$3,163,900 [$43/sf]**
   b. ERV ductwork at exterior: **$3,575,200 [$48/sf]**
4. HEX refrigerant-water heat exchangers, VRF, condenser loop and water source heat pumps, with centralized ERV:
   a. ERV ductwork through internal shaft/core: **$3,514,700 [$47/sf]**
   b. ERV ductwork at exterior: **$3,926,000 [$53/sf]**

BUILDING EVOLUTION CORPORATION
Achieve Performance & Durability Through A Holistic Approach

PLACETAILOR

POAH

HVAC/DHW SYSTEMS:



FINAL chosen strategy

HVAC Options:

1. Unitary Ephoca vertical stack with ERV: **$3,076246 [$42/sf]**
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BUILDING EVOLUTION CORPORATION
Achieve Performance & Durability Through A Holistic Approach

PLACETAILOR

POAH

HVAC/DHW SYSTEMS:

MAIN REASONS FOR SHIFT:

1. Concern over untested Ephoca unit in this climate
2. Concern over total cost of Ephoca unit
3. Minimal interior work with HEX system
4. Ventilation from outside so tenants are not interrupted
5. Relocation of tenants would cost over $1million

HVAC Options:

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BUILDING EVOLUTION CORPORATION
Achieve Performance & Durability Through A Holistic Approach

PLACETAILOR

POAH

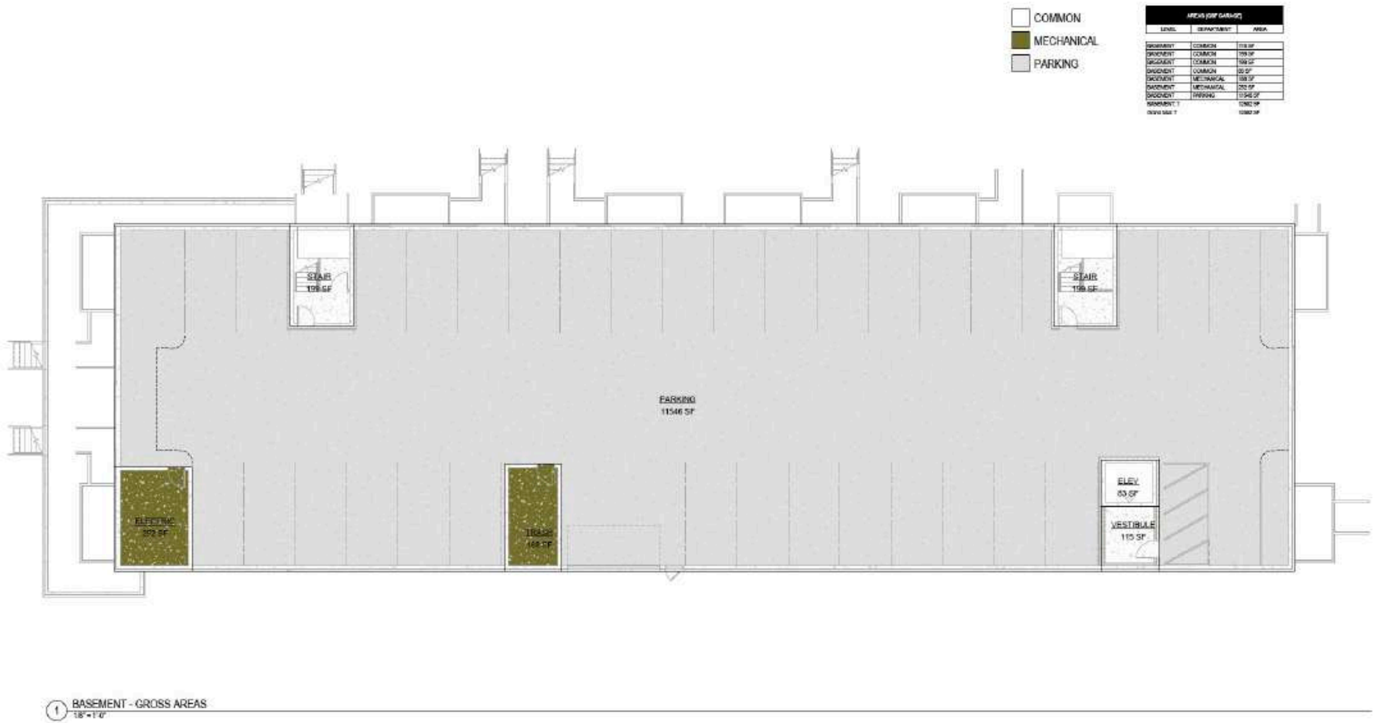
……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

Linden: 32 units Madison, WI

Switch from Ephoca to mini-splits

IN COLLABORATION WITH
Knothe Bruce Architects

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……



☐ COMMON
▨ MECHANICAL
▨ PARKING

AREAS (GSF GARAGE)		
LEVEL	DEPARTMENT	AREA
BASEMENT	COMMON	115 SF
BASEMENT	COMMON	199 SF
BASEMENT	COMMON	199 SF
BASEMENT	COMMON	83 SF
BASEMENT	MECHANICAL	168 SF
BASEMENT	MECHANICAL	252 SF
BASEMENT	PARKING	11546 SF
BASEMENT: 7		12562 SF
GRAND TOTAL: 7		12562 SF

1 BASEMENT - GROSS AREAS
1/8" = 1'-0"

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

- 🟩 1 BEDROOM
- 🟨 2 BEDROOM
- ⬜ COMMON
- ▨ JUNIOR 1 BED
- 🟫 MECHANICAL

AREAS (GSF LEVEL 1)		
LEVEL	DEPARTMENT	AREA
LEVEL 1	1 BEDROOM	793 SF
LEVEL 1	1 BEDROOM	780 SF
LEVEL 1	1 BEDROOM	780 SF
LEVEL 1	1 BEDROOM	771 SF
LEVEL 1	1 BEDROOM	764 SF
LEVEL 1	1 BEDROOM	764 SF
LEVEL 1	1 BEDROOM	772 SF
LEVEL 1	2 BEDROOM	1017 SF
LEVEL 1	2 BEDROOM	1049 SF
LEVEL 1	2 BEDROOM	849 SF
LEVEL 1	COMMON	126 SF
LEVEL 1	COMMON	249 SF
LEVEL 1	COMMON	83 SF
LEVEL 1	COMMON	91 SF
LEVEL 1	COMMON	168 SF
LEVEL 1	COMMON	168 SF
LEVEL 1	COMMON	1033 SF
LEVEL 1	JUNIOR 1 BED	680 SF
LEVEL 1	JUNIOR 1 BED	680 SF
LEVEL 1	MECHANICAL	35 SF
LEVEL 1	MECHANICAL	36 SF
LEVEL 1: 21		11682 SF
Grand total: 21		11682 SF

APARTMENT COUNT (LEVEL 1)		
DEPARTMENT	APARTMENT TYPE	QTY
1 BEDROOM	1 BED	7
2 BEDROOM	2 BED	3
JUNIOR 1 BED	JUNIOR 1 BED	2
Grand total: 12		12

1 LEVEL 1 - GROSS AREAS
1/8" = 1'-0"

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

- 🟨 1 BEDROOM
- 🟨 2 BEDROOM
- 🟫 2 BEDROOM BILEVEL
- ⬜ COMMON
- ⬜ JUNIOR 1 BED
- 🟫 MECHANICAL

AREAS (GSF LEVEL 2)		
LEVEL	DEPARTMENT	AREA
LEVEL 2	1 BEDROOM	794 SF
LEVEL 2	1 BEDROOM	780 SF
LEVEL 2	1 BEDROOM	780 SF
LEVEL 2	1 BEDROOM	757 SF
LEVEL 2	2 BEDROOM	1017 SF
LEVEL 2	2 BEDROOM	1011 SF
LEVEL 2	2 BEDROOM BILEVEL	793 SF
LEVEL 2	2 BEDROOM BILEVEL	785 SF
LEVEL 2	2 BEDROOM BILEVEL	785 SF
LEVEL 2	2 BEDROOM BILEVEL	793 SF
LEVEL 2	COMMON	91 SF
LEVEL 2	COMMON	169 SF
LEVEL 2	COMMON	169 SF
LEVEL 2	COMMON	960 SF
LEVEL 2	JUNIOR 1 BED	680 SF
LEVEL 2	JUNIOR 1 BED	680 SF
LEVEL 2	JUNIOR 1 BED	644 SF
LEVEL 2	MECHANICAL	35 SF
LEVEL 2	MECHANICAL	35 SF
LEVEL 2: 19		11777 SF
GRAND TOTAL: 19		11777 SF

APARTMENT COUNT (LEVEL 2)		
DEPARTMENT	APARTMENT TYPE	QTY
1 BEDROOM	1 BED	4
2 BEDROOM	2 BED	2
2 BEDROOM BILEVEL	2 BED BILEVEL	4
JUNIOR 1 BED	JUNIOR 1 BED	3
GRAND TOTAL: 13		13

2 LEVEL 2 - GROSS AREAS
1/8" = 1'-0"

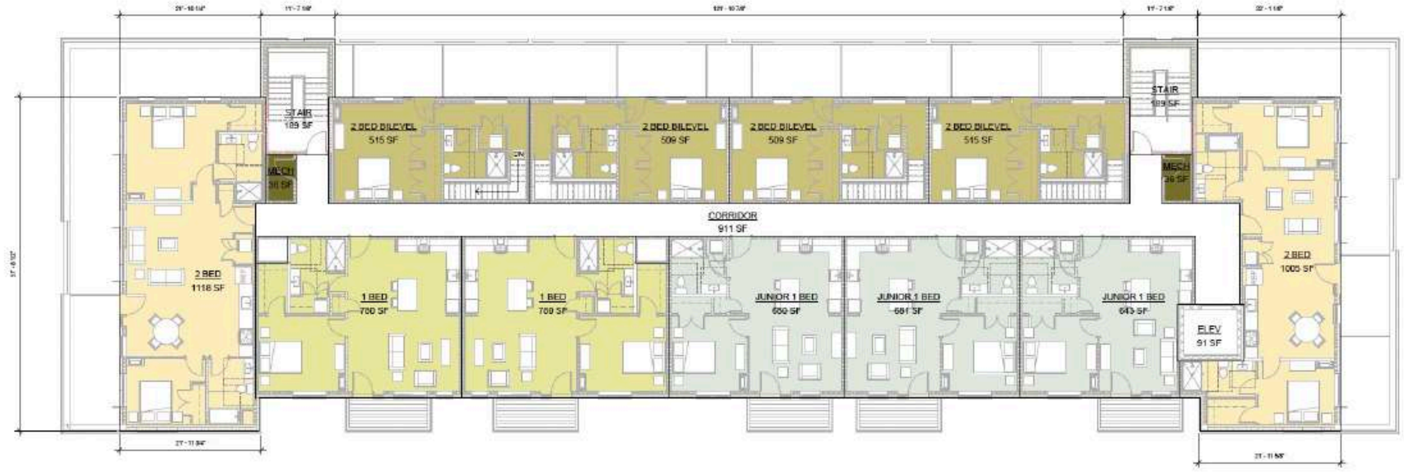
……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

- ▨ 1 BEDROOM
- ▨ 2 BEDROOM
- ▨ 2 BEDROOM BILEVEL
- ☐ COMMON
- ▨ JUNIOR 1 BED
- ■ MECHANICAL

AREAS (GSF LEVEL 3)		
LEVEL	DEPARTMENT	AREA
LEVEL 3	1 BEDROOM	780 SF
LEVEL 3	1 BEDROOM	780 SF
LEVEL 3	2 BEDROOM	1118 SF
LEVEL 3	2 BEDROOM	1005 SF
LEVEL 3	2 BEDROOM BILEVEL	515 SF
LEVEL 3	2 BEDROOM BILEVEL	509 SF
LEVEL 3	2 BEDROOM BILEVEL	509 SF
LEVEL 3	2 BEDROOM BILEVEL	515 SF
LEVEL 3	COMMON	189 SF
LEVEL 3	COMMON	91 SF
LEVEL 3	COMMON	189 SF
LEVEL 3	COMMON	911 SF
LEVEL 3	JUNIOR 1 BED	680 SF
LEVEL 3	JUNIOR 1 BED	681 SF
LEVEL 3	JUNIOR 1 BED	643 SF
LEVEL 3	MECHANICAL	36 SF
LEVEL 3	MECHANICAL	36 SF
LEVEL 3: 17		9190 SF
Grand total: 17		9190 SF

APARTMENT COUNT (LEVEL 3)		
DEPARTMENT	APARTMENT TYPE	QTY
1 BEDROOM	1 BED	2
2 BEDROOM	2 BED	2
2 BEDROOM BILEVEL	2 BED BILEVEL	4
JUNIOR 1 BED	JUNIOR 1 BED	3
Grand total: 11		11

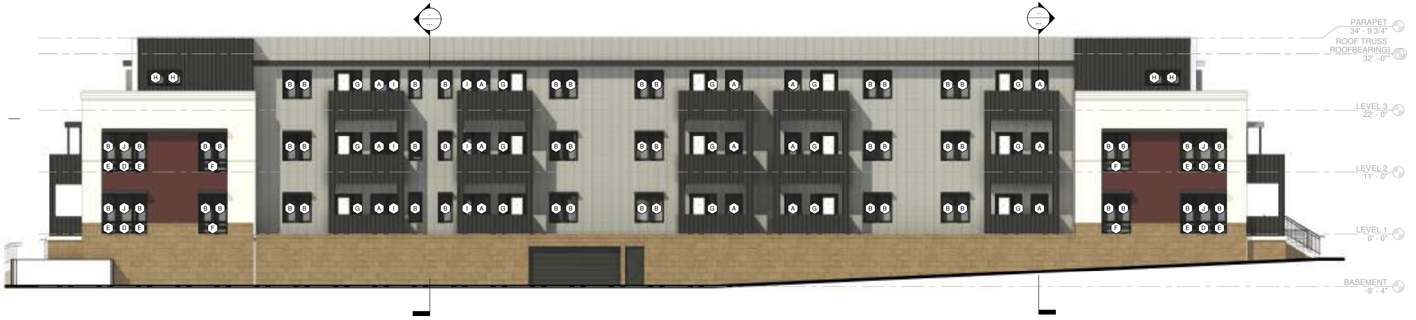
*NOTE: BI-LEVEL UNITS COUNTED 2X, FOR TOTAL UNIT COUNT OF BLDG, ONLY 7 UNITS AT THIS LEVEL



③ LEVEL 3 -GROSS AREAS
1/8" = 1'-0"

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

2 NORTH ELEVATION
1/8" = 1'-0"

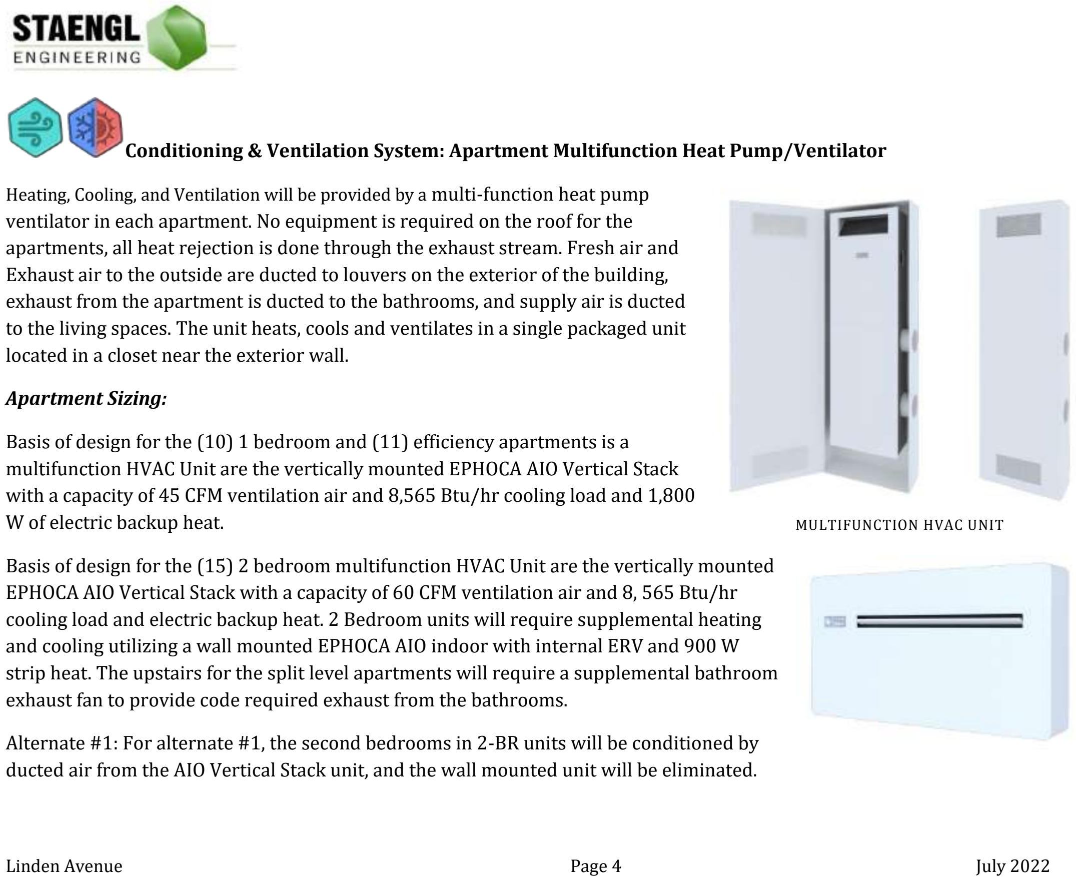


1 SOUTH ELEVATION
1/8" = 1'-0"

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

***NOTES:**

- **Initially looked at Minotair but Ephoca is more efficient at colder temps**
- **Ephoca has built-in “passive” ERV core, Minotair has ”active” ERV**



STAENGL ENGINEERING

Conditioning & Ventilation System: Apartment Multifunction Heat Pump/Ventilator

Heating, Cooling, and Ventilation will be provided by a multi-function heat pump ventilator in each apartment. No equipment is required on the roof for the apartments, all heat rejection is done through the exhaust stream. Fresh air and Exhaust air to the outside are ducted to louvers on the exterior of the building, exhaust from the apartment is ducted to the bathrooms, and supply air is ducted to the living spaces. The unit heats, cools and ventilates in a single packaged unit located in a closet near the exterior wall.

Apartment Sizing:

Basis of design for the (10) 1 bedroom and (11) efficiency apartments is a multifunction HVAC Unit are the vertically mounted EPHOCA AIO Vertical Stack with a capacity of 45 CFM ventilation air and 8,565 Btu/hr cooling load and 1,800 W of electric backup heat.

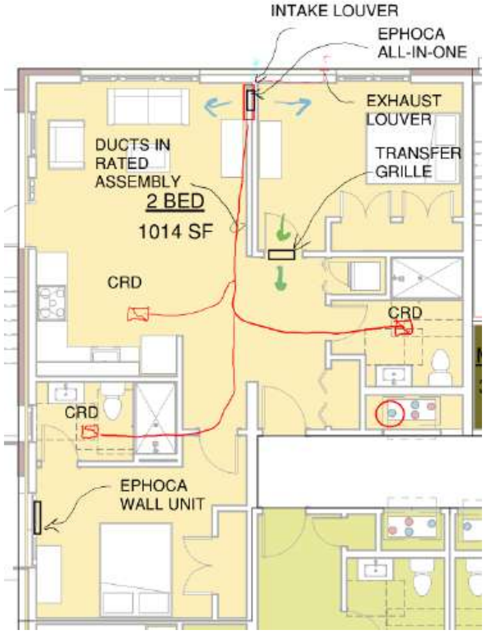
MULTIFUNCTION HVAC UNIT

Basis of design for the (15) 2 bedroom multifunction HVAC Unit are the vertically mounted EPHOCA AIO Vertical Stack with a capacity of 60 CFM ventilation air and 8, 565 Btu/hr cooling load and electric backup heat. 2 Bedroom units will require supplemental heating and cooling utilizing a wall mounted EPHOCA AIO indoor with internal ERV and 900 W strip heat. The upstairs for the split level apartments will require a supplemental bathroom exhaust fan to provide code required exhaust from the bathrooms.

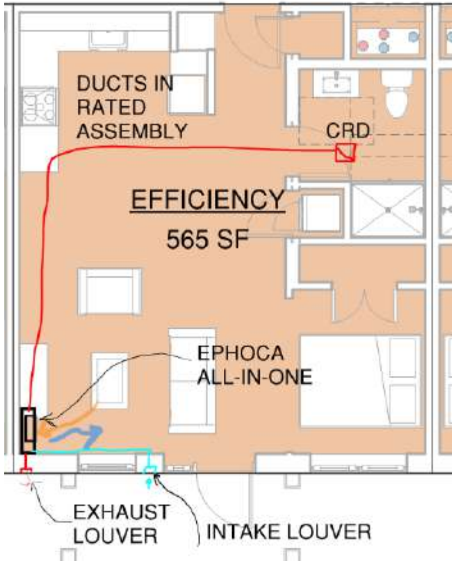
Alternate #1: For alternate #1, the second bedrooms in 2-BR units will be conditioned by ducted air from the AIO Vertical Stack unit, and the wall mounted unit will be eliminated.

Linden Avenue Page 4 July 2022

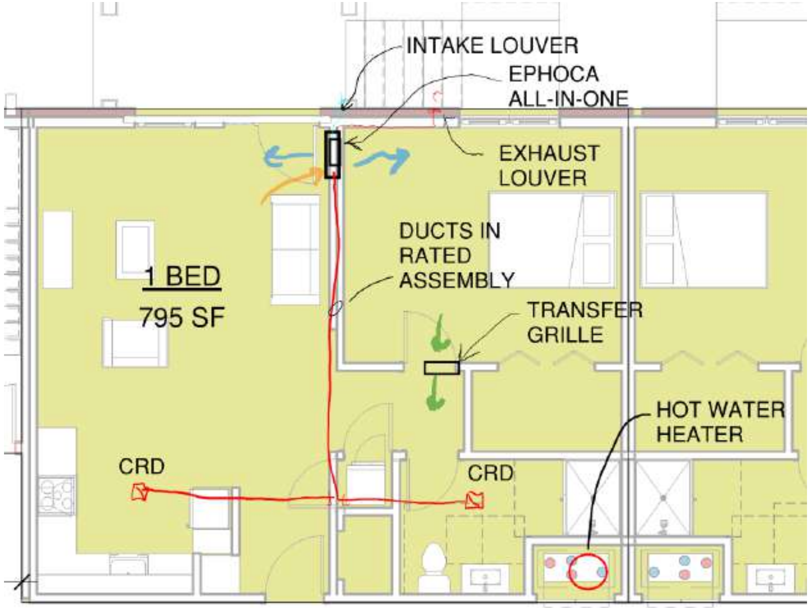
……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……



TWO BEDROOM HVAC SCHEMATIC

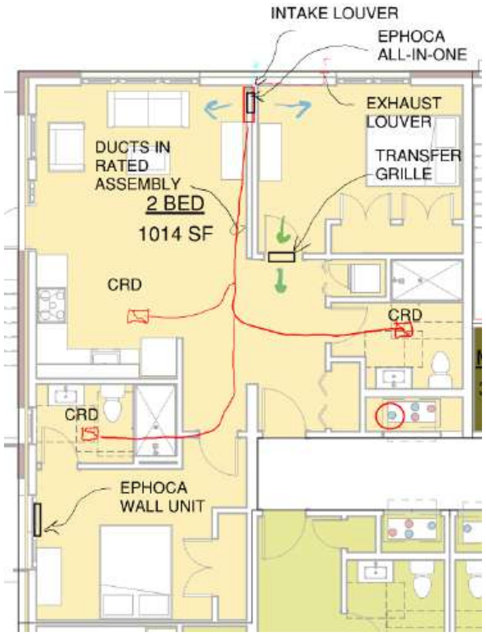


EFFICIENCY HVAC SCHEMATIC

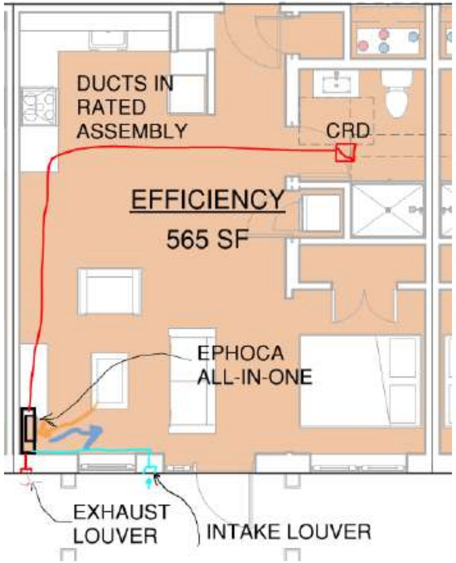


ONE BEDRROM HVAC SCHEMATIC

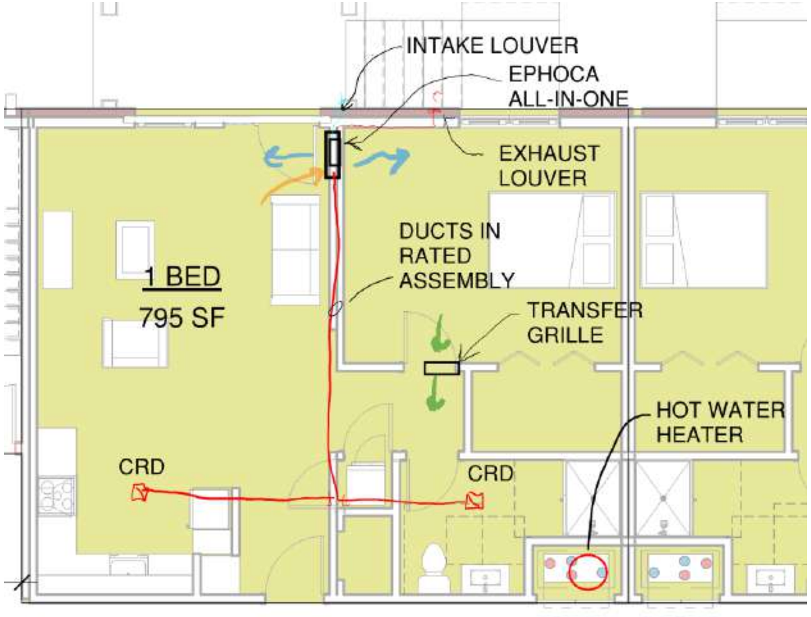
……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……



TWO BEDROOM HVAC SCHEMATIC



EFFICIENCY HVAC SCHEMATIC



ONE BEDRROM HVAC SCHEMATIC

EQUIPMENT COSTS AFTER FREIGHT (from Italy), total cost: $9000/unit

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……

Panasonic

Intelli-Balance™ 100 Energy Recovery Ventilator

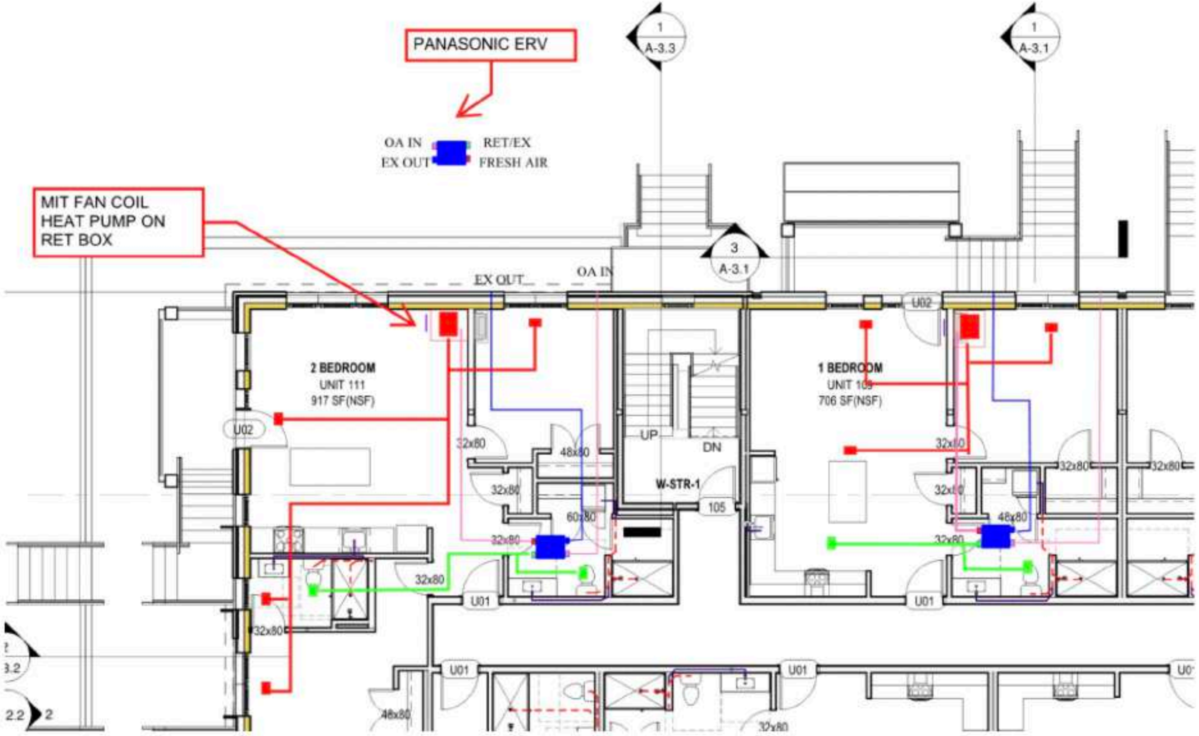
Intelli-Balance™ 100

FV-10VEC2 (Cold Climate)
FV-10VE2 (Temperate Climate)

SVZ-KP12NA & SUZ-KA12NAHZ
12,000 BTU/H MULTI-POSITION AIR HANDLER
12,000 BTU/H HYPER-HEATING UNIVERSAL OUTDOOR UNIT

REPLACE WITH PANASONIC ERV AND MINISPLITS

……CURRENT PROJECTS: MID-STREAM SHIFT IN HVAC STRATEGIES……



REPLACE WITH PANASONIC ERV AND MINISPLITS: SAVED $250,000.00

Multiple Meters

PROS

- Tenants pay their own utilities.
- Simplified ductwork piping and fire protection.
- Much easier to “balance” and commission than Centralized system
- If one system needs maintenance, the rest of the tenants are unaffected.

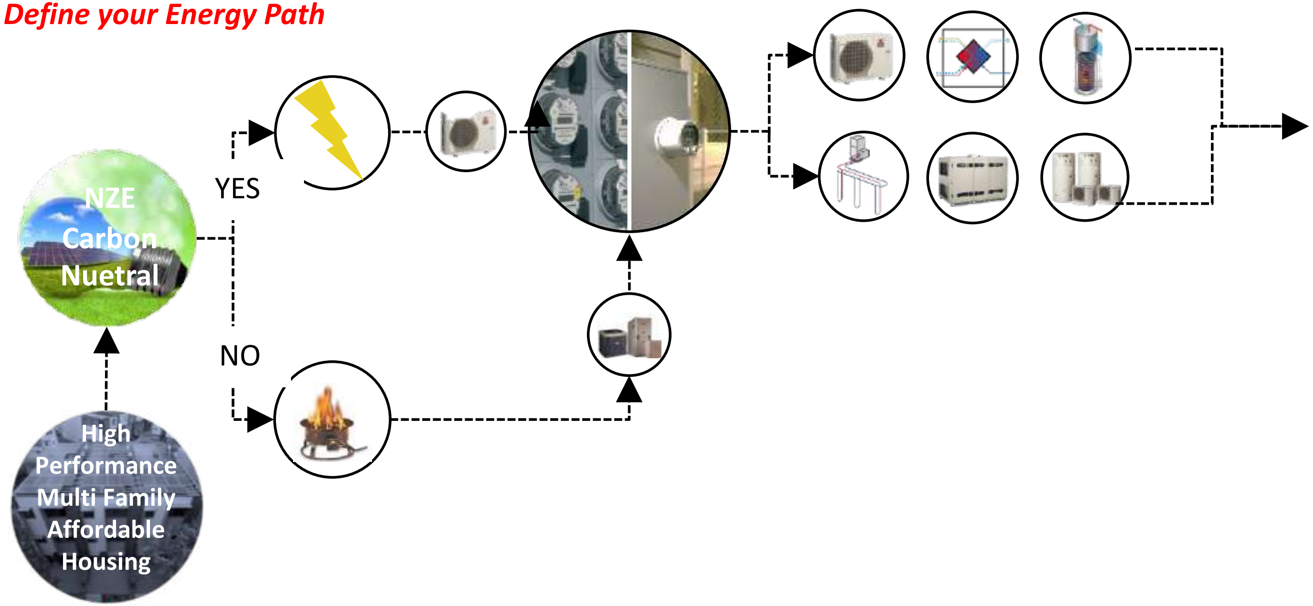
DE-CENTRALIZED SYSTEMS

CONS

- Requires more maintenance for owner.
- Filters in HVAC & DHW systems need to be maintained 3-4 per year.
- Coordination challenge of maintenance with all tenants because systems are often inside their units.
- HVAC / DHW equipment takes up space in apartments (+ cold air!)
- Two punctures in the envelope per ERV/HRV (1 supply and 1 exhaust for each unit) - labor intensive & potential for air leakage.
- >Distance = <Efficiency

STEP #1
Define your Energy Path

STEP #2
Define your Systems Path



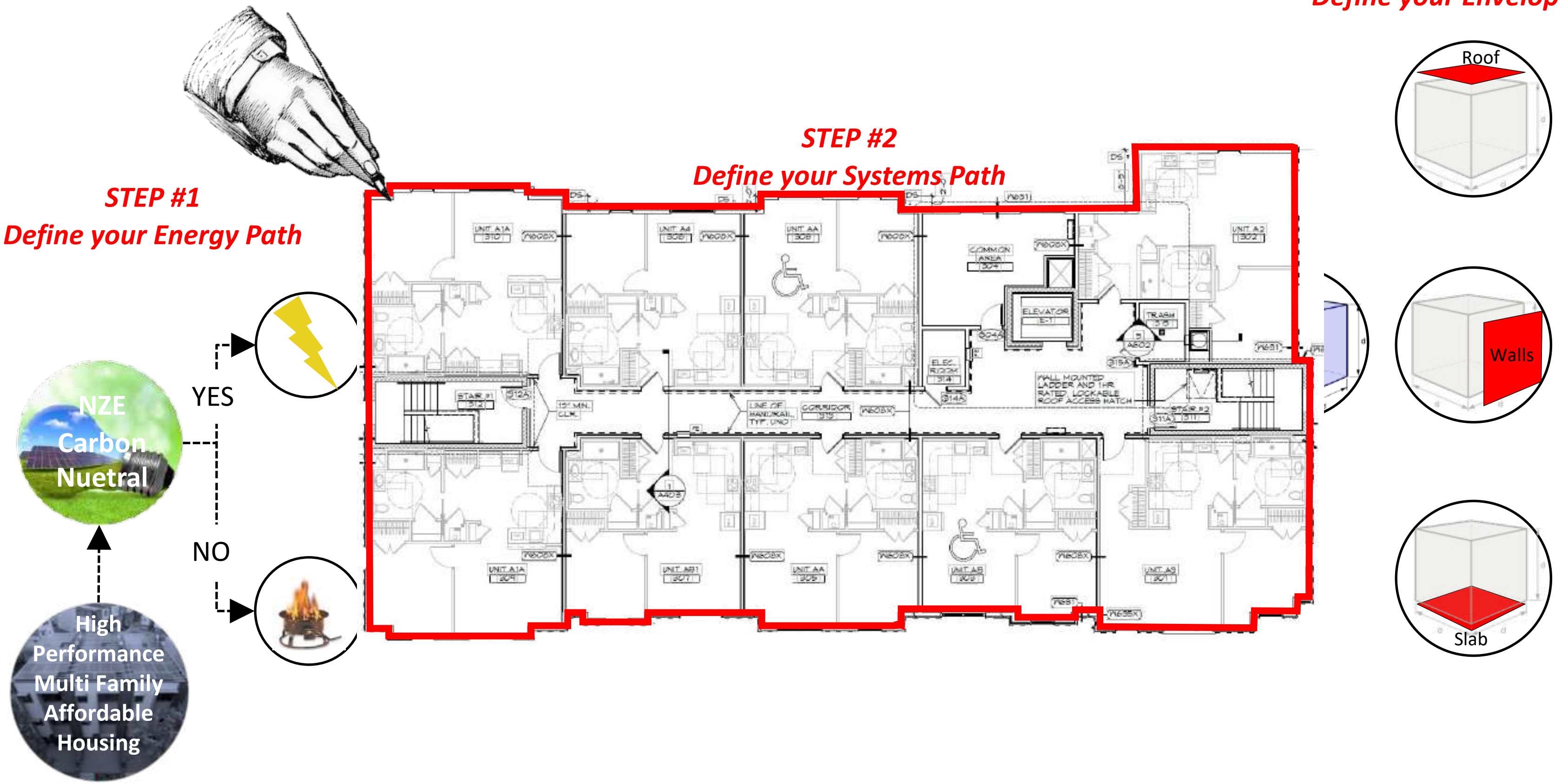
NZE
Carbon
Nuetral

YES

NO

High
Performance
Multi Family
Affordable
Housing

AIR BARRIER



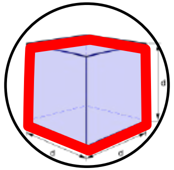
STEP #1
Define your Energy Path

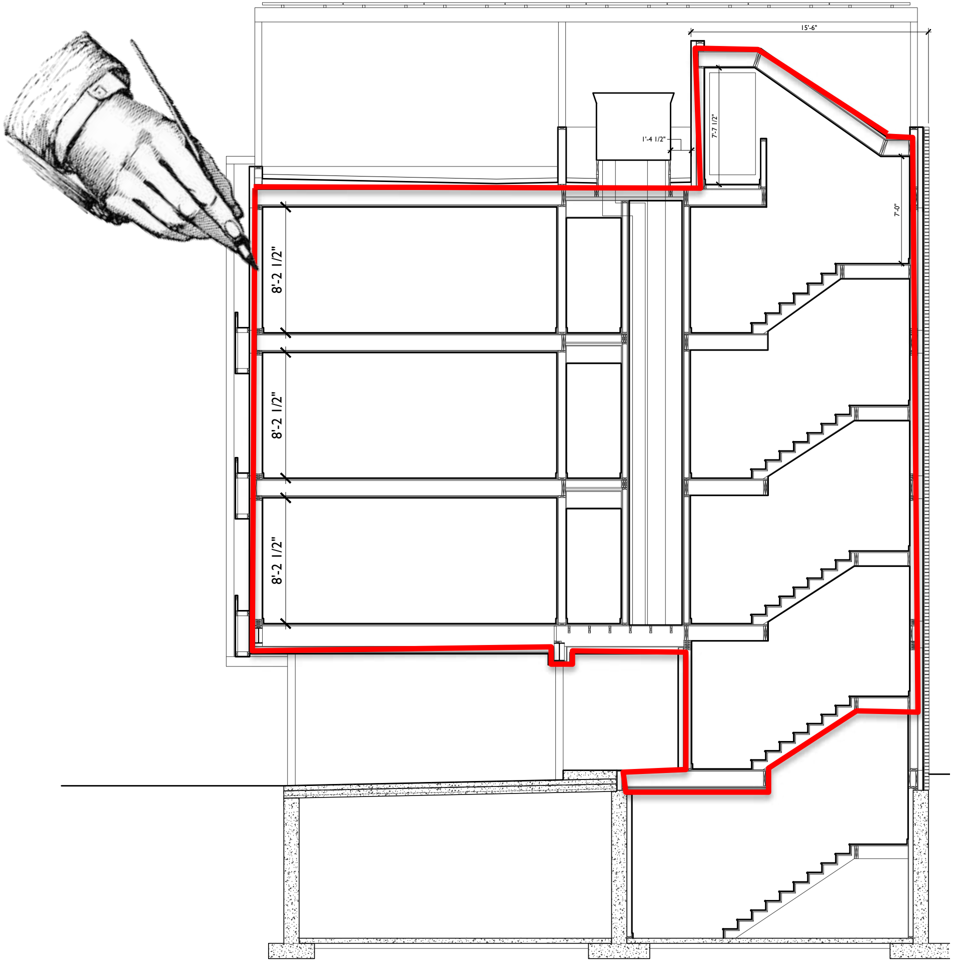
STEP #2
Define your Systems Path

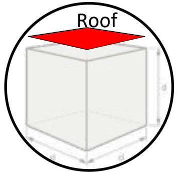
STEP #3
Define your Envelop Path

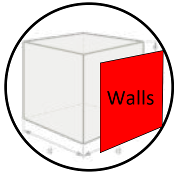
AIR BARRIER

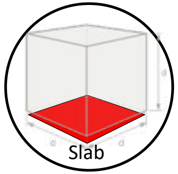
STEP #3
Define your Envelop Path







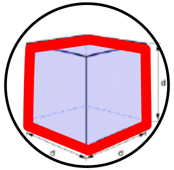


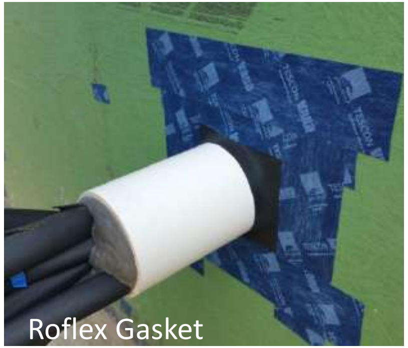


AIR BARRIER

STEP #3

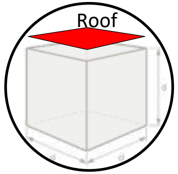
Define your Envelop Path

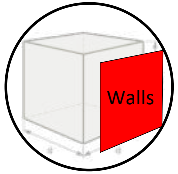


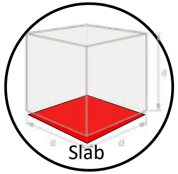

Roflex Gasket


Tescon Vana Gasket


K-flex Gasket





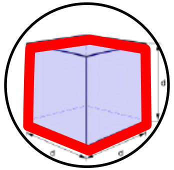


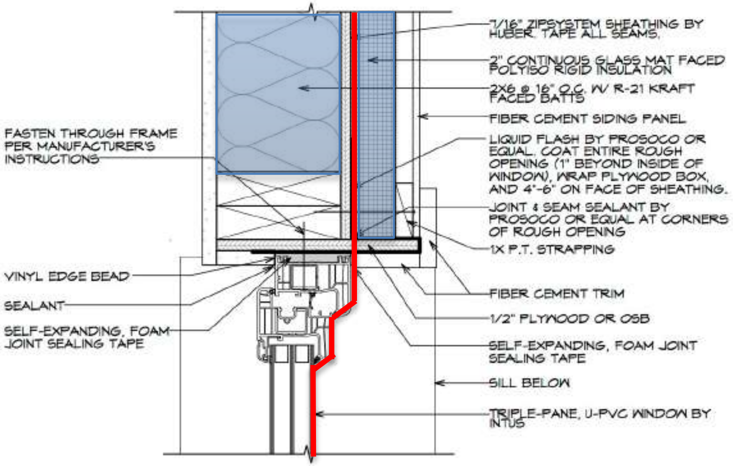
WINDOWS, DOORS

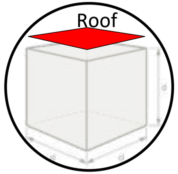
- *Triple pane, Thermally-broken*
- *Tilt & Turn, UPVC*
- *U-values 0.16 - 0.18*
- *Liquid Flashing System*
- *Expanding Foam Tape*

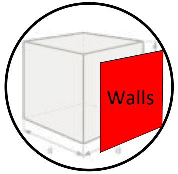
STEP #3

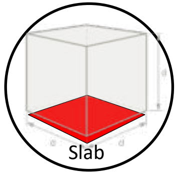
Define your Envelop Path











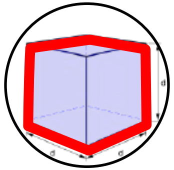
Sacred Heart Residences, Pennrose Properties, Kitchen & Ass., WRT PH Consultant: Window detailing and performance

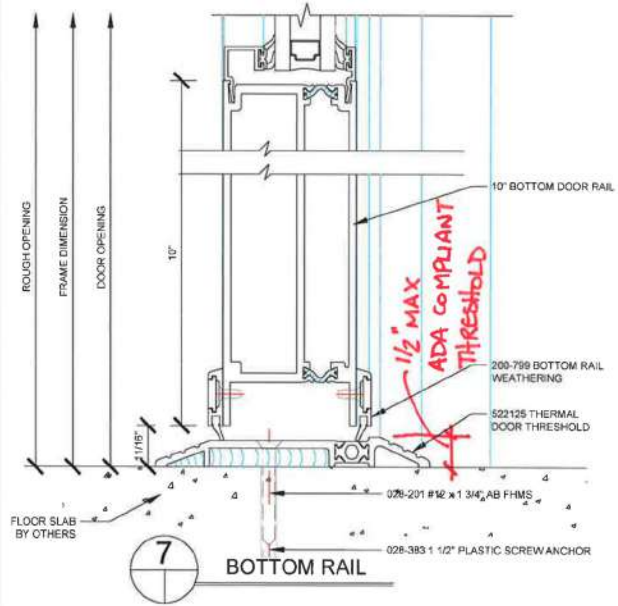
WINDOWS, DOORS

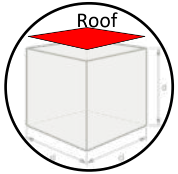
- *Aluminum frames*
- *Thermally broken frames*
- *Double pane glazing, verified with PHPP*
- *U-value 0.24, SHGC 0.39*
- *American doors avoided conflicts with electronic hardware*

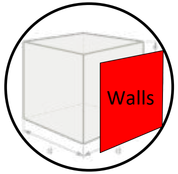
STEP #3

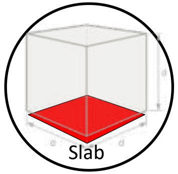
Define your Envelop Path





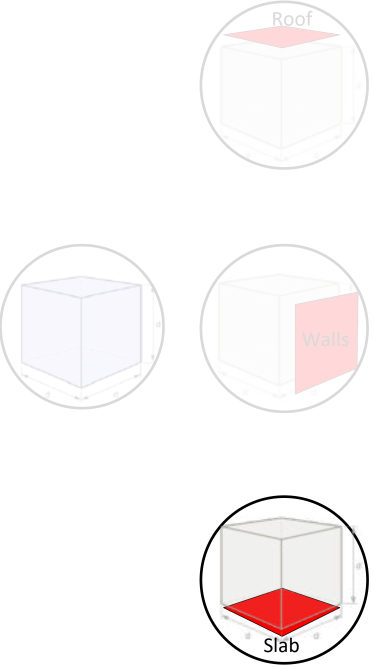




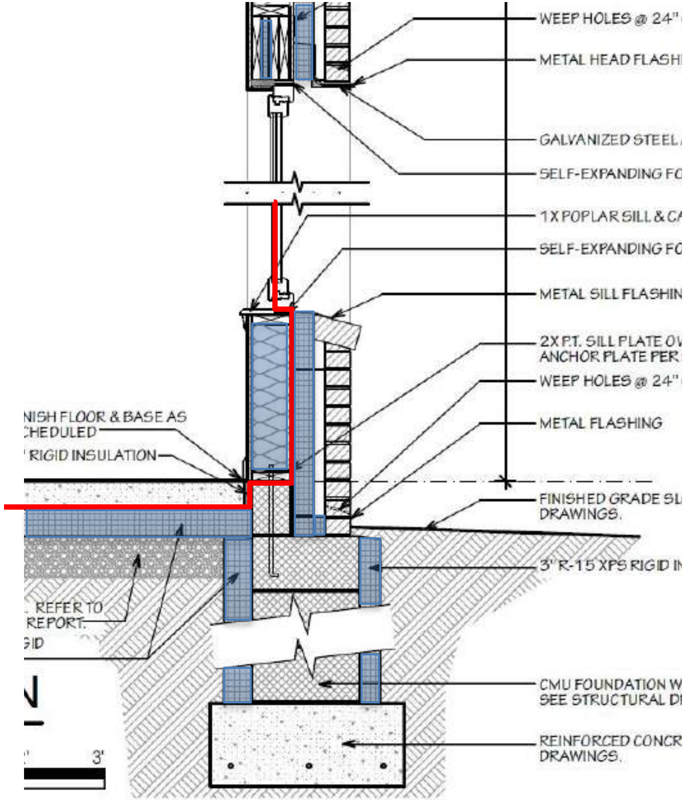


Sacred Heart Residences, Pennrose Properties, Kitchen & Ass., WRT PH Consultant: Doors require a great deal of consideration

CONVENTIONAL CONSTRUCTION

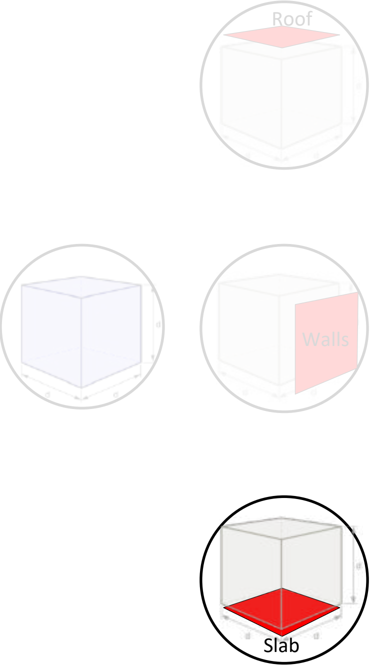


SLAB ON GRADE

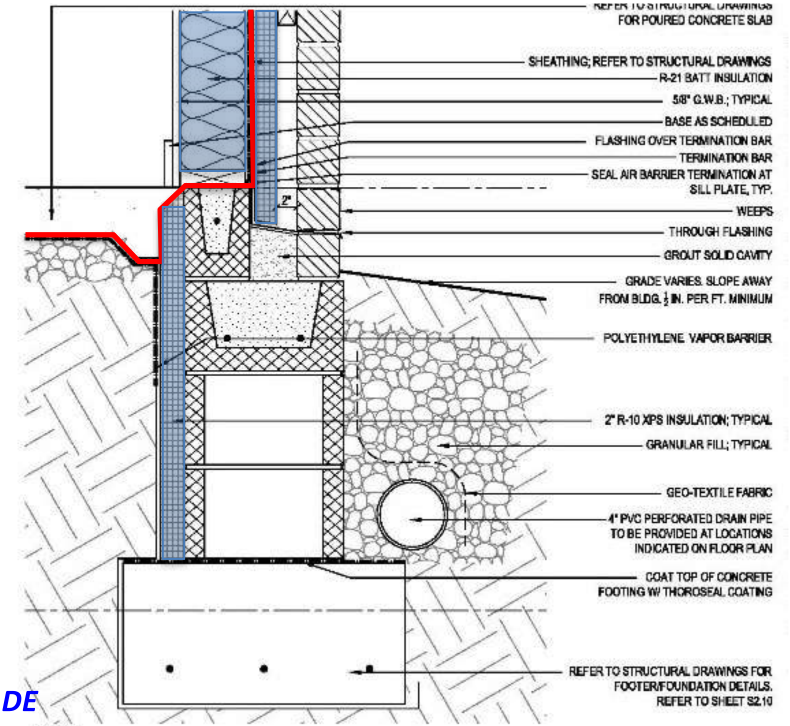


Sacred Heart Residences, Pennrose Properties, Kitchen & Ass., WRT PH Consultant: foundation challenges

CONVENTIONAL CONSTRUCTION



SLAB ON GRADE



1
A7.01
FOUNDATION DETAIL-TYPICAL
SCALE: 1 1/2" = 1'-0"

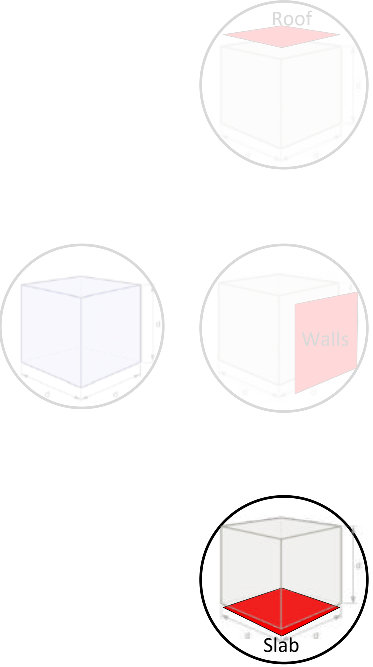
THE COMMUNITY BUILDERS

RDL ARCHITECTS

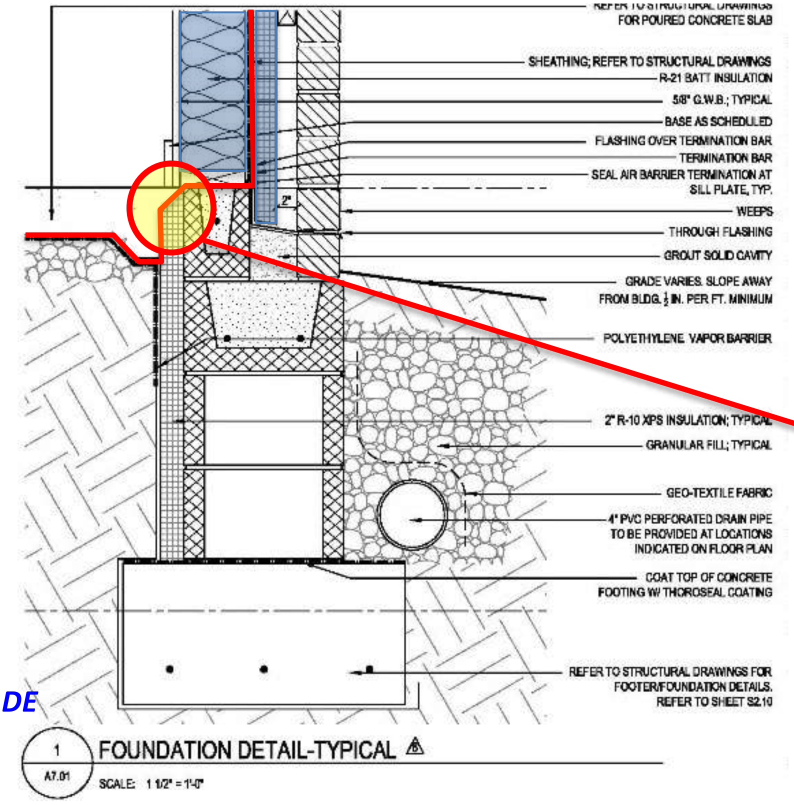
SOTA CONSTRUCTION SERVICES, INC.

Hillcrest Senior Residences: Notice NO SUB-SLAB insulation!!, conventional foundation, thermal analysis

CONVENTIONAL CONSTRUCTION



SLAB ON GRADE



THE COMMUNITY BUILDERS

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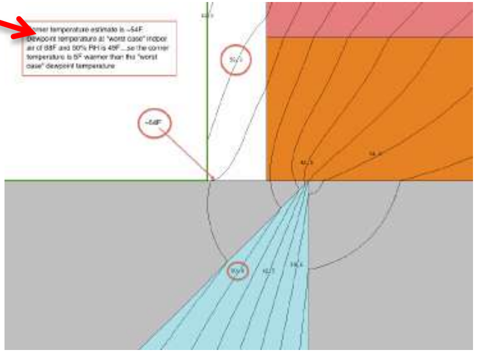
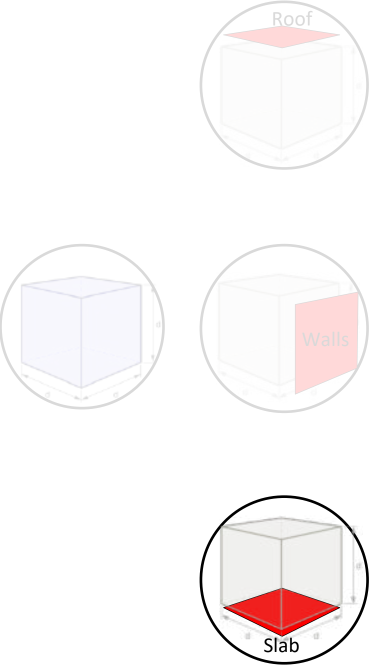
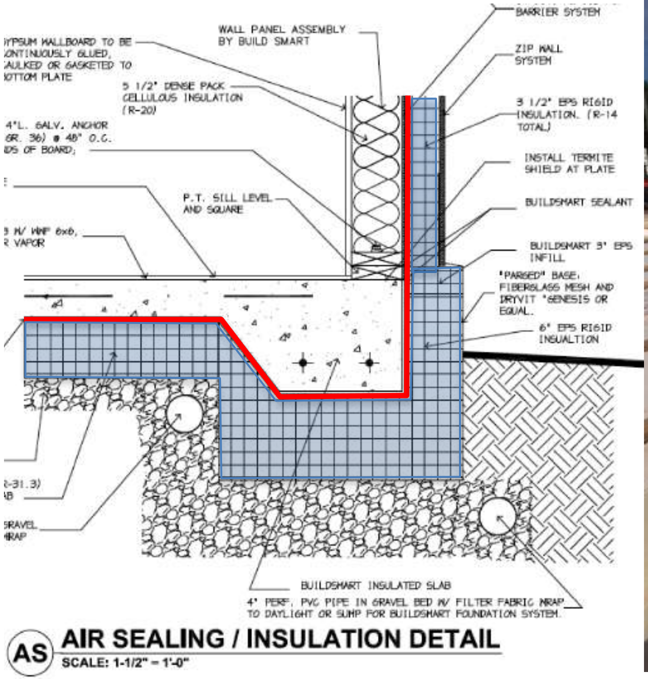


Hillcrest Senior Residences: Notice NO SUB-SLAB insulation!!, conventional foundation, thermal analysis

PREFABRICATION

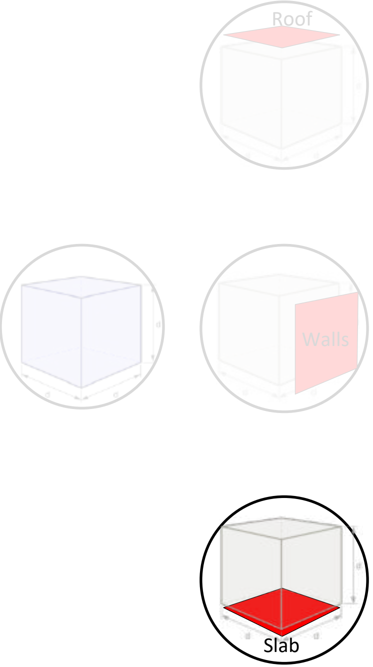


SLAB ON GRADE

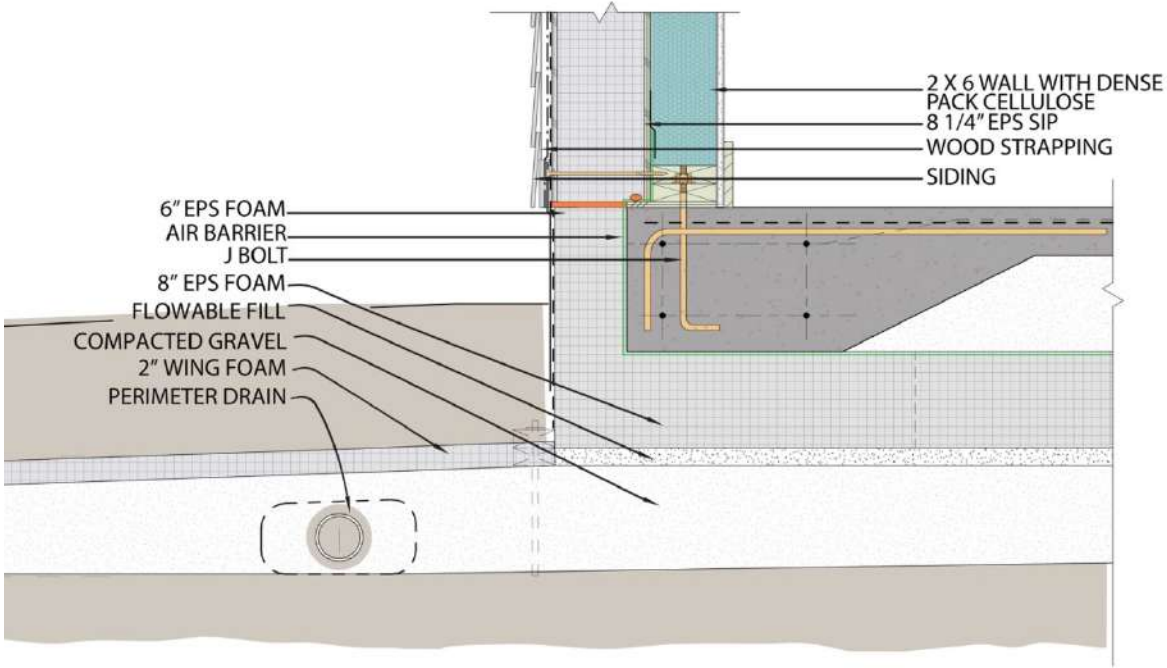


The Whitehall, PHI Certified 2017, Mission First Housing: Prefabricated foundation system, Buildsmart

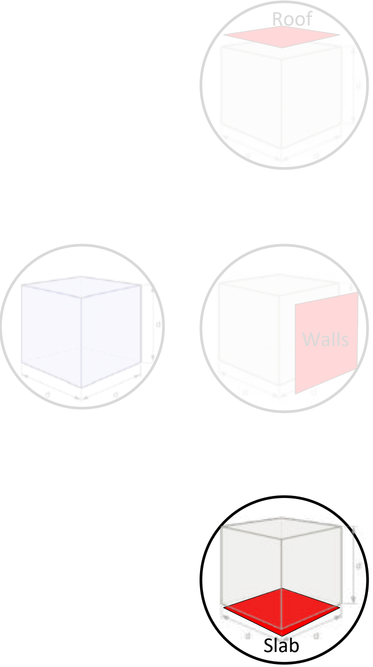
PREFABRICATION



SLAB ON GRADE



G OLOGIC: Typical Slab edge detail

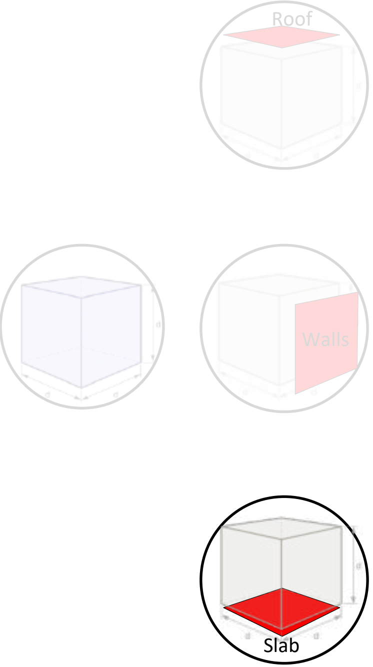


SLAB ON GRADE

The Whitehall, PHI Certified 2017, Mission First Housing

PROS

- Cost Effective
- With prefabricated forms, a monolithic pour of footing/foundation and slab is possible
- Conventional construction skills



SLAB ON GRADE

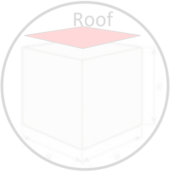
The Whitehall, PHI Certified 2017, Mission First Housing

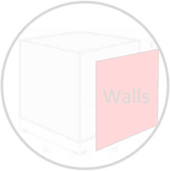
PROS

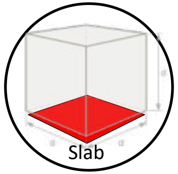
- Cost Effective
- With prefabricated forms, a monolithic pour of footing/foundation and slab is possible
- Conventional construction skills

CONS

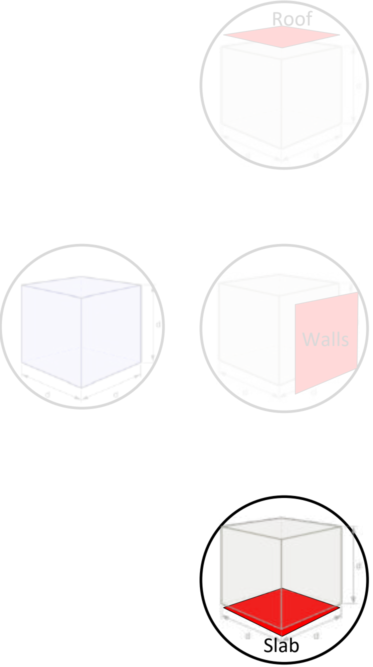
- No basement for storage or utilities
- All sub-grade services (plumbing, electric) need to be precisely located



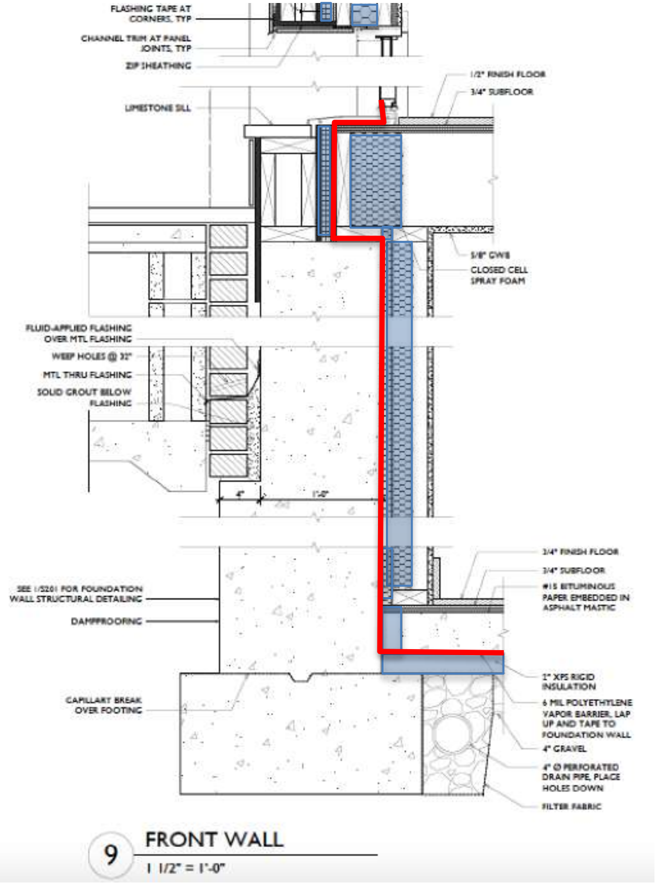




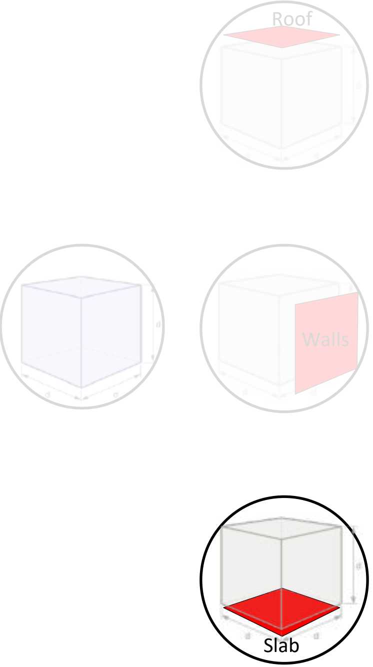
BASEMENT

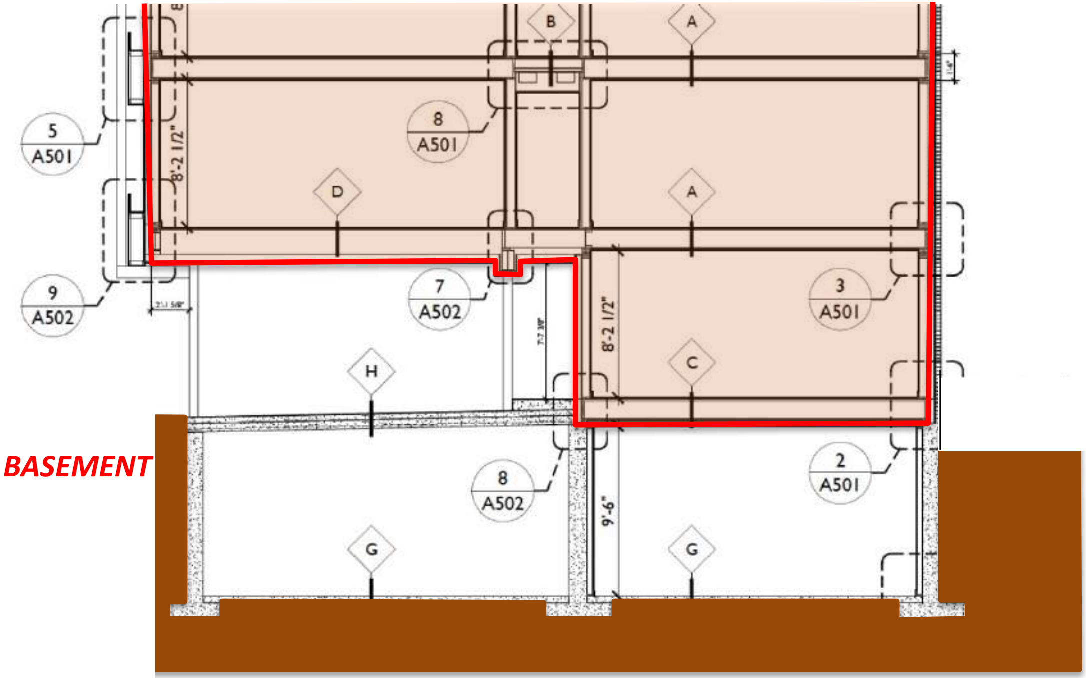


BASEMENT

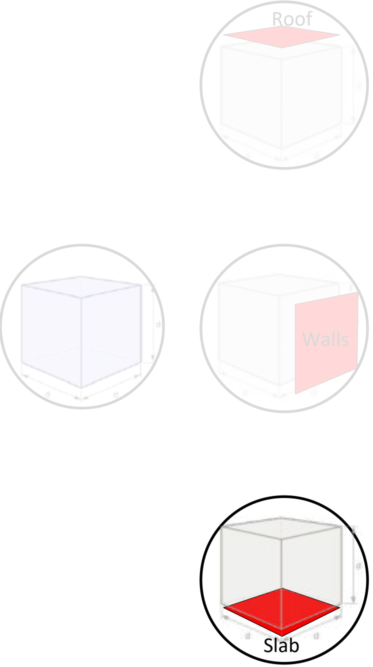


South Point, Innova Development services

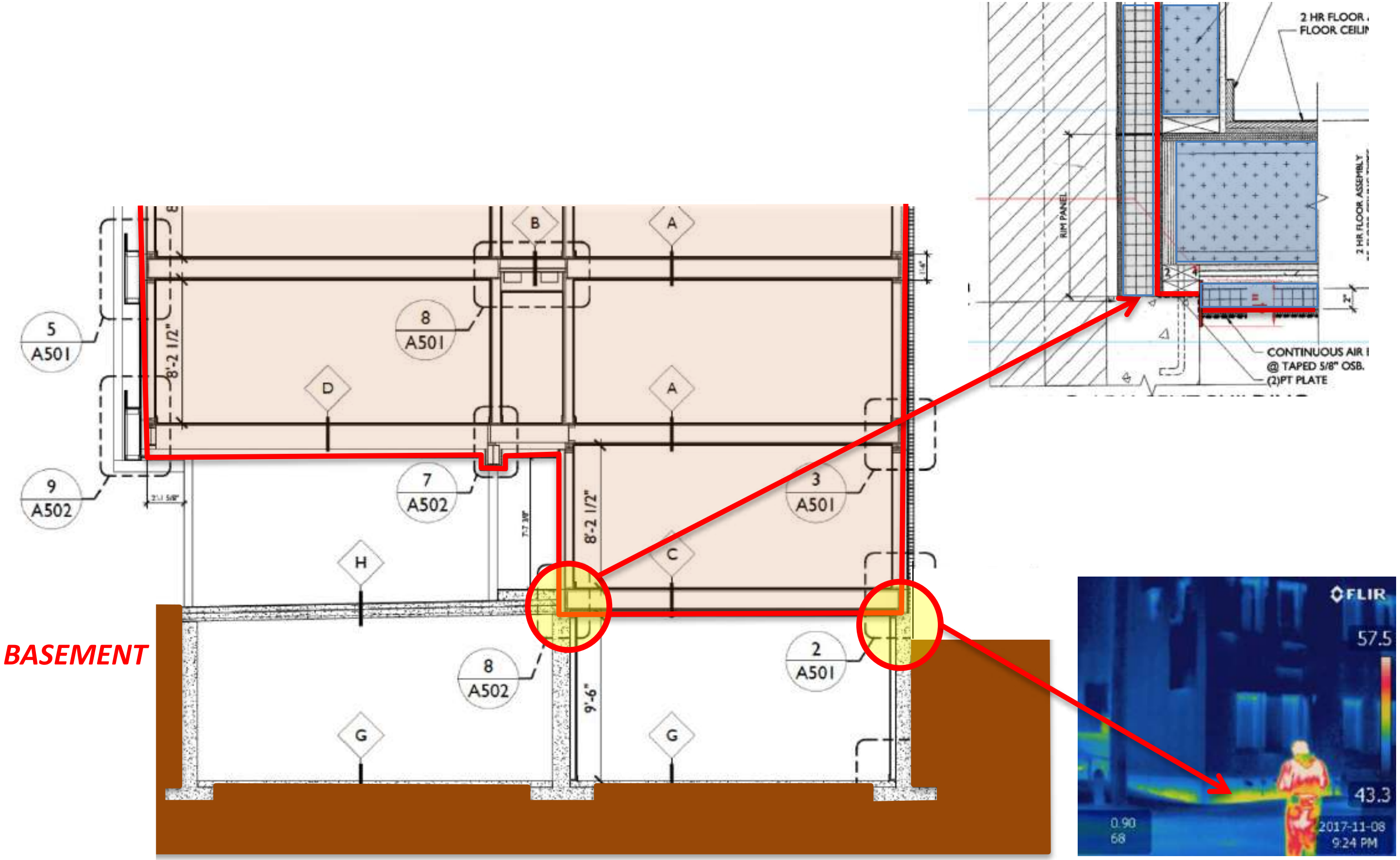




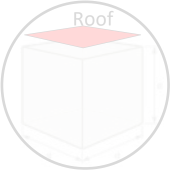
The Battery, PHIUS + Certified, 2017: Basement OUTSIDE of the thermal envelop

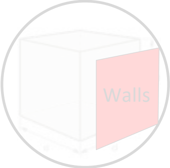


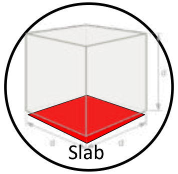
BASEMENT



The Battery, PHIUS + Certified, 2017: Basement OUTSIDE of the thermal envelop







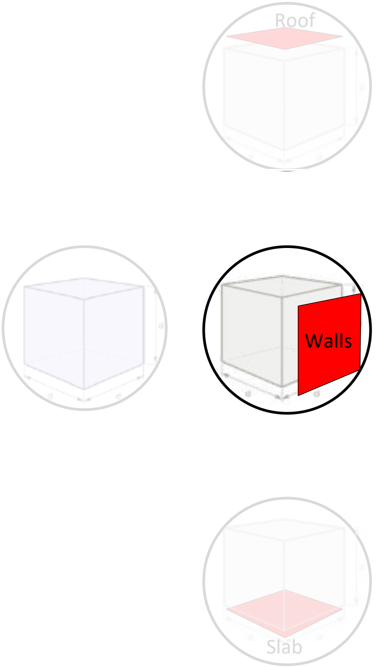
BASEMENT

PROS

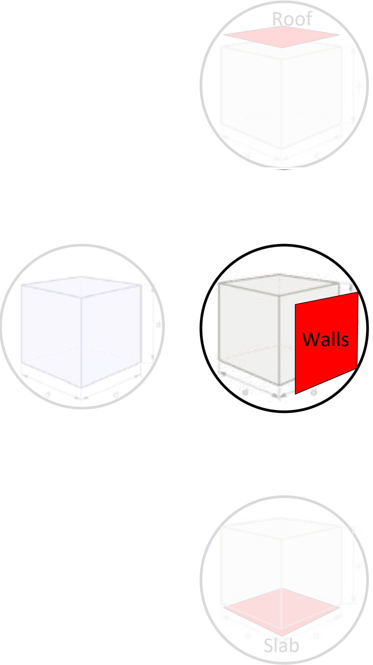
- Space for storage and utilities
- Can have basement INSIDE or OUTSIDE of the thermal envelop
- Conventional construction skills

CONS

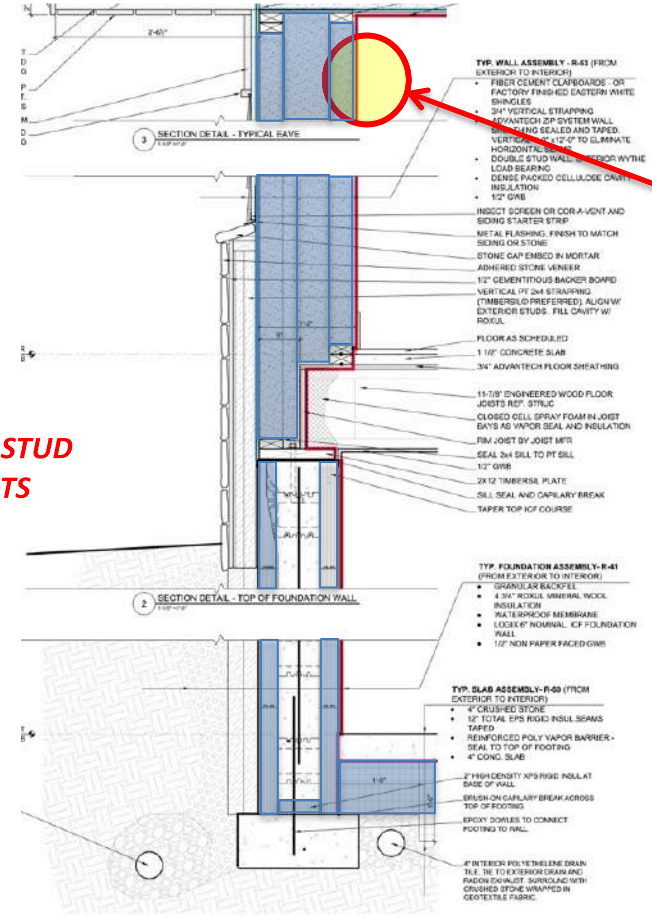
- Expensive, especially if basement is INSIDE thermal envelop



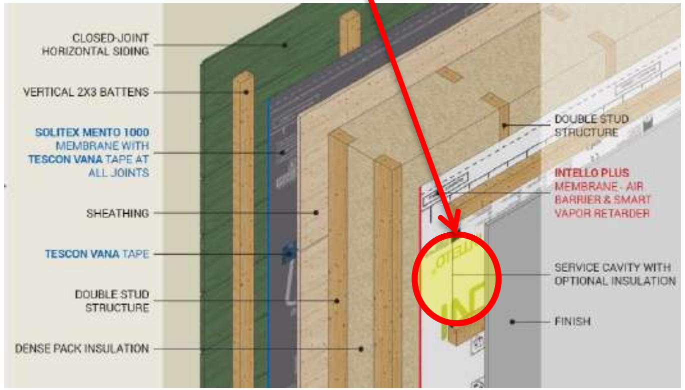
DOUBLE STUD
I-JOISTS



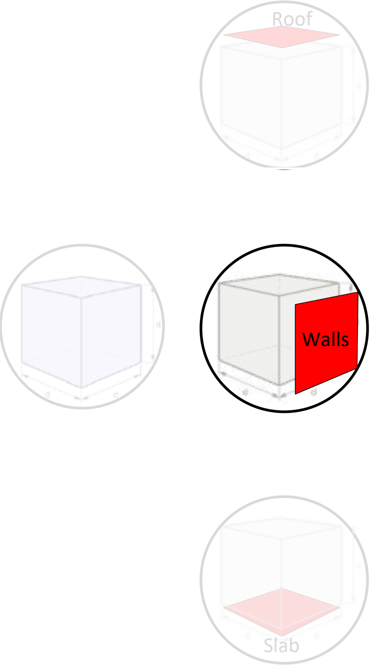
DOUBLE STUD
I-JOISTS



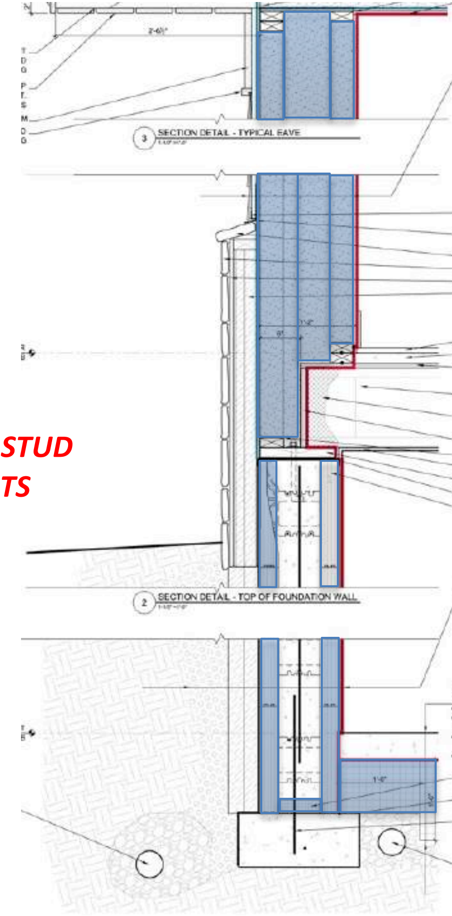
Air-Barrier on INTERIOR



Above: wall section of Edgewaterhaus, Green design Studio, Double stud wall with air barrier on INTERIOR
Right: 475 detailing of double stud wall with Intello plus air-barrier membrane on interior, Mento WRB on exterior



DOUBLE STUD
I-JOISTS



TYP. WALL ASSEMBLY - R-63 (FROM EXTERIOR TO INTERIOR)
- FIBER CEMENT CLAPBOARDS - OR FACTORY FINISHED EASTERN WHITE SHINGLES
- 3/4" VERTICAL STRAPPING
- ADVANTECH ZIP SYSTEM WALL SHEATHING SEALED AND TAPED. VERTICAL 4'-0" x12'-0" TO ELIMINATE HORIZONTAL SEAMS
- DOUBLE STUD WALL. EXTERIOR WYTHE LOAD BEARING
- DENSE PACKED CELLULOSE CAVITY INSULATION
- 1/2" GWB

INSECT SCREEN OR COR-A-VENT AND SIDING STARTER STRIP

METAL FLASHING. FINISH TO MATCH SIDING OR STONE

STONE CAP EMBED IN MORTAR

ADHERED STONE VENEER

1/2" CEMENTITIOUS BACKER BOARD

VERTICAL PT 2x4 STRAPPING (TIMBERSIL© PREFERRED). ALIGN W/ EXTERIOR STUDS. FILL CAVITY W/ ROXUL

FLOOR AS SCHEDULED

1 1/2" CONCRETE SLAB

3/4" ADVANTECH FLOOR SHEATHING

11-7/8" ENGINEERED WOOD FLOOR JOISTS REF. STRUC

CLOSED CELL SPRAY FOAM IN JOIST BAYS AS VAPOR SEAL AND INSULATION

RIM JOIST BY JOIST MFR

SEAL 2x4 SILL TO PT SILL

1/2" GWB

2X12 TIMBERSIL PLATE

SILL SEAL AND CAPILARY BREAK

TAPER TOP ICF COURSE

TYP. FOUNDATION ASSEMBLY- R-41 (FROM EXTERIOR TO INTERIOR)
- GRANULAR BACKFILL
- 4 3/4" ROXUL MINERAL WOOL INSULATION
- WATERPROOF MEMBRANE
- LOGIX 6" NOMINAL ICF FOUNDATION WALL
- 1/2" NON PAPER FACED GWB

TYP. SLAB ASSEMBLY- R-60 (FROM EXTERIOR TO INTERIOR)
- 4" CRUSHED STONE
- 12" TOTAL EPS RIGID INSUL SEAMS TAPED
- REINFORCED POLY VAPOR BARRIER - SEAL TO TOP OF FOOTING
- 4" CONC. SLAB

2" HIGH DENSITY XPS RIGID INSUL AT BASE OF WALL

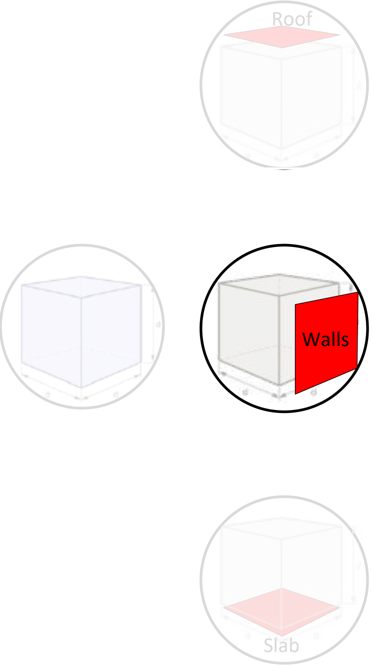
BRUSH-ON CAPILARY BREAK ACROSS TOP OF FOOTING

EPOXY DOWLES TO CONNECT FOOTING TO WALL

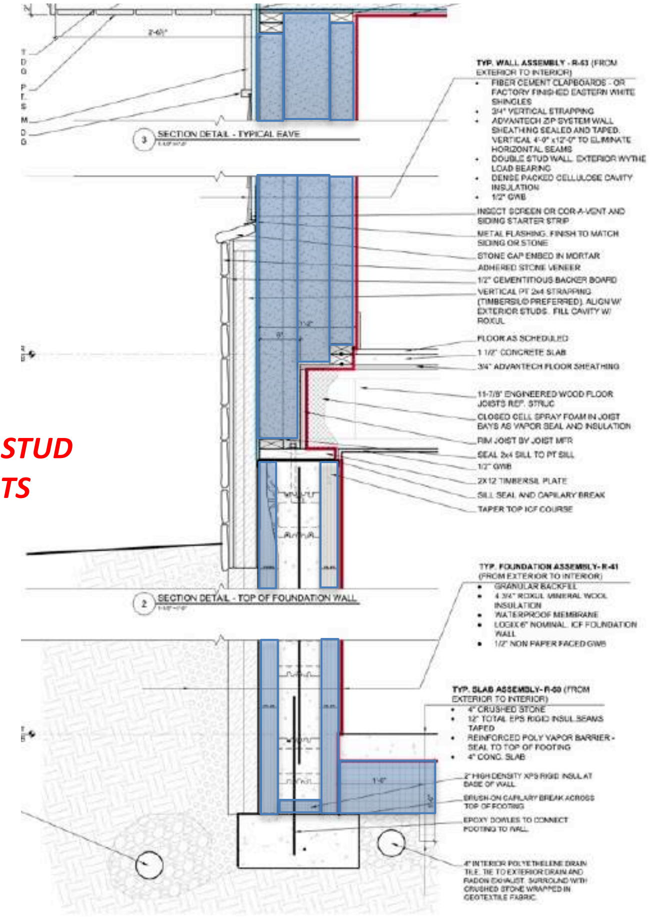
4" INTERIOR POLYETHELENE DRAIN TILE. TIE TO EXTERIOR DRAIN AND RADON EXHAUST. SURROUND WITH CRUSHED STONE WRAPPED IN GEOTEXTILE FABRIC.

SITE BUILD

Above: wall section of Edgewaterhaus, Green design Studio, Double stud wall with air barrier on INTERIOR
Right: Health Net Zero

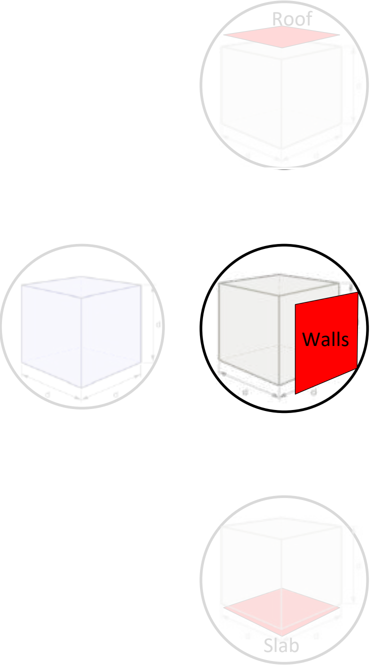


DOUBLE STUD
I-JOISTS

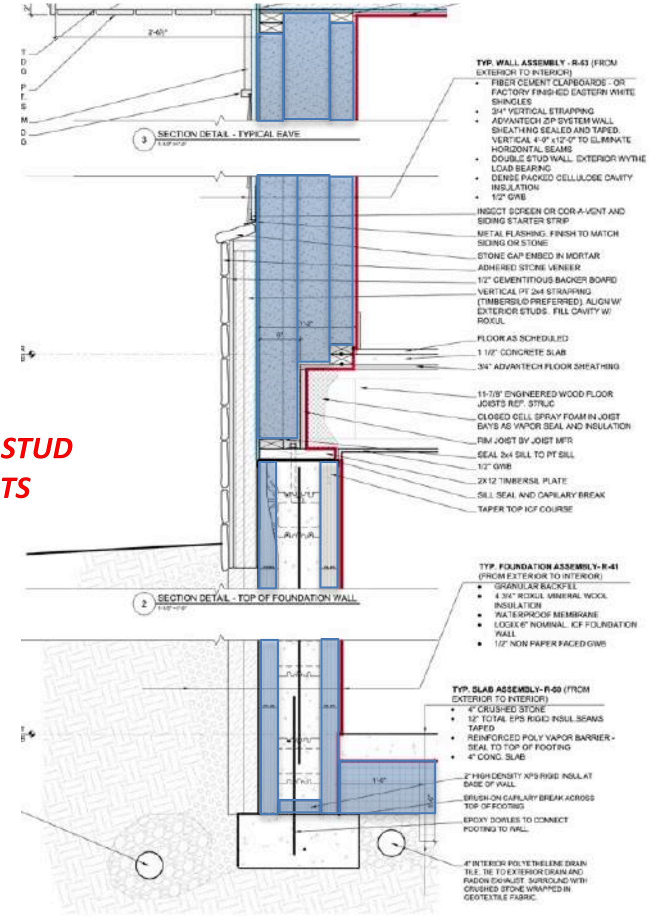


PREFABRICATION

Above: wall section of Edgewaterhaus, Green design Studio, Double stud wall with air barrier on INTERIOR
Right: Ecocor, prefabricated I-JOIST wall system.



DOUBLE STUD
I-JOISTS



PREFABRICATION

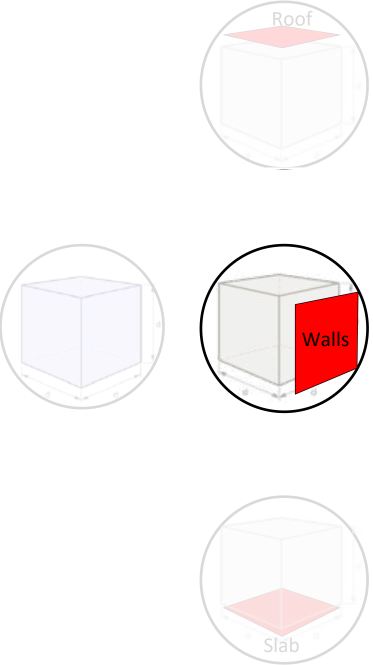
ECOCOR

Above: wall section of Edgewaterhaus, Green design Studio, Double stud wall with air barrier on INTERIOR
Right: Ecocor, prefabricated I-JOIST wall system for Gerard Haus.

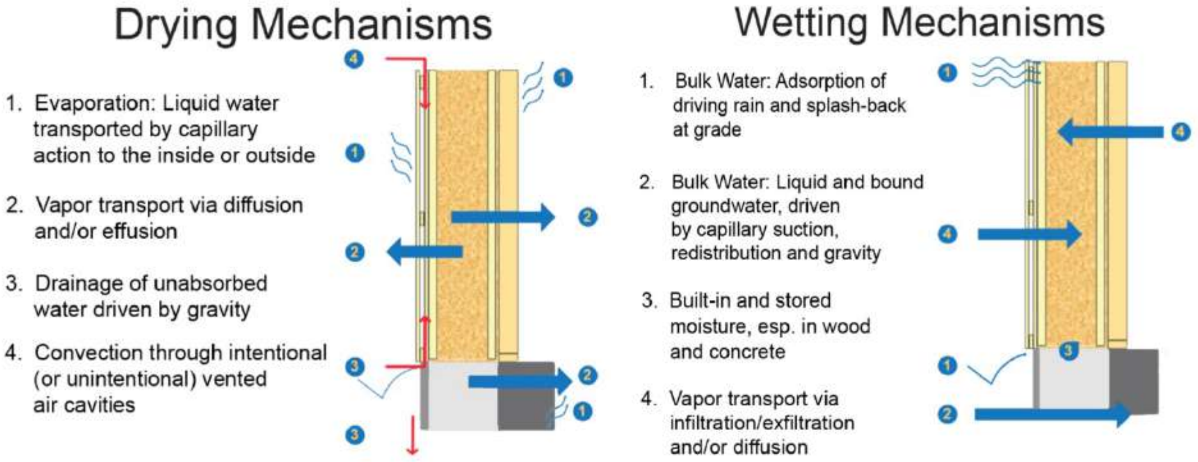
VAPOR OPEN

- ***Dense-packed cellulose/fibre-glass in cavity***
- ***Rigid insulation on exterior fully open drying potential***

(Rockwool, Gutex, cork…)



DOUBLE STUD
I-JOISTS



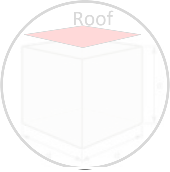
Drying Mechanisms

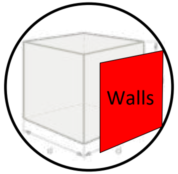
1. Evaporation: Liquid water transported by capillary action to the inside or outside
2. Vapor transport via diffusion and/or effusion
3. Drainage of unabsorbed water driven by gravity
4. Convection through intentional (or unintentional) vented air cavities

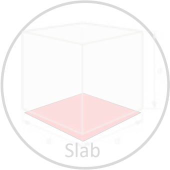
Wetting Mechanisms

1. Bulk Water: Adsorption of driving rain and splash-back at grade
2. Bulk Water: Liquid and bound groundwater, driven by capillary suction, redistribution and gravity
3. Built-in and stored moisture, esp. in wood and concrete
4. Vapor transport via infiltration/exfiltration and/or diffusion

Diagrams by Ecocor







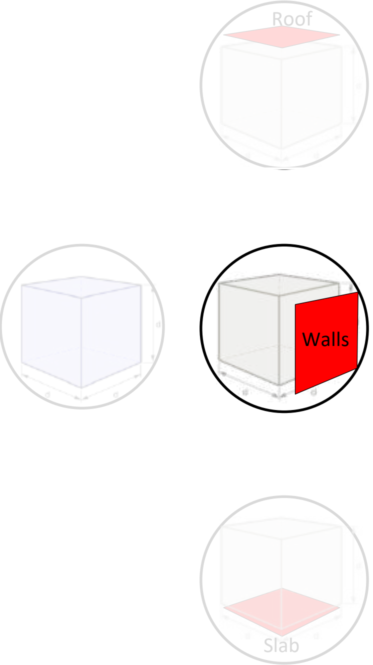
DOUBLE STUD I-JOISTS

PROS

- Less global warming potential for non-foam insulations used
- Insulation maintains R-value in extreme temperatures
- Manages moisture through dispersion and diffusion

CONS

- Expensive intelligent membranes: labor and materials
- Interior Air-Barrier difficult and costly to detail
- Not common construction and therefore significant training required
- Construction sequencing issues



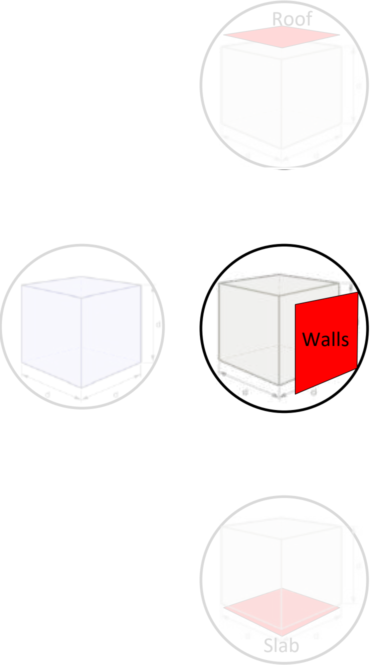
***STUD WALL W/
EXTERIOR
INSULATION***

THE COMMUNITY BUILDERS

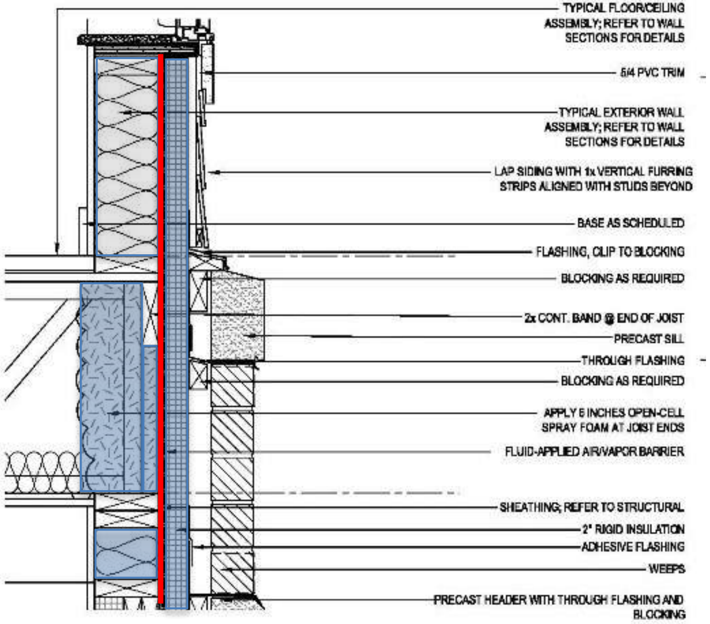
RDL ARCHITECTS

SOTA CONSTRUCTION SERVICES, INC.

SITE BUILD



STUD WALL W/ EXTERIOR INSULATION



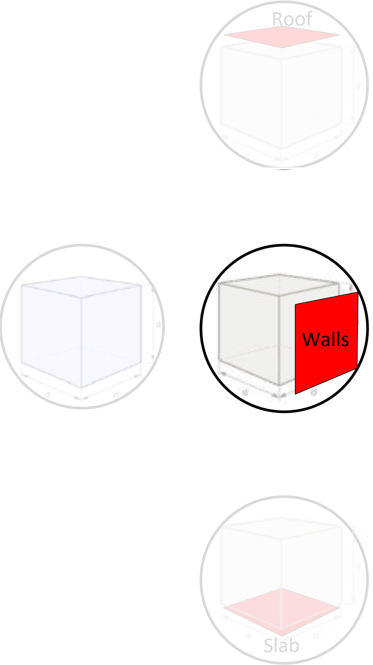
Hillcrest Senior Residences: Typical wall/floor connection

THE COMMUNITY BUILDERS

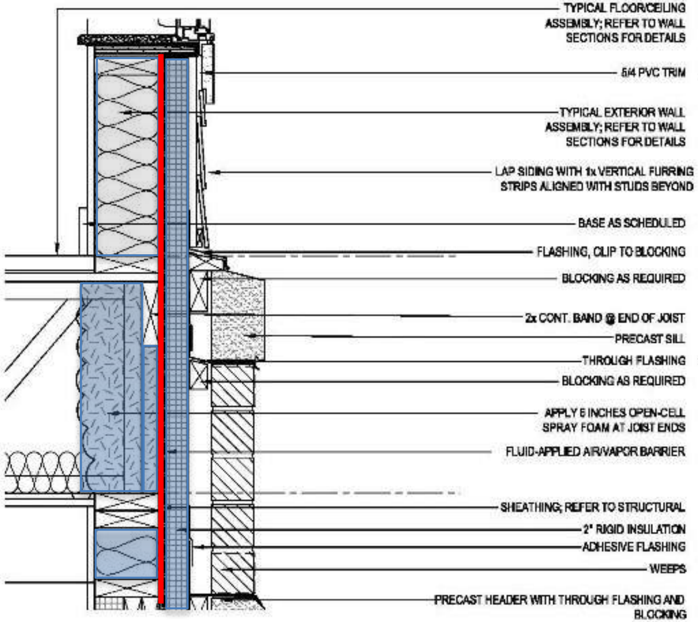
RDL ARCHITECTS

SOTA CONSTRUCTION SERVICES, INC.

SITE BUILD



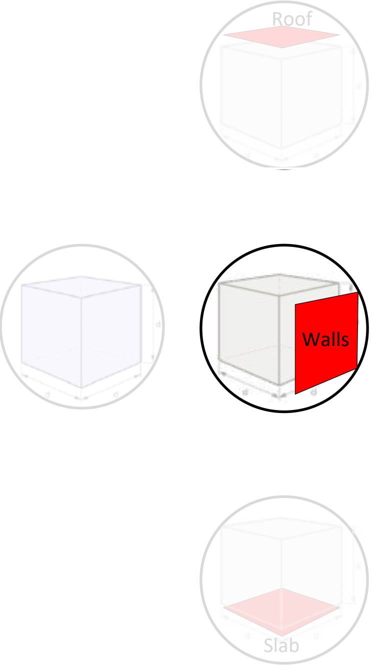
STUD WALL W/ EXTERIOR INSULATION



Sacred Heart Residences, Pennrose Properties, Kitchen & Ass., WRT PH Consultant: SITE BUILD WALLS

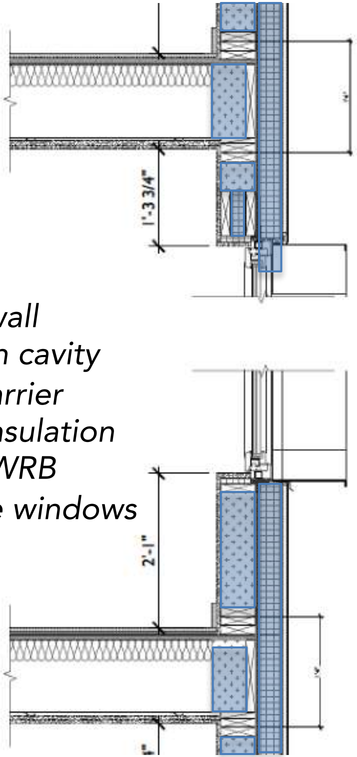
BUILDSMART

PREFABRICATED



STUD WALL W/ EXTERIOR INSULATION

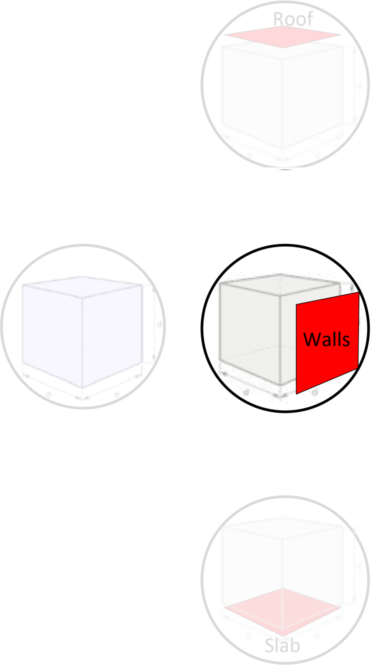
- *2X6 Stud wall*
- *Cellulose in cavity*
- *OSB Air-barrier*
- *3.5″ EPS Insulation*
- *Zip panel WRB*
- *Triple pane windows*



The Battery, PHIUS + Certified, 2017: Buildmart prefabricated wall system, windows/doors installed

BUILDSMART™

PREFABRICATED
Under roof in ONE MONTH!

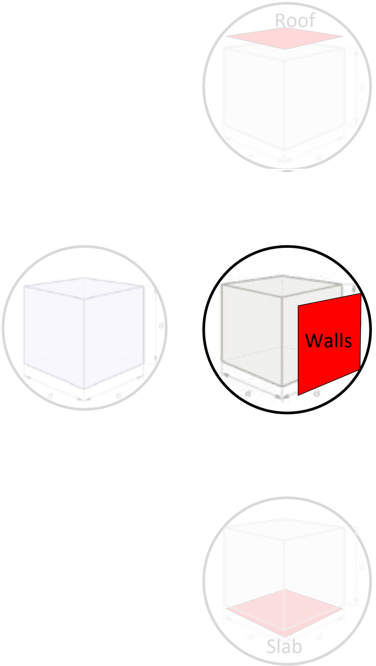


STUD WALL W/ EXTERIOR INSULATION

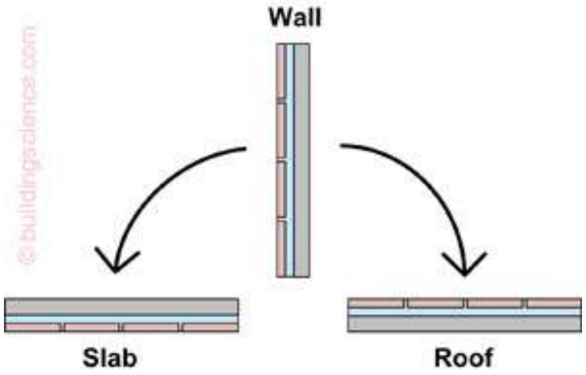
The Battery, PHIUS + Certified, 2017: Buildmart prefabricated wall system, windows/doors installed

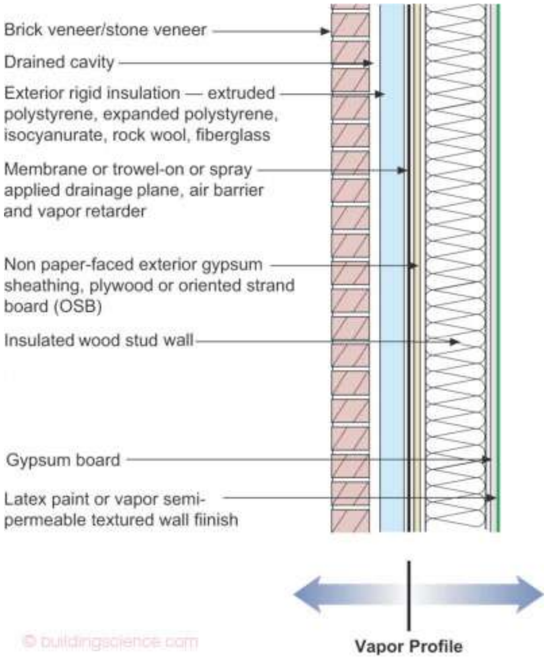
VAPOR CLOSED

- ***Dense-packed cellulose, spray foam, fibre-glass in cavity: Vapor in cavity drys to the INSIDE***
- ***Rigid insulation on exterior (Typical: polyisocianurate, EPS, XPS, Rockwool)***

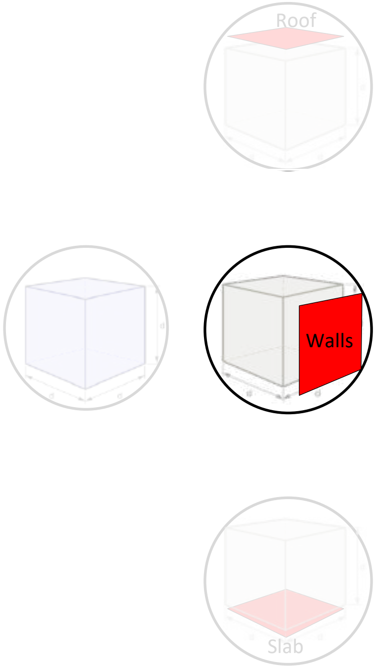


STUD WALL W/ EXTERIOR INSULATION





"The Perfect Wall", Building Science Corp



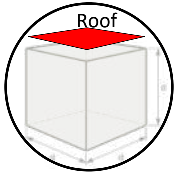
STUD WALL W/ EXTERIOR INSULATION

PROS

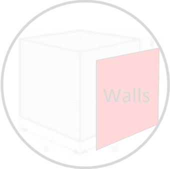
- Most Cost Effective
- Air Barrier is on OUTSIDE, which reduces penetrations
- Everyday framing techniques, little training needed
- With prefabrication, quality control is greatly enhanced

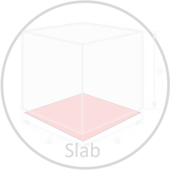
CONS

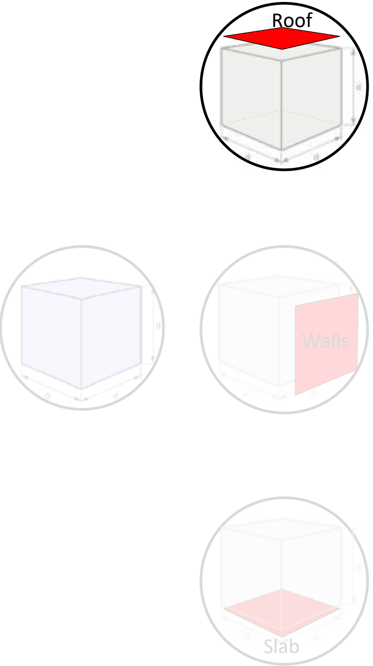
- Exterior insulation adds costs and labor
- Some foams degrade in R-value over time.



PITCHED

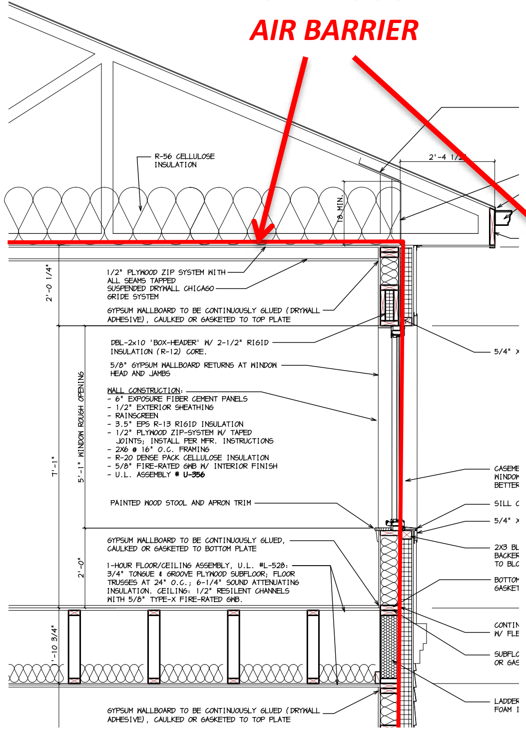




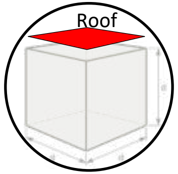


PITCHED

CONTINUOUS AIR BARRIER



The Whitehall, PHI Certified 2017, Mission First Housing: Critical air barrier juncture at ceiling



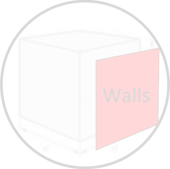
PITCHED

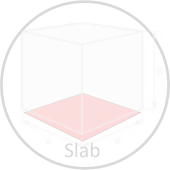
PROS

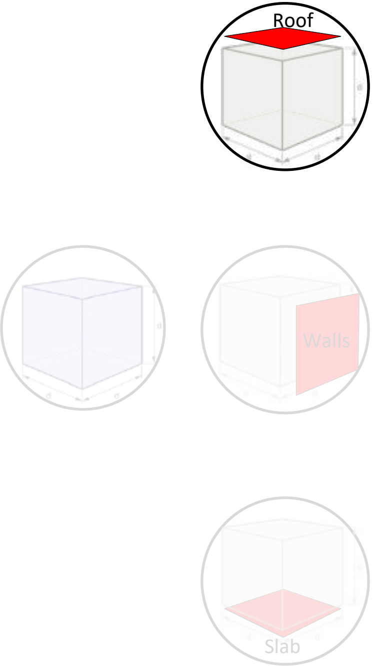
- Cost Effective roof system
- Everyday framing techniques, little training needed
- Pitch of roof to be used for maximizing solar PV pitch

CONS

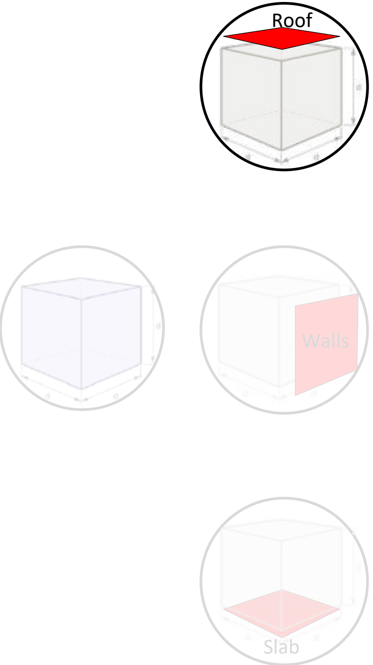
- Limited aesthetic possibilities
- Need for additional layer for air barrier, most costly





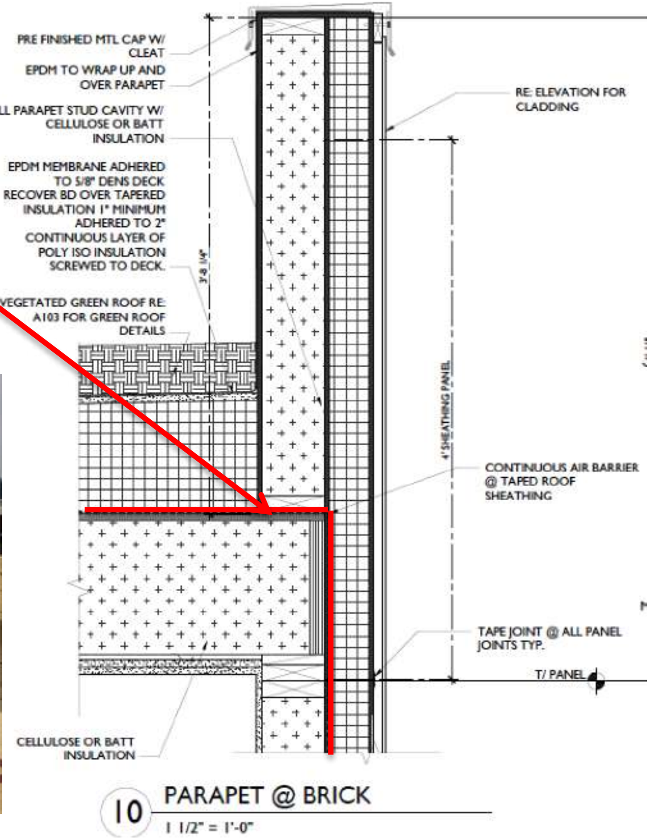


FLAT



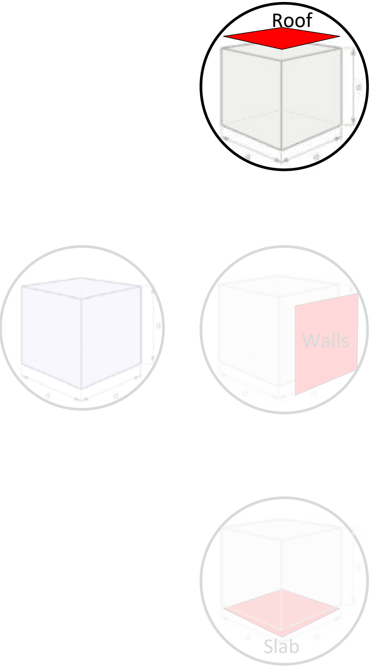
FLAT

ROOF SHEATING DOUBLES AS AIR BARRIER



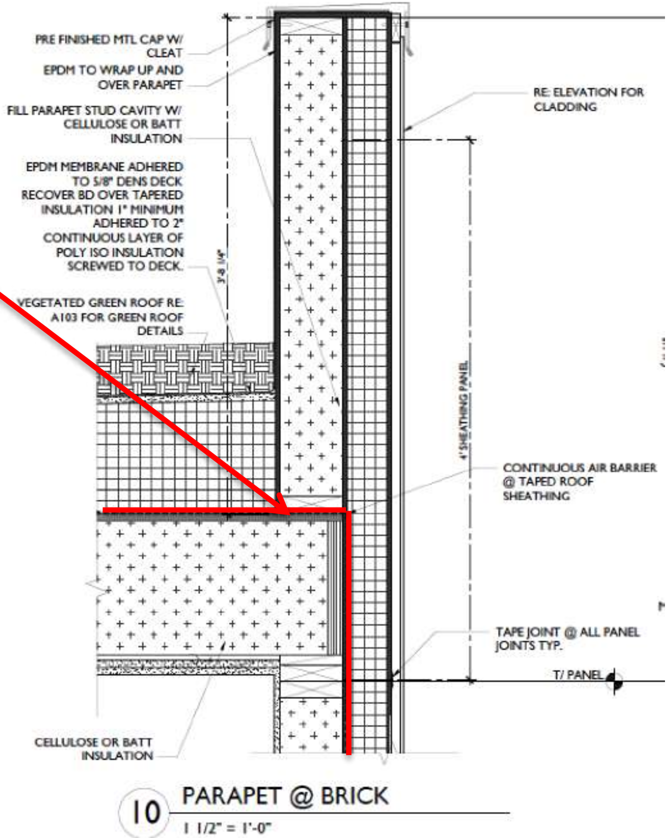
10 PARAPET @ BRICK
1 1/2" = 1'-0"

The Battery, PHIUS + Certified, 2017: FLAT ROOF, green roof, roof sheathing doubles as Air Barrier

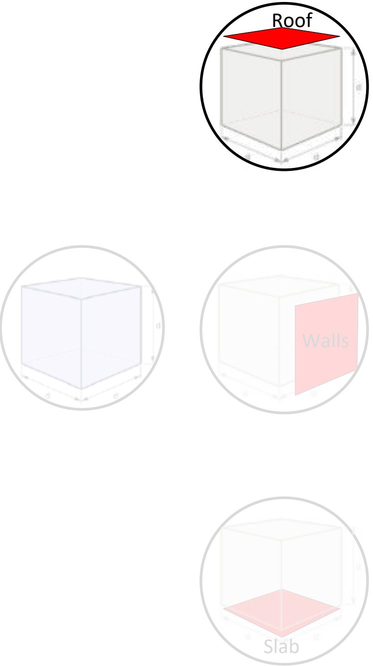


FLAT

ROOF SHEATING DOUBLES AS AIR BARRIER

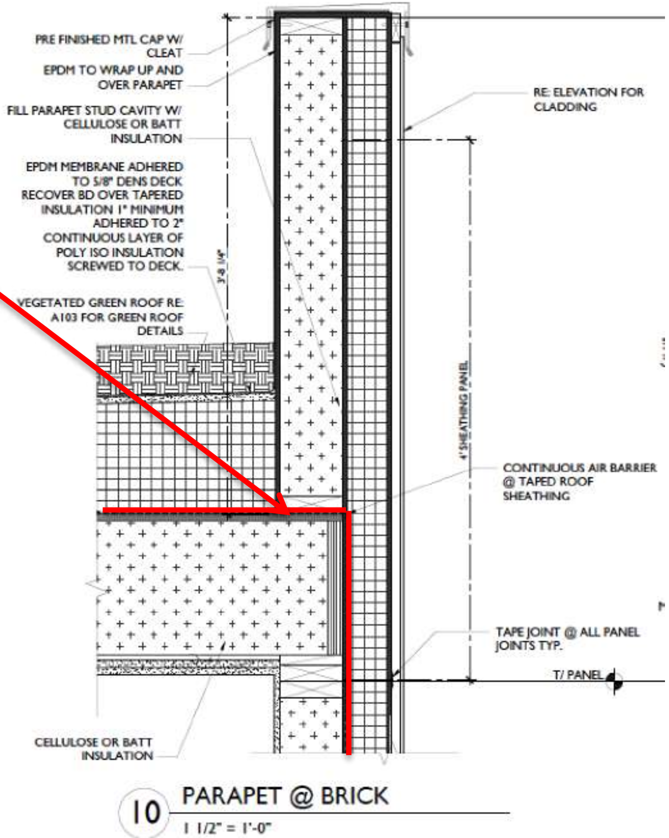


The Battery, PHIUS + Certified, 2017: FLAT ROOF, green roof, roof sheathing doubles as Air Barrier

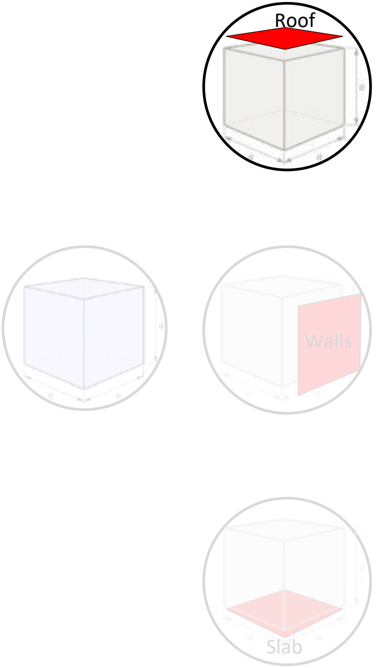


FLAT

ROOF SHEATING DOUBLES AS AIR BARRIER



The Battery, PHIUS + Certified, 2017: FLAT ROOF, green roof, roof sheathing doubles as Air Barrier



FLAT

PROS

- Air Barrier to double as roof sheathing, cost effective
- Widens aesthetic possibilities
- Has potential for green roof and stormwater management
- Ease of installation, most cost effective

CONS

- More costly water proof membranes compared to asphalt shingles

Wynne Senior Residences - 4 Stories, 51 Units, 44,000 SF

- Multi Meter
- Decentralized Heating / Cooling: Ducted Mini Split
- Decentralized ERVs
- Centralized Gas DHW
- Centralized Electric Dryers
- Site Built Foundation and 2x6 Wall Systems w/Exterior Insulation
- Flat Roof

STEP #1

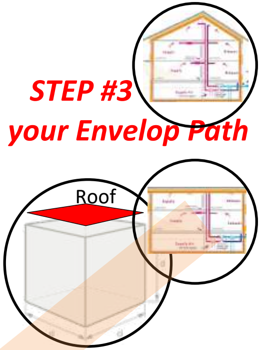
Define your Energy Path

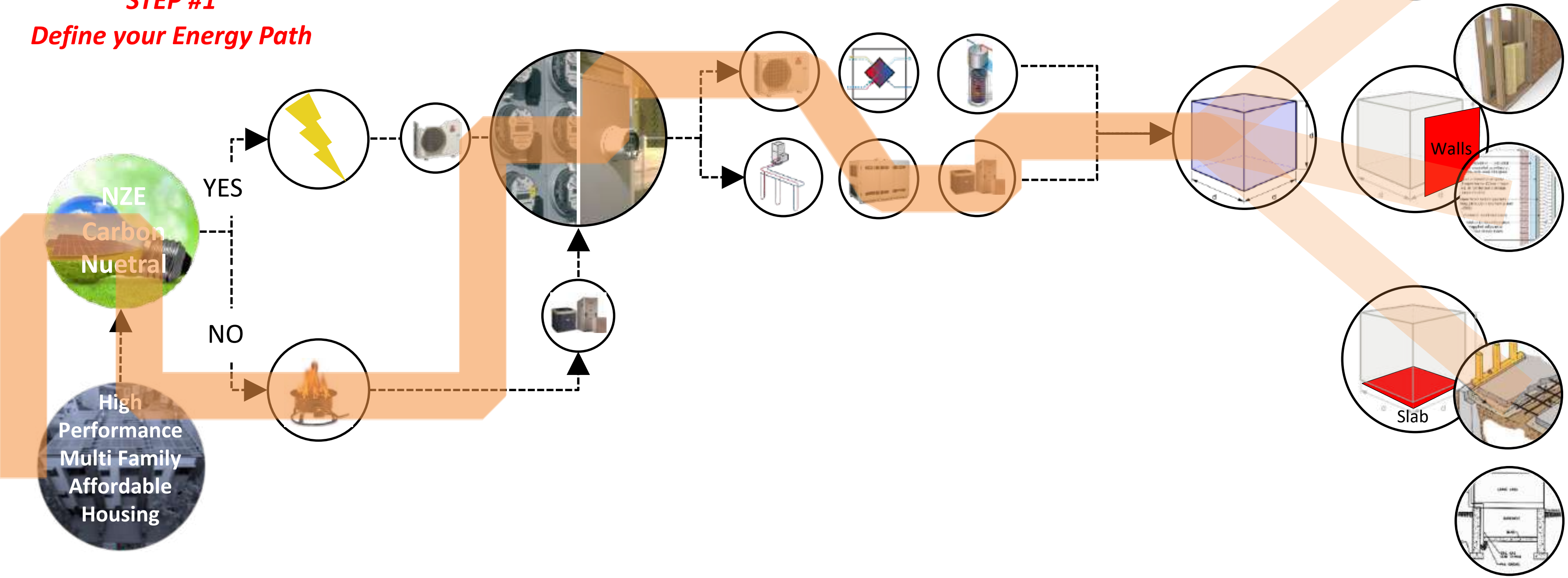
STEP #2

Define your Systems Path

STEP #3

Define your Envelop Path

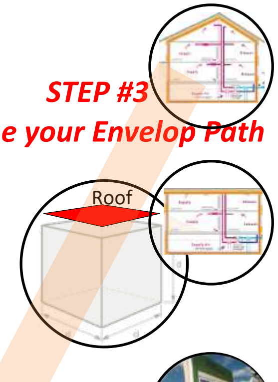




The Whitehall - 3 Stories, 49 Units, 43,000 SF

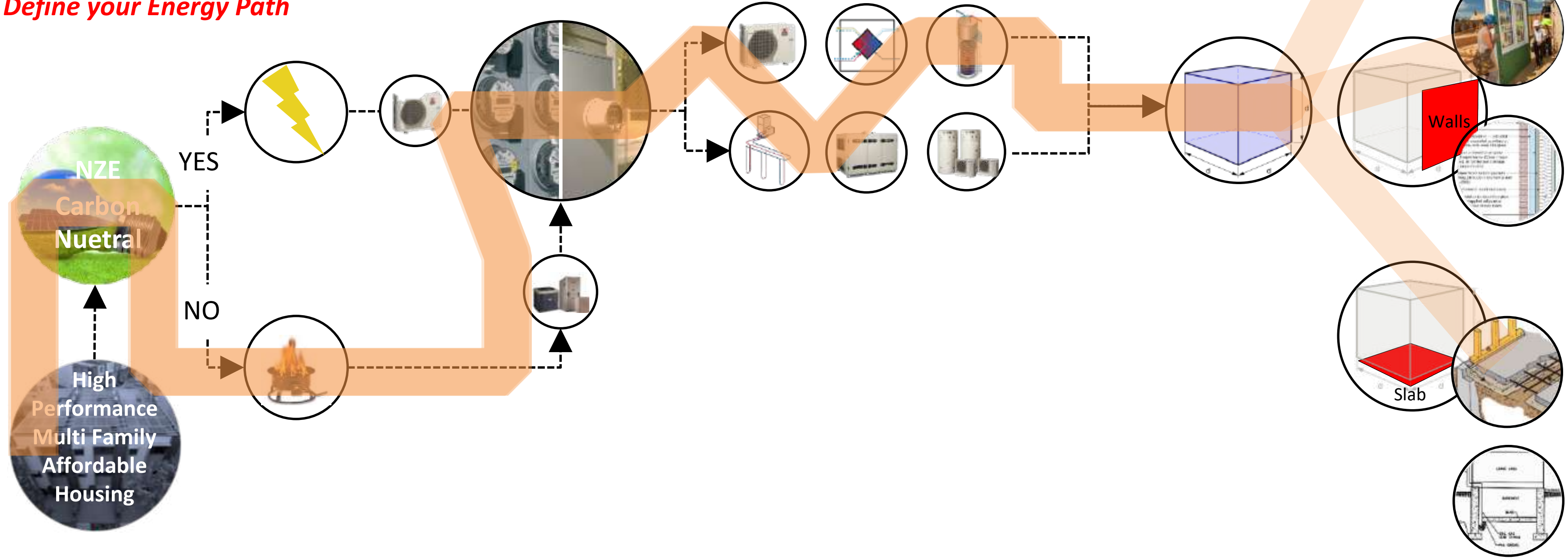
- Multi Meter
- Decentralized Heating / Cooling: Ducted Mini Split
- Decentralized DHW: 50 gal HPWH/Unit
- Centralized ERV
- Centralized Gas Dryers
- Prefabricated Build Smart Foundation and Wall Systems
- Pitched Roof

STEP #3
Define your Envelop Path



STEP #2
Define your Systems Path

STEP #1
Define your Energy Path



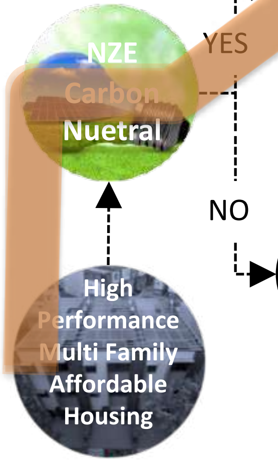
The Battery - 4 Stories, 25 Units, 17,000 SF

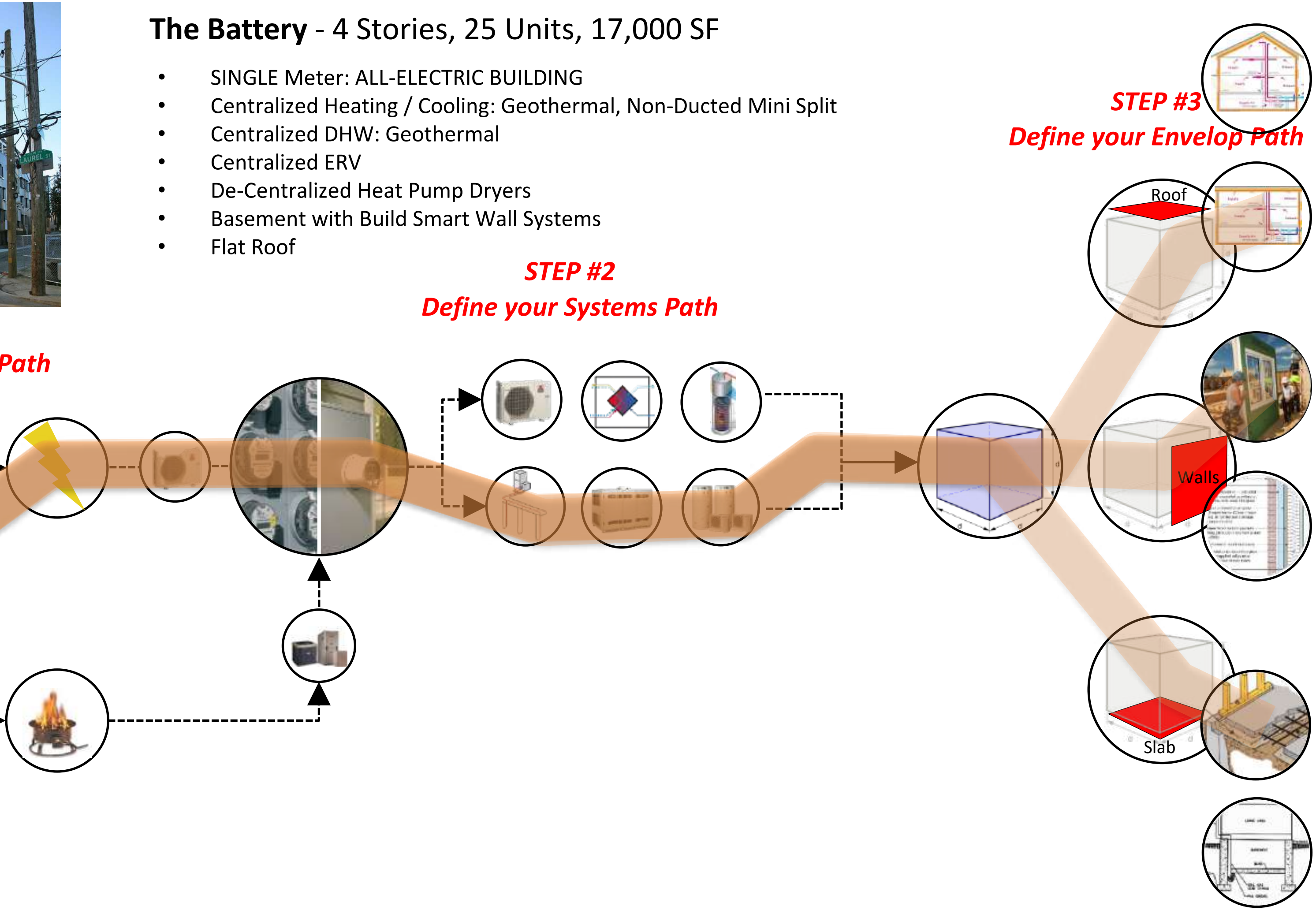
- SINGLE Meter: ALL-ELECTRIC BUILDING
- Centralized Heating / Cooling: Geothermal, Non-Ducted Mini Split
- Centralized DHW: Geothermal
- Centralized ERV
- De-Centralized Heat Pump Dryers
- Basement with Build Smart Wall Systems
- Flat Roof

STEP #1
Define your Energy Path

STEP #2
Define your Systems Path

STEP #3
Define your Envelop Path





Net Zero Village, Rotterdam, NY

zHomes, Issaquah, WA

The Grand Islander, Ilikai Hotel & Luxury Suites, Aston at the Executive Centre, Hilton Hawaiian Village, Waikiki Beach, HI

A Zero Emissions All-Electric Multifamily Construction Guide

The Battery, Philadelphia, PA

Mutual Housing at Spring Lake

REDWOOD ENERGY

SEAN ARMSTRONG: seanarmstrongpm@gmail.com

Domestic Hot Water

The following section provides electric alternatives to gas water heaters, from tiny tanks to water heaters for high rises. This list includes tankless water heaters one might use in commercial bathrooms, heat pump water heaters with integrated tanks (common in new homes), heat pump water heaters using remote tanks (helpful for retrofits), and larger water heaters for whole-house hydronic HVAC.

Large Building Applications (240V-480V)

Apartment buildings, hotels and large commercial facilities usually heat water in a central plant and plumb it throughout the building. These large heat pumps range from 10 tons to 260 tons (1 ton = 12,000 BTUh) and like any central system they require careful design of the pumps, heat exchangers and storage tanks to optimize energy use and heat pump operation. The range of operating temperatures is important—each product has a different maximum output temperature, between 120F and 180F, and a minimum operating temperature between 5F and 45F before it switches off the heat pump and uses resistance to heat the water. Resistance heating, which is 100% efficient vs. the heat pump which is 200-400% efficient should be minimized in order to get the maximum efficiency of heat pump water heaters. Distributed central systems offer an alternative to larger central systems, they are more flexible and reduce the size of heat pumps and the distribution system.

> *On the cost of large central heat pumps: "It is very difficult to get contractors to provide pricing for subsets of work within a larger scope, below is some of the best data we have to date—$1,359/Apt, an incremental cost of $600/apartment more than using a gas boiler, but the estimate does not include the savings from eliminating gas service, which can be $600-$1000/apartment."*
> ***– Shawn Oram, Ecotope***

Large Applications Domestic Hot Water (240V-480V)

	Colmac **CxA** 	***Colmac*** ***CxV*** 	**Mayekawa Unimo "Eco Cute"** HE-HWA-2HTC 	**Aermec ANK** (030,045,050) 	**AO Smith** CHP-120 	**Nyle** (C25A-CSA250A) 
Description	Air source heat pump water heater	Air source heat pump water heater	Water source heat pump water heater	**Multipurpose heat pump -** single unit	Heat pump water heater w/ 112 gal tank	Air source heat pump water heater
Voltage (V)	230/460	230/220	400	208/230	208/240	208/230
Dimension (ft)	3W	-	4.1W x 6.2L x 6.8H	4.2H x 4.8W x 1.5D	5.7H x 1.91W x 3.25D	7L x 4.6W x 5.6H
Ref. Type	R134a	R134a	R744 (CO2)	R134a	134a	134a
Ambient Temp. Range (F)	10 (low)	**-4 – 120 (cold climate)**	14 - 110	45 - 113	20 - 110	40 - 120
Power (W)		4,900 – 6,300		2,810 – 4,520	2,350	-
Amps (A)	21.1 – 86.5	36.8	120	45	67	6.2 -23.9
Heating Cap. (BTUh)	137,500 – 419,400	31,200 – 77,900	200,600 – 284,200	37,670 – 57,598	37,977	27,450 – 272,450
Cooling Cap. (BTUh)	109,700 – 334,100	17,300 – 60,700	-	30,120 – 48,240	-	21,200 – 218,000
Heating (COP)	4.0 - 4.2	1.8 – 3.7	3.40 – 3.89	3. 1 – 4.4	4.2	4.45 - 5.18
Cooling (COP)	3.2 – 3.5	1.0 – 2.9	2.62 – 3.28	-	-	3.88 - 4.20

Individual Heat Pump Water Heaters (240V)

The below water heaters all rely upon heat pumps - no resistance models are shown due to their inefficiency. These products rely on 30-80 gallons of water storage and collect 2.4 – 3.8 units of heat for every one unit of electricity powering the air source heat pump. Some have a 4000 BTU compressor integrated on top of the tank, others use a 12,000-36,000 BTU separate compressor outside that produces more BTUs at a higher efficiency. These models can be used as either serving one dwelling unit or can be combined in a distributed central plant to feed multiple units.

	Sanden CO2 	**Rheem** Prestige Hybrid 	**AO Smith** Voltex Hybrid 	**Bradford White** AeroTherm 	**Steilbel Eltron** Accelera 
Description	Split heat pump water heater	Hybrid (WIFI option adds $150/tank)	Hybrid	Hybrid	Hybrid
Gallons	43, 83	50, 65, 80	50, 66, 80	50, 80	58, 80
Voltage (V)	208/230	208/240	208/240	208/240	220/240
Dimension (ft)	27.5H x 35W x 11D	74H x 24Diam.	69H x 27Diam.	71H x 25Diam.	60H x 27Diam.
Ref. Type	R744 (CO2)	R134a	R134a	R134a	R134a
Ambient Temp. Range (F)	**-20 – 110 (cold climate)**	37 – 145	45 - 109	35 – 120	42 – 108 / 6 – 42
Power (W)			4,500	550 – 4,500	650 - 1500
Max Amps (A)	13	15 – 30	30	30	15
Heating (BTUh)	15,400	4,200	-	-	5,800
Heating (COP)	5.0	-	-	-	-
Energy Factor	3.09 – 3.84	3.55 – 3.70	3.06 – 3.61	2.40 – 3.39	3.05 – 3.39

Small Demand and Low Voltage Applications (120V)

Electric resistance water heaters are best used where hot water is needed in small amounts or when a project requires strict voltage limitations. Tankless water heaters can be used in a restaurant or office bathroom, or a 120 sf tiny house that has no room for a 50-gallon tank or that is not sharing water system with other tiny homes. Electric resistance uses 2 - 4 times more energy than a heat pump but can be the right size for the right demand and they are helpful when there is no 220V electricity available. The 2 to 7-gallon tanks on the market use 120V, while anything larger uses 240V for more heating capability.

	Stiebel Eltron Mini-E Series 	**Stiebel Eltron** SHC Series 	**Bosch Tronic** 3000 Series 
Description	Tankless, Point of use	Mini tank, Point of use	Mini tank, Point of use
Gallons	0.21 (gpm)	6, 4, 2.7	7, 4, 2.7
Voltage (V)	120/110	110/120	120
Dimension (ft)	6H x 7W x 3D	20H x 15W x 15D	17H x 17W x 14D
Power (W)	1,800	1,300	1,440
Max Amps (A)	15	11.3	12
Heating (COP)	0.98	0.98	0.98

Best Practices for Heat Pumps Central Domestic Hot Water Systems[64]

Using heat pumps to provide space cooling dates to the 1920s, for space heating to the 1940s, but using compressors to heat domestic hot water for cafeterias, apartment complexes, dairies[65] and other large uses dates only to the 1970s, and has advanced further in Asia where efficiency is more valued. Consequently, there is less familiarity among North American designers of both the products and practice of designing commercial hot water systems using heat pumps. Below is helpful guidance from the engineers at Ecotope of Seattle, the most experienced designers (25 systems so far) of central domestic hot water heat pumps in North America.

1. ***Heat pumps are not boilers***. Do not oversize the central heat pump for faster recovery, which leads to both higher construction costs and equipment failure. Instead use a series of dispatchable 5-15 ton heat pumps, rather than one larger (e.g. 60 ton) heat pump, and favor hot water storage over hot water production.
2. When designing hot water systems, ***split the pipe recirculation heat loss load from the usage load***. Temperature maintenance of recirculating water is ideal for "multi-pass" heat pumps that handle 110F incoming water (e.g. Aermec, Daiken) and perform 10F temperature bump-ups, while meeting peak loads is best done with a "single pass" heat pump (e.g. Sanden, Colmac) that uses cold incoming water, not recirc water, to efficiently lift temperatures from 50F to 150F.
3. ***Install "heat traps"*** on both hot and cold water sides of storage tanks to prevent migration and mixing.
4. ***Reduce pipe surface area*** to greatest extent possible. Insulate remaining pipes with 1"-4" of foam, depending on space availability. Insulate tanks to at least R-19, same as an outside wall, due to the even more extreme heat loss than found in a wall.
5. ***Design diagnostics into crucial points in the heat plant and distribution system***—electrical gauges to measure power quality, temperature gauges to monitor heat gain and loss, and control valves on the discharge side of pumps to measure pump flow
6. ***Provide redundancy in heat pumps and choose electric resistance storage tanks*** for a durable, dependable design for the eventuality that system components need maintenance.
7. ***Consider adding drain line heat recovery*** to save energy while improving the hot water delivery capacity. This is a simple heat exchanger to transfer heat from the drain line to the incoming cold water input to the water heater.

Figure 12: Ecotope Case Study "RCC" system for 194 unit Multifamily building, using best practices in central heat pumps for domestic hot water, from ACEEE presentation by Shawn Oram.[64]

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[64] Several Presentation Links from Sean Oram of Ecotope are provided: Heat Pumps Are Not Boilers, Shawn Oram Presentation ZNE Retreat July 2018, RCC Pilot Project: Multifamily Heat Pump Water Heaters in Below Grade Parking Garages in the Pacific Northwest, Central Heat Pump Water Heating with 3 Case Studies

[65] C&I Case Studies in Beneficial Electrification (2018): Agribusiness: Dairy Water Heating. Retrieved from: www.cooperative.com/programs-services/bts/documents/techsurveillance/ts-beneficial-electrification-dairy-water-heating-april-2018.pdf

Heating, Ventilation and Air Conditioning

The following guide gives an overview of heating and cooling electric systems that are widely used in multifamily buildings. The sample of products shown includes large central heat pumps, mini-split heat pumps and small packaged terminal heat pumps.

Large Application Heat Pumps (240V – 480V)

Larger application heat pumps are most typically used for central air and water systems. In some cases, apartment heating, cooling and ventilation needs are met by individual units (like PTHP's). These larger systems are used for the common space loads.

	Mitsubishi City Multi Y-Series (PUHY: P72TKMU, P96TKMU, P120TKMU, P144TKMU) 	**Mitsubishi** City Multi W-Series (PQRY: P72TLMU, P96TLMU, P120TLMU, P144TLMU) 	**Mitsubishi** City Multi S-Series (PUMY: P36NHMU, P48NHMU, P60NKMU) 	**Spacepak** Solstice (Extreme) 
Description	Air source heat pump, variable refrigerant flow	Water source heat pump, variable refrigerant flow, (use w/ air source to reach ideal temps.)	Air source heat pump	Air to water, hydronic heating and cooling
Voltage (V)	208/230	230	460	230
Dimension (ft)	5.4H x 5.7W x 2.4D	3.6H x 2.9W x 1.8D		4.0H x 4.5W x 1.5D
Ref. Type	410A	410A	R410a	R410a
Ambient Temp. Range (H/C) (F)	**-13 – 60 / 12 – 115 (cold climate)**	50 – 113 / 50 - 113	**0 – 60 (cold climate)**	**-8 – 105 (cold climate)**
Power (W)	5,700 - 12,200	3,000 – 8,100	12,000 – 16,100	3,880 – 5,963
Max Amps (A)	23 - 53	12 - 35		23.5 - 31
Heating Cap. (BTUh)	80,000 - 160,000	80,000 – 137,00	42,000 – 66,000	42,240 – 66,480
Cooling Cap. (BTUh)	72,000 - 144,000	72,000 – 144,000	36,000 – 60,000	40,000
Heating (COP)	3.56 - 3.95	4.90 – 5.77	3.30 – 3.90	2.12 – 3.26
Cooling (COP)	3.72 - 4.22	5.50 – 6.05	3.25 – 4.16	2.43

Mini-Splits (240V)

Mini split systems are comprised of a compressor outside the building and a fan inside the building. Mini split systems can also have many fans inside the building, commonly referred to as multi split systems, where one outside unit serves multiple fans or zones inside the building. Having multiple zones in the building allows for a more controlled, versatile arrangement of installations and temperature settings compared to a typical split HVAC system. Zones can be at different temperature settings while still being served by one outside unit. Multi/mini split systems can be ductless (where refrigerant lines move heat around the building) or they can have mini ducts where air is moved around the building. There are pros and cons of ducts versus no ducts - having no ducts prevents duct leakage energy losses but having many refrigerant lines running through the building can cause problems if they leak. In general, mini/multi split systems are more efficient than typical HVAC systems. No ducting also has an advantage because of reduced fan loads. Larger variable refrigerant flow systems are also a form of a multi split system but on a larger scale (Mitsubishi City Multi Y-Series above).

	Fujitsu Halcyon Series 	**Mitsubishi** HyperCore FH50 	**LG** LMU18CHV 	**Gree** TERRA 09HP230V1AO 
Description	2 – 4 indoor units, XLTH models		2 zones	1 zone
Dimension (ft)	39H x 38W x 14D	36H x 9W x 12D	2.08H x 2.83W x 1.17	2.25H x 2.92W x 1.19D
Ref. Type	R410a	R410a	R410a	R410a
Ambient Temp. Range (H/C) (F)	**-15 – 75 / 14 – 115 (cold climate)**	**-15 / 115 (cold climate)**	**-4 – 64 F / 14 – 118 C (cold climate)**	5 – 75 / 5 - 118
Power (W)	1,330 – 2,700	1,380 – 1,480	1.31 – 2.04	60 - 65
Max Amps (A)	16.4 - 26	13.6	11.09	7.0
Heating Cap. (BTUh)	22,000 – 36,400	10,900 – 30,700	17,000	9,800
Cooling Cap. (BTUh)	18,000 – 35,200	8,500 – 26,600	15,600	9,000
Heating (COP)	3.60 – 4.04	3.07 - 4.85	3.0	3.2 - 3.8
Cooling (COP)	3.52 – 3.60	3.31 – 5.10		3.66 – 4.25

Ducted Minisplit Heat Pumps

	Carrier 38MGQC183 	**Mitsubishi** MXZ3C24NAHZ2 	**Senville** SENA/18HF/ID 	**Gree** MULTI18HP230V1BO 
Indoor Unit Dimension (in)	36.2 x 8.3 x 25.0	37.4 x 16.4	34.7 x 28.5 x 8.27	35.4 x 7.9 x 24.2
Outdoor Unit Dimension (in)	33.3 x 27.6 x 12.6	41.3 x 37.4 x 13.0	33.3 x 14.3 x 27.64	38.0 x 27.6 x 15.6
Ref. Type	R410A	R410A	R410A	R410A
Ambient Temp. Range (F)	4 - 122	**-13 – 115 (cold climate)**	**-22 (cold climate)**	**-4 – 118 (cold climate)**
Max Amps (A)	20	40	25	25
Heating Cap. (BTUh)	18,500	25,000	18,000	19,000
Cooling Cap. (BTUh)	17,500	22,000	17,000	18,000
Heating (COP)	2.8	2.6	3.0	2.6
Cooling (COP)	5.7	4.5	5.9	4.1
Per Indoor Unit Piping Length (ft)	98	82	98	65
Price for Outdoor Unit	$1,830	$3,110	$1,350	$1,400

	LG LD127HV4 	**Mitsubishi** MXZ2C20NAHZ2 	**Fujitsu** 12RLFCD 	**Pioneer** YN012GMFI22RPD 
Indoor Unit Dim. (in)	7.5 x 27.6 x 38.3	16.4 x 37.4	7.8 x 27.6 x 24.4	27.5 x 17.75 x 7.9
Outdoor Unit Dim. (in)	33.03 x 21.53 x 12.59	41.28 x 37.41 x 13.0	24.5 x 31.08 x 11.3	27.5 x 17.75 x 7.88
Ref. Type	R410A	R410A	R410A	R410A
Ambient Temp Range (F)	**-4 – 118 (cold climate)**	**-13 – 115 (cold climate)**	**-5 – 115 (cold climate)**	**-13 – 122 (cold climate)**
Max Amps (A)	15	29.5	15	15
Heating Cap. (BTUh)	16,000	13,700	16,000	12,000
Cooling Cap. (BTUh)	11,600	18,000	12,000	12,000
Heating (COP)	10.5	9.5	11.5	11.5
Cooling (COP)	19.6	15	20	21.5
Per Indoor Unit Piping Length (ft)	66	82	66	82
Price for Outdoor Unit	$1,960	$2,240	$1,750	$1,550

This is an interview from 2018 between Sean Armstrong of Redwood Energy and Jonathan Moscatello of the Heat Pump Store in Portland, Oregon. Jonathan had just returned from China where he has direct import relationships for ductless mini-split heat pumps, with decades in the business.

Sean: A lot of people are not clear about how heat pumps are sold in the market. Could you explain to us?
Jonathan: Sure, it's not that complicated, but it's true that most people aren't exactly sure how it works. The process starts with the Manufacturer--they sell to Distributors. I don't know what the Manufacturer pricing is, and generally it's not possible to buy directly from the Manufacturer. When you are a Contractor who wants to install a heat pump, you buy from the Distributor. Then you sell it the Client, and at each step there is a markup of 25 to 50%.

Sean: If the contractor is fair and the labor is well-trained and fairly paid, what is the total cost of installing a ductless mini-split with one fancoil?
Jonathan: The lowest cost for a 1 ton, with one fancoil, that you'll see where someone can stay in business is $4,200. For a 2-ton, $5,500 is the lowest price you would see. I did this business for a number of years, and contractors take a lot of risks and work hard in difficult work environments.

Sean: How much does it cost to buy just the materials for a 1 ton mini split heat pump?
Jonathan: What the Contractor pays from the Distributor is $800 and $1,400 a ton, with the average around $1,200. Mitsubishi is an example of a $1,400 per ton product, while $1,200 a ton is found in products from Daikin, Panasonic, LG, and Aurora. What the contractor charges a client is 40% (e.g. Mitsubishi's written recommendations to contractors) to 50% more than their price. So $800-$1400 to the Contractor is $1100--$2100 to the Client, plus labor and additional materials.

Sean: Can you tell us about the cost for buying and installing a heat pump with multi-zone system, where there are 2-5 fan coils scattered in different rooms?
Jonathan: Well, if a 1-ton mini-split cost about $1,200, a 1.5 ton with two fan coils cost $1,600 to $1,800, and a 2-ton compressor with three fancoils cost about $3,200. Of course, this is marked up 40%-50% when sold to a client. The inside fancoils each cost about $450, while the compressor goes up in cost at about $800/ton.

Sean: What about the Labor costs for installing a ductless mini-split?

Jonathan: Labor is a constrained resource. For a full-time job, labor is paid $25 an hour to $35 an hour, and sold to the client at $42 an hour to $60 an hour. To install a 1 ton heat pump by market leading contractors takes 2 to 4 hours, and for contractors who do not install ductless on a daily basis that same work takes 4 to 8 hours because of contractor inefficiency, likely due to their relative inexperience.

Ducted Heat Pumps (240V)

Ducted air conditioning systems are usually driven by a central compressor that pumps air through ducts to vents in different areas throughout the building. These systems pair an outdoor heat pump unit with an indoor evaporator coil and air handler unit, with exception of the Friedrich (G.E. not pictured) product below, which is a packaged system that has all components in one box.

	Friedrich VRP12K 	**Goodman** GSZC180481C 	**Fujitsu** FO2414R 	**York** YZH02412C 	**Carrier** Infinity 25VNA036A003 
Description	Packaged and Ducted	Split and Ducted	Split and Ducted	Split and Ducted	Split and Ducted
Dimension (in)	26W x 25D x 50H	35W x 35D x 38H	26.25H x 23.63L x 23.63D	34H x 42W x 23D	35W x 44H x 28D
Ref. Type	R410a	R410a	R410a	R410a	R410a
Ambient Temp. Range (H/C) (F)	15 - 70	**-5 – 115 (cold climate)**	55 - 125	**-10 – 115 (cold climate)**	**-4 – 68 (cold climate)**
Power (W)	923 - 991	4,830 – 4,840	7,030	2,500 – 3,412	1,050 – 1,240
Heating Cap. (BTUh)	7,100 – 115,00	22,000 – 59,500	17,060 – 60,053	18,000 - 59,000	25,000
Cooling Cap. (BTUh)	4,000 – 23,524	23,000 – 56,500	17,300 – 60,500	19,000 – 58,000	36,000
Heating (COP)	0.64 - 1	1.47 – 6.77	3.6 – 3.8	2 -4	2.3 - 4
Cooling (COP)	3.22 – 3.81	3.66 – 4.10	3.37	4 – 4.4	4 – 4.4

Energy Management Systems and Electric Car Charging

Limited transformer, service and breaker panel capacities are often found in older neighborhoods and buildings, and can be expensive to upgrade, or delay construction to address. In response, multifamily design teams may select lower power draw equipment (e.g. 15 amp HVAC vs. 30 amp HVAC), reduce energy loads (e.g. more insulation = less HVAC power need), or put some loads on a battery and use power management systems. Batteries are also important for essential services like elevators in multifamily buildings and are being used in high-end condo housing as a sale feature. Below are case studies and a variety of technical solutions.

EVBOX		**ChargePoint**	
	• Elvi model: designed for every electric car • Commercial line: load balancing, peak shaving,		• lower capacity (<40A) to each port, avoid panel upgrade • Dynamically share current 40,30,20 Amp • network to allow for demand response

Electricity is delivered to plug-in electric vehicles to ensure the safe recharge of depleted batteries. Chargers have three levels of power supply:

- **Level 1** plugs into a regular home outlet (120V/15Amps) and charge 8-11 miles/hour. It is the least cost solution.
- **Level 2** requires the 240V electricity used by most laundry dryers and electric stoves. With 20amps the car charges at 11-15 miles/hour, 30 amps charges at 16-23 miles/hour, and 40 amps at 22-30 miles/hour.
- **Level 3** requires commercial grade electricity at 480V at 125amps, but can charge 200-300 miles/hour.[66]

Some chargers have capabilities especially attractive to multifamily developers-- ChargePoint's dynamic charging of multiple vehicles avoids panel upgrades, while EVOBOX's Elvi model is designed to charge all types and brands of electric vehicles. When Alameda County's vehicle fleet garage ran out of power capacity in 2017 to support charging the existing 70 vehicles, let alone another 30 to be delivered later that year, they installed ChargePoint products to cost-effectively schedule, prioritize and balance charging demands rather than invest in a new power supply.[67]

Utilizing Electric Vehicles for Building Back-Up

was deployed in Japan after the 2011 tsunami closed the nation's nuclear power plants. Nissan pioneered the "Vehicle-to-Home" practice with a charger that isolates a building from the grid while it relies on vehicle battery power. This can be enough to operate a building for days, or longer if rooftop solar is available to recharge the vehicle, like the Sol Lux example above. The island of Maui, with its constrained grid, and the Los Angeles Air Force Base[69], with its need for resilience during emergencies, began using Nissans for Vehicle-to-Building and Vehicle-to-Grid chargers in 2014.[70] Honda, Mitsubishi, Toyota and other car manufacturers with standard CHAdeMO-certified Level 2 charging plugs can now support bi-directional charging. Tesla is also expected to release a V2B charging system for its cards in late 2019 or early 2020.

Figure 13: Nissan unveils the U.S. commercial offering of Vehicle to Home charging in Los Angeles for 2019 deployment in the U.S., using battery-powered Leaf cars and Fermata Energy bi-directional charging. 68

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[66] Kettles, D. (2015). Electric Vehicle Charging Technology Analysis And Standards. Electric Vehicle Transportation Center. <http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1996-15.pdf>

[67] Dao, T. (2017) "EV Charging Pilot Minimizes Calif. County's Energy Use Spikes. Government Fleet. <https://www.government-fleet.com/142785/ev-charging-pilot-minimizes-calif-countys-energy-use-spikes>

[68] Lambert, F. (2018). "Nissan launches 'Nissan Energy' to commercialize vehicle-to-home/building with the Leaf. Electrek. <https://electrek.co/2018/11/28/nissan-energy-leaf-vehicle-to-home-building/>

[69] Princeton Power Systems (2014). Case Study, L.A. Air Force Base EV Charging Stations. Retrieved from Princeton Power: https://www.princetonpower.com/pdf-new/LAAFB_Case_StudyC.pdf

[70] Hawaiian Electric (2018). Electrification of Transportation: Strategic Roadmap. Retrieved from Energy and Environmental Economics: https://www.ethree.com/wp-content/uploads/2018/04/201803_EOT_roadmap.pdf

Sol Lux Alpha[71] is a four story, all-electric, "nanogrid" condo development built in San Francisco in 2018 that can go off-grid indefinitely during spring, summer and fall with (Figure 14):

- Three "Tesla Powerwall 2" batteries for each condo (42kWh)
- Pre-wiring for "Vehicle to Home/Building" bi-directional electric car chargers planned for installation in the fall of 2019, which allows an electric car to provide battery back-up to each condo and also common loads, tripling on-site battery storage in an emergency. Each long-range electric car stores 60kWh-120kWh of available battery per car.
- 12kWh of Blue Ion batteries for the elevator and incidental common loads.
- 8kW PV of solar array wired to each apartment's dedicated battery system, making 32 kWh/day on average, but usually more during the 8 sunniest months of the year in San Francisco
- Passive House design, high performance heat pumps and Bosch induction ranges

Figure 14: The Sol Lux Alpha apartment complex can operate as a "nanogrid" using the Tesla Powerwall 2, and vehicle to home charging.

Energy Management Systems

One recent innovation in circuit breaker panels is the addition of small computers to monitor and control electricity use. Addressing loads in all-electric multifamily developments is particularly important because there can be multiple large power draws happening simultaneously (like EV charging and laundry) that can be prioritized, rather than upgrading power to supply both.

Eaton[72] Energy Management Circuit Breaker (EMCB)	**Thermolec**[73] DCC-9
	
Smart Panel, Smart Circuit Breaker	EV Power Management
• Programmable breakers to prioritize loads in power outage scenarios, control shedding of lighting and plug loads • Remote cycling of HVAC, WH, to offset energy demands and save money • Can connect with solar monitoring, home networks and demand response • In the future could simplify EV charging.	• Connects EV charger to panel to manage energy loads • real-time reading of total power consumption of electrical panel; if the panel exceeds 80% rated loading, then the it temporarily de-energizes the vehicle charger. Reconnects automatically when other loads allow.

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[71] Passive House Buildings. (2018). "Sol Lux Alpha – Carbon-Neutral Nanogrid Living" <https://passivehousebuildings.com/magazine/fall-2018/sol-lux-alpha-carbon-neutral-nanogrid-living/>

[72] Eaton. (2019). "Energy management circuit breaker" <https://www.eaton.com/us/en-us/markets/innovation-stories/energy-management-circuit-breaker.html>

[73] DCC. (2018). "DCC-9" < https://dcc.technology/dcc-9/>

Electric Cooking

The LED "flame" of a Samsung induction stove (at left) is an example of how intuitive it can be to transition to cleaner, faster and safer all-electric cooking. Gas stoves cause unhealthy levels of Nitrous Oxides that would be illegal if it were from a gas power plant. After just twenty minutes of cooking and a sunny window, a kitchen can have actual smog and trigger asthma and lung ailments. Gas cooking appliances are 25-40% efficient, while electric cooking appliances are 70-95% efficient, meaning electric kitchens use 1/3rd as much energy and require only 1/3rd as much cooling. Using electric appliances avoids the construction costs and costs to run extra gas venting equipment. In addition to being more efficient, induction cooking appliances are faster, provide more temperature control and cause less kitchen fires than gas or radiant electric stoves.[74] Multifamily housing comes in all sizes and layouts, as do the commercial kitchens found in mixed-use apartment buildings. Below are products that facilitate both retrofits and new construction with high performance cooking equipment. Countertop products do not require any installation retrofits and plug into a standard wall outlet. Drop-in cooktops, on the other hand, are installed into a cut-out of the countertop and hard-wired to a 120V or 240V outlet. Electric cooking comes in a variety of technologies, standard electric, glass top radiant electric, and induction.

Glass Top Radiant Range (Less than $550)

Make/Model	**Amana** AER6303MFS 	**Whirlpool** WFE320M0ES 	**Frigidaire** FFEF3052TS 	**GE Appliances** JBS60DKBB 
Wattage	1,800	3,000	100-3,000	3,100
Price	$450	$500	$500	$510
Oven space (cu. ft)	4.8	4.8	4.9	5.3

Glass Top Radiant Range (Greater than $500) (9600W, 240V using a 40amp circuit)

Make/Model	**Kenmore** 92612 	**Frigidaire** Gallery FGIF3036TF 	**Samsung** NE58K9560WS 	**LG** LSSE3026ST 	**Bosch** 800 Series 
Price	$700	$ 1,075	$1,400	$1,700	$2,500

Slide-In Induction Range (9600W, 240V using a 40amp circuit)

Make/Model	**Frigidaire** Gallery FGIS3065PF 	**LG** LSE4617ST 	**GE** Profile PHS930SLSS 	**Café** CHS985SELSS 	**Samsung** NE58K9560WS 
Price	$2,760	$3,000	$2,440	$3,420	$2,240

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[74] See the Induction Cooking Fact Sheet by Tom Lent: https://docs.google.com/document/d/1qiGX6-tFdawfA6Nqp8SYifRbtucX9RzqAdjZ_5NdwBE/edit

Single Burner Countertop Induction (1800W, 120V and using a 15amp circuit)

Make/ Model	**Avantco** ICBTM-20 Light Duty 	**Avantco** IC1800 Heavy Duty 	**Eurodib** C1823 	**NuWave** PIC Platinum 	**Vollrath** Mirage Cadet 59300 
Price	$50	$120	$160	$200	$270
Temp. Range	140°F - 460°F	140°F - 460°F	150°F - 450°F	100°F-575°F	100°F - 400°F

Single Burner Drop-In Induction (1800W, 120V and using a 15amp circuit)

Make/Model	**True Induction** TI-1B 	**Avantco** DC1800 	**Adcraft** IND-DR120V 	**Spring** SM-651R 	**Bon Chef** 12083 
Price	$140	$170	$190	$440	$500
Temp. Range	150°F-450°F	140°F-464°F	Up to 464°F	145°F-185F°	150°F-450°F

Double Burner Countertop Induction (1800W, 120V and using a 15amp circuit)

Make/Model	**Eurodib** S2F1 	**Cuisinart** ICT-60 	**Inducto** 	**Avantco** IC18DB 	**NuWave** PIC Double 
Price	$200	$200	$150	$150	$200
Temp. Range	150-450 F	140F-460F	176° F-460° F	140-460 F	100 – 575 F

Multi Burner Induction Stovetops (9600W, 240V using a 40amp circuit)

Make/Model	**Empava** IDC-36 36" 	**KitchenAid** KCES556 HSS 36" 	**Bosch** NETP068SUC 30" 	**Samsung** NZ36K7880UG 36" 	**Frigidaire** FPIC3677RF 36" 
Price	$900	$1,300	$1,300	$2,300	$2,500

Figure 15: All-Electric Culinary leaders in New York City include many diners, an upscale oyster bar, induction ranges for each customer's Mongolian hot pot and fine Italian dining made with induction woks.

Commercial Electric Kitchens in Mixed Use Buildings

Urban multi-family buildings often have restaurants on the ground floor that benefit from faster, cleaner safer, more efficient all-electric equipment.[75]

- Electric cooking equipment delivers heat three times as effectively than gas equipment—heat delivery efficiency is between 60% and 90%, compared to gas equipment at 25-35% efficient. [76] In addition, energy star commercial electric cooking equipment can reduce loads.
- Faster heat delivery is important during rush hours—at a fast food restaurant an electric fryer produces six more baskets of fries per hour than a gas fryer, directly impacting sales, labor efficiency and profitability.
- Gas inefficiency triples kitchen air conditioning and ventilation loads, and gas combustion pollution (NO2, Formaldehyde) makes kitchens inherently less healthy for chefs.
- Induction electric cooking offers precise temperature control, while gas burns at 3400F and then relies upon inefficiencies in heat transfer, or liquids in the pan to cool it. Induction stoves protect chefs from high temperature burns when they bump cookware.

Commercial Electric Ranges

Make/Model	**Bertazzoni** PRO304INMXE 	**Garland** SS686 	**Vulcan** EV36S4FP1HT2 	**AGA Elise** AEL48IN-SS 	**Lang** R36C-APA 	**Garland** SS684 
Price	$3,000	$6,490	$8,440	$8,930	$10,100	$10,400
Amp/Wattage	45.5 / 12.4	78 /19	13kW	50 / 14.9	103.8/21.6	33kW
Volts	240	240	208	240	208-240	208-240
Heating Type	Induction	Radiant	Radiant	Induction	Radiant	Radiant
Temp. Range	NA	150°F - 550°F	200°F-500°F	NA	150°F - 450°F	150°F - 550°F
Burner Diameter	7"(2x)/ 5"/ 8"	6 ½"(x3)/ 8 ½"(x3)	NA	Flattop	24" griddle/8" element(x4)	NA

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[75] Kostuch Media Ltd. (2017). Why Induction Cooking is the Hottest Trend to Hit Restaurant Kitchens. Food Service and Hospitality. <https://www.foodserviceandhospitality.com/why-induction-cooking-is-the-hottest-trend-to-hit-restaurant-kitchens/>

[76] Source: Andre Saldivar, Foodservice Technology Center, Southern California Edison

Commercial Ovens (208V)

Make/Model	**Bakers Pride** BCO-E1 	**Vulcan** VC5ED-11D1 	**Blodgett** BDO-100-E 	**Garland** SUME-100 
Price	$3,324	$3,715	$3,810	$4,630
Kilowatts	10.5kW	12kW	11kW	10.4kW

Commercial Single Burner Countertop Induction Cooktops (1800 W / 15 Amps / 120V)

Make/Model	**Update** International IC 	**Eurodib** C1813 	**Waring** WIH200 	**ChangBERT** 	**Vollrath** 6950020 
Price	$200	$90	$150	$250	$610
Temp. Range	140°F-460°F	150°F-450°F	Up to 450°F	NA	NA

Electric Induction Woks (240V / 15A)

Make/Model	**Spring** SM-351WCR-8 	**Garland** GI-SH 	**APW** Wyott IWK 	**Vollrath** 6958301 	**Garland** GI-SH/WO/IN 
Price	$1,470	$1,760	$1,950	$2,200	$2,440
kW	3.5	3.5	3	3	5

Electric Fryers

Make/Model	**Dean** SR114E 	**Imperial Range** IFS-40-E 	**Frymaster** RE14C-SD 	**Anets** AEH14X 	**Garland** 36ES11 	**Vulcan** CEF40 
Amp/Wattage	14kW	14kW	39A/14kW	58.3A/14kW	51A/12kW	47A/17kW
Volts	208V	208-240V	208V	240V	240V	208V
Price	$1,650	$1,820	$5,280	$4,140	$5,960	$4,340

Induction Catering / Buffet Equipment

Make/Model	**Garland** GI-HO 1500 Induction Warmer 	**Spring USA** QS7230 Warming table 	**Vollrath** 7552280 60" Buffet Table 	**Bon Chef** 50120 Induction Buffet Case 	**Bon Chef** 50102 96" Buffet Table 
Price	$2,250	$5,700	$6,520	$11,630	$16,120
Amp/ Wattage	NA / 1500W	20A/650W	11.25A / 1350W	50A/NA	30A / 3200W
Voltage	120	120V	120V	220V	110 V

Electric Laundry Dryers

As our building systems become more efficient, the energy use of appliances becomes more apparent. Laundry loads in multifamily housing can sometimes be the largest load, so ensuring that the most efficient equipment is used is important. More surprising may be that the first cause of high consumption is convenience—households with in-unit laundry run twice as many loads as households with only access to a central laundromat.[77] While washing machines and clothes dryers use about the same amount of motor energy per load, boiling the water out of wet laundry uses 81% of all the energy in an average laundry load in 2010[78], assuming one is using a standard ~30% efficient gas dryer, rather than a ~250% efficient electric heat pump dryer.

Energy Star Electric Dryers

Energy Star, a building science program led by the US Environmental Protection Agency (EPA), aims to inform consumers and businesses on how to cut down on operating costs by listing and ranking energy efficient products[79]. Until recently, both residential and commercial/coin-operated clothes drying machines were excluded from the list of Energy Star rated appliances because of their consistently high-power demand between all products available on the market. Innovative technologies like moisture sensing, heat pumps and condensation drying have led to a rise in the availability of residential-grade Energy Star rated dryers[80], although there are no commercial-grade Energy Star listings as of 2019. Some examples of residential-grade Energy Star washers and dryers are shown below. Commercial grade, coin-operated products must be independently evaluated for efficiency, often by requesting that of the company placing laundry machines on-site as a service. All products below are Energy Star.

Standard Electric Dryers

Energy Star ranked Laundry Dryers use a variety of strategies to better eliminate water from clothes, such as fans, humidity sensors and heating technologies. Electric resistance dryers require a vent, while condensing dryers do not. The following products use electric resistance to dry clothes.

	Samsung DV45K76E 	LG DLE1501 	GE GTD65EB 	Maytag MED3500W 	Whirlpool WED75HEFW 	Electrolux EFME417 
Price	$400	$450	$500	$650	$650	$700
Drum Capacity (cu. ft)	7.4	7.4	7.4	7.4	7.4	8.0
kWh/year	607	607	608	608	608	608

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[77] Baylon et. al. (2013). "Residential Building Stock Assessment: Multifamily Characteristics and Energy Use." Ecotope, Inc. for NEEA.

[78] Korn & Dimetrosky. (2010). "Do the Savings Come Out in the Wash? A Large Scale Study of In-Situ Residential Laundry Systems." The Cadmus Group. ACEEE Summer Study on Energy Efficiency in Buildings

[79] U.S. Department of Energy. (2017). "Saving Energy and Money with Appliance and Equipment Standards in the United States" <https://www.energy.gov/sites/prod/files/2017/01/f34/Appliance%20and%20Equipment%20Standards%20Fact%20Sheet-011917_0.pdf>

[80] Janeway, K. (2014). "Finally, the lowly dryer can reach for Energy Star" <https://www.consumerreports.org/cro/news/2014/05/finally-the-humble-dryer-can-reach-for-energy-star/index.htm>

Combination Condensing Washer & Dryer

Condensing Washer/Dryer combine both space and energy efficiency and are ventless—laundry water instead goes down the drain. They are most common in retrofitted apartments in Europe, and run on 120V outlets, using as much energy as a hair dryer on medium and stresses fabrics less. After washing the clothes, the same machine dries the laundry using a condenser. A laundry cycle, from loading to unloading, takes 2-3 hours.

	Magic Chef MCSCWD20W3 	**Haier** HLC1700AXW 	**Summit** SPWD2201SS 	**Deco** DC4400CV 	**LG** WM3488HW 	**Whirlpool** WFC8090GX 
Price	$720	$1,000	$1,000	$1,200	$1,300	$1,500
kWh/year	85 kWh/year	65kWh/year	65kWh/year	96kWh/year	120 kWh/year	180kWh/year
Drum Capacity (cu. ft.)	-	2.0	2.0	3.5	2.3	2.8
Volts/Amps	-	120V/10A	115V/12A	110V/15A	120V/15A	240V/30A

Heat Pump Dryers

Heat pump dryers are also ventless but maintain a higher temperature than a condensing dryer and lower than that of electric resistance, and therefore dry clothing at a rate between the two. Note that smaller drum sizes hold less clothes, and consequently take less time to dry.

	Samsung DV22N685H 	**Blomberg** DHP24400W 	**Kenmore** Elite 81783 	**Beko** HPD24412W 	**Whirlpool** WED9290FC 	**Miele** TWI180WP 
Price	$1,000	$1,100	$1,100	$1,300	$1,700	$1,900
kWh/year	145kWh/year	149kWh/year	-	149kWh/year	531kWh/year	133kWh/year
Drum Capacity (cu. ft.)	4.0	4.1	7.4	4.1	7.4	4.1
Cycle Time (min)	60	46	-	46	75	35

Electric Landscaping

Powerful commercial-grade electric landscaping equipment uses lightweight batteries and efficient motors that are half as loud as gas equivalents, produce no local air pollution, and are easier to maintain. Modern batteries now offer comparable length of operating time to gas tanks, and batteries are safer to store than gasoline, oil and rags.

	Blower	**Chain Saw**	**Pole Pruner**	**Trimmer**	**Hedge Trimmer**	
STIHL[81]	BGA 100 ($350) 	MSA 160 C-BQ ($350) 	HTA 85 ($490) 	FSA 130 R ($400) 	HAS 94 R ($500) 	RMA 510 ($520) 
Husqvarna[82]	550iBTX ($500) 	T536Li XP ($400) 	536LiPT5 ($500) 	536LiLX **($300)** 	536LiHD60X ($430) 	LE221R ($430) 
RYOBI[83]	RY40440 ($270) 	P549 ($200) 	RY40561 ($200) 	RY40250 ($160) 	RY40610A ($150) 	RY48ZTR100 ($4100) 

*Prices will vary – visit retailers for the most current cost information.

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[81] STIHL. (2019) "AP Series" <https://www.stihlusa.com/products/battery-products/ap-series/>

[82] Husqvarna. (2019). "Battery Series" https://www.husqvarna.com/us/products/battery/

[83] RYOBI. (2019). "Lawn and Garden" https://www.ryobitools.com/outdoor

Electric Fireplaces

Swirling, fire-like mist lit with LEDs and a log fire's worth of heat: these are the new electric fireplaces. They're less expensive than gas stoves, safer, cleaner, and plug into a normal 120V wall outlet. They provide heat in a more efficient and smokeless way – a 3,000-Watt electric fireplace can warm spaces up to 800 feet and look great doing it. From convincing to dramatic, electric fireplaces are ready to match the tastes of any owner. Outdoor electric space heaters are similarly versatile and ready to replace headache-inducing propane burners.

Indoor Electric Fireplaces

	ClassicFlame Felicity 	**Amantii** Zero Clearance 	**Modern Flames** CLX Series 
Size	46.6"W, 19.75"H,5"D	29.5"W, 38.75"H, 8.5" D	144" W,25.5" H, 5.3" D
Price	$350	$1,300	$7,500
Voltage/Amps	120V/12.5A	120V/12.5A	120V
Heat Output	1,500W	1,500W	1,500W

	Dimplex Opti-Myst Pro 1000 	**Napoleon** See-thru 	**Dynasty** DY-BT79 
Size	40.1" W, 9.5"H, 12" D	50"W, 18.4"H, 9"D	80"W, 19.3" H, 7" D
Price	$2100	$2,000	$1,300
Voltage/Amps	120V	120V/240V	120V/10.8A
Heat Output	460W	3,000W	1,300W

Outdoor Electric Fireplaces/Heaters

	Dimplex Opti-Myst Pro 500 	**Touchstone** Sideline 	**EnerG+** Patio Heater 
Size	20" W, 9.5"H, 12" D	50"W,17.9"H ,6"D	11" W, 4'3"H,11"D
Price	$1300	$574	$186.99
Voltage/Amps	120V/3.83A	120V/11A	110V/13A
Heat Output	230W	1,500W	1,500W

Electric Barbeques

Electric BBQ grills heat up much more quickly than charcoal or gas grills and distribute heat more evenly over the entire grill area. With no charcoal fumes and no propane gas burning, they are safer and can be used indoors in inclement weather. Electric grills are cheaper to operate, clean up easier, need little maintenance and can also be used in high rise buildings where typical combustion grills are not allowed due to fire code restrictions.

	Electri Chef The Safire 115V 	**Electri Chef** Emerald 24" 	**Electri Chef** Ruby 32" Built-in 	**Kenyon** B70590 	**Kenyon** B70060 
Size (sq. in.)	224	336	448	115	115
Price	$700	$3,600	$3,500	$1200	$650
Voltage	115V	220V	220V	120V	120V

	Weber 55020001 	**Char-Broil** 804142 	**Kuma** Profile 150 	**Americana** 9359U8.181 	**Maverick** E-50S 
Size (sq. in.)	280	240	145	200	173
Price	$320	$200	$220	$245	$180
Voltage	120V	120V	110	120V	120V

Electrically Heated Swimming Pools and Hot Tubs

Many commercial buildings (e.g. hotels, corporate campuses) have swimming pools and hot tubs. Utilizing a heat pump can be an efficient way to address the energy demands of heating a pool. To size a heat pump pool heater, assume the heat pump must produce 4 to 6 BTUs/Hour for each gallon of heated pool water, with higher productivity needed when the incoming water is colder in the winter. In addition, solar thermal can an efficient way to heat pools.

Figure 16: Pacific Companies Zero Net Energy apartment complexes built in 2014 with heat pumps for the hot tub and swimming pools. (left King Station Apartments, King City, CA and right Belle Vista Senior Apartments, Lakeport, CA.)

Pool and Hot Tub Heat Pumps

Listed briefly below are heat pump specifically designed for pools and cost $2400-$4200 for 90,000 BTUs/Hr to 140,000 BTUs/Hr of heating, about 1/10th the price of a similar-sized solar thermal pool heater. Heat pumps significantly reduce construction costs compared to solar thermal while providing the same ~80% offset of energy use by using ambient heat in the air, while working all 12 months of a year, compared to 5 to 8 months of renewable pool heating with solar thermal panels.

Hayward Heat Pro

Pentair

PHNIX

Aquacal Heatwave

IN SUMMARY…….

1. Encourage Prefabrication, it WORKS!
2. Encourage Vertical Integration, it WORKS!
3. KISS: Keep It Simple Stupid
4. Educate tenants/owners on systems and utilities
5. Leverage utility savings to build more housing!!
6. HFA's should incentivize Passive House MORE than other sustainable standards
7. Require ALL-ELECTRIC BUILDINGS
8. Include PV + PH as part of your capital stack
9. Policy over Pilot Projects!

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