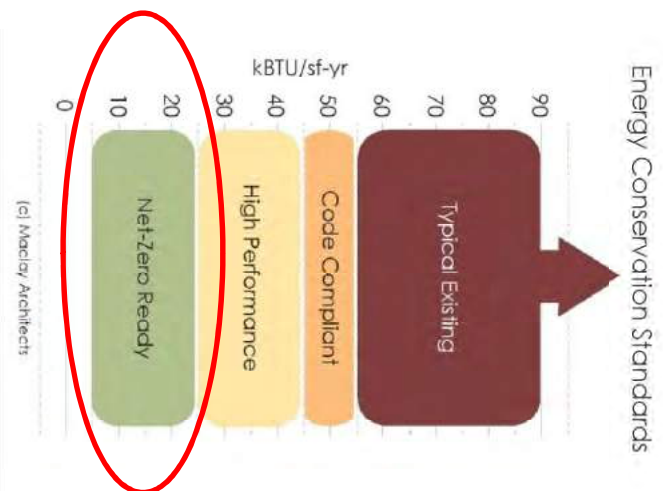


Purpose

- Explore the financial feasibility of net zero energy buildings above code buildings
- Examine the feasibility of a net zero community



Building Overview

Six typical new construction buildings were analyzed

- Single Family
- Multifamily – Duplex
- Multifamily - Quadplex
- Office – Open
- Office - Closed
- Office/Manufacturing



Figure 3: Residential single family home
source: Huntington Homes



Figure 4: Rendering of the multifamily housing
source: Huntington Homes

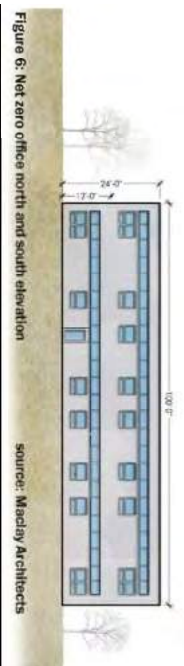


Figure 6: Net zero office north and south elevation

source: Mactay Architects

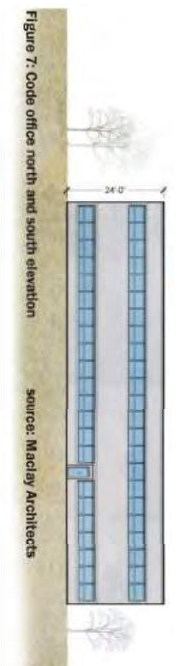


Figure 7: Code office north and south elevation

source: Mactay Architects

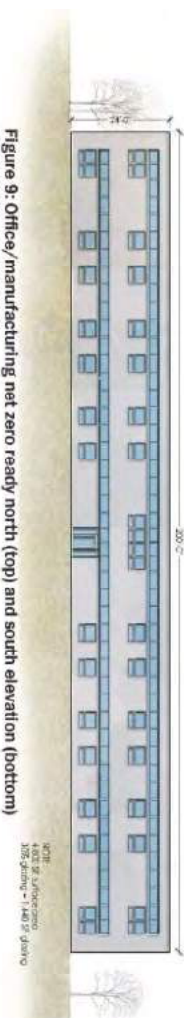
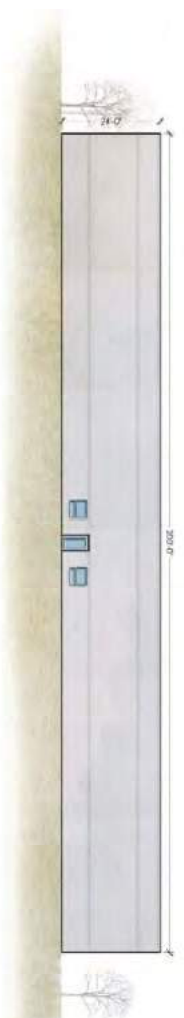


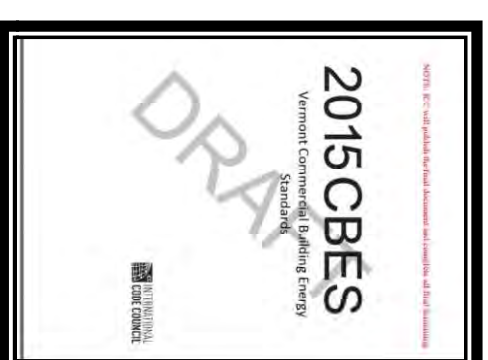
Figure 9: Office/manufacturing net zero ready north (top) and south elevation (bottom)
source: Mactay Architects

NOTE:
4102' sq. Landed area
3152 sq. ft. - 1440' sq. Glass

Code Standard

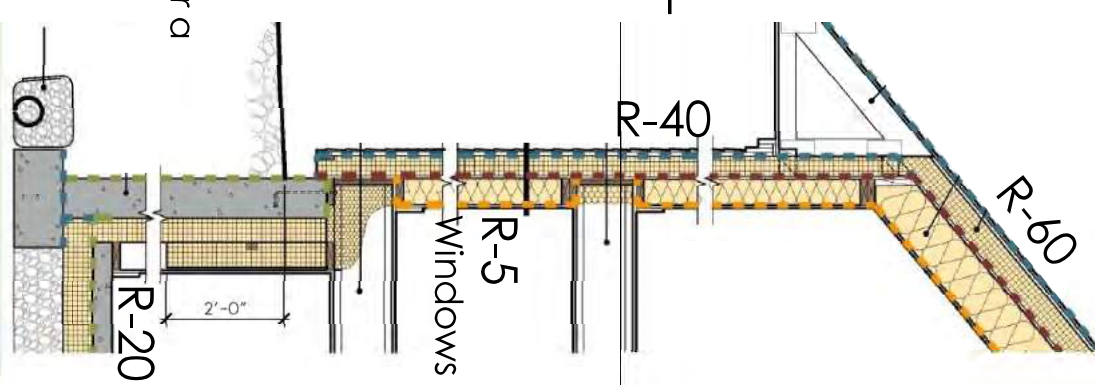
- Envelope:
 - R25 walls, R15 basement, R49 roof, R 3.2 windows
 - 0.5 cfm/sf above grade surface area @ 50 Pascals
- Mechanical / DHW:
 - Residential -Propane-fired furnaces for heating and DHW,
 - Commercial -Rooftop propane-fired heating and cooling units with demand controlled outside air
- Ventilation: no heat recovery

Code Used: 2015 Vermont Residential Building Energy Standards (RBES) and the 2015 Vermont Commercial Building Energy Standards (CBES) draft dated 11/24/2014



Net Zero Ready Standard

- Envelope:
 - R60, R40, R20, R5
 - 0.1 cfm/sf above grade surface area@ 50 Pascals
 - Mechanical: Air source heat pumps
 - Ventilation: Residential –HRV, Commercial - ERV
 - DHW: Residential -heat pump unit
Commercial -electric resistance
 - PV: sized to be net zero on an annual basis
- Assume \$3/ watt installed cost (based on Vermont price in Oct 2014 for a roof mounted array)



Financial Analysis

INPUTS

- Energy consumption
- Capital costs for energy efficiency
- Capital costs for PV
- Financing assumptions



OUTCOMES

- 1st year ownership and operating costs
- Cumulative capital, operating, and finance costs

Financial Analysis

INPUTS

- Energy consumption
- Capital costs for energy efficiency
- Capital costs for PV
- Financing assumptions



OUTCOMES

- 1st year ownership and operating costs
- Cumulative capital, operating, and finance costs

	Code [2]		Net Zero Ready		% energy savings above code
	(kBtu/sf-yr)	(kWh/sq.m-yr)	(kBtu/sf-yr)	(kWh/sq.m-yr)	
SF	49	156	17	54	65%
27,000					

Financial Analysis

INPUTS

- Energy consumption
- Capital costs for energy efficiency
- Capital costs for PV
- Financing assumptions



OUTCOMES

- 1st year ownership and operating costs
- Cumulative capital, operating, and finance costs

Building Component	Code Single Family	NZS Single Family	Added Cost	Category Added Cost
Windows	Double-glazed windows: U=0.32 Triple-glazed windows: U=0.20	Air infiltration 18.0 L	\$6,792	
Air/Vapor Barrier	Air infiltration of 0.5 cfm/50/ft ² above grade surface area	Air infiltration 18.0 L cfm/50/ft ² above grade surface area	\$2,172	
Insulation	Basement Walls, R-15	Basement Walls, R-20	\$6,176	\$25,724
	Basement slab none	R-20 slab edge; basement slab R-20		
	R10m insulation R-21	R10m insulation R&2	\$596	
	Walls, R-25	Walls, R-40	\$3,064	\$1,834
Ventilation	Attic R-49	Attic R-60		
	Rate: (# BR's + 1) * 25 cfm, exhaust only	rate: (# BR's + 1) * 25 cfm, heat recovery ducted	\$3,890	\$500
Domestic Hot Water	From boiler	ASHP with a net COP of 1.5 [1]	\$2,600	
HVAC	propane 85% sealed combustion boiler	ASHP, annual heat COP 2.3	-55,900	
PV	Solar PV none	7.7 kW system	\$23,392	\$23,392

*All costs have been rounded to two significant digits

Total Added Cost without PV	\$26,000
Added Envelope Cost Per Square Foot	\$16.00
Added Mechanical Cost Per Square Foot	\$0.30
Total Added Cost Per Square Foot	\$16.30

Financial Analysis

INPUTS

- Energy consumption
- Capital costs for energy efficiency
- Capital costs for PV
- Financing assumptions



OUTCOMES

- 1st year ownership and operating costs
- Cumulative capital, operating, and finance costs



© MacLay Architects

Financial Analysis

INPUTS

- Energy consumption
- Capital costs for energy efficiency
- Capital costs for PV
- Financing assumptions



OUTCOMES

- 1st year ownership and operating costs
- Cumulative capital, operating, and finance costs

Financial Analysis

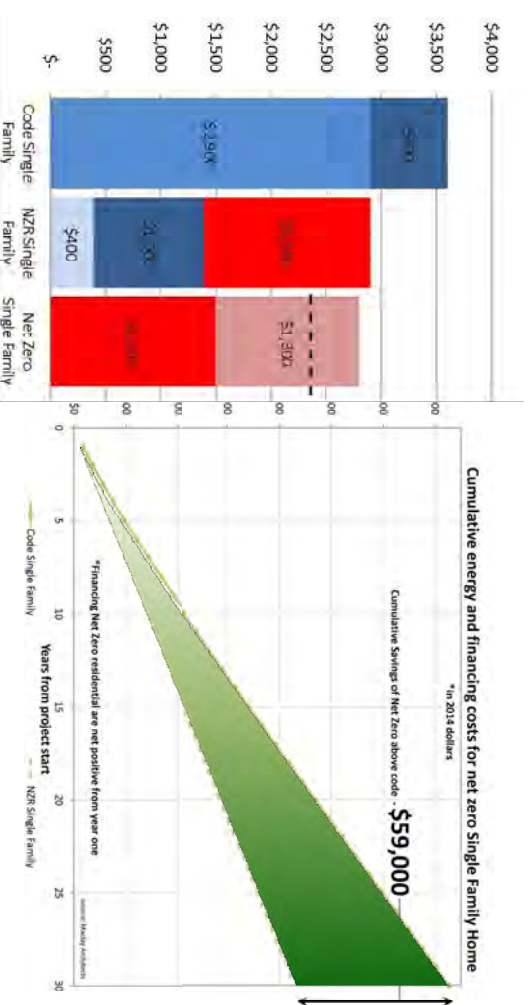
INPUTS

- Energy consumption
- Capital costs for energy efficiency
- Capital costs for PV
- Financing assumptions



OUTCOMES

- 1st year ownership and operating costs
- Cumulative capital, operating, and finance costs



Energy Consumption

- Residential annual energy per dwelling unit

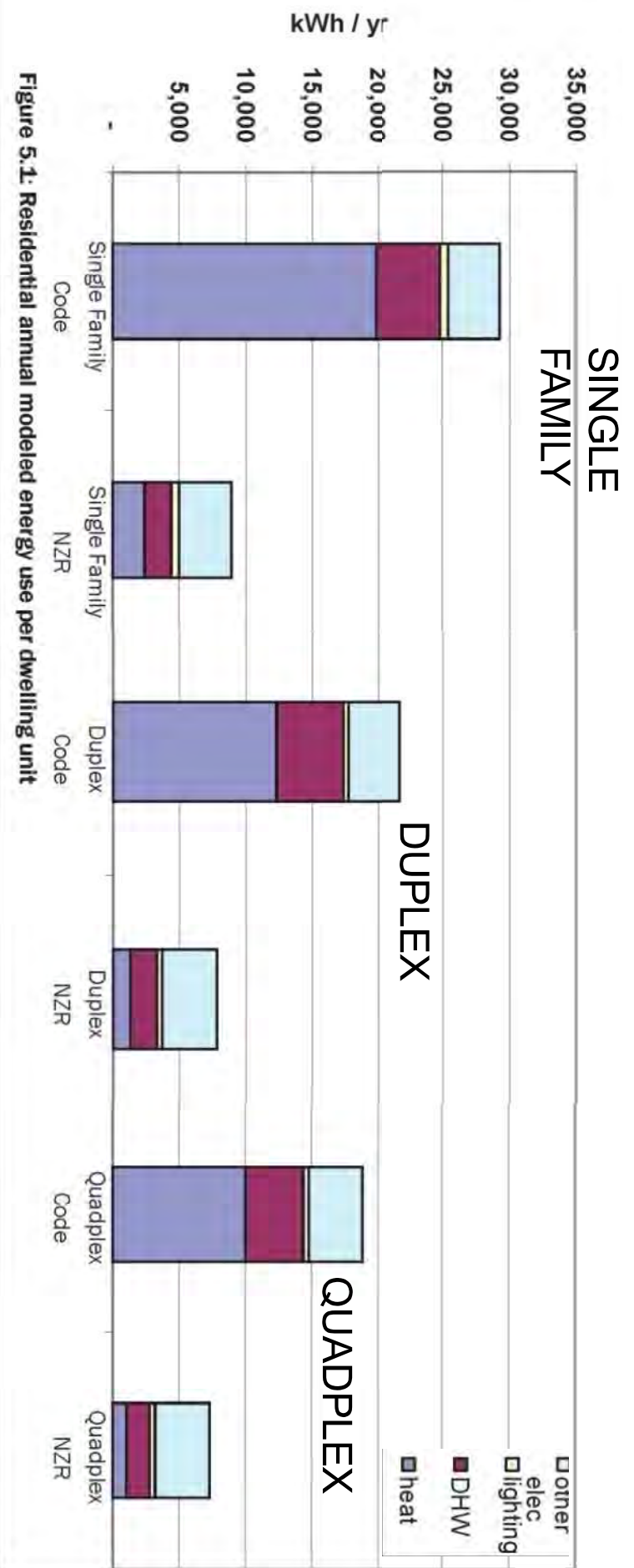


Figure 5.1: Residential annual modeled energy use per dwelling unit

Energy Consumption

- Commercial annual energy

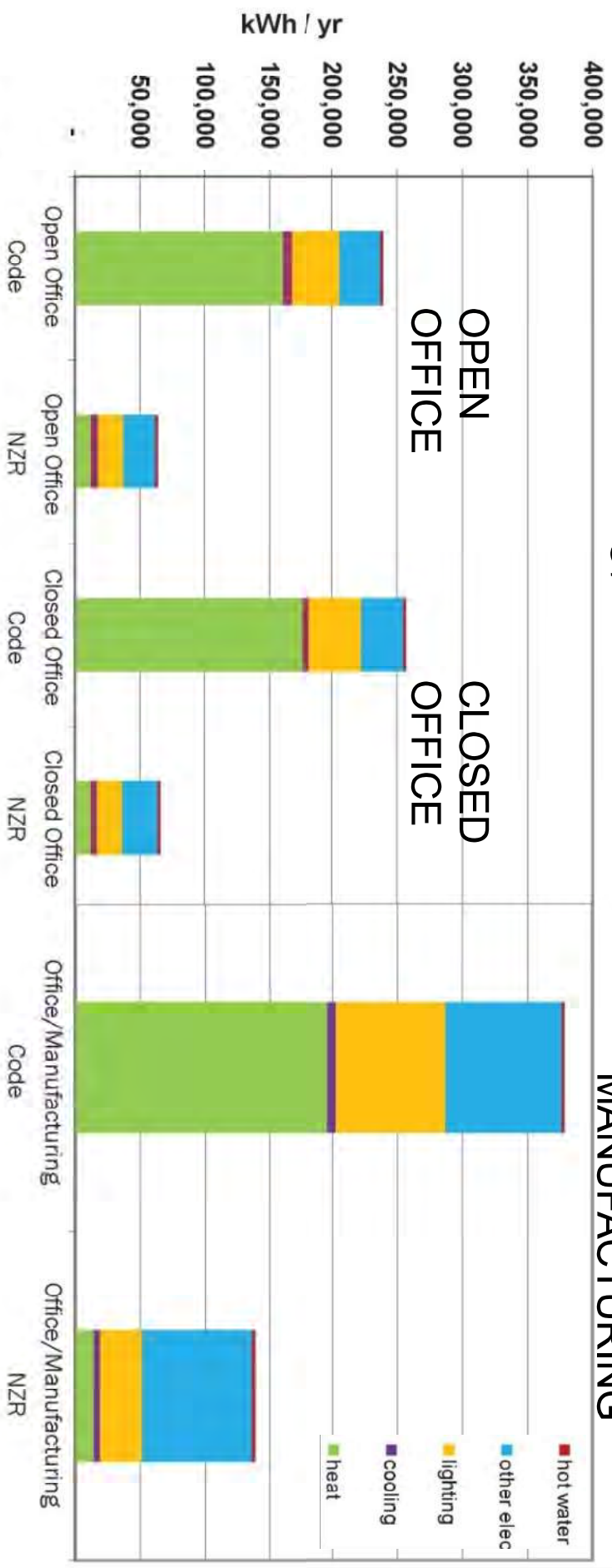


Figure 5.2: Commercial annual modeled energy use

Energy Use Intensity (EUI)

	Code [2]		Net Zero Ready		% energy savings above code
SF	(kBTU/sf-yr)	(kWh/sq.m-yr)	(kBTU/sf-yr)	(kWh/sq.m-yr)	
Single Family					
Duplex [1]	1,612	62	196	20	67%
Quaddplex [1]	1,120	64	203	25	61%
Open Office	1,120	56	176	24	57%
Closed Office	13,000	62	196	17	72%
Office/Manufacturing	13,000	67	210	18	74%
	27,000	49	156	17	65%

Community Energy

Type	SQUARE FOOTAGE (SF)			CODE EUI (kBtu/sf-yr)			NET ZERO READY EUI (kBtu/sf-yr)			TOTAL	
	Office	Manufacturing	Residential	Office	Manufacturing	Residential	Office	Manufacturing	Residential	Total Code Energy (kBtu/yr)	Total Net Zero Ready Energy (kBtu/yr)
Commercial	11200	0	0	160000	62	62	17	17		9,900,000	2,700,000
Office	10000	17000	0	34000	62	49				2,900,000	900,000
Office/manufacturing											
COMMERCIAL SUBTOTAL SF: 214,000				COMMERCIAL TOTAL kBtu/yr:				12,800,000		3,600,000	
Residential											
Large Single Family	2,200	15,000			62		20			900,000	300,000
Small Single Family	1,600	18,000			62		20			1,100,000	400,000
Duplex	1,100	19,000			64		25			1,200,000	480,000
Quadplex	1,100	34,000			56		24			1,900,000	800,000
RESIDENTIAL SUBTOTAL SF: 86,000				RESIDENTIAL TOTAL kBtu/yr:				5,100,000		1,980,000	

COMMUNITY TOTAL SF	300,000
COMMUNITY TOTAL kBtu/yr	18,000,000
Annual Demand (kWh/yr)	5,000,000
PV System Size (kW)	5,750
PV System Size (MW)	5.8
Target Area of PV (SF)	390,000

COMMUNITY TOTAL SF	300,000
COMMUNITY TOTAL kBtu/yr	18,000,000
Annual Demand (kWh/yr)	5,000,000
PV System Size (kW)	5,750
PV System Size (MW)	5.8

CODE	NZR
300,000	
18,000,000	5,600,000
5,000,000	2,000,000
5,750	2,300
5.8	2.3

Renewable Energy Overlay

- 2.3 MW of PV to be NZ
- Rooftops and carports maximized
- + 7.5 acres of ground mounted

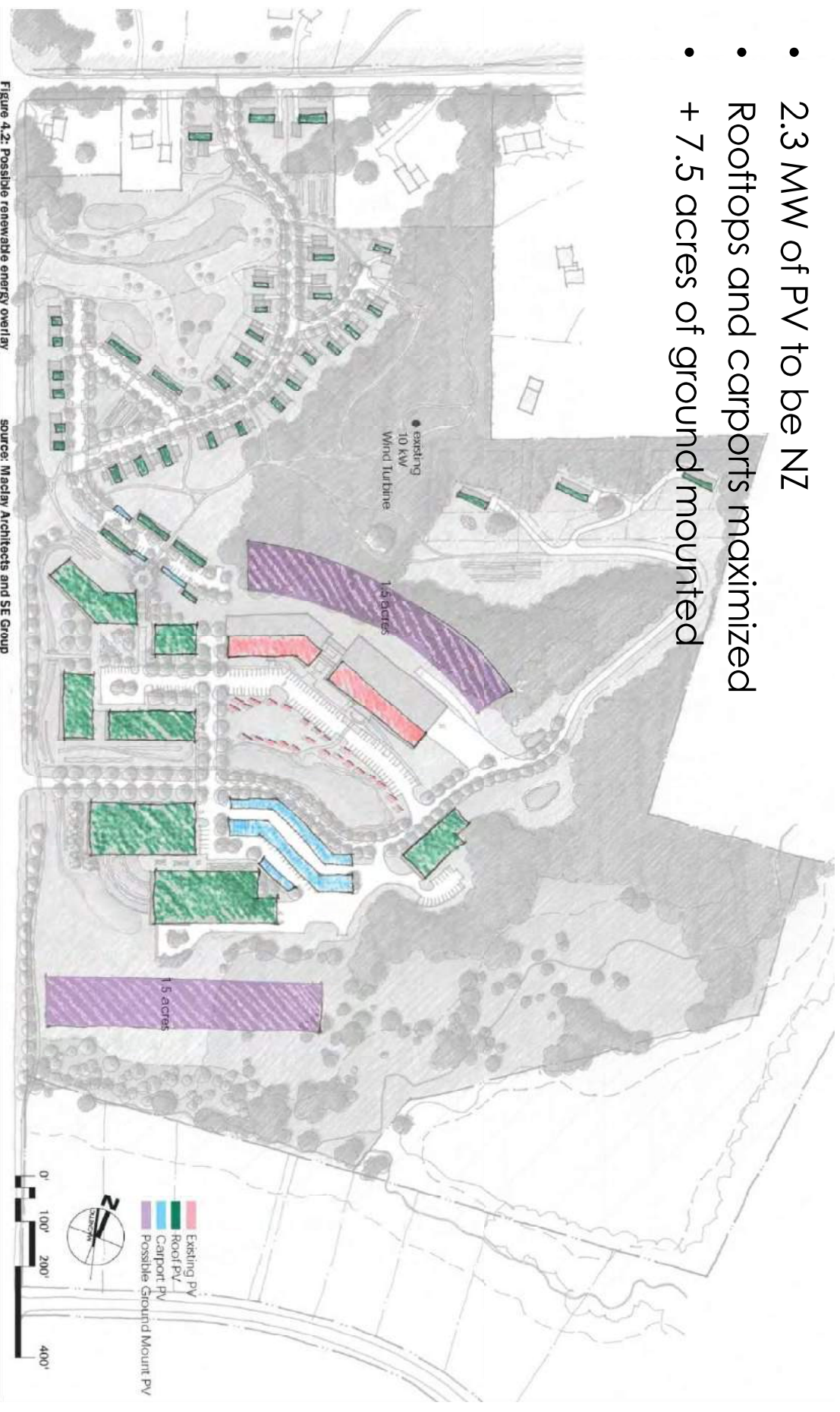


Figure 4.2: Possible renewable energy overlay

source: MacIay Architects and SE Group

Cost Estimate

SINGLE FAMILY

Building Component	Code Single Family	NZR Single Family	Added Cost	Category Added Cost
Windows	Double-glazed windows; U=0.32	Triple-glazed windows; U=0.20	\$6,792	
	Air Infiltration of 0.5 cfm/50/sf above grade surface area	Air Infiltration is 0.1 cfm/50/sf above grade surface area	\$2,172	
Air/Vapor Barrier	Basement Walls, R-15; basement slab none	Basement Walls, R-20; R-20 slab edge; basement slab R-20	\$6,176	\$25,724
	Rim Insulation R21	Rim Insulation R42	\$696	
	Walls: R-25 Attic R-49	Walls: R-40 Attic R-60	\$8,064 \$1,824	
Insulation	Rate: (# BR's + 1) *25 cfm, exhaust only	Rate: (# BR's + 1) *25 cfm, heat recovery ducted	\$3,900	
	Domestic Hot Water	ASHP with a net COP of 1.5 [1]	\$2,600	\$500
Mech	HVAC	ASHP, annual heat COP 2.3	-\$5,900	
	Solar PV	7.7 kW system	\$23,332	\$23,332
*All totals have been rounded to two significant digits				
Total Added Cost without PV			\$26,000	
Added Envelope Cost Per Square Foot			\$16.00	
Added Mechanical Cost Per Square Foot			\$0.30	
Total Added Cost Per Square Foot			\$16.00	



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Cost Estimate - Residential

Table 6.1: Residential cost per square foot for each building type

	Cost / sf	Cost above Code \$/sf	% of project cost for additional energy upgrades
Code Single Family	\$ 120	NA	0
	\$ 136	\$ 16	12%
	\$ 151	\$ 31	20%
Code Duplex	\$ 120	NA	0
	\$ 135	\$ 15	11%
	\$ 153	\$ 33	22%
Code Quadplex	\$ 120	NA	0
	\$ 133	\$ 13	10%
	\$ 150	\$ 30	20%



Cost Estimate - Commercial

Table 6.2: Commercial cost per square foot for each building type

	Total Building Cost / sf	Cost above Code \$/sf	% of project cost for additional efficiency upgrades
Code Office Open	\$ 131	NA	0%
NZR Office Open	\$ 140	\$ 9	7%
NZ Office Open	\$ 153	\$ 22	16%
Code Office Closed	\$ 154	NA	0%
NZR Office Closed	\$ 164	\$ 10	6%
NZ Office Closed	\$ 178	\$ 24	14%
Code Manufacturing	\$ 107	NA	0%
NZR Manufacturing	\$ 124	\$ 17	13%
NZ Manufacturing	\$ 137	\$ 30	24%

Cost Estimate – Commercial Open Versus Closed Office

Table 6.6: Additional open v. closed office costs per square foot

	Project Cost / sf	Cost above Code \$/sf
Code Office Open	\$ 131	NA
Code Office Closed	\$ 155	\$ 24
NZ Office Open	\$ 140	NA
NZR Office Closed	\$ 165	\$ 25

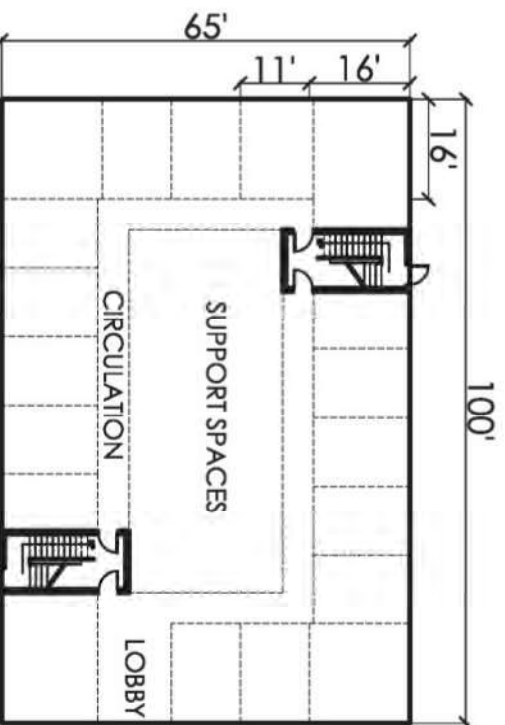


Figure 3.2: Closed office building first floor plan

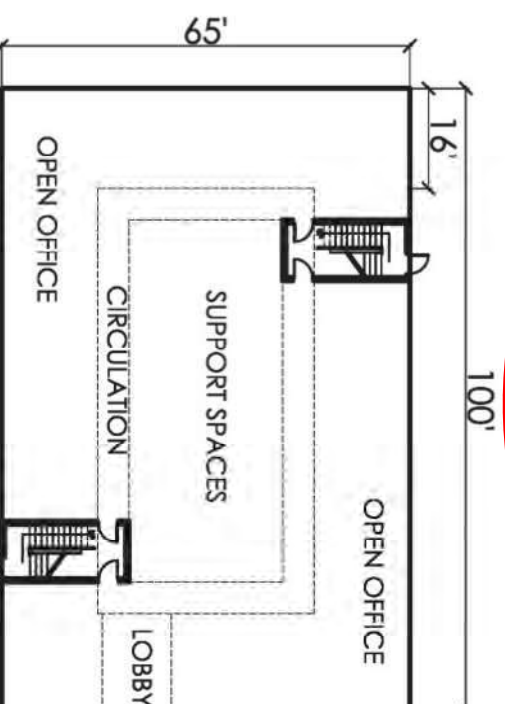


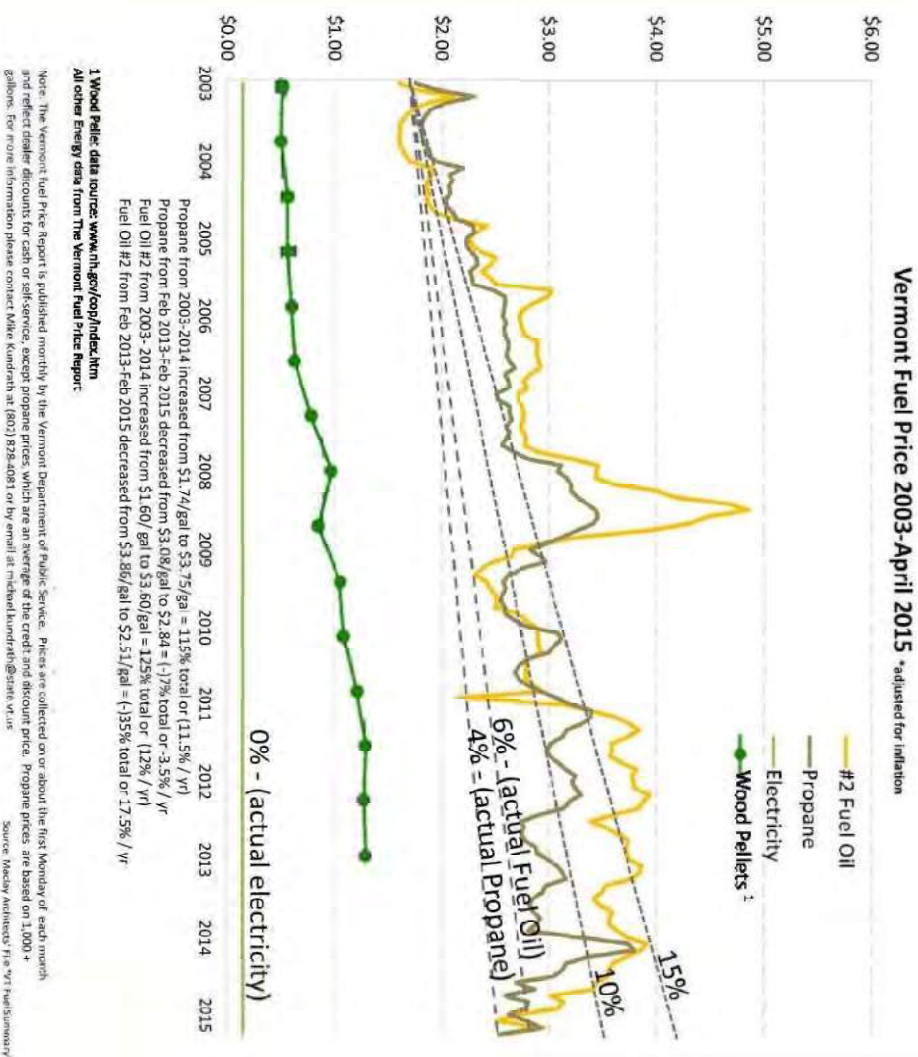
Figure 3.4: Open office building first floor plan



Fuel Escalation – 5%

- From 2004-2015 average fuel oil escalation is 6% /yr
- Propane escalation is 4% /yr
- Yearly variation ranges from: 77% to -23%
- Report assumes 5% with “Solar Plateau” –no inflation on cost of propane after year 7 (\$4.13 / gal)

- Starting costs:
- Electricity = \$0.15 / kWh
 - Propane = \$3.08 / gal



Financial Analysis - Outcomes

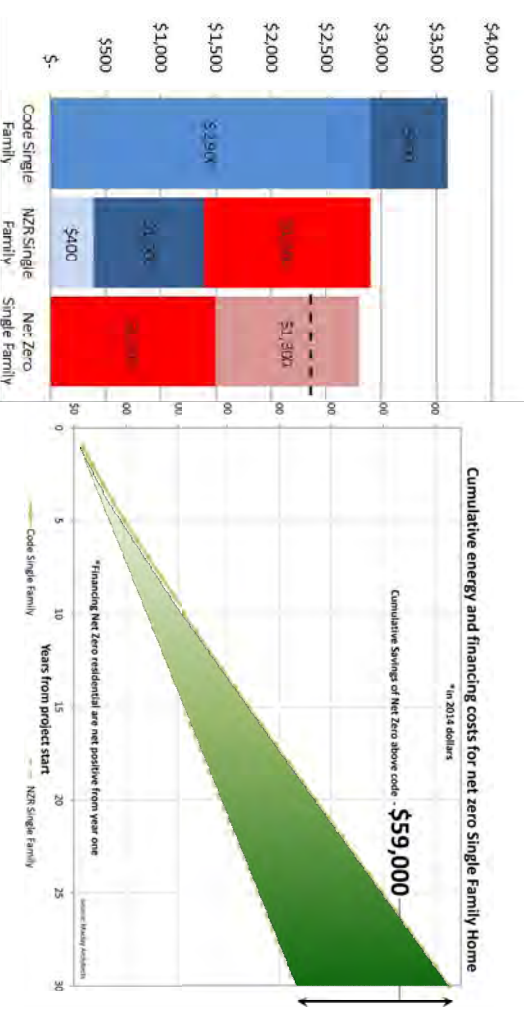
INPUTS

- Energy consumption
- Capital costs for energy efficiency
- Capital costs for PV
- Financing assumptions



OUTCOMES

- 1st year ownership and operating costs
- Cumulative capital, operating, and finance costs



- 32,000 sf proposed single family residential



Single Family Residential



Figure 3: Residential single family home
source: Huntington Homes

- 1,600 sf
- 3 bedroom
- 2.5 bath
- 4 occupants

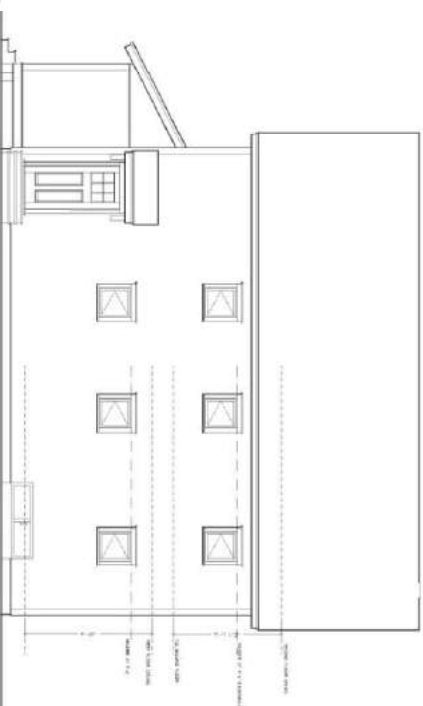


Figure 2.2: Residential single family north elevation
source: Huntington Homes

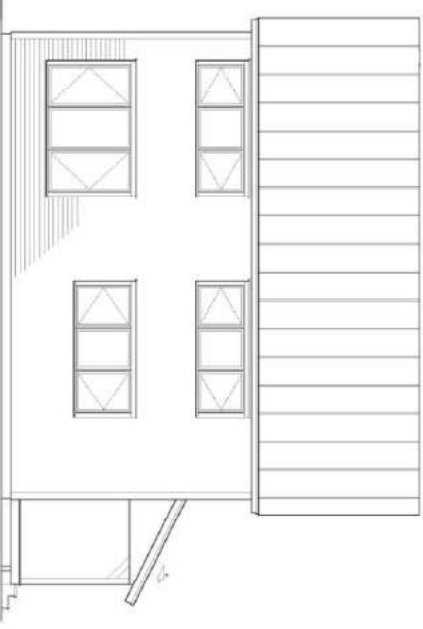


Figure 2.3: Residential single family south elevation
source: Huntington Homes



Figure 2.4: Residential single family first floor plan
source: Huntington Homes

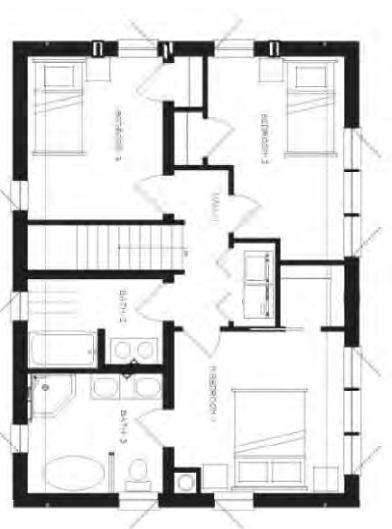


Figure 2.5: Residential single family second floor plan
source: Huntington Homes